Appendix 1
Interior Drainage Analysis – Jefferson Parish

Introduction

Study Purpose

To answer the questions regarding the performance of the hurricane protection system, the interior drainage analysis focused on the filling and unwatering of the separate areas protected by levees and pump stations, referred to as basins. Interior drainage models were developed for Jefferson, Orleans, St. Bernard and Plaquemines Parishes to simulate water levels for what happened during Hurricane Katrina and what would have happened had all the hurricane protection facilities remained intact and functioned as intended.

The primary components of the hurricane protection system are the levees and floodwalls designed and constructed by the Corps of Engineers. Other drainage and flood control features (land topography, streets, culverts, bridges, storm sewers, roadside ditches, canals, and pump stations) work in concert with the Corps of Engineers levees and floodwalls as an integral part of the overall drainage and flood damage reduction system and are included in the models.

Interior drainage models are needed for estimating water elevations inside leveed areas, or basins, for a catastrophic condition such as Hurricane Katrina and for understanding the relationship between HPS components. Results from the interior drainage models can be used to determine the extent, depth and duration of flooding for multiple failure and non-failure scenarios. The models can also be used to:

- Support the Risk modeling effort
- Estimate time needed to unwater an area
- Support evacuation planning
- Evaluate design options of the HPS to include multiple interior drainage scenarios

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This appendix will provide details of the development of the HEC-HMS and HEC-RAS models for Jefferson Parish East and West banks. In summary, an HEC-HMS model was developed to transform the Katrina precipitation into runoff for input to the HEC-RAS models. HEC-RAS models were developed to simulate the four conditions discussed below

This model was developed to help answer questions 3 and 4 listed on page 1 of Volume VI. Question 3 is answered by the Katrina simulation listed below. Question 4 is a more difficult one to answer. This is mainly due to the variety of possible combinations of system features, especially pumps. It was decided to bracket these combinations with the three hypothetical combinations listed below.

One of the major difficulties is determining what pumps may have continuing operating. There are many potential factors that can cause pump stations to not operate during a hurricane event. Some of these are power failures, pump equipment failures, clogged pump intakes, flooding of the pump equipment, loss of municipal water supply used to cool pump equipment and no safe housing for operators at the pump stations resulting in pump abandonment. Because there is such a wide range of possible pumping scenarios that could occur during a hurricane event, it is difficult to establish a pumping scenario for what could have happened. At best, a variety of possible scenarios could be run to evaluate the potential range of possible consequences. For the purposes of the IPET analysis, it was decided to operate the pumps two ways. (1) As they actually operated during hurricane Katrina and (2) the pumps operated throughout the hurricane.

Described below are the 4 scenarios shown in this appendix.

Katrina

Simulate what happened during Hurricane Katrina with the hurricane protection facilities and pump stations performing as actually occurred. Compare results to observed and measured high water marks. Pre-Katrina elevations are used for top of floodwalls and levees.

Hypothetical 1 – Resilient Levees and Floodwalls

Simulate what would have happened during Hurricane Katrina had all levees and floodwalls remained intact. There are no levee or floodwall breaches or failures for this scenario even where overtopping occurs. Pump stations operate as they did in the Katrina event. Pre-Katrina elevations are used for top of floodwalls and levees. This scenario is meant to simulate what could have happened if all levees and floodwalls had protection that would allow them to be overtop but not breach. For Jefferson Parish, since there were no levee or floodwall breaches, the results of this scenario match the results of the Katrina scenario.

Hypothetical 2 – Resilient Floodwalls, Levees and Pump Stations

Simulate what would have happened during Hurricane Katrina had all levees, floodwalls and pump stations remained intact and operating. There are no levee or floodwall breaches or failures for this scenario even where overtopping occurs. Pump stations operate continuously throughout the hurricane. Pump operations are based on the pump efficiency curves which reflect tailwater impacts. Pre-Katrina elevations are used for top of floodwalls and levees. It is understood, that in their present state, most pump stations would not have been able to stay in operation during

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Katrina. However, this scenario was simulated to provide an upper limit on what could have been the best possible scenario had no failures occurred.

Hypothetical 3 – Resilient Floodwalls

Simulate what would have happened during Hurricane Katrina had all floodwalls, which failed from foundation failures, remained intact. All other areas are modeled as they actually functioned. Pump stations operate as they did in the Katrina event. Pre-Katrina elevations are used for top of floodwalls and levees For Jefferson Parish, since there were no levee or floodwall breaches, the results of this scenario match the results of the Katrina scenario.

Table 1-1 lists the simulation scenarios in a matrix format.

Table 1-1
Katrina Simulations

	Simulation			
Conditions	**Katrina**	**Hypothetical 1**	**Hypothetical 2**	**Hypothetical 3**
Pumps operate as during Katrina	X	X		X
Pumps operate throughout Katrina			X	
Levee and floodwall breaches occur everywhere as during Katrina	X			
Levee and floodwall breaches occur on West wall of IHNC and in, St Bernard, New Orleans East and Plaquemines as during Katrina				X
Levee and floodwalls overtop but do not breach		X	X	
No failures on 17th Street and London Ave				X
Levee and floodwall elevations based on pre-Katrina elevations	X	X	X	X

Review of Existing Data

Prior to Hurricane Katrina, Jefferson Parish was developing hydrologic and hydraulic models to produce digital flood insurance rate maps (DFIRMS) as part of FEMA's map modernization program. Models were being developed for all of Jefferson Parish's watersheds within the hurricane protection levees, specifically: East Bank, Hoey's, Bayou Segnette, Ames-Westwego, Harvey-Estelle-Cousins and East of Harvey Canal. HEC-HMS 2.2.2 and HEC-RAS 3.1.3 models were developed for the six basins. The HEC-RAS models were converted from UNET models previously developed by others. The HEC-RAS models were then modified using Jefferson Parish LIDAR mapping, flown in 2002, additional field surveys and data from as-built plans in order to reflect 2005 existing conditions. Additional geometry files for 1995, 1998, 2001 and 2002 were developed for calibration purposes based on the selected calibration storms by basin.

Only the 2005 geometry was used for this study. Only the East Bank, Bayou-Segnette, Ames-Westwego, Harvey-Estelle-Cousins and East of Harvey Canal basins were modeled. The Hoey's basin was not used since it overlapped with models in Orleans Parish. However, data from the Hoey's basin model was provided for use in the Orleans Parish modeling effort.

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General Modeling Approach

The general modeling approach focused on developing updated models for the Katrina event and no levee failure condition using the current Jefferson Parish DFIRM RAS models. The DFIRM model was geo-referenced and reviewed for accuracy and completeness. An updated version of HEC-RAS 3.2, provided by HEC, was used to facilitate efficient geo-referencing as well as improve stability during pump operations. Significant changes to channel geometry, structures, cross-sections and storage areas were made throughout the Bayou Segnette, Ames-Westwego and East of Harvey Canal basins in order to improve model accuracy. During this period, GeoRAS layers were developed, ArcGIS map documents were produced and the project datum was adjusted to NAVD 88 (1994, 1996 Epoch). Concurrent to geo-referencing and model review, the HMS models were converted to HMS 3.0.0 and model parameters were reviewed. Following geo-referencing and conversion of the HMS models, each basin's boundary conditions were developed for the event scenario. The model was run under a "drawdown" condition to produce the scenario's initial conditions, during which the models underwent further review and debugging. After successfully developing the initial conditions, each scenario was run to a period following the peak inundation when stages returned to normal operating levels. Stage observations at pump stations and high water marks were then compared to computed stages to determine model accuracy for the Katrina event simulation. After reviewing model output, inundation depth grids were developed in ArcMap and flood maps were produced.

Hydrologic Model Development

Background

As previously mentioned, Jefferson Parish is divided into six sub-basins (see Figure 1-1): East Bank, Hoey's, Bayou Segnette, Ames-Westwego, Harvey-Estelle-Cousins and East of Harvey Canal. All runoff travels to the downstream pump stations, where it is pumped to the outer canals or Lake Pontchartrain. With the exception of Bayou Segnette, the sub-basins are urbanized with extensive storm drain systems. HMS sub-basins originally developed by others for Bayou Segnette, Ames-Westwego and East of Harvey Canal were later revised for the Katrina modeling effort. Curve numbers, slopes and sub-basin boundaries were adjusted to improve model accuracy for the Katrina event.

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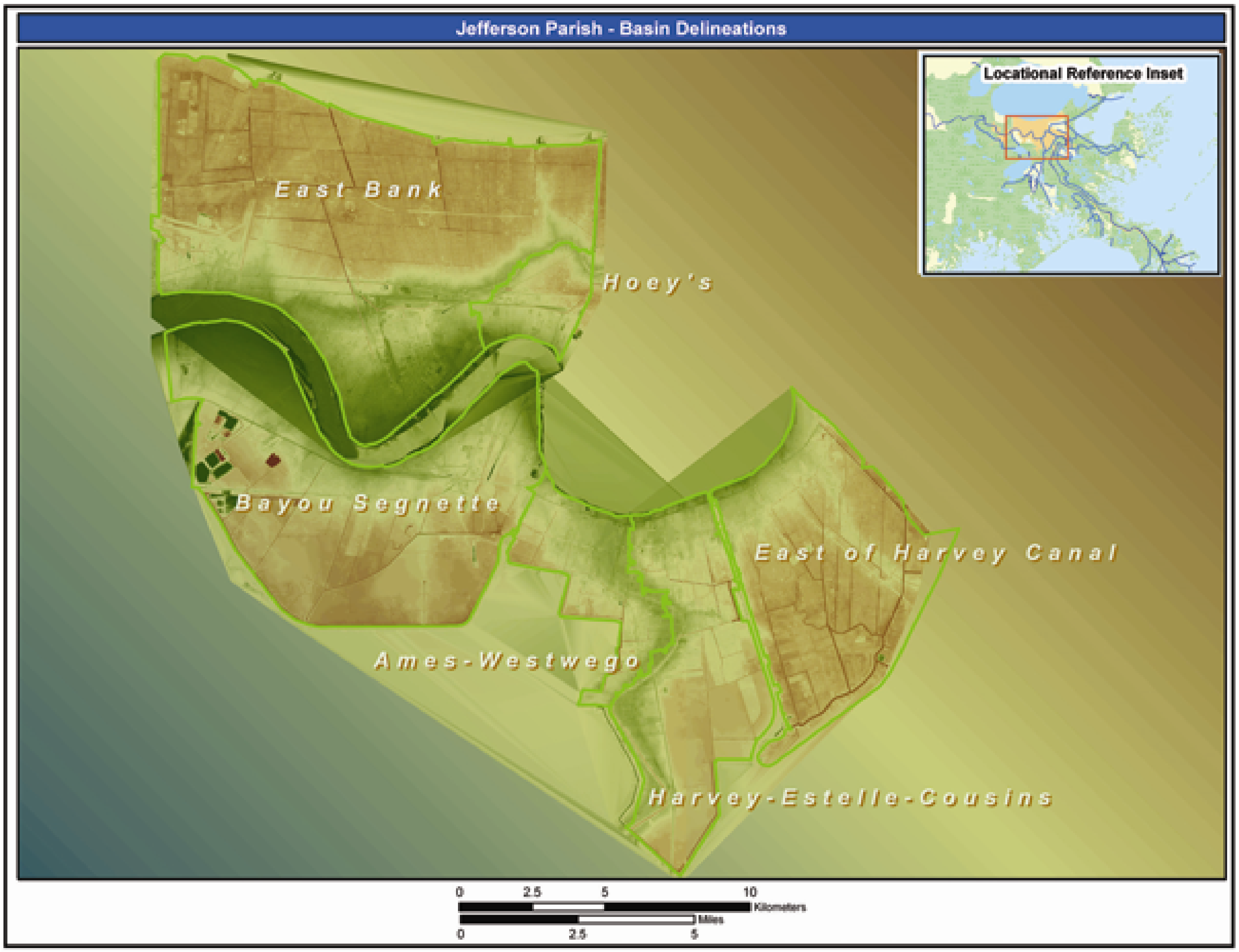

Figure 1-1. Jefferson Parish HMS Basin Delineations

Development of GIS Watershed Model

Sub-basin shape files were manually delineated in ArcGIS using contour data, storm drains mapping and canal geometry as shown in Figure 1-2. . Basin boundaries correspond to storage areas defined in the HEC-RAS model for this area. A shapefile of subbasin boundaries was used for estimating HEC-HMS model parameters, curve numbers and lag times, and determining subbasin average precipitation from the radar-rainfall data.

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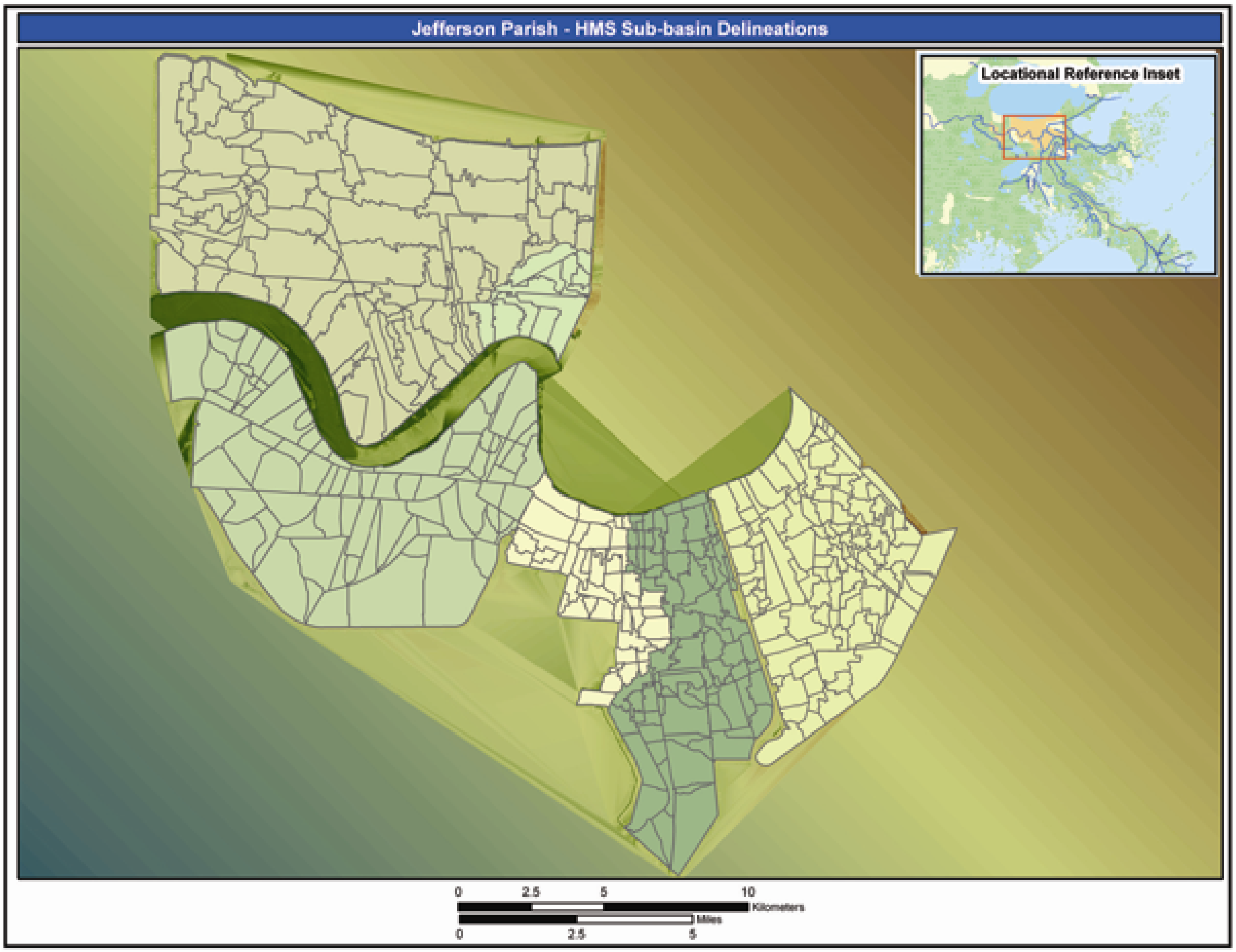

Figure 1-2. Jefferson Parish HMS Sub-Basin Delineations

Model Parameters

Model parameters used for the Katrina event were selected from the previously developed HMS models. Curve numbers for East Bank, Harvey-Estelle-Cousins, Ames-Westwego and East of Harvey Canal remained the same, while curve numbers for Bayou Segnette were re-computed based on revised sub-basin delineation. Curve numbers for all basins were developed using existing zoning maps provided by Jefferson Parish, the NRCS soil survey and aerial photographs. Directly connected imperviousness for East Bank, Hoey's and Harvey-Estelle-Cousins was estimated at 25% of the impervious percentage for each land use. Flow paths were also taken from the previously developed HMS models for all basins. The slope used in the lag time calculations was taken from the previously developed HMS models for East Bank and Harvey-Estelle-Cousins. For Bayou Segnette, Ames-Westwego and East of Harvey Canal, the average sub-basin slope was developed using ESRI's ArcMap Spatial Analyst surface analysis slope calculator and zonal statistics tool. A slope surface analysis was completed at a 200' cell size and averaged for each sub-basin.

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Rainfall Data

Radar rainfall data, referred to as Multisensor Precipitation Estimator (MPE), was used as a boundary condition in the hydrologic models to determine runoff hydrographs produced by the Hurricane Katrina event. MPE data from the Lower Mississippi River Forecast Center (LMRFC) was downloaded from the following website: http://dipper.nws.noaa.gov/hdsb/data/nexrad/lmrfc_mpe.php. Raw radar data is adjusted using rain gage measurements and possibly satellite data to produce the MPE product.

The radar-rainfall data was imported into a GIS program. The GIS program was used to compute subbasin average precipitation; the downloaded radar-rainfall data was a raster or gridded coverage of precipitation. Also, the downloaded radar-rainfall data provides hourly estimates of precipitation. A precipitation hyetograph was computed for each subbasin in the Jefferson Parish basin models. The individual hyetographs were imported into an HEC-DSS file where they were read by HEC-HMS. . Total rainfall from Hurricane Katrina varied from 9 to 12 inches across subbasins in Jefferson Parish (Figure 1-3).

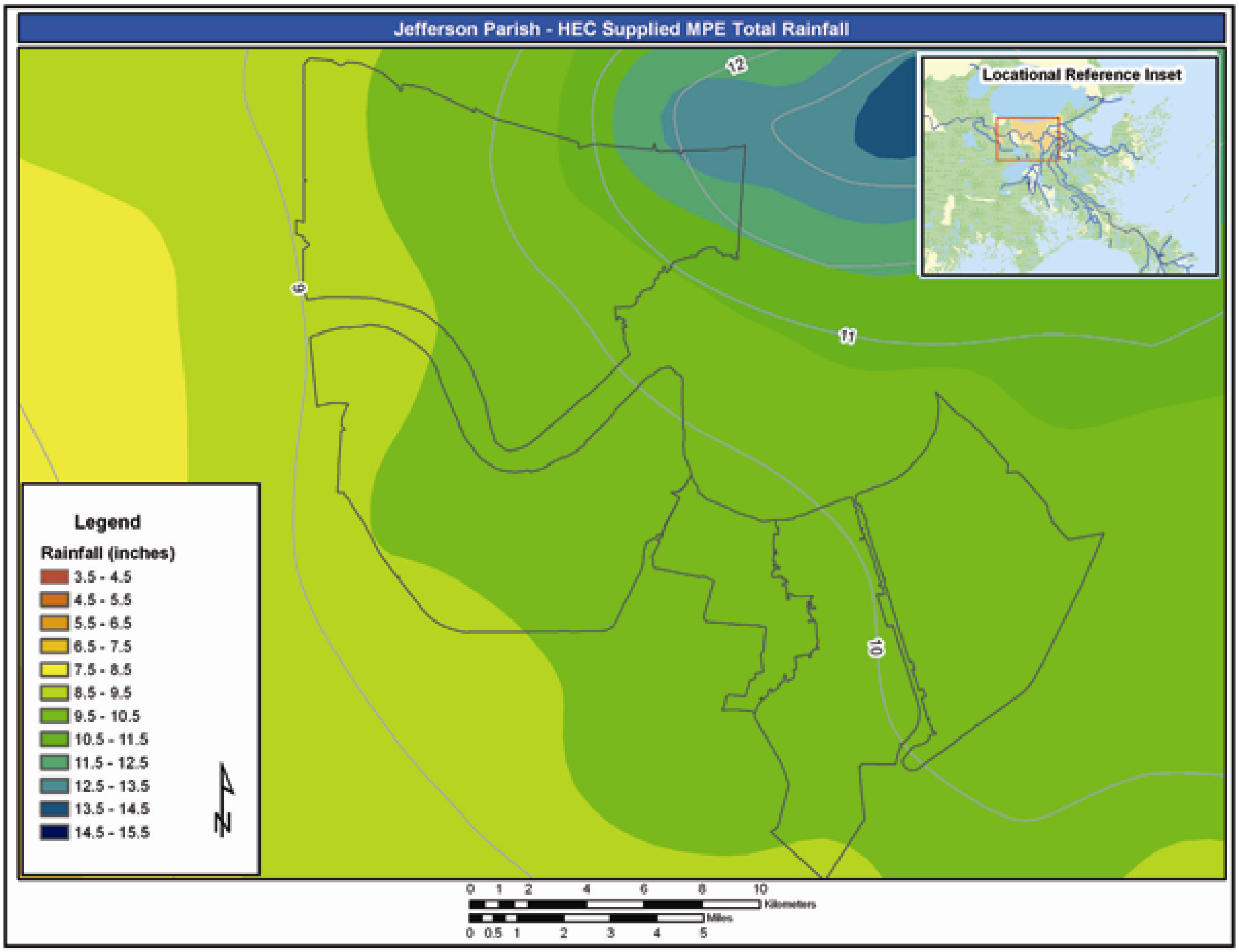

Figure 1-3. Jefferson Parish Total Rainfall Contours

Model Results

For Katrina, the average rainfall and runoff in acre-feet by basin is shown in Figure 1-4. Figure 1-4 also includes the total estimated backflow for the East Bank basin. Each basin's total runoff and representative rainfall distribution is plotted in Figures 1-5 through 1-9. Total runoff volume by basin was 21,100 acre-ft, 12,400 acre-ft, 3,200 acre-ft, 6,300 acre-ft and 9,600 acre-ft for East Bank, Bayou Segnette, Ames-Westwego, Harvey-Estelle-Cousins and East of Harvey Canal, respectively. The total estimated backflow for the East Bank basin was 2,500 acre-ft,

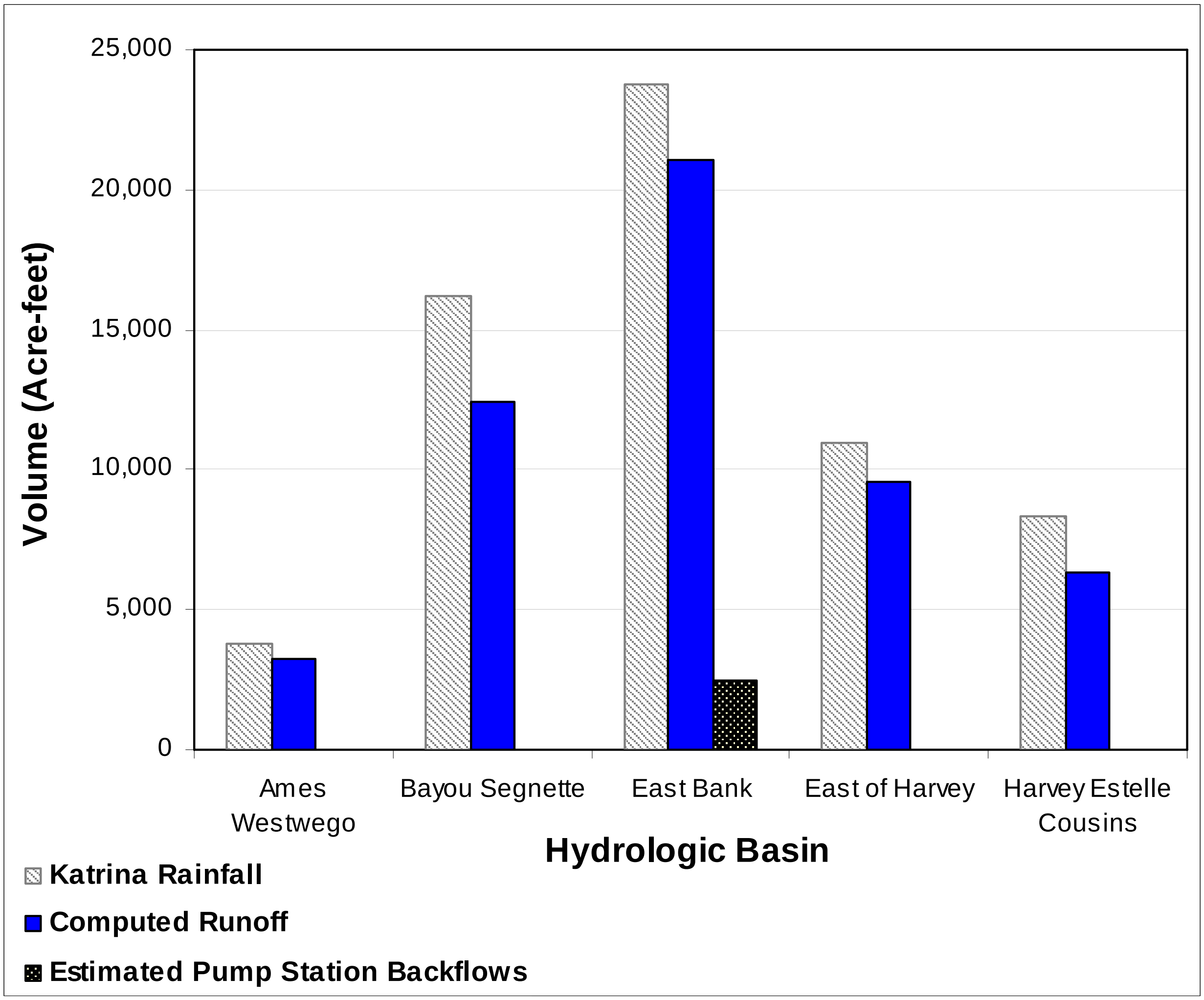

Figure 1-4. Jefferson Parish Total Rainfall, Runoff and Estimated Backflows by Basin

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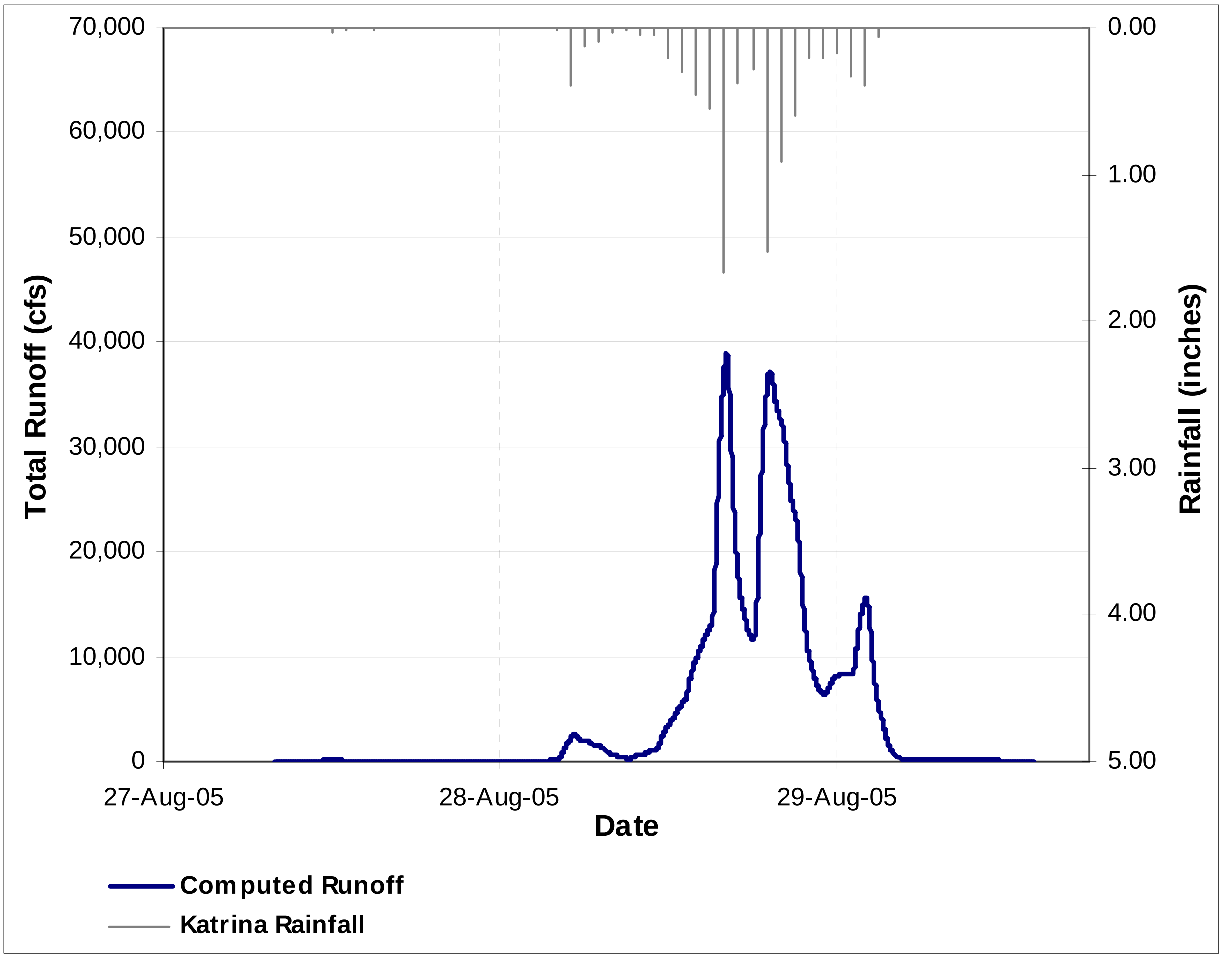

Figure 1-5. East Bank Total Computed Runoff and Typical Katrina Rainfall Distribution

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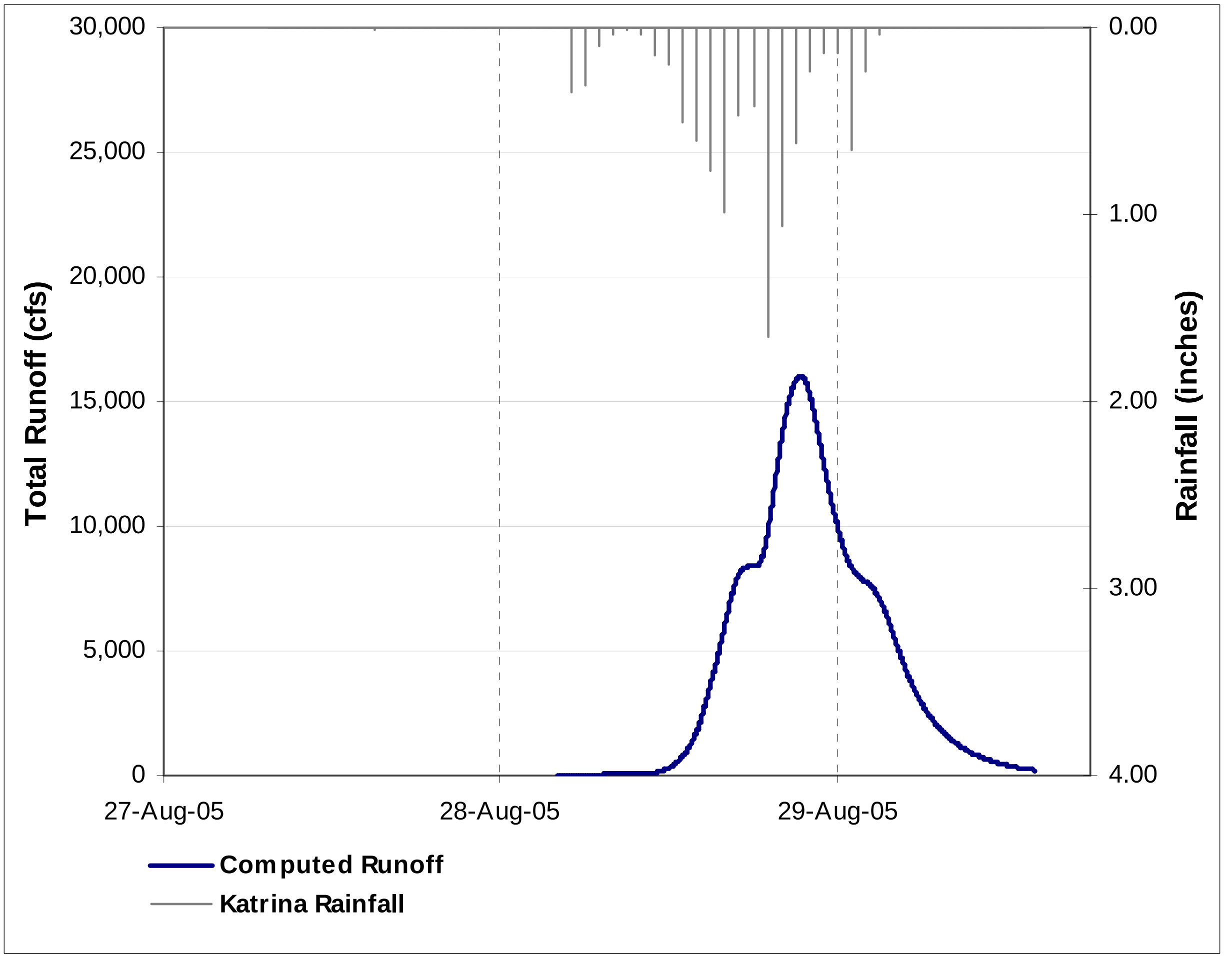

Figure 1-6. Bayou Segnette Total Computed Runoff and Typical Katrina Rainfall Distribution

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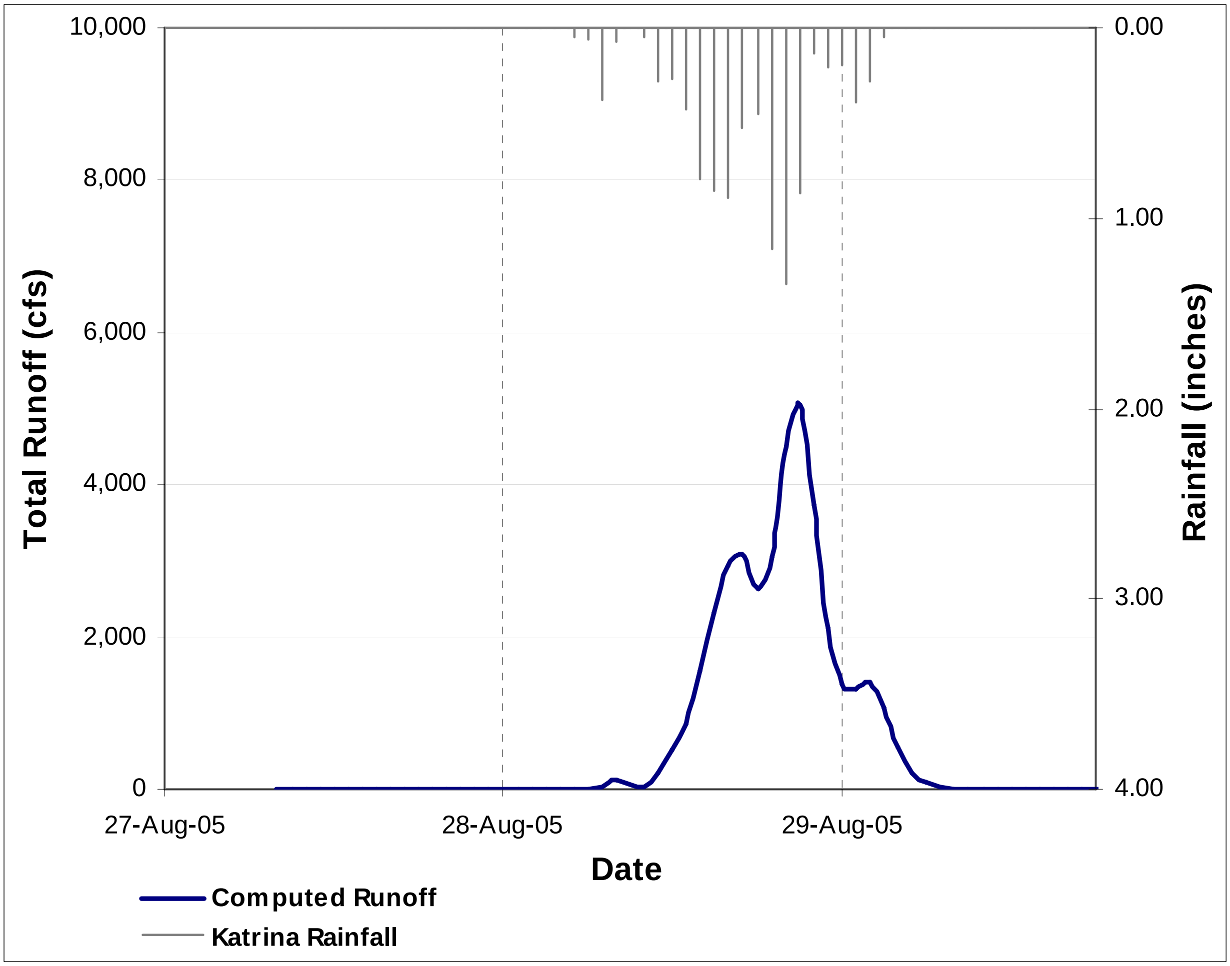

Figure 1-7. Ames-Westwego Total Computed Runoff and Typical Katrina Rainfall Distribution

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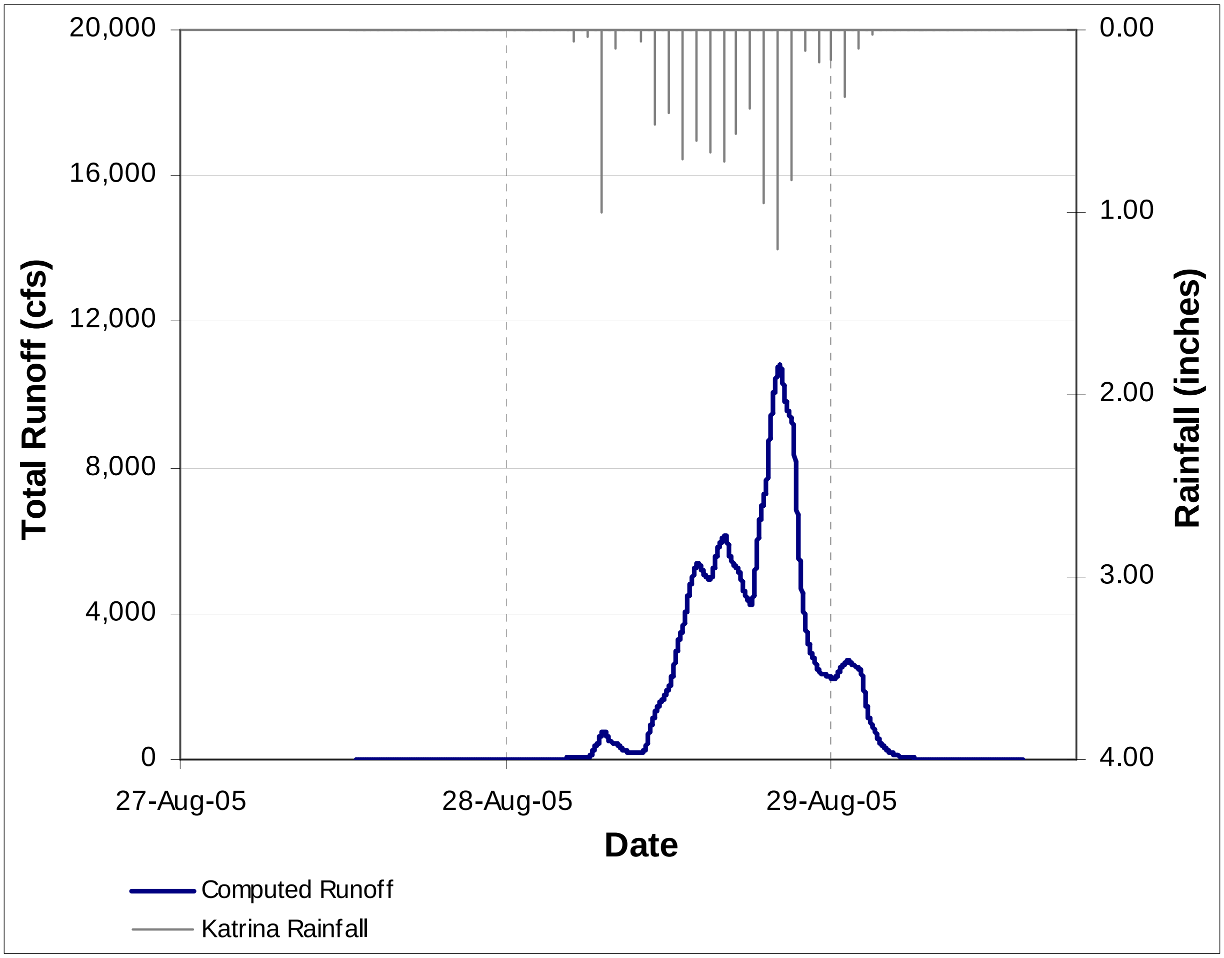

Figure 1-8. Harvey-Estelle-Cousins Total Computed Runoff and Typical Katrina Rainfall Distribution

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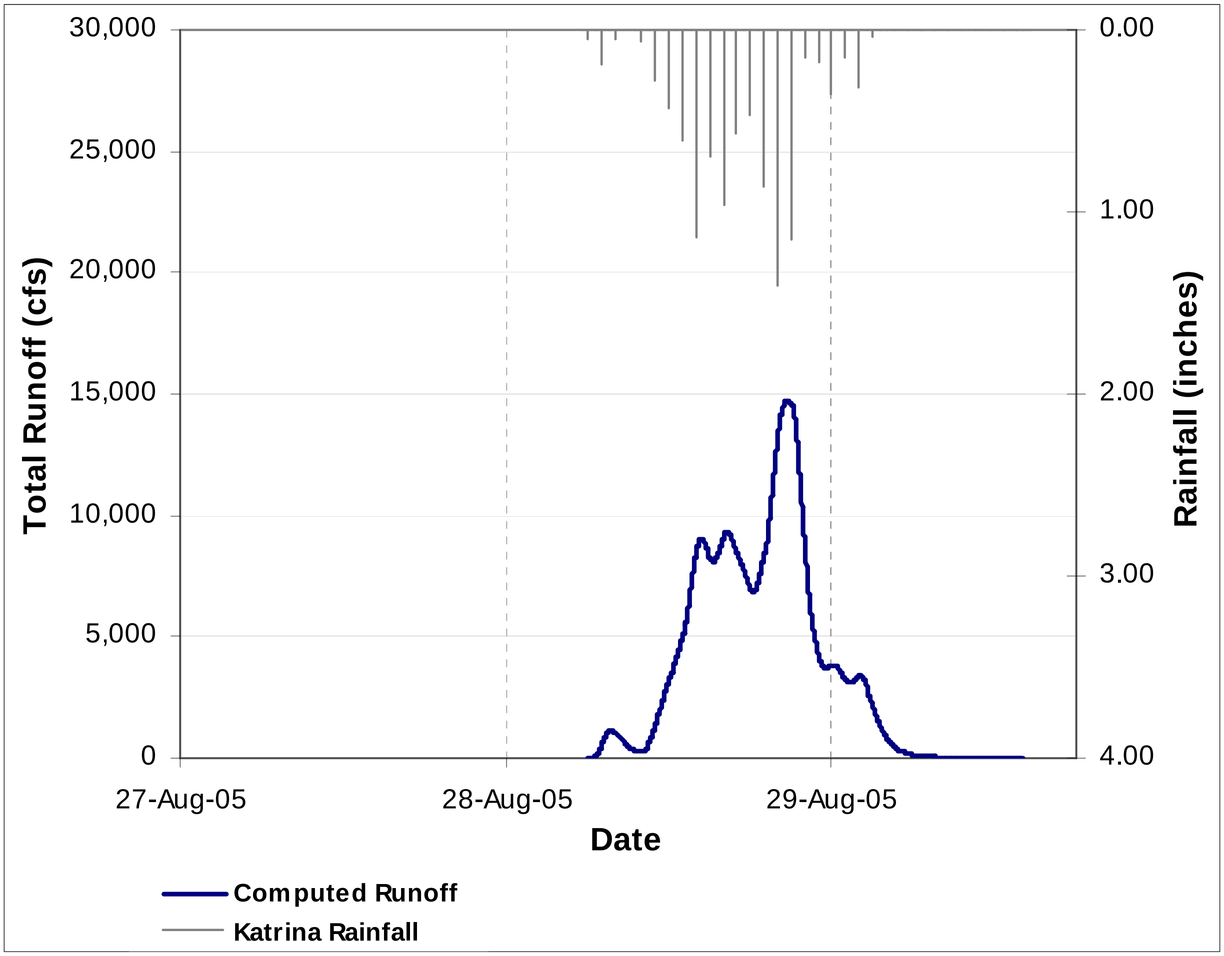

Figure 1-9. East of Harvey Canal Total Computed Runoff and Typical Katrina Rainfall Distribution

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with the Elmwood pump station contributing 2,230 acre-ft. Tables 1-21 through 1-6 present the drainage area, peak discharge, time of peak discharge and runoff volume for each sub-basin within each of the basins.

Table 1-2
Summary of Hydrologic Analysis Results for East Bank Sub-basins 1-30

Subbasin Name	Drainage Area (mi^2)	Peak Discharge (cfs)	Time of Peak	Runoff Volume (in)
EB 1	0.32	284	29Aug2005, 04:12	7.9
EB 2	0.10	97	29Aug2005, 04:04	8.4
EB 3	0.22	184	29Aug2005, 04:24	8.4
EB 4	0.34	324	29Aug2005, 04:08	8.4
EB 5	0.71	637	29Aug2005, 04:14	8.2
EB 6	0.15	152	29Aug2005, 04:04	8.4
EB 7	0.32	243	29Aug2005, 04:36	8.5
EB 8	0.34	344	29Aug2005, 04:04	8.5
EB 9	0.18	185	29Aug2005, 04:02	8.6
EB 10	0.15	158	29Aug2005, 04:02	8.4
EB 11	0.13	124	29Aug2005, 04:08	8.6
EB 12	0.06	67	29Aug2005, 04:02	8.6
EB 13	0.16	152	29Aug2005, 04:12	8.6
EB 14	0.20	203	29Aug2005, 04:04	8.6
EB 15	0.48	446	29Aug2005, 04:10	8.2
EB 16	0.48	480	29Aug2005, 04:06	8.6
EB 17	0.05	50	29Aug2005, 04:00	8.6
EB 18	1.38	1071	29Aug2005, 07:26	7.6
EB 19	0.33	260	29Aug2005, 07:34	8.4
EB 20	0.19	151	29Aug2005, 07:18	8.1
EB 21	0.47	394	29Aug2005, 07:16	8.3
EB 22	0.42	408	29Aug2005, 04:06	8.6
EB 23	0.95	990	29Aug2005, 04:02	8.6
EB 24	0.55	511	29Aug2005, 04:06	8.6
EB 25	0.51	424	29Aug2005, 07:28	8.2
EB 26	0.30	286	29Aug2005, 07:08	8.4
EB 27	0.23	265	29Aug2005, 04:04	9.3
EB 28	0.18	205	29Aug2005, 04:04	9.3
EB 29	0.09	100	29Aug2005, 04:04	9.3
EB 30	0.11	115	29Aug2005, 04:02	8.4

Table 1-2 (Continued)
Summary of Hydrologic Analysis Results for East Bank Sub-basins 31-60

Subbasin Name	Drainage Area (mi^2)	Peak Discharge (cfs)	Time of Peak	Runoff Volume (in)
EB 31	0.17	177	29Aug2005, 04:06	8.7
EB 32	0.18	191	29Aug2005, 04:02	8.7
EB 33	0.06	54	29Aug2005, 04:00	8.6
EB 34	0.16	146	29Aug2005, 04:04	8.6
EB 35	0.31	212	29Aug2005, 07:50	8.0
EB 36	1.31	1248	29Aug2005, 07:08	8.7
EB 37	1.31	1211	29Aug2005, 04:20	8.9
EB 38	0.78	769	29Aug2005, 04:20	9.3
EB 39	0.68	763	29Aug2005, 04:04	9.1
EB 40	1.62	1555	29Aug2005, 04:08	8.5
EB 41	0.28	270	29Aug2005, 07:06	8.2
EB 42	0.75	632	29Aug2005, 07:24	8.0
EB 43	0.42	369	29Aug2005, 07:40	8.4
EB 44	0.95	823	29Aug2005, 07:40	8.7
EB 45	0.42	374	29Aug2005, 07:38	8.8
EB 46	0.17	162	29Aug2005, 07:06	8.5
EB 47	0.07	63	29Aug2005, 07:02	8.2
EB 48	1.20	1019	29Aug2005, 07:24	8.1
EB 49	0.55	464	29Aug2005, 07:24	7.9
EB 50	0.11	114	29Aug2005, 07:00	8.4
EB 51	0.15	166	29Aug2005, 04:02	9.0
EB 52	0.23	268	29Aug2005, 04:02	9.2
EB 53	0.69	533	29Aug2005, 08:22	8.4
EB 54	0.21	182	29Aug2005, 07:32	8.6
EB 55	0.10	90	29Aug2005, 07:06	8.8
EB 56	0.16	148	29Aug2005, 07:06	8.8
EB 57	0.52	486	29Aug2005, 07:06	8.5
EB 58	0.06	54	29Aug2005, 07:10	8.8
EB 59	0.25	209	29Aug2005, 08:00	8.6
EB 60	0.44	418	29Aug2005, 07:06	8.7

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Table 1-2 (Concluded)
Summary of Hydrologic Analysis Results for East Bank Sub-basins 61-105

Subbasin Name	Drainage Area (mi^2)	Peak Discharge (cfs)	Time of Peak	Runoff Volume (in)
EB 61	0.24	200	29Aug2005, 08:02	8.7
EB 62	0.47	422	29Aug2005, 07:06	8.5
EB 63	0.20	192	29Aug2005, 07:04	8.7
EB 64	0.13	120	29Aug2005, 07:02	8.8
EB 65	0.14	132	29Aug2005, 07:06	8.5
EB 66	0.34	319	29Aug2005, 07:06	8.8
EB 67	0.11	103	29Aug2005, 07:04	8.8
EB 68	0.11	100	29Aug2005, 07:10	8.8
EB 69	0.25	211	29Aug2005, 07:14	7.7
EB 70	0.32	332	29Aug2005, 04:06	8.9
EB 71	1.50	1504	29Aug2005, 04:04	8.8
EB 72	1.91	2003	29Aug2005, 04:06	8.8
EB 73	1.08	1132	29Aug2005, 04:08	9.1
EB 74	0.35	402	29Aug2005, 04:04	9.2
EB 75	0.22	255	29Aug2005, 04:00	9.0
EB 76	0.28	275	29Aug2005, 07:08	8.8
EB 77	0.08	71	29Aug2005, 07:14	8.0
EB 78	1.75	1610	29Aug2005, 04:12	8.8
EB 79	0.22	182	29Aug2005, 08:10	8.4
EB 80	0.09	78	29Aug2005, 07:22	8.6
EB 81	0.14	114	29Aug2005, 08:08	8.4
EB 82	0.10	88	29Aug2005, 04:14	8.8
EB 83	0.06	56	29Aug2005, 04:06	8.9
EB 84	0.10	90	29Aug2005, 04:08	8.8
EB 85	0.07	65	29Aug2005, 04:06	8.7
EB 86	0.26	215	29Aug2005, 08:08	8.3
EB 87	0.61	484	29Aug2005, 04:22	8.8
EB 88	0.12	133	29Aug2005, 04:02	8.8
EB 89	0.41	451	29Aug2005, 04:06	9.4
EB 90	0.24	271	29Aug2005, 04:00	9.2
EB 91	0.16	126	29Aug2005, 07:30	8.4
EB 92	1.59	1361	29Aug2005, 04:16	8.9
EB 93	1.20	1271	29Aug2005, 04:04	10.2
EB 94	1.42	1527	29Aug2005, 04:04	11.6
EB 95	0.19	174	29Aug2005, 04:04	8.6
EB 96	0.04	32	29Aug2005, 04:04	8.3
EB 97	0.33	299	29Aug2005, 04:08	8.8
EB 98	0.13	157	29Aug2005, 04:00	13.8
EB 99	0.09	98	29Aug2005, 04:10	14.4
EB 100	0.24	233	29Aug2005, 04:02	9.1
EB 101	0.39	336	29Aug2005, 04:12	8.7
EB 102	0.40	429	29Aug2005, 04:10	13.4
EB 103	0.33	340	29Aug2005, 04:04	11.5
EB 104	0.24	282	29Aug2005, 04:06	14.5
EB 105	0.93	1034	29Aug2005, 04:08	14.2

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Table 1-3
Summary of Hydrologic Analysis Results for Bayou Segnette Sub-basins 1-40

Subbasin Name	Drainage Area (mi^2)	Peak Discharge (cfs)	Time of Peak	Runoff Volume (in)
1	0.82	474	29Aug2005, 10:26	7.8
2	0.23	167	29Aug2005, 09:02	7.7
3	0.64	477	29Aug2005, 09:04	8.9
4	0.20	133	29Aug2005, 09:16	7.6
5	0.77	511	29Aug2005, 09:22	7.6
6	0.20	123	29Aug2005, 09:28	6.9
7	0.20	134	29Aug2005, 09:04	7.1
8	0.45	313	29Aug2005, 09:06	7.4
9	0.63	335	29Aug2005, 10:38	7.4
10	0.51	313	29Aug2005, 09:56	7.9
11	0.19	130	29Aug2005, 08:56	7.5
12	0.38	242	29Aug2005, 09:40	7.9
13	0.09	68	29Aug2005, 08:50	7.5
14	0.11	83	29Aug2005, 08:30	7.7
15	0.13	93	29Aug2005, 08:58	7.7
16	0.18	133	29Aug2005, 08:44	7.1
17	0.11	79	29Aug2005, 08:46	7.9
18	0.21	120	29Aug2005, 10:02	7.2
19	0.43	295	29Aug2005, 09:18	7.7
20	0.05	41	29Aug2005, 08:24	7.8
21	0.48	278	29Aug2005, 10:20	8.1
22	0.18	96	29Aug2005, 10:42	7.4
23	0.59	373	29Aug2005, 09:36	7.4
24	0.11	84	29Aug2005, 08:36	7.7
25	0.09	68	29Aug2005, 08:36	7.6
26	0.77	434	29Aug2005, 10:20	7.7
27	0.16	118	29Aug2005, 08:44	7.6
28	0.63	399	29Aug2005, 09:32	7.4
29	0.16	106	29Aug2005, 09:20	7.8
30	0.43	257	29Aug2005, 09:46	7.7
31	0.14	87	29Aug2005, 09:40	7.8
32	0.05	37	29Aug2005, 08:16	6.9
33	0.03	22	29Aug2005, 08:26	7.0
34	0.05	35	29Aug2005, 08:28	7.4
35	0.16	103	29Aug2005, 09:02	7.5
36	0.25	167	29Aug2005, 09:22	7.8
37	0.05	38	29Aug2005, 08:12	7.0
38	0.28	169	29Aug2005, 09:28	7.3
39	0.31	195	29Aug2005, 09:24	7.5
40	0.19	127	29Aug2005, 09:00	7.7

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Table 1-3 (Concluded)
Summary of Hydrologic Analysis Results for Bayou Segnette Sub-basins 41-85

Subbasin Name	Drainage Area (mi^2)	Peak Discharge (cfs)	Time of Peak	Runoff Volume (in)
41	0.27	191	29Aug2005, 08:46	7.7
42	0.32	233	29Aug2005, 08:44	8.1
43	0.25	175	29Aug2005, 09:00	8.1
44	0.28	183	29Aug2005, 09:06	7.3
45	0.12	89	29Aug2005, 08:14	7.4
46	2.06	920	29Aug2005, 11:52	7.7
47	0.34	229	29Aug2005, 09:06	7.7
48	0.45	293	29Aug2005, 09:26	7.9
49	0.26	150	29Aug2005, 10:02	7.6
50	0.22	139	29Aug2005, 09:30	7.8
51	0.64	305	29Aug2005, 11:06	7.6
52	0.16	99	29Aug2005, 09:24	7.5
53	2.08	769	29Aug2005, 12:58	7.1
54	0.42	184	29Aug2005, 11:34	7.2
55	0.35	152	29Aug2005, 11:14	7.2
56	0.31	144	29Aug2005, 10:54	7.2
57	0.44	241	29Aug2005, 10:02	7.4
58	0.57	300	29Aug2005, 10:32	7.5
59	0.29	226	29Aug2005, 07:54	7.6
60	1.27	679	29Aug2005, 10:26	7.7
61	0.45	258	29Aug2005, 10:14	7.9
62	0.12	83	29Aug2005, 08:24	7.0
63	0.16	117	29Aug2005, 08:22	7.1
64	0.09	72	29Aug2005, 07:56	7.1
65	0.07	54	29Aug2005, 07:46	7.5
66	0.47	258	29Aug2005, 09:50	7.4
67	0.31	204	29Aug2005, 08:42	7.3
68	1.28	489	29Aug2005, 12:20	6.8
69	0.18	100	29Aug2005, 09:50	6.8
70	0.29	174	29Aug2005, 09:18	6.8
71	0.87	297	29Aug2005, 13:36	6.8
72	0.30	161	29Aug2005, 09:42	6.5
73	0.22	162	29Aug2005, 08:12	6.9
74	0.26	114	29Aug2005, 10:40	6.4
75	0.11	62	29Aug2005, 09:04	6.5
76	0.09	54	29Aug2005, 09:06	6.3
77	0.49	286	29Aug2005, 09:32	6.9
78	0.11	80	29Aug2005, 07:54	6.6
79	0.06	47	29Aug2005, 07:48	6.8
80	0.20	120	29Aug2005, 08:56	7.2
81	0.32	167	29Aug2005, 09:46	6.9
82	0.15	74	29Aug2005, 09:56	7.0
83	0.40	270	29Aug2005, 08:50	7.4
84	0.87	664	29Aug2005, 08:00	7.0
85	0.76	595	29Aug2005, 07:50	7.0

Table 1-4
Summary of Hydrologic Analysis Results for Ames-Westwego

Subbasin Name	Drainage Area (mi^2)	Peak Discharge (cfs)	Time of Peak	Runoff Volume (in)
1	0.05	46	29Aug2005, 08:04	8.9
2	0.05	44	29Aug2005, 08:08	8.8
3	0.18	142	29Aug2005, 09:04	8.9
4	0.13	88	29Aug2005, 09:28	8.5
5	0.12	85	29Aug2005, 09:08	8.3
6	0.19	124	29Aug2005, 09:22	8.1
7	0.08	63	29Aug2005, 08:08	8.4
8	0.18	120	29Aug2005, 09:18	8.1
9	0.10	78	29Aug2005, 08:24	8.6
10	0.10	75	29Aug2005, 08:38	8.3
11	0.30	189	29Aug2005, 09:38	8.1
12	0.08	53	29Aug2005, 09:14	7.9
13	0.09	68	29Aug2005, 08:46	8.2
14	0.06	50	29Aug2005, 08:20	8.3
15	0.22	147	29Aug2005, 08:38	8.5
16	0.16	118	29Aug2005, 08:36	8.4
17	0.03	29	29Aug2005, 08:06	7.7
18	0.14	106	29Aug2005, 08:26	7.8
19	0.25	182	29Aug2005, 08:46	8.2
20	0.11	82	29Aug2005, 08:28	8.3
21	0.01	12	29Aug2005, 08:04	8.7
22	0.22	198	29Aug2005, 08:24	9.1
23	0.30	219	29Aug2005, 09:22	8.7
24	0.13	90	29Aug2005, 09:14	8.6
25	0.20	138	29Aug2005, 09:02	8.1
26	0.09	77	29Aug2005, 08:10	8.3
27	0.18	142	29Aug2005, 08:30	8.5
28	0.08	61	29Aug2005, 08:34	7.7
29	0.19	127	29Aug2005, 09:04	7.9
30	0.21	144	29Aug2005, 09:06	8.5
31	0.16	110	29Aug2005, 08:56	7.9
32	0.15	121	29Aug2005, 08:16	8.5
33	0.19	138	29Aug2005, 08:34	8.0
34	0.06	51	29Aug2005, 08:02	9.0
35	0.16	116	29Aug2005, 08:44	8.1
36	0.13	99	29Aug2005, 09:16	8.7
37	0.45	372	29Aug2005, 08:36	8.5
38	0.66	463	29Aug2005, 09:38	8.7
39	0.25	190	29Aug2005, 08:52	8.7
40	0.19	137	29Aug2005, 08:58	8.0
41	0.12	76	29Aug2005, 09:18	7.5
42	0.16	108	29Aug2005, 08:58	7.5
43	0.18	125	29Aug2005, 08:40	7.4
44	0.18	122	29Aug2005, 08:32	8.3

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Table 1-5
Summary of Hydrologic Analysis Results for Harvey-Estelle-Cousins Sub-basins 1-40

Subbasin Name	Drainage Area (mi^2)	Peak Discharge (cfs)	Time of Peak	Runoff Volume (in)
HEC 1	0.06	52	29Aug2005, 08:04	8.0
HEC 2	0.09	77	29Aug2005, 08:00	7.8
HEC 3	0.09	72	29Aug2005, 08:02	7.2
HEC 4	0.03	27	29Aug2005, 08:02	7.8
HEC 5	0.03	26	29Aug2005, 08:02	7.6
HEC 6	0.05	42	29Aug2005, 08:04	7.6
HEC 7	0.07	52	29Aug2005, 08:12	6.3
HEC 8	0.14	111	29Aug2005, 08:08	7.3
HEC 9	0.08	78	29Aug2005, 08:00	8.6
HEC 10	0.07	65	29Aug2005, 08:00	7.6
HEC 11	0.10	90	29Aug2005, 08:06	8.1
HEC 12	0.14	114	29Aug2005, 08:14	7.3
HEC 13	0.09	71	29Aug2005, 08:02	7.2
HEC 14	0.17	147	29Aug2005, 08:18	8.3
HEC 15	0.33	268	29Aug2005, 08:08	8.1
HEC 16	0.09	81	29Aug2005, 08:00	8.6
HEC 17	0.36	320	29Aug2005, 08:04	8.2
HEC 18	0.24	211	29Aug2005, 08:04	8.0
HEC 19	0.42	352	29Aug2005, 08:08	7.7
HEC 20	0.13	122	29Aug2005, 08:00	9.0
HEC 21	0.34	304	29Aug2005, 08:02	8.0
HEC 22	0.14	124	29Aug2005, 08:14	8.2
HEC 23	0.12	110	29Aug2005, 08:04	8.0
HEC 24	0.04	39	29Aug2005, 08:04	8.7
HEC 25	0.13	122	29Aug2005, 08:00	8.4
HEC 26	0.12	104	29Aug2005, 08:08	8.5
HEC 27	0.02	20	29Aug2005, 08:00	8.5
HEC 28	0.14	128	29Aug2005, 08:00	8.7
HEC 29	0.07	66	29Aug2005, 08:04	8.7
HEC 30	0.20	165	29Aug2005, 08:02	7.7
HEC 31	0.35	289	29Aug2005, 08:08	8.0
HEC 32	0.19	146	29Aug2005, 08:30	8.3
HEC 33	0.17	141	29Aug2005, 08:06	8.5
HEC 34	0.15	109	29Aug2005, 08:36	7.2
HEC 35	0.22	188	29Aug2005, 08:00	8.4
HEC 36	0.24	202	29Aug2005, 08:02	8.3
HEC 37	0.04	34	29Aug2005, 08:02	7.6
HEC 38	0.06	50	29Aug2005, 08:04	7.2
HEC 39	0.12	105	29Aug2005, 08:04	8.4
HEC 40	0.03	25	29Aug2005, 08:00	8.2

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Table 1-5 (Concluded)
Summary of Hydrologic Analysis Results for Harvey-Estelle-Cousins Sub-basins 41-81

Subbasin Name	Drainage Area (mi^2)	Peak Discharge (cfs)	Time of Peak	Runoff Volume (in)
HEC 41	0.04	33	29Aug2005, 08:20	7.2
HEC 42	0.03	24	29Aug2005, 08:02	8.3
HEC 43	0.18	154	29Aug2005, 08:04	8.5
HEC 44	0.35	280	29Aug2005, 08:06	7.6
HEC 45	0.27	220	29Aug2005, 08:06	7.5
HEC 46	0.45	347	29Aug2005, 08:16	7.5
HEC 47	0.16	115	29Aug2005, 08:34	7.4
HEC 48	0.27	214	29Aug2005, 08:16	7.5
HEC 49	0.24	168	29Aug2005, 08:08	7.3
HEC 50	0.21	172	29Aug2005, 08:02	8.5
HEC 51	0.42	254	29Aug2005, 09:04	7.1
HEC 52	0.11	60	29Aug2005, 09:16	6.9
HEC 53	0.44	250	29Aug2005, 09:00	6.9
HEC 54	0.05	33	29Aug2005, 08:46	7.0
HEC 55	0.21	115	29Aug2005, 09:10	6.9
HEC 56	0.02	18	29Aug2005, 08:02	7.0
HEC 57	0.05	36	29Aug2005, 08:02	7.4
HEC 58	0.05	35	29Aug2005, 08:10	7.5
HEC 59	0.16	121	29Aug2005, 08:00	8.0
HEC 60	0.06	42	29Aug2005, 08:02	7.8
HEC 61	0.11	83	29Aug2005, 08:02	8.0
HEC 62	0.05	34	29Aug2005, 08:10	6.8
HEC 63	0.05	33	29Aug2005, 08:12	7.5
HEC 64	0.16	100	29Aug2005, 08:44	6.7
HEC 65	0.27	212	29Aug2005, 08:04	7.2
HEC 66	0.11	72	29Aug2005, 08:52	6.9
HEC 67	0.67	352	29Aug2005, 09:32	6.8
HEC 68	0.18	124	29Aug2005, 08:08	7.6
HEC 69	0.14	86	29Aug2005, 08:40	6.8
HEC 70	0.15	91	29Aug2005, 08:30	6.9
HEC 71	0.17	110	29Aug2005, 08:16	6.9
HEC 72	0.74	403	29Aug2005, 09:14	6.9
HEC 73	0.29	205	29Aug2005, 08:22	7.7
HEC 74	0.25	177	29Aug2005, 08:02	7.4
HEC 75	0.49	347	29Aug2005, 08:02	7.3
HEC 76	0.20	126	29Aug2005, 08:26	7.1
HEC 77	0.50	325	29Aug2005, 08:02	7.2
HEC 78	0.30	164	29Aug2005, 08:32	6.7
HEC 79	0.33	175	29Aug2005, 08:36	6.8
HEC 80	1.19	582	29Aug2005, 09:10	6.4
HEC 81	0.09	52	29Aug2005, 08:40	6.9

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Table 1-6
Summary of Hydrologic Analysis Results for East of Harvey Canal Sub-basins 1-30

Subbasin Name	Drainage Area (mi^2)	Peak Discharge (cfs)	Time of Peak	Runoff Volume (in)
1	0.20	162	29Aug2005, 08:46	9.0
2	0.44	308	29Aug2005, 09:26	8.7
3	0.10	80	29Aug2005, 08:46	9.0
4	0.19	146	29Aug2005, 08:56	8.8
5	0.27	202	29Aug2005, 09:10	8.9
6	0.06	51	29Aug2005, 08:24	9.3
7	0.10	82	29Aug2005, 08:48	8.9
8	0.07	53	29Aug2005, 08:50	8.9
9	0.14	110	29Aug2005, 08:32	9.1
10	0.08	70	29Aug2005, 08:14	9.2
11	0.04	33	29Aug2005, 08:18	8.9
12	0.05	45	29Aug2005, 08:18	8.7
13	0.04	35	29Aug2005, 08:16	8.8
14	0.11	92	29Aug2005, 08:24	9.3
15	0.02	16	29Aug2005, 08:00	10.0
16	0.00	4	29Aug2005, 08:00	10.1
17	0.01	8	29Aug2005, 08:00	9.8
18	0.44	220	29Aug2005, 11:14	8.2
19	0.12	91	29Aug2005, 09:12	9.4
20	0.40	357	29Aug2005, 08:18	9.3
21	0.24	178	29Aug2005, 09:10	8.9
22	0.59	465	29Aug2005, 08:36	8.6
23	0.09	54	29Aug2005, 10:16	7.9
24	0.33	264	29Aug2005, 08:34	8.9
25	0.39	258	29Aug2005, 09:24	7.3
26	0.16	129	29Aug2005, 08:26	8.7
27	0.38	340	29Aug2005, 08:38	9.2
28	0.06	50	29Aug2005, 08:06	9.1
29	0.30	255	29Aug2005, 09:08	9.0
30	0.04	36	29Aug2005, 08:02	9.1

Table 1-6 (Continued)
Summary of Hydrologic Analysis Results for East of Harvey Canal Sub-basins 31-80

Subbasin Name	Drainage Area (mi^2)	Peak Discharge (cfs)	Time of Peak	Runoff Volume (in)
31	0.17	144	29Aug2005, 08:08	8.7
32	0.25	243	29Aug2005, 08:16	9.3
33	0.48	443	29Aug2005, 08:32	9.1
34	0.09	87	29Aug2005, 08:18	9.3
39	0.07	73	29Aug2005, 08:08	9.0
41	0.29	282	29Aug2005, 08:20	9.3
42	0.26	233	29Aug2005, 08:34	8.8
43	0.14	133	29Aug2005, 08:20	9.0
44	0.12	109	29Aug2005, 08:20	8.6
45	0.15	123	29Aug2005, 08:32	8.8
46	0.13	119	29Aug2005, 08:30	8.7
47	0.12	111	29Aug2005, 08:14	8.9
48	0.16	128	29Aug2005, 08:26	8.6
50	0.17	146	29Aug2005, 08:38	9.0
51	0.09	82	29Aug2005, 08:18	9.5
52	0.14	114	29Aug2005, 08:24	9.2
53	0.03	26	29Aug2005, 08:14	8.6
54	0.23	181	29Aug2005, 08:46	9.0
55	0.05	45	29Aug2005, 08:08	9.1
56	0.13	95	29Aug2005, 08:54	8.7
57	0.20	149	29Aug2005, 08:36	8.7
58	0.07	56	29Aug2005, 08:08	8.8
59	0.11	86	29Aug2005, 08:10	8.6
60	0.08	66	29Aug2005, 08:08	9.1
61	0.06	50	29Aug2005, 08:02	9.3
62	0.06	56	29Aug2005, 08:00	9.6
63	0.05	44	29Aug2005, 08:04	9.1
64	0.07	61	29Aug2005, 08:14	8.9
65	0.05	41	29Aug2005, 08:04	8.9
66	0.11	86	29Aug2005, 08:44	8.8
67	0.13	111	29Aug2005, 08:10	8.7
68	0.10	81	29Aug2005, 08:28	8.6
69	0.07	59	29Aug2005, 08:12	8.4
70	0.10	89	29Aug2005, 08:04	8.6
71	0.11	88	29Aug2005, 08:10	8.9
72	0.22	170	29Aug2005, 08:20	8.3
73	0.26	199	29Aug2005, 08:22	8.6
74	0.12	93	29Aug2005, 08:12	8.7
75	0.20	173	29Aug2005, 08:18	8.9
76	0.13	106	29Aug2005, 08:24	8.7
77	0.14	105	29Aug2005, 09:02	8.7
78	0.08	60	29Aug2005, 08:18	9.2
79	0.03	28	29Aug2005, 08:02	8.8
80	0.13	97	29Aug2005, 08:48	8.3

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Table 1-6 (Concluded)
Summary of Hydrologic Analysis Results for East of Harvey Canal Sub-basins 81-118

Subbasin Name	Drainage Area (mi^2)	Peak Discharge (cfs)	Time of Peak	Runoff Volume (in)
81	0.06	50	29Aug2005, 08:18	9.0
82	0.18	135	29Aug2005, 08:44	8.7
83	0.12	85	29Aug2005, 09:04	8.7
84	0.23	161	29Aug2005, 09:10	8.8
85	0.16	114	29Aug2005, 08:56	8.3
86	0.13	99	29Aug2005, 08:42	9.2
87	0.02	17	29Aug2005, 08:10	9.2
88	0.31	209	29Aug2005, 09:16	8.6
89	0.07	52	29Aug2005, 08:18	8.8
90	0.04	31	29Aug2005, 08:26	8.7
91	0.08	58	29Aug2005, 09:08	8.5
92	0.11	83	29Aug2005, 08:24	9.5
93	0.33	213	29Aug2005, 09:14	8.9
94	0.02	18	29Aug2005, 08:08	8.3
95	0.47	307	29Aug2005, 09:38	9.1
96	0.44	297	29Aug2005, 09:22	8.9
97	0.26	185	29Aug2005, 09:06	8.8
98	0.39	262	29Aug2005, 09:24	8.6
99	0.04	39	29Aug2005, 08:04	9.1
100	0.35	244	29Aug2005, 09:10	8.1
101	0.18	137	29Aug2005, 08:32	8.7
102	0.20	150	29Aug2005, 08:56	8.9
103	0.20	134	29Aug2005, 09:06	8.7
104	0.11	70	29Aug2005, 09:02	8.3
105	0.26	191	29Aug2005, 08:38	9.4
106	0.43	287	29Aug2005, 09:08	9.1
107	0.18	124	29Aug2005, 08:50	9.2
108	0.10	81	29Aug2005, 08:10	8.1
109	0.03	29	29Aug2005, 08:04	8.9
110	0.59	396	29Aug2005, 09:20	8.5
111	0.21	162	29Aug2005, 08:22	8.5
112	0.20	148	29Aug2005, 08:36	8.8
113	0.49	345	29Aug2005, 09:04	9.2
114	0.13	93	29Aug2005, 08:40	9.5
115	0.76	532	29Aug2005, 08:48	9.6
116	0.35	254	29Aug2005, 08:28	9.7
117	0.20	136	29Aug2005, 08:30	9.3
118	0.46	285	29Aug2005, 08:56	9.0

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RAS Interior Modeling

Background

Jefferson Parish consists of six basins hydraulically isolated from each other. Basin drainage areas are shown in Table 1-7. The East Bank basin drains to the North toward Lake Pontchartrain, where water is pumped to the lake by pump stations Parish Line, Duncan, Elmwood, Suburban, Bonnabel and Canal Street. East of Harvey Canal drains generally to the South and East, where water is pumped to the Intracoastal Waterway by pump stations Hero, Planter's and Engineer's. Harvey-Estelle-Cousins generally drains to the East, with pump stations Estelle, New Estelle, Cousins and Harvey routing flow to the Harvey Canal. The Ames-Westwego basin flows south to pump stations Westwego I, Westwego II, Westminster and Ames, where flow is diverted to Lake Cataouatche and the Intracoastal Waterway. Bayou Segnette also flows south, where water is pumped to Lake Cataouatche and the Intracoastal Waterway through pump stations Bayou Segnette, Lake Cataouatche I and Lake Cataouatche II.

Table 1-7
Jefferson Parish Basin Drainage Areas

Basin	Drainage Area (acres)
Ames-Westwego	4,637
Bayou Segnette	20,078
East Bank	28,155
East of Harvey	12,994
Harvey-Estelle-Cousins	10,160

Datum Reconciliation

The original UNET and HEC-RAS models were developed in the Cairo datum. The difference between Cairo Datum and NAVD 88 is +20.43 ft. Elevations were adjusted to NAVD 88 (1994, 1996). Channel cross-sections, structures, storage areas and pump stations were adjusted using the HEC-RAS datum adjustment tool.

Terrain Model

Jefferson Parish obtained 1 ft LIDAR contour mapping as part of the DFIRM mapping update in 2002. The LIDAR mapping was in NAVD 88 and developed in accordance to FEMA mapping standards. The contour mapping and bare earth points were used to develop a TIN through ArcView. The TIN was then used to develop grid elevation files of varying resolution as needed during model development.

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Basic Geometric Data using GIS

The majority of geometric data was obtained from the previously developed models; however, storage areas were developed using ArcGIS and the above mentioned terrain data for Bayou Segnette, Ames-Westwego and East of Harvey Canal.

Manning's n-Values

Channel Manning's n-values were used based on the original UNET and HEC-RAS models. During the DFIRM RAS model development, n values were adjusted based on field inspections. Typical values for cross-section channels range between 0.01-0.04 depending on the type of channel lining. Channel overbank n values were typically between 0.011-0.05. The condition of vegetation (e.g., thickness and height) at the time of the storm event is unknown. Manning's n values tend to decrease as flow rates and velocities increase, a feature that is not allowed in HEC-RAS. Consequently, an average value was chosen to represent the channel shape and average lining characteristics based on previously conducted field inspections.

Bridges

Numerous bridges exist throughout Jefferson Parish, including low-lying culverts and multiple pier based bridge structures. Pier bridge low flow methods included energy only, momentum and Yarnell methods, while the high flow method was typically pressure and/or weir flow with default coefficients. Drag and pier shape coefficients, culvert entrance loss coefficients, Manning's n-values, chart numbers and scale numbers were obtained from the existing models. Culvert exit loss coefficients were set to 1.0 and deck weir coefficients were set to 2.6. HTab parameters were set with the intention of developing HTab curves sufficient for modeling the Katrina event. This included fifty points on the free flow curve, fifty submerged curves and typically forty points on a submerged curve. Tail-water, head-water and maximum flow rate values were set as necessary. Pipeline crossings were modeled as bridges where it was determined that the pipeline was a significant obstruction to flow. All pipeline crossings were modeled using the energy only loss methods.

Ineffective Flow Areas

Temporary ineffective flow areas were added at culvert and bridge locations to simulate the slack water found in the contraction and expansion area upstream and downstream of the structure. Once the water surface exceeds the high point of a temporary ineffective flow area, the ineffective area is removed and the region provides normal conveyance. HEC-RAS also allows the user to specify permanent ineffective flow areas that remain in place once exceeded. Ineffective area station locations were determined based on upstream and downstream ratios described in the HEC-RAS documentation. Ineffective area elevations were set at either the bridge deck elevation or slightly below. If required, ineffective areas were adjusted to improve the stability of the model.

Blocked Obstructions

Blocked obstructions were not necessary and had not been included in the previously developed models.

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Storage Areas

Storage areas were developed subsequent to geo-referencing according to the stream network, aerials, contours and Jefferson Parish GIS layers (including pipes, canals and culverts). Boundaries were drawn in ArcMap as feature classes and exported to HEC-RAS using GeoRAS 4.1.1. Volume-elevation data was reviewed and adjusted to account for negative volumes and vertical slopes produced by GeoRAS. Vertical slopes can occur near initial elevations that maintain small amounts of volume and can cause instabilities during low-flow periods; therefore, a minor slope was added to storage area volume-elevation curves if necessary. Storage area connections were developed manually using contours and aerials and set to linear routing with a typical coefficient of 0.15.

Inline Structures

The original models did not contain inline structures; however, inline structures were added to improve stability at large drops in channel invert. These inline structures were typically one foot from the upstream cross-section, four feet in width and maintained a weir coefficient of 2.2.

Lateral Structures and Storage Area Connections

Lateral structures were developed along channel banks to convey lateral overflow from reaches to storage areas. Lateral structures were placed at the minimum elevation connecting storage areas and channels based on the terrain model, contours and aerials. For Bayou Segnette, Ames-Westwego and East of Harvey Canal, lateral structures were developed with a length of 100 feet and constant elevation equivalent to the minimum elevation. For areas where the minimum elevation did not span 100 feet, station elevation data (i.e. the levee profile) was entered according to contour elevations. East Bank lateral structures were developed using GeoRAS and the terrain model, generally spanning 200-400 feet in length and located at low points along the canal. Harvey-Estelle-Cousins lateral structures were developed with lengths of 100 to 400 feet corresponding to the depressed areas along the canal. Weir elevations were determined manually from the 2002 LIDAR contour data. A weir coefficient of 1.3 was used for lateral structures in the Ames-Westwego basin, while a coefficient of 1.0 was used for the remaining basins

Boundaries between storage areas in Jefferson Parish are typically low-lying roadways or high points in the natural ground contours. These boundaries do not represent standard broad crested weir structures, therefore all storage area connections were set to linear routing. Linear routing also served to reinforce model stability, an issue that remained a primary concern during model development. Minimum elevations were determined manually based on the terrain model, contours and aerial photos. Linear routing coefficients were set to 0.02 for all basins.

The linear routing equation is as follows:

$$Q = k\left(\Delta S\right) / Hour$$

where

Q = Flow

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k = Linear Routing Coefficient (Varies from 0.0 to 1.0)

ΔS = Available Storage (Difference in head times the surface area of receiving storage area)

Because equation computes a rate per hour the magnitude is divided by the time step to get flow per time step. User must also enter a minimum elevation for flow to pass between storage areas. If both storage areas are below this elevation no flow is exchanged. If one storage area has a stage greater than the minimum elevation, the head difference is the elevation of the storage area minus the user entered minimum elevation for passing flow.

Levees

Levee overtopping and breaching were not reported along the exterior boundaries of Jefferson Parish. Therefore, exterior levees were not included.

Pump Stations

Pump station operations were a critical aspect of modeling the Katrina event. Pump operation logs, surveys and a summarized operations table were provided by the pump performance team, and for the majority of pump stations these operations were implemented. Pump station operations during the Hurricane Katrina were collected by the interior drainage pump performance team and are available in Volume VI, Appendix 7. Within each West bank basin; however, discrepancies were found within the pump station Operator's Logs and between the Operator's Logs and the survey forms. These discrepancies were reconciled as follows:

For the East of Harvey Basin, at the Planter's Pump Station, two inconsistencies were noted and assumptions were made:

On 8/30/2005, Planter's Pump Station Operator's Logs contained inconsistent hours pumped and multiple log sheets for the day with varying observed water elevations. Only the Operator's Log sheet showing pumping for 8/30/2005 was assumed to be correct. Pumping hours were assumed to be incorrect and were assumed to match the on-off times written on the Operator's Log sheet.

On 8/31/2005, the original Pump Operations Table indicated both Pumps 1 and 2 were running. Further examination of Operator's logs indicated that it was actually the two (2) on-site generators which were running. This assumption agrees with the total hours pumped.

For the East of Harvey Basin, at the Hero Pump Station, several minor inconsistencies were noted:

On 8/30/05, Operator's Logs for the 12:00 am to 6:00 pm shift indicate a total hours pumped of 15.5 hours. However, pump on-off times indicate a total pumping time of 28 hours. It appears the operator only used the pump time for Pump No. 5 which was 15.5 hours; however, Pump No. 4 was also running for 12.5 hours. It was assumed that the correct total pumped was 28 hours.

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On 8/30/05, Operator's Logs for the 6:00 pm to 12:00 am shift indicate a total hours pumped of 31.25 hours, while examination of on-off times indicates 24.25 hours of total pumping. (It appears the generator running time was included in the total hours pumped.) A total pumping time of 24.25 hours was assumed.

On 8/31/2005, the original Pump Operations Table indicated that Pump No. 2 had turned off at midnight (24:00 of 8/30/2005). However, the Operator's Log indicates that Pump No. 2 continued pumping 2 additional hours until 2:00 am. This agrees with the total hours pumped and was assumed in the model.

For the Bayou Segnette Basin, at the Bayou Segnette Pump Station, the following assumption was made:

One of the 610 CFS pumps (EMD 2) which was indicated to turn off at noon on 8/28/2005 was actually in continuous operation until 8:30 am on the next day (8/29/2005). Although this assumption conflicts with the total hours pumped on the operator's log, it matches the Operator's log on-off times and allows the model to draw the basin down to normal stage.

For the Ames-Westwego Basin at the Ames Pump Station,

On 30 August, pump station operator logs stated that Pump 1, Pump 2, EMD #1 and EMD #3 were running for various periods. After discussions with the pump team, it was assumed that since EMD #3 was on, Pump #3 was on as well. Therefore, Pump #3 was modeled as on for 22 hours on 30 August from 12:45 am to 10:45 pm.

For the Harvey Estelle Cousins Basin, the only potential inconsistency involved the Harvey Pump Station:

The pump survey forms indicate that the pumps were operated in anticipation of the hurricane on 28 and 29 August, however, there was no record of the specific pumping operations in the log. The assumption used in the modeling was that the pumps were utilized through 0900 on 29 August to maintain canal levels at normal levels. The pump station was evacuated at 1300 on 29 August.

During the flood event, it is believed that backflows occurred at several East Bank pump stations. Backflows occur when pumps are off and high outer canal stages force flow through a pump into the interior canal. Two backflow prevention options are present at the East Bank pump stations: valve gates and air suppression. Where valve gates are present, backflows were not thought to have occurred unless the gates were not completely closed. Where air suppression is present, it is thought that pool-to-pool head differences were likely high enough to overcome the backflow prevention mechanism.

To determine the approximate amount of pump backflow at the affected pump stations, backflow rating curves were developed. These curves are based on multiple assumptions but represent the best information available at the time. Detailed information on the backflow computations are available in Volume VI, Appendix 7. The backflow hydrographs used for the East Bank basin were determined using these pump backflow curves provided by the Portland District. The pump backflow calculations are based on the outer canal stage, H_1, the interior

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stage at the pump station, H_2, and the pool-to-pool head differential, further referred to as the tail-water, TW, where

$$TW = HW_1 - HW_2$$

The following two backflows scenarios can occur:

1. Standard backflow, where some air is present in the pipe
2. Fully primed backflow (i.e. siphon flow), where the pipe is fully flowing

The above scenarios can occur under the following three conditions:

1. If the outer canal stage is above the controlling crest (i.e. highest invert) of the discharge pipe, regular backflows occurs.
2. If the outer canal stage rises above the soffit elevation (i.e. highest point) of the discharge pipe, siphon flow occurs.
3. If a particular combination of H_1 and TW specified by the Portland District occurs, siphon flow occurs.

Condition 2 occurs if there is an open air vent in the system; if a vent does not exist, condition 3 occurs. However, it is unknown whether air vents were open at any of the pump stations in question; therefore, conditions 2 and 3 were used for the each pump. In cases where both standard backflow and siphon flow occurred, the larger of the two flows was selected.

The following is a description of the backflow analysis for each of the pump stations for the East Bank basin. In general, backflows occurred after the operators evacuated the pump station and backflows were assumed to cease when operator's returned to the pump station. Cairo Datum, referred to as CD, is used in the following summary since the pump backflow information was supplied in Cairo Datum.

East Bank - Bonnabel Pump Station

Maximum stage for outer canal was 31.44 ft CD.

Pumps 1 & 2

- Pumps were closed with gate valves.
- No backflows are believed to have occurred.

Pumps 3 – 5

- Air suppression was used to prevent backflow.
- It is believed that backflows may have occurred due to high stages in the outer canal causing the air suppression to be overcome.
- Backflows were calculated, since $H_1 \geq 29.5$ ft CD.

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- Siphon flows <u>were not</u> calculated, since $H_1 < 33.0$ ft CD.

East Bank – Suburban Pump Station

Maximum stage for the outer canal was 30.21 ft CD.

Pumps 1 & 2

- Air suppression was used to prevent backflow.
- It is believed that backflows may have occurred due to high stages in the outer canal causing the air suppression to be overcome.
- Backflows <u>were</u> calculated, since $H_1 \geq 28.43$ ft CD.
- Siphon flows <u>were not</u> calculated, since $H_1 < 32.2$ ft CD.

Pump 3

- Air suppression was used to prevent backflow.
- It is believed that backflows may have occurred due to high stages in the outer canal causing the air suppression to be overcome.
- Backflows <u>were</u> calculated, since $H_1 \geq 26.0$ ft CD.
- Siphon flows <u>were</u> calculated, since $H_1 > 29.0$ ft CD.

Pumps 4 – 6

- Pumps were closed with gate valves.
- <u>No backflows</u> were believed to have occurred.

Pumps 7 & 8

- Air suppression was used to prevent backflow.
- It is believed that backflows may have occurred due to high stages in the outer canal causing the air suppression to be overcome.
- Backflows <u>were</u> calculated, since $H_1 \geq 29.5$ ft CD.
- Siphon flows <u>were not</u> calculated, since $H_1 < 33.5$ ft CD.

East Bank – Elmwood Pump Station

Maximum stage for the outer canal was 30.21 ft CD.

Pumps 1 – 8

- Pumps were closed with gate valves.
- <u>No backflows</u> were believed to have occurred.

Pumps 9 & 10

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- Air suppression was used to prevent backflow.
- It is believed that backflows may have occurred due to high stages in the outer canal causing the air suppression to be overcome.
- Backflows were calculated, since $H_1 \geq 24.0$ ft CD.
- Siphon flows were calculated. Siphon flows occurred when TW = 15.69 ft CD and $H_1 = 27.02$ ft CD based on Portland District supplied data.

East Bank – Duncan Pump Station

Maximum stage for the outer canal was 30.206 ft CD.

Pumps 1 & 2

- Initially, pumps were closed with gate valves.
- Operators returned to the pump station at 8 pm on 8/29/2005 and attempted to re-start the pumps, but were unsuccessful due to high stages. A safety block was triggered which prevented pumps from restarting for 30 minutes. As a result the valve gates were open for 30 minutes allowing backflows to potentially occur. Therefore, back flows were only calculated from 8:00 pm to 8:30 pm on 8/29/2005.
- Backflows were calculated, since $H_1 \geq 24.1$ ft CD.
- Siphon flows were calculated. Gate valves were opened and Siphon flow conditions were met at 8:00 pm on 8/29/2005 when TW = 13.76 ft CD and $H_1 = 29.47$ ft CD. Siphon flow stopped at 8:30 pm.
- Note: Siphon flows were used in place of regular back flows, since siphon flows were greater.

Pumps 3 – 6

- Air suppression was used to prevent backflow.
- It is believed that backflows may have occurred due to high stages in the outer canal causing the air suppression to be overcome.
- Backflows were calculated, since $H_1 \geq 29.5$ ft CD.
- Siphon flows were not calculated, since $H_1 < 33$ ft CD.

East Bank – Parish Line Pump Station

All pumps were closed with gate valves. No backflows were believed to have occurred.

East Bank – Canal Street Pump Station

Pumps 1 – 4

- Pumps were left running on automatic when the station was evacuated.
- When operators returned, pumps 1, 2 and 4 were running and pump 3 was jammed.
- Investigators did not believe that backflows occurred.
- Back flows were not calculated, since it was assumed that no backflows occurred.

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Figures 1-10 through 1-13 represent the computed backflows according to the above assumptions and based on modeled stages. These flows were added as lateral inflows at the nearest cross-section upstream of the pump stations.

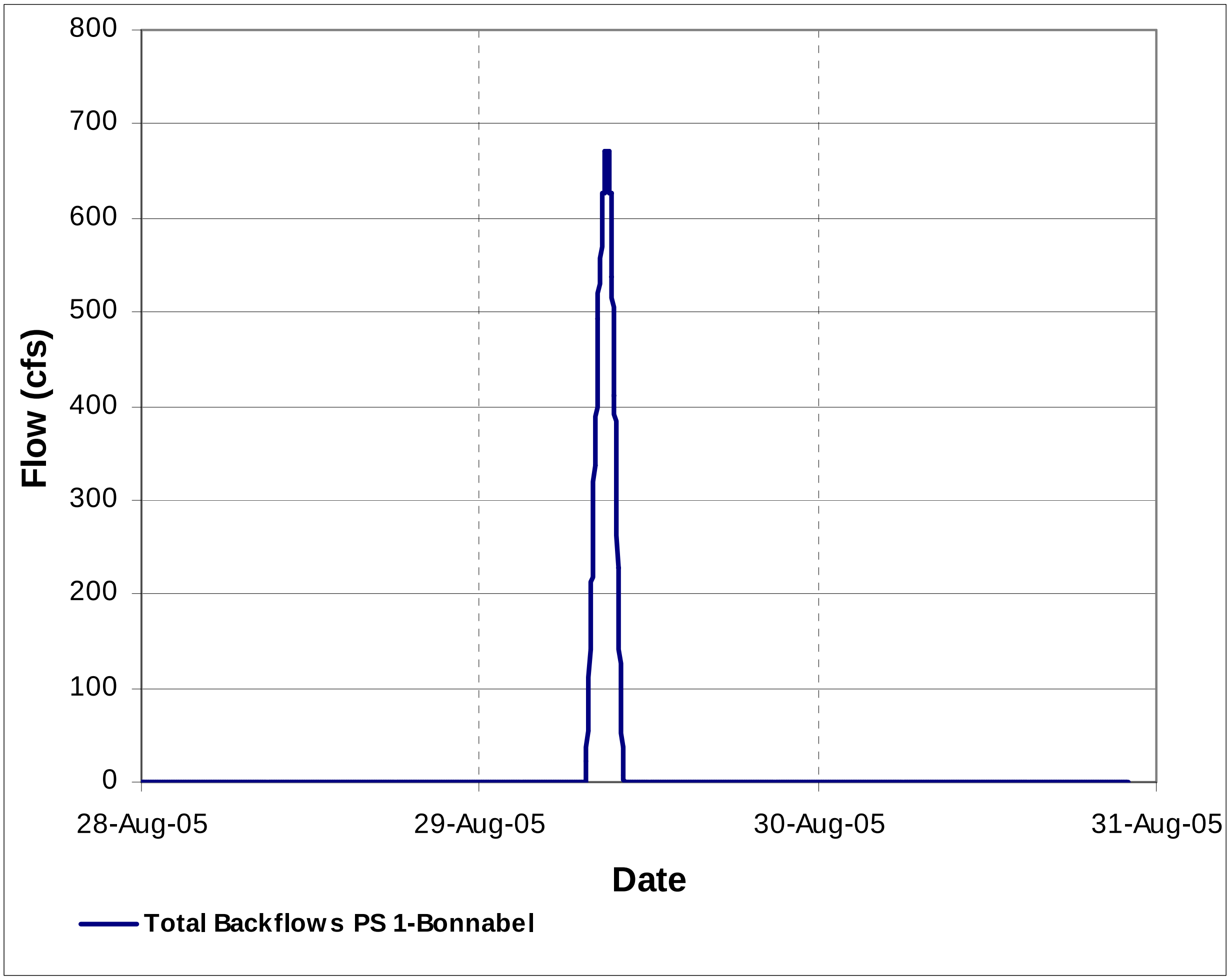

Figure 1-10. Estimated Backflow Hydrograph, East Bank, Bonnabel Pump Station

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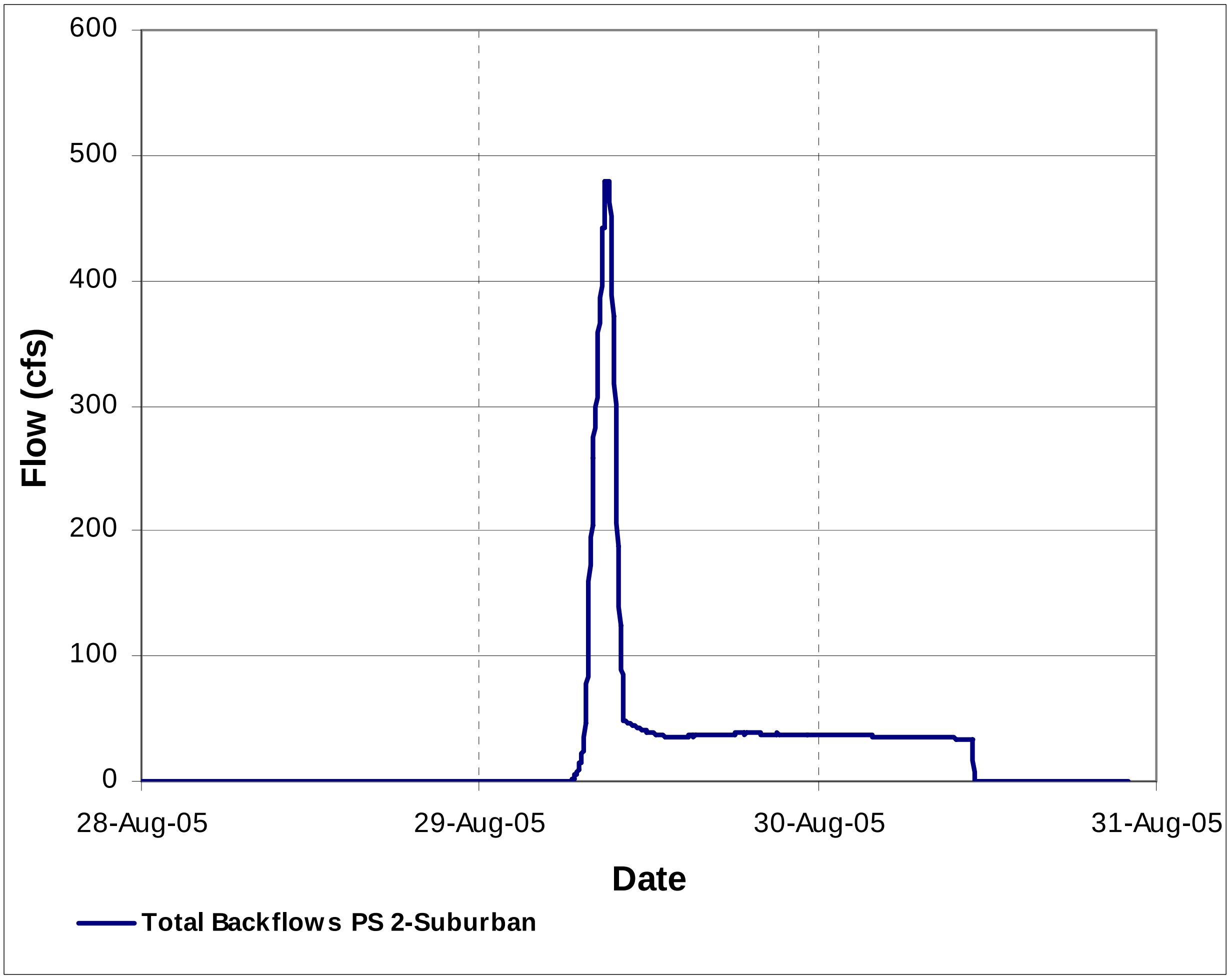

Figure 1-11. Estimated Backflow Hydrograph, East Bank, Suburban Pump Station

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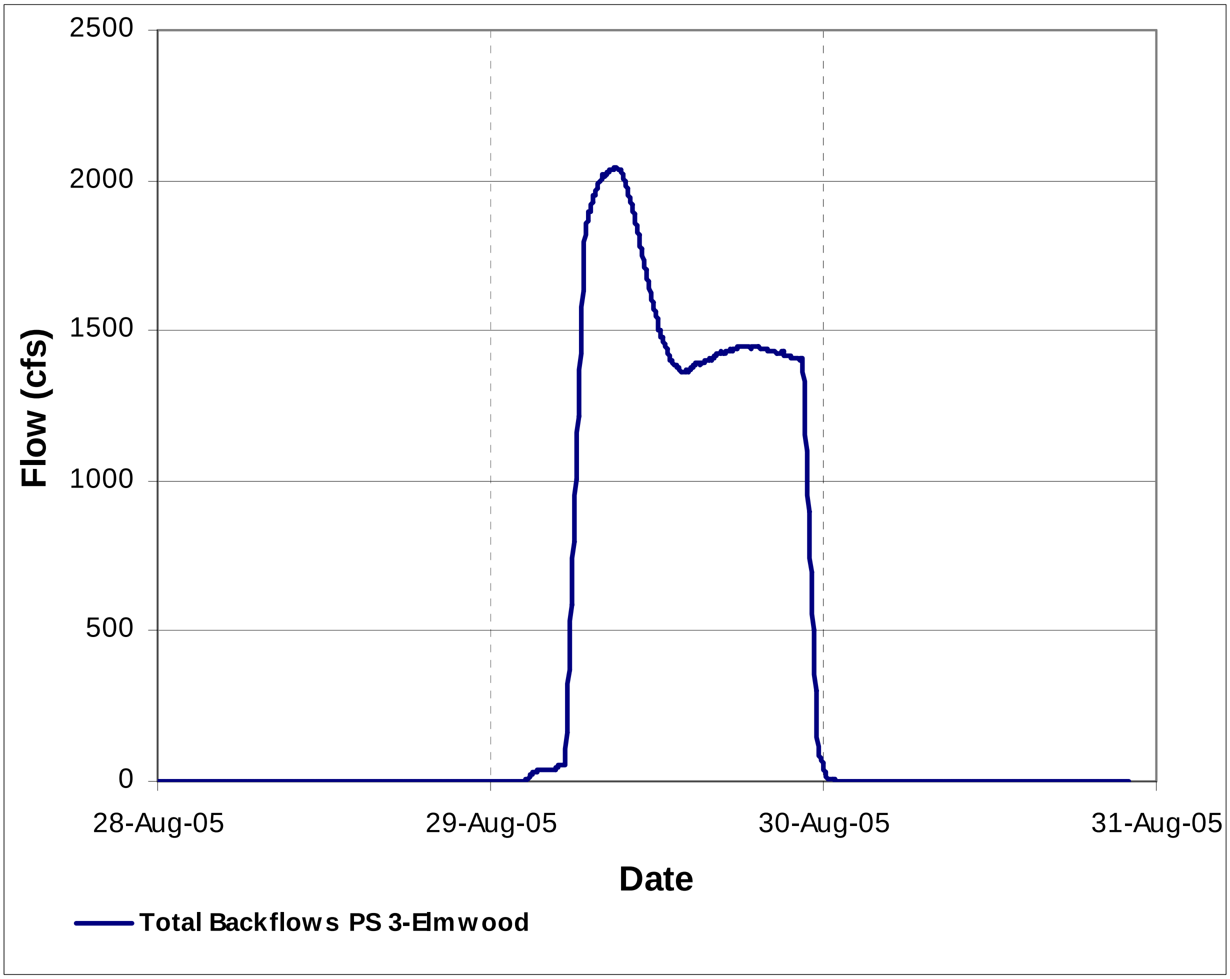

Figure 1-12. Estimated Backflow Hydrograph, East Bank, Elmwood Pump Station

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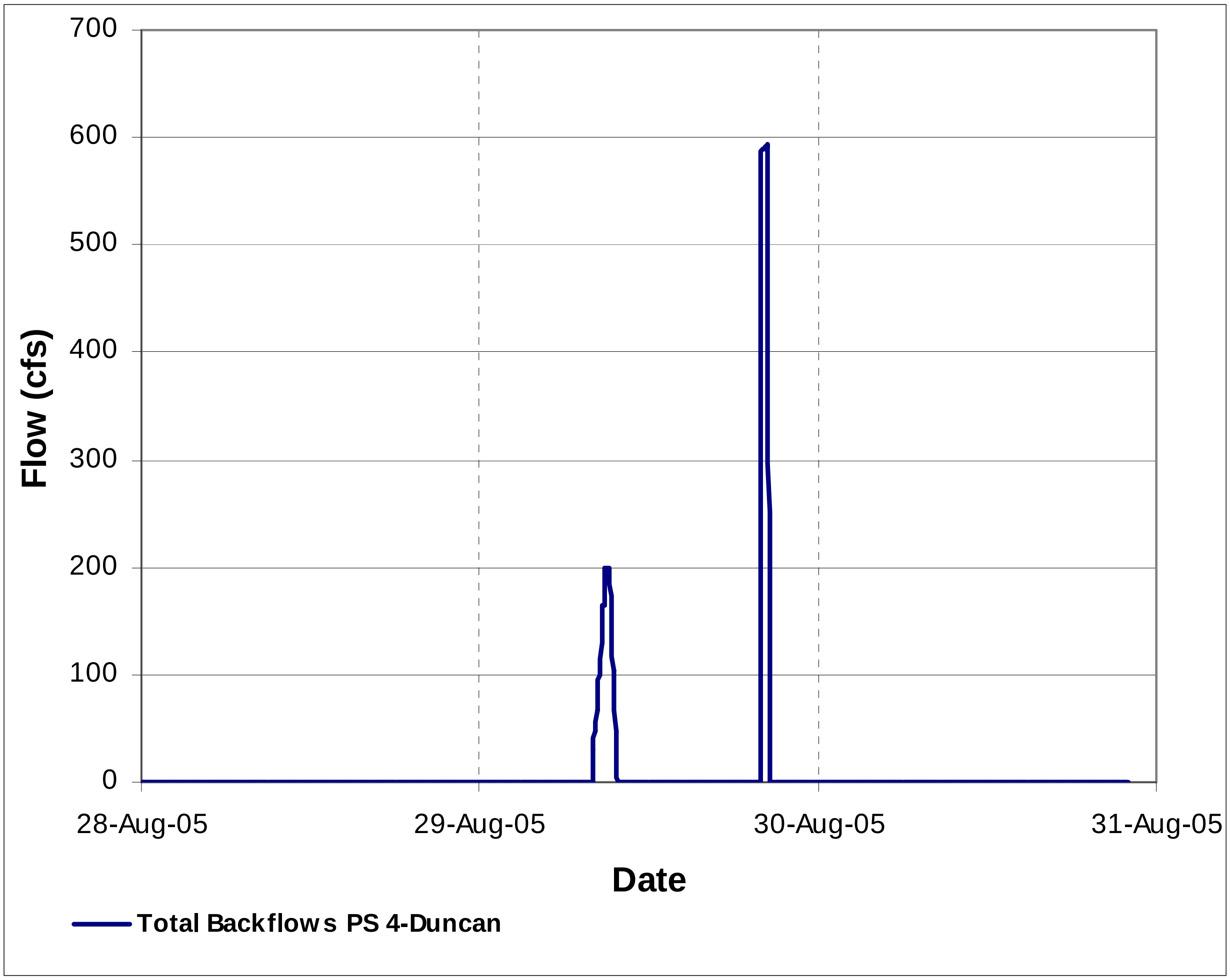

Figure 1-13. Estimated Backflow Hydrographs, East Bank, Duncan Pump Station

Storm Drain System

The storm drain system within Jefferson Parish consists of open canals, enclosed canal sections and storm drains. The storm drain system was not included in the modeling. Open canals and larger enclosed canals with connections to open canal sections were included in the models. Figure 1-14 represents the HEC-RAS reaches from the geometry files for Jefferson Parish.

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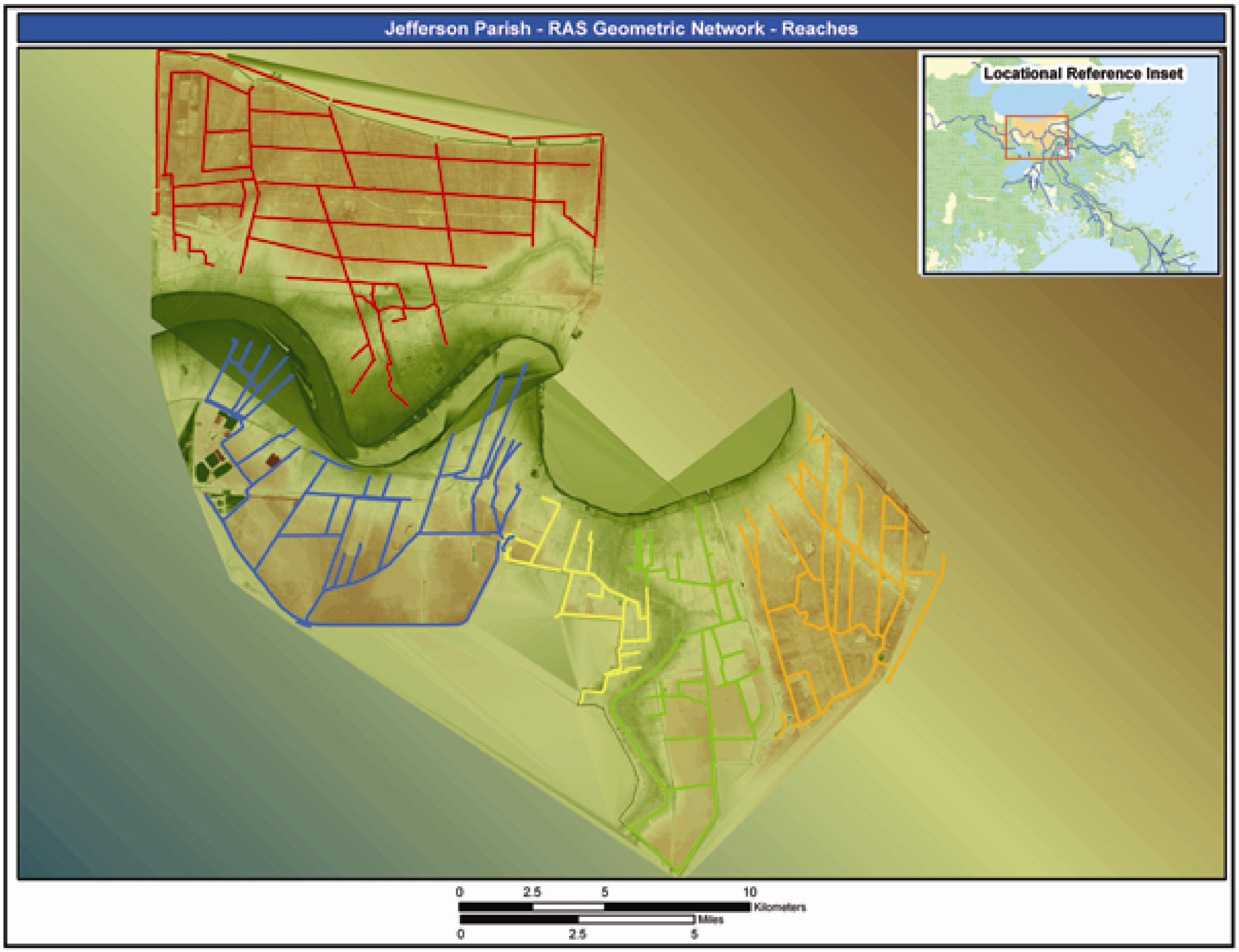

Figure 1-14. Jefferson Parish RAS Geometric Reach Network

Flow Data and Boundary Conditions

Each HMS sub-basin contributes to a reach or storage area as a lateral or point inflow. Boundary conditions for Jefferson Parish are numerous (roughly 100 per basin) and exist mainly as lateral inflows to reaches due to the primarily urban nature of the system. There are, however, many locations where a sub-basin was applied as a point inflow into a reach (e.g. outfall from a landfill or discharge from a principal storm drain pipe) or storage area (e.g. storage area primarily represents a depressed wetland). Upstream boundary conditions were associated with a sub-basin. Each upstream boundary condition has a minimum flow of at least 5 cfs, though several have either 10 or 15 cfs depending on the flow regime during low flow conditions. These base flows were used to prevent the model from experiencing dry conditions during low flow periods. Base flows were also added to several canals in the middle of a reach where a topographic high point occurred. Base flows were removed at the downstream pump stations to prevent accumulation of flow. Downstream boundary conditions were defined as flow and were set to 1 cfs for the entire event.

Outer canals were defined as having an upstream flow boundary condition and a downstream stage boundary condition developed from the ADCIRC 75% stage hydrographs (see Table 1-8 for the ADCIRC locations used). West bank ADCIRC hydrographs were linearly interpolated during periods when the stage was outside the ADCIRC range of elevations. East Bank ADCIRC hydrographs were adjusted to match nearby high water marks. The adjustment procedure consisted of comparing the ADCIRC points provided to the nearest high-water marks. The ratio of the difference between the maximum and minimum ADCIRC stage and the high-water mark and minimum ADCIRC stage was used to adjust the ADCIRC hydrograph. Figures 1-15 and 1-16 show the original and adjusted stage hydrographs at ADCIRC Points 138 and 140, respectively. ADCIRC Point 138 is located in Lake Pontchartrain north-east of the Elmwood pump station approximately 1.2 miles. ADCIRC Point 140 is located at the north-east corner of East Bank on the shore of Lake Pontchartrain near the confluence of the 17th Street Canal. Information on the ADCIRC modeling can be found in Volume IV.

Table 1-8
Outer Canal Stage Boundary Conditions

Basin	RAS River Name	Reach	Adcirc Point	Notes
East Bank	AdCirc	Reach 136	136	Adjusted peak to match high water marks
East Bank	AdCirc	Reach 137B	137	Adjusted peak to match high water marks
East Bank	AdCirc	Reach 137A	137	Adjusted peak to match high water marks
East Bank	AdCirc	Reach 138A	138	Adjusted peak to match high water marks
East Bank	AdCirc	Reach 138B	138	Adjusted peak to match high water marks
East Bank	AdCirc	Reach 140A	140	Adjusted peak to match high water marks
East Bank	AdCirc	Reach 17thStrCanal	140	Adjusted peak to match high water marks
East Bank	AdCirc	Reach 136B	136	Adjusted peak to match high water marks
Bayou Segnette	Lake Cat	Outer	90	Interpolated missing data points.
Bayou Segnette	Bayou	Outer	90	Interpolated missing data points.
Ames Westwego	Wwego	Outer	90	Interpolated missing data points.
Ames Westwego	Dugues	Outer	90	Interpolated missing data points.
Ames Westwego	Ames	Outer	90	Interpolated missing data points.
Harvey Estelle	Harvey Canal	Harvey Canal	89	No notes
East of Harvey	EngineerPlanters	EngPlantPUMPTO	625	No notes
East of Harvey	HeroPumpTo	HeroPumpTo	559	No notes

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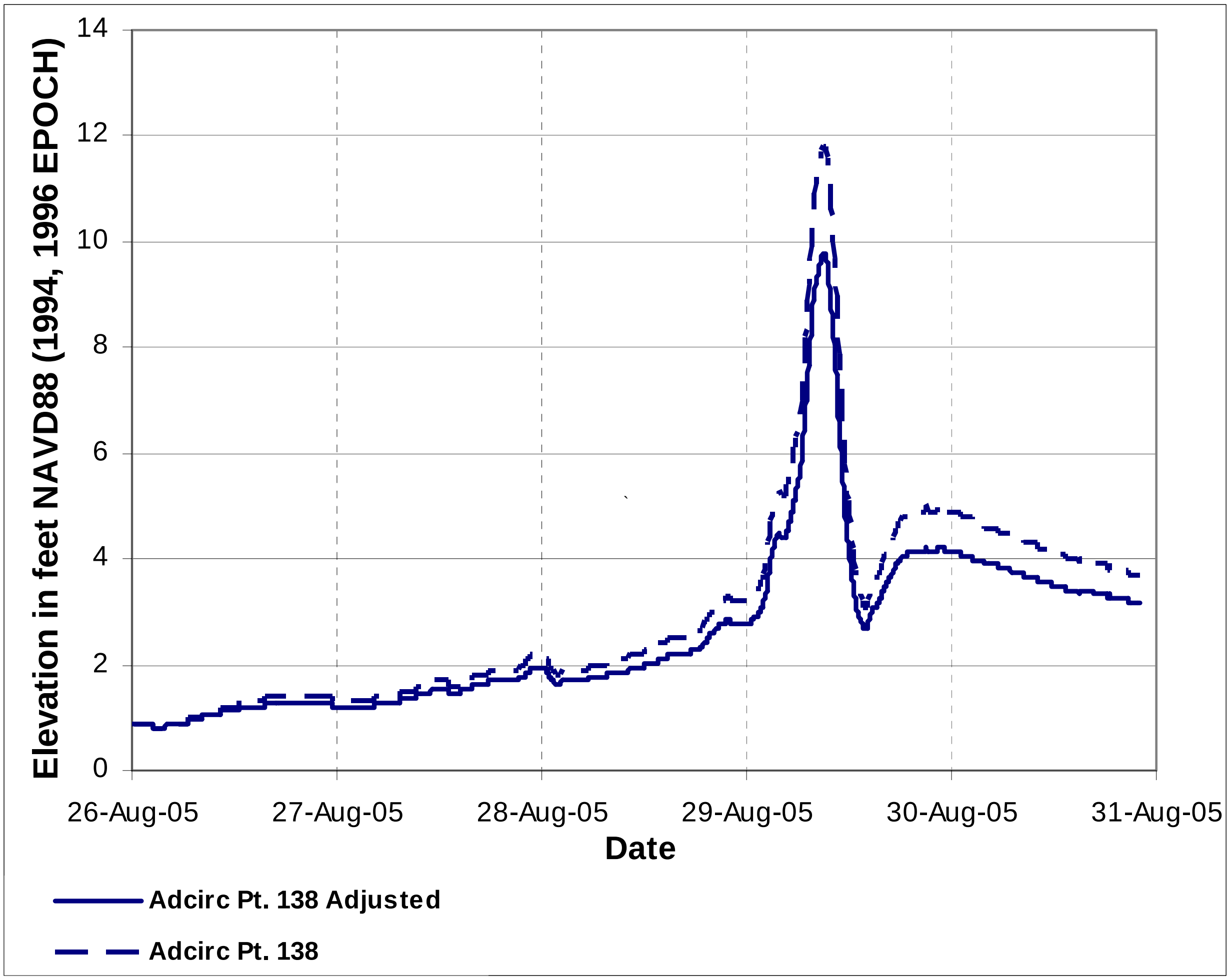

Figure 1-15. Adjusted ADCIRC Hydrograph, Point 138

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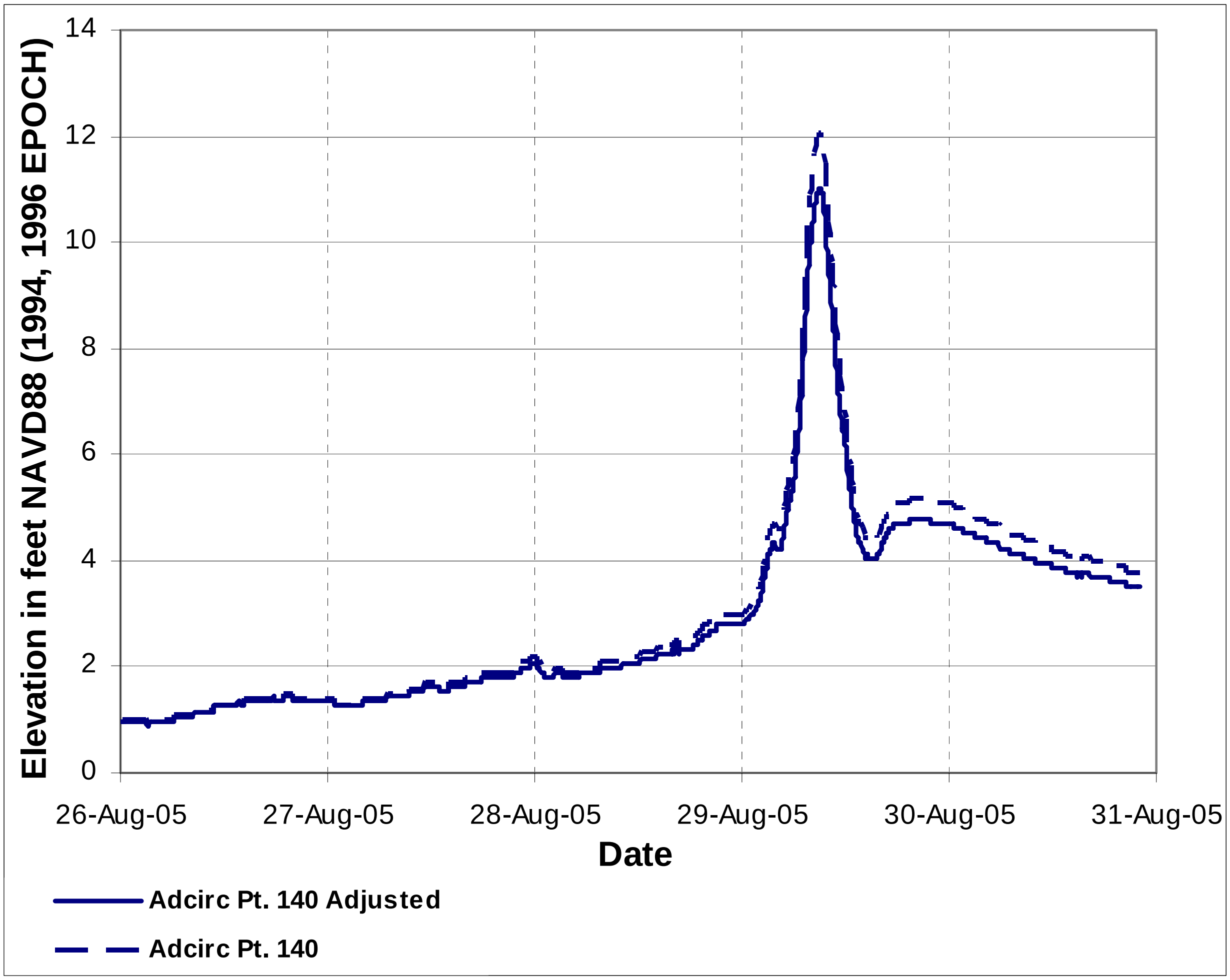

Figure 1-16. Adjusted ADCIRC Hydrograph, Point 140

Levee Overtopping and Breaching

Levee overtopping and breaching were not observed in Jefferson Parish during Katrina and were not included in the models.

Model Calibration

The model results were compared to the high-water marks and pump operator observed stages within the Jefferson parish basins. The model results compared favorably, therefore the model parameters were not adjusted. The only changes to the models during the comparison was to the pump operating times based on review of the pump operator logs, surveys and operation summary tables.

Model Results and Floodplain Mapping

For the Katrina event, Jefferson Parish model results compare favorably to observed high water marks and pump operator observed stages. Flood inundation maps representing the

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Katrina event and the Hypothetical 2 scenario were computed for Jefferson Parish. Since there were no wall or levee breaches in Jefferson Parish, Hypothetical 1 and Hypothetical 3 were not computed since results would match the Katrina simulation   A detailed discussion is presented below, accompanied by inundation maps and hydrographs corresponding to each basin.

East Bank

Figure 1-17 shows the area flooded within the East Bank basin based on the model results. On average, the observed high water marks were within 0.38 feet of the model results, as shown in Table 1-9. Figure 18 shows flooding for the East Bank for the Hypothetical 2 scenario. Figures 1-19 though 1-24 display the modeled stage hydrographs at East Bank pump stations and include any operator observed stages and nearby high-water marks for the Katrina event. For the majority of East Bank operator observed stages at the beginning and end of Katrina, the time of occurrence was approximated based on the interview descriptions. Operator observed stages recorded near the peak of the event were typically accompanied by a known time.

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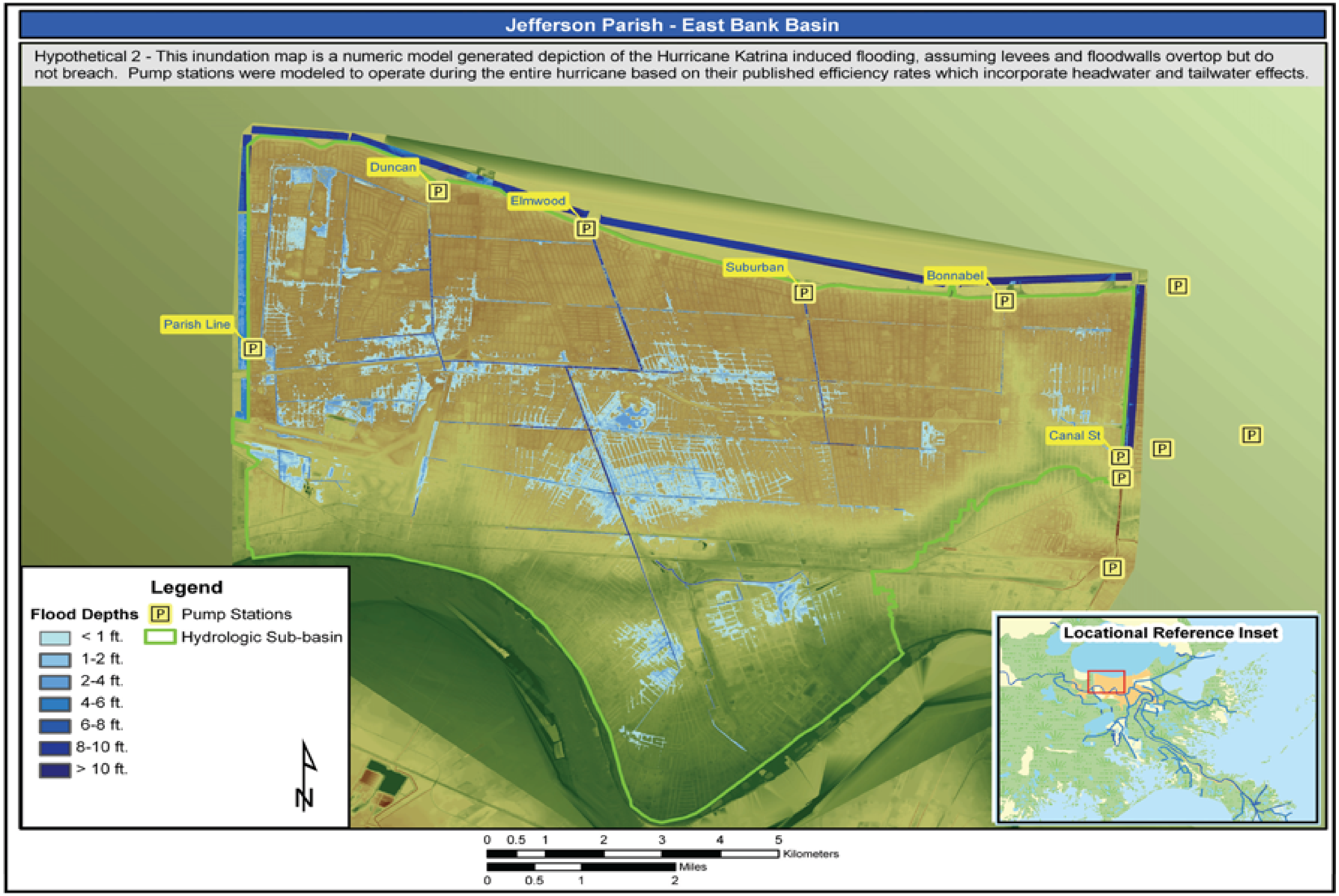

Figure 1-17. Jefferson Parish East Bank Modeled Katrina Event Flood Inundation

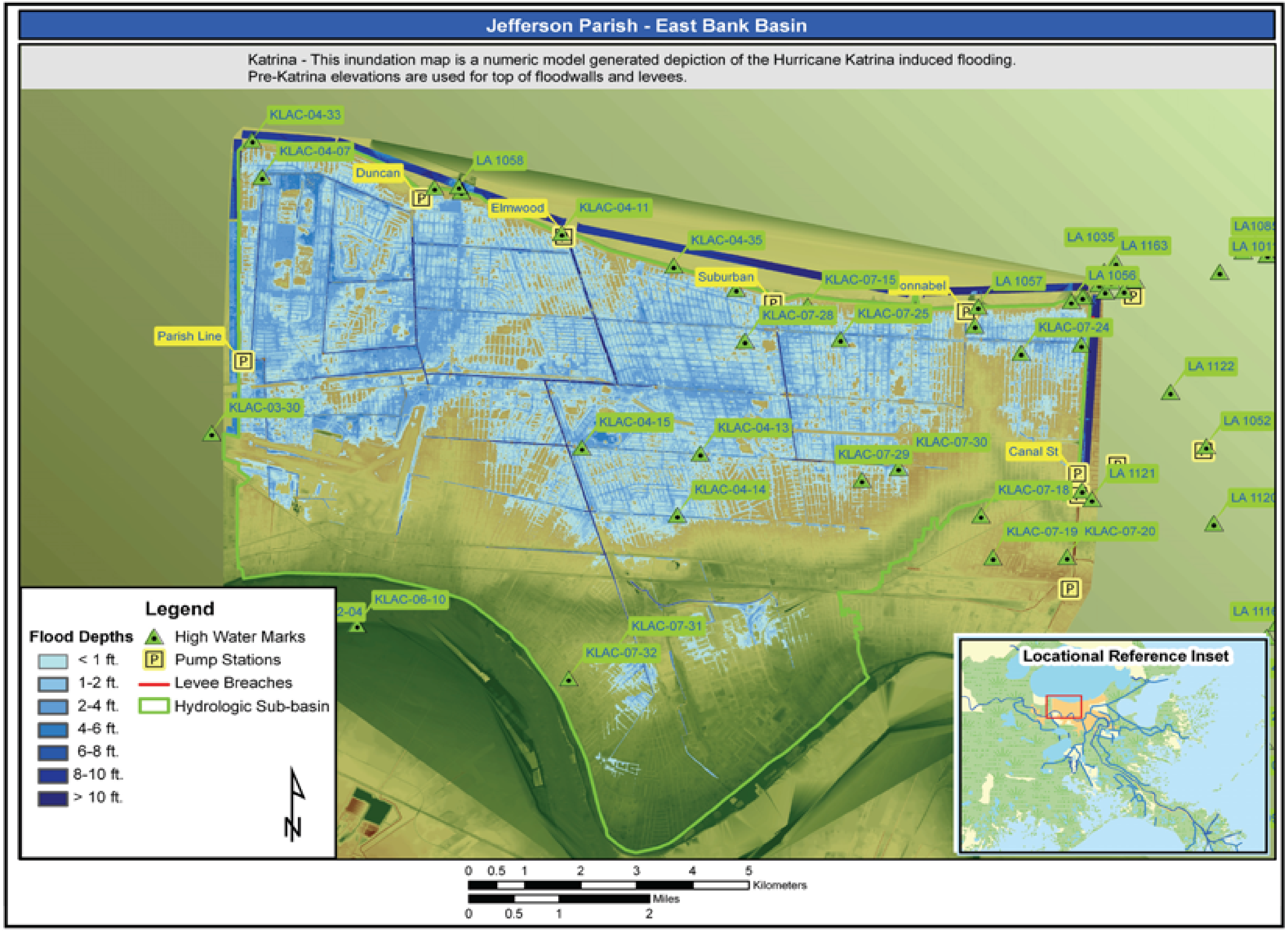

Figure 1-18 Jefferson Parish East Bank Hypothetical 2 Scenario Flood Inundation

Table 1-9
East Bank Modeled versus Observed High Water Marks

Observed Location	**Observed Stage** (ft NAVD 88)	**Modeled Stage** (ft NAVD 88)	**Difference** (ft)	**Hypothetical 2** (ft NAVD 88)
HW KLAC-04-07	-4.3	-3.8	**0.5**	-6.4
HW KLAC-04-13	-3.9	-3.6	**0.3**	-4.8
HW KLAC-04-14	-3.7	-2.9	**0.8**	-3.1
HW KLAC-04-15	-3.8	-3.6	**0.2**	-4.9
HW KLAC-07-14	-3.4	-3.8	**-0.4**	-11.9
HW KLAC-07-15	-3.5	-3.8	**-0.3**	-7.9
HW KLAC-07-16	-3.6	-3.7	**-0.1**	-8.4
HW KLAC-07-21	-3.2	-3.8	**-0.6**	-10.2
HW KLAC-07-23	-3.3	-3.7	**-0.4**	-9.8
HW KLAC-07-24	-3.1	-3.7	**-0.6**	-7.9
HW KLAC-07-25	-3.3	-3.8	**-0.5**	-7.5
HW KLAC-07-28	-3.8	-3.8	**0.0**	-7.9
HW KLAC-07-29	-3.6	-3.8	**-0.2**	-5.1
HW KLAC-07-30	-3.4	-3.7	**-0.3**	-4.6
PS Bonnabel 08/29 22:00	-2.9	-4.0	**-1.0**	-12.5
PS Bonnabel 08/30 11:00	-12.4	-11.7	**0.78**	-12.5
PS Suburban 08/30 11:00	-2.5	-5.4	**-2.9**	-12.8
PS Suburban 09/01 00:00	-12.4	-12.5	**-0.1**	-12.5
PS Elmwood 08/28 17:00	-13.4	-12.2	**1.2**	-12.3
PS Elmwood 08/29 22:30	-2.4	-4.1	**-1.7**	-12.7
PS Elmwood 08/31 08:30	-12.2	-12.4	**-0.1**	-12.6
PS Duncan 08/28 17:00	-13.4	-12.2	**1.2**	-12.6
PS Duncan 08/29 20:00	-3.1	-3.9	**-0.7**	-12.5
PS Duncan 08/31 00:00	-8.4	-12.3	**-3.9**	-12.5
PS Parish Line 08/28 17:00	-13.9	-12.2	**1.7**	-12.3
PS Parish Line 08/29 18:00	-3.1	-3.8	**-0.7**	-10.9
PS Parish Line 08/31 19:00	-11.4	-12.4	**-0.9**	-12.5
PS Canal St. 08/28 21:00	-6.9	-7.1	**-0.1**	-7.1

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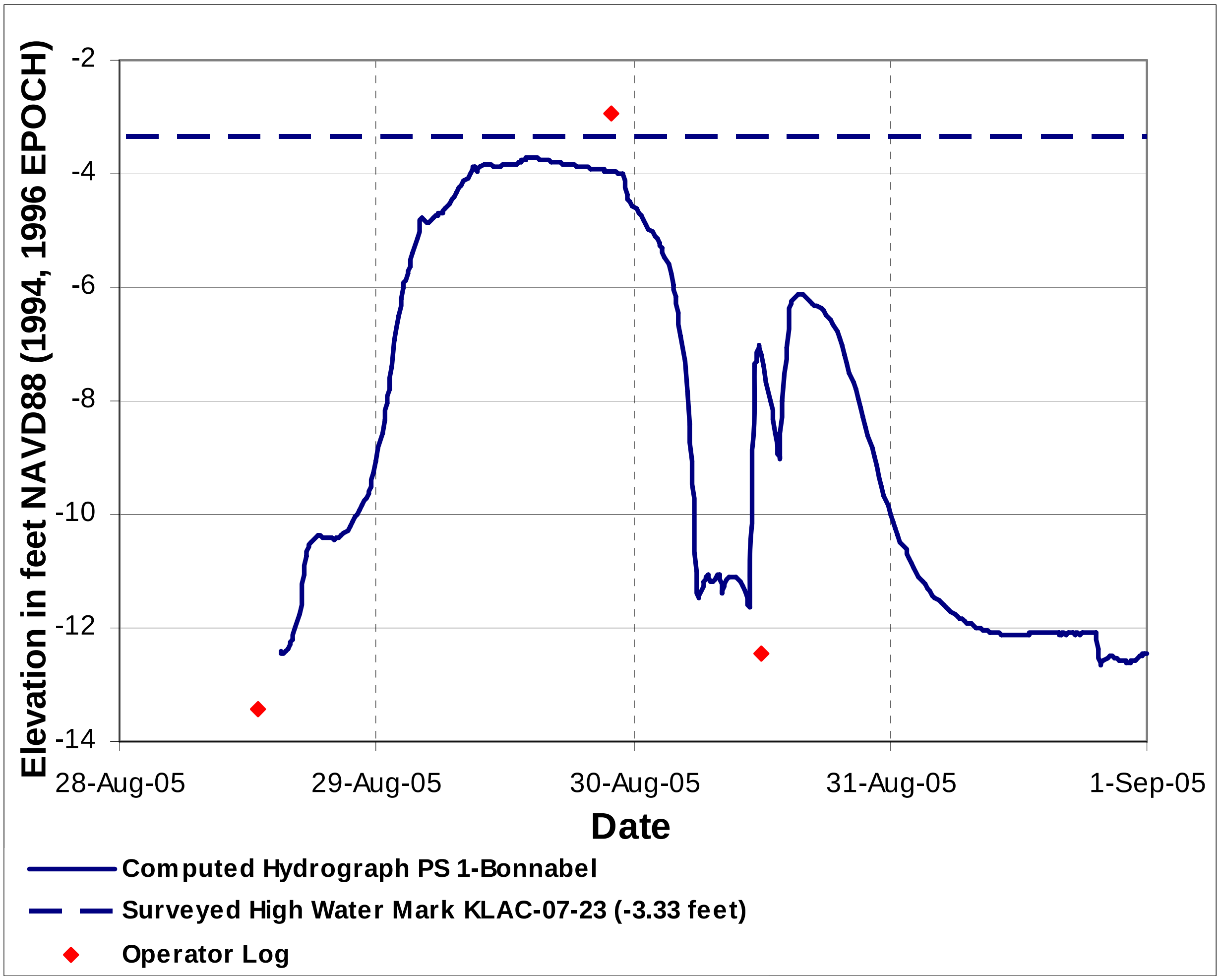

Figure 1-19. Katrina Event Computed Results, East Bank, Bonnabel Pump Station

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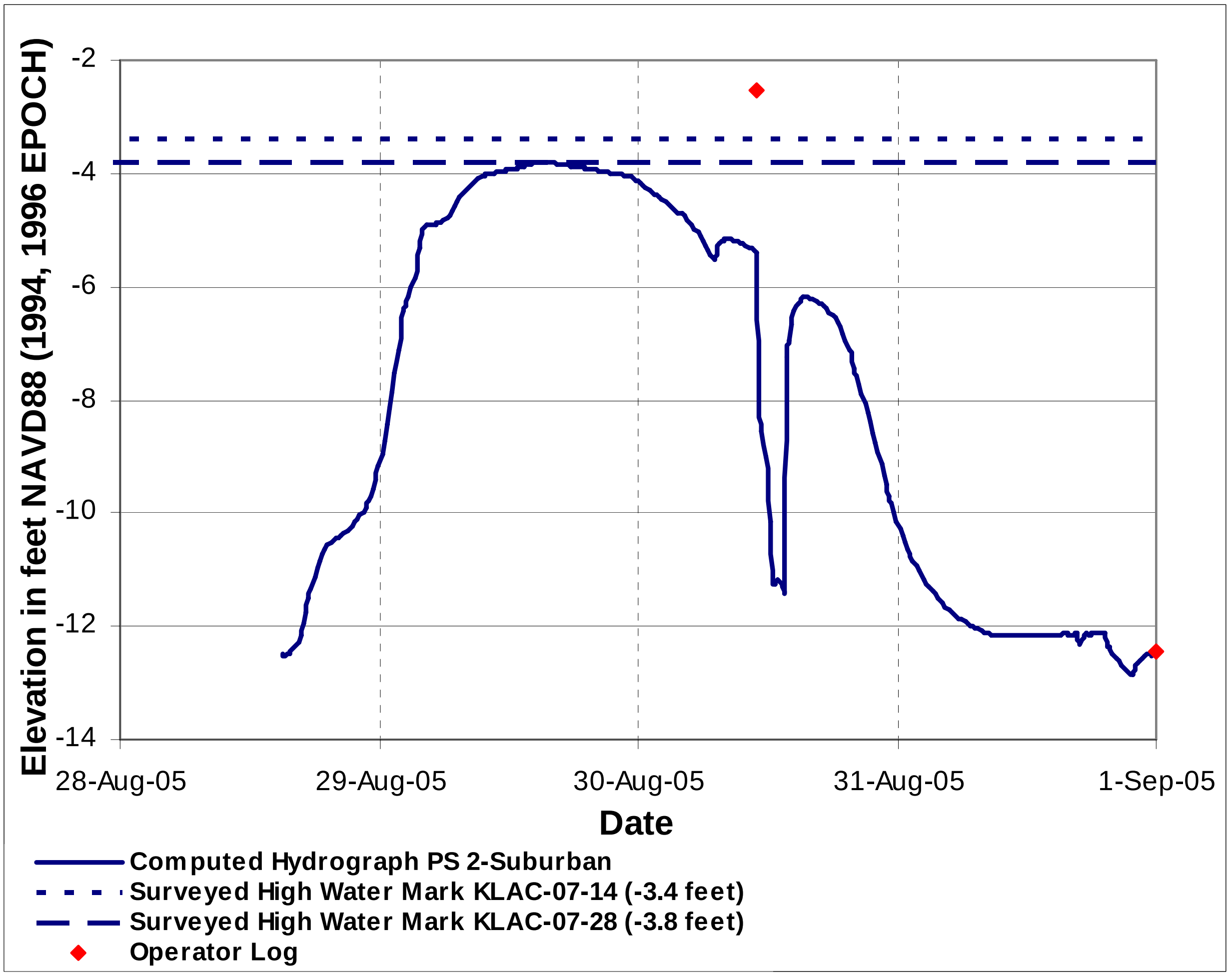

Figure 1-20. Katrina Event Computed Results, East Bank, Suburban Pump Station

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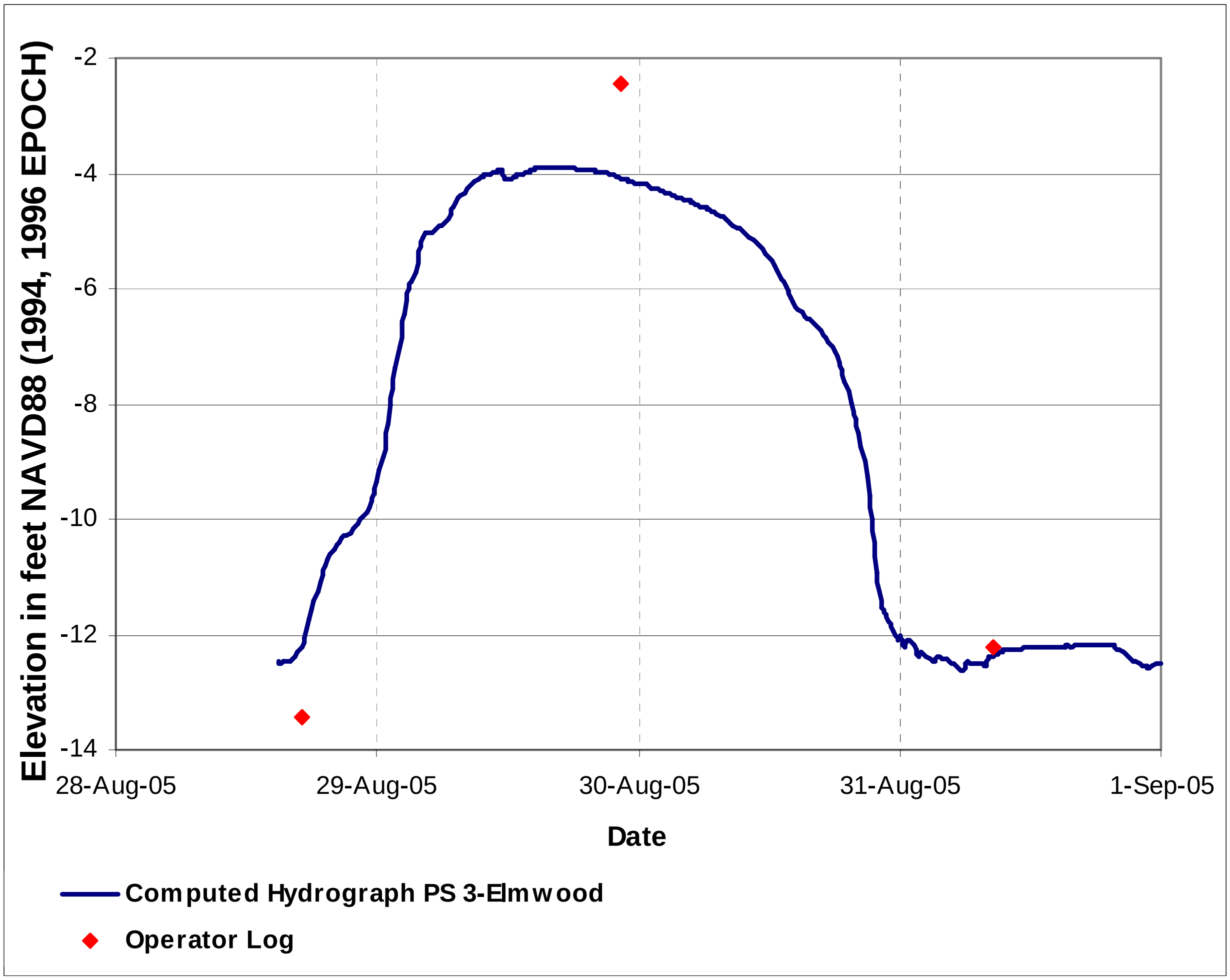

Figure 1-21. Katrina Event Computed Results, East Bank, Elmwood Pump Station

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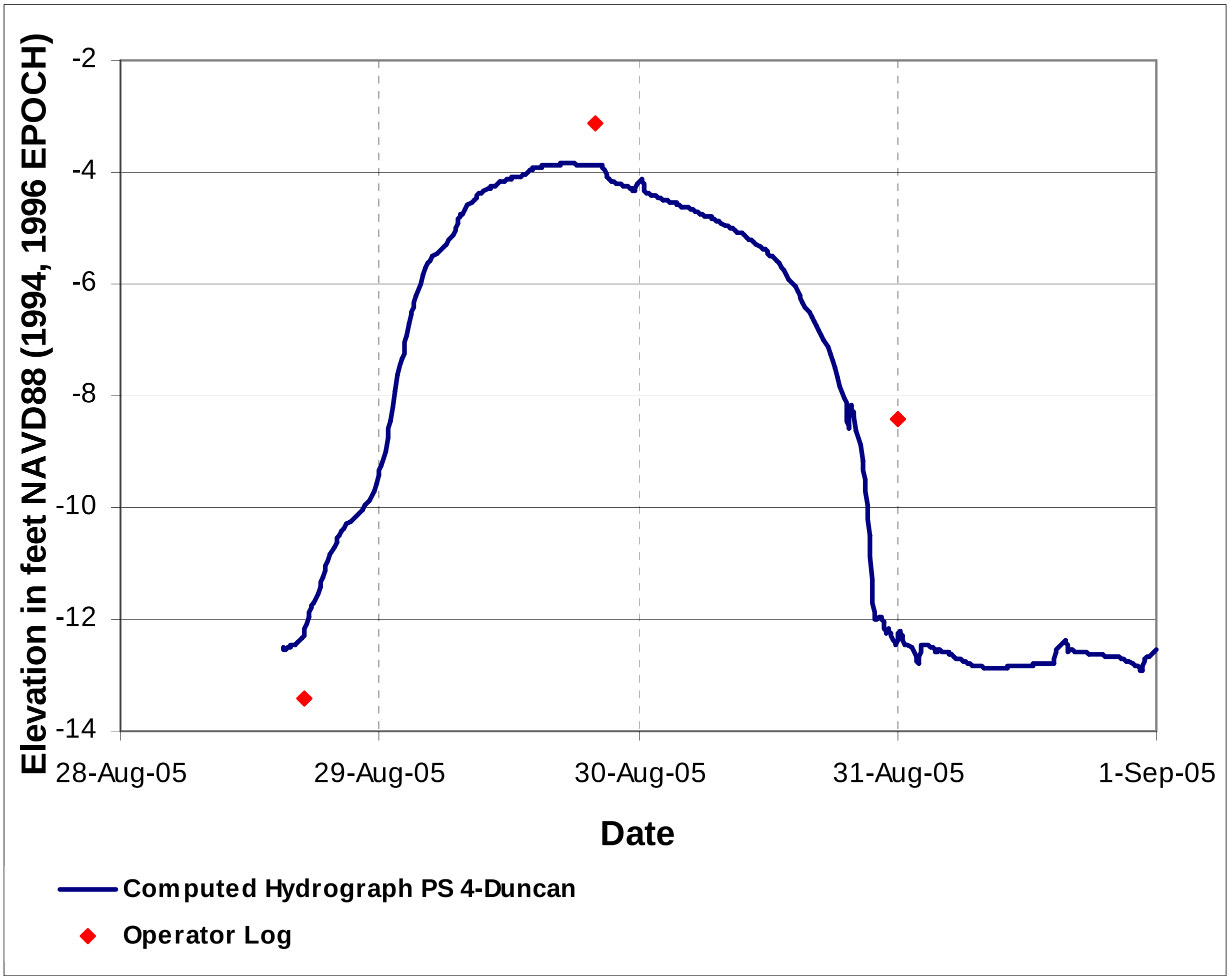

Figure 1-22. Katrina Event Computed Results, East Bank, Duncan Pump Station

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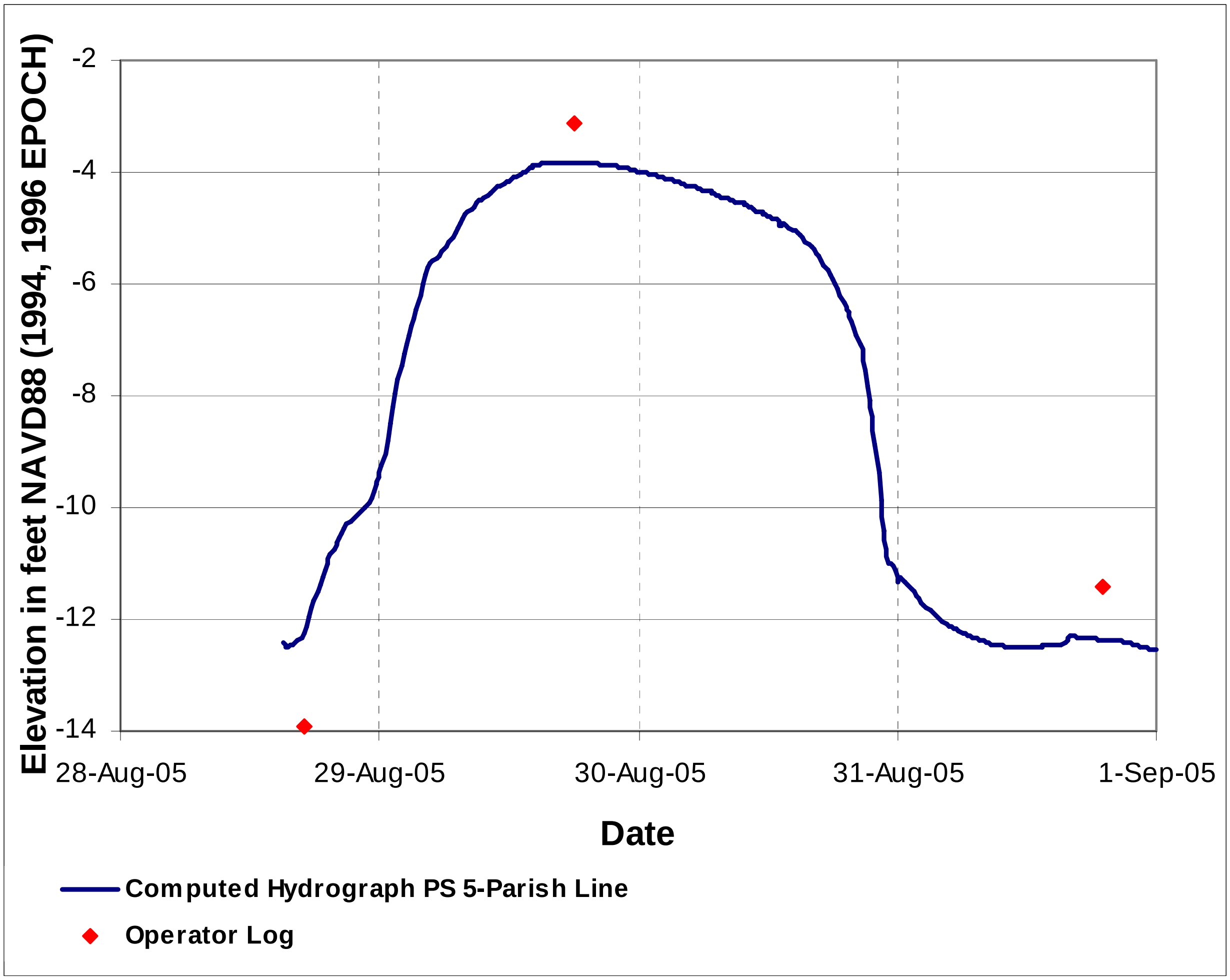

Figure 1-23. Katrina Event Computed Results, East Bank, Parish Line Pump Station

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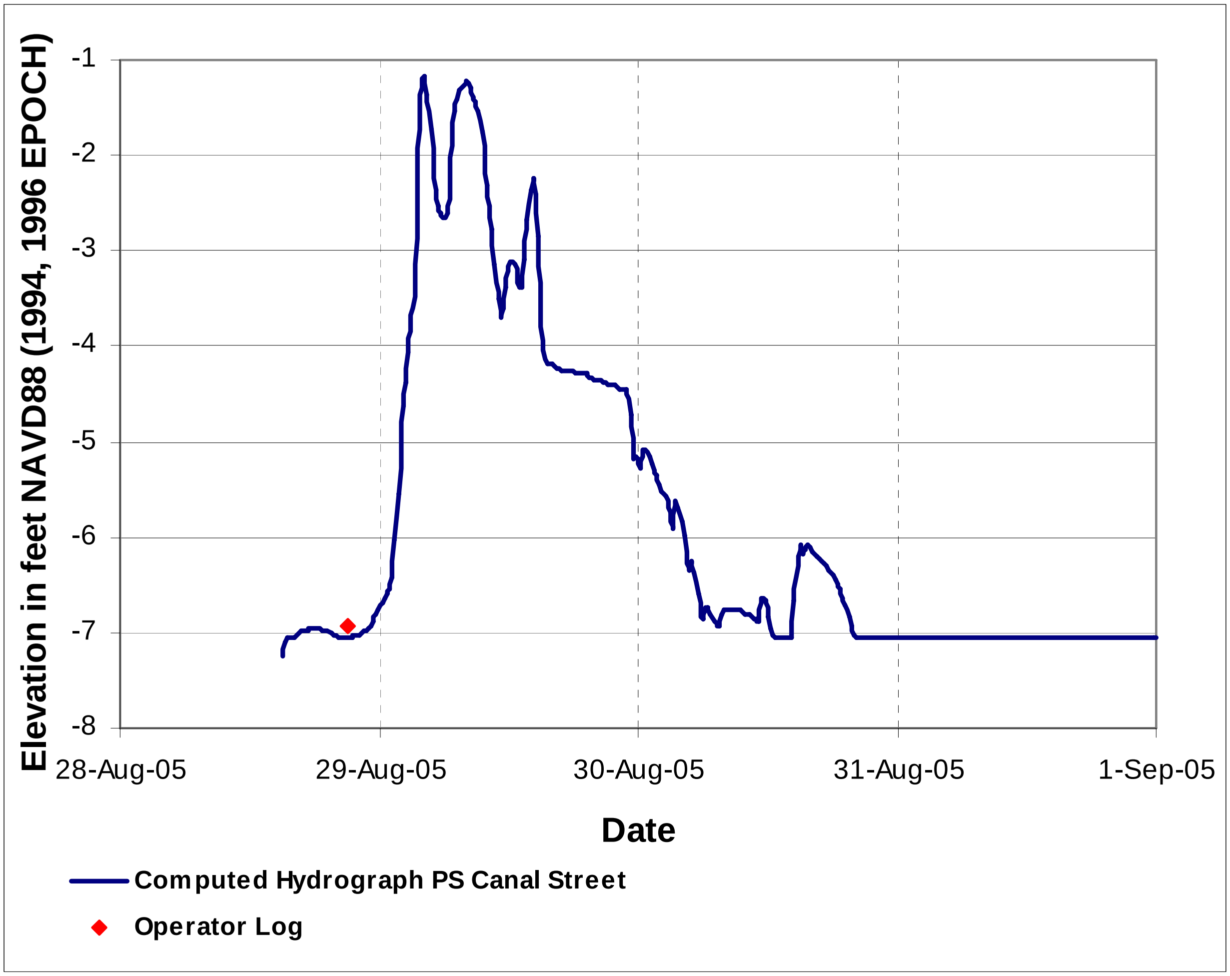

Figure 1-24. Katrina Event Computed Results, East Bank, Canal Street Pump Station

Bayou Segnette

Figure 1-25 shows the area flooded within the Bayou Segnette basin for the Katrina scenario. On average, the observed high water marks were within 0.4 feet of the model results, as shown in Table 1-10. Figure 1-26 shows the flooded area for the Hypothetical scenario. Figures 1-27 and 1-28 display the modeled stage hydrographs at Bayou Segnette pump stations and include any operator observed stages and nearby high-water marks.

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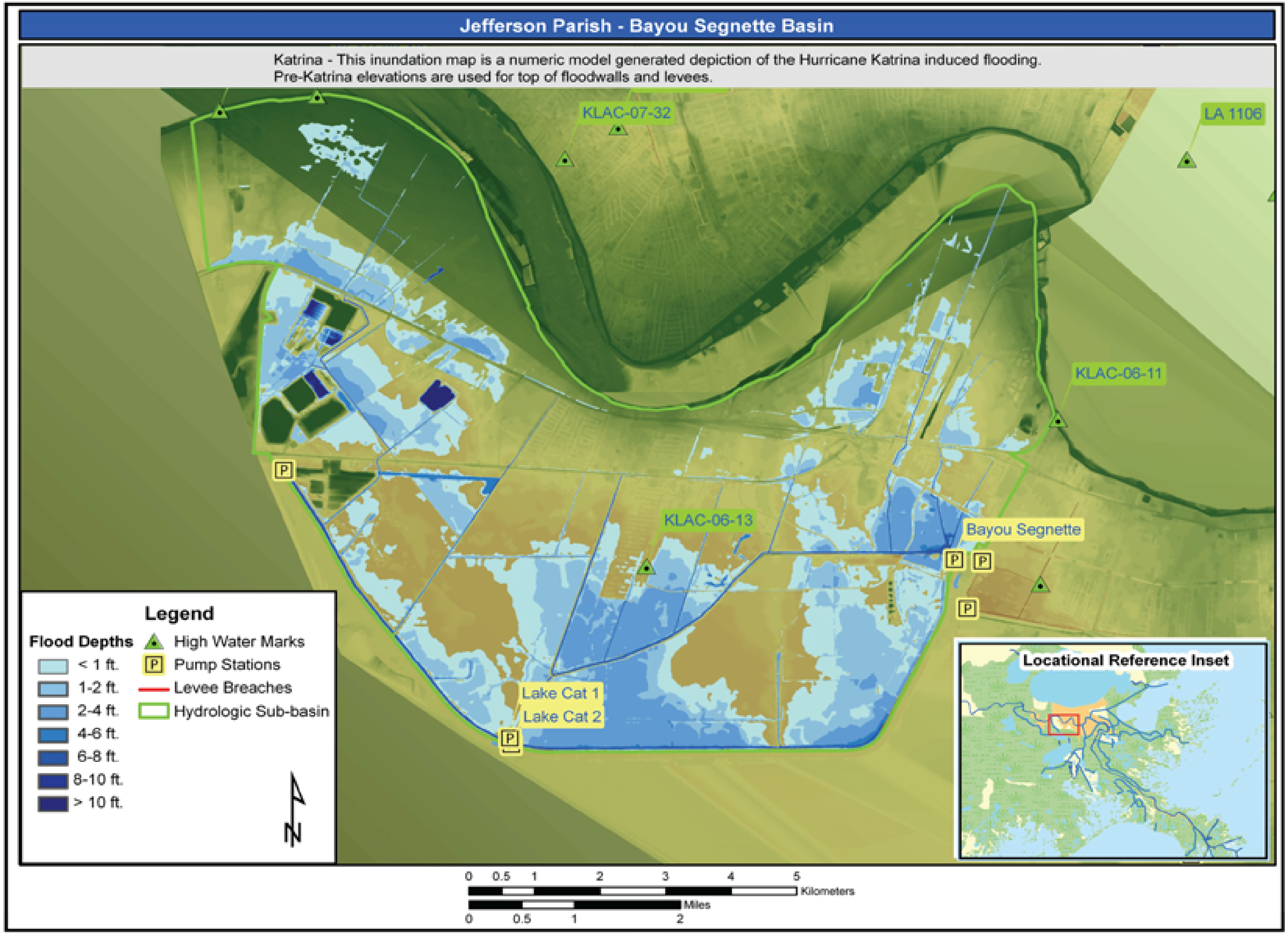
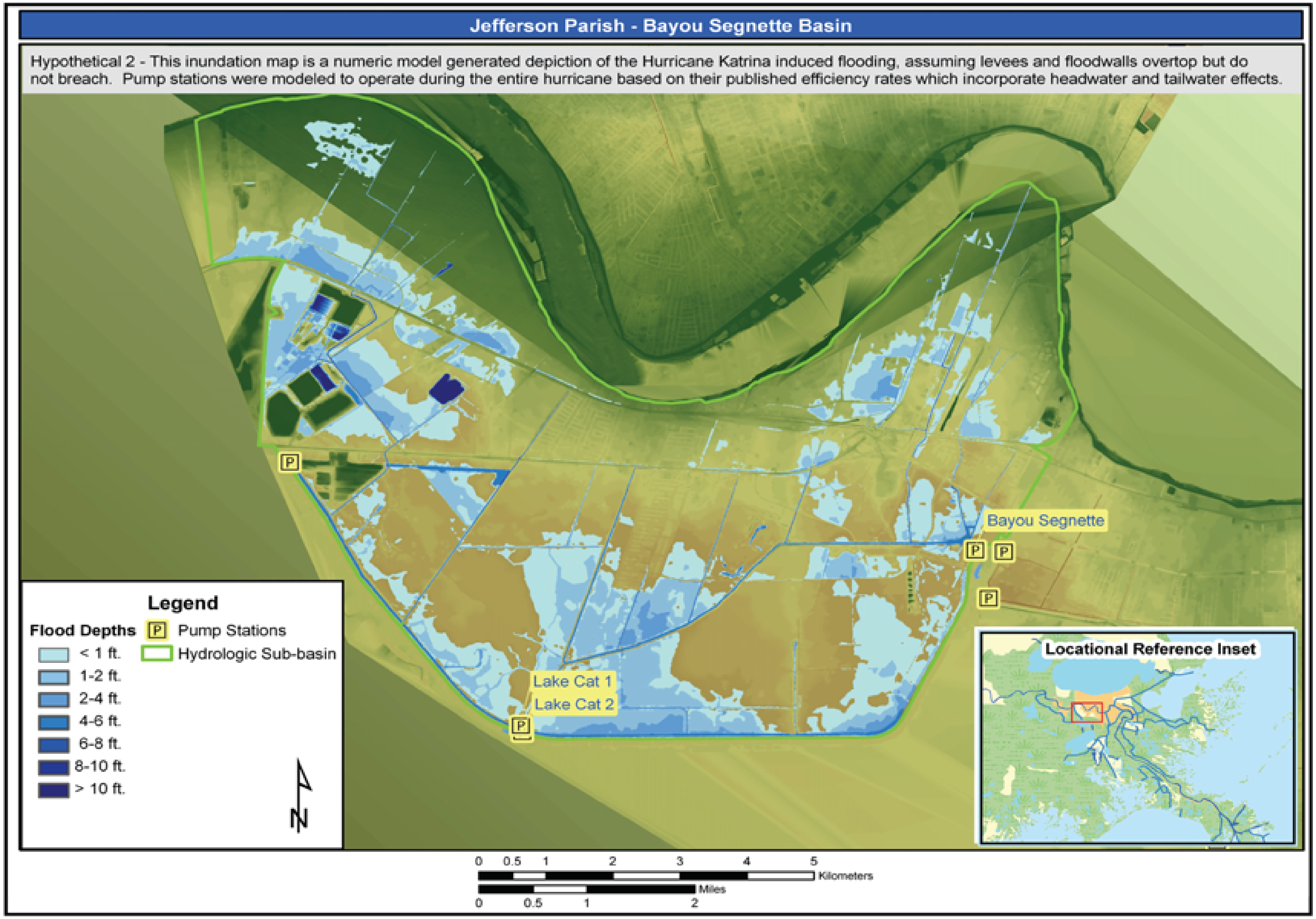


Figure 1-25. Bayou Segnette Modeled Katrina Event Flood Inundation



Jefferson Parish - Bayou Segnette Basin

Hypothetical 2 - This inundation map is a numeric model generated depiction of the Hurricane Katrina induced flooding, assuming levees and floodwalls overtop but do not breach. Pump stations were modeled to operate during the entire hurricane based on their published efficiency rates which incorporate headwater and tailwater effects.

Figure1-26. Bayou Segnette Hypothetical 2 Scenario Flood Inundation

Table 1-10
Bayou Segnette Modeled versus Observed High Water Marks

Observed Location	Observed Stage (ft NAVD 88)	Modeled Stage (ft NAVD 88)	Difference (ft)	Hypothetical 2 (ft NAVD 88)
HW KLAC-06-13	-3.6	-3.2	**0.4**	-5.7
PS Bayou Segnette 08/28 06:00	-10.1	-10.0	**0.1**	-10.7
PS Bayou Segnette 08/28 14:30	-10.7	-10.0	**0.7**	-10.7
PS Bayou Segnette 08/30 02:30	-2.1	-2.7	**-0.6**	-8.9
PS Bayou Segnette 08/30 23:45	-9.4	-8.6	**0.8**	-9.5
PS Bayou Segnette 08/31 00:15	-8.0	-8.5	**-0.5**	-9.7
PS Bayou Segnette 08/31 23:45	-9.4	-9.1	**0.3**	-10.7
PS Lake Cat. 1 08/28 06:00	-9.9	-9.9	**0.0**	-10.6
PS Lake Cat. 1 08/28 14:00	-9.9	-9.9	**0.0**	-10.6
PS Lake Cat. 1 08/30 00:00	-4.3	-3.3	**1.0**	-4.5
PS Lake Cat. 1 08/31 00:00	-3.7	-3.5	**0.2**	-5.9
PS Lake Cat. 1 09/01 00:00	-3.3	-4.3	**-0.9**	-10.6

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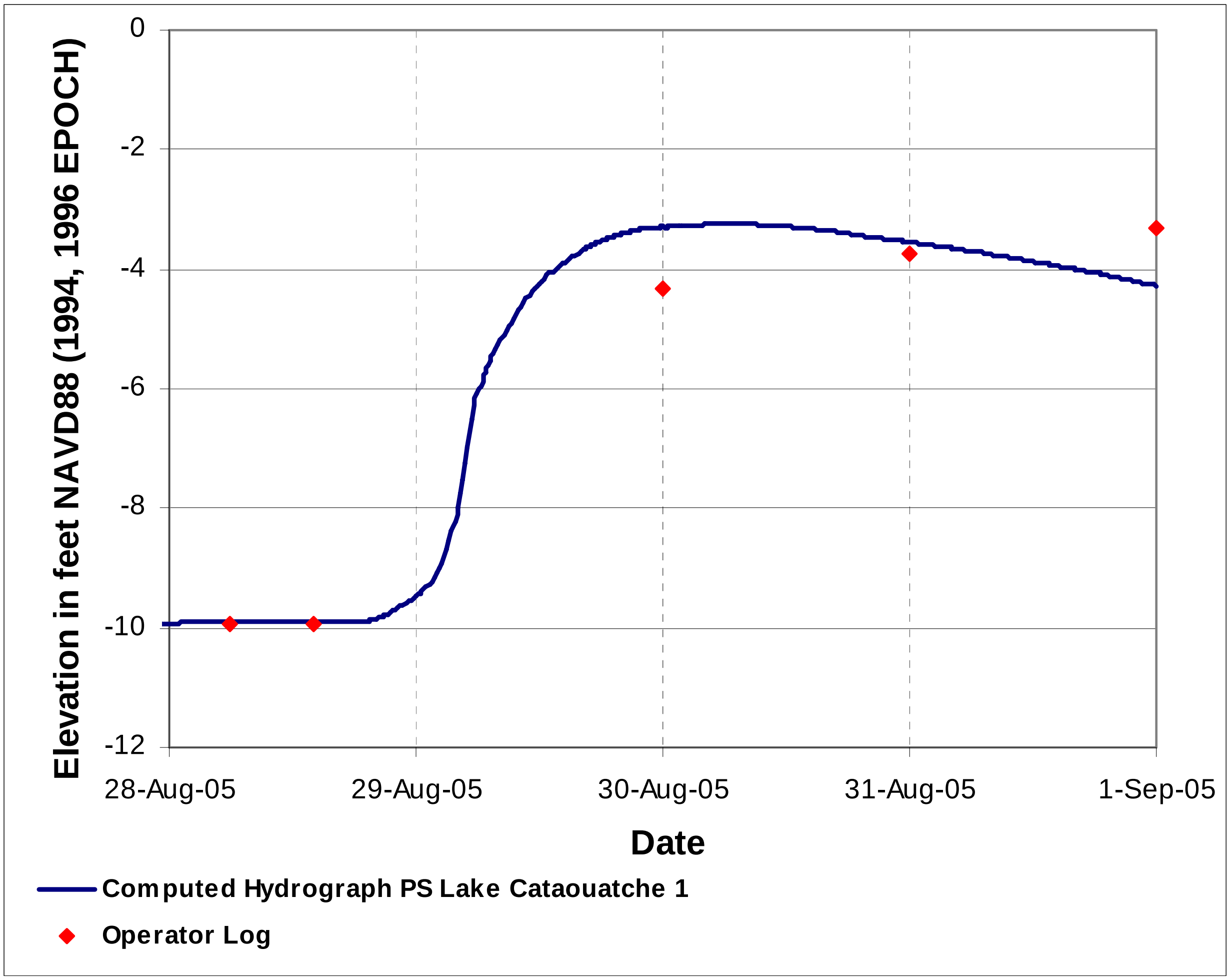

Figure 1-27. Katrina Event Computed Results, Bayou Segnette, Lake Cataouatche 1 Pump Station

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

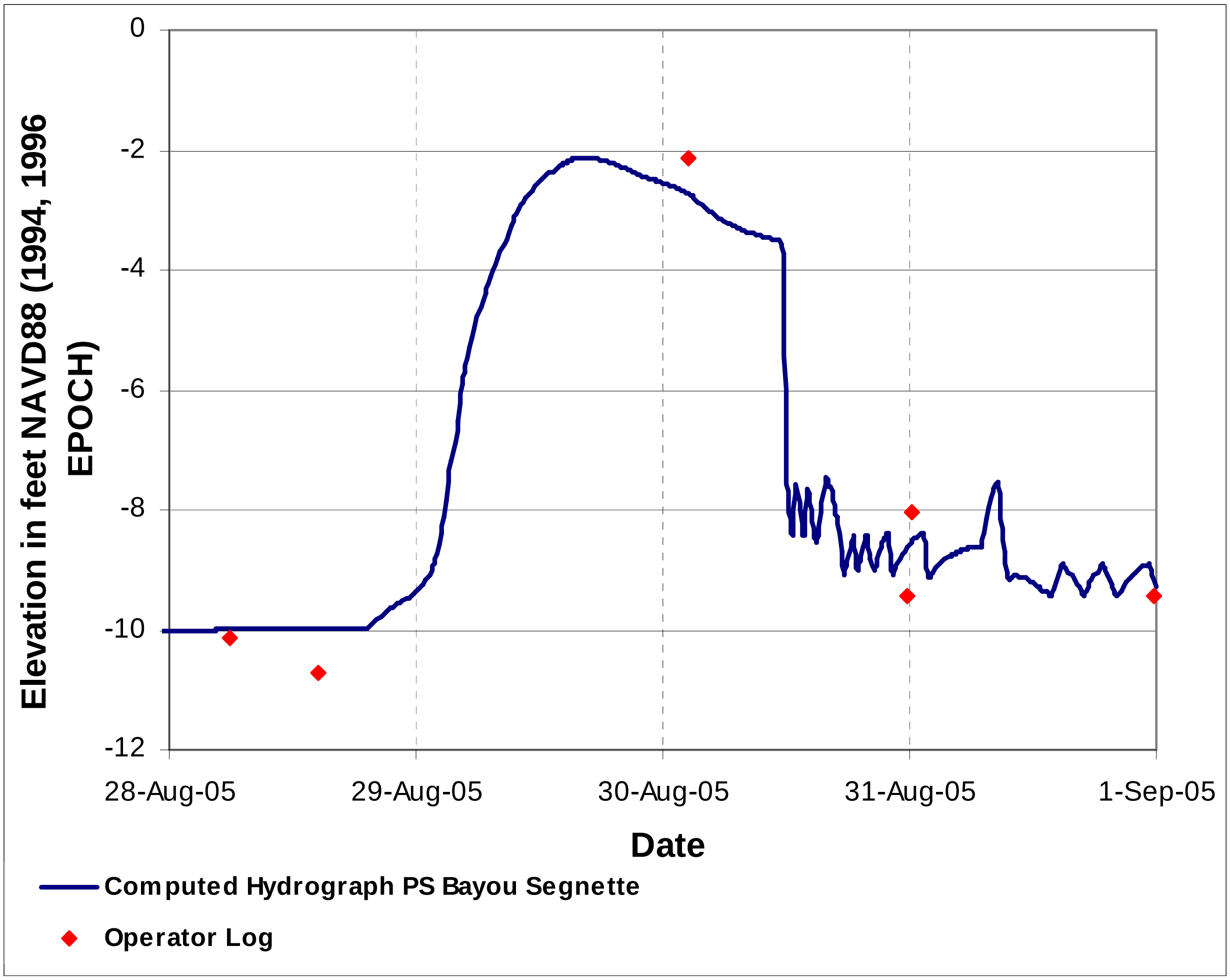

Figure 1-28. Katrina Event Computed Results, Bayou Segnette, Bayou Segnette Pump Station

Ames-Westwego

Figure 1-29 shows the area flooded within the Ames-Westwego basin based on the Katrina scenario. On average, the observed high water marks were within 0. 8 feet of the model results, as shown in Table 1-11. Figure 1-30 shows the flooded area for the Hypothetical 2 scenario. Figures 1-31 though 1-34 display the modeled stage hydrographs at Ames-Westwego pump stations and include any operator observed stages and nearby high-water marks.

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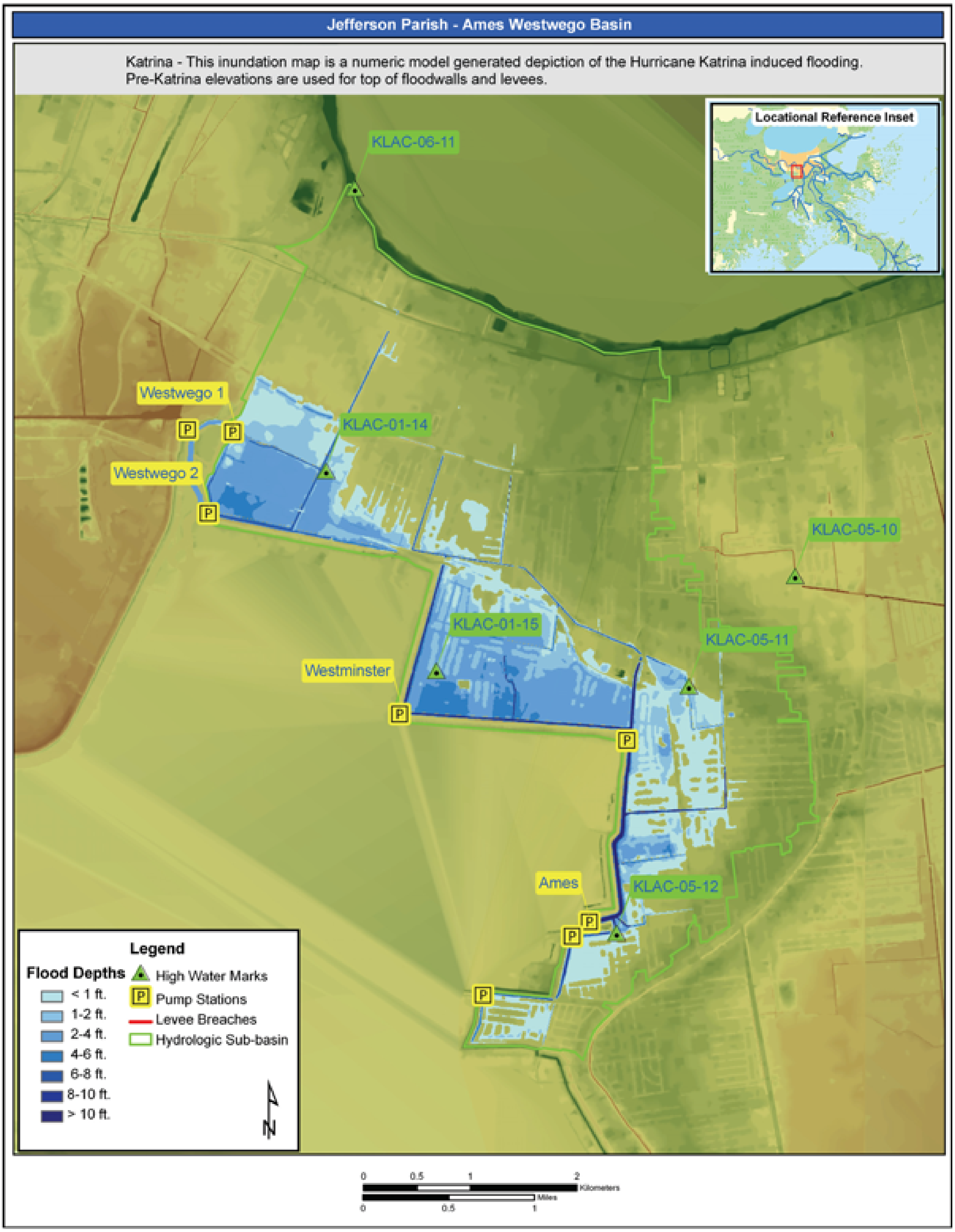

Figure 1-29. Ames-Westwego Modeled Katrina Event Flood Inundation

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

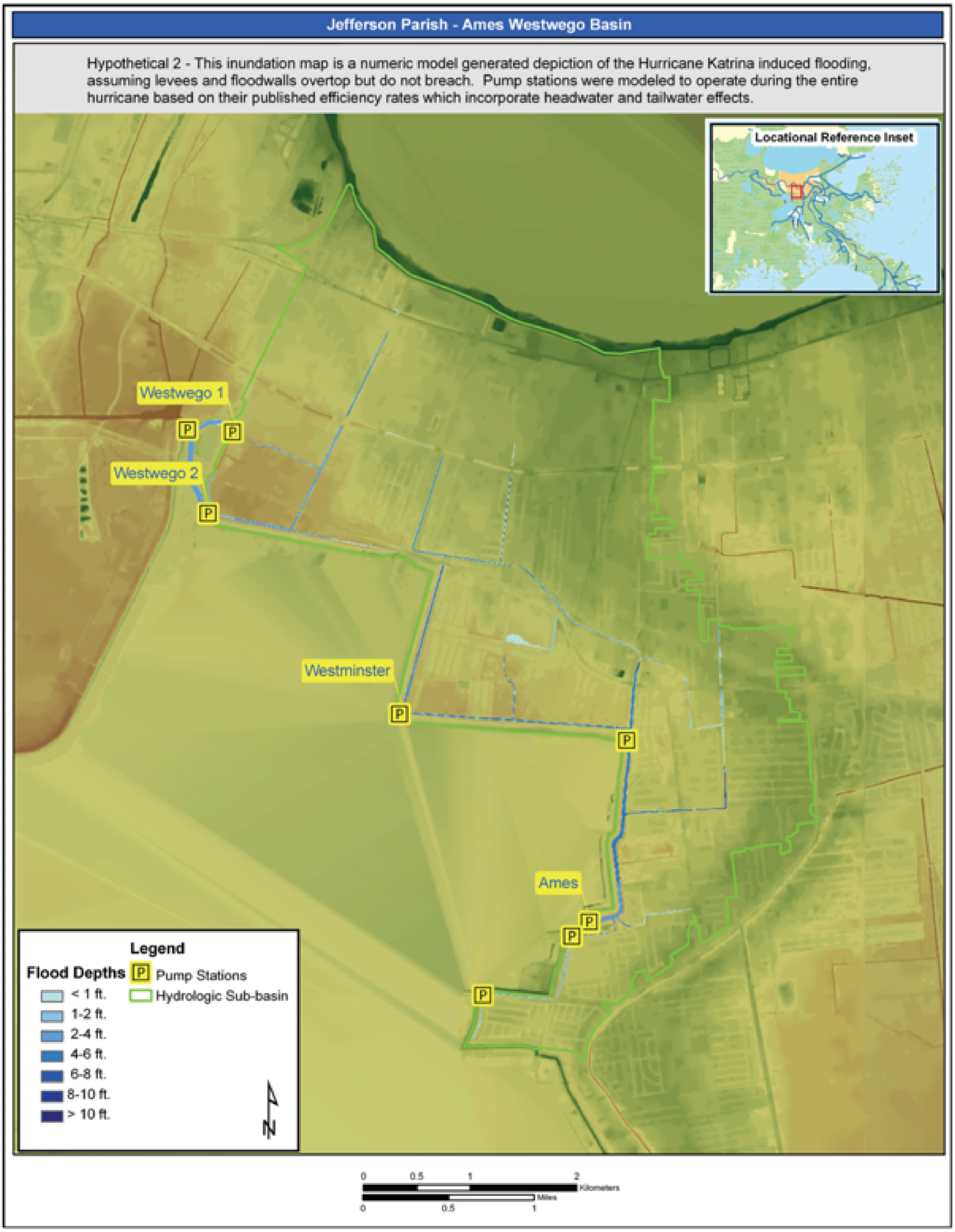

Figure 1-30. Ames Westwego Hypothetical 2 Scenario Flood Inundation

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Table 1-11
Ames-Westwego Modeled versus Observed High Water Marks

Observed Location	Observed Stage (ft NAVD 88)	Modeled Stage (ft NAVD 88)	Difference (ft)	Hypothetical 2 (ft NAVD 88)
HW KLAC-01-14	-1.2	-0.7	**0.5**	-6.3
HW KLAC-01-15	1.2	1.5	**0.3**	-5.3
HW KLAC-05-11	0.9	2.0	**1.1**	-3.0
HW KLAC-05-12	0.4	1.5	**1.1**	-6.1
PS WW1 08/28 06:00	-7.9	-7.9	**0.0**	-7.9
PS WW1 08/28 12:00	-7.9	-7.9	**0.0**	-7.9
PS WW1 08/30 00:00	-0.9	-0.9	**0.1**	-7.3
PS WW1 08/30 09:00	-6.9	-5.0	**2.0**	-7.3
PS WW2 08/28 06:00	-7.7	-7.9	**-0.2**	-7.9
PS WW2 08/28 17:00	-8.1	-7.9	**0.3**	-7.9
PS WW2 08/29 22:00	-0.9	-0.7	**0.2**	-7.3
PS WW2 08/30 00:00	-1.0	-0.9	**0.1**	-7.3
PS WW2 08/31 00:00	-7.2	-5.6	**1.6**	-7.2
PS WW2 08/31 08:00	-6.5	-4.9	**1.7**	-7.1
PS Westminster 08/29 00:00	-7.4	-7.2	**0.2**	-8.4
PS Ames 08/28 06:00	-9.8	-9.7	**0.2**	-10.8
PS Ames 08/28 16:00	-11.9	-10.6	**1.4**	-10.9
PS Ames 08/29 21:30	1.7	1.5	**-0.2**	-9.8
PS Ames 08/30 00:00	1.7	1.5	**-0.2**	-10.4
PS Ames 08/31 00:00	-10.4	-10.0	**0.5**	-10.3
PS Ames 08/31 12:00	-7.9	-10.5	**-2.6**	-10.2

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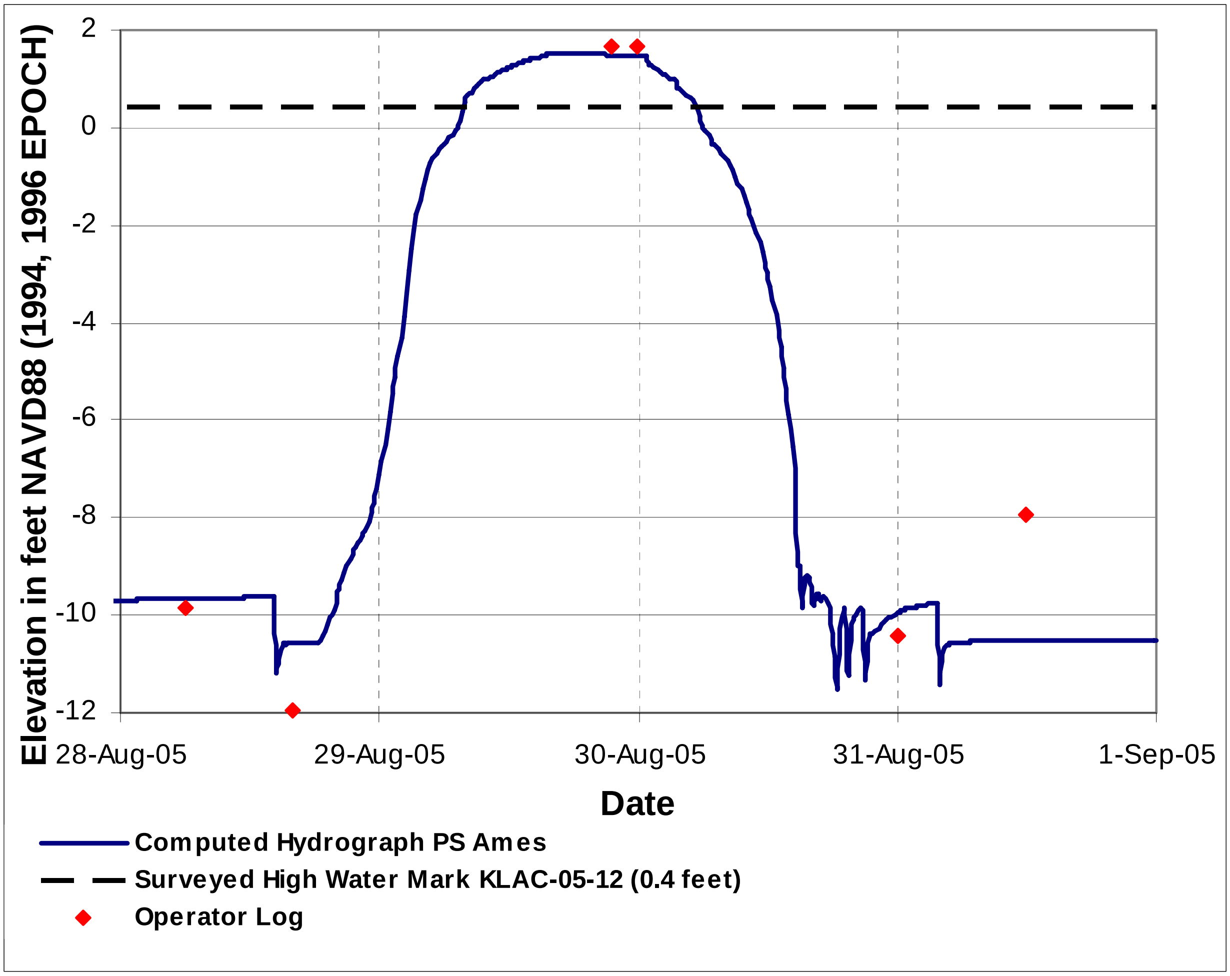

Figure 1-31. Katrina Event Computed Results, Ames-Westwego, Ames Pump Station

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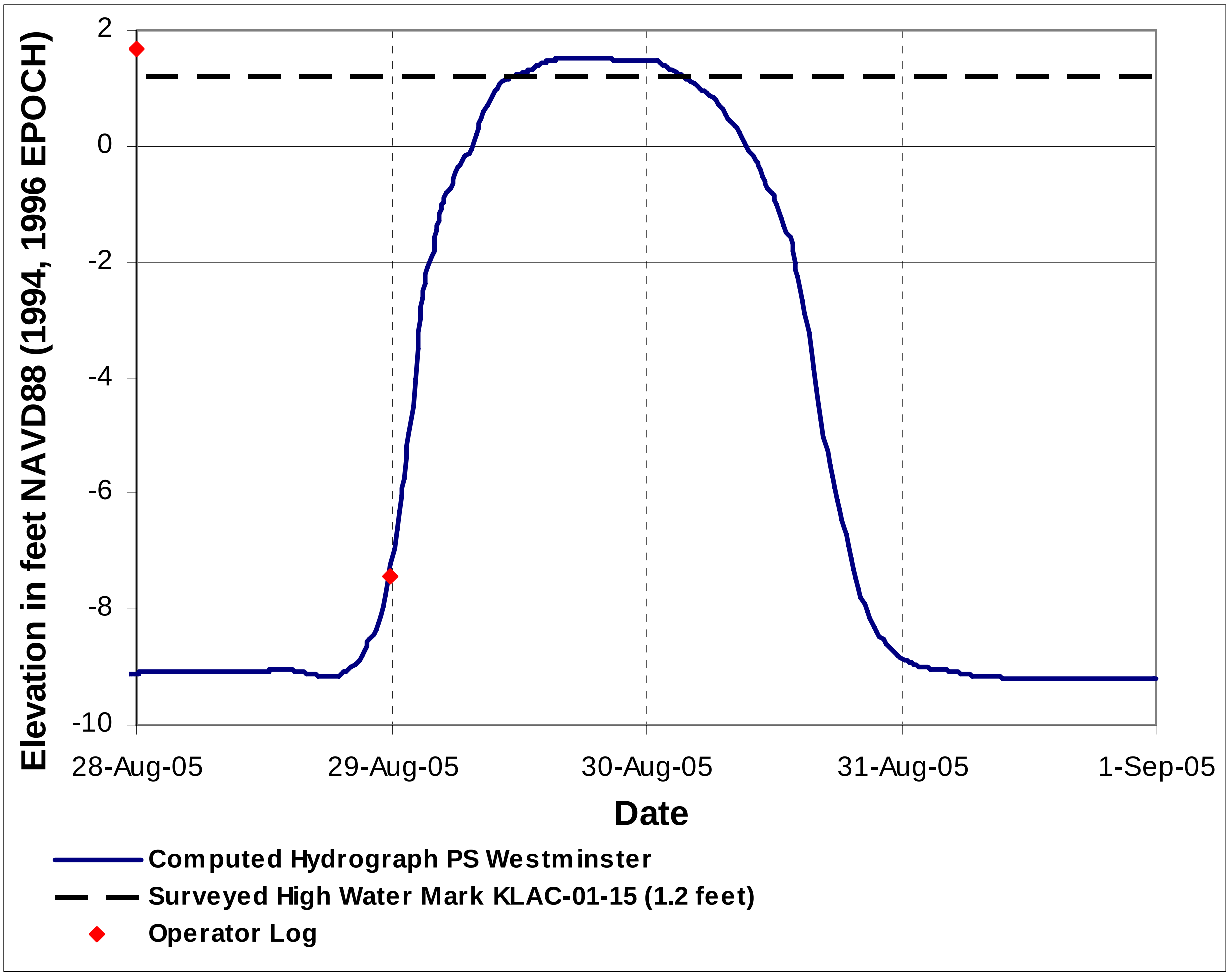

Figure 1-32. Katrina Event Computed Results, Ames-Westwego, Westminster Pump Station

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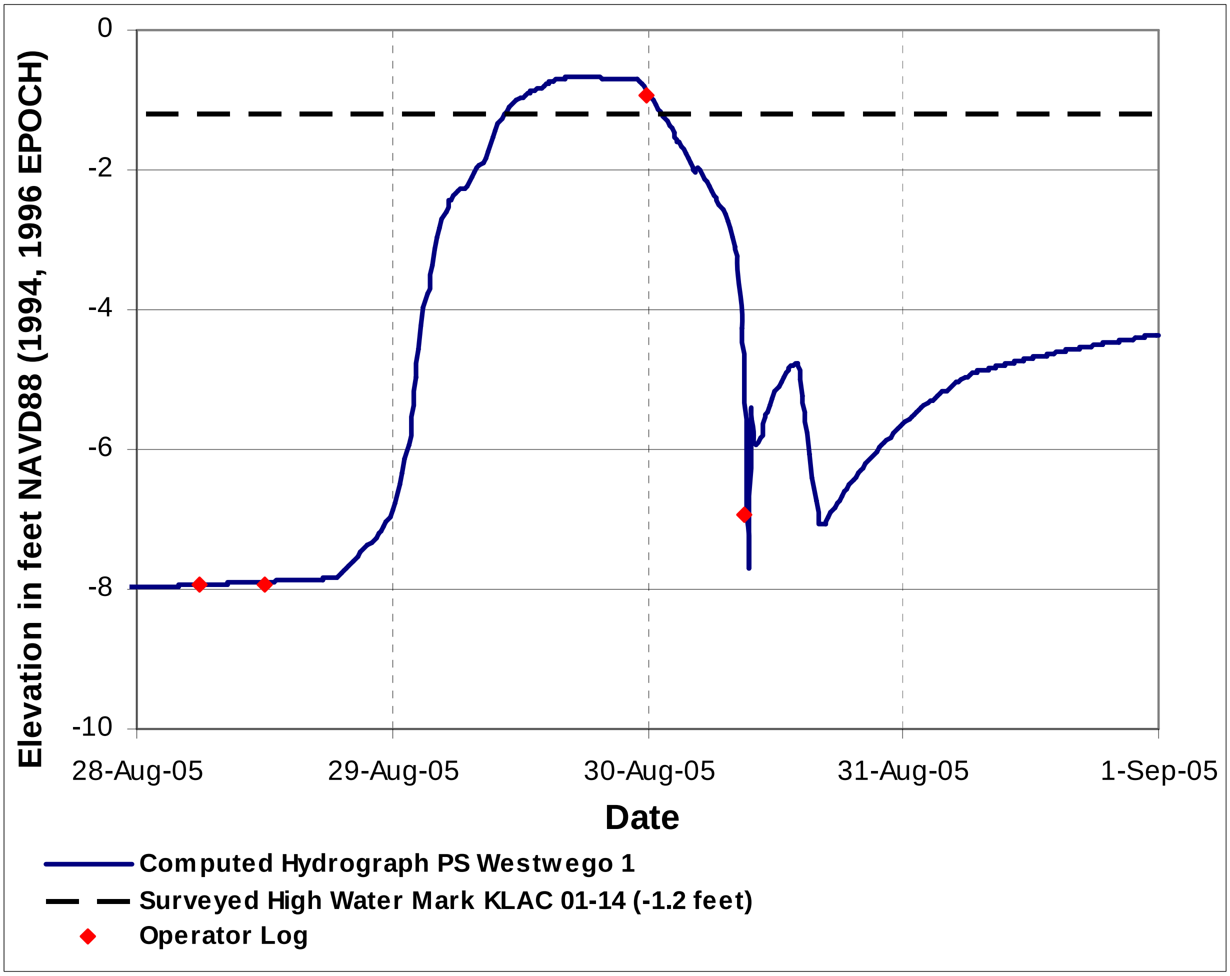

Figure 1-33. Katrina Event Computed Results, Ames-Westwego, Westwego 1 Pump Station

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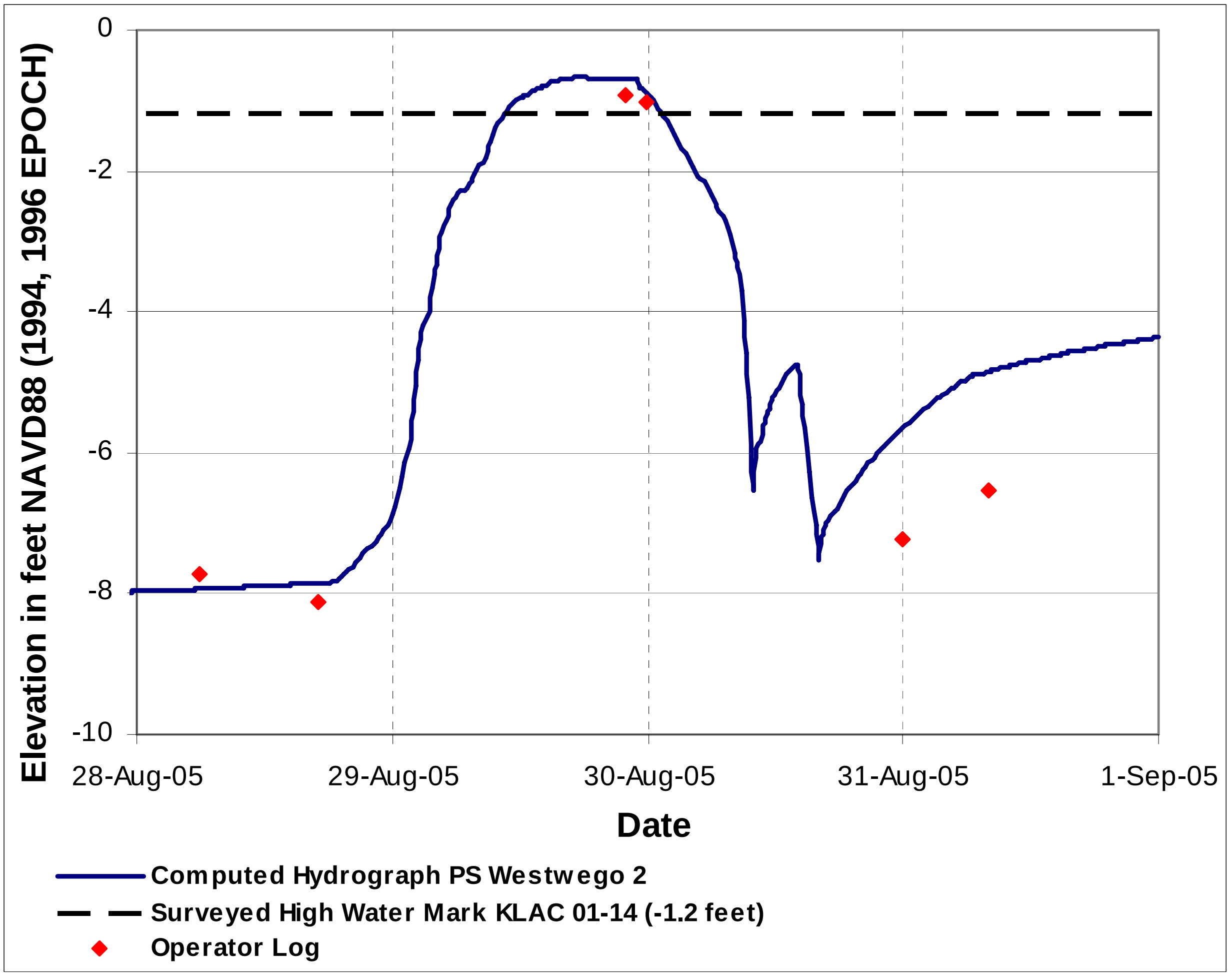

Figure 1-34. Katrina Event Computed Results, Ames-Westwego, Westwego 2 Pump Station

Harvey-Estelle-Cousins

Figure 1-35 shows the area flooded within the Harvey-Estelle-Cousins basin based on the Katrina scenario. On average, the observed high water marks were within 0.8 feet of the model results, as shown in Table 1-12. Figure 1-36 shows the flooded area for the Hypothetical 2 scenario. Figures 1-37 though 1-39 display the modeled stage hydrographs at Harvey-Estelle-Cousins pump stations and include any operator observed stages and nearby high-water marks.

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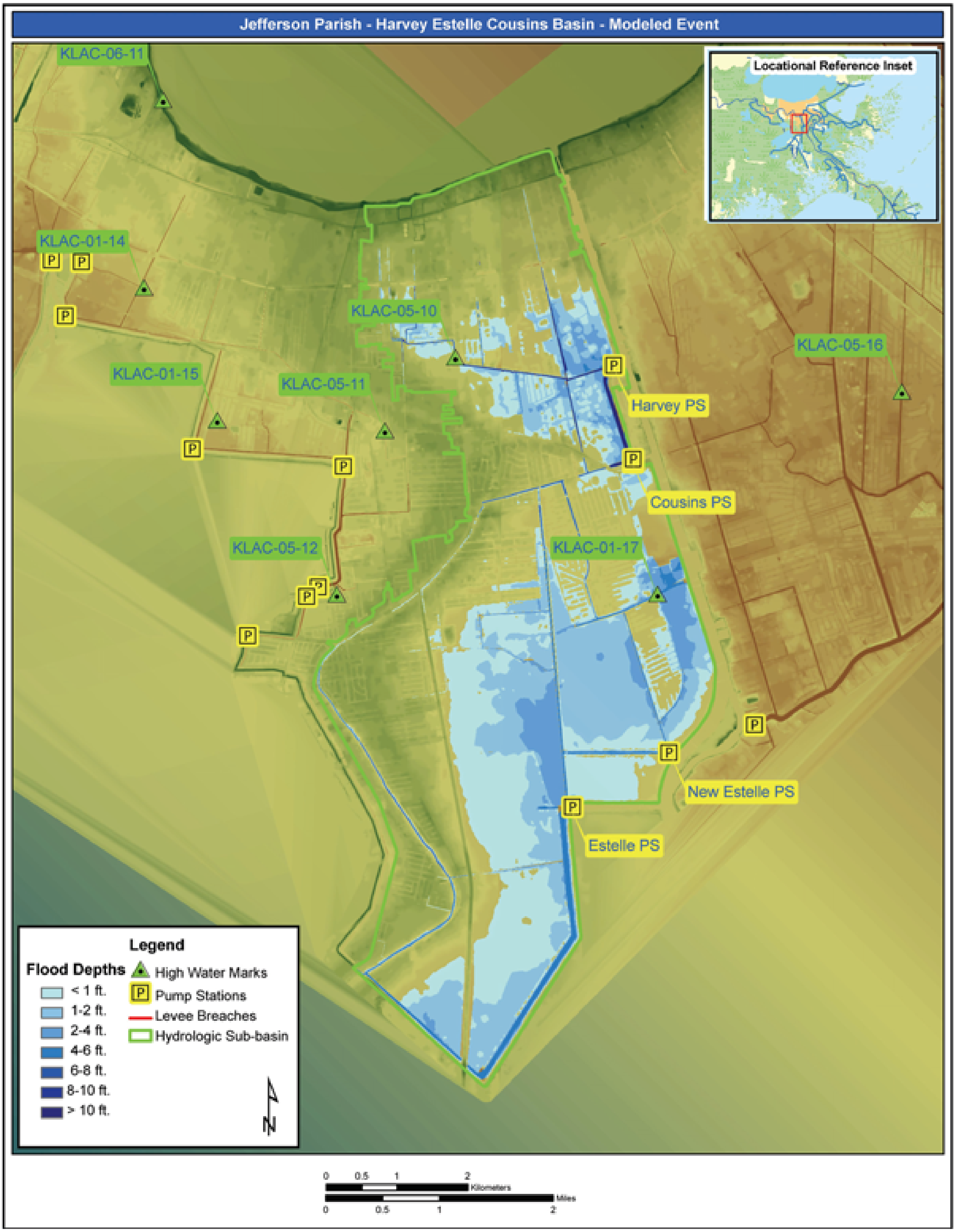

Figure 1-35. Harvey-Estelle-Cousins Modeled Katrina Event Flood Inundation

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

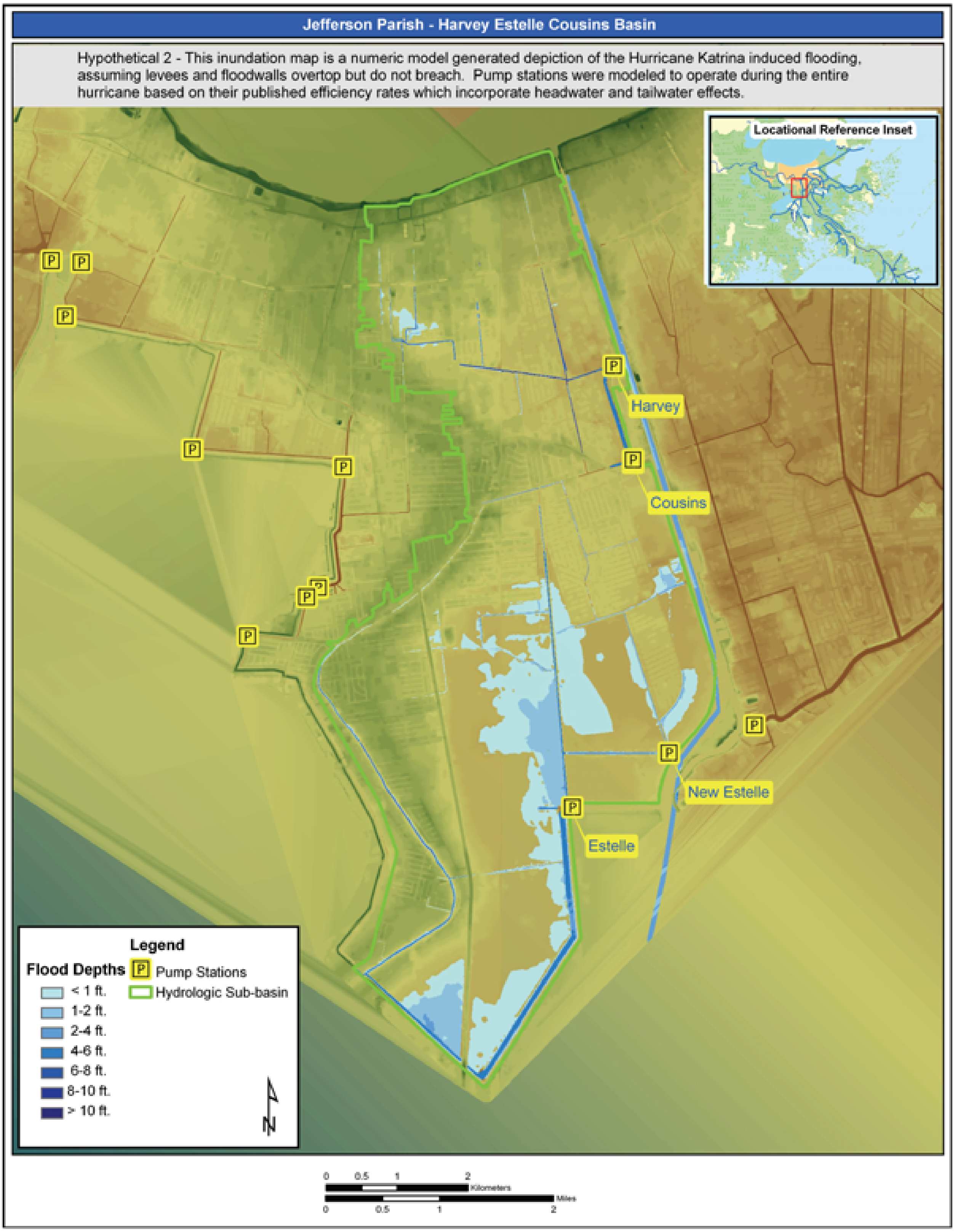

Figure 1-36. Harvey-Estelle-Cousins Hypothetical 2 Scenario Flood Inundation

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Table 1-12
Harvey-Estelle-Cousins Modeled versus Observed High Water Marks

Observed Location	Observed Stage (ft NAVD 88)	Modeled Stage (ft NAVD 88)	Difference (ft)	Hypothetical 2 (ft NAVD 88)
HW KLAC-01-17	-1.8	-0.7	**1.1**	-3.8
HW KLAC-05-10	0.4	0.8	**0.4**	-0.3
PS New Estelle 08/28 06:00	-6.4	-5.3	**1.1**	-5.3
PS New Estelle 08/28 14:00	-7.9	-5.2	**2.7**	-5.3
PS New Estelle 08/30 00:00	-0.4	-1.4	**-1.0**	-5.0
PS New Estelle 08/31 00:00	-1.6	-2.0	**-0.4**	-5.7
PS Harvey 08/28 06:00	-11.3	-11.1	**0.2**	-11.3
PS Harvey 08/29 00:00	-9.8	-10.9	**-1.0**	-11.0
PS Harvey 08/30 00:00	-7.5	-0.6	**6.9**	-11.2
PS Harvey 08/31 00:00	-11.9	-10.6	**1.4**	-11.2

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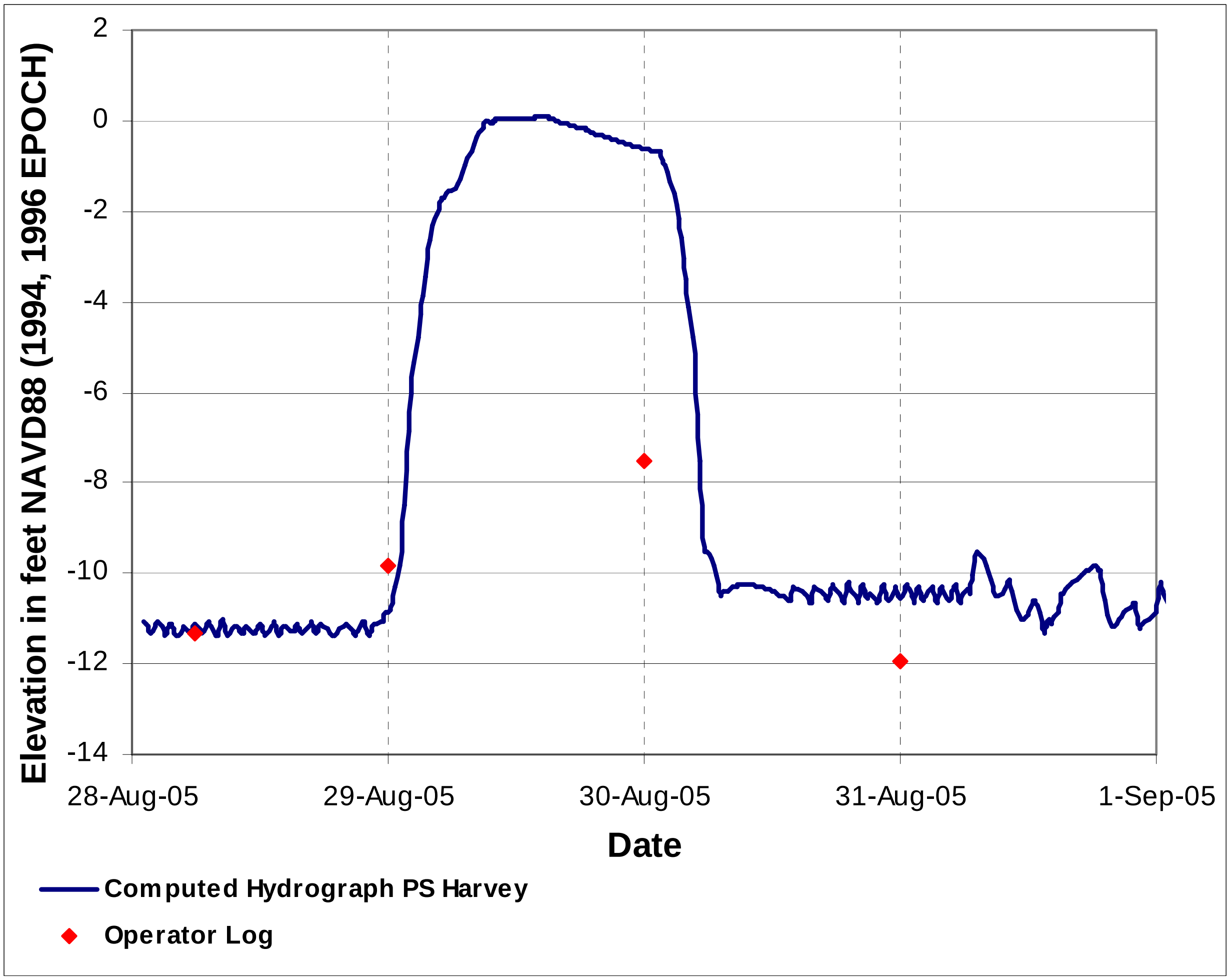

Figure 1-37. Katrina Event Computed Results, Harvey-Estelle-Cousins, Harvey Pump Station

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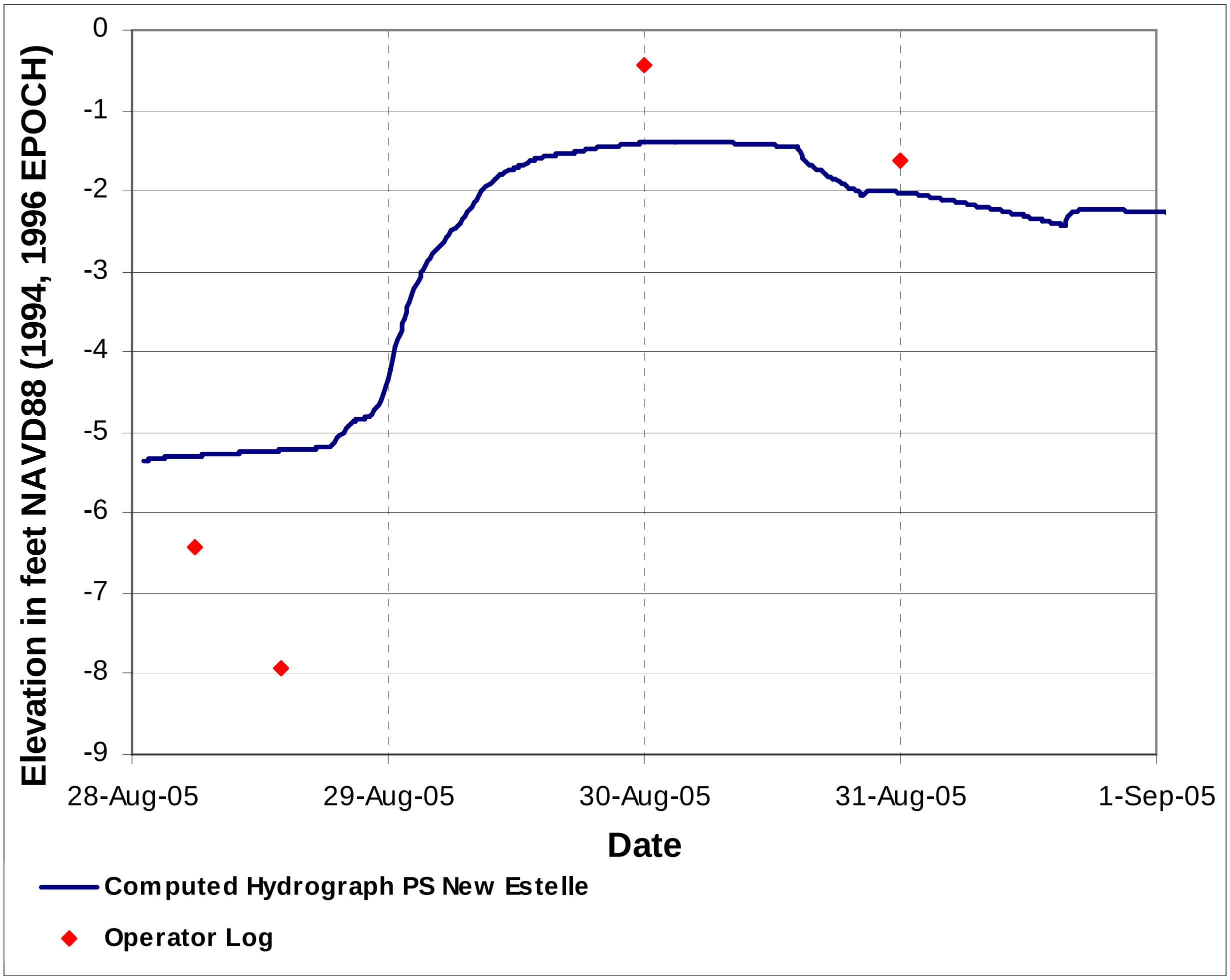

Figure 1-38. Katrina Event Computed Results, Harvey-Estelle-Cousins, New Estelle Pump Station

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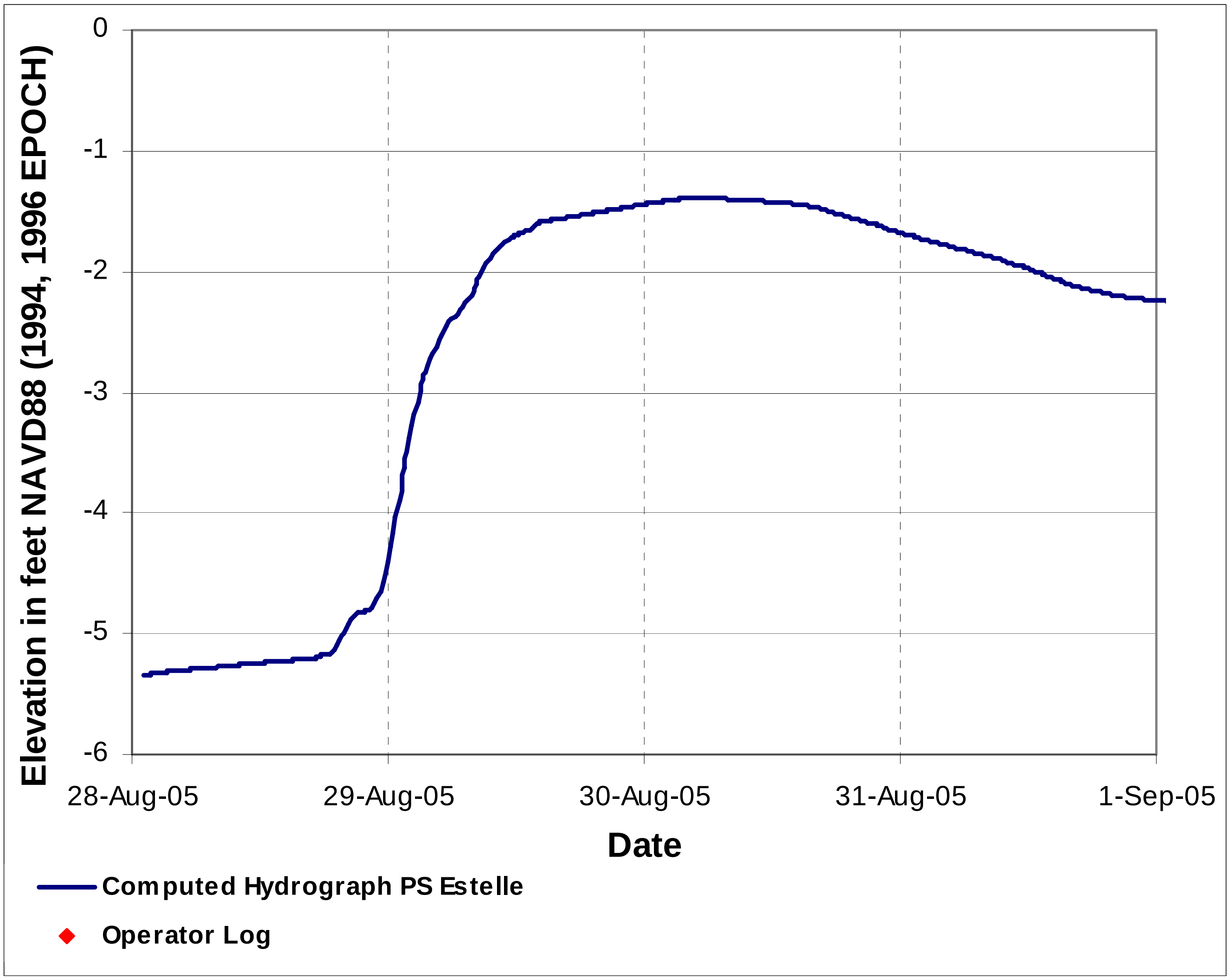

Figure 1-39. Katrina Event Computed Results, Harvey-Estelle-Cousins, Estelle Pump Station

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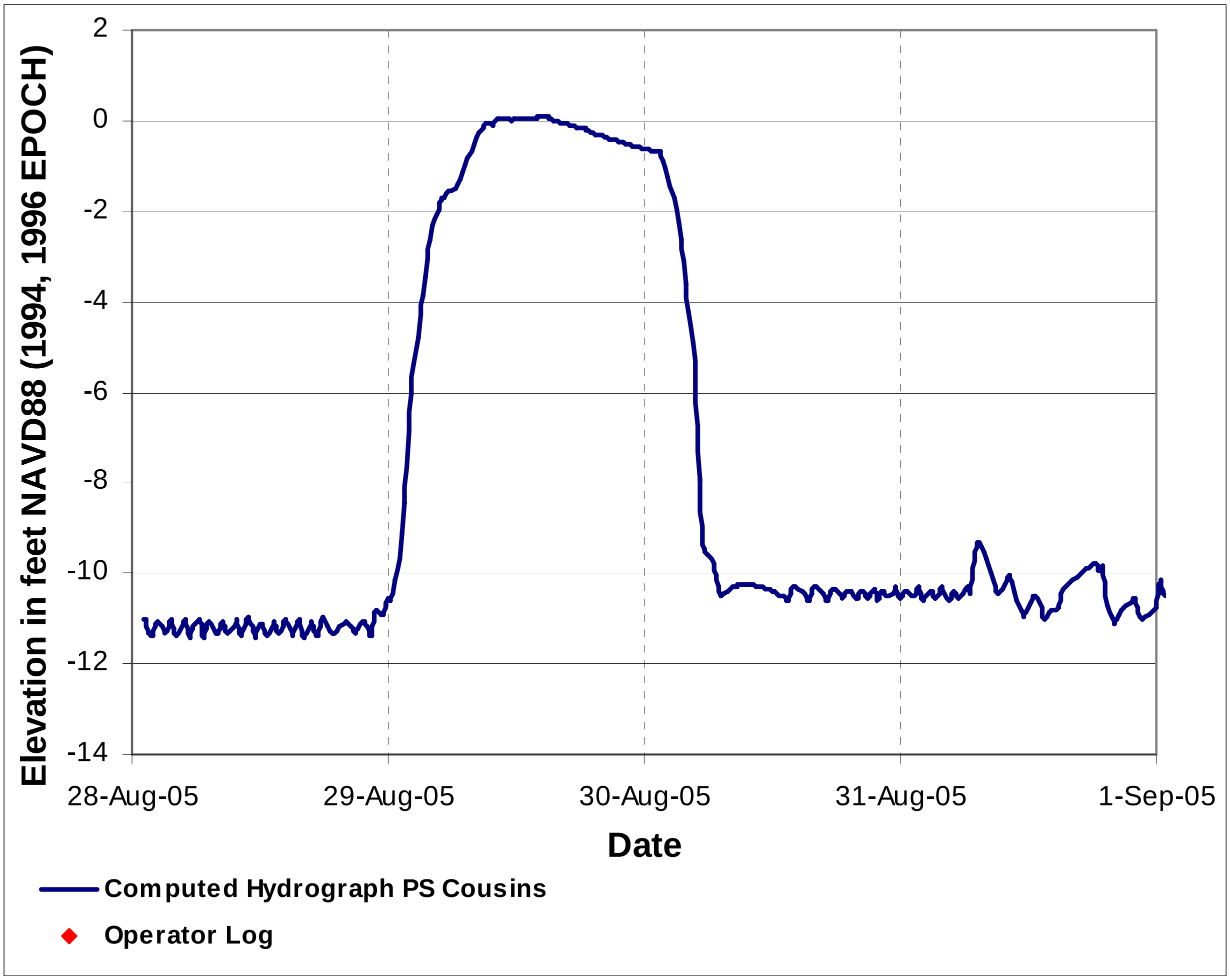

Figure 1-40. Katrina Event Computed Results, Harvey-Estelle-Cousins, Cousins Pump Station

East of Harvey Canal

Figure 1-41 shows the area flooded based on the Katrina scenario. On average, the observed high water marks were within 1.4 feet of the model results, as shown in Table 1-13. Figure 1-42 shows the flooded area for the Hypothetical 2 scenario. Figures 1-43 though 1-45 display the modeled stage hydrographs at East Bank pump stations and include any operator observed stages and nearby high-water marks. The accuracy of high water marks KLAC-05-16 and KLAC-05-14 is uncertain since they are located in central portions of the basin yet correspond to elevations well below downstream operator recorded stages.

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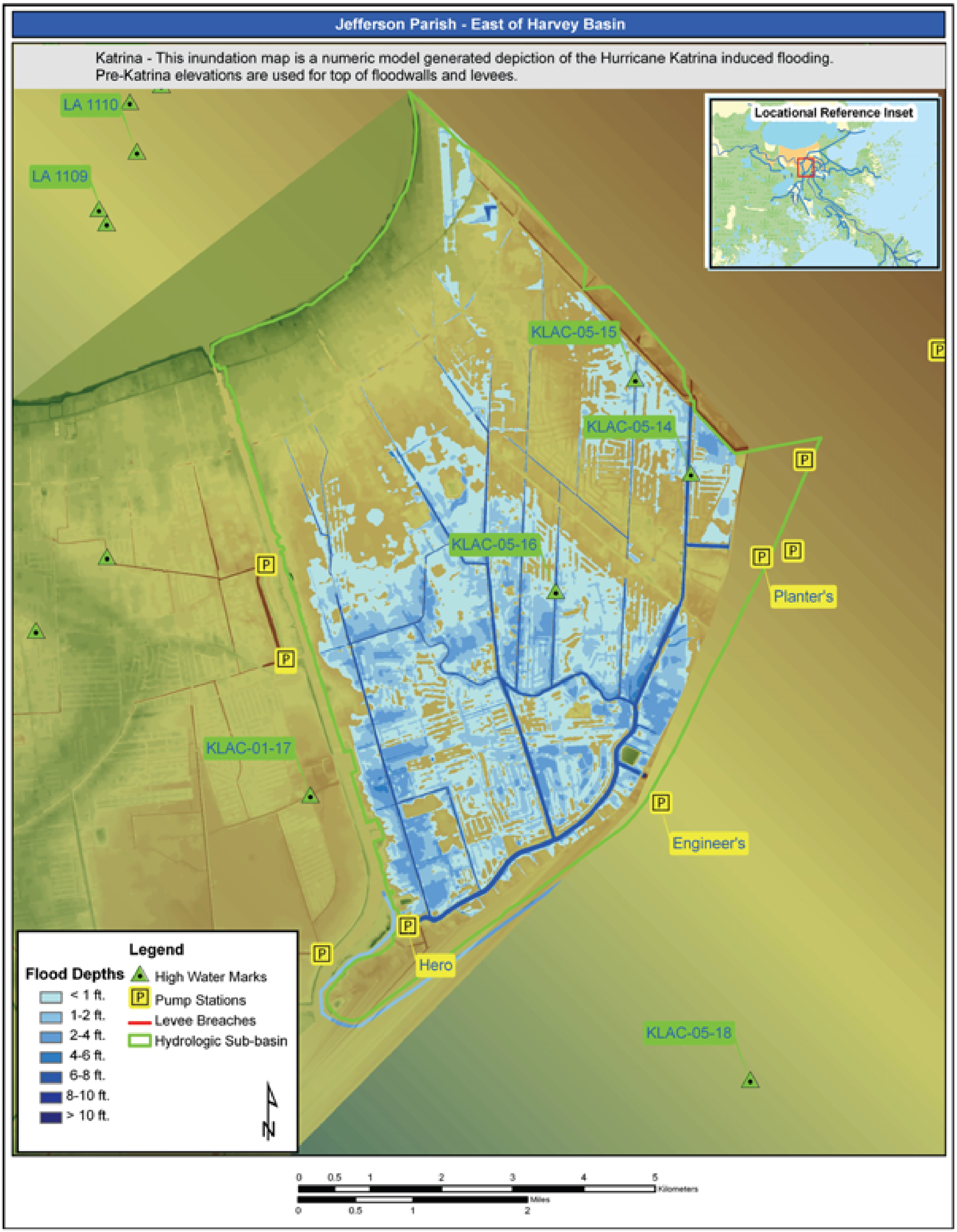

Figure 1-41. East of Harvey Canal Modeled Katrina Event Flood Inundation

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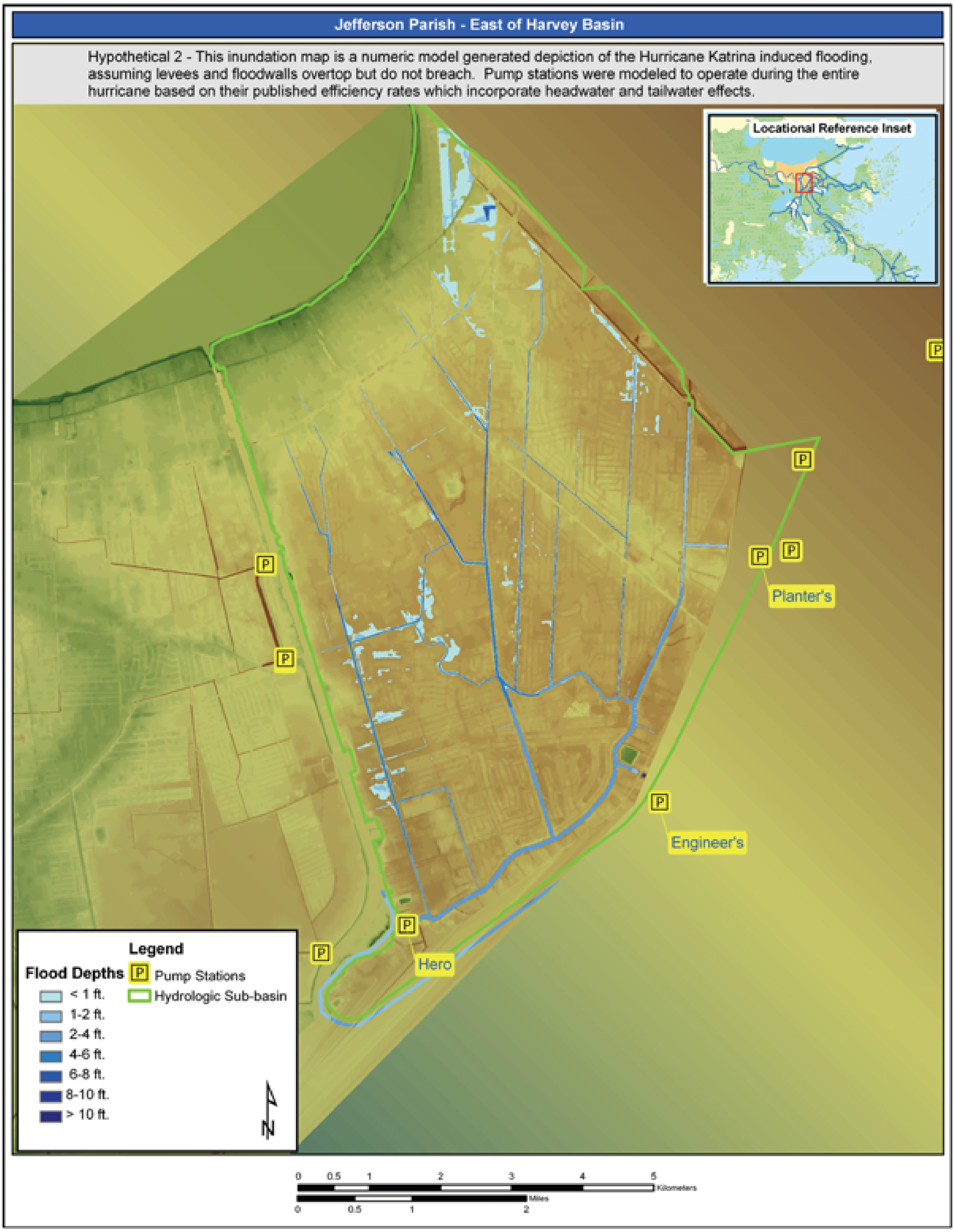

Figure 1-42. East of Harvey Canal Hypothetical 2 Scenario Flood Inundation

Table 1-13
East of Harvey Canal Modeled versus Observed High Water Marks

Observed Location	**Observed Stage** (ft NAVD 88)	**Modeled Stage** (ft NAVD 88)	**Difference** (ft)	**Hypothetical 2** (ft NAVD 88)
HW KLAC-05-14	-4.3	-3.1	**1.2**	-9.4
HW KLAC-05-15	-3.7	-3.2	**0.5**	-4.0
HW KLAC-05-16	-5.7	-3.1	**2.6**	-6.1
PS Hero 08/30 00:00	-3.2	-3.2	**0.0**	-11.7
PS Hero 08/30 18:00	-7.8	-11.4	**-3.6**	-11.7
PS Hero 08/30 23:45	-11.0	-11.5	**-0.5**	-11.8
PS Hero 08/31 00:00	-12.0	-11.5	**0.5**	-11.8
PS Hero 09/01 00:00	-11.0	-11.4	**-0.4**	-11.8
PS Planters 08/30 06:30	-3.8	-3.7	**0.2**	-11.7
PS Planters 08/31 00:00	-11.2	-11.5	**-0.2**	-11.8
PS Planters 09/01 00:00	-11.2	-11.4	**-0.1**	-11.8
PS Engineers 08/30 00:00	-3.5	-3.2	**0.4**	-11.7
PS Engineers 08/30 23:45	-11.2	-11.5	**-0.2**	-11.8
PS Engineers 09/31 00:00	-11.3	-11.5	**-0.1**	-11.8
PS Engineers 09/01 00:00	-11.2	-11.4	**-0.1**	-11.2

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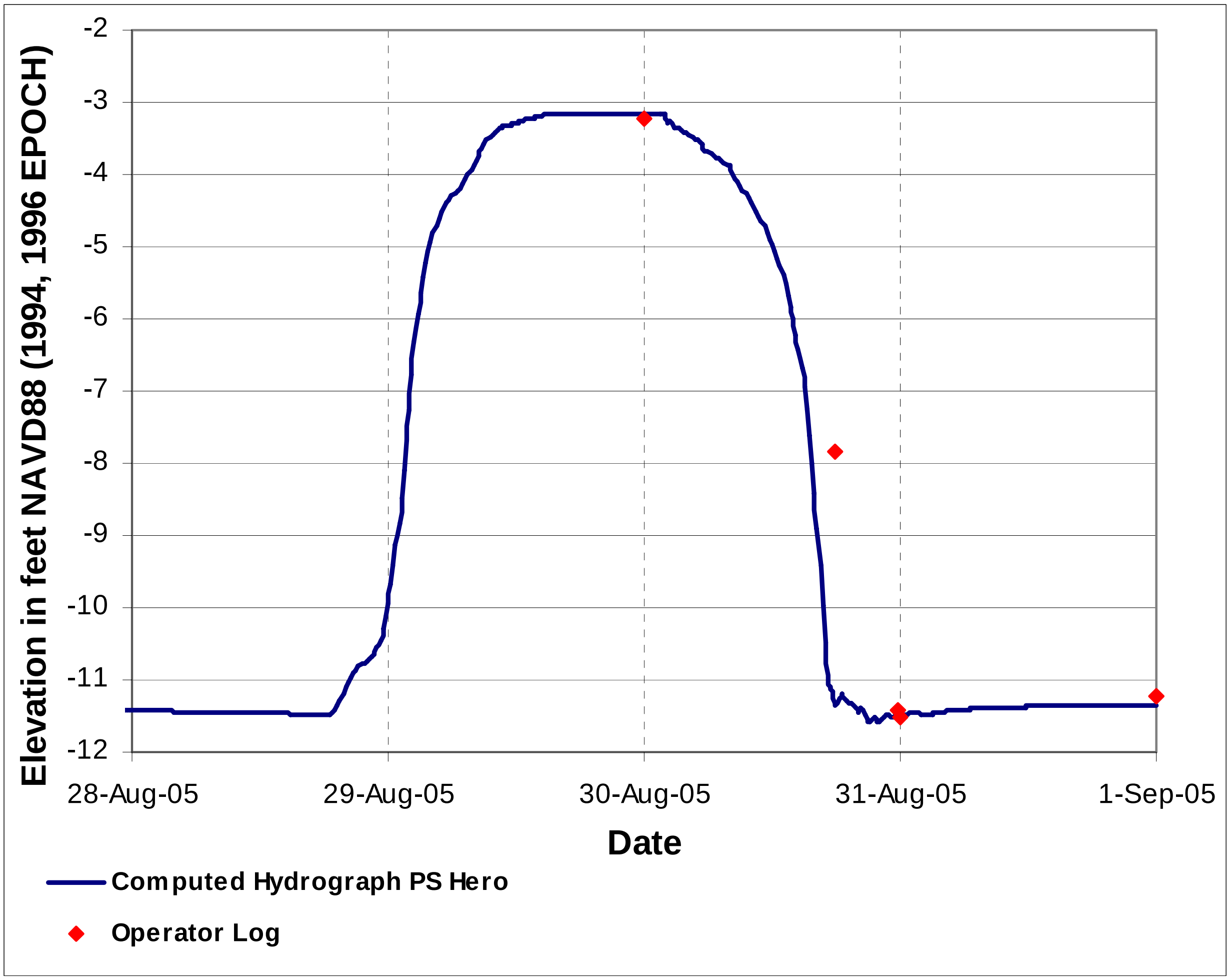

Figure 1-43. Katrina Event Computed Results, East of Harvey, Hero Pump Station

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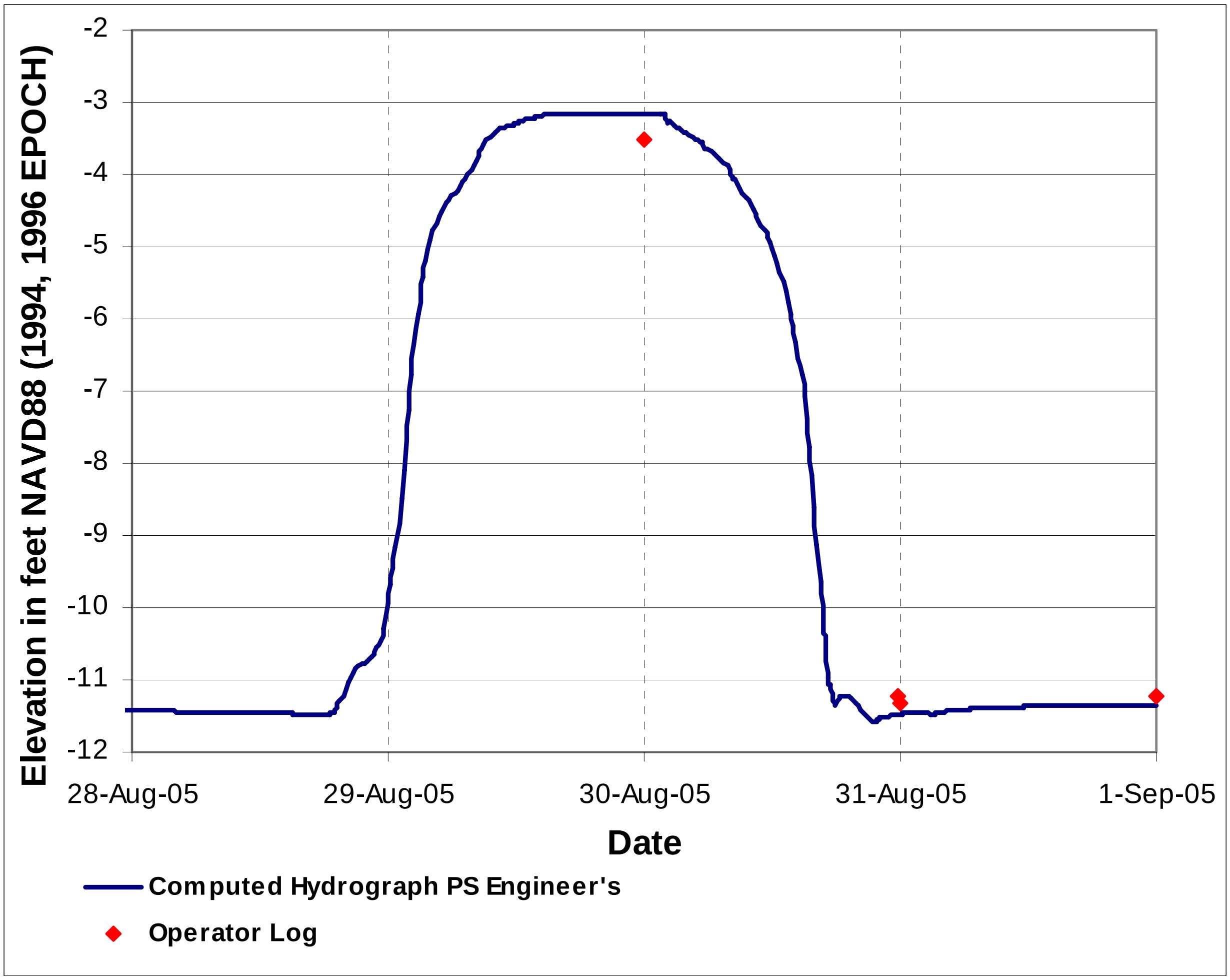

Figure 1-44. Katrina Event Computed Results, East of Harvey, Engineer's Pump Station

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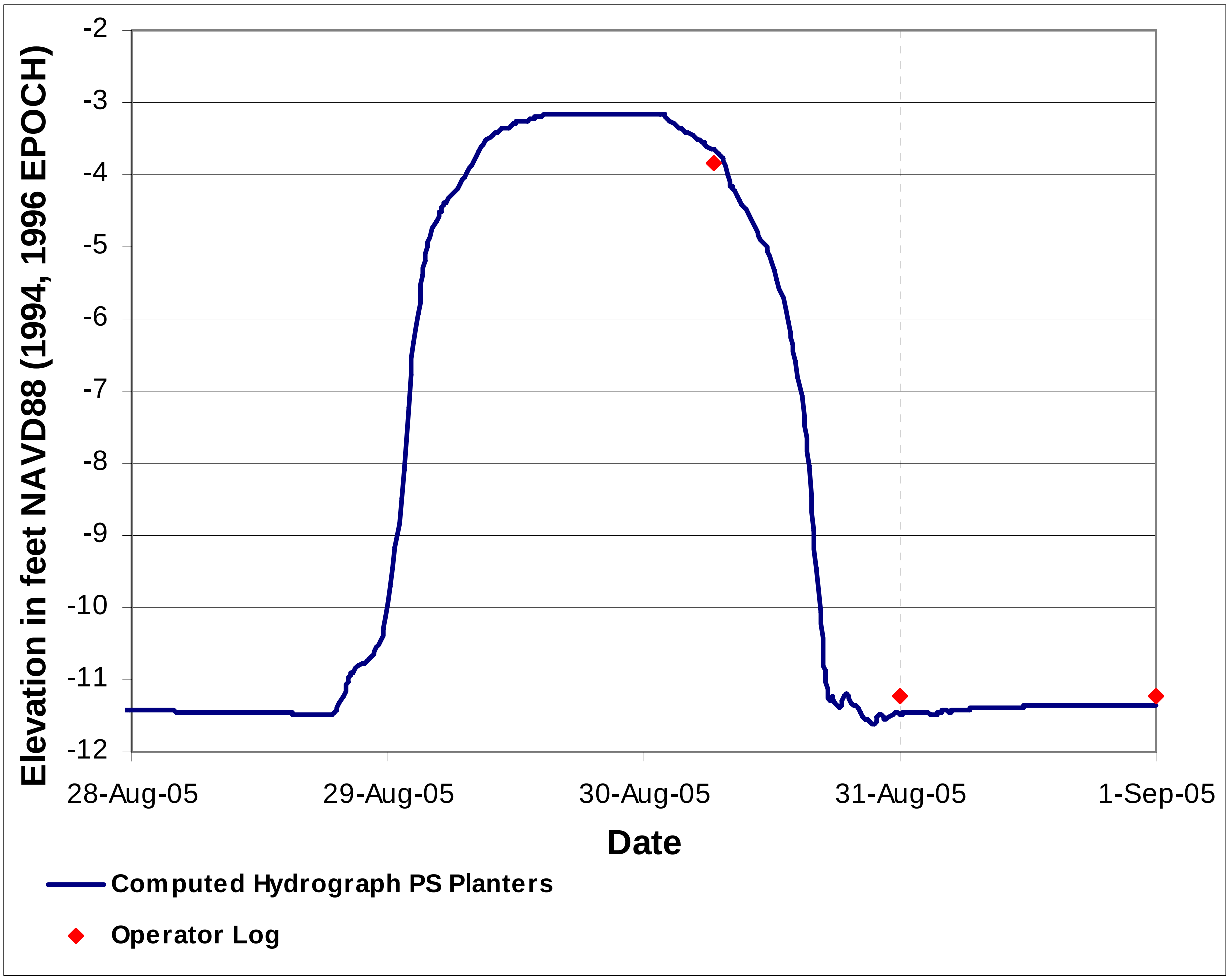

Figure 1-45. Katrina Event Computed Results, East of Harvey, Planter’s Pump Station

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Appendix 2
Interior Drainage Analysis – Orleans East Bank - June 2006

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Introduction

Study Purpose

The numerical model investigation of Hurricane Katrina flooding in Orleans East Bank was conducted to help answer questions regarding the performance of the hurricane protection system, and to obtain an understanding of how floodwaters, from various sources, flowed through metropolitan New Orleans. Inundation sources included rainfall and water that overtopped and breached levees and floodwalls. The numerical model was used to simulate actual flooding events during Hurricane Katrina. The model was also used to evaluate three postulated scenarios where various combinations of floodwall and levee breaches and pump station operations were assumed.

The primary components of the hurricane protection system are the levees and floodwalls designed and constructed by the Corps of Engineers. Other drainage and flood control features (land topography, streets, culverts, bridges, storm sewers, roadside ditches, canals, and pump stations) work in concert with the Corps of Engineers levees and floodwalls as an integral part of the overall drainage and flood damage reduction system and are included in the models.

Interior drainage models are needed for estimating water elevations inside leveed areas, or basins, for a catastrophic condition such as Hurricane Katrina and for understanding the relationship between HPS components. Results from the interior drainage models can be used to determine the extent, depth and duration of flooding for multiple failure and non-failure scenarios. The models can also be used to:

- Support the Risk modeling effort
- Estimate time needed to unwater an area
- Support evacuation planning
- Evaluate design options of the HPS to include multiple interior drainage scenarios

During the hurricane, water from the storm surge overtopped and breached floodwalls and levees causing water levels inside the levees to rise rapidly. The interior areas continued to receive floodwaters as a function of the capacity of the breached openings until water surface elevations reached the level of Lake Pontchartrain. Interior drainage models are even more useful for estimating peak water elevations and extent of possible flooding, if any, when the hurricane protection system performs satisfactorily or without catastrophic failure. The models can also be used to estimate the time needed to dewater an area once it is flooded.

The study investigated the impact of pumping stations and storm drains on flooding. During the course of Hurricane Katrina, pump stations became ineffective due to flooding from levee breaches, loss of power, and evacuation of operators. When large volumes of water entered the Orleans East Bank Basin through breaches and over floodwalls, storm drains became a source of flooding rather than a means of floodwater evacuation because of backflow.

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Sections of the Orleans East Bank Basin are separated by ridges and elevated railroads. During the initial stages of flooding, these barriers served to contain floodwaters. Flooding in protected sub-areas was limited to backflow through the storm drains. Eventually, most of the barriers were overtopped so that flood elevations in the entire Orleans East Bank Basin were almost the same.

This appendix will provide details of the development of the HEC-HMS and HEC-RAS models for the Orleans East Bank basin. In summary, an HEC-HMS model was developed to transform the Katrina precipitation into runoff for input to the HEC-RAS models. HEC-RAS models were developed to simulate the four conditions discussed below

This model was developed to help answer questions 3 and 4 listed on page 1 of Volume VI. Question 3 is answered by the Katrina simulation listed below. Question 4 is a more difficult one to answer. This is mainly due to the variety of possible combinations of system features, especially pumps. It was decided to bracket these combinations with the three hypothetical combinations listed below.

One of the major difficulties is determining what pumps may have continuing operating. There are many potential factors that can cause pump stations to become inoperable during a hurricane event. Some of these are power failures, pump equipment failures, clogged pump intakes, flooding of the pump equipment, loss of municipal water supply used to cool pump equipment and no safe housing for operators at the pump stations resulting in pump abandonment. Because there is such a wide range of possible pumping scenarios that could occur during a hurricane event, it is difficult to establish a pumping scenario for what could have happened. At best, a variety of possible scenarios could be run to evaluate the potential range of possible consequences. For the purposes of the IPET analysis, it was decided to operate the pumps two ways. The first being the best estimate of how they actually operated during hurricane Katrina and the second being the pumps operated throughout the hurricane.

Described below are the 4 scenarios shown in this appendix.

Katrina

Simulate what happened during Hurricane Katrina with the hurricane protection facilities and pump stations performing as actually occurred. Compare results to observed and measured high water marks. Pre-Katrina elevations are used for top of floodwalls and levees.

Hypothetical 1 – Resilient Levees and Floodwalls

Simulate what would have happened during Hurricane Katrina had all levees and floodwalls remained intact. There are no levee or floodwall breaches or failures for this scenario even where overtopping occurs. Pump stations operate as they did in the Katrina event. Pre-Katrina elevations are used for top of floodwalls and levees. This scenario is meant to simulate what could have happened if all levees and floodwalls had protection that would allow them to be overtop but not breach.

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Hypothetical 2 – Resilient Floodwalls, Levees and Pump Stations

Simulate what would have happened during Hurricane Katrina had all levees, floodwalls and pump stations remained intact and operating. There are no levee or floodwall breaches or failures for this scenario even where overtopping occurs. Pump stations operate continuously throughout the hurricane. Pump operations are based on the pump efficiency curves which reflect tailwater impacts. Pre-Katrina elevations are used for top of floodwalls and levees. It is understood, that in their present state, most pump stations would not have been able to stay in operation during Katrina. However, this scenario was simulated to provide an upper limit on what could have been the best possible scenario had no failures occurred.

Hypothetical 3 – Resilient Floodwalls

Simulate what would have happened during Hurricane Katrina had all floodwalls, which failed from foundation failures, remained intact. For this simulation there are no failures on 17th Street or London Ave Canals. However, there are failures on the IHNC since the surge and waves overtopped the walls, exceeding design and resulting in breaches. All other areas are modeled as they actually functioned. Pump stations operate as they did in the Katrina event. Pre-Katrina elevations are used for top of floodwalls and levees.

Table 2-1 lists the simulation scenarios in a matrix format.

Table 2-1
Katrina Simulations

Conditions	Simulation			
	Katrina	Hypothetical 1	Hypothetical 2	Hypothetical 3
Pumps operate as during Katrina	X	X		X
Pumps operate throughout Katrina			X	
Levee and floodwall breaches occur everywhere as during Katrina	X			
Levee and floodwall breaches occur on West wall of IHNC and in, St Bernard, New Orleans East and Plaquemines as during Katrina				X
Levee and floodwalls overtop but do not breach		X	X	
No failures on 17th Street and London Ave		X	X	X
Levee and floodwall elevations based on pre-Katrina elevations	X	X	X	X

Review of Existing Data

Sufficient existing data were not available for construction of a reliable numerical model during the initial study phases. Data available at the beginning of the model study included topographic elevations of the Orleans East Bank Basin that were obtained from existing digital

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terrain models and dimensions of most of the storm drains and channels that were obtained from previously developed numerical models. Initially, dimensions of many geometric features and elevations of the Hurricane Katrina storm surge were approximated with the anticipation that reliable data would eventually become available. Dimensions of several geometric features were estimated from photographs, rough field measurements, or inductive reasoning. Preliminary ADCIRC numerical model calculations of Hurricane Katrina storm surge elevations were used for boundary conditions. The development and results of the ADCIRC modeling are discussed in Volume IV of this report. During the course of the numerical model study, additional data became available. Most of these data were incorporated into the model. This included data on pump station operation, pump rating curves, and stage hydrographs developed from high-water marks. Unfortunately, some of the critical data were not available in a time frame that allowed incorporation into the model. These include surveys of railroad grades and some channels.

General Modeling Approach

The unsteady flow HEC-RAS program developed by the US Army Corps of Engineers (USACE) Hydrologic Engineer Center (HEC) was used to develop the hydraulic model for Orleans East Bank. The modeling approach was to identify storage areas that were bounded by ridges and/or elevated roads and railroads and then calculate flow between the storage areas. The Orleans East Bank unsteady flow HEC-RAS model consists of 20 storage areas connected by storm drains, open channels and overtopping ridges. External boundary conditions defined the inflow into the numerical model. The Katrina storm-surge stage hydrographs, determined by the IPET data collection team, were used as the initial external boundaries to the model. During the model calibration phase of the study, some of these hydrographs were adjusted slightly. Adjustments were made only within the range of observed data. Additional water surface elevation that might have occurred due to waves is accounted for implicitly with the calibration procedure. The model used the weir equation to calculate inflow over floodwalls and levees that were overtopped. Flows through breaches were calculated in the model based on a specified failure algorithm. Flow was allowed to pass either way through the breaches as a function of head differential across the breach. Rainfall runoff, captured in the storage areas, was calculated using HEC-HMS rainfall-runoff program. Pump station discharges were also simulated in the model to account for movement between storage areas and expulsion of flood waters from the Orleans East Bank Basin. Major storm drains and canals were modeled as a means to transfer flows between storage areas. Flow between these storm drains and the storage areas was simulated using only major tributary culverts. Minor storm drains and drop inlets were ignored. Storage areas were also connected by weirs defined by railroad grades, roads, underpasses and natural ridges. In this manner all the storage areas were interconnected for the matrix solution of the unsteady flow equations in HEC-RAS.

Hydrologic Model Development

Background

The purpose of the hydrologic modeling was to transform Hurricane Katrina rainfall within the Orleans East Bank study area into runoff that was then applied to the unsteady flow hydraulic

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model (HEC-RAS). The Corps of Engineers Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS) was used for this study.

Basin Model

The HEC-HMS model was constructed to correspond directly to the HEC-RAS model. The HEC-HMS sub-basin boundaries are a reflection of the HEC-RAS storage area boundaries. Applying this method allows the HEC-HMS model to transform Hurricane Katrina precipitation directly into runoff for each sub-basin. The computed hydrograph was input to HEC-RAS as storage area inflow. Figure 2-1 depicts the HMS basin model setup for the Orleans East Bank Basin.

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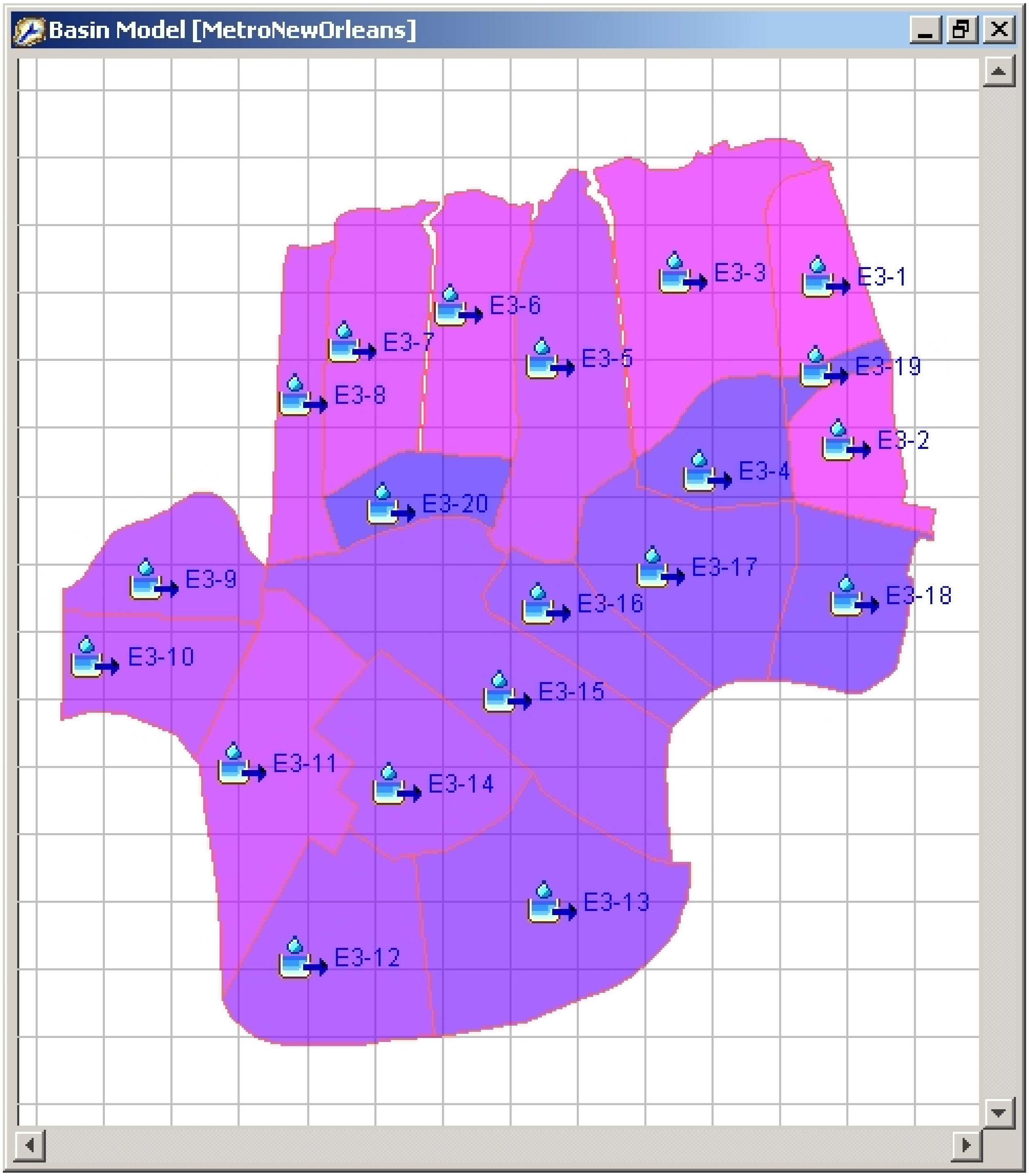

Figure 2-1. Orleans East Bank HEC-HMS Basin Model

Rainfall

Radar rainfall data, referred to as Multisensor Precipitation Estimator (MPE), was used as a boundary condition in the hydrologic model to determine runoff hydrographs produced by Hurricane Katrina. MPE data from the Lower Mississippi River Forecast Center (LMRFC) was downloaded from the following website: http://dipper.nws.noaa.gov/hdsb/data/nexrad/lmrfc_mpe.php. Raw radar data was adjusted using rain gage measurements and possibly satellite data to produce the MPE product. Figure 2-2 shows the amount of precipitation estimated by the MPE product for a one hour period on August 29, 2005 from 0600-0700.

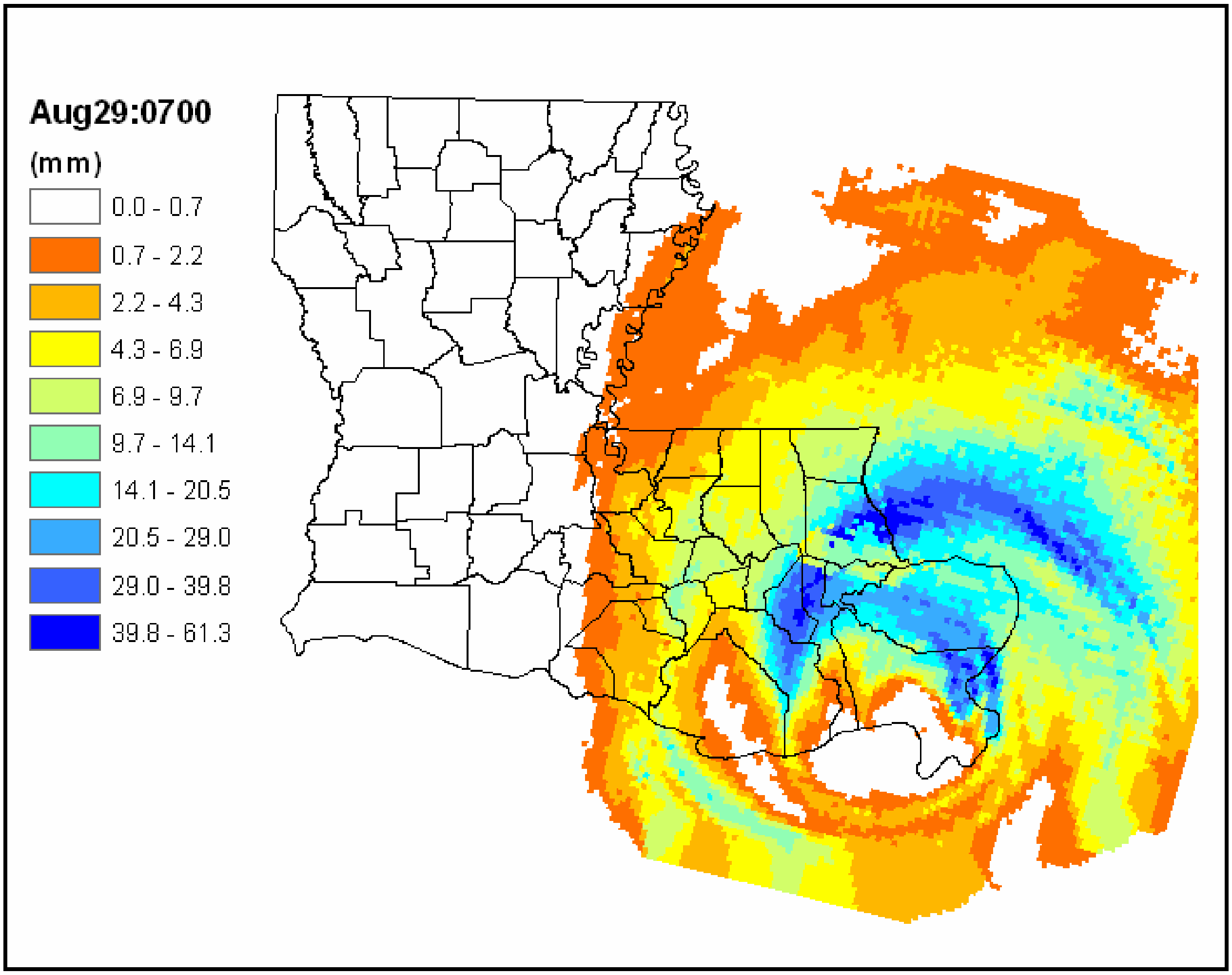

Figure 2-2. Hurricane Katrina Precipitation Sample

The radar rainfall data was imported into a Geo-spatial Information System (GIS) where a precipitation hyetograph was computed for each sub-basin in the HEC-HMS model. The individual hyetographs were imported into a DSS file where they were read by HEC-HMS. Sample hyetographs for Storage areas E3-6 and E3-12 are shown in Figure 2-3.

Based on Weather Bureau Technical Paper 40 (1961), the 100-year rainfall (24-hour duration) for New Orleans is 12.58 inches. Radar estimated 24-hour duration rainfall during

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Hurricane Katrina for the HEC-HMS drainage areas (RAS storage areas) is shown in Table 2-2. As can be seen from Table 2-1, the 24-hr rainfall at five storage areas (1, 12, 13, 14, and 19) exceeded the TP-40 100-yr (24-hr duration) rainfall. Total radar estimated rainfall for the Orleans East Bank Basin is shown in Figure 2-4.

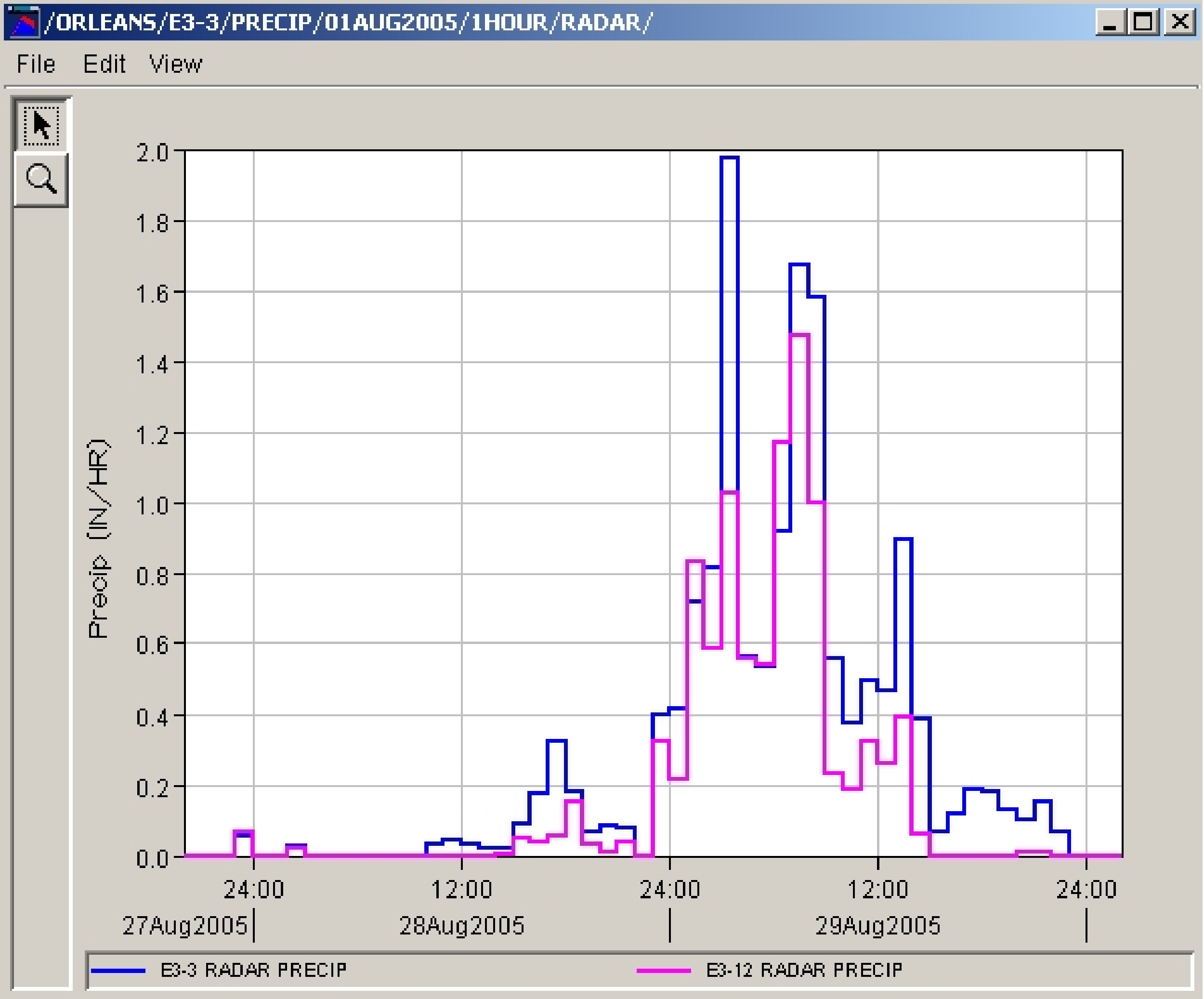

Figure 2-3. Katrina Rainfall Hyetographs for Storage Areas E3-6 and E3-12

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Table 2-2
Radar Estimated 24-hour Duration Rainfall During Hurricane Katrina

Storage Area	24-hr Rainfall
E3-1	13.16
E3-2	9.89
E3-3	10.06
E3-4	9.55
E3-5	10.09
E3-6	9.86
E3-7	10.68
E3-8	10.81
E3-9	11.13
E3-10	10.50
E3-11	11.23
E3-12	13.59
E3-13	12.91
E3-14	12.71
E3-15	12.19
E3-16	10.05
E3-17	11.13
E3-18	10.50
E3-19	13.16
E3-20	9.86

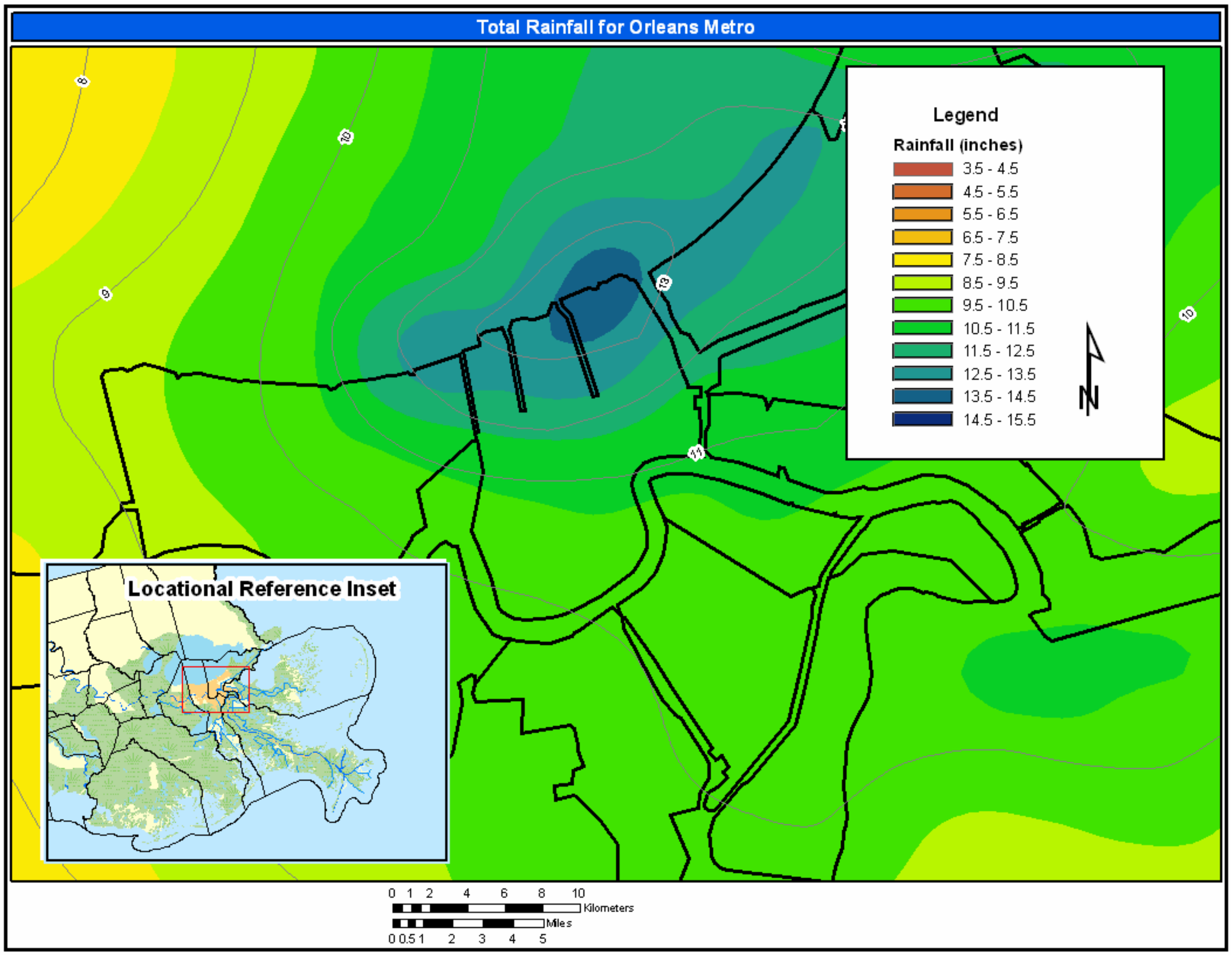

Figure 2-4. Total Radar Estimated Rainfall from Hurricane Katrina

Land Use and Soil Data

Land use and soil data were used to estimate SCS curve numbers. Land use data were obtained from the New Orleans District (MVN). The land use data consisted of raster coverage of 24 different land use types, as listed in Table 2-3. Soil data, contained in the Soil Survey Geographic (SSURGO) Database, was downloaded from the following National Resources Conservation Service (NRCS) website: http://www..ncgc.nrcs.usda.gov/products/datasets/ssurgo/. SSURGO is a digital copy of the original county soil survey maps and provides the most detailed soil maps from the NRCS.

Loss Rates

Loss rates were computed by determining the amount of precipitation intercepted by the canopy and depressions on the land surface and the amount of precipitation that infiltrated into the soil. Precipitation that is not lost to interception or infiltration is called “excess precipitation” and becomes direct runoff. The Soil Conservation Service (SCS) Curve Number (CN) method was used to model interception and infiltration. The SCS CN method estimates precipitation loss and excess as a function of cumulative precipitation, soil cover, land use, and antecedent

Table 2-3
Curve Numbers by Land Use and Soil Type

	LAND USE	A	B	C	D
1	Fresh Marsh	39	61	74	80
2	Intermediate Marsh	39	61	74	80
3	Brackish Marsh	39	61	74	80
4	Saline Marsh	39	61	74	80
5	Wetland Forest-Deciduous	43	65	76	82
6	Wetland Forest- Evergreen	49	69	79	84
7	Wetland Forest- Mixed	39	61	74	80
8	Upland Forest- Deciduous	32	58	72	79
9	Upland Forest- Evergreen	43	65	76	82
10	Upland Forest- Mixed	39	61	74	80
11	Dense Pine Thicket	32	58	72	79
12	Wetland Scrub/shrub - deciduous	30	48	65	73
13	Wetland Scrub/Shrub - evergreen	35	56	70	77
14	Wetland Scrub/Shrub - Mixed	30	55	68	75
15	Upland Scrub/Shrub - Deciduous	30	48	65	73
16	Upland Scrub/Shrub - Evergreen	35	56	70	77
17	Upland Scrub/Shrub - Mixed	30	55	68	75
18	Agriculture-Cropland-Grassland	49	69	79	84
19	Vegetated Urban	49	69	79	84
20	Non-Vegetated Urban	71	80	87	91
21	Upland Barren	77	86	91	94
22	Wetland Barren	68	79	86	89
23	Wetland Complex	85	85	85	85
24	Water	100	100	100	100

moisture. This method uses a single parameter, a curve number, to estimate the amount of precipitation excess/loss from a storm event. Studies have been conducted to determine appropriate curve number values for combinations of land use type and condition, soil type, and the moisture state of the watershed.

Table 2-3 was used to estimate a curve number value for each combination of land use and soil type in the study area. Each soil type in the SSURGO Database was assigned to one of the four hydrologic soil groups. (A, B, C or D). The percent impervious cover is already included in the curve number value in Table 2-3. More information about the background and use in the SCS curve number method can be found in Soil Conservation Service (1971, 1986).

By factoring in land use and soil type, curve numbers were developed for each of the 20 storage areas of the Orleans East Bank model, ranging in values from 84 to 89. A complete list of the curve numbers developed for each of the twenty storage areas are as shown in Table 2-4.

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Table 2-4
Storage Area Weighted Curve Numbers Orleans East Bank

Storage Area	Area in Acres	Curve Number
E3-1	862	86
E3-2	799	88
E3-3	2,162	86
E3-4	834	86
E3-5	1,909	86
E3-6	1,240	85
E3-7	1,377	84
E3-8	838	85
E3-9	958	85
E3-10	1,032	88
E3-11	1,927	85
E3-12	1,763	85
E3-13	2,410	86
E3-14	1,397	86
E3-15	2,838	86
E3-16	877	85
E3-17	1,735	85
E3-18	1,123	86
E3-19	169	89
E3-20	632	85

Transform

Excess precipitation was transformed to a runoff hydrograph using the SCS unit hydrograph method. The SCS developed a dimensionless unit hydrograph after analyzing unit hydrographs from a number of small, gaged watersheds. The dimensionless unit hydrograph is used to develop a unit hydrograph given drainage area and lag time. A detailed description of the SCS dimensionless unit hydrograph can be found in SCS Technical Report 55 (1986) and the National Engineering Handbook (1971).

Surface area in each of the 20 drainage areas (storage areas in HEC-RAS) was computed using GIS and then input into HEC-HMS. Lag time was computed by using the Kirpich estimate of travel time for the longest flow path (Chow, Handbook of Applied Hydrology, 1964).

Lag times for the SCS unit hydrograph method were estimated using the following equation:

$$t_l = 0.00013\left(\frac{L^{0.77}}{Y^{0.385}}\right)$$

Where t_l is the sub-basin lag (hr), L is the hydraulic length (ft) and Y is the average sub-basin land slope (percent). Calculated lag times are shown in Table 2-5.

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Table 2-5
Computed Lag Times

Sub-basin Name	Hydraulic Length (ft)	Average Sub-basin Land Slope %	Lag Time (minutes)
E3-1	11,444	0.04	123
E3-2	4,600	0.11	43
E3-3	9,960	0.10	80
E3-4	6,530	0.12	54
E3-5	8,530	0.12	67
E3-6	6,600	0.14	52
E3-7	7,000	0.11	58
E3-8	7,560	0.11	63
E3-9	6,180	0.11	53
E3-10	6,470	0.12	53
E3-11	14,930	0.07	123
E3-12	8,300	0.17	57
E3-13	9,590	0.15	67
E3-14	4,210	0.07	47
E3-15	13,340	0.09	105
E3-16	10,560	0.09	89
E3-17	19,470	0.08	82
E3-18	5,210	0.12	64
E3-19	4,240	0.07	47
E3-20	3,060	0.16	27

Model Results

Figure 2-5 depicts results for HEC-HMS sub-basin E3-3. The upper graph shows precipitation and precipitation loss. The lower graph shows the runoff from the sub-basin. This runoff hydrograph is entered in the HEC-RAS model in Storage Area E3-3. The same procedure is used for the other 19 storage areas. Complete summary results are shown in Table 2-6.

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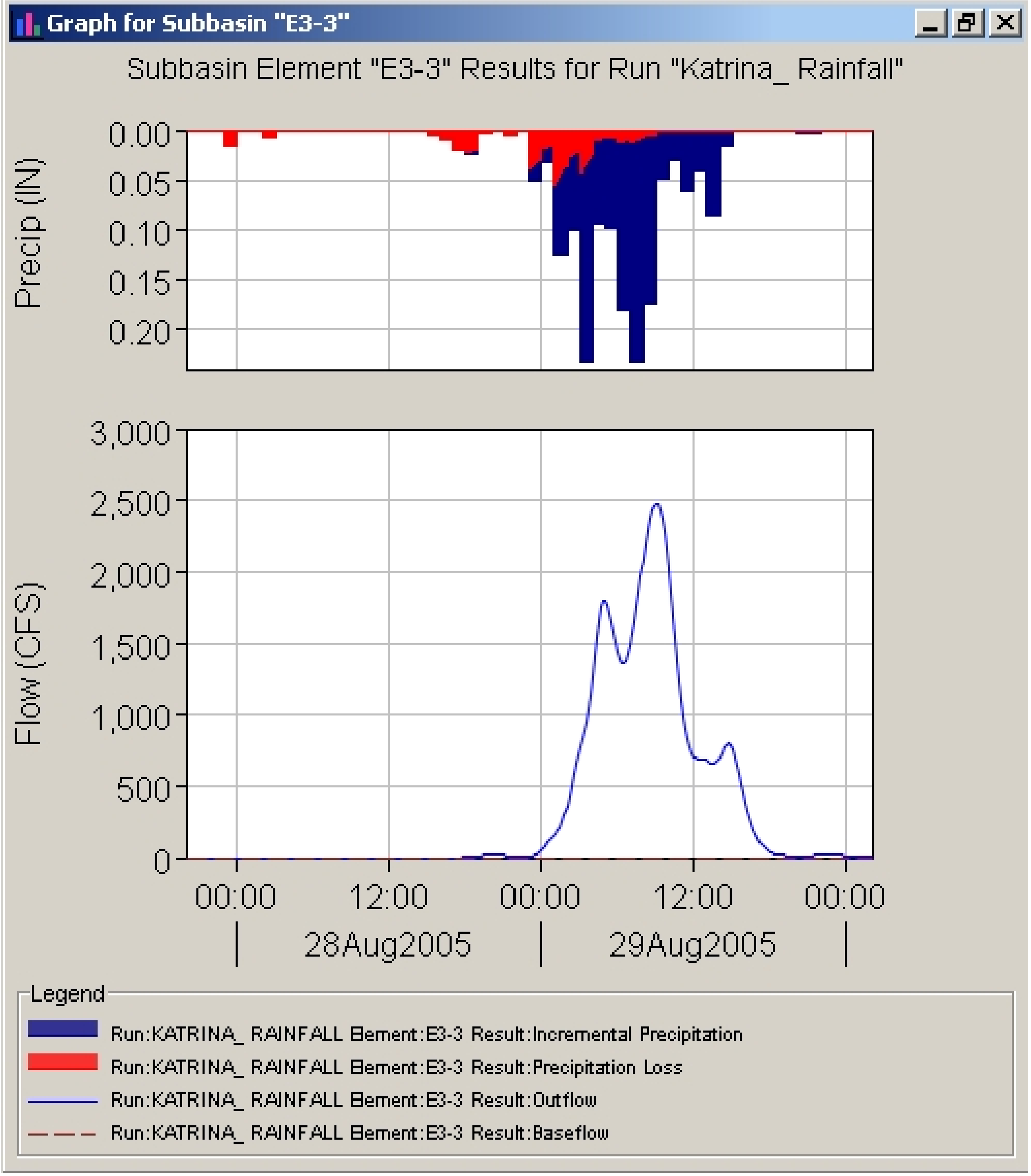

Figure 2-5. HEC-HMS Sub-basin Results

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Table 2-6
Summary of Hydrologic Analysis Results

Sub-basin Name	Drainage Area (mi2)	Peak Discharge (cfs)	Time of Peak	Runoff Volume (in)
Sub-basin E3-1	1.35	1,105	29Aug2005, 10:02	12.36
Sub-basin E3-2	1.25	1,013	29Aug2005, 08:15	8.56
Sub-basin E3-3	3.38	2,502	29Aug2005, 09:01	8.52
Sub-basin E3-4	1.30	1,074	29Aug2005, 08:28	7.93
Sub-basin E3-5	2.98	2,501	29Aug2005, 08:45	8.37
Sub-basin E3-6	1.94	1,596	29Aug2005, 08:28	8.14
Sub-basin E3-7	2.15	1,753	29Aug2005, 08:39	8.84
Sub-basin E3-8	1.31	1,112	29Aug2005, 08:51	9.12
Sub-basin E3-9	1.50	1,338	29Aug2005, 08:37	9.51
Sub-basin E3-10	1.61	1,534	29Aug2005, 08:35	9.06
Sub-basin E3-11	3.01	2,304	29Aug2005, 09:52	9.49
Sub-basin E3-12	2.76	2,589	29Aug2005, 08:56	12.48
Sub-basin E3-13	3.77	3,329	29Aug2005, 09:09	11.84
Sub-basin E3-14	2.18	2,227	29Aug2005, 04:22	11.37
Sub-basin E3-15	4.43	3,306	29Aug2005, 09:34	10.83
Sub-basin E3-16	1.37	951	29Aug2005, 08:59	8.30
Sub-basin E3-17	2.71	2,248	29Aug2005, 09:14	9.51
Sub-basin E3-18	1.76	1,583	29Aug2005, 08:49	8.80
Sub-basin E3-19	0.26	213	29Aug2005, 08:18	8.68
Sub-basin E3-20	0.99	891	29Aug2005, 08:08	8.97

Hydraulic Model Development

Background

The Orleans East Bank HEC-RAS model consists of 20 storage areas connected by storm drains, open channels and overtopping ridges. The model limits are Lake Pontchartrain on the north, the Mississippi River on the south, the Inner Harbor Navigation Canal (IHNC) on the east and the 17th Street Canal, Fairmont Drive and Causeway Boulevard on the west. Potential flood waters enter the Orleans East Bank model as rainfall, levee and floodwall overtopping and through breaches in the levees and floodwalls. Flood waters initially accumulate in storage areas until depths are sufficient for water to flow into the storm drains and open channels. This occurs immediately with the onset of rainfall. Storm waters are pumped from the local drainage system into either Lake Pontchartrain or the IHNC as long as power is available and operators remain at the pump stations. Levee overtopping and breaching overwhelm the drainage system causing significant flooding. As water levels increase, flood flows move between storage areas across roads, railroads and ridges. These high water connections are treated as weirs in the HEC-RAS model.

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Datum Reconciliation

Elevations reported herein are related to the NAVD88 (1994, 1996) datum. The digital terrain model used to define storage area elevations and ridge elevations in the HEC-RAS model are related to the NAVD88 (1994, 1996) datum. Surveys of the breaches and top of levee taken following Hurricane Katrina were provided using the NAVD88 (2004.65) datum. These elevations were adjusted to NAVD88 (1994, 1996) elevations in the HEC-RAS model by adding 0.4 ft. Elevations for the storm drains and pump stations were originally provided using the Cairo datum. Cairo elevations were adjusted to NAVD88 (1994, 1996) in the HEC-RAS model by subtracting 20.43 ft. Surge elevations from the ADCIRC model were provided using NGVD29 datum. ADCIRC elevations were adjusted to NAVD88 (1994, 1996) elevations in the HEC-RAS model by subtracting 0.2 ft.

Terrain Model

Elevation data in the Orleans East Bank area was obtained through the use of the Louisiana Atlas website (http://atlas.lsu.edu). The LIDAR data used is a result of a statewide project started in 2000. The systems being used in the project are accurate to 15-30 cm RMSE, depending on land cover, and will support contours of 1ft to 2ft vertical map accuracy standards. The files are represented by quadrangle 5-meter DEM data files. These accuracies meet FEMA standards for floodplain reevaluation studies and map modernization programs designed to update the Flood Insurance Rate Maps.

Basic Geometric Data

Most of the storm drain and open channel dimensions used in the HEC-RAS model were extracted from an XP-SWMM model developed by Brown Cunningham and Gannuch Engineers, Architects and Consultants, Inc. The XP-SWMM model was completed in 2005 for the USACE New Orleans District to simulate 10-year flooding conditions. Elevations in the XP-SWMM model were based on the Cairo datum. Model elevations were converted to NAVD88 (1994, 1996) datum for inclusion in the HEC-RAS model. The XP-SWMM model data was used to define dimensions for both the storm drains actually modeled in the HEC-RAS model and for the inlets that connected the storm drains to the storage areas.

Brown Cunningham and Gannuch (BCG) also provided a HEC-RAS steady state model of the Palmetto Canal. This model was developed for the Sewerage and Water Board of New Orleans as part of a Master Drainage Study between 2002 and 2005. Bridges across the Palmetto Canal were included in the model. Elevations in the BCG HEC-RAS model were based on the Cairo datum. Model elevations were converted to NAVD88 (1994, 1996) datum for inclusion in the unsteady flow HEC-RAS model.

USACE New Orleans District provided a HEC-2 model of the London Avenue Canal. The model was several years old and included some bridges that have subsequently been removed. Aerial photographs from Google Earth were used to determine if bridges in the HEC-2 model should be removed for the unsteady HEC-RAS model. Except for data in the HEC-2 model, no information was available relating to bridge modifications that may have occurred since the HEC-2 model was constructed. There were no data available for the Lakeshore Drive Bridge at

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the confluence with Lake Pontchartrain. Elevations in the USACE New Orleans model of London Canal were based on the NGVD29 datum. Model elevations were converted to NAVD88 (1994, 1996) datum by subtracting 0.2 ft for inclusion in the unsteady flow HEC-RAS model. Canal bottom elevations were adjusted somewhat based on survey data collected in September 2005.

USACE New Orleans District provided a HEC-RAS model of the Orleans Avenue Canal. The model included bridges over the Orleans Avenue Canal. Bridge geometry was not field checked. Elevations in the USACE New Orleans model of the Orleans Avenue Canal were based on the NAVD88 (1994, 1996) datum and no model elevation adjustment was necessary for inclusion in the unsteady flow HEC-RAS model.

USACE New Orleans District provided a HEC-RAS model of the 17th Street Canal. The model included bridges over the 17th Street Canal. No data were available relating to the debris accumulation on the Lake Pontchartrain side of Old Hammond Highway. Canal bottom elevations were adjusted somewhat based on survey data collected after Hurricane Katrina. Elevations in the USACE New Orleans model of the 17th Street Canal were based on the NAVD88 (1994, 1996) datum and no model elevation adjustment was necessary for inclusion in the unsteady flow HEC-RAS model.

CTE, a Chicago based A and E firm, provided a steady state HEC-RAS model of the Earhart and Airline Drains in the Hoey Basin. The model included bridges and culverts. There was no information on tributary drainage structures in the model. Elevations in the CTE model were based on the Cairo datum. Model elevations were converted to NAVD88 (1994, 1996) datum for inclusion in the HEC-RAS model.

Channels and storm drains included in the unsteady flow HEC-RAS model are shown in Figure 2-6. The names chosen for the model are based on nearby streets and do not necessarily reflect the appropriate local names.

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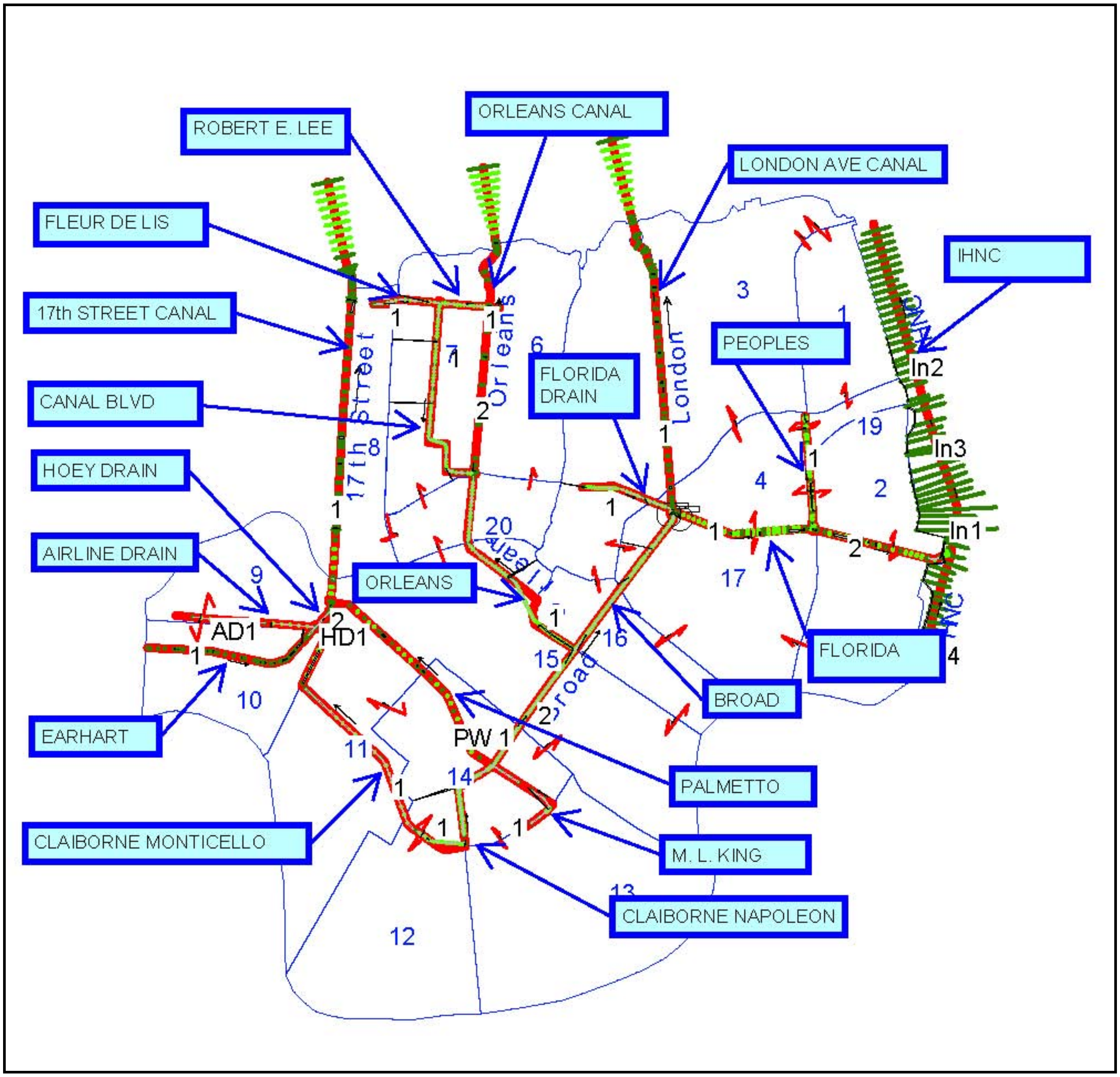

Figure 2-6. Channels and Storm Drains Modeled in HEC-RAS Model

Manning's n-Values

HEC-RAS uses Manning's equation to compute friction forces, which are then used in the unsteady flow equations in performing unsteady flow simulations. Manning's roughness coefficients, commonly called Manning's n values are assigned to each channel, bridge, culvert and tunnel in the geometry file used in the unsteady flow computations. The Manning's n values that were used in the model were obtained from the XP-SWMM model provided by BCG which models underground flow and HEC-2 models that were developed by New Orleans District. These values were checked with the guidance furnished in HEC-RAS documentation. For earthen channels, values ranged from .024 to .04 depending on the condition of the main channel with overbank n values ranging from .03 to .05. The n value for concrete lined channels varied

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from 0.014 to 0.018 depending on the condition of the channel bottom and side slopes. The Manning’s n values were also modified in reaches where the condition of the channel dictated the use of different values. The Manning’s n values varied from 0.014 to 0.018 in the tunnel reaches depending on the shape and condition of the concrete.

Bridges

Bridges and box culverts were analyzed as part of the HEC-RAS model for the whole basin. HEC-RAS computes flow through the bridges or culverts using the Bernoulli or Energy Equation. Hydraulic losses in the large concrete box culverts and arch pipes were computed using entrance and exit loss coefficients recommended in the HEC-RAS Reference Manual. These were 0.3 to 0.5 and 0.5 to 1.0 respectively, depending on what local conditions require.

Storage Areas

Storage area elevation-volume curves were developed from the digital terrain model and from calculated storm drain volumes. In order to properly model the movement of floodwater from one sub-area to another in the Orleans East Bank Basin, the total area was subdivided into 20 sub-areas, as previously shown in Figure 2-1. These areas were selected based on the physical barriers that separated them such as natural high ground, railroads, levees, channel floodwalls and other barriers. The HEC-GeoRAS model was used with the digital terrain model to compute the elevation-storage data of each sub-area. Once this data was computed, it was exported to the unsteady flow HEC-RAS model. Additional storage volume was added in some sub-areas to account for volume available in underground storm drains that were not simulated in the model. Dimensions and elevations for these storm drains were extracted from the XP-SWMM model input files.

Storage Area Connections

There are several underground storm drains and culverts that remove normal floodwater from the various storage areas; however, a flood event like Hurricane Katrina overwhelms the drainage system and floodwaters have to move overland from one storage area to another. In order to model the movement of floodwater from one storage area to another, HEC-RAS has an option that allows storage areas to be connected by a weir, culvert or a combination of the two. The majority of the 20 storage areas were connected using the weir flow option. Some of the storage areas were separated by railroads which had smooth crested weirs; however other areas were separated by natural high ground with streets acting as small channels between the areas. A cross section was taken using LIDAR data in ARC-MAP to determine the length-elevation rating curve of the weir section across the controlling high ground and streets between the storage areas. When HEC-RAS computes flow across a weir at low head conditions, it performs the computations more efficiently and with more stability if the weir length-elevation rating curve is smoothed out with the weir crest increasing from low to high elevations in a smooth transition. Therefore, in reaches where there were numerous changes in elevation due to the crossing streets, the data was computed in even horizontal increments then smoothed by sorting the elevations from low to high and inputting this data into the model as the weir crest. An example of the procedure is shown in Figures 2-7 and 2-8.

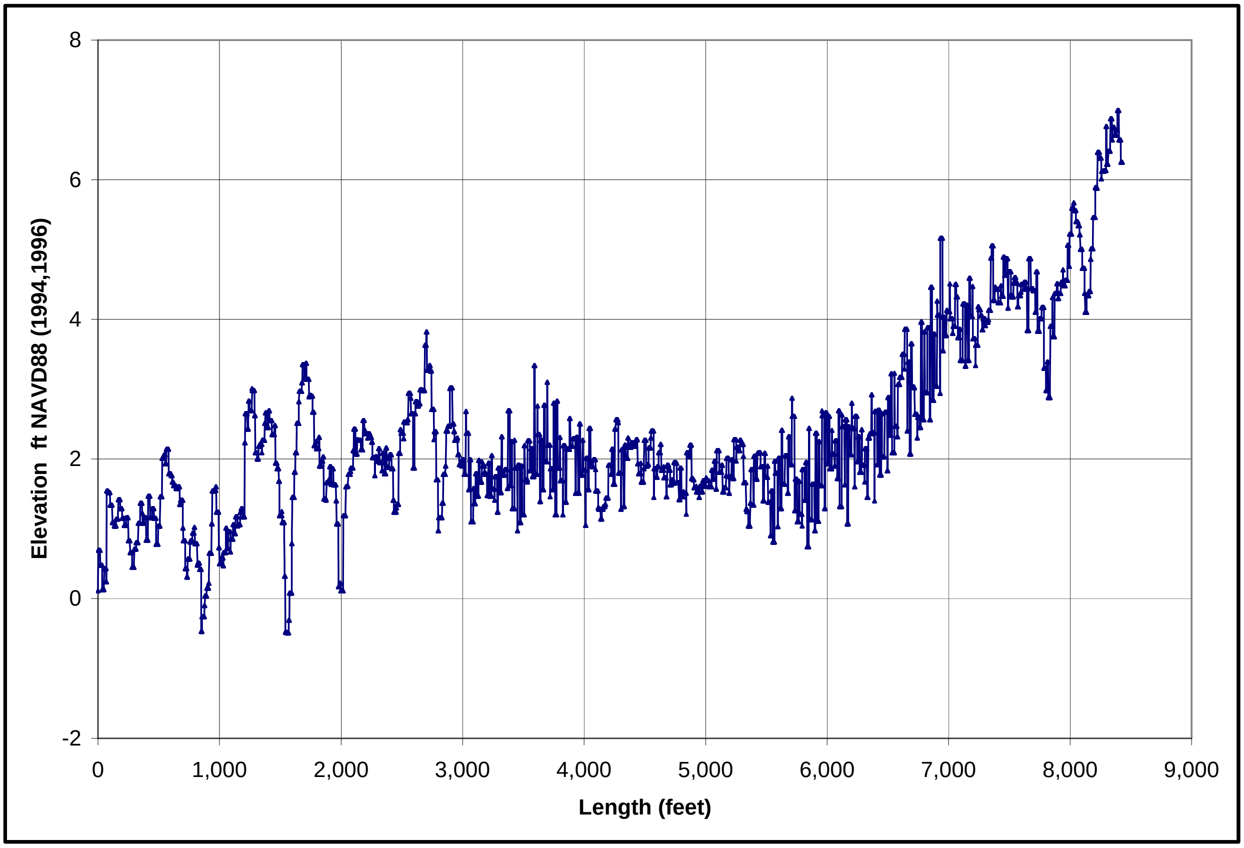

Figure 2-7. Digitized Weir Profile Between Storage Areas E3-16 and E3-17

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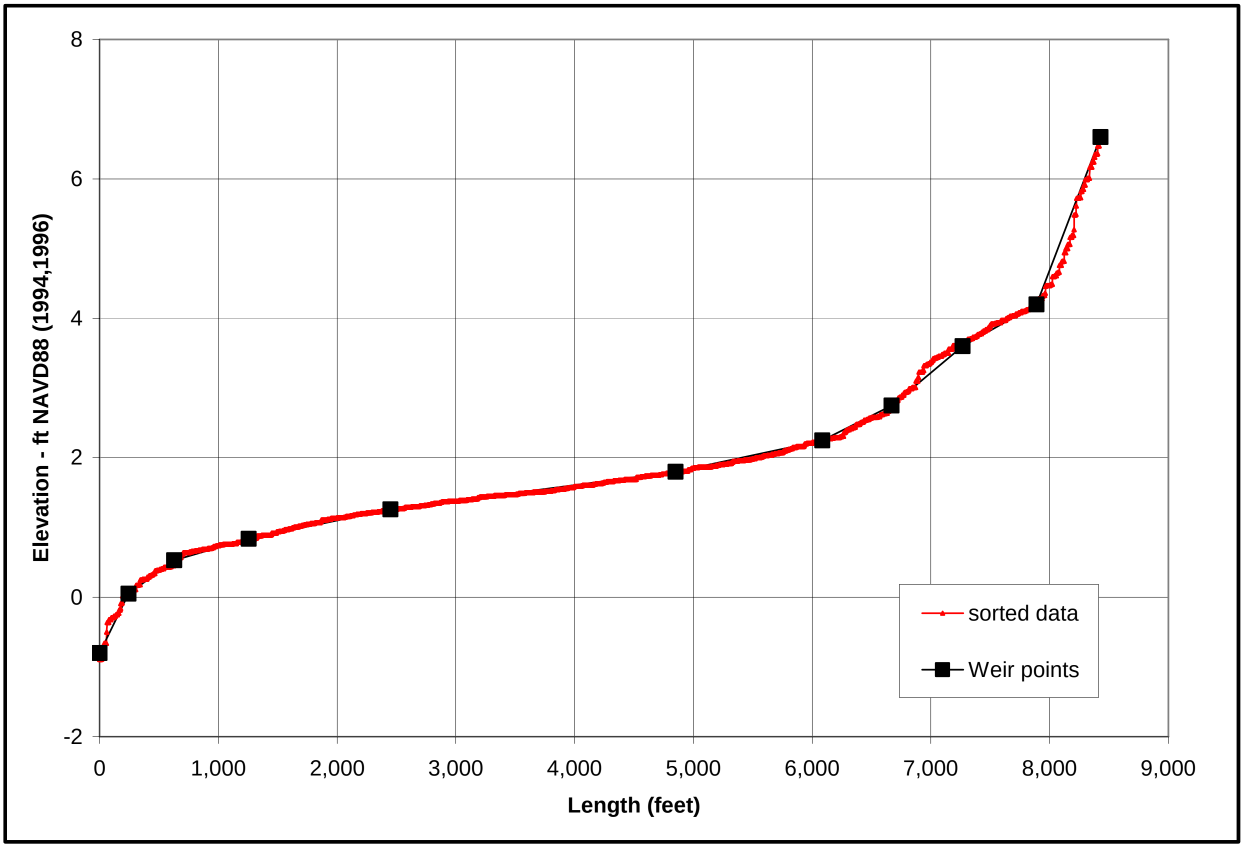

Figure 2-8. Sorted Weir Profile Between Storage Areas E3-16 and E3-17 Pumping Stations

Pump Stations

Eight pumping stations were included in the unsteady flow HEC-RAS model of Orleans East Bank. A summary of pump station characteristics is shown in Table 2-7. Detailed pump data was collected by the U.S. Army Corps of Engineers Hydroelectric Design Center (HDC). This pump data can be found in Volume VI, Appendix 7 of this report. Pump station locations are shown in Figure 2-9. If a pump station receives water or pumps water to more than one location, it is necessary to model the pump stations separately in the numerical model. Hence, the figure shows Pump Station 2a and 2b, 3a and 3b and 4a and 4b. Operating schedules of the pumping stations, during Hurricane Katrina, were provided by HDC. Pump station data included discharge-head rating curves for each pump at each pumping station. Some of these curves had to be extrapolated in the HEC-RAS model. There were very limited data regarding start-up elevations for individual pumps. Interviews with pump operators conducted by HDC suggest that operators are not held to a rigid schedule with respect to turning pumps on and off. Operations are based on existing sump elevations, downstream conditions, and weather forecasts. In the unsteady HEC-RAS model, start-up times for the pumps were set so that all pumps would be operating when the sump elevation reached -7.4 ft NAVD88 (1994, 1996). Start-up and shut-off times for individual pumps were set in the model to provide a smooth transition, over several minutes, from an estimated station start-up elevation to elevation -7.4 ft. The model does not

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simulate channel surges that might develop with instantaneous start-up or shut-down of the pump station.

Table 2-7
Pump Station Summary Data

Pump Station	Location/Name	Intake	Discharge	Rated Station Capacity CFS
1	Broad Street and Martin L. King Blvd.	Martin Luther King and Broad Street Drains	Palmetto Canal	6,825
2	Broad Street and St Louis Street	Broad Street Drain	Orleans Canal and Broad St Drain	3,150
3	London Ave Canal at Florida Avenue	Broad Street and Florida Avenue Drains	London Avenue Canal and Florida Avenue Canal	4,260
4	London Avenue Canal at Prentiss Avenue	Prentiss Avenue Drains on both East and West side of Canal.	London Avenue Canal (Lake Pontchartrain)	3,720
6	17th Street Canal	17th Street Canal	17th Street Canal (Lake Pontchartrain)	9,480
7	Orleans Avenue Canal	Orleans Avenue Drain	Orleans Avenue Canal (Lake Pontchartrain)	2,690
12	Pontchartrain Blvd.	Fleur de Lis Drain	Lake Pontchartrain	1,000
19	Florida Avenue	Florida Avenue Canal	Inner Harbor Navigation Canal	3,650

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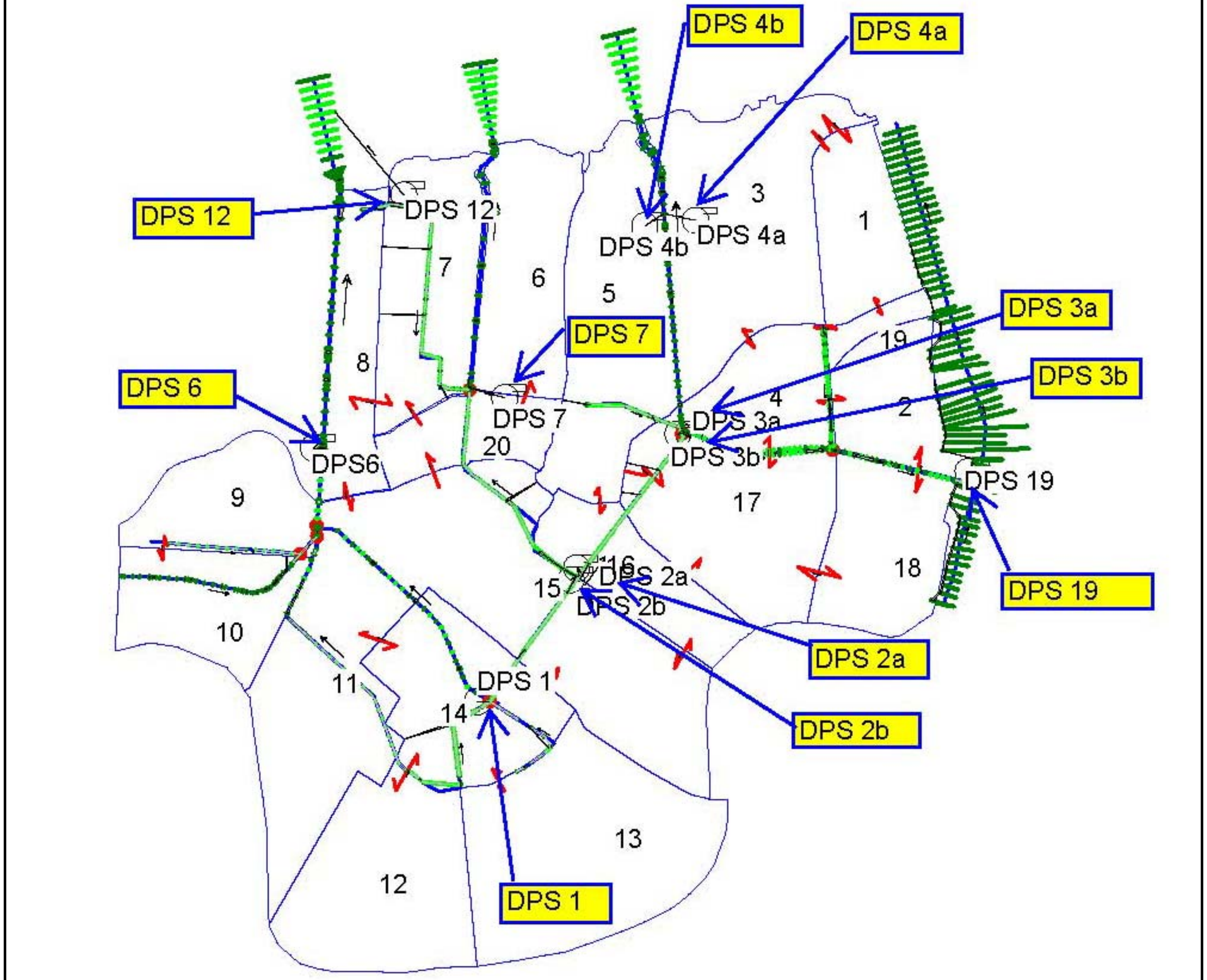

Figure 2-9. Pump Stations Modeled in HEC-RAS Model

Pump operations at most of the pump stations during Hurricane Katrina were investigated by HDC. A time-line was developed based on review of operation logs. Based on these time-lines, Hurricane Katrina-specific operational rule curves, that set maximum pump station capacities, where set in the unsteady flow HEC-RAS model to simulate shut-down times for the pump stations. Pump station 1 was shut down at 0900 on 30 Aug. Operators reported that the station was shut down because Pump Station 6, which is downstream, had already been shut down and there was no where for the water to go. Pump Station 2 shut down at 0630 on 29 Aug. Pump stations 3 and 7 were shut down at 0730 on 29 Aug shortly after breaches in the 17th Street and London Avenue Canals. Pump station 4 operated until 0900 on 29 Aug. Pump station 6 had a power outage between 0400 and 0900 on 29 Aug and was inoperable. The pumps restarted at

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0900 and continued pumping until 1700 on 29 Aug when they were shut down. Pump station 12 did not operate during the storm. Pump Station 19 was shut down at 0530 on 29 Aug, at about the same time as the Inner Harbor Navigation Canal began to breach. This station came back on line at 1500 on 30 Aug for 4.5 hours. The station operated intermittently until the end of the unsteady flow simulation at 0000 5 Sep.

Storm Drain System

The drainage system for Orleans East Bank consists of many features that are typical of large urban cities in the United States, and some features that are unique because much of the area is below sea level. As in any urbanized area, catch basins and drop-inlets receive surface runoff from yards and streets, and excess runoff runs down slope in the streets and/or overland to areas of lower elevation. Runoff that can enter drop-inlets proceeds underground in small pipes, 21 inches or less in diameter, called the tertiary system that collect local flows and convey them to the secondary system, 21 inches to 30 inches in diameter, where several of these local flows combine. Generally pipes or box culverts that are larger than 30 inches in diameter are considered to be part of the secondary system. The primary drainage system is composed of enclosed culverts and man-made mainly prismatic open channels. The primary conveyances were modeled in the HEC-RAS Unsteady model, along with drainage pump stations.

Flow Data and Boundary Conditions

The storm-surge elevation boundary conditions used in the unsteady flow HEC-RAS model were initially based on stage-hydrographs obtained from preliminary ADCIRC simulations. The ADCIRC model and results are discussed in Volume IV of this report. . When measured and observed data from the IPET data collection team became available, these data were incorporated into the model. The stage hydrograph in the IHNC was based on measured data from the IHNC Lock. Hydrograph peaks were adjusted based on observed high water marks along the IHNC. During the calibration phase of the study final stage hydrograph peaks in the IHNC were determined. Adjustments were made only within the range of observed data. Additional water surface elevation from wave heights are accounted for implicitly with the calibration procedure. The stage hydrographs in Lake Pontchartrain were based on stage hydrographs developed by the IPET data collection team, and USGS gage data from the Pass Manchac gage. Preliminary peak stages at the HEC-RAS storm surge boundaries provided by the ADCIRC and data collection groups are compared to those used in the numerical model in Table 2-8. Initially, stage hydrograph peak values were selected based on average values. Final values were selected during the calibration phase of the study.

Boundary conditions must also be set in the unsteady flow HEC-RAS model at the upstream end of storm drains and channels. Discharge boundaries in the model are shown in Table 2-9. A minimum discharge of 50 cfs was set at each upstream boundary. During the course of the study, inflow at some boundaries was increased to improve model stability. In order to account for the introduction of these arbitrary flows into the model, an equivalent volume of water was pumped out of the appropriate drainage basin throughout the model simulation. These artificial pumping rates continued in the model after the actual pump stations were shut down.

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Table 2-8
Peak Katrina Storm Surge Elevations Feet NAVD88 (1994, 1996)

Boundary	Preliminary ADCIRC Elevations	Preliminary High Water Mark Elevations	Final Elevation used in HEC-RAS
Lake Pontchartrain at the 17th Street Canal	12.1	11.2	11.2
Lake Pontchartrain at the Orleans Avenue Canal	11.5	11.5	11.5
Lake Pontchartrain at the London Avenue Canal	11.1	11.8	11.8
IHNC Lake Pontchartrain to Interstate 10	10.8 - 13.8	12.8-13.3*	13.3
IHNC Interstate 10 to Florida Avenue	13.8 - 15.0	14.7	14.7
IHNC Florida Avenue to Miss River Lock	15.0 - 15.8	14.7 – 15.6	15.5

* At Interstate 10.

Table 2-9
HEC-RAS Boundary Conditions at Upstream End of Storm Drains

Storm Drain	Station at Upstream End	Boundary Discharge CFS
Airline Drain	68+00	50
Broad St Drain	164+60	150
Claiborne-Monticello Drain	146+00	150
Claiborne-Napoleon Drain	85+50	100
Earhart Channel	111+00	50
Fleur De Lis Drain	22+83	100
Florida Drain	50+00	50
Martin Luther King Drain	118+61	100
Orleans Channel	250+70	50
Peoples Channel	61+50	50
Robert E. Lee Drain	35+40	50

Levee Overtopping and Breaching

Levee breaching and overtopping were the major sources of flooding in Orleans East Bank. The 17th Street Levee breached about 500 ft south of the Old Hammond Highway Bridge, initially flooding the area between the 17th Street and Orleans Canals and between Lake Pontchartrain and the ridge along Metairie Road and City Park Avenue. The London Avenue Canal breached at two locations. The west breach occurred just south of Robert E. Lee Boulevard, initially flooding the area between the London Avenue Canal and Bayou St John and between Lake Pontchartrain and the Gentilly Ridge. The east breach of the London Avenue Canal occurred just north of Mirabeau Avenue, initially flooding the area between the London Avenue Canal and Peoples Avenue and between Lake Pontchartrain and Gentilly Ridge. Eventually, water flowing through these breaches reached elevations sufficient to flow over the ridges and into the southern portion of Orleans East Bank. Flows overtopped the Inner Harbor

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Navigation Canal floodwall at the peak of the storm surge. There was a breach through a floodwall opening just south of Interstate-10. The floodgate was not operable and sandbags placed in the opening did not hold. Just north of Florida Avenue and Pumping Station 19 the floodwall failed and a connecting earth levee also breached. Overtopping and breaching of the Inner Harbor Navigation Canal floodwall caused flooding in the areas adjacent to the floodwall. Flood volumes were sufficient to overtop elevated railroads and ridges so that water flowed into both southern and northern areas of Orleans East Bank.

Dimensions of the 17th Street Canal Breach were estimated from survey data collected by the USACE Vicksburg District on 6 Sep 05. The datum for this survey was NAVD88 (2004, 2006), so no adjustment was necessary for inclusion into the unsteady flow HEC-RAS model. A trapezoidal approximation of the breach cross sectional area was used in the numerical model. The cross section had a 300-ft-wide base width with 1V:1H side slopes. The base elevation of the breach was estimated to be 0.0 NAVD88 (1994, 1996). Photographs indicated that the weir crest was not well defined and partially obstructed by the sloughed levee embankment. A coefficient of 1.9 was determined during the model calibration phase of the study. The breach commencement time was set at 0630 on 29 Aug based on anecdotal evidence and information presented in the 10 Mar 06 Draft Report by the Interagency Performance Evaluation Task Force (page V-5). Breach development time was set at four hours, also based on anecdotal evidence from the report.

Dimensions of the London Avenue Canal west breach were estimated from survey data collected by the USACE Vicksburg District on 16 Sep 05. The datum for this survey was NAVD88 (2004, 2006), so no adjustment was necessary for inclusion into the unsteady flow HEC-RAS model. A trapezoidal approximation of the breach cross sectional area was used in the numerical model. The cross section had a 180-ft-wide base width with 1V:1H side slopes. The base elevation of the breach was estimated to be 0.0 NAVD88 (1994, 1996). To be consistent with assumptions at the 17th Street breach, a breach weir coefficient of 1.9 was used. The breach commencement time was set at 0900 on 29 Aug and assumed to be fully developed by 1230 on 29 Aug based on anecdotal evidence and information presented in the 10 Mar 06 Draft Report by the Interagency Performance Evaluation Task Force (page V-8).

Dimensions of the London Avenue Canal east breach were estimated from survey data collected by the USACE Vicksburg District on 16 Sep 05. The datum for this survey was NAVD88 (2004, 2006), so no adjustment was necessary for inclusion into the unsteady flow HEC-RAS model. A trapezoidal approximation of the breach cross sectional area was used in the numerical model. The cross section had a 100-ft-wide base width with 1V:1H side slopes. The base elevation of the breach was estimated to be -4.0 NAVD88 (1994, 1996). To be consistent with assumptions at the 17th Street breach, a breach weir coefficient of 1.9 was used. The breach commencement time was set at 0900 on 29 Aug and assumed to be fully developed by 1130 on 29 Aug based on anecdotal evidence and information presented in the 10 Mar 06 Draft Report by the Interagency Performance Evaluation Task Force (page V-8

The Orleans Avenue Canal Levee in the vicinity of the pumping station overtopped at the peak of the storm surge. There were no survey data available to define the length or the elevation of the overtopping section. Dimensions and elevations used in the numerical model were estimated from photographs. Estimated weir lengths of 150 ft at elevation 11.3 and 50 ft at

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elevation 9.8 were used. The overflow section through the Orleans Avenue Levee does not have a defined crest, so a low coefficient of 1.0 was used for the weir calculations.

The IHNC floodwall between Lake Pontchartrain and Interstate-10 was overtopped during the Katrina storm. The elevation of the top of the floodwall ranges between 13.4 and 12.8 ft NAVD88 (1994, 1996). The overtopping section is 3,300 ft long at an elevation of 12.8 ft. Maximum storm surge elevations provided by the IPET data collection team ranged between 12.8 and 13.3 ft. Preliminary ADCIRC estimates for maximum storm surge in this reach varied between 13.7 and 10.8 ft. A maximum water surface elevation of 13.3 ft was used in the model. This water-surface elevation was determined during the calibration phase of the study and includes any contribution from waves. The floodwall acts as a sharp crested weir. A weir coefficient of 2.8 was used in the numerical model for the 3300-ft-long weir. The model calculated a small volume of water overtopping the floodwall in this reach.

The average IHNC floodwall top-of-wall elevation is 13.4 ft NAVD88 (1994, 1996) between Interstate-10 and Florida Avenue. Maximum storm surge elevation along this reach of the IHNC, provided by the IPET data collection team, ranged between 13.4 and 15.8 ft. the most reliable data indicated a maximum water-surface elevation of 14.7 ft. Preliminary ADCIRC estimates of maximum storm surge in this reach varied between 13.8 and 15.0 ft. A maximum water surface elevation of 14.7 ft was used in the model. This water-surface elevation was determined during the calibration phase of the study. In this reach, the floodwall is located between 800 and 1,500 ft from the IHNC and any contribution from waves is considered to be negligible. Significant flow overtopped the floodwall in this reach. A weir coefficient of 2.8 was used for the 7,500-ft-long sharp-crested weir. In addition to the overtopping, there was a breach of a sandbag plug placed in a floodwall opening near Interstate 10. This breach was 37-ft-wide and had a base elevation of 5.1 ft. The breach was assumed to commence at 0430 on 29 Aug and to be fully developed in 30 minutes. These times were selected based on anecdotal evidence and information presented in the 10 Mar 06 Draft Report by the Interagency Performance Evaluation Task Force (page V-9). The floodwall itself failed north of Florida Avenue. The floodwall failure was treated as a breach with a 90-ft base width, a 1V:5H side slope and a base elevation of 7.0 ft. The breach time was set at 0730 on 29 Aug and was assumed to be completed in 30 minutes. These times were selected based on anecdotal evidence and information presented in the 10 Mar 06 Draft Report by the Interagency Performance Evaluation Task Force (page V-9). An earthen levee between the IHNC floodwall and the canal itself was overtopped and breached. The top of levee elevation was 11.5 ft. A weir coefficient of 2.3 was used for the 1,440-ft-long earthen levee. The breach width was taken to be 125-ft wide with a rectangular cross-section and a breach base elevation of 5.0 ft. The breach time was assumed to commence at 0730 on 29 Aug and to be fully developed in 30 minutes. These times were selected based on the anecdotal evidence.

The IHNC floodwall top-of-wall elevation varies between 13.2 and 13.6 ft NAVD88 (1994, 1996) between Florida Avenue and the Mississippi River Lock. Maximum storm surge elevations along this reach of the IHNC, provided by the IPET data collection team, varied between 15.6 and 13.6 ft. Preliminary ADCIRC estimates for maximum storm surge in this reach varied between 15.8 and 15.0 ft. A maximum water surface elevation of 15.5 ft was used in the model. This water-surface elevation was determined during the calibration phase of the

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study and includes any contribution from waves. Significant flow overtopped the floodwall in this reach. A weir coefficient of 2.8 was used for the 7,250-ft-long weir.

Model Calibration

The HEC-RAS model was calibrated so that calculated storage area water surface elevations were within 0.2 ft of the range of the measured high water marks. In storage area 20 there were too few high water marks to justify model adjustment. High water marks were supplied by the IPET data collection team. Anecdotal reports of flood timing events conditions were also used to verify model results. A comparison of calculated and measured high water marks is shown in Table 2-10.

Table 2-10
Calculated and Measured High Water Marks

Storage Area	Measured High Water ft NAVD88 (1994, 1996)			Calculated High Water ft NAVD88 (1994, 1996)
	Number of HWM	Average	Range	
E3-1	1	2.6	2.6	2.8
E3-2	5	4.7	3.4-5.3	4.9
E3-3	3	2.9	2.2-3.3	3.0
E3-4	3	3.9	3.8-4.0	3.6
E5-5	3	3.1	3.0-3.2	3.0
E6-6	2	3.2	3.2-3.3	3.5
E7-7	3	3.7	3.6-3.8	3.7
E3-8	1	3.8	3.8	3.7
E3-9	2	2.8	2.8	2.7
E3-10	0			2.7
E3-11	4	3.0	2.9-3.1	3.0
E3-12	0			3.0
E3-13	6	2.6	2.4-2.8	3.0
E3-14	6	2.9	2.8-3.0	3.0
E3-15	9	2.8	2.3-3.0	3.0
E3-16	1	2.9	2.9	3.0
E3-17	7	3.3	3.0-4.0	3.6
E3-18	7	4.7	2.4-5.7	4.9
E3-19	0			3.1
E3-20	1	2.5	2.5	3.5

Model calibration is accomplished by adjusting model boundary conditions to better simulate known prototype behavior. Typically, variables with the highest uncertainty are used as calibration parameters. The primary model adjustment parameter was the water-surface elevation in the IHNC. The peak of the storm surge hydrograph was adjusted within the range of measured high water marks to provide sufficient volumes of water to duplicate flooding levels in the storage areas 2 and 18.

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In the calibration phase of this study, Storage Area E3-20 was added to the model. Initial calculated model results had water surface elevations in the area east of the 17th Street Canal and west of City Park lower than depths indicated by high water marks. It was necessary to include the elevated railroad, located just south of Interstate-610 and the underpass at Canal Boulevard in the HEC-RAS model in order to simulate the backwater depths from the railroad.

Weir coefficients in the storage area connections were also adjusted during the calibration phase of the study. Weir coefficients were varied only within a range acceptable in practice.

Comparison of Anecdotal and Calculated Flow Over Gentilly Ridge

Calculated flow patterns were compared to anecdotal reports of flow during Hurricane Katrina. The IPET data collection team reported that water was flowing north over Gentilly Ridge into the area west of the London Canal at 1000 on 29 Aug (10 Mar 06 Draft Report - page V-8). They also reported that water was flowing north over Gentilly ridge at 1230 on 29 Aug into the area east of London Canal (10 Mar 06 Draft Report - page V-9). Calculated discharges over Gentilly Ridge for these two locations are shown in Figure 2-10. Calculations show 4,610 cfs flowing north over Gentilly ridge into the area west of London Canal at 1000. Calculations show 5,280 cfs flowing north over Gentilly ridge into the area east of London Canal at 1230. Calculated results were consistent with the anecdotal evidence.

The figure also demonstrates directions and sources of flooding. Initially, on 29 Aug, floodwaters were flowing north over Gentilly Ridge. The source of these floodwaters was the storm surge overtopping the levees and floodwalls along the IHNC. Then on 30 and 31 Aug, the direction of the floodwaters reversed, flowing south over Gentilly Ridge. The source of these floodwaters was the breaches in the London Avenue Canal.

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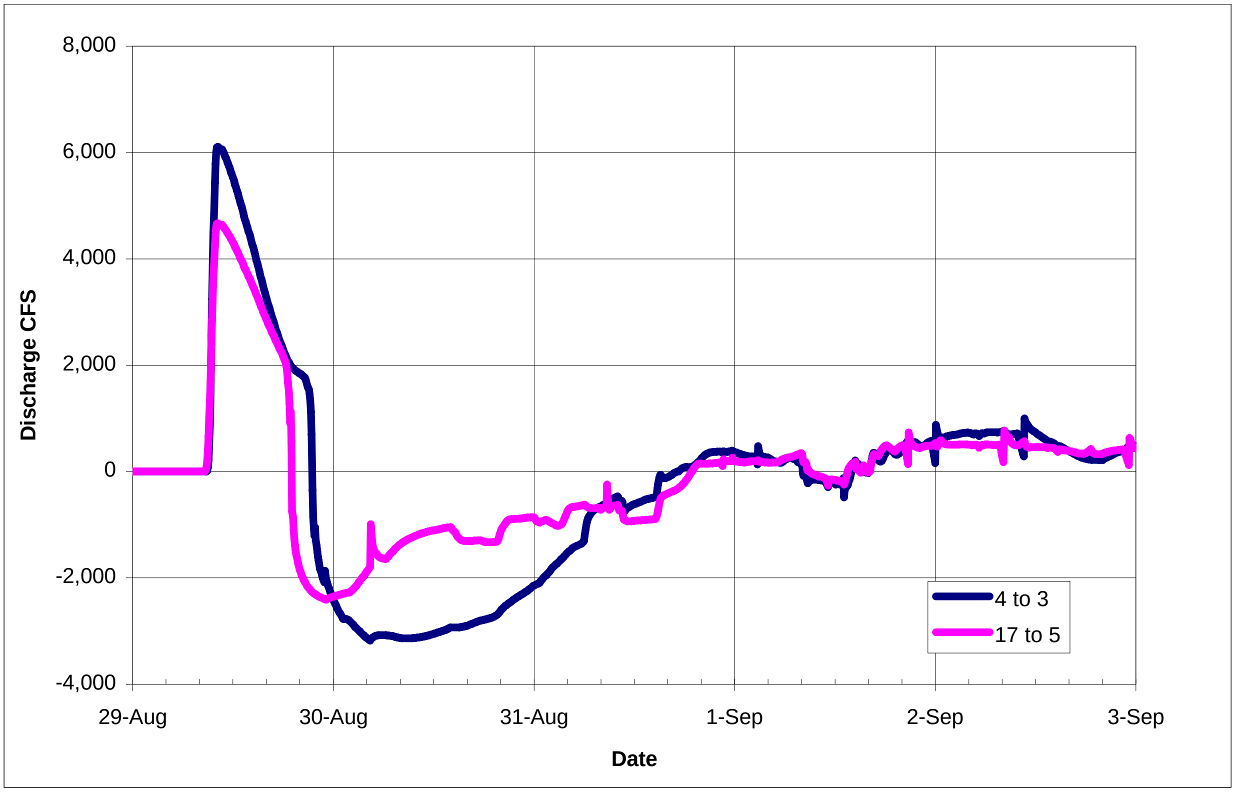

Figure 2-10. Calculated Flow North Over Gentilly Ridge into Area West of London Canal (17 To 5) and into Area East of London Canal (4 to 3)

Comparison of Measured and Calculated Stages on Palmetto Canal

The calculated stage hydrograph in the Palmetto Canal at Jeff Davis Parkway was compared to measured stages during Hurricane Katrina in Figure 2-11. The gage data was supplied by BCG. The higher model elevations shown in the figure for 28 Aug are due to an artificial low discharge in the Palmetto Canal used for numerical stability. However, this figure shows consistency in the timing of stage increases with rainfall during the initial phases of Hurricane Katrina flooding. Calculated elevations were found to be dependent on pumping operations at Pumping Station 1. Pumping operations in the model were adjusted as part of the calibration procedure. After the shut down of pumps at 0900 on 30 Aug, the calculated and measured stages are in good agreement. This is the time frame when flow from the levee breaches and floodwall overtopping reaches this portion of Orleans East Bank. Measured and calculated maximum stages for Hurricane Katrina are in good agreement.

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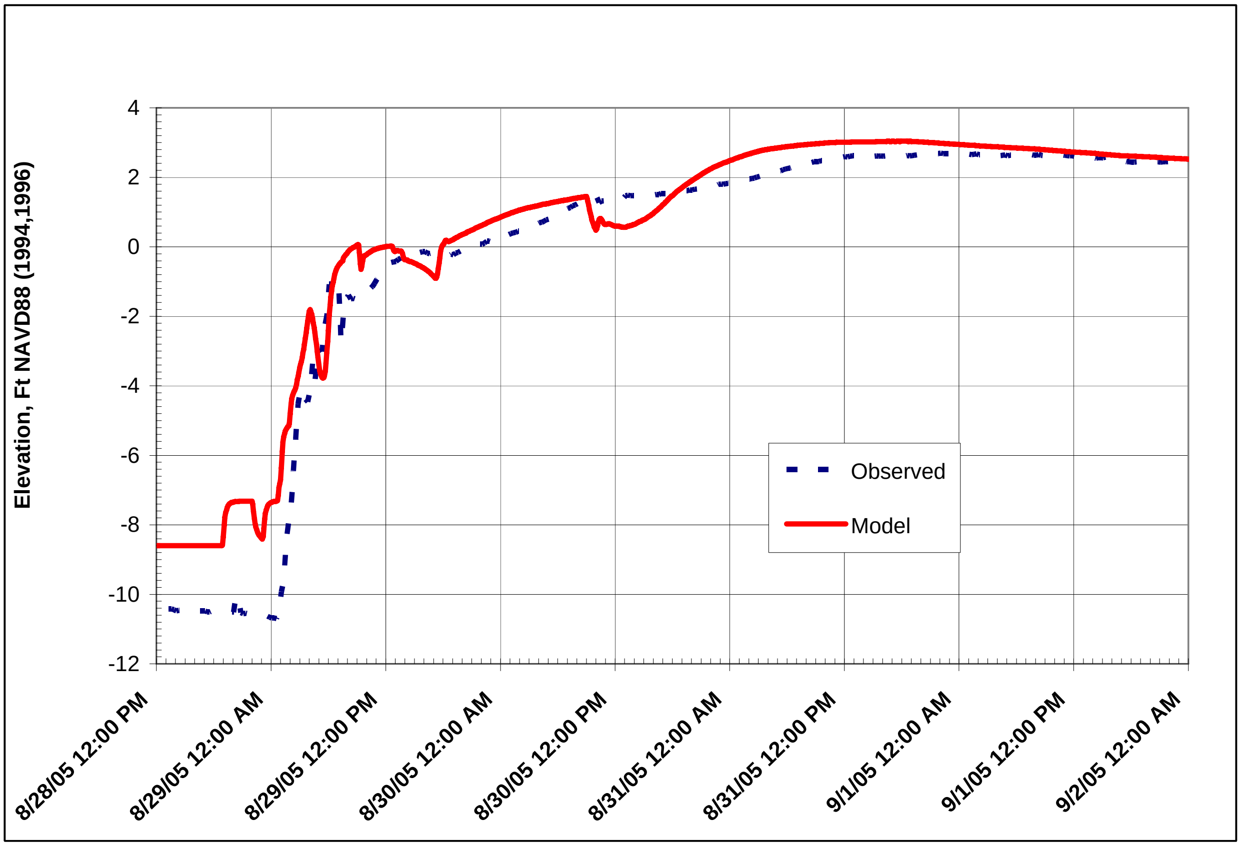

Figure 2-11. Calculated and Measured Stages on the Palmetto Canal at Jeff Davis Parkway During Katrina

Model Results and Floodplain Mapping

Maximum flood depths in Orleans East Bank, calculated for Hurricane Katrina, are shown in Figure 2-12 and tabulated in Table 2-11. This simulation is labeled "Katrina." Flooding from the simulated Hurricane Katrina event includes rainfall estimated from radar data, inflow from breaches and inflow from overtopping of the IHNC levees and floodwalls. Pump operations, estimated from pump logs, were included in the model.

These results should be considered approximate. Railroad grade elevations were estimated from a digital terrain model to approximately define weir crest elevations. Many bridges and channels had dimensions from old model studies that were unconfirmed by field checks. Other

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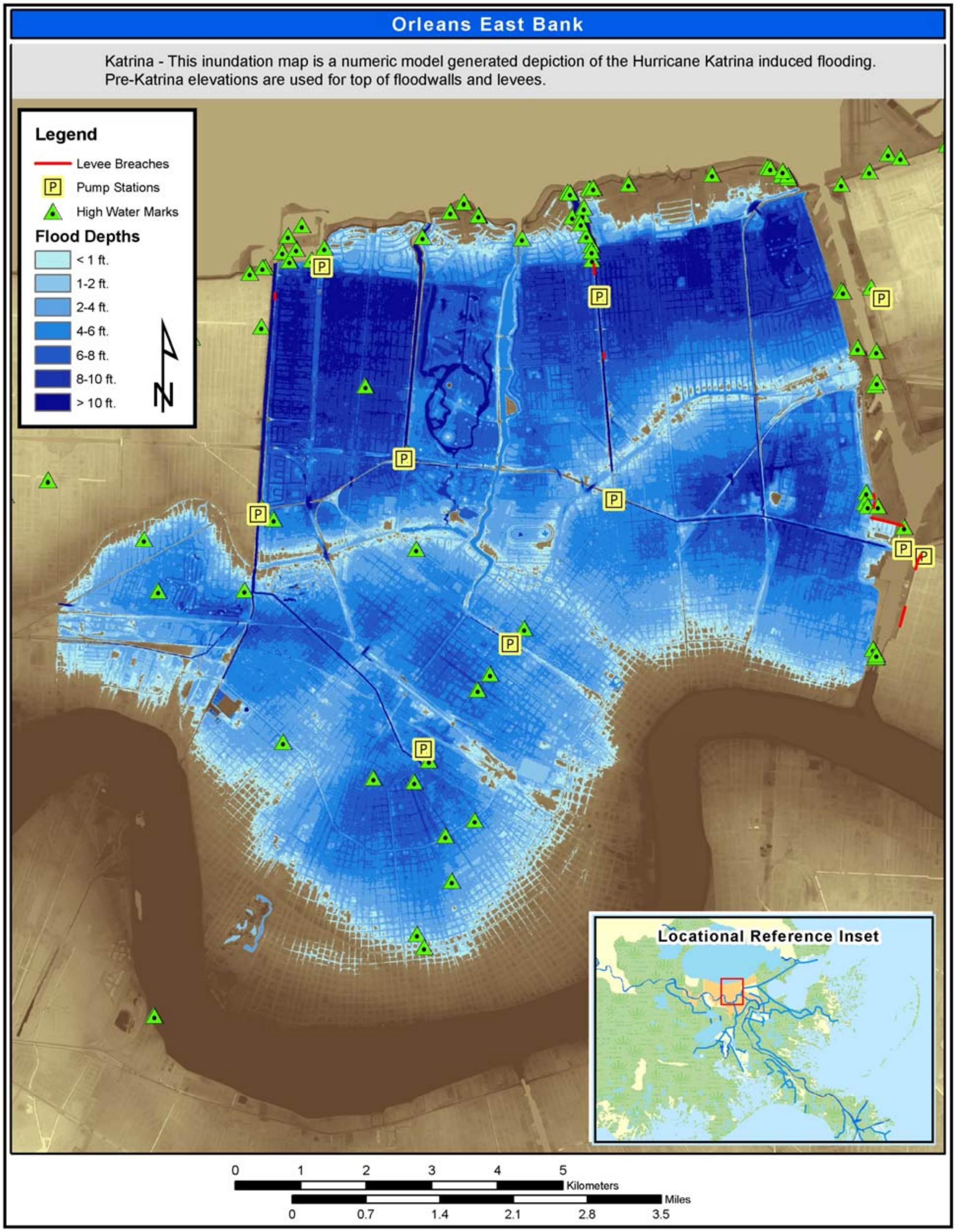

Figure 2-12. Calculated Maximum Flood Depths from Hurricane Katrina

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Table 2-11
Calculated Water Surface Elevations from Katrina
Ft NAVD88 (1994, 1996)

Storage Area	Actual Katrina Events	Hypothetical 1 **Resilient Levees and Floodwalls** No Breaches and Pumps as Operated during Katrina	Hypothetical 2 **Resilient Floodwalls, Levees and Pump Stations** No Breaches and 100% Pumps	**Hypothetical 3** **Resilient Floodwalls** IHNC Breaches and Pumps as Operated During Hurricane Katrina
E3-1	2.8	-1.0	-5.0	-0.2
E3-2	4.9	4.4	4.3	4.9
E3-3	3.0	-1.0	-5.6	-0.1
E3-4	3.6	2.9	2.7	3.6
E5-5	3.0	0.3	-3.6	1.2
E6-6	3.5	-3.0	-3.3	-2.4
E7-7	3.7	-3.1	-6.4	-2.3
E3-8	3.7	-3.1	-5.0	-2.3
E3-9	2.7	0.5	-1.4	0.5
E3-10	2.7	0.5	-0.8	0.5
E3-11	3.0	0.7	-1.2	0.7
E3-12	3.0	-0.6	-0.6	-0.6
E3-13	3.0	-0.9	-1.1	-0.8
E3-14	3.0	-1.0	-3.2	-0.8
E3-15	3.0	-1.0	-3.0	0.2
E3-16	3.0	1.6	1.3	2.3
E3-17	3.6	2.9	2.6	3.6
E3-18	4.9	4.4	4.2	4.9
E3-19	3.1	2.7	2.5	3.1
E3-20	3.5	-2.6	-2.8	-2.3

bridges and channels had dimensions assigned based on photographs or simply by knowledge of structures. Pump start-up elevations in the model are based on intuitive assignments, partially influenced by numerical stability requirements.

HEC-RAS model results indicate that the most important factor determining the maximum elevations in Orleans East Bank was the water surface elevations in Lake Pontchartrain on the recession of the storm surge hydrograph. Water continued to flow through the breaches until the water levels in the lake and Orleans East Bank were essentially equal. Floodwaters were able to flow over ridges and through storm drains into all areas of Orleans East Bank. Maximum water surface elevations in areas west of the IHNC were initially higher than the rest of Orleans East Bank due to the magnitude of the overtopping flows. However, the long duration of flooding was due to inflow through the breaches. Flooding in the Hoey's Basin and the Pontchartrain Park Basin (Storage Area 1) was caused primarily by flows backing up through storm drains.

The HEC-RAS numerical model was used to estimate flooding depths that would have occurred in Orleans East Bank during Hurricane Katrina had all levees and floodwalls remained intact. This hypothetical case is called "Resilient Levees and Floodwalls". Overtopping of levees and floodwalls are included in this scenario. Levee and floodwall breaches are not

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included in the simulation, even in areas where overtopping occurred. Pump stations are assumed to operate as they did during Hurricane Katrina. Pre-Katrina elevations are used for the top of all levees and floodwalls. This scenario simulates what could have happened if all levees and floodwalls had protection that would allow them to overtop but not breach. Calculations showed that the maximum flooding depths in the storage areas south of Gentilly Ridge and west of the IHNC were about 0.5 ft less than those calculated in the "Katrina" simulation. However, the flooding depths after the peak were significantly less. Flood depths in the remaining sub-areas of Orleans East Bank were significantly less than those calculated for the "Katrina" simulation. Tabulated results are shown in Table 2-11 and calculated depths are plotted in Figure 2-13.

The HEC-RAS model was used to estimate the flooding depths that would have occurred in Orleans East Bank during Hurricane Katrina had all levees, floodwalls and pump stations remained intact. This hypothetical case is called "Resilient Floodwalls, Levees and Pump Stations." Overtopping of floodwalls and levees are included in this scenario. Levee and floodwall breaches are not included in the simulation, even in areas where overtopping occurred. Pre-Katrina elevations are used for the top of all levees and floodwalls. Pumps stations are assumed to operate at 100-percent capacity continuously throughout the simulation. Pump operations are based on the pump efficiency curves that reflect tailwater impacts. This simulation was included to provide an upper limit on what could have been the best possible scenario had no failures occurred. This simulation should not be considered to be a realistic scenario of what could have occurred during the hurricane. The 100-percent pump capacity assumption is unrealistic for several reasons. Pump curves in the model are based on data for new pumps. Some of the pumps are over 90 years old. In addition, pump operation logs from the Katrina event reveal that the pump stations were not operated at 100-percent capacity even when that was an option. This suggests that standard operation does not necessarily include 100-percent capacity. Pump logs also indicate that pumps are tripped off frequently during operations. Numerous power interruptions were encountered during the storm before flooding became a problem. Calculations for the "Resilient Floodwalls, Levees and Pump Stations" scenario showed that the maximum flooding depths in the storage areas south of Gentilly Ridge and west of the IHNC were 0.6 to 0.7 ft less than those calculated in the "Katrina" simulation. The duration of flooding in these areas was significantly less due to continuous operation of pumps. Flooding in areas farther west of the IHNC was also less than for the "Katrina" case and the other hypothetical cases, because of continuous pumping. Flood depths in the remaining sub-areas of Orleans East Bank were significantly less than those calculated for the "Katrina" simulation. Tabulated results for this case are shown in Table 2-11 and calculated depths are plotted in Figure 2-14.

The HEC-RAS numerical model was also used to estimate the flooding depths that would have occurred in Orleans East Bank during Hurricane Katrina had the levees and floodwalls on the 17th Street and London Avenue Canals not breached and the pump stations operated the same as they did during Hurricane Katrina. This hypothetical case is called "Resilient Floodwalls." In this scenario, actual Hurricane Katrina overtopping of the IHNC was included in the simulation. Calculated flooding depths in the storage areas south of Gentilly Ridge and west of the IHNC were slightly higher for this scenario than for the "Resilient Levees and Floodwalls" case. This is because more the IHNC breaches allowed water to enter Orleans East Bank for a

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longer time. Tabulated results are shown in Table 2-11 and calculated depths are plotted in Figure 2-15.

Results from the hypothetical simulations are more uncertain than results from the model used to simulate actual events during Hurricane Katrina. The numerical model was assembled to simulate the "actual" condition. Issues related to exchange of flow between storm drains and storage areas at low elevations were not significant in the "actual" model and therefore not addressed in sufficient detail for low elevation simulations. To adequately model the low elevation condition more data and additional work on the numerical model would be required. This work would include better definition of storage elevation-volume curves at low elevations to include more storm drain volume and more detailed modeling of lateral storm drain inlets. Additional data requirements include locations and dimensions of small lateral storm drains.

Flow Through Breaches

The unsteady flow HEC-RAS model calculated flow hydrographs through the levee breaches and over the IHNC floodwall. The hydrographs for the 17th Street, London West and London East breaches are shown in Figure 2-16. Water began to flow back through the breaches into Lake Pontchartrain on 31 Aug. The flow reversal began at 17th Street at 1630, London West at 1830 and London East at 1930. Overtopping of the IHNC floodwalls occurred over a much shorter duration than the canal breaches because the natural ground is higher. No flow reversal was calculated back into the IHNC. Calculated flow over the IHNC floodwall north of Interstate-10 occurred for 1.75 hours. Between Interstate-10 and Pumping Station 19 calculated overtopping and flow through breaches occurred for 22 hours. Without breaches, the duration of overtopping was about 6.5 hours. South of Pumping Station 19, calculated overtopping occurred for about 2.5 hours. Hydrographs of flow over and through the IHNC are shown in Figures 2-17 and 2-18. Total calculated volumes of flow entering Orleans East Bank are tabulated in Table 2-12. Table 2-13 lists the percentages of inflow contributed by rainfall, overtopping and breaching.

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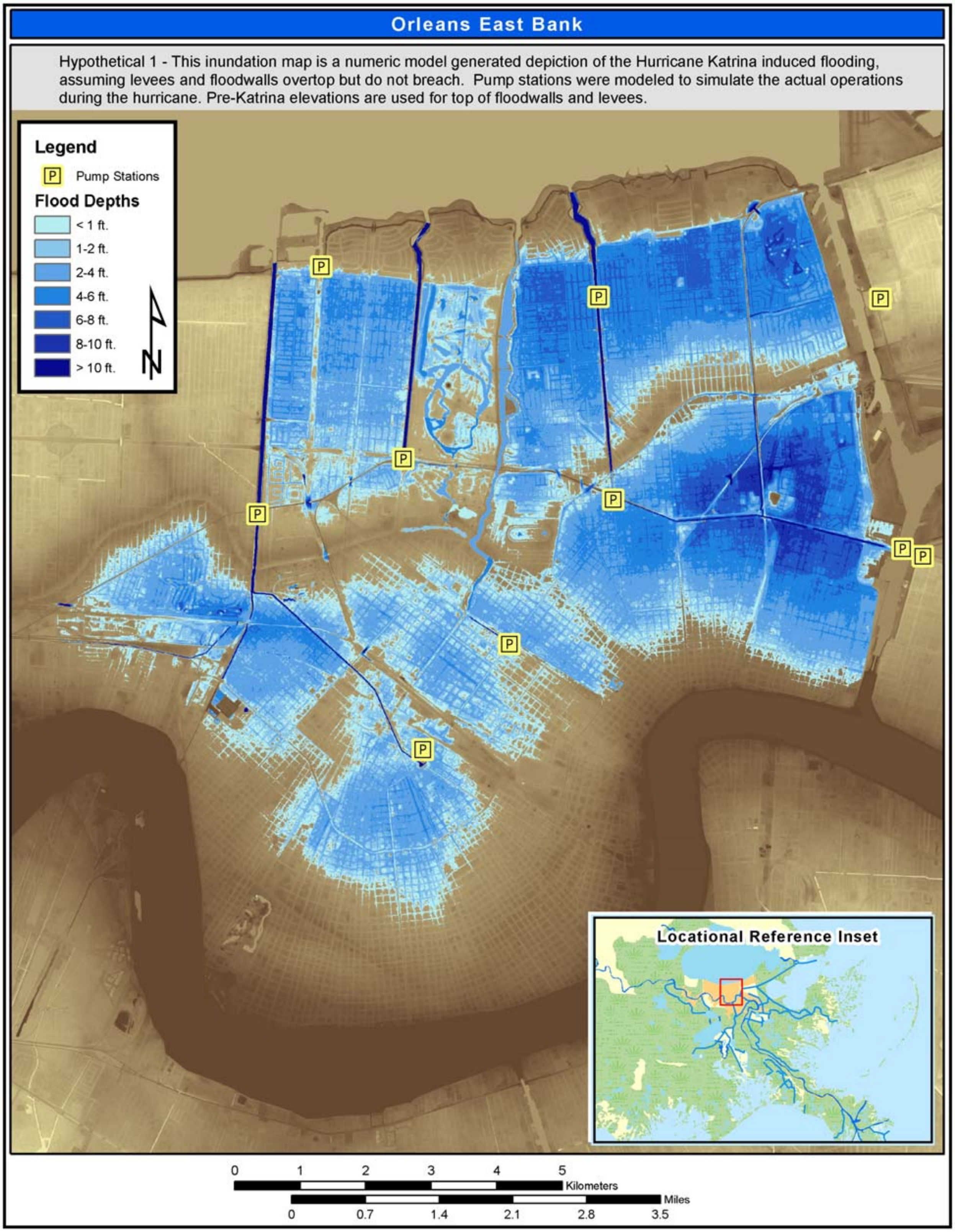

Hypothetical 1 - This inundation map is a numeric model generated depiction of the Hurricane Katrina induced flooding, assuming levees and floodwalls overtop but do not breach. Pump stations were modeled to simulate the actual operations during the hurricane. Pre-Katrina elevations are used for top of floodwalls and levees.

Figure 2-13. Calculated Flood Depths for Resilient Levees and Floodwalls - Assuming No Levee or Floodwall Breaches and Pump Stations as Operated During Hurricane Katrina.

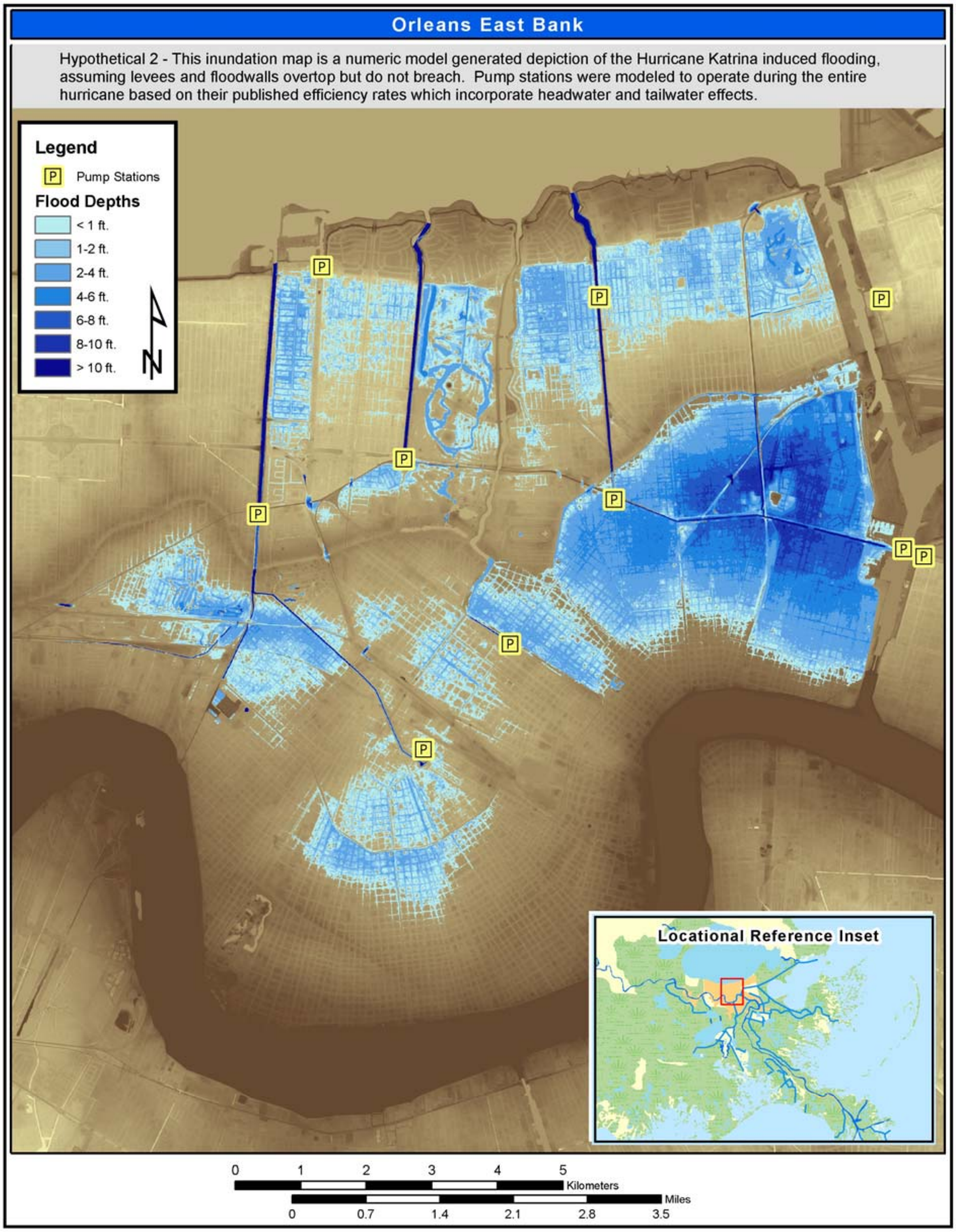

Figure 2-14. Calculated Flood Depths for Resilient Floodwalls, Levees and Pump Stations - Assuming No Levee or Floodwall Breaches and Pump Stations Operated Continuously at 100 Percent Capacity.

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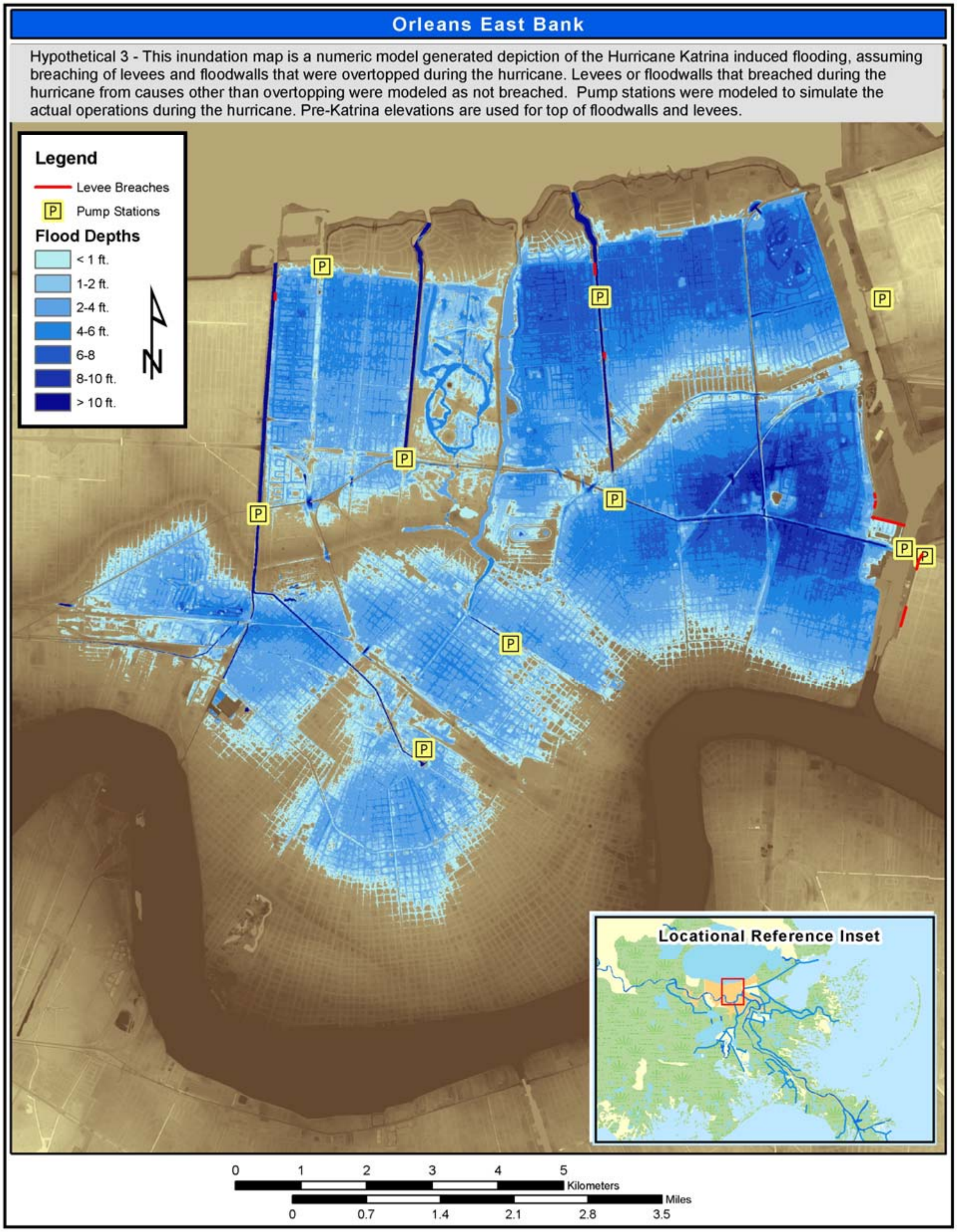

Hypothetical 3 - This inundation map is a numeric model generated depiction of the Hurricane Katrina induced flooding, assuming breaching of levees and floodwalls that were overtopped during the hurricane. Levees or floodwalls that breached during the hurricane from causes other than overtopping were modeled as not breached. Pump stations were modeled to simulate the actual operations during the hurricane. Pre-Katrina elevations are used for top of floodwalls and levees.

Figure 2-15. Calculated Flood Depths for Resilient Floodwalls - Assuming No Levee or Floodwall Breaches on the 17th Street and London Avenue Canals and Pump Stations as Operated During Hurricane Katrina.

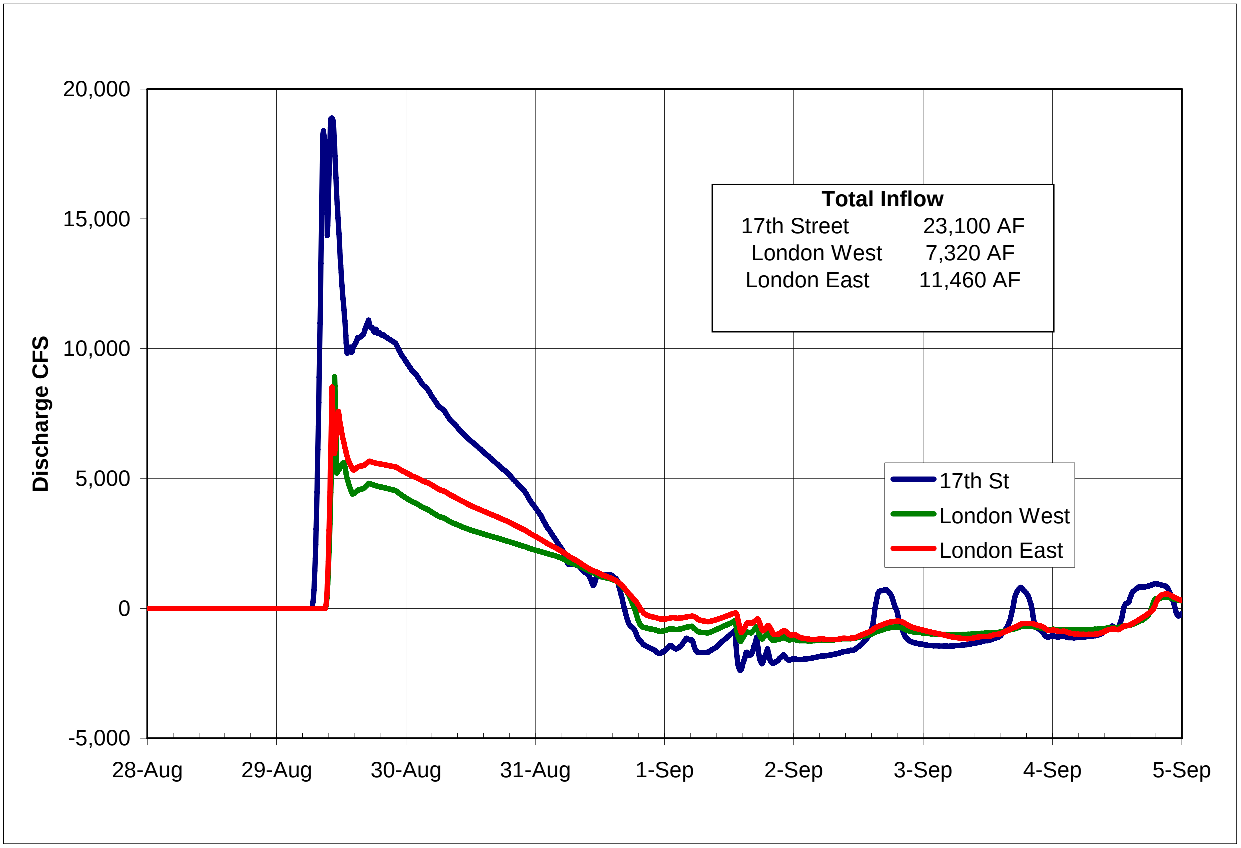

Figure 2-16. Calculated Flow Through Levee Breaches. Based on Observed Stage Hydrographs

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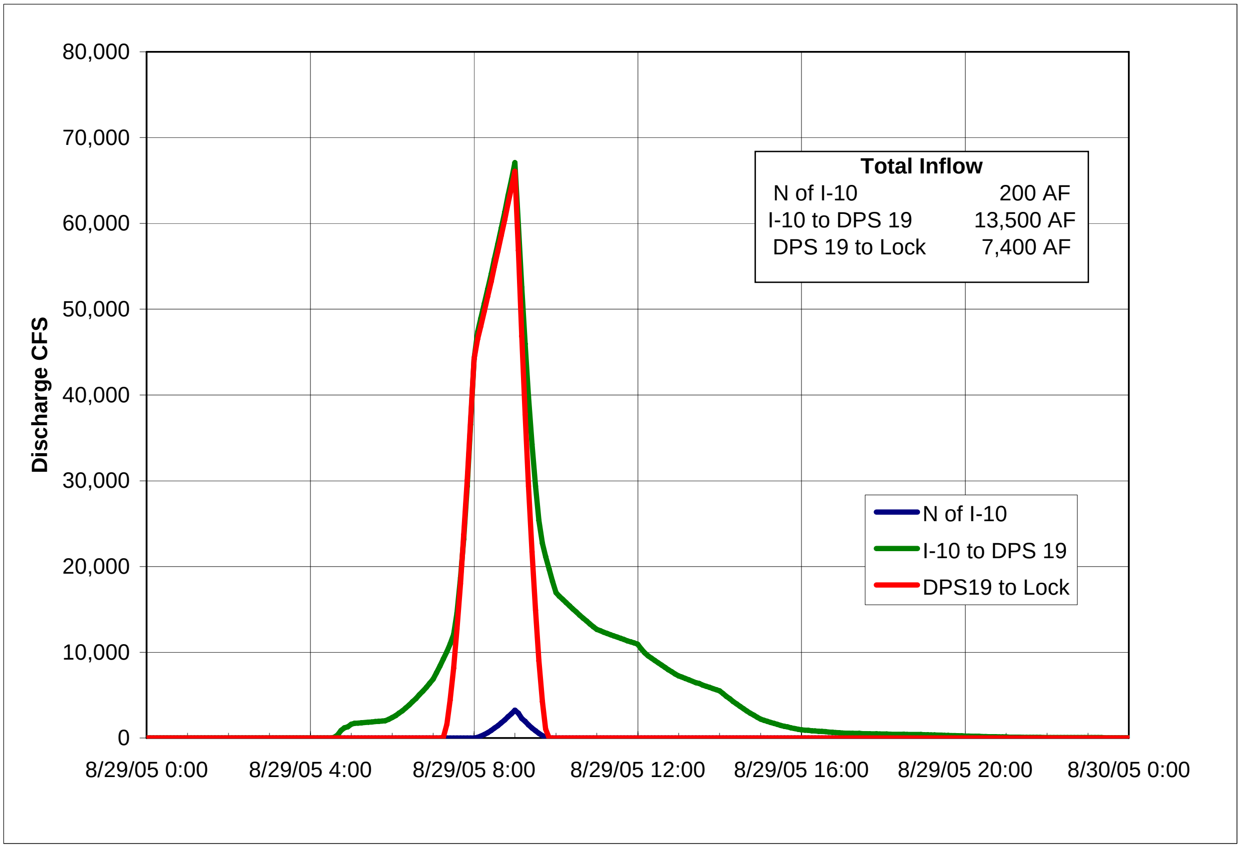

Figure 2-17. Calculated Flow Through and Over Inner Harbor Navigation Canal Floodwalls. Based on Preliminary ADCIRC Hydrographs Adjusted Using Gage Data from IHNC Lock

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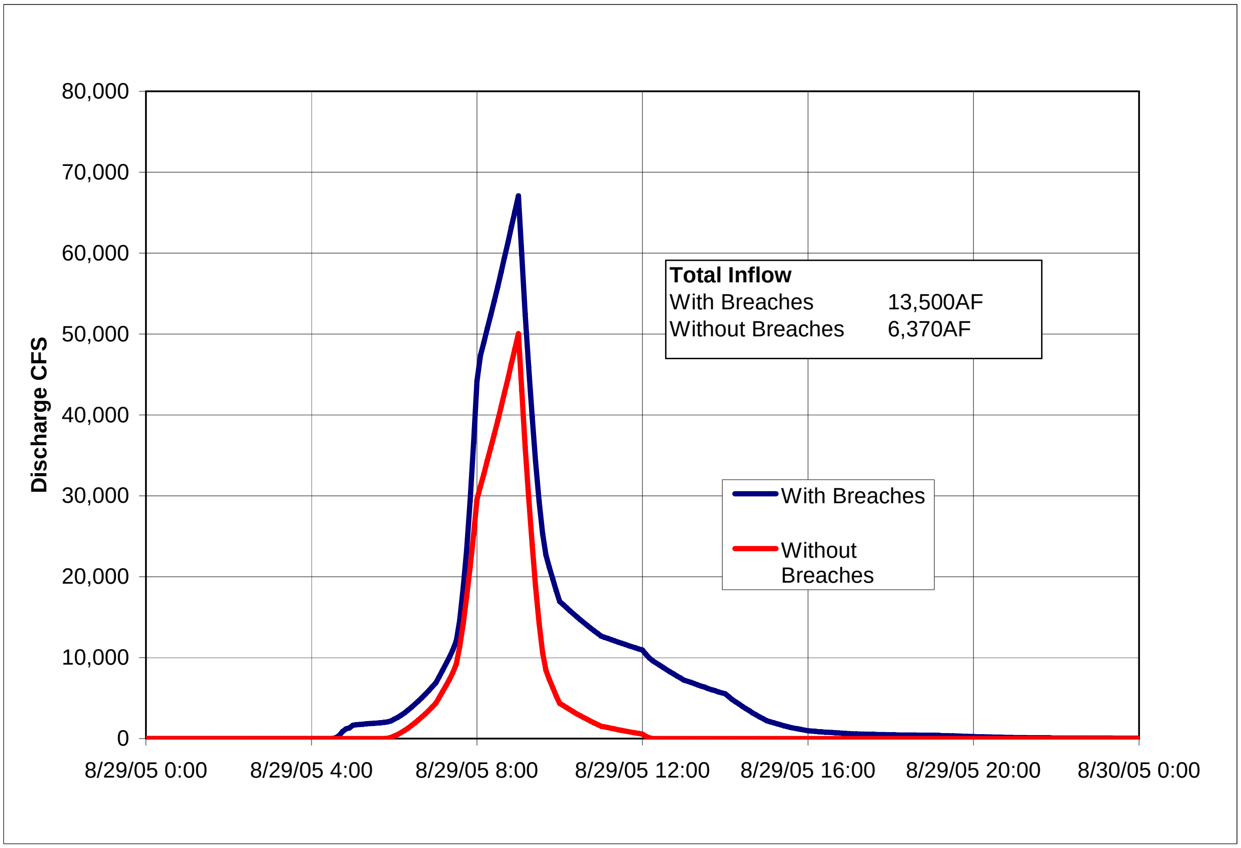

Figure 2-18. Comparison of Calculated Flow at IHNC Floodwall Between I-10 and Pumping Station 19 With and Without Breaches During Hurricane Katrina. Based on Preliminary ADCIRC Hydrographs Adjusted Using Gage Data from IHNC Lock.

Table 2-12
Calculated Volume of Flow into Orleans East Bank

Location	Inflow with Breaches Acre-Feet	Inflow without Breaches Acre-Feet
Rainfall Runoff	21,900	21,900
17th Street	23,100	0
Orleans	40	40
London West	7,320	0
London East	11,460	0
IHNC north of I-10	200	200
IHNC I-10 to DPS 19	13,500	6,370
IHNC DPS19 to Lock	7,400	7,400
Total	84,920	35,910

Table 2-13
Inflow Percentages into Orleans East Bank

Type	Percent
Rainfall Runoff	26
Breaches	58
Overtopping	16

Water Surface Elevations in Storage Areas

The pattern of flooding in Orleans East Bank can be demonstrated using calculated flood elevations in the storage areas. Four representative storage area calculations for the Katrina, No Breaches and Katrina Pumping, No Breaches with 100% Pumping, and IHNC Breaches with Katrina Pumping cases are presented. Storage Area 2 is located adjacent to the IHNC floodwall between I-10 and Florida Avenue and demonstrates flooding patterns in an area subject to IHNC overtopping. Storage Area 5 is located west of the London Avenue Canal and demonstrates flooding patterns in an area subject to canal breaches and IHNC overtopping. Storage Area 7 is located on the east side of the 17th Street Canal and demonstrates flooding patterns in an area subject to canal breaches. Storage Area 14 is located in downtown New Orleans and demonstrates flooding patterns in an area subject to overtopping of ridges and backflow through storm drains.

Calculated water-surface elevations in Storage Area 2 are shown in Figure 2-19. The peak flooding elevation is similar for all four scenarios. This is because most of the water comes from overtopping of the floodwall, which occurs in all three cases. The peak water-surface elevation is higher for the Katrina and IHNC Breaches with Katrina Pumping cases because floodwall and levee breaches are included. The peak water-surface elevation is not maintained for very long because floodwaters quickly flow over railroads and through culverts into adjacent storage areas. Water surface elevations remain at a higher level for the Katrina case because the flood waters from the canal breaches eventually reach this area and there is a continued supply of water from Lake Pontchartrain. Flood levels also remain high for the three cases with Katrina pumping because of the low pumping capacity. Flood waters are removed from this area by 1 Sep 05 with the No Breaches with 100% Pumping case. There is no pumping station in this storage area so floodwaters must exit through the storm drain system.

Calculated water-surface elevations in Storage Area 5 are shown in Figure 2-20. Calculated water surface elevations began to rise similarly for all four cases with the onset of rainfall during the early morning hours of Aug 29. The rate of rise was less for the 100% pumping case because pumps were not operated at 100% capacity during Hurricane Katrina. Flood waters from the IHNC overtopping reached this area causing additional increases in water-surface elevations. Water continued to rise with the Katrina case due to water received from the London Avenue breach. Model results indicate that without the London Avenue breach water-surface elevations would have been about 2 ft lower than occurred in the Katrina case.

Calculated water-surface elevations in Storage Area 7 are shown in Figure 2-21. Calculated water surface elevations began to rise similarly for all four cases with the onset of rainfall during

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the early morning hours of Aug 29. The rate of rise was less for the 100% pumping case because pumps were not operated at 100% capacity during Hurricane Katrina. Flood waters from the IHNC overtopping reached this area causing additional increases in water-surface elevations, but the rate of rise was much less than in Storage Area 5. Sub-basin storage between the IHNC and Storage Area 7 was responsible for reducing the flooding in Storage Area 7. In the Katrina case, rapid increases in water surface elevations occurred when the 17th Street levee breached.

Calculated water-surface elevations in Storage Area 14 are shown in Figure 2-22. Calculated water surface elevations began to rise similarly for all four cases with the onset of rainfall during the early morning hours of Aug 29. The rate of rise was less for the 100% pumping case because pumps were not operated at 100% capacity during Hurricane Katrina. Calculations suggest that flood waters from the IHNC overtopping and/or the levee breaches did not reach this area until Aug 30. Calculated water-surface elevations were declining during the late hours of Aug 29 and the early morning hours of Aug 29. Pump Station 1, which evacuates this sub area, was shut down at 9:00 on Aug 30. This corresponds to the time when calculated increases in water-surface elevations occurred for the cases with No Breaches with Katrina Pumping and IHNC Breaches and Katrina Pumping. With the Katrina case, pumping at Pumping Station 1 was overwhelmed by inflow from the 17th Street and London Avenue breaches.

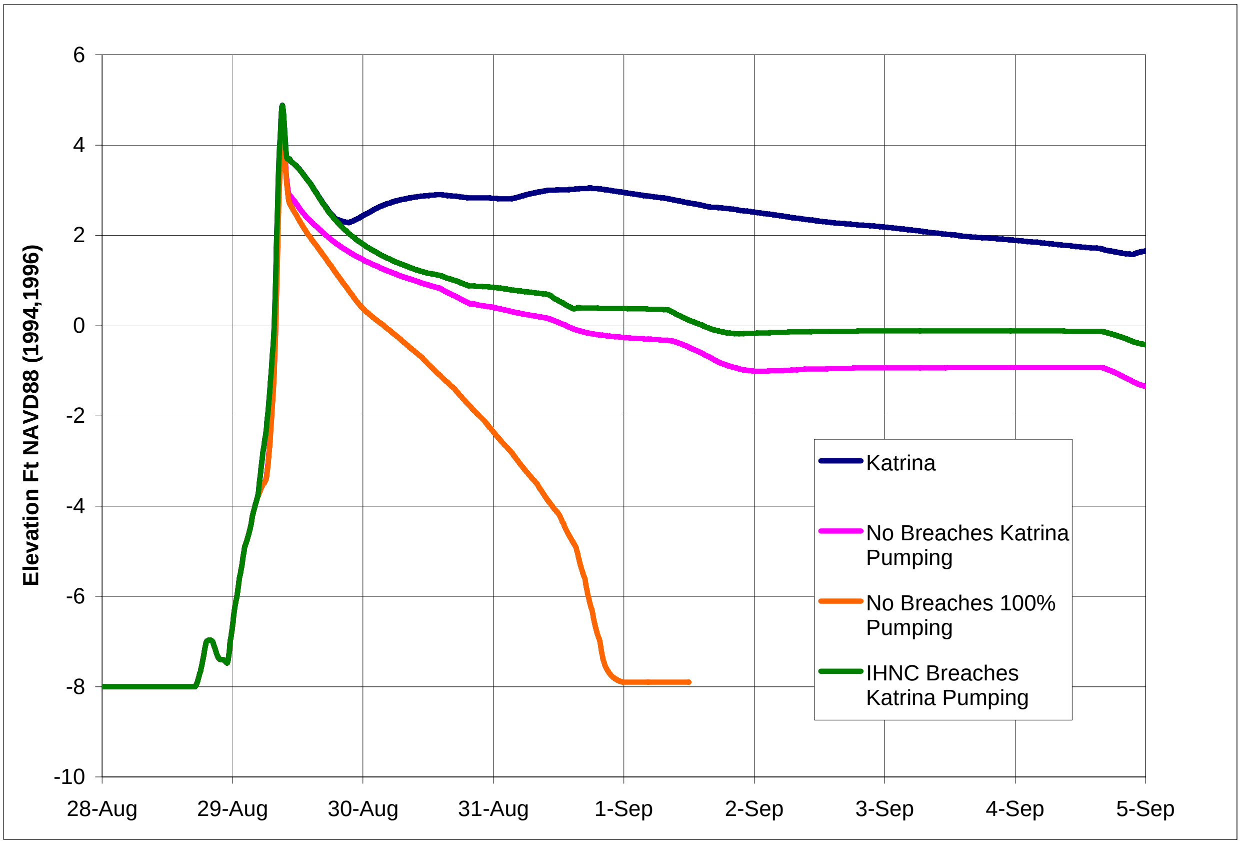

Figure 2-19. Calculated Water-Surface Elevations in Storage Area 2

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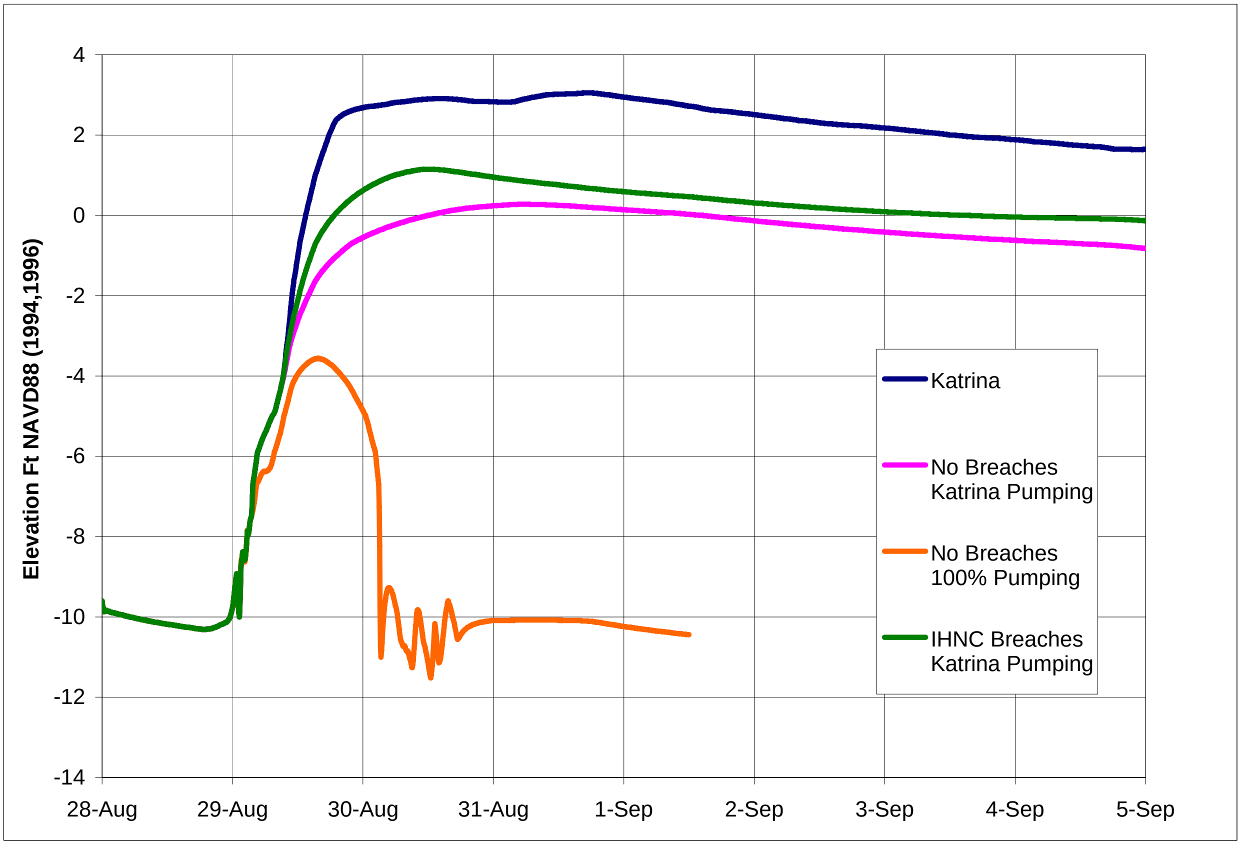

Figure 2-20. Calculated Water-Surface Elevations in Storage Area 5

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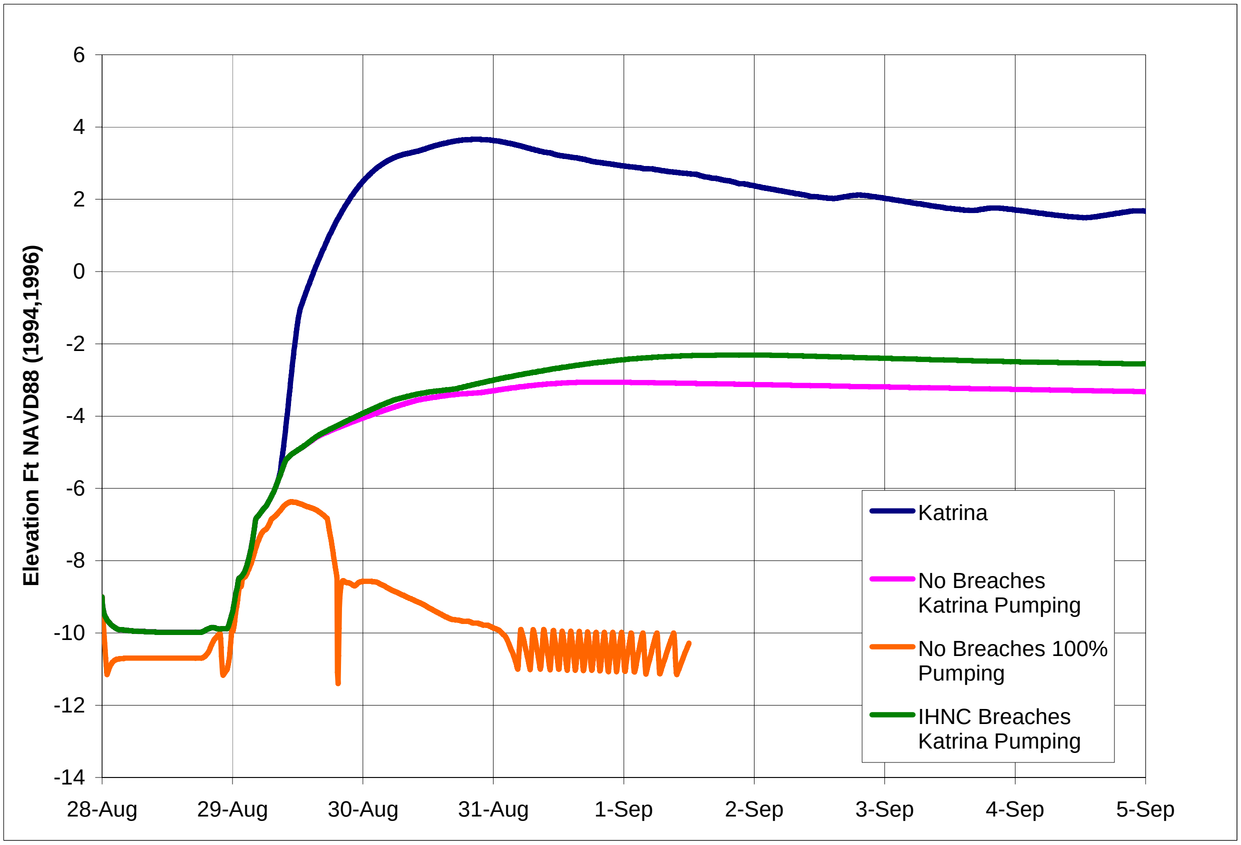

Figure 2-21. Calculated Water-Surface Elevations in Storage Area 7

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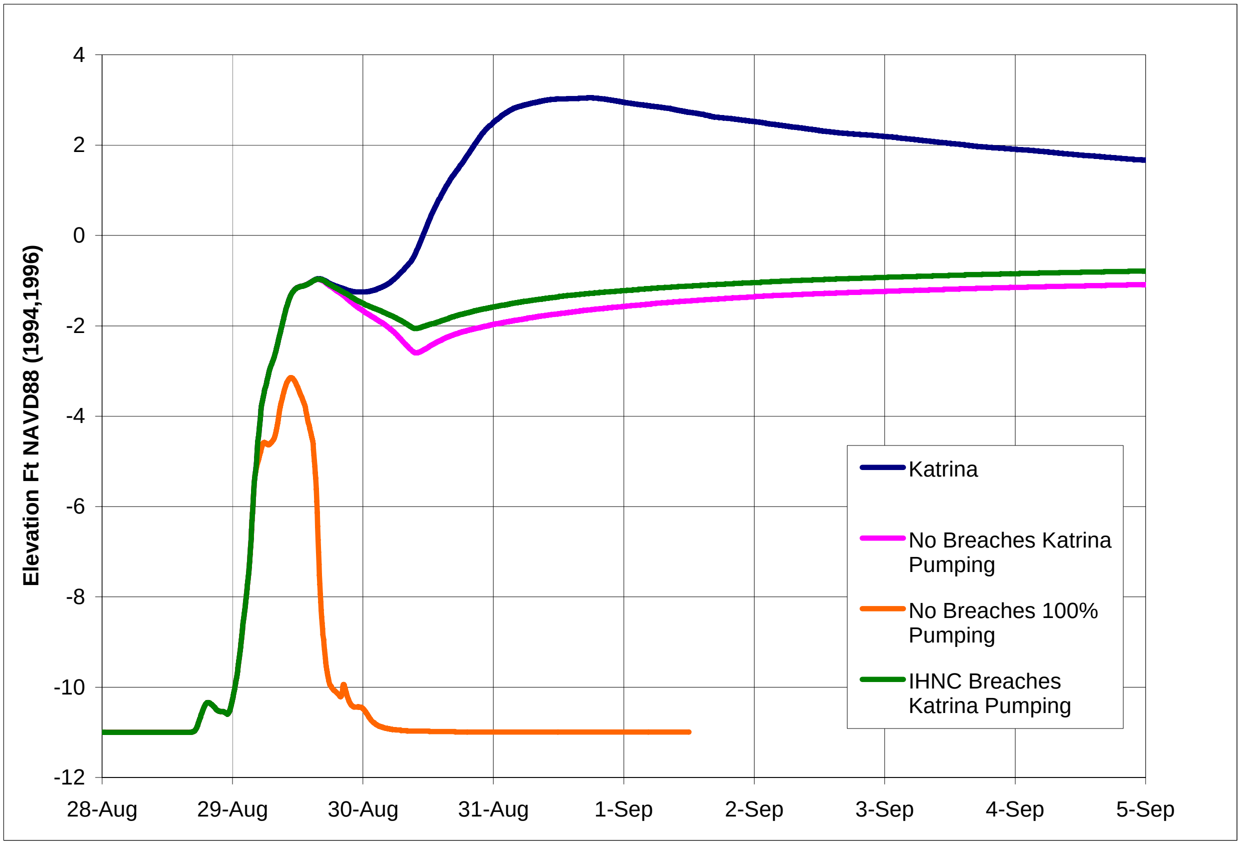

Figure 2-22. Calculated Water-Surface Elevations in Storage Area 14

Conclusions

The unsteady flow HEC-RAS model was able to simulate Hurricane Katrina flooding in Orleans East Bank. Maximum high water was predicted within 0.2 ft. Timing of flooding appeared to be reasonable. Additional data, including drainage network dimensions and pump operations are required to improve model reliability. However, for the "Katrina" simulation, the additional data would not change predicted results significantly. The more detailed model would provide more precise calibration parameters that would provide more confidence in alternative condition simulations. It is recommended that additional analyses be conducted when more detailed data becomes available in order to verify and/or correct the results presented in this report.

The numerical model predicted approximate flooding elevations for three hypothetical Hurricane Katrina scenarios. In Hypothetical Scenario 1, there were no breaches in the levees or floodwalls and all pumps as operated during Hurricane Katrina. In Hypothetical Scenario 2, there were no breaches in the levees or floodwalls and all pump operated continuously at 100 percent capacity. In Hypothetical Scenario 3, there were no breaches in the 17th Street and London Avenue Floodwalls and pumps operated as during Katrina. Results from the hypothetical scenarios contain uncertainty because the duration of flooding was reduced by the

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reduced volume of flow so that conditions were significantly different from the calibrated model conditions. Analysis of other hydrologic events of lower frequency would require additional geometric data to be included in the numerical model.

Appendix 3
Interior Drainage Analysis – New Orleans East

Introduction

Study Purpose

To answer the questions regarding the performance of the hurricane protection system, the interior drainage analysis focused on the filling and unwatering of the separate areas protected by levees and pump stations, referred to as basins. Interior drainage models were developed for Jefferson, Orleans, St. Bernard and Plaquemines Parishes to simulate water levels for what happened during Hurricane Katrina and what would have happened had all the hurricane protection facilities remained intact and functioned as intended.

The primary components of the hurricane protection system are the levees and floodwalls designed and constructed by the Corps of Engineers. Other drainage and flood control features (land topography, streets, culverts, bridges, storm sewers, roadside ditches, canals, and pump stations) work in concert with the Corps of Engineers levees and floodwalls as an integral part of the overall drainage and flood damage reduction system and are included in the models.

Interior drainage models are needed for estimating water elevations inside leveed areas, or basins, for a catastrophic condition such as Hurricane Katrina and for understanding the relationship between HPS components. Results from the interior drainage models can be used to determine the extent, depth and duration of flooding for multiple failure and non-failure scenarios. The models can also be used to:

- Support the Risk modeling effort
- Estimate time needed to unwater an area
- Support evacuation planning
- Evaluate design options of the HPS to include multiple interior drainage scenarios

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This appendix will provide details of the development of the HEC-HMS and HEC-RAS models for the New Orleans East basin. In summary, an HEC-HMS model was developed to transform the Katrina precipitation into runoff for input to the HEC-RAS models. HEC-RAS models were developed to simulate the four conditions discussed below

This model was developed to help answer questions 3 and 4 listed on page 1 of Volume VI. Question 3 is answered by the Katrina simulation listed below. Question 4 is a more difficult one to answer. This is mainly due to the variety of possible combinations of system features, especially pumps. It was decided to bracket these combinations with the three hypothetical combinations listed below.

One of the major difficulties is determining what pumps may have continuing operating. There are many potential factors that can cause pump stations to not operate during a hurricane event. Some of these are power failures, pump equipment failures, clogged pump intakes, flooding of the pump equipment, loss of municipal water supply used to cool pump equipment and no safe housing for operators at the pump stations resulting in pump abandonment. Because there is such a wide range of possible pumping scenarios that could occur during a hurricane event, it is difficult to establish a pumping scenario for what could have happened. At best, a variety of possible scenarios could be run to evaluate the potential range of possible consequences. For the purposes of the IPET analysis, it was decided to operate the pumps two ways. (1) As they actually operated during hurricane Katrina and (2) the pumps operated throughout the hurricane.

Described below are the 4 scenarios shown in this appendix.

Katrina

Simulate what happened during Hurricane Katrina with the hurricane protection facilities and pump stations performing as actually occurred. Compare results to observed and measured high water marks. Pre-Katrina elevations are used for top of floodwalls and levees.

Hypothetical 1 – Resilient Levees and Floodwalls

Simulate what would have happened during Hurricane Katrina had all levees and floodwalls remained intact. There are no levee or floodwall breaches or failures for this scenario even where overtopping occurs. Pump stations operate as they did in the Katrina event. Pre-Katrina elevations are used for top of floodwalls and levees. This scenario is meant to simulate what could have happened if all levees and floodwalls had protection that would allow them to be overtop but not breach.

Hypothetical 2 – Resilient Floodwalls, Levees and Pump Stations

Simulate what would have happened during Hurricane Katrina had all levees, floodwalls and pump stations remained intact and operating. There are no levee or floodwall breaches or failures for this scenario even where overtopping occurs. Pump stations operate continuously throughout the hurricane. Pump operations are based on the pump efficiency curves which reflect tailwater impacts. Pre-Katrina elevations are used for top of floodwalls and levees. It is understood, that in their present state, most pump stations would not have been able to stay in operation during

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Katrina. However, this scenario was simulated to provide an upper limit on what could have been the best possible scenario had no failures occurred.

Hypothetical 3 – Resilient Floodwalls

Simulate what would have happened during Hurricane Katrina had all floodwalls, which failed from foundation failures, remained intact. All other areas are modeled as they actually functioned. Pump stations operate as they did in the Katrina event. Pre-Katrina elevations are used for top of floodwalls and levees. The result of this scenario for New Orleans East is that the inundation matches the Katrina simulation.

Table 3-1 lists the simulation scenarios in a matrix format.

Table 3-1
Katrina Simulations

Conditions	Simulation			
	Katrina	**Hypothetical 1**	**Hypothetical 2**	**Hypothetical 3**
Pumps operate as during Katrina	X	X		X
Pumps operate throughout Katrina			X	
Levee and floodwall breaches occur everywhere as during Katrina	X			
Levee and floodwall breaches occur on West wall of IHNC and in, St Bernard, New Orleans East and Plaquemines as during Katrina				X
Levee and floodwalls overtop but do not breach		X	X	
No failures on 17th Street and London Ave				X
Levee and floodwall elevations based on pre-Katrina elevations	X	X	X	X

Review of Existing Data

The model used for the IPET analysis of the New Orleans East area was developed by combining and modifying three HEC-RAS models that were developed as part of the Orleans Parish Digital Flood Insurance Rate Maps (DFIRM) Study, which was completed in 2005. The three areas that were modeled were called Area I, Area J, and Area K. A hydrologic model developed in HEC-HMS and a hydraulic model developed in HEC-RAS was used to analyze each of these areas separately for the Orleans Parish DFIRM study. The areas modeled are shown in Figure 3-1 and detail for Areas I, J and K are shown in Figures 3-2 to 3-4.

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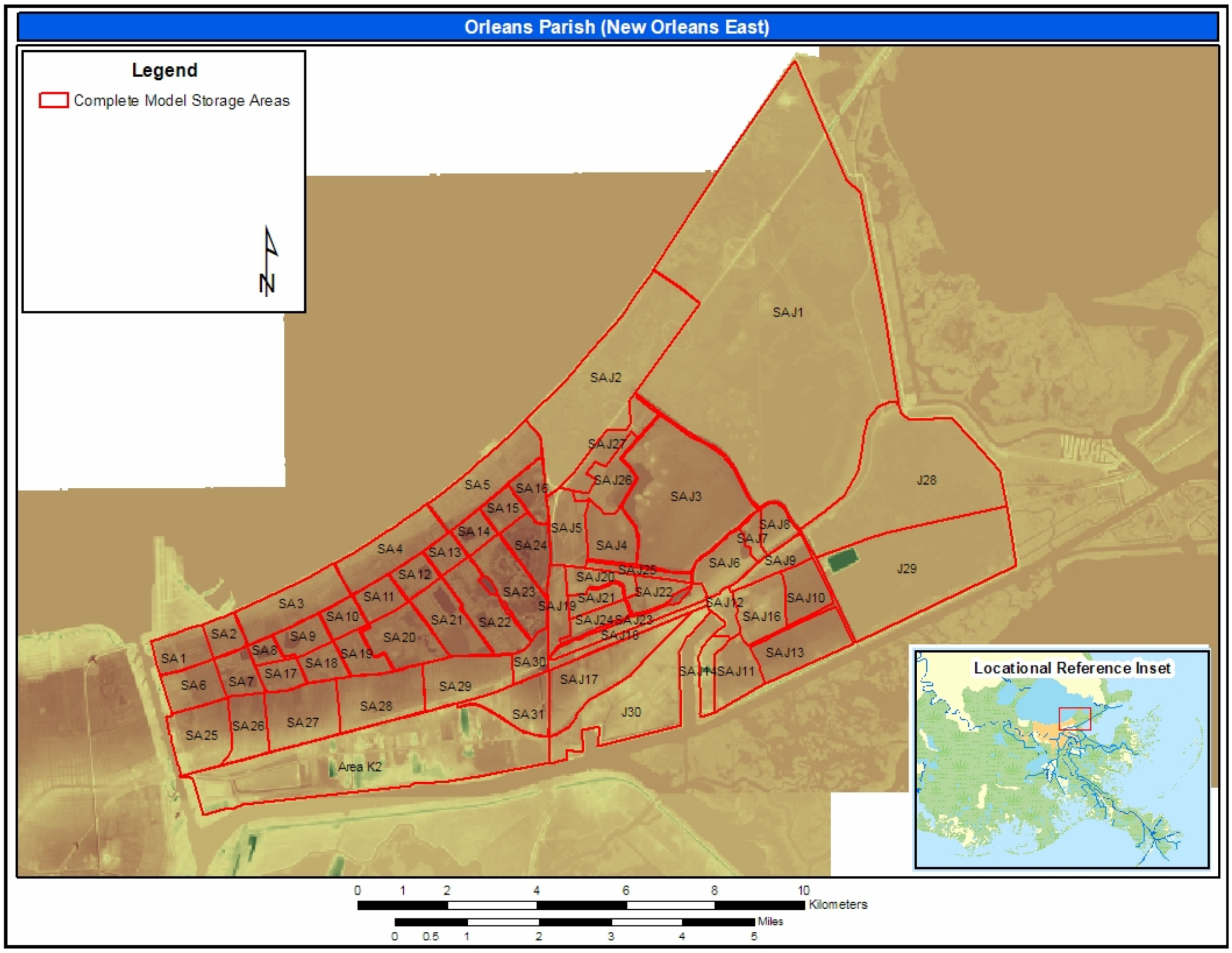

Figure 3-1. New Orleans East Study Area

General Modeling Approach

The hydrologic models developed for the three areas represented the rainfall runoff characteristics of the land. The HMS model produced flow hydrographs for each of the sub basins in the entire area. HEC-RAS was used to represent the characteristics of the drainage canals and the topography of the modeled areas. Flow hydrographs from HEC-HMS were entered into the hydraulic model along with hurricane surge (ADCIRC Model Results) and levee breach information in order to calculate water surfaces for the entire study area.

Hydrologic Model Development

Background

New Orleans East is comprised of three major study areas that are hydrologically separated by highway and railroad embankments. The three areas are called Area I, area J, and Area K. This naming convention of these areas was developed during the FEMA DFIRM Study.

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The Area I (Citrus) Watershed

Area I, shown in Figure 3-2, is an incorporated area in the Parish of Orleans and lies in the northeastern part of Orleans parish. It is bounded by the Inner Harbor Navigation Canal on the west, Interstate 510 on the east, Lake Pontchartrain on the north and Chef Menteur Highway on the south. The study area is approximately 13.9 square miles with mainly concrete lined drainage channels. The study area has many portions that act as sump areas. The elevations of these storage areas are sometimes lower than that of the channel banks. The watershed was divided into 31 sub basins, which were determined by the forced drainage network, topography, roadways and railroads.

The Area J Watershed

The Area J watershed, shown in Figure 3-3, is approximately 33 mi^2 and is bounded by the New Orleans East Lakefront levee on the north, the New Orleans East Southpoint Gulf Intercoastal Waterway (G.I.W.W) levee on the east side, the New Orleans East back levee, the Michoud Canal Floodwall and the Citrus Back Levee/N.A.S.A. – N.O.P.S.I, on the south side and the Paris Road levee on a portion of the west side. There is also a levee on the east bank of Maxent Canal. The watershed is also protected from tidal flooding occurring from hurricanes and tropical storms by a hurricane protection levee, which was constructed as part of the Lake Pontchartrain and Vicinity Hurricane Protection project maintained by the U.S. Corps of Engineers. The watershed was divided into 30 sub basins, which were determined by the forced drainage network, topography, roadways and railroads.

The shallow flooding problems experienced by Area J are due to both extremely low-lying areas, which have subsided after the study area was surrounded by levees, and inadequate subsurface drainage. A small portion of the Area J watershed is comprised of the Six Flags Theme Park, and residential and commercial buildings while the majority of the watershed is comprised of marsh and the Bayou Savage National Wildlife Refuge. The refuge is primarily comprised of fresh and brackish marsh and open water and is connected to the remaining portion of the study area by a siphon entering from the north through Maxent Canal and a flap gate entering from the east of the study area through a sluice gate on Bayou Sauvage. The area west of the Bayou Savage National Wildlife Refuge contains all development located in the study area and is under forced drainage through a series of subsurface culverts, open water canals and lakes and Drainage Pump Stations. The New Orleans Sewerage and Water Board maintains two Drainage Pump Stations in the forced drainage system. Drainage Pump Station No. 15 has a rated pump capacity of 750 cfs. and is located on Maxent Canal at the Intercoastal Waterway and Drainage Pump Station No. 18 has a rated pump capacity of 150 cfs. and is located on Maxent Canal east of the Village de L'est subdivision. Ultimately, all water is pumped through the forced drainage system into the Intercoastal Waterway.

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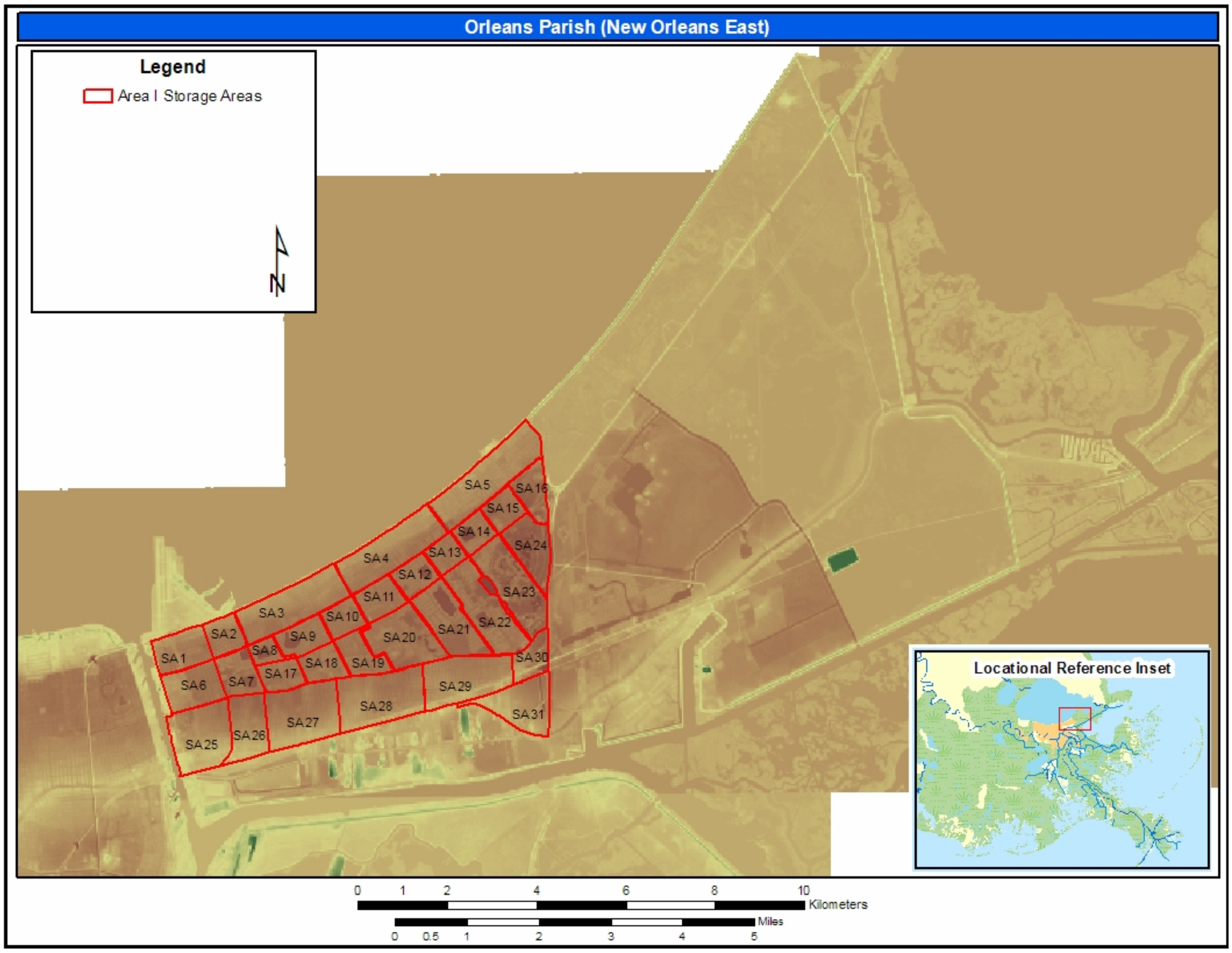

Figure 3-2. New Orleans East Study Area I

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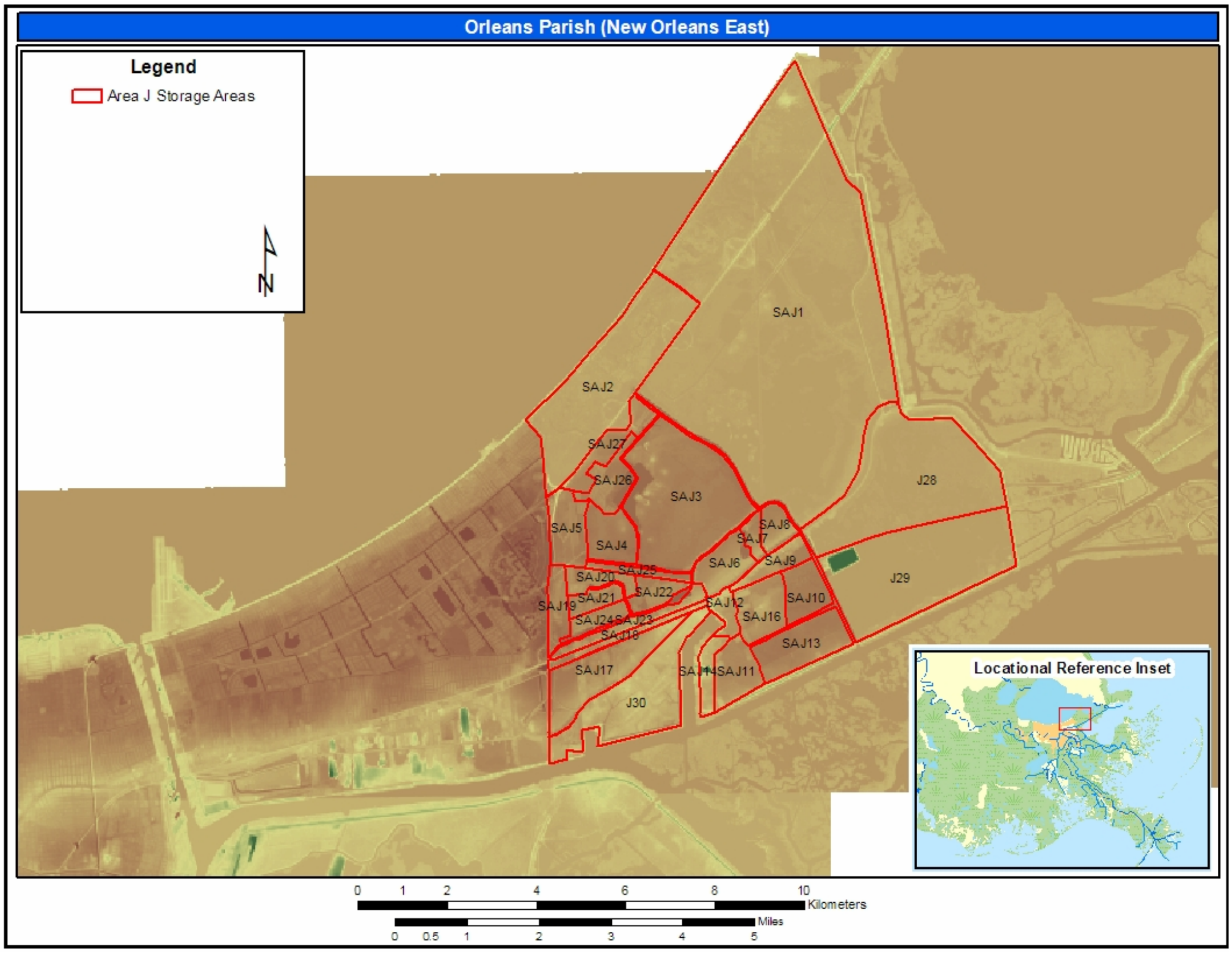

Figure 3-3. New Orleans East Study Area J

Area K Watershed

The Area K Watershed encompasses an area of approximately 3.9 square miles. This basin is bounded on the south by the New Orleans and Vicinity Hurricane Protection Levee (NOVHPL) along the Mississippi River Gulf Outlet, on the east by Interstate Highway 510, on the west by the NOVHPL along the Inner Harbor Navigation Canal (IHNC), and on the north by the CSX Railroad and Old Gentilly Road. The western part of the watershed contains the former MacFrugal's warehouse and the Auto Auction of New Orleans storage yard. The eastern portion of the watershed is largely undeveloped with patches of paved areas.

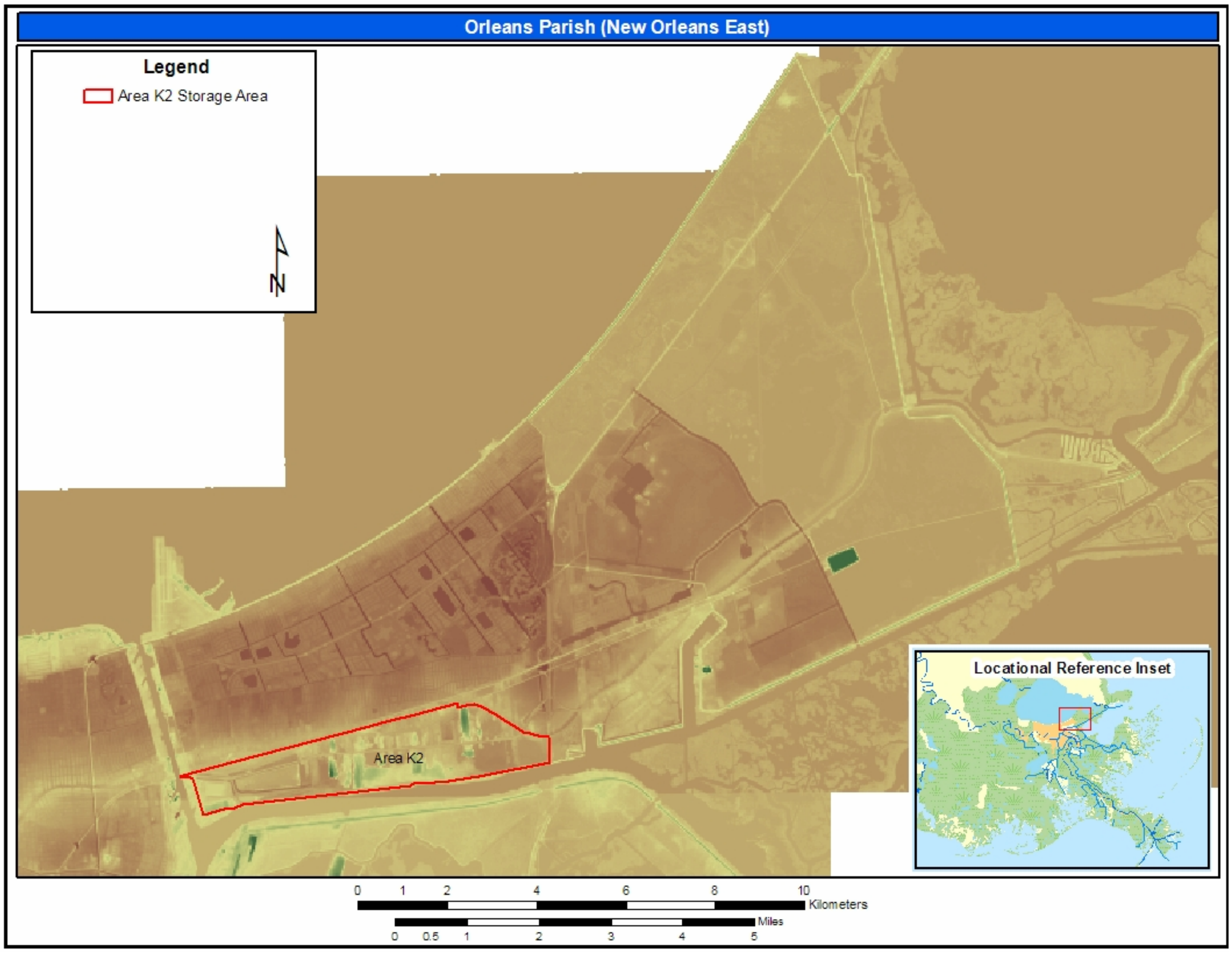

Figure 3-4. New Orleans East Study Area K

Development of GIS Watershed Model

Sub basin boundaries were developed from a combination of data sources for the entire New Orleans East study area. The LIDAR data for each storage area was useful where there was a great elevation difference in the terrain. In order to visually aid the basin delineation, a color-coded LIDAR map was developed. The definition of the storage area boundaries were mostly determined from USGS quadrangle maps and aerial photography in conjunction with the drainage maps of the area.

Model Parameters

Soils in the primarily marshy areas of the Bayou Sauvage National Wildlife Refuge are primarily Clovelly muck and Lafitte muck. These soils are very poorly drained, slightly saline and organic. They are classified in hydrologic soil group D. Soils in the areas west of the refuge are comprised of Kenner, Lafitte, Clovelly, Kenner, and Allemandes muck, Sharkey silty clay loam, Harahan clay, and Aquents dredged. All are very poorly drained soils in hydrologic soil group D. These soils types are typically seen in marsh areas.

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Most of the Area J watershed is comprised of freshwater and brackish marsh. Any commercial and industrial areas are located near the Michoud slip. Six Flags Theme Park and a few commercial and industrial businesses are located in the western portion of Area J. The majority of developed areas are located in Area I, which consist mostly of single and multi family residences. There are also commercial businesses along with some industrial use. There is a golf course in the eastern edge of Area I, with open spaces and wooded areas. The heaviest industrial use lands are located South of Chef Menteur Highway in Area K. Area K is primarily undeveloped interspersed with light industrial and landfill uses. There is one small cemetery in the basin as well. The light industrial uses consist largely of marshalling yards for tractor-trailers and containers and auto salvage yards. These areas are either paved or have been covered with shell increasing the runoff. Many of these light industrial areas have been filled as well. Remaining undeveloped areas appear to be wetland areas that function as storage areas during rainfall events.

Two approaches were taken to determine the hydrographs for each sub basin. Some sub basins are extremely low lying, offering little change in slope and large areas available for the storage of water. Modeling these areas utilizing most traditional hydrologic engineering methods could be inaccurate due to the fact that most methods don’t compensate for such small slopes and such large areas available for storage. Each of these sub basins’ corresponding rainfall was converted from inches per hour to cubic feet per second by converting the rainfall hyetographs in a spreadsheet. This will result in a total flow hydrograph (no lag time) for the entire sub basin. This approach differs from the synthetic unit hydrograph approach where outflow hydrographs include a lag time. Sub basins with fewer storage areas and larger slopes such as Area I, were modeled in HEC-HMS utilizing the Soil Conservation Service (SCS) unit hydrograph procedure. The SCS method can be used for urban areas that are less than 2000 acres or 3.1 mi2. Time of concentration was computed through SCS equations, which include the slope of the sub basin, the length of travel and the SCS curve number. The SCS curve number is related to soil type, land use and antecedent moisture conditions. Runoff curve numbers between 85 and 94 were used for watersheds depending on the land use. These curve numbers fell under antecedent moisture condition II. Initial losses were left blank and computed by HEC-HMS. When the SCS loss rate method is used in HMS, 20% of the maximum retention is taken to be the initial abstraction or “initial loss in inches”. The percent impervious was based on a visual inspection of Digital Ortho Quarter Quads along with USGS quadrangle maps.

Losses for Area K were taken from the previous Flood Insurance Study completed in 1984. The loss rates used in that study were 0.1 inches per hour for the first hour of the event, and 0.05 inches per hour for each hour thereafter. These loss rates were verified to previous events. Since development in the basin has been moderate, these rates should still be reasonable assumptions and yield a slightly conservative result. The percent impervious cover is already included in the curve number value in Table 3-2. More information about the background and use in the SCS curve number method can be found in Soil Conservation Service (1971, 1986).

Table 3-2
Curve Numbers

	Land Use	A	B	C	D
1	Fresh Marsh	39	61	74	80
	Intermediate Marsh	39	61	74	80
3	Brackish Marsh	39	61	74	80
4	Saline Marsh	39	61	74	80
5	Wetland Forest-Deciduous	43	65	76	82
6	Wetland Forest- Evergreen	49	69	79	84
7	Wetland Forest- Mixed	39	61	74	80
8	Upland Forest- Deciduous	32	58	72	79
9	Upland Forest- Evergreen	43	65	76	82
10	Upland Forest- Mixed	39	61	74	80
11	Dense Pine Thicket	32	58	72	79
12	Wetland Scrub/shrub - deciduous	30	48	65	73
13	Wetland Scrub/Shrub - evergreen	35	56	70	77
14	Wetland Scrub/Shrub - Mixed	30	55	68	75
15	Upland Scrub/Shrub - Deciduous	30	48	65	73
16	Upland Scrub/Shrub - Evergreen	35	56	70	77
17	Upland Scrub/Shrub - Mixed	30	55	68	75
18	Agriculture-Cropland-Grassland	49	69	79	84
19	Vegetated Urban	49	69	79	84
20	Non-Vegetated Urban	71	80	87	91
21	Upland Barren	77	86	91	94
22	Wetland Barren	68	79	86	89
23	Wetland Complex	85	85	85	85
24	Water	100	100	100	100

Rainfall

Radar rainfall data, referred to as Multisensor Precipitation Estimator (MPE), was used as a boundary condition in the hydrologic models to determine runoff hydrographs produced by the Hurricane Katrina event. MPE data from the Lower Mississippi River Forecast Center (LMRFC) was downloaded from: *http://dipper.nws.noaa.gov/hdsb/data/nexrad/lmrfc_mpe.php*.

Raw radar data is adjusted using rain gage measurements and possibly satellite data to produce the MPE product. Figure 3-5 shows the amount of precipitation estimated by the MPE product from August 29, 0600 – 0700.

The radar rainfall data was imported into a GIS where a precipitation hyetograph was computed for each subbasin in the different basin models. The individual hyetographs were imported into a DSS file where they were read by HEC-HMS.

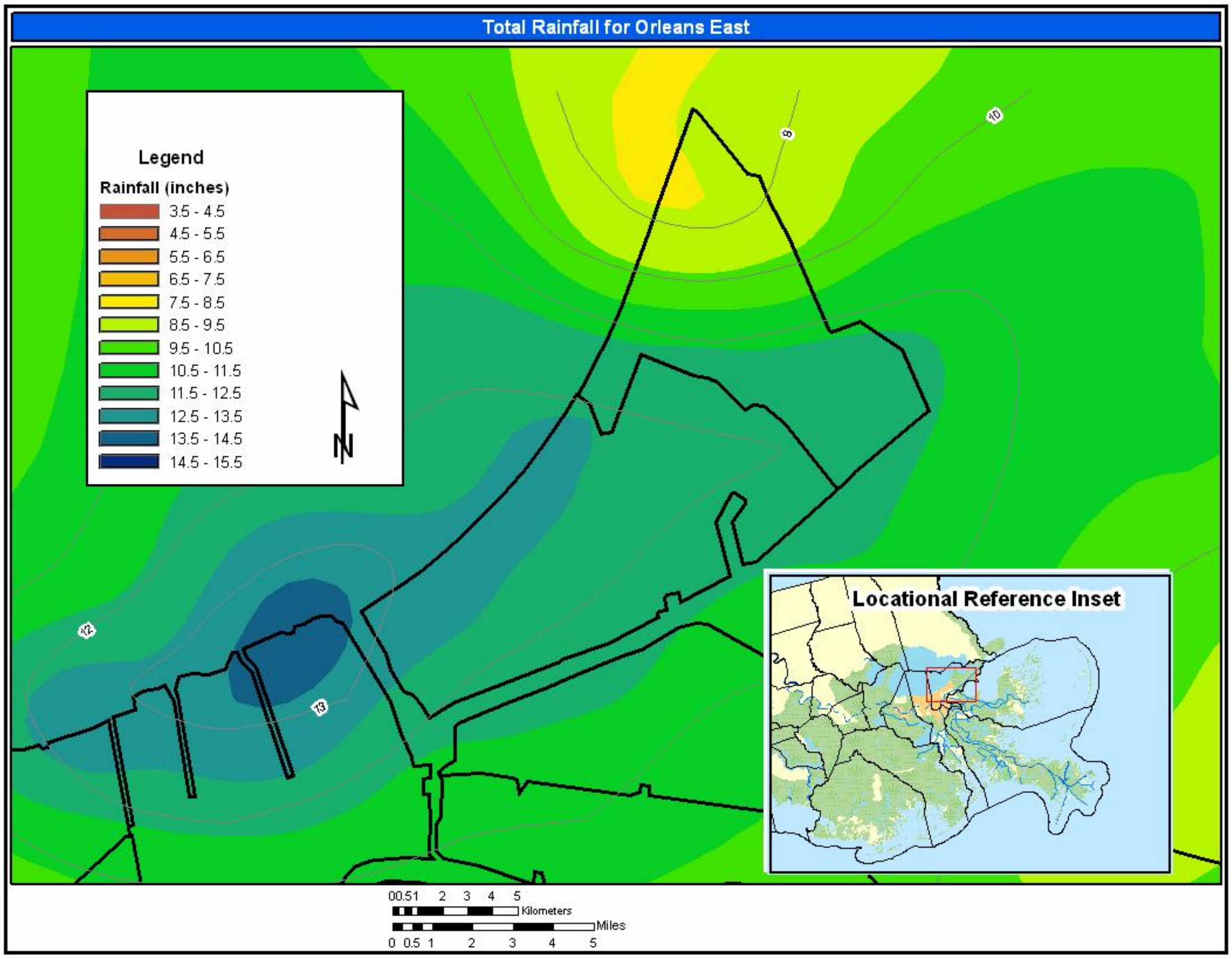

Figure 3-5. Total Rainfall for Hurricane Katrina in New Orleans East

Model Results

Summary output from the HEC-HMS model is available in Tables 3-3 to 3-5. A complete runoff hydrograph was also computed by the program. This information was stored in an HEC-DSS file and provided as a boundary condition for the HEC-RAS model of the New Orleans East basin.

Model Results

Table 3-3
Summary of Hydrologic Analysis Results for Area J

Subbasin Name	Drainage Area (mi2)	Peak Discharge (cfs)	Time of Peak	Runoff Volume (in)
Subbasin-1	5.2	4083	29Aug2005, 08:39	9.3
Subbasin-10	0.1	56	29Aug2005, 12:29	9.4
Subbasin-11	0.08	43	29Aug2005, 12:53	9.8
Subbasin-12	0.09	57	29Aug2005, 11:35	9.5
Subbasin-13	0.12	62	29Aug2005, 13:13	9.7
Subbasin-14	0.12	69	29Aug2005, 12:36	11.2
Subbasin-15	0.05	31	29Aug2005, 12:01	10.0
Subbasin-16	0.07	34	29Aug2005, 13:34	9.7
Subbasin-17	0.07	42	29Aug2005, 11:49	10.5
Subbasin-18	0.12	69	29Aug2005, 12:42	11.4
Subbasin-19	0.21	106	29Aug2005, 13:19	10.0
Subbasin-2	1.01	939	29Aug2005, 08:46	11.4
Subbasin-20	0.16	100	29Aug2005, 11:54	11.0
Subbasin-21	0.28	168	29Aug2005, 12:22	11.5
Subbasin-22	0.2	131	29Aug2005, 11:40	11.5
Subbasin-23	0.08	53	29Aug2005, 11:33	11.4
Subbasin-24	0.09	63	29Aug2005, 11:06	11.5
Subbasin-25	0.12	79	29Aug2005, 11:27	10.7
Subbasin-26	0.08	63	29Aug2005, 11:26	11.6
Subbasin-27	1.24	660	29Aug2005, 14:33	11.0
Subbasin-28	1.08	1306	29Aug2005, 09:27	12.5
Subbasin-29	0.36	420	29Aug2005, 09:28	12.2
Subbasin-3	0.16	154	29Aug2005, 09:05	10.4
Subbasin-30	0.59	301	29Aug2005, 12:54	10.1
Subbasin-4	0.17	93	29Aug2005, 13:02	11.0
Subbasin-5	0.97	473	29Aug2005, 14:15	10.8
Subbasin-6	0.19	96	29Aug2005, 13:47	10.3
Subbasin-7	0.19	186	29Aug2005, 10:02	10.8
Subbasin-8	0.06	57	29Aug2005, 10:28	11.0
Subbasin-9	0.1	65	29Aug2005, 12:04	11.2

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Table 3-4
Summary of Hydrologic Analysis Results for Area I

Subbasin Name	Drainage Area (mi2)	Peak Discharge (cfs)	Time of Peak	Runoff Volume (in)
Subbasin-1	0.492	447	29Aug2005, 09:50	13.1
Subbasin-10	0.226	233	29Aug2005, 09:05	12.2
Subbasin-11	0.279	278	29Aug2005, 09:15	12.5
Subbasin-12	0.241	240	29Aug2005, 09:20	12.5
Subbasin-13	0.192	189	29Aug2005, 09:25	12.5
Subbasin-14	0.217	217	29Aug2005, 09:15	12.5
Subbasin-15	0.227	226	29Aug2005, 09:20	12.5
Subbasin-16	0.287	261	29Aug2005, 09:20	10.4
Subbasin-17	0.234	243	29Aug2005, 09:05	13.1
Subbasin-18	0.261	241	29Aug2005, 09:50	12.3
Subbasin-19	0.281	279	29Aug2005, 09:20	11.9
Subbasin-2	0.243	240	29Aug2005, 09:25	13.1
Subbasin-20	0.644	609	29Aug2005, 09:40	12.0
Subbasin-21	0.587	531	29Aug2005, 10:00	12.4
Subbasin-22	0.68	574	29Aug2005, 10:25	12.4
Subbasin-23	0.691	483	29Aug2005, 11:15	10.9
Subbasin-24	0.434	382	29Aug2005, 09:05	10.8
Subbasin-25	0.606	589	29Aug2005, 09:20	12.6
Subbasin-26	0.452	452	29Aug2005, 09:20	13.1
Subbasin-27	0.798	730	29Aug2005, 09:50	12.6
Subbasin-28	0.838	761	29Aug2005, 09:55	11.9
Subbasin-29	0.728	624	29Aug2005, 10:05	11.8
Subbasin-3	0.786	759	29Aug2005, 09:30	12.5
Subbasin-30	0.249	173	29Aug2005, 10:10	9.7
Subbasin-31	0.366	200	29Aug2005, 11:45	9.5
Subbasin-4	0.783	761	29Aug2005, 09:30	12.5
Subbasin-5	0.874	858	29Aug2005, 09:35	12.4
Subbasin-6	0.443	439	29Aug2005, 09:25	13.1
Subbasin-7	0.313	299	29Aug2005, 09:35	13.1
Subbasin-8	0.136	119	29Aug2005, 10:05	13.1
Subbasin-9	0.492	447	29Aug2005, 09:50	13.1

Table 3-5
Summary of Hydrologic Analysis Results for Area K

Subbasin Name	Drainage Area (mi2)	Peak Discharge (cfs)	Time of Peak	Runoff Volume (in)
Subbasin-1	4.0998	3370	29Aug2005, 09:50	10.3

RAS Interior Modeling

Background

The HEC-RAS Model for New Orleans East was developed by combining and modifying the three separate HEC-RAS models developed for Area I, Area J, and Area K. These models consisted of geometry and flow models for all three areas. The models were merged to produce one geometry model for the entire area of New Orleans East.

Many additions were made to this combined model to capture significant wave overtopping and to incorporate storm surge boundary conditions obtained from the ADCIRC model. All areas in the area are subject to ponding of runoff and shallow flooding due to inadequate subsurface drainage and the sheet flow associated with overland travel of excess water that cannot enter the subsurface system. This excess water collects in depressions and may remain trapped between roadways for hours or even days before finally being carried away by the drainage system.

The drainage system for Orleans Parish consists of many features that are typical of large urban cities in the United States, and some features that are unique because much of the area is below sea level. As in any urbanized area, catch basins and drop-inlets receive surface runoff from yards and streets, and excess runoff runs down slope in the streets and/or overland to areas of lower elevation. Runoff that can enter drop-inlets proceeds underground in small pipes, 21 inches or less in diameter, called the tertiary system. The tertiary system collects local flows and conveys to the secondary system, 21 inches to 30 inches in diameter, where several of these local flows combine. Generally pipes or box culverts that are larger than 30 inches in diameter are considered to be part of the secondary system. The primary drainage system is almost entirely composed of man-made prismatic trapezoidal open channels. The open channels and pump stations were modeled in the HEC-RAS Unsteady model.

The hydrographs used for the internal boundary conditions were computed with the HEC-HMS program as described in the Hydrologic Analysis section of this report. The hydrographs were entered into the HEC-RAS model as lateral inflows to the Storage Areas. The excess water flowed from the storage areas through lateral weirs and culverts into the canals. Additionally, storage areas were interconnected with weirs, culverts, and linear routing where appropriate. In general, storage area connections were modeled with weirs when there was a high ground feature between two storage areas (such as an elevated railroad or highway). Culverts were used in conjunction with weirs when they existed below roadways and the railroad tracks. Weirs were also used to model the connection between storage areas where there are interior levees. The HEC-RAS linear routing option was used between storage areas in locations where water would mostly travel overland from one storage area to another, and there was not a significantly high embankment between the storage areas.

Datum Reconciliation

Various sources of data were used to construct the model. The Area I model was constructed using "as-built" drawings supplied to the U.S. Army Corps of Engineers New Orleans District by the New Orleans Sewage and Water Board (NOSWB) as "in-kind" services for the FEMA Map

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Modernization project. These drawing were in Cairo Datum. The model was converted to NAVD88 1996 EPOCH. The Area J model was originally constructed by the U.S. Army Corps of Engineers New Orleans District as a part of the FEMA Map Modernization project. Surveys were used to construct the model and were in NAVD88 1996 EPOCH . No conversion was necessary. The Area K2 model is a storage area which the elevation-volume curve was made using Light Detection and Ranging (LiDAR) surveys performed of South Louisiana for the Federal Emergency Management Agency in 2004. The results of the HEC-RAS model, therefore, are in NAVD88 1996 EPOCH.

Terrain Model

The primary source of topographic data in the terrain model for RAS was Light Detection and Ranging (LiDAR) surveys performed of South Louisiana for the Federal Emergency Management Agency in 2001. The datum of the LiDAR is NAVD88 1994, 1996 epoch. The vertical accuracy for this data is +/- 0.7 feet. The horizontal projection is Louisiana State Plane South 1983 feet. The basin boundaries for the HMS models are in the same projection. The data collected during these LIDAR surveys were processed using Geographic Information System (GIS) technology to develop other information needed for the modeling of this basin. Additional information from visits to the site was used to supplement data obtained from the LIDAR surveys

Basic Geometric Data using GIS

Stage-area relationships were developed from the LiDAR data for each storage area where excess runoff would accumulate to simulate the storage capability. The LiDAR data set was used to set the heights of the drainage divides, such as levees, roads, and railroad grades, for the RAS model. It was also used in determining the heights of the lateral weirs that connect the storage areas to the drainage canals or reaches. As described above, data was obtained from various sources. Levee profiles in RAS were constructed using LiDAR data flown for the New Orleans and vicinity levees after Hurricane Katrina. Breach location, size, and depth were from this same data set and from the field investigation from the Levee and Floodwall Performance team. The compilation of data sets, as described above, were used as a basis to put the model together. Cross sections were taken from the individual models.

The models were not originally georeferenced. HEC-RAS was modified by engineers at the Hydrologic Engineering Center to employ common georeferencing tools. The new tools enabled movement of the cross section within RAS. By putting an image behind the model, identifiable features i.e., bridges, culverts, structures, were used to move the cross sections spatially to align with the image in turn geo-referencing the model. This was done on a reach by reach basis. After the reaches were georeferenced, the storage areas were imported from the Geo-RAS import file and automatically placed spatially correct. Geo-referencing the model was necessary so inundation maps could be generated.

Manning’s n-Values

HEC-RAS uses Manning's equation to compute friction forces, which are then used in the unsteady flow equations in performing unsteady flow simulations. Therefore, Manning's roughness coefficients, commonly called Manning's n values have to be assigned to each channel, bridge and culvert. Coefficients used in the model were taken from the HEC-RAS documentation and are applied to a particular channel type independent of size. The Manning’s numbers that were used for this area were similar to the Manning’s numbers used on other nearby unsteady flow models. For an earthen channel, typical values of 0.03 to 0.04 were used for the main channel with 0.05 for the overbanks. For a concrete lined channel 0.015 was used for all channel concrete surfaces with 0.05 for the overbanks. The Manning’s n values were modified where the condition of the channel dictated the use of different numbers, such as the earthen segment of Dwyer Canal and upstream portions of Charbonnet Canal. Higher Manning’s n-values are used in these locations because of the poor maintenance conditions of these canals. In some instances there canals were so overgrown with brush, that small to medium size trees were growing there.

Bridges

Bridges and box culverts were analyzed as part of the HEC-RAS model. HEC-RAS computes flow through the bridge or culvert using the Bernoulli or Energy Equation. Entrance and exit losses are also computed using coefficients input for each structure. Bridge losses were determined in two ways: (1) analytical analysis based on direct observation and (2) the application of the HEC-RAS model to duplicate observations.

Hydraulic losses in large concrete box culverts and arch pipes were computed using entrance and exit loss coefficients recommended in the HEC-RAS Reference Manual. These were 0.3 to 0.5 and 0.5 to 1.0 respectively, depending on what local conditions require.

Ineffective Flow Areas

Ineffective flow areas were set for the I-10 box culverts in Gannon Canal and Berg Canal to simulate the slack water found in the contraction and expansion area upstream and downstream of the structure. Many of the structures in this model are almost as wide as the canals; therefore no ineffective flow areas were placed on the cross sections outside of these structures.

Storage Areas

Initial conditions data of the storage areas were initially based on what was used for the Orleans Parish DFIRM Study. As changes were made to the storage areas, it was determined to set the initial water surfaces in the storage areas to approximately one foot above its invert elevation. Storage areas in the New Orleans East area were used as imported from the existing RAS model. Their elevation-capacity relations were updated using the current terrain model. The storage areas were further defined based upon locations of pumping stations. The elevation-

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volume relationships for all of the storage areas were extracted from the GIS using GeoRAS. As mentioned previously, storage areas were hydraulically connected to the channels by using lateral weirs. Storage areas were interconnected to each other with either a weir, weir and culverts, or using the HEC-RAS linear routing option.

Inline Structures

Inline structures were used in Farrar Canal to represent the structures built to regulate the water level in the lagoon at Joe Brown Park. These structures are located at each end of the lagoon, one upstream and one downstream. The inline weirs in HEC-RAS most accurately represent the operation of these structures.

Lateral Structures and Storage Area Connections

For the weirs connecting storage areas to the canals, weir coefficients of around 1.0 were used. These values are lower than one might think of for a traditional lateral weir that is designed to remove flow from a stream to an over bank area. However, lateral weirs, as used in this model, are to allow water in a storage area to flow overland and get into the canals. This is not a typical physical weir situation, and therefore using traditional weir coefficients would transfer the water too quickly from the storage area to the canal. It has been found through experience, and model calibration with other models, that values around 1.0 seem to provide the appropriate transfer of flow between the canals and the storage areas. Also, for the events modeled, the canals fill up very quickly, and the water surface elevation in the canal generally matches the elevation in the storage area as it rises and falls. The lateral weirs end up being submerged and only passing their necessary flows to fill the small canals to the elevations in the storage areas.

Weir coefficients for storage area connections that represent high ground between storage areas were set at more traditional values around 2.6 to 3.0, depending on the shape of the overflow area. In a few areas these coefficients were lowered for calibration purposes. Model calibration is discussed further later in this appendix.

Linear routing coefficients were set to values ranging from 0.1 to 0.2 for the storage area connections in which linear routing was used. The linear routing equation is as follows:

$$Q = K\left(\Delta S\right) / \text{Hour}$$

where:

Q = Flow

K = Linear Routing Coefficient (Varies from 0.0 to 1.0)

ΔS = Available Storage (Difference in head times the surface area of receiving storage area)

Because equation computes a rate per hour the magnitude is divided by the time step to get flow per time step. User must also enter a minimum elevation for flow to pass between storage areas. If both storage areas are below this elevation no flow is exchanged. If one storage area has a stage greater than the minimum elevation, the head difference is the elevation of the storage area minus the user entered minimum elevation for passing flow.

Levees

Primary levee locations were selected from the EDRC shape file. Another file contained levee footprints that showed locations of the back levees, but not their elevations. The levee elevations in the RAS model are, consequently, a combination of the lidar elevations for the primary levees and general elevation information gleaned from the LSU terrain files for the back levee elevations. Because the levees are such a key piece of information to the results of this model, one recommendation for model improvement would be to have a detailed top of levee profile survey performed for all exterior and interior levees.

Pump Stations

The New Orleans Sewerage and Water Board operates two major drainage-pumping stations in Area J. Additional data on pump stations can be found in Appendix VII. These are listed in Table 3-6. The first, and smaller of the two, is the Maxent Pumping Station. This is located on Bayou Michoud just downstream of the Alcee Fortier Boulevard Bridge. The Maxent Pumping Station is a 150 cfs pumping station consisting of 2 pumps of 75 cfs each. These pump stations are operated automatically based upon stages in the inlet basin.

The second, and larger, of the two pump stations in Area J is Drainage Pumping Station Number 15 (DPS 15). This pumping station pumps water from the Maxent Canal into the Mississippi River Gulf Outlet. DPS 15 consists of 3-250 cfs pumps for a total pumping station capacity of 750 cfs. This station is automated, but Sewerage and Water Board Staff is deployed to the station during heavy rain events to monitor its operation.

Table 3-6
Area J Pump Station On/Off Water Surface Elevations

	Maxent WSEL		**No. 15 WSEL**	
	On	**Off**	**On**	**Off**
Pump 1	-7.4	-8.1	-7.2	-8.0
Pump 2	-7.2	-7.9	-6.9	-7.7
Pump 3			-6.6	-7.4

The Sewerage and Water Board operate 4 pumping stations in area I that provide the drainage service for the basin. They are listed in Table 3-7. These are the Dwyer Road Pump Station, St. Charles Pump Station (No. 16), Citrus Pump Station (No. 10), and Jahncke Pump Station (No. 14). There is no significant suction basin storage available for the Drainage Pumping Stations (DPS) because of the urban setting in which they operate. All of the pump

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stations discharge directly to tide water. These stations are manned 24 hours around the clock and the Central Control Office has full knowledge of the status of each pump in the entire system at any given moment. The pumps are started in sequence, once sufficient water has arrived at the station to justify operating another pump. These pump operating criteria were based on the pump station reports during the hurricane.

Table 3-7
Area I Pump Station On/Off Water Surface Elevations

	Dwyer Road WSEL		Citrus WSEL		St. Charles WSEL		Jahncke WSEL	
	On	Off	On	Off	On	Off	On	Off
pump 1	-7.0	-8.0	-11.4	-11.9	-11.9	-12.9	-11.9	-13.4
pump 2			-11.2	-11.7	-11.7	-12.7	-11.7	-13.2
pump 3			-11.0	-11.5	-11.2	-12.5	-11.5	-13.0
pump 4			-10.8	-11.3	-10.7	-12.3	-11.3	-12.8

The New Orleans Sewerage and Water Board operates three major drainage-pumping stations in Area K. They are listed in Table 3-8. Each of these pumping stations are assumed to operate at 75% capacity during all events to account for station inefficiencies such as trash needing removal from trash screens as well as power outages. The first is Drainage Pumping Station Number 20, also known as the Almonaster-Michoud or AMID Pumping Station, which drains Area K1. The Amid Pump Station is located on a drainage canal just west of the CSX Railroad spur south of Chef Menteur Highway. Maximum capacity of the AMID pump station is 500 cfs.

A second pump station is located at the end of Grant Street south of Chef Menteur Highway near the Mississippi River Gulf Outlet (MRGO). This is a 182 cfs capacity pump station draining Area K2, and was assumed to consist of 4-48 cfs pumps (information was supplied on 2 - 48 cfs pumps by the Sewerage and Water Board). The final pump station draining Area K is the Elaine Street Pump Station, which has a 90 cfs capacity. This is the second pump station which helps drain sub area K2. As the name implies this pumping station is located south of Chef Menteur Highway near the MRGO on Elaine Street. No information on this station was available other than it includes 2-45 cfs pumps. Operating criteria for this pump were assumed to be similar to those for the Grant Street Pumping station since they drain the same area and are connected to the same canal network.

Table 3-8
Area K Pump Station On/Off Water Surface Elevations

	AMID WSEL		Grant St. WSEL		Elaine St. WSEL	
	On	Off	On	Off	On	Off
Pump 1	-3.4	-5.6	-2.9	-5.4	-4.9	-5.9
Pump 2	-4.4	-6.4	-2.4	-3.4	-4.5	-5.5
Pump 3			-4.9	-6.0	-4.9	-5.9
Pump 4					-4.8	-5.8
Pump 5					-4.7	-5.7

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Actual hour-to-hour pump station operations were modeled in HEC RAS using advanced control rules to overrides the allowable pump capacity based on the pump efficiency curves. The advanced control rules were developed to best represent the pump station operation report logs for the time covering hurricane Katrina for each pump station in the study area. The major factor effecting the operation of the pump stations during the event was the lost of power to the stations, due to area wide power failures or flooding of the electrical systems and back-up generators, all of which made the pump stations inoperable.

Flow Data and Boundary Conditions

The rainfall-runoff hydrographs developed by the HMS model were applied to the appropriate storage area as inflow hydrographs. The upstream boundary condition for the internal drainage canals was a minimal flow condition that was considered the base flow condition. That flow was determined by running the model with the minimum flow that was possible to run. The pump stations act as internal boundary conditions. The upstream and downstream boundary conditions for the external reaches were based on the hydrographs produced by the ADCIRC program representing the stages for Katrina. These were modified where there were additional data in the form of surveyed high water marks. The ADCIRC modeling results were entered as stage hydrograph boundary conditions in HEC-RAS. The external reaches containing the ADCIRC modeling results were connected to the interior storage areas via lateral weirs (called lateral structures in HEC-RAS). The lateral structures were input as the station and elevations along the tops of the exterior levees. These lateral structures were used to model levee overtopping and levee breaches that occurred during the Hurricane Katrina event.

Levee Overtopping and Breaching

Levee overtopping is significant in this area. Its occurrence and impacts depend primarily on the levee crest elevations and storm surge heights. The exterior levees suffered extensive damage from breaching and overtopping during the storm. In the RAS model this was represented by 8 different breaches along the, GIWW, MRGO, and one small breach along Lake Pontchartrain. Exterior stages were high enough to overflow the levees and floodwalls at several locations, especially the levees on the south side of New Orleans East (along the GIWW and MRGO), as well as along the IHNC.

The levee and floodwall system of the entire New Orleans area experienced over 8,500 linear feet of breaches. This does not include the all the areas where levee overtopping occurred. The largest of the breaches occurred in the southeast corner of Area J on the GIWW. In this area there were four major levee/floodwall breaches, which grow in size as you move east. The largest breach occurred approximately in the location of where the eastern hurricane protection levee meets the north GIWW levee. Here, the original levee height was about 12.0 feet NAVD88 (1994, 1996). The breach here was 5000 feet long and had a final bottom elevation of 10.0 feet NAVD88 (1994, 1996). Although the depth of the breach was only 2 feet, with a length of 5000 feet, the amount of water entering the system here was tremendous. The next breach occurred very near the first breach. Here the original levee height about 12.0 feet NAVD88

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(1994, 1996). This breach was 1200 feet long and had a final depth of 9.5 feet NAVD88 (1994, 1996). The final two breaches occurring on this levee reach were 800 feet long and 139 feet long respectively. There final bottom elevations were 10.5 feet NAVD88 (1994, 1996) and 5.5 feet NAVD88 (1994, 1996).

The next area of breaches occurred along the north levee of the MRGO/GIWW at the south end of Area K, just to the East of the Elaine St. pumping station. There were three breaches along this levee reach. Here the original levee height is about 13.0 feet NAVD88 (1994, 1996). The first breach occurred about 1500 feet east of Elaine St. pump station. The breach length was 480 feet with a final bottom elevation of 11.0 feet NAVD88 (1994, 1996). The next breach had a length of 550 feet and a final bottom elevation of 8.5 feet NAVD88 (1994, 1996). The final breach in this levee reach had a length of 380 feet and a final bottom elevation of 11.0 feet NAVD88 (1994, 1996).

The last breach in the New Orleans East study area occurred in the northeast portion of Area I. This breach was near the New Orleans Lakefront Airport. The breach length was 60 feet and had a final bottom elevation of 2.0 feet NAVD88 (1994, 1996).

The RAS model was run with no breaching using the unmodified ADCIRC exterior stage hydrographs to come up with the peak freeflow component. The peak freeflow component was then subtracted from the total peak overflow to determine the wave overtopping component. The computed wave overtopping component was then compared with the wave overtopping rate using the ACEs (Automated Coastal Engineering System) program along with the STWAVE parameters for peak conditions. Based on this analysis it was determined that the wave overtopping component comprised as much as 60% of the total peak overflow.

The exterior levees suffered extensive damage from breaching and overtopping during the storm. In the RAS model this was represented by 13 different breaches totaling approximately 39000 feet distance along the IHNC (Inner Harbor Navigation Canal), GIWW (Gulf Inner Coastal Waterway), and the MRGO (Mississippi River Gulf Outlet). Exterior stages were high enough to overflow the levees and floodwalls at locations along the MRGO and the IHNC. The different components of the overflow were determined from analyses performed the High Resolution Hydrodynamics team. The overflow analysis was broken into the freeflow component and wave overtopping component. For the New Orleans East analysis, all levees were assumed to be at their pre-Katrina and no breaches were considered. The RAS model was run with no breaching using the unmodified ADCIRC exterior stage hydrographs to come up with the peak freeflow component. The peak freeflow component was then subtracted from the total peak overflow to determine the wave overtopping component. The computed wave overtopping component was then compared with the wave overtopping rate using the ACEs (Automated Coastal Engineering System) program along with the STWAVE parameters for peak conditions. Based on this analysis it was determined that the wave overtopping component comprised as much as 60% of the total overflow into New Orleans East. Volume IV discusses the ADCIRC and high resolution results.

Total calculated volume percentages of flow entering New Orleans East are shown in Table 3-9.

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Table 3-9
Calculated Inflow Volume Percentages into New Orleans East

Total Volume (ac-ft)	Percent		
	Rainfall	Breaches	Overtopping
142,400	13	17	70

Model Calibration

The 100-year synthetic frequency-based rainfalls of 24 hours duration were initially applied to the model and flood conditions were determined for the watershed. The results of this model run were used as an initial calibration/verification based on knowledge of the 100-year storm in the area. The Katrina event was then run through the model. Further calibration of the model was performed for the Katrina event in order to get the model to reproduce observed high water marks and eyewitness accounts of the timing and height of the flooding.

The HEC-RAS model is being driven externally using stage hydrographs from the ADCIRC model. Therefore, the accuracy of the interior stage computations depends largely on the accuracy of the boundary conditions provided by the ADCIRC results. After the model was completely put together, and the ADCIRC model results were applied as exterior boundary conditions, it was found that not enough volume of water was getting into the New Orleans East interior area. Almost all of the computed water surfaces were lower than the observed high water marks. During the calibration phase, the ADCIRC stage boundary conditions were adjusted to better match observed high water marks on the exterior sides of the levees. This adjustment greatly improved the calculations of the amount of water overtopping the levees and going through the breaches. This single change provided the greatest amount of improvement in the model matching high water marks and computing the volume of water entering the interior area more closely to what was observed. This change was applied to the areas that were not subjected from direct wave attack. For the areas that were subjected to direct wave overtopping the unmodified ADCIRC hydrograph was used along with the calculating the wave overtopping using the wave parameters from the STWAVE program as described in the Levee Overtopping and Breaching paragraph.

The interior area flood heights were verified through surveyed high water marks and eyewitness accounts of what happened during the flooding. The model was considered to be calibrated when the computed maximum water surface elevations were within a reasonable range of the observed high water marks. Listed in the Table 3-10 are computed stages versus observed high water marks for several of the key locations in the model (All elevations are shown in the NAVD88 (1994, 1996) datum). The locations are described by the corresponding storage area name used in the HEC-RAS model.

Table 3-10
Computed Stages versus High Water Marks

HEC-RAS Storage Area	HEC-RAS Computed Elevation	Observed Elevation
Area K2	7.9	7.65

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SAJ11	3.1	3.0
SA26	-1.2	-1.26
SA29	-1.2	-1.1
SA4	-1.2	-1.0
SA23	-1.2	-1.0

Most of the water came into the New Orleans East area through overtopping and breaching of the levees on the south side of the Parish, along the Gulf Intercoastal Waterway (GIWW). Additional water came into the parish through overtopping that occurred along the IHNC levees on the east side, and a minor breach and small amount of overtopping that occurred along the lake Pontchartrain levee near the Airport area on the north east side.

The southwestern portion of the area, labeled as Area K2 in the HEC-RAS model, received a tremendous amount of water from overtopping that occurred in that area. Additionally, three large sections of the floodwall along the GIWW were pushed over at an angle during the overtopping. While these floodwalls did not completely fail, the fact that they were pushed over at and angle caused additional flooding in the area. These three sections of floodwall were modeled as levee breaches in HEC-RAS. The levee breach option was used to lower the elevations of the tops of the floodwalls to represent them leaning over. Water flowed into Area K2 from the levee overtopping and then proceeded north and east. To the north, Area K2 is bounded by an elevated railroad track. Water filled up in area K2 and then started spilling over the railroad track to the north. Eyewitness accounts stated that they saw water depths of 4-5 feet overtopping this railroad during the event. The average elevation of the railroad in this area ranges between 3 to 4 feet in elevation. The high water mark listed in area K2 of 7.65 is substantiated by these eyewitness accounts. Water also moved to the east side of Area K2, going over roadways and then getting into the Charbonnet canal. Once in the Charbonnet canal, water moved through the canal to the north. A series of culverts that go underneath the railroad and the highways in this area greatly constricted the amount of water that could move north through this canal. During the initial calibration runs, water cam into Area K2 very quickly, filled the storage area, and began spilling over the railroad tracks. In order to get a better match of the observed high water mark and eye witness accounts for this area, it was necessary to lower all of the weir coefficients used for modeling flow going over the railroad tracks. Because storage areas in HEC-RAS are modeled using level pool routing methods, the water was coming into area K2 from the south and very quickly going over the railroad tracks to the north. In order to slow the flow down and increase the computed stages in Area K2 it was necessary to lower the railroad weir coefficients down to values around 1.0. While this is much lower than traditional weir coefficients, it was necessary to calibrate this portion of the model.

The southeastern portion of the parish received a tremendous amount of water through over topping of the levees and some significant levee breaches. Most of the levee breaches occurred in the very southeast portion of the area. These breaches put a very large volume of water into the wetlands area on the east side of the parish. In the HEC-RAS model, the breaches in this area were sent into a storage area labeled J29. Water came into this wetland area and moved both north and west. To the north the wetlands area is broken up by the railroad tracks going east to west. To the west, the wetlands area is bounded by and interior levee system called the back

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levee. Water filled this first storage area and then proceeded to overtop the railroad to the north, as well as the back levee system to the east. Water continued north through the wetlands area, but also overtopped levees along the western side of the wetlands as it moved north and filled the wetlands to stages higher than the back levee system. Overtopping of the back levee system allowed water to come into both agricultural and residential areas. The levee breach dimensions in this area were measured from post Katrina LiDAR data of the levee system. Overtopping weir coefficients were set to 2.6 as all of the levees in this area are earth levees and overtopping is assumed to occur like broad crested weir flow. Levee breaches were set to occur over a 1hour period. During the calibration, a few of the larger breaches were changed to a 0.9 hour breach time in order to get a better match of volume and a high water mark in storage area SAJ11 to the east of this area.

The only other changes in model parameters was to adjust the linear routing coefficients that were used to move water from one storage area to another for those areas that did not have an extensive high ground barrier between them. The northwest portion of the Parish is bounded by the Lake Pontchartrain levees to the north, the IHNC levees to the west, the railroad line to the south, and I-510 to the east. This area is the main residential area in the study area. This entire area filled to around the same water elevation, varying between -0.9 to -1.26 (based on the high water marks in this area). This area also has some of the lowest ground elevations in the Parish. Most of the water got into this area from water that overtopped the railroad line to the south and then moved north into this area. Additional water came into this area from overtopping of levees along the IHNC as well as some overtopping and a small breach that occurred along lake Pontchartrain on the north west side. This area is modeled as a series of canals, small storage areas, and pump stations. There are no major physical barriers to prevent water from moving from one area to another once the water surface elevations reach levels to flood the streets. Storage areas were connected to the canals by using lateral weirs that would allow water to go both into and out of the canals. Additionally, to model flow going overland from one storage area to another, a simple linear routing equation is used. Initial values for linear routing coefficients between these storage areas were set to a value of 0.1. During the calibration phase it was found that water was not moving fast enough between the storage areas going to the north. The linear routing coefficients were then change to values of 0.2 to improve the timing of moving water to the north as well as the final computed water surface elevations.

Model Results and Floodplain Mapping

The model reproduced the Hurricane Katrina event within reasonable tolerances. The most significant influx of water came from the storm surge along the southeast portion of the parish. Approximately 4500 feet of the most southerly portion of the Pontchartrain levee along the Bayou Savage Wildlife Management area overtopped. Also, 8,500 feet of levee breached along the most easterly portion of the GIWW. These two breaches allowed enormous amounts of water to travel in to the Bayou Savage area and migrate north and west to the developed areas. Minor breaching occurred along the west portion of the GIWW levee. Figure 3-6 shows the depth of flooding due to Hurricane Katrina.

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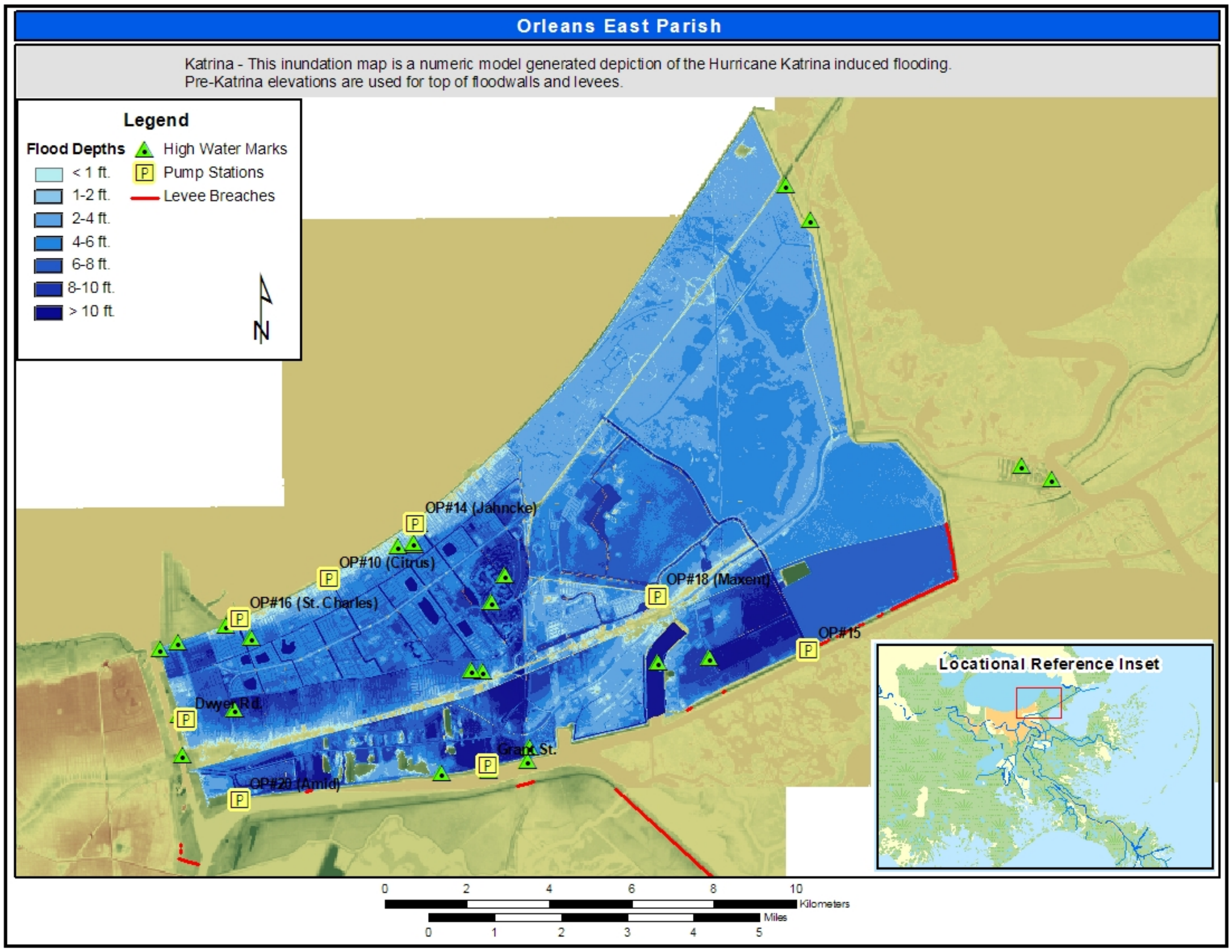

Figure 3-6. Depth of Flooding from Hurricane Katrina

The Geodetic Vertical Survey Assessment team was assigned to collect high water marks in the area. Several teams were sent out to the area shortly after the water receded to locate and set the marks. The team was then sent out to survey the high water marks. There is indication that two types of high water marks were taken. The first being what the initial team perceived as being the ultimate high water. That's shown in the plots below when the peak of the hydrograph coincides with the high water mark. The second being the "settled out" high water. That's indicated by the hydrograph matching the high water mark several hours after the peak. However, few high water marks exist in the New Orleans East area. Figures 3-7 to 3-12 show the comparison between the surveyed high water marks and the computed RAS hydrographs.

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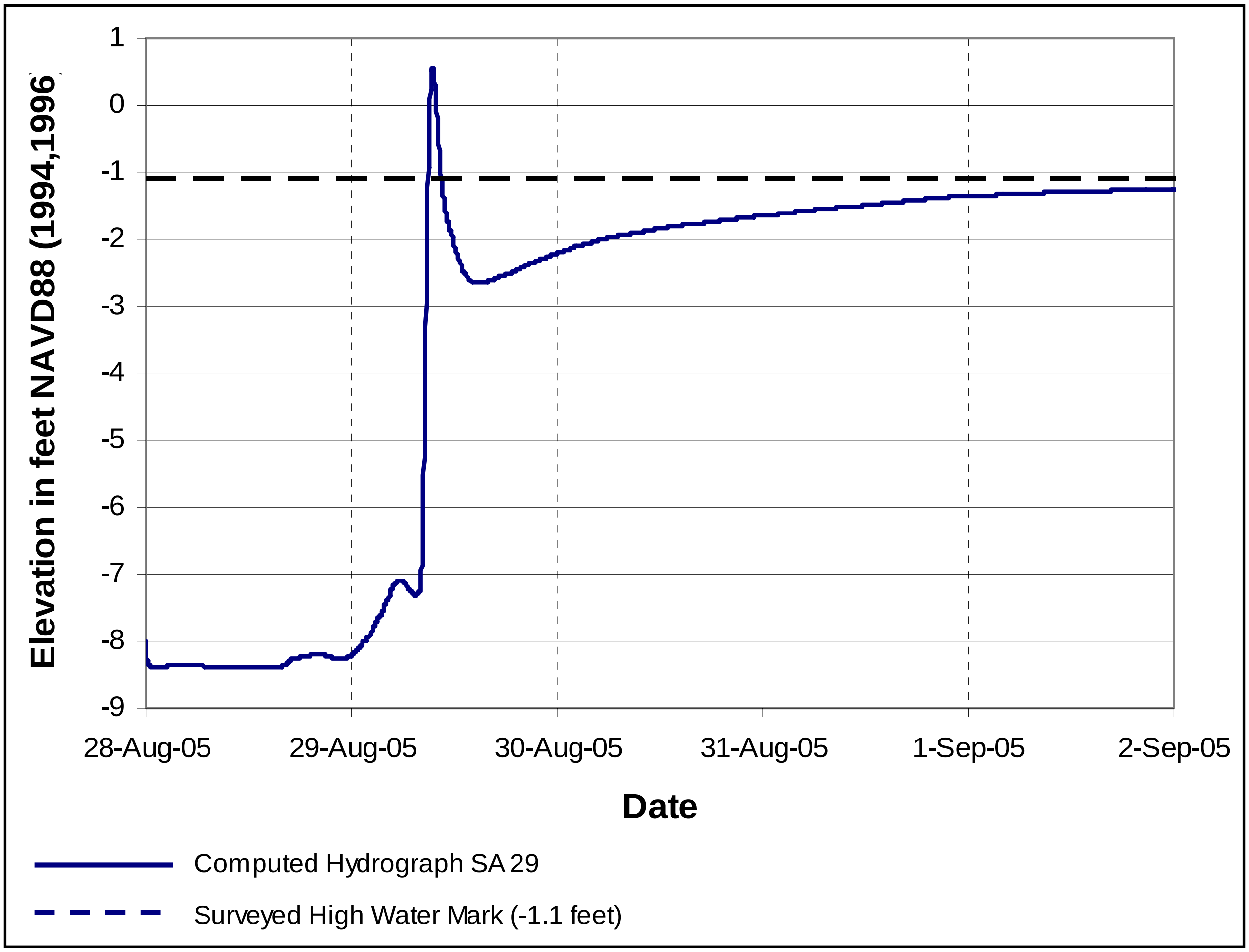

Figure 3-7. SA 29 Hydrograph

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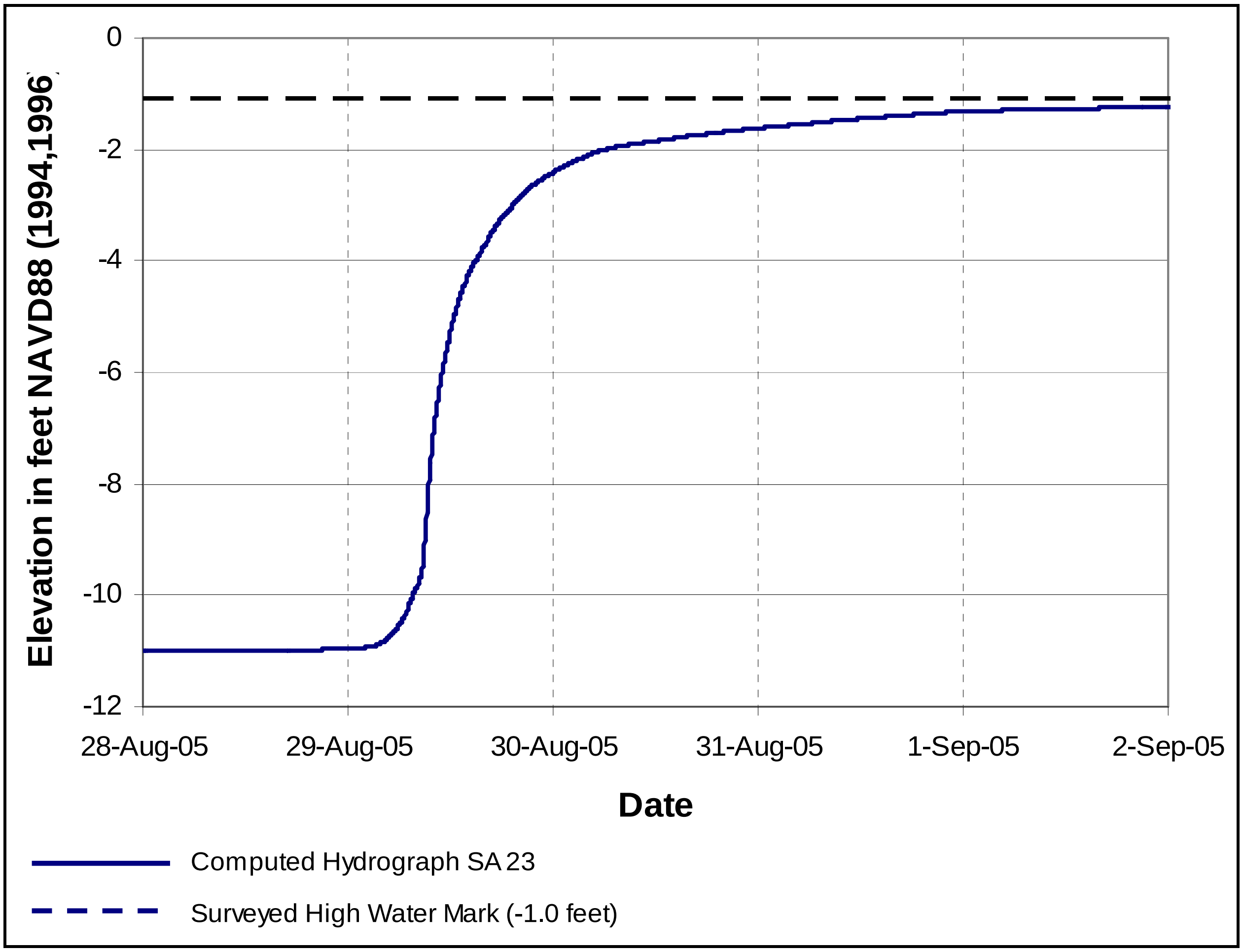

Figure 3-8. SA 23 Hydrograph

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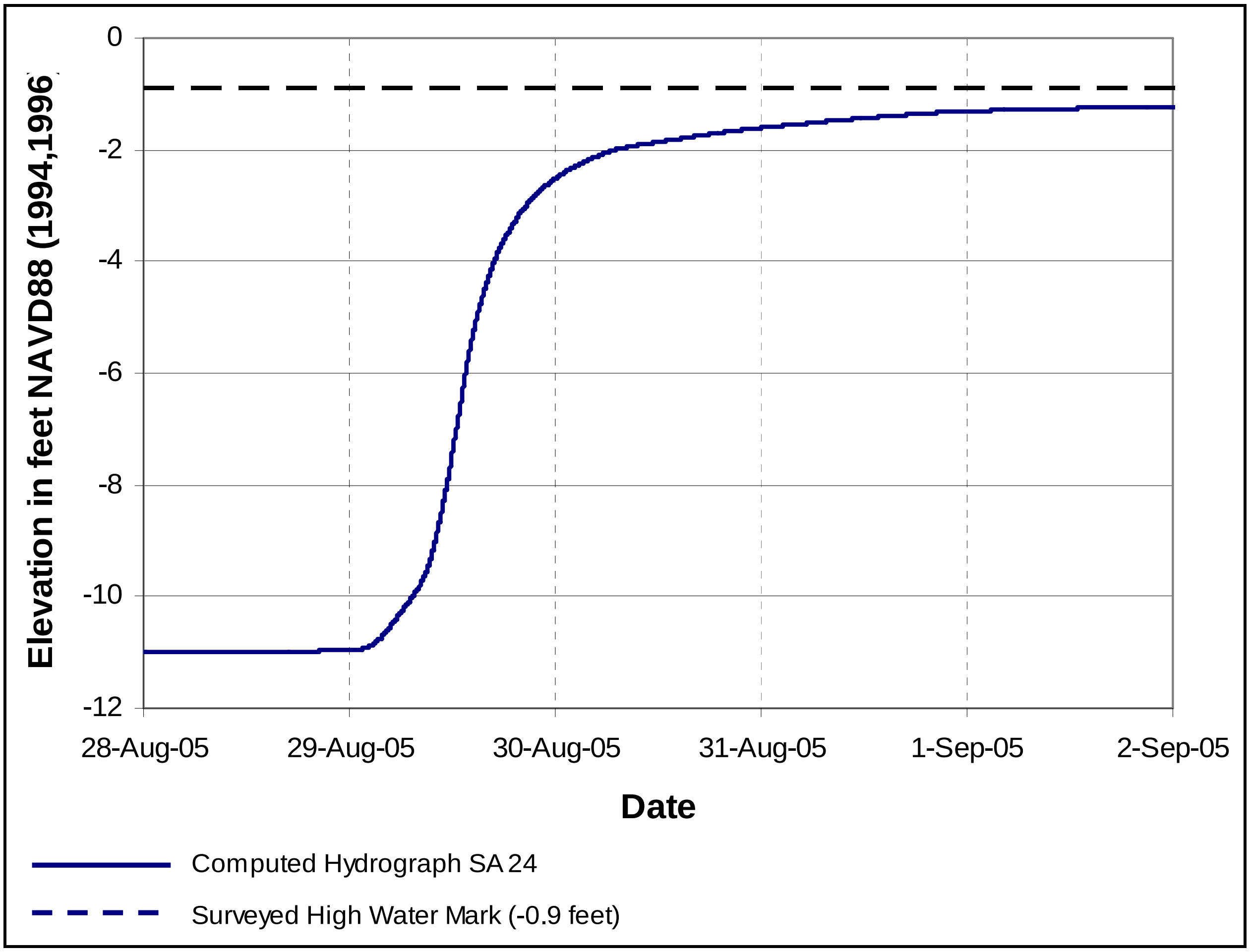

Figure 3-9. SA 24 Hydrograph

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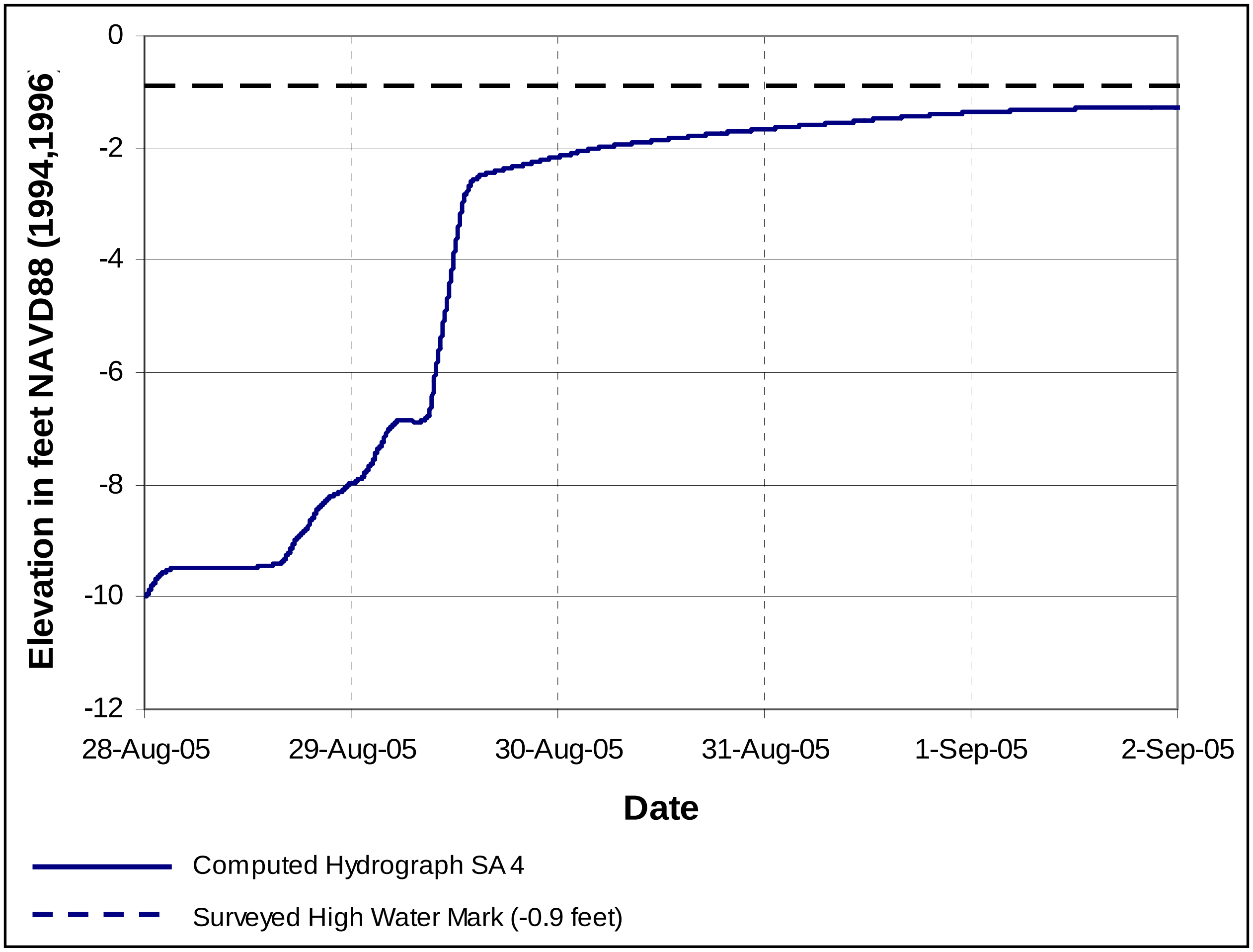

Figure 3-10. SA 4 Hydrograph

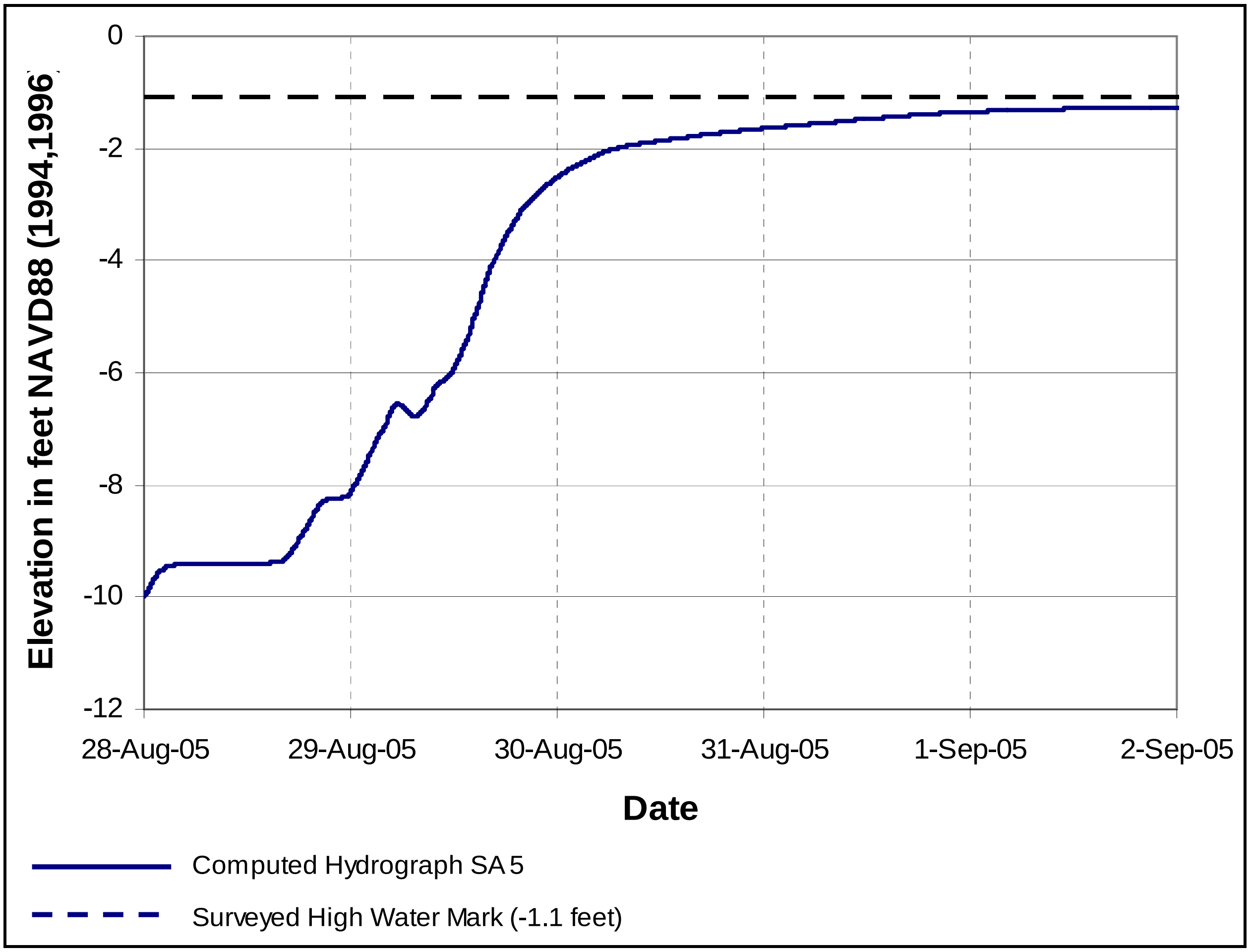

Figure 3-11. SA 5 Hydrograph

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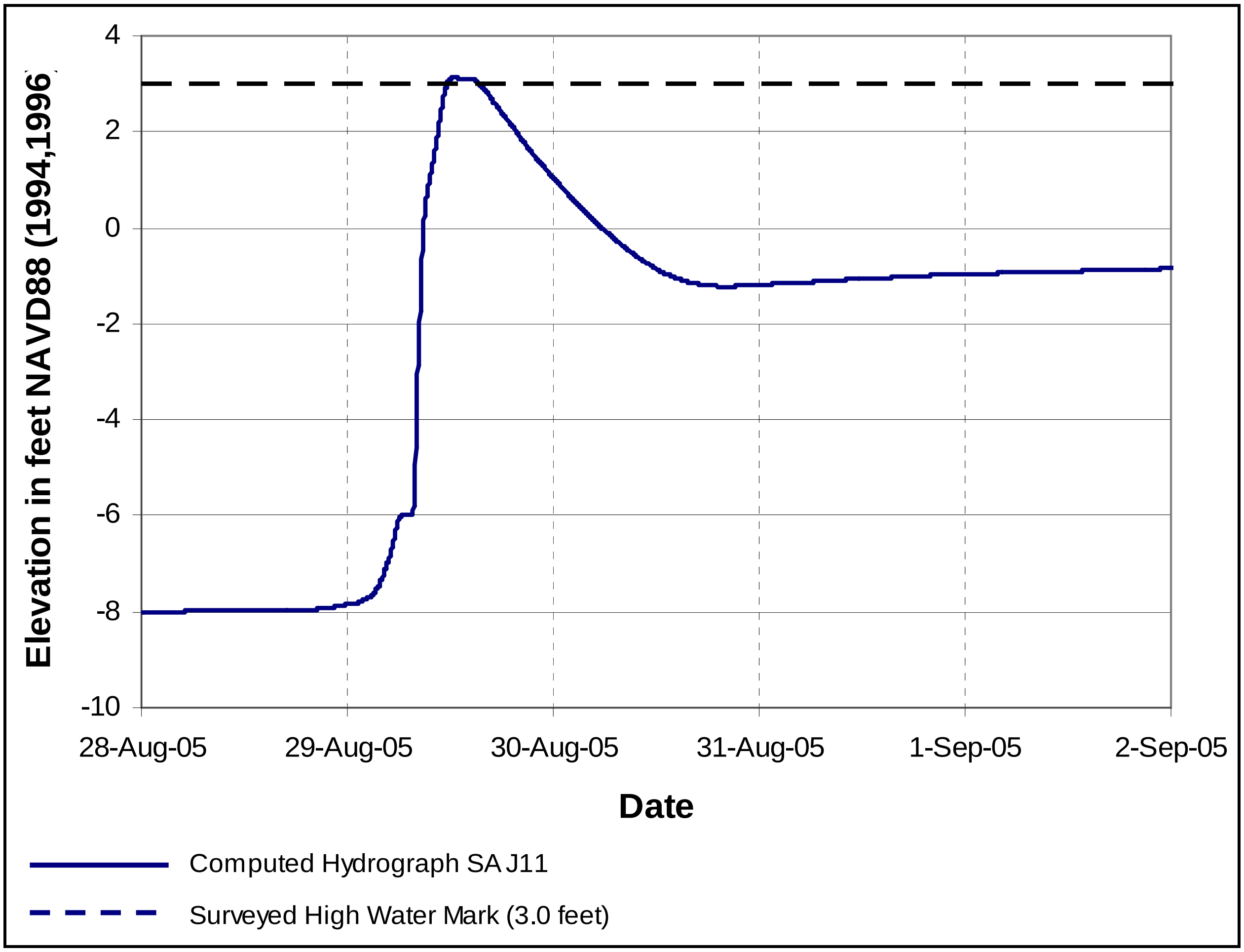

Figure 3-12. SA J11 Hydrograph

Figure 3-13 shows depth of flooding due to the Hypothetical 1 scenario and Figure 3-14 shows depth of flooding for the Hypothetical 2 scenario. Table 3-11 shows a comparison of stages for the three scenarios for New Orleans East.

Table 3-11
Computed Stages for Katrina, Hypothetical 1 and Hypothetical 2

HEC-RAS Storage Area	Katrina	Hypothetical 1	Hypothetical 2
Area K2	7.9	7.5	7.4
SAJ11	4.2	-2.7	-3.0
SA26	1.4	0.3	0.2
SA29	0.5	-0.4	-0.5
SA4	-1.2	-2.1	-3.6
SA23	-1.2	-2.1	-3.8

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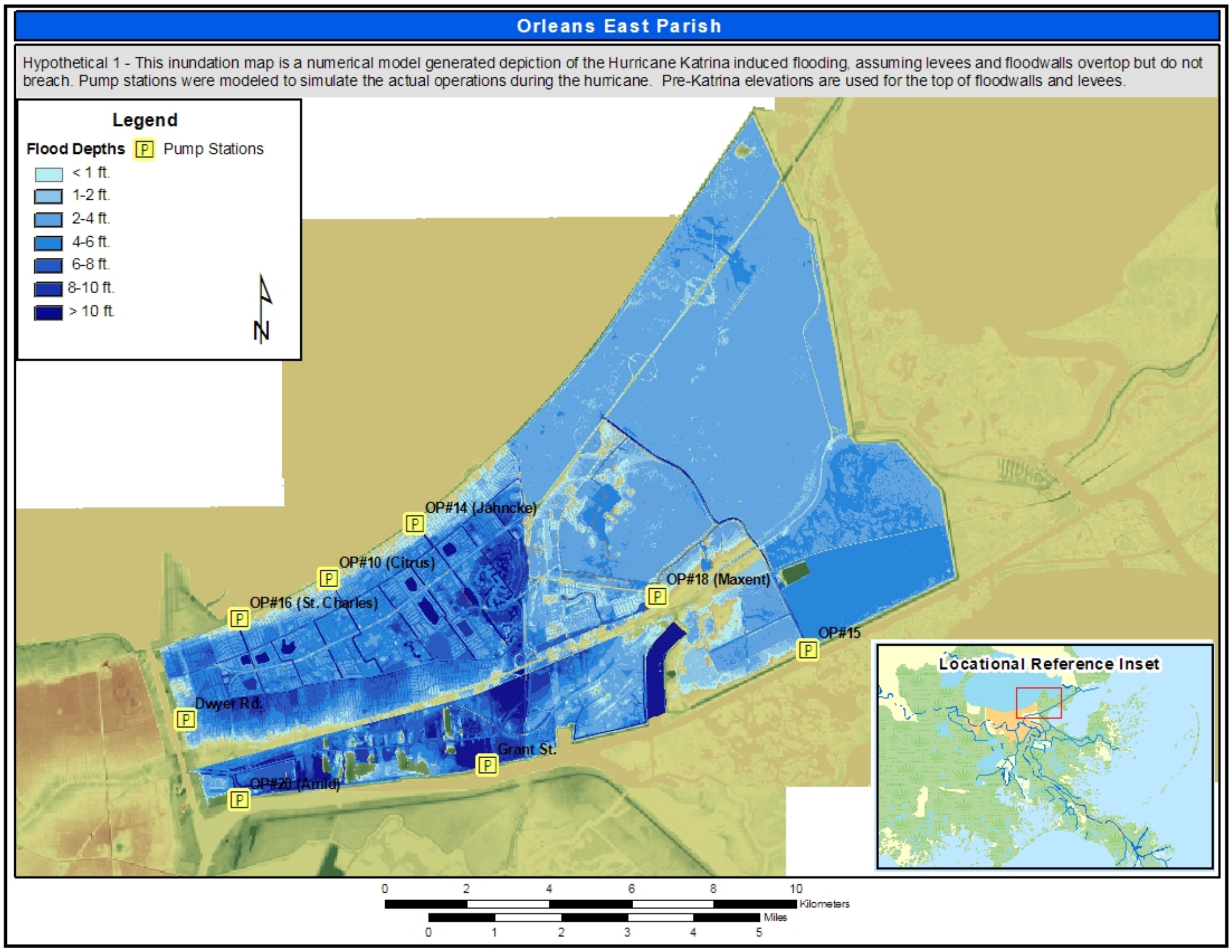

Figure 3-13. Depth of Flooding from Hypothetical 1 Scenario

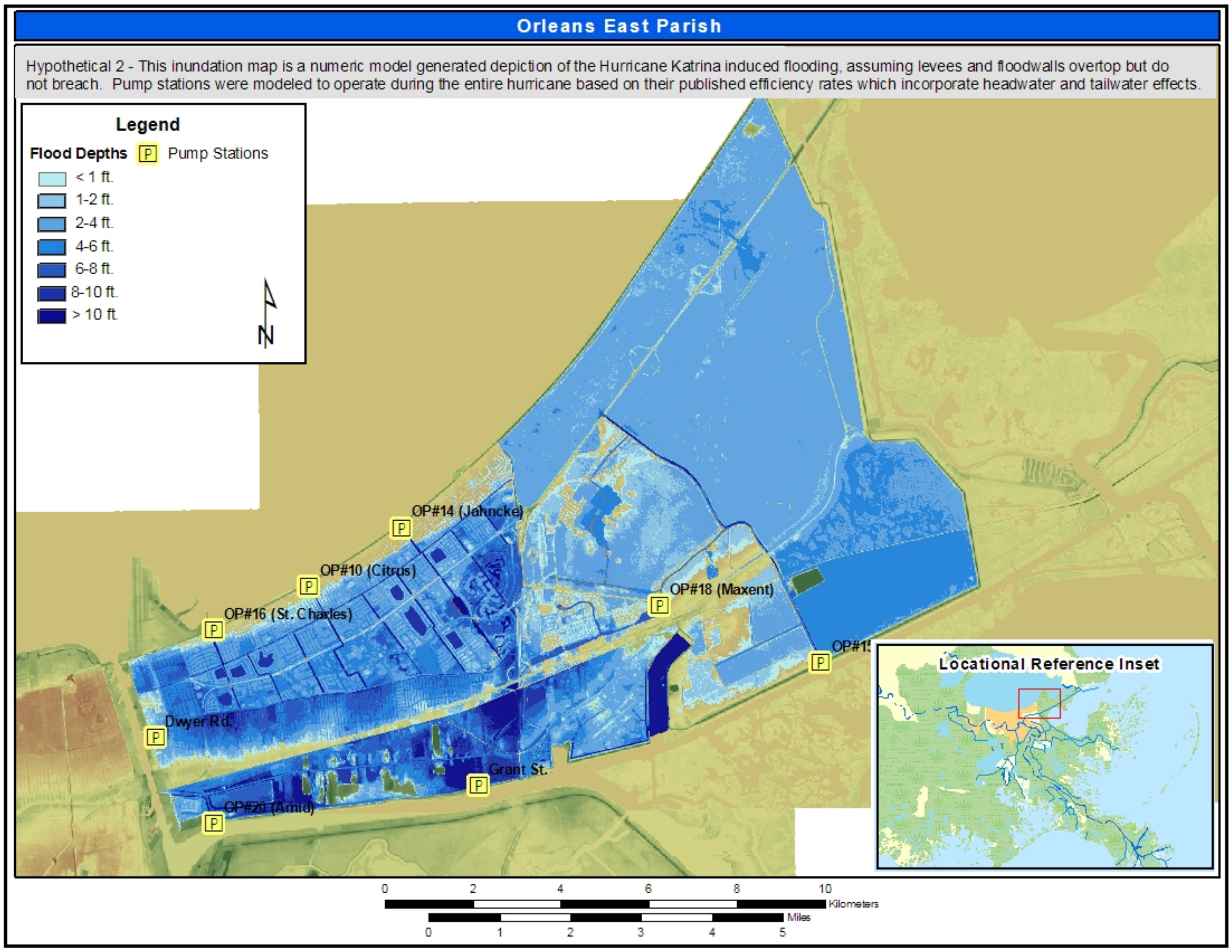

Figure 3-14. Depth of Flooding from Hypothetical 2 Scenario

Figures 3-15 to 3-22 show the overtopping hydrograph at several of the levees and floodwalls in New Orleans East. These figures show the even without breaching, large amounts of water would have entered the New Orleans East area and resulted in widespread flooding.

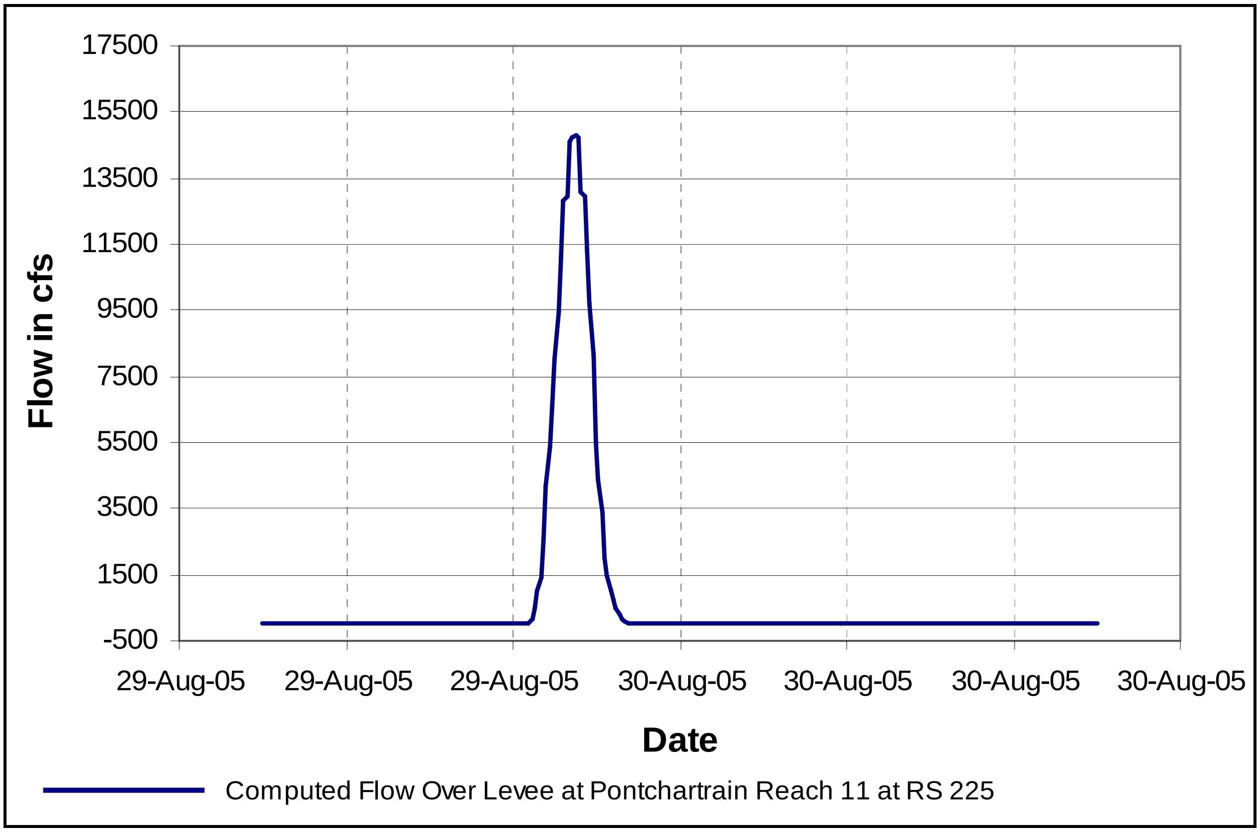

Figure 3-15. Overtopping on Reach 11 at RS 225

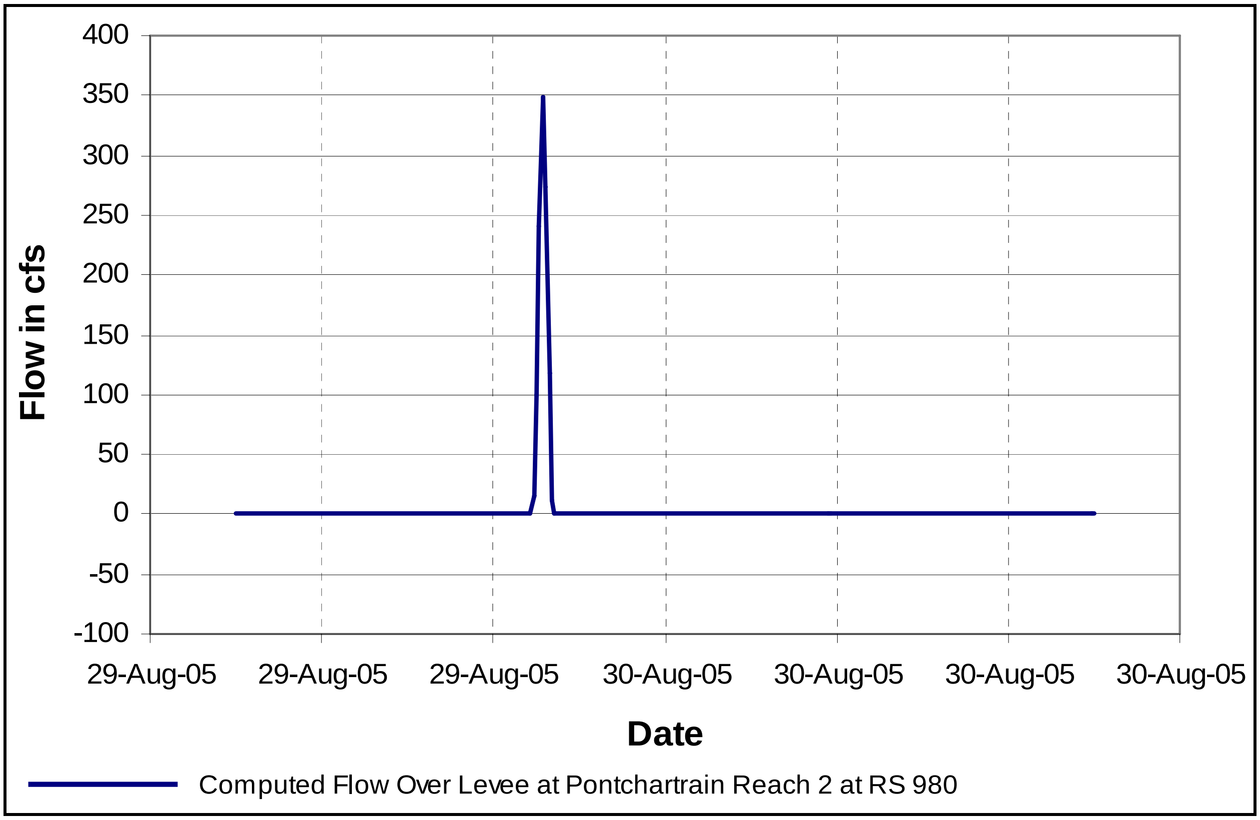

Figure 3-16. Overtopping on Reach 2 at RS 980

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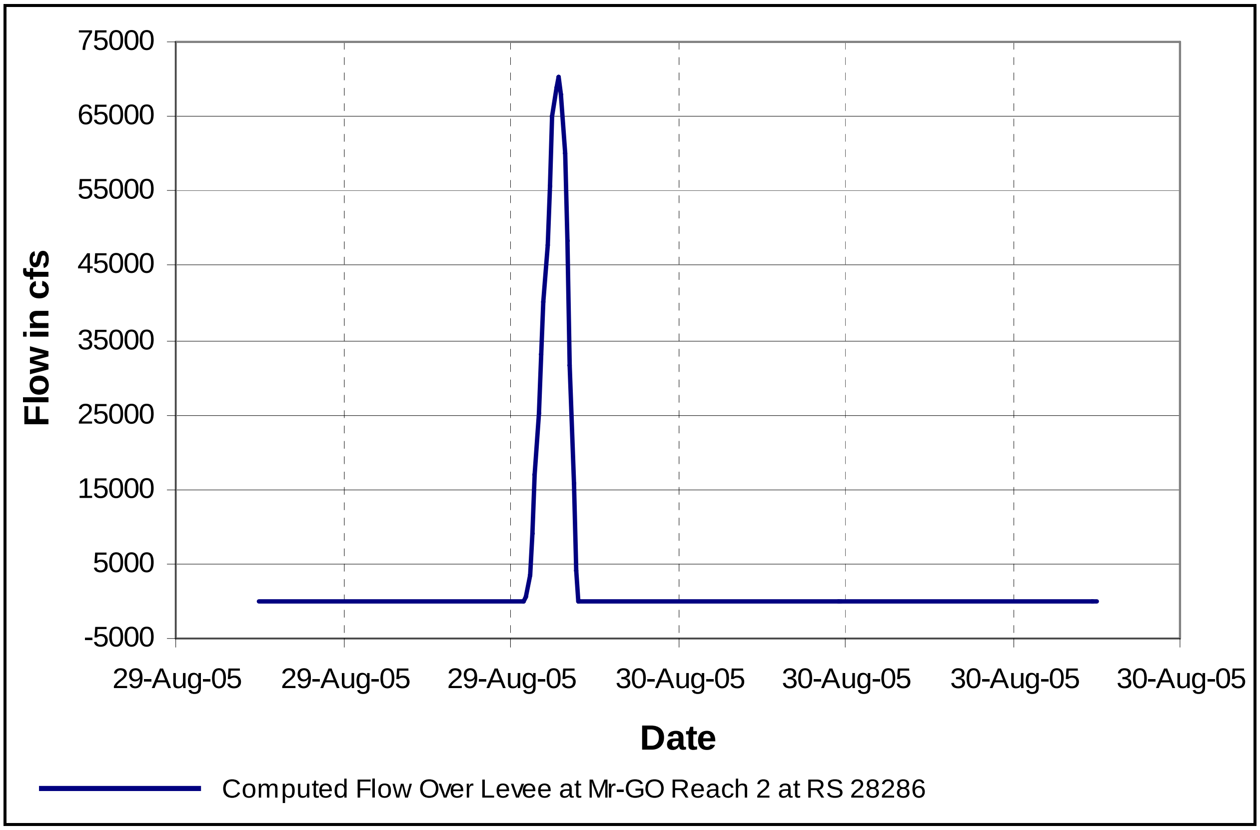

Figure 3-17. Overtopping on MRGO Reach 2 at RS 28286

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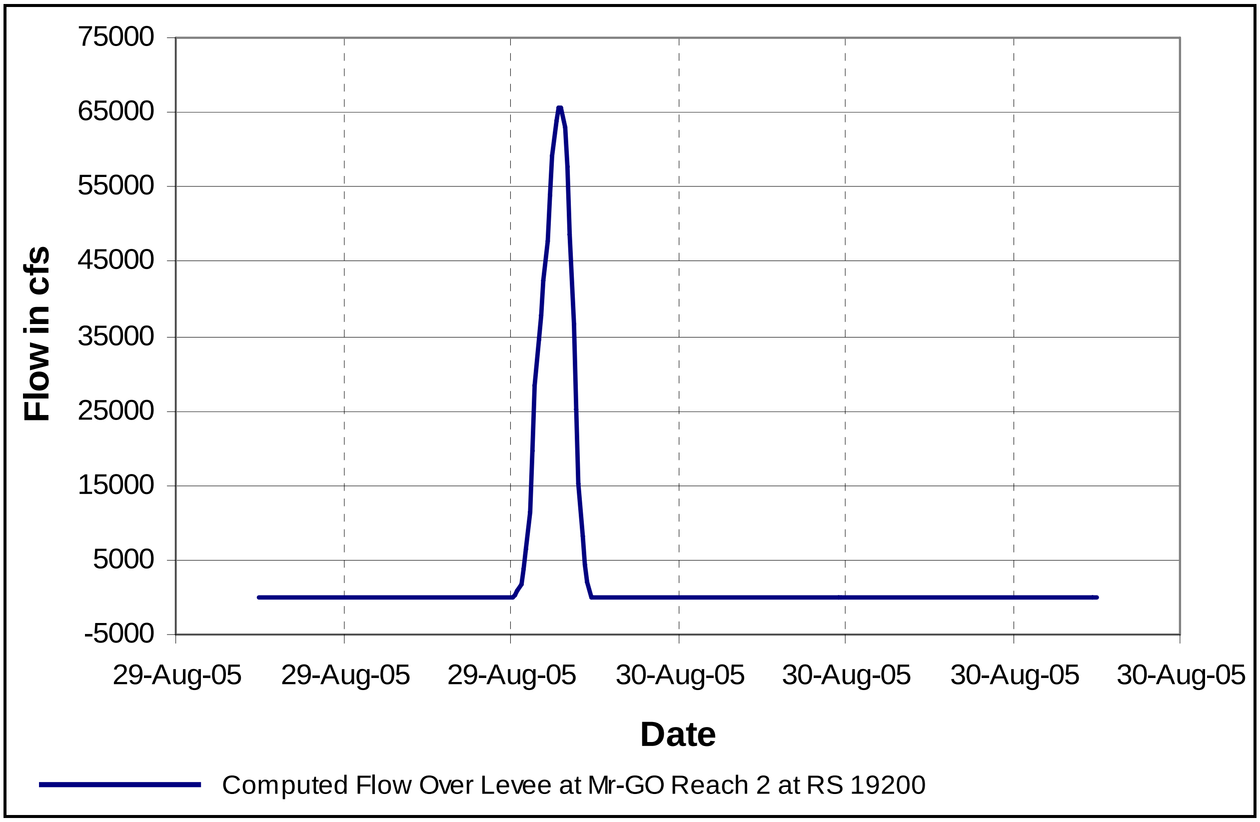

Figure 3-18. Overtopping on MRGO Reach 2 at RS 19200

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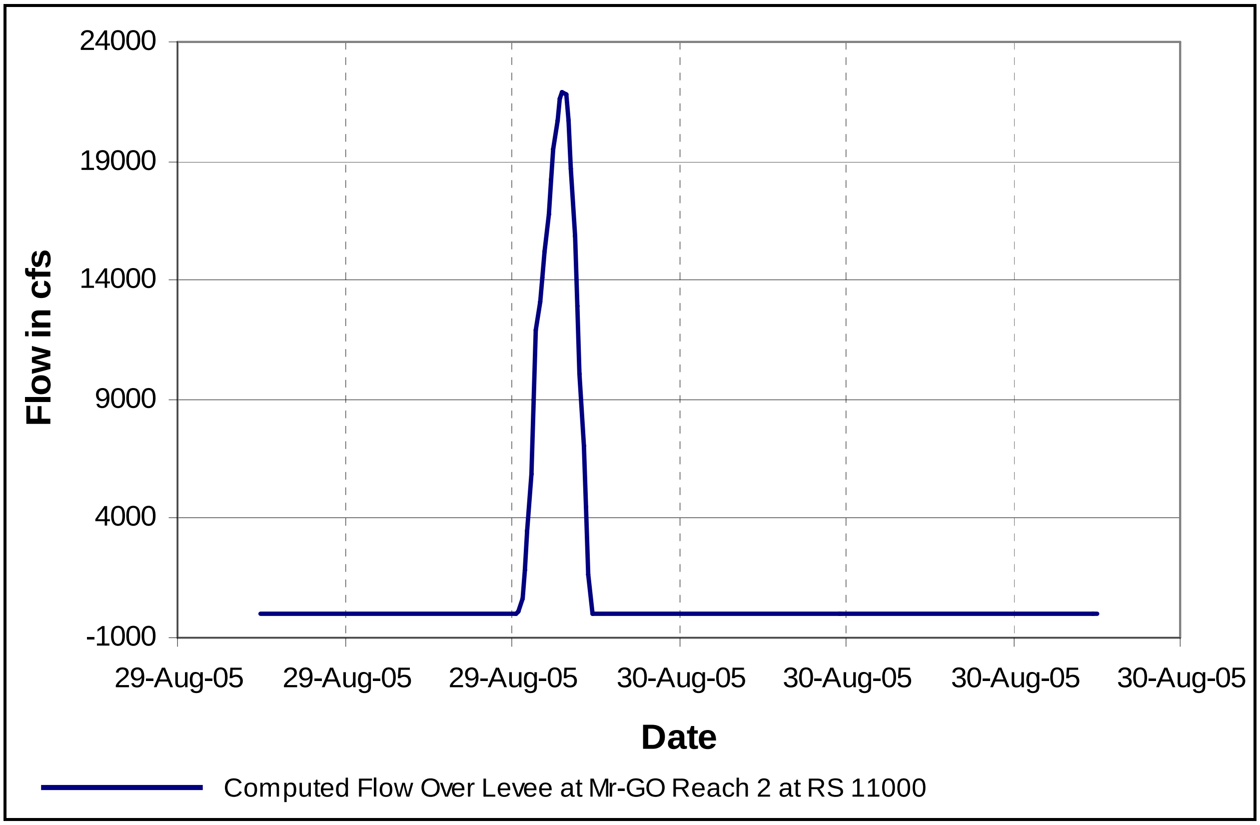

Figure 3-19. Overtopping on MRGO Reach 2 at RS 11000

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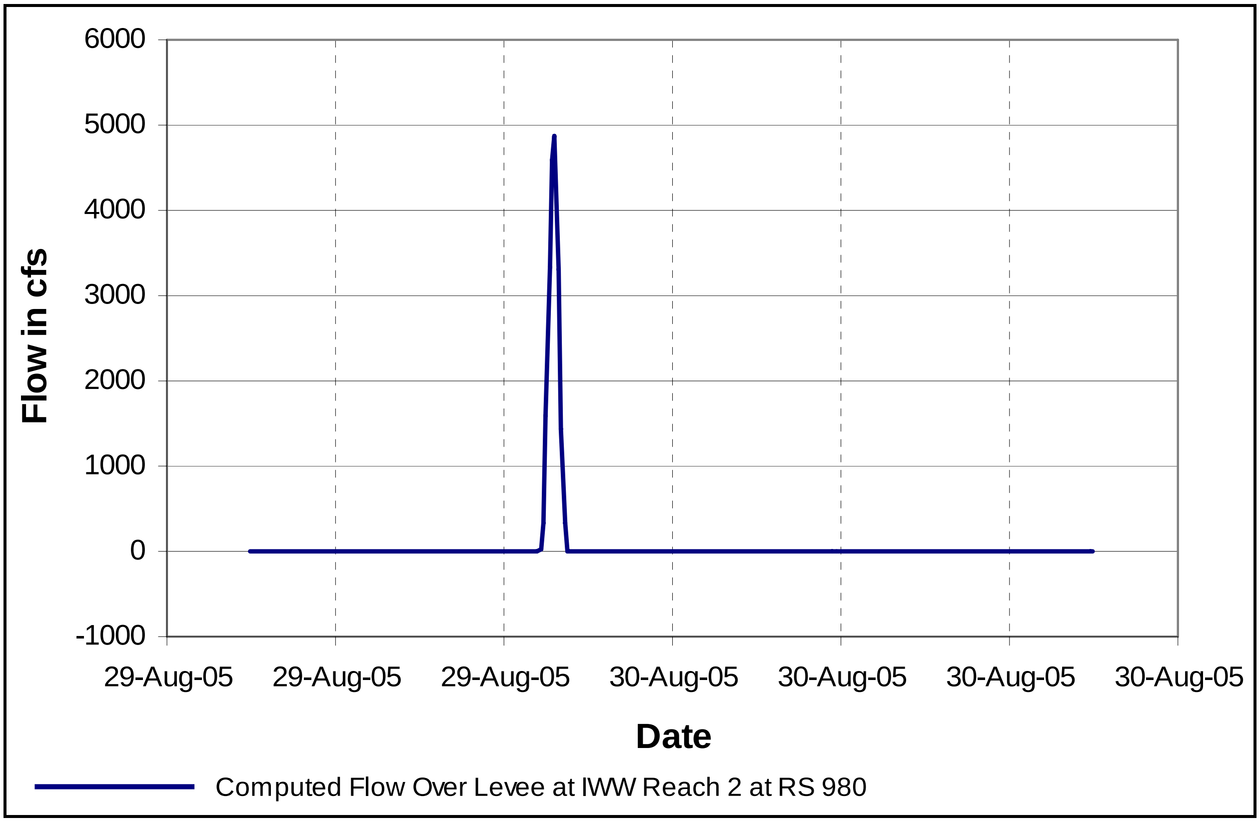

Figure 3-20. Overtopping on GIWW Reach 2 at RS 980

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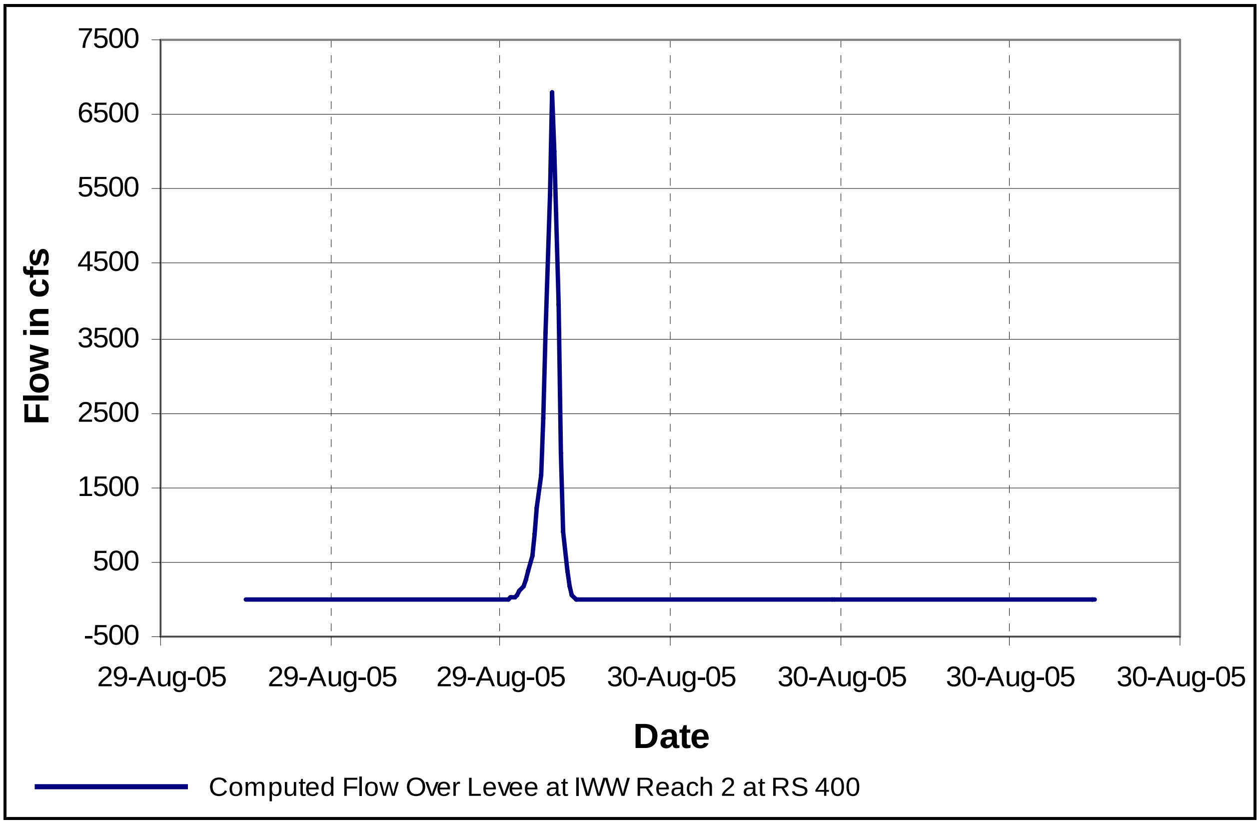

Figure 3-21. Overtopping on GIWW Reach 2 at RS 400

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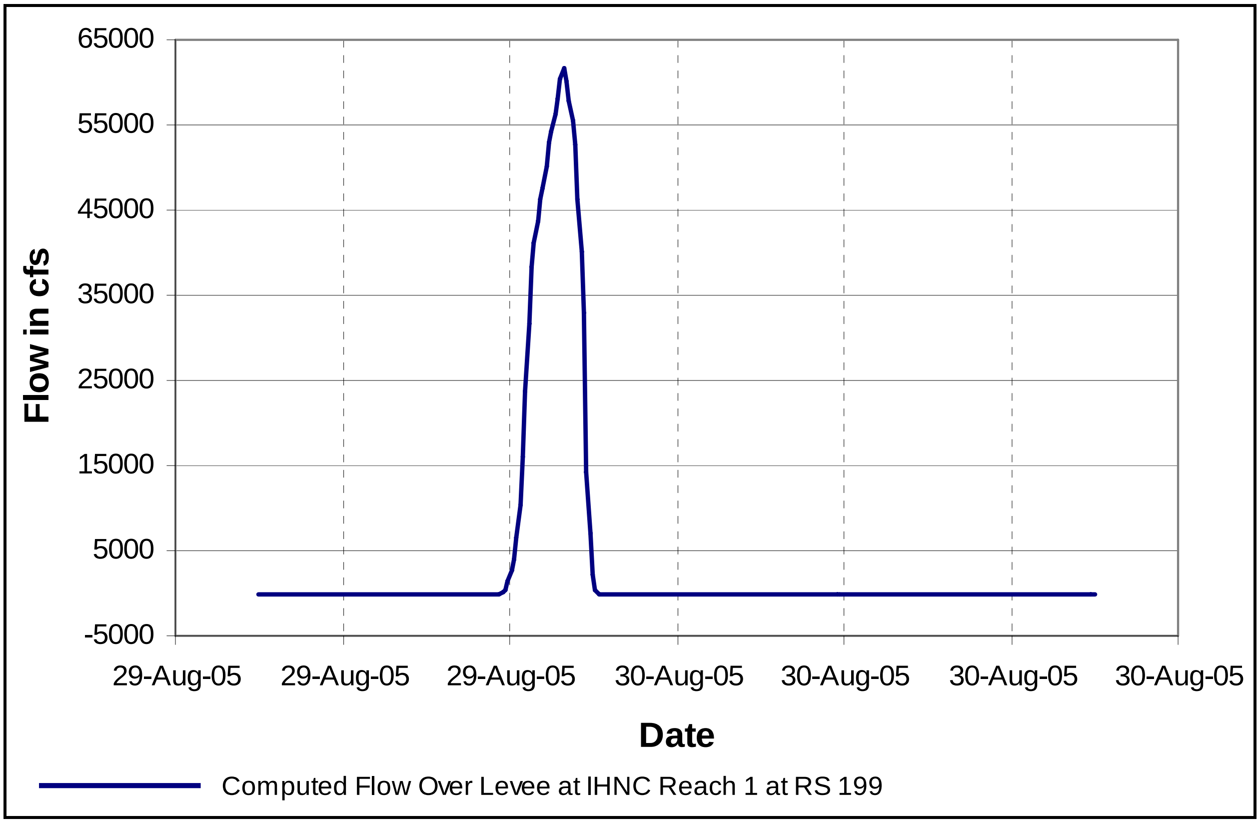

Figure 3-22. Overtopping on GIWW Reach 1 at RS 199

Appendix 4
Interior Drainage Analysis – St. Bernard Parish and the Lower Ninth Ward of Orleans Parish

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Introduction

Study Purpose

To answer the questions regarding the performance of the hurricane protection system, the interior drainage analysis focused on the filling and unwatering of the separate areas protected by levees and pump stations, referred to as basins. Interior drainage models were developed for Jefferson, Orleans, St. Bernard and Plaquemines Parishes to simulate water levels for what happened during Hurricane Katrina and what would have happened had all the hurricane protection facilities remained intact and functioned as intended.

The primary components of the hurricane protection system are the levees and floodwalls designed and constructed by the Corps of Engineers. Other drainage and flood control features (land topography, streets, culverts, bridges, storm sewers, roadside ditches, canals, and pump stations) work in concert with the Corps of Engineers levees and floodwalls as an integral part of the overall drainage and flood damage reduction system and are included in the models.

Interior drainage models are needed for estimating water elevations inside leveed areas, or basins, for a catastrophic condition such as Hurricane Katrina and for understanding the relationship between HPS components. Results from the interior drainage models can be used to determine the extent, depth and duration of flooding for multiple failure and non-failure scenarios. The models can also be used to:

- Support the Risk modeling effort
- Estimate time needed to unwater an area
- Support evacuation planning
- Evaluate design options of the HPS to include multiple interior drainage scenarios

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This appendix will provide details of the development of the HEC-HMS and HEC-RAS models for St Bernard Parish and the Lower 9th Ward of Orleans Parish. In summary, an HEC-HMS model was developed to transform the Katrina precipitation into runoff for input to the HEC-RAS models. HEC-RAS models were developed to simulate the four conditions discussed below

This model was developed to help answer questions 3 and 4 listed on page 1 of Volume VI. Question 3 is answered by the Katrina simulation listed below. Question 4 is a more difficult one to answer. This is mainly due to the variety of possible combinations of system features, especially pumps. It was decided to bracket these combinations with the three hypothetical combinations listed below.

One of the major difficulties is determining what pumps may have continuing operating. There are many potential factors that can cause pump stations to not operate during a hurricane event. Some of these are power failures, pump equipment failures, clogged pump intakes, flooding of the pump equipment, loss of municipal water supply used to cool pump equipment and no safe housing for operators at the pump stations resulting in pump abandonment. Because there is such a wide range of possible pumping scenarios that could occur during a hurricane event, it is difficult to establish a pumping scenario for what could have happened. At best, a variety of possible scenarios could be run to evaluate the potential range of possible consequences. For the purposes of the IPET analysis, it was decided to operate the pumps two ways. (1) As they actually operated during hurricane Katrina and (2) the pumps operated throughout the hurricane.

Described below are the 4 scenarios shown in this appendix.

Katrina

Simulate what happened during Hurricane Katrina with the hurricane protection facilities and pump stations performing as actually occurred. Compare results to observed and measured high water marks. Pre-Katrina elevations are used for top of floodwalls and levees.

Hypothetical 1 – Resilient Levees and Floodwalls

Simulate what would have happened during Hurricane Katrina had all levees and floodwalls remained intact. There are no levee or floodwall breaches or failures for this scenario even where overtopping occurs. Pump stations operate as they did in the Katrina event. Pre-Katrina elevations are used for top of floodwalls and levees. This scenario is meant to simulate what could have happened if all levees and floodwalls had protection that would allow them to be overtop but not breach.

Hypothetical 2 – Resilient Floodwalls, Levees and Pump Stations

Simulate what would have happened during Hurricane Katrina had all levees, floodwalls and pump stations remained intact and operating. There are no levee or floodwall breaches or failures for this scenario even where overtopping occurs. Pump stations operate continuously throughout the hurricane. Pump operations are based on the pump efficiency curves which reflect tailwater impacts. Pre-Katrina elevations are used for top of floodwalls and levees. It is understood, that in their present state, most pump stations would not have been able to stay in operation during

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Katrina. However, this scenario was simulated to provide an upper limit on what could have been the best possible scenario had no failures occurred.

Hypothetical 3 – Resilient Floodwalls

Simulate what would have happened during Hurricane Katrina had all floodwalls, which failed from foundation failures, remained intact. All other areas are modeled as they actually functioned. Pump stations operate as they did in the Katrina event. Pre-Katrina elevations are used for top of floodwalls and levees. The result of this scenario for St Bernard Parish and the Lower 9th Ward of Orleans Parish, is that the inundation matches the inundation for the Katrina simulation.

Table 4-1 lists the simulation scenarios in a matrix format.

Table 4-1
Katrina Simulations

Conditions	Simulation			
	Katrina	**Hypothetical 1**	**Hypothetical 2**	**Hypothetical 3**
Pumps operate as during Katrina	X	X		X
Pumps operate throughout Katrina			X	
Levee and floodwall breaches occur everywhere as during Katrina	X			
Levee and floodwall breaches occur on West wall of IHNC and in, St Bernard, New Orleans East and Plaquemines as during Katrina				X
Levee and floodwalls overtop but do not breach		X	X	
No failures on 17th Street and London Ave				X
Levee and floodwall elevations based on pre-Katrina elevations	X	X	X	X

Review of Existing Data

An ungeoreferenced HEC-RAS Unsteady model of Area 1 St. Bernard Parish, from Paris Road to the Orleans Parish line existed before Hurricane Katrina. It was developed for a flood reduction (rainfall only) study for the area. Surveys of the channel network were conducted by the Louisiana Department of Transportation and Development (LADOTD) and the Lake Borgne Levee District for this study. The terrain surface was developed from LIDAR data flown specifically for St. Bernard Parish. The stage-storage relationships were developed from this data.

General Modeling Approach

The hydrologic model developed for the study area represented the rainfall runoff characteristics of the land. The HMS model produced flow hydrographs for each of the sub basins in the entire area. HEC-RAS Unsteady was used to represent the characteristics of the drainage canals and the topography of the modeled areas. Flow hydrographs from HEC-HMS were entered into the hydraulic model along with hurricane surge (ADCIRC Model Results) and levee breach information in order to calculate water surfaces for the entire study area.

Hydrologic Model Development

Background

HEC-HMS version 3.0.0 was used to model the rainfall-runoff response for the Hurricane Katrina event for subbasins in St. Bernard Parish. Subbasin boundaries in the HEC-HMS model correspond to storage areas defined in the HEC-RAS model. Rainfall for each subbasin was determined using radar-rainfall estimates from the National Weather Service. The SCS curve number and the SCS dimensionless unit hydrograph methods were used to compute runoff hydrographs given basin average precipitation. GIS data, like landuse and soil data, were used to estimate SCS curve numbers and lag times.

Development of GIS Watershed Model

Subbasin boundaries for the St. Bernard Parish HEC-HMS model are shown in Figure 4-1. Basin boundaries correspond to storage areas defined in the HEC-RAS model for this area. Delineation of subbasin boundaries is described in RAS Interior Modeling Section later in this appendix. A shapefile of subbasin boundaries was used for estimating HEC-HMS model parameters, curve numbers and lag times, and determining subbasin average precipitation from the radar-rainfall data. The shapefile was also used as the background map in the HEC-HMS basin model.

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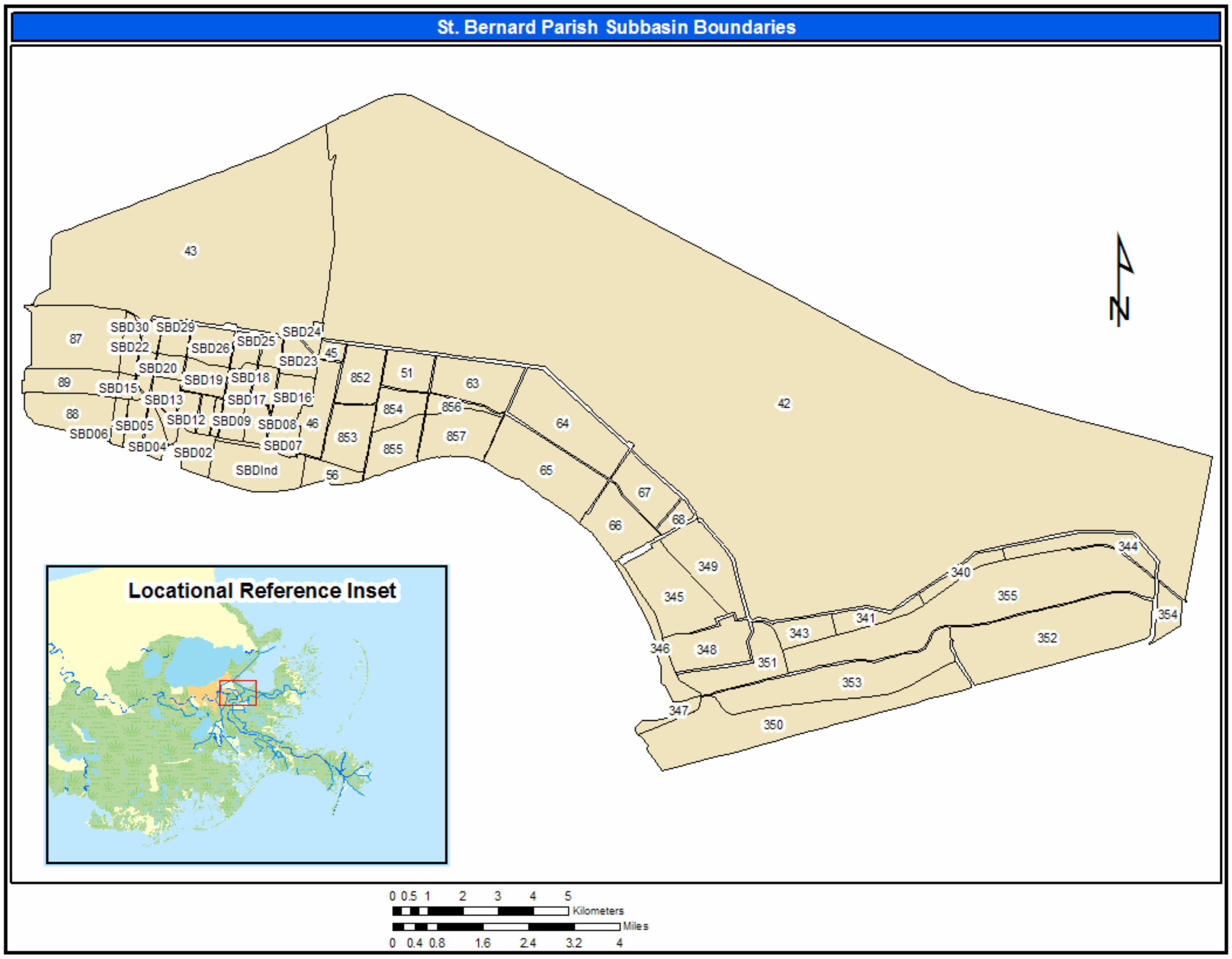

Figure 4-1. St. Bernard Parish Subbasin Boundaries

Model Parameters

Landuse and soil data. Landuse and soil data were used to estimate SCS curve numbers. Landuse data was obtained from the New Orleans District (MVN). The landuse data was a raster coverage of 24 different landuse types (Table 4-2). Soil data, contained in the Soil Survey Geographic (SSURGO) Database, was downloaded from the following National Resources Conservation Service (NRCS) website: http://www.ncgc.nrcs.usda.gov/products/datasets/ssurgo/. The SSURGO dataset is a digital copy of county soil survey maps and provides the most level of detailed for digital soil maps from the NRCS.

Table 4-2
Landuse Categories

LANDUSE	A	B	C	D
Fresh Marsh	39	61	74	80
Intermediate Marsh	39	61	74	80
Brackish Marsh	39	61	74	80
Saline Marsh	39	61	74	80
Wetland Forest-Deciduous	43	65	76	82
Wetland Forest- Evergreen	49	69	79	84
Wetland Forest- Mixed	39	61	74	80
Upland Forest- Deciduous	32	58	72	79
Upland Forest- Evergreen	43	65	76	82
Upland Forest- Mixed	39	61	74	80
Dense Pine Thicket	32	58	72	79
Wetland Scrub/shrub - deciduous	30	48	65	73
Wetland Scrub/Shrub - evergreen	35	56	70	77
Wetland Scrub/Shrub - Mixed	30	55	68	75
Upland Scrub/Shrub - Deciduous	30	48	65	73
Upland Scrub/Shrub - Evergreen	35	56	70	77
Upland Scrub/Shrub - Mixed	30	55	68	75
Agriculture-Cropland-Grassland	49	69	79	84
Vegetated Urban	49	69	79	84
Non-Vegetated Urban	71	80	87	91
Upland Barren	77	86	91	94
Wetland Barren	68	79	86	89
Wetland Complex	85	85	85	85
Water	100	100	100	100

Loss rates. Loss rates are used to account for the amount of precipitation intercepted by the canopy and depressions on the land surface and the amount of precipitation that infiltrates into the soil. Precipitation that is not lost to interception or infiltration is called “excess precipitation” and becomes direct runoff. The Soil Conservation Service (SCS) Curve Number (CN) method was used to model interception and infiltration. The SCS CN method estimates precipitation loss and excess as a function of cumulative precipitation, soil cover, landuse, and antecedent moisture. This method uses a single parameter, a curve number, to estimate the amount of precipitation excess\loss from a storm event. Studies have been carried out to determine appropriate curve number values for combinations of landuse type and condition, soil type, and the moisture state of the watershed.

Table 4-2 was used to estimate a curve number value for each combination of landuse and soil type in the study area. The hydrologic soil group (A, B, C, or D) is one of the soil properties contained in the SSURGO database. The percent impervious cover is already included in the curve number value in Table 4-2. More information about the background and use in the SCS curve number method can be found in Soil Conservation Service (1971, 1986). Figure 4-2 and Figure 4-3 show landuse types and hydrologic soil groups, respectively, in St. Bernard Parish.

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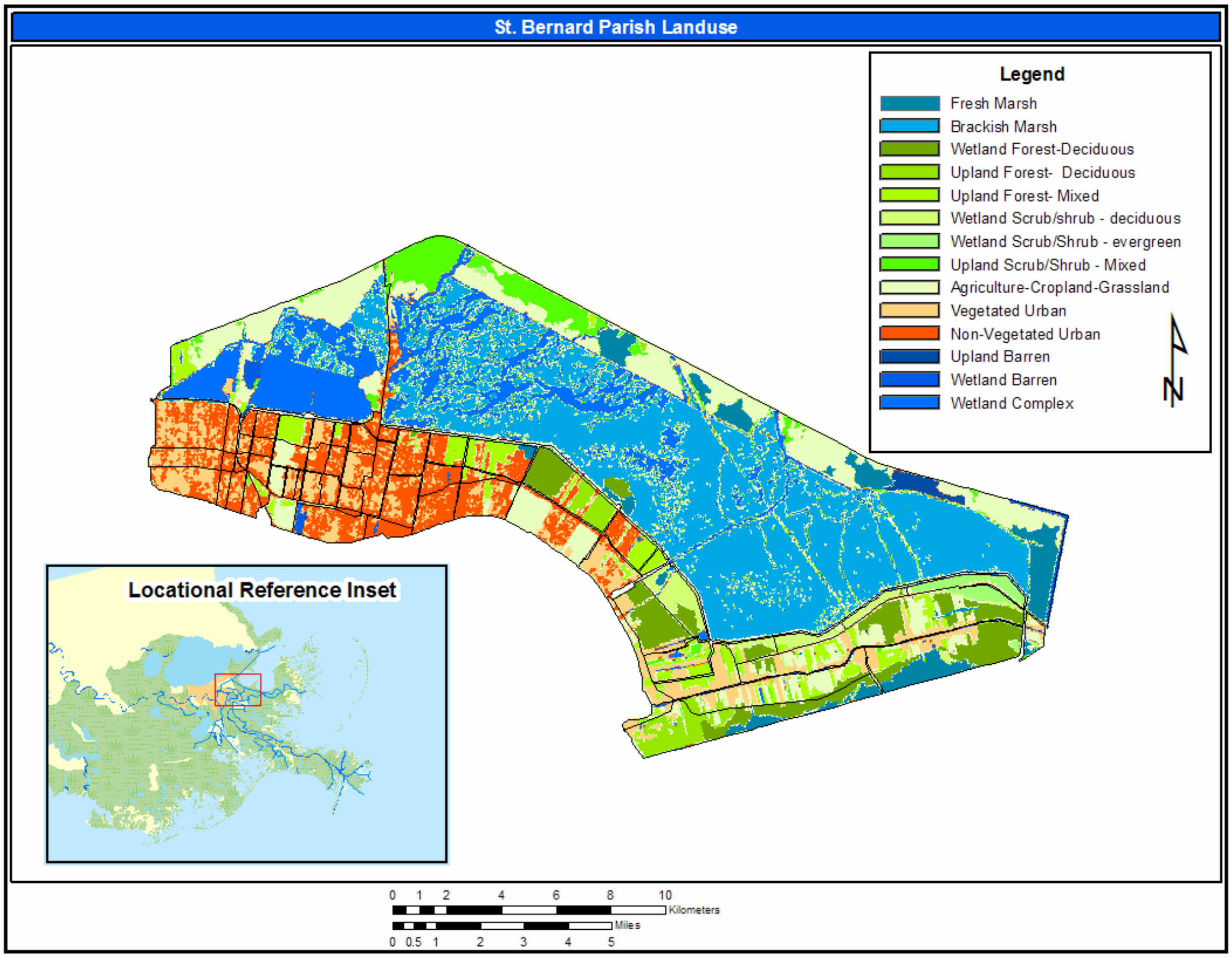

Figure 4-2. Landuse Types in St. Bernard Parish

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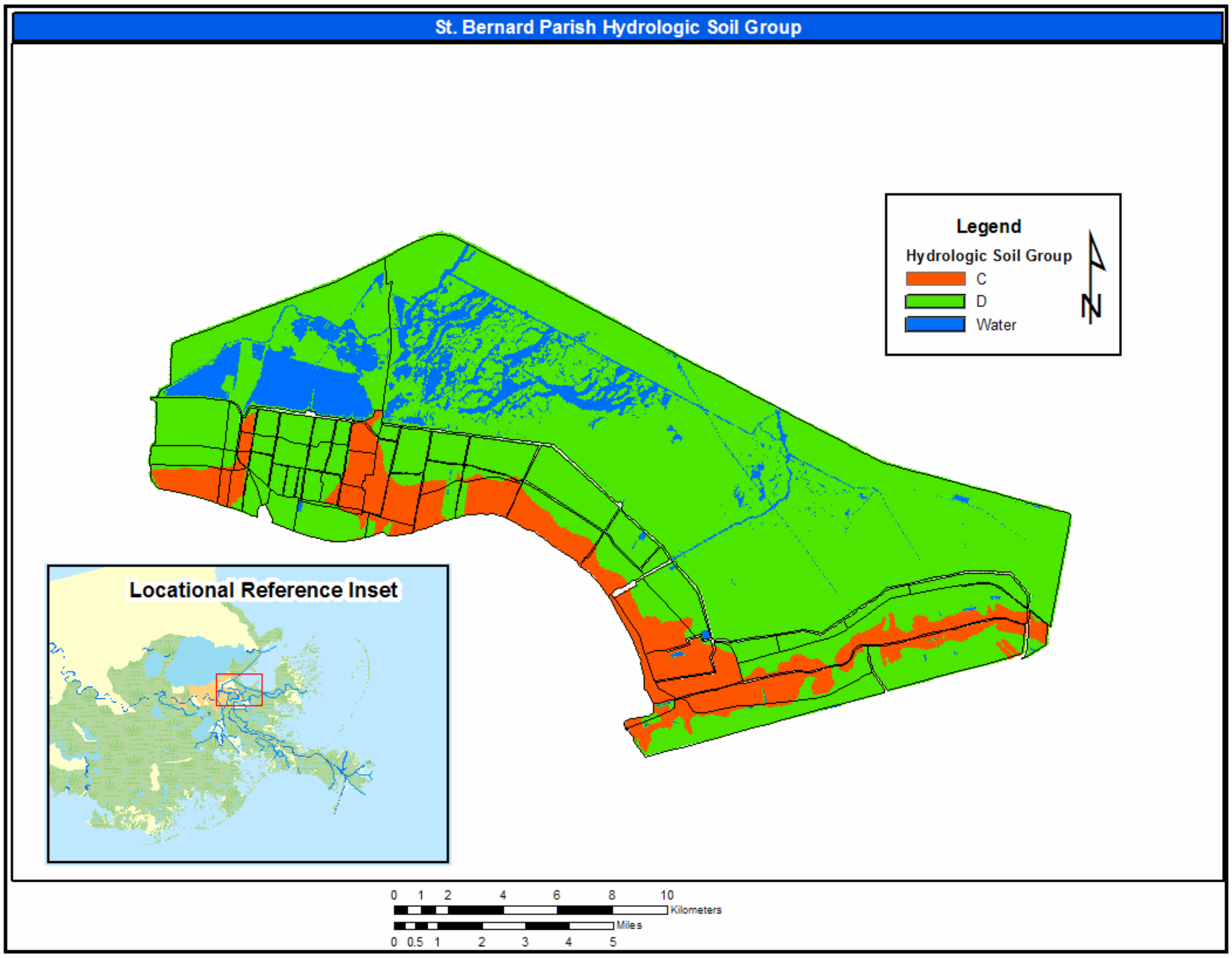

Figure 4-3. Hydrologic Soil Groups in St. Bernard Parish

The ArcGIS map calculator was used to create a raster coverage of curve numbers from these two data sets and the curve number lookup table (Figure 4-4). Subbasin average curve numbers were computed for each subbasin using the subbasin boundary shapefile and the curve number raster coverage (Table 4-3).

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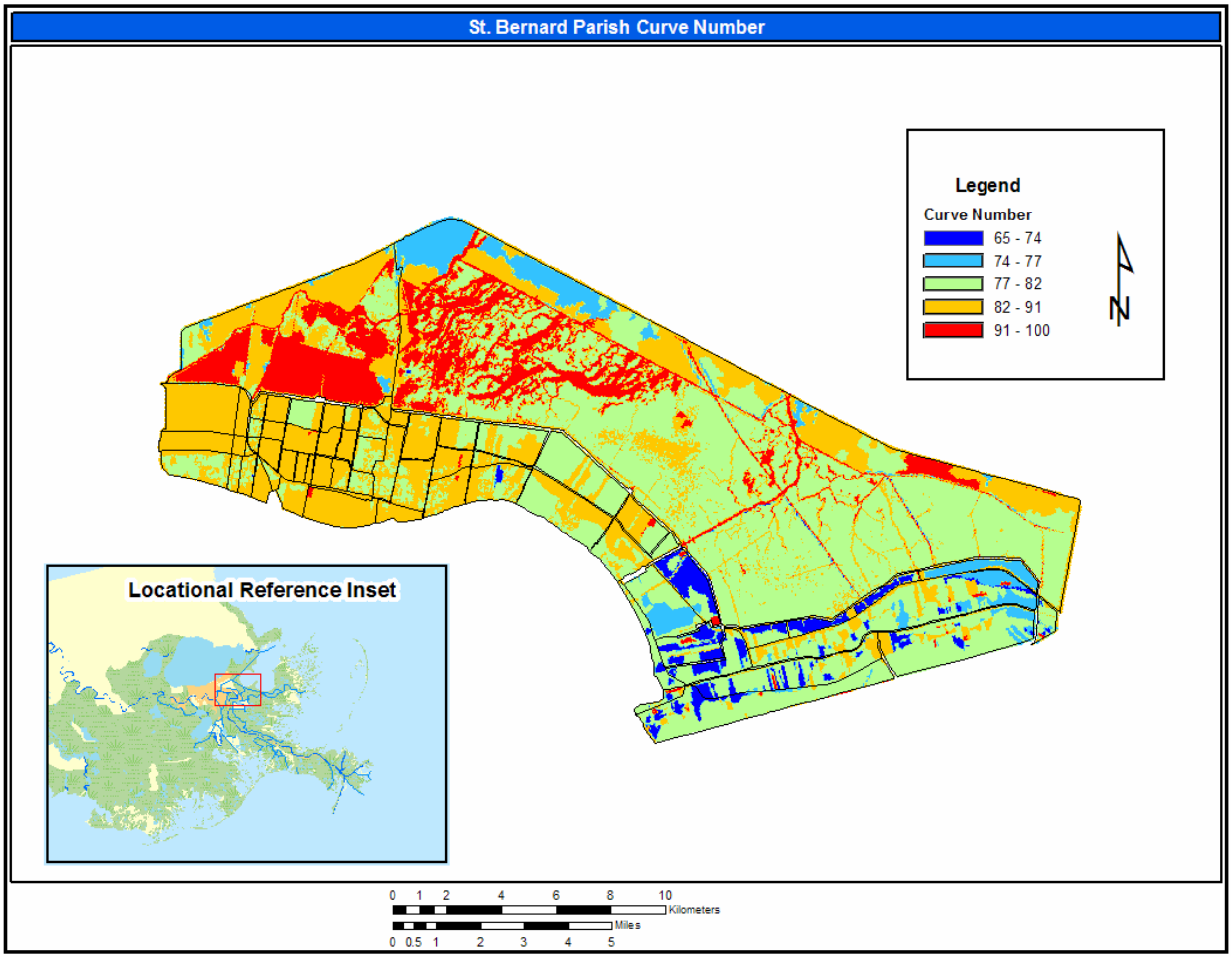

Figure 4-4. Curve Number Grid

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Table 4-3
Subbasin Average Curve Numbers

Subbasin Name	Subbasin Average Curve Number
340	77
341	76
343	80
344	78
345	79
346	79
347	81
348	77
349	77
350	80
351	78
352	80
353	79
354	80
355	80
42	84
43	90
45	89
46	84
51	85
56	88
63	84
64	82
65	82
66	83
67	86
68	80
852	87
853	84
854	88
855	87
856	85
857	84
87	86
88	82
89	86
SBD01	86
SBD02	84
SBD03	85
SBD04	87
SBD05	84
SBD06	83
SBD07	82
SBD08	85
SBD09	85
SBD10	87
SBD11	85
SBD12	85
SBD13	87
SBD14	84
SBD15	89
SBD16	82
SBD17	89
SBD18	89

(Continued)

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Table 4-3 (Concluded)

Subbasin Name	Subbasin Average Curve Number
SBD19	86
SBD20	88
SBD21	82
SBD22	88
SBD23	84
SBD24	86
SBD25	85
SBD26	82
SBD27	85
SBD28	87
SBD29	88
SBD30	85
SBDInd	88

Transform. Excess precipitation was transformed to a runoff hydrograph using the SCS unit hydrograph method. The SCS developed a dimensionless unit hydrograph after analyzing unit hydrographs from a number of small, gaged watersheds. The dimensionless unit hydrograph is used to develop a unit hydrograph given drainage area and lag time. A detailed description of the SCS dimensionless unit hydrograph can be found in SCS Technical Report 55 (1986) and the National Engineering Handbook (1971).

Lag times for the SCS unit hydrograph method were estimated using the following equation:

$$t_l = \frac{L^{0.8} * (1000 - 9CN)^{0.7}}{1900 * CN^{0.7} * Y^{0.5}}$$

where t_l is the subbasin lag (hr), L is the hydraulic length (ft), CN is the subbasin average curve number, and Y is the average subbasin land slope (percent). The hydraulic length was determined visually using topographic maps of St. Bernard Parish. Terrain Data, 30 meter DEMs, were used to compute the average land slope for each subbasin. Computed lag times are shown in Table 4-4.

Table 4-4
Computed Lag Times

Subbasin Name	Hydraulic Length (ft)	Average Subbasin Land Slope %	Lag Time (minutes)
340	795	0.2	40
341	1559	0.6	41
343	1986	0.6	42
344	913	0.6	24
345	6937	1.2	83
346	12089	3.0	85
347	4314	1.8	44
348	5929	0.5	118
349	8107	1.7	86
350	4332	0.8	71

(Continued)

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Table 4-4 (Concluded)

Subbasin Name	Hydraulic Length (ft)	Average Subbasin Land Slope %	Lag Time (minutes)
351	5701	0.7	95
352	9639	0.6	150
353	18790	0.4	337
354	1862	1.1	30
355	22441	0.5	333
42	45013	0.6	455
43	18467	0.7	167
45	1980	2.4	16
46	7087	1.3	68
51	2649	0.1	112
56	4368	3.3	26
63	3450	0.1	142
64	3468	0.1	154
65	3380	1.4	39
66	3359	1.8	34
67	2674	0.1	110
68	2738	2.4	27
852	4991	0.7	65
853	5260	0.9	64
854	4101	0.7	54
855	6414	1.2	60
856	1464	0.5	32
857	6810	1.4	66
87	11319	0.8	117
88	6470	1.5	64
89	6847	1.2	65
SBD01	6017	1.5	53
SBD02	4036	2.7	31
SBD03	3431	3.7	23
SBD04	4327	3.4	26
SBD05	3945	1.3	44
SBD06	3322	1.0	45
SBD07	2974	1.0	43
SBD08	3231	0.6	53
SBD09	3216	1.1	39
SBD10	2720	1.5	28
SBD11	2770	0.8	40
SBD12	3001	0.9	42
SBD13	3201	2.2	26
SBD14	1131	3.5	10
SBD15	2052	1.3	22
SBD16	3592	0.6	62
SBD17	3549	0.7	45
SBD18	2559	0.4	46
SBD19	3852	0.1	143
SBD20	2415	0.6	38
SBD21	1998	1.3	28
SBD22	4353	1.6	38
SBD23	3458	1.2	40
SBD24	2483	0.1	100
SBD25	2685	0.1	111
SBD26	3953	0.1	171
SBD27	1530	1.0	23
SBD28	2217	4.4	14
SBD29	2826	0.3	60
SBD30	2404	1.2	30
SBDInd	7114	2.1	48

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Rainfall Data

Radar rainfall data, referred to as Multisensor Precipitation Estimator (MPE), was used as a boundary condition in the hydrologic models to determine runoff hydrographs produced by the Hurricane Katrina event. MPE data from the Lower Mississippi River Forecast Center (LMRFC) was downloaded from the following website: http://dipper.nws.noaa.gov/hdsb/data/nexrad/lmrfc_mpe.php. Raw radar data is adjusted using rain gage measurements and possibly satellite data to produce the MPE product.

The radar-rainfall data was imported into a GIS program. The GIS program was used to compute subbasin average precipitation; the downloaded radar-rainfall data was a raster or gridded coverage of precipitation. Also, the downloaded radar-rainfall data provides hourly estimates of precipitation. A precipitation hyetograph was computed for each subbasin in the St. Bernard Parish basin models. The individual hyetographs were imported into an HEC-DSS file where they were read by HEC-HMS. Total rainfall from Hurricane Katrina varied from 7 to 12 inches across subbasin in St. Bernard Parish (Figure 4-5). The precipitation hyetograph for the subbasin 42 is shown in Figure 4-6. This figure shows the time distribution of rainfall from Hurricane Katrina.

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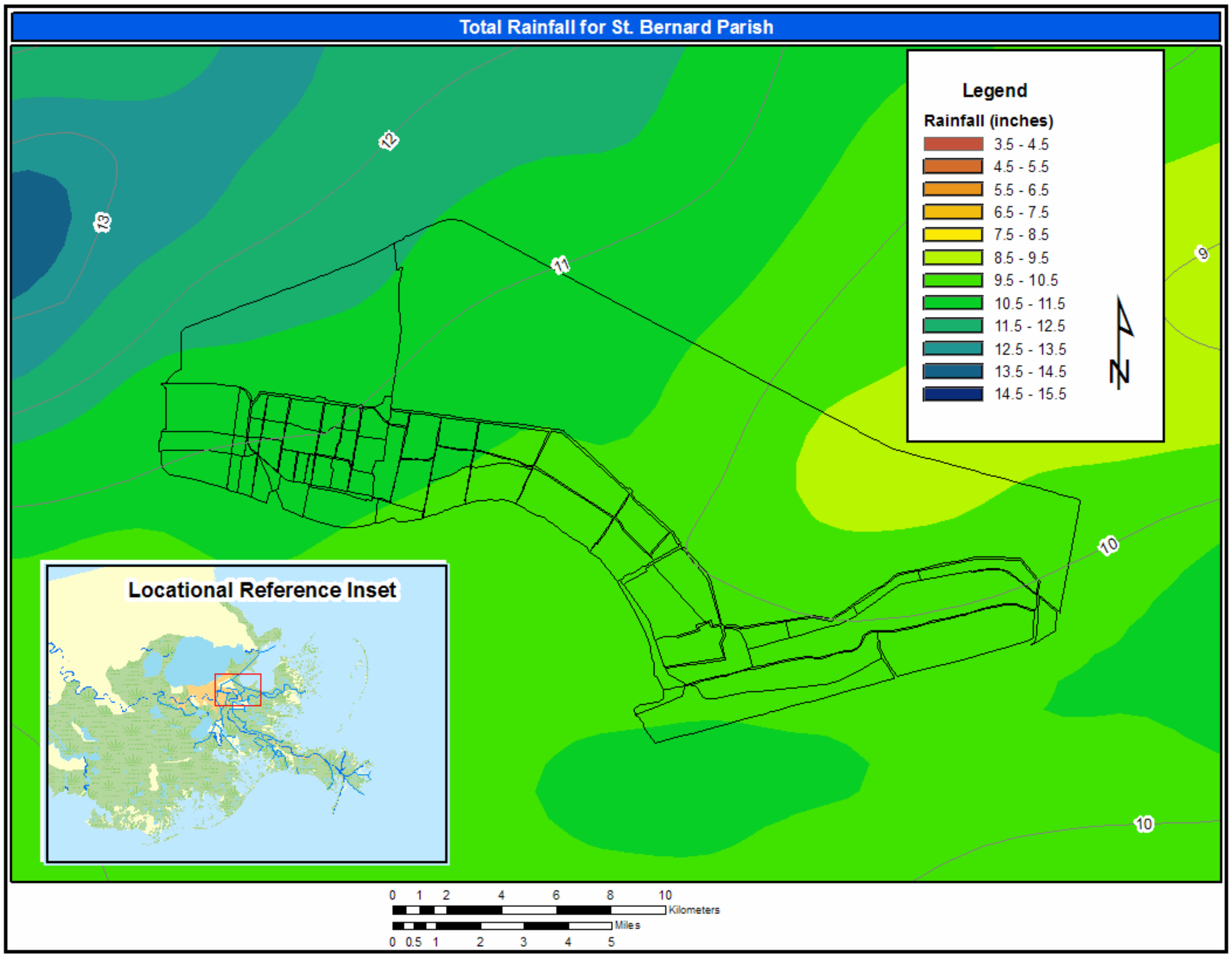

Figure 4-5. Total Storm Rainfall

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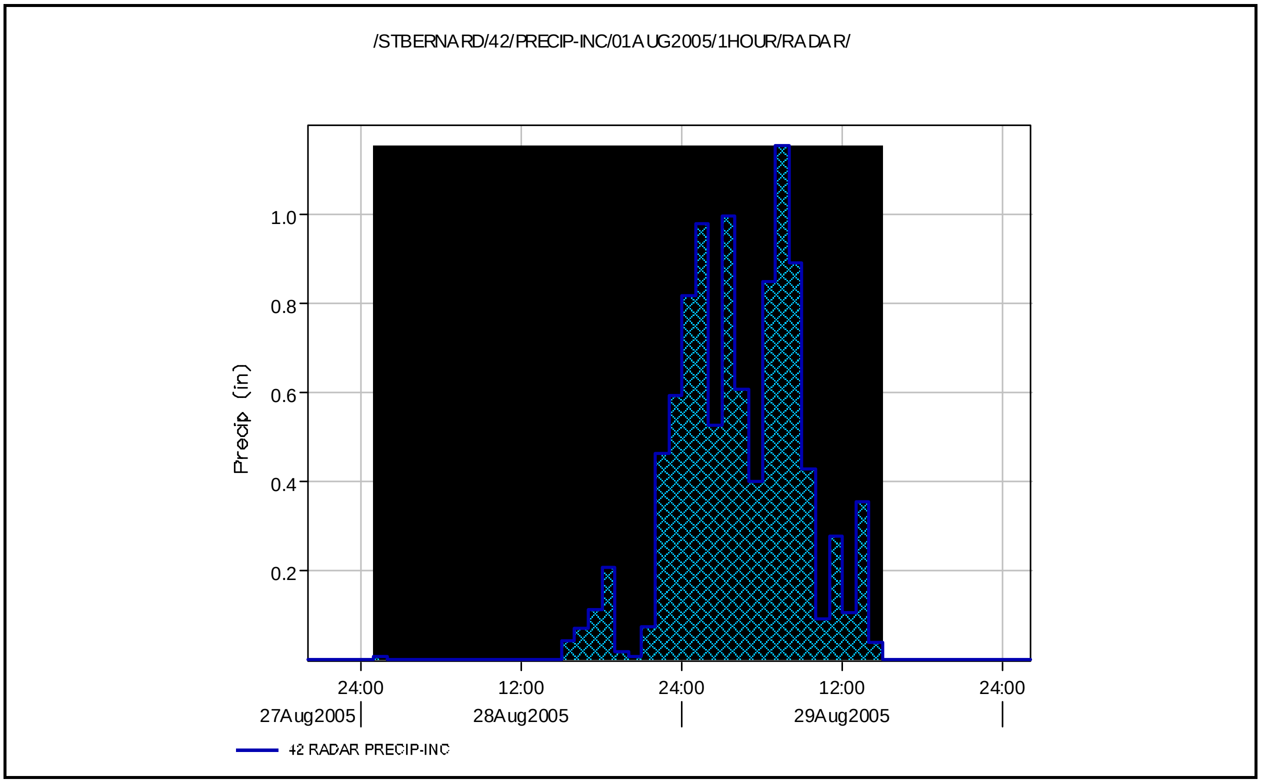

Figure 4-6. Average Rainfall for Subbasin 42

Model Results

Summary output from the HEC-HMS model is available in Table 4-5. A complete runoff hydrograph was also computed by the program. This information was stored in an HEC-DSS file and provided as a boundary condition for the HEC-RAS model of St. Bernard Parish.

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Table 4-5
Summary Output from HEC-HMS Model

Subbasin Name	Drainage Area (mi2)	Peak Discharge (cfs)	Time of Peak	Runoff Volume (in)
340	0.2100	118	29Aug2005, 08:12	6.9
341	0.2600	145	29Aug2005, 08:13	6.8
343	0.3000	172	29Aug2005, 08:13	7.3
344	0.4600	276	29Aug2005, 08:03	7.1
345	1.0000	504	29Aug2005, 09:32	7.3
346	0.3300	163	29Aug2005, 09:31	7.5
347	0.1400	75	29Aug2005, 09:09	8.3
348	0.6500	300	29Aug2005, 09:55	7.0
349	0.7400	364	29Aug2005, 09:34	7.0
350	2.0600	1015	29Aug2005, 08:43	8.2
351	0.6200	292	29Aug2005, 09:19	7.42
352	2.1300	873	29Aug2005, 09:23	7.42
353	1.4800	509	29Aug2005, 11:34	7. 8
354	0.2100	126	29Aug2005, 08:05	7.4
355	3.0400	1037	29Aug2005, 11:13	7.3
42	37.7900	13532	29Aug2005, 13:53	8.2
43	7.7600	5388	29Aug2005, 10:31	10.3
45	0.0900	76	29Aug2005, 09:00	9.5
46	0.4700	365	29Aug2005, 09:19	8.8
51	0.3600	241	29Aug2005, 09:50	8.8
56	0.2300	194	29Aug2005, 09:00	9.3
63	0.7000	385	29Aug2005, 10:11	8.3
64	1.1500	618	29Aug2005, 10:21	8.3
65	1.1900	789	29Aug2005, 08:26	8.1
66	0.6200	371	29Aug2005, 09:05	7.9
67	0.5000	297	29Aug2005, 09:52	8.9
68	0.1100	63	29Aug2005, 09:03	7.4
852	0.4700	372	29Aug2005, 09:16	9.2
853	0.5500	431	29Aug2005, 09:16	8.8
854	0.3200	260	29Aug2005, 09:10	9.3
855	0.4800	385	29Aug2005, 09:13	9.2
856	0.1400	97	29Aug2005, 08:15	8.5
857	0.6700	429	29Aug2005, 09:04	8.4
87	1.1600	894	29Aug2005, 09:48	9.3
88	0.6500	563	29Aug2005, 08:57	8.4
89	0.4600	407	29Aug2005, 08:57	8.9
SBD01	0.0700	59	29Aug2005, 09:08	9.1
SBD02	0.2800	259	29Aug2005, 08:24	8.9
SBD03	0.0900	84	29Aug2005, 08:11	9.1
SBD04	0.1800	170	29Aug2005, 08:15	9.3
SBD05	0.2000	181	29Aug2005, 09:01	8.9
SBD06	0.1300	117	29Aug2005, 09:01	8.8
SBD07	0.1800	145	29Aug2005, 09:06	8.6
SBD08	0.1800	150	29Aug2005, 09:08	9.0

(Continued)

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Table 4-5 (Concluded)

Subbasin Name	Drainage Area (mi2)	Peak Discharge (cfs)	Time of Peak	Runoff Volume (in)
SBD09	0.1800	165	29Aug2005, 08:43	9.1
SBD10	0.0600	56	29Aug2005, 08:18	9.3
SBD11	0.1100	100	29Aug2005, 08:47	9.1
SBD12	0.1500	137	29Aug2005, 08:58	9.1
SBD13	0.1800	170	29Aug2005, 08:15	9.3
SBD14	0.0500	47	29Aug2005, 08:01	8.9
SBD15	0.0800	77	29Aug2005, 08:10	9.6
SBD16	0.3000	233	29Aug2005, 09:15	8.6
SBD17	0.1700	141	29Aug2005, 09:06	9.5
SBD18	0.1700	155	29Aug2005, 09:01	9.6
SBD19	0.2700	192	29Aug2005, 10:13	9.2
SBD20	0.1300	121	29Aug2005, 08:38	9.4
SBD21	0.0800	73	29Aug2005, 08:19	8.7
SBD22	0.1800	169	29Aug2005, 08:29	9.6
SBD23	0.2200	180	29Aug2005, 09:04	8.8
SBD24	0.1200	86	29Aug2005, 09:41	9.1
SBD25	0.1700	128	29Aug2005, 09:49	9.1
SBD26	0.3000	196	29Aug2005, 10:35	8. 8
SBD27	0.0300	28	29Aug2005, 08:11	9.1
SBD28	0.0900	77	29Aug2005, 08:02	9.5
SBD29	0.1800	162	29Aug2005, 09:06	9.7
SBD30	0.1000	95	29Aug2005, 08:17	9.3
SBDInd	0.7300	634	29Aug2005, 09:05	9.4

RAS Interior Modeling

Background

The leveed areas of St. Bernard Parish and the Lower Ninth Ward of Orleans Parish are subject to ponding of runoff and shallow flooding due to inadequate subsurface drainage and the sheet flow associated with overland travel of excess water that cannot enter the subsurface system. This excess water collects in depressions and may remain trapped between roadways for hours or even days before finally being carried away by the drainage system. Extreme tropical storm events overwhelm the flood protection system through wave-overtopping, free-flow over the line of protection, and structural failure of the levees.

Datum Reconciliation

Various sources of data were used to construct the model. The U.S. Army Corps of Engineers New Orleans District used the Area 1 model constructed by the New Orleans District for the St. Bernard Parish Flood Control Project in 2003-2004. The Area 1 model is bounded by the Orleans-St. Bernard Parish line to the west, the 40 Arpent Canal to the north, the Mississippi River to the south, and LA Hwy 47 (Paris Road) to the east. The original model was constructed from surveys taken for the above study. The surveys were taken in NAVD88 1994, 1996 EPOCH so no transformation was done. The results of the model are also in NAVD88 1994, 1996. For the rest of the study area, the topographic data was taken from the LIDAR surveys discussed below. Surveys for the remaining channels in Areas 2 and 3 were not available in time to be included in the model. Channel cross sections were based on aerial photography, site visits, the Master Drainage Plan, and interviews with Lake Borgne Levee District personnel.

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Terrain Model

The primary source of topographic data in the ponding areas were LIDAR surveys of South Louisiana taken for the Federal Emergency Management Agency in 2004. The data collected during these LIDAR surveys were processed using Geographic Information System (GIS) technology to produce the stage-volume curves for each of the 67 storage areas in the study area. Additional information from visits to the site was used to supplement data obtained from the LIDAR surveys.

No LIDAR data was published for the Martello Castle NE quarter quad. Terrain was derived from other data sources. In particular, intensity values from a high-resolution photo of Martello Castle NE were used and the color intensity values were mapped to a range of elevations from a small area of neighboring LIDAR. After plotting inundation mapping it became apparent that the terrain data generated for this area did not match adjoining terrain. Searches for additional terrain data have been fruitless. Therefore, the derived terrain data was left in the model

Basic Geometric Data using GIS

The LIDAR data set was used to set the heights of the drainage divides, such as levees, roads, and railroad grades, for the RAS model. It was also used in determining the heights of the lateral weirs that connect the storage areas to the drainage canals or reaches. As described above, data was obtained from various sources. Levee profiles in RAS were constructed using LiDAR data flown for the New Orleans and vicinity levees after Hurricane Katrina. Breach location, size, and depth were from this same data set and from data provided by the IPET floodwall and levee performance team. The compilations of data sets, as described above, were used as a basis to put the model together. Cross sections were taken from the individual models.

The Area 1 model was not originally georeferenced. HEC-RAS was modified by engineers at the Hydrologic Engineering Center in Davis, California to employ common georeferencing tools. The new tools enabled movement of the cross section within RAS. By putting an image behind the model, identifiable features i.e., bridges, culverts, structures, were used to move the cross sections spatially to align with the image in turn geo-referencing the model. This was done on a reach by reach basis. After the reaches were georeferenced, the storage areas were imported from the Geo-RAS import file and automatically placed correctly spatially. Geo-referencing the model was necessary so inundation mapping could be done.

The Lower Ninth Ward, Orleans Parish, was done using drainage maps provided by the New Orleans Sewage and Water Board (NOSWB) of the sub-surface system and the above LiDAR data set. The remaining St. Bernard Parish from LA Hwy 47 to the Chalmette Loop levee was done using LiDAR and the St. Bernard Master Drainage Plan completed by the Louisiana Department of Transportation and Development (LADOTD) in 1992 for the Lake Borgne Levee District. The Master Drainage Plan surveys are in NGVD1929 1984 EPOCH. The surveys were transformed to NAVD88 1996 EPOCH before coding them in to the RAS model.

A survey request was issued by the Interior Modeling Team to the Geodetic Vertical Survey Assessment team. The request was for canal surveys of the remaining area of St. Bernard. Because of the devastation by Hurricane Katrina and because a large number of the channels

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were filled in from the surge, the surveys weren't received in time to use in the model. After the surveys were received, a cursory review was done to insure the data used from the Master Drainage Plan coincided with the surveys. Most surveys were done at structures so comparisons were done to bridges, culvert sizes and numbers. In places where the surveys differed from the Master Drainage Plan, adjustments were made to the model.

Inundation maps showing the hurricane Katrina event and an updated and more resilient, non-breached system were generated.

Manning's *n*-Values

The Manning's *n*-value used for an earthen channel was .05 to .03 with .04 being the most common value used. For concrete lined channels and culverts the Manning's value used was .018 to .012 with .015 being the most common value used. These values were used consistently throughout the study area.

Bridges

Bridges and box culverts were analyzed as part of the HEC-RAS model for the whole basin. HEC-RAS computes flow through the modeled bridge or culvert using the Bernoulli or Energy Equation. Entrance and exit losses are also computed using coefficients input for each structure. Bridge losses were determined in two ways: (1) Through direct observation and (2) the application of the HEC-RAS model to duplicate observations. Hydraulic losses in large concrete box culverts and arch pipes were computed using entrance and exit loss coefficients recommended in the HEC-RAS Reference Manual. These were 0.3 to 0.5 and 0.5 to 1.0 respectively, depending on what local conditions require.

Ineffective Flow Areas

Ineffective flow areas were set for bridges and culverts to simulate the slack water found in the contraction and expansion of the channel upstream and downstream of the structure. Many of the structures in this model are almost as wide as the canals; therefore no ineffective flow areas were placed on the cross sections outside of these structures.

Storage Areas

The study area was divided up into 67 storage areas. LIDAR data was used to determine the stage-volume relationship for each storage area by extracting it from the GIS data set using GeoRAS. The storage areas were defined by the drainage divides such as roads, railroad embankments, drainage canals, and/or levees. As mentioned previously, storage areas were hydraulically connected to the canals by using lateral weirs. Storage areas were interconnected to each other with a weir, weir and culverts, or using the HEC-RAS linear routing option.

Lateral Structures and Storage Area Connections

For the weirs connecting storage areas to the canals, weir coefficients of around 1.0 were used. These values are lower than one might think of for a traditional lateral weir that is

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designed to remove flow from a stream to an overbank area. However, lateral weirs as used in this model are to allow water in a storage area to flow overland and get into the canals. This is not really a physical weir situation, and therefore using traditional weir coefficients would transfer the water too quickly from the storage area to the canal. It has been found through experience and model calibration with other models that values around 1.0 seem to provide the appropriate transfer of flow between the canals and the storage areas. Also, for these events modeled, the canals fill up very quickly, and they end up going up in elevation with the storage area elevation changes. The lateral weirs end up being submerged and only passing the necessary flows to fill the small canals to the elevations in the storage areas.

Weir coefficients for storage area connections that represent high ground between storage areas were set at more traditional values around 2.6 to 3.0, depending on the shape of the overflow area. In a few areas these coefficients were lowered for calibration purposes. Model calibration is discussed further later in this appendix.

Linear routing coefficients were set to values ranging from 0.1 to 0.2 for the storage area connections in which linear routing was used. The linear routing equation is as follows:

$$Q = k\left(\Delta S\right)/Hour$$

where:

Q = Flow

k = Linear Routing Coefficient (Varies from 0.0 to 1.0)

ΔS = Available Storage (Difference in head times the surface area of receiving storage area)

Because equation computes a rate per hour the magnitude is divided by the time step to get flow per time step. User must also enter a minimum elevation for flow to pass between storage areas. If both storage areas are below this elevation no flow is exchanged. If one storage area has a stage greater than the minimum elevation, the head difference is the elevation of the storage area minus the user entered minimum elevation for passing flow.

Levees

The line of protection from storm events is comprised of floodwalls and earthen levees. Primary levee locations were selected from LiDAR data. Additionally, data was available which showed footprints of the back levees, but not their elevations. The levee elevations in the RAS model are, consequently, a combination of the LIDAR elevations for the primary levees and general elevation information gleaned from the LSU terrain files for the back levee elevations. Because the levees are such a key piece of information to the results of this model, one recommendation for model improvement would be to have a detailed top of levee profile survey performed for all exterior and interior levees.

Pump Stations

This area is drained by 9 pump stations, one in Orleans Parish operated by the New Orleans Sewerage and Water Board (NOS&W) and the balance by the Lake Borgne Levee District. All

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of the pump stations with the exception of St. Mary P.S. 8 discharge into the Bayou Bienvenue and Bayou Dupre sump area that is between the Mississippi River Gulf Outlet (MRGO) Hurricane Protection Levee and the Forty Arpent Levee. The Bayou Bienvenue and Bayou Dupre sump area drains by gravity into Lake Borgne through two flood control gates. The St. Mary pump station discharges into the Lake Lery basin that is located south of the study area.

In the RAS model it was attempted to model the pump operation as close to what actually occurred as possible, such as power failures caused by power outages and flooding. Modifications to the pump operation as described by IPET Task 8 consist of slightly altering the start elevation of some of the pump stations and staggering the turning on the pumps as the flow increases for all of the pump stations. These modifications were made for model stability purposes. Further information on the operation of the pump stations is described in appendix & of this Volume. A list of the pump stations that drain this area is shown below in Table 4-6.

Table 4-6
Pump Station Information

Pump Station Name	Pump From	Pump To	Capacity (cfs)
Orleans P.S. # 5	Lower Ninth Ward	Bayou Bienvenue	2260
P.S. # 1 Fortification	Area 1	Bayou Bienvenue	1254
P.S. # 6 Jean Lafitte	Area 1	Bayou Bienvenue	1002
P.S. # 2 Guichard	Area 1	Bayou Bienvenue	724
P.S. # 3 Bayou Villere	Area 2	Bayou Bienvenue	500
P.S. # 7 Bayou Ducros	Area 2	Bayou Bienvenue	1002
P.S. # 4 Meraux	Area 2	Bayou Dupre	1203
P.S. # 5 E.J. Gore	Area 3	Bayou Dupre	660
P.S. # 8 St. Mary	Area 3	Lake Lery	837

Storm Drain System

The drainage system for St. Bernard Parish consists of many features that are typical of large urban cities in the United States, and some features that are unique because much of the area is below sea level. As in any urbanized area, catch basins and drop-inlets receive surface runoff from yards and streets, and excess runoff runs down slope in the streets and/or overland to areas of lower elevation. Runoff that can enter drop-inlets proceeds underground in small pipes, 21 inches or less in diameter, called the tertiary system that collect local flows and convey them to the secondary system, 21 inches to 30 inches in diameter, where several of these local flows combine. Generally pipes or box culverts that are larger than 30 inches in diameter are considered to be part of the secondary system. The primary drainage system is almost entirely composed of man-made mainly prismatic trapezoidal open channels, except for the portion of Orleans Parish (the lower Ninth Ward) that is a part of this model. The Lower Ninth Ward is

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comprised entirely of enclosed culverts. The primary drainage system and the drainage pump stations were modeled in the HEC-RAS Unsteady model.

Flow Data and Boundary Conditions

The rainfall-runoff hydrographs developed by the HMS model were applied to the appropriate storage area as inflow hydrographs. The upstream boundary condition for the internal drainage canals was a minimal flow condition that was considered the base flow condition. That flow was determined by running the model with the minimum flow that was possible to run. The pump stations act as internal boundary conditions. The upstream and downstream boundary conditions for the external reaches were based on the hydrographs produced by the ADCIRC program representing the stages for Katrina. These were modified where there was additional data in the form of surveyed high water marks. The ADCIRC modeling results were entered as stage hydrograph boundary conditions in HEC-RAS. The external reaches containing the ADCIRC modeling results were connected to the interior storage areas via lateral weirs (called lateral structures in HEC-RAS). The lateral structures were input as the station and elevations along the tops of the exterior levees. These lateral structures were used to model levee overtopping and levee breaches that occurred during the Hurricane Katrina event.

Levee Overtopping and Breaching

The exterior levees suffered extensive damage from breaching and overtopping during the storm. In the RAS model this was represented by 13 different breaches totaling approximately 39000 feet distance along the IHNC (Inner Harbor Navigation Canal), GIWW (Gulf Inner Coastal Waterway), and the MRGO (Mississippi River Gulf Outlet). Exterior stages were high enough to overflow the levees and floodwalls at locations along the MRGO and the IHNC. The total peak overflow was determined from analyses performed by the High Resolution Hydrodynamics team. The overflow analysis was broken into the freeflow component and wave overtopping component. For the St Bernard analysis, all levees were assumed to be at their pre-Katrina and no breaches were considered. The RAS model was run with no breaching using the unmodified ADCIRC exterior stage hydrographs to come up with the peak freeflow component. The peak freeflow component was then subtracted from the total peak overflow to determine the wave overtopping component. The computed wave overtopping component was then compared with the wave overtopping rate using the ACEs (Automated Coastal Engineering System) program along with the STWAVE parameters for peak conditions. Based on this analysis it was determined that the wave overtopping component comprised as much as 28% of the total overflow into St Bernard Parish.

Total calculated volume percentages of flow entering St Bernard Parish are tabulated in Table 4-7.

Table 4-7
Calculated Inflow Volume Percentages into Plaquemines

Total Volume	Percent

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	Rainfall	Breaches	Overtopping
429,000	8	63	29

Model Calibration

The 100-year synthetic frequency-based rainfalls of 24 hours duration were initially applied to the model and flood conditions were determined for the watershed. The results of this model run were used as an initial calibration/verification based on knowledge of the 100 year storm in the area. The Katrina event was then run through the model. Further calibration of the model was performed for the Katrina event in order to get the model to reproduce observed high water marks and eyewitness accounts of the timing and height of the flooding.

The HEC-RAS model is being driven externally using stage hydrographs from the ADCIRC model. Therefore, the accuracy of the interior stage computations depends largely on the accuracy of the boundary conditions provided by the ADCIRC results. After the model was completely put together, and the ADCIRC model results were applied as exterior boundary conditions, it was found that not enough volume of water was getting into the St. Bernard interior area. Almost all of the computed water surfaces were lower than the observed high water marks. During the calibration phase, the ADCIRC stage boundary conditions were adjusted to better match observed high water marks on the exterior sides of the levees and the amount of time the levees and floodwalls took to breach were adjusted. These adjustments greatly improved the calculations of the amount of water overtopping the levees and going through the breaches. This single change provided the greatest amount of improvement in the model matching high water marks and computing the volume of water entering the interior area more closely to what was observed. This change was applied to the areas that were not subjected from direct wave attack. For the areas that were subjected to direct wave overtopping the unmodified ADCIRC hydrograph was used along with the calculating the wave overtopping using the wave parameters from the STWAVE program as described in the Levee Overtopping and Breaching paragraph.

The interior area flood heights were verified through surveyed high water marks and eyewitness accounts of what happened during the flooding. The model was considered to be calibrated when the computed maximum water surface elevations were within a reasonable range of the observed high water marks. Listed in Table 4-8 are computed stages versus observed high water marks for several of the key locations in the model (All elevations are shown in the NAVD88 1994, 1996 datum). The locations are described by the corresponding storage area name used in the HEC-RAS model.

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Table 4-8
Computed Elevation Versus Observed Elevation

HEC-RAS Storage Area	HEC-RAS Computed Elevation	Observed Elevation
SA351	10.2	10.8
SA853	9.7	10.3
SA46	9.7	9.9
SA30	10.0	9.9
SA5	10.7	11.0
SA64	10.4	10.5

Flooding in this area was from predominately two directions. From the west through the overtopped and then collapsed IHNC floodwall into the lower Ninth Ward and from the northeast over the collapsed MRGO levees and eventually over the Forty Arpent levee into the developed areas of St. Bernard Parish.

Model Results and Floodplain Mapping

The model reproduced the Hurricane Katrina event within reasonable tolerances. The floodwall collapse along the IHNC, levee breaching, and surge and wave overtopping along the MRGO resulted in the almost total inundation of this area. The RAS model was able to replicate the inundation.

The model results showing the extent and depth of flooding for Katrina are shown in Figure 4-7.

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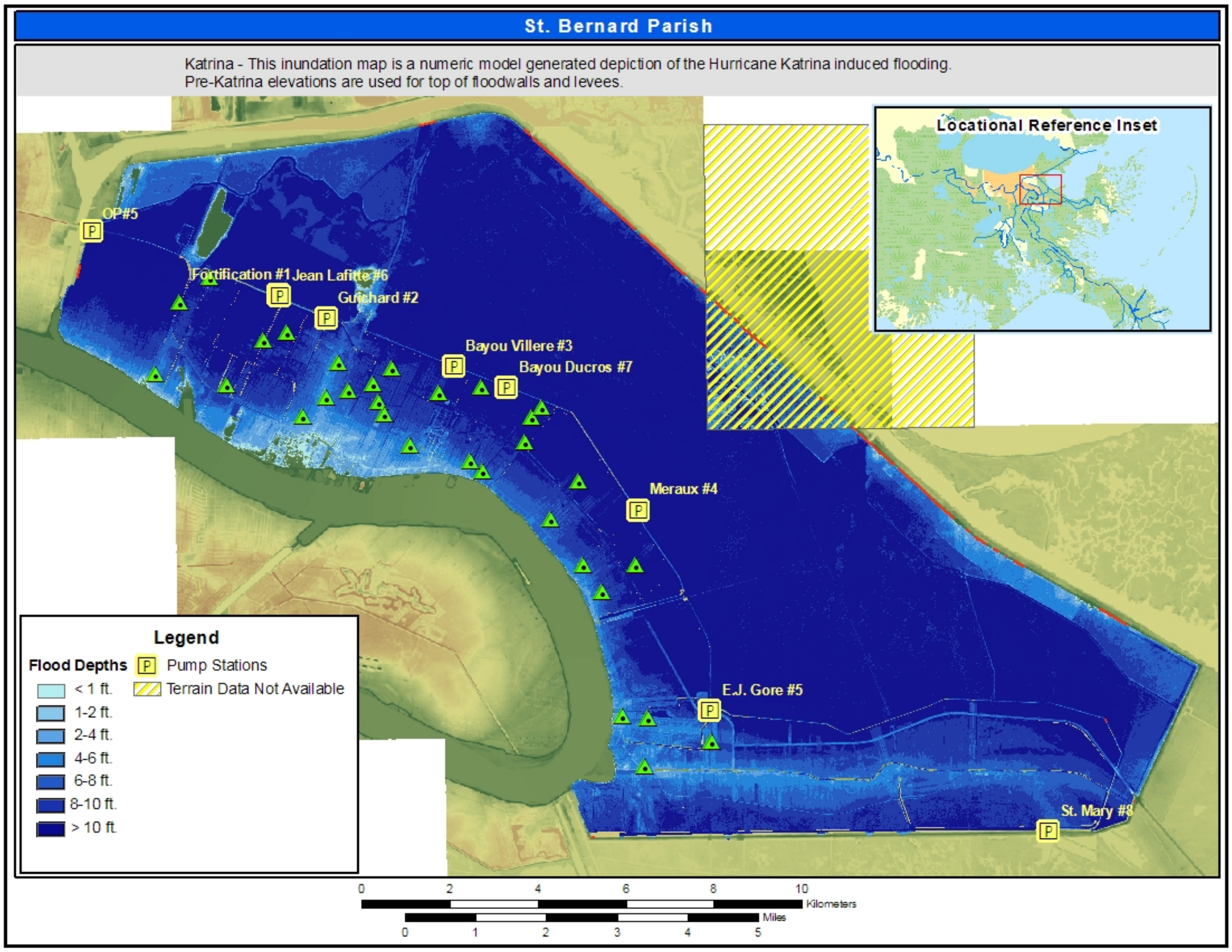

Figure 4-7. Maximum Flood Depths from Katrina Event

The Geodetic Vertical Survey Assessment team collected high water marks in the area. Several teams were sent out to the area shortly after the water receded to locate and set the marks. Other teams were then sent out to "survey in" those marks. There is indication that two types of high water marks were taken. The first being what the initial team perceived as being the ultimate high water. That's shown in the plots below when the peak of the hydrograph coincides with the high water mark. The second being the "settled out" high water. That's indicative by the hydrograph matching the high water mark several hours after the peak. The hydrographs shown are of the first type.

A comparison between the computed stage hydrograph and the observed high water mark for Storage Areas 5 and 64 for the Katrina scenario are shown in Figures 4-8 and 4-11. The computed flow hydrograph for the two sample storage areas for the Katrina scenario are shown in Figures 4-9 and 4-12. Figures 4-10 and 4-13 show the computed stage and flow hydrographs for Storage Areas 5 and 64 for the Katrina scenario.

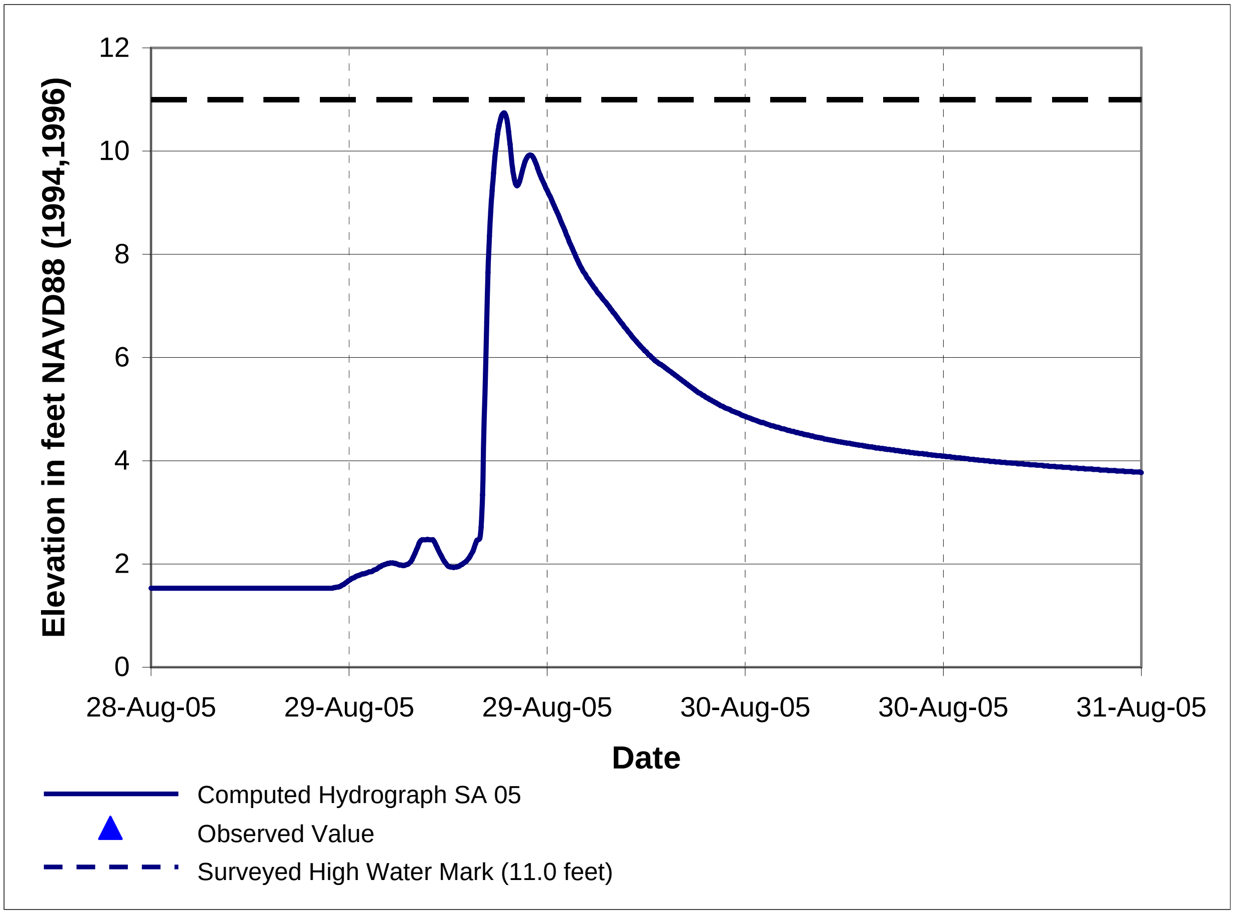

Figure 4-8. Computed Stage Hydrograph for Storage Area 05 for Katrina Simulation

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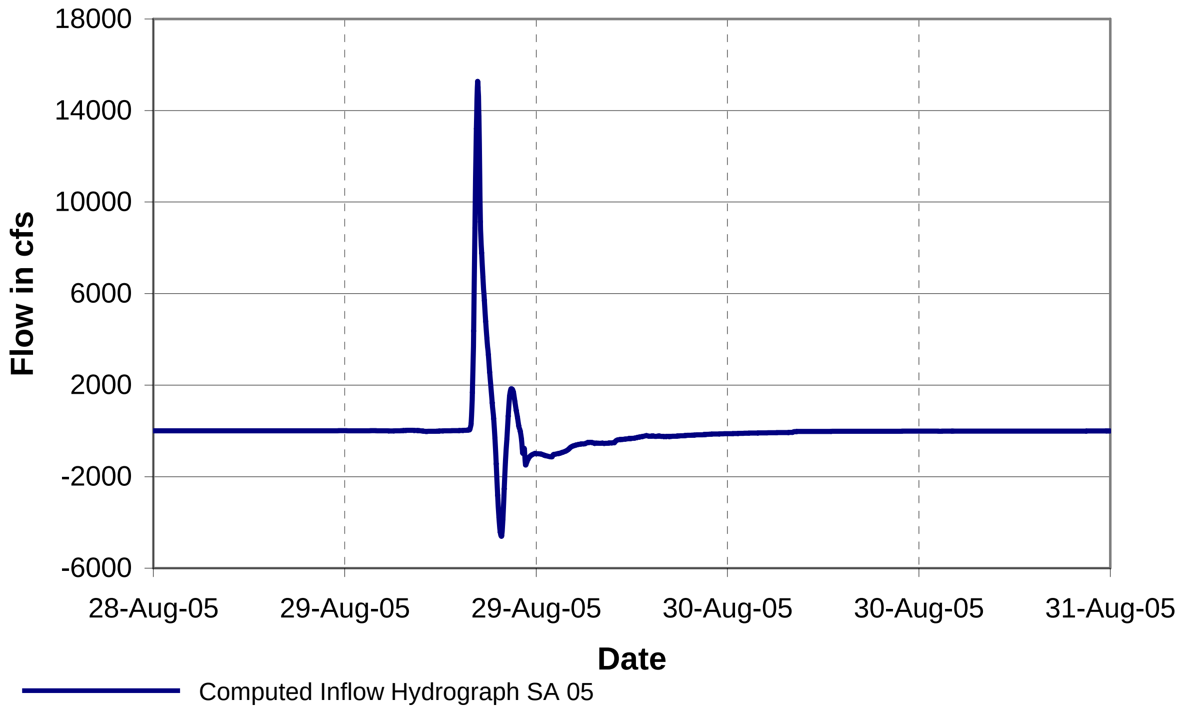

Figure 4-9. Computed Inflow Hydrograph to Storage Area 05 for Katrina Simulation

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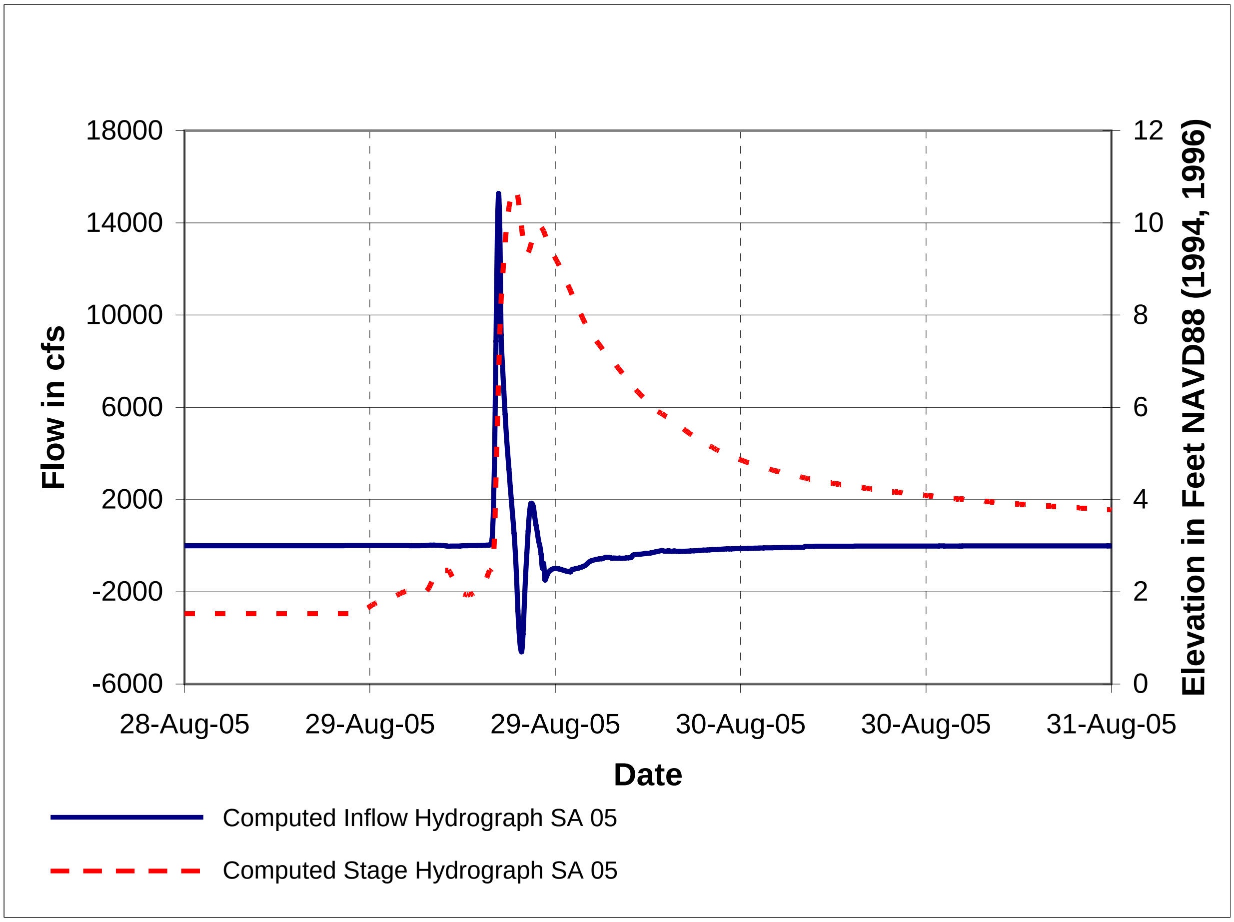

Figure 4-10. Computed Stage and Flow Hydrographs for Storage Area 05 for Katrina Simulation

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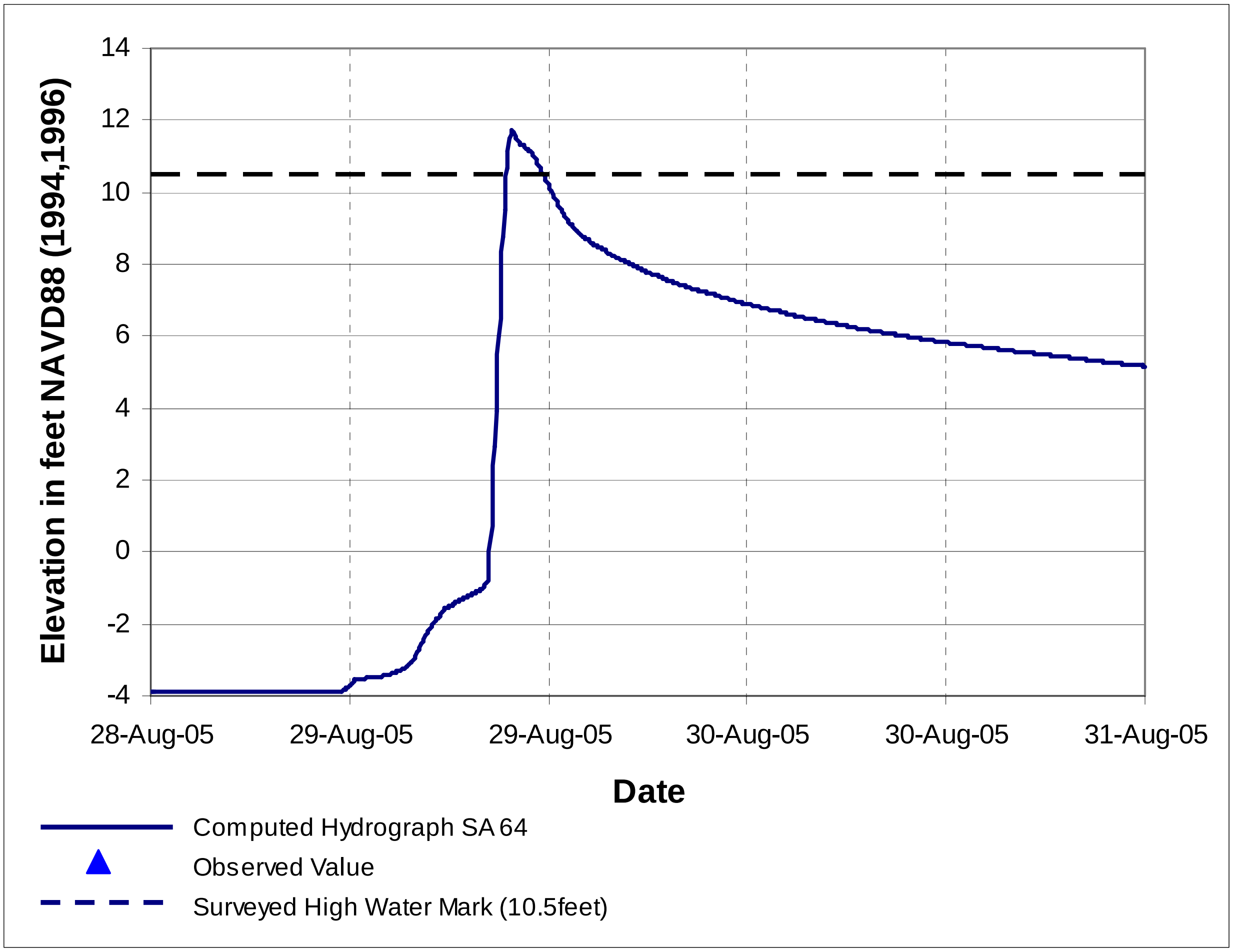

Figure 4-11. Computed Stage Hydrograph for Storage Area 64 for Katrina Simulation

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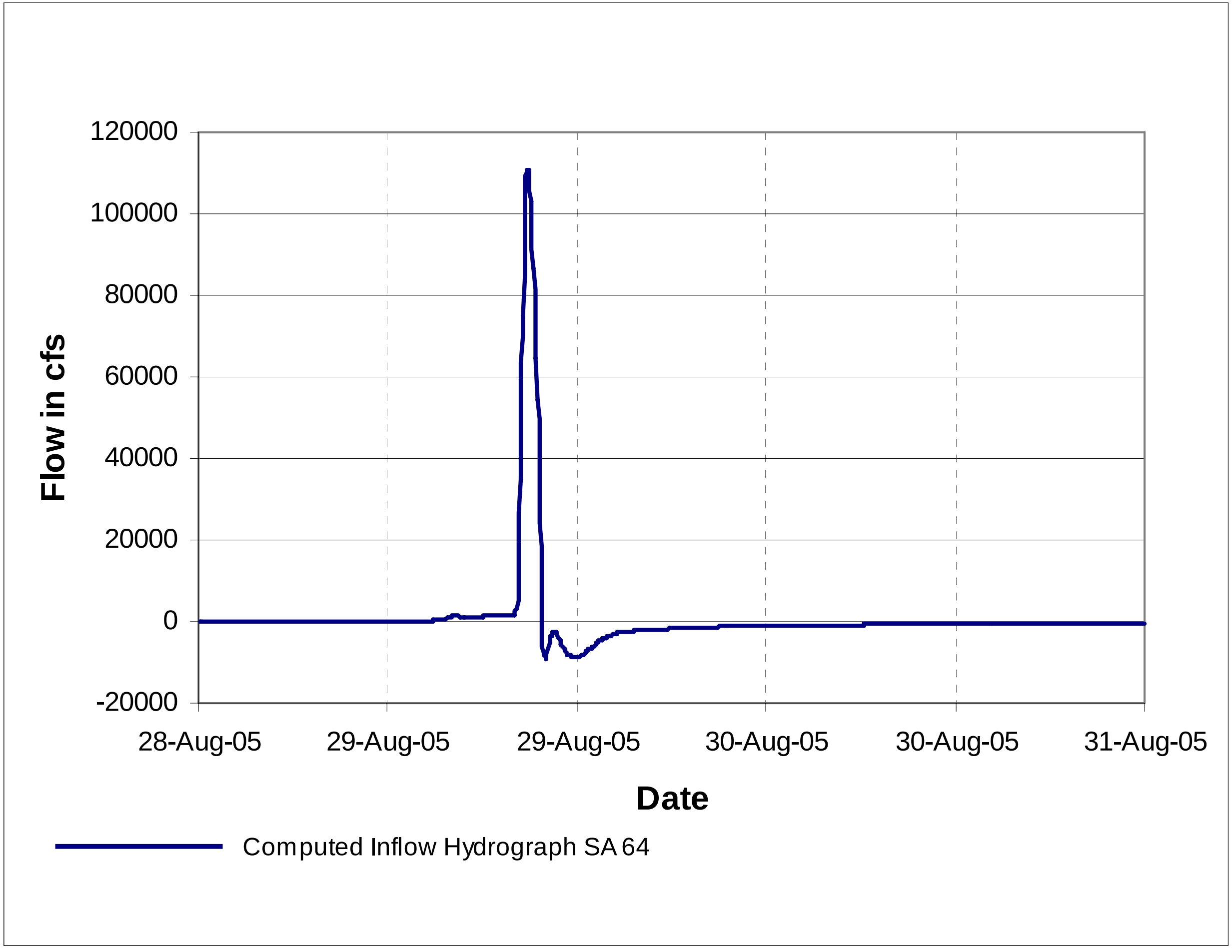

Figure 4-12. Computed Inflow Hydrograph for Storage Area 64 for Katrina Simulation

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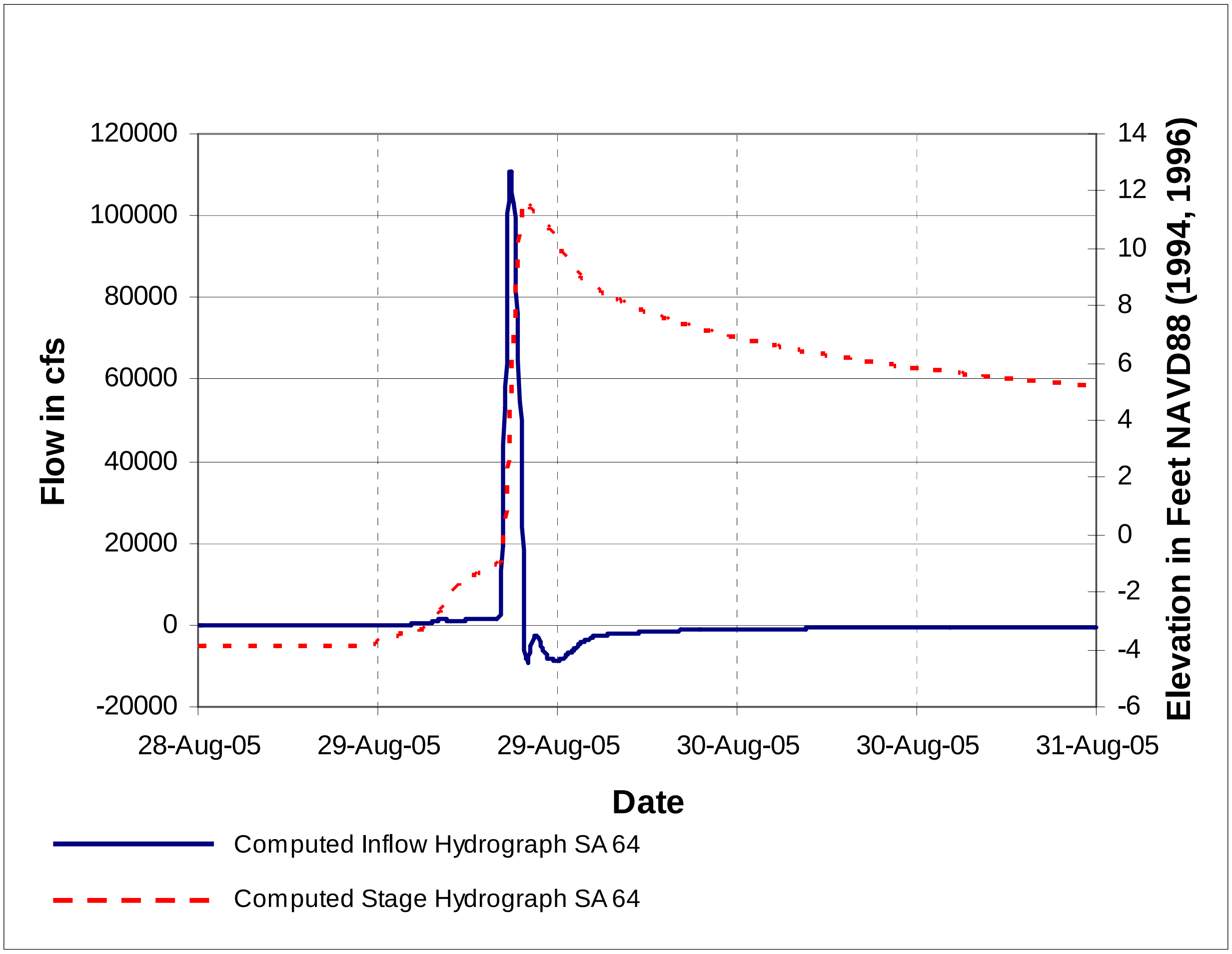

Figure 4-13. Computed Stage and Flow Hydrographs for Storage Area 64 for Katrina Simulation

Figure 4-14 shows depth of flooding due to the Hypothetical 1 scenario and Figure 4-15 shows depth of flooding for the Hypothetical 2 scenario. Table 4-9 shows a comparison of stages for the three scenarios for St Bernard. The inundation resulting for Hypothetical 3 matches the Katrina inundation.

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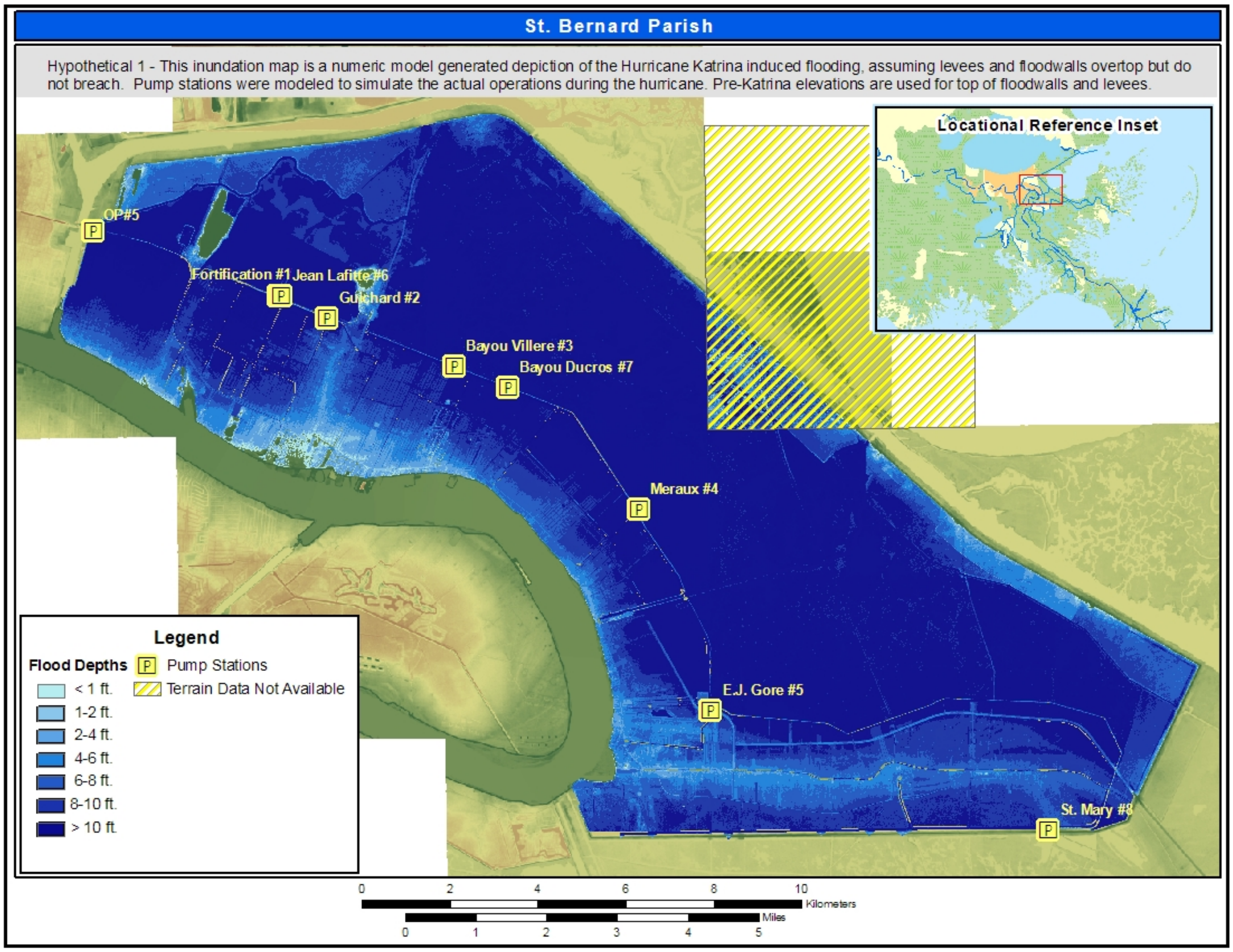
Table 4-9
Computed Stages for Katrina, Hypothetical 1 and Hypothetical 2

HEC-RAS Storage Area	Katrina	Hypothetical 1	Hypothetical 2
SA351	11.3	6.9	6.9
SA853	10.8	3.9	4.3
SA46	10.8	3.9	4.3
SA30	10.8	3.8	2.7
SA5	11.0	5.6	5.3
SA64	11.9	4.0	4.3



Hypothetical 1 - This inundation map is a numeric model generated depiction of the Hurricane Katrina induced flooding, assuming levees and floodwalls overtop but do not breach. Pump stations were modeled to simulate the actual operations during the hurricane. Pre-Katrina elevations are used for top of floodwalls and levees.

Figure 4-14. Depth of Flooding from Hypothetical 1 Scenario

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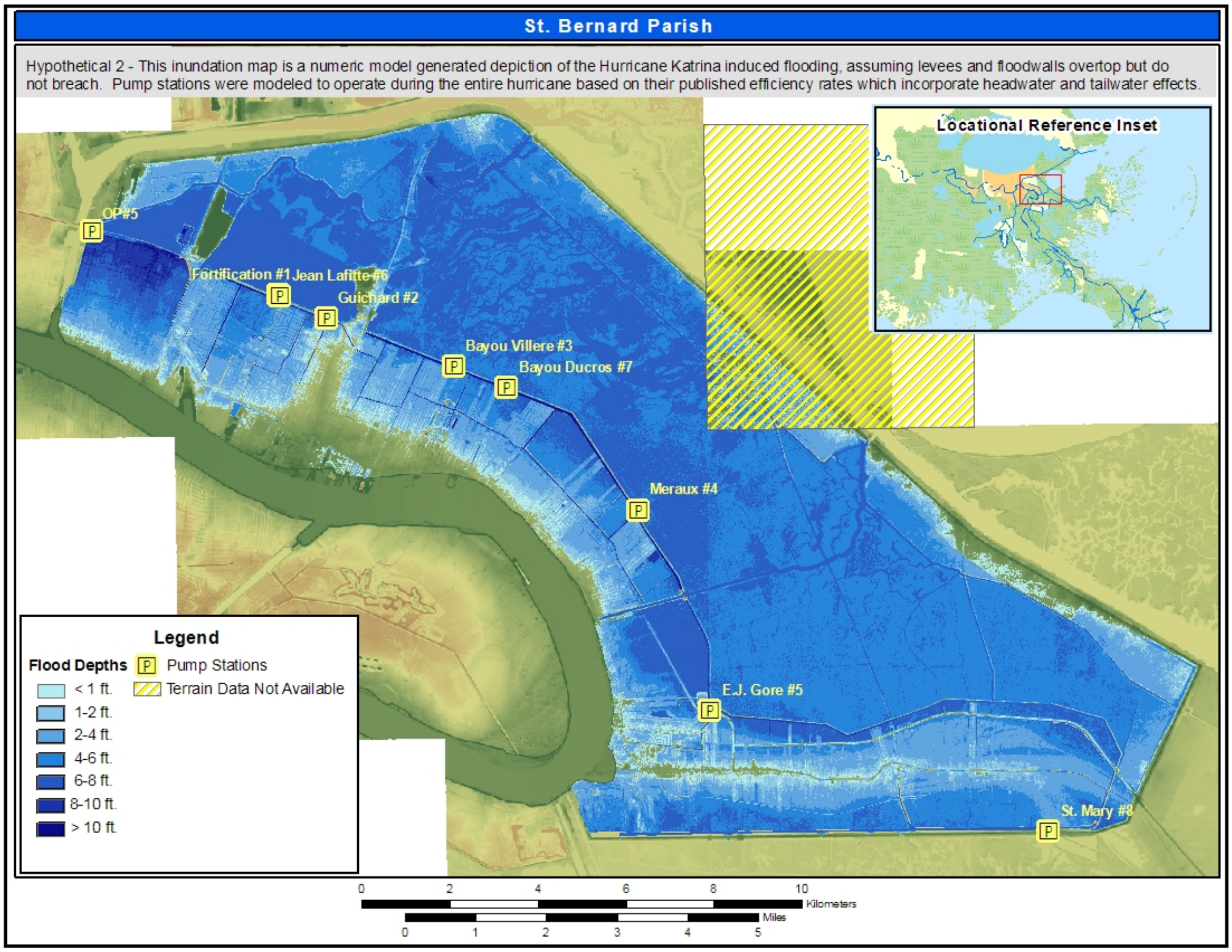

Figure 4-15. Depth of Flooding from Hypothetical 2 Scenario

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Appendix 5
Interior Drainage Analysis – Plaquemines Parish

Introduction

To answer the questions regarding the performance of the hurricane protection system, the interior drainage analysis focused on the filling and unwatering of the separate areas protected by levees and pump stations, referred to as basins. Interior drainage models were developed for Jefferson, Orleans, St. Bernard and Plaquemines Parishes to simulate water levels for what happened during Hurricane Katrina and what would have happened had all the hurricane protection facilities remained intact and functioned as intended.

The primary components of the hurricane protection system are the levees and floodwalls designed and constructed by the Corps of Engineers. Other drainage and flood control features (land topography, streets, culverts, bridges, storm sewers, roadside ditches, canals, and pump stations) work in concert with the Corps of Engineers levees and floodwalls as an integral part of the overall drainage and flood damage reduction system and are included in the models.

Interior drainage models are needed for estimating water elevations inside leveed areas, or basins, for a catastrophic condition such as Hurricane Katrina and for understanding the relationship between HPS components. Results from the interior drainage models can be used to determine the extent, depth and duration of flooding for multiple failure and non-failure scenarios. The models can also be used to:

- Support the Risk modeling effort
- Estimate time needed to unwater an area
- Support evacuation planning
- Evaluate design options of the HPS to include multiple interior drainage scenarios

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This appendix will provide details of the development of the HEC-HMS and HEC-RAS models for Plaquemines Parish. In summary, an HEC-HMS model was developed to transform the Katrina precipitation into runoff for input to the HEC-RAS models. HEC-RAS models were developed to simulate the four conditions discussed below

This model was developed to help answer questions 3 and 4 listed on page 1 of Volume VI. Question 3 is answered by the Katrina simulation listed below. Question 4 is a more difficult one to answer. This is mainly due to the variety of possible combinations of system features, especially pumps. It was decided to bracket these combinations with the three hypothetical combinations listed below.

One of the major difficulties is determining what pumps may have continuing operating. There are many potential factors that can cause pump stations to not operate during a hurricane event. Some of these are power failures, pump equipment failures, clogged pump intakes, flooding of the pump equipment, loss of municipal water supply used to cool pump equipment and no safe housing for operators at the pump stations resulting in pump abandonment. Because there is such a wide range of possible pumping scenarios that could occur during a hurricane event, it is difficult to establish a pumping scenario for what could have happened. At best, a variety of possible scenarios could be run to evaluate the potential range of possible consequences. For the purposes of the IPET analysis, it was decided to operate the pumps two ways. (1) As they actually operated during hurricane Katrina and (2) the pumps operated throughout the hurricane.

Described below are the 4 scenarios shown in this appendix.

- **Katrina**
  Simulate what happened during Hurricane Katrina with the hurricane protection facilities and pump stations performing as actually occurred. Compare results to observed and measured high water marks. Pre-Katrina elevations are used for top of floodwalls and levees.
- **Hypothetical 1 – Resilient Levees and Floodwalls**
  Simulate what would have happened during Hurricane Katrina had all levees and floodwalls remained intact. There are no levee or floodwall breaches or failures for this scenario even where overtopping occurs. Pump stations operate as they did in the Katrina event. Pre-Katrina elevations are used for top of floodwalls and levees. This scenario is meant to simulate what could have happened if all levees and floodwalls had protection that would allow them to be overtop but not breach.
- **Hypothetical 2 – Resilient Floodwalls, Levees and Pump Stations**
  Simulate what would have happened during Hurricane Katrina had all levees, floodwalls and pump stations remained intact and operating. There are no levee or floodwall breaches or failures for this scenario even where overtopping occurs. Pump stations operate continuously throughout the hurricane. Pump operations are based on the pump efficiency curves which reflect tailwater impacts. Pre-Katrina elevations are used for top of floodwalls and levees. It is understood, that in their present state, most pump stations would not have been able to stay in operation during Katrina. However, this scenario was

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simulated to provide an upper limit on what could have been the best possible scenario had no failures occurred.

- **Hypothetical 3 – Resilient Floodwalls**
  Simulate what would have happened during Hurricane Katrina had all floodwalls, which failed from foundation failures, remained intact. All other areas are modeled as they actually functioned. Pump stations operate as they did in the Katrina event. Pre-Katrina elevations are used for top of floodwalls and levees. The result of this scenario for Plaquemines Parish is that the inundation matches the Katrina simulation.

Table 5-1 lists the simulation scenarios in a matrix format.

Table 5-1
Katrina Simulations

Conditions	Simulation			
	Katrina	**Hypothetical 1**	**Hypothetical 2**	**Hypothetical 3**
Pumps operate as during Katrina	X	X		X
Pumps operate throughout Katrina			X	
Levee and floodwall breaches occur everywhere as during Katrina	X			
Levee and floodwall breaches occur on West wall of IHNC and in, St Bernard, New Orleans East and Plaquemines as during Katrina				X
Levee and floodwalls overtop but do not breach		X	X	
No failures on 17th Street and London Ave				X
Levee and floodwall elevations based on pre-Katrina elevations	X	X	X	X

Review of Existing Data

The basic Plaquemines Parish HEC-RAS model was developed by combining two existing RAS models that were developed and provided by MVN. Those models were a geometry model of the mainstem Mississippi River from about RM 319.7 to RM 1.1 and a local model of the Belle Chasse area. The Mississippi model extent was reduced to cover RM 89.9 to RM 1.1.

Additions were then made to this combined model to capture significant areas between the frontline and back levees and to incorporate the storm surge boundary conditions obtained from the ADCIRC model. The model was also extended up to approximately RM 103 on the Mississippi to allow for future input from the stage gage at that location. A portion of the Intracoastal Waterway that connects it to the Mississippi River through the Algiers Lock and also to the Belle Chasse area via the Belle Chasse pumps was added.

General Modeling Approach

The hydrologic models developed for Plaquemines Parish represent the rainfall runoff characteristics of the area. The HMS model produced flow hydrographs for each of the sub basins in the entire area. HEC-RAS was used to represent the characteristics of the drainage

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canals and the topography of the modeled areas. Flow hydrographs from HEC-HMS were entered into the hydraulic model along with hurricane surge (ADCIRC Model Results) and levee breach information in order to calculate water surfaces for the entire study area.

Hydrologic Model Development

Background

HEC-HMS version 3.0.0 was used to model the rainfall-runoff response for the Hurricane Katrina event for subbasins in Plaquemines Parish. Subbasin boundaries in the HEC-HMS model correspond to storage areas defined in the HEC-RAS model. Rainfall for each subbasin was determined using radar-rainfall estimates from the National Weather Service. The SCS curve number and the SCS dimensionless unit hydrograph methods were used to compute runoff hydrographs given basin average precipitation. GIS data, like landuse and soil data, were used to estimate SCS curve numbers and lag times.

Development of GIS Watershed Model

Subbasin boundaries for the Plaquemines Parish HEC-HMS model are shown in Figure 5-1 and Figure 5-2. Basin boundaries correspond to storage areas defined in the HEC-RAS model for this area. A shapefile of subbasin boundaries was used for estimating HEC-HMS model parameters, curve numbers and lag times, and determining subbasin average precipitation from the radar-rainfall data. The shapefile was also used as the background map in the HEC-HMS basin model.

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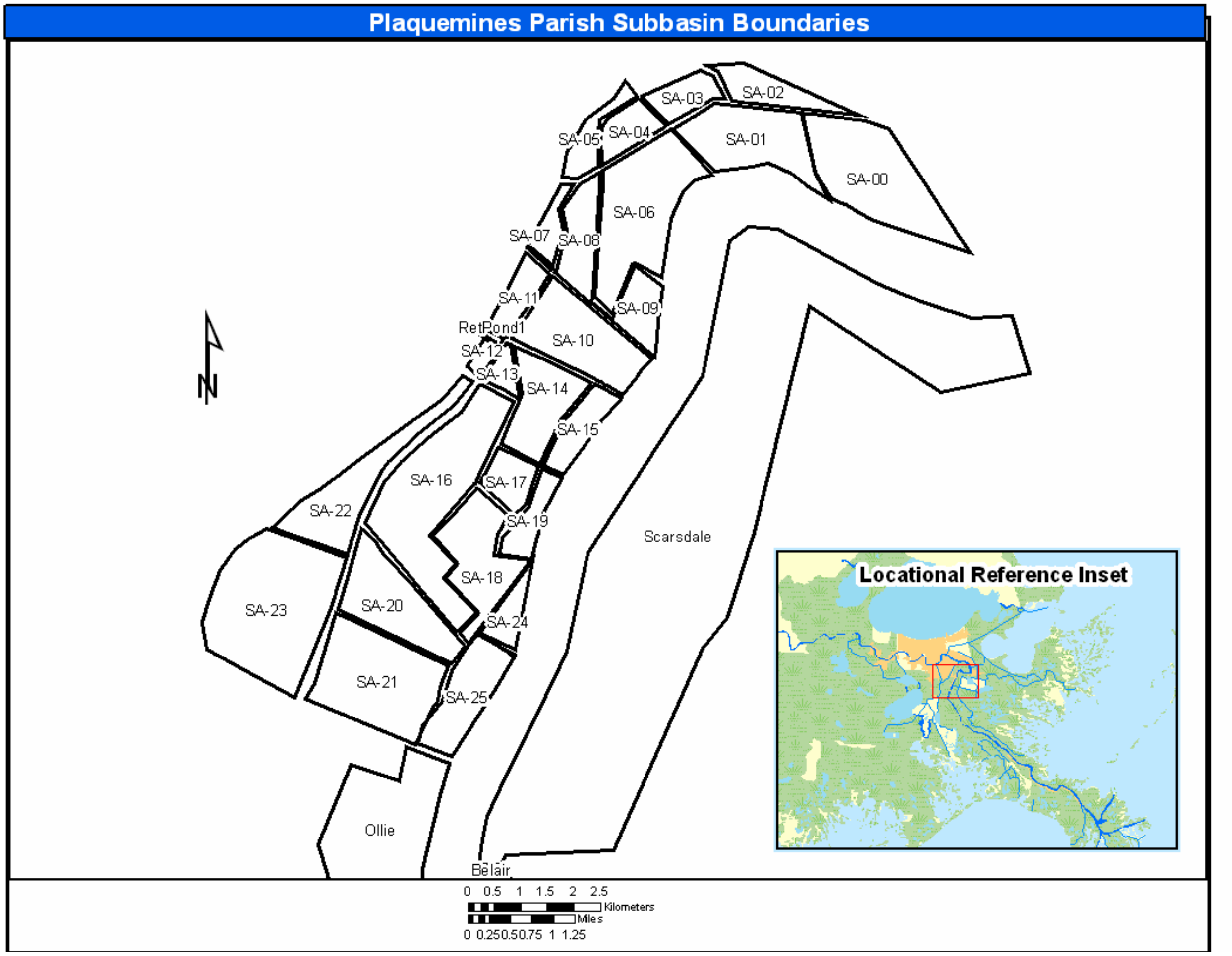

Figure 5-1. Subbasin Boundaries Northern Half of Parish

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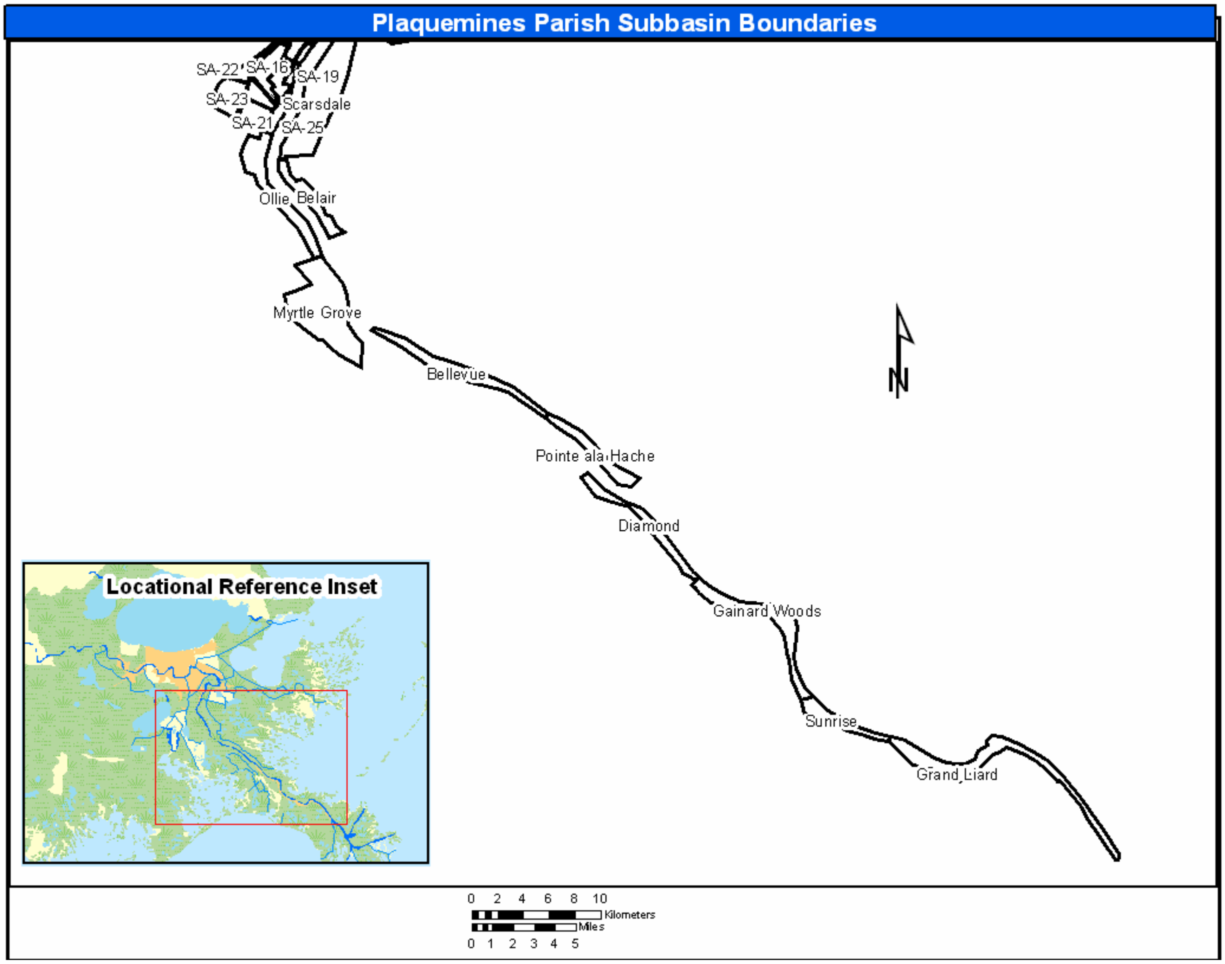

Figure 5-2. Subbasin Boundaries Southern Half of Parish

Landuse and Soil Data

Landuse and soil data were used to estimate SCS curve numbers. Landuse data was obtained from the New Orleans District (MVN). The landuse data was a raster coverage of 24 different landuse types (Table 5-2, Landscape Categories). Soil data, contained in the Soil Survey Geographic (SSURGO) Database, was downloaded from the following National Resources Conservation Service (NRCS) website: http://www.ncgc.nrcs.usda.gov/products/datasets/ssurgo/. The SSURGO dataset is a digital copy of county soil survey maps and provides the most level of detailed for digital soil maps from the NRCS.

Table 5-2
Landuse Categories

LANDUSE	A	B	C	D
Fresh Marsh	39	61	74	80
Intermediate Marsh	39	61	74	80
Brackish Marsh	39	61	74	80
Saline Marsh	39	61	74	80
Wetland Forest-Deciduous	43	65	76	82
Wetland Forest- Evergreen	49	69	79	84
Wetland Forest- Mixed	39	61	74	80
Upland Forest- Deciduous	32	58	72	79
Upland Forest- Evergreen	43	65	76	82
Upland Forest- Mixed	39	61	74	80
Dense Pine Thicket	32	58	72	79
Wetland Scrub/shrub - deciduous	30	48	65	73
Wetland Scrub/Shrub - evergreen	35	56	70	77
Wetland Scrub/Shrub - Mixed	30	55	68	75
Upland Scrub/Shrub - Deciduous	30	48	65	73
Upland Scrub/Shrub - Evergreen	35	56	70	77
Upland Scrub/Shrub - Mixed	30	55	68	75
Agriculture-Cropland-Grassland	49	69	79	84
Vegetated Urban	49	69	79	84
Non-Vegetated Urban	71	80	87	91
Upland Barren	77	86	91	94
Wetland Barren	68	79	86	89
Wetland Complex	85	85	85	85
Water	100	100	100	100

Loss Rates

Loss rates are used to account for the amount of precipitation intercepted by the canopy and depressions on the land surface and the amount of precipitation that infiltrates into the soil. Precipitation that is not lost to interception or infiltration is called “excess precipitation” and becomes direct runoff. The Soil Conservation Service (SCS) Curve Number (CN) method was used to model interception and infiltration. The SCS CN method estimates precipitation loss and excess as a function of cumulative precipitation, soil cover, landuse, and antecedent moisture. This method uses a single parameter, a curve number, to estimate the amount of precipitation excess\loss from a storm event. Studies have been carried out to determine appropriate curve number values for combinations of landuse type and condition, soil type, and the moisture state of the watershed.

Table 5-2 was used to estimate a curve number value for each combination of landuse and soil type in the study area. The hydrologic soil group (A, B, C, or D) is one of the soil properties contained in the SSURGO database. The percent impervious cover is already included in the curve number value in Table 5-1. More information about the background and use in the SCS

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curve number method can be found in Soil Conservation Service (1971, 1986). Figure 5-3 and Figure 5-4 show landuse types and hydrologic soil groups, respectively, in Plaquemines Parish. The ArcGIS map calculator was used to create a raster coverage of curve numbers from these two data sets and the curve number lookup table (Figure 5-5). Subbasin average curve numbers were computed for each subbasin using the subbasin boundary shapefile and the curve number raster coverage (Table 5-3).

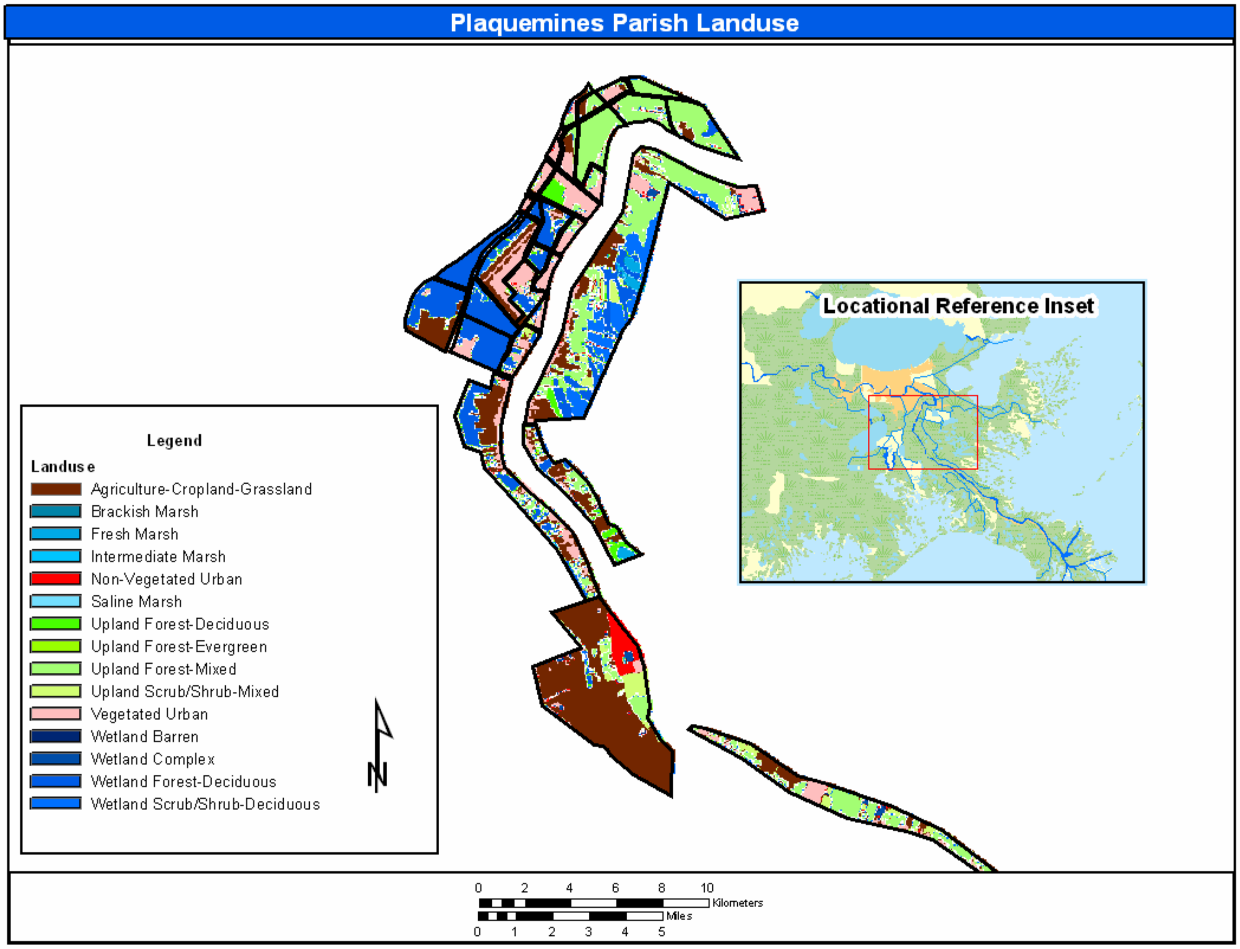

Figure 5-3. Landuse Types in Plaquemines Parish

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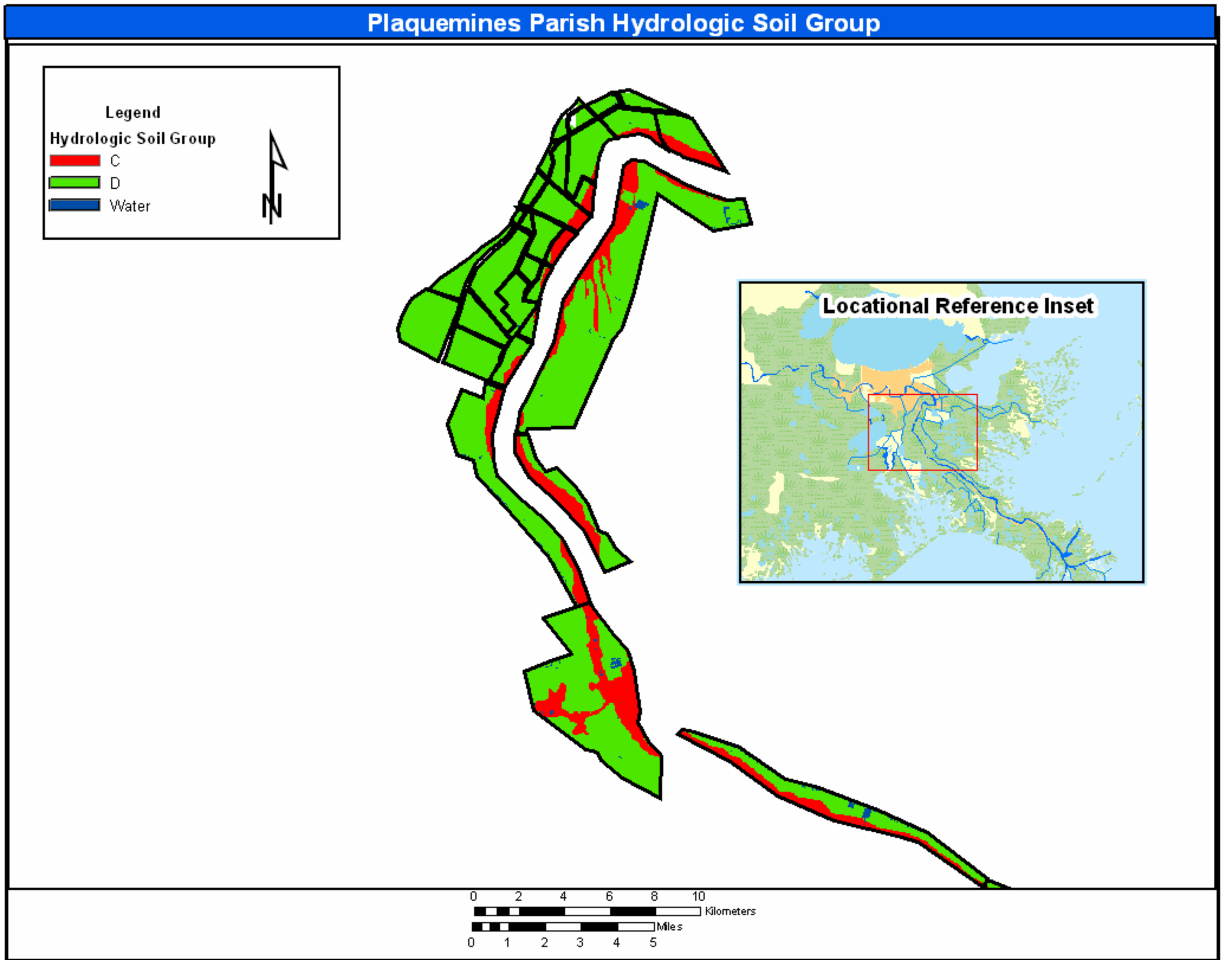

Figure 5-4. Hydrologic Soil Groups in Plaquemines Parish

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Table 5-3
Subbasin Average Curve Numbers

Subbasin Name	Subbasin Average Curve Number
Belair	80
Bellevue	80
Diamond	82
Gainard Woods	82
Grand Liard	84
Myrtle Grove	82
Ollie	82
Pointe ala Hache	81
RetPond1	95
SA-00	79
SA-01	79
SA-02	80
SA-03	83
SA-04	81
SA-05	84
SA-06	80
SA-07	84
SA-08	82
SA-09	79
SA-10	81
SA-11	84
SA-12	84
SA-13	82
SA-14	81
SA-15	78
SA-16	83
SA-17	82
SA-18	83
SA-19	82
SA-20	81
SA-21	82
SA-22	82
SA-23	83
SA-24	82
SA-25	81
Scarsdale	79
Sunrise	84

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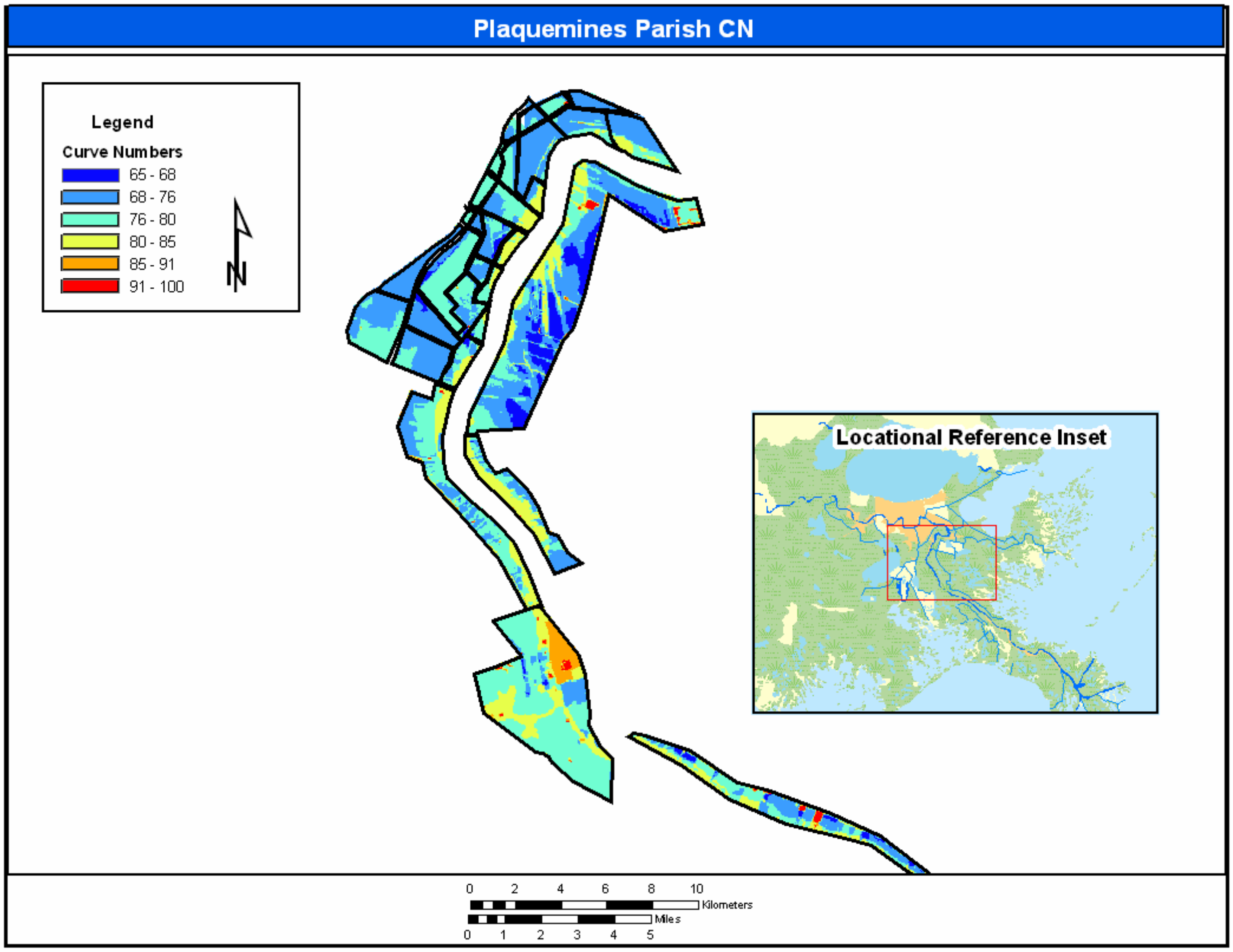

Figure 5-5. Curve Number Grid

Transform

Excess precipitation was transformed to a runoff hydrograph using the SCS unit hydrograph method. The SCS developed a dimensionless unit hydrograph after analyzing unit hydrographs from a number of small, gaged watersheds. The dimensionless unit hydrograph is used to develop a unit hydrograph given drainage area and lag time. A detailed description of the SCS dimensionless unit hydrograph can be found in SCS Technical Report 55 (1986) and the National Engineering Handbook (1971).

Lag times for the SCS unit hydrograph method were estimated using the following equation:

$$t_l = \frac{L^{0.8} * (1000 - 9CN)^{0.7}}{1900 * CN^{0.7} * Y^{0.5}}$$

where t_l is the subbasin lag (hr), L is the hydraulic length (ft), CN is the subbasin average curve number, and Y is the average subbasin land slope (percent). The hydraulic length was determined visually using topographic maps of Plaquemines Parish. Terrain Data, 30 meter

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DEMs, were used to compute the average land slope for each subbasin. Computed lag times are shown in Table 5-4.

Table 5-4
Computed Lag Times

Subbasin Name	Hydraulic Length (ft)	Average Subbasin Land Slope %	Lag Time (minutes)
Belair	3761	1.5	44
Bellevue	3399	3.0	29
Diamond	2515	1.9	27
Gainard Woods	4597	1.7	46
Grand Liard	4911	3.1	34
Myrtle Grove	16586	0.5	243
Ollie	7610	0.9	98
Pointe ala Hache	2480	2.1	26
RetPond1	1125	0.2	26
SA-00	9331	1.6	92
SA-01	8101	2.4	68
SA-02	2180	2.0	25
SA-03	2221	0.8	37
SA-04	2305	0.7	43
SA-05	3292	2.8	26
SA-06	8216	1.6	80
SA-07	2629	0.1	98
SA-08	5084	1.7	50
SA-09	5508	2.5	48
SA-10	5029	0.9	72
SA-11	5305	0.1	198
SA-12	2281	0.2	68
SA-13	1752	0.1	89
SA-14	3899	0.1	173
SA-15	2162	2.6	23
SA-16	3331	0.1	143
SA-17	3812	0.1	165
SA-18	5540	0.1	215
SA-19	3030	3.0	25
SA-20	6356	0.1	256
SA-21	2041	0.1	100
SA-22	4871	0.2	136
SA-23	5824	0.1	224
SA-24	884	1.0	17
SA-25	2369	0.5	54
Scarsdale	13012	1.0	153
Sunrise	2091	2.7	18

Rainfall Data

Radar rainfall data, referred to as Multisensor Precipitation Estimator (MPE), was used as a boundary condition in the hydrologic models to determine runoff hydrographs produced by the Hurricane Katrina event. MPE data from the Lower Mississippi River Forecast Center (LMRFC) was downloaded from the following website: http://dipper.nws.noaa.gov/hdsb/data/nexrad/lmrfc_mpe.php. Raw radar data is adjusted using rain gage measurements and possibly satellite data to produce the MPE product.

The radar-rainfall data was imported into a GIS program. The GIS program was used to compute subbasin average precipitation; the downloaded radar-rainfall data was a raster or

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gridded coverage of precipitation. Also, the downloaded radar-rainfall data provides hourly estimates of precipitation. A precipitation hyetograph was computed for each subbasin in the Plaquemines Parish basin models. The individual hyetographs were imported into an HEC-DSS file where they were read by HEC-HMS. Total rainfall from Hurricane Katrina varied from 7 to 10 inches across subbasin in Plaquemines Parish (Figure 5-6). As an example, the precipitation hyetograph for the "Myrtle Grove" subbasin is shown in Figure 5-7 . This figure shows the time distribution of rainfall from Hurricane Katrina.

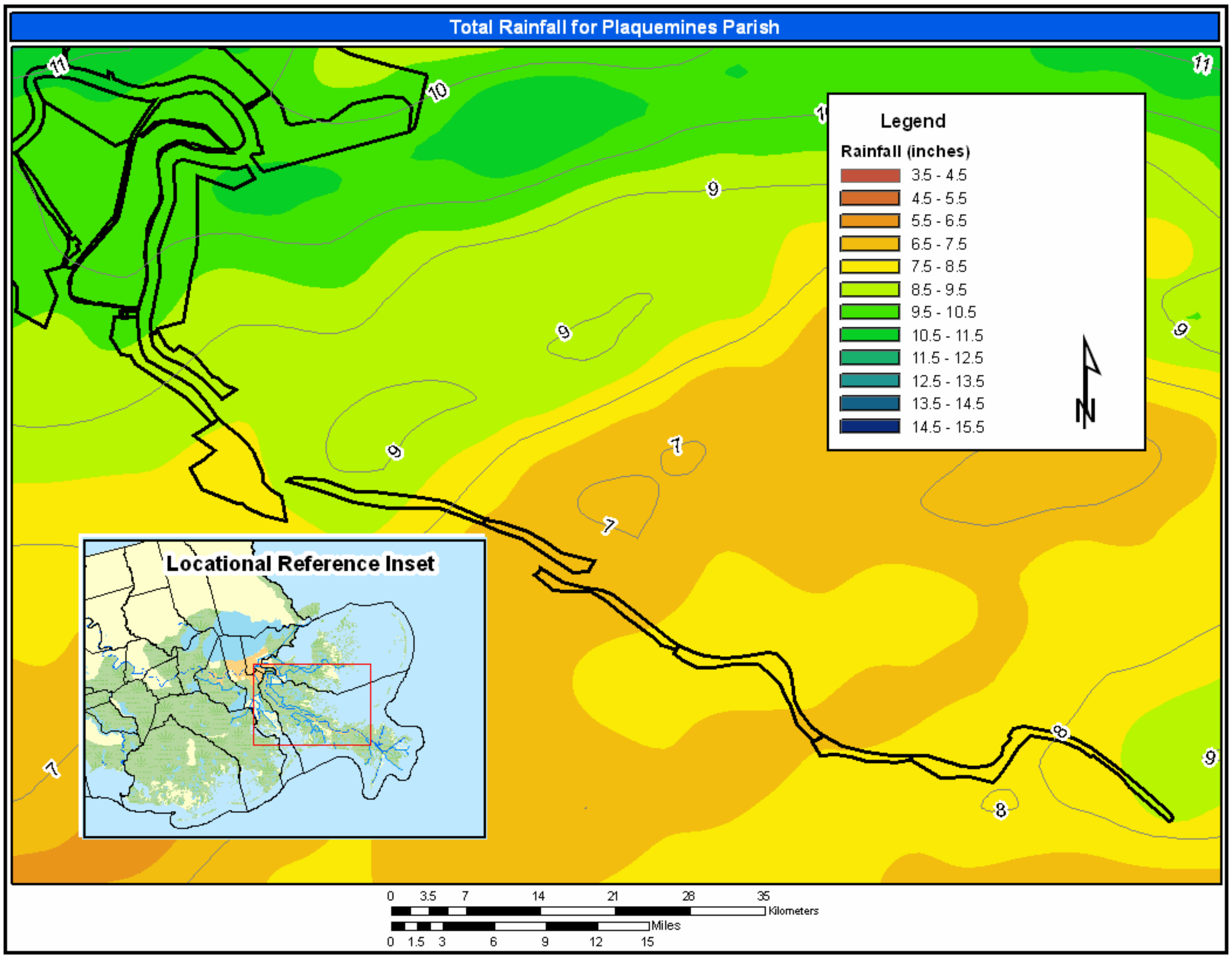

Figure 5-6. Total Storm Precipitation

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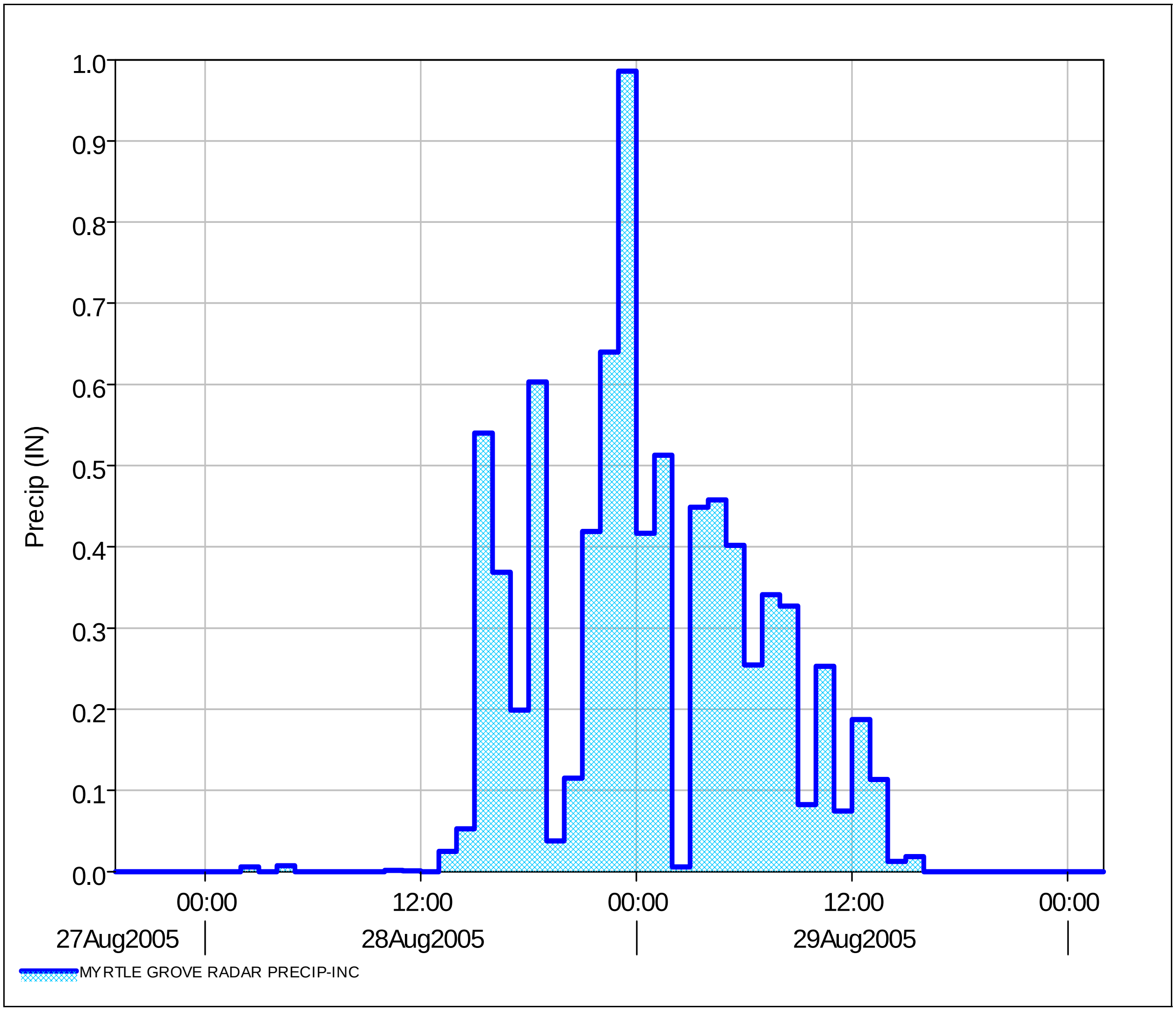

Figure 5-7. Average Rainfall for Myrtle Grove Subbasin

Model Results

Summary output from the HEC-HMS model is available in Table 5-5. A complete runoff hydrograph was also computed by the program. This information was stored in an HEC-DSS file and provided as inflows to storage areas for the HEC-RAS model of Plaquemines Parish.

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Table 5-5
Summary Output from HEC-HMS Model

Subbasin Name	Drainage Area (mi2)	Peak Discharge (cfs)	Time of Peak	Runoff Volume (in)
Belair	1317	1317	29Aug2005, 00:20	6.2
Bellevue	1438	1438	29Aug2005, 05:09	5.9
Diamond	1025	1025	29Aug2005, 04:09	4.9
Gainard Woods	2720	2719	28Aug2005, 18:25	5.4
Grand Liard	3655	3654	28Aug2005, 22:13	5.6
Myrtle Grove	2550	2549	29Aug2005, 04:00	5.8
Ollie	1944	1944	29Aug2005, 01:39	6.7
Pointe ala Hache	782	781	29Aug2005, 04:10	4.8
RetPond1	16	15	29Aug2005, 08:07	9.4
SA-00	762	761	29Aug2005, 09:36	6.9
SA-01	625	624	29Aug2005, 09:17	7.00
SA-02	302	301	29Aug2005, 09:02	6.9
SA-03	219	219	29Aug2005, 09:05	7.4
SA-04	191	190	29Aug2005, 08:58	7.3
SA-05	208	208	29Aug2005, 08:10	7.4
SA-06	863	863	29Aug2005, 09:16	7.2
SA-07	127	127	29Aug2005, 09:28	7.3
SA-08	315	314	29Aug2005, 08:39	7.4
SA-09	222	221	29Aug2005, 08:43	7.2
SA-10	591	590	29Aug2005, 09:09	7.6
SA-11	146	146	29Aug2005, 10:44	7.7
SA-12	60	59	29Aug2005, 08:54	8.1
SA-13	87	87	29Aug2005, 09:17	7.8
SA-14	326	326	29Aug2005, 10:21	7.7
SA-15	206	206	29Aug2005, 08:09	7.3
SA-16	956	955	29Aug2005, 09:58	7.8
SA-17	147	147	29Aug2005, 10:15	7.8
SA-18	352	351	29Aug2005, 10:46	7.8
SA-19	156	155	29Aug2005, 09:00	7.7
SA-20	372	372	29Aug2005, 11:16	7.5
SA-21	750	750	29Aug2005, 09:22	7.5
SA-22	478	477	29Aug2005, 09:53	7.7
SA-23	875	875	29Aug2005, 10:54	7.6
SA-24	135	134	29Aug2005, 01:02	7.7
SA-25	361	360	29Aug2005, 01:22	7.4
Scarsdale	5068	5068	29Aug2005, 10:06	7.1
Sunrise	1046	1046	29Aug2005, 00:02	5.2

RAS Interior Modeling

Background

Channel geometries were obtained from existing HEC-RAS models provided by the Corps of Engineers New Orleans District office (MVN) which had been prepared for other studies. Several reaches were added to attach the storm surge boundary conditions (ADCIRC) to the RAS model. The ADCIRC model and results are detailed in Volume IV of this report. Simple trapezoidal cross sections were used for these reaches. The elevation-volume relationships for the storage areas that were added to the model were extracted from the GIS using GeoRAS.

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Datum Reconciliation

All data used in these simulations were used as obtained and no adjustments were made. The data that were used were the existing RAS geometric models, the ADCIRC stage hydrographs, the reported high water marks and the digital terrain model. An analysis of the datum adjustments for this area indicated a maximum vertical modification of 0.3 ft. would be required to achieve datum correspondence for all of these data files. ADCIRC data was referenced to NGVD29 and all other data to NAVD88.

This magnitude of adjustment was considered to be minor for this study and, therefore, neglected.

Terrain Model

The primary source of topographic data in the terrain model for RAS was Light Detection and Ranging (LiDAR) surveys performed of South Louisiana for the Federal Emergency Management Agency in 2001. The datum of the LiDAR is NAVD88 1994, 1996 EPOCH. The vertical accuracy for this data is +/- 0.7 feet. The horizontal projection is Louisiana State Plane South 1983 feet. The basin boundaries for the HMS models are in the same projection. The data collected during these LIDAR surveys were processed using Geographic Information System (GIS) technology to develop other information needed for the modeling of this basin. Additional information from visits to the site was used to supplement data obtained from the LIDAR surveys

Basic Geometric Data Using GIS

All of the channel and structure geometry that was used for the HEC-RAS Mississippi River and Belle Chasse areas was imported from prior studies. Storage areas within the Belle Chasse area were also imported; their elevation-volume relations were updated using the current LiDAR elevations. The storage areas, storage area connections, pump stations, levee profiles and breach locations that were added were described using information obtained from MVN and NPD and the current LiDAR topography

Manning's *n*-Values

All hydraulic coefficients for the channels were kept from the imported data. Manning's *n*-values for the mainstem Mississippi River varied from 0.027 to 0.012 (lower values in the lower parts) for the channel and were 0.12 in the overbanks. Values for the Belle Chasse area were typically 0.045 for the channel and 0.1 for the overbanks. As these data had been calibrated and utilized for other studies, the roughnesses were not modified. Similar values were utilized for the added boundary condition reaches that connect to the ADCIRC stage hydrographs.

Bridges

Bridges were not significant hydraulic controls within this area. The bridges that were extant in the Bell Chasse area RAS model were included and not subsequently modified.

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Ineffective Flow Areas

Ineffective flow areas were not added or modified.

Blocked Obstructions

Blocked obstructions were not identified nor added.

Storage Areas

Storage area shapes, locations and connections in the Belle Chasse area were used as imported from the existing RAS model. Their elevation-capacity relations were updated using the current terrain model. The ADCIRC results indicate low water surface elevations here during the Katrina event and no levee breaches were reported in this area. Other large storage areas along the main stem Mississippi River were delineated using a shape files that identified the levee footprints for both the mainstem and back levees. The storage areas were further defined based upon locations of pumping stations. The elevation-volume relationships for all of the storage areas were extracted from the terrain using GeoRAS.

Inline Structures

Inline structures were not identified nor added.

Levees

Primary channel (mainstem) levee elevations for the RAS model were selected using information from a GIS shape file. A second shape file contained levee footprints showing the locations of the back levees, but not their elevations. The levee elevations in the RAS model are, consequently, a combination of the LiDAR elevations for the primary levees and general elevation information gleaned from the LSU files for the back levee elevations.

Pump Stations

Pump station locations were obtained from a GIS shapefile. Operating characteristics of the pumps were collected by the US Army Corps of Engineers Hydroelectric Design Center (HDC) located at the Portland District. This pump date is detailed in Appendix 6 of Volume VI of this report.

The Belle Chasse area HEC-RAS model that was obtained from MVN had utilized rating curves to simulate the Belle Chasse pumps. These pumps discharge into the Intracoastal Canal which was not included in the Belle Chasse RAS model obtained from MVN. Because the Intracoastal Canal was added to the Plaquemines model, these pumps were also added and simulated using the information described above. This allowed the modeling of hydraulic connectivity between the Belle Chasse area, the Intracoastal Canal and the ADCIRC stage hydrographs to the West of the Intracoastal Canal as shown below.

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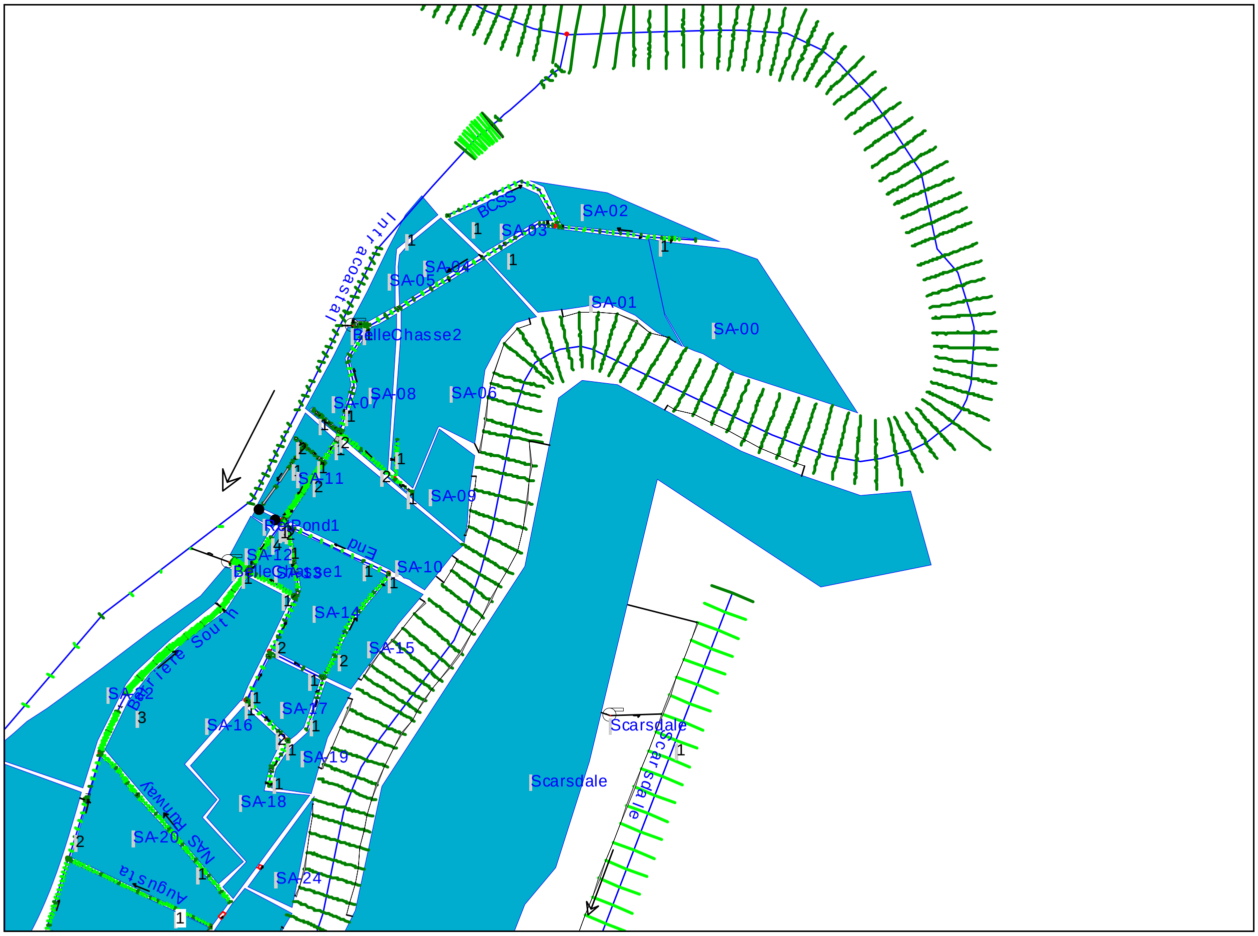

Figure 5-8. Belle Chasse Area

Storm Drain System

No storm drain systems were modeled in Plaquemines Parish.

Flow Data and Boundary Conditions

The boundary conditions used are stage hydrographs obtained from the ADCIRC simulations. The approach for developing the model was to define areas between the back levees and the main levees as storage areas by examining topographic maps, aerial imagery, etc. These storage areas were then connected to the main river via lateral weirs with elevations taken from the primary levee elevation shape file. The storage areas were then connected to the storm surge boundary conditions with large reaches outside of the back levees. These connections were via lateral weirs set at elevations determined from topography maps, etc. The only boundary conditions being used are stage hydrographs from the ADCIRC simulations.

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The RAS reaches and their associated ADCIRC boundary condition nodes are given in Table 5-6.

Table 5-6
Association of ADCIRC Data for Reach Stage Boundary Conditions

RAS Reach	ADCIRC U/S bc point	ADCIRC D/S bc point
Miss 1	107	junction
Miss 2	Junction	100
Intracoastal	Junction	89
Ollie	89	88
Myrtle Grove	88	104
Diamond	104	103
Gainard Woods	103	102
Sunrise	102	96
Grand Liard	96	95
Scarsdale	106	122
Belair	122	121
Bellevue	121	104
Pointe a la Hache	104	118
Lower East	118	114

Levee Overtopping and Breaching

Levee overtopping did occur in this area. Its occurrence and impacts depended primarily on the levee crest elevations and storage area capacities. Breaching of the back levees did occur, but was apparently a minor contributor to flooding compared with overtopping and general storm surge action. The locations and dimensions of three breaches (in the Bellevue, Sunrise and Gainard Woods reaches) were obtained from information in the report “Damage Assessment to Plaquemines Parish Federal Levees.”, 11 Jan. 2006. The information in that report was used to define the parameters for those three breaches located in the back levees. The Bellevue levee breach was reported to be ultimately about 190 ft. wide at the bottom. HEC-RAS parameters that were used for this breach were: side slopes of 0.5 to 1, bottom elev. of -21 ft., time of failure development of 2 hrs., and trigger water surface elevation of 10 ft. For the Sunrise levee failure, the bottom width was estimated to be about 180 ft., side slopes of 0.5 to 1, final bottom elev. at -20 ft., failure time of 2 hrs., and trigger elev. of 10 ft. Another breach was located in the Gainard Woods back levee. It had a bottom width of about 125 ft., bottom elev. of -14 ft., estimated time of failure development of 2 hrs., and trigger water surface elev. of 10 ft.

Total calculated volumes of flow entering Plaquemines Parish are tabulated in Table 5-7. Table 5-8 lists the percentages of inflow contributed by rainfall, surge overtopping, wave overtopping and breaching.

Table 5-7
Calculated Inflow Volume Percentages into Plaquemines

Total Volume	Percent		
	Rainfall	Breaches	Overtopping
155,000	16	69	15

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Model Calibration

The model is being driven externally using stage hydrographs from the ADCIRC model. Therefore, the accuracy of the stage computations depends largely on the accuracy of the boundary condition stages from the ADCIRC results. Some observed high water marks are shown in Table 5-8

Table 5-8
Summary of High Water Mark Data for Plaquemines Parish

ID	LAT	LONG	Location	Side Of Levee	Date_	Elev_ft	RAS loc
LA 1075	29.944	-90.003	Miss River	Unprotected	October 6, 2005	9.5	MS RM 91
LA 1076	29.862	-89.971	Miss River	Unprotected	October 6, 2005	17.3	MS RM 76.6
LA 1077	29.388	-89.596	Miss River	Unprotected	October 6, 2005	14.2	MS RM 30
LA 1078	29.388	-89.596	Miss River	Unprotected	October 6, 2005	14.4	MS RM 29.5
LA 1219	29.259	-89.362	Plaq Parish	Protected	January 0, 1900	11.9	Grand Liard
LA 1220	29.339	-89.496	Plaq Parish	Protected	January 0, 1900	11.9	Grand Liard
LA 1221	29.353	-89.525	Plaq Parish	Protected	January 0, 1900	13.7	Sunrise
LA 1222	29.354	-89.527	Plaq Parish	Protected	January 0, 1900	13.7	Grand Liard
LA 1223	29.358	-89.531	Plaq Parish	Protected	January 0, 1900	13.9	Grand Liard
LA 1224	29.368	-89.535	Plaq Parish	Protected	January 0, 1900	15.3	MS RM 25.9
LA 1225	29.393	-89.603	Plaq Parish	Protected	January 0, 1900	16.2	Gainard Woods
LA 1226	29.448	-89.628	Plaq Parish	Protected	January 0, 1900	14.7	Gainard Woods

Note that there is a range of reported high water marks at locations associated with a single RAS storage area. Some of those observations vary by several feet within these areas. For example, the observations reported within the storage area identified as Gainard Woods vary from 14.7 to 16.2 ft. These areas have horizontal water surfaces in the RAS computations; therefore, the model parameters were adjusted to reproduce a maximum water surface elevation within those reported to be observed. The model parameters that were adjusted were the hydraulic connectivity parameters between the storage areas. Additional detail could be added to the RAS model in an attempt to reproduce these details; however, it is concluded that the variance in data reflect local hydraulics and wind wave action that are not included in the RAS model.

Pump station operation. Pump station operations for the calibration scenario were taken from the above timeline and capacity data provided by HDC. It was assumed that during periods that the pump status was reported as “NA”, nothing was being pumped; during periods that the status was reported as “NR”, pumps were operating at the reported capacities.

Boundary conditions. This model was initially driven by stage boundary conditions obtained from ADCIRC results at locations nearby the RAS reach boundary locations as shown above. It was determined that these ADCIRC results should be scaled to match the observed high water mark data. This was done for those portions of the ADCIRC stage hydrographs above elev. 7 ft. The hydrographs were essentially triangular above that elev. so the peak could be scaled to the nearby high water mark elevation and then connected to the lower part of the

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hydrograph by linear interpolation. Note that the spatial locations of the ADCIRC data, the observations and the RAS reach boundaries do not coincide spatially. Therefore, the peak stage values were estimated at the necessary locations. Furthermore, several observed high water marks were located within individual RAS storage areas. A storage area has a horizontal water surface; and, therefore, only one maximum computed water surface elevation. The model was considered to be calibrated when the computed maximum water surface elevation was within the range of the observed. For example, the observed high water marks within the Grand Liard storage area range from11.9 to 13.9 ft., mostly around 13.7 ft. The simulation result was 12.8 ft.

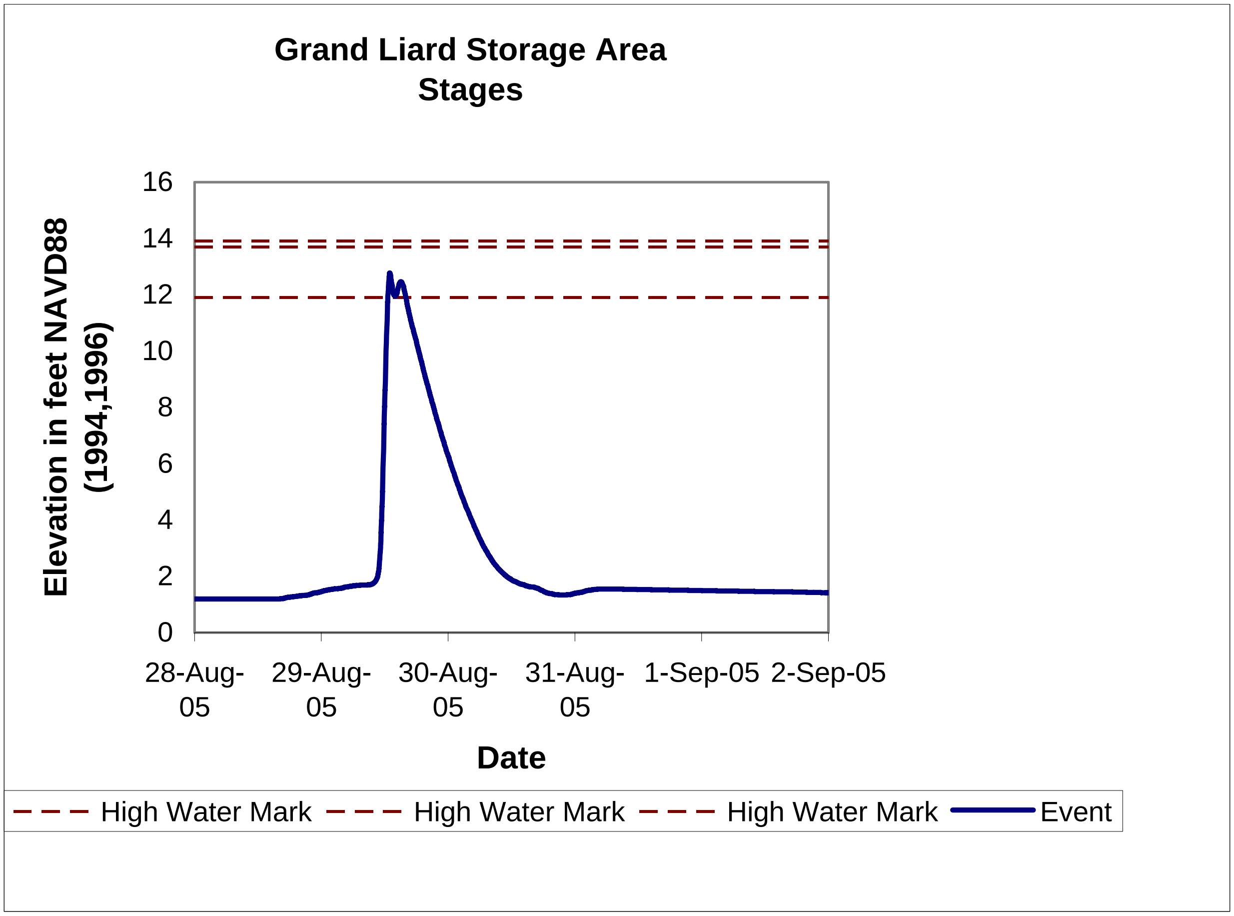

Figure 5-9. Grand Liard Elevations

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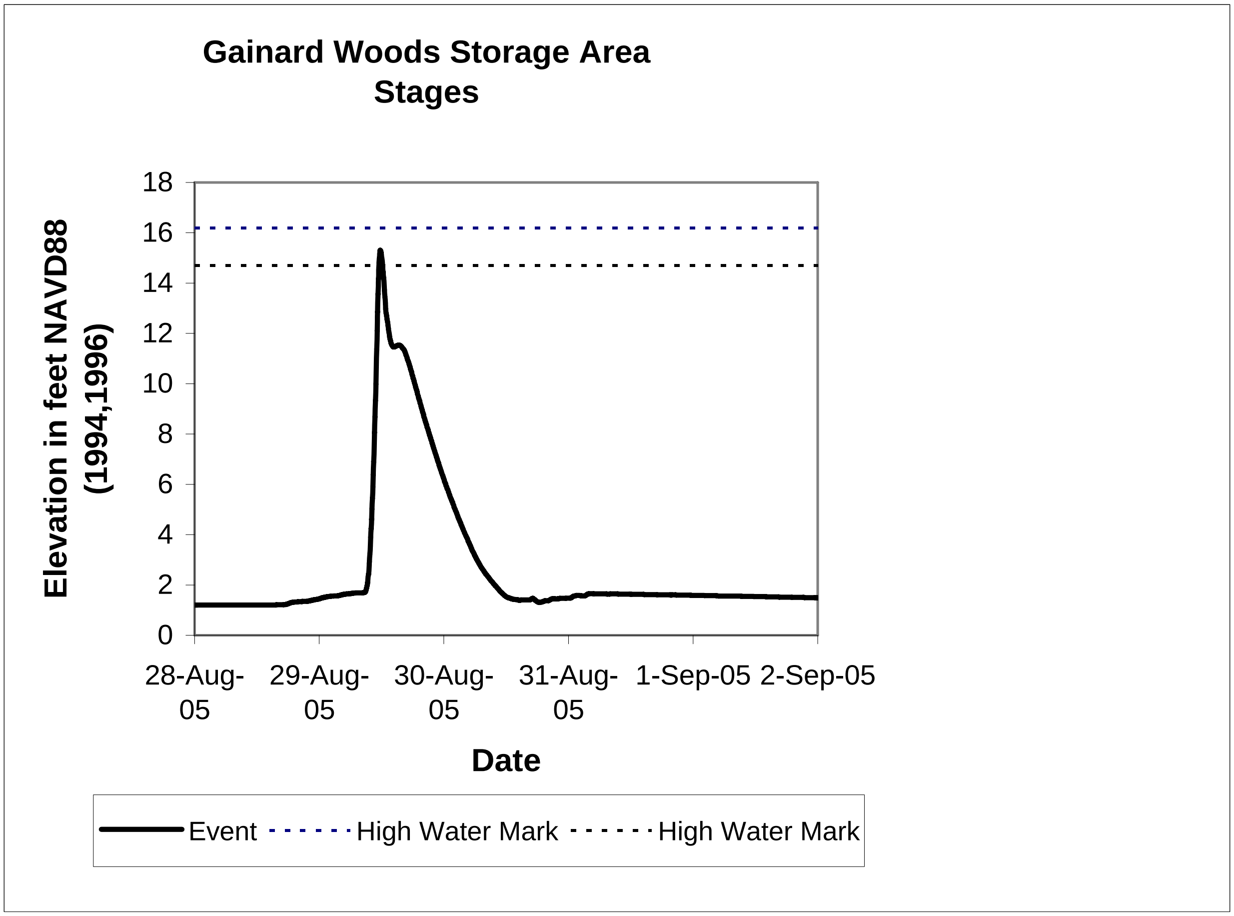

Figure 5-10. Gainard Woods Elevations

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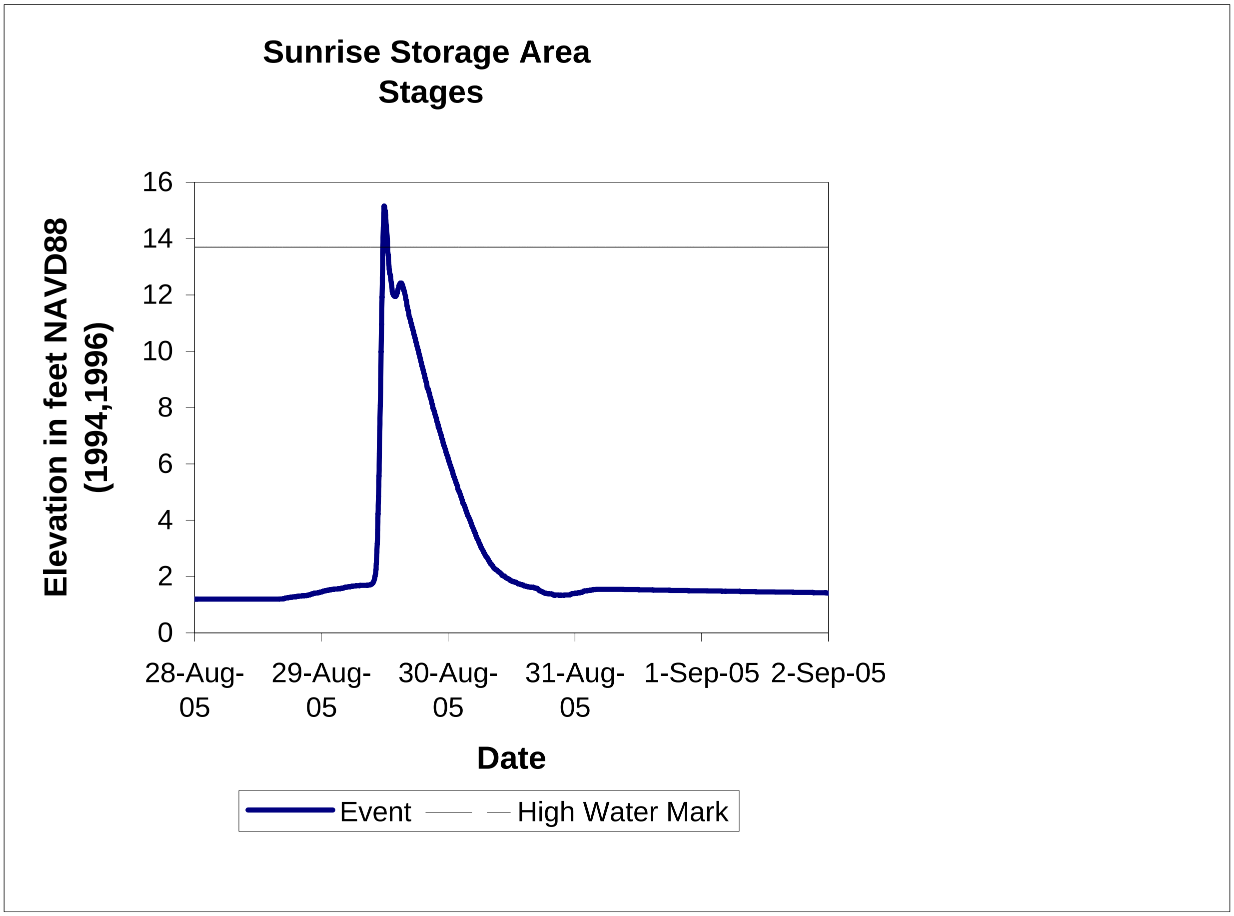

Figure 5-11. Sunrise Elevations

The simulated results for these storage areas indicate that the drawdown during the event occurred more rapidly than for the situation with the levees intact. This reflects that water left these leveed areas through the breaches after the peak flooding conditions more rapidly than would have occurred had there been no levee breaches.

Model Results and Floodplain Mapping

The areas within Plaquemines Parish that are of most interest are modeled as storage areas that have horizontal water surfaces at any point in time. Plots of stage hydrographs for these areas, as shown above, depict the characteristics of most interest when evaluating the different conditions. The maximum flood depths for the Katrina scenario are shown in Figures 5-12 and 5-13. The maximum flood depths for the Hypothetical 1 scenario are shown in Figures 5-14 and 5-15. The maximum flood depths for the Hypothetical 2 scenario are shown in Figures 5-16 and 5-17. Inundation for Hypothetical 3 is the same as the Katrina scenario. Table 5-9 shows a comparison of stages for the three scenarios for Plaquemines.

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Table 5-9
Computed Stages for Katrina, Hypothetical 1 and Hypothetical 2

HEC-RAS Storage Area	Katrina	Hypothetical 1	Hypothetical 2
Belair	15.3	15.3	15.0
Bellevue	16.9	12.9	12.7
Diamond	16.1	16.1	16.0
Gainard Woods	15.3	15.3	15.1
Grand Liard	12.8	12.9	12.9
Myrtle Grove	4.4	4.4	4.4
Ollie	2.3	2.3	2.3
Pointe a la Hache	16.9	12.9	12.7
Scarsdale	10.1	10.1	10.1
Sunrise	15.2	15.1	15.1

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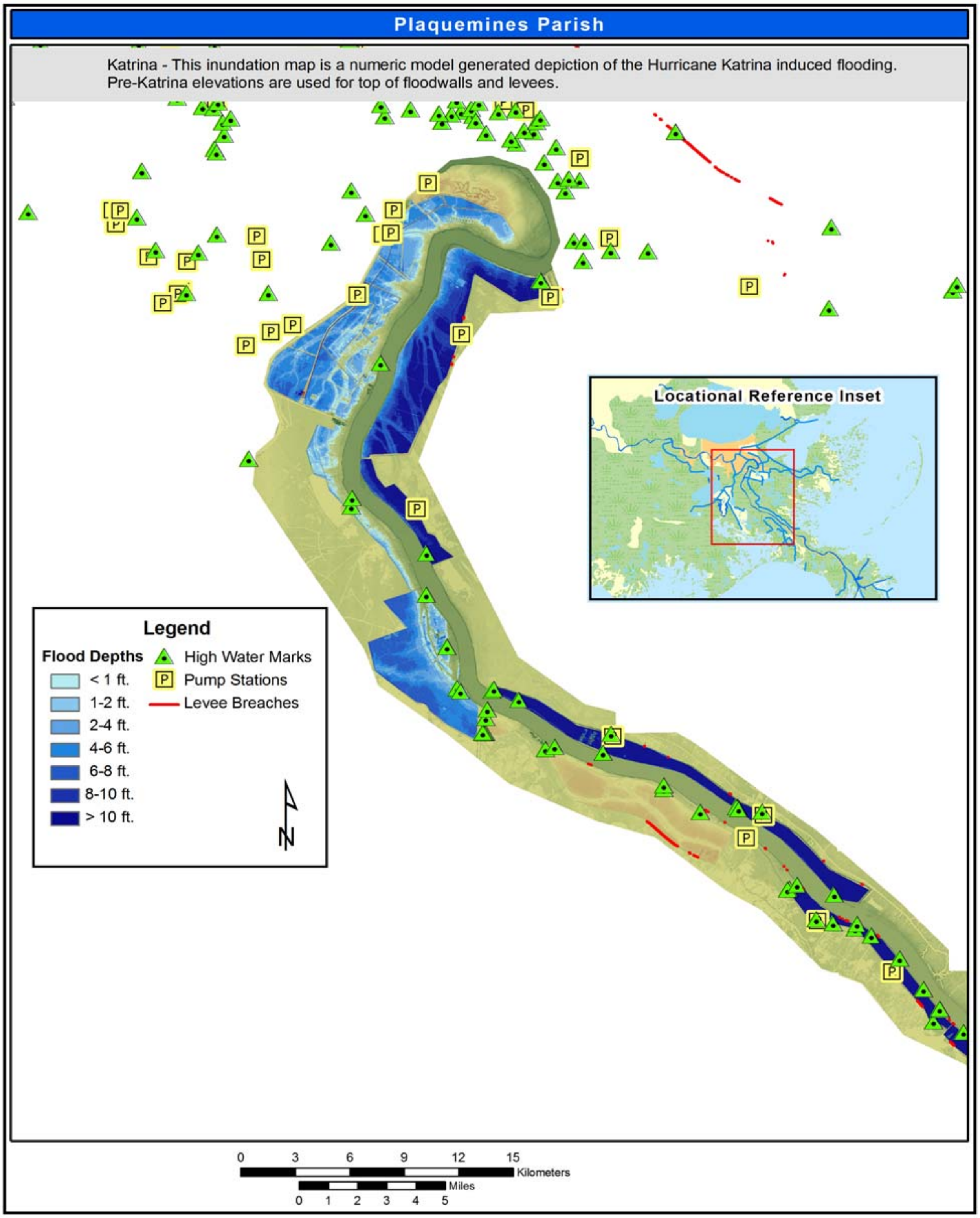

Katrina - This inundation map is a numeric model generated depiction of the Hurricane Katrina induced flooding. Pre-Katrina elevations are used for top of floodwalls and levees.

Figure 5-12. Calculated Flood Depths for Hurricane Katrina – Upper Portion

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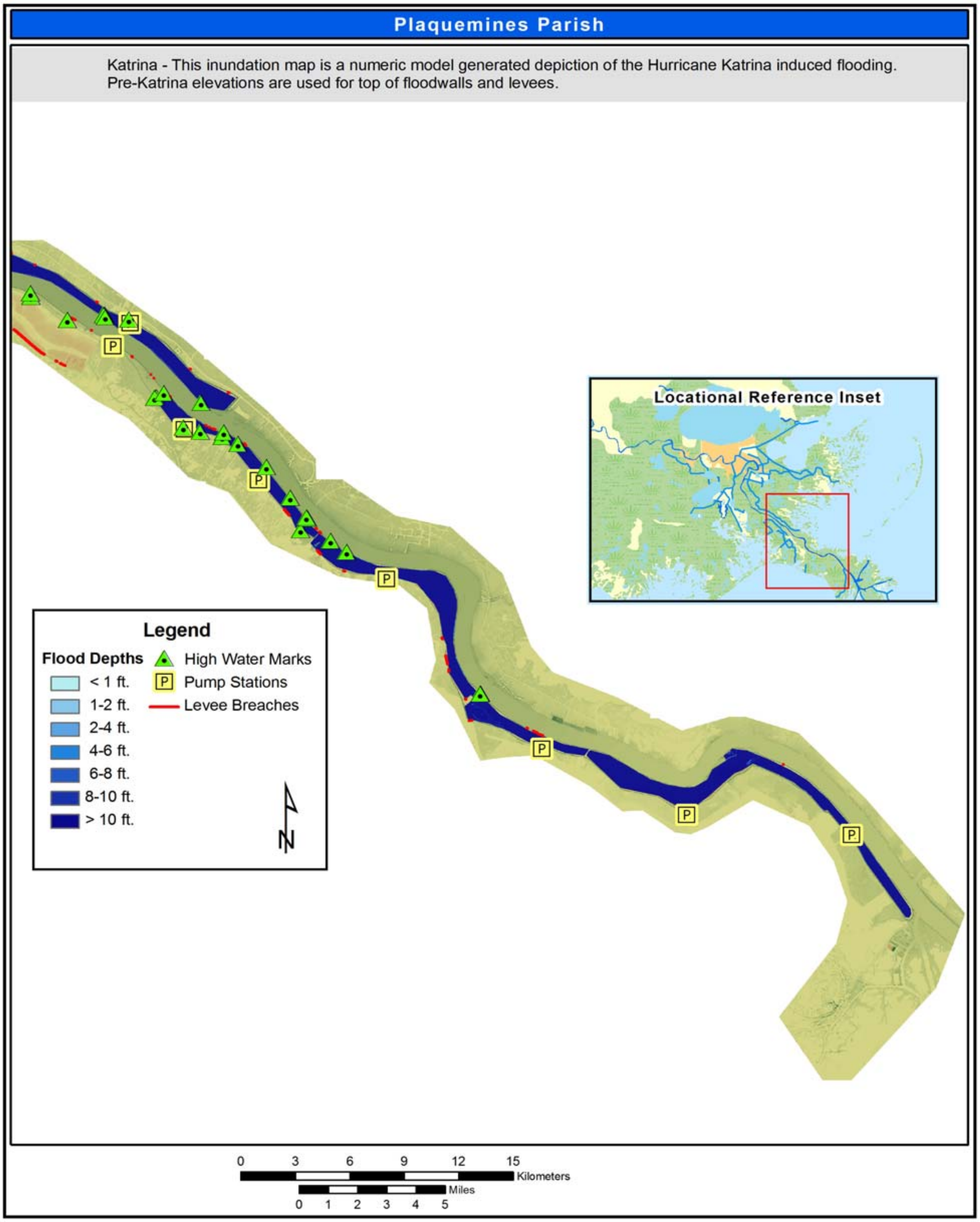

Figure 5-13. Calculated Flood Depths for Hurricane Katrina – Lower Portion

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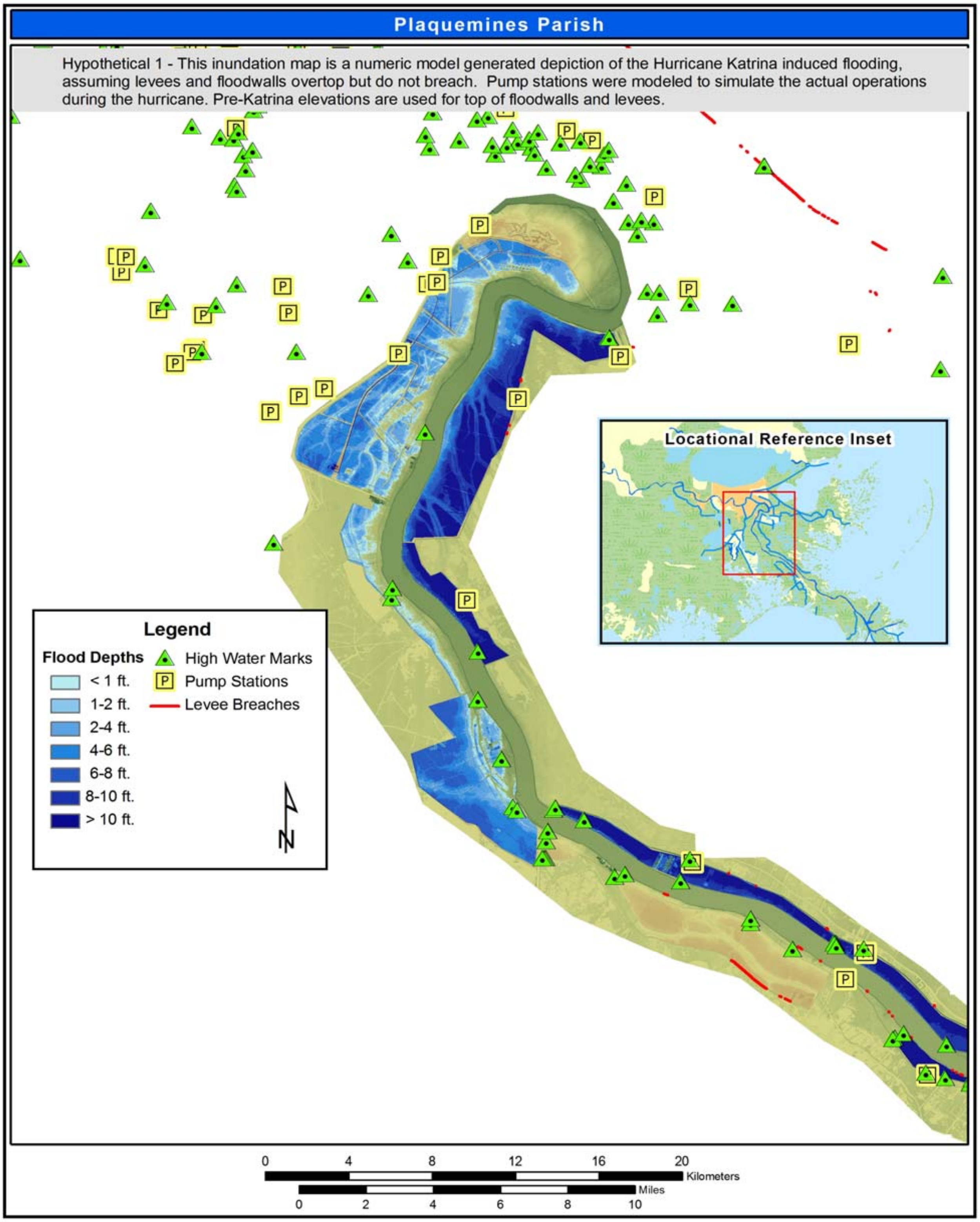
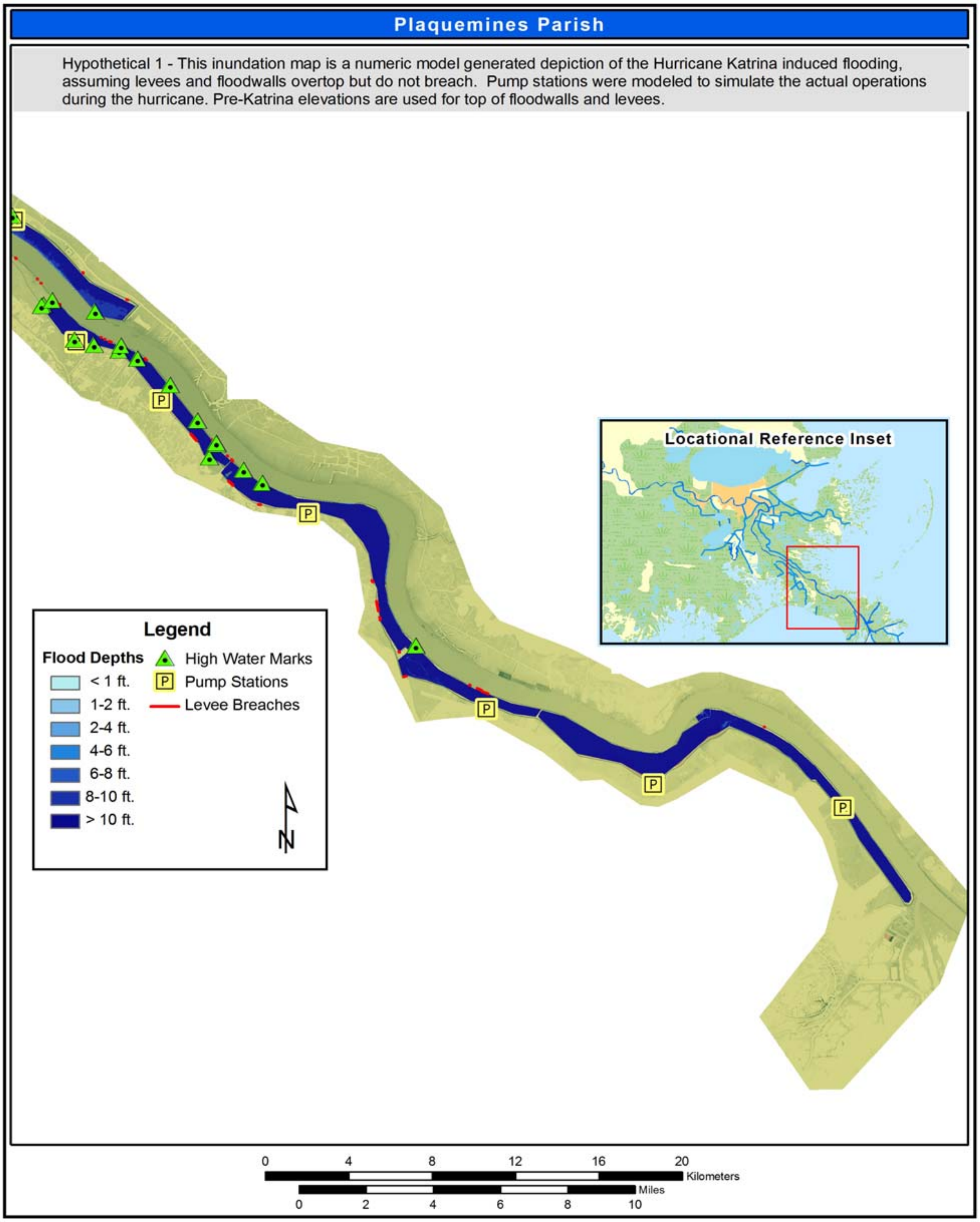


Hypothetical 1 - This inundation map is a numeric model generated depiction of the Hurricane Katrina induced flooding, assuming levees and floodwalls overtop but do not breach. Pump stations were modeled to simulate the actual operations during the hurricane. Pre-Katrina elevations are used for top of floodwalls and levees.

Figure 5-14. Calculated Flood Depths for Hypothetical 1 – Upper Portion



Plaquemines Parish

Hypothetical 1 - This inundation map is a numeric model generated depiction of the Hurricane Katrina induced flooding, assuming levees and floodwalls overtop but do not breach. Pump stations were modeled to simulate the actual operations during the hurricane. Pre-Katrina elevations are used for top of floodwalls and levees.

Figure 5-15. Calculated Flood Depths for Hypothetical 1 - Lower Portion

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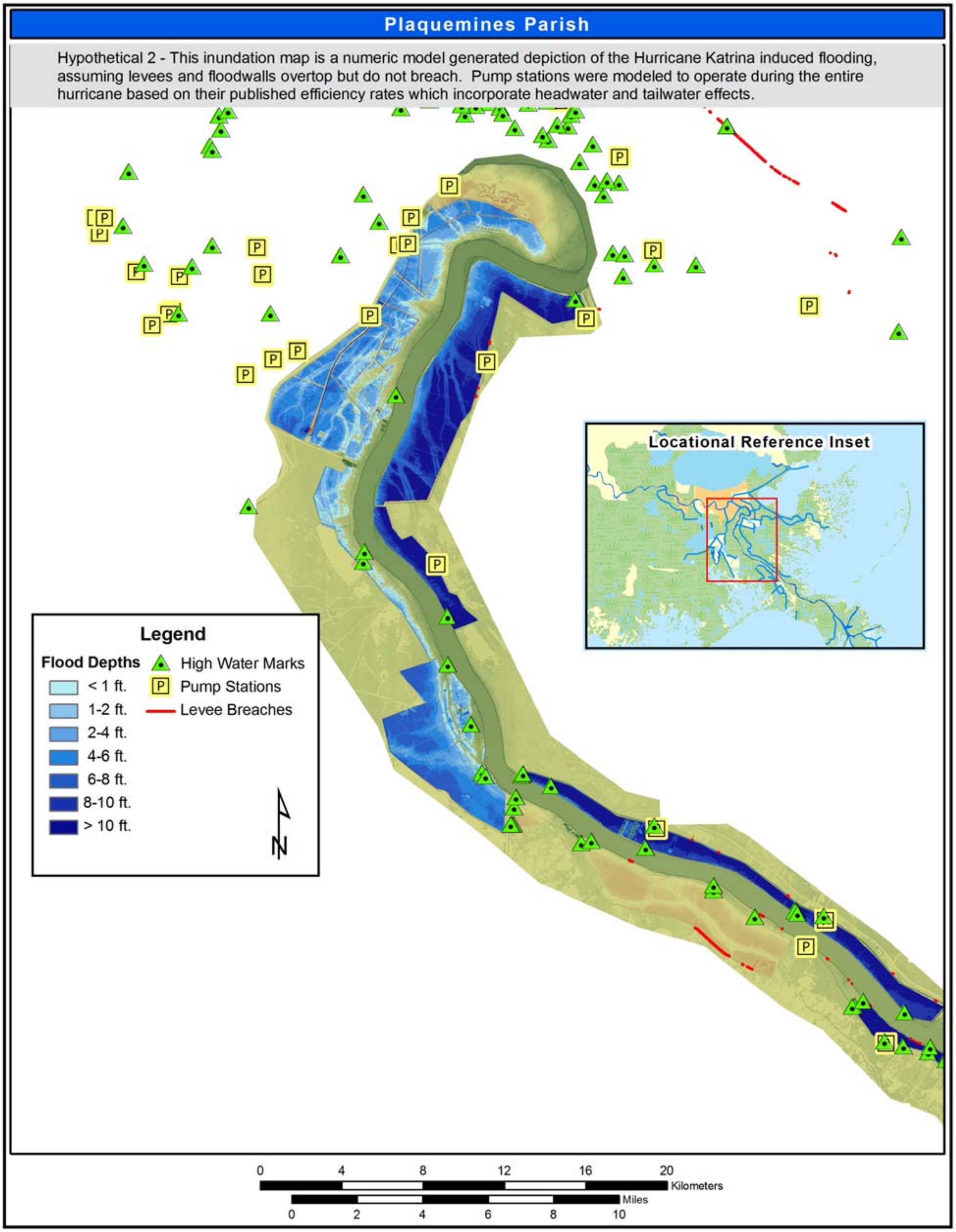

Figure 5-16. Calculated Flood Depths for Hypothetical 2 - Upper Portion

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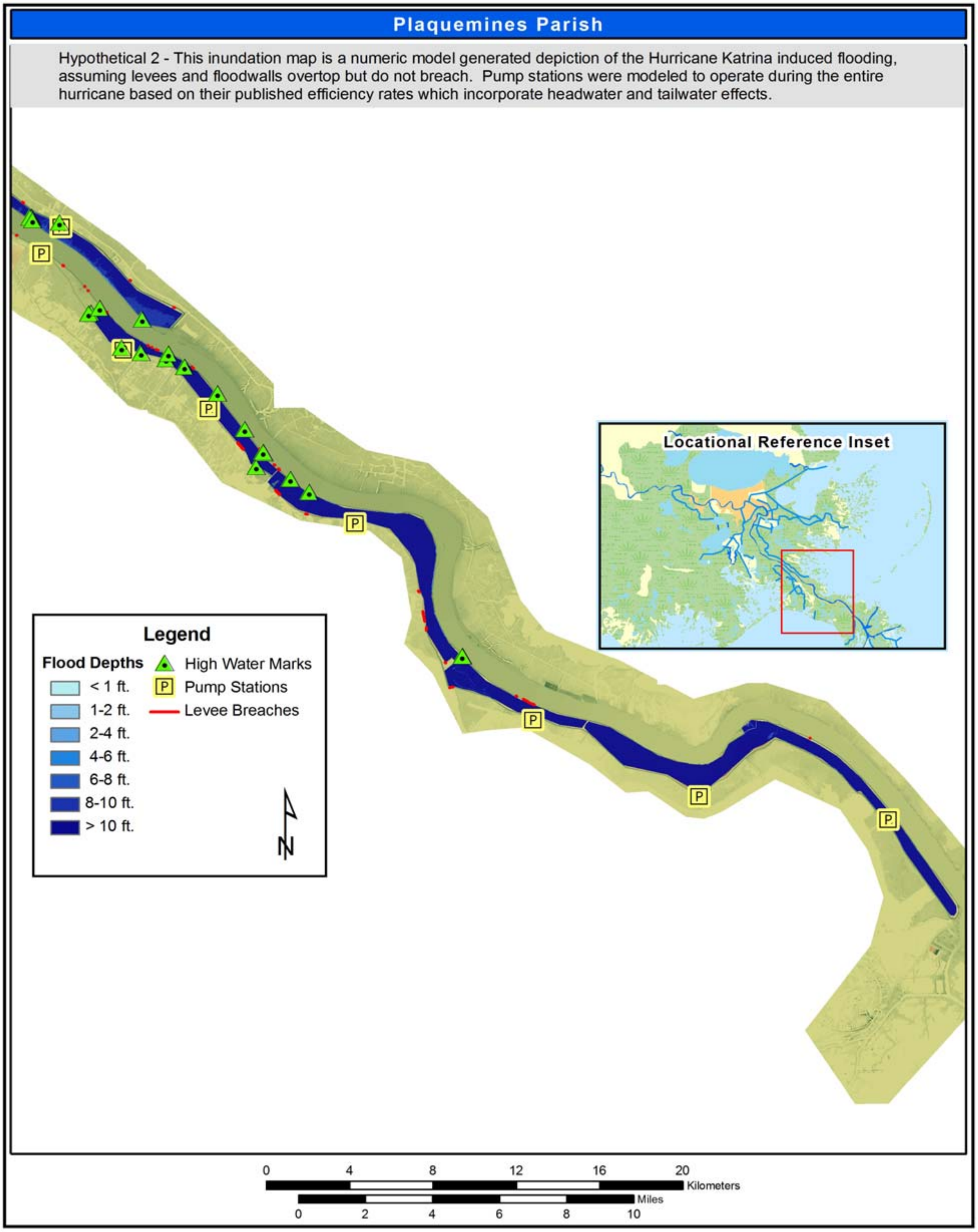

Figure 5-17. Calculated Flood Depths for Hypothetical 2 - Lower Portion

Appendix 6

Hydraulic Model Parameter Sensitivity Analysis

Introduction

Interior Modeling of the New Orleans area was performed with the HEC-RAS software. Due to limited data and time constraints, model calibration was only performed for the Katrina event using observed information obtained for that event. In order to evaluate the appropriateness of the model parameters, a sensitivity analysis of key parameters was performed for the New Orleans East model. Figure 6-1 shows the HEC-RAS schematic of the New Orleans East model.

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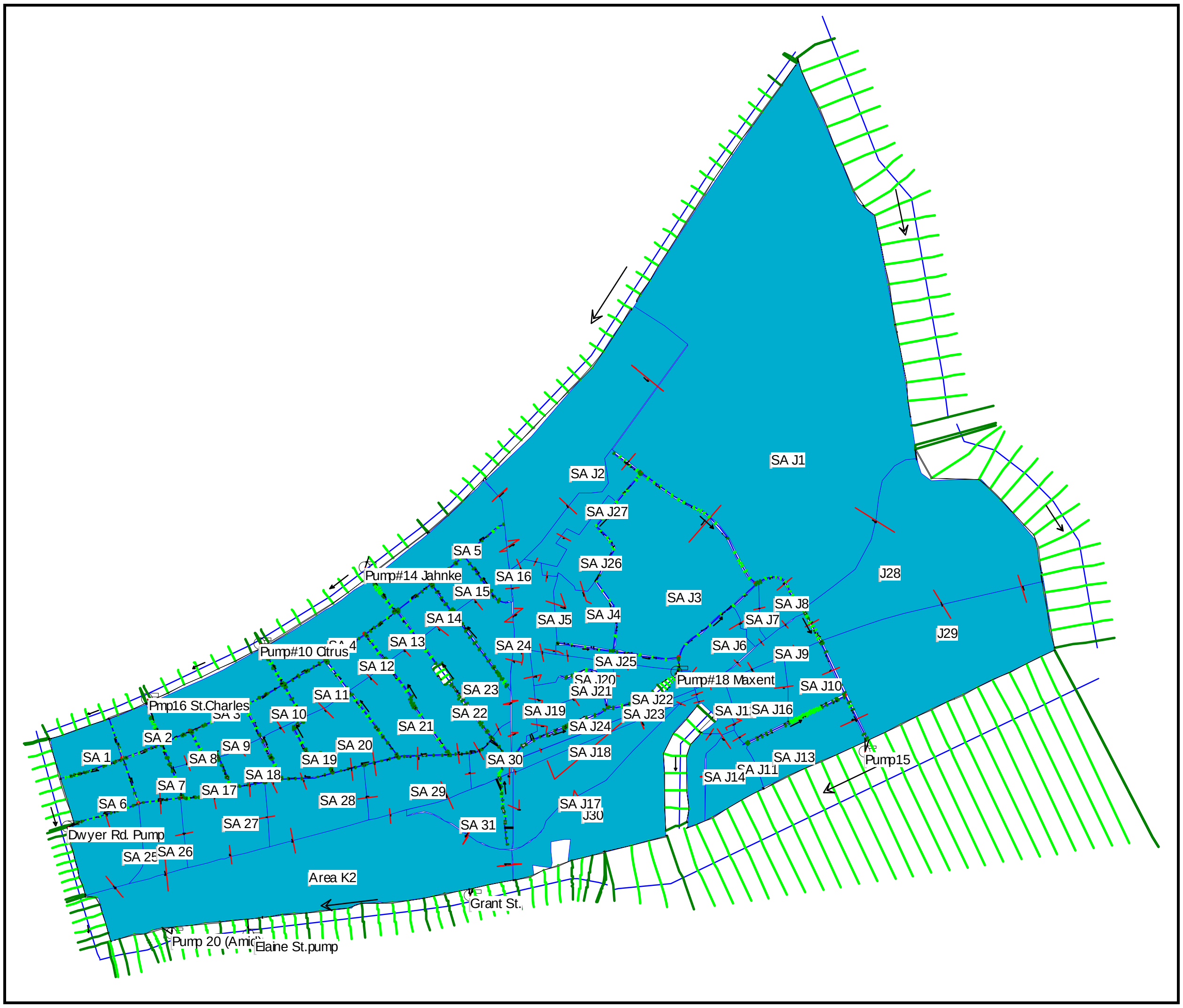

Figure 6-1. HEC-RAS Model Schematic for New Orleans East Area

Parameters Adjusted

In order to test the sensitivity of the model to parameter adjustments, a limited set of model parameters were adjusted up and down. The parameters selected are assumed to be the key parameters that would most affect the outcome of the model results. Table 6-1 lists the selected model parameters and the range of values used in the sensitivity analysis.

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Table 6-1
Key Model Parameters Adjusted

Model Parameter	Low Value	Medium Value	High Value
Levee Breach Times	½ hour	1 hour	2 hours
External Levee Weir Coefficients	- 10%	Calibrated Values	+ 10%
Internal Weir and Linear Routing Coefficients	- 10%	Calibrated Values	+ 10%
Main Channel Manning's n Values	- 10%	Calibrated Values	+ 10%

As shown in Table 6-1, the key parameters selected for the sensitivity analysis were: levee breach times; external levee weir coefficients; internal weir and linear routing coefficients; and main channel Manning's *n* values. The levee breach times and external levee weir coefficients were selected for testing because they directly affect how much, and how fast, water got into the New Orleans East basin through levee overtopping and breaching. The interior weir and linear routing coefficients were selected because they directly affect how water will move within the basin once it gets into the interior area. Main channel Manning's *n* values were also selected because they will impact water movement (velocities) and stages in the canals. No overbank Manning *n* values were adjusted because most river reaches in the model are canals, and the overbank areas were modeled with storage areas. Very little overbank area is modeled with cross sections.

Sensitivity Analysis Results

The model was first run for the Katrina Hurricane event and calibrated to match the observed high water marks and information gathered from interviewing residents who stayed during the event. Results for the Hurricane Katrina event applied to the New Orleans East model are documented in appendix 3 of Volume VI of this report. For this sensitivity analysis, key parameters were adjusted up and down and the model was run for a high and low range of each key parameter adjusted. Model results are shown for key locations within the model (Storage Areas: K2; J29; J11, J30, and SA4). These areas were selected because high water marks were available for most of these areas or because of their proximity to the major breaches. The following are the model results for each of the parameters.

Levee Breach Times

All of the levee breaches that occurred in the New Orleans East basin were on the south side of the basin, except for one small breach that occurred on the north east side near the airport. The major levee breaches occurred on the south east side of the basin. These earthen levees were completely overrun but the storm surge, and significant breaches occurred in this area. Some very large breaches were observed in this area, and those breaches were modeled separately in HEC-RAS. Many small breaches also occurred in this area. Many of these breaches were lumped together and modeled as a single breach in HEC-RAS. Additionally, three long sections of floodwall leaned over during the event near the Elaine Street pumping station along the Gulf Intracoastal Water Way (GIWW) while they were being overtopped. The three walls leaning over were also modeled as levee breaches, in order to have the weir sections lower during the event. All totaled, eight breaches were modeled in the HEC-RAS model.

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The breach times used in the model for the final calibrated model run ranged from 0.9 hours to 1.0 hours. For the purpose of this sensitivity analysis, one run was made with all breach times set to 0.5 hours, and another run was made with all breach times set to 2 hours. The following are stage and flow hydrograph plots at key locations from within the interior area (Figures 6-2 through 6-6). Most of the plots also have the observed high water mark for that area shown on the plot.

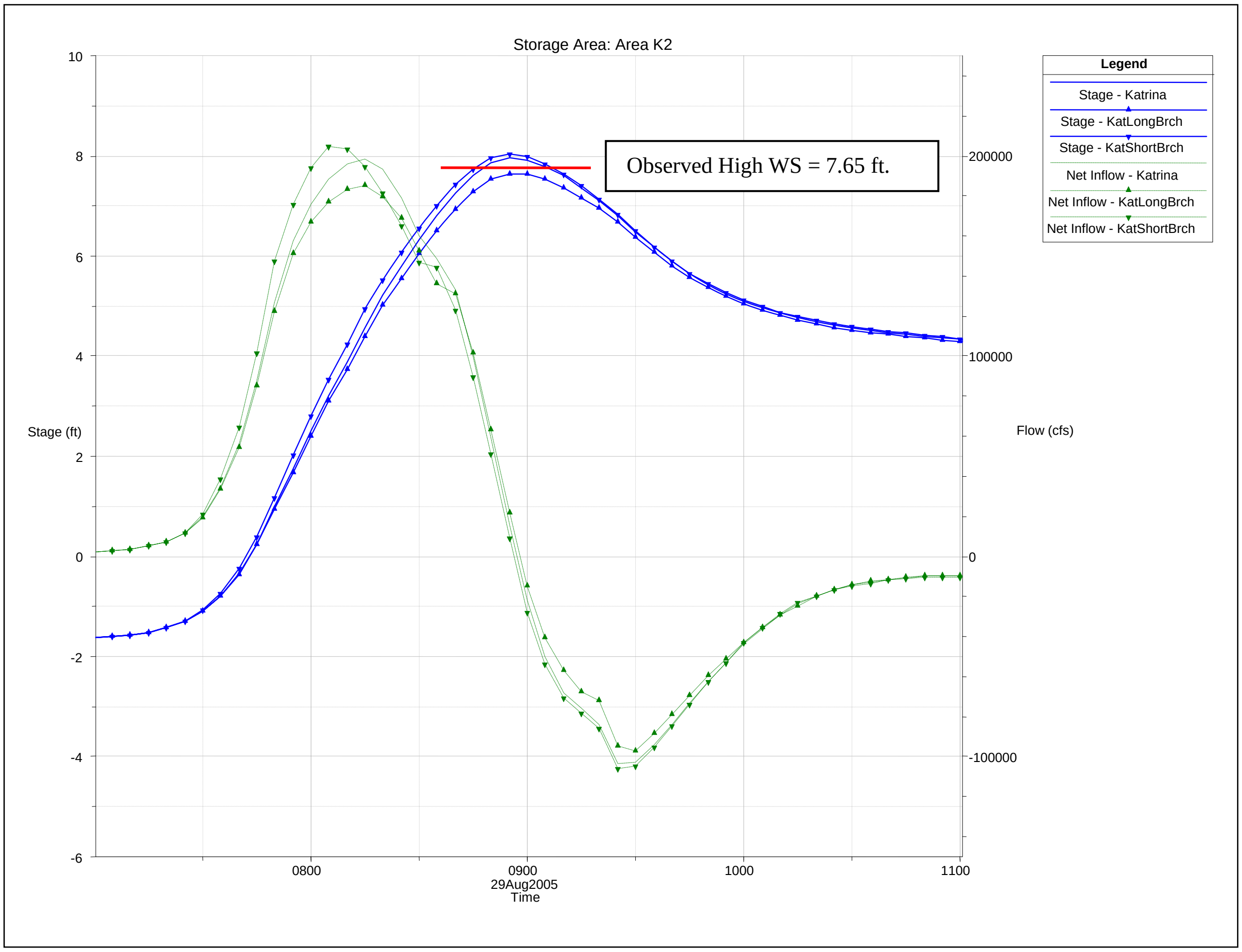

Figure 6-2. Flow and Stage for Storage Area K2

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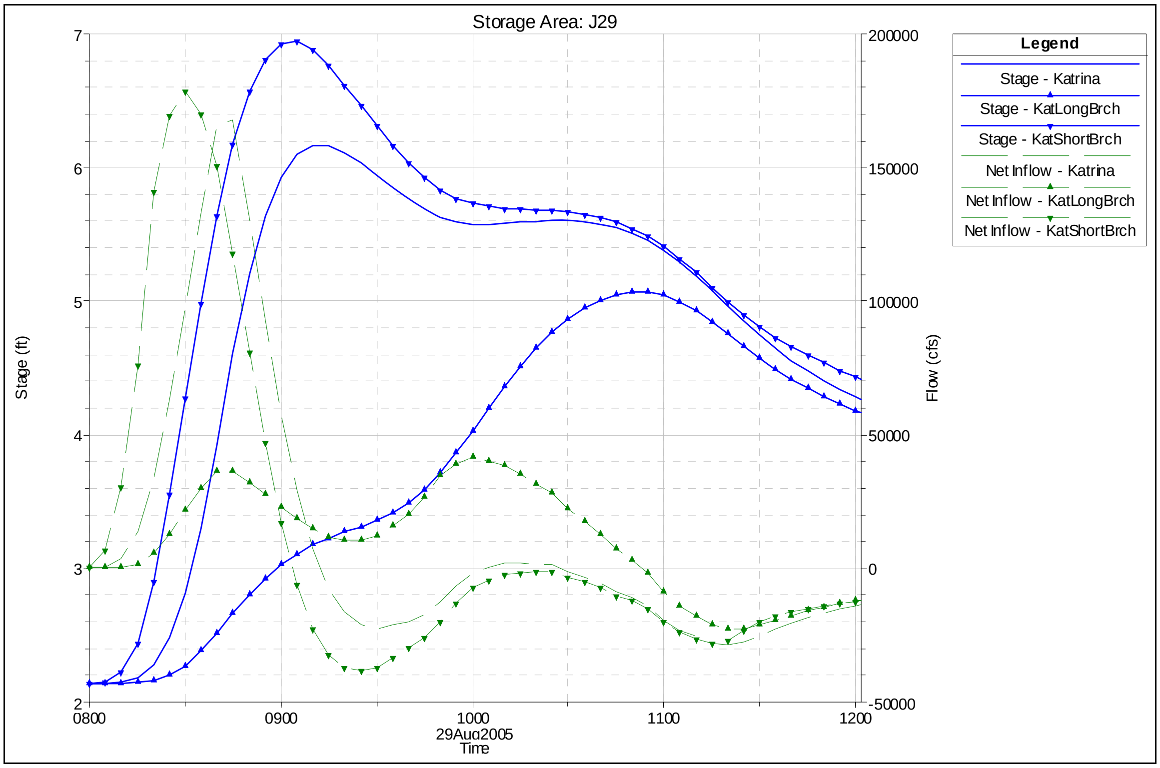

Figure 6-3. Computed Stage and Flow for Storage Area J29

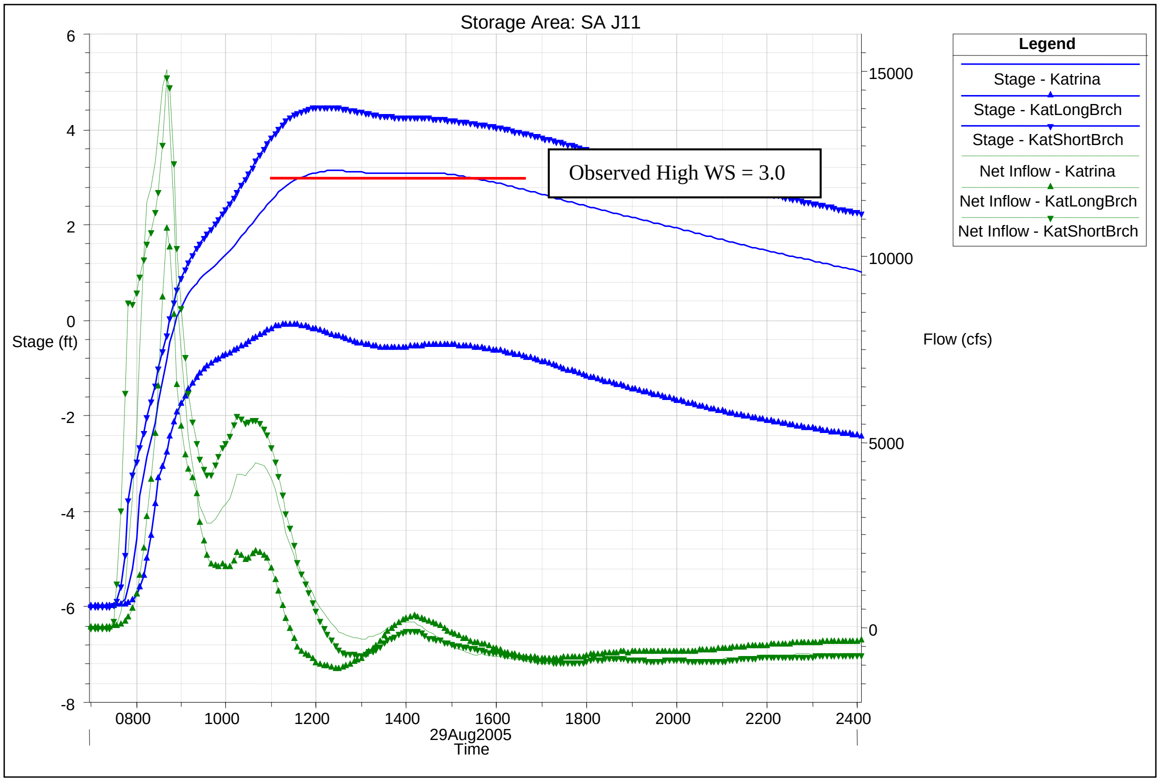

Figure 6-4. Computed Stage and Flow for Storage Area SA J11

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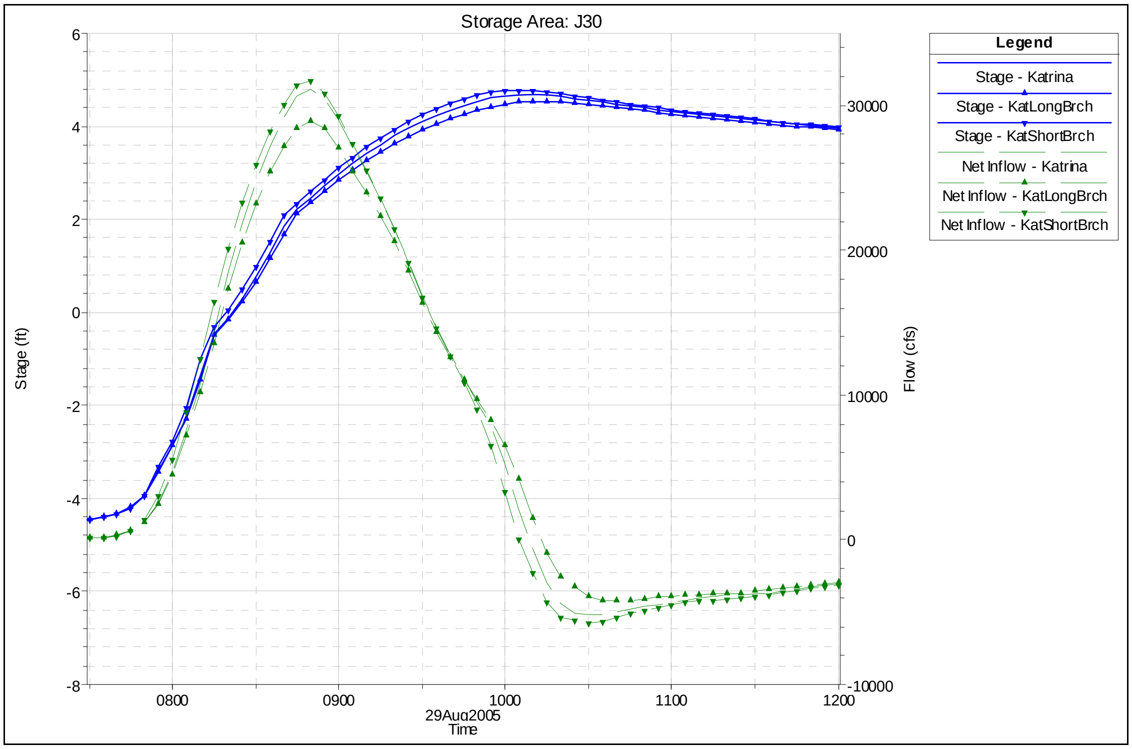

Figure 6-5. Computed Stage and Flow for Storage Area J30

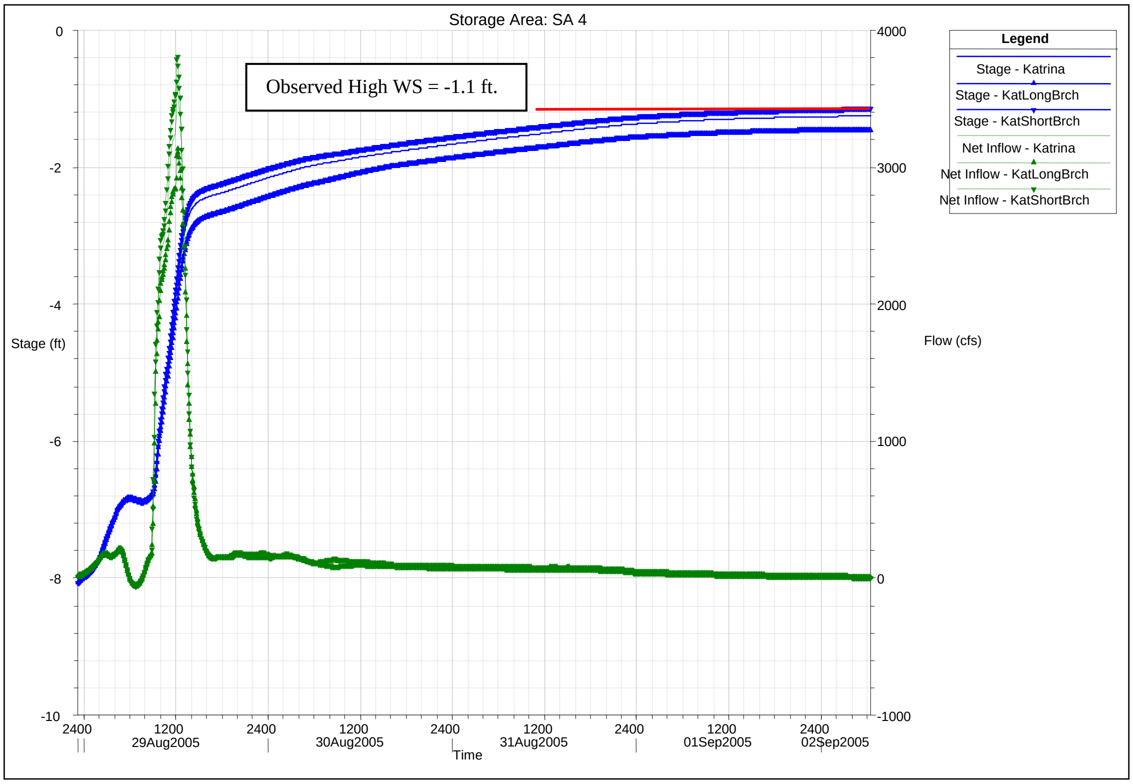

Figure 6-6. Computed Stage and Flow for Storage Area SA 4

As shown in Figures 6-2 through 6-6, the range of breach times has the greatest impact in the interior areas closest to the major levee breaches that occurred (i.e. area J29 and J11). Less of an impact is shown in areas K2 and J30, since these areas did not have significant levee breaches. No breach occurred near area J30, and the flood wall leaned over near K2, but did not fail. However areas K2 and J30 did have significant levee overtopping, which is why the levee breach times do not significantly change the results for these two areas. Area SA 4 is on the North side of the interior area. This area filled up slowly and is representative of the overall volume of water getting into the system As shown in Figure 6-6, the levee breach times of 0.5 hours and 1 hour were not significantly different for the final stage and overall volume of water getting into the New Orleans East parish. However, the 2 hour breach time produced a stage about 0.2 feet lower and a smaller overall volume of water got into the parish.

Looking at the observed high water marks, this sensitivity analysis demonstrates that the 1-hour breach times produce better overall stages across the entire parish, as well as a better estimate of the volume of water that entered into the system. A few locations showed slightly better peaks for the 0.5 hour breach, but many other locations showed that those breach times ended up with to high a water surface elevation and volume across the system.

Exterior Levee Weir Coefficients

Water going over the exterior levee systems is modeled as weir flow in HEC-RAS. For earth levees with broad crests, a weir coefficient of 2.6 was applied. For areas that contained floodwalls, a weir coefficient of 3.1 was used. This value would be typical for modeling a sharp crested weir, which was assumed to be appropriate for water going over a floodwall.

Most of the water that came into the New Orleans East area got into the system by overtopping the levees. Therefore an accurate estimate of a weir flow computation will have a significant impact on the results of the interior modeling. To test the sensitivity of the weir flow computations, the coefficients were all adjusted up by 10% for one run, and they were all adjusted down by 10% for another run. These two runs were then compared to the calibrated model results and the high water marks. Figures 6-7 through 6-11 show the results of changing weir coefficients for the same locations used for the levee breach time comparison.

As shown in Figures 6-7 through 6-11, varying the exterior levee weir coefficients produced a stage range from 1-2 feet, with most areas showing around the 1 foot stage range. Therefore the results are obviously sensitive to the exterior levee weir coefficients. When the model was developed, the weir coefficients were set at standard values and they were not changed during the calibration. The levee station and elevation information was obtained from the latest post Katrina LIDAR data that was developed for all of the levees. While this data is not as accurate as a detailed field survey of the levee profiles, it was the most accurate information available for the levee elevations. The other important variable affecting the overtopping flow is the exterior stage data. As noted previously the exterior stage hydrographs are based on the ADCIRC model runs for hurricane Katrina, with adjustments made to match the observed high water marks found on the exterior sides of the levees. Assuming the levee station elevation data is reasonable, and that the exterior water surface elevations are as good as we are going to be able to estimate, then

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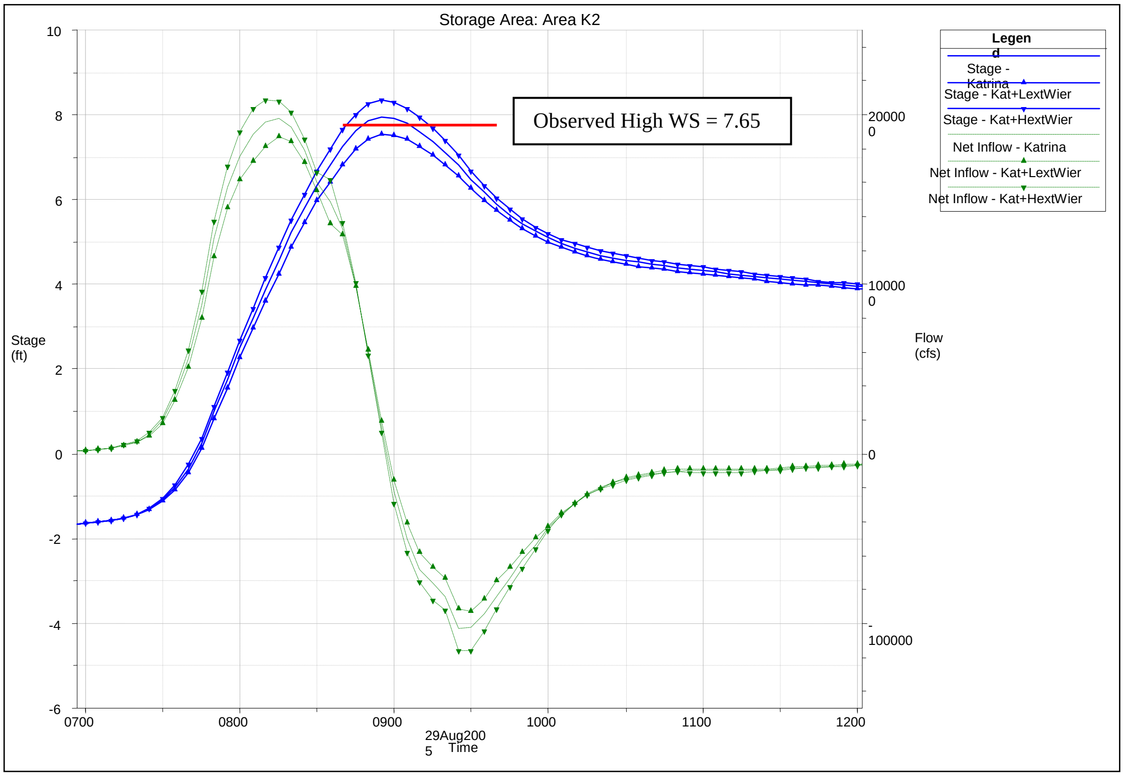

Figure 6-7. Computed Stage and Flow for Storage Area K2

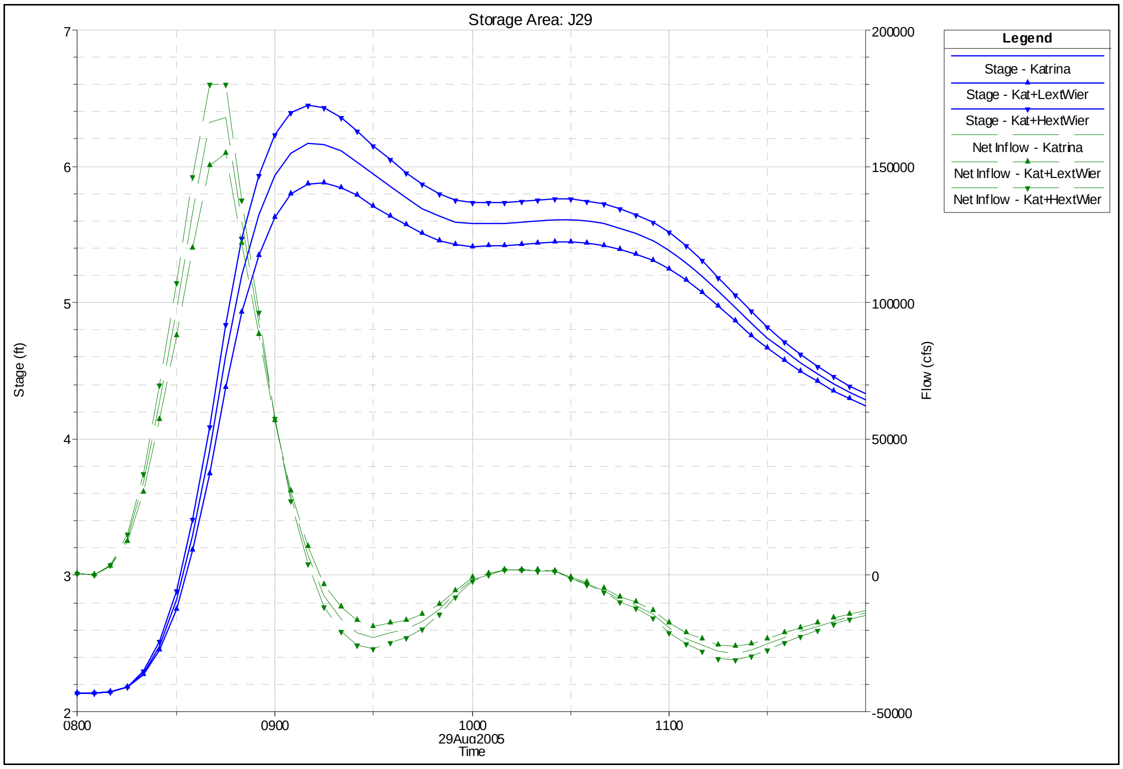

Figure 6-8. Computed Stage and Flow for Storage Area J29

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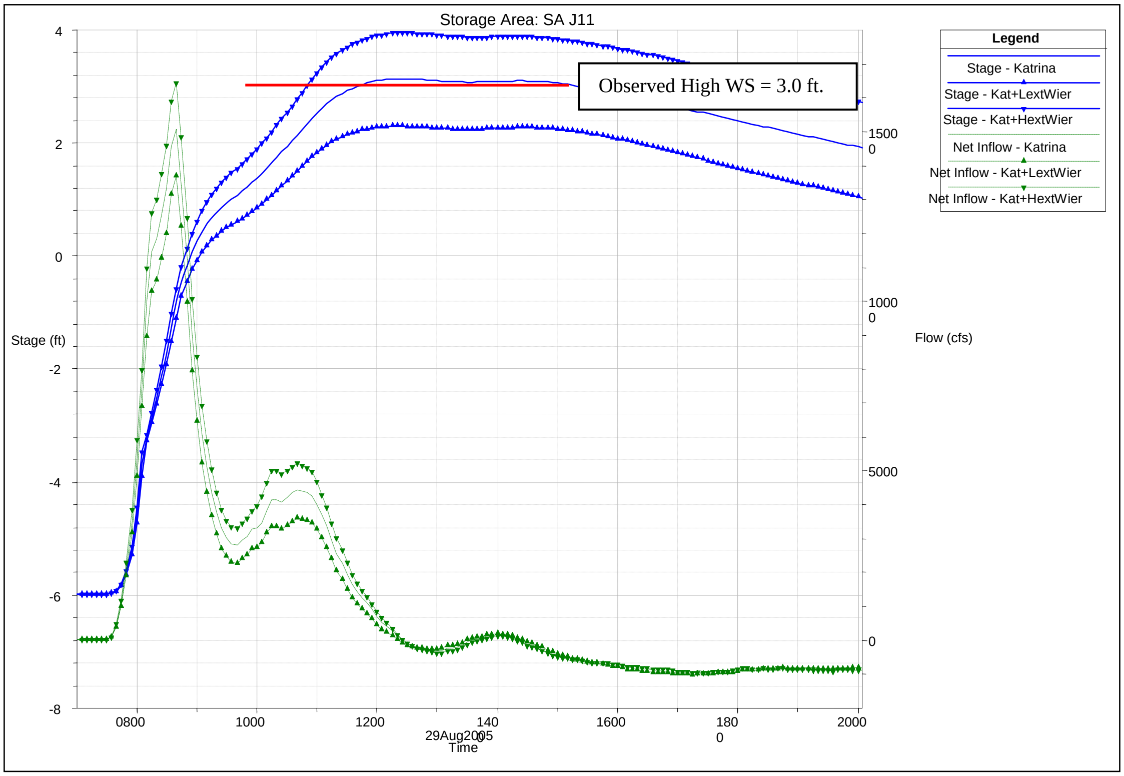
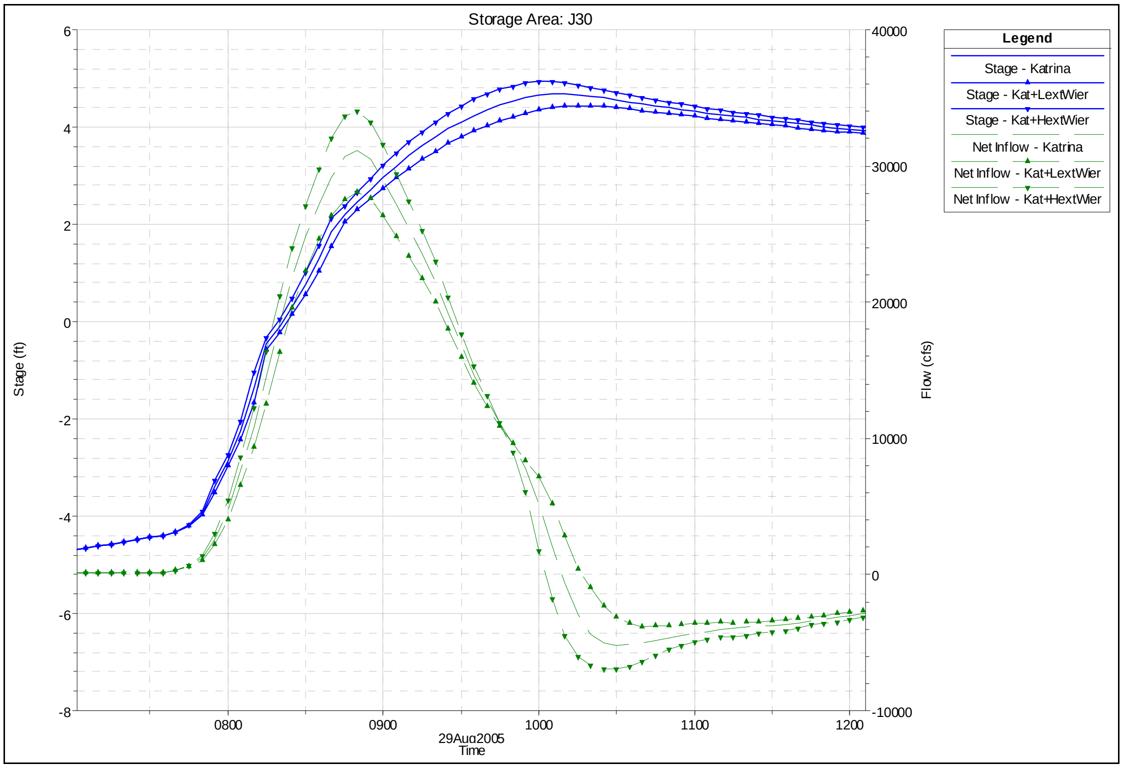


Figure 6-9. Computed Stage and Flow for Storage Area SA J11



This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Figure 6-10. Computed Stage and Flow for Storage Area J30

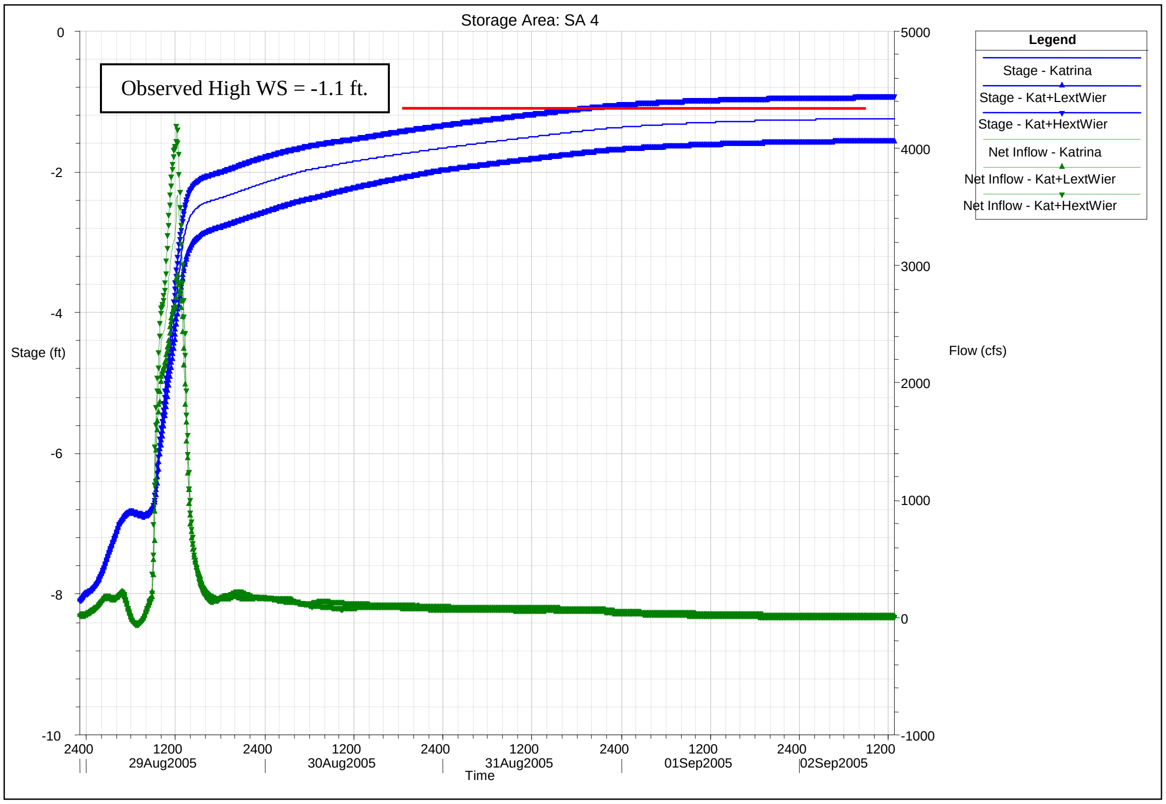


Figure 6-11. Computed Stage and Flow for Storage Area SA 4

using the standard weir coefficients produces the best overall interior area stages and volumes as compared to the observed high water marks.

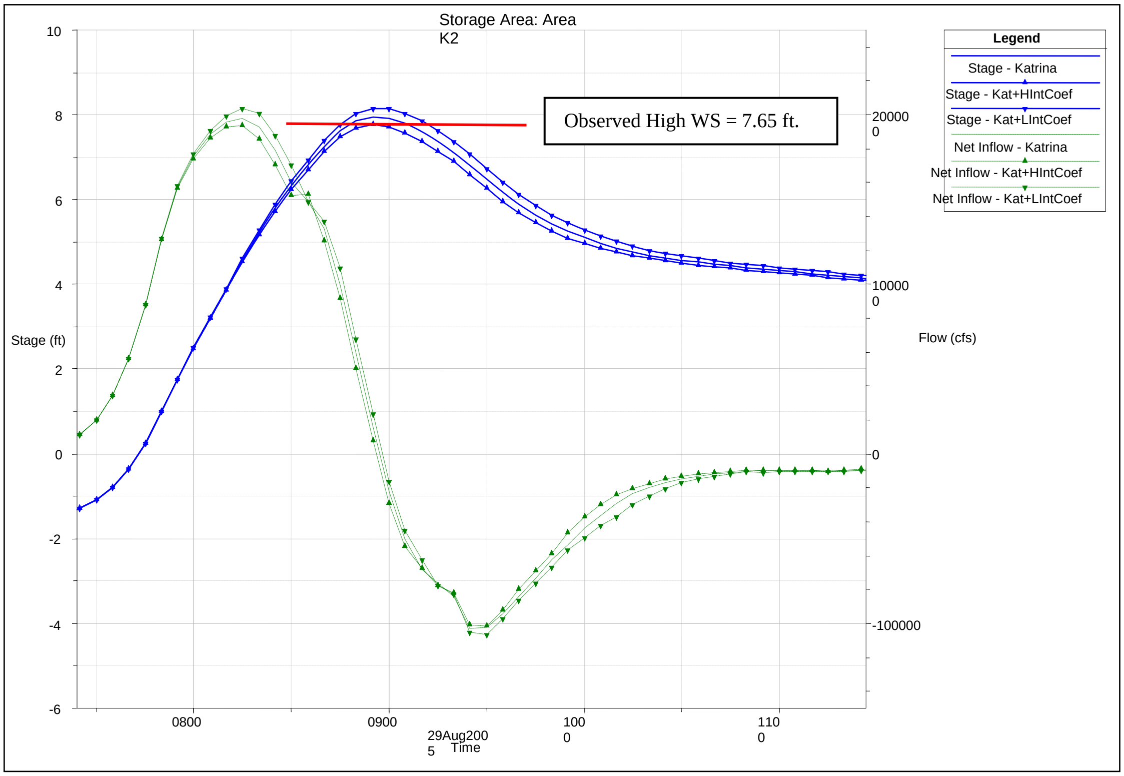
Interior Weir and Linear Routing Coefficients

The interior area has been modeled with canals, pump stations, and storage areas, all of which are hydraulically connected together. Storage areas represent the land surfaces. Each storage area was modeled as a subbasin in HEC-HMS. Rainfall runoff calculations were performed, and the runoff hydrographs were used as input into the storage areas within HEC-RAS. The storage areas are hydraulically connected to the canals by using weir profiles and equations. The high ground that separates the canal water from the land surface is entered as station and elevation data. This profile is then used to pass flow between the canals and the surface areas using a weir equation. Flow can go in either direction, and weir submergence is calculated to reduce the flow when both the canal water surface and the storage area water surface are near the same elevation. Storage areas that are laid out directly next to each other, but have no canal between them, are also hydraulically connected. If high ground exists between two storage areas, then a weir profile and equation is used to pass flow between the storage areas. If there is no high ground between the storage areas, then a linear routing option is used to pass flow between the storage areas.

For the areas modeled as weir profiles, that had high ground between the storage areas, the weir coefficients for these weirs were set to typical values (i.e. 2.6 for broad crested weir shapes. For the areas next to a canal, water will typically move out of and into a canal as sheet flow away from or into the canal area. A weir equation is used to model this hydraulic connection. Use of typical weir coefficients would result in water entering or leaving the canals too quickly. Therefore, values much lower than normal weir coefficients must be used for this type of hydraulic connection. Past experience in developing and using HEC-RAS models with this type of modeling has shown that coefficients around 1.0 tend to produce reasonable results for transitioning flow into and out of a channel with overbank flow. Obviously though, these coefficients need to be calibrated to ensure they are producing reasonable and consistent results.

Because this model was only calibrated to the Hurricane Katrina event, the interior weir and linear routing coefficients were selected as part of the sensitivity analysis to test what would happen with higher and lower values than what was used for the final calibrated model. The following plots show the flow and stage hydrographs for three runs: the calibrated model run; a run in which all of the interior weir and linear routing coefficients were increased by 10%; and a run in which all of the interior weir and linear routing coefficients were decreased by 10%.

As shown in Figures 6-12 through 6-16, modifying the interior weir and linear routing coefficients did not significantly change the results. The largest change in stage was roughly 0.4 feet from the low value to the high value. Additionally, the timing of the hydrographs did not change significantly. The reason changing these values did not make a significant difference, is that the interior area is so overwhelmed with water. The interior weirs that separate the canals from the storage areas, and between storage areas, become highly submerged. The final water surfaces are much more a function of the volume of water getting into the system for this event.



Observed High WS = 7.65 ft.

Figure 6-12. Computed Stage and Flow for Storage Area K2

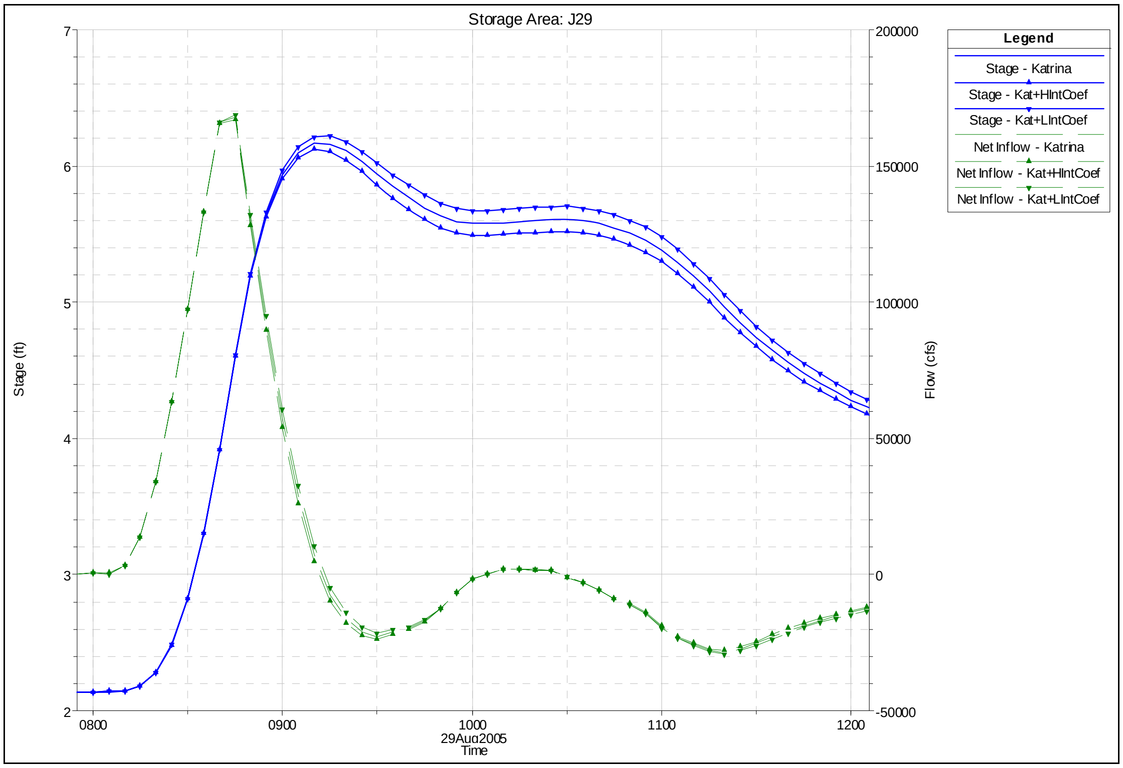


Figure 6-13. Computed Stage and Flow for Storage Area J29

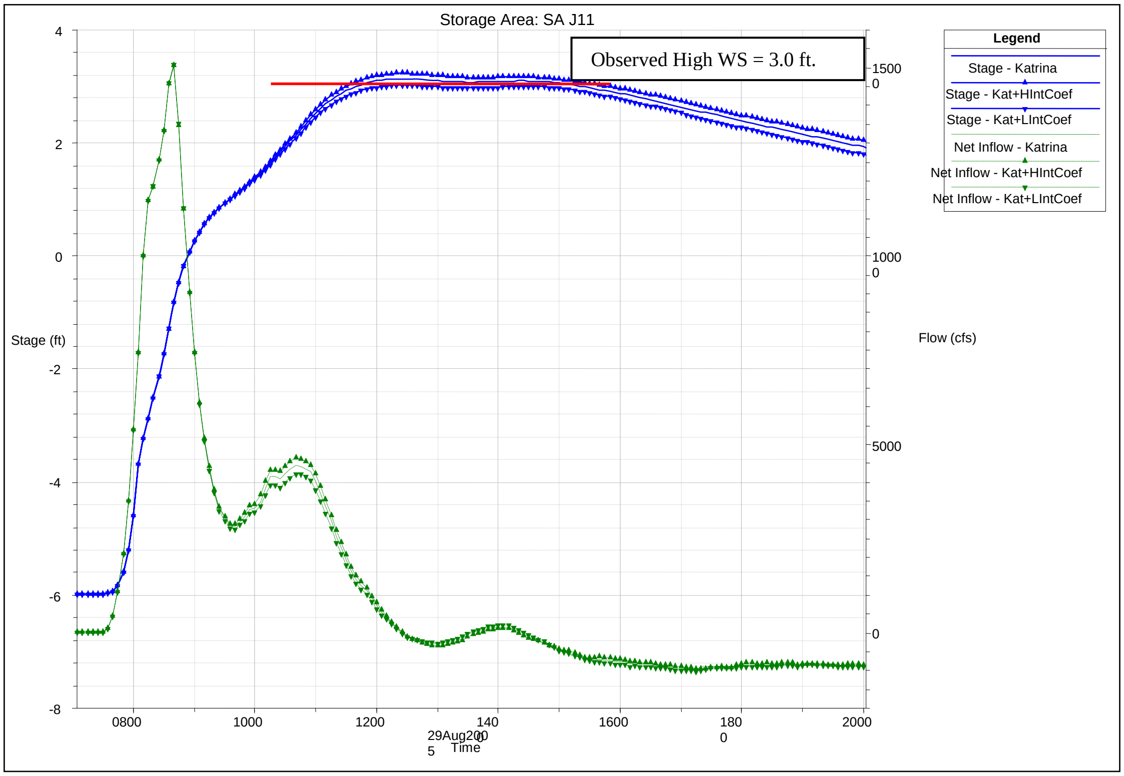


Figure 6-14. Computed Stage and Flow for Storage Area J11

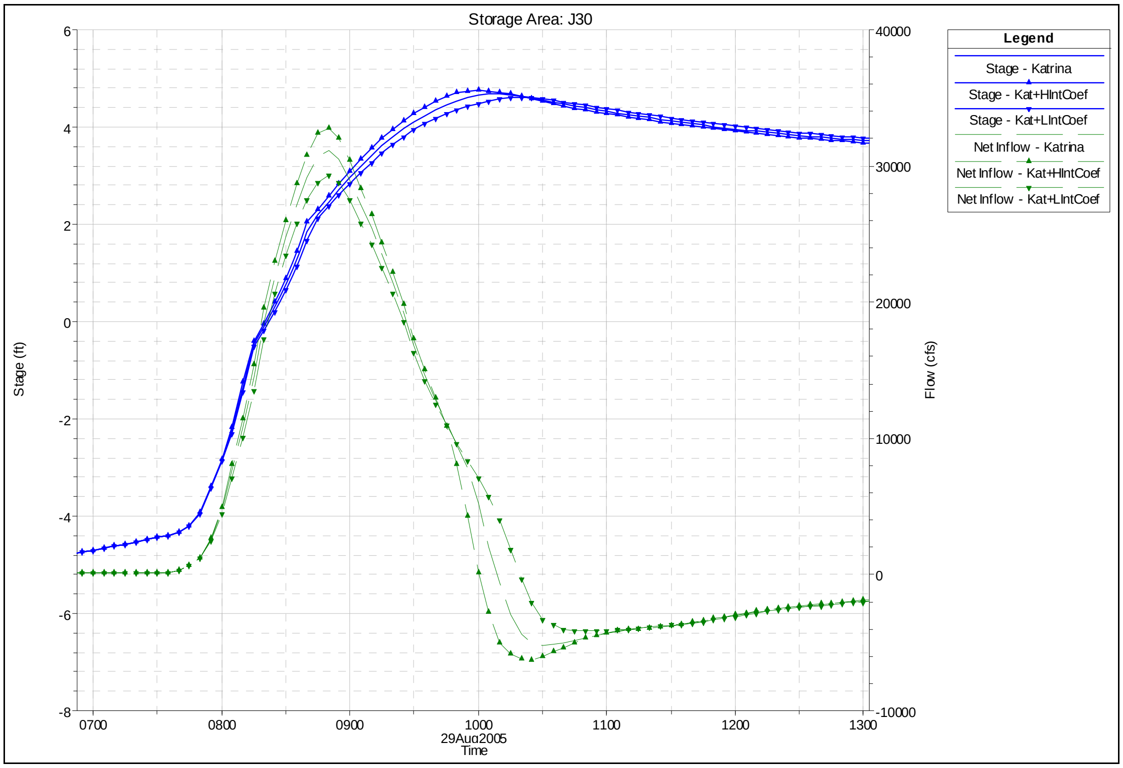


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Figure 6-15. Computed Stage and Flow for Storage Area J30

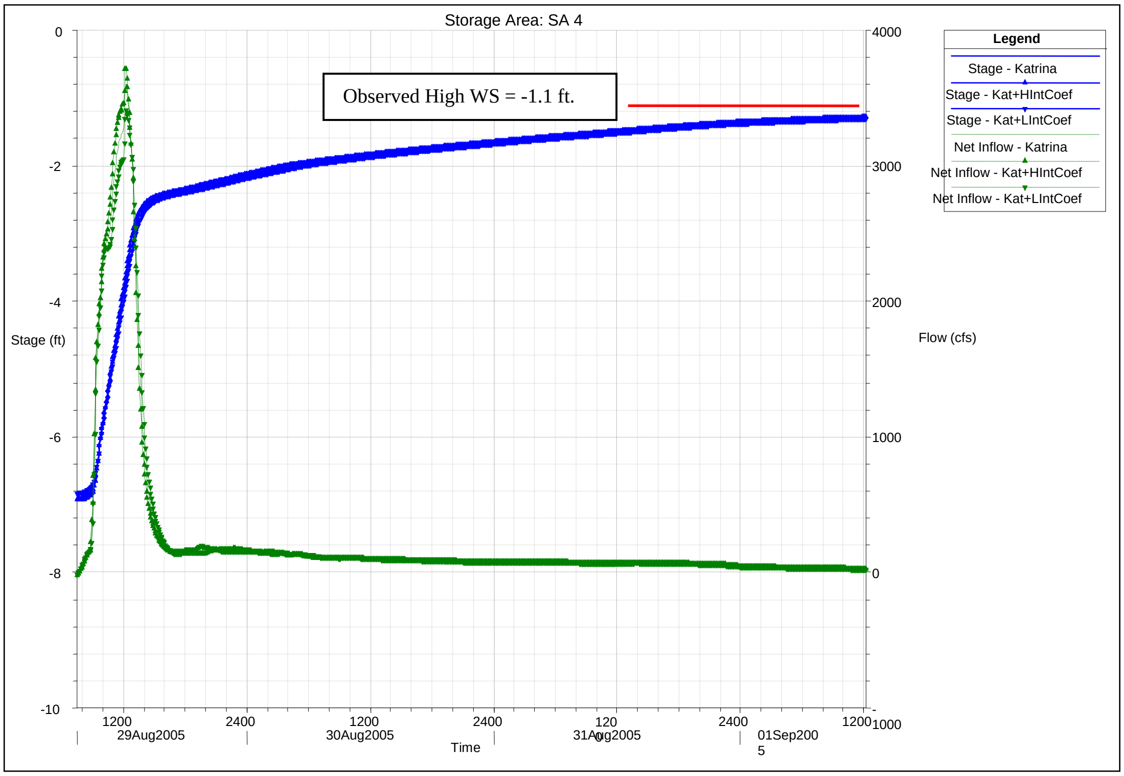


Figure 6-16. Computed Stage and Flow for Storage Area SA 4

Main Channel Manning's n Values

The final set of parameters that were tested were the main channel Manning's *n* values. The Manning's *n* values for all of the canals were adjusted up 10% and down 10% in order to test their sensitivity. The following plots show the resulting hydrographs for the low, mean, and high range of Manning's *n* values.

As shown in Figures 6-17 through 6-21, changing the Manning's *n* values did not change the results significantly. In fact, this parameter had the least affect in the results as compared to the other parameters that were investigated. The main reason for this is that the canals ended up carry only a very small percentage of the flow that entered into the New Orleans East interior area. Because the canals were quickly overwhelmed by the event, most of the water moved over the land surface from one area to another.

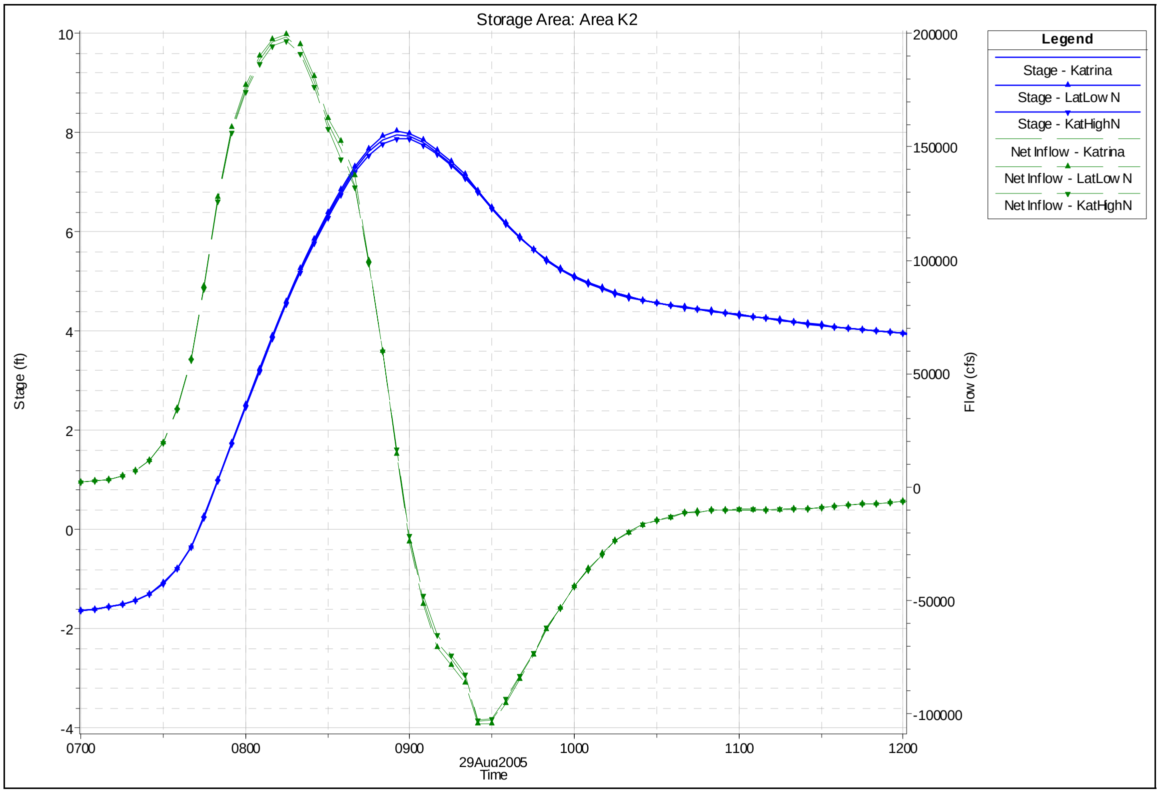
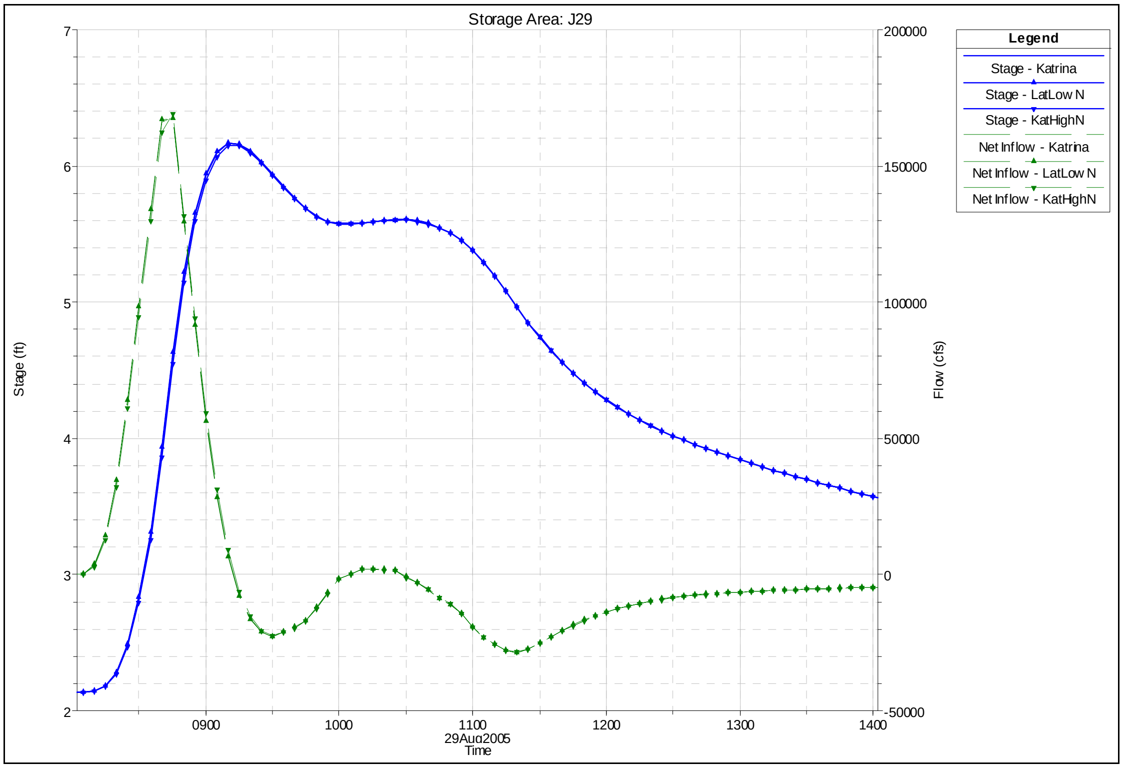


Figure 6-17. Computed Stage and Flow for Storage Area K2



This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Figure 6-18. Computed Stage and Flow for Storage Area J29

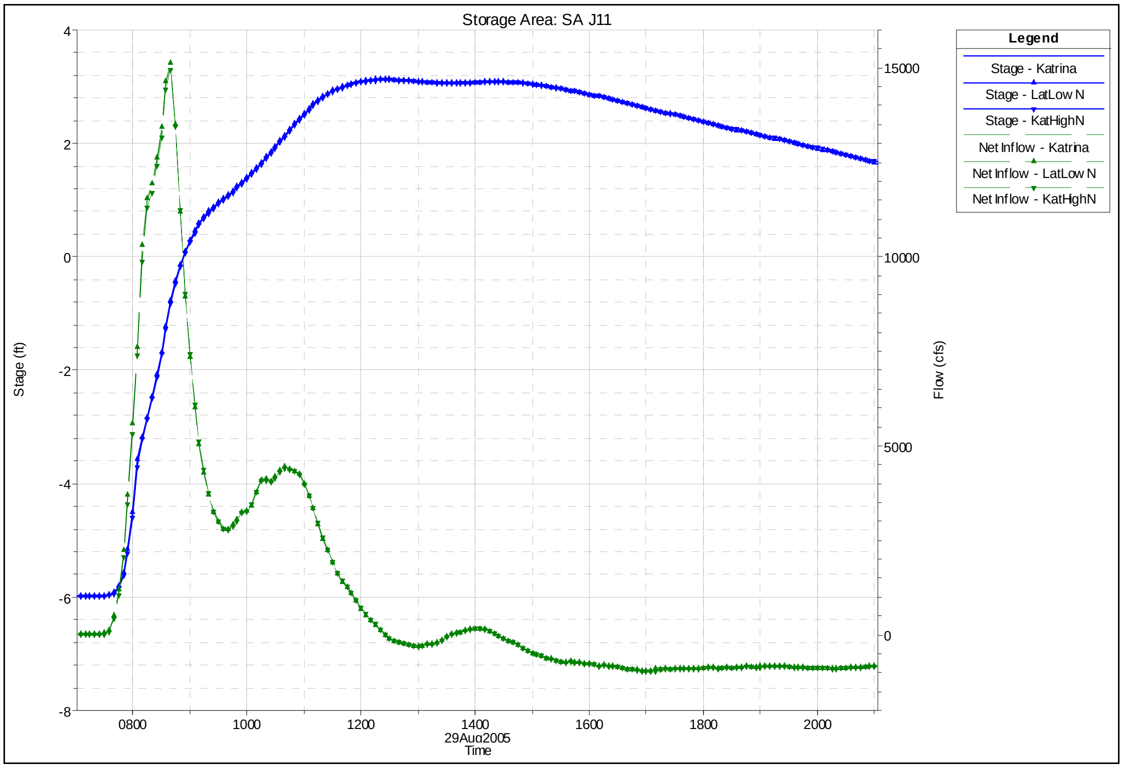


Figure 6-19. Computed Stage and Flow for Storage Area J11

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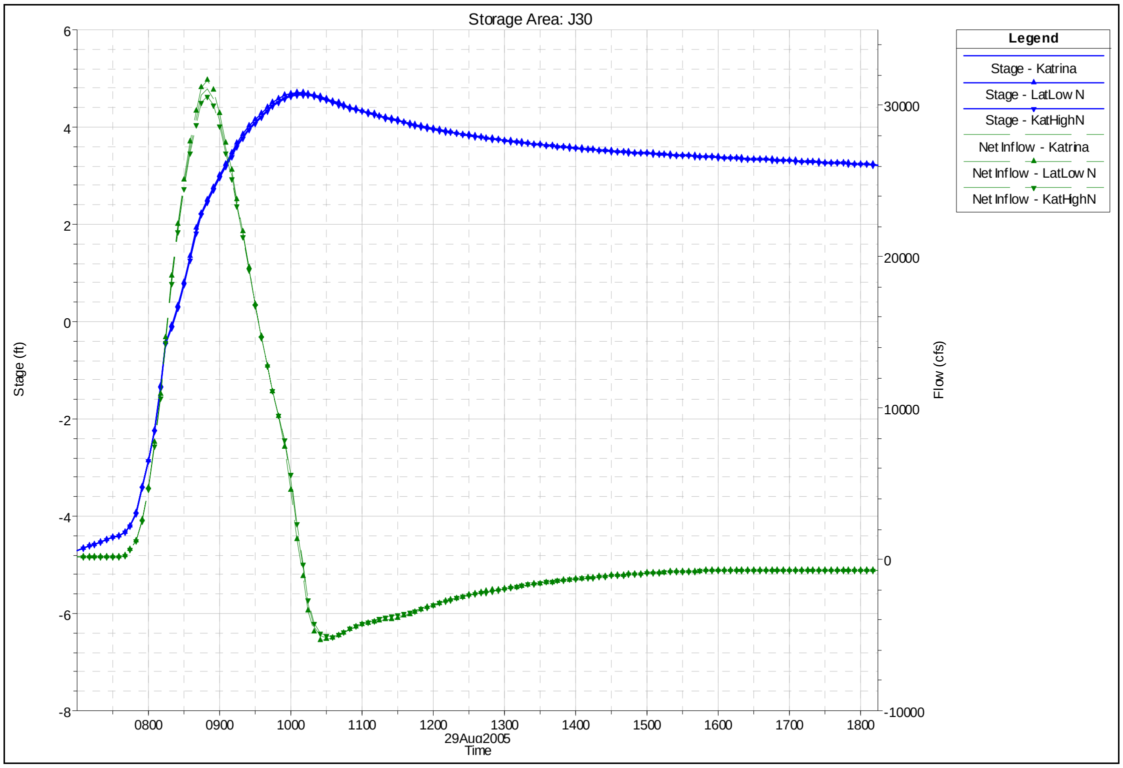

Figure 6-20. Computed Stage and Flow for Storage Area J30

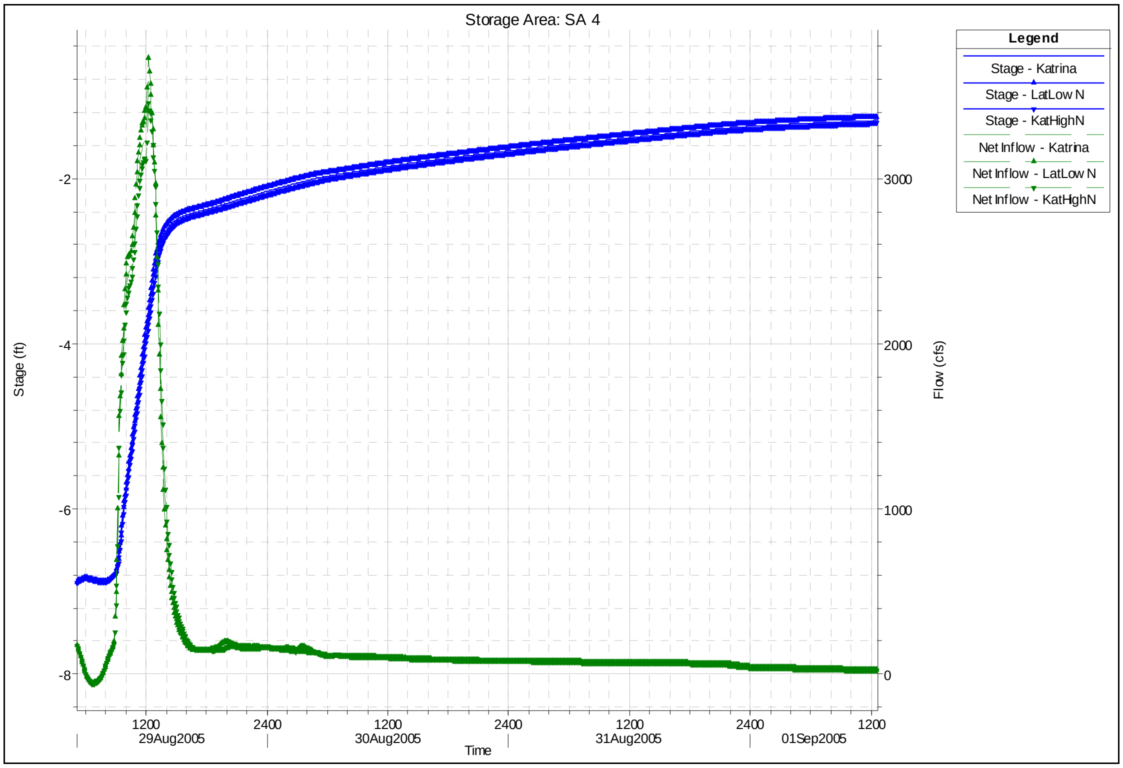

Figure 6-21. Computed Stage and Flow for Storage Area SA 4

Conclusions

As shown from this sensitivity analysis, the model was most sensitive to changes in the levee breach times and the exterior area weir coefficients. While changing the interior weir coefficients, linear routing coefficients, and main channel Manning's *n* values did not change the results significantly. These results are not unexpected for this event. The interior area is completely overwhelmed by water. Therefore, the variables that control how much water can get into the interior area should be the most sensitive to the final results. Based on this sensitivity analysis, the selected values for all of the coefficients are giving reasonable results. Changes to model parameters would not improve the results.

Appendix 7
Pumping Station Technical and Detailed Report

Contents

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

List of Tables

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

List of Equations

List of Figures

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

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7.1 General Summary

The mission of the IPET pumping station analysis is to examine the pumping stations' capabilities before, during, and after Hurricane Katrina in four of the New Orleans District parishes: Jefferson, Orleans, St. Bernard, and Plaquemines. The analysis includes the following information:

- An explanation of the pump stations function in the flooding during the hurricane
- An examination of damages to the pump stations resulting from the flooding
- An assessment of the extent of flooding and damages due to the pump stations if no catastrophic breaching had occurred
- A determination of the risk and reliability of the pumping stations' capabilities in the hurricane protection system (HPS) both prior to Katrina, and after planned repairs and improvements
- A list of lessons learned regarding the pump stations

The analysis looks at a total of 83 pump stations from the four parishes. There are additional stations in Orleans and Jefferson Parishes that were not considered for this report because their combined capacity was less than 5% of the total capacity. The analysis incorporated data from sources such as operation logs, interviews, pump manufactures' literature, pump station drawings, and parish meetings.

Sections 7.2 through 7.6 break the analysis into parish summaries and individual pump station reports. The parish summaries include a map of the parish, a pump equipment table, and a list of improvements suggested by the parish, Task Force Guardian,[1] and the Task 8 of IPET[2]. The pump station summaries are more detailed and are organized by parish and drainage area. They are located after the parish summaries. The first page of each summary includes elevation and aerial[3] photos of the station before and after the hurricane, location by latitude and longitude, a physical address, and a contact phone number. Below is a description of the additional information that is provided in each pump station description.

7.1.1 Modeling

One of the functions of this part of the report is to provide information for the interior drainage modeling team. The team used the information to model the drainage and pumping that occurred during the hurricane.

To assist the interior drainage modeling team, the individual pump start and stop times were extracted from the available operating logs collected in the field. The team was mostly concerned with the day before Hurricane Katrina made landfall (August 28) until that specific area was dewatered. Not all start and stop times were clearly documented or legible and efforts were taken to clarify the operating logs with the station operators. This information was then sent to the

---

[1] Task Force Guardian was created to rebuild the Hurricane Protection System including the Pump Stations.

[2] Task 8 of the IPET team was assigned to the pumping station performance.

[3] Aerial photos were gathered using Google Earth Pro

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interior drainage modeling team for use in the numerical models. These tables are available at the end of each of the specific Parish's summary.

In addition, the available recorded intake and discharge water levels were provided within the same dates as stated above. At most of the stations there are data loggers that record water levels automatically. These machines work off of air pressure and for the most part became inoperable when the power was lost during the storm[4].

7.1.2 Parishes

Louisiana is sub-divided into parishes. Parishes are equivalent to what many states refer to as "counties." This analysis looks at four of the parishes that sustained pump station damage in New Orleans District. The parish summaries will include the following sections.

7.1.2.1 Parish Map

The map displays the locations of each pump station in the specified parish. Pump stations that sustained damage to the pumping capacity during the hurricane are labeled in red, pump stations that sustained minor damage to other than the pumping capacity are labeled in orange, and pump stations that had no damage are labeled in white. The map presents the boundaries of the drainage basins in the specified parish. The boundaries in these cases are not always a levee or flood wall. These boundaries lines were drawn to assist in pinpointing which pumps work to drain that particular area.

7.1.2.2 Drainage Basins

Each of the four parishes is divided into drainage basins. The basins usually follow natural topographical lines. They are often bordered by levees or ridges of relatively higher elevations. The parish summaries list the parish's drainage basins and indicate which pump stations are located in each.

A particular neighborhood is generally affected by all the pumps in its drainage basin. The conditions throughout a drainage basin are usually similar. If one part of the basin floods, the flooding will likely spread through the rest of the basin. The flood may be contained within the basin, but as it increases it can spill into neighboring basins. The capacity of a pump station contributes to the drainage of the entire basin. For example, if one pump station is disabled, the entire basin will drain more slowly.

7.1.2.3 Pumps

Each parish summary includes a table listing all the pumps in the parish, along with their characteristics. The pumps are organized by station.

7.1.2.4 Parish Damages

The parish Project Information Report (PIR) list estimates for the costs of repairs to the pumping stations. These are available in the summary for each parish. They show the estimated

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[4] Jefferson Parish uses a SCADA system for monitoring and recording their equipment parameters which would make it easier to acquire the data. However in this case we were not provided with the SCADA logs of the water levels do to some legal issues the Parish was involved in at the time of collection.

cost of repairs for each individual station, and subtotals for each drainage basin. At the bottom they give an estimated total cost for the entire parish.

The costs in the tables include only the cost of repairs due to damages caused by Hurricane Katrina. These costs were determined by the New Orleans District Army Corps of Engineers. They do not include the costs of any upgrades that would improve the stations beyond their performance before the hurricane.

7.1.2.5 Improvements Suggested by Each Parish

The IPET pumping station team requested a list of suggested improvements from each Parish to be incorporated in this report. These lists are not the suggestions of the IPET team and therefore further studies may be necessary to establish improvements.

The suggestions are for improving the performance of the stations, such as improved reverse flow prevention and methods for operating the stations during a hurricane.

7.1.3 Pump Stations

The function of the pump stations is to remove excess water accumulated from rainfall and seepage from the surrounding bodies of water. New Orleans area is surrounded by several bodies of water, including the Gulf of Mexico, Lake Pontchartrain, and the Mississippi River. The natural elevation of most of the land is lower than the surrounding bodies of water. Levees and floodwalls are designed to prevent the surrounding bodies of water from freely flowing into the area. They also keep water from flowing out. Flooding will occur if accumulated precipitation and seepage from surrounding bodies of water are not removed. An elaborate system of canals directs the accumulated water to the pump stations. The pump stations remove the accumulated water by discharging the water to other side of the levees and floodwalls.

The pump stations are designed to keep up with natural rainfall and seepage. The stations are not designed for, or capable of, keeping up with flooding caused by breached levees.

This appendix provides information regarding 74 significant pump stations in the New Orleans area. Below is an explanation of the provided information.

7.1.3.1 Description

The pump station descriptions present basic data about the station. Each includes the station's drainage area, plant capacity, the body of water from which it pumps, the body of water to which it pumps, owner, number of pumps, types of pump drivers, year the pumps were installed, and type of discharge gates. They also include operational information, including the water elevations where the pumps are turned on and off.

7.1.3.2 Pump Capacity Status

Due to the impacts of Hurricane Katrina, many of the pump stations were rendered inoperative. There are four reasons why Pump stations failed to operate during the storm:

- **Evacuation**: Operating crews were not available to run the pumps. At some stations in Jefferson Parish and St. Bernard Parish, the crews were directed to evacuate before the

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hurricane arrived. At some stations, crews evacuated for safety reasons due to rising floodwaters.

- **Flooding of station equipment:** This includes equipment that was flooded when the levees were overtopped or breeched and pumps that were turned off when it became apparent that they were merely circulating floodwaters through the breeches.
- **Loss of electrical service to the pumps:** Failure of both the primary and backup power supply systems.
- **Loss of lubricating and cooling water**: Some pumping stations rely on potable water from municipal water services for lubricating and cooling the pumps. Raw water from the canal or floodwaters is not clean enough to function as a substitute.

The pie-chart shown in Figure 7-1 indicates how the combined pumping capacity of Orleans, Jefferson, St. Bernard, and Plaquemines parishes were affected by the storm. Additionally, charts are shown for each parish in the appropriate parish sections. At some stations, more than one of the four failure types occurred. Only the circumstance that initially shut down each station is indicated. If a particular pump station was shut down due to flooding, and then later lost electricity, the lost capacity is only indicated to be due to flooding.

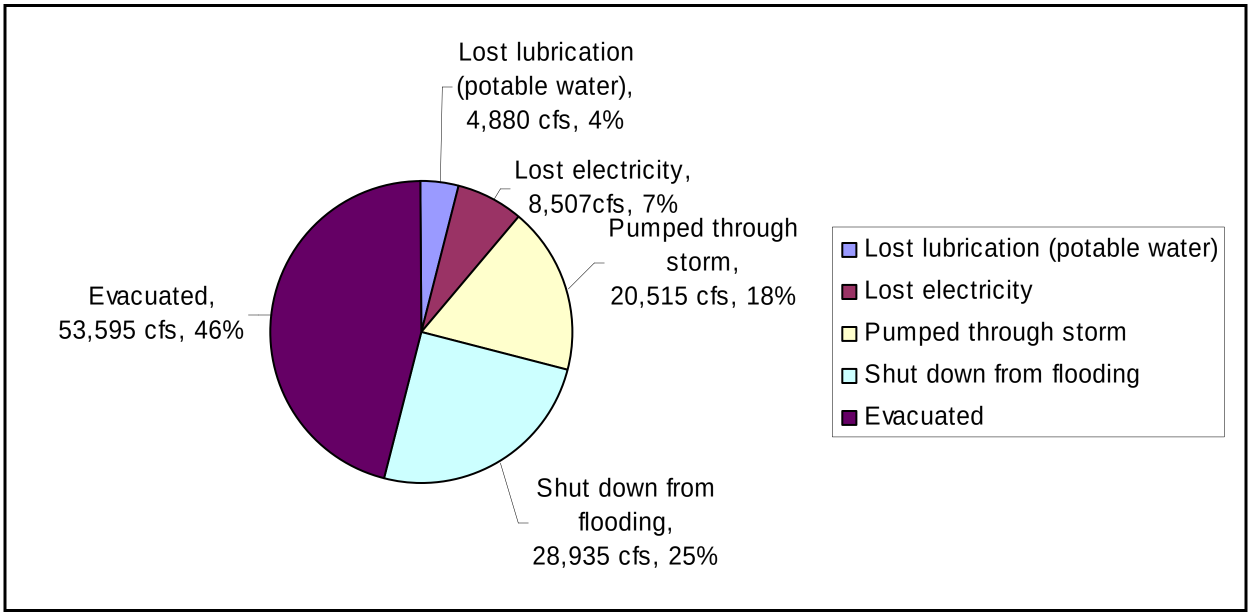

Figure 7-1 - New Orleans area pump status during Hurricane Katrina (by rated capacity)

Note: This figure and the pie charts that follow indicate cubic feet per second (cfs) volumes that are based upon the rated capacities of the pumps.

7.1.3.2.1 *Orleans Parish*

No pumps were initially shut down due to evacuations in Orleans Parish. Figure 7-2 shows that most of the parish's rated pumping capacity (59%) was lost due to flooding.

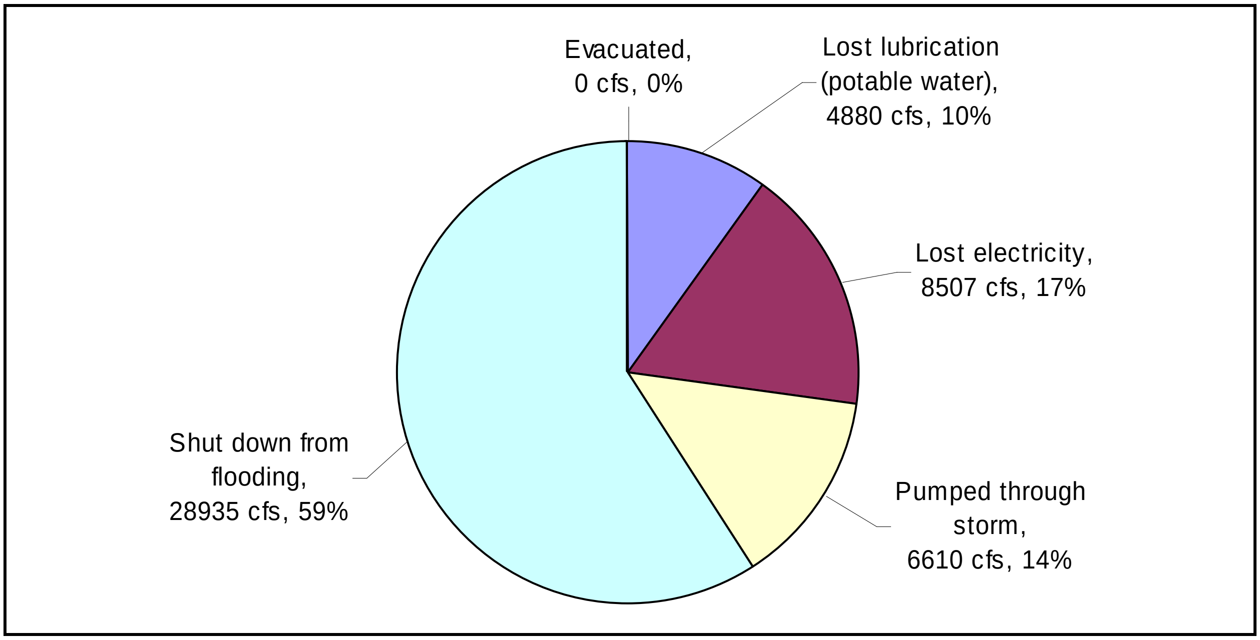

Figure 7-2 - Orleans Parish pump status during Hurricane Katrina (by rated capacity)

Figure 7-2 gives a summary of the performance of all of the pumping stations in Orleans Parish. The circumstances varied significantly from basin to basin. The following sections indicate pumping performance by basin.

7.1.3.2.1.1 East Drainage Basin

Figure 7-3 shows that most of the East Drainage Basin's rated capacity (55%) pumped through the storm. None of the stations were shut down from flooding. About a third of the stations stopped pumping because they lost electricity. The remaining 14% of the stations shut down because they lost access to the city's potable water.

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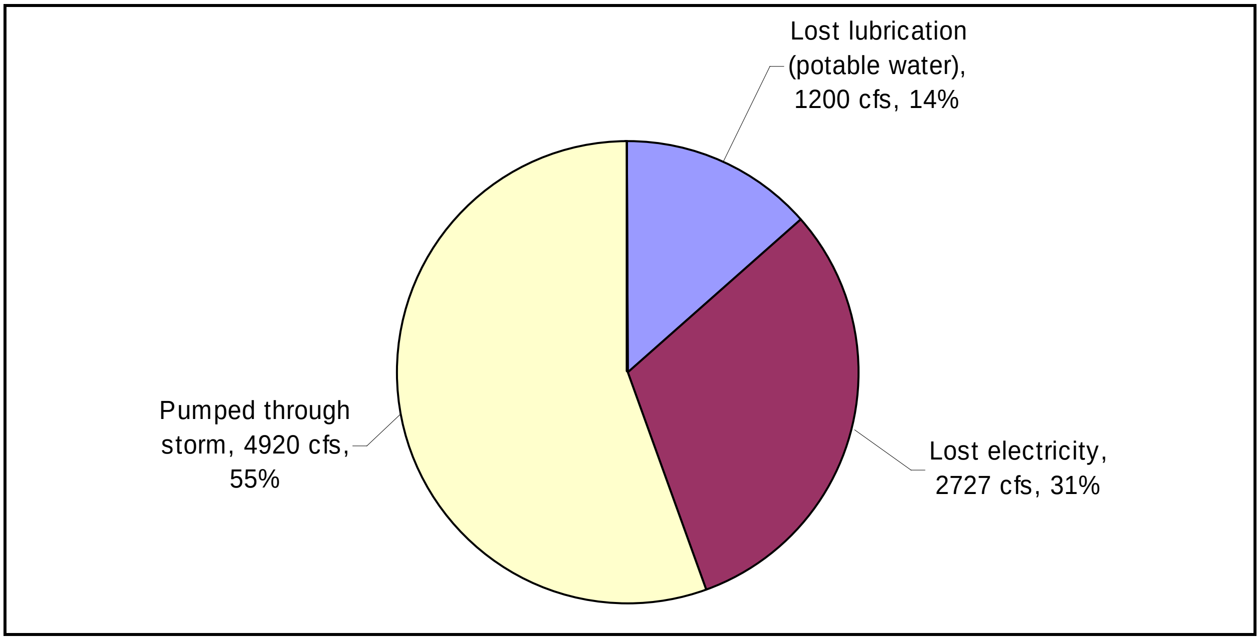

Figure 7-3 - Orleans Parish - East pump status during Hurricane Katrina (by rated capacity)

7.1.3.2.1.2 East Bank Drainage Basin

Eighty-three percent of the rated pump capacity in the East Bank Drainage Basin was rendered inoperable due to the flooding. Had they not been flooded, some of these stations might have lost their electricity or potable water.

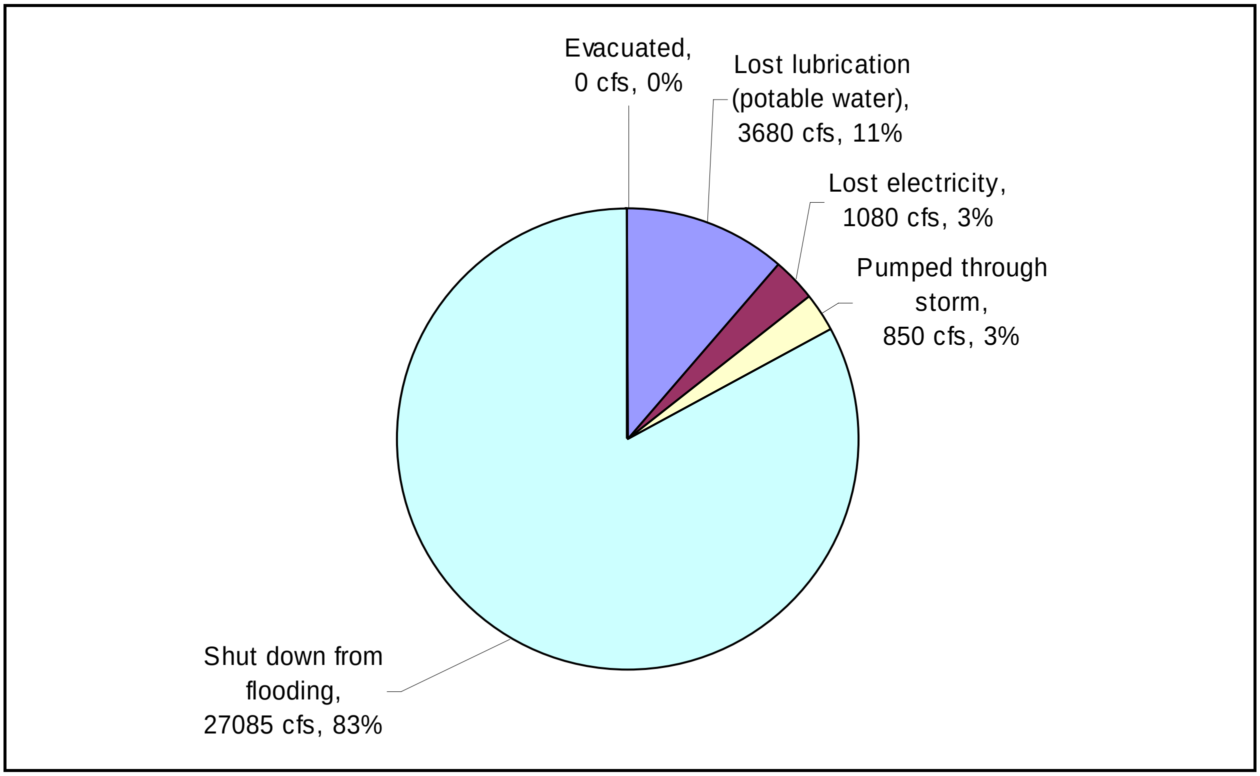

Figure 7-4 - Orleans Parish - East Bank pump status during Hurricane Katrina (by rated capacity)

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7.1.3.2.1.3 East Bank - Lower 9th Ward

There is only one pump station in the Lower 9th Ward, and it was shut down due to flooding from the breeches.

7.1.3.2.1.4 West Bank - Algiers

There is only one pump station in the Algiers Drainage Basin, and it was shut down due to a loss of electricity.

7.1.3.2.1.5 West Bank – English Turn

There is only one pump station in the English Turn Drainage Basin, and it pumped through the storm.

7.1.3.2.2 *Jefferson Parish*

Figure 7-5 shows that 82% of the pump capacity in Jefferson Parish was unavailable due to crew evacuations. One of the drainage basins (Jefferson Parish - West Bank - Cataouatche) had 100% of the pumping capacity off line due to evacuations. Pumping capacity charts for the other three drainage basins in Jefferson Parish are shown below. None of the pumping stations in Jefferson parish were rendered inoperable due to flooded equipment.

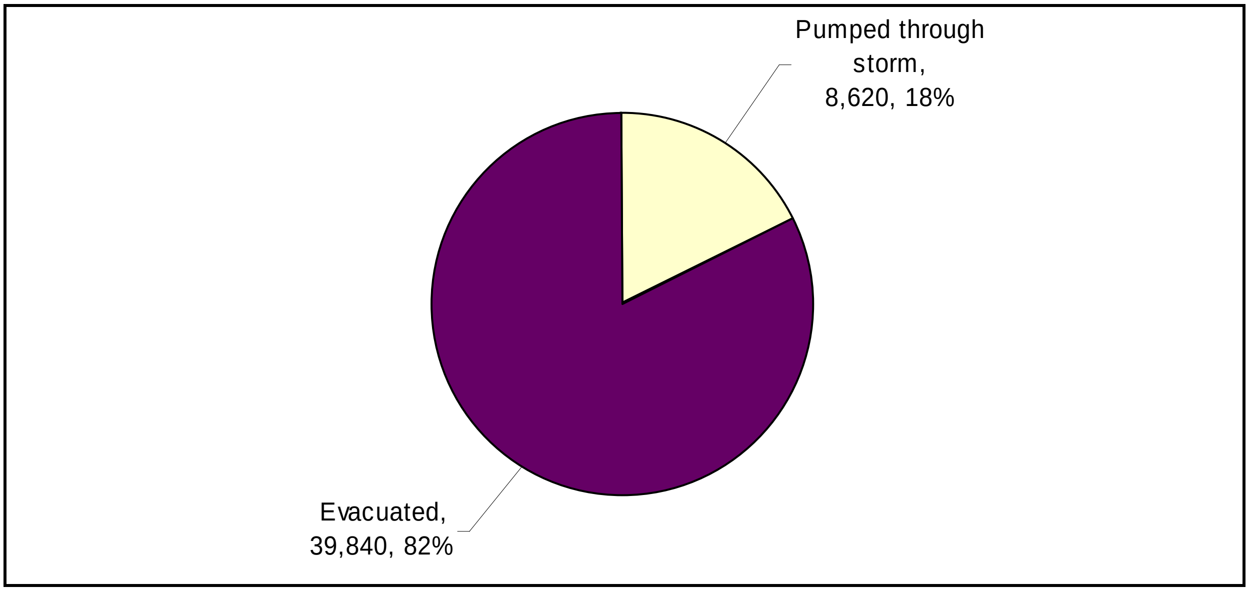

Figure 7-5 - Jefferson Parish pump status during Hurricane Katrina (by rated capacity)

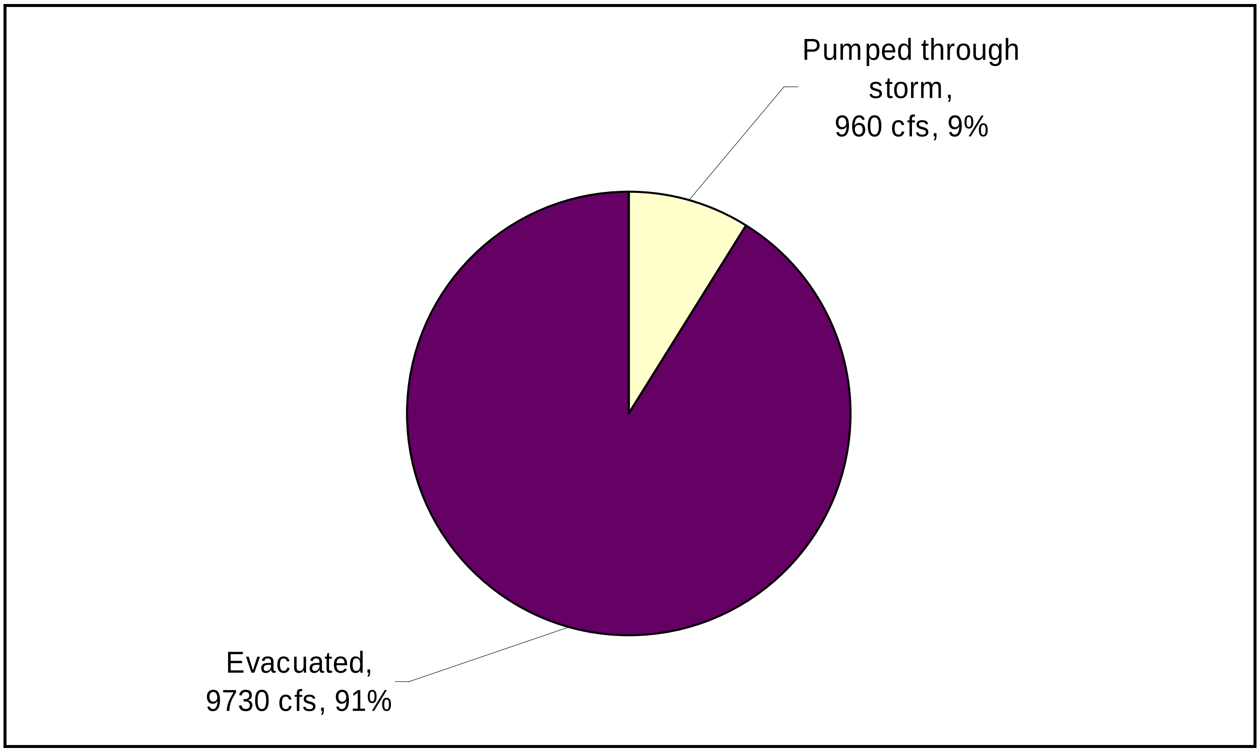

Figure 7-6 - Jefferson Parish - West Bank - West of Harvey pump status during Hurricane Katrina (by rated capacity)

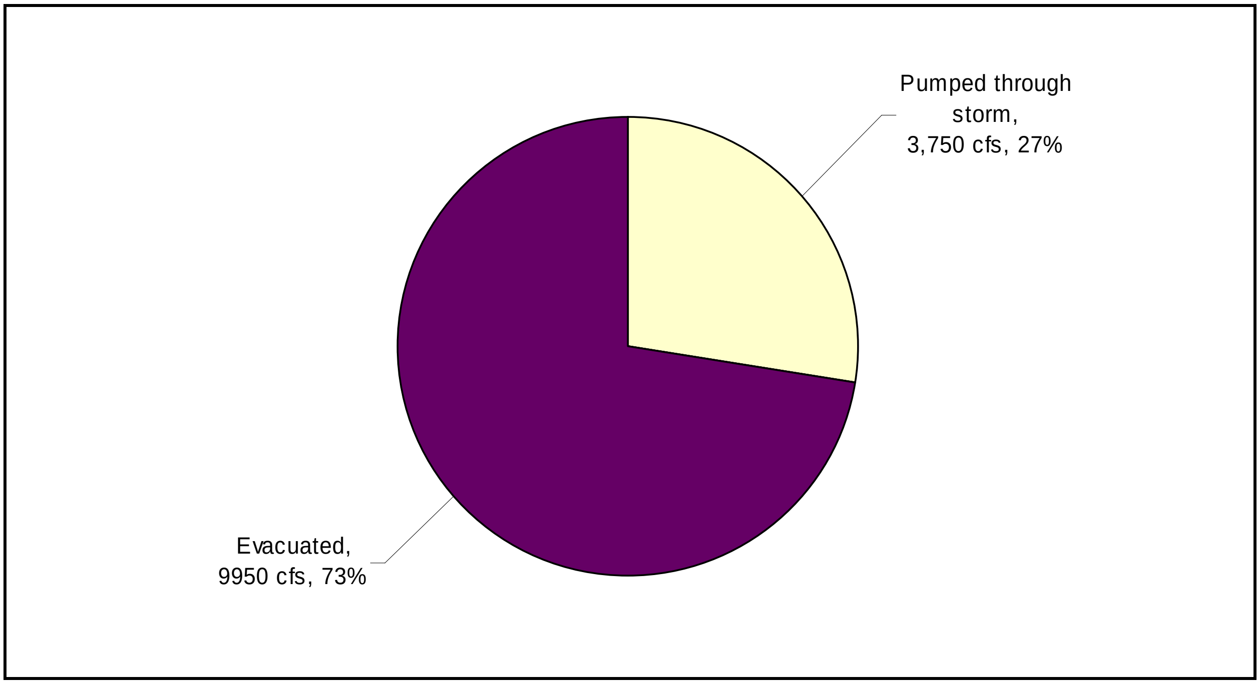

Figure 7-7 - Jefferson Parish - West Bank - East of Harvey pump status during Hurricane Katrina (by rated capacity)

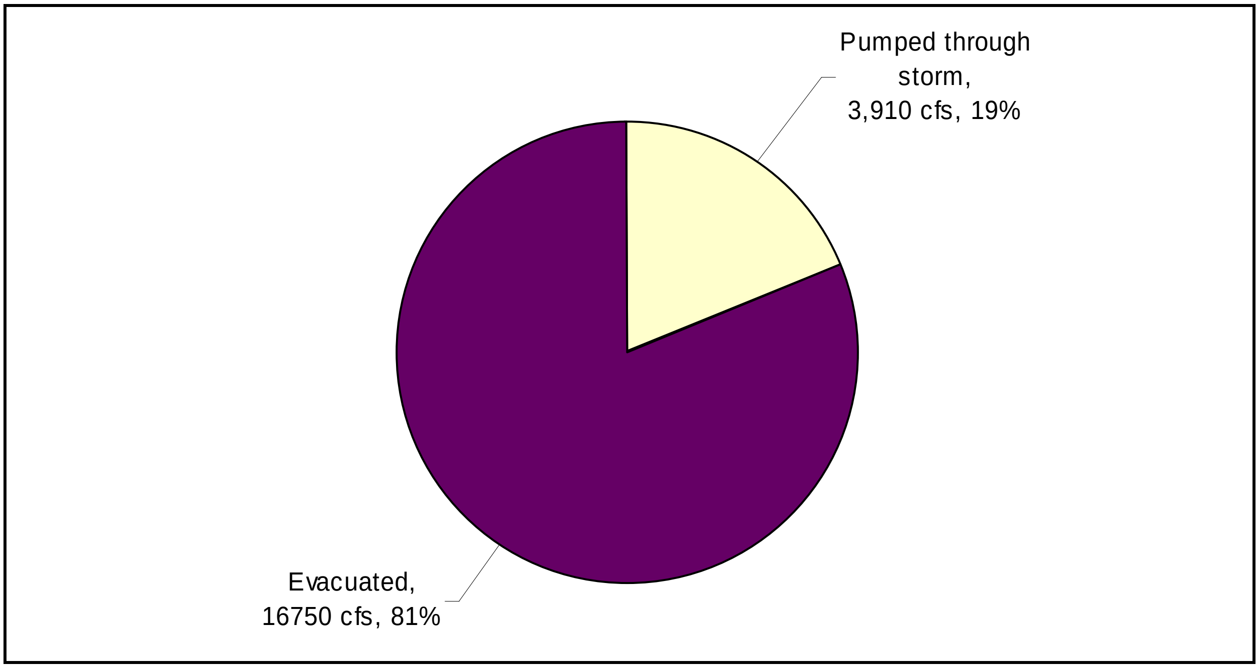

Figure 7-8 - Jefferson Parish - East Bank pump status during Hurricane Katrina (by rated capacity)

7.1.3.2.3 *St. Bernard Parish*

The pump stations in St. Bernard Parish did not operate during the storm due to evacuations prior to the arrival of the hurricane. Pumping equipment was damaged by flooding at three of the eight pumping stations serving the parish.

7.1.3.2.4 *Plaquemines Parish*

Figure 7-9 shows that 56% of Plaquemines Parish's rated pump capacity was out of service due to crew evacuations. The remaining 44% of the rated capacity pumped through the storm.

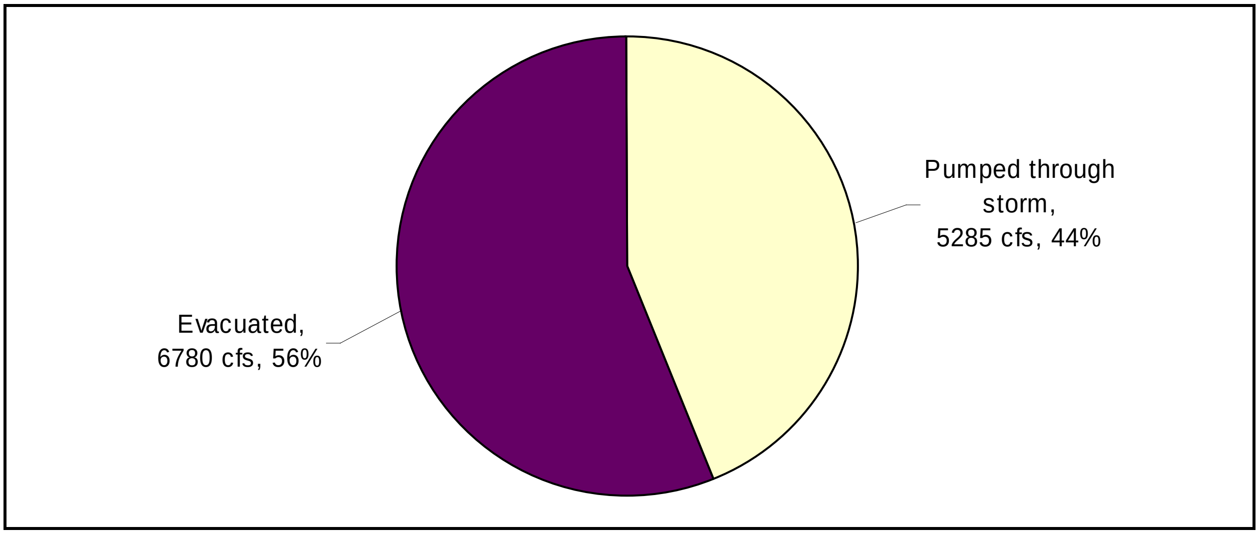

Figure 7-9 - Plaquemines Parish pump status during Hurricane Katrina (by rated capacity)

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

All of the East Bank pumping stations in Plaquemines Parish were evacuated, and did not operate during the storm.

As shown in Figure 7-10, 59% of the parish's West Bank rated pump capacity was not evacuated and pumped during the storm.

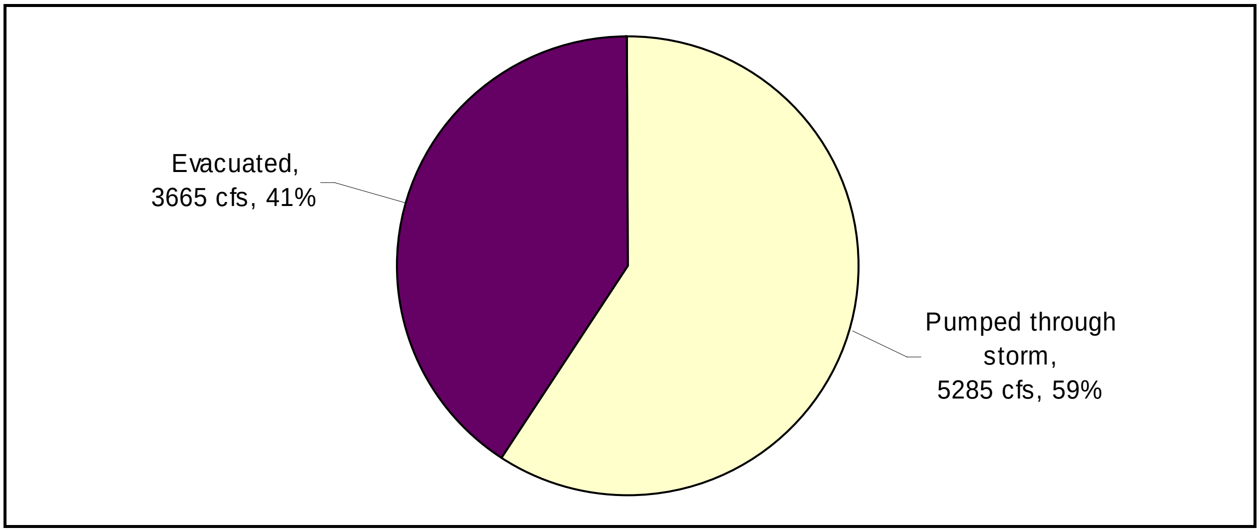

Figure 7-10 - Plaquemines Parish - West Bank pump status during Hurricane Katrina (by rated capacity)

7.1.3.3 Damages

The most severe damages to the pump stations were due to the flooding that submerged vital equipment. Pump stations whose operating floors were near ground level sustained more damage than those whose operating floors were located above the flood level. Damages due to flooding of the operating floor often include inoperable equipment such as engines, electric generators, and air compressors. Sometimes additional damage resulted when salt water contaminated fuel systems, or when a station ran out of clean water to lubricate its equipment and used raw water instead.

Table 7-1 shows the number of pumps out of service by parish and the pumping capacities before and after the hurricane. The damage to the pumps was especially severe in Orleans Parish while there was no damage to pumps in Jefferson Parish.

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Table 7-1
Pumps Out of Service from the Storm / Flooding and Respective Pump Capacity by Parish[5]

Parish	Number of Pumps		Pump Capacity (cfs)		
	Total	Out of Service	Before Storm / Flooding	After Storm / Flooding	Percent Available after Storm / Flooding
Orleans	114	65	49,782	14,070	28%
St. Bernard	28	15	6,976	3,794	54%
Plaquemines	54	20	13,984	10,517	75%
Jefferson	101	0	44,184	44,184	100%

High winds and flooding caused structural damage to almost all stations, regardless of the elevation of the operating floor. Table 7-2 does not incorporate structural damage.

Table 7-2
Estimated Cost of Repairs by Parish

Parish	Estimated Cost of Repairs
Orleans	$39,633,000
St. Bernard	$10,688,000
Plaquemines	$8,177,000
Jefferson	$758,000

The summary for each pump station includes a list of the damages caused by Hurricane Katrina. The information in the damage summaries was acquired from the Project Information Reports for each of the four parishes stated earlier in this section. The PIR's contain much more detailed information about damages than what is provided in this appendix, and can be obtained from the New Orleans District office.

Each pump station damage summary lists the estimated cost of damages to the station. The listed cost only includes the cost to repair damages caused by the hurricane. It does not include any costs to improve or upgrade the station.

7.1.3.4 Katrina Event

The Katrina Event timeline presents events that occurred at a particular station around the time of the hurricane. The information in the timeline comes from operator logs that were filled out at the times the events occurred, and from interviews with the operators that occurred after the hurricane. The timelines include major events, such as losses of electricity and pump station evacuations. For various reasons, such as the flooding of operating rooms, many records are lost and are not included. For this reason, some timelines include significantly less data than others. In order to give an idea of when the events occurred relative to the storm, the timelines include the approximate time when Hurricane Katrina made landfall.

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[5] The pump station damage was acquired for each Parish from the New Orleans District Project Information Reports (PIR). The data refers to the status of the pumps after the storm, before any repairs were made.

7.1.3.5 Operational Curves

To aid in modeling the pumping systems, operational curves are provided for the pumps. At the time of the writing of this report, only the curves for Orleans Parish have been generated. It is anticipated that the curves for the other three parishes will be available by the time this report is published.

7.1.3.5.1 *New Orleans Pump Stations*

New Orleans area is surrounded by several bodies of water, including the Gulf of Mexico, Lake Pontchartrain, and the Mississippi River. The natural elevation of most of the land is lower than the surrounding bodies of water. Levees and floodwalls usually prevent bodies of water from freely flowing into the area. They also keep water from flowing out. Flooding will occur if accumulated precipitation and seepage from surrounding bodies of water are not removed. Extensive systems of canals direct the accumulated water to pump stations for drainage. The sizes of pumps needed to remove water are determined by the elevations of the reservoirs and the amount of water that needs to be removed. These parameters change regularly, so pump stations often use different sizes of pumps with different capacities to adapt to the changes.

7.1.3.5.2 *Generation of Operational Curves*

7.1.3.5.2.1 Pump Stations and Terminology

Water left on its own will flow downward. This is because water at a higher elevation has a higher energy state than water at a lower elevation. The elevation of most cities is higher than nearby bodies of water, so precipitation naturally drains to the bodies of water. This does not naturally occur in many of the areas in and around New Orleans since the ground elevation is so low. Additional energy must be added to the ground water to transport it to the higher elevation bodies of water.

Pumps are a method of adding that energy to the system and sending water uphill. There are many different types of pumps, but almost all of the large capacity pumps accomplish this displacement of fluid by rotating an impeller, which adds energy to the fluid. The added energy increases the pressure of the water and causes it to flow in a direction that runs counter to its nature. The pressure increase is referred to as an energy, or “head,” increase, as fluid pressure is referred to as “head”.

In a reservoir of a fluid, the pressure at the surface is the same as the atmospheric pressure. The pressure increases with the depth of the water because of the weight of the water above. The pressure change is a function of depth and the specific weight of the fluid. Therefore, if the specific weight of the fluid is known, it is possible to describe the pressure at any point in the system in terms of the depth of the point of reference or observation. This is expressed in Equation 7-1.

Equation 7-1 – Gage Pressure in Static Reservoir

$$P_{Gage} = \gamma \cdot H$$

where

P_{Gage} = Gage pressure*
γ = Specific weight of fluid
H = Elevation of the reference point

Equation 7-1 can be simplified to describe the pressure, or head, in terms of the elevation of the reference point, as shown in Equation 7-2.

Equation 7-2 – Pressure in Terms of Head

$$\frac{P_{Gage}}{\gamma} = H$$

Therefore, at the bottom of a reservoir with a depth of 20 ft, it is said to have 20 ft of head. More specifically, it is referred to as "pressure head", which is one of many classifications of head. The different classifications of head are described below and mathematically in 7.1.3.5.2.5:

- **Pressure head** is the head resulting from the pressure, normally tied to the fluid depth.
- **Hydrostatic head** at a given point is the sum of pressure head plus the elevation level with respect to a specific reference datum. Thus in a stagnant body of water (such as a lake), the pressure head increases with depth while the hydrostatic head is constant regardless of depth. Essentially the hydrostatic head defines the potential energy of the fluid at any location. Hydrostatic head is also referred to as **Piezometric head**.
- **Velocity head** is the kinetic (motion portion of) energy of the flow at a location in the conduit. This is based on the velocity (speed of water) passing a location and is proportional to the square of the velocity. (This can be measured by partly submerging an L-shaped hollow tube by placing one end of the tube face directly into the flow and measuring how high the water rises in the tube above the water surface.)
- **Static head** is the elevation change from one reservoir's surface elevation to another reservoir's surface elevation.
- **Total dynamic head** or **total head** is the sum of the potential and kinetic energy terms, or the sum of the hydrostatic head and the velocity head. This represents all head (or mechanical energy) at a given location. In a stagnant lake, the total head and hydrostatic head are equal because there is little or no velocity in lake to create **velocity head**.
- **Head loss** is the amount of extra energy required to overcome friction, piping junctions, and other losses in energy caused by changes in conduit geometry.

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* Gage pressure means that the surface of the fluid has no external pressure applied to it (i.e. air pressure). Gage pressure is the liquid pressure relative to the water surface, where the gage pressure is assumed to be zero by neglecting the external air pressure: Gage pressure = absolute pressure – atmospheric pressure.

Figure 7-11 shows the relationship between total dynamic head, static head, and head loss.

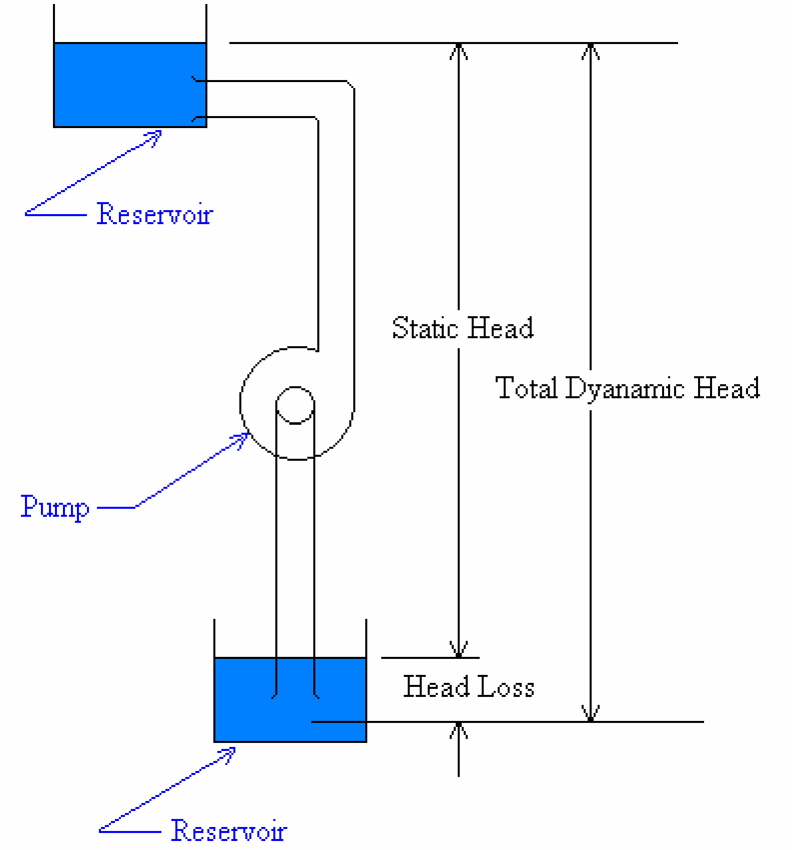

Figure 7-11 – Elevation View Defining Total Dynamic Head, Static Head, and Head Loss Relationship

As seen in Figure 7-11, pumps can increase the pressure (or head) of a system. The water surface elevation of the reservoir (or system) can be increased exactly by the amount of static head of the pump.

In the case of the greater New Orleans area, the purposes of the pumping stations are to evacuate accumulated precipitation occurring during storms since much of the area is below the level of Lake Pontchartrain, sea level, and the Mississippi River. To do this, it must transport the water uphill against the natural gradient.

Figure 7-12 shows a typical pump station. The difference in elevation between the suction (flow in) and the discharge (flow out) sides is the static head that the pump would need to supply to overcome the downhill gradient. The magnitude of static head that the pump needs to supply is proportional to the difference in elevations.

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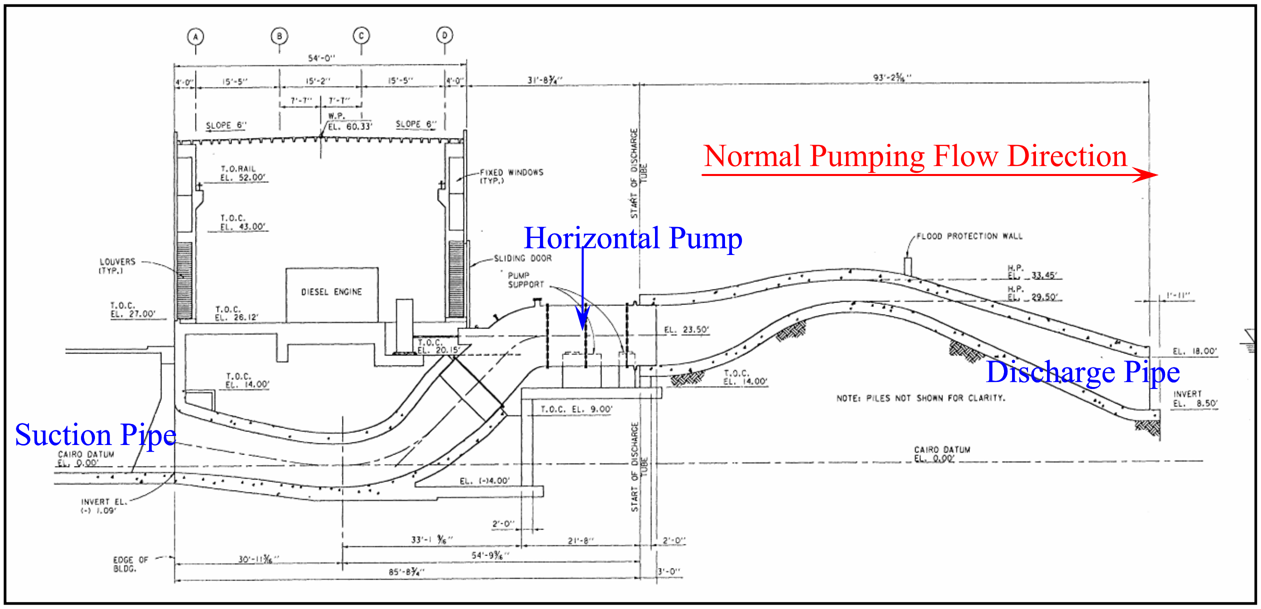

Figure 7-12 – Typical Section through Suction Tube, Horizontal Pump, and Discharge Tube

7.1.3.5.2.2 Pump Curves

The amount of water that is pumped in a specific amount of time is known as the volumetric flow rate. As the head changes, so does the volumetric flow rate. The volumetric flow rate will decrease with an increase in static head because more energy is required to move the water, which has a stronger back pressure. This means that the rate at which the pump will move the fluid will change if the difference between the suction and discharge head changes. Pump manufacturers test their pumps and develop **pump curves** that describe the relationship between the volumetric flow rate and the total dynamic head. This relationship described is known as a capacity. Figure 7-13 shows a typical pump curve.

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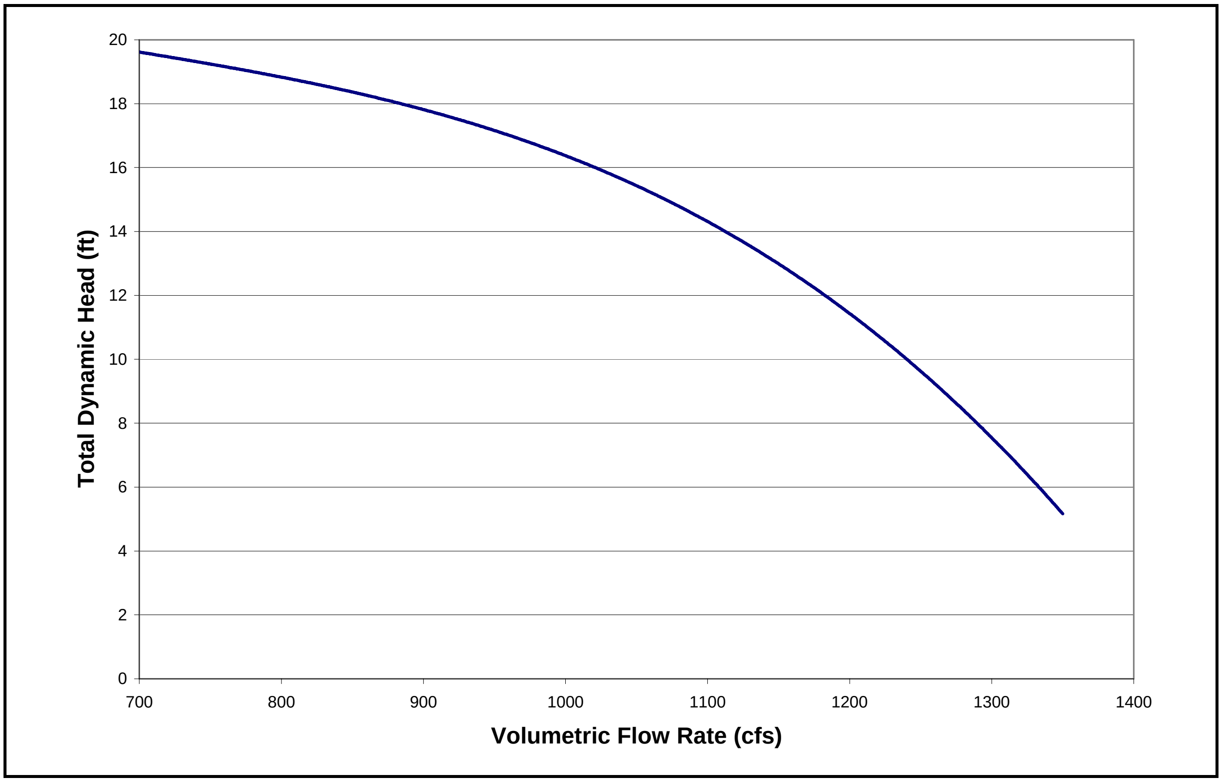

Figure 7-13 – Typical Pump Curve

The tests that develop the pump curves are done in a laboratory. Since these tests are done for the pump alone, they do not take into account all of the piping of the system. Piping systems have bends, shape changes, tees, and other junctions, which reduce flow. Moreover, the friction in a piping system also alters the flow. Thus, the pump must add extra energy to overcome the losses of the water flowing in the system, or the dynamic head loss. This means that to pass flow, a pump must overcome a head greater than the static head due to the elevation difference (see Figure 7-11).

Because the pump curves do not take into account the head loss of the system, they only describe the total dynamic head of the system. For modeling purposes, it is more desirable to have a curve that uses the static head versus the volumetric flow rate rather than the total dynamic head versus the volumetric flow rate because that takes into account the minor and friction losses in a system. Such a curve displays the volumetric flow rate at a known static head, and is the goal of this section.

7.1.3.5.2.3 System Curves

A **system curve** takes into account the losses of the system because it includes both the static head and the head losses. The losses are a function of the volumetric flow rate and can be predicted and calculated. Figure 7-14 shows a typical system curve in red. It is plotted on the same graph as the pump curve. The system curve includes the static head as well as the head loss through the system, hence the gradual rise of the curve with increased flow rate.

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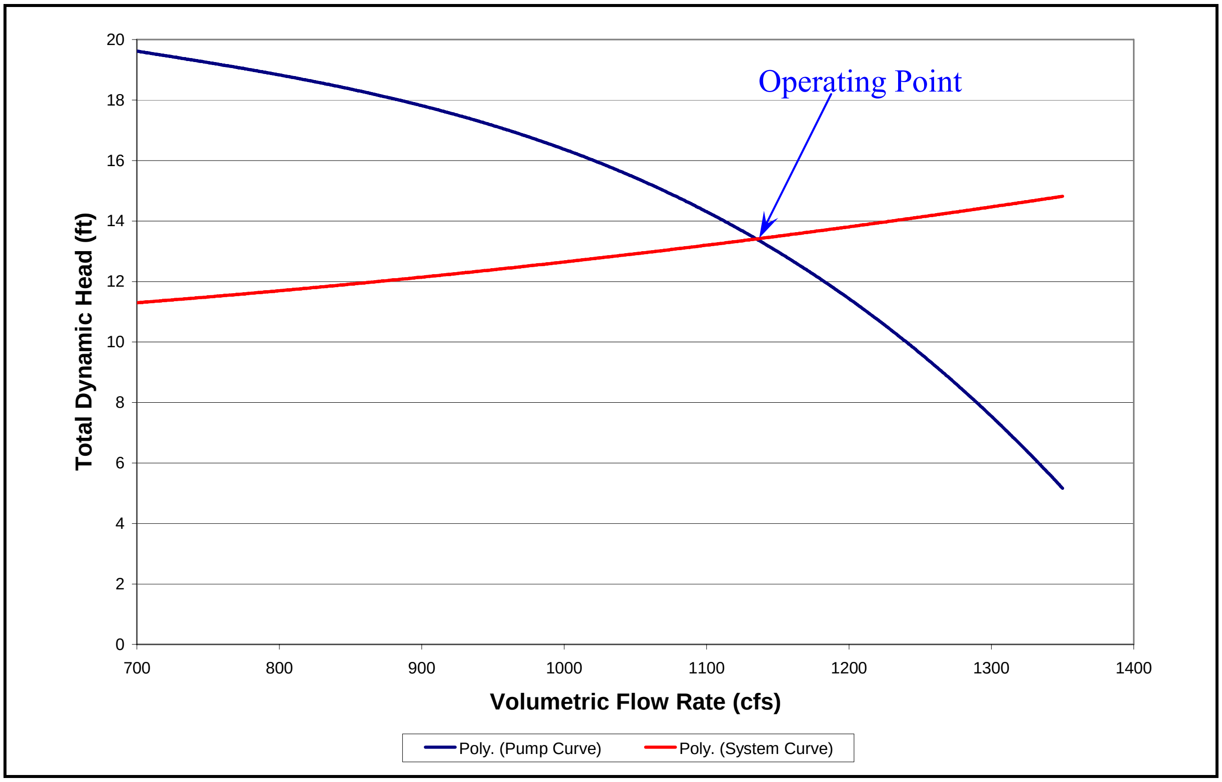

Figure 7-14 – Typical System Curve

The point of intersection on Figure 7-14 between the pump curve and the system curve describes the operating point. At this point the system head losses become greater than the head provided by the pump. In other words, as one moves right of the operating point along the x-axis, the pump cannot provide enough head to overcome the friction and minor losses in the system, so the water will simply not flow in normal operation. Moreover, the pump will operate only at the operating point. This means that the head and the flow rate described by the operating point are what will physically be seen by the pump. This is because the system curve is developed from the static head and the friction and minor losses (see 7.1.3.5.2.5 for more detail). Thus, it accounts for the entire system and adequately describes what is actually at the pump station.

Each of the system curves are dependent on the static head that the system experiences. Thus, the system curve is for a discrete operating condition. For the purposes of this report, a broader curve needed to be made which describes all the known operating conditions the pump experiences. This curve is known as the **operational curve**.

Creating the system curve was a step in determining the operational curve. As a discrete operating condition was used to generate the operational curves, a consistent method was applied to each system curve. This required that the pump stations that discharged into the dame body of water use the same water elevation in the computer model. Several pump stations were able to record the intake and discharge water elevations. This data was entered into the computer model in order to generate the system curves. However, if the data was not available, estimations were made due to proximity or on design points. This means that while the system curves may roughly describe how the system operates during a hurricane, the curves presented do not show how the system did, in fact, operate during Hurricane Katrina.

7.1.3.5.2.4 Operational Curves

As mentioned in 7.1.3.5.2.3, the system curve is comprised of the static head and the head loss. The friction and minor losses are functions of the volumetric flow rate, but the static head is not. Rather, the static head depends solely on the elevation changes. Figure 7-14 shows the system curve at only one static head. In cases such as New Orleans where the elevation of the fluid surfaces change, the operating point on the system curve changes as well. The infinite number of operating points generated by the change in static head can be determined. When all of the different operating points' volumetric flow rates are plotted on a chart, they create the **operational curve**.

Figure 7-11 shows that the total dynamic head is a combination of the head loss and the static head. Therefore, the static head equals the total dynamic head minus the head loss. The **operational curve** shows volumetric flow rate as a function of static head. This means that the axes will be rotated with the volumetric flow rate on the y-axis and the static head on the x-axis. This was done because the static head is known or can be determined from analysis. Thus, the volumetric flow rate of the system can be predicted. A typical operational curve can be found in Figure 7-15.

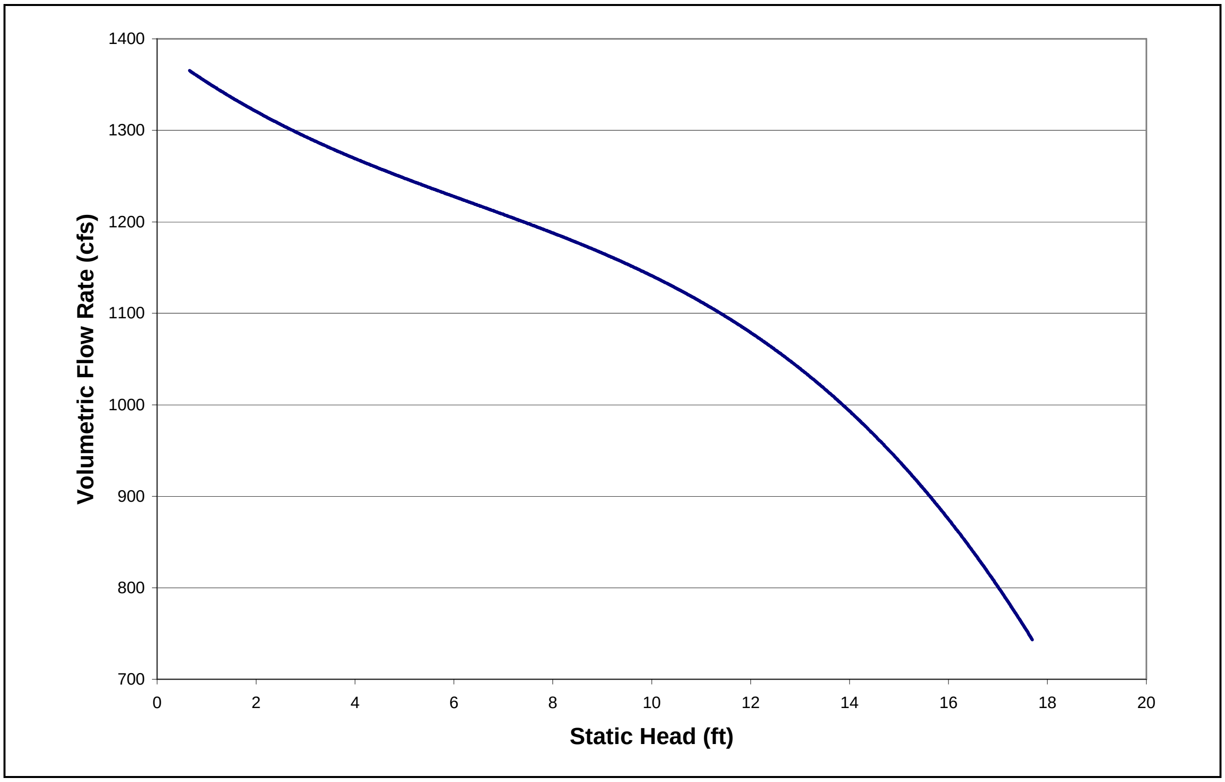

Figure 7-15 – Typical Operational Curve

The operational curve describes the capacity of the pump as a function of the static head. It can be used to determine the rate at which a pump is moving its fluid if the difference between the elevations of the reservoirs is known. If the static head is known, it can be found on the x-axis of the operational curve chart. Then, if a line is extended vertically until it reaches the operational curve, the value at which it reaches on the y-axis will be the volumetric flow rate of the pump for that static head. Also, all operational curves in this report will include an equation describing them.

The operational curves in this report are built from pump curves supplied by either the project or the manufacturer. Once obtained, the pump curve is curve-fit to a mathematical expression constrained within the limits of the data. When the pump curve for a particular pump was not available, the pump curve is assumed to be similar to other pumps of the same make and model. If there are no pump curves available for a similar pump, no operational curve is provided.

7.1.3.5.2.5 System Curve Generation

As mentioned in 7.1.3.5.2.3, the losses in the system can be predicted. This is done by using the energy equation, which accounts for all the energy in the system. Equation 7-3 shows the energy equation.

Equation 7-3 – Energy Equation

$$\frac{P_1}{\gamma_1}+\frac{v_1^2}{2g}+z_1+h_{pump}=\frac{P_2}{\gamma_2}+\frac{v_2^2}{2g}+z_2+h_{turbine}+\sum K\cdot\frac{v^2}{2g}+\sum f\cdot\frac{L}{D}\cdot\frac{v^2}{2g}$$

where

$P_1 =$ Pressure at reference point 1
$\gamma_1 =$ Specific weight of fluid at reference point 1
$v_1 =$ Velocity at reference point 1
$g =$ Gravitational constant
$z_1 =$ Elevation at reference point 1
$h_{pump} =$ Head of the pump
$P_2 =$ Pressure at reference point 2
$\gamma_2 =$ Specific weight of fluid at reference point 2
$v_2 =$ Velocity at reference point 2
$z_2 =$ Elevation at reference point
$h_{turbine} =$ Head of the turbine
$K =$ Minor loss coefficient
$f =$ Friction loss coefficient
$L =$ Length of the pipe
$D =$ Diameter of the pipe

Also note, using definitions from 7.1.3.5.2.1:

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$\frac{P_1}{\gamma_1} =$ Pressure head

$\frac{v_1^2}{2g} =$ Velocity head

$\frac{P_1}{\gamma_1} + z_1 =$ Hydrostatic/piezometric head

$$\frac{P_1}{\gamma_1} + \frac{v_1^2}{2g} + z_1 + h_{pump} \text{ or } \frac{P_2}{\gamma_2} + \frac{v_2^2}{2g} + z_2 + h_{turbine} + \sum K \cdot \frac{v^2}{2g} + \sum f \cdot \frac{L}{D} \cdot \frac{v^2}{2g}$$

= Total dynamic head

$\sum K \cdot \frac{v^2}{2g} + \sum f \cdot \frac{L}{D} \cdot \frac{v^2}{2g} =$ Head loss

For the given application of a pump station (see Figure 7-11), this equation simplifies to Equation 7-4.

Equation 7-4 – Simplified Energy Equation

$$z_2 - z_1 = h_{pump} - \sum K \cdot \frac{v^2}{2g} - \sum f \cdot \frac{L}{D} \cdot \frac{v^2}{2g}$$

where

$z_2 =$ Water surface elevation of suction pool

$z_1 =$ Water surface elevation of discharge pool

$h_{pump} =$ Head of the pump

$\sum K \cdot \frac{v^2}{2g} =$ Head of sum of minor losses (including losses due to tees, bends, and changes in piping)

$\sum f \cdot \frac{L}{D} \cdot \frac{v^2}{2g} =$ Head of sum of friction losses throughout system

$v =$ Velocity where minor or friction loss is applied

Equation 7-4 expresses the previously mentioned fact that in order for the pump to reach the change in elevation, it must overcome losses. The final two terms represent the losses in the system. These terms depend on the existing characteristics of the system. The condition was determined using drawings, pictures, and other necessary data were provided by the project when available. Any known factors that could contribute to the losses were accounted for.

Due to the large number of curves that needed to be developed each system was modeled by entering information into a computer program called AFT Fathom™. Figure 7-16 shows a typical model setup in AFT Fathom™ with the symbols used overlaid on the drawing that is being modeled.

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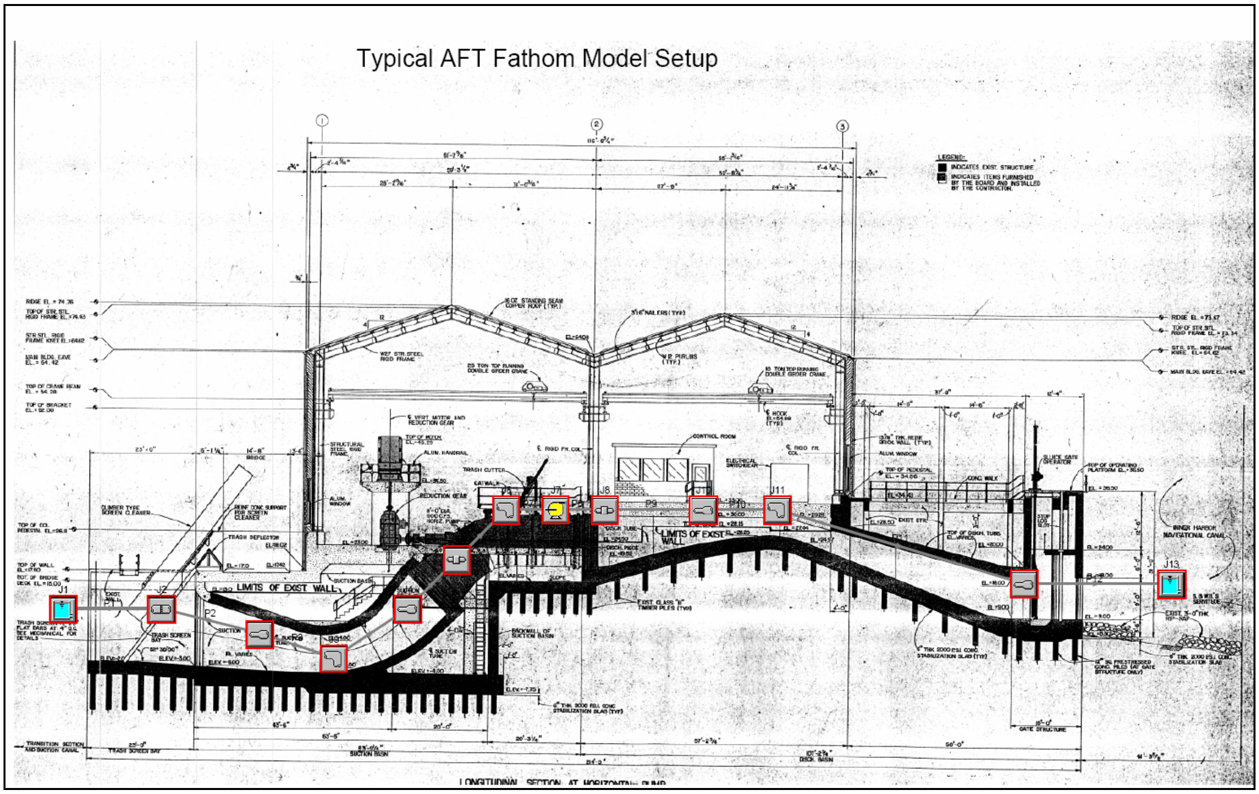


Figure 7-16 – Typical AFT Fathom™ Model Setup

AFT Fathom™ uses junctions connected by pipes in order to generate the losses in the system. There are several different symbols used; Figure 7-17 defines what the different symbols are.

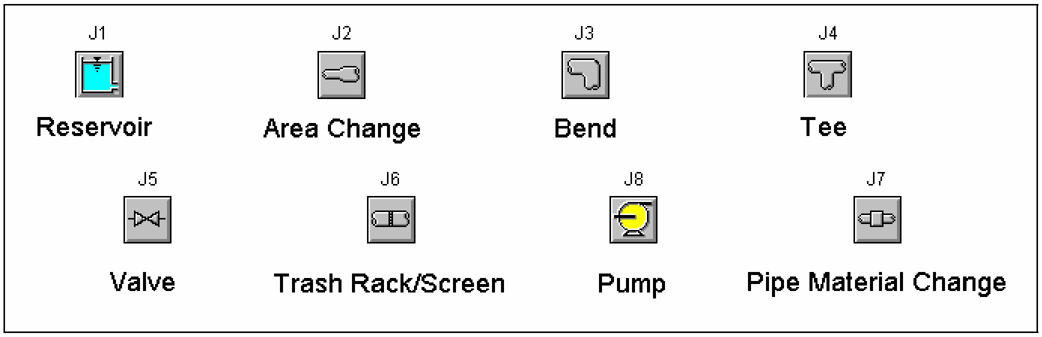


Figure 7-17 – Symbols Used in AFT Fathom™ and Definitions

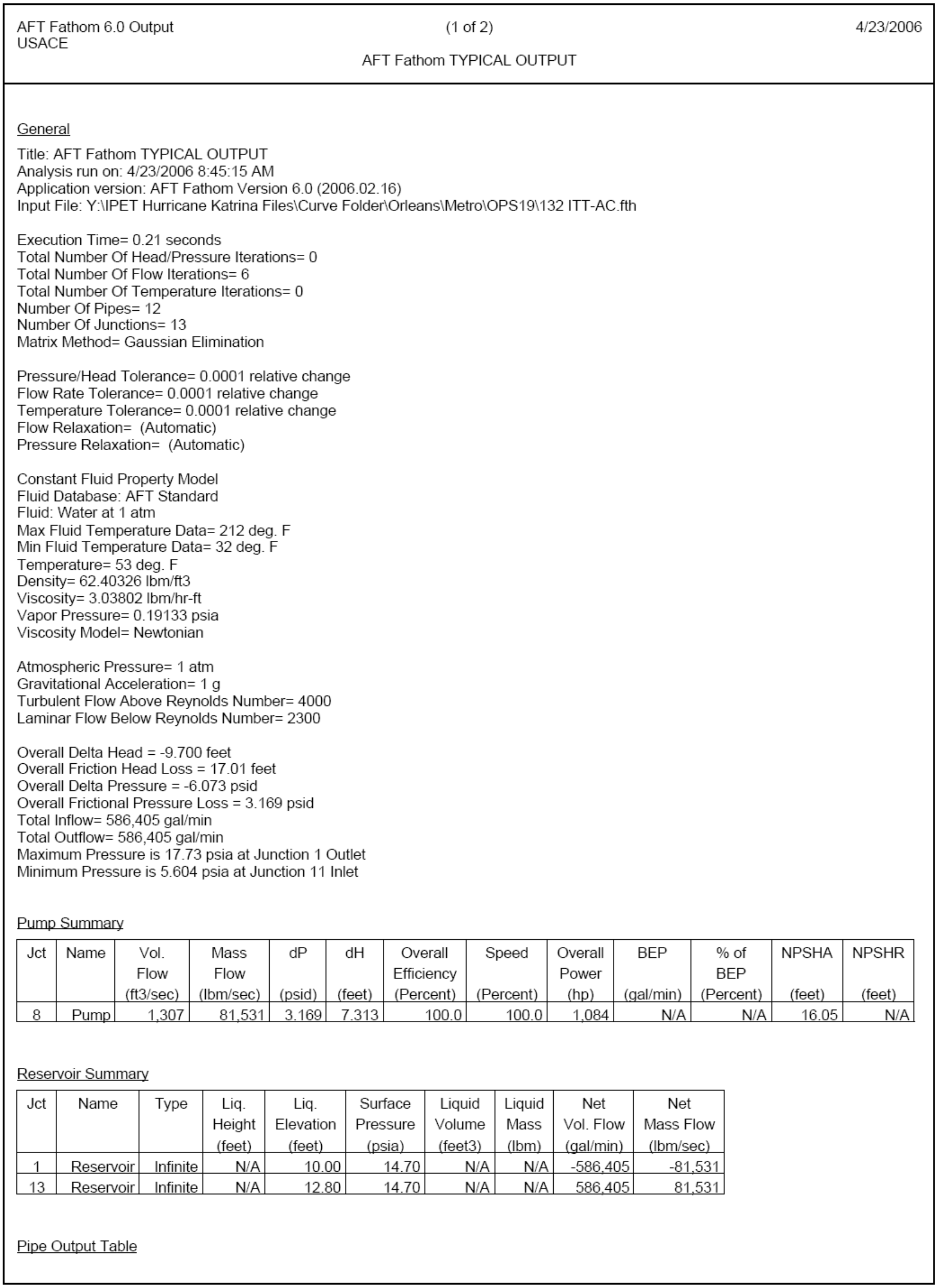
For each junction and pipe, certain inputs are necessary in order for AFT Fathom™ to be able to model the system. Table 7-3 shows the necessary inputs for each source of loss in the system.

Table 7-3
Required Input for AFT Fathom™

Cause of Loss	**Input 1**	**Input 2**	**Input 3**	**Input 4**	**Input 5**
Reservoir	Surface Elevation	Pipe Elevation	Pipe Inlet K Factor	Pipe Outlet K factor	Surface Pressure
Area Change	Inlet Elevation	Outlet Elevation	Angle of Change	Pipe Areas (calculated)	
Bend	Inlet Elevation	Outlet Elevation	Angle of Bend	r/D Factor	Type
Tee	Inlet Elevation	Outlet Elevation	Arrangement*	Angle	Type
Valve	Inlet Elevation	Outlet Elevation	Type*	K Factor*	
Trash Rack/Screen	Inlet Elevation	Outlet Elevation	Flow Area*	K Factor	
Pump	Inlet Elevation	Outlet Elevation	Pump Curve		
Pipe Material Change	Inlet Elevation	Outlet Elevation	K Factor		
Pipe	Length	Inner Diameter	Absolute Roughness	Hydraulic Diameter*	

*Depending on model, may be optional

After all the inputs were entered into the AFT Fathom™ program, it was possible to determine the system curves, which were developed by simply applying all the appropriate data into Equation 7-4**.** AFT Fathom™ was also able to determine further information about the system. A typical AFT Fathom™ output can be seen in Figure 7-18 and Figure 7-19.



AFT Fathom 6.0 Output
USACE

(1 of 2)

4/23/2006

AFT Fathom TYPICAL OUTPUT

General

Title: AFT Fathom TYPICAL OUTPUT
Analysis run on: 4/23/2006 8:45:15 AM
Application version: AFT Fathom Version 6.0 (2006.02.16)
Input File: Y:\IPET Hurricane Katrina Files\Curve Folder\Orleans\Metro\OPS19\132 ITT-AC.fth

Execution Time= 0.21 seconds
Total Number Of Head/Pressure Iterations= 0
Total Number Of Flow Iterations= 6
Total Number Of Temperature Iterations= 0
Number Of Pipes= 12
Number Of Junctions= 13
Matrix Method= Gaussian Elimination

Pressure/Head Tolerance= 0.0001 relative change
Flow Rate Tolerance= 0.0001 relative change
Temperature Tolerance= 0.0001 relative change
Flow Relaxation= (Automatic)
Pressure Relaxation= (Automatic)

Constant Fluid Property Model
Fluid Database: AFT Standard
Fluid: Water at 1 atm
Max Fluid Temperature Data= 212 deg. F
Min Fluid Temperature Data= 32 deg. F
Temperature= 53 deg. F
Density= 62.40326 lbm/ft3
Viscosity= 3.03802 lbm/hr-ft
Vapor Pressure= 0.19133 psia
Viscosity Model= Newtonian

Atmospheric Pressure= 1 atm
Gravitational Acceleration= 1 g
Turbulent Flow Above Reynolds Number= 4000
Laminar Flow Below Reynolds Number= 2300

Overall Delta Head = -9.700 feet
Overall Friction Head Loss = 17.01 feet
Overall Delta Pressure = -6.073 psid
Overall Frictional Pressure Loss = 3.169 psid
Total Inflow= 586,405 gal/min
Total Outflow= 586,405 gal/min
Maximum Pressure is 17.73 psia at Junction 1 Outlet
Minimum Pressure is 5.604 psia at Junction 11 Inlet

Pump Summary

Jct	Name	Vol. Flow (ft3/sec)	Mass Flow (lbm/sec)	dP (psid)	dH (feet)	Overall Efficiency (Percent)	Speed (Percent)	Overall Power (hp)	BEP (gal/min)	% of BEP (Percent)	NPSHA (feet)	NPSHR (feet)
8	Pump	1,307	81,531	3.169	7.313	100.0	100.0	1,084	N/A	N/A	16.05	N/A

Reservoir Summary

Jct	Name	Type	Liq. Height (feet)	Liq. Elevation (feet)	Surface Pressure (psia)	Liquid Volume (feet3)	Liquid Mass (lbm)	Net Vol. Flow (gal/min)	Net Mass Flow (lbm/sec)
1	Reservoir	Infinite	N/A	10.00	14.70	N/A	N/A	-586,405	-81,531
13	Reservoir	Infinite	N/A	12.80	14.70	N/A	N/A	586,405	81,531

Pipe Output Table

Figure 7-18 – Typical AFT Fathom™ Output Page 1

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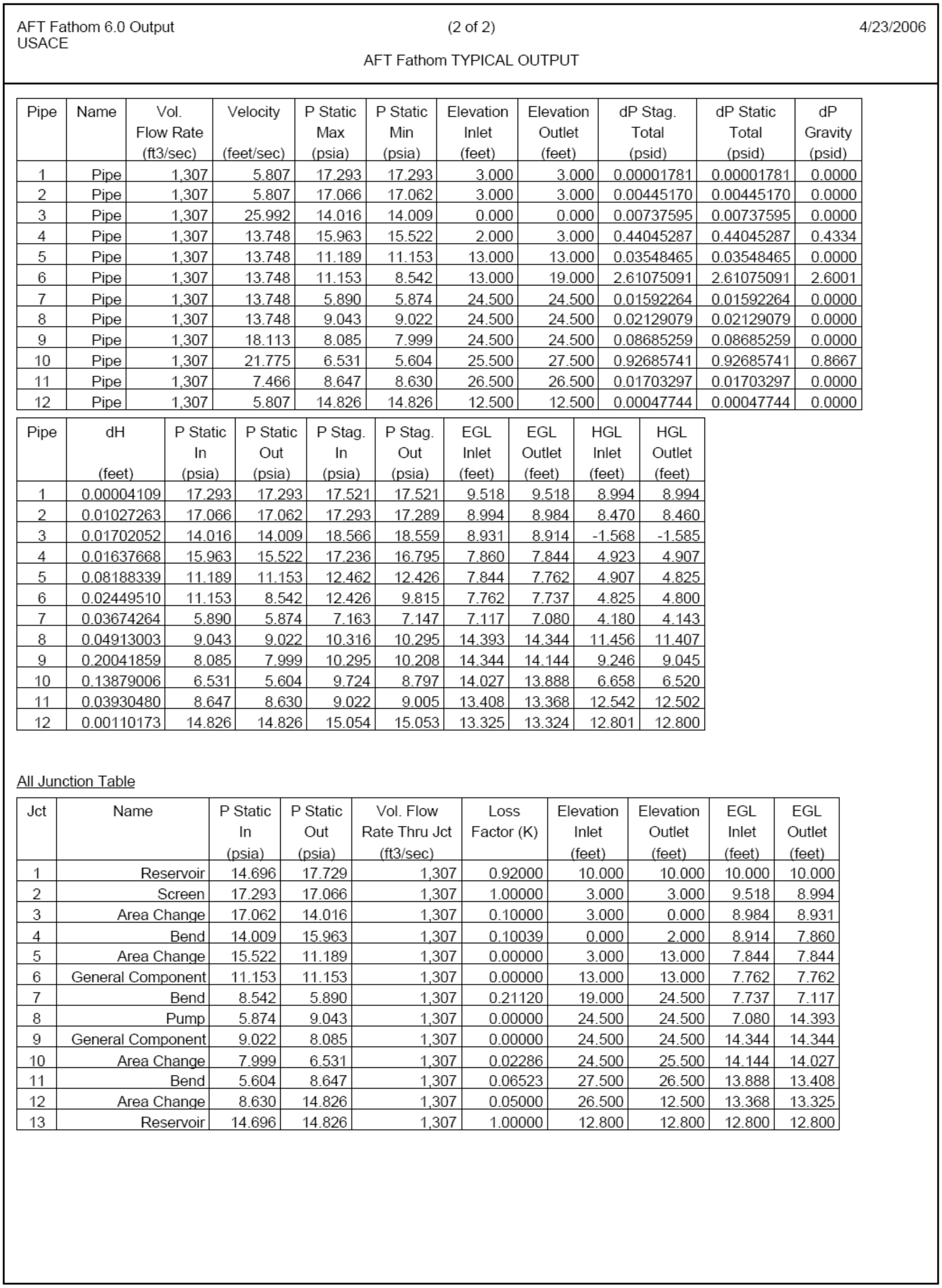

AFT Fathom 6.0 Output (2 of 2) 4/23/2006
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AFT Fathom TYPICAL OUTPUT

Pipe	Name	Vol. Flow Rate (ft3/sec)	Velocity (feet/sec)	P Static Max (psia)	P Static Min (psia)	Elevation Inlet (feet)	Elevation Outlet (feet)	dP Stag. Total (psid)	dP Static Total (psid)	dP Gravity (psid)
1	Pipe	1,307	5.807	17.293	17.293	3.000	3.000	0.00001781	0.00001781	0.0000
2	Pipe	1,307	5.807	17.066	17.062	3.000	3.000	0.00445170	0.00445170	0.0000
3	Pipe	1,307	25.992	14.016	14.009	0.000	0.000	0.00737595	0.00737595	0.0000
4	Pipe	1,307	13.748	15.963	15.522	2.000	3.000	0.44045287	0.44045287	0.4334
5	Pipe	1,307	13.748	11.189	11.153	13.000	13.000	0.03548465	0.03548465	0.0000
6	Pipe	1,307	13.748	11.153	8.542	13.000	19.000	2.61075091	2.61075091	2.6001
7	Pipe	1,307	13.748	5.890	5.874	24.500	24.500	0.01592264	0.01592264	0.0000
8	Pipe	1,307	13.748	9.043	9.022	24.500	24.500	0.02129079	0.02129079	0.0000
9	Pipe	1,307	18.113	8.085	7.999	24.500	24.500	0.08685259	0.08685259	0.0000
10	Pipe	1,307	21.775	6.531	5.604	25.500	27.500	0.92685741	0.92685741	0.8667
11	Pipe	1,307	7.466	8.647	8.630	26.500	26.500	0.01703297	0.01703297	0.0000
12	Pipe	1,307	5.807	14.826	14.826	12.500	12.500	0.00047744	0.00047744	0.0000

Pipe	dH (feet)	P Static In (psia)	P Static Out (psia)	P Stag. In (psia)	P Stag. Out (psia)	EGL Inlet (feet)	EGL Outlet (feet)	HGL Inlet (feet)	HGL Outlet (feet)
1	0.00004109	17.293	17.293	17.521	17.521	9.518	9.518	8.994	8.994
2	0.01027263	17.066	17.062	17.293	17.289	8.994	8.984	8.470	8.460
3	0.01702052	14.016	14.009	18.566	18.559	8.931	8.914	-1.568	-1.585
4	0.01637668	15.963	15.522	17.236	16.795	7.860	7.844	4.923	4.907
5	0.08188339	11.189	11.153	12.462	12.426	7.844	7.762	4.907	4.825
6	0.02449510	11.153	8.542	12.426	9.815	7.762	7.737	4.825	4.800
7	0.03674264	5.890	5.874	7.163	7.147	7.117	7.080	4.180	4.143
8	0.04913003	9.043	9.022	10.316	10.295	14.393	14.344	11.456	11.407
9	0.20041859	8.085	7.999	10.295	10.208	14.344	14.144	9.246	9.045
10	0.13879006	6.531	5.604	9.724	8.797	14.027	13.888	6.658	6.520
11	0.03930480	8.647	8.630	9.022	9.005	13.408	13.368	12.542	12.502
12	0.00110173	14.826	14.826	15.054	15.053	13.325	13.324	12.801	12.800

All Junction Table

Jct	Name	P Static In (psia)	P Static Out (psia)	Vol. Flow Rate Thru Jct (ft3/sec)	Loss Factor (K)	Elevation Inlet (feet)	Elevation Outlet (feet)	EGL Inlet (feet)	EGL Outlet (feet)
1	Reservoir	14.696	17.729	1,307	0.92000	10.000	10.000	10.000	10.000
2	Screen	17.293	17.066	1,307	1.00000	3.000	3.000	9.518	8.994
3	Area Change	17.062	14.016	1,307	0.10000	3.000	0.000	8.984	8.931
4	Bend	14.009	15.963	1,307	0.10039	0.000	2.000	8.914	7.860
5	Area Change	15.522	11.189	1,307	0.00000	3.000	13.000	7.844	7.844
6	General Component	11.153	11.153	1,307	0.00000	13.000	13.000	7.762	7.762
7	Bend	8.542	5.890	1,307	0.21120	19.000	24.500	7.737	7.117
8	Pump	5.874	9.043	1,307	0.00000	24.500	24.500	7.080	14.393
9	General Component	9.022	8.085	1,307	0.00000	24.500	24.500	14.344	14.344
10	Area Change	7.999	6.531	1,307	0.02286	24.500	25.500	14.144	14.027
11	Bend	5.604	8.647	1,307	0.06523	27.500	26.500	13.888	13.408
12	Area Change	8.630	14.826	1,307	0.05000	26.500	12.500	13.368	13.325
13	Reservoir	14.696	14.826	1,307	1.00000	12.800	12.800	12.800	12.800

Figure 7-19 - Typical AFT Fathom™ Output Page 2

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The output will reflect entered data such as the elevations as well as results from the modeling process, such as the Minor Loss Coefficients (K factors) and the Volumetric Flow Rate. AFT Fathom™ also generates the system curve, which shows the losses as a function of the volumetric flow rate (see Figure 7-14). This process was verified by using hand calculations based off of Equation 7-4.

7.1.3.5.2.6 Operational Curve Generation

Since both the pump curve and the system curve were obtained, it was possible to create an operational curve. As mentioned in 7.1.3.5.2.4, the operational curve shows the difference between the pump curve and the losses. This is stated in Equation 7-5, which is a verbal expression of Equation 7-4.

Equation 7-5 – Total Dynamic Head, System Losses, and Static Head Relationship

$$Static\ Head = Total\ Dynamic\ Head - System\ Losses$$

Since both the pump curve and the system curves are functions of the volumetric flow rate, they were combined to create the operational curve (see Figure 7-15). This curve was then plotted with the volumetric flow rate as a function of the static head in order to model the flow through the pumps of a given static head.

7.1.3.5.2.7 Engineering Judgment Used in Generation of Operational Curves

The generation of the operational curves is a clearly defined process. This process, however, is ideal: it presents the most accurate operational curve possible for the most accurate pump. In order to continue with this idealized process, many assumptions were made. The most important assumptions were that the system was brand new, the trash rack had a minor loss coefficient (K factor) of 1.0, that the operational curve is generated at the head during the hurricane, and that all the design considerations from differing manufacturers were similar.

The pump curves supplied by the manufacturer were the result of a test conducted when the pump was brand new. Some of the pump installations dates reach back to 1914. While there are newer pumps as well, the majority of the pumps are not able to perform up to the pump curves provided due to deterioration. Thus, what is represented in the pump curve is the best possible scenario for the pump to achieve when in a “new” condition, but not likely what the pumps actually are capable of doing.[6]

The assumption that the trash rack has a loss coefficient of 1.0 is a difficult one to prove or disprove. During the storm, debris may or may not have piled up, causing an effective head differential greater than the difference in the static head. This is also dependent on the type of trash rack. Since there was apparently no data gathered regarding the debris amount or its impact on the flow, the assumption utilized is that there was a foot of head loss at a velocity of

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[6] It is also possible to alter the absolute roughness of the piping material in order to accommodate for age in the piping. This process was utilized in the reverse flow calculations, but not in the operational curves, as can be seen in Table 7-4. There is not a proven process able to represent the deterioration of the pumps.

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8 feet per second, or the loss coefficient is 1.0. Any information regarding the amount of debris would greatly increase the accuracy of the model.

As described earlier, the losses of the system depend on the total dynamic head. It was assumed that the estimated head during Hurricane Katrina would be the best input to determine the losses in the system because it would average out the volumetric flow rates experienced. The head during Hurricane Katrina was taken from canal and tide readings during a storm surge around 8:00 am on September 29, 2005 (during the hurricane). When readings were not available for a particular station, they were estimated using readings from nearby stations, from operator interviews, or from design points. In some cases, such as the 144” Wood Screw at OP 2 in Orleans Parish, the system curve shown does not have an operating point. This is because the static head is such that the system curve would intersect the pump curve beyond the data provided by the pump curve. The analysis provided by AFT Fathom™ extrapolated the pump curve to provide an estimated operating point. The capacities provided in such situations should not be used to determine capacities during Hurricane Katrina. The operational curve, however, is not altered by the static head chosen at which to model the system.

Often, necessary data regarding inputs into AFT Fathom™ such as one listed in Table 7-3 was not available at the time these curves were generated. In those cases, appropriate engineering judgment was utilized. Table 7-4 shows general assumptions that were made in each of the models.

Table 7-4
Assumptions Used in all Models

Cause of Loss	Necessary Input 1	Assumed Value	Necessary Input 2	Assumed Value	Necessary Input 3	Assumed Value
Reservoir	Pipe Inlet K Factor	0.92 or 0.5	Pipe Outlet K Factor	1.0	Surface Pressure	1 atmosphere
Bend	Type	Smooth or mitre				
Trash Rack/Screen	K Factor	1.0				
Pipe	Absolute Roughness Steel	0.0018	Absolute Roughness Concrete	0.014		

Other than these judgments that were made for all models, other assumptions were made. These specific assumptions were listed on the layout of the model and on the operational curve. All of the assumptions are directly correlated with the accuracy of the model; in other words, better data would increase the accuracy.

With all these assumption employed, the operational curves were generated. These curves will adequately describe the volumetric flow rate as a function of the static head plus any trash buildup that would cause losses in excess of the modeled loss coefficient of 1.0.

7.1.3.6 Reverse Flow Curves

Reverse flow is the unintended consequence of backwards flow through a pump system from the normal pump discharge side (lake or outlet canal) to the normal pump intake side (drainage area). In Figure 7-20 - Reverse Flow Schematic with H1, H2, and pertinent locations below, H1 is the water surface elevation in the normal pump discharge lake (or outlet canal) and H2 is the water surface elevation in the pump intake side (drainage area). Reverse flow can be caused by several possible scenarios:

- a power outage during pumping operation
- pump failure due to excessive outlet head during operation
- the level of the discharge lake exceeds discharge piping crest (C2 in Figure 7-20) when pump is shut off

Reverse flow can be prevented by

- having a crest invert of the discharge conduit (C2 in Figure 7-20) being higher than the maximum lake level (H1)
- continuous pump operation (if maximum pump head is not exceeded)
- automatic check valves, flap valves, or tide gates
- operation of standard closure valves (e.g. butterfly)
- air injection into discharge piping after shutoff (assuming minimal air leakage and/or a large static head difference between H1 and H2 does not push or "wash out" the air)

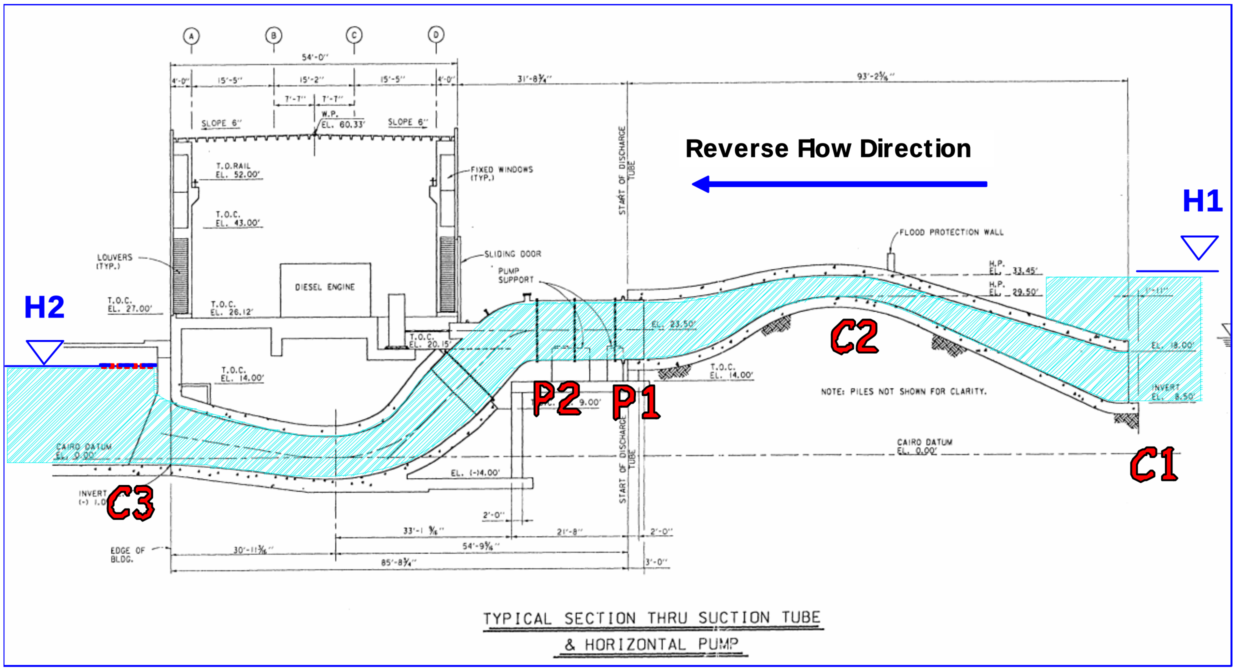

Figure 7-20 - Reverse Flow Schematic with H1, H2, and pertinent locations

7.1.3.6.1 *Definition of pipe or conduit geometry terms*

Figure 7-21 displays the most important geometrical terms and dimensions for both circular pipe and rectangular conduit cross-sections.

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Invert = Bottom level of the area defined by the inner walls of a conduit
Soffit = Top level of the area defined by the inner walls of a conduit
Inside dia. = Diameter of the pipe inside the walls (referred to as ID)
ID = Soffit – invert
Outside dia. = Outside or external diameter of pipe (referred to as OD)
Flow Area = Area (blue in Figure 7-21) defined by the inside walls.

For Circular pipe:

$$FlowArea = 0.785 \cdot ID^2$$

For Rectangular Conduit:

$$FlowArea = height \cdot width$$

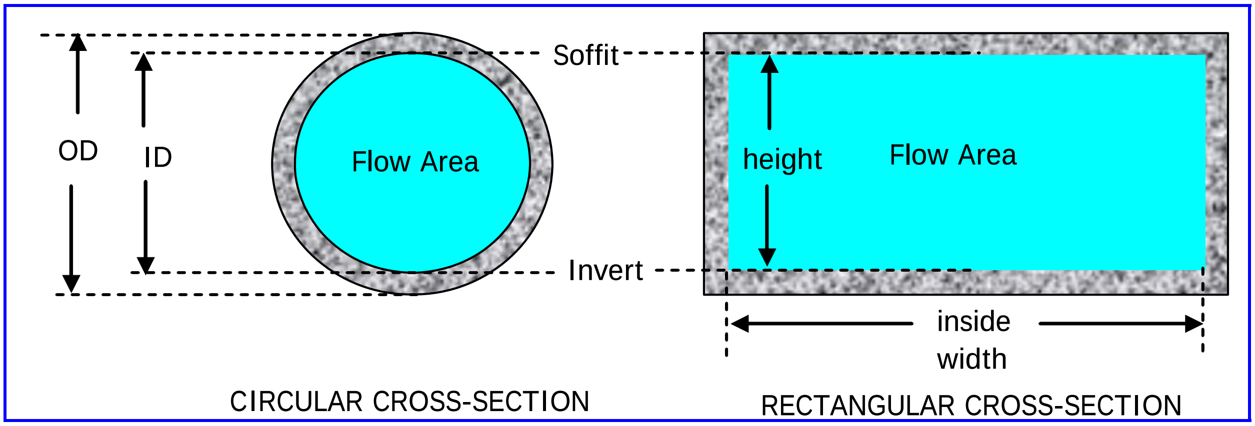

Figure 7-21 - Geometry Terms and Dimensions for Circular and Rectangular Conduits

In hydraulic analyses, the important parameters are invert, soffit, and flow area. These dimensions determine or affect flow rate and velocities. The invert elevation of the crest of the conduit will often determine when reverse flow starts or stops. The soffit elevation at the crest is also important in terms of causing a change in flow regime (defined in 7.1.3.6.4). Flow area largely defines the capacity of the conduit to convey flow.

7.1.3.6.2 *Hydraulic Definitions Pertaining to Reverse Flow*

The following hydraulic definitions refer to terms previously defined in the *Pump Stations and Terminology* section and Figure 7-22.

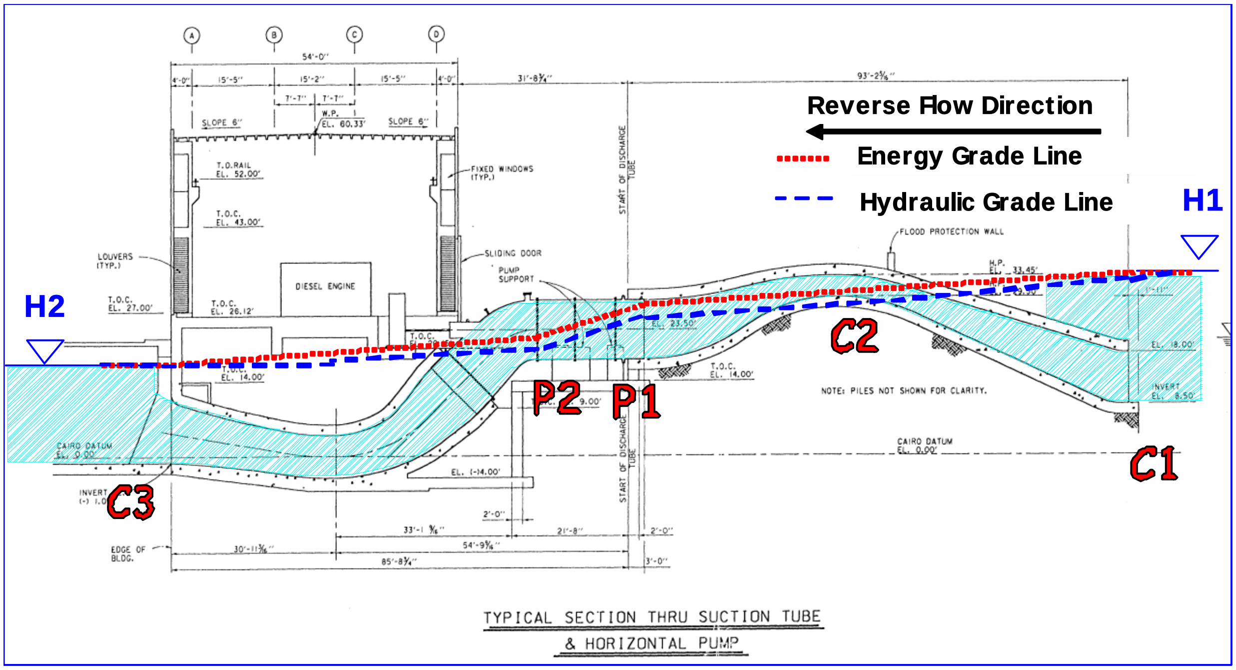

Figure 7-22 – Typical Hydraulic Profile for Primed Conduit Reverse Flow with EGL and HGL

Open Channel flow is non-pressurized flow where the water surface level is lower than the soffit of the conduit (i.e. flow does not make contact with the soffit and the pipe is not flowing full).

Energy gradeline (EGL) is the slope of the **total head** along a flow profile (red dashed line in Figure 7-22). At a given location (say P2 in Figure 7-22) along the conduit, the elevation of the EGL is equal to the total head at that location. The equations for EGL are slightly different for pressurized or open channel flow (refer to Figure 7-24 for open channel):

Equation 7-6 – Pressurized Flow

$$EGL_{P2} = z_{P2} + \frac{P_{P2}}{\gamma} + \frac{V_{P2}^{\;2}}{2g}$$

Equation 7-7 – Open Channel Flow

$$EGL_{P2} = Zi + Y_{P2} + \frac{V_{P2}^{\;2}}{2g}$$

In which:

EGL_{P2}= Energy gradeline elevation (or total head) at location P2

z_{P2} = Reference elevation at location P2 where pressure P_{P2} occurs.

Zi = Invert elevation at location P2

Y_{P2} = Flow depth at location P2.

V_{P2} = Velocity at location P2

g = gravitational constant (= 32.2 feet/second^2)

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Hydraulic gradeline (**HGL**) is the slope of the **hydrostatic head** along a profile (blue dashed line in Figure 7-22). With open channel flow, the hydrostatic head is equal to the water surface elevation, and the HGL is represented by the water surface (See locations C2, P1 or P2 in Figure 7-24). At a given location along the conduit, the elevation of the HGL is equal to the hydrostatic head at that location. The equations for HGL are slightly different for pressurized (Figure 7-22) or open channel flow (refer to Figure 7-24 for open channel).

Equation 7-8 – Pressurized Flow

$$HGL_{P2} = z_{P2} + \frac{P_{P2}}{\gamma}$$

Equation 7-9 – Open Channel Flow

$$HGL_{P2} = Zi + Y_{P2}$$

In which:

HGL_{P2}= Hydraulic gradeline elevation (or hydrostatic head) at location P2

Specific energy is the difference between the energy gradeline elevation (EGL) and invert elevation. This term is relevant only to open channel flow. For any value of specific energy and a certain cross-sectional geometry, there exist a range of potential flow rates, velocities, and depths that will have that same specific energy.

Equation 7-10 – Specific Energy

$$E = EGL - Zi = Y + \frac{V^2}{2g}$$

In which:

E = Specific energy

Critical energy is a special condition of specific energy in which there is only one flow rate, velocity and depth for that given specific energy level (See Figure 7-23). This flow rate is the maximum that can occur at that specific energy level (E). (Conversely for a given flow rate, critical energy is the minimum specific energy for that flow rate.) When specific energy levels are low (e.g. H1 is not much higher than the crest invert at C2), inflow into the system will be controlled by critical energy at the crest (C2) of the conduit. Critical energy only occurs with open channel flow at the bottleneck or choke point of a system caused by a high point, narrowed section, or combination of both, within a conduit. This location is typically at the crest of the discharge conduit in a pump system and the amount of available critical energy determines how much flow rate continues past this choke point. Hence this condition is called ‘critical control’ since the flow rate in the system is governed by the level of critical energy at the key point in the system. As H1 rises with respect to the crest or critical control point, critical control will ultimately relinquish to full flow conditions.

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The methods for determining this flow rate is discussed under the definition of 'Unprimed Flow' in 7.1.3.6.3: Different Flow Regimes of Reverse Flow.

Critical depth is the flow depth at the location where critical energy occurs. Critical depth is the threshold depth that divides slow and deep flow (subcritical) on the upstream side and fast and shallow flow (supercritical) on the downstream side. Critical depth is determined from the solution of the following equation:

Equation 7-11 – Velocity at critical depth location

$$Vc = \sqrt{\frac{Ac(Yc)\cdot g}{Tc(Yc)}}$$

In which:

Vc = Velocity at critical depth location.

Ac(Yc) = Flow Area at critical depth (Yc) and is function of the depth.

Tc(Yc) = Top width at critical depth (Yc) and is function of flow depth when conduit is non-rectangular.

Yc =Critical depth of flow depth at which critical energy occurs.

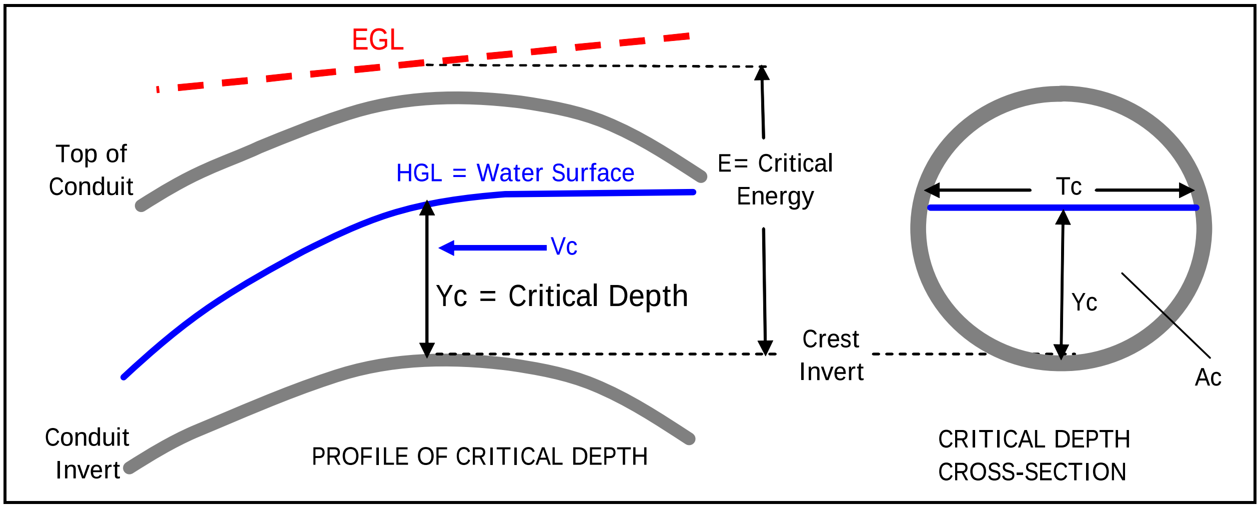

Figure 7-23 – Schematic for Critical Depth, Specific Energy, and Critical Energy

7.1.3.6.3 *Different Flow Regimes of Reverse Flow*

As explained in 7.1.3.5.2.1: Pump Stations and Terminology, water left on its own will flow downward. Given a condition of H1>H2 without the pump operation to apply a positive pump head or some means of system closure, water flow will tend to resume a natural course of action by flowing downward or backwards through the pump station. There are two primary flow regimes for reverse flow: **Unprimed Flow**, and **Primed Flow**. Within the primed flow regime, there are two subcategories: **Siphon Flow** and **Non-Siphon Primed Flow**. Below are definitions of flow regimes utilized in the methodology for reverse flow calculations:

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Unprimed flow does not fill the entire conduit and is controlled at the system crest invert (C2) by critical depth and critical energy. Water passes through the higher sections of the conduit as open channel flow (See Figure 7-24). Unprimed flow is strictly a function of H1 and independent of H2 (the downstream water level from the drainage area).

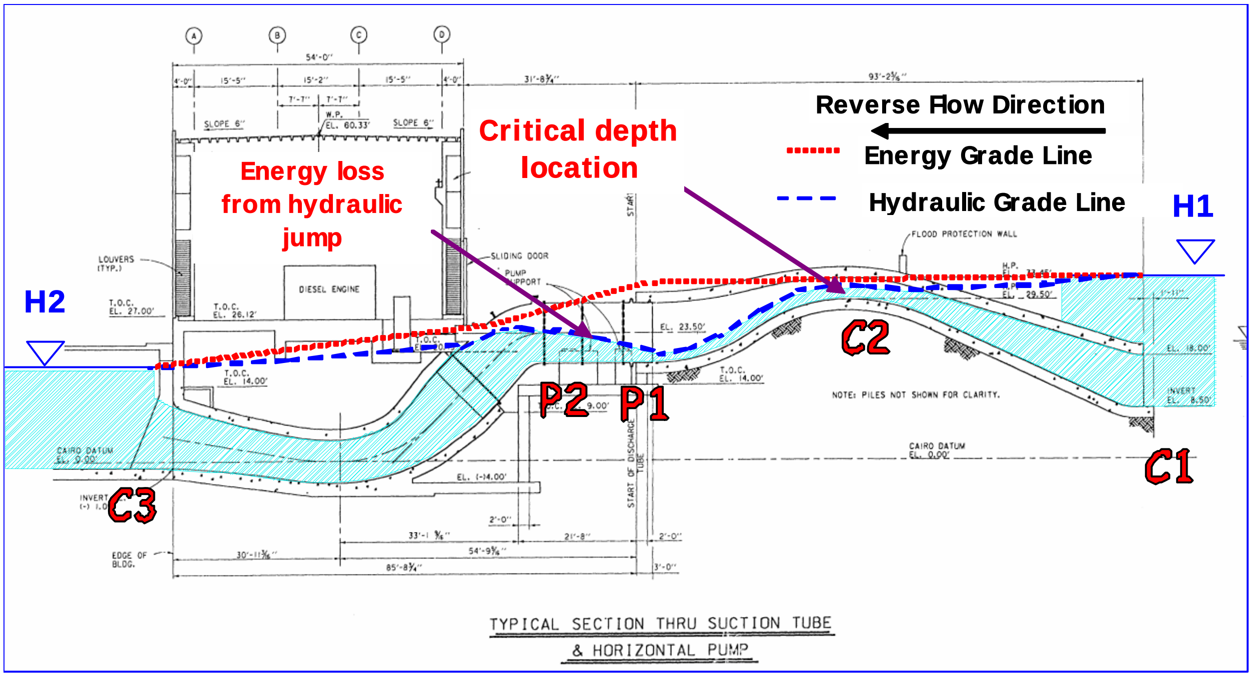

Figure 7-24 – Hydraulic Profile for Unprimed Flow (or Critical Control)

Primed conduit (or full) **flow** is a condition in which the pipe or conduit is entirely filled with water. Figure 7-25 shows a typical hydraulic profile for primed flow, which is a function of the difference between H1 and H2. The slopes of the EGL (red) and HGL (blue) in the figure show how the total head and hydrostatic head levels are expended through the system while providing a connection between H1 to H2. Primed flow follows the same principals described in 7.1.3.5.2.1: Pump Stations and Terminology, the only differences being the absence of positive pump head and the direction of flow. (Conversely, with reverse flow the pump represents the chief cause of head loss in the system and the EGL slope is steeper through the pump section.)

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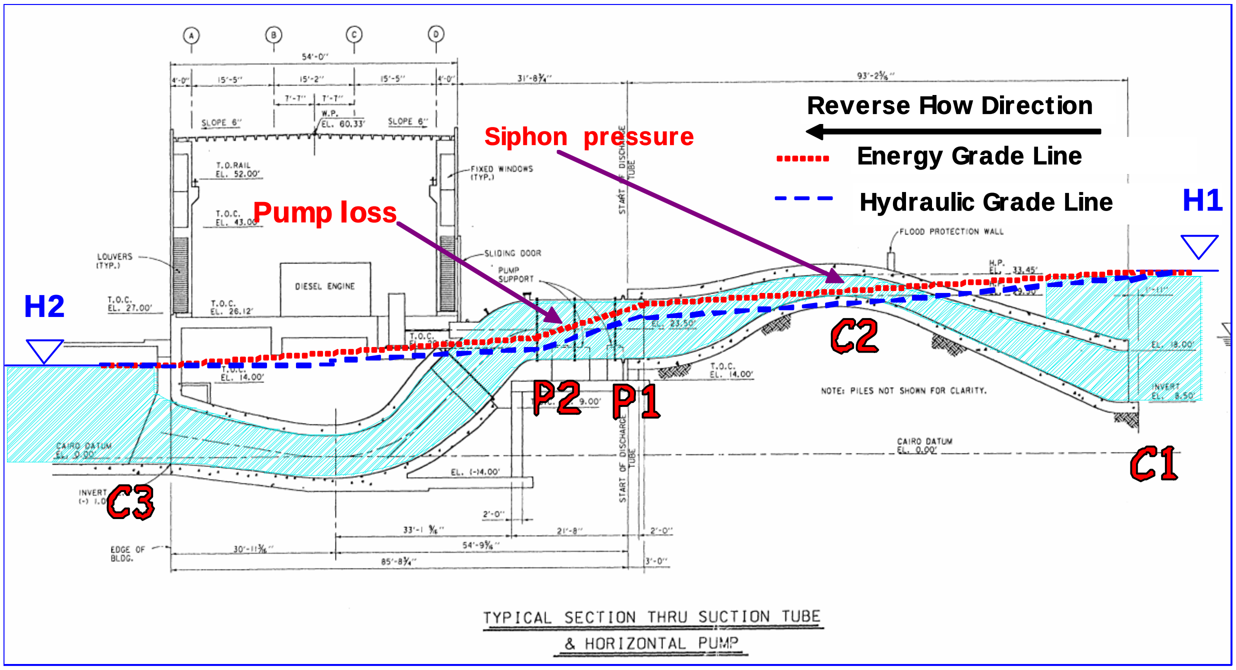

Figure 7-25 - Hydraulic Profile for Primed Flow (or Full Flow) under Siphon Conditions

Siphon flow is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit, or the gage pressure becomes negative. Most cases of reverse flow will fall into this category. Figure 7-25 represents a siphon flow condition. Negative gage pressure, or 'siphon pressure', will occur at locations where the soffit (top) of the conduit is higher than the HGL line (dashed blue). Thus siphon pressure clearly is present at locations C2 and P2 in Figure 7-25.

There are certain limitations to siphon flow. If there is an open air vent at or near the crest, then siphon flow is no longer possible, and either unprimed flow or the non-siphon primed flow will result. This is because the outside atmosphere sends a continual supply of air into the conduit through the vent and prevents significant siphon pressures from developing. Assuming no vent, siphon flow is also limited by the magnitude of negative gage pressure or how far the pressure drops below atmospheric pressure. In theory, in a very smoothly designed hydraulic system, a siphon flow condition can be maintained to absolute pressures down to vapor pressure[7] (or gage pressure = vapor pressure - atmospheric pressure). In practice however, the absolute pressures rarely can go as low as vapor pressure since few systems are perfectly air tight and any sudden geometrical changes will cause cavitation, or localized vaporization, which would break the siphon through premature vaporization or air coming out of solution..

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[7] Vapor pressure is the threshold absolute pressure where water changes from liquid phase to gas phase. It is a function of water temperature. Vapor pressure is usually much lower in magnitude than atmospheric pressure, and rises with temperature--ultimately matching standard atmospheric pressure (14.7 psia) when the water is heated to 212 degrees Fahrenheit.

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Non-siphon primed flow is the other category within the primed flow regime. In this case, all gage pressures are positive and the HGL is above is above the soffit of the conduit throughout the system. The non-siphon primed flow condition occurs when either H1 becomes very high, H2 (drainage area level) becomes relatively high or the combination of the two.

The two main flow regimes have distinctive methods of flow computation. All of the regimes and subcategories have specific trigger points which will initiate or halt the respective regime of flow (often signaling a switch from one regime to another).

7.1.3.6.4 *Methods of Estimating Reverse Flow Rates*

The reverse flow curves were developed based on two primary assumptions: (1) unprimed or critical depth control at the discharge piping crest (C2) and (2) primed or full flow control as a function of head difference between discharge lake/canal water level (H1) and drainage area water level (H2).

1) Unprimed Flow (or Critical Control): Unless the reverse flow was initiated by pump or power failure while the system was primed, the critical control assumption applies once a rising discharge lake exceeds the crest invert. This continues until pump system primes and converts to primed (or full) flow. The equation for reverse flow under critical control is presented below. The discharge lake/canal level (H1) provides the total head (left side of equation) that drives the flow which is in turn opposed by the resisting parameters or forces, incorporated in the sum of the critical energy at the discharge piping crest (C2), the elevation of the crest invert (C2) and head losses between H1 and C2 (right side of equation).

Equation 7-12 – Discharge side lake (or canal) water surface level

$$H1 = Zcr + Yc + \frac{Vc^2}{2g} + \frac{Qc^2}{2g} \cdot \left[\sum \frac{K_i}{A_i^2} + \sum \frac{\left({fL}/{D} \right)_i}{A_i^2} \right]$$

In which,

H1 = Discharge side lake (or canal) water surface level;

Zcr = Invert elevation at discharge pipe crest (C2);

Vc = Critical velocity at crest (C2);

Qc = Flow rate (or critical flow rate);

Yc = Critical depth at crest (C2);

Ac = Critical flow area at crest (C2);

i = subscript for locations or conduit segments between H1 and C2.

K_i = Minor loss coefficient at location i.

A_i = Flow area at location i or average area for conduit section i.

f = Friction factor for conduit section i.

L = Length of conduit section i.

D = Average hydraulic diameter of conduit segment i.

Σ means the summation of all terms where minor loss coefficients or friction terms for sections of conduit that must be accounted in order to determine the head loss between two points—in this case between H1 and system crest (C2).

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Note that the terms and the relationships used the right most term (in brackets) are the same terms used to define head losses in the *Pump Stations and Terminology* section. H1 represents the total head available to drive the reverse flow, and the net head (or net energy) to drive the flow is equal to H1 – Zcr, or the difference between the discharge lake/canal level and the invert of the crest at C2. This net head is also equal to the sum of the critical energy and head losses between H1 and C2. The sum of the Yc and Vc terms represent the critical energy at the crest (C2). Thus the net energy (H1 – Zcr) must be larger than critical energy to overcome the head losses between H1 and C2.

Equation 7-1 is rearranged to a more efficient form to solve for Qc (flow):

Equation 7-13 – Discharge side lake (or canal) water surface level

$$H1 = Zcr + Yc + Qc^2 \cdot \left(\frac{1}{2g * Ac^2} + K'\text{int} \right)$$

In which:

K’int = sum of minor and friction loss coefficients between crest and lake divided by square of respective flow areas and 2 x gravity.

Equation 7-14 – Sum of the minor and friction losses

$$K'\text{int} = \left[\sum \frac{K_i}{A_i^2} + \sum \frac{\left({fL}/{D} \right)_i}{A_i^2} \right] \cdot \frac{1}{2g} \quad \textit{(i for all areas and sections between H1 and C2)}$$

Equation 7-13 must be solved by iterative means.

2) Primed (or Full) Flow Control: This occurs when a pump system becomes primed and most or all air has been flushed out. This will typically happen as the lake level (H1) rises towards the soffit (inside top) of the discharge pipe at the crest (C2), and will continue until either the lake level (H1) falls below the top opening of the discharge outlet conduit or the internal pressure in the conduit nears vapor pressure. The siphon flow rate is determined by finding a magnitude which produces an equivalent system head loss to the head difference between the discharge lake and intake canal:

Equation 7-15 – Discharge side lake (or canal) water surface level

$$H1 = H2 + \frac{Q^2}{2g} \cdot \left[\sum \frac{K_i}{A_i^2} + \sum \frac{\left({fL}/{D} \right)_i}{A_i^2} \right]$$

In which,

Q = Primed conduit (or full) flow rate;

H2 = Normal intake side (drainage area) water level.

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Σ in this case covers all minor loss and friction terms between is H1 and H2.

H1 again represents the total head available to drive the reverse flow, and the net head (or net energy) to drive the flow is equal to H1 – H2. This net head is also equal to the total system head losses. Again the right most term represents the head losses through the system. Aside from the absence of critical energy, the key difference with primed flow and unprimed flow computations is that the net energy is the difference between H1 and H2 instead of H1 and C2.

Equation 7-15 can be refined to provide a direct solution for flow rate (Q):

Equation 7-16 – Flow Rate

$$Q = \sqrt{\frac{H1 - H2}{K'}}$$

K' = sum of minor and friction loss coefficients through entire pumping system divided by respective flow areas and 2 x gravity.

Equation 7-17 – Minor and Friction Losses

$$K' = \left[\sum \frac{K_i}{A_i^2} + \sum \frac{\left({}^{fL}\!/\!{}_{D} \right)_i}{A_i^2} \right] \cdot \frac{1}{2g}$$

(i for all areas and sections between H1 and H2)

7.1.3.6.5 *Minor Loss Coefficients for Pump Units*

In addition to the minor loss coefficients described in the *Pump Stations and Terminology* section, there is also the loss through the pump unit. This represents the largest head loss in the system (See Figure 7-25). In addition to the impeller blades, there are flow guidance vanes situated downstream (under normal pump operation) of the pump unit to straighten the swirling flow issuing from the pump impellers. Often there are also flow straighteners leading into the pump impellers from the normal intake side. Shape changes and flow areas changes also create losses. The flow must also pass around the shaft. In most cases, the impellers were locked against reverse rotation; however, there were many cases where the impeller blades were not locked to prevent reverse rotation. There are different basic pump configurations (axial pumps, wood screw and centrifugal pumps), each of which creates a different head loss signature or loss coefficient.

Under standard hydraulic design procedure, the loss coefficients for each of these different types (and status) of pump units would be determined from physical hydraulic models. However, no such existing information could be found and the brief project schedule did not allow adequate time to conduct any physical models tests.

Thus all of the above factors were incorporated to estimate a loss coefficient for the different basic pump configurations through analytical means. Based on opinions provided by pump

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manufacturers and expertise in the corps USACE Hydroelectric Design Center, a general rule of thumb guided the estimates: for the rated head of the pump, the reverse flow rates should be slightly less than the rated flow of the operating pump. The analytical methods included estimations of drag across the impellers and applications of loss coefficients of hydraulically similar features (such as partially open butterfly valve to represent the flow vanes.) Centrifugal pumps were treated as complex bifurcated manifolds.

Typically the loss portion attributed to the fixed impeller blades composed the largest portion of the loss for the pump unit. For free rotating impeller conditions (no brakes to prevent reverse rotation), the fixed impeller blades loss coefficient was reduced by 70%, thus making the overall unit loss coefficient for unlocked units about 50% of the values for the loss coefficients for locked units. Centrifugal pumps were considered different since effectively it becomes a moving bifurcated manifold and is probably unstable in the balancing of flow between the two paths of the bifurcations.

Given the numerous assumptions required to estimate the pump loss coefficients, there is considerable uncertainty in these values. For this reason, the estimated accuracy of reverse flow rates is ± 30% under primed flow conditions (the accuracy is higher for unprimed flow because the pump loss coefficient does not figure into the computations).

Table 7-5 presents the pump loss coefficients used in the development of reverse flow curves:

Table 7-5
Pump Loss Coefficients used in Reverse Flow Computations

Pump Type	Brakes to Prevent Reverse Rotation?	
	Yes	**No**
Axial (propeller)	6.5	3.5
Wood Screw	9.0	4.5
Centrifugal	3.5	3.5

7.1.3.6.6 *Definition of Trigger Points and Methodologies to Determine Trigger points:*

Trigger points for each pump configuration that are likely to initiate and/or modify the characteristics of reverse flow were developed. These are listed within the reverse flow sections of individual pump stations and organized within individual parishes. This section identifies the conditions which either trigger the initiation of reverse flow, change flow rates due to change in flow regimes (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graphs provided for each distinctive pump configuration within each pump station. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on discharge side lake/canal water surface elevation (H1).

1. Pump failure or power failure automatically triggers primed flow:
Primed conduit reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or

flap valve to prevent reverse flow. (This is assuming that H1 is not so low as to prevent the siphon from developing (see trigger point for siphon breaker defined in 2 d below—this also defines when the primed siphon flow will end.). The system conduit is already primed from the pumping operation.

2. Water-elevation trigger points

The following four types of trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (e.g. pump failure), the fourth water level trigger point (siphon breaker) applies to ending a siphon primed flow condition and the 2b ii (vented condition) applies to ending non-siphon primed flow if an air vent automatically opens with a pump failure.

a) **Water elevation (H1) that triggers unprimed flow**
   Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of the unprimed flow.

b) **Water elevation (H1) that triggers primed or full flow**

   - **Water elevation that triggers siphon primed flow**
     Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the soffit of the conduit crest in the pumping system.

     The threshold for which siphon flow develops is unpredictable and is dependent on conditions and system geometry. A sudden rise in the lake water surface could send through a pulse that primes the conduit. Highly variable air pressures experienced on the local scale at a pump station during the hurricane might also induce (or halt) siphon flow. Also, minor cracks or air leaks in the conduit could also prevent or break the siphon before it would normally give way (trigger point 2 d). The current assumptions for H1 threshold values are reasonable for relatively quiescent conditions and a typical discharge conduit that slopes uniformly away from the crest.

     The confidence in this trigger point is reduced by complicated geometry and several unknowns. In some pump systems, the stopped pumps will impede flow and force hydraulic jumps downstream of the crest. Air is usually entrained with the formation of hydraulic jumps, thus beginning a potential mechanism that systematically moves air out of the system (assuming the jump has enough strength to create air entrainment).

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Given all these factors, a future modeler may choose to use a lower value than the specified trigger point (H1 = soffit) to initiate siphon flow, such as H1 = conduit centerline at crest or H1 = 0.5 * (soffit + invert) at crest.

- **Water elevation that triggers non-siphon primed flow**
  If there is an open vent in the system, a table for minimum H1 elevations for versus H2 elevations is provided for the conditions that would trigger primed flow. The following is an example of tables displayed for each pump:

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.							
H2 =	8.0	10.7	13.3	16.0	18.7	21.3	24.0
H1 >	149	137	124	111	98	86	73

In most cases, the H1 values are prohibitively high. As H1 peaks and ultimately falls back, this trigger point will also represent the end of non-siphon primed flow or a switch to the unprimed flow regime.

c) **Water elevation (H1) that stops unprimed flow**
Unprimed flow stops at the same H1 that initiates unprimed flow.

d) **Water elevation (H1) that stops primed conduit flow**
There are two conditions which ends primed flow under siphon condition. Figure 7-26 shows the two locations which can cause the siphon flow to end. Siphon flow stops when:

- The elevation of the discharge lake/canal water level (H1) falls below the top of the pump system discharge pipe outlet (C1) plus about 1 foot drawdown. This condition will allow air directly into the system and thus end the siphon. In estimating the H1 threshold, a drawdown of 1 foot was assumed in the water surface approaching the conduit from the lake.
- When the pressure at the soffit of the crest pipe (C2) drops below -9.5 psi gage pressure. This is estimated threshold is based on ¾ the difference between an assumed atmospheric pressure of 13 psia[8] and a vapor pressure of 0.4 psia (for water temperature of 70 degrees). The actual siphon breaker pressure threshold may vary depending on system configuration and the amount of air leakage in the conduit.

Both of the above cases are siphon breakers. Once the siphon breaks, then either unprimed flow resumes, or flow stops if H1 is already below the system crest invert at C2

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[8] Psia stands for pounds force per square inch in absolute pressure. Absolute pressure = gage pressure + atmospheric pressure.

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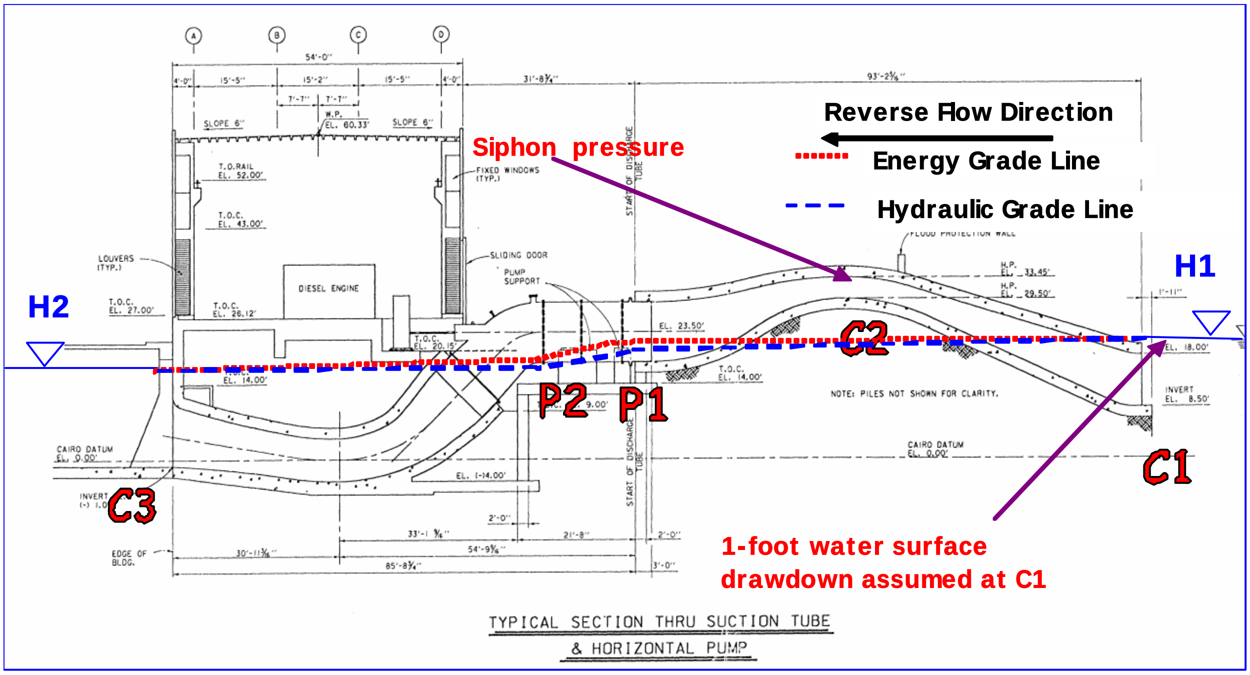

Figure 7-26 - Locations Where Siphon Flow Can be Broken

7.1.3.6.7 *General Assumptions*

Estimated accuracy for unprimed (critical control) flow: If the conduit crest is located between the discharge lake and the pump unit, the computed flow rates are estimated to be accurate within ± 10%.

If the conduit crest is located within the pump unit or between the pump and drainage area canal, the computed flow rates are estimated to be accurate within ± 30%. This is due to the uncertainty of the loss coefficient through the pump unit.

Estimated accuracy for primed (full) flow: The computed flow rates are estimated to accurate within ± 30%, due to the uncertainty of the loss coefficient through the pump unit.

Additional sources of error: If conduit geometry data is deficient, the error bands become greater than 30% (or 10% for most unprimed flow) depending on the extent or importance (e.g. pump impeller diameter, system drawings, elevation of system crest, etc.) of missing information.

7.1.3.6.8 *Conclusions*

Modifications could be made to the estimates if more detailed information becomes available to make more conclusive backflow rating curve assumptions. The CENWP-EC-HD and CENWP-HDC will continue to seek more data on pump loss coefficients.

Computation of reverse flow curves for a given pump station does not necessarily imply that reverse flow actually occurred during the Katrina event, but may instead provide future tools if further investigations are required based on reverse flow assumptions.

7.2 Jefferson Parish

Jefferson Parish is located west of the city of New Orleans and borders the west side of Orleans Parish. Figure 7-27 is a map of Jefferson Parish with the pump stations that were studied identified by red dots. Jefferson Parish is separated by the Mississippi River into East and West Banks. The East Bank pump stations are connected by a grid of canals. The canals running east and west serve to equalize flow between the major outfall canals, allowing rain water to flow in different directions depending on the rainfall patterns and available capacities at the pump stations. The West Bank is subdivided into sub-basins that, for smaller rainfall events, operate independently. However, over-bank flow does occur between adjacent sub-basins for a 10-year event. This report examined 6 pump stations on the East Bank with a total of 36 pumps and 17 pump stations on the West Bank with a total of 65 pumps.

Figure 7-27 is a map showing the Jefferson Parish pump stations that were used in this report. The locations of the pump stations were verified by Global Positioning System (GPS) and/or by using Google Earth Pro. The GPS coordinates were then input into Microsoft Streets and Trips (shown below).

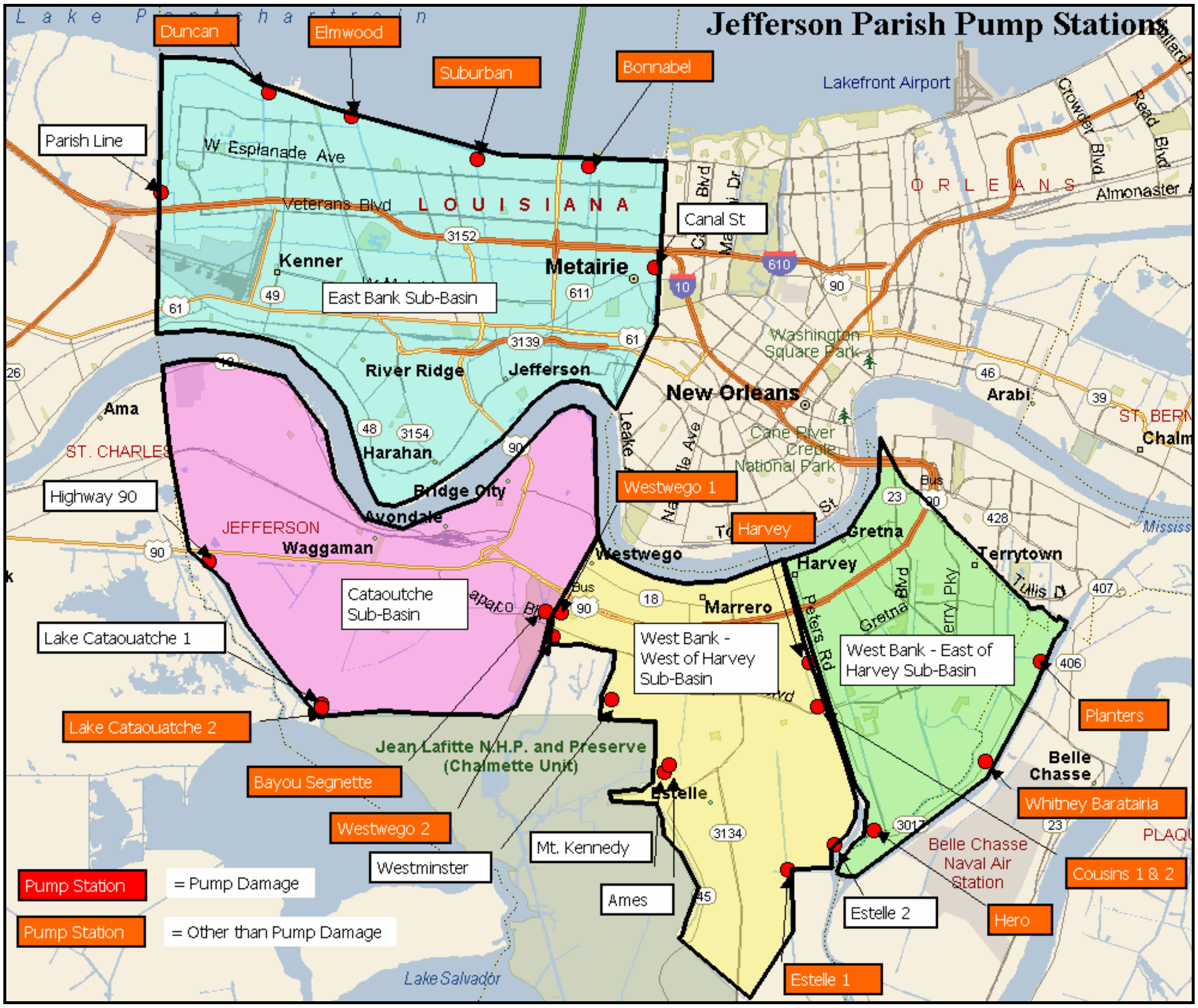

Figure 7-27 - Jefferson Parish Pump Station Locations

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Table 7-8 and Table 7-9 contain information about each individual pump at each of the examined pump stations in Jefferson Parish. The list is composed of information that was collected in the field. Not all information was available for each pump and was left blank or highlighted.

Table 7-6
Summary of Jefferson Parish Pump Stations by Drainage Basin

Basin	East Bank	Cataouatche	West Bank – West of Harvey	West Bank-East of Harvey	Total
Number of pump stations	6	4	9	3	22
Number of pumps	36	24	29	15	104
Total rated capacity (cfs)	20,662	3,346	10,695	9,958	44,661
Estimated cost of damages	$558,000	$3,000	$136,000	$61,000	$758,000

7.2.1 Drainage Basins

7.2.1.1 East Bank

The East Bank Drainage Basin is bordered by Lake Pontchartrain on the north, and the Mississippi River on the south. The drainage system includes the surrounding bodies of water, as well as Bonnabel, Suburban, Elmwood, Duncan, Canal, and17th Street Canals. The basin has six significant pump stations, which are summarized below. Section 7.6.1.1provides more detailed descriptions.

Bonnabel

Intake location:	Bonnabel
Discharge location:	Lake Pontchartrain
Nominal capacity:	3750

Pump	Capacity (cfs)	Year (Installed)	Driver Electric /Diesel	Pump Configuration
1	300	1986	Electric 60 HZ	Vertical
2	300	1986	Electric 60 HZ	Vertical
3	1050	1986	Diesel	Horizontal
4	1050	1986	Diesel	Horizontal
5	1050	1986	Diesel	Horizontal

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Suburban

Intake location: Suburban
Discharge location: Lake Pontchartrain
Nominal capacity: 5155 cfs

Pump	Capacity (cfs)	Year (Installed)	Driver Electric /Diesel	Pump Configuration
1	1050	1983	Diesel	Horizontal
2	1050	1970	Diesel	Horizontal
3	55	1970	Electric 60 HZ	Vertical
4	300	1970	Diesel	Vertical
5	300	1970	Diesel	Vertical
6	300	1983	Electric 60 HZ	Vertical
7	1050	2005	Diesel	Horizontal
8	1050	2005	Diesel	Horizontal

Elmwood

Intake location: Elmwood Canal
Discharge location: Lake Pontchartrain
Nominal capacity: 5912 cfs

Pump	Capacity (cfs)	Year (Installed)	Driver Electric /Diesel	Pump Configuration
1	303	1981	Diesel	Vertical
2	303	1981	Diesel	Vertical
3	550	1981	Diesel	Vertical
4	550	1981	Diesel	Vertical
5	550	1981	Diesel	Vertical
6	550	1981	Diesel	Vertical
7	303	1981	Diesel	Vertical
8	303	1981	Diesel	Vertical
9	1250	2004	Diesel	Horizontal
10	1250	2004	Diesel	Horizontal

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Duncan
Intake location: Duncan Canal
Discharge location: Lake Pontchartrain
Nominal capacity: 4800 cfs

Pump	Capacity (cfs)	Year (Installed)	Driver Electric /Diesel	Pump Configuration
1	300	1986	Electric 60 HZ	Vertical
2	300	1986	Electric 60 HZ	Vertical
3	1050	1986	Diesel	Horizontal
4	1050	1986	Diesel	Horizontal
5	1050	1986	Diesel	Horizontal
6	1050	1986	Diesel	Horizontal

Parish Line
Intake location: 16th & 17th Street Canal
Discharge location: Lake Pontchartrain
Nominal capacity: 885 cfs

Pump	Capacity (cfs)	Year (Installed)	Driver Electric /Diesel	Pump Configuration
1	295	1987	Electric 60 HZ	Vertical
2	295	1987	Electric 60 HZ	Vertical
3	295	1987	Electric 60 HZ	Vertical

Canal Street
Intake location: Canal
Discharge location: 17th Street Canal
Nominal capacity: 160 cfs

Pump	Capacity (cfs)	Year (Installed)	Driver Electric /Diesel	Pump Configuration
1	40	1998	Electric 60 HZ	Vertical
2	40	1998	Electric 60 HZ	Vertical
3	40	1998	Electric 60 HZ	Vertical
4	40	1998	Electric 60 HZ	Vertical

7.2.1.2 West Bank – East of Harvey

The East of Harvey drainage basin on the West Bank has 3 significant pump stations. The basin is bordered b the Mississippi River on the north, and the Intracoastal Waterway on the southwest. The drainage system consists of the surrounding bodies of water, as well as the

Planters Bypass and Hero Outfall Canals. The three pump stations are briefly described below. Section 7.6.1.2 provides more detailed descriptions.

Planters

Intake location:	Planters Bypass Canal
Discharge location:	Intracoastal Waterway
Nominal capacity:	2360 cfs

Pump	Capacity (cfs)	Year (Installed)	Driver Electric /Diesel	Pump Configuration
1	289	1973	Diesel	Vertical
2	289	1973	Diesel	Vertical
3	289	1973	Diesel	Vertical
4	289	1973	Diesel	Vertical
5	52	1973	Electric	Vertical
6	288	1988	Electric	Vertical
7	288	1988	Electric	Vertical
8	288	1988	Electric	Vertical
9	288	1988	Electric	Vertical

Hero

Intake location:	Hero Outfall Canal
Discharge location:	Intracoastal Waterway
Nominal capacity:	3852 cfs

Pump	Capacity (cfs)	Year (Installed)	Driver Electric /Diesel	Pump Configuration
1	100	1997	Electric	Vertical
2	300	1997	Electric	Vertical
3	300	1997	Electric	Vertical
4	1020	1989	Diesel	Horizontal
5	1020	1989	Diesel	Horizontal
6	300	1997	Electric	Vertical
7	203	1984	Diesel	Horizontal
8	203	1984	Diesel	Horizontal
9	203	1984	Diesel	Horizontal
10	203	1984	Diesel	Horizontal

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Whitney Barataria

Intake location: Not Recorded
Discharge location: Intracoastal Canal
Nominal capacity: 3750 cfs

Pump	Capacity (cfs)	Year (Installed)	Driver Electric /Diesel	Pump Configuration
1	1250	2005	Diesel	Hoizontal
2	1250	2005	Diesel	Hoizontal
3	1250	2005	Diesel	Hoizontal

7.2.1.3 West Bank – West of Harvey

The West Bank – West of Harvey drainage basin has 8 significant pump stations, which are briefly described below. Section 7.6.1.2 provides more details. The basin is bordered by the Mississippi River on the north. The drainage system includes the Mississippi River, as well as wetlands and the First Ave., Two Mile, Cousins, Harvey, Pipeline, Kenta/Seivers, Grand Cross, Inner Milladoun, Bayou Segnette, WPA, G, and H Canals.

Harvey

Intake location: First Ave. & Two Mile Canal
Discharge location: First Ave. & Two Mile Canal
Nominal capacity: 960 cfs

Pump	Capacity (cfs)	Year (Installed)	Driver Electric /Diesel	Pump Configuration
1	320	1986	Electric	Vertical
2	320	1986	Electric	Vertical
3	320	1986	Electric	Vertical

Cousins No. 1

Intake location: Cousins Canal & First Ave. Canal
Discharge location: Harvey Canal
Nominal capacity: 800 cfs

Pump	Capacity (cfs)	Year (Installed)	Driver Electric /Diesel	Pump Configuration
1	50	1973	Electric	Vertical
2	250	1973	Diesel	Vertical
3	250	1973	Diesel	Vertical
4	250	1973	Diesel	Vertical

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Cousins No. 2

Intake location: Cousins Canal & First Ave. Canal
Discharge location: Harvey Canal
Nominal capacity: 2200 cfs

Pump	Capacity (cfs)	Year (Installed)	Driver Electric /Diesel	Pump Configuration
1	1100	1985	Diesel	Horizontal
2	1100	1985	Diesel	Horizontal

Estelle 1

Intake location: Pipeline Canal
Discharge location: Intracoastal Waterway
Nominal capacity: 515 cfs

Pump	Capacity (cfs)	Year (Installed)	Driver Electric /Diesel	Pump Configuration
1	138	1962	Electric	Vertical
2	138	1962	Electric	Vertical
3	138	1962	Electric	Vertical
4	101	1962	Electric	Vertical

Estelle 2

Intake location: Pipeline & Canal G
Discharge location: Intracoastal Waterway
Nominal capacity: 1140 cfs

Pump	Capacity (cfs)	Year (Installed)	Driver Electric /Diesel	Pump Configuration
1	570	1998	Diesel	Horizontal
2	570	1998	Diesel	Horizontal

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Mount Kennedy

Intake location: Kenta/Seivers Canal
Discharge location: Bayou Segnette
Nominal capacity: 501 cfs

Pump	Capacity (cfs)	Year (Installed)	Driver Electric /Diesel	Pump Configuration
1	167	2005	Electric	Vertical
2	167	2005	Electric	Vertical
3	167	2005	Electric	Vertical

Westminster

Intake location: Grand Cross
Discharge location: Wetlands
Nominal capacity: 1248 cfs

Pump	Capacity (cfs)	Year (Installed)	Driver Electric /Diesel	Pump Configuration
1	312	1998	Electric	Vertical
2	312	1998	Electric	Vertical
3	312	1998	Electric	Vertical
4	312	1998	Electric	Vertical

Ames

Intake location: Inner Milladoun
Discharge location: Bayou Segnette
Nominal capacity: 1930 cfs

Pump	Capacity (cfs)	Year (Installed)	Driver Electric /Diesel	Pump Configuration
1	390	1985	Electric	Vertical
2	390	1985	Electric	Vertical
3	1150	1985	Diesel	Horizontal

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Westwego No. 1

Intake location:	WPA Canal
Discharge location:	Bayou Segnette
Nominal capacity:	300 cfs

Pump	Capacity (cfs)	Year (Installed)	Driver Electric /Diesel	Pump Configuration
1	300	1969	Diesel	Vertical

Westwego No. 2

Intake location:	Ave H Canal
Discharge location:	Bayou Segnette
Nominal capacity:	935 cfs

Pump	Capacity (cfs)	Year (Installed)	Driver Electric /Diesel	Pump Configuration
1	312	1985	Diesel	Vertical
2	312	1985	Diesel	Vertical
3	311	1997	Electric	Vertical

7.2.1.4 West Bank – West of Harvey (Cataouatche)

The West Bank-West of Harvey Cataouatche drainage basin has four significant pump stations, which are briefly described below. Section 7.6.1.2 provides more detailed information. The basin is bordered by the Mississippi River on the north and east sides. Its drainage system includes the river, Lake Cataouatche, and the Main, Waggaman, and Bayou Segnette Canals.

Lake Cataouatche No. 1

Intake location:	Main Canal
Discharge location:	Lake Cataouatche
Nominal capacity:	500 cfs

Pump	Capacity (cfs)	Year (Installed)	Driver Electric /Diesel	Pump Configuration
1	250	1978	Diesel	Vertical
2	250	1978	Diesel	Vertical

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Lake Cataouatche No. 2
Intake location: Main Canal
Discharge location: Lake Cataouatche
Nominal capacity: 600 cfs

Pump	Capacity (cfs)	Year (Installed)	Driver Electric /Diesel	Pump Configuration
1	300	1985	Diesel	Vertical
2	300	1985	Diesel	Vertical

Highway 90
Intake location: Waggaman Canal
Discharge location: Outer Cataouatche Canal
Nominal capacity: 145 cfs

Pump	Capacity (cfs)	Year (Installed)	Driver Electric /Diesel	Pump Configuration
1	45	1969	Electric	Vertical
2	45	1969	Electric	Vertical
3	55	1969	Electric	Vertical

Bayou Segnette
Intake location: Main Canal
Discharge location: Bayou Segnette
Nominal capacity: 2156 cfs

Pump	Capacity (cfs)	Year (Installed)	Driver Electric /Diesel	Pump Configuration
New 1	610	2005	Diesel	Horizontal
New 2	610	2005	Diesel	Horizontal
1	156	1962	Diesel	Vertical
2	156	1962	Diesel	Vertical
3	156	1962	Diesel	Vertical
4	156	1962	Diesel	Vertical
5	156	1962	Diesel	Vertical
6	156	1962	Diesel	Vertical

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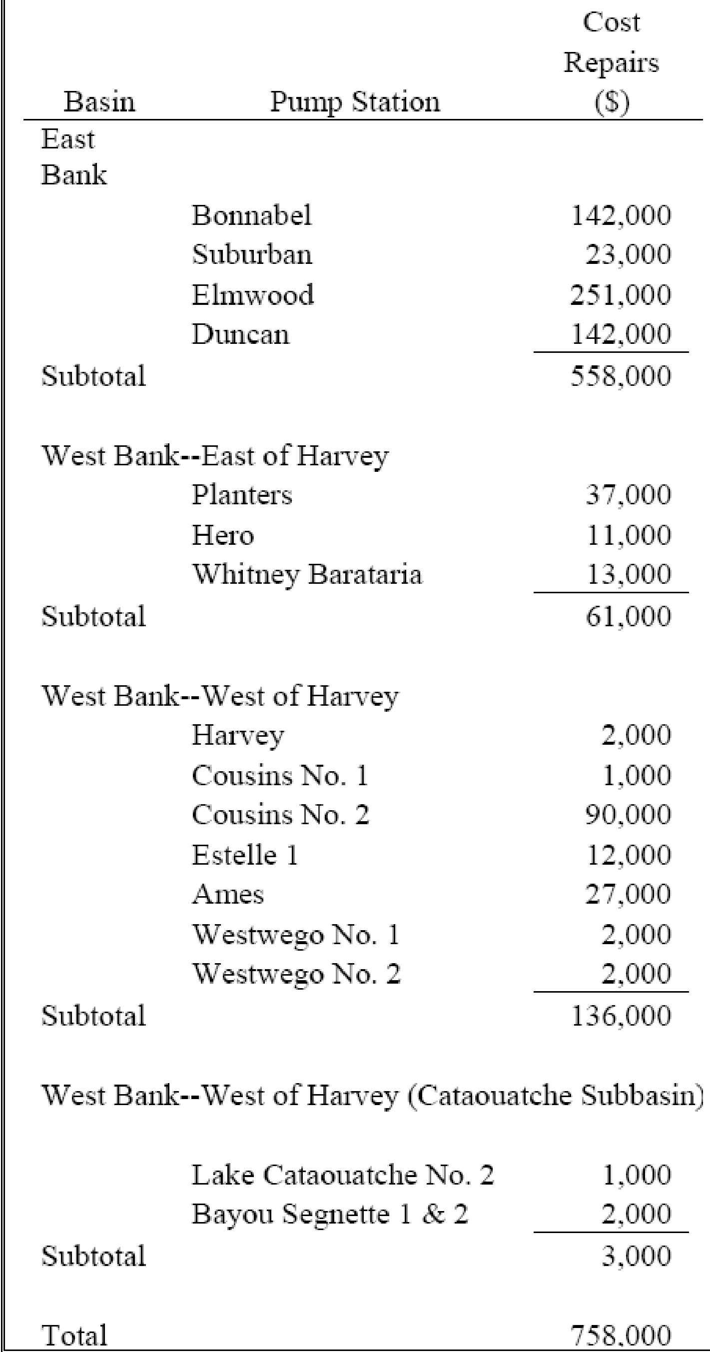
7.2.2 Damage Summary

Table 7-7
Estimated Costs of Repairs to Jefferson Parish Pump Stations[1]



Basin	Pump Station	Cost Repairs ($)
East Bank		
	Bonnabel	142,000
	Suburban	23,000
	Elmwood	251,000
	Duncan	142,000
Subtotal		558,000
West Bank--East of Harvey		
	Planters	37,000
	Hero	11,000
	Whitney Barataria	13,000
Subtotal		61,000
West Bank--West of Harvey		
	Harvey	2,000
	Cousins No. 1	1,000
	Cousins No. 2	90,000
	Estelle 1	12,000
	Ames	27,000
	Westwego No. 1	2,000
	Westwego No. 2	2,000
Subtotal		136,000
West Bank--West of Harvey (Cataouatche Subbasin)		
	Lake Cataouatche No. 2	1,000
	Bayou Segnette 1 & 2	2,000
Subtotal		3,000
Total		758,000

[1] Taken from the Jefferson Parish PIR

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7.2.3 Improvements Suggested by the Parish

The COE met with members of the Jefferson Parish Department of Drainage to discuss pump station improvements that would increase the pumping performance in the future. The suggested improvements are listed below.

1. **Safe houses**
   Station hurricane hardening and safe house areas for pump station operators need to be provided along with adequate remote/automatic controls and monitoring of critical equipment to allow operations during storm events. The work effort is underway, but there may be some changes in concepts.

2. **Wind resistant stations**
   There were roof failures at some of the pump station complexes. USACE is currently working with Jefferson Parish on repairs to damaged stations. Jefferson Parish may request additional wind resistance be incorporated into the designs.

3. **Backflow prevention**
   All the stations need backflow prevention capability for all stations, especially the outfalls to Lake Pontchartrain.

4. **Surge protection**
   The stations need to be protected from high storm surges. Criteria similar to that used for levees and floodwalls needs to be incorporated into the stations.

5. **Debris removal**
   Debris is not a significant problem at the pump stations; however the parish has paid $50 million for trash and debris removal and collection. This could potentially affect maintenance and operations of the pumping facilities. Jefferson Parish would like financial assistance with this issue.

6. **Reliable communications**
   The stations need a reliable communications system during storms. They lost the ability to communicate after the storm.

7. **Funding for alternative drainage**
   A closure structure for the 17th Street Canal may create a need to provide a drainage alternative for the station that discharges to that canal. Funding for that effort would be requested.

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Table 7-8
Jefferson Parish Pumping Equipment Table

Name	Pump	Capacity (cfs)	Pump Manufacture	Pump Size (in)	Pump Model Number	Pump Serial Number	Installed (year)	Driver Electric /Diesel	Rated Pump Speed (rpm)	Pump Type (Vertical/Horizontal)	Pump Elevation (Cairo)	Pump Curve (yes/no)	Discharge Gates (type)	Rated Head (ft)	Track Rack Design Head (ft)	Intake Location	Discharge Location	Intake water elevation at Start (Cairo)	Intake water elevation at Stop (Cairo)	Intake water elevation range (Cairo)	Water elevations that effects station (Cairo)	Bearing Lubrication (oil/water)	Backstops or brakes (yes/no)
JP#1 Bonnabel	1	300	Allis-Chalmers (ITT-AC)	84	WCAX	840-9040	1986	Electric 60 HZ	320	Vertical	21	Yes	Gate Valve	14	1	Bonnabel	Lake Pontchartrain	8.3	8.1	0.2	20.67	Oil	Yes
	2	300	Allis-Chalmers (ITT-AC)	84	WCAX	840-9041	1986	Electric 60 HZ	320	Vertical	21	Yes	Gate Valve	14	1	Bonnabel	Lake Pontchartrain	8.3	8.1	0.2	20.67	Oil	Yes
	3	1050	Allis-Chalmers (ITT-AC)	132	Horizontal	850-9025	1986	Diesel	100	Horizontal	22.5	Yes	None	11	1	Bonnabel	Lake Pontchartrain	8.8	8.2	0.6	20.67	Oil	Yes
	4	1050	Allis-Chalmers (ITT-AC)	132	Horizontal	850-9026	1986	Diesel	100	Horizontal	22.5	Yes	None	11	1	Bonnabel	Lake Pontchartrain	9	8.2	0.8	20.67	Oil	Yes
	5	1050	Allis-Chalmers (ITT-AC)	132	Horizontal	850-9027	1986	Diesel	100	Horizontal	22.5	Yes	None	11	1	Bonnabel	Lake Pontchartrain	9.4	8.2	1.2	20.67	Oil	Yes
	Total	**3750**																					
JP#2 Suburban	1	1050	Allis-Chalmers (ITT-AC)	132	Horizontal	3-850-9051	1983	Diesel	100	Horizontal	19.5	yes	None	11	1	Suburban	Lake Pontchartrain	8.6	8	0.6	27	Oil	Yes
	2	1050	Fairbanks Morse	132	Horizontal	K2N2053448	1970	Diesel	100	Horizontal	19.6	no	None	11	1	Suburban	Lake Pontchartrain	8.6	8	0.6	27	Oil	Yes
	3	55	Fairbanks Morse	30	Vertical	K2N2053449	1970	Electric 60 HZ	700	Vertical	21	no	None	9	1	Suburban	Lake Pontchartrain	8.1	8	0.1	27	Oil	Yes
	4	300	Peerless Pump	72	Vertical		1970	Diesel	302	Vertical	21.5	yes	Gate Valves	14	1	Suburban	Lake Pontchartrain	8.2	8	0.2	27	Oil	Yes
	5	300	Peerless Pump	72	Vertical		1970	Diesel	302	Vertical	21.5	yes	Gate Valves	14	1	Suburban	Lake Pontchartrain	8.2	8	0.2	27	Oil	Yes
	6	300	Allis-Chalmers (ITT-AC)	84	Vertical		1983	Electric 60 HZ	327	Vertical	21	yes	Gate Valves	14	1	Suburban	Lake Pontchartrain	8.2	8	0.2	27	Oil	Yes
	7	1050	ITT-AC	132			2005	Diesel		Horizontal		yes	None	7.5	1	Suburban	Lake Pontchartrain						
	8	1050	ITT-AC	132			2005	Diesel		Horizontal		yes	None	7.5	1	Suburban	Lake Pontchartrain						
	Total	**5155**																					
JP#3 Elmwood	1	303	Patterson Pump Co.	72	Vertical	78BT3180-G72	1981	Diesel	300	Vertical	21.5	yes	Gate Valves	16.5	1	Elmwood Canal	Lake Pontchartrain	8.7	8.2	0.5	25.5	Oil	Yes
	2	303	Patterson Pump Co.	72	Vertical	78BT3183-G72	1981	Diesel	300	Vertical	21.5	yes	Gate Valves	16.5	1	Elmwood Canal	Lake Pontchartrain	8.7	8.2	0.5	25.5	Oil	Yes
	3	550	Couch (MWI)	96	Vertical	5070	1981	Diesel	215	Vertical	20.5	yes	Gate Valves	15.6	1	Elmwood Canal	Lake Pontchartrain	8.7	8.2	0.5	25.5	Oil	Yes
	4	550	Couch (MWI)	96	Vertical	5071	1981	Diesel	215	Vertical	20.5	yes	Gate Valves	15.6	1	Elmwood Canal	Lake Pontchartrain	8.7	8.2	0.5	25.5	Oil	Yes
	5	550	Couch (MWI)	96	Vertical	5073	1981	Diesel	215	Vertical	20.5	yes	Gate Valves	15.6	1	Elmwood Canal	Lake Pontchartrain	8.7	8.2	0.5	25.5	Oil	Yes
	6	550	Couch (MWI)	96	Vertical	5072	1981	Diesel	215	Vertical	20.5	yes	Gate Valves	15.6	1	Elmwood Canal	Lake Pontchartrain	8.7	8.2	0.5	25.5	Oil	Yes
	7	303	Patterson Pump Co.	72	Vertical	78BT3182-G72	1981	Diesel	300	Vertical	21.5	yes	Gate Valves	16.5	1	Elmwood Canal	Lake Pontchartrain	8.5	8.2	0.3	25.5	Oil	Yes
	8	303	Patterson Pump Co.	72	Vertical	78BT3181-G72	1981	Diesel	300	Vertical	21.5	yes	Gate Valves	16.5	1	Elmwood Canal	Lake Pontchartrain	8.5	8.2	0.3	25.5	Oil	Yes
	9	1250	ITT-AC	132	WCXH	1-0850-70153-04	2004	Diesel	100	Horizontal	28	yes	None	5.5	1	Elmwood Canal	Lake Pontchartrain	9.5	8.2	1.3	25.5	Oil	Yes
	10	1250	ITT-AC	132	WCXH	1-0850-70153-04	2004	Diesel	100	Horizontal	28	yes	None	5.5	1	Elmwood Canal	Lake Pontchartrain	9.5	8.2	1.3	25.5	Oil	Yes
	Total	**5912**																					
JP#4 Duncan	1	300	Allis-Chalmers (ITT-AC)	84		840-9043	1986	Electric 60 HZ	320	Vertical	21.5	No	Gate Valves	14	1	Duncan Canal	Lake Pontchartrain	8.5	8	0.5	14.5	Oil	Yes
	2	300	Allis-Chalmers (ITT-AC)	84		840-9042	1986	Electric 60 HZ	320	Vertical	21.5	No	Gate Valves	14	1	Duncan Canal	Lake Pontchartrain	8.5	8	0.5	14.5	Oil	Yes
	3	1050	Allis-Chalmers (ITT-AC)	132	Horizontal	850-9031	1986	Diesel	100	Horizontal	19.5	No	None	11	1	Duncan Canal	Lake Pontchartrain	9	8	1	14.5	Oil	Yes
	4	1050	Allis-Chalmers (ITT-AC)	132	Horizontal	850-9029	1986	Diesel	100	Horizontal	19.5	No	None	11	1	Duncan Canal	Lake Pontchartrain	9	8	1	14.5	Oil	Yes
	5	1050	Allis-Chalmers (ITT-AC)	132	Horizontal	850-9030	1986	Diesel	100	Horizontal	19.5	No	None	11	1	Duncan Canal	Lake Pontchartrain	9	8	1	14.5	Oil	Yes
	6	1050	Allis-Chalmers (ITT-AC)	132	Horizontal	850-9028	1986	Diesel	100	Horizontal	19.5	No	None	11	1	Duncan Canal	Lake Pontchartrain	9	8	1	14.5	Oil	Yes
	Total	**4800**																					
JP#5 Parish Line	1	295	Allis-Chalmers (ITT-AC)	84	Vertical	1-0840-70028-02	1987	Electric 60 HZ	320	Vertical	24	Yes	Gate Valves	14	1	16 and 17	Lake Pontchartrain	9.5	9	0.5	18	Oil	Yes
	2	295	Allis-Chalmers (ITT-AC)	84	Vertical	1-0840-70028-03	1987	Electric 60 HZ	320	Vertical	24	Yes	Gate Valves	14	1	16 and 17	Lake Pontchartrain	9.5	9	0.5	18	Oil	Yes
	3	295	Allis-Chalmers (ITT-AC)	84	Vertical	1-0840-70028-01	1987	Electric 60 HZ	320	Vertical	24	Yes	Gate Valves	14	1	16 and 17	Lake Pontchartrain	9.5	9	0.5	18	Oil	Yes
	Total	**885**																					
Canal Street	1	40	Johnston Pump Co.	30	Vertical	965E2311-A	1998	Electric 60 HZ	710	Vertical	26	Yes	None	10	1	Canal	17 th Street Canal	15	14	1	24	Oil	Yes
	2	40	Johnston Pump Co.	30	Vertical	965E2311-B	1998	Electric 60 HZ	710	Vertical	26	Yes	None	10	1	Canal	17 th Street Canal	15.4	14	1.4	24	Oil	Yes
	3	40	Johnston Pump Co.	30	Vertical	965E2311-C	1998	Electric 60 HZ	710	Vertical	26	Yes	None	10	1	Canal	17 th Street Canal	15.8	14	1.8	24	Oil	Yes
	4	40	Johnston Pump Co.	30	Vertical	965E2311-D	1998	Electric 60 HZ	710	Vertical	26	Yes	None	10	1	Canal	17 th Street Canal	16	14	2	24	Oil	Yes
	Total	**160**																					
Ames	1	390	Patterson Pump Co.	84	AFB	22BT6570	1985	Electric	275	Vertical	19.4	Yes	Butterfly valve	9.5	NA	Inner Milladoun	Bayou Segnette	11.5	10.5	1	21	Water	Yes
	2	390	Patterson Pump Co.	84	AFB		1985	Electric	275	Vertical	19.4	Yes	Butterfly valve	9.5	NA	Inner Milladoun	Bayou Segnette	11.5	10.5	1	21	Water	Yes
	3	1150	Allis-Chalmers (ITT-AC)	132	115-621-504	850-09076?	1985	Diesel	100	Horizontal	23.5	Yes	Air Suppression	9.5	NA	Inner Milladoun	Bayou Segnette	11.5	10.5	1	21	Water	Yes
	Total	**1930**																					
Bayou Segnette	New 1	610	Allis-Chalmers (ITT-AC)	96	115-621-513	1-8050-70158-02	2005	Diesel	137.5	Horizontal	22	No	Air Suppression	8.5	NA	Main Canal	Bayou Segnette	11.5	10	1.5	28	Oil	Yes
	New 2	610	Allis-Chalmers (ITT-AC)	96	115-621-513	1-8050-70158-01	2005	Diesel	137.5	Horizontal	22	No	Air Suppression	8.5	NA	Main Canal	Bayou Segnette	11.5	10	1.5	28	Oil	Yes
	1	156	Johnston Pump Co.	54	Vertical		1962	Diesel	440	Vertical	5	Yes	Gate Valves	7	NA	Main Canal	Bayou Segnette	11.5	10	1.5	27	Water	Yes
	2	156	Johnston Pump Co.	54	Vertical	JU1394	1962	Diesel	440	Vertical	5	Yes	Gate Valves	7	NA	Main Canal	Bayou Segnette	11.5	10	1.5	27	Oil	Yes
	3	156	Johnston Pump Co.	54	Vertical	JU1395	1962	Diesel	440	Vertical	5	Yes	Gate Valves	7	NA	Main Canal	Bayou Segnette	11.5	10	1.5	27	Oil	Yes
	4	156	Johnston Pump Co.	54	Vertical	JU1396	1962	Diesel	440	Vertical	5	Yes	Gate Valves	7	NA	Main Canal	Bayou Segnette	11.5	10	1.5	27	Oil	Yes
	5	156	Johnston Pump Co.	54	Vertical	JU1397	1962	Diesel	440	Vertical	5	Yes	Gate Valves	7	NA	Main Canal	Bayou Segnette	11.5	10	1.5	27	Oil	Yes
	6	156	Johnston Pump Co.	54	Vertical	JU1398	1962	Diesel	440	Vertical	5	Yes	Gate Valves	7	NA	Main Canal	Bayou Segnette	11.5	10	1.5	27	Water	Yes
	Total	**2156**																					
Cousins 1	1	50	Peerless Pump	36	PL		1973	Electric	720	Vertical	4.5	Yes	None	14	NA	Cousins Canal & First Ave. Canal	Harvey Canal	10.5	9.5	1	25.5	Oil	Yes
	2	250	Peerless Pump	72	Vertical		1973	Diesel	302	Vertical	4.5	Yes	None		NA	Cousins Canal & First Ave. Canal	Harvey Canal	10.5	9.5	1	25.5	Oil	Yes
	3	250	Peerless Pump	72	Vertical		1973	Diesel	302	Vertical	4.5	Yes	None		NA	Cousins Canal & First Ave. Canal	Harvey Canal	10.5	9.5	1	25.5	Oil	Yes
	4	250	Peerless Pump	72	Vertical		1973	Diesel	302	Vertical	4.5	Yes	None		NA	Cousins Canal & First Ave. Canal	Harvey Canal	10.5	9.5	1	25.5	Oil	Yes
	Total	**800**																					
Cousins 2	1	1100	Allis-Chalmers (ITT-AC)	132	115-621-504	850-9077	1985	Diesel	100	Horizontal	23	Yes	None	11	NA	Cousins & First Ave. canals	Harvey Canal	10.5	9.5	1	26	Oil	Yes
	2	1100	Allis-Chalmers (ITT-AC)	132	115-621-504	850-9078	1985	Diesel	100	Horizontal	23	Yes	None	11	NA	Cousins & First Ave. canals	Harvey Canal	10.5	9.5	1	26	Oil	Yes
	Total	**2200**																					
Estelle 1	1	138	Peerless Pump	52	54PL	147721	1962	Electric	380	Vertical	9.5	Yes	None	9	1	Pipeline Canal	Intercoastal Waterway	16	14.5	1.5	32.5	Oil	Yes
	2	138	Peerless Pump	52	54PL	147719	1962	Electric	380	Vertical	9.5	Yes	None	9	1	Pipeline Canal	Intercoastal Waterway	16	14.5	1.5	32.5	Oil	Yes
	3	138	Peerless Pump	52	54PL	147720	1962	Electric	380	Vertical	9.5	Yes	None	9	1	Pipeline Canal	Intercoastal Waterway	16	14.5	1.5	32.5	Oil	Yes
	4	101	Lo-Lift	48		82-6520	1962	Electric	430	Vertical	9.5	No	None		1	Pipeline Canal	Intercoastal Waterway	16	14.5	1.5	32.5	Oil	Yes
	Total	**515**																					
Estelle 2	1	570	Allis-Chalmers (ITT-AC)	96	115-621-551	1-0850-70127-01	1998	Diesel	137.5	Horizontal	21	Yes	Air Suppression	10	1	Pipeline & Canal G	Intercoastal Waterway	15.1	13.5	1.6	26.5	Oil	Yes
	2	570	Allis-Chalmers (ITT-AC)	96	115-621-551	1-0850-70127-01	1998	Diesel	137.5	Horizontal	21	Yes	Air Suppression	10	1	Pipeline & Canal G	Intercoastal Waterway	15.1	13.5	1.6	26.5	Oil	Yes
	Total	**1140**																					
Harvey	1	320	Allis-Chalmers (ITT-AC)	72	115-143-525	840-9173	1986	Electric	321	Vertical	5.88	No	None	10	1	First Ave. & Two Mile Canal	Harvey Canal	10.5	9.5	1	27.5	Oil	Yes
	2	320	Allis-Chalmers (ITT-AC)	72	115-143-525	840-9171	1986	Electric	321	Vertical	5.88	No	None	10	1	First Ave. & Two Mile Canal	Harvey Canal	10.5	9.5	1	27.5	Oil	Yes

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Table 7-9
Jefferson Parish Pumping Equipment Table continued

Name	Pump	Capacity (cfs)	Pump Manufacture	Pump Size (in)	Pump Model Number	Pump Serial Number	Installed (year)	Driver Electric /Diesel	Rated Pump Speed (rpm)	Pump Type (Vertical/Horizontal)	Pump Elevation (Cairo)	Pump Curve (yes/no)	Discharge Gates (type)	Rated Head (ft)	Track Rack Design Head (ft)	Intake Location	Discharge Location	Intake water elevation at Start (Cairo)	Intake water elevation at Stop (Cairo)	Intake water elevation range (Cairo)	Water elevations that effects station (Cairo)	Bearing Lubrication (oil/water)	Backstops or brakes (yes/no)
	3	320	Allis-Chalmers (ITT-AC)	72	115-143-525	840-9172	1986	Electric	321	Vertical	5.88	No	None	10	1	First Ave. & Two Mile Canal	Harvey Canal	10.5	9.5	1	27.5	Oil	Yes
	Total	**960**																					
Hero	1	100		48			1997	Electric	138	Vertical	4.5	Yes	None	12.5	NA	Hero Outfall Canal	Intercoastal Waterway	10	9.5	0.5	21.5	Oil	Yes
	2	300	Allis-Chalmers (ITT-AC)	72	WCXH?		1997	Electric	138	Vertical	4.5	Yes	None	12.5	NA	Hero Outfall Canal	Intercoastal Waterway	10	9.5	0.5	21.5	Oil	Yes
	3	300	Allis-Chalmers (ITT-AC)	72	WCXH?		1997	Electric	138	Vertical	4.5	Yes	None	12.5	NA	Hero Outfall Canal	Intercoastal Waterway	10	9.5	0.5	21.5	Oil	Yes
	4	1020	Wood Screw	160	Horizontal		1989	Diesel	85	Horizontal	17	Yes	None	10	NA	Hero Outfall Canal	Intercoastal Waterway	10	9.5	0.5	21.5	Oil	Yes
	5	1020	Wood Screw	160	Horizontal		1989	Diesel	85	Horizontal	17	Yes	None	10	NA	Hero Outfall Canal	Intercoastal Waterway	10	9.5	0.5	21.5	Oil	Yes
	6	300	Allis-Chalmers (ITT-AC)	72	WCXH?		1997	Electric	138	Vertical	4.5	Yes	None	12.5	NA	Hero Outfall Canal	Intercoastal Waterway	10	9.5	0.5	21.5	Oil	Yes
	7	203	Allis-Chalmers (ITT-AC)	58		840-9069	1984	Diesel	226	Horizontal	17	Yes	None	12.5	NA	Hero Outfall Canal	Intercoastal Waterway	10	9.5	0.5	21.5	Oil	Yes
	8	203	Allis-Chalmers (ITT-AC)	58		840-9068	1984	Diesel	226	Horizontal	17	Yes	None	12.5	NA	Hero Outfall Canal	Intercoastal Waterway	10	9.5	0.5	21.5	Oil	Yes
	9	203	Allis-Chalmers (ITT-AC)	58		840-9067	1984	Diesel	226	Horizontal	17	Yes	None	12.5	NA	Hero Outfall Canal	Intercoastal Waterway	10	9.5	0.5	21.5	Oil	Yes
	10	203	Allis-Chalmers (ITT-AC)	58		840-9066	1984	Diesel	226	Horizontal	17	Yes	None	12.5	NA	Hero Outfall Canal	Intercoastal Waterway	10	9.5	0.5	21.5	Oil	Yes
	Total	**3852**																					
Highway 90	1	45	Lo-Lift	84		83-6722	1969	Electric	275	Vertical	9	No	None	9	NA	Waggaman Canal	Outer Cataouatche Canal	15	14	1	25	Oil	Yes
	2	45	American Industrial	84	30-24P	89-7669-30	1969	Electric	275	Vertical	9	No	None	9	NA	Waggaman Canal	Outer Cataouatche Canal	15	14	1	25	Oil	Yes
	3	55	Lo-Lift	132		82-6626	1969	Electric	100	Vertical	9	No	None	12	NA	Waggaman Canal	Outer Cataouatche Canal	15	14	1	25	Oil	Yes
	Total	**145**																					
Lake Cataouatche 1	1	250	Couch (MWI)	60	Vertical	6489	1978	Diesel	327	Vertical	5.5	No	Check Valve	9	NA	Main Canal	Lake Cataouatche	11.8	10.5	1.3	21	Oil	No
	2	250	Couch (MWI)	60	Vertical		1978	Diesel	327	Vertical	5.5	No	Check Valve	9	NA	Main Canal	Lake Cataouatche	11.8	10.5	1.3	21	Oil	No
	Total	**500**																					
Lake Cataouatche 2	1	300	Patterson Pump Co.	72	AFV	82BT6836-G7	1985	Diesel	270	Vertical	5.5	Yes	None	6.5	NA	Main Canal	Lake Cataouatche	11.8	10.5	1.3	24	Oil	Yes
	2	300	Patterson Pump Co.	72	AFV	82BT6835-G7	1985	Diesel	270	Vertical	5.5	Yes	None	6.5	NA	Main Canal	Lake Cataouatche	11.8	10.5	1.3	24	Oil	Yes
	Total	**600**																					
Mt. Kennedy	1	167	Fairbanks Morse	54	P310AE	470489	2005	Electric	295	Vertical	8	Yes	None	8.9	NA	Kenta/Seivers Canal	Bayou Segnette	14.5	13	1.5	23	Oil	Yes
	2	167	Fairbanks Morse	54	P310AE	470489-1	2005	Electric	295	Vertical	8	Yes	None	8.9	NA	Kenta/Seivers Canal	Bayou Segnette	14.5	13	1.5	23	Oil	Yes
	3	167	Fairbanks Morse	54	P310AE	470489-2	2005	Electric	295	Vertical	8	Yes	None	8.9	NA	Kenta/Seivers Canal	Bayou Segnette	14.5	13	1.5	23	Oil	Yes
	Total	**501**																					
Planters	1	289	Johnston Pump Co.	72		GC-4000	1973	Diesel	250	Vertical	4.5	Yes	None	16	NA	Planters by Pass Canal	Intercoastal Waterway	10	9.5	0.5	25	Oil	Yes
	2	289	Johnston Pump Co.	72			1973	Diesel	250	Vertical	4.5	Yes	None	16	NA	Planters by Pass Canal	Intercoastal Waterway	10	9.5	0.5	25	Oil	Yes
	3	289	Johnston Pump Co.	72		GC-4002	1973	Diesel	250	Vertical	4.5	Yes	None	16	NA	Planters by Pass Canal	Intercoastal Waterway	10	9.5	0.5	25	Oil	Yes
	4	289	Johnston Pump Co.	72			1973	Diesel	250	Vertical	4.5	Yes	None	16	NA	Planters by Pass Canal	Intercoastal Waterway	10	9.5	0.5	25	Oil	Yes
	5	52	Johnston Pump Co.	36		GC-4004	1973	Electric	585	Vertical	4.5	Yes	None	10	NA	Planters by Pass Canal	Intercoastal Waterway	10	9.5	0.5	25	Oil	Yes
	6	288	Allis-Chalmers (ITT-AC)	84	115-143-521	840-9087	1988	Electric	321	Vertical	4.5	Yes	None	16	NA	Planters by Pass Canal	Intercoastal Waterway	10	9.5	0.5	25	Oil	Yes
	7	288	Allis-Chalmers (ITT-AC)	84	115-143-521	840-9089	1988	Electric	321	Vertical	4.5	Yes	None	16	NA	Planters by Pass Canal	Intercoastal Waterway	10	9.5	0.5	25	Oil	Yes
	8	288	Allis-Chalmers (ITT-AC)	84	115-143-521	840-9088	1988	Electric	321	Vertical	4.5	Yes	None	16	NA	Planters by Pass Canal	Intercoastal Waterway	10	9.5	0.5	25	Oil	Yes
	9	288	Allis-Chalmers (ITT-AC)	84	115-143-521	840-9086	1988	Electric	321	Vertical	4.5	Yes	None	16	NA	Planters by Pass Canal	Intercoastal Waterway	10	9.5	0.5	25	Oil	Yes
	Total	**2360**																					
Westminster	1	312	Allis-Chalmers (ITT-AC)	72	WCAX	1-840-70128-02	1998	Electric	311	Vertical	8	Yes	Air Suppression	8	NA	Grand Cross	Wetlands	14	13	1	22	Oil	Yes
	2	312	Allis-Chalmers (ITT-AC)	72	WCAX	1-840-70128-01	1998	Electric	311	Vertical	8	Yes	Air Suppression	8	NA	Grand Cross	Wetlands	14	13	1	22	Oil	Yes
	3	312	Allis-Chalmers (ITT-AC)	72	WCAX	1-840-70128-04	1998	Electric	311	Vertical	8	Yes	Air Suppression	8	NA	Grand Cross	Wetlands	14	13	1	22	Oil	Yes
	4	312	Allis-Chalmers (ITT-AC)	72	WCAX	1-840-70128-03	1998	Electric	311	Vertical	8	Yes	Air Suppression	8	NA	Grand Cross	Wetlands	14	13	1	22	Oil	Yes
	Total	**1248**																					
Westwego 1	1	300	Johnston Pump Co.	84	Vertical		1969	Diesel	320	Vertical	8.5	No	None		NA	WPA Canal	Bayou Segnette	14.5	13.5	1	32	Oil	No
	Total	**300**																					
Westwego 2	1	312	Allis-Chalmers (ITT-AC)	84	WCAX	840-9181	1985	Diesel	310	Vertical	7	Yes	Manual gate valves	8.5	NA	Ave H Canal	Bayou Segnette	13.5	12	1.5	31	Water	Yes
	2	312	Allis-Chalmers (ITT-AC)	84	WCAX	840-9180	1985	Diesel	310	Vertical	7	Yes	Manual gate valves	8.5	NA	Ave H Canal	Bayou Segnette	13.5	12	1.5	31	Water	Yes
	3	311	Allis-Chalmers (ITT-AC)	84	WCAX	84070108-01	1997	Electric	310	Vertical	7	Yes	Manual gate valves		NA	Ave H Canal	Bayou Segnette	13.5	12	1.5	31	Water	Yes
	Total	**935**																					
Whitney Barataria	1	1250	Allis-Chalmers (ITT-AC)	132	115-621-512	1-0850-70153-05		Electric	100			No	Air Suppression	5.5	1	Canal	Intercoastal Canal	10	9	1	19.5	Oil	Yes
	2	1250	Allis-Chalmers (ITT-AC)	132	115-621-512	1-0850-70153-06		Electric	100			No	Air Suppression	5.5	1	Canal	Intercoastal Canal	10	9	1	19.5	Oil	Yes
	3	1250	Allis-Chalmers (ITT-AC)	132	115-621-512	1-0850-70153-07		Electric	100			No	Air Suppression	5.5	1	Canal	Intercoastal Canal	10	9	1	19.5	Oil	Yes
	Total	**3750**																					

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Table 7-10
Jefferson Parish Pumping Start and Stop Times by Individual Pumps

Pump Station	Pump	Capacity (cfs)	28-Aug-05		29-Aug-05		30-Aug-05		31-Aug-05		1-Sep-05		2-Sep-05		3-Sep-05		4-Sep-05		5-Sep-05	
			Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop
JP#1 Bonnabel	1	300	10:55 13:30	11:35 13:40					19:25	20:30	0:35	1:50	11:05 21:30	12:00 22:25	7:40 16:35 23:05	8:55 17:25 23:50				
	2	300																		
	3	1050			23:00	RUN	RUN	11:00												
	4	1050			23:00	RUN	RUN	11:00												
	5	1050			23:00	RUN	RUN	11:00												
	Total	**3750**																		
JP#2 Suburban	1	1050					11:00	13:30												
	2	1050					11:00	13:30												
	3	55					11:00	13:30												
	4	300					11:00	▨			16:00	RUN	RUN	16:35	12:10 20:50	14:05 22:30				
	5	300					11:00	▨							12:15	13:45				
	6	300	11:00	12:40			11:00	▨	15:15 16:55 19:25	15:20 17:00 21:50	0:40 6:20 16:00	3:05 8:50 RUN	RUN 18:50	16:35 21:20	4:55	9:55				
	7*	1200					11:00	▨												
	8*	1200					11:00	13:30												
	Total	**5455**																		
JP#3 Elmwood	1	300			11:30	RUN	RUN	RUN	RUN	8:00					12:40	RUN	RUN	11:50		
	2	300			11:30	RUN	RUN	RUN	RUN	8:00										
	3	550			11:30	RUN	RUN	RUN	RUN	8:00										
	4	550			11:30	RUN	RUN	RUN	RUN	8:00										
	5	550			11:30	RUN	RUN	RUN	RUN	8:00							12:35	14:05		
	6	550			11:30	RUN	RUN	RUN	RUN	8:00										
	7	300	11:00	13:25	11:30	RUN	RUN	RUN	RUN	8:00							12:15	14:10		
	8	300	11:00	13:25	11:30	RUN	RUN	RUN	RUN	8:00							12:20	21:00		
	9	1250																		
	10	1250																		
	Total	**5900**																		
JP#4 Duncan	1	300	10:55	13:15							7:45	RUN	RUN	17:00						
	2	300	11:00	13:15			19:40	RUN	RUN 15:35	3:50 RUN	RUN	7:40								
	3	1050																		
	4	1050			20:45	20:55	12:15	RUN	RUN	7:25					10:40	14:55				
	5	1050			20:50	20:55	12:25	RUN	RUN	14:40										
	6	1050			20:55	RUN	RUN	19:30												
	Total	**4800**																		
JP#5 Parish Line	1	295					12:45 17:25 20:55	13:20 19:25 RUN	RUN	6:50										
	2	295					12:45 16:25 RUN	13:25 RUN RUN	RUN	6:05										
	3	295					12:50 15:15 RUN	13:00 RUN RUN	RUN	17:45										
	Total	**885**																		
JP #6 Canal Street	1	40			2:00 3:50	2:10 RUN	RUN	12:05	7:20 17:40 18:35 19:25	7:45 18:15 18:50 20:10	9:00	9:20								
	2	40			2:15	RUN	RUN	17:40	5:30 8:30 15:05 17:25 18:50 19:55 22:20	5:55 9:10 15:35 18:35 19:35 22:15 RUN	RUN	6:15								
	3	40			3:35	RUN	RUN	2:35												
	4	40			3:45	5:25			15:05	15:40										
	Total	**160**																		
West Bank - East of Harvey																				
Planters	1	288	▨	▨	▨	▨	7:35	21:00	0:01	12:00										
	2	288	▨	▨	▨	▨	7:35	19:35	11:50	12:00										
	3	288	▨	▨	▨	▨	7:45	21:45												
	4	288	▨	▨	▨	▨	7:45 23:00 RUN	22:15 RUN RUN	RUN	2:00										
	5	52																		
	6	288	▨	▨	▨	▨														
	7	288	▨	▨	▨	▨	19:45	22:45												
	8	288	▨	▨	▨	▨			12:00	23:45										
	9	288	▨	▨	▨	▨	19:30	20:00												
	Total	**2356**																		
Hero	1	100	▨	▨	▨	▨														
	2	300	▨	▨	▨	▨	19:15 RUN RUN	RUN RUN RUN	RUN	0:00	13:00	21:30								
	3	300	▨	▨	▨	▨	18:30 RUN RUN	RUN RUN RUN	RUN	3:00	13:00	21:30								
	4	1020	▨	▨	▨	▨	18:00 5:30	21:30 18:00												
	5	1020	▨	▨	▨	▨	18:00 2:30	23:00 18:00												
	6	300	▨	▨	▨	▨	18:30 RUN RUN	RUN RUN RUN	RUN	3:00	13:00	21:30								
	7	203	▨	▨	▨	▨														
	8	203	▨	▨	▨	▨														
	9	203	▨	▨	▨	▨					13:15	13:45								
	10	203	▨	▨	▨	▨														
	Total	**3852**																		
Whitney Barataria	1	1250	▨	▨	▨	▨	2:00	20:00			13:30	17:30								
	2	1250	▨	▨	▨	▨	2:00	21:00												
	3	1250	▨	▨	▨	▨	2:00	22:00												
	Total	**3750**																		
West Bank West of Harvey																				
Harvey	1	320							7:10 12:45 18:15 22:00	9:10 14:45 20:45 22:30										
	2	320							10:15 15:00 18:55 22:00	14:15 17:00 19:55 0:00										
	3	320					21:25	21:55	7:25 16:25 18:55 20:45	11:25 18:25 19:25 22:30										
	Total	**960**																		
Cousins 1	1	50	▨	▨	▨	▨														
	2	250	▨	▨	▨	▨	2:00	10:30												
	3	250	▨	▨	▨	▨	2:00	9:30												
	4	250	▨	▨	▨	▨	2:00	8:30												
	Total	**800**																		
Cousins 2	1	1100	▨	▨	▨	▨	1:30	10:30												
	2	1100	▨	▨	▨	▨	1:30	12:00	0:01	6:30	12:30	18:00								
	Total	**2200**																		
Estelle 1	1	150																		
	2	150																		
	3	150																		
	4	232																		
	Total	**682**																		
Estelle 2	1	570			▨	▨	14:30	RUN	RUN	15:30										
	2	570	8:15	13:15	▨	▨	14:30	15:00												
	Total	**1140**																		
Ames	1	390					3:15	4:30	5:15 20:00	6:15 20:30	■	■	■	■	■	■	■	■	■	■
	2	390	2:15	3:15			4:30	22:00	3:45	6:15	■	■	■	■	■	■	■	■	■	■
	3	1150									■	■	■	■	■	■	■	■	■	■
	Total	**1930**																		
Westwego 1	1	300			▨	▨	0:01 8:30	4:30 9:30	▨	▨										
	Total	**300**																		
Westwego 2	1	312	12:00	13:00	23:00	RUN	RUN	10:00												
	2	312			23:00	RUN	RUN 14:00	10:00 16:00												
	Total	**624**																		
Westminister	1	312																		
	2	312																		
	3	312																		
	4	312																		
	Total	**1248**																		
Mt. Kennedy	1	167																		
	2	167																		
	3	167																		
	Total	**501**																		
West Bank - Cataouatche Subbasin																				
Bayou Segnette	New 1	610	▨	▨	▨	▨	11:15	0:00	▨	▨										
	New 2	610	▨	▨	▨	▨	11:30	0:00	▨	▨										
	1	156	▨	▨	▨	▨	11:45 21:15	20:30 0:00	▨	▨	0:01 8:30	7:00 13:00								
	2	156	▨	▨	▨	▨	3:00	20:00	▨	▨	11:00	13:00								
	3	156	▨	▨	▨	▨	3:00	20:00	▨	▨	8:30	13:00								
	4	156	▨	▨	▨	▨	3:00	20:00	▨	▨	0:01 8:30	7:00 13:00								
	5	156	▨	▨	▨	▨	3:00	20:00	▨	▨	8:30	13:00								
	6	156	▨	▨	▨	▨	11:45	20:30	▨	▨	▨	▨								
	Total	**2156**																		
Lake Cataouatche 1	1	250			▨	▨					14:00	0:00								
	2	250			▨	▨	0:01	RUN	RUN	RUN	RUN	9:30								
	Total	**500**																		
Lake Cataouatche 2	1	300																		
	2	300																		
	Total	**600**																		
Highway 90	1	45																		
	2	?																		
	3	45																		
	Total	**90**																		

*** Pump not approved for use, except emergencies**
Time in Local CST Day Light Savings

Pumps Not Available	**NA**
Continued to Run	**Run**
Damaged/ Lost/ Unavalble Record	▨
Information was not obtained (Area	■

7.3 Orleans Parish Summary

Orleans Parish is located in southern Louisiana. Figure 7-28 is a map of Orleans Parish with the pump stations that were studied identified by blue dots. The New Orleans Sewerage and Water Board (NOS&WB) operates and maintains all of the pump stations in Orleans Parish. The Parish is separated by the Mississippi River into East and West Banks. The East Bank is subdivided into three more areas by the Inner-Harbor Navigation Canal. The pump stations are connected by a grid of canals both above and below the ground which direct flow from the higher elevations along the Mississippi river banks toward the pump stations. This report examined 21 pump stations on the East Bank with a total of 101 pumps and 2 pump stations on the West Bank with a total of 12 pumps.

Figure 7-28 is a map showing the Orleans Parish pump stations that were used in this report. The locations of the pump stations were verified by Global Positioning System (GPS) and/or by using Google Earth Pro. The GPS coordinates were then input into Microsoft Streets and Trips (shown below).

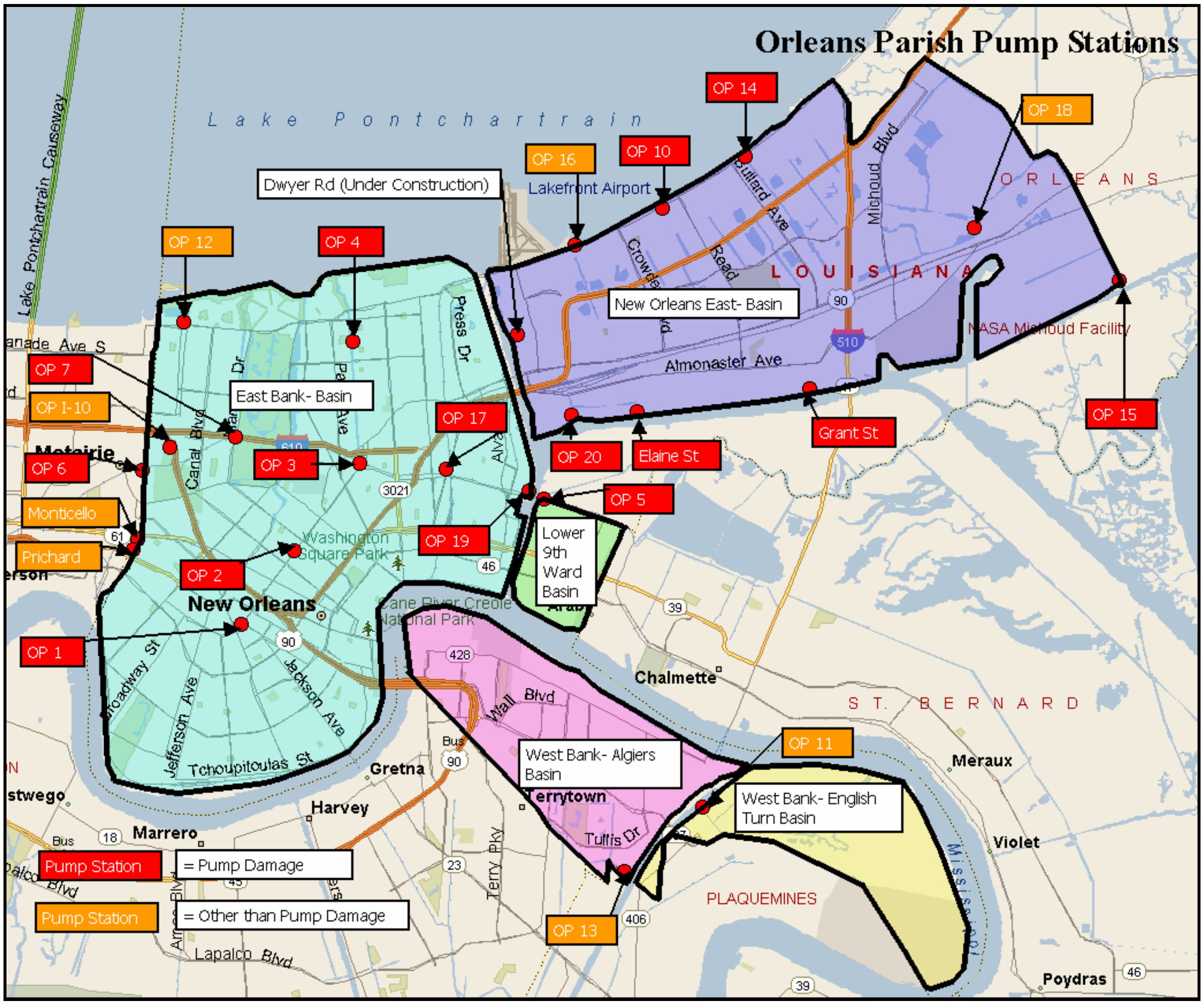


Figure 7-28 - Orleans Parish Pump Station Locations

Table 7-13 and Table 7-14 contain information about each individual pump at each pump station in Orleans Parish. The list is composed of information that was collected in the field. Not all information was available for each pump and was left blank or highlighted.

Table 7-11
Summary of Orleans Parish Pump Stations by Drainage Basin

Basin	East Bank	East	East Bank-Lower 9th Ward	West Bank-Algiers	West Bank-English Turn	Total
Number of pump stations	12	8	1	1	1	23
Number of pumps	68	28	7	7	5	115
Total rated capacity (cfs)	36,615	4,852	1,850	4,700	1,690	49,707
Estimated cost of damages	Not Recorded	Not Recorded	Not Recorded	Not Recorded	Not Recorded	Not Recorded

7.3.1 Drainage Basins

Orleans Parish consists of five drainage basins. The majority of the pump stations are in the East Bank and East basins. The Lower Ninth Ward, Algiers, and English Turn Basins have one pump station each. The Orleans Parish pump stations are listed below under their appropriate basins. Details for each pump station are listed in Section 7.6.2.

7.3.1.1 East Bank

The East Bank Drainage Basin has 12 pump stations. It is bordered by Lake Pontchartrain on the north, the Mississippi River on the south, Jefferson Parish east bank on the west, and the innerharbor navigation canal on the east. Its drainage system includes the surrounding bodies of water, the interior drainage canals, and the pump stations. Below is a brief summary of each of the 12 pump stations. Section 7.6.2.1 provides more detailed information.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

OP 1

Intake location: Melpomene and Broad Ave Canals
Discharge location: Palmetto Canal
Nominal capacity: 6825 cfs

Pump	Capacity (cfs)	Installed (year)	Driver Electric /Diesel	Pump Type (Vertical/Horizontal)
A	550	1929	Electric 25 Hz	Horizontal
B	550	1929	Electric 25 Hz	Horizontal
C	1000	1929	Electric 25 Hz	Horizontal
D	1000	1929	Electric 25 Hz	Horizontal
E	1000	1929	Electric 25 Hz	Horizontal
F	1100	1991	Electric 60 Hz	Horizontal
G	1100	1991	Electric 60 Hz	Horizontal
V1	225	n/a	Electric 25 Hz	Vertical
V2	225	n/a	Electric 25 Hz	Vertical
CD1	60	n/a	Electric 25 Hz	Vertical
CD2	15	n/a	Electric 25 Hz	Centrifugal

OP 2

Intake location: Broad Street Canal
Discharge location: OP 3 & 7
Nominal capacity: 3150 cfs

Pump	Capacity (cfs)	Installed (year)	Driver Electric /Diesel	Pump Configuration
A	550	1914	Electric 25 Hz	Horizontal
B	550	1914	Electric 25 Hz	Horizontal
C	1000	1914	Electric 25 Hz	Horizontal
D	1000	1914	Electric 25 Hz	Horizontal
CD2	25	1974	Electric 25 Hz	Centrifugal
CD3	25	1974	Electric 25 Hz	Centrifugal

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

OP 3

Intake location: OP 2
Discharge location: London Ave Canal
Nominal capacity: 4340 cfs

Pump	Capacity (cfs)	Installed (year)	Driver Electric /Diesel	Pump Configuration
A	590	1916	Electric 25 Hz	Horizontal
B	590	1916	Electric 25 Hz	Horizontal
C	1000	1930	Electric 25 Hz	Horizontal
D	1000	1930	Electric 25 Hz	Horizontal
E	1000	1930	Electric 25 Hz	Horizontal
CD 1	80	1916	Electric 25 Hz	Centrifugal
CD 2	80	1916	Electric 25 Hz	Centrifugal

OP 4

Intake location: Prentiss Ave and St. Anthony Canals
Discharge location: London Ave Canal
Nominal capacity: 3720 cfs

Pump	Capacity (cfs)	Installed (year)	Driver Electric /Diesel	Pump Configuration
1	320	1938	Electric 60 Hz	Centrifugal
2	320	1938	Electric 60 Hz	Centrifugal
C	1000	1957	Electric 25 Hz	Horizontal
D	1000	1957	Electric 25 Hz	Horizontal
E	1000	1957	Electric 25 Hz	Horizontal
CD1	80	n/a	Electric 25 Hz	Vertical

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

OP 6

Intake location: Palmetto Canal
Discharge location: Forcemain and 17th St Canal
Nominal capacity: 9480 cfs

Pump	Capacity (cfs)	Installed (year)	Driver Electric /Diesel	Pump Configuration
A	550	1914	Electric 25 Hz	Horizontal
B	550	1914	Electric 25 Hz	Horizontal
C	1000	1928	Electric 25 Hz	Horizontal
D	1000	1928	Electric 25 Hz	Horizontal
E	1000	1928	Electric 25 Hz	Horizontal
F	1000	1928	Electric 25 Hz	Horizontal
G	1000	1984	Electric 25 Hz	Horizontal
H	1100	1984	Electric 60 Hz	Horizontal
I	1100	1984	Electric 60 Hz	Horizontal
CD 1	90	1984	Electric 60 Hz	Vertical
CD 2	90	1984	Electric 60 Hz	Vertical
1	250	1983	Electric 60 Hz	Vertical
2	250	1983	Electric 60 Hz	Vertical
3	250	1983	Electric 60 Hz	Vertical
4	250	1983	Electric 60 Hz	Vertical

OP 7

Intake location: OP 2
Discharge location: London Canal
Nominal capacity: 2690 cfs

Pump	Capacity (cfs)	Installed (year)	Driver Electric /Diesel	Pump Configuration
A	550	1931	Electric 25 Hz	Horizontal
C	1000	1908	Electric 25 Hz	Horizontal
D	1000	1908	Electric 60 Hz	Horizontal
CD 1	70	n/a	Electric 25 Hz	Vertical
CD 2	70	n/a	Electric 25 Hz	Vertical

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

OP 12

Intake location: Robert E. Lee and Fluer De Lis Canals
Discharge location: Lake Pontchartrain
Nominal capacity: 1000 cfs

Pump	Capacity (cfs)	Installed (year)	Driver Electric /Diesel	Pump Configuration
D	1000	1961	Electric 25 Hz	Horizontal

OP 17 (Station D)

Intake location: Peoples and Florida Ave. Canals
Discharge location: Mississippi River
Nominal capacity: 160 cfs

Pump	**Capacity (cfs)**	**Installed (year)**	**Driver Electric /Diesel**	**Pump Configuration**
A	40	1975	Electric 60 Hz	Centrifugal
B	40	1975	Electric 60 Hz	Centrifugal
C	40	1975	Electric 60 Hz	Centrifugal
D	40	1975	Electric 60 Hz	Centrifugal

OP 19

Intake location: Florida Ave Canal
Discharge location: Industrial Canal (Lake Pontchartrain)
Nominal capacity: 3920 cfs

Pump	**Capacity (cfs)**	**Installed (year)**	**Driver Electric /Diesel**	**Pump Configuration**
H1	1100	1975	Electric 60 Hz	Horizontal
H2	1100	1975	Electric 60 Hz	Horizontal
H3	1100	1975	Electric 60 Hz	Horizontal
V1	310	1975	Electric 60 Hz	Vertical
V2	310	1975	Electric 60 Hz	Vertical

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

I 10

Intake location: Railroad Underpass
Discharge location: 17th St Canal
Nominal capacity: 850 cfs

Pump	Capacity (cfs)	Installed (year)	Driver Electric /Diesel	Pump Configuration
1	250	n/a	Electric 60 Hz	Vertical
2	250	n/a	Electric 60 Hz	Vertical
3	250	n/a	Electric 60 Hz	Vertical
CD1	100	n/a	Electric 60 Hz	Centrifugal

Prichard

Intake location: Carrollton Drainage
Discharge location: Monticello Canal
Nominal capacity: 250 cfs

Pump	Capacity (cfs)	Installed (year)	Driver Electric /Diesel	Pump Configuration
1	125	n/a	Electric 60 Hz	Vertical
2	125	n/a	Electric 60 Hz	Vertical
CD1	n/a	n/a	Electric 60 Hz	Vertical

Monticello

Intake location: Carrollton Drainage
Discharge location: Monticello Canal
Nominal capacity: 99 cfs

Pump	Capacity (cfs)	Installed (year)	Driver Electric /Diesel	Pump Configuration
1	33	1979	Electric 60 Hz	Vertical
2	33	1979	Electric 60 Hz	Vertical
3	33	1979	Electric 60 Hz	Vertical

7.3.1.2 East

The East Drainage Basin consists of eight pump stations, and a ninth station is being built. It is bordered by Lake Pontchartrain on the north, the Intracoastal Waterway on the South, and the IHNC on the west. Its drainage system includes the surrounding bodies of water, as well as the Citrus, Morrison, Jahncke, St. Charles, Amid, Grant St., Elaine St., and Maxent Canals, and the Village de'l East Lagoon. Below is a brief summary of each of the 9 pump stations. Section 7.6.2.3 provides more detailed information.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

OP 10 – Citrus

Intake location:	Citrus Canal
Discharge location:	Lake Pontchartrain
Nominal capacity:	1000 cfs

Pump	Capacity (cfs)	Installed (year)	Driver Electric /Diesel	Pump Configuration
1	250	1984	Electric 60 Hz	Vertical
2	250	1984	Electric 60 Hz	Vertical
3	250	1984	Electric 60 Hz	Vertical
4	250	1984	Electric 60 Hz	Vertical

OP 14 – Jahncke

Intake location:	Morrison and Jahncke Canals
Discharge location:	Lake Pontchartrain
Nominal capacity:	1200 cfs

Pump	Capacity (cfs)	Installed (year)	Driver Electric /Diesel	Pump Configuration
1	300	n/a	Diesel	Vertical
2	300	n/a	Diesel	Vertical
3	300	n/a	Diesel	Vertical
4	300	n/a	Diesel	Vertical

OP 16 – St. Charles

Intake location:	St. Charles Canal
Discharge location:	Lake Pontchartrain
Nominal capacity:	1000 cfs

Pump	Capacity (cfs)	Installed (year)	Driver Electric /Diesel	Pump Configuration
1	250	1966	Electric 60 Hz	Vertical
2	250	1966	Electric 60 Hz	Vertical
3	250	1966	Electric 60 Hz	Vertical
4	250	1966	Electric 60 Hz	Vertical

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

OP 18 – Maxent

Intake location:	Village de'l East Lagoon
Discharge location:	Maxent Canal
Nominal capacity:	60 cfs

Pump	Capacity (cfs)	Installed (year)	Driver Electric /Diesel	Pump Configuration
1	30	1983	Electric 60 Hz	Vertical
2	30	1983	Electric 60 Hz	Vertical

OP 20 – Amid

Intake location:	Amid Canal
Discharge location:	Intracoastal Waterway
Nominal capacity:	500 cfs

Pump	Capacity (cfs)	Installed (year)	Driver Electric /Diesel	Pump Configuration
1	250	1989	Electric 60 Hz	Vertical
2	250	1989	Electric 60 Hz	Vertical

Grant St

Intake location:	Grant St Canal
Discharge location:	Intracoastal Waterway
Nominal capacity:	192 cfs

Pump	Capacity (cfs)	Installed (year)	Driver Electric /Diesel	Pump Configuration
1	8	n/a	Electric 60 Hz	Vertical
2	8	n/a	Electric 60 Hz	Vertical
3	8	n/a	Electric 60 Hz	Vertical
4	8	n/a	Electric 60 Hz	Vertical
5	80	1990	Electric 60 Hz	Vertical
6	80	1990	Electric 60 Hz	Vertical

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Elaine St
Intake location: Elaine St Canal
Discharge location: Intracoastal Waterway
Nominal capacity: 90 cfs

Pump	Capacity (cfs)	Installed (year)	Driver Electric /Diesel	Pump Configuration
1	45	1975	Electric 60 Hz	Vertical
2	45	1975	Electric 60 Hz	Vertical

OP 15
Intake location: Maxent Canal
Discharge location: Intracoastal Waterway
Nominal capacity: 750 cfs

Pump	Capacity (cfs)	Installed (year)	Driver Electric /Diesel	Pump Configuration
1	250	Not Recorded	Electric 60 Hz	Vertical
2	250	1997	Diesel	Vertical
3	250	1997	Diesel	Vertical

7.3.1.3 East Bank – Lower Ninth Ward

The Lower Ninth Ward drainage basin is bordered by the IHNC on the west, and the Mississippi River on the south. It only has one significant pump station, which is described below. Section 7.6.2.2 provides more detailed information.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

OP 5

Intake location: Florida and Jourdan Ave. Canals
Discharge location: Lake Borgne
Nominal capacity: 2260 cfs

Pump	Capacity (cfs)	Installed (year)	Driver Electric /Diesel	Pump Configuration
A	550	1914	Electric 25 Hz	Horizontal
B	550	1914	Electric 25 Hz	Horizontal
D	1000	1961	Electric 25 Hz	Horizontal
CD1	40	n/a	Electric 25 Hz	Centrifugal
CD2	40	n/a	Electric 25 Hz	Centrifugal
CD3	40	1975	Electric 25 Hz	Centrifugal
CD4	40	1975	Electric 25 Hz	Centrifugal

7.3.1.4 West Bank – English Turn

The West Bank – English Turn drainage basin is bordered by the Intracoastal Waterway on its northwest side. The Mississippi River wraps around its north and east sides. It only has one significant pump station, which is described below. Section 7.6.2.4.1 provides more detailed information.

OP 11

Intake location: Donner Canal
Discharge location: Intracoastal Waterway
Nominal capacity: 1690 cfs

Pump	Capacity (cfs)	Installed (year)	Driver Electric /Diesel	Pump Configuration
A	250	1953	Electric 25 Hz	Horizontal
B	250	1953	Electric 25 Hz	Horizontal
D	570	1990	Electric 60 Hz	Horizontal
E	570	1990	Electric 60 Hz	Horizontal
CD - 3C	30	1953	Electric 25 Hz	Centrifugal

7.3.1.5 West Bank – Algiers

The West Bank – Algiers drainage basin is bordered by the Intracoastal Waterway on the southeast. The Mississippi River wraps around the west, north, and east sides. It only has one significant pump station, which is described below. Section 7.6.2.4.2 provides more detailed information.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

OP 13

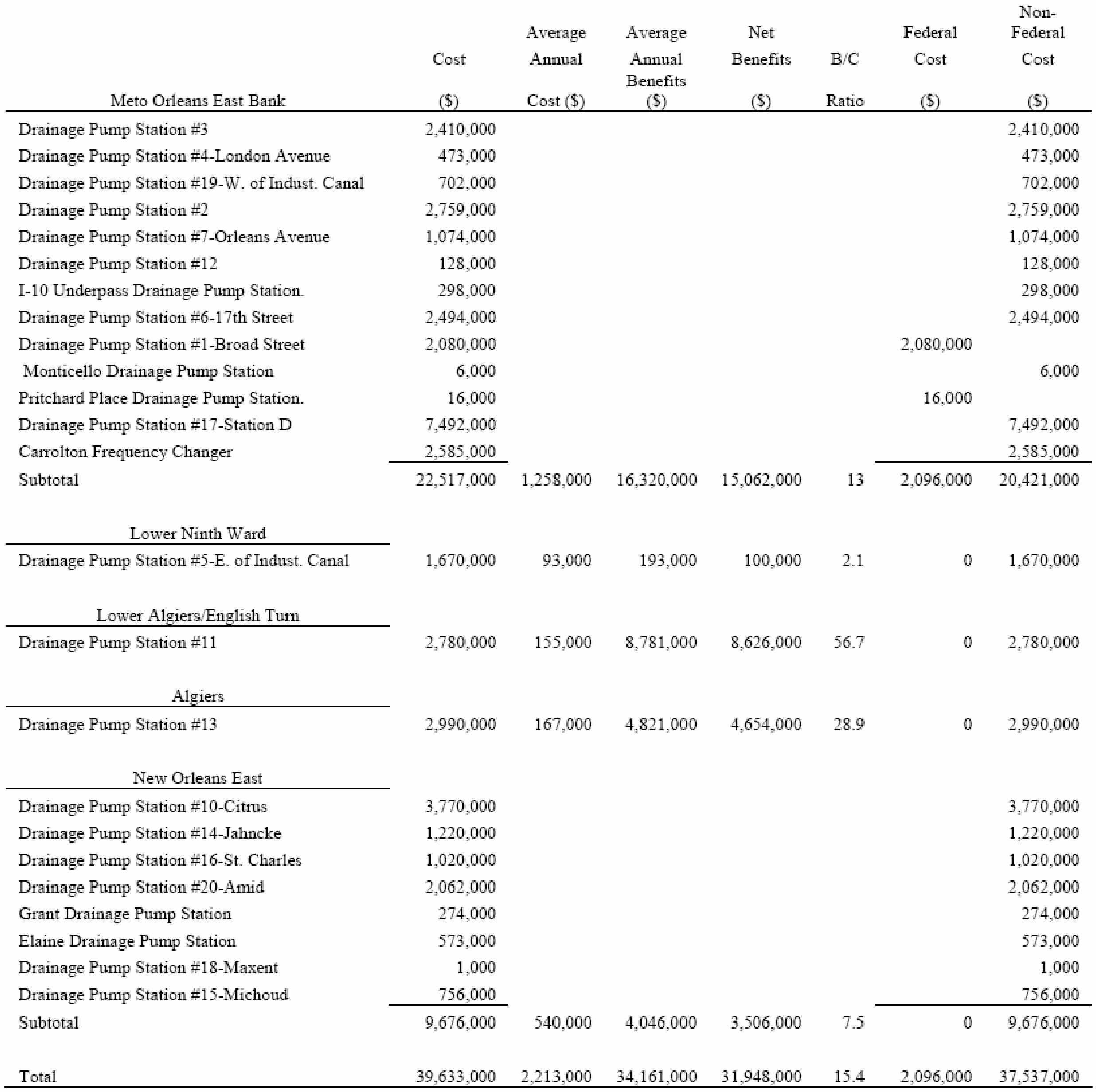
Intake location: Nolan and East Donner Canals
Discharge location: Intracoastal Waterway
Nominal capacity: 4700 cfs

Pump	Capacity (cfs)	Installed (year)	Driver Electric /Diesel	Pump Configuration
V1	250	1981	Electric 60 Hz	Vertical
V2	250	1981	Electric 60 Hz	Vertical
CD 3	50	1981	Electric 60 Hz	Vertical
D4	1000	1981	Diesel	Horizontal
D5	1000	1981	Diesel	Horizontal
6	1075	1981	Electric 60 Hz	Horizontal
7	1075	1981	Electric 60 Hz	Horizontal

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.3.2 Damage Summary

Table 7-12
Estimated Costs of Repairs to Orleans Parish Pump Stations[1]



Meto Orleans East Bank	Cost ($)	Average Annual Cost ($)	Average Annual Benefits ($)	Net Benefits ($)	B/C Ratio	Federal Cost ($)	Non-Federal Cost ($)
Drainage Pump Station #3	2,410,000						2,410,000
Drainage Pump Station #4-London Avenue	473,000						473,000
Drainage Pump Station #19-W. of Indust. Canal	702,000						702,000
Drainage Pump Station #2	2,759,000						2,759,000
Drainage Pump Station #7-Orleans Avenue	1,074,000						1,074,000
Drainage Pump Station #12	128,000						128,000
I-10 Underpass Drainage Pump Station.	298,000						298,000
Drainage Pump Station #6-17th Street	2,494,000						2,494,000
Drainage Pump Station #1-Broad Street	2,080,000					2,080,000	
Monticello Drainage Pump Station	6,000						6,000
Pritchard Place Drainage Pump Station.	16,000					16,000	
Drainage Pump Station #17-Station D	7,492,000						7,492,000
Carrolton Frequency Changer	2,585,000						2,585,000
Subtotal	22,517,000	1,258,000	16,320,000	15,062,000	13	2,096,000	20,421,000
Lower Ninth Ward							
Drainage Pump Station #5-E. of Indust. Canal	1,670,000	93,000	193,000	100,000	2.1	0	1,670,000
Lower Algiers/English Turn							
Drainage Pump Station #11	2,780,000	155,000	8,781,000	8,626,000	56.7	0	2,780,000
Algiers							
Drainage Pump Station #13	2,990,000	167,000	4,821,000	4,654,000	28.9	0	2,990,000
New Orleans East							
Drainage Pump Station #10-Citrus	3,770,000						3,770,000
Drainage Pump Station #14-Jahncke	1,220,000						1,220,000
Drainage Pump Station #16-St. Charles	1,020,000						1,020,000
Drainage Pump Station #20-Amid	2,062,000						2,062,000
Grant Drainage Pump Station	274,000						274,000
Elaine Drainage Pump Station	573,000						573,000
Drainage Pump Station #18-Maxent	1,000						1,000
Drainage Pump Station #15-Michoud	756,000						756,000
Subtotal	9,676,000	540,000	4,046,000	3,506,000	7.5	0	9,676,000
Total	39,633,000	2,213,000	34,161,000	31,948,000	15.4	2,096,000	37,537,000

[1] Taken from the Orleans Parish PIR

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7.3.3 Improvements Suggested by the Parish

The COE met with members of the S&WB to discuss pump station improvements that would increase the pumping performance in the future. The suggested improvements are listed below.

1. Backup water system
The stations need a backup potable water system for the pump bearing cooling and lubricating system. They currently use the city water system. When the city water system failed during the hurricane, raw water from the canals was used instead. The canal water damaged the bearings.

2. Small diesel generating sets
Diesel generators will provide stations with electricity when the local power is down.

3. Window protection
The windows at the stations need to be protected during a hurricane. They need manual shutters that can be quickly deployed. They are usually made out of plywood.

4. Dry passageways for cars
Railroad underpasses for cars can be flooded. They must be kept drained by pump stations. Overpasses would eliminate the need for the pump stations. Another option is to make improvements to current facilities, such as providing back-up generators or increasing pumping capacity

5. Automatic trash rakes
The caternary type trash rakes are not effective during hurricanes. They require excessive maintenance to keep them operating. This is not possible when wind speeds exceed 60 mph. The Parish would like to replace them with automatic “climber” type rakes. They have already installed these at some stations, and they require less maintenance and are more effective.

6. Replace old equipment
Many of the stations have very old electrical and mechanical equipment that is difficult to maintain. The S&WB does not have resources to replace or rehabilitate this equipment.

7. Guaranteed source of power
The local power company refuses to connect their lines to some plants due to back payment issues with the S&WB.

8. Generating assets
The S&WB is planning on asking the US Congress for money to add 10 MW of 60 Hz generating assets to complement and backup their existing generating assets.

9. Means to obtain fuel
Bringing fuel to the stations during and after Katrina was a significant problem. This is complex challenge to overcome. Excess fuel that is stored for emergencies will deteriorate if it is not used for years.

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10. An exhaust system

During a hurricane, the louvers that ventilate the pump stations are shut to keep out rain. Heat produced by the pumps is then contained within the station. The exhaust system would keep the station at a reasonable temperature for the operators.

11. Communications upgrade

The communications system needs to be able to interface with other systems, such as fire, police and emergency management personnel.

12. Funding

If few people return to Orleans Parish, S&WB will have less funding from system users. This could impact the board's ability to operate and maintain the existing infrastructure.

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Table 7-13
Orleans Parish Pumping Equipment Table

Name	Pump	Capacity (cfs)	Pump Manufacture	Pump Size (in)	Pump Model Number	Pump Serial Number	Installed (year)	Driver Electric /Diesel	Rated Pump Speed (rpm)	Pump Type (Vertical/Horizontal)	Pump Elevation (Cairo)	Pump Curve (yes/no)	Discharge Gates (type)	Rated Head (ft)	Track Rack Design Head (ft)	Intake Location	Discharge Location	Intake water elevation at Start (Cairo)	Intake water elevation at Stop (Cairo)	Intake water elevation range (Cairo)	Water elevations that effects station (Cairo)	Bearing Lubrication (oil/water)	Backstops or brakes (yes/no)
OP 1	A	550	Wood Screw	144			1929	Electric 25 Hz	75	Horizontal	27.25	Yes	None	5.75	N/A	Melpomene and Broad Ave Canals	Palmetto Canal	10.5	9	1.5	7.6	oil	No
	B	550	Wood Screw	144			1929	Electric 25 Hz	75	Horizontal	27.25	Yes	None	5.75	N/A	Melpomene and Broad Ave Canals	Palmetto Canal	10.5	9	1.5	7.6	oil	No
	C	1000	Wood Screw	168			1929	Electric 25 Hz	83.3	Horizontal	27.25	Yes	None		N/A	Melpomene and Broad Ave Canals	Palmetto Canal	10.5	9	1.5	7.6	oil	No
	D	1000	Wood Screw	168			1929	Electric 25 Hz	83.3	Horizontal	27.25	Yes	None		N/A	Melpomene and Broad Ave Canals	Palmetto Canal	10.5	9	1.5	7.6	oil	No
	E	1000	Wood Screw	168			1929	Electric 25 Hz	83.3	Horizontal	27.25	Yes	None		N/A	Melpomene and Broad Ave Canals	Palmetto Canal	10.5	9	1.5	7.6	oil	No
	F	1100	Allis-Chalmers (ITT-AC)	132			1991	Electric 60 Hz	100	Horizontal	25.5	Yes	None	8	N/A	Melpomene and Broad Ave Canals	Palmetto Canal	10.5	9	1.5	7.6	oil	No
	G	1100	Allis-Chalmers (ITT-AC)	132			1991	Electric 60 Hz	100	Horizontal	25.5	Yes	None	8	N/A	Melpomene and Broad Ave Canals	Palmetto Canal	10.5	9	1.5	7.6	oil	No
	V1	225	Fairbanks Morse	60				Electric 25 Hz	294	Vertical		Yes	None		N/A	Melpomene and Broad Ave Canals	Palmetto Canal	10.5	9	1.5	7.6	oil	No
	V2	225	Fairbanks Morse	60				Electric 25 Hz	294	Vertical		Yes	None		N/A	Melpomene and Broad Ave Canals	Palmetto Canal	10.5	9	1.5	7.6	oil	No
	CD1	60	Fairbanks Morse	36				Electric 25 Hz	214	Vertical		Yes	None		N/A	Melpomene and Broad Ave Canals	Palmetto Canal	10.5	9	1.5	7.6	oil	No
	CD2	15	Wood Screw	36				Electric 25 Hz	214	Centrifugal		Yes	None		N/A	Melpomene and Broad Ave Canals	Palmetto Canal	10.5	9	1.5	7.6	oil	No
	Total	**6825**																					
OP 2	A	550	Wood Screw	144			1914	Electric 25 Hz		Horizontal	27.25	Yes	Gate Valves		N/A	Broad Street Canal	OPS 3	12	11	1	-4.4	oil	No
	B	550	Wood Screw	144			1914	Electric 25 Hz		Horizontal	27.25	Yes	Gate Valves		N/A	Broad Street Canal	OPS 3	12	11	1	-4.4	oil	No
	C	1000	Wood Screw	168			1914	Electric 25 Hz		Horizontal	27.25	Yes	None		N/A	Broad Street Canal	OPS 7	11	10	1	-4.4	oil	No
	D	1000	Wood Screw	168			1914	Electric 25 Hz		Horizontal	27.25	Yes	None		N/A	Broad Street Canal	OPS 7	11	10	1	-4.4	oil	No
	CD2	25	Wood Screw	42			1974	Electric 25 Hz		Centrifugal	26	No	None		N/A	Broad Street Canal	OPS 3	11	10	1	-4.4	oil	No
	CD3	25	Wood Screw	42			1974	Electric 25 Hz		Centrifugal	26	No	None		N/A	Broad Street Canal	OPS 3	11	10	1	-4.4	oil	No
	Total	**3150**																					
OP 3	A	590	Wood Screw	144			1916	Electric 25 Hz	83.3	Horizontal	28.5	Yes	None	5.14	N/A	OPS 2	London Ave Canal	11	9.5	1.5	0.3	oil	Yes
	B	590	Wood Screw	144			1916	Electric 25 Hz	83.3	Horizontal	28.5	Yes	None	5.14	N/A	OPS 2	London Ave Canal	11	9.5	1.5	0.3	oil	Yes
	C	1000	Wood Screw	168			1930	Electric 25 Hz	93.8	Horizontal	28.5	Yes	None		N/A	OPS 2	London Ave Canal	12	10.5	1.5	0.3	oil	Yes
	D	1000	Wood Screw	168			1930	Electric 25 Hz	93.8	Horizontal	28.5	Yes	None		N/A	OPS 2	London Ave Canal	12	10.5	1.5	0.3	oil	Yes
	E	1000	Wood Screw	168			1930	Electric 25 Hz	93.8	Horizontal	28.5	Yes	None		N/A	OPS 2	London Ave Canal	12	10.5	1.5	0.3	oil	Yes
	CD 1	80			Centrifugal		1916	Electric 25 Hz	250	Centrifugal	27	No	None		N/A	OPS 2	London Ave Canal	10.5	9	1.5	0.3	oil	Yes
	CD 2	80			Centrifugal		1916	Electric 25 Hz	250	Centrifugal	27	No	None		N/A	OPS 2	London Ave Canal	10.5	9	1.5	0.3	oil	Yes
	Total	**4340**																					
OP 4	1	320	Wood Screw	84			1938	Electric 60 Hz	885	Centrifugal	24.75	Yes	Gate Valve		N/A	Prentiss Ave and St. Anthony	London Ave Canal	9	8.5	0.5	5.6	oil	No
	2	320	Wood Screw	84			1938	Electric 60 Hz	885	Centrifugal	24.75	Yes	Gate Valve		N/A	Prentiss Ave and St. Anthony	London Ave Canal	9	8.5	0.5	5.6	oil	No
	C	1000	Worthington Pump Co.	126		1617667	1957	Electric 25 Hz	500	Horizontal	27.5	Yes	None	12	N/A	Prentiss Ave and St. Anthony	London Ave Canal	10.5	9	1.5	5.6	oil	No
	D	1000	Allis-Chalmers (ITT-AC)	132			1957	Electric 25 Hz	494	Horizontal	27.5	Yes	None		N/A	Prentiss Ave and St. Anthony	London Ave Canal	10.5	9	1.5	5.6	oil	No
	E	1000	Allis-Chalmers (ITT-AC)	132			1957	Electric 25 Hz	494	Horizontal	27.5	Yes	None		N/A	Prentiss Ave and St. Anthony	London Ave Canal	10.5	9	1.5	5.6	oil	No
	CD1	80		30				Electric 25 Hz	161	Vertical		No	None		N/A	Prentiss Ave and St. Anthony	London Ave Canal	8.5	4	4.5	5.6	oil	No
	Total	**3720**																					
OP 5	A	550	Wood Screw	126			1914	Electric 25 Hz	83.3	Horizontal	30	No	None	14	N/A	Florida and Jourdan Ave. Canals	Lake Borgne	8	5.4	2.6	-5	oil	No
	B	550	Wood Screw	126			1914	Electric 25 Hz	83,3	Horizontal	30	No	None	14	N/A	Florida and Jourdan Ave. Canals	Lake Borgne	8	5.4	2.6	-5	oil	No
	D	1000	Wood Screw	144			1961	Electric 25 Hz	493	Horizontal		No	None		N/A	Florida and Jourdan Ave. Canals	Lake Borgne	8	5.4	2.6	-5	oil	No
	CD1	40	Wood Trash	30				Electric 25 Hz	150	Centrifugal	25.5	No	None		N/A	Florida and Jourdan Ave. Canals	Lake Borgne	8	5.4	2.6	-5	oil	No
	CD2	40	Wood Trash	30				Electric 25 Hz	150	Centrifugal	25.5	No	None		N/A	Florida and Jourdan Ave. Canals	Lake Borgne	8	5.4	2.6	-5	oil	No
	CD3	40	Wood Trash	30			1975	Electric 25 Hz	150	Centrifugal	25.5	No	None		N/A	Florida and Jourdan Ave. Canals	Lake Borgne	8	5.4	2.6	-5	oil	No
	CD4	40	Wood Trash	30			1975	Electric 25 Hz	150	Centrifugal	25.5	No	None		N/A	Florida and Jourdan Ave. Canals	Lake Borgne	8	5.4	2.6	-5	oil	No
	Total	**2260**																					
OP 6	A	550	Wood Screw	144			1914	Electric 25 Hz	83.3	Horizontal	26.5	Yes	Gate Valve		N/A	Palmetto Canal	17th St Canal	10	8	2	-6.2	oil	Yes
	B	550	Wood Screw	144			1914	Electric 25 Hz	83.3	Horizontal	26.5	Yes	Gate Valve		N/A	Palmetto Canal	17th St Canal	10	8	2	-6.2	oil	Yes
	C	1000	Wood Screw	168			1928	Electric 25 Hz	93.8	Horizontal	26.5	Yes	Gate Valve	14	N/A	Palmetto Canal	17th St Canal	10	8	2	-6.2	oil	Yes
	D	1000	Wood Screw	168			1928	Electric 25 Hz	93.8	Horizontal	26.5	Yes	Gate Valve	14	N/A	Palmetto Canal	17th St Canal	10	8	2	-6.2	oil	Yes
	E	1000	Wood Screw	168			1928	Electric 25 Hz	93.8	Horizontal	26.5	Yes	Gate Valve	14	N/A	Palmetto Canal	17th St Canal	10	8	2	-6.2	oil	Yes
	F	1000	Wood Screw	168			1928	Electric 25 Hz	93.8	Horizontal	26.5	Yes	Gate Valve	14	N/A	Palmetto Canal	17th St Canal	10	8	2	-6.2	oil	Yes
	G	1000	Worthington Pump Co.	126			1984	Electric 25 Hz	492	Horizontal	25.7	Yes	Gate Valve		N/A	Palmetto Canal	17th St Canal	10	8	2	-6.2	oil	Yes
	H	1100	Allis-Chalmers (ITT-AC)	126			1984	Electric 60 Hz	1190	Horizontal	25.7	Yes	Gate Valve	12	N/A	Palmetto Canal	17th St Canal	10	8	2	-6.2	oil	Yes
	I	1100	Allis-Chalmers (ITT-AC)	126			1984	Electric 60 Hz	1190	Horizontal	25.7	Yes	Gate Valve	12	N/A	Palmetto Canal	17th St Canal	10	8	2	-6.2	oil	Yes
	CD 1	90	Fairbanks Morse	30			1984	Electric 25 Hz	214	Vertical		Yes	Gate Valve		N/A	Palmetto Canal	Forcemain	10	8	2	-6.2	oil	Yes
	CD 2	90	Fairbanks Morse	30			1984	Electric 25 Hz	214	Vertical		Yes	Gate Valve		N/A	Palmetto Canal	Forcemain	10	8	2	-6.2	oil	Yes
	1	250	Patterson Pump Co.	68x84	AFV	85BT9114-G84	1983	Electric 60 Hz	320	Vertical	9.5	Yes	Gate Valve	16	N/A	Palmetto Canal	17th St Canal	10	8	2	-6.2	oil	Yes
	2	250	Patterson Pump Co.	68x84	AFV	85BT9115-G84	1983	Electric 60 Hz	320	Vertical	9.5	Yes	Gate Valve	16	N/A	Palmetto Canal	17th St Canal	10	8	2	-6.2	oil	Yes
	3	250	Patterson Pump Co.	68x84	AFV	85BT9116-G84	1983	Electric 60 Hz	320	Vertical	9.5	Yes	Gate Valve	16	N/A	Palmetto Canal	17th St Canal	10	8	2	-6.2	oil	Yes
	4	250	Patterson Pump Co.	68x84	AFV	85BT9117-G84	1983	Electric 60 Hz	320	Vertical	9.5	Yes	Gate Valve	16	N/A	Palmetto Canal	17th St Canal	10	8	2	-6.2	oil	Yes
	Total	**9480**																					
OP 7	A	550	Wood Screw	144			1931	Electric 25 Hz	83.3	Horizontal	28.5	Yes	None		1	OPS 2	London Canal	11.5	10.5	1	-7.6	oil	Yes
	C	1000	Wood Screw	168			1908	Electric 25 Hz	93.8	Horizontal		Yes	None		1	OPS 2	London Canal	11.5	10.5	1	-7.6	oil	Yes
	D	1000	Wood Screw	168			1908	Electric 60 Hz	885	Horizontal		Yes	None		1	OPS 2	London Canal	11.5	10.5	1	-7.6	oil	No
	CD 1	70	Fairbanks Morse	30				Electric 25 Hz	167	Vertical		Yes	Gate Valve		1	OPS 2	Forcemain	11.5	10.5	1	-7.6	oil	No
	CD 2	70	Fairbanks Morse	30				Electric 25 Hz	167	Vertical		Yes	Gate Valve		1	OPS 2	Forcemain	11.5	10.5	1	-7.6	oil	No
	Total	**2690**																					
OP 12	D	1000	Worthington Pump Co.	126			1961	Electric 25 Hz		Horizontal	25.5	No	Floodgate	14	N/A	Robert E. Lee and Fluer De Lis	Lake Pontchartrain	11	9.5	1.5	4.6	oil	Yes
	Total	**1000**																					
OP 17 (Station D)	A	40		30	30x63		1975	Electric 60 Hz		Centrifugal	13.17	Yes	Gate Valves		N/A	Peoples and Florida Ave. Canals	Mississippi River	8.5	6	2.5	5	oil	No
	B	40		30	30x63		1975	Electric 60 Hz		Centrifugal	13.17	Yes	Gate Valves		N/A	Peoples and Florida Ave. Canals	Mississippi River	8.5	6	2.5	5	oil	No
	C	40		30	30x63		1975	Electric 60 Hz		Centrifugal	13.17	Yes	Gate Valves		N/A	Peoples and Florida Ave. Canals	Mississippi River	8.5	6	2.5	5	oil	No
	D	40		30	30x63		1975	Electric 60 Hz		Centrifugal	13.17	Yes	Gate Valves		N/A	Peoples and Florida Ave. Canals	Mississippi River	8.5	6	2.5	5	oil	No
	Total	**160**																					
OP 19	H1	1100	Allis-Chalmers (ITT-AC)	132	141x32	0850-70051-01	1975	Electric 60 Hz	1190	Horizontal		Yes	Sluice Gates	12.8	N/A	Florida Ave Canal	Industrial Canal (Lake	8.5	6	2.5	13	oil	Yes
	H2	1100	Allis-Chalmers (ITT-AC)	132	141x32	0850-70051-02	1975	Electric 60 Hz	1190	Horizontal		Yes	Sluice Gates	12.8	N/A	Florida Ave Canal	Industrial Canal (Lake	8.5	6	2.5	13	oil	Yes
	H3	1100	Allis-Chalmers (ITT-AC)	132	141x32	0850-70051-03	1975	Electric 60 Hz	1190	Horizontal		Yes	Sluice Gates	12.8	N/A	Florida Ave Canal	Industrial Canal (Lake	8.5	6	2.5	13	oil	Yes
	V1	310	Allis-Chalmers (ITT-AC)	84		1-840-70051-05	1975	Electric 60 Hz	320	Vertical		Yes	Sluice Gates	15.1	N/A	Florida Ave Canal	Industrial Canal (Lake	8.5	6	2.5	13	oil	Yes
	V2	310	Allis-Chalmers (ITT-AC)	84		1-840-70051-05	1975	Electric 60 Hz	320	Vertical		Yes	Sluice Gates	15.1	N/A	Florida Ave Canal	Industrial Canal (Lake	8.5	6	2.5	13	oil	Yes
	Total	**3920**																					
PS I 10	1	250	Fairbanks Morse	64?	6360 LMA	3321271		Electric 60 Hz	295	Vertical		No	Check Valves	31.5	N/A		17th St Canal	1.9	-1.6	3.5	16	oil	Yes
	2	250	Fairbanks Morse	64?	6360 LMA	3321272		Electric 60 Hz	295	Vertical		No	Check Valves	31.5	N/A		17th St Canal	1.9	-1.6	3.5	16	oil	Yes
	3	250	Fairbanks Morse	64?	6360 LMA	3321273		Electric 60 Hz	295	Vertical		No	Check Valves	31.5	N/A		17th St Canal	1.9	-1.6	3.5	16	oil	Yes

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Table 7-14
Orleans Parish Pumping Equipment Table cont

Name	Pump	Capacity (cfs)	Pump Manufacture	Pump Size (in)	Pump Model Number	Pump Serial Number	Installed (year)	Driver Electric /Diesel	Rated Pump Speed (rpm)	Pump Type (Vertical/Horizontal)	Pump Elevation (Cairo)	Pump Curve (yes/no)	Discharge Gates (type)	Rated Head (ft)	Track Rack Design Head (ft)	Intake Location	Discharge Location	Intake water elevation at Start (Cairo)	Intake water elevation at Stop (Cairo)	Intake water elevation range (Cairo)	Water elevations that effects station (Cairo)	Bearing Lubrication (oil/water)	Backstops or brakes (yes/no)
	CD1	100	Fairbanks Morse		6360 LMA	332110		Electric 60 Hz	505	Centrifugal		No	Check Valves	36	N/A		17th St Canal	1.9	-1.6	3.5	16	oil	Yes
	Total	**850**																					
Prichard	1	125	MWI	48		7224		Electric 60 Hz	442	Vertical	-2	No	None	22.65	N/A	Carrollton Drainage	Monticello Canal	6	4	2	4	oil	Yes
	2	125	MWI	48		7223		Electric 60 Hz	442	Vertical	-2	No	None	22.65	N/A	Carrollton Drainage	Monticello Canal	7	5	2	4	oil	Yes
	CD1							Electric 60 Hz		Vertical	-7.75	No	None	22.65	N/A	Carrollton Drainage	Monticello Canal				4	oil	Yes
	Total	**250**																					
Monticello (Upper Protection)	1	70	Fairbanks Morse	30			1979	Electric 60 Hz		Vertical		No	None		N/A	Carrollton Drainage	Monticello Canal	8	7	1	4.8	oil	No
	2	70	Fairbanks Morse	30			1979	Electric 60 Hz		Vertical		No	None		N/A	Carrollton Drainage	Monticello Canal	8.5	7.5	1	4.8	oil	No
	3	70	Fairbanks Morse	30			1979	Electric 60 Hz		Vertical		No	None		N/A	Carrollton Drainage	Monticello Canal	9	8	1	4.8	oil	No
	Total	**210**																					
OP 10 (Citrus)	1	250	Allis-Chalmers (ITT-AC)		102x84	850-9327	1984	Electric 60 Hz	320	Vertical	7	Yes	Gate Valves	21.5	N/A	Citrus Canal	Lake Pontchartrain	9	6.5	2.5	15.75	oil	Yes
	2	250	Allis-Chalmers (ITT-AC)		102x84	850-9328	1984	Electric 60 Hz	320	Vertical	7	Yes	Gate Valves	21.5	N/A	Citrus Canal	Lake Pontchartrain	9	6.5	2.5	15.75	oil	Yes
	3	250	Allis-Chalmers (ITT-AC)		102x84	850-9329	1984	Electric 60 Hz	320	Vertical	7	Yes	Gate Valves	21.5	N/A	Citrus Canal	Lake Pontchartrain	10	7	3	15.75	oil	Yes
	4	250	Allis-Chalmers (ITT-AC)		102x84	850-9330	1984	Electric 60 Hz	320	Vertical	7	Yes	Gate Valves	21.5	N/A	Citrus Canal	Lake Pontchartrain	10	7	3	15.75	oil	Yes
	Total	**1000**																					
OP 14 (Jahncke)	1	300	Wood Screw	84		502228R4		Diesel	230	Vertical		Yes	Gate Valves	17	N/A	Morrison and Jahncke Canals	Lake Pontchartrain	8.5	7	1.5	20	oil	Yes
	2	300	Wood Screw	84		502228R2		Diesel	230	Vertical		Yes	Gate Valves	17	N/A	Morrison and Jahncke Canals	Lake Pontchartrain	9	8	1	20	oil	Yes
	3	300	Wood Screw	84		502228R3		Diesel	230	Vertical		Yes	Gate Valves	17	N/A	Morrison and Jahncke Canals	Lake Pontchartrain	10	9	1	20	oil	Yes
	4	300	Wood Screw	84		502228R1		Diesel	230	Vertical		Yes	Gate Valves	17	N/A	Morrison and Jahncke Canals	Lake Pontchartrain	9.5	8.5	1	20	oil	Yes
	Total	**1200**																					
OP 16 (St. Charles)	1	250	Fairbanks Morse	64	Vertical	800493	1966	Electric 60 Hz	327	Vertical	8.25	Yes	None	16	N/A	St. Charles Canal	Lake Pontchartrain	8.5	7.5	1	17	oil	No
	2	250	Fairbanks Morse	64	Vertical	800494	1966	Electric 60 Hz	327	Vertical	8.25	Yes	None	16	N/A	St. Charles Canal	Lake Pontchartrain	8.5	7.5	1	17	oil	No
	3	250	Fairbanks Morse	64	Vertical	800495	1966	Electric 60 Hz	327	Vertical	8.25	Yes	None	16	N/A	St. Charles Canal	Lake Pontchartrain	8.5	7.5	1	17	oil	No
	4	250	Fairbanks Morse	64	Vertical	800496	1966	Electric 60 Hz	327	Vertical	8.25	Yes	None	16	N/A	St. Charles Canal	Lake Pontchartrain	8.5	7.5	1	17	oil	No
	Total	**1000**																					
OP 18 (Maxent)	1	30	Johnston Pump Co.	72	Vertical		1983	Electric 60 Hz		Vertical		Yes	None		N/A	Village de'l East Lagoon	Maxent Canal	13.2	12.5	0.7	ground level	oil	No
	2	30	Johnston Pump Co.	72	Vertical		1983	Electric 60 Hz		Vertical		Yes	None		N/A	Village de'l East Lagoon	Maxent Canal	13.5	12.5	1	ground level	oil	No
	Total	**60**																					
OP 20 (Amid)	1	250	Patterson Pump Co.	72	68 x 72		1989	Electric 60 Hz	295	Vertical	-6.5	Yes	Gate Valve	8.5	N/A	Amid Canal	Intracoastal Waterway	17	14.8	2.2	5.75	oil	Yes
	2	250	Patterson Pump Co.	72	68 x 72		1989	Electric 60 Hz	295	Vertical	-6.5	Yes	Gate Valve	8.5	N/A	Amid Canal	Intracoastal Waterway	16	14	2	5.75	oil	Yes
	Total	**500**																					
Grant St.	1	8		14	Vertical			Electric 60 Hz		Vertical	15.46	No	Gate Valve		N/A	Grant St Canal	Intracoastal Waterway					oil	No
	2	8		14	Vertical			Electric 60 Hz		Vertical	15.46	No	Gate Valve		N/A	Grant St Canal	Intracoastal Waterway					oil	No
	3	8		14	Vertical			Electric 60 Hz		Vertical	15.46	No	Gate Valve		N/A	Grant St Canal	Intracoastal Waterway					oil	No
	4	8		14	Vertical			Electric 60 Hz		Vertical	15.46	No	Gate Valve		N/A	Grant St Canal	Intracoastal Waterway					oil	No
	5	80		30	Vertical		1990	Electric 60 Hz		Vertical		Yes	Gate Valve		N/A	Grant St Canal	Intracoastal Waterway	17.5	16	1.5	6.6	oil	No
	6	80		30	Vertical		1990	Electric 60 Hz		Vertical		Yes	Gate Valve		N/A	Grant St Canal	Intracoastal Waterway	18	17	1	6.6	oil	No
	Total	**192**																					
Elaine St.	1	45	Fairbanks Morse	30	Fig. 6320		1975	Electric 60 Hz		Vertical	12.63	Yes	None		N/A	Elaine St Canal	Intracoastal Waterway				1.5	oil	No
	2	45	Fairbanks Morse	30	Fig. 6320		1975	Electric 60 Hz		Vertical	12.63	Yes	None		N/A	Elaine St Canal	Intracoastal Waterway				1.5	oil	No
	Total	**90**																					
OP 15	1	250	Fairbanks Morse	72	Vertical			Electric 60 Hz		Vertical	-7	Yes	No		N/A	Maxent Canal	Intracoastal Waterway	13.2	12.5	0.7	19.6	oil	Yes
	2	250	Fairbanks Morse	72	Vertical		1997	Diesel		Vertical	-7	Yes	No		N/A	Maxent Canal	Intracoastal Waterway	13.5	12.5	1	19.6	oil	Yes
	3	250	Fairbanks Morse	72	Vertical		1997	Diesel		Vertical	-7	Yes	No		N/A	Maxent Canal	Intracoastal Waterway	13.5	12.5	1	19.6	oil	Yes
	Total	**750**																					
OP 11	A	250	Wood Screw	96		Order #: 13379	1953	Electric 25 Hz	125	Horizontal	26.5	Yes	None	8	N/A	Donner Canal	Intracoastal Waterway	12	11	1	28	oil	No
	B	250	Wood Screw	96			1953	Electric 25 Hz	125	Horizontal	26.5	Yes	None	8	N/A	Donner Canal	Intracoastal Waterway	12	11	1	28	oil	No
	D	570	ITT-AC	96		1-0850-70092-01	1990	Electric 60 Hz	135	Horizontal	26.5	Yes	None	12	N/A	Donner Canal	Intracoastal Waterway	13	12	1	28	oil	Yes
	E	570	ITT-AC	96		1-0850-70092-02	1990	Electric 60 Hz	135	Horizontal	26.5	Yes	None	12	N/A	Donner Canal	Intracoastal Waterway	13	12	1	28	oil	Yes
	CD - 3C	30		30	Centrifugal		1953	Electric 25 Hz	125	Centrifugal		Yes	None	8	N/A	Donner Canal	Intracoastal Waterway	11	10	1	28	oil	No
	Total	**1670**																					
OP 13	V1	250	Worthington Pump Co.	72	Vertical		1981	Electric 60 Hz	351	Vertical	6	Yes	None		N/A	Nolan and East Donner Canals	Intracoastal Waterway	9	8.5	0.5	5.6	oil	No
	V2	250	Worthington Pump Co.	72	Vertical		1981	Electric 60 Hz	351	Vertical	6	Yes	None		N/A	Nolan and East Donner Canals	Intracoastal Waterway	9	8.5	0.5	5.6	oil	No
	CD 3	50	Patterson Pump Co.	36	Vertical	AF-C02825?	1981	Electric 60 Hz	590?	Vertical	15.5	Yes	None	9.5?	N/A	Nolan and East Donner Canals	Intracoastal Waterway	8	7	1	5.6	oil	No
	D4	1000	Worthington Pump Co.	126	Horizontal		1981	Diesel	100	Horizontal	25.5	Yes	None	12	N/A	Nolan and East Donner Canals	Intracoastal Waterway	10	9	1	5.6	oil	No
	D5	1000	Worthington Pump Co.	126	Horizontal	1618079	1981	Diesel	100	Horizontal	25.5	Yes	None	12	N/A	Nolan and East Donner Canals	Intracoastal Waterway	10	9	1	5.6	oil	No
	6	1075	ITT-AC	132	Horizontal	850-9216	1981	Electric 60 Hz	100	Horizontal	25.5	Yes	None	11	N/A	Nolan and East Donner Canals	Intracoastal Waterway	8.5	8	0.5	5.6	oil	No
	7	1075	ITT-AC	132	Horizontal	850-9217	1981	Electric 60 Hz	100	Horizontal	25.5	Yes	None	11	N/A	Nolan and East Donner Canals	Intracoastal Waterway	8.5	8	0.5	5.6	oil	No
	Total	**4700**																					

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Table 7-15
Orleans Parish Pumping Start and Stop Times by Individual Pumps

Pump Station	Pump	Capacity (cfs)	8/28/2005		8/29/2005		8/30/2005		8/31/2005		9/1/2005		9/2/2005		9/3/2005		9/4/2005		9/5/2005		9/6/2005		9/7/2005		9/8/2005	
			Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop
East Orleans																										
OP#1	A	550			1:23 6:06 7:05	3:58 8:53 Run	Run 12:32	9:45 2:25	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	B	550			0:59 4:23	3:58 Run	Run	9:45	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	C	1000			2:00 2:23 3:46 5:41	2:13 2:45 4:53 8:53			▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	D	1000			2:16 7:26	8:50 Run	Run	9:45	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	E	1000			1:44 7:31	6:50 Run	Run	9:45	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	F	1215	NA		NA		NA		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	G	1215	NA		NA		NA		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	Y1	225	19:20	20:01	0:01 2:46 4:10	1:24 3:58 20:57			▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	Y2	225	19:20	20:51	0:01 2:46 4:10	1:24 3:58 16:15			▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	CD1	60							▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	CD2	15							▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	Total	7055																								
OP#2	A	550	▨	▨	▨	▨	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	B	550	▨	▨	▨	▨	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	C	1000	▨	▨	▨	▨	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	D	1000	▨	▨	▨	▨	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	CD2	25	▨	▨	▨	▨	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	CD3	25	▨	▨	▨	▨	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Total	3150																								
OP#3	A	590	16:23 20:47 22:50	17:45 21:07 23:18	0:36 1:15 1:50 1:56 2:22 2:45 3:30 3:41 7:45 NR	1:02 1:35 NR 2:17 2:32 3:08 3:34 7:25 7:50 8:20	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	■	■	■	■
	B	590	22:55	23:09	0:42 1:17 2:15 2:57 3:05 7:45 NR	0:59 1:33 NR 3:02 7:25 7:50 8:20	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	■	■	■	■
	C	1000			2:36 2:41 3:38 4:57 5:11 5:54	NR 3:04 NR 5:04 NR NR	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	■	■	■	■
	D	1000			0:07 0:56 3:08	0:27 2:39 7:10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	■	■	■	■
	E	1000			1:32 NR 2:00 6:09	1:44 1:55 3:55 8:20																	■	■	■	■
	CD 1	80	Run	15:21			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	■	■	■	■
	CD 2	80	Run	15:21			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	■	■	■	■
	Total	4340																								
OP#4	1	320	4:13	4:55	1:00	3:00	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	2	320	4:17	5:55	1:00	3:00	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	C	1000			2:00 5:18 5:56	3:15 NR 9:45	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	D	1000			4:36	9:45	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	E	1000			3:07 6:10	NR 9:45	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	CD1	80					▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	Total	3720																								
OP#5	A	550			2:47	4:00	NA	NA	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	NA	NA	NA	NA	NA	NA
	B	550			2:30 9:00	4:00 18:10	NA	NA	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	NA	NA	NA	NA	NA	NA
	C	1000			1:50 3:05 2:00	2:15 4:00 18:10	NA	NA	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	NA	NA	NA	NA	NA	NA
	D	1000			2:10 9:00	4:00 18:10	NA	NA	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	NA	NA	NA	NA	NA	NA
	E	1000			2:20 14:30	4:00 18:10	NA	NA	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	NA	NA	NA	NA	NA	NA
	F	1000			1:25	4:00	NA	NA	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	NA	NA	NA	NA	NA	NA
	G	1000			2:00 9:00	4:00 18:10	NA	NA	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	NA	NA	NA	NA	NA	NA
	H	1100			1:45	4:00	NA	NA	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	3:13	7:34			1:43 2:23	2:03 Run
	I	1100	21:05	21:50	0:06	4:00	NA	NA	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	4:53	Run	Run	Run	Run	Run
	CD 1	90					NA	NA	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	NA	NA	NA	NA	NA	NA
	CD 2	90	0:52	18:10			NA	NA	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	NA	NA	NA	NA	NA	NA
	1	250			2:31	4:00	NA	NA	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	7:45	Run	Run	Run	Run	Run
	2	250			2:33	4:00	NA	NA	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	7:15	Run	Run	Run	Run	Run
	3	250					NA	NA	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	NA	NA	NA	NA	NA	NA
	4	250					NA	NA	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	7:45	Run	Run	Run	Run	Run
	Total	9480																								
OP#7	A	550			1:44 3:36	3:15 5:55	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	C	1000			1:53 2:10 2:50 4:22	2:05 2:15 4:05 5:55	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	D	1000			2:00 2:13	2:01 4:24	NA	NA	NA	NA	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	CD 1	70	18:39	Run	Run	3:38	NA	NA	NA	NA	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	CD 2	70					NA	NA	NA	NA	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	Total	2690																								
OP#12	D	1000			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Total	1000																								
OP#17 (Station D)	A	150	Run	Run	Run 3:00	2:58 5:20	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA
	D	150	Run	Run	Run 3:00	2:59 6:00	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA
	Total	300																								
OP#19	H1	1100	16:01 16:56 17:53 20:25 21:16	16:34 17:07 19:20 20:47 NR	0:16 1:25 1:47	0:16 1:27 ▨											▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	H2	1100	11:26 13:14	11:45 13:26	0:51 2:06 3:12 4:47	1:50 2:53 4:05 ▨											▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	H3	1100	22:29	NR	0:07 0:47 4:45	0:08 4:05 ▨											▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	Y1	310															▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	Y2	310															▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	Total	3920																								
PS 110	1	250	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	2	250	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	3	250	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	CD1	100	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	Total	850																								
Prichard	1	125	23:15	23:20	1:18 2:45 4:58 5:20	1:23 4:55 5:15 6:50	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	2	125					▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	CD1						▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	Total	250																								
Monticello (Upper Protection)	1	33	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	2	33	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	3	33	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	Total	99																								
Lower Ninth Ward																										
OP#5	A	550	▨	▨	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	B	550	▨	▨	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	D	1000	▨	▨	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	CD1	40	▨	▨	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	CD2	40	▨	▨	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	CD3	40	▨	▨	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	CD4	40	▨	▨	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Total	2260																								
Orleans East																										
OP#10 (Citrus)	1	250	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	2	250	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	3	250	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	4	250	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	Total	1000																								
OP#14 (Jahncke)	1	300	7:30	8:55	3:07	9:00	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	2	300			2:05	7:30	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	3	300	13:15	13:25	1:10	9:00	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	4	300			NR 15:03	7:50 NR	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	Total	1200																								
OP#16 (St. Charles)	1	250	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	2	250	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	3	250	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	4	250	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	Total	1000																								
OP#18 (Maxent)	1	75	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	2	75	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	Total	150																								
OP#20 (Amid)	1	250	22:55	23:13	NA	NA	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	2	250	17:40	18:10	NA	NA	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	Total	500																								
Grant St.	1	8	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	2	8	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	3	8	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	4	8	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	5	70	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	6	70	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	Total	172																								
Elaine St.	1	45	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	2	45	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	Total	90																								
OP#15	1	250			▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	2	250	16:05	16:20	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	3	250	16:30	16:35	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	Total	750																								
English Turn																										
OP#11	A	250			8:45	12:20	0:01	19:15	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	B	250			0:45	12:20	0:01	19:15	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	D	570							■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	E	570	7:49 16:28	9:12 17:00	4:17 7:30	7:05 8:35	0:01	21:20	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	CD-30	50							■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Total	1690																								
Algiers																										
OP#13	Y1	250	4:20	5:50																	17:10	18:20			▨	▨
	Y2	250															17:00	21:40	10:00 17:00	14:15 20:30	12:10 17:10	14:30 18:00	9:45	12:15	▨	▨
	CD 3	50	6:50 14:30 18:00	NR NR 21:21													17:00	21:40	10:00	17:00	12:10	17:30			▨	▨
	D4	1000			2:40	Run	Run	16:15																	▨	▨
	D5	1000			2:10	Run	Run NR	7:40 16:15	11:14	15:40	12:25	17:15			9:15	13:00									▨	▨
	6	1075																							▨	▨
	7	1075																							▨	▨
	Total	4700																								

Pump Station	Pump	Capacity (cfs)	9/9/2005		9/10/2005		9/11/2005		9/12/2005		9/13/2005		9/14/2005		9/15/2005		9/16/2005		9/17/2005		9/18/2005		9/19/2005		9/20/2005		9/21/2005	
			Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop
East Orleans																												
OP#1	A	550	▨	▨	▨	▨	▨	▨	▨	▨	NA	NA	NA	NA	NA	NA	■	■	■	■	■	■	■	■	■	■	■	■
	B	550	▨	▨	▨	▨	▨	▨	▨	▨	NA	NA	NA	NA	NA	NA	■	■	■	■	■	■	■	■	■	■	■	■
	C	1000	▨	▨	▨	▨	▨	▨	▨	▨	NA	NA	NA	NA	NA	NA	■	■	■	■	■	■	■	■	■	■	■	■
	D	1000	▨	▨	▨	▨	▨	▨	▨	▨	NA	NA	NA	NA	NA	NA	■	■	■	■	■	■	■	■	■	■	■	■
	E	1000	▨	▨	▨	▨	▨	▨	▨	▨	NA	NA	NA	NA	NA	NA	■	■	■	■	■	■	■	■	■	■	■	■
	F	1215	▨	▨	▨	▨	▨	▨	▨	▨							■	■	■	■	■	■	■	■	■	■	■	■
	G	1215	▨	▨	▨	▨	▨	▨	▨	▨			14:50 16:35 21:43	15:25 17:00 22:25	6:45 14:25 22:50	7:50 15:20 23:35	■	■	■	■	■	■	■	■	■	■	■	■
	Y1	225	▨	▨	▨	▨	▨	▨	▨	▨							■	■	■	■	■	■	■	■	■	■	■	■
	Y2	225	▨	▨	▨	▨	▨	▨	▨	▨	5:22	6:05	9:44 10:25	10:10 17:10			■	■	■	■	■	■	■	■	■	■	■	■
	CD1	60	▨	▨	▨	▨	▨	▨	▨	▨							■	■	■	■	■	■	■	■	■	■	■	■
	CD2	15	▨	▨	▨	▨	▨	▨	▨	▨							■	■	■	■	■	■	■	■	■	■	■	■
	Total	7055																										
OP#2	A	550	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	B	550	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	C	1000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	D	1000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	CD2	25	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	CD3	25	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Total	3150																										
OP#3	A	590	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	B	590	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	C	1000	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	D	1000	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	E	1000	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	CD 1	80	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	CD 2	80	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Total	4340																										
OP#4	1	320	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	■	■	■	■	■	■
	2	320	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	■	■	■	■	■	■
	C	1000	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	■	■	■	■	■	■
	D	1000	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	■	■	■	■	■	■
	E	1000	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	■	■	■	■	■	■
	CD1	80	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	■	■	■	■	■	■
	Total	3720																										
OP#5	A	550	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	B	550	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	C	1000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	D	1000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	E	1000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	F	1000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	G	1000	NA 23:30	NA Run	Run	Run	Run	Run	Run 20:30	19:30 Run	Run	Run	Run	20:08														
	H	1100	Run 11:10	8:15 15:35	18:37	Run	Run 8:20 15:47	7:55 14:04 Run	Run	19:30																		
	I	1100	Run 11:10	8:15 15:35	18:45	Run	Run 8:12 15:47	7:55 14:04 Run	Run	19:30			6:10 23:05	20:08 Run	Run 3:30 6:30 12:09 17:30 23:10	1:24 3:20 9:40 14:20 19:40 Run	Run 6:50 11:50 21:48	4:20 9:12 17:00 23:23	6:30 10:55 14:55 20:11	9:05 12:02 17:05 21:19	3:50 7:20 11:45 19:30	5:13 8:43 12:32 20:43	5:00 12:35 15:30 17:00 17:50 22:30	6:55 15:27 14:40 17:25 18:55 23:48	8:58 17:10	8:20 19:20	8:55	10:15
	CD 1	90	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	CD 2	90	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	1	250	Run 10:12	8:15 15:35	18:30	Run	Run 16:32	14:02 20:10	19:48	23:40	3:47 11:36 15:07 17:32	10:16 13:47 16:15 22:10	6:27	7:05	8:05	9:15	21:44	22:25	6:45	9:05								
	2	250	Run 10:12	8:16 15:35	18:30	Run	Run 15:32	14:02 20:10	19:48	23:40	15:07	16:15																
	3	250	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	4	250	Run 11:10	8:15 15:35	18:30	Run	Run 16:32	14:02 20:10																				
	Total	9480																										
OP#7	A	550	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	C	1000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	D	1000	▨	▨	▨	▨	▨	▨	▨	▨	15:00	19:05	▨	▨	▨	▨	7:22 13:30 18:15	10:39 16:32 21:28	0:31 8:12 13:10 17:44 21:36	3:00 10:35 15:04 18:05 23:15	3:05 15:20 21:40	5:03 17:05 23:40	NA		11:03 19:00	12:23 20:50	9:10 NA	10:00
	CD 1	70	▨	▨	▨	▨	▨	▨	▨	▨			▨	▨	▨	▨												
	CD 2	70	▨	▨	▨	▨	▨	▨	▨	▨			▨	▨	▨	▨												
	Total	2690																										
OP#12	D	1000	NA	NA	NA	NA	18:19	Run	Run	11:15	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Total	1000																										
OP#17 (Station D)	A	150	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA
	D	150	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA
	Total	300																										
OP#19	H1	1100	▨	▨	▨	▨	▨	▨	▨	▨					■	■	■	■	■	■	■	■	■	■	■	■	■	■
	H2	1100	▨	▨	▨	▨	▨	▨	▨	▨					■	■	■	■	■	■	■	■	■	■	■	■	■	■
	H3	1100	▨	▨	▨	▨	▨	▨	▨	▨					■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Y1	310	▨	▨	▨	▨	▨	▨	▨	▨					■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Y2	310	▨	▨	▨	▨	▨	▨	▨	▨					■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Total	3920																										
PS 110	1	250	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	2	250	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	3	250	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	CD1	100	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	Total	850																										
Prichard	1	125	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	■	■	■	■	■	■	■	■	■	■	■	■
	2	125	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	■	■	■	■	■	■	■	■	■	■	■	■
	CD1		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	■	■	■	■	■	■	■	■	■	■	■	■
	Total	250																										
Monticello (Upper Protection)	1	33	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	2	33	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	3	33	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	Total	99																										
Lower Ninth Ward																												
OP#5	A	550	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	B	550	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	D	1000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	CD1	40	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	CD2	40	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	CD3	40	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	CD4	40	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Total	2260																										
Orleans East																												
OP#10 (Citrus)	1	250	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	2	250	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	3	250	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	4	250	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	Total	1000																										
OP#14 (Jahncke)	1	300	▨	▨	▨	▨	▨	▨	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	2	300	▨	▨	▨	▨	▨	▨	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	3	300	▨	▨	▨	▨	▨	▨	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	4	300	▨	▨	▨	▨	▨	▨	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Total	1200																										
OP#16 (St. Charles)	1	250	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	2	250	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	3	250	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	4	250	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	Total	1000																										
OP#18 (Maxent)	1	75	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	2	75	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	Total	150																										
OP#20 (Amid)	1	250	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	2	250	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	Total	500																										
Grant St.	1	8	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	2	8	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	3	8	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	4	8	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	5	70	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	6	70	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	Total	172																										
Elaine St.	1	45	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	2	45	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	Total	90																										
OP#15	1	250	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	2	250	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	3	250	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	Total	750																										
English Turn																												
OP#11	A	250	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	B	250	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	D	570	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	E	570	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	CD-30	50	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Total	1690																										
Algiers																												
OP#13	Y1	250	▨	▨	▨	▨	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Y2	250	▨	▨	▨	▨	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	CD 3	50	▨	▨	▨	▨	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	D4	1000	▨	▨	▨	▨	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	D5	1000	▨	▨	▨	▨	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	6	1075	▨	▨	▨	▨	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	7	1075	▨	▨	▨	▨	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Total	4700																										

Time in Local CST Day Light Savings

Pumps Not Available	NA
Not Reported	NR
Continued to Run	Run
Damaged/ Lost/ Unavaible Record	▨
Information was not obtained (Area	■

7.4 Plaquemines Parish Summary

Plaquemines Parish is located south of the city of New Orleans in the southern most part of Louisiana. Figure 7-29 is a map of Plaquemines Parish with the pump stations that were studied identified by yellow dots. Plaquemines Parish is divided by the Mississippi river into east and west banks. To alleviate flooding from rainfall, pumps drain the area. The Plaquemines Parish Government owns and operates the 21 pump stations located along the outer levee. Rainfall runoff is collected through a system of culverts, canals, and ditches delivering the storm water runoff to the pump stations. The pump stations discharge the runoff over the levee into the marsh. This report examined the 21 pump stations with a total of 54 pumps.

Figure 7-29 is a map showing the Plaquemines Parish pump stations that were used in this report. The locations of the pump stations were verified by Global Positioning System (GPS) and/or by using Google Earth Pro. The GPS coordinates were then input into Microsoft Streets and Trips (shown below).

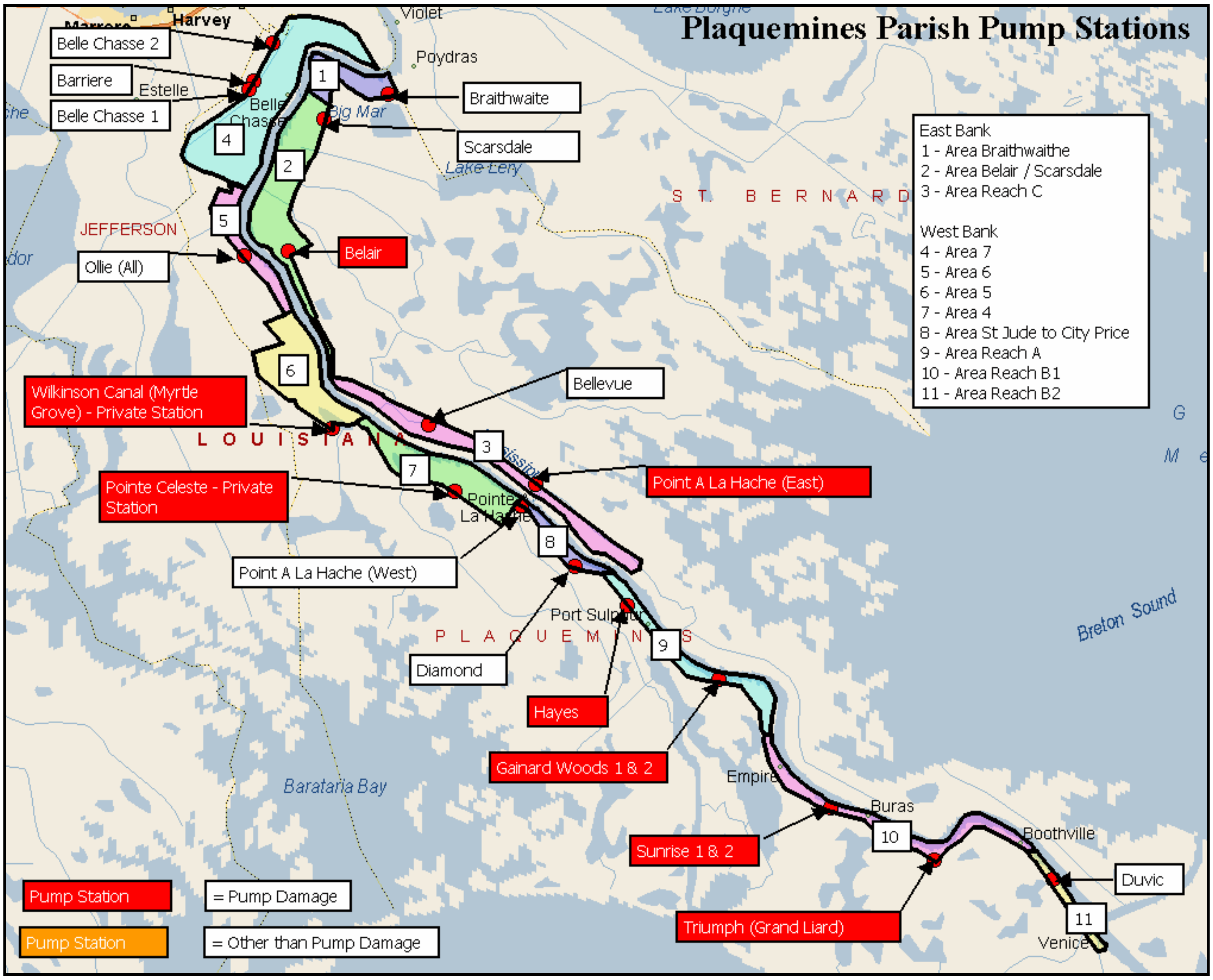

Figure 7-29 - Plaquemines Parish Pump Station Locations

Table 7-18 contains information about each individual pump at each pump station in Plaquemines Parish. The list is composed of information that was collected in the field. Not all information was available for each pump and was left blank or highlighted.

Table 7-16
Summary of Plaquemines Pump Stations by Bank

Bank	West Bank	East Bank	Total
Number of pump stations	13	5	18
Number of pumps	39	11	50
Total rated capacity (cfs)	3,115	10,737	13,852
Estimated cost of damages	$5,968,000	$2,209,000	$8,177,000

7.4.1 Drainage Basin

Plaquemines Parish consists of ten separate drainage basins. These basins have one or two pump stations, with the exception being the East Bank – Braithwaite, which has three pump stations. Plaquemines parish borders the Mississippi River. The pump stations generally discharge into marshes, although there are exceptions. The pump stations predominantly use diesel driven vertical pumps. Details for each pump station are listed in Section 7.6.3.

7.4.1.1 East Bank – Braithwaite

Braithwaite

Intake location:	Braithwaite Pond
Discharge location:	Marsh
Nominal capacity:	105 cfs

Pump	Capacity (cfs)	Year (Installed)	Driver Electric /Diesel	Pump Configuration
1	40	1974	Diesel	Vertical
2	65	1974	Diesel	Vertical

7.4.1.2 East Bank – Belair/Scarsdale

Belair

Intake location:	Pointe A La Hache Drainage Canal
Discharge location:	Marsh
Nominal capacity:	130 cfs

Pump	Capacity (cfs)	Year (Installed)	Driver Electric /Diesel	Pump Configuration
1	130	1950	Diesel	Vertical

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Scarsdale

Intake location: Scarsdale Drainage Canal
Discharge location: Marsh
Nominal capacity: 1,784 cfs

Pump	Capacity (cfs)	Year (Installed)	Driver Electric /Diesel	Pump Configuration
1	446	1965	Diesel	Horizontal
2	446	1965	Diesel	Horizontal
3	446	1965	Diesel	Horizontal
4	446	1965	Diesel	Horizontal

7.4.1.3 East Bank – Reach C

Bellevue

Intake location: Pointe A La Hache Drainage Canal
Discharge location: Marsh
Nominal capacity: 516 cfs

Pump	Capacity (cfs)	Year (Installed)	Driver Electric /Diesel	Pump Configuration
1	258	1972	Diesel	Horizontal
2	258	1972	Diesel	Horizontal

East Point a la Hache

Intake location: Pointe A La Hache Drainage Canal
Discharge location: Marsh
Nominal capacity: 580 cfs

Pump	Capacity (cfs)	Year (Installed)	Driver Electric /Diesel	Pump Configuration
1	290	1972	Diesel	Horizontal
2	290	1972	Diesel	Horizontal

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.4.1.4 West Bank – Area 7

Belle Chasse 1

Intake location: Barriere Canal
Discharge location: Intracoastal Waterway
Nominal capacity: 3,556 cfs

Pump	Capacity (cfs)	Year (Installed)	Driver Electric /Diesel	Pump Configuration
1	800	1955	Diesel	Horizontal
2	800	1955	Diesel	Horizontal
3	150	1955	Diesel	Vertical
4	903	1963	Diesel	Horizontal
5	903	1963	Diesel	Horizontal

Belle Chasse 2

Intake location: Belle Chasse Drainage Canal
Discharge location: Intracoastal Waterway
Nominal capacity: 1,050 cfs

Pump	Capacity (cfs)	Year (Installed)	Driver Electric /Diesel	Pump Configuration
1	350	n/a	Diesel	Vertical
2	350	n/a	Diesel	Vertical
3	350	n/a	Diesel	Vertical

Barriere Road

Intake location: Barreire Pond
Discharge location: Intracoastal Waterway
Nominal capacity: 25 cfs

Pump	Capacity (cfs)	Year (Installed)	Driver Electric /Diesel	Pump Configuration
1	25	n/a	Diesel	Vertical

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.4.1.5 West Bank – Area 6

Ollie Lower

Intake location: Ollie Canal
Discharge location: Ollie Outfall Canal
Nominal capacity: 440 cfs

Pump	Capacity (cfs)	Year (Installed)	Driver Electric /Diesel	Pump Configuration
1	140	Not Recorded	Diesel	Vertical
2	150	1981	Diesel	Vertical
3	150	1981	Diesel	Vertical

Ollie Upper

Intake location: Ollie Canal
Discharge location: Ollie Outfall Canal
Nominal capacity: 140 cfs

Pump	Capacity (cfs)	Year (Installed)	Driver Electric /Diesel	Pump Configuration
1	Not Recorded	1964	Diesel	Vertical
2	140	1964	Diesel	Vertical

7.4.1.6 West Bank – St. Jude to City Price

West Pointe a la Hache

Intake location: West Pointe A La Hache Canal
Discharge location: Jefferson Lake Canal
Nominal capacity: 45 cfs

Pump	Capacity (cfs)	Year (Installed)	Driver Electric /Diesel	Pump Configuration
1	15	n/a	Diesel	Vertical
2	15	n/a	Diesel	Vertical
3	15	n/a	Electric	Vertical

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Diamond

Intake location: Diamond Drainage Canal
Discharge location: Marsh
Nominal capacity: 256 cfs

Pump	Capacity (cfs)	Year (Installed)	Driver Electric /Diesel	Pump Configuration
1	128	1976	Diesel	Vertical
2	128	1976	Diesel	Vertical

7.4.1.7 West Bank – Reach A

Hayes

Intake location: Hayes Drainage Canal
Discharge location: Marsh
Nominal capacity: 500 cfs

Pump	Capacity (cfs)	Year (Installed)	Driver Electric /Diesel	Pump Configuration
1	250	1963	Diesel	Horizontal
2	250	1963	Diesel	Horizontal

Gainard Woods 1

Intake location: Gainard Woods Canal
Discharge location: Marsh
Nominal capacity: 410 cfs

Pump	Capacity (cfs)	Year (Installed)	Driver Electric /Diesel	Pump Configuration
1	205	1960	Diesel	Vertical
2	205	1960	Diesel	Vertical

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Gainard Woods 2
Intake location: Gainard Woods Canal
Discharge location: Marsh
Nominal capacity: 570 cfs

Pump	Capacity (cfs)	Year (Installed)	Driver Electric /Diesel	Pump Configuration
1	285	1985	Diesel	Vertical
2	285	1985	Diesel	Vertical

7.4.1.8 West Bank – Reach B-1

Sunrise 1
Intake location: Sunrise Drainage Canal
Discharge location: Marsh
Nominal capacity: 180 cfs

Pump	Capacity (cfs)	Year (Installed)	Driver Electric /Diesel	Pump Configuration
1	90	1960	Diesel	Vertical
2	90	1960	Diesel	Vertical

Sunrise 2
Intake location: Sunrise Drainage Canal
Discharge location: Marsh
Nominal capacity: 290 cfs

Pump	Capacity (cfs)	Year (Installed)	Driver Electric /Diesel	Pump Configuration
1	145	1979	Diesel	Vertical
2	145	1979	Diesel	Vertical

Grand Liard/Triumph
Intake location: Bural Drainage Canal
Discharge location: Grand Liard Marsh
Nominal capacity: 840 cfs

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.4.1.9 West Bank – Reach B-2

Duvic

Intake location: Venice Drainage Canal
Discharge location: Bayou Duvic
Nominal capacity: 560 cfs

Pump	Capacity (cfs)	Year (Installed)	Driver Electric /Diesel	Pump Configuration
1	280	1976	Diesel	Vertical
2	280	1976	Diesel	Vertical

7.4.1.10 West Bank – Area 5

Wilkinson Canal (Myrtle Grove)

Intake location: Unnamed Canal
Discharge location: Marsh
Nominal capacity: 980 cfs

Pump	Capacity (cfs)	Year (Installed)	Driver Electric /Diesel	Pump Configuration
101	223	n/a	Diesel	Vertical
102	223	n/a	Diesel	Vertical
103	267	n/a	Diesel	Vertical
104	267	n/a	Diesel	Vertical

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.4.1.11 West Bank – Area 4

Pointe Celeste (Upper and Lower)

Intake location:	Unnamed Canal
Discharge location:	Marsh
Nominal capacity:	895 cfs

Pump	Capacity (cfs)	Year (Installed)	Driver Electric /Diesel	Pump Configuration
105	223	n/a	Diesel	Vertical
106	223	n/a	Diesel	Vertical
107	223	n/a	Diesel	Vertical
108	223	n/a	Diesel	Vertical

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.4.2 Damage Summary

Table 7-17
Estimated Costs of Damages to Pump Stations in Plaquemines Parish[1]

Location	Drainage Area	Pump Station Name	Cost ($)
East Bank	Braithwaite		
		Braithwaite	101,000
East Bank	Belair/Scarsdale		
		Belair	538,000
		Scarsdale	413,000
		Subtotal	951,000
East Bank	Reach C		
		Bellevue	281,000
		East Point a la Hache	876,000
		Subtotal	1,157,000
West Bank	Area 7 West		
		Belle Chasse 1	6,000
		Belle Chasse 2	0
		Barriere Road	0
		Subtotal	6,000
West Bank	Area 6 West		
		Ollie (Upper, Lower and New)	2,000
West Bank	St. Jude to City Price		
		West Point a la Hache	121,000
		Diamond	212,000
		Subtotal	333,000
West Bank	Reach A		
		Hayes	1,411,000
		Gainard Woods (1 and 2)	1,881,000
		Subtotal	3,292,000
West Bank	Reach B-1		
		Sunrise (1 & 2)	841,000
		Grand Liard/Triumph	536,000
		Subtotal	1,377,000
West Bank	Reach B-2		
		Duvic	144,000
West Bank	Area 5 West		
		Wilkinson Canal	338,000
West Bank	Area 4 West		
		Pointe Celeste (upper and lower)	476,000
Total			8,177,000

[1] Taken from the Plaquemines Parish PIR

7.4.3 Improvements Suggested by the Parish

The COE met with members of Plaquemines Parish to discuss pump station improvements that would increase the pumping performance in the future. The suggested improvements are listed below.

1. Accommodations for employees
Following the storm, there was limited availability of housing and food for the operators and staff.

2. Fuel and fuel delivery
The stations need to capability to refuel. On-site storage could be increased where needed.

3. Improved communications system
During the storm the stations lost communication capability and relied on relay of short range capability from station to station. Access to emergency systems was limited because of significant chatter from many responders trying to use same system. The stations need to be able to communicate with other stations, as well as other emergency response agencies, such as law enforcement.

4. Trash and debris remedy
This is a significant issue because canals and conveyance systems, roadways, access points and pump stations are all disabled affected by trees, vegetation, and other debris. Significant amounts of debris limited access in some areas. Removal from conveyance systems and pump stations only the first step. It must later be collected, transported, disposed of. It cannot be left on access and rights of way.

5. Off-road vehicle
The stations need to be able to transport personnel and equipment to areas with limited access.

6. After-storm inspection
The parish needs means, such as by helicopter, to inspect damage after a storm. Currently it is difficult to travel through the area to determine the locations and extent of damage to facilities, and to make assessments for recovery.

7. Access to pump stations
Due to debris, high-water, and other challenging roadway conditions, it is difficult or impossible to travel to stations to begin unwatering. Roadways in remote regions were especially difficult to travel.

8. Breach repair
Before the pumps can perform, the levee breaches must be repaired.

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9. Elevate pump stations

Raising equipment, fuel facilities, etc. will protect the stations from substantial flooding damage. The southern stations are already elevated, but the northern stations are susceptible to flooding. This would also improve unwatering capability.

10. Repair of flat tires

Personnel supported other efforts, such as emergency vehicles, law enforcement, etc. One issue was a significant number of flat tires as vehicles travel through, over and near trash, debris, damaged homes and buildings, etc. This effort took time away from the repairing of the pump stations.

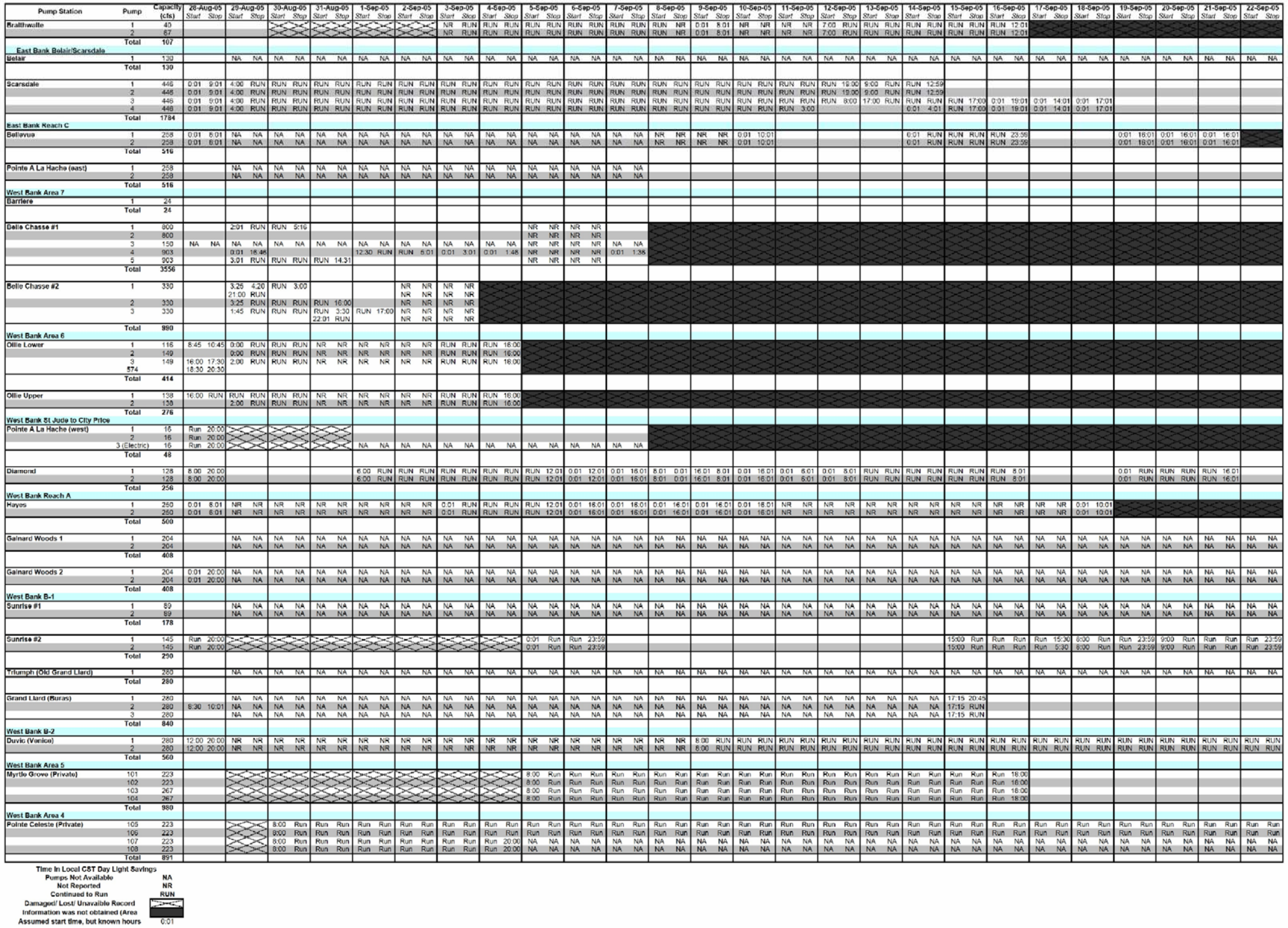
This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Table 7-18
Plaquemines Parish Pumping Equipment Table

Name	Pump	Capacity (cfs)	Pump Manufacture	Pump Size (in)	Pump Model Number	Pump Serial Number	Installed (year)	Driver Electric /Diesel	Rated Pump Speed (rpm)	Pump Type (Vertical/Horizontal)	Pump Elevation (NGVD)	Pump Curve (yes/no)	Discharge Gates (type)	Rated Head (ft)	Track Rack Design Head (ft)	Intake Location	Discharge Location	Intake water elevation at Start (NGVD)	Intake water elevation at Stop (NGVD)	Intake water elevation range (NGVD)	Water elevations that effects station (NGVD)	Bearing Lubrication (oil/water)	Backstops or brakes (yes/no)
Barreire Pond	1	24	Quality Industries Inc.	16	1152120	787	n/a	Diesel	n/a	Vertical	-15.5	No	None	20	n/a	Barreire Pond	Intercostal Waterway	-8.3	-10.5	2.2	-1.5	Oil	No
	Total	**24**																					
Belair	1	130	Fairbanks Morse	54			1950	Diesel	n/a	Vertical	-9	No	None	n/a	n/a	Pointe A La Hache Drainage Canal	Marsh	-3	-4	1	9.5	Oil	No
	Total	**130**																					
Belle Chasse #1	1	800	Hardie-Tynes	126	RR-335		1955	Diesel	97	Horizontal	10.5	No	None	8	n/a	Barriere Canal	Intercostal Waterway	-8.5	-9.5	1	10.5	Oil	Yes
	2	800	Hardie-Tynes	126	RR-335		1955	Diesel	97	Horizontal	10.5	No	None	8	n/a	Barriere Canal	Intercostal Waterway	-8.5	-9.5	1	10.5	Oil	Yes
	3	150	Fairbanks Morse	?		794401	1955	Diesel	248	Vertical	-14.5	No	None	8	n/a	Barriere Canal	Intercostal Waterway	-8.5	-9.5	1	10.5	Oil	Yes
	4	903	Worthington Pump Co.	126		1591736	1963	Diesel	n/a	Horizontal	10.5	No	None	8	n/a	Barriere Canal	Intercostal Waterway	-8.5	-9.5	1	10.5	Oil	Yes
	5	903	Worthington Pump Co.	126		1591736	1963	Diesel	n/a	Horizontal	10.5	No	None	8	n/a	Barriere Canal	Intercostal Waterway	-8.5	-9.5	1	10.5	Oil	Yes
	Total	**3556**																					
Belle Chasse #2	1	350	Reddy Buffalo	72	66 x 72	88962	n/a	Diesel	272	Vertical	-17	No	None	15.43	n/a	Belle Chasse Drainage Canal	Intercostal Waterway	-8.5	-12	3.5	14	Oil	Yes
	2	350	Reddy Buffalo	72	66 x 72	88963	n/a	Diesel	272	Vertical	-17	No	None	15.43	n/a	Belle Chasse Drainage Canal	Intercostal Waterway	-8.5	-12	3.5	14	Oil	Yes
	3	350	Reddy Buffalo	72	66 x 72	88964	n/a	Diesel	272	Vertical	-17	No	None	15.43	n/a	Belle Chasse Drainage Canal	Intercostal Waterway	-8.5	-12	3.5	14	Oil	Yes
	Total	**1050**																					
Bellevue	1	258	Fairbanks Morse		Fig. 6320	K2P2-058243-2	1972	Diesel	n/a	Horizontal	9.5	No	None	9.5	n/a	Pointe A La Hache Drainage Canal	Marsh	-3	-4	1	16.5	Oil	Yes
	2	258	Fairbanks Morse		Fig. 6320	K2P2-058243-3	1972	Diesel	n/a	Horizontal	9.5	No	None	9.5	n/a	Pointe A La Hache Drainage Canal	Marsh	-3	-4	1	16.5	Oil	Yes
	Total	**516**																					
Braithwaite	1	40	Lo-Lift	36 x 13	30 x 13	55-2210	1974	Diesel	900	Vertical	-10	No	None	13	n/a	Braithwaite Pond	Marsh	-4.3	-5	0.7	13	Oil	No
	2	65	Lo-Lift	30 X 17	30 X 17	61-2674	1974	Diesel	900	Vertical	-10	No	None	10	n/a	Braithwaite Pond	Marsh	-4.3	-5	0.7	13	Oil	No
	Total	**105**																					
Diamond	1	128	Patterson Pump Co.	48 x 54	SAFV	76BT-1881-G-5	1976	Diesel	280	Vertical	-9.5	No	None	13	n/a	Diamond Drainage Canal	Marsh	-4	-4.5	0.5	14.5	Oil	Yes
	2	128	Patterson Pump Co.	48 x 54	SAFV	76BT-1882-G-5	1976	Diesel	280	Vertical	-9.5	No	None	13	n/a	Diamond Drainage Canal	Marsh	-4	-4.5	0.5	14.5	Oil	Yes
	Total	**256**																					
Duvic (Venice)	1	280	Johnston Pump Co.	74	60 VHS	PG 1982	1976	Diesel	n/a	Vertical	-14	No	None	n/a	n/a	Venice Drainage Canal	Bayou Duvic	-8.8	-9	0.2	21.5	Oil	No
	2	280	Johnston Pump Co.	74	60 VHS	PG 1983	1976	Diesel	n/a	Vertical	-14	No	None	n/a	n/a	Venice Drainage Canal	Bayou Duvic	-8.8	-9	0.2	21.5	Oil	No
	Total	**560**																					
Gainard Woods 1	1	205	Fairbanks Morse	60	Fig. 6310	797481	1960	Diesel	n/a	Vertical	-12	No	None	n/a	n/a	Gainard Woods Canal	Marsh	-6	-7	1	12.5	Oil	No
	2	205	Fairbanks Morse	60	Fig. 6310		1960	Diesel	n/a	Vertical	-12	No	None	n/a	n/a	Gainard Woods Canal	Marsh	-6	-7	1	12.5	Oil	No
	Total	**410**																					
Gainard Woods 2	1	284	Patterson Pump Co.	72 x 72	AFV	85T8564-G72	1985	Diesel	382	Vertical	-12	No	None	10.5	n/a	Gainard Woods Canal	Marsh	-6	-7	1	4.5	Oil	Yes
	2	284	Patterson Pump Co.	72 x 72	AFV	85T8565-G72	1985	Diesel	382	Vertical	-12	No	None	10.5	n/a	Gainard Woods Canal	Marsh	-6	-7	1	4.5	Oil	Yes
	Total	**568**																					
Grand Liard (Buras)	1	280	Johnston Pump Co.	78	60 VHS	PG 1979	1976	Diesel	n/a	Vertical	-14	No	None	n/a	n/a	Bural Drainage Canal	Gran Liard Marsh	-8.8	-9	0.2	21.5	Oil	No
	2	280	Johnston Pump Co.	78	60 VHS	PG 1980	1976	Diesel	n/a	Vertical	-14	No	None	n/a	n/a	Bural Drainage Canal	Gran Liard Marsh	-8.8	-9	0.2	21.5	Oil	No
	3	280	Johnston Pump Co.	78	60 VHS	PG 1981	1976	Diesel	n/a	Vertical	-14	No	None	n/a	n/a	Bural Drainage Canal	Gran Liard Marsh	-8.8	-9	0.2	21.5	Oil	No
	Total	**840**																					
Hayes	1	250	Fairbanks Morse	72	Fig. 6320	798969	1963	Diesel	n/a	Horizontal	9	No	None	n/a	n/a	Hayes Drainage Canal	Marsh	-4.5	-5.5	1	12.5	Oil	Yes
	2	250	Fairbanks Morse	72	Fig. 6320	798969	1963	Diesel	n/a	Horizontal	9	No	None	n/a	n/a	Hayes Drainage Canal	Marsh	-4.5	-5.5	1	12.5	Oil	Yes
	Total	**500**																					
Myrtle Grove (Private)	101	223	Goulds (ITT-AC)	54		38870-2	n/a	Diesel	n/a	Vertical	-10	No	None	n/a	n/a	Unnamed Canal	Marsh	-4.5	-5	0.5	14	Oil	Yes
	102	223	Goulds (ITT-AC)	54		38870-1	n/a	Diesel	n/a	Vertical	-10	No	None	n/a	n/a	Unnamed Canal	Marsh	-4.5	-5	0.5	14	Oil	Yes
	103	267	Goulds (ITT-AC)	60			n/a	Diesel	n/a	Vertical	-10	no	None	n/a	n/a	Unnamed Canal	Marsh	-4.5	-5	0.5	14	Oil	Yes
	104	267	Goulds (ITT-AC)	60			n/a	Diesel	n/a	Vertical	-10	no	None	n/a	n/a	Unnamed Canal	Marsh	-4.5	-5	0.5	14	Oil	Yes
	Total	**980**																					
Ollie Lower	1	140	Fairbanks Morse	54		795378	n/a	Diesel	n/a	Vertical	-10.2	No	None	n/a	n/a	Ollie Canal	Ollie Outfall Canal	-4.8	-5.2	0.4	15	Oil	No
	2	150	Patterson Pump Co.	48 x 54	SAFV	81BT6082-G54	1981	Diesel	290	Vertical	-10.2	No	None	12.5	n/a	Ollie Canal	Ollie Outfall Canal	-4.8	-5.2	0.4	15	Oil	No
	3	150	Patterson Pump Co.	48 x 54	SAFV	81BT6083-G54	1981	Diesel	290	Vertical	-10.2	No	None	12.5	n/a	Ollie Canal	Ollie Outfall Canal	-4.8	-5.2	0.4	15	Oil	No
	Total	**440**																					
Ollie Upper	1	140	Fairbanks Morse	54		PL3003	1964	Diesel	?	Vertical	-10.2	No	None	n/a	n/a	Ollie Canal	Ollie Outfall Canal	-4.8	-5.2	0.4	7.5	Oil	yes
	2	140	Fairbanks Morse	54	Fig. 6310	798831	1964	Diesel	317	Vertical	-10.2	No	None	n/a	n/a	Ollie Canal	Ollie Outfall Canal	-4.8	-5.2	0.4	7.5	Oil	yes
	Total	**280**																					
Pointe A La Hache (east)	1	290	Fairbanks Morse	72	Fig. 6320	K2P2-058243	1972	Diesel	290	Horizontal	9.5	No	None	9.5	n/a	Pointe A La Hache Drainage Canal	Marsh	-3	-4	1	16.5	Oil	Yes
	2	290	Fairbanks Morse	72	Fig. 6320	K2P2-058243-1	1972	Diesel	290	Horizontal	9.5	No	None	9.5	n/a	Pointe A La Hache Drainage Canal	Marsh	-3	-4	1	16.5	Oil	Yes
	Total	**580**																					
Pointe A La Hache (west)	1	15	Lo-Lift	16	Size #16	82-6473	n/a	Diesel	n/a	Vertical	-7	No	None	n/a	n/a	West Pointe A La Hache Canal	Jefferson Lake Canal	-1.5	-2	0.5	11.5	Oil	Yes
	2	15	Lo-Lift	16	Size #16		n/a	Diesel	n/a	Vertical	-7	No	None	n/a	n/a	West Pointe A La Hache Canal	Jefferson Lake Canal	-1.5	-2	0.5	11.5	Oil	Yes
	3	15	Lo-Lift	16	Size #16	8819-16	n/a	Electric	1160	Vertical	-7	No	None	n/a	n/a	West Pointe A La Hache Canal	Jefferson Lake Canal	-1.5	-2	0.5	11.5	Oil	Yes
	Total	**45**																					
Pointe Celeste (Private)	105	223	Goulds (ITT-AC)	54			n/a	Diesel	n/a	Vertical	-10	No	None	n/a	n/a	Unnamed Canal	Marsh	-4.5	-5	0.5	8.5	Oil	Yes
	106	223	Goulds (ITT-AC)	54			n/a	Diesel	n/a	Vertical	-10	No	None	n/a	n/a	Unnamed Canal	Marsh	-4.5	-5	0.5	8.5	Oil	Yes
	107	223	Goulds (ITT-AC)	54			n/a	Diesel	n/a	Vertical	-10	No	None	n/a	n/a	Unnamed Canal	Marsh	-4.5	-5	0.5	8.5	Oil	Yes
	108	223	Goulds (ITT-AC)	54			n/a	Diesel	n/a	Vertical	-10	No	None	n/a	n/a	Unnamed Canal	Marsh	-4.5	-5	0.5	8.5	Oil	Yes
	Total	**892**																					
Scarsdale	1	446	Fairbanks Morse	84	Fig. 6320	799102	1965	Diesel	167	Horizontal	10	No	None	8	n/a	Scarsdale Drainage Canal	Marsh	-4.4	-5.3	0.9	11	Oil	Yes
	2	446	Fairbanks Morse	84	Fig. 6320	799100	1965	Diesel	167	Horizontal	10	No	None	8	n/a	Scarsdale Drainage Canal	Marsh	-4.4	-5.3	0.9	11	Oil	Yes
	3	446	Fairbanks Morse	84	Fig. 6320	799099	1965	Diesel	167	Horizontal	10	No	None	8	n/a	Scarsdale Drainage Canal	Marsh	-4.4	-5.3	0.9	11	Oil	Yes
	4	446	Fairbanks Morse	84	Fig. 6320	799101	1965	Diesel	167	Horizontal	10	No	None	8	n/a	Scarsdale Drainage Canal	Marsh	-4.4	-5.3	0.9	11	Oil	Yes
	Total	**1784**																					
Sunrise #1	1	90	Fairbanks Morse	42	Fig. 6310	797484	1960	Diesel	342	Vertical	-12	No	None	n/a	n/a	Sunrise Drainage Canal	Marsh	-5.7	-7	1.3	5	Oil	No
	2	90	Fairbanks Morse	42	Fig. 6310	797483	1960	Diesel	342	Vertical	-12	No	None	n/a	n/a	Sunrise Drainage Canal	Marsh	-5.7	-7	1.3	5	Oil	No
	Total	**180**																					
Sunrise #2	1	145	Patterson Pump Co.	48 x 54	SAFV	79BT4013-G54	1979	Diesel	290	Vertical	-12	No	None	13	n/a	Sunrise Drainage Canal	Marsh	-5.7	-7	1.3	15.5	Oil	Yes
	2	145	Patterson Pump Co.	48 x 54	SAFV	79BT4013-G55	1979	Diesel	290	Vertical	-12	No	None	13	n/a	Sunrise Drainage Canal	Marsh	-5.7	-7	1.3	15.5	Oil	Yes
	Total	**290**																					
Triumph	1	135	Fairbanks Morse	54		AF 10119	n/a	Diesel	n/a	Vertical	-14.8	No	None	n/a	n/a	Bural Drainage Canal	Gran Liard Marsh	-8.8	-9.8	1	11	Oil	No
	Total	**135**																					

n/a - Information is not available

Table 7-19
Plaquemines Parish Pumping Start and Stop Times by Individual Pumps



Pump Station	Pump	Capacity (cfs)	28-Aug-05		29-Aug-05		30-Aug-05		31-Aug-05		1-Sep-05		2-Sep-05		3-Sep-05		4-Sep-05		5-Sep-05		6-Sep-05		7-Sep-05		8-Sep-05		9-Sep-05	
			Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop
Braithwaite	1	40					▨	▨	▨	▨	▨	▨	▨	▨	NR	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	NR	0:01	8:01
	2	67					▨	▨	▨	▨	▨	▨	▨	▨	NR	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	NR	0:01	8:01
	Total	107																										
East Bank Belair/Scarsdale																												
Belair	1	130			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Total	130																										
Scarsdale	1	446	0:01	9:01	4:00	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN
	2	446	0:01	9:01	4:00	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN
	3	446	0:01	9:01	4:00	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN
	4	446	0:01	9:01	4:00	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN
	Total	1784																										
East Bank Reach C																												
Bellevue	1	258	0:01	8:01	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NR	NR	NR	NR
	2	258	0:01	8:01	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NR	NR	NR	NR
	Total	516																										
Pointe A La Hache (east)	1	258			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA				
	2	258			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA				
	Total	516																										
West Bank Area 7																												
Barriere	1	24																										
	Total	24																										
Belle Chasse #1	1	800			2:01	RUN	RUN	5:16											NR	NR	NR	NR			■	■	■	■
	2	800																	NR	NR	NR	NR			■	■	■	■
	3	150	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NR	NR	NR	NR	NA	NA	■	■	■	■
	4	903			0:01	16:46					12:30	RUN	RUN	5:01	0:01	3:01	0:01	1:48	NR	NR	NR	NR	0:01	1:36	■	■	■	■
	5	903			3:01	RUN	RUN	RUN	RUN	14:31									NR	NR	NR	NR			■	■	■	■
	Total	3556																										
Belle Chasse #2	1	330			3:25	4:20	RUN	3:00					NR	NR	NR	NR	■	■	■	■	■	■	■	■	■	■	■	■
					21:00	RUN							NR	NR	NR	NR	■	■	■	■	■	■	■	■	■	■	■	■
	2	330			3:25	RUN	RUN	RUN	RUN	16:00			NR	NR	NR	NR	■	■	■	■	■	■	■	■	■	■	■	■
	3	330			1:45	RUN	RUN	RUN	RUN	3:30	RUN	17:00	NR	NR	NR	NR	■	■	■	■	■	■	■	■	■	■	■	■
									22:01	RUN			NR	NR	NR	NR	■	■	■	■	■	■	■	■	■	■	■	■
	Total	990																										
West Bank Area 6																												
Ollie Lower	1	116	8:45	10:45	0:00	RUN	RUN	RUN	NR	NR	NR	NR	NR	NR	RUN	RUN	RUN	16:00	■	■	■	■	■	■	■	■	■	■
	2	149			0:00	RUN	RUN	RUN	NR	NR	NR	NR	NR	NR	RUN	RUN	RUN	16:00	■	■	■	■	■	■	■	■	■	■
	3	149	16:00	17:30	2:00	RUN	RUN	RUN	NR	NR	NR	NR	NR	NR	RUN	RUN	RUN	16:00	■	■	■	■	■	■	■	■	■	■
	574		18:30	20:30															■	■	■	■	■	■	■	■	■	■
	Total	414																										
Ollie Upper	1	138	16:00	RUN	RUN	RUN	RUN	RUN	NR	NR	NR	NR	NR	NR	RUN	RUN	RUN	16:00	■	■	■	■	■	■	■	■	■	■
	2	138			2:00	RUN	RUN	RUN	NR	NR	NR	NR	NR	NR	RUN	RUN	RUN	16:00	■	■	■	■	■	■	■	■	■	■
	Total	276																										
West Bank St Jude to City Price																												
Pointe A La Hache (west)	1	16	Run	20:00	▨	▨	▨	▨	▨	▨															■	■	■	■
	2	16	Run	20:00	▨	▨	▨	▨	▨	▨															■	■	■	■
	3 (Electric)	16	Run	20:00	▨	▨	▨	▨	▨	▨	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	■	■	■	■
	Total	48																										
Diamond	1	128	8:00	20:00							6:00	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	12:01	0:01	12:01	0:01	16:01	8:01	0:01	16:01	8:01
	2	128	8:00	20:00							6:00	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	12:01	0:01	12:01	0:01	16:01	8:01	0:01	16:01	8:01
	Total	256																										
West Bank Reach A																												
Hayes	1	250	0:01	8:01	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0:01	RUN	RUN	RUN	RUN	12:01	0:01	16:01	0:01	16:01	0:01	16:01	0:01	16:01
	2	250	0:01	6:01	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0:01	RUN	RUN	RUN	RUN	12:01	0:01	16:01	0:01	16:01	0:01	16:01	0:01	16:01
	Total	500																										
Gainard Woods 1	1	204			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	2	204			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Total	408																										
Gainard Woods 2	1	204	0:01	20:00	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	2	204	0:01	20:00	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Total	408																										
West Bank B-1																												
Sunrise #1	1	89			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	2	89			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Total	178																										
Sunrise #2	1	145	Run	20:00	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	0:01	Run	Run	23:59						
	2	145	Run	20:00	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	0:01	Run	Run	23:59						
	Total	290																										
Triumph (Old Grand Llard)	1	280			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Total	280																										
Grand Llard (Buras)	1	280			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	2	280	8:30	10:01	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	3	280			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Total	840																										
West Bank B-2																												
Duvic (Venice)	1	280	12:00	20:00	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	8:00	RUN
	2	280	12:00	20:00	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	8:00	RUN
	Total	560																										
West Bank Area 5																												
Myrtle Grove (Private)	101	223			▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	8:00	Run	Run	Run	Run	Run	Run	Run	Run	Run
	102	223			▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	8:00	Run	Run	Run	Run	Run	Run	Run	Run	Run
	103	267			▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	8:00	Run	Run	Run	Run	Run	Run	Run	Run	Run
	104	267			▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	8:00	Run	Run	Run	Run	Run	Run	Run	Run	Run
	Total	980																										
West Bank Area 4																												
Pointe Celeste (Private)	105	223			▨	▨	8:00	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run
	106	223			▨	▨	8:00	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run
	107	223			▨	▨	8:00	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	20:00	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	108	223			▨	▨	8:00	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	20:00	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Total	891																										

Pump Station	Pump	Capacity (cfs)	10-Sep-05		11-Sep-05		12-Sep-05		13-Sep-05		14-Sep-05		15-Sep-05		16-Sep-05		17-Sep-05		18-Sep-05		19-Sep-05		20-Sep-05		21-Sep-05		22-Sep-05	
			Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop
Braithwaite	1	40	NR	NR	NR	NR	7:00	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	12:01	■	■	■	■	■	■	■	■	■	■	■	■
	2	67	NR	NR	NR	NR	7:00	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	12:01	■	■	■	■	■	■	■	■	■	■	■	■
	Total	107																										
East Bank Belair/Scarsdale																												
Belair	1	130	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Total	130																										
Scarsdale	1	446	RUN	RUN	RUN	RUN	RUN	19:00	9:00	RUN	RUN	12:59																
	2	446	RUN	RUN	RUN	RUN	RUN	19:00	9:00	RUN	RUN	12:59																
	3	446	RUN	RUN	RUN	RUN	RUN	8:00	17:00	RUN	RUN	RUN	RUN	17:00	0:01	19:01	0:01	14:01	0:01	17:01								
	4	446	RUN	RUN	RUN	3:00					0:01	4:01	RUN	17:00	0:01	19:01	0:01	14:01	0:01	17:01								
	Total	1784																										
East Bank Reach C																												
Bellevue	1	258	0:01	10:01							0:01	RUN	RUN	RUN	RUN	23:59					0:01	16:01	0:01	16:01	0:01	16:01	■	■
	2	258	0:01	10:01							0:01	RUN	RUN	RUN	RUN	23:59					0:01	16:01	0:01	16:01	0:01	16:01	■	■
	Total	516																										
Pointe A La Hache (east)	1	258																										
	2	258																										
	Total	516																										
West Bank Area 7																												
Barriere	1	24																										
	Total	24																										
Belle Chasse #1	1	800	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	2	800	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	3	150	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	4	903	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	5	903	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Total	3556																										
Belle Chasse #2	1	330	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	2	330	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	3	330	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Total	990																										
West Bank Area 6																												
Ollie Lower	1	116	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	2	149	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	3	149	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	574		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Total	414																										
Ollie Upper	1	138	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	2	138	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Total	276																										
West Bank St Jude to City Price																												
Pointe A La Hache (west)	1	16	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	2	16	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	3 (Electric)	16	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Total	48																										
Diamond	1	128	0:01	16:01	0:01	6:01	0:01	8:01	RUN	RUN	RUN	RUN	RUN	RUN	RUN	8:01					0:01	RUN	RUN	RUN	RUN	16:01		
	2	128	0:01	16:01	0:01	6:01	0:01	8:01	RUN	RUN	RUN	RUN	RUN	RUN	RUN	8:01					0:01	RUN	RUN	RUN	RUN	16:01		
	Total	256																										
West Bank Reach A																												
Hayes	1	250	0:01	16:01	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0:01	10:01	■	■	■	■	■	■	■	■
	2	250	0:01	16:01	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0:01	10:01	■	■	■	■	■	■	■	■
	Total	500																										
Gainard Woods 1	1	204	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	2	204	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Total	408																										
Gainard Woods 2	1	204	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	2	204	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Total	408																										
West Bank B-1																												
Sunrise #1	1	89	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	2	89	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Total	178																										
Sunrise #2	1	145											15:00	Run	Run	Run	Run	15:30	8:00	Run	Run	23:59	9:00	Run	Run	Run	Run	23:59
	2	145											15:00	Run	Run	Run	Run	5:30	8:00	Run	Run	23:59	9:00	Run	Run	Run	Run	23:59
	Total	290																										
Triumph (Old Grand Llard)	1	280	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Total	280																										
Grand Llard (Buras)	1	280	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	17:15	20:45														
	2	280	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	17:15	RUN														
	3	280	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	17:15	RUN														
	Total	840																										
West Bank B-2																												
Duvic (Venice)	1	280	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN
	2	280	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN	RUN
	Total	560																										
West Bank Area 5																												
Myrtle Grove (Private)	101	223	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	18:00												
	102	223	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	18:00												
	103	267	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	16:00												
	104	267	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	18:00												
	Total	980																										
West Bank Area 4																												
Pointe Celeste (Private)	105	223	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run
	106	223	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run
	107	223	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	108	223	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Total	891																										

Time In Local CST Day Light Savings	
Pumps Not Available	NA
Not Reported	NR
Continued to Run	RUN
Damaged/ Lost/ Unavaible Record	▨
Information was not obtained (Area	■
Assumed start time, but known hours	0:01

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.5 St Bernard Parish Summary

St Bernard Parish is located east of the city of New Orleans and borders the east side of Orleans Parish. Figure 7-30 is a map of St Bernard Parish with the pump stations that were studied identified by red dots. St Bernard Parish is located on the east bank of the Mississippi River. To alleviate flooding from rainfall, pumps drain the area. The Lake Borgne Basin Levee District owns and operates eight pump station located along the interior back levee. Rainfall runoff is collected through a system of culverts, canals, and ditches delivering the storm water runoff to the pump stations. The pump stations discharge the runoff over the interior back levee into the marsh north and east of the levee. This report examined the 8 Parish pump stations with a total of 28 pumps.

Figure 7-30 is a map showing the St Bernard Parish pump stations that were used in this report. The locations of the pump stations were verified by Global Positioning System (GPS) and/or by using Google Earth Pro. The GPS coordinates were then input into Microsoft Streets and Trips (shown below).

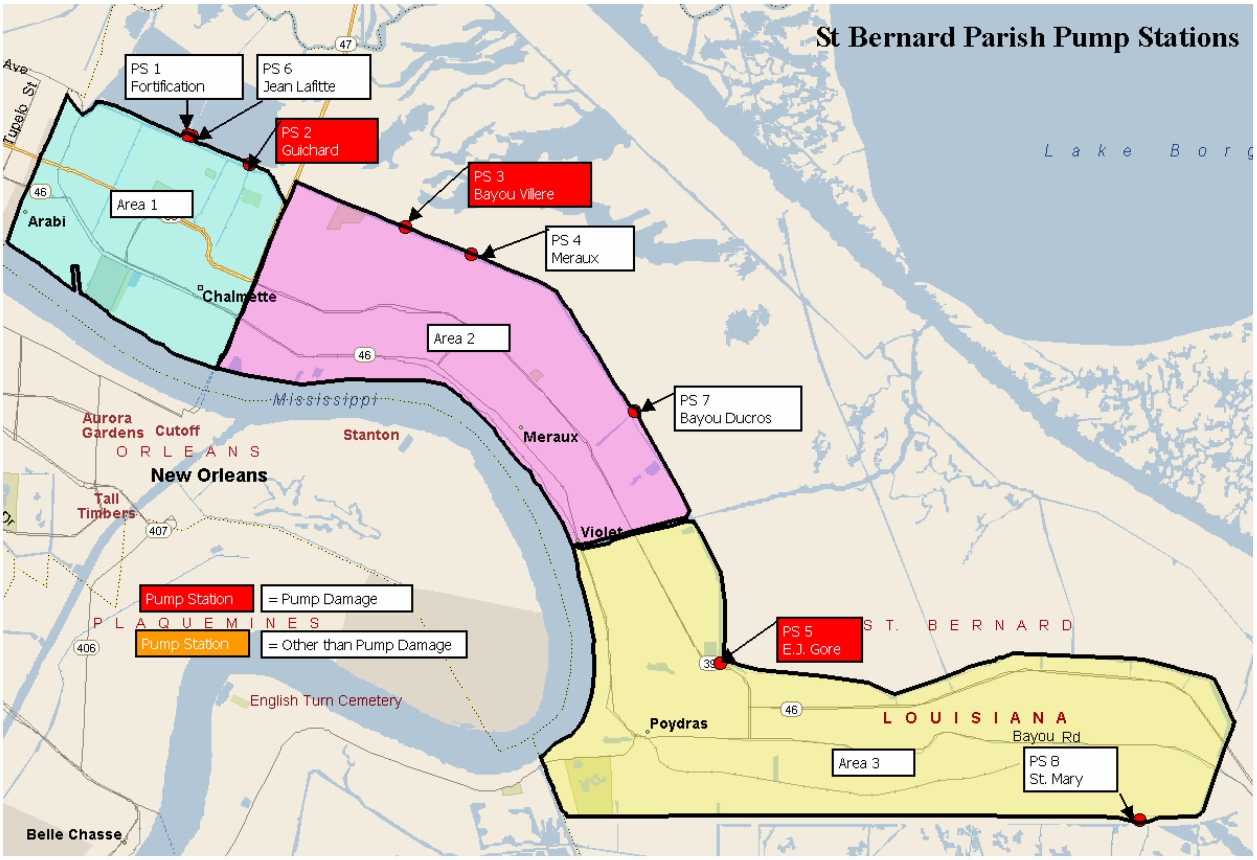


Figure 7-30 – St Bernard Parish Pump Station Locations

Table 7-20 contains information about each individual pump at each of the examined pump stations in St Bernard Parish. The list is composed of information that was collected in the field. Not all information was available for each pump and was left blank or highlighted.

Table 7-20
Summary of St. Bernard pump Stations By Drainage Basin

Basin	Area 1	Area 2	Area 3	Total
Number of pump stations	3	3	2	8
Number of pumps	10	9	9	28
Total rated capacity (cfs)	2,805	2,725	1,445	6,975
Estimated cost of damages	$4,192,000	$3,427,000	$3,069,000	$10,688,000

7.5.1 Drainage Basins

St. Bernard Parish consists of three drainage basins. All of the pump stations lay on the borders of the drainage basins. The stations are evenly distributed through the parish; with area three having two pump stations while area one and two each have three pump stations. All the pump stations have a suction basin from a canal and discharge into various bayous and lakes in the surrounding area. The pump stations vary between vertical and horizontal pump configurations. Details for each pump station are listed in Section 7.6.4.

7.5.1.1 Area 1

PS 1 – Fortification

Intake location:	Florida Walk Canal
Discharge location:	Bayou Bienvenue
Nominal capacity:	981 cfs

Pump	Capacity (cfs)	Year Installed	Driver Electric /Diesel	Pump Configuration
1	446	1972	Diesel	Vertical
2	89	1972	Electric 60 Hz	Vertical
3	446	1972	Diesel	Vertical

PS 2 – Guichard

Intake location:	Florida Walk Canal
Discharge location:	Bayou Bienvenue
Nominal capacity:	724 cfs

Pump	Capacity (cfs)	Year Installed	Driver Electric /Diesel	Pump Configuration
1	111	1950's	Diesel	Horizontal
2	223	1950's	Diesel	Horizontal
3	167	1950's	Diesel	Horizontal
4	223	1950's	Diesel	Horizontal

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PS 6 – Jean Lafitte

Intake location: Forty Arpent Canal
Discharge location: Bayou Bienvenue
Nominal capacity: 999 cfs

Pump	Capacity (cfs)	Year Installed	Driver Electric /Diesel	Pump Configuration
1	333	1990	Diesel	Vertical
2	333	1990	Diesel	Vertical
3	333	1990	Diesel	Vertical

7.5.1.2 Area 2

PS 3 – Bayou Villere

Intake location: Forty Arpent Canal
Discharge location: Bayou Villere
Nominal capacity: 801 cfs

Pump	Capacity (cfs)	Year Installed	Driver Electric /Diesel	Pump Configuration
1	267	1950's	Diesel	Horizontal
2	267	1950's	Diesel	Horizontal
3	267	1950's	Diesel	Horizontal

PS 4 – Meraux

Intake location: Forty Arpent Canal
Discharge location: Bayou Dupre
Nominal capacity: 981 cfs

Pump	Capacity (cfs)	Year Installed	Driver Electric /Diesel	Pump Configuration
1	446	1972	Diesel	Vertical
2	89	1972	Electric 60 Hz	Vertical
3	446	1972	Diesel	Vertical

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

PS 7 – Bayou Ducros
Intake location: Forty Arpent Canal
Discharge location: Bayou Ducros
Nominal capacity: 945 cfs

Pump	Capacity (cfs)	Year Installed	Driver Electric /Diesel	Pump Configuration
1	315	1992	Diesel	Vertical
2	315	1992	Diesel	Vertical
3	315	1992	Diesel	Vertical

7.5.1.3 Area 3

PS 5 – E.J. Gore
Intake location: Forty Arpent Canal
Discharge location: Bayou Dupre
Nominal capacity: 666 cfs

Pump	Capacity (cfs)	Year Installed	Driver Electric /Diesel	Pump Configuration
1	111	1980's	Diesel	Horizontal
2	111	1980's	Diesel	Horizontal
3	111	1980's	Diesel	Horizontal
4	111	1980's	Diesel	Horizontal
5	111	1980's	Diesel	Horizontal
6	111	1980's	Diesel	Horizontal

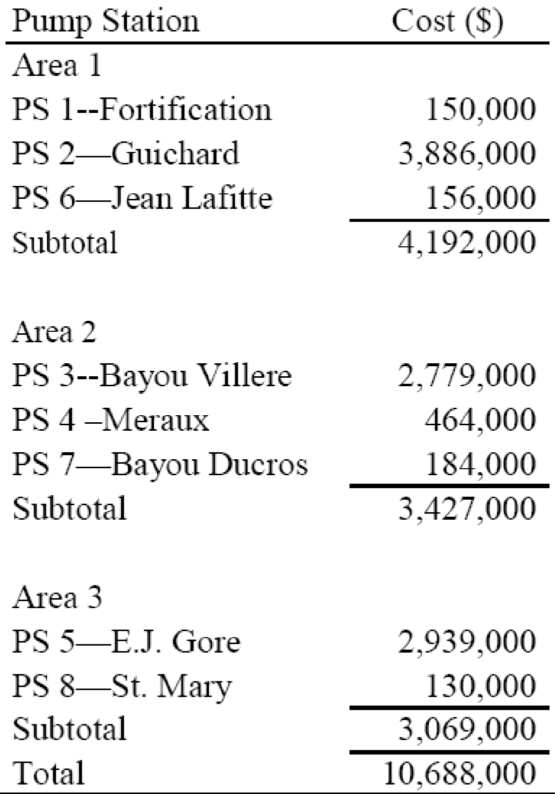
PS 8 – St. Mary
Intake location: Forty Arpent Canal
Discharge location: Lake Lery
Nominal capacity: 780 cfs

Pump	Capacity (cfs)	Year Installed	Driver Electric /Diesel	Pump Configuration
1	260	1996	Diesel	Vertical
2	260	1996	Diesel	Vertical
3	260	1996	Diesel	Vertical

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.5.2 Damage Summary

Table 7-21
Summary of St. Bernard Parish Pump Station Damages[1]



Pump Station	Cost ($)
Area 1	
PS 1--Fortification	150,000
PS 2—Guichard	3,886,000
PS 6—Jean Lafitte	156,000
Subtotal	4,192,000
Area 2	
PS 3--Bayou Villere	2,779,000
PS 4 –Meraux	464,000
PS 7—Bayou Ducros	184,000
Subtotal	3,427,000
Area 3	
PS 5—E.J. Gore	2,939,000
PS 8—St. Mary	130,000
Subtotal	3,069,000
Total	10,688,000

[1] Taken from the St. Bernard Parish PIR

7.5.3 Improvements Suggested by the Parish

The COE met with St. Bernard Parish to discuss pump station improvements that would increase the pumping performance in the future. The suggested improvements are listed in Table 7-22. The first and second columns list and explain the improvements. The columns on the right indicate which pump stations each improvement could be applied. A number in the “Pump Station” column indicates a quantity of a product, while an “X” indicates a system improvement.

Table 7-22
Suggested Improvements for St. Bernard Parish Pump Stations

Betterment	Details	Pump Station 1	2	3	4	5	6	7	8
New tainter gates	These will prevent reverse flow.	5			5				
Valves or Bulkheads	These will prevent reverse flow.		4	3			3	3	
Remote start system	A remote start system would allow the pumps to be started from a nearby station. This would decrease the response time. Once the station is started, an operator would be sent to monitor the plant.		X	X		X			
New engines	Some stations have 35 year old German diesel engines. Replacement parts are virtually impossible to obtain.	X			X				
SCADA system	This would measure data such as flow rates, water levels, rain fall, and wind speed. It would also record engine and pump parameters such as start and stop time, temperatures, pressures, and fuel consumption rates.	X	X	X	X	X	X	X	X
T1 type line	This line would transfer data from the stations to the main facility. It would allow for central data storage and the ability to know all operational status in near real time.	X	X	X	X	X	X	X	X
Overhead crane overhaul	Deteriorated cranes are unsafe to operate at rated loads.	X			X				
Automatic trash rakes	The caternary type trash rakes currently located at most of the stations do not work well during hurricanes. They require operators to keep them operating, as well as someone outdoors to tend them. This is not possible when wind speeds exceed 60 mph. Automatic "climber" type rakes are needed.	X	X	X	X	X	X	X	X
Safe house	This would allow operators to quickly start the pumps after a hurricane (might not be necessary with a SCADA system).	X	X	X	X	X	X	X	X
Re-painting		X			X				
Additional capacity	Area 3 floods every time 3" of rain falls. This can be solved by increasing Station 5's capacity by 1,000 cfs, or building a new station.					X			
Feasibility study	Prior to Katrina, a feasibility study was 75% complete for Drainage Area 1. It was to recommend adding 2,000 cfs of pumping capacity. The study needs to incorporated post-Katrina changes	X	X				X		
Means to obtain fuel	Bringing fuel to the stations during and after Katrina was a significant problem. This is complex challenge to overcome.	X	X	X	X	X	X	X	X
New tainter gates	These will prevent reverse flow.	5			5				
Communications upgrade	The current portable radios do not have the range to reach every station. During the storm, the repeater went out and the operators had to relay messages on to other stations.	X	X	X	X	X	X	X	X

(Continued)

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Table 22 (Concluded)

Betterment	Details	Pump Station							
		1	2	3	4	5	6	7	8
Access road	A road is needed from PS 7 to PS 4. The only existing access road is through a community, and it crosses a canal that is nearly impossible to navigate during storms.				X				
Spare pump and hydraulic driver	Water quality problems from nearby oxidation ponds cause PS 5's hydraulic pump's seals to fail frequently. A spare pump & hydraulic driver is needed to maintain station capacity while repairs are made.					1			
Fixed hoist	A fixed hoist is needed to quickly remove and re-install the pumps for the repairs mentioned above.					1			
Raise fuel vent pipes	Water contaminated the fuel during Katrina. Raising the vent pipes would help prevent this.	X	X	X	X	X	X	X	X

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Table 7-23
St Bernard Parish Pumping Equipment Table

Name	Pump	Capacity	Pump Manufacture	Pump Size	Pump Model Number	Pump Serial Number	Installed	Driver	Rated Pump Speed	Pump Type	Pump Elevation	Pump Curve	Discharge Gates	Rated Head	Track Rack Design Head	Intake Location	Discharge Location	Intake water elevation at Start	Intake water elevation at Stop	Intake water elevation range	Water elevations that effects station	Bearing Lubrication	Backstops or brakes
		(cfs)		(in)			(year)	Electric /Diesel	(rpm)	(Vertical/Horizontal)	(NGVD)	(yes/no)	(type)	(ft)	(ft)			(NGVD)	(NGVD)	(NGVD)	(NGVD)	(oil/water)	(yes/no)
Fortification #1	1	446	Baldwin-Lima-Hamilton (Patterson)	94 x 128	AFV		1972	Diesel	212	Vertical	-1.5	yes	tainter gates	19	n/a	Florida Walk Canal	Bayou Bienvenue	-6.0	-6.5	0.5	8	Oil	No
	2	89	Baldwin-Lima-Hamilton (Patterson)	42 x 54	AFV		1972	Electric 60 Hz	505	Vertical	-1.5	yes	tainter gates	20	n/a	Florida Walk Canal	Bayou Bienvenue	-6.0	-6.5	0.5	8	Oil	No
	3	446	Baldwin-Lima-Hamilton (Patterson)	94 x 128	AFV		1972	Diesel	212	Vertical	-1.5	yes	tainter gates	19	n/a	Florida Walk Canal	Bayou Bienvenue	-6.0	-6.5	0.5	8	Oil	No
	Total	**981**																					
Guichard #2	1	111	M&W (MWI)	42	NC342P12		1950's	Diesel	n/a	Horizontal	-8	yes	none	n/a	n/a	Florida Walk Canal	Bayou Bienvenue	-6.0	-6.5	0.5	4	Oil	No
	2	223	M&W (MWI)	60	NC360P12		1950's	Diesel	n/a	Horizontal	-8	yes	none	n/a	n/a	Florida Walk Canal	Bayou Bienvenue	-6.0	-6.5	0.5	4	Oil	No
	3	167	Fairbanks Morse	?	Horizontal		1950's	Diesel	n/a	Horizontal	-8	yes	none	n/a	n/a	Florida Walk Canal	Bayou Bienvenue	-6.0	-6.5	0.5	4	Oil	No
	4	223	M&W (MWI)	60	NC360P12		1950's	Diesel	n/a	Horizontal	-8	yes	none	n/a	n/a	Florida Walk Canal	Bayou Bienvenue	-6.0	-6.5	0.5	4	Oil	No
	Total	**724**																					
Bayou Villere #3	1**	267	M&W (MWI)	60	NC360P12		1950's	Diesel	n/a	Horizontal	-8	yes	butterfly valve	n/a	n/a	Forty Arpent Canal	Bayou Villere	-6.0	-6.5	0.5	12	Oil	Yes
	2**	267	M&W (MWI)	60	NC360P12		1950's	Diesel	n/a	Horizontal	-8	yes	butterfly valve	n/a	n/a	Forty Arpent Canal	Bayou Villere	-6.0	-6.5	0.5	12	Oil	Yes
	3***	267	M&W (MWI)	60	NC360P12		1950's	Diesel	n/a	Horizontal	-8	yes	none	n/a	n/a	Forty Arpent Canal	Bayou Villere	-6.0	-6.5	0.5	12	Oil	No
	Total	**801**																					
Meraux #4	1	446	Baldwin-Lima-Hamilton (Patterson)	94 x 128	AFV		1972	Diesel	212	Vertical	-1.5	yes	floodgate	19	n/a	Forty Arpent Canal	Bayou Dupre	-6.0	-6.5	0.5	16	Grease	No
	2	89	Baldwin-Lima-Hamilton (Patterson)	42 x 54	AFV		1972	Electric 60 Hz	505	Vertical	-1.5	yes	floodgate	20	n/a	Forty Arpent Canal	Bayou Dupre	-6.0	-6.5	0.5	16	Grease	No
	3	446	Baldwin-Lima-Hamilton (Patterson)	94 x 128	AFV		1972	Diesel	212	Vertical	-1.5	yes	floodgate	19	n/a	Forty Arpent Canal	Bayou Dupre	-6.0	-6.5	0.5	16	Grease	No
	Total	**981**																					
E.J. Gore #5	1	111	M&W (MWI)	42	NC342P12		1980's	Diesel	n/a	Horizontal	-8	yes	flap gates	n/a	n/a	Forty Arpent Canal	Bayou Dupre	0.0	-0.5	0.5	4	Oil	No
	2	111	M&W (MWI)	42	NC342P13		1980's	Diesel	n/a	Horizontal	-8	yes	flap gates	n/a	n/a	Forty Arpent Canal	Bayou Dupre	0.0	-0.5	0.5	4	Oil	No
	3	111	M&W (MWI)	42	NC342P14		1980's	Diesel	n/a	Horizontal	-8	yes	flap gates	n/a	n/a	Forty Arpent Canal	Bayou Dupre	0.0	-0.5	0.5	4	Oil	No
	4	111	M&W (MWI)	42	NC342P15		1980's	Diesel	n/a	Horizontal	-8	yes	flap gates	n/a	n/a	Forty Arpent Canal	Bayou Dupre	0.0	-0.5	0.5	4	Oil	No
	5	111	M&W (MWI)	42	NC342P16		1980's	Diesel	n/a	Horizontal	-8	yes	flap gates	n/a	n/a	Forty Arpent Canal	Bayou Dupre	0.0	-0.5	0.5	4	Oil	No
	6	111	M&W (MWI)	42	NC342P17		1980's	Diesel	n/a	Horizontal	-8	yes	flap gates	n/a	n/a	Forty Arpent Canal	Bayou Dupre	0.0	-0.5	0.5	4	Oil	No
	Total	**666**																					
Jean Lafitte #6	1	333	Patterson Pump Co.	75 x 72	AFV	90PT-14688-88-G72	1990	Diesel	272	Vertical	-8	yes	none	12	n/a	Florida Walk Canal	Bayou Bienvenue	-6.0	-6.5	0.5	9	Grease	Yes
	2	333	Patterson Pump Co.	75 x 72	AFV	90PT-14688-89-G72	1990	Diesel	272	Vertical	-8	yes	none	12	n/a	Florida Walk Canal	Bayou Bienvenue	-6.0	-6.5	0.5	9	Grease	Yes
	3	333	Patterson Pump Co.	75 x 72	AFV	90PT-14688-90-G73	1990	Diesel	272	Vertical	-8	yes	none	12	n/a	Florida Walk Canal	Bayou Bienvenue	-6.0	-6.5	0.5	9	Grease	Yes
	Total	**999**																					
Bayou Ducros #7	1	315	Patterson Pump Co.	75 x 72	AFV	90B14685-G72	1992	Diesel	265	Vertical	-8	yes	none	11.5	n/a	Forty Arpent Canal	Bayou Ducros	-6.0	-6.5	0.5	16	Grease	Yes
	2	315	Patterson Pump Co.	75 x 72	AFV	90B14686-G72	1992	Diesel	265	Vertical	-8	yes	none	11.5	n/a	Forty Arpent Canal	Bayou Ducros	-6.0	-6.5	0.5	16	Grease	Yes
	3	315	Patterson Pump Co.	75 x 72	AFV	90B14687-G72	1992	Diesel	265	Vertical	-8	yes	none	11.5	n/a	Forty Arpent Canal	Bayou Ducros	-6.0	-6.5	0.5	16	Grease	Yes
	Total	**945**																					
St. Mary #8	1	260	ITT-AC	108 x 66	115-143543	1-0840-70720-02	1996	Diesel	230	Vertical	-9 (intake)	yes	none	2.5	n/a	Twenty Arpent Canal	Lake Lery	0.0	-0.5	0.5	18	Grease	Yes
	2	260	ITT-AC	108 x 66	115-143543	1-0840-70720-01	1996	Diesel	230	Vertical	-9 (intake)	yes	none	2.5	n/a	Twenty Arpent Canal	Lake Lery	0.0	-0.5	0.5	18	Grease	Yes
	3	260	ITT-AC	108 x 66	115-143543	1-0840-70720-03	1996	Diesel	230	Vertical	-9 (intake)	yes	none	2.5	n/a	Twenty Arpent Canal	Lake Lery	0.0	-0.5	0.5	18	Grease	Yes
	Total	**780**																					

*** Elevations estimated by Bob Turner/Lake Borgne Levee District and from engineering plans (when available)**

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Table 7-24
Plaquemines Parish Pumping Start and Stop Times by Individual Pumps

Pump Station	Pump	Capacity (cfs)	8/28/2005		8/29/2005		8/30/2005		8/31/2005		9/1/2005		9/2/2005		9/3/2005		9/4/2005		9/5/2005		9/6/2005		9/7/2005		9/8/2005		9/9/2005		9/10/2005		9/11/2005		9/12/2005		9/13/2005		9/14/2005		9/15/2005	
			Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop
Area 1																																								
Fortification #1	1 (East)	577	▨		▨		▨		▨		NA		NR		NR		NR		NR		NR		NR		NR		22:30	Run	Run	22:00	NR		NR		■		■		■	
	2 (Center)	100	▨		▨		▨		▨		NR		NR		NR		NR		NR		NR		NR		NR		NR		NR		NR		NR		■		■		■	
	3 (West)	577	▨		▨		▨		▨		20:00	Run	Run	11:30	9:00	16:00	9:00	22:00	NR		NR		NR		NR		NR		20:30	22:00	23:00	Run	Run	1:40	■		■		■	
	Total	**1254**																																						
Guichard #2	1	111	NR		NR		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
	2	223	NR		NR		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
	3	167	NR		NR		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
	4	223	NR		NR		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
	Total	**724**																																						
Jean Lafitte #6	1	334	16:00	16:45	▨		14:45	22:00	6:00	20:00	6:00	Run	Run	6:00	8:00 20:30	19:30 Run	Run	14:00	7:30	22:00	22:00	Run	Run 22:00	1:00 Run	Run	Run	Run	Run	Run	Run	Run 11:30 16:30 22:30	9:00 13:30 18:30 0:00	3:30	5:00	■		■		■	
	2	334	16:00	16:45	▨		14:45	22:00	6:00	20:00	6:00	Run	Run	6:00	8:00 20:30	19:30 Run	Run	14:00	7:30	22:00	22:00	Run	Run 22:00	1:00 Run	Run	Run	Run	Run	Run	Run	Run 11:30 16:30 22:30	9:00 13:30 18:30 0:00	3:30	5:00	■		■		■	
	3	334	16:00	16:45	▨		14:45	22:00	6:00	20:00	6:00	Run	Run	6:00	8:00 20:30	19:30 Run	Run	14:00	7:30	22:00	22:00	Run	Run 22:00	1:00 Run	Run	Run	Run	Run	Run	Run	Run 11:30 16:30 22:30	9:00 13:30 18:30 0:00	3:30	5:00	■		■		■	
	Total	**1002**																																						
Area 2																																								
Bayou Villere #3	1	n/a	NR		NR		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
	2	n/a	NR		NR		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
	3	n/a	NR		NR		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
	Total	**500**																																						
Meraux #4	1 (East)	557	19:05	20:25	▨		▨		▨		▨		▨		9:20	16:20	▨		▨		4:30	Run	Run	Run	Run	Run	Run	Run	Run	1:30	■		■		■		■		■	
	2 (Electric)	89	NR		▨		▨		▨		▨		▨		NR		▨		▨		NR		NR		NR		NR		NR		■		■		■		■		■	
	3 (West)	557	NR		▨		▨		▨		▨		▨		NR		▨		▨		NR		NR		NR		NR		NR		■		■		■		■		■	
	Total	**1203**																																						
Bayou Ducros #7	1	334	7:40 17:00 19:35	9:10 17:45 20:05	▨		▨		▨		▨		▨		8:00	Run	Run 18:00	16:00 Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	0:00	8:30	12:00	■		■		■		■		■	
	2	334	7:40 17:00 19:35	9:10 17:45 20:05	▨		▨		▨		▨		▨		8:00	Run	Run 18:00	16:00 Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	0:00	8:30	12:00	■		■		■		■		■	
	3	334	7:40 17:00 19:35	9:10 17:45 20:05	▨		▨		▨		▨		▨		8:00	Run	Run 18:00	16:00 Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	0:00	8:30	12:00	■		■		■		■		■	
	Total	**1002**																																						
Area 3																																								
E.J. Gore #5	1	110	▨		▨		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
	2	110	▨		▨		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
	3	110	▨		▨		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
	4	110	▨		▨		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
	5	110	▨		▨		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
	6	110	▨		▨		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
	Total	**660**																																						
St. Mary #8	1	279									15:45	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	20:00			15:00	Run	Run	17:30	14:00	19:30	7:00	Run	Run	Run	Run	1:00
	2	279	9:15	0:00							15:45	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	14:00	6:00	Run	Run	21:30	14:00	16:30	7:15	Run	Run	Run	Run	3:00
	3	279													11:45	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	14:00	6:00	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run	6:00
	Total	**837**																																						

Time in Local CST Day Light Savings

Pumps Not Available	**NA**
Not Reported	**NR**
Continued to Run	**Run**
Damaged/ Lost/ Unavaible Record	▨
Information was not obtained (Area considered Unwatered)	■

7.6 Detailed Pump Station Information

7.6.1 Jefferson Parish Pump Stations

7.6.1.1 East Bank Stations

7.6.1.1.1 *Bonnabel*

Jefferson Parish – East Bank Drainage Basin

1500 Beverly Garden Dr
Metairie, LA 70002

Latitude: 30.01872˚ Longitude: -90.14526˚

7.6.1.1.1.1 Before and After Hurricane Katrina Photos

Before Hurricane Katrina: View from the inlet canal

Before Hurricane Katrina: Aerial view of the pump station

After Hurricane Katrina: View from the discharge

After Hurricane Katrina: Aerial view of the pump station

7.6.1.1.1.2 Description[9]

Drainage area:	East Bank
Nominal Capacity:	3750 cfs
Drains water from:	Bonnabel Canal
Discharges water to:	Lake Pontchartrain
Owner:	Jefferson Parish Department of Drainage
Number of pumps:	5
Pump orientation:	3 horizontal 2 vertical
Pump driver:	2 electric 60 Hz motors 3 diesels
Water level to switch pumps on:	8.3 feet (Cairo)
Water level to switch pumps off:	8.1 feet (Cairo)
Water level that affects operation:	24.65 feet (Cairo). Water will enter gearbox on diesel pumps
Reverse flow protection:	Pumps 1 and 2 have gate valves. Pumps 3, 4, and 5 use air suppression.

7.6.1.1.1.3 Damages[10]

Estimated cost of repairs:	$142,000[11]
Relative level of damage:	Minor
Severity of circumstances:	Water entered the basement, but not the operating floor.
Equipment damaged:	Louvers for exhaust fans and generators, vent pipes for the fuel day tanks, and heating elements to the interior heaters.
Building damage:	There is approximately 6,600 sq. ft of roof damage.
Misc. damage:	Gutters, lightning rods, and cables.

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[9] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[10] Data for damages are taken from the Project Information Report, which can be obtained from the Parish.

[11] This cost only includes repairs to damages due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

7.6.1.1.1.4 Katrina Event

Date	Time	Event
8/28/2005	1:00 PM	The survey states that the canal was pumped down to 7.0 ft.
	5:00 PM	The survey states that the station was evacuated and all the pumps were turned off.
8/29/2005	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	10:00 PM	The survey states that the crews returned after the storm and observed that rain water had entered pump station through the damaged roof. The control panel was also damaged. Water in the street was up to 4 ft. and the water in the canal was at 17.5 ft.
	11:00 PM	The survey states that the operators restarted pumps 3, 4, and 5. Pumps 1 and 2 could not be operated due to high levels of water in Lake Pontchartrain.
8/30/2005	-	The survey states that the crews operated 3 diesel pumps for 12 hours until un-watering was complete.

7.6.1.1.1.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.1.1.1.6 Pump Operational Curves

Operational curves have been developed for Bonnabel. They are not included in this report at this time, but will be inserted in the future.

7.6.1.1.1.7 Pump Reverse Flow

There are three pumps at this station for which reverse flow rating curves were computed (two pumps were excluded). Reverse flow rating curves were not computed for pumps 1 and 2 because the pumps had closed gate valves during the storm. The reverse flow data and curves are presented in the order of the pump numbering utilized in the summary tables included in this appendix. In cases where there are multiple pumps of equivalent size and system configuration, a single rating curve represents all of them at a unit rate per pump.

Pump No.	Pump Capacity (cfs)	Pump Size (in)	Reverse Flow Computed?		Rating Curve Ref. No.
			Yes	No	
1	300	84		X	
2	300	84		X	
3	1050	132	X		1
4	1050	132	X		1
5	1050	132	X		1

For a general explanation of reverse flow (terminology, figures, methodology, equations and assumptions), refer to the Reverse Flow Section at the beginning of this appendix. Reverse flow computations for a given pump station do not necessarily imply that reverse flow actually occurred there during the Katrina event. But these curves may instead be used as future tools if further investigations are required based on reverse flow assumptions.

1. Reverse Flow Rating Curve

#1 - Bonnabel PS, P3, P4, P5 - 132 in.

Elevation Datum (ft):	Cairo
Crest Elevation (ft) =	29.5

H1 = Lake or outlet canal water level (normal pump discharge side)
H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use* $Q = \mathrm{sqrt}((H1-H2)/K')$

$K' =$ *1.26444E-05* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 29.5 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal

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reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 33.0 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.							
H2 =	8.0	10.0	12.0	14.0	16.0	18.0	20.0
H1 >	38	37	37	37	36	36	35

Water elevation (H1) that stops unprimed flow: 29.5 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 16.5 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.

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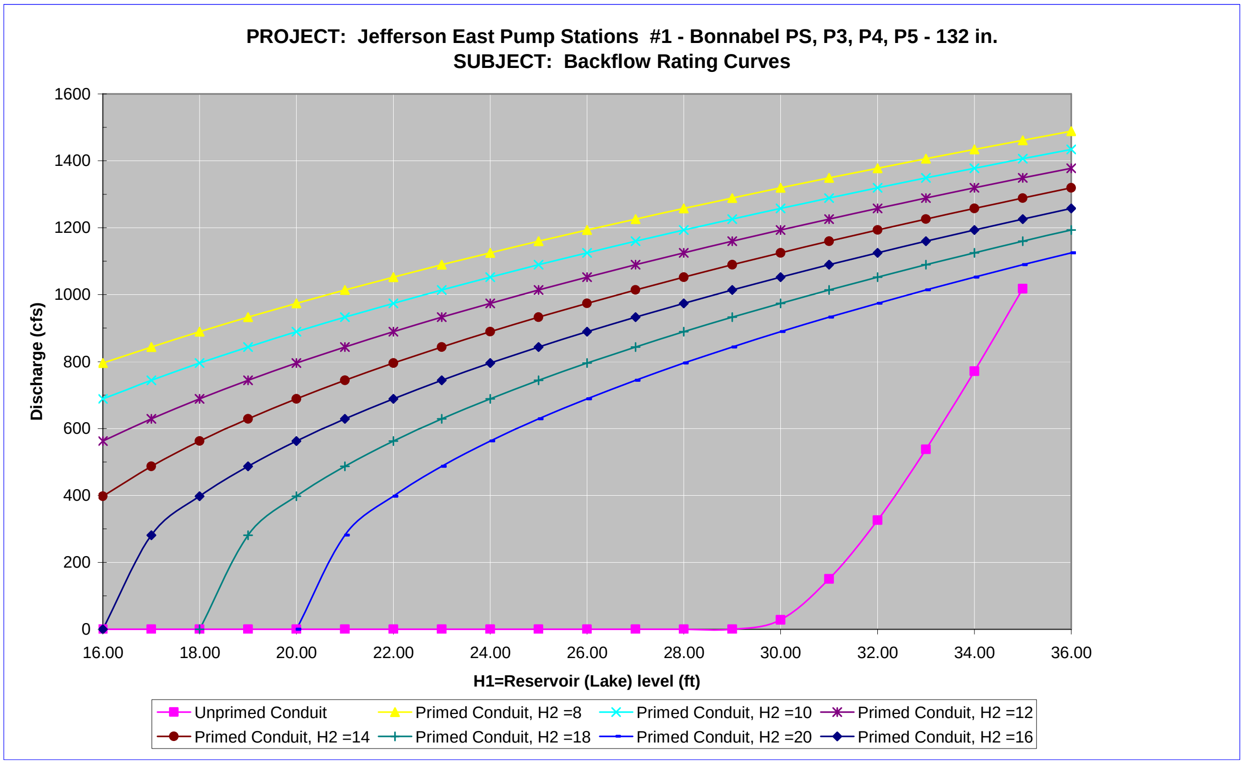

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:
Pump loss coefficient = 6.50
Intake loss = 0.5
Exit Loss = 1.0
Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Discharge conduit derived and scaled from PS#1 drawing: Discharge Tube Area Floor Plan.

Pump Intake appears same as JPE PS #4.

Elevations in Cairo Datum.

4 Data Needs or Deficiencies:

More complete drawings for intake and discharge tubes with elevations & dimensions.

5 Backflow prevention:

Available: Pumps 3, 4, and 5 (diesel) use air suppression.
Mechanism to prevent reverse rotation.

Used: Used air suppression, but operator indicated that water got high enough to overcome air suppression and reverse flow did come back through pumps 3, 4, and 5.

7.6.1.1.1.8 Fuel Endurance Calculations

Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. To calculate the time, a few assumptions are required. The first assumption is the HHV[12] of diesel fuel being used is 130,000 Btu[13] per gallon of fuel[14]. The second assumption is the diesel engines are at least 35% efficient[15]. This station has 4 diesel driven pumps with the same rated horsepower and 1 diesel generator. The station did not report any issues with running out of fuel. Below are the fuel endurance calculations.

---

[12] High heating value

[13] British thermal units

[14] http://www.exxon.com/USA-English/GFM/Products_Services/Fuels/Diesel_Fuels_FAQ.asp

[15] Standard Handbook for Mechanical Engineers, Eighth Edition, pg 9-106

The rated wattage of the diesel generator $G := 1660\text{kW}$ $\text{hp} = 0.75\,\text{kW}$

The rated horsepower of the diesel driver $P := 3070\text{hp}$

The assumed efficiency of the diesels $\varepsilon := 35\%$

The actual power required from the fuel $G_a := \dfrac{G}{\varepsilon}$ $G_a = 6360.28\,\text{hp}$

$P_a := \dfrac{P}{\varepsilon}$ $P_a = 8771.43\,\text{hp}$

The higher heating value $\text{HHV} := 130000\,\dfrac{\text{BTU}}{\text{gal}}$

The burn rate

$BR_1 := \dfrac{G_a}{\text{HHV}}$ $BR_1 = 124.49\,\dfrac{\text{gal}}{\text{hr}}$

$BR_2 := \dfrac{P_a}{\text{HHV}}$ $BR_2 = 171.68\,\dfrac{\text{gal}}{\text{hr}}$

There are 2-19,500 gallon tanks and 4-475 gallon tanks at this station.

Total volume of fuel $V_T := (2\cdot 19500 + 4\cdot 475)\text{gal}$

The fuel endurance of the station $FE := \dfrac{V_T}{BR_1 + 4BR_2}$ $FE = 50.42\,\text{hr}$

$FE = 2.1\,\text{day}$

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.1.1.2 *Suburban*

Jefferson Parish – East Bank Drainage Basin

4800 Lake Villa Dr
Metairie, LA 70006

Latitude: 30.02035˚ Longitude: -90.18110˚

7.6.1.1.2.1 Before and After Hurricane Katrina Photos

Before Hurricane Katrina: View from the inlet canal

Before Hurricane Katrina: Aerial view of the pump station

After Hurricane Katrina: View from the discharge

After Hurricane Katrina: Aerial view of the pump station

7.6.1.1.2.2 Description[16]

Drainage area:	East Bank
Nominal Capacity:	5155 cfs
Drains water from:	Suburban Canal
Discharges water to:	Lake Pontchartrain
Owner:	Jefferson Parish Department of Drainage
Number of pumps:	8
Pump orientation:	4 horizontal 4 vertical
Pump driver:	2 electric 60 Hz motors 6 diesels
Water level to switch pumps on:	8.1 feet (Cairo)
Water level to switch pumps off:	8.0 feet (Cairo)
Water level that affects operation:	24 feet (Cairo). Water will enter backup generator.
Reverse flow protection:	Pumps 4, 5, and 6 have gate valves. Pumps 1, 2, 7, and 8 use air suppression. Pump 3 contains no backflow prevention system.

7.6.1.1.2.3 [17]Damages

Estimated cost of repairs:	$23,000[18]
Relative level of damage:	Minor
Severity of circumstances:	Flooding reached the basement, but not the operating floor
Equipment damaged:	Two control panels for the sump pumps, motor operated valves.
Building damage:	Damage done to the doors.
Misc. damage:	Damage consists of flapper for exhaust cover and lighting.

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[16] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[17] Data for damages are taken from the Project Information Report, which can be obtained from the Parish.

[18] This cost only includes repairs to damages due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

7.6.1.1.2.4 Katrina Event

Date	Time	Event
8/28/2005	-	The operators checked the automatic controls.
	5:00 PM	The operators evacuated the station.
	-	The operator came back to the station at night and the canal elevation was at 13.5 ft (Cairo). The pumps were on.
8/29/2005	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	-	The survey states the pumps are automatic, so the pumps ran through out the storm. Pump 3 was damaged due to debris inside the pump. The operator reversed the flow to clean out debris and the pump was back online.
8/30/2005	-	The survey states that the operators set up the pumps to make sure that no water flowed into the 17th street canal. The intake canal did not need to be pumped down.

7.6.1.1.2.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.1.1.2.6 Pump Operational Curves

Operational curves have been developed for Suburban. They are not included in this report at this time, but will be inserted in the future.

7.6.1.1.2.7 Pump Reverse Flow

There are five pumps at this station for which reverse flow rating curves were computed (three pumps were excluded). Reverse flow rating curves were not computed for pumps 4, 5 and 6 because the pumps had closed gate valves during the non-operating period of the storm. The reverse flow data and curves are presented in the order of the pump numbering utilized in the summary tables included in this appendix. In cases where there are multiple pumps of equivalent size and system configuration, a single rating curve represents all of them at a unit rate per pump.

Pump No.	Pump Capacity (cfs)	Pump Size (in)	Reverse Flow Computed?		Rating Curve Ref. No.
			Yes	No	
1	1050	132	X		1
2	1050	132	X		1
3	55	30	X		2
4	300	84		X	
5	300	84		X	
6	300	84		X	
7	1050		X		3
8	1050		X		3

For a general explanation of reverse flow (terminology, figures, methodology, equations and assumptions), refer to the Reverse Flow Section at the beginning of this appendix. Reverse flow computations for a given pump station do not necessarily imply that reverse flow actually occurred there during the Katrina event. But these curves may instead be used as future tools if further investigations are required based on reverse flow assumptions.

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Reverse Flow Rating Curve

2 - Suburban PS, P1, P2 - 132 in.

Elevation Datum (ft): Cairo

Crest Elevation (ft) = 28.43

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use* $Q = \mathrm{sqrt}((H1-H2)/K')$

K' = *1.36864E-05* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 28.4 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal

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reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 32.2 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

H2 =	8.0	10.0	12.0	14.0	16.0	18.0	20.0
H1 >	37	37	36	36	35	35	35

Water elevation (H1) that stops unprimed flow: 28.4 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 14.8 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.

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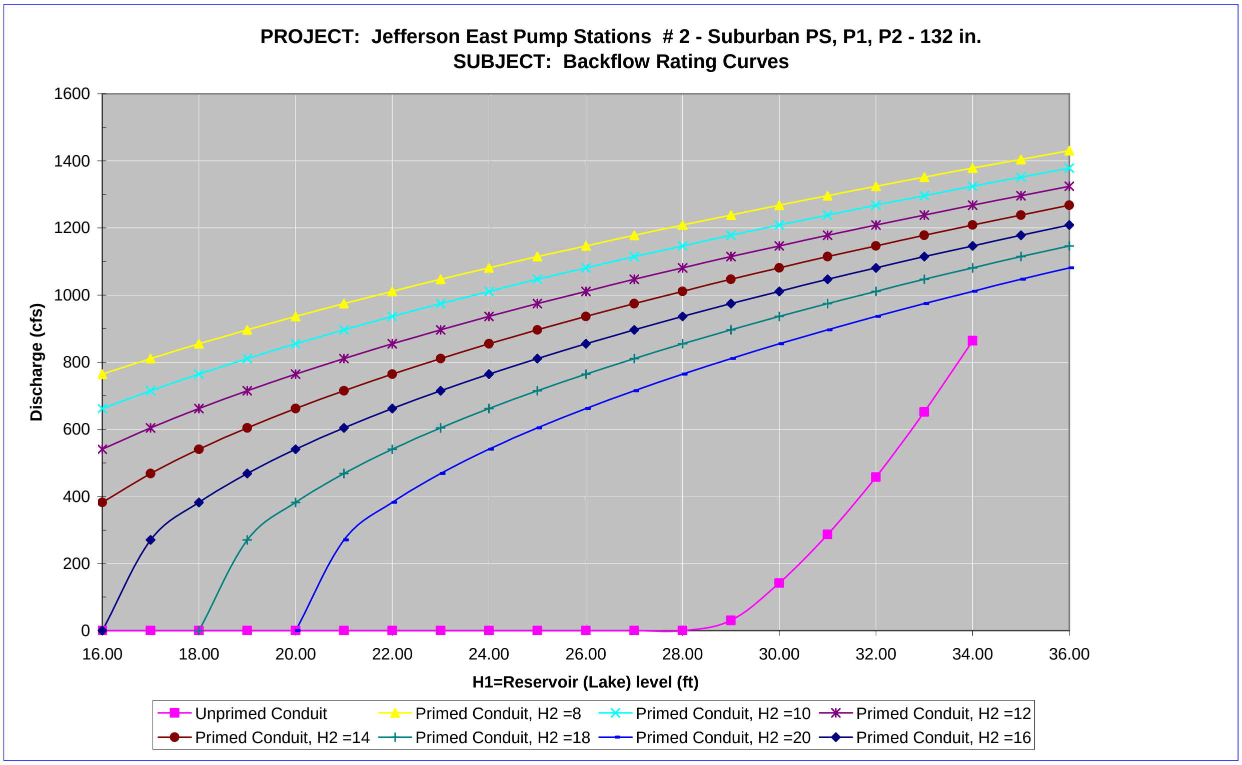

Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	6.50
Intake loss =	0.5
Exit Loss =	1.0

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Pump 1 & 2 per survey are same as pumps 6 & 1 in drawings, respectively.
Configuration of systems for Pump 2 = Pump 1
Elevations in Cairo Datum.

4 Data Needs or Deficiencies:

Clarifying drawings that distinguish between pump 1 & 2 (since pump 1 was installed years later).

5 Backflow prevention:

Available:	Pumps 1 & 2 use air suppression. Mechanism to prevent reverse rotation.
Used:	Operators believe reverse flow occurred.

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Reverse Flow Rating Curve

2 - Suburban PS, P3 - 30 in.

Elevation Datum (ft): Cairo

Crest Elevation (ft) = 26

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use* $Q = \mathrm{sqrt}((H1-H2)/K')$

$K' = 0.002871342 \quad sec^2/ft^5$

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 26.0 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal

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reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 29.0 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.							
H2 =	8.0	10.0	12.0	14.0	16.0	18.0	20.0
H1 >	34	33	33	32	32	31	31

Water elevation (H1) that stops unprimed flow: 26.0 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 20.9 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.

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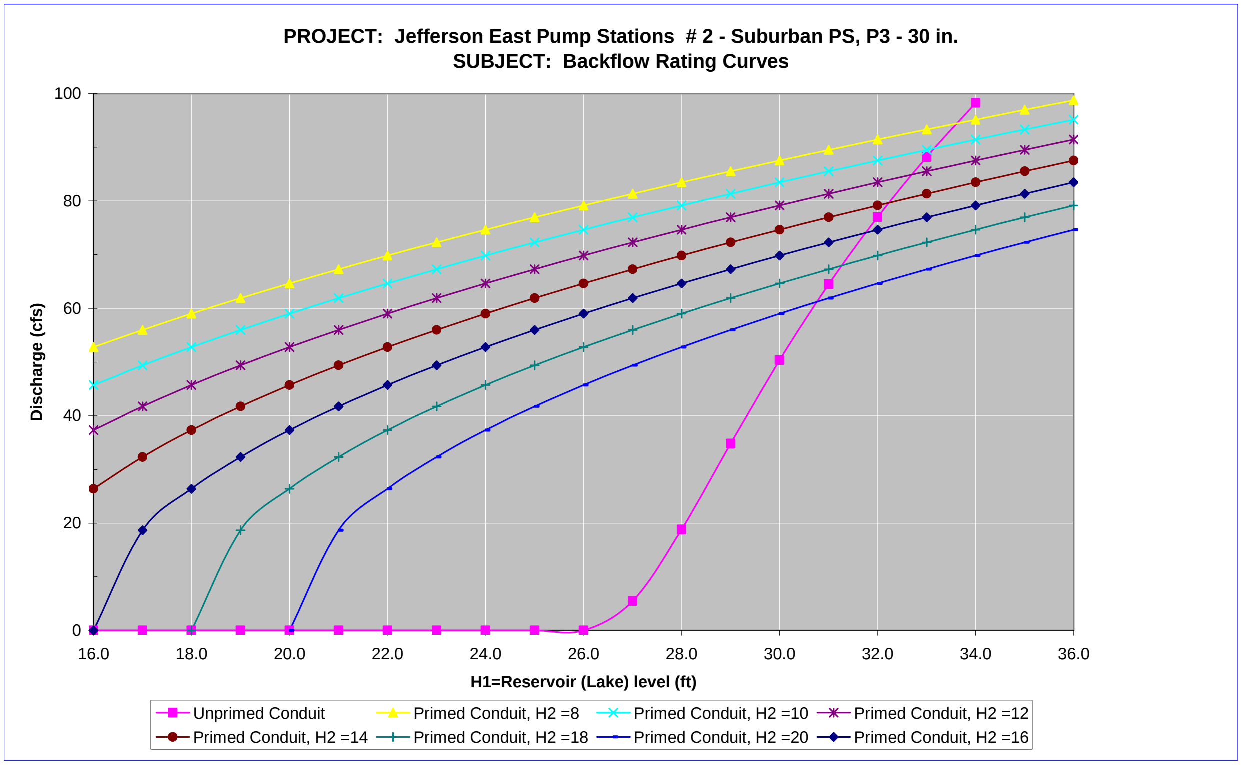

Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	6.50
Intake loss =	0.92
Exit Loss =	1.3

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Assume crest elevation = 26 feet per as-built--not 30 feet as stated in survey.
Elevations in Cairo Datum.

4 Data Needs or Deficiencies:

5 Backflow prevention:

Available:	No backflow prevention. Mechanism to prevent reverse rotation.
Used:	Operators believe reverse flow occurred.

Reverse Flow Rating Curve

2 - Suburban PS, P7, P8 - 144 x 132 in.

Elevation Datum (ft):	Cairo
Crest Elevation (ft) =	29.5

H1 = Lake or outlet canal water level (normal pump discharge side)
H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use Q = sqrt((H1-H2)/K')*
K' = *1.25734E-05* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 29.5 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal

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reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 33.5 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

H2 =	8.0	10.0	12.0	14.0	16.0	18.0	20.0
H1 >	38	38	37	37	37	36	36

Water elevation (H1) that stops unprimed flow: 29.5 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 13.5 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.

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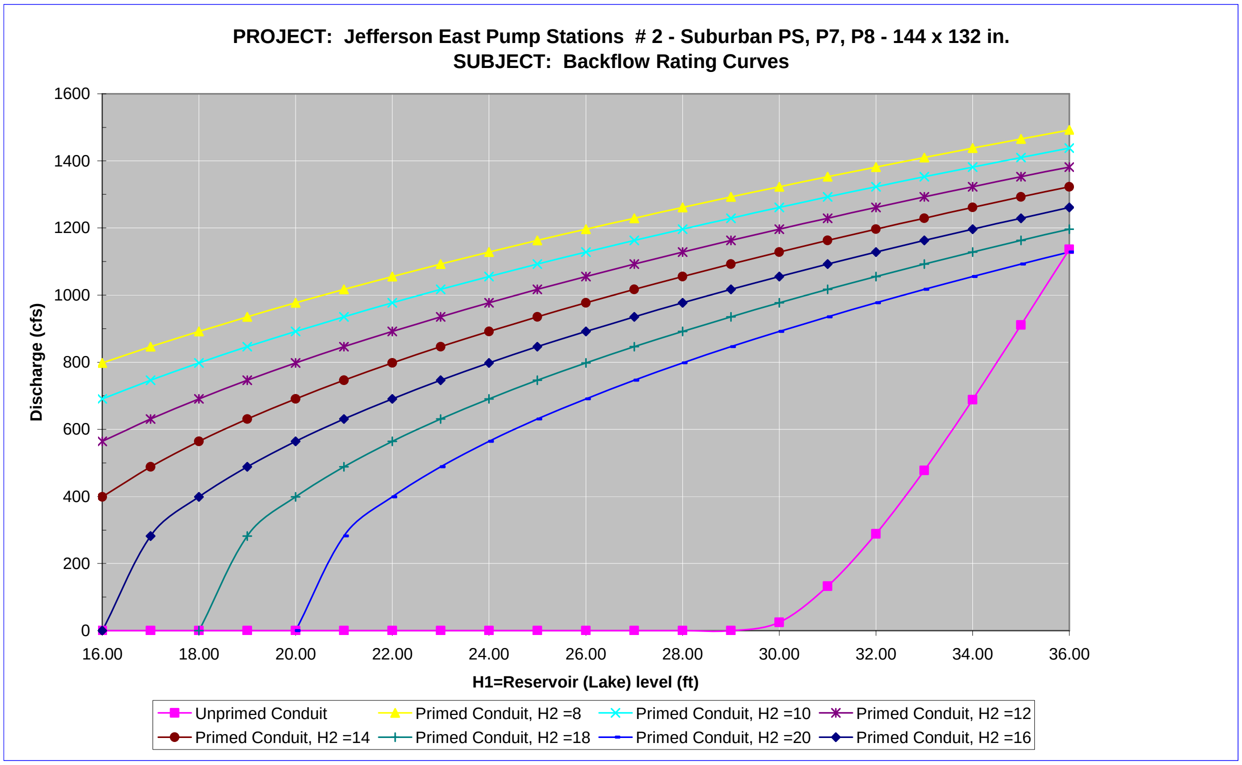

Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	6.50
Intake loss =	0.5
Exit Loss =	1.0

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

No drawings provided that specifically apply to pumps 7 & 8.

Assume 1997 drawings for Suburban apply (designed after latest installation of pump 1-6, 1983).

PS 7 & 8 installed in 2005, per survey.

Assume 132" impeller-- Based on Pump H-Q rating curve provided.

(Summary worksheet has pump size at 102 X 84")

Elevations in Cairo Datum.

4 Data Needs or Deficiencies:

Drawings of pump stations 7 & 8

5 Backflow prevention:

Available: Pumps 7 & 8 use air suppression.

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	Mechanism to prevent reverse rotation.
Used:	Air Injection failed to prevent reverse flow due to air leakage.
	Operator believed pump 8 had reverse flow.

7.6.1.1.2.8 Fuel Endurance Calculations

Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. To calculate the time, a few assumptions are required. The first assumption is the HHV[19] of diesel fuel being used is 130,000 Btu[20] per gallon of fuel[21]. The second assumption is the diesel engines are at least 35% efficient[22]. This station has 7 diesel driven pumps with different rated horsepower. The station did not report any issues with running out of fuel. Below are the fuel endurance calculations.

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[19] High heating value

[20] British thermal units

[21] http://www.exxon.com/USA-English/GFM/Products_Services/Fuels/Diesel_Fuels_FAQ.asp

[22] Standard Handbook for Mechanical Engineers, Eighth Edition, pg 9-106

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The rated horsepower of the diesel drivers $P_1 := 3070\,hp \quad P_2 := 2000\,hp$

$$P_3 := 1400\,hp \quad P_4 := 3400\,hp$$

The assumed efficiency of the diesels $\varepsilon := 35\%$

The actual power required from the fuel

$$P_{a1} := \frac{P_1}{\varepsilon} \qquad P_{a1} = 8771.43\ hp$$

$$P_{a2} := \frac{P_2}{\varepsilon} \qquad P_{a2} = 5714.29\ hp$$

$$P_{a3} := \frac{P_3}{\varepsilon} \qquad P_{a3} = 4000\ hp$$

$$P_{a4} := \frac{P_4}{\varepsilon} \qquad P_{a4} = 9714.29\ hp$$

The higher heating value $HHV := 130000\,\frac{BTU}{gal}$

The burn rates

$$BR_1 := \frac{P_{a1}}{HHV} \qquad BR_1 = 171.68\,\frac{gal}{hr}$$

$$BR_2 := \frac{P_{a2}}{HHV} \qquad BR_2 = 111.84\,\frac{gal}{hr}$$

$$BR_3 := \frac{P_{a3}}{HHV} \qquad BR_3 = 78.29\,\frac{gal}{hr}$$

$$BR_4 := \frac{P_{a4}}{HHV} \qquad BR_4 = 190.13\,\frac{gal}{hr}$$

There are 3-16,000 gallon tanks, 3-500 and 2-1,000 gallon tanks at this station.

Total volume of fuel $V_T := (3 \cdot 16000 + 3 \cdot 500 + 2 \cdot 1000)gal$

The fuel endurance of the station

$$FE := \frac{V_T}{BR_1 + BR_2 + 2BR_3 + 2BR_4} \qquad FE = 62.78\ hr$$

$$FE = 2.62\ day$$

7.6.1.1.3 *Elmwood*

Jefferson Parish – East Bank Drainage Basin

5400 Caryota Dr
Metairie, LA 70003

Latitude: 30.03208˚ Longitude: -90.21911˚

7.6.1.1.3.1 Before and After Hurricane Katrina Photos

Before Hurricane Katrina: View from the side

Before Hurricane Katrina: Aerial view of the pump station

After Hurricane Katrina: View from the intake canal

After Hurricane Katrina: Aerial view of the pump station

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7.6.1.1.3.2 Description[23]

Drainage area:	East Bank
Nominal Capacity:	5910 cfs
Drains water from:	Elmwood Canal
Discharges water to:	Lake Pontchartrain
Owner:	Jefferson Parish Department of Drainage
Number of pumps:	10
Pump orientation:	2 horizontal 8 vertical
Pump driver:	10 diesels
Discharge gates:	8 gate valves
Water level to switch pumps on:	8.5 feet (Cairo)
Water level to switch pumps off:	8.2 feet (Cairo)
Water level that affects operation:	25.5 feet (Cairo). Water enters diesel engine starter near pumps 9 and 10.
Reverse flow protection:	Pumps 1-8 all use gate valves and air suppression for backflow prevention. Pumps 9 and 10 use air suppression only.

7.6.1.1.3.3 Damages[24]

Estimated cost of repairs:	$251,000[25]
Relative level of damage:	Minor
Severity of circumstances:	Flooding reached the basement, but not the operating floor.
Equipment damaged:	No significant equipment damage was recorded.
Building damage:	Roof, windows, and vent stack are all damaged.
Misc. damage:	Exhaust covers and lighting damage.

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[23] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[24] Data for damages are taken from the Project Information Report, which can be obtained from the Parish.

[25] This cost only includes repairs to damages due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

7.6.1.1.3.4 Katrina Event

Date	Time	Event
8/28/2005	-	The survey states that all the pumps were operational prior to the hurricane.
	-	The survey states that canal was pumped down to 7.0 ft. The operators put the horizontal pumps on air suppression and closed the gate valves on the smaller pumps.
	5:00 PM	The operators evacuated station.
8/29/2005	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	-	During the storm, all the gate valves were closed and the horizontal pumps were air suppressed. Reverse flow did likely occur through the system and the street was flooded to approximately 18ft.
	-	The survey states that water did not reach main slab where pumps were located. However, water was in the basement up to elevation 17.5 ft (Cairo Datum)
	10:30 PM	The survey states that the operators returned to the station. The power was out. The operators observed canal level of around 18ft. The generator was turned on.
	11:30 PM	The survey states that the operators began running Pumps 1 through 8. Pumps 9 and 10 were not running because a new operator was not familiar with the new pumps.
8/31/2005	8:30 AM	The survey states that the un-watering was complete. The canal had returned to normal operation levels.

7.6.1.1.3.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.1.1.3.6 Pump Operational Curves

Operational curves have been developed for Elmwood. They are not included in this report at this time, but will be inserted in the future.

7.6.1.1.3.7 Pump Reverse Flow

There are two pumps at this station for which reverse flow rating curves were computed (no pumps were excluded). The reverse flow data and curves are presented in the order of the pump numbering utilized in the summary tables included in this appendix. In cases where there are multiple pumps of equivalent size and system configuration, a single rating curve represents all of them at a unit rate per pump.

Pump No.	Pump Capacity (cfs)	Pump Size (in)	Reverse Flow Computed?		Rating Curve Ref. No.
			Yes	No	
9	1250	132	X		1
10	1250	132	X		1

For a general explanation of reverse flow (terminology, figures, methodology, equations and assumptions), refer to the Reverse Flow Section at the beginning of this appendix. Reverse flow computations for a given pump station do not necessarily imply that reverse flow actually occurred there during the Katrina event. But these curves may instead be used as future tools if further investigations are required based on reverse flow assumptions.

Reverse Flow Rating Curve

3 - Elmwood PS, P9, P10 - 132 in.

Elevation Datum (ft):	Cairo
Crest Elevation (ft) =	24

H1 = Lake or outlet canal water level (normal pump discharge side)
H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use* $Q = \mathrm{sqrt}((H1-H2)/K')$
$K' =$ 1.27125E-05 sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 24.0 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated

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unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 35.0 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

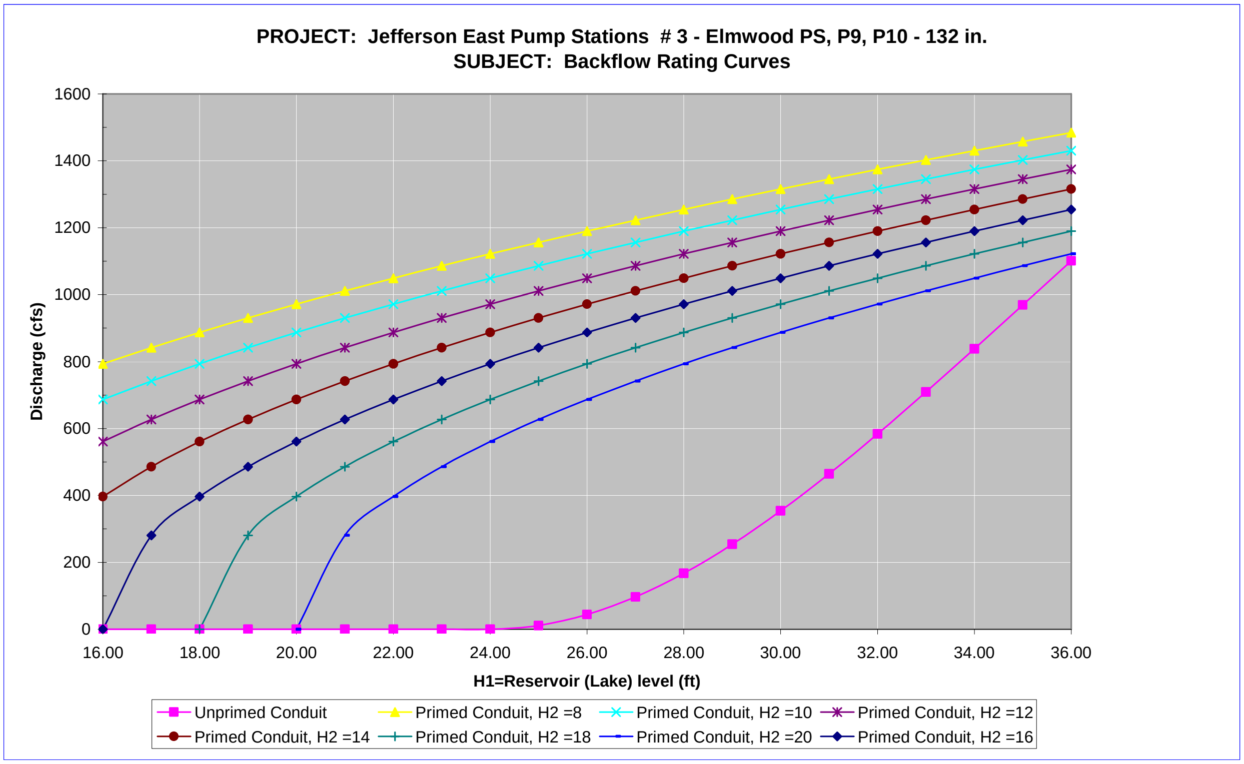
H2 =	8.0	10.0	12.0	14.0	16.0	18.0	20.0
H1 >	41	40	40	39	39	39	38

Water elevation (H1) that stops unprimed flow: 24.0 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 18.0 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	6.50
Intake loss =	0.92
Exit Loss =	1.0

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

No drawings provided that specifically apply to pumps 9 & 10, installed in 2004.

Assume 1997 drawings for Suburban PS #2 apply for pump intake side.

Both use have same pumps and were installed 1 year apart.

Assume 132" impeller-- Based on Pump H-Q rating curve provided.

Survey states discharge piping is same configuration as other pumps at PS#3.

Assume discharge piping is proportional to 1999 As-built drawing No. 9: Discharge Piping Geometry.

3 Data Assumptions continued:

Approximate representative diameter for outlet diffuser.

Elevations in Cairo Datum.

4 Data Needs or Deficiencies:

Drawings of Intake and Discharge piping.

5 Backflow prevention:

Available:	Pumps 9 and 10 (horizontal) use air suppression. Mechanism to prevent reverse rotation.
Used:	Operator say reverse flow occurred. He felt the current from the pump station trying to push him out towards the canal. Backflow would have been through pumps 9 and 10. Street was flooded to elevation 18 feet.

7.6.1.1.3.8 Fuel Endurance Calculation

Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. To calculate the time, a few assumptions are required. The first assumption is the HHV[26] of diesel fuel being used is 130,000 Btu[27] per gallon

---

[26] High heating value

[27] British thermal units

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

of fuel[28]. The second assumption is the diesel engines are at least 35% efficient[29]. This station has 10 diesel driven pumps with different rated horsepower. The station did not report any issues with running out of fuel. Below are the fuel endurance calculations.

The rated horsepower of the diesel drivers $P_1 := 793\text{hp} \quad P_2 := 1276\text{hp} \quad P_3 := 3400\text{hp}$

The assumed efficiency of the diesels $\varepsilon := 35\%$

The actual power required from the fuel

$$P_{a1} := \frac{P_1}{\varepsilon} \qquad P_{a1} = 2265.71\ \text{hp}$$

$$P_{a2} := \frac{P_2}{\varepsilon} \qquad P_{a2} = 3645.71\ \text{hp}$$

$$P_{a3} := \frac{P_3}{\varepsilon} \qquad P_{a3} = 9714.29\ \text{hp}$$

The higher heating value

$$HHV := 130000\,\frac{\text{BTU}}{\text{gal}}$$

The burn rates

$$BR_1 := \frac{P_{a1}}{HHV} \qquad BR_1 = 44.35\,\frac{\text{gal}}{\text{hr}}$$

$$BR_2 := \frac{P_{a2}}{HHV} \qquad BR_2 = 71.36\,\frac{\text{gal}}{\text{hr}}$$

$$BR_3 := \frac{P_{a3}}{HHV} \qquad BR_3 = 190.13\,\frac{\text{gal}}{\text{hr}}$$

There are 3-16,000 gallon tanks, 4-475 gallon tanks and 2-1,000 gallon tanks at this station.

Total volume of fuel

$$V_T := (3\cdot 16000 + 4\cdot 475 + 2\cdot 1000)\text{gal}$$

The fuel endurance of the station

$$FE := \frac{V_T}{4BR_1 + 4BR_2 + 2BR_3} \qquad FE = 61.56\,\text{hr}$$

$$FE = 2.57\,\text{day}$$

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[28] http://www.exxon.com/USA-English/GFM/Products_Services/Fuels/Diesel_Fuels_FAQ.asp

[29] Standard Handbook for Mechanical Engineers, Eighth Edition, pg 9-106

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.1.1.4 *Duncan*

Jefferson Parish – East Bank Drainage Basin

1600 Joseph Yenni Blvd
Kenner, LA 70065

Latitude: 30.03833˚ Longitude: -90.24498˚

7.6.1.1.4.1 Before and After Hurricane Katrina Photos

Before Hurricane Katrina: View from the side

Before Hurricane Katrina: Aerial view of the pump station

After Hurricane Katrina: View from the discharge side

After Hurricane Katrina: Aerial view of the pump station

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.1.1.4.2 Description[30]

Drainage area: East Bank

Nominal Capacity: 4800 cfs

Drains water from: Duncan Canal

Discharges water to: Lake Pontchartrain

Owner: Jefferson Parish Department of Drainage

Number of pumps: 6

Pump orientation: 4 horizontal
2 vertical

Pump driver: 2 electric 60 Hz motors
4 diesel

Discharge gates: 2 gate valves

Water level to switch pumps on: 8.5 feet (Cairo)

Water level to switch pumps off: 8.0 feet (Cairo)

Water level that affects operation: 14.5 feet (Cairo). Water will enter gearbox on diesel pumps

Reverse flow protection: Pumps 1 and 2 have gate valves. Pumps 3, 4, 5, and 6 all use air suppression.

7.6.1.1.4.3 Damages[31]

Estimated cost of repairs: $142,000[32]

Relative level of damage: Minor

Severity of circumstances: Water did not flood the station.

Equipment damaged: No significant equipment damage was recorded.

Building damage: There was approximately 7,700 sq. ft. of roof damage.

Misc. damage: Damage consists of gutters, exhaust covers, lightning rods/cables, and exterior lighting.

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[30] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[31] Data for damages are taken from the Project Information Report, which can be obtained from the Parish.

[32] This cost only includes repairs to damages due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

7.6.1.1.4.4 Katrina Event

Date	Time	Event
8/28/2005	-	The survey states that all the pumps were operational prior to Hurricane Katrina.
	-	The survey states that the canal was pumped down to 7.0 ft. The operators put horizontal pumps on air suppression and closed the gate valves on smaller pumps (the pumps were shut down).
	5:00 PM	The operators were given the order to evacuate.
8/29/2005	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	-	The survey states that water did not come into the station. During the storm all the gate valves were closed and the diesel pumps were air suppressed. Reverse flow did likely occur due to the high level of discharge.
8/31/2005	-	The survey states that Pump 3 was operational and was used to aid in un-watering. Water was off the streets around the station. The water level in the canal was around 12 ft.
9/5/2005	-	The survey states that the canal was down to normal operating levels.

7.6.1.1.4.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.1.1.4.6 Pump Operational Curves

Operational curves have been developed for Duncan. They are not included in this report at this time, but will be inserted in the future.

7.6.1.1.4.7 Pump Reverse Flow

There are six pumps at this station for which reverse flow rating curves were computed (two pumps were excluded). The reverse flow data and curves are presented in the order of the pump numbering utilized in the summary tables included in this appendix. In cases where there are multiple pumps of equivalent size and system configuration, a single rating curve represents all of them at a unit rate per pump.

Pump No.	Pump Capacity (cfs)	Pump Size (in)	Reverse Flow Computed?		Rating Curve Ref. No.
			Yes	No	
1	300	84	X		1
2	300	84	X		1
3	1050	132	X		2
4	1050	132	X		2
5	1050	132	X		2
6	1050	132	X		2

For a general explanation of reverse flow (terminology, figures, methodology, equations and assumptions), refer to the Reverse Flow Section at the beginning of this appendix. Reverse flow computations for a given pump station do not necessarily imply that reverse flow actually occurred there during the Katrina event. But these curves may instead be used as future tools if further investigations are required based on reverse flow assumptions.

Reverse Flow Rating Curve

4 - Duncan PS, P1, P2 - 84 in.

Elevation Datum (ft): Cairo

Crest Elevation (ft) = 24.1

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use* $Q = \mathrm{sqrt}((H1-H2)/K')$

$K' =$ *0.000172428* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 24.1 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated

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unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 31.1 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

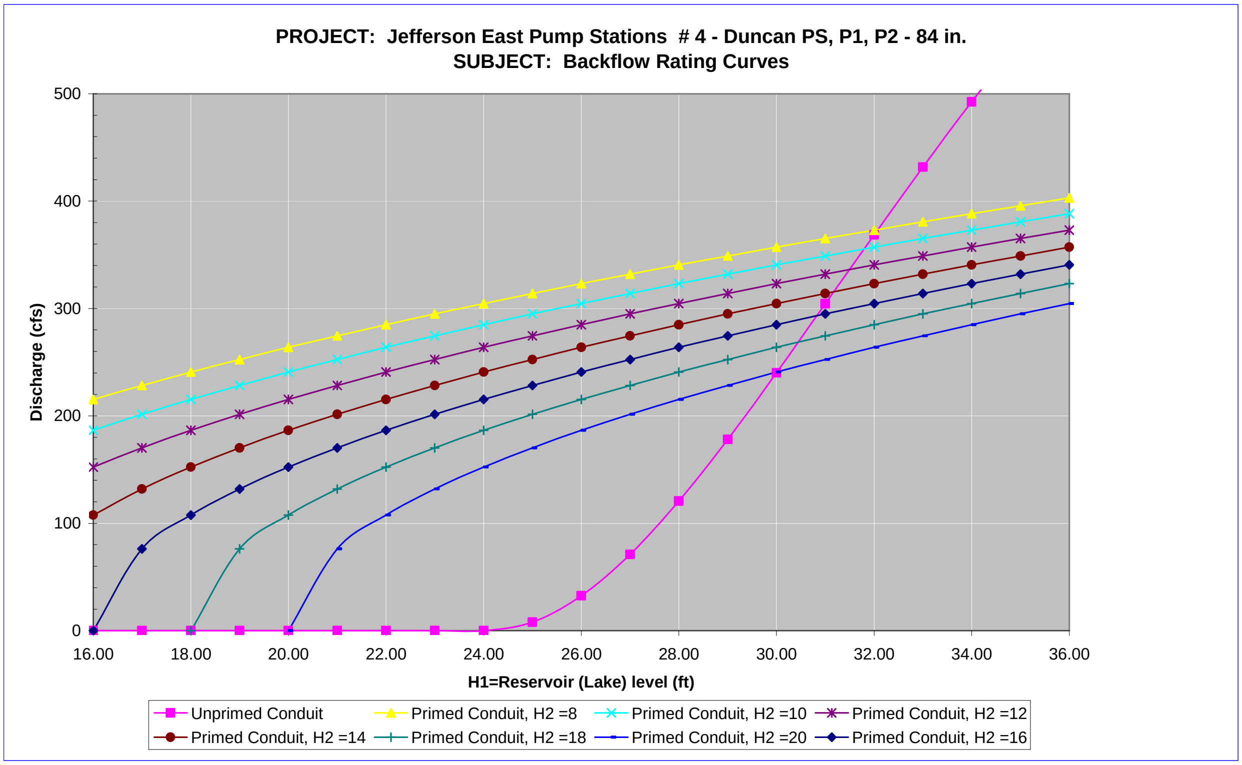
H2 =	8.0	10.0	12.0	14.0	16.0	18.0	20.0
H1 >	33	33	33	33	32	32	32

Water elevation (H1) that stops unprimed flow: 24.1 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 18.7 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	6.50
Intake loss =	0.92
Exit Loss =	1.3

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Elevations in Cairo Datum.

4 Data Needs or Deficiencies:

None

5 Backflow prevention:

Available:	Gate Valves. Mechanism to prevent reverse rotation.
Used:	Operators says reverse flow occurred in Pumps 1 & 2. Gates were closed during storm. The pumps were later turned on then automatically shut down due to high head pressure. Safety lock prevents restarting pumps for 30 minutes and backflow occurred. The operators could not close the valves because the high level of discharge prevented access.

Reverse Flow Rating Curve

4 - Duncan PS, P3, P4, P5, P6 - 132 in.

Elevation Datum (ft):	Cairo
Crest Elevation (ft) =	29.5

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

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For primed flow rates: *Use* $Q = \mathrm{sqrt}((H1-H2)/K')$
K' = *1.24929E-05* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 29.5 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 33.0 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

H2 =	8.0	10.0	12.0	14.0	16.0	18.0	20.0
H1 >	38	37	37	37	36	36	35

Water elevation (H1) that stops unprimed flow: 29.5 ft

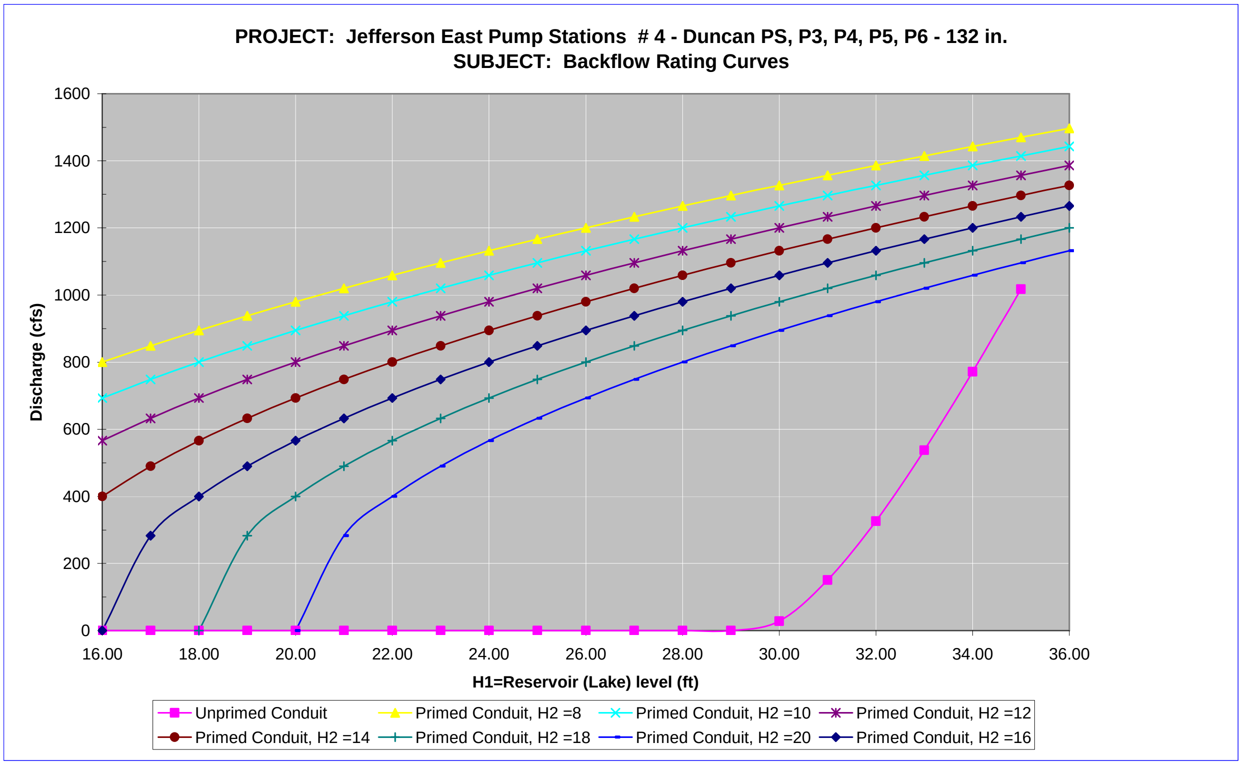
Unprimed flow stops at the same H1 that initiates unprimed flow.

16.5 ft

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Water elevation (H1) that stops primed conduit flow:

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	6.50
Intake loss =	0.5
Exit Loss =	1.0

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Assume same configuration of PS#1 (Bonnabel) pumps 3-5.

Pump Intake appears same as PS #1--which listed dimensions.

Discharge conduit derived and scaled from PS#1 drawings (Discharge Tube Area Floor Plan).

Comparable dimensions are the same with PS#1.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Elevations in Cairo Datum.

4 Data Needs or Deficiencies:

More complete drawings for intake and discharge tubes with elevations & dimensions.

5 Backflow prevention:

Available:	Pumps 3 - 6 use air suppression. Mechanism to prevent reverse rotation.
Used:	Operators believe reverse flow occurred. 300 cfs pumps (1 & 2) reverse flowed; operators assume 1050 cfs pumps (3 - 6) also reverse flowed.

7.6.1.1.4.8 Fuel Endurance Calculations

Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. To calculate the time, a few assumptions are required. The first assumption is the HHV[33] of diesel fuel being used is 130,000 Btu[34] per gallon of fuel[35]. The second assumption is the diesel engines are at least 35% efficient[36]. This station has 4 diesel driven pumps with the same rated horsepower and 1 diesel generator. The station did not report any issues with running out of fuel. Below are the fuel endurance calculations.

---

[33] High heating value

[34] British thermal units

[35] http://www.exxon.com/USA-English/GFM/Products_Services/Fuels/Diesel_Fuels_FAQ.asp

[36] Standard Handbook for Mechanical Engineers, Eighth Edition, pg 9-106

The rated wattage of the diesel generator $G := 1660\text{kW}$ $hp = 0.75\,\text{kW}$

The rated horsepower of the diesel driver $P := 3070\text{hp}$

The assumed efficiency of the diesels $\varepsilon := 35\%$

The actual power required from the fuel $G_a := \frac{G}{\varepsilon}$ $G_a = 6360.28\,\text{hp}$

$P_a := \frac{P}{\varepsilon}$ $P_a = 8771.43\,\text{hp}$

The higher heating value $HHV := 130000\,\frac{\text{BTU}}{\text{gal}}$

The burn rate

$BR_1 := \frac{G_a}{HHV}$ $BR_1 = 124.49\,\frac{\text{gal}}{\text{hr}}$

$BR_2 := \frac{P_a}{HHV}$ $BR_2 = 171.68\,\frac{\text{gal}}{\text{hr}}$

There are 3-19,500 gallon tanks and 5-500 gallon tanks at this station.

Total volume of fuel $V_T := (3\cdot 19500 + 5\cdot 500)\text{gal}$

The fuel endurance of the station $FE := \frac{V_T}{BR_1 + 4BR_2}$ $FE = 75.2\,\text{hr}$

$FE = 3.13\,\text{day}$

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.1.1.5 *Parish Line*

Jefferson Parish – East Bank Drainage Basin

3100 Grand Lake
Kenner, LA 70065

Latitude: 30.01140˚ Longitude: -90.27838˚

7.6.1.1.5.1 Before and After Hurricane Katrina Photos

Before Hurricane Katrina: View from the intake canal

Before Hurricane Katrina: Aerial view of the pump station

After Hurricane Katrina: View from the side

After Hurricane Katrina: Aerial view of the pump station

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.1.1.5.2 Description[37]

Drainage area:	East Bank
Nominal Capacity:	885 cfs
Drains water from:	Grand Lake Canal
Discharges water to:	St. Charles Canal **(**Lake Pontchartrain)
Owner:	Jefferson Parish Department of Drainage
Number of pumps:	3
Pump orientation:	3 vertical
Pump driver:	3 electric 60 Hz motors
Water level to switch pumps on:	9.5 feet (Cairo)
Water level to switch pumps off:	9.0 feet (Cairo)
Water level that affects operation:	18 feet (Cairo). Water would enter transformer which would impact all pumps.
Reverse flow protection:	All three pumps have gate valves.

7.6.1.1.5.3 Damages[38]

Estimated cost of repairs:	$0[39]
Relative level of damage:	None
Severity of circumstances:	Water did not enter station.
Damages	No significant damages reported.

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[37] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[38] Data for damages are taken from the Project Information Report, which can be obtained from the Parish.

[39] This cost only includes repairs to damages due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.1.1.5.4 Katrina Event

Date	Time	Event
8/28/2005	-	All the pumps were operational prior to the arrival of Hurricane Katrina. The survey states that the canal was pumped down to 6.5ft. Closed gate valves on smaller groups.
	-	The operators were ordered to evacuate.
8/29/2005	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	-	During the storm, all gate valves were closed. The survey states that water did not come into station. However, water did enter basement of pump station at an elevation of 17.3ft.
	6:00 PM	The survey states that the operators returned to the station. The power was out. The operators observed a canal level of around 17.3ft. There were problems with the relay to bypass electric to put pumps on generator, so the pump station did not pump that day.
8/30/2005	12:00 PM	The survey states that pumping began with Pump 2 after the relay problem was fixed. At first, Pumps 1 and 3 were not used because their gate valves are manual and were difficult to reach after the hurricane. Pump 2 has an automatic gate valve.
8/31/2005	-	The canal was down to normal operating levels by evening.

7.6.1.1.5.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.1.1.5.6 Pump Operational Curves

Operational curves have been developed for Parish Line. They are not included in this report at this time, but will be inserted in the future.

7.6.1.1.5.7 Pump Reverse Flow

No reverse flow curves were developed for this station since all pumps were reported to have closed gate valves during the non-operating period of the storm.

7.6.1.1.5.8 Fuel Endurance Calculations

Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. To calculate the time, a few assumptions are required. The first assumption is the HHV[40] of diesel fuel being used is 130,000 Btu[41] per gallon of fuel[42]. The second assumption is the diesel engines are at least 35% efficient[43]. This station has 2 diesel generators with the same rated horsepower. The station did not report any issues with running out of fuel. Below are the fuel endurance calculations.

---

[40] High heating value

[41] British thermal units

[42] http://www.exxon.com/USA-English/GFM/Products_Services/Fuels/Diesel_Fuels_FAQ.asp

[43] Standard Handbook for Mechanical Engineers, Eighth Edition, pg 9-106

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

The rated wattage of the diesel generator	$G := 1500\text{kW}$	$\text{hp} = 0.75\,\text{kW}$
The assumed efficiency of the diesels	$\varepsilon := 35\%$	
The actual power required from the fuel	$G_a := \frac{G}{\varepsilon}$	$G_a = 5747.24\,\text{hp}$
The higher heating value	$HHV := 130000\,\frac{\text{BTU}}{\text{gal}}$	
The burn rate	$BR := \frac{G_a}{HHV}$	$BR = 112.49\,\frac{\text{gal}}{\text{hr}}$

There are 1-12,000 gallon tanks, 2-1,000 gallon tanks and 1-500 gallon tanks at this station.

Total volume of fuel	$V_T := (1\cdot 12000 + 1\cdot 500 + 2\cdot 1000)\text{gal}$	
The fuel endurance of the station	$FE := \frac{V_T}{2BR}$	$FE = 64.45\,\text{hr}$
		$FE = 2.69\,\text{day}$

7.6.1.1.6 *Canal Street*

Jefferson Parish – East Bank Drainage Basin

100 Canal St
Metairie, LA 70005

Latitude: 29.99055˚ Longitude: -90.12453˚

7.6.1.1.6.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina: View from the side

Before Hurricane Katrina: Aerial view of the pump station

After Hurricane Katrina: View from the intake canal

After Hurricane Katrina: Aerial view of the pump station

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.1.1.6.2 Description[44]

Drainage area:	East Bank
Nominal Capacity:	160 cfs
Drains water from:	Canal St. Canal
Discharges water to:	17th Street Canal (Lake Pontchartrain)
Owner:	Jefferson Parish Department of Drainage
Number of pumps:	4
Pump orientation:	4 vertical
Pump driver:	4 electric 60 Hz motors
Water level to switch pumps on:	15 feet (Cairo)
Water level to switch pumps off:	14 feet (Cairo)
Water level that affects operation:	24 feet (Cairo) Water would reach electrical panel inside building and stop pump operations.
Reverse flow protection:	None

7.6.1.1.6.3 Damages[45]

Estimated cost of repairs:	$0[46]
Relative level of damage:	None
Severity of circumstances:	Water did not enter station.
Damages	No significant damages reported.

---

[44] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[45] Data for damages are taken from the Project Information Report, which can be obtained from the Parish.

[46] This cost only includes repairs to damages due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.1.1.6.4 Katrina Event

Date	Time	Event
8/28/2005	-	The operators checked the automatic controls.
	5:00 PM	The operators evacuated the station.
	-	The operator came back to the station at night and the canal elevation was at 13.5 ft (Cairo). The pumps were on.
8/29/2005	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	-	The survey states the pumps are automatic, so the pumps ran through out the storm. Pump 3 was damaged due to debris inside the pump. The operator reversed the flow to clean out debris and the pump was back online.
8/30/2005	-	The survey states that the operators set up the pumps to make sure that no water flowed into the 17th street canal. The intake canal did not need to be pumped down.

7.6.1.1.6.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.1.1.6.6 Pump Operational Curves

Operational curves have been developed for Canal Street. They are not included in this report at this time, but will be inserted in the future.

7.6.1.1.6.7 Pump Reverse Flow

There are four pumps at this station for which reverse flow rating curves were computed (no pumps were excluded). The reverse flow data and curves are presented in the order of the pump numbering utilized in the summary tables included in this appendix. In cases where there are multiple pumps of equivalent size and system configuration, a single rating curve represents all of them at a unit rate per pump.

Pump No.	**Pump Capacity (cfs)**	**Pump Size (in)**	**Reverse Flow Computed?**		**Rating Curve Ref. No.**
			Yes	**No**	
1	40	30	X		1
2	40	30	X		1
3	40	30	X		1
4	40	30	X		1

For a general explanation of reverse flow (terminology, figures, methodology, equations and assumptions), refer to the Reverse Flow Section at the beginning of this appendix. Reverse flow computations for a given pump station do not necessarily imply that reverse flow actually occurred there during the Katrina event. But these curves may instead be used as future tools if further investigations are required based on reverse flow assumptions.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Reverse Flow Rating Curve

Canal Street PS, P1, P2, P3, P4 - 30 in.

Elevation Datum (ft): Cairo

Crest Elevation (ft) = 27

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: Use Q = sqrt((H1-H2)/K')

K' = 0.00691119 sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 27.0 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated

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unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 29.5 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

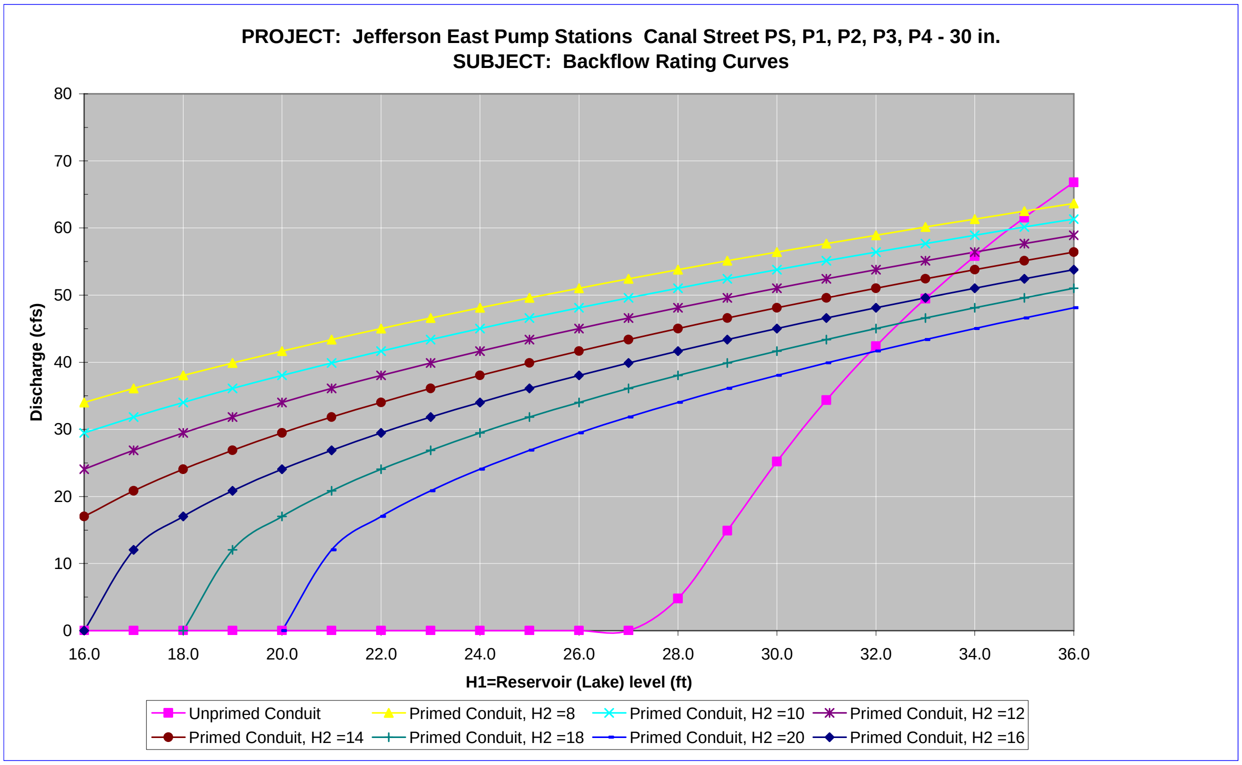
Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.							
H2 =	8.0	10.0	12.0	14.0	16.0	18.0	20.0
H1 >	35	35	34	34	33	33	32

Water elevation (H1) that stops unprimed flow: 27.0 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 16.0 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.



PROJECT: Jefferson East Pump Stations Canal Street PS, P1, P2, P3, P4 - 30 in.
SUBJECT: Backflow Rating Curves

Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	6.50
Intake loss =	0.92
Exit Loss =	1.3

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Pipe lengths for all pumps same as Pump 3 (actually vary).

Discharge piping shown in different datum (NGVD):

Converted to Cairo by matching CL elevations at crest.

Elevations in Cairo Datum

4 Data Needs or Deficiencies:

5 Backflow prevention:

Available:	Operator states there is no backflow prevention but elevation of discharge piping is high. Drawings show butterfly valves, however survey says there are no backflow prevention devices. Mechanism to prevent reverse rotation.
Used:	Operator states no reverse flow occurred, however no statement on closure of valves. Pumps were left running in automatic when operators left on 8/28. When rechecked on 8/29, pump 3 was blocked with debris. Reverse flow was used to clear debris and resume operation. All 4 pumps are electrically driven. Survey says all pumps were set to make sure no water flowed into 17th street canal.

7.6.1.1.6.8 Fuel Endurance Calculations

Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. To calculate the time, a few assumptions are required. The first assumption is the HHV[47] of diesel fuel being used is 130,000 Btu[48] per gallon of fuel[49]. The second assumption is the diesel engines are at least 35% efficient[50]. This station has 1 diesel generator. The station did not report any issues with running out of fuel. Below are the fuel endurance calculations.

---

[47] High heating value

[48] British thermal units

[49] http://www.exxon.com/USA-English/GFM/Products_Services/Fuels/Diesel_Fuels_FAQ.asp

[50] Standard Handbook for Mechanical Engineers, Eighth Edition, pg 9-106

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

The rated wattage of the diesel generator $G := 500\text{kW}$ $\text{hp} = 0.75\,\text{kW}$

The assumed efficiency of the diesels $\varepsilon := 35\%$

The actual power required from the fuel $G_a := \dfrac{G}{\varepsilon}$ $G_a = 1915.75\,\text{hp}$

The higher heating value $\text{HHV} := 130000\,\dfrac{\text{BTU}}{\text{gal}}$

The burn rate $\text{BR} := \dfrac{G_a}{\text{HHV}}$ $\text{BR} = 37.5\,\dfrac{\text{gal}}{\text{hr}}$

There is 1-12,000 gallon tank at this station.

Total volume of fuel $V_T := (1 \cdot 12000)\text{gal}$

The fuel endurance of the station $\text{FE} := \dfrac{V_T}{\text{BR}}$ $\text{FE} = 320.03\,\text{hr}$

$\text{FE} = 13.33\,\text{day}$

7.6.1.2 West Bank - Cataouatche Sub-Basin Stations

7.6.1.2.1 *Bayou Segnette*

Jefferson Parish – West Bank - West of Harvey (Cataouatche) Drainage Basin

801 Louisiana St
Westwego, LA 70094

Latitude: 29.89770˚ Longitude: -90.15793˚

7.6.1.2.1.1 Before and After Hurricane Katrina Photos

Before Hurricane Katrina: View from the side

Before Hurricane Katrina: Aerial view of the pump station

After Hurricane Katrina: View from the discharge

After Hurricane Katrina: Aerial view of the pump station

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.1.2.1.2 Description[51]

Drainage area: West Bank-West of Harvey (Cataouatche Sub basin)

Nominal Capacity: 2155 cfs

Drains water from: Main Canal

Discharges water to: Bayou Segnette

Owner: Jefferson Parish Department of Drainage

Number of pumps: 8

Pump orientation: 6 vertical
2 unknown

Pump driver: 8 diesel

Water level to switch pumps on: 11.5 feet (Cairo)

Water level to switch pumps off: 10.5 feet (Cairo)

Water level that affects operation: New building - 28.0 feet (Cairo) Water would flood fuel transfer pump. Old building – 27.5 feet (Cairo). Water would short electrical control panels.

Reverse flow protection: 6 gate valves
2 air suppressions

7.6.1.2.1.3 Damages[52]

Estimated cost of repairs: $2,000[53]

Relative level of damage: Minor

Severity of circumstances: Flooding did not reach the operating floor

Equipment damaged: No significant equipment damage was recorded.

Building damage: There was minor damage to the corrugated roof.

Misc. damage: No significant miscellaneous damage recorded.

---

[51] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[52] Data for damages are taken from the Project Information Report, which can be obtained from the Parish.

[53] This cost only includes repairs to damages due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

7.6.1.2.1.4 Katrina Event

Date	Time	Event
8/28/2005	-	All the pumps at both buildings were operational prior to the hurricane.
	-	The survey states that both buildings were used for pre-Katrina drawdown. Event: The information provided for this date, was obtained from an interview, this account conflicts with the logs which suggest no pumping occurred on this date
	2:00 PM	The survey states that the pumps were shut down and the operators evacuated.
8/29/2005	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	-	The survey states that the water stayed below the floor of the building.
8/30/2005	10:30 PM	The survey states that the operators returned and restarted all the pumps until the un-watering was complete.
9/1/2005	1:00 PM	Un-watering was complete.

7.6.1.2.1.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.1.2.1.6 Pump Operational Curves

Operational curves were not developed for Bayou Segnette. The necessary data had been collected and the operational curves will be developed in the future.

7.6.1.2.1.7 Pump Reverse Flow

There are eight pumps at this station for which reverse flow rating curves were computed (no pumps were excluded). The reverse flow data and curves are presented in the order of the pump numbering utilized in the summary tables included in this appendix. In cases where there are multiple pumps of equivalent size and system configuration, a single rating curve represents all of them at a unit rate per pump.

Pump No.	Pump Capacity (cfs)	Pump Size (in)	Reverse Flow Computed?		Rating Curve Ref. No.
			Yes	No	
New 1	610	96	X		1
New 2	610	96	X		1
1	156	54	X		2
2	156	54	X		2
3	156	54	X		2
4	156	54	X		2
5	156	54	X		2
6	156	54	X		2

For a general explanation of reverse flow (terminology, figures, methodology, equations and assumptions), refer to the Reverse Flow Section at the beginning of this appendix. Reverse flow computations for a given pump station do not necessarily imply that reverse flow actually occurred there during the Katrina event. But these curves may instead be used as future tools if further investigations are required based on reverse flow assumptions.

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Reverse Flow Rating Curve

PS Bayou Segnette, Pumps New 1 & New 2 - 96-in. Horiz.

Elevation Datum (ft): Cairo

Crest Elevation (ft) = 27.5

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: Use Q = sqrt((H1-H2)/K')

K' = 4.35842E-05 sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 27.5 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated

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unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 35.5 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

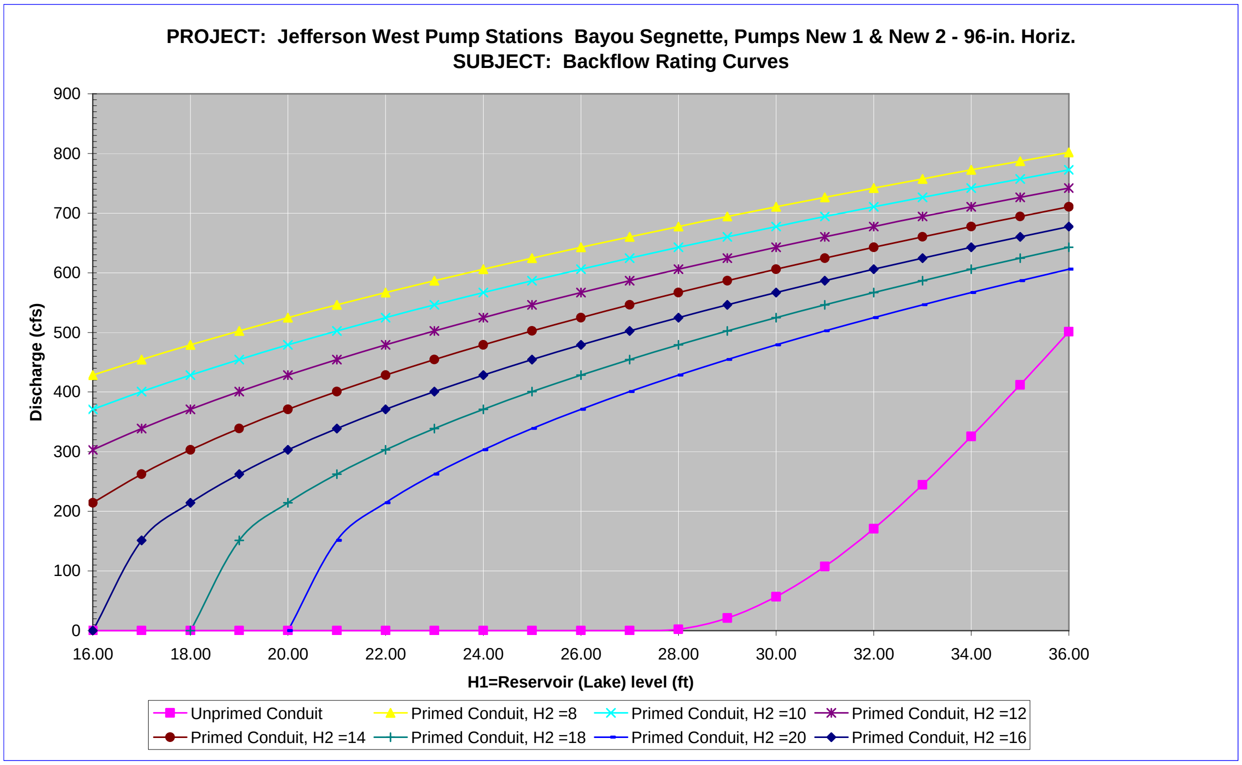
H2 =	8.0	10.0	12.0	14.0	16.0	18.0	20.0
H1 >	41	40	40	39	39	39	38

Water elevation (H1) that stops unprimed flow: 27.5 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 20.2 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.



This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	6.50
Intake loss =	0.92
Exit Loss =	1.0

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

These two pumps were assumed similar to Estelle 2 based on similar capacity, size, type, and serial numbers.

The bend near intake is a smooth transitioning 45 bend.

The losses associated with changes in shape are captured with expansion coefficients.

4 Data Needs or Deficiencies:

Drawings with exact dimensions.

More photos.

5 Backflow prevention:

Available:	Air suppression (both pumps). All pumps had backstops.
Used:	Unknown

Reverse Flow Rating Curve

PS Bayou Segnette, Pumps 1, 2, 3, 4, 5, 6 - 54-in. Vertical

Elevation Datum (ft): Cairo

Crest Elevation (ft) = 25.75

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level

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(H1) and the drainage area water level (H2):

For primed flow rates: Use Q = sqrt((H1-H2)/K')
K' = 0.000567644 sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 25.8 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 30.3 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

H2 =	8.0	10.0	12.0	14.0	16.0	18.0	20.0
H1 >	34	34	34	33	33	33	32

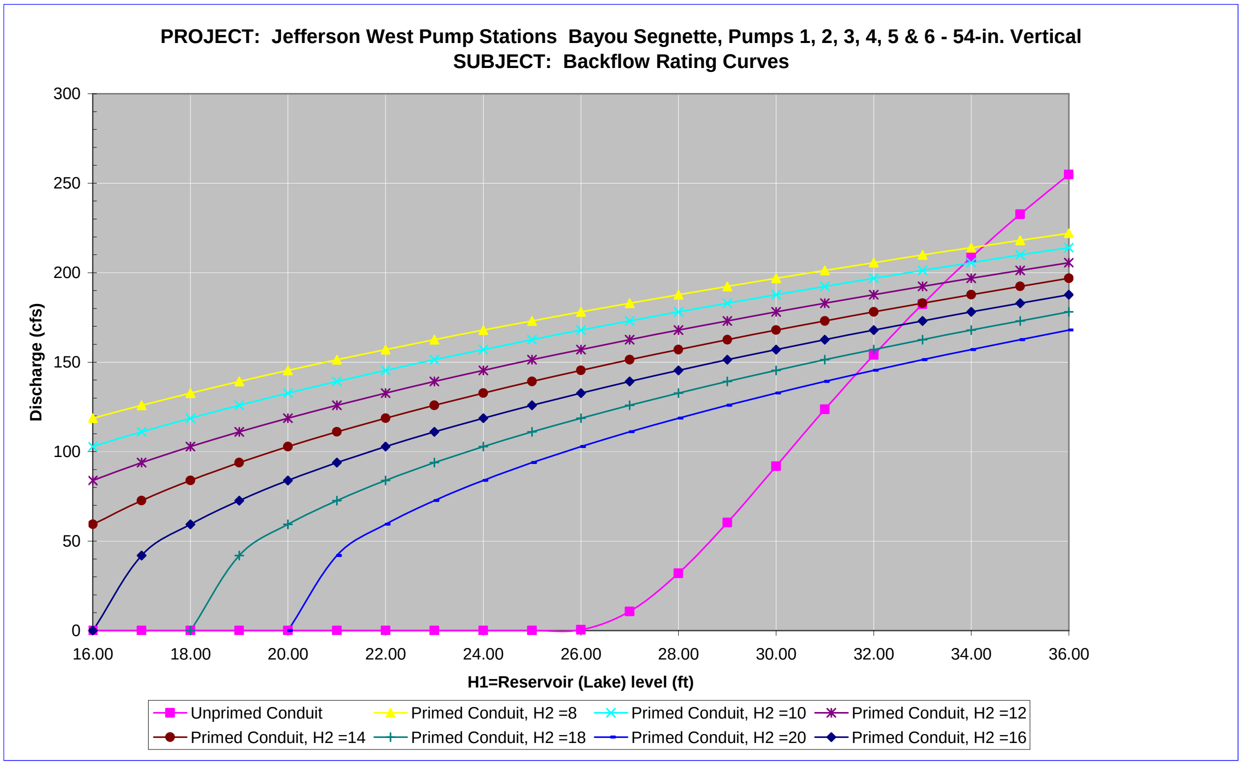
Water elevation (H1) that stops unprimed flow: 25.8 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Water elevation (H1) that stops primed conduit flow: 20.0 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	6.50
Intake loss =	0.92
Exit Loss =	1.3

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

The outlet of the discharge pipe was assumed parallel to the discharge basin floor.
Each bend was a single mitered bends.
All elevations and lengths were scaled from the drawings.

4 Data Needs or Deficiencies:

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Drawings with exact dimensions.
More photos.

5 Backflow prevention:

Available:	Manual Gate Valves (all six pumps). Mechanism to prevent reverse rotation.
Used:	Unknown

7.6.1.2.1.8 Fuel Endurance Calculations

Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. To calculate the time, a few assumptions are required. The first assumption is the HHV[54] of diesel fuel being used is 130,000 Btu[55] per gallon of fuel[56]. The second assumption is the diesel engines are at least 35% efficient[57]. This station has 2 diesel driven pumps with the same rated horsepower at the new station and 6 diesel driven pumps with the same rated horsepower at the old station. The station did not report any issues with running out of fuel. Below are the fuel endurance calculations.

---

[54] High heating value
[55] British thermal units
[56] http://www.exxon.com/USA-English/GFM/Products_Services/Fuels/Diesel_Fuels_FAQ.asp
[57] Standard Handbook for Mechanical Engineers, Eighth Edition, pg 9-106

New Station

Note: New Station pump drivers assumed at 900 hp due to similarity of manufacturer, size and capacity to drivers found at Estelle 2.

The rated horsepower of the diesel driver $P := 900\text{hp}$

The assumed efficiency of the diesels $\varepsilon := 35\%$

The actual power required from the fuel $P_a := \frac{P}{\varepsilon}$ $P_a = 2571.43\,\text{hp}$

The higher heating value $HHV := 130000\frac{BTU}{gal}$

$BR := \frac{P_a}{HHV}$ $BR = 50.329\frac{gal}{hr}$

There are 2-20,000 gallon tanks and 2-1000 gallon tanks at this station.

Total volume of fuel $V_T := (2\cdot 20000 + 2\cdot 1000)\text{gal}$

The fuel endurance of the station $FE := \frac{V_T}{2BR}$ $FE = 417.251\,\text{hr}$

$FE = 17.385\,\text{day}$

Old Station

The rated horsepower of the diesel driver $P := 600\text{hp}$

The assumed efficiency of the diesels $\varepsilon := 35\%$

The actual power required from the fuel $P_a := \frac{P}{\varepsilon}$ $P_a = 1714.29\,\text{hp}$

The higher heating value $HHV := 130000\frac{BTU}{gal}$

$BR := \frac{P_a}{HHV}$ $BR = 33.553\frac{gal}{hr}$

There are 2-14,000 gallon tanks and 6-500 gallon tanks at this station.

Total volume of fuel $V_T := (2\cdot 14000 + 6\cdot 500)\text{gal}$

The fuel endurance of the station $FE := \frac{V_T}{6BR}$ $FE = 153.985\,\text{hr}$

$FE = 6.416\,\text{day}$

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.1.2.2 *Highway 90*

Jefferson Parish – West Bank - West of Harvey (Cataouatche) Drainage Basin

Highway 90 and St Charles Parish Line
Westwego, LA 70094

Latitude: 29.91126˚ Longitude: -90.26433˚

7.6.1.2.2.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Before Hurricane Katrina: Aerial view of the pump station

After Hurricane Katrina: View from the building to the discharge

After Hurricane Katrina: Aerial view of the pump station

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.1.2.2.2 Description[58]

Drainage area:	West Bank – West of Harvey: Cataouatche Sub basin
Nominal Capacity:	90 cfs
Drains water from:	Waggaman Canal
Discharges water to:	Outer Cataouatche Canal
Owner:	Jefferson Parish Department of Drainage
Number of pumps:	3
Pump orientation:	Not available
Pump driver:	3 electric
Water level to switch pumps on:	15.0 feet (Cairo)
Water level to switch pumps off:	14.0 feet (Cairo)
Water level that affects operation:	25.0 feet (Cairo) Water would flood switch gear.
Reverse flow protection:	None

7.6.1.2.2.3 Damages[59]

Estimated cost of repairs:	$0[60]
Relative level of damage:	None
Severity of circumstances:	Water did not enter station.
Damages	No significant damages reported.

7.6.1.2.2.4 Katrina Event

Date	Time	Event
	-	The survey states that the station was not used prior or after the hurricane. Water stayed below the floor of the building and all pumps were operational prior to the hurricane.

7.6.1.2.2.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

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[58] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[59] Data for damages are taken from the Project Information Report, which can be obtained from the Parish.

[60] This cost only includes repairs to damages due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.1.2.2.6 Pump Operational Curves

Operational curves were not developed for Highway 90. The necessary data had been collected and the operational curves will be developed in the future.

7.6.1.2.2.7 Pump Reverse Flow

A reverse flow rating was computed for this station but is not presented since the discharge pipes cross over the top of the levee wall. Also there is an automatic vacuum breaker valve to prevent reverse siphon flow in the event of pump failure or power outage. Reverse flow is not relevant if it only occurs when the levee is overtopped.

7.6.1.2.2.8 Fuel Endurance Calculations

We do not have any record of pumps that run on fuel at this pump station.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.1.2.3 *Lake Cataouatche 1*

Jefferson Parish – West Bank - West of Harvey (Cataouatche) Drainage Basin

3901 Highway
Westwego, LA 70094

Latitude: 29.87127˚ Longitude: -90.22873˚

7.6.1.2.3.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Before Hurricane Katrina: Aerial view of the pump station

After Hurricane Katrina: View from the intake canal

Photo Not Obtained

After Hurricane Katrina

7.6.1.2.3.2 Description[61]

Drainage area:	West Bank-West of Harvey (Cataouatche Sub basin)
Nominal Capacity:	500 cfs
Drains water from:	Main Canal
Discharges water to:	Lake Cataouatche
Owner:	Jefferson Parish Department of Drainage
Number of pumps:	2
Pump orientation:	2 vertical
Pump driver:	2 diesel
Water level to switch pumps on:	11.8 feet (Cairo)
Water level to switch pumps off:	10.5 feet (Cairo)
Water level that affects operation:	21.0 feet (Cairo) Electric fuel transfer pump would be flooded.
Reverse flow protection:	Check valves

7.6.1.2.3.3 Damages[62]

Estimated cost of repairs:	$0[63]
Relative level of damage:	None
Severity of circumstances:	Water did not enter station.
Damages	No significant damages reported.

7.6.1.2.3.4 Katrina Event

Date	Time	Event
8/27/2005	-	The survey states that both pumps were used for pre-Katrina drawdown.
8/28/2005	3:00 PM	The survey states that the operators shut down the pumps and evacuated the station.
8/29/2005	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	10:30 PM	The survey states that the operators returned.
	-	The survey states that the water did not reach the floor of the building.
9/1/2005	12:00 AM	The survey states that pump 1 was turned on until the unwatering was complete.
	10:00 AM	The survey states that the unwatering was complete.

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[61] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[62] Data for damages are taken from the Project Information Report, which can be obtained from the Parish.

[63] This cost only includes repairs to damages due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.1.2.3.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.1.2.3.6 Pump Operational Curves

Operational curves were not developed for Lake Cataouatche 1. The necessary data had been collected and the operational curves will be developed in the future.

7.6.1.2.3.7 Pump Reverse Flow

No reverse flow curves were developed for this station since the pumps have automatic check valves to prevent reverse flow.

7.6.1.2.3.8 Fuel Endurance Calculations

Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. To calculate the time, a few assumptions are required. The first assumption is the HHV[64] of diesel fuel being used is 130,000 Btu[65] per gallon of fuel[66]. The second assumption is the diesel engines are at least 35% efficient[67]. This station has 2 diesel driven pumps with the same rated horsepower. The station did not report any issues with running out of fuel. Below are the fuel endurance calculations.

The rated horsepower of the diesel driver $P := 665\text{hp}$

The assumed efficiency of the diesels $\varepsilon := 35\%$

The actual power required from the fuel $P_a := \frac{P}{\varepsilon}$ $P_a = 1900\,\text{hp}$

The higher heating value $HHV := 130000\,\frac{\text{BTU}}{\text{gal}}$

$BR := \frac{P_a}{HHV}$ $BR = 37.188\,\frac{\text{gal}}{\text{hr}}$

There are 2-7,000 gallon tanks and 2-500 gallon tanks at this station.

$V_T := (2\cdot 7000 + 2\cdot 500)\text{gal}$

The fuel endurance of the station $FE := \frac{V_T}{2BR}$ $FE = 201.679\,\text{hr}$

$FE = 8.403\,\text{day}$

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[64] High heating value

[65] British thermal units

[66] http://www.exxon.com/USA-English/GFM/Products_Services/Fuels/Diesel_Fuels_FAQ.asp

[67] Standard Handbook for Mechanical Engineers, Eighth Edition, pg 9-106

7.6.1.2.4 *Lake Cataouatche 2*

Jefferson Parish – West Bank - West of Harvey (Cataouatche) Drainage Basin

3901 Highway
Westwego, LA 70094

Latitude: 29.87127˚ Longitude: -90.22873˚

7.6.1.2.4.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Before Hurricane Katrina: Aerial view of the pump station

After Hurricane Katrina: View from the intake canal

Photo Not Obtained

After Hurricane Katrina

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.1.2.4.2 Description[68]

Drainage area:	West Bank-West of Harvey (Cataouatche Sub basin)
Nominal Capacity:	600 cfs
Drains water from:	Main Canal
Discharges water to:	Lake Cataouatche
Owner:	Jefferson Parish Department of Drainage
Number of pumps:	2
Pump orientation:	2 vertical
Pump driver:	2 diesels
Water level to switch pumps on:	11.8 feet (Cairo)
Water level to switch pumps off:	10.5 feet (Cairo)
Water level that affects operation:	21.0 feet (Cairo) Electric fuel transfer pump would be flooded.
Reverse flow protection:	None

7.6.1.2.4.3 Damages[69]

Estimated cost of repairs:	$1,000[70]
Relative level of damage:	Minor
Severity of circumstances:	Flooding did not reach the operating floor.
Equipment damaged:	No significant equipment damage was recorded.
Building damage:	Consists of damage to the corrugated fiberglass skylight panel and roof.
Misc. damage:	No significant miscellaneous damage was recorded.

---

[68] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[69] Data for damages are taken from the Project Information Report, which can be obtained from the Parish.

[70] This cost only includes repairs to damages due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

7.6.1.2.4.4 Katrina Event

Date	Time	Event
8/28/2005	-	The survey states that prior to the storm pump 1 was operational, and that pump 2 was inoperable.
	3:00 PM	The survey states that the crew was evacuated.
8/29/2005	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	10:30 PM	The survey states that the operators returned and restarted the pumps. All pumps were run until completely de-watered on 9/01/2005 at about 1:00pm
	-	The survey states that flooding did not reach the floor of the building.
9/1/2005	1:00 PM	The survey states that the unwatering was complete.

7.6.1.2.4.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.1.2.4.6 Pump Operational Curves

Operational curves were not developed for Lake Cataouatche 2. The necessary data had been collected and the operational curves will be developed in the future.

7.6.1.2.4.7 Pump Reverse Flow

There are two pumps at this station for which reverse flow rating curves were computed (no pumps were excluded). The reverse flow data and curves are presented in the order of the pump numbering utilized in the summary tables included in this appendix. In cases where there are multiple pumps of equivalent size and system configuration, a single rating curve represents all of them at a unit rate per pump.

Pump No.	Pump Capacity (cfs)	Pump Size (in)	Reverse Flow Computed?		Rating Curve Ref. No.
			Yes	No	
1	303	72	X		1
2	303	72	X		1

For a general explanation of reverse flow (terminology, figures, methodology, equations and assumptions), refer to the Reverse Flow Section at the beginning of this appendix. Reverse flow computations for a given pump station do not necessarily imply that reverse flow actually occurred there during the Katrina event. But these curves may instead be used as future tools if further investigations are required based on reverse flow assumptions.

Reverse Flow Rating Curve

PS Lake Cataouatche 2, Pumps 1 & 2 - 72-in. Vertical

Elevation Datum (ft):	NGVD
Crest Elevation (ft) =	7.5

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use Q = sqrt((H1-H2)/K')*
K' = *0.000172661* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 7.5 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 13.5 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

minimum H1 elevations for given H2 elevations that would trigger primed flow.

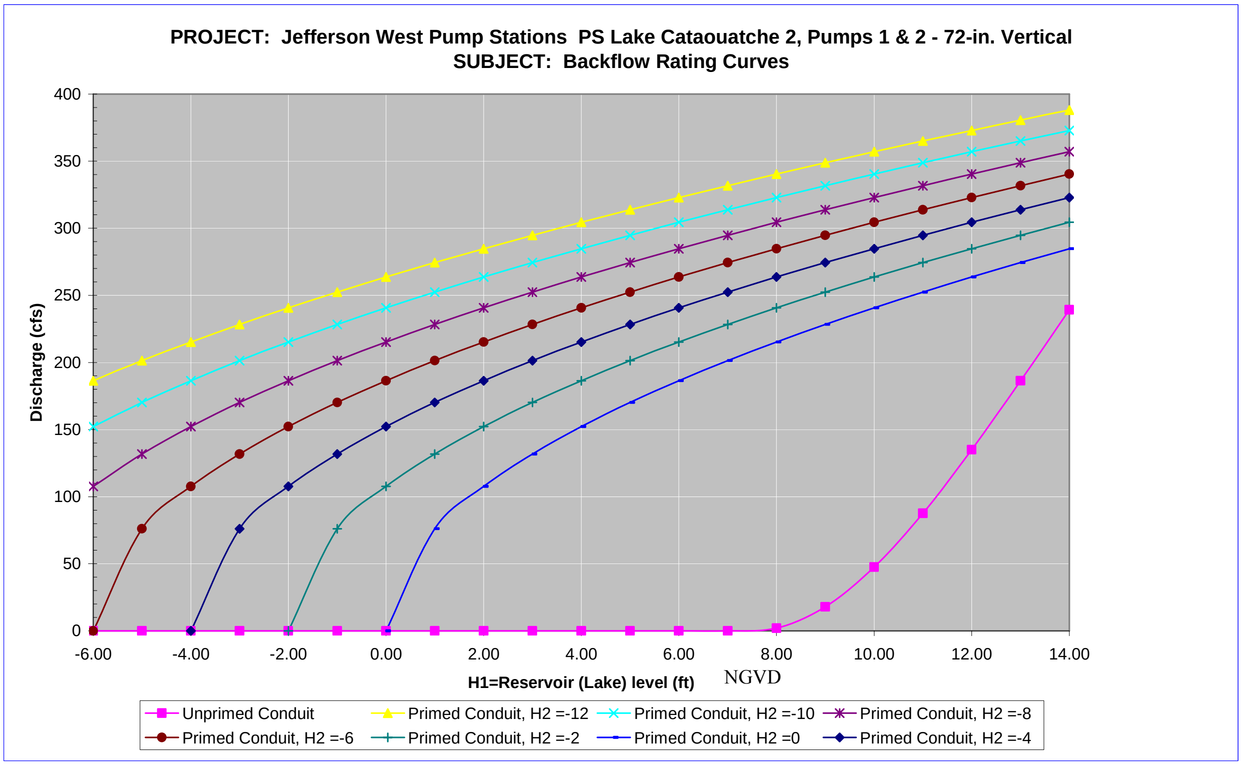
Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.							
H2 =	-12.0	-10.0	-8.0	-6.0	-4.0	-2.0	0.0
H1 >	18	17	17	17	16	16	16

Water elevation (H1) that stops unprimed flow: 7.5 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 0.3 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	6.50
Intake loss =	1.5

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Exit Loss = 1.3

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

The cross sectional area of the discharge outlet was circular.

Assumed 1.5 entrance loss due to diffuser connected to discharge pipe exit.

4 Data Needs or Deficiencies:

None

5 Backflow prevention:

Available: No backflow prevention system.

Mechanism to prevent reverse rotation.

Used: Operator states reverse flow did not occur.

7.6.1.2.4.8 Fuel Endurance Calculations

Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. To calculate the time, a few assumptions are required. The first assumption is the HHV[71] of diesel fuel being used is 130,000 Btu[72] per gallon of fuel[73]. The second assumption is the diesel engines are at least 35% efficient[74]. This station has 2 diesel driven pumps with the same rated horsepower. The station did not report any issues with running out of fuel. Below are the fuel endurance calculations.

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[71] High heating value

[72] British thermal units

[73] http://www.exxon.com/USA-English/GFM/Products_Services/Fuels/Diesel_Fuels_FAQ.asp

[74] Standard Handbook for Mechanical Engineers, Eighth Edition, pg 9-106

The rated horsepower of the diesel driver $P := 561\,\text{hp}$

The assumed efficiency of the diesels $\varepsilon := 35\%$

The actual power required from the fuel $P_a := \frac{P}{\varepsilon}$ $P_a = 1602.86\,\text{hp}$

The higher heating value $HHV := 130000\,\frac{\text{BTU}}{\text{gal}}$

$$BR := \frac{P_a}{HHV} \qquad BR = 31.372\,\frac{\text{gal}}{\text{hr}}$$

There are 1-10,000 gallon tanks and 2-300 gallon tanks at this station.

$$V_T := (1 \cdot 10000 + 2 \cdot 300)\,\text{gal}$$

The fuel endurance of the station $FE := \frac{V_T}{2BR}$ $FE = 168.94\,\text{hr}$

$$FE = 7.039\,\text{day}$$

7.6.1.3 West Bank – West of Harvey

7.6.1.3.1 *Ames*

Jefferson Parish – West Bank - West of Harvey Drainage Basin

5100 Rochester Dr
Marrero, LA 70072

Latitude: 29.85463˚ Longitude: -90.11961˚

7.6.1.3.1.1 Before and After Hurricane Katrina Photos

Before Hurricane Katrina: View from the side

Before Hurricane Katrina: Aerial view of the pump station

After Hurricane Katrina: View from the intake canal

After Hurricane Katrina: Aerial view of the pump station

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.1.3.1.2 Description[75]

Drainage area:	West Bank – West of Harvey
Nominal Capacity:	1930 cfs
Drains water from:	Inner Milladoun
Discharges water to:	Bayou Segnette
Owner:	Jefferson Parish Department of Drainage
Number of pumps:	3
Pump orientation:	2 vertical 1 horizontal
Pump driver:	2 electric 1 diesel
Water level to switch pumps on:	11.5 feet (Cairo)
Water level to switch pumps off:	10.5 feet (Cairo)
Water level that affects operation:	21.0 feet (Cairo) Water would flood electrical transformers.
Reverse flow protection:	2 butterfly valves 1 air suppression

7.6.1.3.1.3 Damages[76]

Estimated cost of repairs:	$27,000[77]
Relative level of damage:	Minor
Severity of circumstances:	Flooding did not reach the operating floor.
Equipment damaged:	No significant equipment damage was recorded.
Building damage:	There was extensive damage to the skylight wall panels and flashing.

---

[75] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[76] Data for damages are taken from the Project Information Report, which can be obtained from the Parish.

[77] This cost only includes repairs to damages due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.1.3.1.4 Katrina Event

Date	Time	Event
8/27/2005	-	The survey states that the operators used Pump 1 for the pre Katrina drawdown.
8/28/2005	-	The survey states that all the pumps were operational prior to Hurricane Katrina.
	3:00 PM	The survey states that the station was evacuated for safety.
8/29/2005	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	-	The survey states that the water stayed below the floor of the building.
8/31/2005	-	The survey states that the operators returned and pumped with 2 pumps.
9/1/2005	-	The un-watering was complete.

7.6.1.3.1.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.1.3.1.6 Pump Operational Curves

Operational curves were not developed for Ames. The necessary data had been collected and the operational curves will be developed in the future.

7.6.1.3.1.7 Pump Reverse Flow

There are three pumps at this station for which reverse flow rating curves were computed (no pumps were excluded). The reverse flow data and curves are presented in the order of the pump numbering utilized in the summary tables included in this appendix. In cases where there are multiple pumps of equivalent size and system configuration, a single rating curve represents all of them at a unit rate per pump.

Pump No.	Pump Capacity (cfs)	Pump Size (in)	Reverse Flow Computed?		Rating Curve Ref. No.
			Yes	No	
1	390	75 x 84	X		1
2	390	75 x 84	X		1
3	1000	132	X		2

For a general explanation of reverse flow (terminology, figures, methodology, equations and assumptions), refer to the Reverse Flow Section at the beginning of this appendix. Reverse flow computations for a given pump station do not necessarily imply that reverse flow actually occurred there during the Katrina event. But these curves may instead be used as future tools if further investigations are required based on reverse flow assumptions.

Reverse Flow Rating Curve

PS Ames, Pumps 1 & 2 - 75x84in. Vertical

Elevation Datum (ft):	Cairo
Crest Elevation (ft) =	25.5

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use Q = sqrt((H1-H2)/K')*
K' = *0.000110934* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 25.5 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 32.5 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for

minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

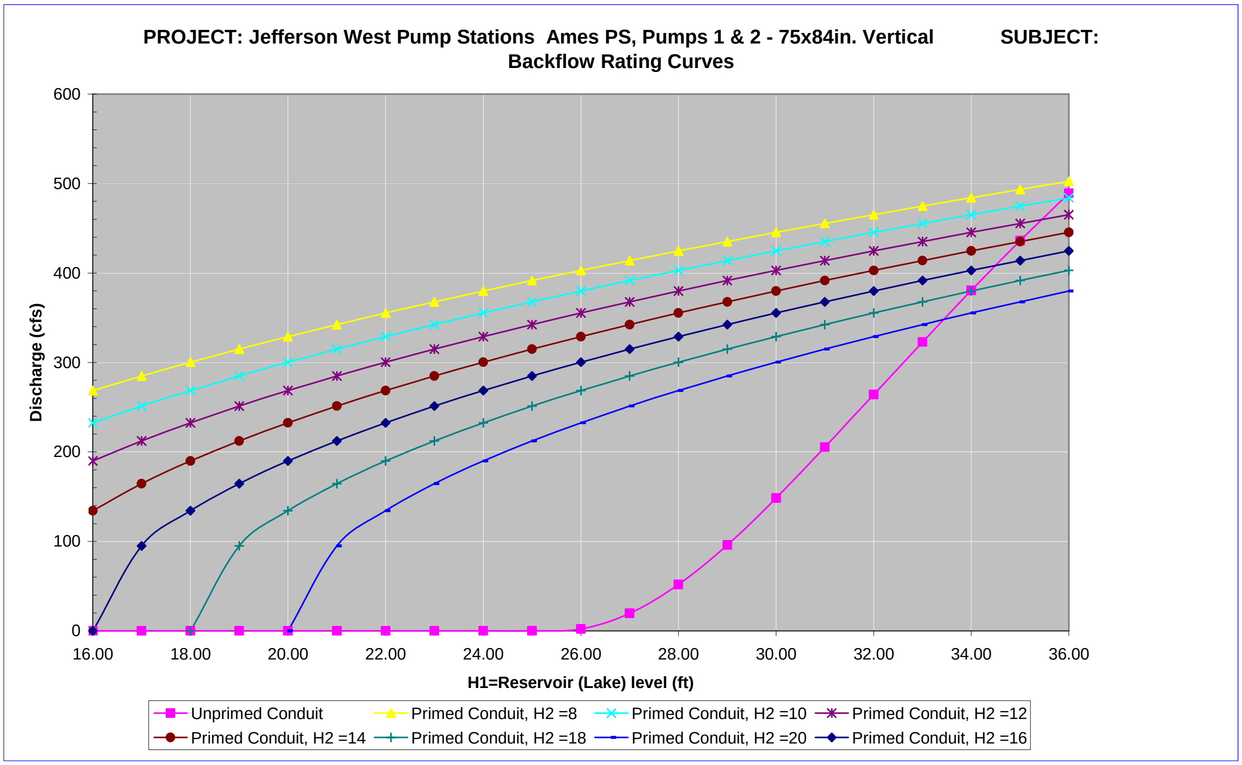
H2 =	8.0	10.0	12.0	14.0	16.0	18.0	20.0
H1 >	37	37	36	36	35	35	35

Water elevation (H1) that stops unprimed flow:	25.5	ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow:	17.4	ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	6.50
Intake loss =	0.92

Exit Loss = 1.3

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Elevations in Cairo Datum.

Drawings are accurate and to scale.

Rated head from pump curve.

4 Data Needs or Deficiencies:

5 Backflow prevention:

Available:	Equipped with a butterfly valve to prevent reverse flow. Backstops to prevent reverse rotation.
Used:	Station was evacuated for the storm. Based on high water marks, operators believe reverse flow did not occur.

Reverse Flow Rating Curve

PS Ames, Pump 3 - 132in

Elevation Datum (ft):	Cairo
Crest Elevation (ft) =	25.5

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use* $Q = \mathrm{sqrt}((H1-H2)/K')$

$K' =$ *1.20391E-05* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 25.5 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 30.0 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

H2 =	8.0	10.0	12.0	14.0	16.0	18.0	20.0
H1 >	32	32	32	32	31	31	31

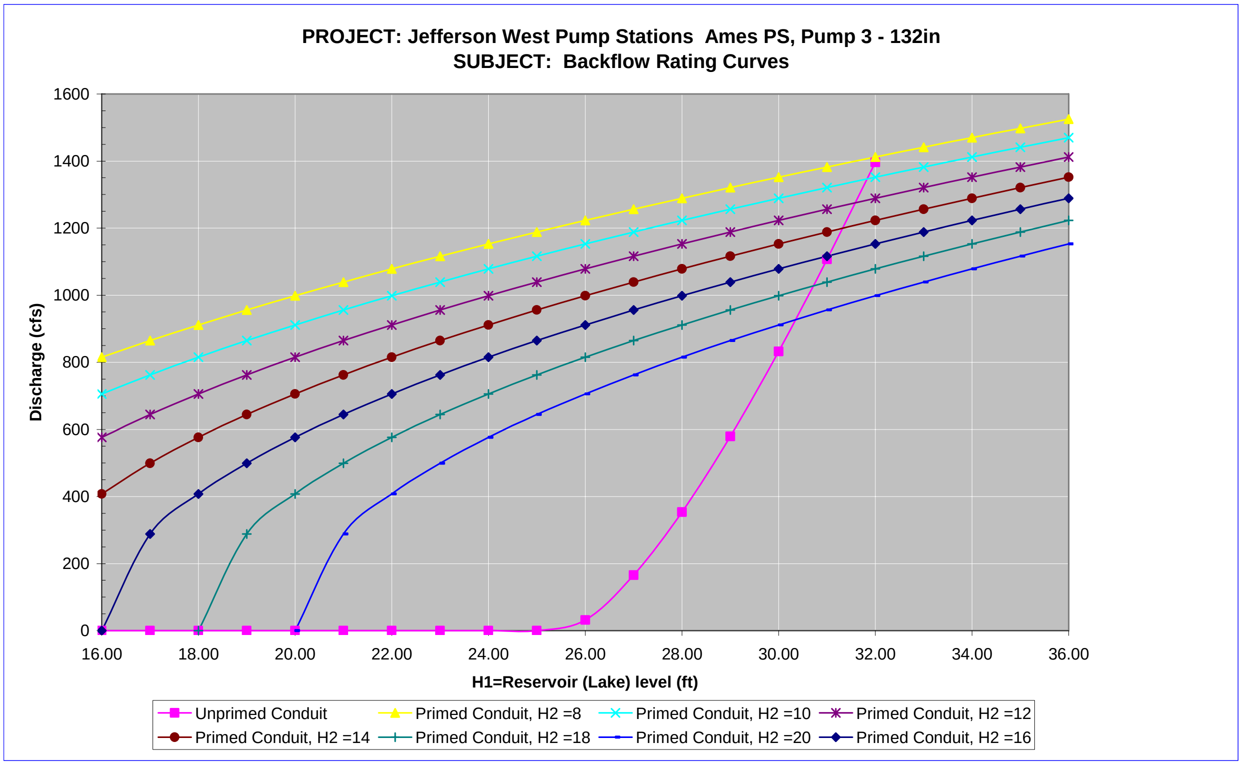
Water elevation (H1) that stops unprimed flow: 25.5 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 15.5 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	6.50
Intake loss =	0.5
Exit Loss =	1.0

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Elevations in Cairo Datum.

Drawings are accurate and to scale.

4 Data Needs or Deficiencies:

None.

5 Backflow prevention:

Available:	Equipped with a butterfly valve to prevent reverse flow. Backstops to prevent reverse rotation.
Used:	Station was evacuated for the storm. Based on high water marks, operators believe reverse flow did not occur.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.1.3.1.8 Fuel Endurance Calculations

Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. To calculate the time, a few assumptions are required. The first assumption is the HHV[78] of diesel fuel being used is 130,000 Btu[79] per gallon of fuel[80]. The second assumption is the diesel engines are at least 35% efficient[81]. This station has 1 diesel driven pump and 1 diesel generator. The station did not report any issues with running out of fuel. Below are the fuel endurance calculations.

The rated wattage of the diesel generator	$G := 1660\,kW$	$hp = 0.746\,kW$
The rated horsepower of the diesel driver	$P := 2305\,hp$	
The assumed efficiency of the diesels	$\varepsilon := 35\%$	
The actual power required from the fuel	$G_a := \frac{G}{\varepsilon}$	$G_a = 6360.28\,hp$
	$P_a := \frac{P}{\varepsilon}$	$P_a = 6585.71\,hp$
The higher heating value	$HHV := 130000\,\frac{BTU}{gal}$	
The burn rate	$BR_1 := \frac{G_a}{HHV}$	$BR_1 = 124.487\,\frac{gal}{hr}$
	$BR_2 := \frac{P_a}{HHV}$	$BR_2 = 128.899\,\frac{gal}{hr}$

There are 2-10,000 gallon tanks and 2-450 gallon tanks at this station.

Total volume of fuel	$V_T := (2 \cdot 10000 + 2 \cdot 450)\,gal$	
The fuel endurance of the station	$FE := \frac{V_T}{BR_1 + BR_2}$	$FE = 82.483\,hr$
		$FE = 3.437\,day$

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[78] High heating value

[79] British thermal units

[80] http://www.exxon.com/USA-English/GFM/Products_Services/Fuels/Diesel_Fuels_FAQ.asp

[81] Standard Handbook for Mechanical Engineers, Eighth Edition, pg 9-106

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.1.3.2 *Cousins 1*

Jefferson Parish – West Bank - West of Harvey Drainage Basin

2466 Destrehan Ave
Harvey, LA 70058

Latitude: 30.03208˚ Longitude: -90.21911˚

7.6.1.3.2.1 Before and After Hurricane Katrina Photos

Before Hurricane Katrina: View from the inlet canal

Before Hurricane Katrina: Aerial view of the pump station

After Hurricane Katrina: View from the discharge

After Hurricane Katrina: Aerial view of the pump station

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.1.3.2.2 Description[82]

Drainage area:	West Bank- West of Harvey
Nominal Capacity:	800 cfs
Drains water from:	Cousins Canal and First Ave. Canal
Discharges water to:	Harvey Canal
Owner:	Jefferson Parish Department of Drainage
Number of pumps:	4
Pump orientation:	4 vertical
Pump driver:	1 electric 3 diesel
Water level to switch pumps on:	10.5 feet (Cairo)
Water level to switch pumps off:	9.5 feet (Cairo)
Water level that affects operation:	25.5 feet (Cairo). Water would flood engine air intake.
Reverse flow protection:	None

7.6.1.3.2.3 Damages[83]

Estimated cost of repairs:	$1,000[84]
Relative level of damage:	Minor
Severity of circumstances:	Flooding did not reach the operating floor.
Equipment damaged:	No significant equipment damage was recorded.
Building damage:	There were three broken windows.
Misc. damage:	No significant miscellaneous damage recorded.

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[82] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[83] Data for damages are taken from the Project Information Report, which can be obtained from the Parish.

[84] This cost only includes repairs to damages due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.1.3.2.4 Katrina Event

Date	Time	Event
8/28/2005	-	The survey states three pumps ran for 7 hours for pre-Katrina drawdown.
	3:00 PM	The station was evacuated.
	-	The survey states that all the pumps were operational prior to the arrival of Hurricane Katrina.
8/29/2005	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	-	The survey states that the water stayed below the floor of the building.
8/30/2005	1:00 AM	The survey states that the operators returned and found water at 23.00 ft. in the canal. 3 pumps were used for un-watering.
9/1/2005	-	The survey states that the canal was un-watered.

7.6.1.3.2.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.1.3.2.6 Pump Operational Curves

Operational curves were not developed for Cousins 1. The necessary data had been collected and the operational curves will be developed in the future.

7.6.1.3.2.7 Pump Reverse Flow

There are four pumps at this station for which reverse flow rating curves were computed (no pumps were excluded). The reverse flow data and curves are presented in the order of the pump numbering utilized in the summary tables included in this appendix. In cases where there are multiple pumps of equivalent size and system configuration, a single rating curve represents all of them at a unit rate per pump.

Pump No.	Pump Capacity (cfs)	Pump Size (in)	Reverse Flow Computed?		Rating Curve Ref. No.
			Yes	No	
1	50	36	X		1
2	250	72	X		2
3	250	72	X		2
4	250	72	X		2

For a general explanation of reverse flow (terminology, figures, methodology, equations and assumptions), refer to the Reverse Flow Section at the beginning of this appendix. Reverse flow computations for a given pump station do not necessarily imply that reverse flow actually occurred there during the Katrina event. But these curves may instead be used as future tools if further investigations are required based on reverse flow assumptions.

Reverse Flow Rating Curve

PS Cousins 1, Pump 1 - 36-in. Vertical Pump

Elevation Datum (ft):	Cairo
Crest Elevation (ft) =	22.5

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: Use $Q = \sqrt{(H1-H2)/K'}$

$K' = 0.002867561$ sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 22.5 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated

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unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 25.5 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

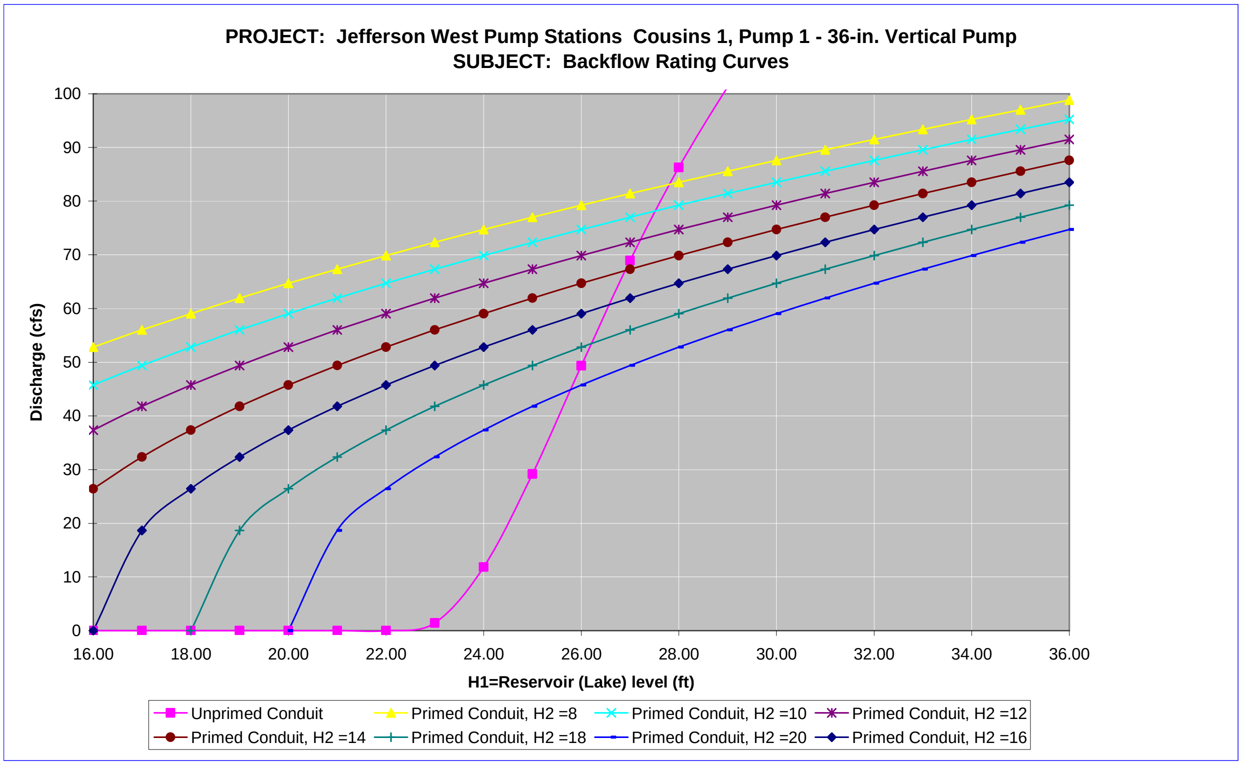
Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.							
H2 =	8.0	10.0	12.0	14.0	16.0	18.0	20.0
H1 >	28	28	27	27	27	27	26

Water elevation (H1) that stops unprimed flow: 22.5 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 17.1 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	6.50
Intake loss =	0.92
Exit Loss =	1.3

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

The outlet of the discharge pipe was assumed parallel to the discharge basin floor.
Each bend was a single mitered bend.
All elevations and lengths were scaled from the drawings.

4 Data Needs or Deficiencies:
Drawings with exact dimensions.
More photos.

5 Backflow prevention:

Available:	No backflow prevention. Backstops to prevent reverse rotation installed.
Used:	Operator states reverse flow did not occur.

Reverse Flow Rating Curve

PS Cousins 1, Pumps 2, 3, 4 - 72-in. Vertical Pump

Elevation Datum (ft):	Cairo
Crest Elevation (ft) =	22.5

H1 = Lake or outlet canal water level (normal pump discharge side)
H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: $Q = \sqrt{(H1-H2)/K'}$ *Use*

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$K' = \quad 0.000178522 \quad sec^2/ft^5$

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 22.5 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 28.5 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

H2 =	8.0	10.0	12.0	14.0	16.0	18.0	20.0
H1 >	31	31	31	31	30	30	30

Water elevation (H1) that stops unprimed flow: 22.5 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 17.1 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1)

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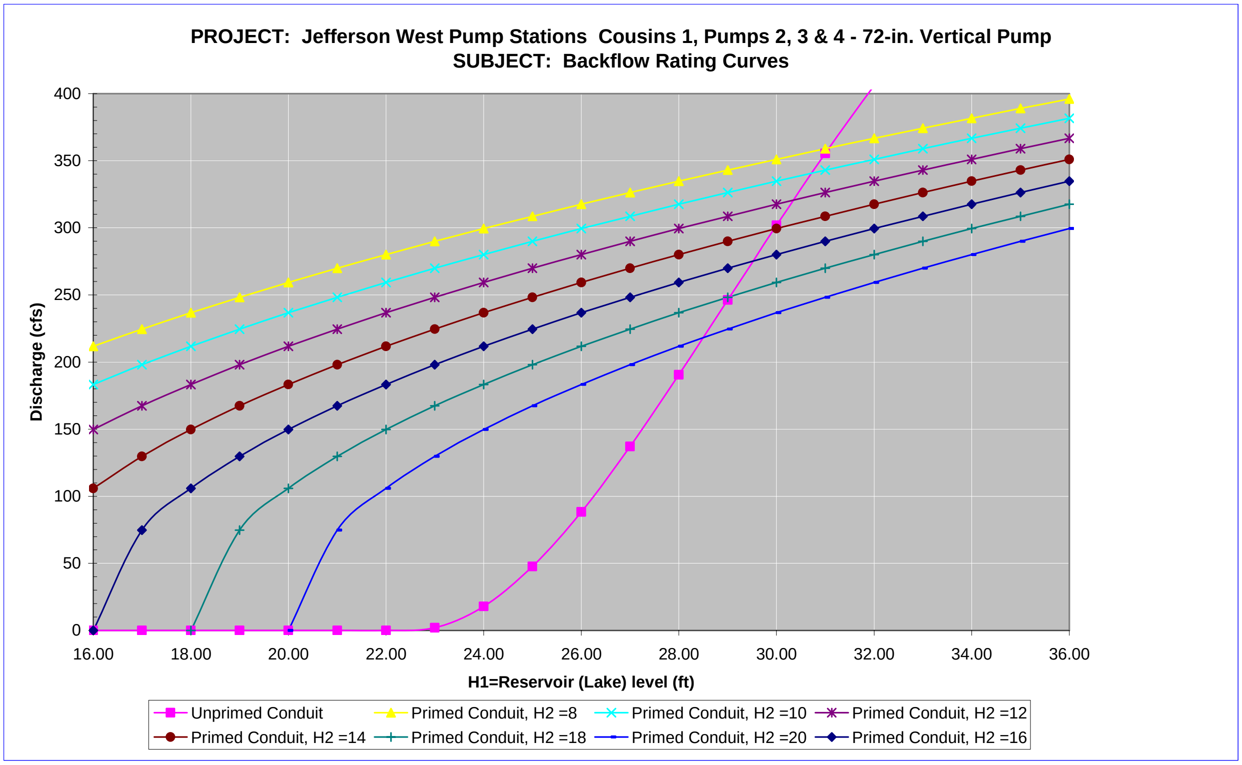
is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	6.50
Intake loss =	0.92
Exit Loss =	1.3

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

The outlet of the discharge pipe was assumed parallel to the discharge basin floor.
Each bend was a single mitered bends.
All elevations and lengths were scaled from the drawings.

4 Data Needs or Deficiencies:
Drawings with exact dimensions.
More photos

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

5 Backflow prevention:

Available:	No backflow prevention. Backstops to prevent reverse rotation installed.
Used:	Operator states reverse flow did not occur.

7.6.1.3.2.8 Fuel Endurance Calculations

Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. To calculate the time, a few assumptions are required. The first assumption is the HHV[85] of diesel fuel being used is 130,000 Btu[86] per gallon of fuel[87]. The second assumption is the diesel engines are at least 35% efficient[88]. This station has 4 diesel driven pumps with the same rated horsepower. The station did not report any issues with running out of fuel. Below are the fuel endurance calculations.

The rated horsepower of the diesel driver $P := 1000\,hp$

The assumed efficiency of the diesels $\varepsilon := 35\%$

The actual power required from the fuel $P_a := \dfrac{P}{\varepsilon}$ $P_a = 2857.14\,hp$

The higher heating value $HHV := 130000\dfrac{BTU}{gal}$

$BR := \dfrac{P_a}{HHV}$ $BR = 55.922\dfrac{gal}{hr}$

There are 3-15,000 gallon tanks and 2-500 gallon tanks at this station.

Total volume of fuel $V_T := (3\cdot 15000 + 2\cdot 500)\,gal$

The fuel endurance of the station $FE := \dfrac{V_T}{4BR}$ $FE = 205.645\,hr$

$FE = 8.569\,day$

---

[85] High heating value

[86] British thermal units

[87] http://www.exxon.com/USA-English/GFM/Products_Services/Fuels/Diesel_Fuels_FAQ.asp

[88] Standard Handbook for Mechanical Engineers, Eighth Edition, pg 9-106

7.6.1.3.3 *Cousins 2*

Jefferson Parish – West Bank - West of Harvey Drainage Basin

2466 Destrehan Ave
Harvey, LA 70058

Latitude: 30.03208˚ Longitude: -90.21911˚

7.6.1.3.3.1 Before and After Hurricane Katrina Photos

Before Hurricane Katrina: View from the inlet canal

Before Hurricane Katrina: Aerial view of the pump station

After Hurricane Katrina: View from the side

After Hurricane Katrina: Aerial view of the pump station

7.6.1.3.3.2 Description[89]

Drainage area:	West Bank- West of Harvey
Nominal Capacity:	2200 cfs
Drains water from:	Cousins Canal and First Ave. Canal
Discharges water to:	Harvey Canal
Owner:	Jefferson Parish Department of Drainage
Number of pumps:	2
Pump orientation:	Not available
Pump driver:	2 diesel
Water level to switch pumps on:	10.5 feet (Cairo)
Water level to switch pumps off:	9.5 feet (Cairo)
Water level that affects operation:	26.0 feet (Cairo) Water would flood fuel transfer pump.
Reverse flow protection:	None

7.6.1.3.3.3 Damages[90]

Estimated cost of repairs:	$90,000[91]
Relative level of damage:	Minor
Severity of circumstances:	Flooding did not reach the operating floor.
Equipment damaged:	No significant equipment damage was recorded.
Building damage:	There was approximately 6,000 sq. ft. of roof damage.
Misc. damage:	Consists of gutters, lightning rods, and exhaust fan covers.

---

[89] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[90] Data for damages are taken from the Project Information Report, which can be obtained from the Parish.

[91] This cost only includes repairs to damages due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

7.6.1.3.3.4 Katrina Event

Date	Time	Event
8/28/2005	-	The survey states that three pumps were used for pre-Katrina drawdown. Pumps ran for approximately 7 hours.
	3:00 PM	The station was evacuated.
8/29/2005	6:30 AM	Hurricane Katrina made landfall in Louisiana.
8/30/2005	-	The survey states that the operators returned at 1:00am to find water at 23.00 ft. in the canal. 3 pumps were used for de-watering.
9/1/2005	-	The survey states that the canal was dewatered

7.6.1.3.3.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.1.3.3.6 Pump Operational Curves

Operational curves were not developed for Cousins 2. The necessary data had been collected and the operational curves will be developed in the future.

7.6.1.3.3.7 Pump Reverse Flow

There are two pumps at this station for which reverse flow rating curves were computed (no pumps were excluded). The reverse flow data and curves are presented in the order of the pump numbering utilized in the summary tables included in this appendix. In cases where there are multiple pumps of equivalent size and system configuration, a single rating curve represents all of them at a unit rate per pump.

Pump No.	**Pump Capacity (cfs)**	**Pump Size (in)**	**Reverse Flow Computed?**		**Rating Curve Ref. No.**
			Yes	**No**	
1	1000	132	X		1
2	1000	132	X		1

For a general explanation of reverse flow (terminology, figures, methodology, equations and assumptions), refer to the Reverse Flow Section at the beginning of this appendix. Reverse flow computations for a given pump station do not necessarily imply that reverse flow actually occurred there during the Katrina event. But these curves may instead be used as future tools if further investigations are required based on reverse flow assumptions.

Reverse Flow Rating Curve

PS Cousins 2, Pumps 1 & 2 - 132in

Elevation Datum (ft):	Cairo
Crest Elevation (ft) =	25.5

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

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Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use* $Q = \mathrm{sqrt}((H1-H2)/K')$

$K' =$ *1.28026E-05* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 25.5 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 29.4 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in

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the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

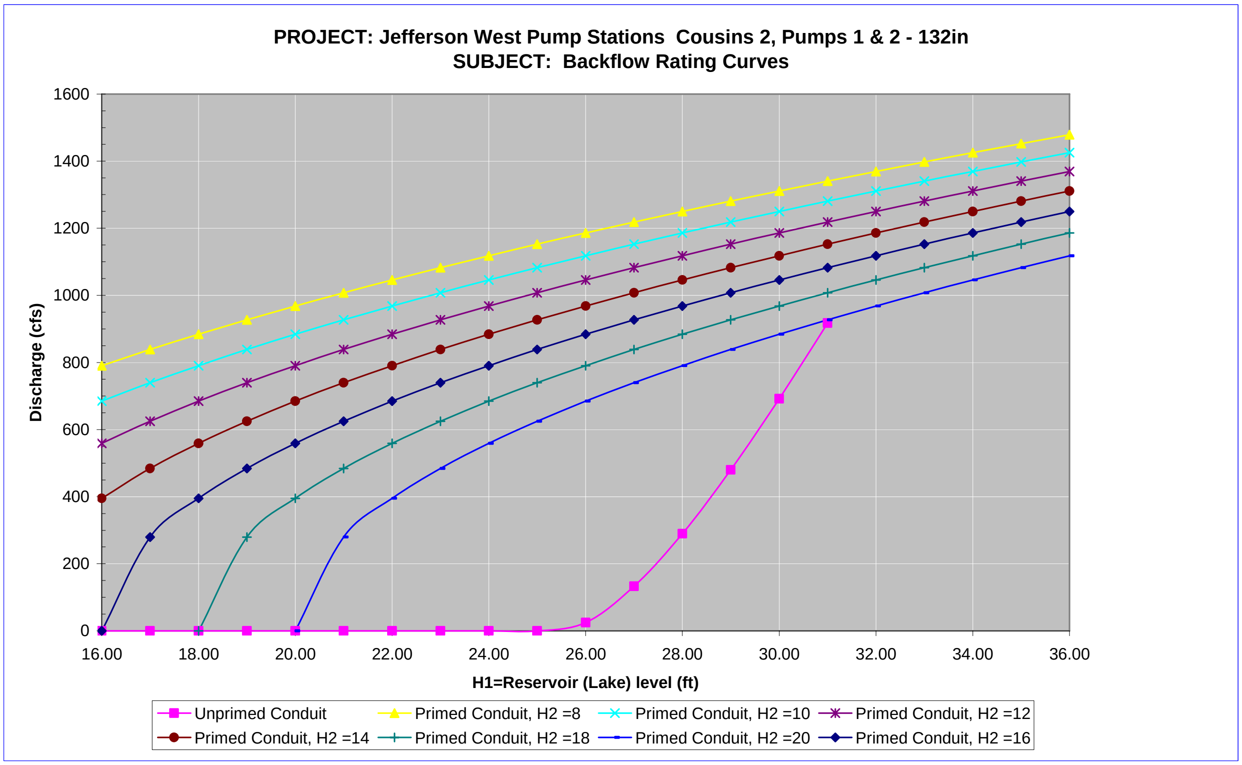
Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.							
H2 =	8.0	10.0	12.0	14.0	16.0	18.0	20.0
H1 >	33	33	33	32	32	31	31

Water elevation (H1) that stops unprimed flow: 25.5 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 14.4 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	6.50
Intake loss =	0.5

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Exit Loss = 1.0

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Elevations in Cairo Datum.

Drawings are accurate and to scale.

4 Data Needs or Deficiencies:

None

5 Backflow prevention:

Available: No backflow prevention system.

Backstops to prevent reverse rotation.

Used: Station was evacuated for the storm.

Based on high water marks operators believe reverse flow did not occur.

7.6.1.3.3.8 Fuel Endurance Calculations

Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. To calculate the time, a few assumptions are required. The first assumption is the HHV[92] of diesel fuel being used is 130,000 Btu[93] per gallon of fuel[94]. The second assumption is the diesel engines are at least 35% efficient[95]. This station has 2 diesel driven pumps with the same rated horsepower. The station did not report any issues with running out of fuel. Below are the fuel endurance calculations.

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[92] High heating value

[93] British thermal units

[94] http://www.exxon.com/USA-English/GFM/Products_Services/Fuels/Diesel_Fuels_FAQ.asp

[95] Standard Handbook for Mechanical Engineers, Eighth Edition, pg 9-106

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

The rated horsepower of the diesel driver $P := 2305\,hp$

The assumed efficiency of the diesels $\varepsilon := 35\%$

The actual power required from the fuel $P_a := \frac{P}{\varepsilon}$ $P_a = 6585.71\,hp$

The higher heating value $HHV := 130000\,\frac{BTU}{gal}$

$BR := \frac{P_a}{HHV}$ $BR = 128.899\,\frac{gal}{hr}$

There are 3-15,000 gallon tanks and 2-500 gallon tanks at this station.

Total volume of fuel $V_T := (3 \cdot 15000 + 2 \cdot 500)\,gal$

The fuel endurance of the station $FE := \frac{V_T}{2BR}$ $FE = 178.434\,hr$

$FE = 7.435\,day$

7.6.1.3.4 *Estelle 1*

Jefferson Parish – West Bank - West of Harvey Drainage Basin

2195 Barataria Blvd
Marrero, LA 70072

Latitude: 29.82728˚ Longitude: -90.08315˚

7.6.1.3.4.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Before Hurricane Katrina: Aerial view of the pump station

After Hurricane Katrina: View from the side

After Hurricane Katrina: Aerial view of the pump station

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.1.3.4.2 Description[96]

Drainage area:	West Bank- West of Harvey
Nominal Capacity:	680 cfs
Drains water from:	Pipeline Canal
Discharges water to:	Intracoastal Waterway
Owner:	Jefferson Parish Department of Drainage
Number of pumps:	4
Pump orientation:	Not available
Pump driver:	4 electric
Water level to switch pumps on:	16 feet (Cairo)
Water level to switch pumps off:	14.5 feet (Cairo)
Water level that affects operation:	32.5 feet (Cairo) Water would flood generator.
Reverse flow protection:	None

7.6.1.3.4.3 Damages[97]

Estimated cost of repairs:	$12,000[98]
Relative level of damage:	Minor
Severity of circumstances:	Flooding did not reach the operating floor.
Equipment damaged:	Fuel line and the trash racks are damaged.
Building damage:	There was damage to the corrugated metal roof and to the office doors.
Misc. damage:	Consists of light pole, exterior lighting, and lighting rods.

7.6.1.3.4.4 Katrina Event

Date	Time	Event
	-	The survey states that the station was not used before, during, or immediately after Hurricane Katrina.

7.6.1.3.4.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

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[96] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[97] Data for damages are taken from the Project Information Report, which can be obtained from the Parish.

[98] This cost only includes repairs to damages due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

7.6.1.3.4.6 Pump Operational Curves

Operational curves were not developed for Estelle 1. The necessary data had been collected and the operational curves will be developed in the future.

7.6.1.3.4.7 Pump Reverse Flow

A reverse flow rating curve was computed for this station but is not presented since the discharge pipes cross over the top of the levee wall. Also there is an automatic vacuum breaker valve to prevent reverse siphon flow in the event of pump failure or power outage. Reverse flow is not relevant if it only occurs when the levee is overtopped.

7.6.1.3.4.8 Fuel Endurance Calculations

We do not have any record of pumps that run on fuel at this pump station.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.1.3.5 *Estelle 2*

Jefferson Parish – West Bank - West of Harvey Drainage Basin

3850 Destrehan Ave
Harvey, LA 70058

Latitude: 29.83416˚ Longitude: -90.06851˚

7.6.1.3.5.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Before Hurricane Katrina: Aerial view of the pump station

After Hurricane Katrina: View from the intake canal

After Hurricane Katrina: Aerial view of the pump station

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.1.3.5.2 Description[99]

Drainage area:	West Bank- West of Harvey
Nominal Capacity:	1140 cfs
Drains water from:	Pipeline and Canal G
Discharges water to:	Intracoastal Waterway
Owner:	Jefferson Parish Department of Drainage
Number of pumps:	2
Pump orientation:	Not available
Pump driver:	2 diesel
Water level to switch pumps on:	15.1 feet (Cairo)
Water level to switch pumps off:	13.5 feet (Cairo)
Water level that affects operation:	26.5 feet (Cairo) Water would overtop motor and gears.
Reverse flow protection:	Air suppression

7.6.1.3.5.3 Damages[100]

Estimated cost of repairs:	$0[101]
Relative level of damage:	None
Severity of circumstances:	Water did not enter station.
Damages	No significant damages reported.

7.6.1.3.5.4 Katrina Event

Date	Time	Event
8/26/2005	-	The survey states that the operators pumping water in canal down
8/28/2005	1:30 PM	The survey states that the operators evacuated station.
	-	The survey states that the station was operable and available prior to hurricane's arrival
8/29/2005	6:30 AM	Hurricane Katrina made landfall in Louisiana.
8/30/2005	2:00 PM	The survey states that the operators r and ran rakes and pumps. (Initially they could not return because water overtopped access road.)

7.6.1.3.5.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

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[99] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[100] Data for damages are taken from the Project Information Report, which can be obtained from the Parish.

[101] This cost only includes repairs to damages due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

7.6.1.3.5.6 Pump Operational Curves

Operational curves were not developed for Estelle 2. The necessary data had been collected and the operational curves will be developed in the future.

7.6.1.3.5.7 Pump Reverse Flow

There are two pumps at this station for which reverse flow rating curves were computed (no pumps were excluded). The reverse flow data and curves are presented in the order of the pump numbering utilized in the summary tables included in this appendix. In cases where there are multiple pumps of equivalent size and system configuration, a single rating curve represents all of them at a unit rate per pump.

Pump No.	Pump Capacity (cfs)	Pump Size (in)	Reverse Flow Computed?		Rating Curve Ref. No.
			Yes	No	
1	570	96	X		1
2	570	96	X		1

For a general explanation of reverse flow (terminology, figures, methodology, equations and assumptions), refer to the Reverse Flow Section at the beginning of this appendix. Reverse flow computations for a given pump station do not necessarily imply that reverse flow actually occurred there during the Katrina event. But these curves may instead be used as future tools if further investigations are required based on reverse flow assumptions.

Reverse Flow Rating Curve

PS Estelle 2, Pumps 1, 2 - 96-in. Horiz. Pump

Elevation Datum (ft): Cairo

Crest Elevation (ft) = 26.5

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use* $Q = \mathrm{sqrt}((H1-H2)/K')$

$K' =$ 4.38005E-05 sec^2/ft^5

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 26.5 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 34.5 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.							
H2 =	8.0	10.0	12.0	14.0	16.0	18.0	20.0
H1 >	39	39	39	38	38	37	37

Water elevation (H1) that stops unprimed flow: 26.5 ft

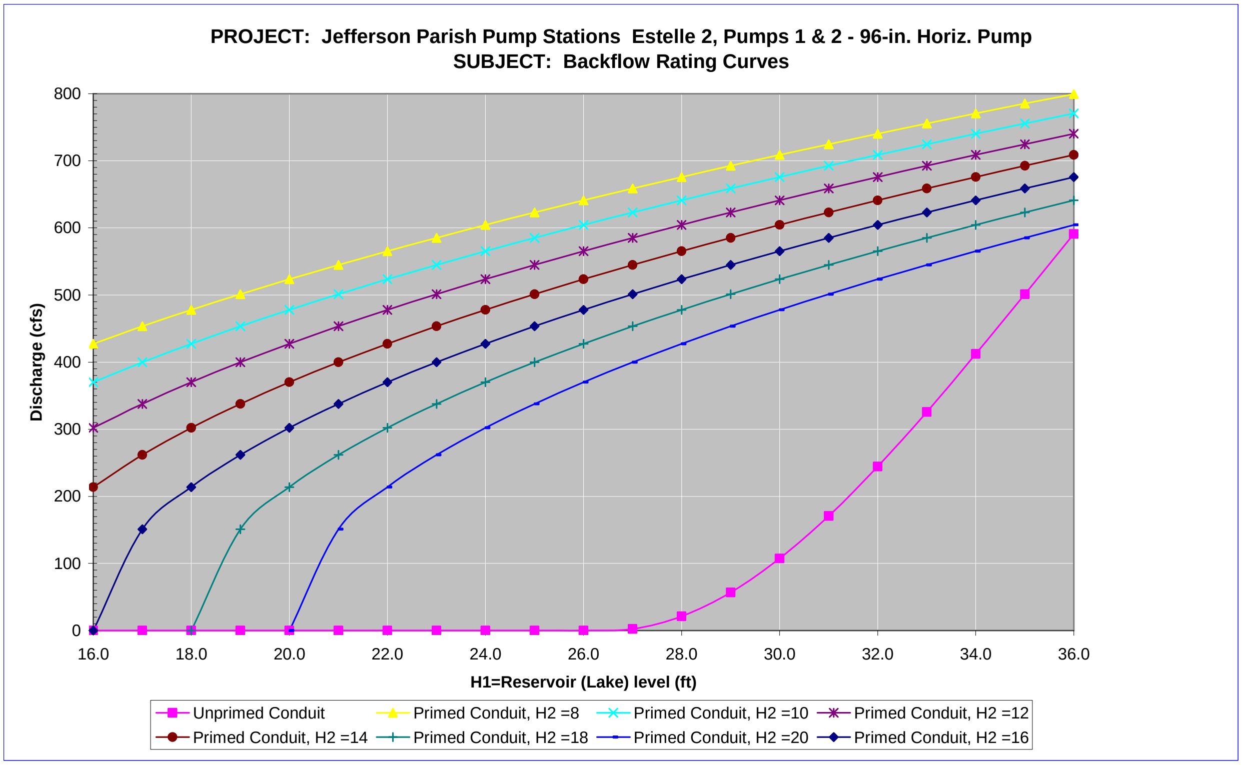
Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 19.2 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.



<u>Notes:</u>

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	6.50
Intake loss =	0.92
Exit Loss =	1.0

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

The bend near intake is a smooth transitioning 45 bend.

The losses associated with changes in shape are captured with expansion coefficients.

The area applied to the losses for change of shape was equal to the outlet (C3).

4 Data Needs or Deficiencies:

None

5 Backflow prevention:

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Available:	Air suppression system. Mechanism prevents reverse rotation.
Used:	Yes Operator states that no reverse flow occurred.

7.6.1.3.5.8 Fuel Endurance Calculations

Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. To calculate the time, a few assumptions are required. The first assumption is the HHV[102] of diesel fuel being used is 130,000 Btu[103] per gallon of fuel[104]. The second assumption is the diesel engines are at least 35% efficient[105]. This station has 2 diesel driven pumps with the same rated horsepower. The station did not report any issues with running out of fuel. Below are the fuel endurance calculations.

The rated horsepower of the diesel driver	$P := 900\,hp$	
The assumed efficiency of the diesels	$\varepsilon := 35\%$	
The actual power required from the fuel	$P_a := \frac{P}{\varepsilon}$	$P_a = 2571.43\,hp$
The higher heating value	$HHV := 130000\,\frac{BTU}{gal}$	
	$BR := \frac{P_a}{HHV}$	$BR = 50.329\,\frac{gal}{hr}$

There are 2-6,480 gallon tanks at this station.

$$V_T := (2 \cdot 6480)\,gal$$

The fuel endurance of the station	$FE := \frac{V_T}{2BR}$	$FE = 128.752\,hr$
		$FE = 5.365\,day$

---

[102] High heating value

[103] British thermal units

[104] http://www.exxon.com/USA-English/GFM/Products_Services/Fuels/Diesel_Fuels_FAQ.asp

[105] Standard Handbook for Mechanical Engineers, Eighth Edition, pg 9-106

7.6.1.3.6 ***Harvey***

Jefferson Parish – West Bank - West of Harvey Drainage Basin

1660 Destrehan Ave
Harvey, LA 70072

Latitude: 29.88311˚ Longitude: -90.07586˚

7.6.1.3.6.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Before Hurricane Katrina: Aerial view of the pump station

After Hurricane Katrina: View from the discharge

After Hurricane Katrina: Aerial view of the pump station

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.1.3.6.2 Description[106]

Drainage area:	West Bank- West of Harvey
Nominal Capacity:	960 cfs
Drains water from:	First Ave. and Two Mile Canal
Discharges water to:	Harvey Canal
Owner:	Jefferson Parish Department of Drainage
Number of pumps:	3
Pump orientation:	Not available
Pump driver:	3 electric
Water level to switch pumps on:	10.5 feet (Cairo)
Water level to switch pumps off:	9.5 feet (Cairo)
Water level that affects operation:	27.5 feet (Cairo). Water would overtop electric motors.
Reverse flow protection:	None

7.6.1.3.6.3 Damages[107]

Estimated cost of repairs:	$2,000[108]
Relative level of damage:	Minor
Severity of circumstances:	Flooding did not reach the operating floor.
Equipment damaged:	No significant equipment damage was recorded.
Building damage:	Consists of damage done to the louvers and the roof.
Misc. damage:	No significant miscellaneous damage recorded.

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[106] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[107] Data for damages are taken from the Project Information Report, which can be obtained from the Parish.

[108] This cost only includes repairs to damages due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.1.3.6.4 Katrina Event

Date	Time	Event
8/28/2005	-	The survey states that the operators pumped water in canal down to 7.5ft.
	-	The survey states that all the pumps were operational prior to the arrival of Hurricane Katrina.
8/29/2005	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	1:00 PM	The survey states that the operators evacuated station.
	-	The survey states that the water stayed below the floor of the building.
8/30/2005	9:00 AM	The survey states that the operators returned and found water levels between 20ft-23ft. There was difficulty getting personnel to station. Station lost electric power during the storm and ran the generator after power loss.

7.6.1.3.6.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.1.3.6.6 Pump Operational Curves

Operational curves were not developed for Harvey. The necessary data had been collected and the operational curves will be developed in the future.

7.6.1.3.6.7 Pump Reverse Flow

Reverse flow rating curves were computed for this station but are not presented since the discharge pipes cross over the top of the levee wall. Also there is vent to prevent reverse siphon flow in the event of pump failure or power outage. Reverse flow is not relevant if it only occurs when the levee is overtopped.

7.6.1.3.6.8 Fuel Endurance Calculations

Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. To calculate the time, a few assumptions are required. The first assumption is the HHV[109] of diesel fuel being used is 130,000 Btu[110] per gallon of fuel[111]. The second assumption is the diesel engines are at least 35% efficient[112]. This station has 1 diesel generator. The station did not report any issues with running out of fuel. Below are the fuel endurance calculations.

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[109] High heating value

[110] British thermal units

[111] http://www.exxon.com/USA-English/GFM/Products_Services/Fuels/Diesel_Fuels_FAQ.asp

[112] Standard Handbook for Mechanical Engineers, Eighth Edition, pg 9-106

The rated wattage of the diesel generator $G := 2050\,kW$ $hp = 0.746\,kW$

The assumed efficiency of the diesels $\varepsilon := 35\%$

The actual power required from the fuel $G_a := \frac{G}{\varepsilon}$ $G_a = 7854.56\,hp$

The higher heating value $HHV := 130000\,\frac{BTU}{gal}$

$BR := \frac{G_a}{HHV}$ $BR = 153.734\,\frac{gal}{hr}$

There is 1-10,000 gallon tank at this station.

$V_T := (1 \cdot 10000)\,gal$

The fuel endurance of the station $FE := \frac{V_T}{BR}$ $FE = 65.047\,hr$

$FE = 2.71\,day$

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.1.3.7 *Mt Kennedy*

Jefferson Parish – West Bank - West of Harvey Drainage Basin

Mt Kennedy Dr
Marrero, LA 70072

Latitude: 29.85382˚ Longitude: -90.12096˚

7.6.1.3.7.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Before Hurricane Katrina: Aerial view of the pump station

After Hurricane Katrina: View from the intake canal

After Hurricane Katrina: Aerial view of the pump station

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.1.3.7.2 Description[113]

Drainage area:	West Bank- West of Harvey
Nominal Capacity:	500 cfs
Drains water from:	Kenta / Seivers Canal
Discharges water to:	Bayou Segnette
Owner:	Jefferson Parish Department of Drainage
Number of pumps:	3
Pump orientation:	Not available
Pump driver:	3 electric
Water level to switch pumps on:	14.5 feet (Cairo)
Water level to switch pumps off:	13 feet (Cairo)
Water level that affects operation:	23 feet (Cairo). Water would flood electric panels.
Reverse flow protection:	None

7.6.1.3.7.3 Damages[114]

Estimated cost of repairs:	$0[115]
Relative level of damage:	None
Severity of circumstances:	Water did not enter station.
Damages	No significant damages reported.

7.6.1.3.7.4 Katrina Event

Date	Time	Event
	-	The survey states that the pump the hurricane. Water stayed below station floor. The city power went out during the Hurricane; however, a back-up generator was brought to the site before the storm, so crews would have power when they returned

7.6.1.3.7.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.1.3.7.6 Pump Operational Curves

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[113] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[114] Data for damages are taken from the Project Information Report, which can be obtained from the Parish.

[115] This cost only includes repairs to damages due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

Operational curves were not developed for Mount Kennedy. The necessary data had been collected and the operational curves will be developed in the future.

7.6.1.3.7.7 Pump Reverse Flow

There are three pumps at this station for which reverse flow rating curves were computed (no pumps were excluded). The reverse flow data and curves are presented in the order of the pump numbering utilized in the summary tables included in this appendix. In cases where there are multiple pumps of equivalent size and system configuration, a single rating curve represents all of them at a unit rate per pump.

Pump No.	Pump Capacity (cfs)	Pump Size (in)	Reverse Flow Computed?		Rating Curve Ref. No.
			Yes	No	
1	167	54	X		1
2	167	54	X		1
3	167	54	X		1

For a general explanation of reverse flow (terminology, figures, methodology, equations and assumptions), refer to the Reverse Flow Section at the beginning of this appendix. Reverse flow computations for a given pump station do not necessarily imply that reverse flow actually occurred there during the Katrina event. But these curves may instead be used as future tools if further investigations are required based on reverse flow assumptions.

Reverse Flow Rating Curve

PS Mt Kennedy, Pumps 1, 2, 3 - 54-in. Vertical Pump

Elevation Datum (ft): Cairo

Crest Elevation (ft) = 25

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use* $Q = sqrt((H1-H2)/K')$

$K' = 0.000579058 \quad sec^2/ft^5$

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:
Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:
The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 25.0 ft
Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 29.5 ft
Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

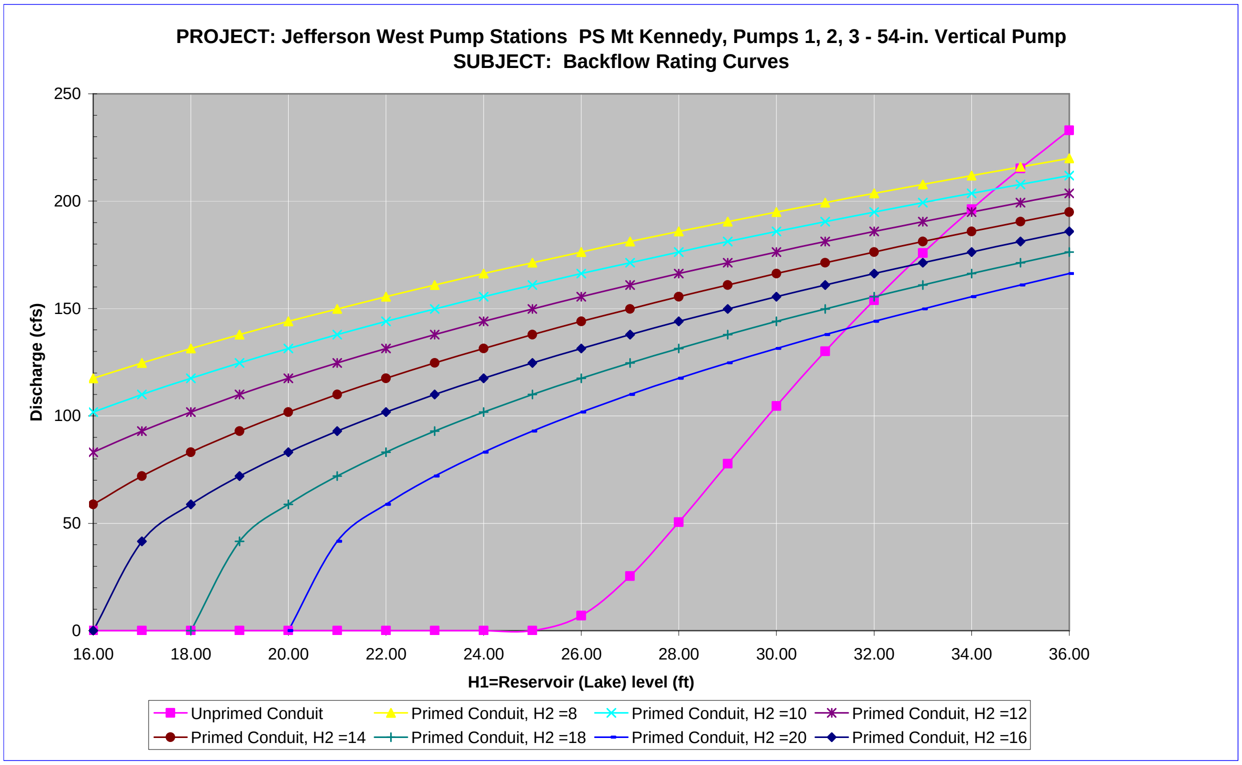
Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

H2 =	8.0	10.0	12.0	14.0	16.0	18.0	20.0
H1 >	35	35	34	34	33	33	32

Water elevation (H1) that stops unprimed flow: 25.0 ft
Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 21.3 ft
Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	6.50
Intake loss =	0.92
Exit Loss =	1.3

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

The cross sectional area of the discharge outlet was circular.

The 90 degree bend was assumed to be 2X45 degree composite bend.

The pump exit elevation was estimated to be 3 ft.

4 Data Needs or Deficiencies:

None

5 Backflow prevention:

Available:	No backflow prevention system. Mechanism to prevent reverse flow.
Used:	Operator states reverse flow did not occur

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.1.3.7.8 Fuel Endurance Calculations

We do not have any record of pumps that run on fuel at this pump station.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.1.3.8 *Westminster*

Jefferson Parish – West Bank - West of Harvey Drainage Basin

2050 Watling Dr
Marrero, LA 70072

Latitude: 29.87346˚ Longitude: -90.13800˚

7.6.1.3.8.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Before Hurricane Katrina: Aerial view of the pump station

After Hurricane Katrina: View from the side

After Hurricane Katrina: Aerial view of the pump station

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.1.3.8.2 Description[116]

Drainage area:	West Bank- West of Harvey
Nominal Capacity:	1245 cfs
Drains water from:	Grand Cross
Discharges water to:	Wetlands
Owner:	Jefferson Parish Department of Drainage
Number of pumps:	4
Pump orientation:	Not available
Pump driver:	4 electric
Water level to switch pumps on:	14.0 feet (Cairo)
Water level to switch pumps off:	13.0 feet (Cairo)
Water level that affects operation:	22 feet (Cairo). Would flood electrical substation.
Reverse flow protection:	Air suppression

7.6.1.3.8.3 Damages[117]

Estimated cost of repairs:	\$0[118]
Relative level of damage:	None
Severity of circumstances:	Water did not enter station.
Damages	No significant damages reported.

7.6.1.3.8.4 Katrina Event

Date	Time	Event
8/28/2005	-	The station was not in use. All the pumps were operational.
8/29/2005	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	3:00 PM	The survey states that the station was evacuated for safety at 3:00pm
		The station lost power.
	-	Flooding did not reach the operating floor.
	-	The station was not used after the hurricane.

7.6.1.3.8.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

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[116] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[117] Data for damages are taken from the Project Information Report, which can be obtained from the Parish.

[118] This cost only includes repairs to damages due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

7.6.1.3.8.6 Pump Operational Curves

Operational curves were not developed for Westminster. The necessary data had been collected and the operational curves will be developed in the future.

7.6.1.3.8.7 Pump Reverse Flow

There are four pumps at this station for which reverse flow rating curves were computed (no pumps were excluded). The reverse flow data and curves are presented in the order of the pump numbering utilized in the summary tables included in this appendix. In cases where there are multiple pumps of equivalent size and system configuration, a single rating curve represents all of them at a unit rate per pump.

Pump No.	Pump Capacity (cfs)	Pump Size (in)	Reverse Flow Computed?		Rating Curve Ref. No.
			Yes	No	
1	312	102 x 72	X		1
2	312	102 x 72	X		1
3	312	102 x 72	X		1
4	312	102 x 72	X		1

For a general explanation of reverse flow (terminology, figures, methodology, equations and assumptions), refer to the Reverse Flow Section at the beginning of this appendix. Reverse flow computations for a given pump station do not necessarily imply that reverse flow actually occurred there during the Katrina event. But these curves may instead be used as future tools if further investigations are required based on reverse flow assumptions.

Reverse Flow Rating Curve

PS Westminster, Pumps 1, 2, 3, 4, 72-in.

Elevation Datum (ft):	Cairo
Crest Elevation (ft) =	25.5

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use* $Q = \mathrm{sqrt}((H1-H2)/K')$

$K' = 0.000114408 \quad sec^2/ft^5$

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 25.5 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 32.5 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

H2 =	0.0	4.0	8.0	12.0	16.0	20.0	24.0
H1 >	29	28	28	27	27	26	26

Water elevation (H1) that stops unprimed flow: 25.5 ft

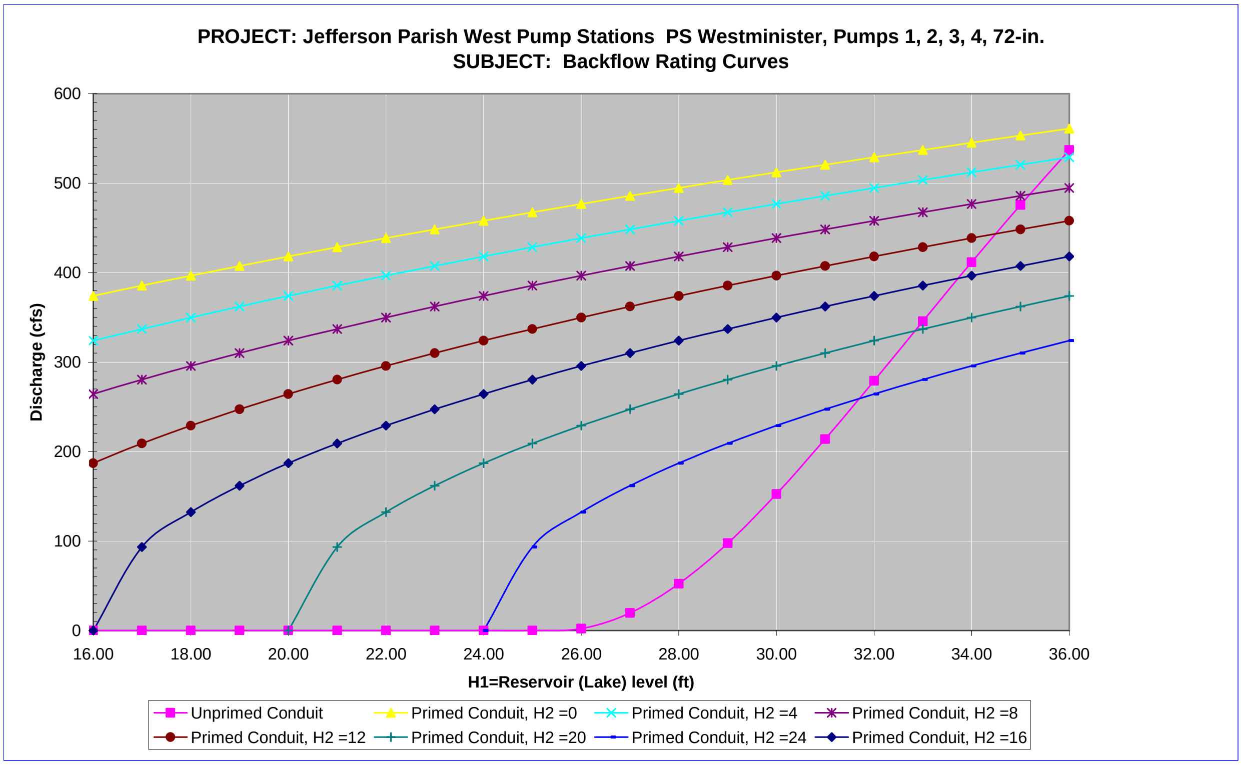
Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 19.6 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	6.50
Intake loss =	0.92
Exit Loss =	1.0

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Pumps 1, 2, 3, & 4 are identical in manufacturing & installation.

Elevations in Cairo Datum.

Pump flow rates & rated head taken from pump curves.

All length measurements were center line lengths.

4 Data Needs or Deficiencies:

None.

5 Backflow prevention:

Available: Air suppression for backflow prevention.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Backstops installed to prevent reverse rotation.

Used: Water not high enough for backflow.

7.6.1.3.8.8 Fuel Endurance Calculations

We do not have any record of pumps that run on fuel at this pump station.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.1.3.9 *Westwego 1*

Jefferson Parish – West Bank - West of Harvey Drainage Basin

100 Vic A Pitre
Westwego, LA 70094

Latitude: 29.89702˚ Longitude: -90.15387˚

7.6.1.3.9.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Before Hurricane Katrina: Aerial view of the pump station

After Hurricane Katrina: View from the intake canal

After Hurricane Katrina: Aerial view of the pump station

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.1.3.9.2 Description[119]

Drainage area:	West Bank- West of Harvey
Nominal Capacity:	300 cfs
Drains water from:	WPA Canal
Discharges water to:	Bayou Segnette
Owner:	Jefferson Parish Department of Drainage
Number of pumps:	1
Pump orientation:	Vertical
Pump driver:	Diesel
Water level to switch pumps on:	14.5 feet (Cairo)
Water level to switch pumps off:	13.5 feet (Cairo)
Water level that affects operation:	32 feet (Cairo). Water would overtop motor.
Reverse flow protection:	None

7.6.1.3.9.3 Damages[120]

Estimated cost of repairs:	$2,000[121]
Relative level of damage:	Minor
Severity of circumstances:	Flooding did not reach the operating floor.
Equipment damaged:	No significant equipment damage was recorded.
Building damage:	Consists of damage to the roof and windows.
Misc. damage:	No significant miscellaneous damage was recorded.

7.6.1.3.9.4 Katrina Event

Date	Time	Event
8/28/2005	-	The pump was available prior to the hurricane. It was not used for pre-Katrina drawdown.
8/29/2005	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	-	Flooding did not reach the operating floor.
8/30/2005	-	The survey states that the operator returned and started the pump.
	9:00 AM	The unwatering was complete.

7.6.1.3.9.5 Repair Status

---

[119] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[120] Data for damages are taken from the Project Information Report, which can be obtained from the Parish.

[121] This cost only includes repairs to damages due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.1.3.9.6 Pump Operational Curves

Operational curves were not developed for Westwego 1. The necessary data had been collected and the operational curves will be developed in the future.

7.6.1.3.9.7 Pump Reverse Flow

There is one pumps at this station for which reverse flow rating curves were computed (no pumps were excluded). The reverse flow data and curves are presented in the order of the pump numbering utilized in the summary tables included in this appendix. In cases where there are multiple pumps of equivalent size and system configuration, a single rating curve represents all of them at a unit rate per pump.

Pump No.	Pump Capacity (cfs)	Pump Size (in)	Reverse Flow Computed?		Rating Curve Ref. No.
			Yes	No	
1	300	84	X		1

For a general explanation of reverse flow (terminology, figures, methodology, equations and assumptions), refer to the Reverse Flow Section at the beginning of this appendix. Reverse flow computations for a given pump station do not necessarily imply that reverse flow actually occurred there during the Katrina event. But these curves may instead be used as future tools if further investigations are required based on reverse flow assumptions.

Reverse Flow Rating Curve

PS Westwego 1, Pump 1 - 84-in. Vertical Pump

Elevation Datum (ft): Cairo
Crest Elevation (ft) = 24
H1 = Lake or outlet canal water level (normal pump discharge side)
H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use* $Q = \mathrm{sqrt}((H1-H2)/K')$

$K' =$ *6.55745E-05* sec^2/ft^5

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 24.0 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 31.0 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

H2 =	8.0	10.0	12.0	14.0	16.0	18.0	20.0
H1 >	39	38	38	37	36	36	35

Water elevation (H1) that stops unprimed flow: 24.0 ft

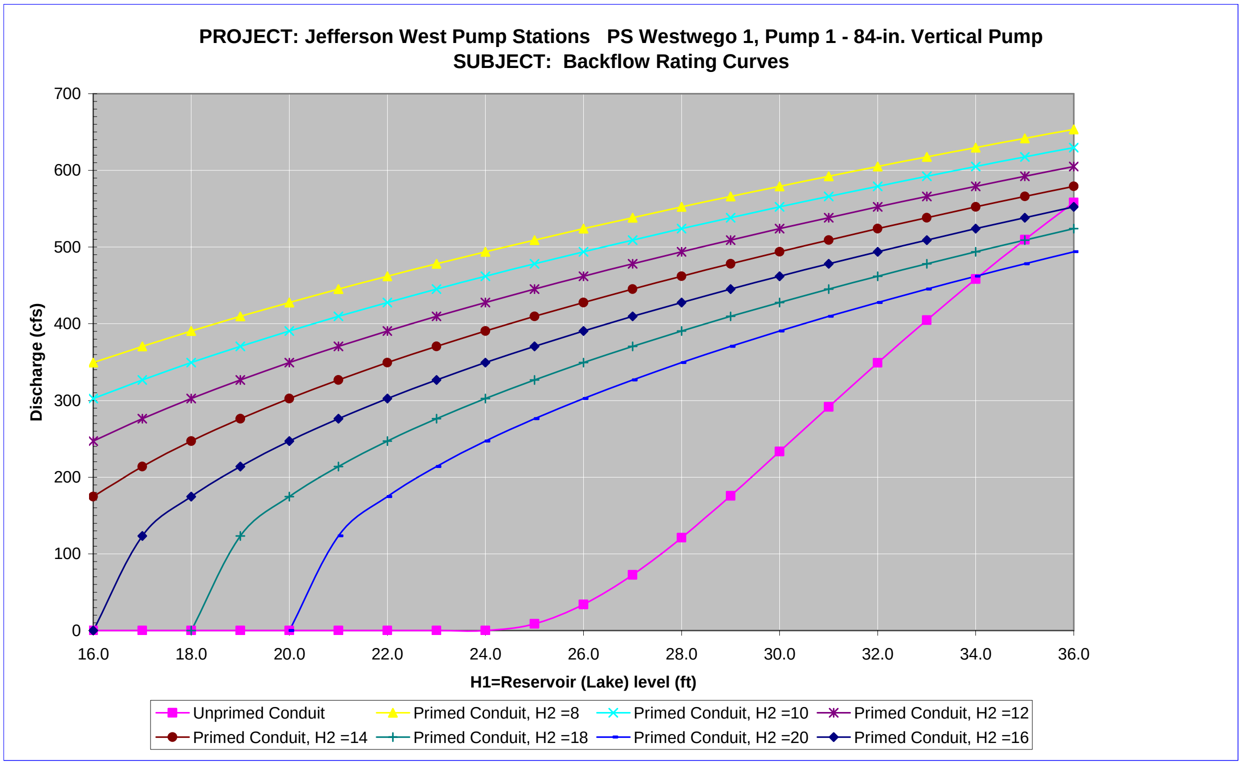
Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 11.3 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient = 3.50
Intake loss = 0.92
Exit Loss = 1.3
Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

The bend near the discharge outlet was a single mitered bends.
All dimensions were scaled from the drawings.

4 Data Needs or Deficiencies:

Drawings with exact dimensions.
More photos.

5 Backflow prevention:

Available: No backflow prevention system.
No brakes to prevent reverse rotation.

Used: Unknown.

7.6.1.3.9.8 Fuel Endurance Calculations

Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. To calculate the time, a few assumptions are required. The first assumption is the HHV[122] of diesel fuel being used is 130,000 Btu[123] per gallon of fuel[124]. The second assumption is the diesel engines are at least 35% efficient[125]. This station has 1 diesel driven pump. The station did not report any issues with running out of fuel. Below are the fuel endurance calculations.

The rated horsepower of the diesel driver $P := 700\text{hp}$

The assumed efficiency of the diesels $\varepsilon := 35\%$

The actual power required from the fuel $P_a := \frac{P}{\varepsilon}$ $P_a = 2000\,\text{hp}$

The higher heating value $HHV := 130000\frac{BTU}{gal}$

$BR := \frac{P_a}{HHV}$ $BR = 39.145\,\frac{gal}{hr}$

There are 2-8,000 gallon tanks at this station.

$V_T := (2\cdot 8000)\text{gal}$

The fuel endurance of the station $FE := \frac{V_T}{BR}$ $FE = 408.735\,\text{hr}$

$FE = 17.031\,\text{day}$

---

[122] High heating value

[123] British thermal units

[124] http://www.exxon.com/USA-English/GFM/Products_Services/Fuels/Diesel_Fuels_FAQ.asp

[125] Standard Handbook for Mechanical Engineers, Eighth Edition, pg 9-106

7.6.1.3.10 *Westwego 2*

Jefferson Parish – West Bank - West of Harvey Drainage Basin

820 Laroussini St
Westwego, LA 70094

Latitude: 29.89058˚ Longitude: -90.15600˚

7.6.1.3.10.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Before Hurricane Katrina: Aerial view of the pump station

After Hurricane Katrina: View from the intake canal

After Hurricane Katrina: Aerial view of the pump station

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.1.3.10.2 Description[126]

Drainage area:	West Bank- West of Harvey
Nominal Capacity:	935 cfs
Drains water from:	Ave. H Canal
Discharges water to:	Bayou Segnette
Owner:	Jefferson Parish Department of Drainage
Number of pumps:	3
Pump orientation:	Not available
Pump driver:	2 diesels 1 unknown
Water level to switch pumps on:	13.5 feet (Cairo)
Water level to switch pumps off:	12.0 feet (Cairo)
Water level that affects operation:	31 feet (Cairo). Electric fuel transfer pump would flood)
Reverse flow protection:	Manual gate valves

7.6.1.3.10.3 Damages[127]

Estimated cost of repairs:	$2,000[128]
Relative level of damage:	Minor
Severity of circumstances:	Flooding did not reach the operating floor.
Equipment damaged:	No significant equipment damage was recorded.
Building damage:	Consists of broken windows and a leaking roof.
Misc. damage:	No significant miscellaneous damage was recorded.

---

[126] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[127] Data for damages are taken from the Project Information Report, which can be obtained from the Parish.

[128] This cost only includes repairs to damages due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.1.3.10.4 Katrina Event

Date	Time	Event
8/28/2005	3:00 PM	The survey states that the station was evacuated.
	-	The survey states that two pumps were used for pre-Katrina drawdown. Pump 1 was used for one hour. Pump 2 was used for three hours.
	-	One of the pumps was inoperable prior to the hurricane.
8/29/2005	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	11:00 AM	The survey states that the operators returned and restarted pumps 1 and 2.
	-	The survey states that the water stayed below the operating floor
8/30/2005	12:00 PM	The survey states that the unwatering was complete.

7.6.1.3.10.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.1.3.10.6 Pump Operational Curves

Operational curves were not developed for Westwego 2. The necessary data had been collected and the operational curves will be developed in the future.

7.6.1.3.10.7 Pump Reverse Flow

There are three pumps at this station for which reverse flow rating curves were computed (no pumps were excluded). The reverse flow data and curves are presented in the order of the pump numbering utilized in the summary tables included in this appendix. In cases where there are multiple pumps of equivalent size and system configuration, a single rating curve represents all of them at a unit rate per pump.

Pump No.	**Pump Capacity (cfs)**	**Pump Size (in)**	**Reverse Flow Computed?**		**Rating Curve Ref. No.**
			Yes	**No**	
1	312	102 x 84	X		1
2	312	102 x 84	X		1
3	312	102 x 84	X		1

For a general explanation of reverse flow (terminology, figures, methodology, equations and assumptions), refer to the Reverse Flow Section at the beginning of this appendix. Reverse flow computations for a given pump station do not necessarily imply that reverse flow actually occurred there during the Katrina event. But these curves may instead be used as future tools if further investigations are required based on reverse flow assumptions.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Reverse Flow Rating Curve

PS Westwego 2, Pumps 1, 2, 3 - 84-in. Vertical Pump

Elevation Datum (ft):	Cairo
Crest Elevation (ft) =	22.5

H1 = Lake or outlet canal water level (normal pump discharge side)
H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use Q = sqrt((H1-H2)/K')*
K' = *8.94932E-05* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 22.5 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 29.5 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

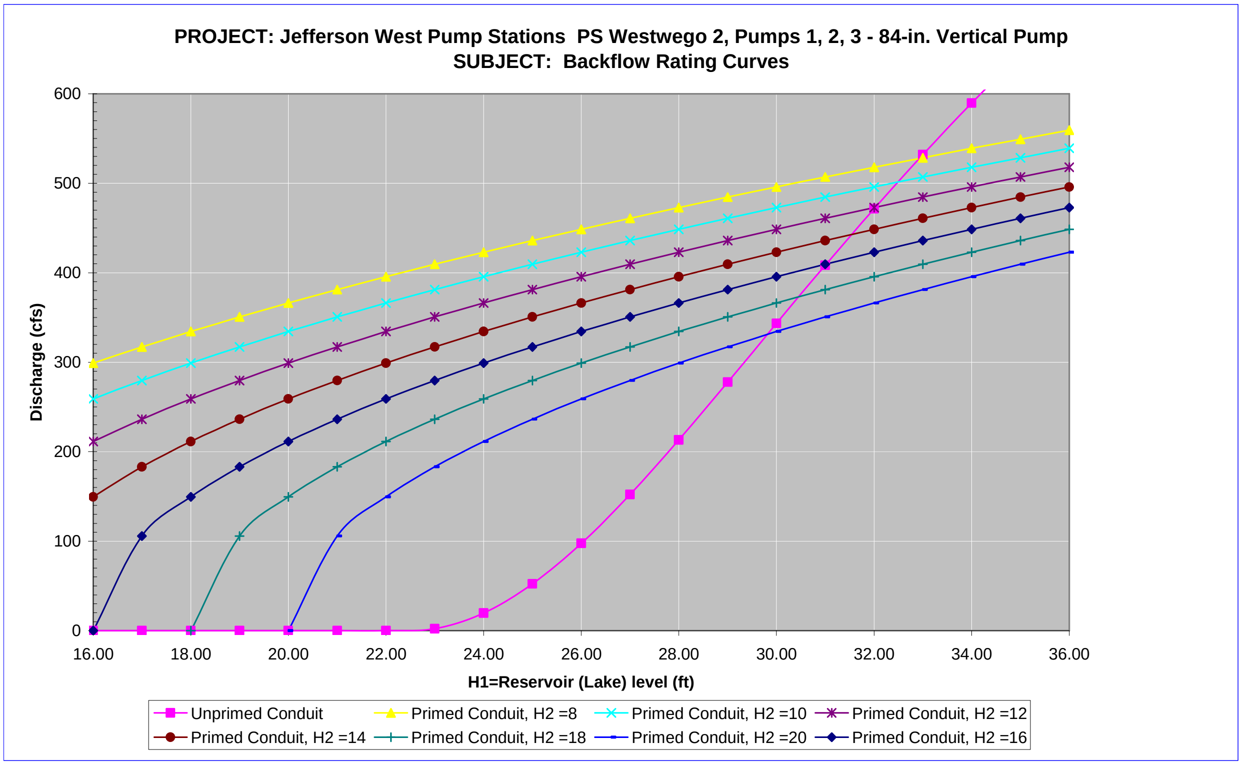
H2 =	8.0	10.0	12.0	14.0	16.0	18.0	20.0
H1 >	33	33	33	32	32	32	31

Water elevation (H1) that stops unprimed flow: 22.5 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 17.6 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	6.50
Intake loss =	0.92
Exit Loss =	1.3

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

The bend near intake is a smooth transitioning 45 bend.

The losses associated with changes in shape are captured with expansion coefficients.

The area applied to the losses for change of shape was equal to the outlet (C3).

General pump summary sheet lists only 2 pumps, however drawings & survey confirm 3 pumps.

4 Data Needs or Deficiencies:

None

5 Backflow prevention:

Available:	Manual operation gate valves. Mechanism to prevent reverse rotation.
Used:	Operator states reverse flow did not occur.

7.6.1.3.10.8 Fuel Endurance Calculations

Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. To calculate the time, a few assumptions are required. The first assumption is the HHV[129] of diesel fuel being used is 130,000 Btu[130] per gallon of fuel[131]. The second assumption is the diesel engines are at least 35% efficient[132]. This station has 2 diesel driven pumps with the same rated horsepower. The station did not report any issues with running out of fuel. Below are the fuel endurance calculations.

---

[129] High heating value

[130] British thermal units

[131] http://www.exxon.com/USA-English/GFM/Products_Services/Fuels/Diesel_Fuels_FAQ.asp

[132] Standard Handbook for Mechanical Engineers, Eighth Edition, pg 9-106

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

The rated horsepower of the diesel driver $P := 846\text{hp}$

The assumed efficiency of the diesels $\varepsilon := 35\%$

The actual power required from the fuel $P_a := \dfrac{P}{\varepsilon}$ $P_a = 2417.14\,\text{hp}$

The higher heating value $HHV := 130000\,\dfrac{\text{BTU}}{\text{gal}}$

$BR := \dfrac{P_a}{HHV}$ $BR = 47.31\,\dfrac{\text{gal}}{\text{hr}}$

There are 2-5,000 gallon tanks and 2-300 gallon tanks at this station.

$V_T := (2\cdot 5000 + 2\cdot 300)\text{gal}$

The fuel endurance of the station $FE := \dfrac{V_T}{2BR}$ $FE = 112.028\,\text{hr}$

$FE = 4.668\,\text{day}$

7.6.1.4 West Bank – East of Harvey

7.6.1.4.1 *Hero*

Jefferson Parish – West Bank – East of Harvey Drainage Basin

4644 Peters Road
Harvey, LA 70058

Latitude: 29.83766˚ Longitude: -90.05629˚

7.6.1.4.1.1 Before and After Hurricane Katrina Photos

Before Hurricane Katrina: View from the intake canal

Before Hurricane Katrina: Aerial view of the pump station

After Hurricane Katrina: View from the intake canal

After Hurricane Katrina: Aerial view of the pump station

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.1.4.1.2 Description[133]

Drainage area: West Bank- East of Harvey

Nominal Capacity: 3850 cfs

Drains water from: Hero Outfall Canal

Discharges water to: Intracoastal Waterway

Owner: Jefferson Parish Department of Drainage

Number of pumps: 10

Pump orientation: Not available

Pump driver: 4 electric
6 diesel

Water level to switch pumps on:

Water level to switch pumps off:

Water level that affects operation: 21.5 feet (Cairo). Water would flood electrical switch gears and electronic fuel pump for diesel generator

Reverse flow protection: None

7.6.1.4.1.3 Damages[134]

Estimated cost of repairs: $11,000[135]

Relative level of damage: Minor

Severity of circumstances: Flooding did not reach the operating floor.

Equipment damaged: No significant equipment damage was recorded.

Building damage: Includes damage to the roof, vents, flashing, exhaust stacks, and electric cable tray.

Misc. damage: No significant miscellaneous damage recorded.

---

[133] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[134] Data for damages are taken from the Project Information Report, which can be obtained from the Parish.

[135] This cost only includes repairs to damages due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.1.4.1.4 Katrina Event

Date	Time	Event
8/28/2005	-	Pump 1 was down prior to the storm. All other pumps were operational and were used for pre-Katrina drawdown until the operators were evacuated.
	1:45 PM	The survey states that the operators evacuated the station.
8/29/2005	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	-	The survey states that the water stayed below the floor of the building.
8/30/2005	12:30 AM	The survey states that the operators returned to the station.
9/2/2005	12:00 AM	The survey states that all the unwatering was complete.

7.6.1.4.1.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.1.4.1.6 Pump Operational Curves

Operational curves were not developed for Hero. The necessary data had been collected and the operational curves will be developed in the future.

7.6.1.4.1.7 Pump Reverse Flow

There are ten pumps at this station for which reverse flow rating curves were computed (no pumps were excluded). The reverse flow data and curves are presented in the order of the pump numbering utilized in the summary tables included in this appendix. In cases where there are multiple pumps of equivalent size and system configuration, a single rating curve represents all of them at a unit rate per pump.

Pump No.	Pump Capacity (cfs)	Pump Size (in)	Reverse Flow Computed?		Rating Curve Ref. No.
			Yes	No	
1	100	48	X		1
2	300	72	X		2
3	300	72	X		2
4	1020	160	X		3
5	1020	160	X		3
6	300	72	X		2
7	203	60	X		4
8	203	60	X		4
9	203	60	X		4
10	203	60	X		4

For a general explanation of reverse flow (terminology, figures, methodology, equations and assumptions), refer to the Reverse Flow Section at the beginning of this appendix. Reverse flow computations for a given pump station do not necessarily imply that reverse flow actually occurred there during the Katrina event. But these curves may instead be used as future tools if further investigations are required based on reverse flow assumptions.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Reverse Flow Rating Curve

PS Hero, Pump 1, 48-in.

Elevation Datum (ft):	Cairo
Crest Elevation (ft) =	26.5

H1 = Lake or outlet canal water level (normal pump discharge side)
H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: Use $Q = \sqrt{(H1-H2)/K'}$
$K' =$ 0.000442727 sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 26.5 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated

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unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 30.5 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

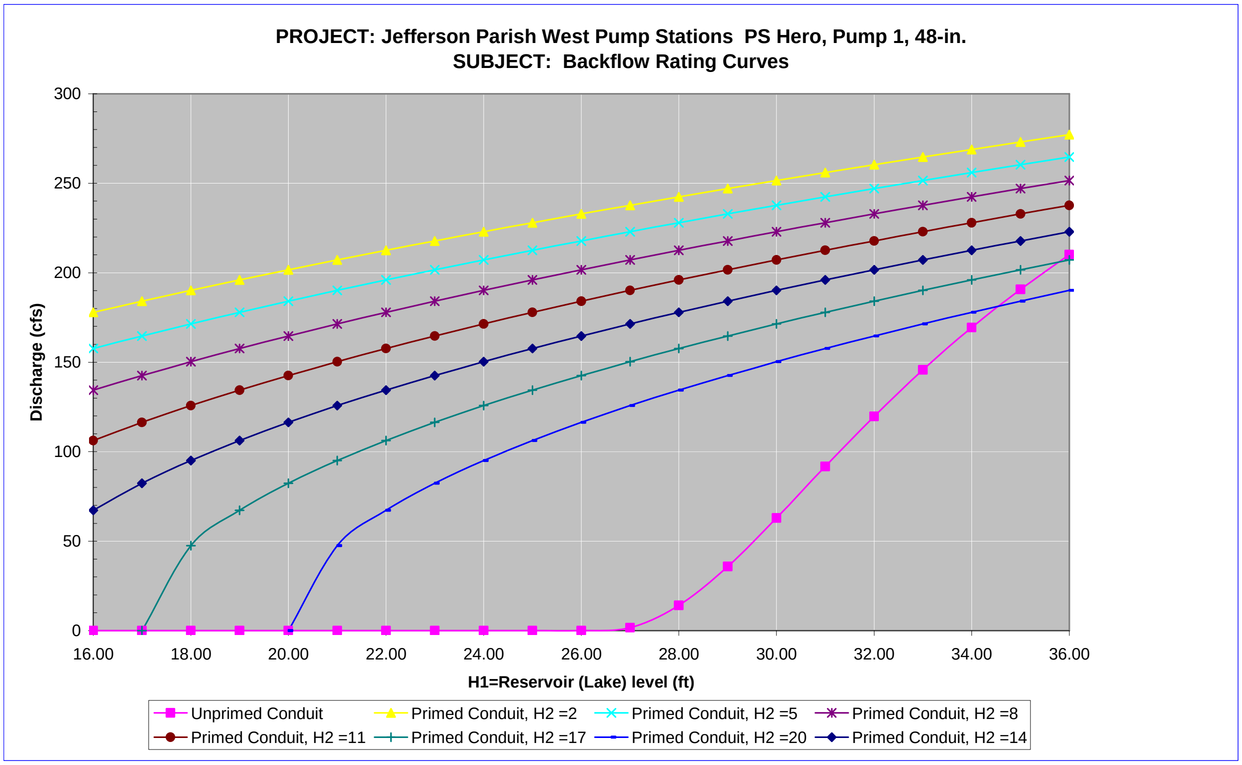
H2 =	2.0	5.0	8.0	11.0	14.0	17.0	20.0
H1 >	36	35	34	33	31	30	29

Water elevation (H1) that stops unprimed flow: 26.5 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 19.5 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.



This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	3.50
Intake loss =	0.92
Exit Loss =	1.0

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

No profile drawings of pump. Assumed the elevations were the same as the drawings based on photos.

Assumed the length of the pump is the same as Pumps 2, 3, & 6.

The flow area is doubled because there are two branches coming into the pump.

Elevations in Cairo Datum.

4 Data Needs or Deficiencies:

Profile drawings of the pump.

5 Backflow prevention:

Available:	No backflow prevention. Backstops in place to prevent reverse rotation.
Used:	None. Operators stated that backflow did not occur because the water did not get high enough.

Reverse Flow Rating Curve

PS Hero, Pumps 2, 3, & 6, 72-in.

Elevation Datum (ft):	Cairo
Crest Elevation (ft) =	26.5

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level

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(H1) and the drainage area water level (H2):

For primed flow rates: Use Q = sqrt((H1-H2)/K')
K' = 6.04565E-05 sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 26.5 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 33.5 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

H2 =	2.0	5.0	8.0	11.0	14.0	17.0	20.0
H1 >	34	33	32	31	30	29	29

Water elevation (H1) that stops unprimed flow: 26.5 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

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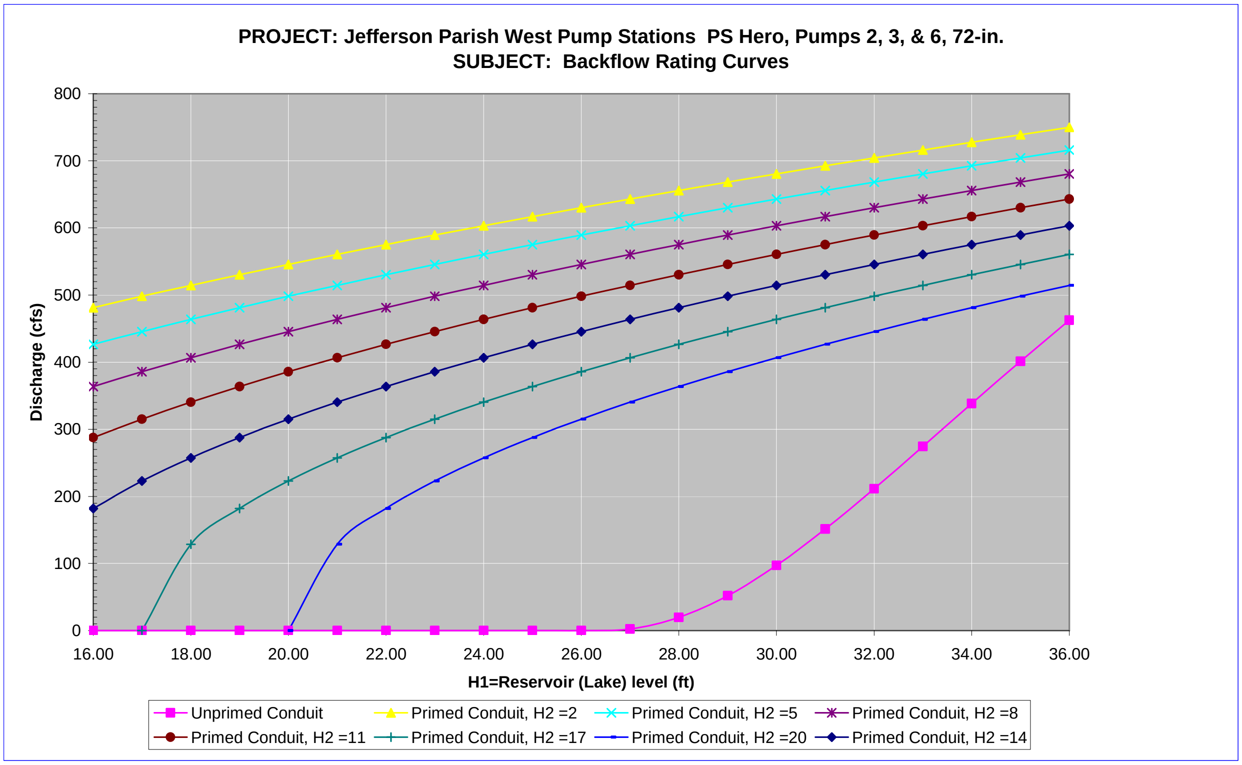
Water elevation (H1) that stops primed conduit flow: 19.5 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	3.50
Intake loss =	0.92
Exit Loss =	1.0

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

No profile drawings of intake piping or pumps. Assumed the elevations & layout was the same as pumps 7-10.

The intake had dual pipes. Determined the losses for one pipe & then doubled to get the total losses.

The flow area is doubled because there are two branches coming into the pump.

Elevations in Cairo Datum.

4 Data Needs or Deficiencies:

Profile drawings of the intake piping & pumps.

5 Backflow prevention:

Available:	No backflow prevention. Backstops in place to prevent reverse rotation.
Used:	None. Operators stated that backflow did not occur because the water did not get high enough.

Reverse Flow Rating Curve

PS Hero, Pumps 4 & 5, 160-in.

Elevation Datum (ft):	Cairo
Crest Elevation (ft) =	26.5

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: Use $Q = \text{sqrt}((H1-H2)/K')$

$K' =$ 7.34066E-06 sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

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Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 26.5 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 40.0 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

H2 =	2.0	5.0	8.0	11.0	14.0	17.0	20.0
H1 >	31	30	30	29	29	28	28

Water elevation (H1) that stops unprimed flow: 26.5 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 17.4 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.

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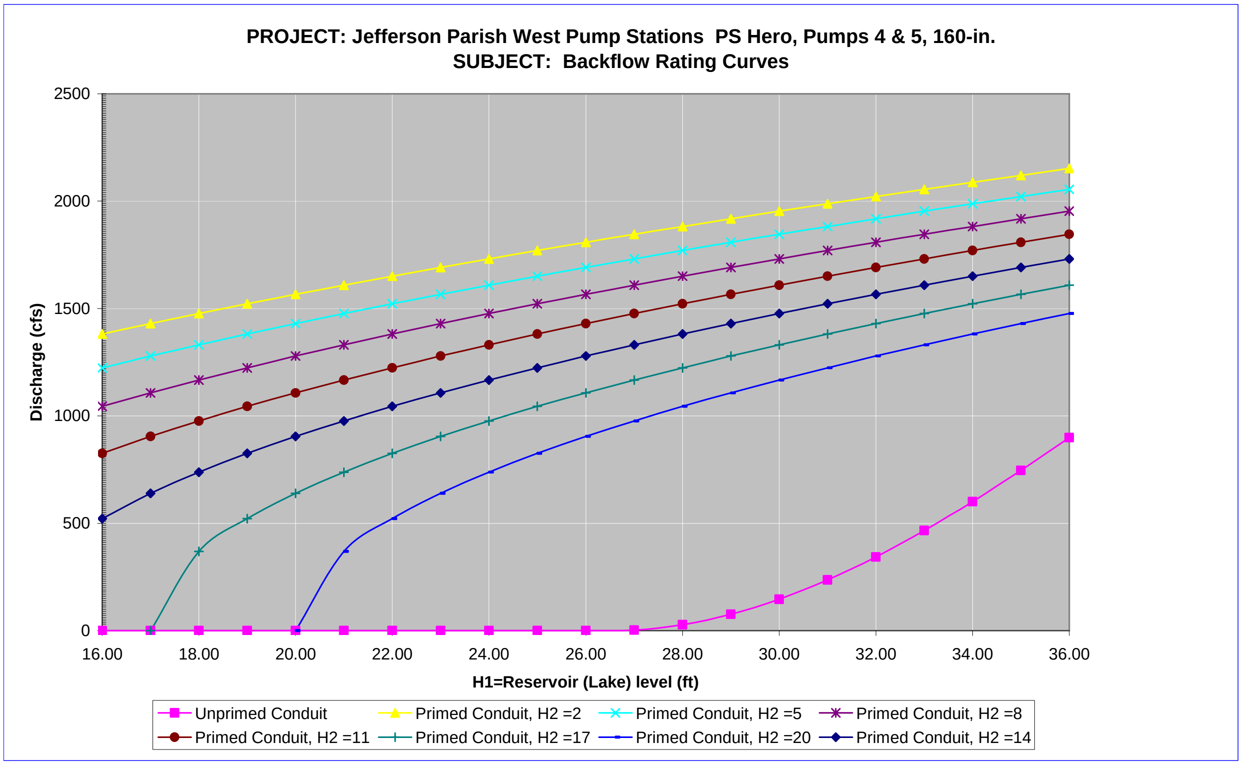

Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	9.00
Intake loss =	0.92
Exit Loss =	1.0

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

No drawings of the intake. Assumed the intake is rectangle because it is concrete. Width is assumed to be
the same as the pipe (13.5 ft)
Elevations in Cairo Datum

4 Data Needs or Deficiencies:

Drawings of the inlet.

5 Backflow prevention:

Available: No backflow prevention.
Backstops in place to prevent reverse rotation.

Used:	None. Operators stated that backflow did not occur because the water did not get high enough.

Reverse Flow Rating Curve

PS Hero, Pumps 7, 8, 9, & 10, 60-in.

Elevation Datum (ft):	Cairo
Crest Elevation (ft) =	26.33

H1 = Lake or outlet canal water level (normal pump discharge side)
H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use Q = sqrt((H1-H2)/K')*
K' = *0.000289876* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

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Water elevation (H1) that triggers unprimed flow: 26.3 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 32.3 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

H2 =	2.0	5.0	8.0	11.0	14.0	17.0	20.0
H1 >	35	35	34	34	34	34	33

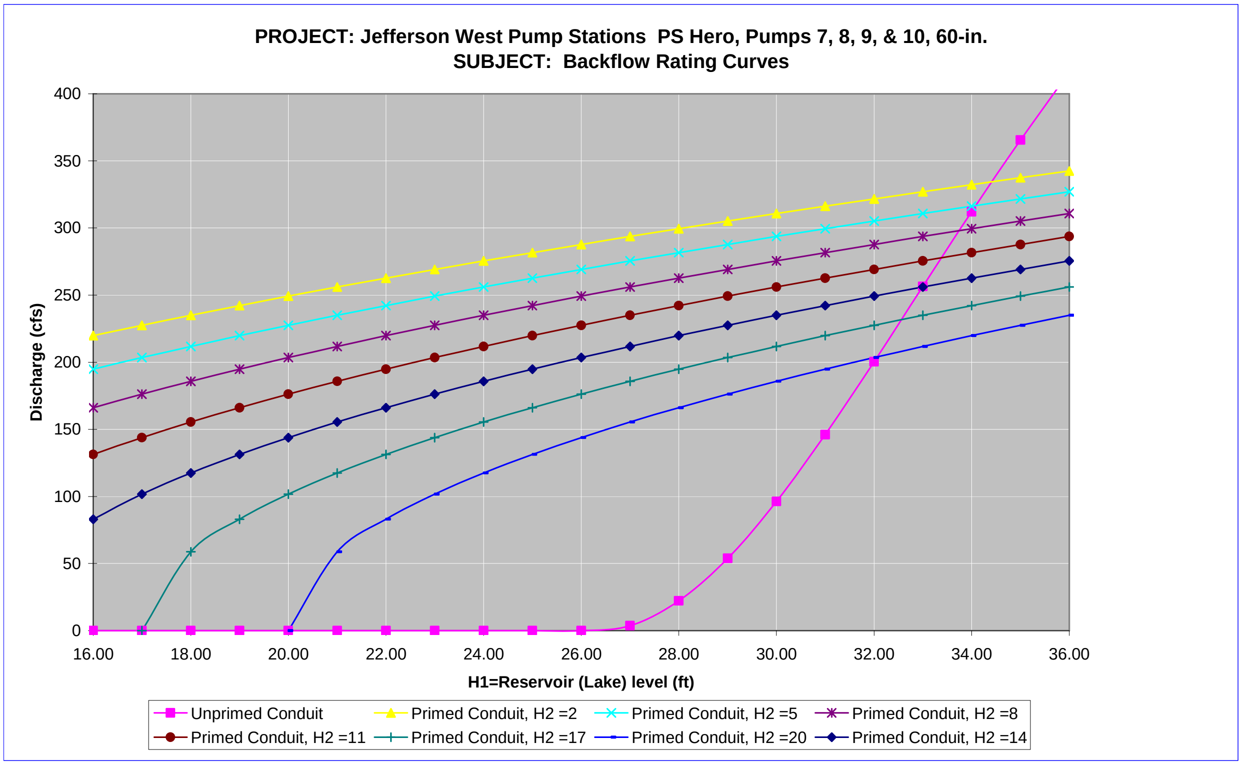
Water elevation (H1) that stops unprimed flow: 26.3 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 19.0 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.


PROJECT: Jefferson West Pump Stations PS Hero, Pumps 7, 8, 9, & 10, 60-in.
SUBJECT: Backflow Rating Curves

Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	6.50
Intake loss =	0.92
Exit Loss =	1.0

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

No impeller size given. Estimate by scaling off the drawings.

Elevations in Cairo Datum.

Pumps 7, 8, 9, & 10 are identical in manufacturing & installation.

Pump rated head taken from pump curve.

All length measurements were center line lengths.

4 Data Needs or Deficiencies:

Actual impeller size.

5 Backflow prevention:

Available: No backflow prevention.
Backstops in place to prevent reverse rotation.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Used:	None. Operators stated that backflow did not occur because the water did not get high enough.

7.6.1.4.1.8 Fuel Endurance Calculations

Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. To calculate the time, a few assumptions are required. The first assumption is the HHV[136] of diesel fuel being used is 130,000 Btu[137] per gallon of fuel[138]. The second assumption is the diesel engines are at least 35% efficient[139]. This station has 2 diesel driven pumps with the same rated horsepower and 2 diesel generators with the same rated horsepower. The station did not report any issues with running out of fuel. Below are the fuel endurance calculations.

---

[136] High heating value

[137] British thermal units

[138] http://www.exxon.com/USA-English/GFM/Products_Services/Fuels/Diesel_Fuels_FAQ.asp

[139] Standard Handbook for Mechanical Engineers, Eighth Edition, pg 9-106

The rated wattage of the diesel generator $G := 2050\,\mathrm{kW}$ $\quad hp = 0.746\,\mathrm{kW}$

The rated horsepower of the diesel driver $P := 2305\,\mathrm{hp}$

The assumed efficiency of the diesels $\varepsilon := 35\%$

The actual power required from the fuel $G_a := \frac{G}{\varepsilon}$ $\quad G_a = 7854.56\,\mathrm{hp}$

$P_a := \frac{P}{\varepsilon}$ $\quad P_a = 6585.71\,\mathrm{hp}$

The higher heating value $HHV := 130000\,\frac{BTU}{gal}$

$BR_1 := \frac{G_a}{HHV}$ $\quad BR_1 = 153.734\,\frac{gal}{hr}$

$BR_2 := \frac{P_a}{HHV}$ $\quad BR_2 = 128.899\,\frac{gal}{hr}$

There are 3-14,500 gallon tanks and 2-500 gallon tanks at this station.

$$V_T := (3\cdot 14500 + 2\cdot 500)\,gal$$

The fuel endurance of the station $FE := \frac{V_T}{2BR_1 + 2BR_2}$ $\quad FE = 78.724\,\mathrm{hr}$

$FE = 3.28\,\mathrm{day}$

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7.6.1.4.2 *Planters*

Jefferson Parish – West Bank - East of Harvey Drainage Basin

268 W Bypass Rd
Belle Chasse, LA 70037

Latitude: 29.88342˚ Longitude: -90.00442˚

7.6.1.4.2.1 Before and After Hurricane Katrina Photos

Before Hurricane Katrina: View from the intake canal

Before Hurricane Katrina: Aerial view of the pump station

After Hurricane Katrina: View from the intake canal

After Hurricane Katrina: Aerial view of the pump station

7.6.1.4.2.2 Description[140]

Drainage area:	West Bank- East of Harvey
Nominal Capacity:	2350 cfs
Drains water from:	Planters by Pass Canal
Discharges water to:	Intracoastal Waterway
Owner:	Jefferson Parish Department of Drainage
Number of pumps:	9
Pump orientation:	Not available
Pump driver:	4 diesels 5 electric
Water level to switch pumps on:	10 feet (Cairo)
Water level to switch pumps off:	9.5 feet (Cairo)
Water level that affects operation:	25 feet (Cairo). Water would flood gearbox panels.
Reverse flow protection:	None

7.6.1.4.2.3 Damages[141]

Estimated cost of repairs:	$37,000[142]
Relative level of damage:	Minor
Severity of circumstances:	Flooding did not reach the operating floor.
Equipment damaged:	No significant equipment damage was recorded.
Building damage:	Consists of damage to the skylight wall panels, flashing, and roof.
Misc. damage:	No significant miscellaneous damage recorded.

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[140] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[141] Data for damages are taken from the Project Information Report, which can be obtained from the Parish.

[142] This cost only includes repairs to damages due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

7.6.1.4.2.4 Katrina Event

Date	Time	Event
8/28/2005	6:00 AM	The survey states that the operators pumped down the canal with all 9 pumps before the storm.
	5:00 PM	The survey states that the last operator was evacuated.
8/29/2005	6:30 AM	Hurricane Katrina made landfall in Louisiana.
		The survey states that the water stayed below the operating floor.
8/30/2005	6:30 AM	The survey states that the operators returned
	10:45 PM	The survey states that the canal was pumped to 9.7ft(Cairo Datum)

7.6.1.4.2.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.1.4.2.6 Pump Operational Curves

Operational curves were not developed for Planters. The necessary data had been collected and the operational curves will be developed in the future.

7.6.1.4.2.7 Pump Reverse Flow

There are nine pumps at this station for which reverse flow rating curves were computed (no pumps were excluded). The reverse flow data and curves are presented in the order of the pump numbering utilized in the summary tables included in this appendix. In cases where there are multiple pumps of equivalent size and system configuration, a single rating curve represents all of them at a unit rate per pump.

Pump No.	**Pump Capacity (cfs)**	**Pump Size (in)**	**Reverse Flow Computed?**		**Rating Curve Ref. No.**
			Yes	**No**	
1	288	84	X		1
2	288	84	X		1
3	288	84	X		1
4	288	84	X		1
5	52	36	X		2
6	288	102 x 84	X		3
7	288	102 x 84	X		3
8	288	102 x 84	X		3
9	288	102 x 84	X		3

For a general explanation of reverse flow (terminology, figures, methodology, equations and assumptions), refer to the Reverse Flow Section at the beginning of this appendix. Reverse flow computations for a given pump station do not necessarily imply that reverse flow actually occurred there during the Katrina event. But these curves may instead be used as future tools if further investigations are required based on reverse flow assumptions.

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Reverse Flow Rating Curve

PS Planters, Pumps 1, 2, 3, 4 -78-in. Vertical Pump

Elevation Datum (ft):	Cairo
Crest Elevation (ft) =	25.5

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use Q = sqrt((H1-H2)/K')*

$K' = 0.000128837 \quad sec^2/ft^5$

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 25.5 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated

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unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 32.0 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

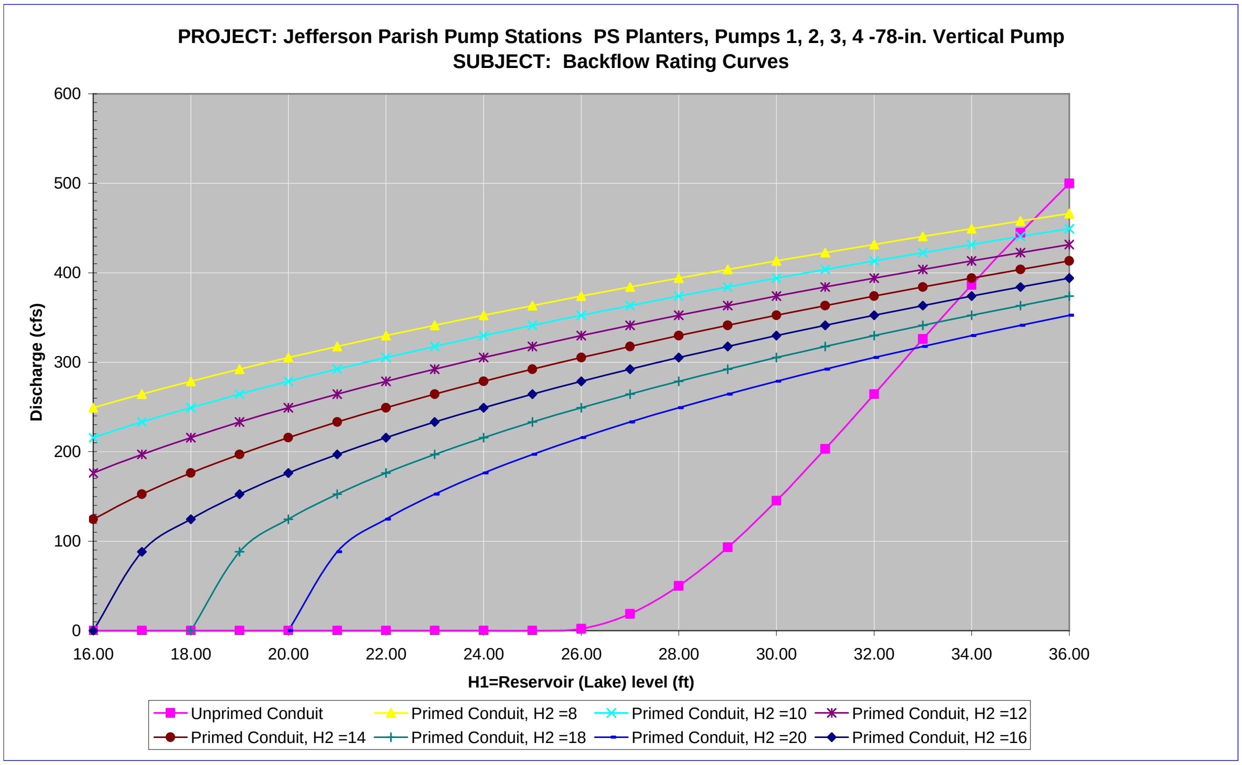
H2 =	8.0	10.0	12.0	14.0	16.0	18.0	20.0
H1 >	36	35	35	35	34	34	34

Water elevation (H1) that stops unprimed flow: 25.5 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 17.0 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.



This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	6.50
Intake loss =	0.92
Exit Loss =	1.3

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Scaled Pump entrance, exit, and intake elevations from drawings.

90 degree bend r/d ration = 1.

90 degree bend was a composite 2X45 bend.

4 Data Needs or Deficiencies:

Dimensioned elevation view drawings for 90 degree bend and pump intake, entrance, and exit.

5 Backflow prevention:

Available:	No backflow prevention system. Mechanism to prevent reverse rotation.
Used:	Operator states no reverse flow.

Reverse Flow Rating Curve

PS Planters, Pump 5 - 36-in. Vertical Pump

Elevation Datum (ft):	Cairo
Crest Elevation (ft) =	25.5

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use $Q = \mathrm{sqrt}((H1-H2)/K')$*

K' = *0.002839276* *sec^2/ft^5*

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Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 25.5 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 28.5 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

H2 =	8.0	10.0	12.0	14.0	16.0	18.0	20.0
H1 >	32	31	31	31	31	30	30

Water elevation (H1) that stops unprimed flow: 25.5 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 12.0 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure

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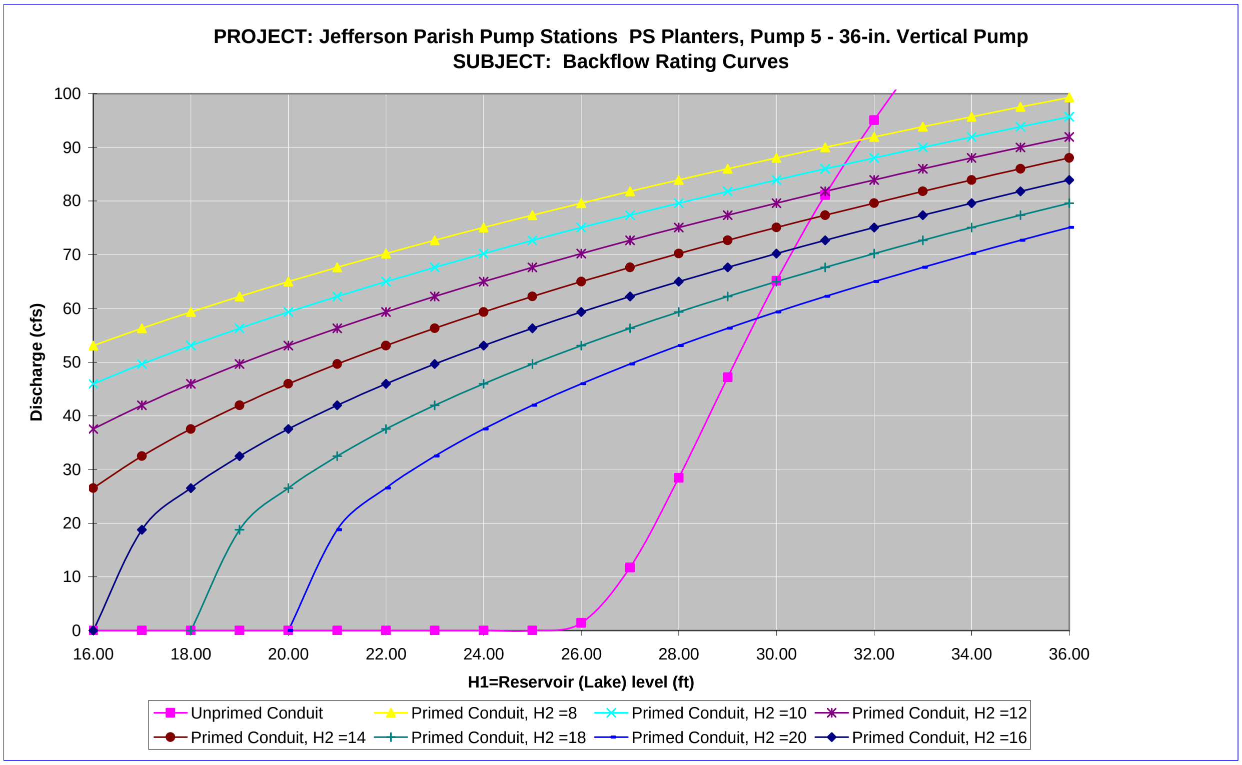
at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	6.50
Intake loss =	0.92
Exit Loss =	1.3

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Scaled Pump entrance, exit, and intake elevations from drawings.

90 degree bend r/d ration = 1.

90 degree bend was a composite 2X45 bend.

4 Data Needs or Deficiencies:

Dimensioned elevation view drawings for 90 degree bend and pump intake, entrance, and exit.

5 Backflow prevention:

Available: No backflow prevention system.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Mechanism to prevent reverse rotation.
Used: Operator states no reverse flow.

Reverse Flow Rating Curve

PS Planters, Pumps 6, 7, 8, 9 - 84-in. Vertical Pump

Elevation Datum (ft):	Cairo
Crest Elevation (ft) =	26.25

H1 = Lake or outlet canal water level (normal pump discharge side)
H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use* $Q = \mathrm{sqrt}((H1-H2)/K')$

$K' =$ *0.000121782* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 26.3 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 32.8 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

H2 =	8.0	10.0	12.0	14.0	16.0	18.0	20.0
H1 >	38	37	37	37	36	36	35

Water elevation (H1) that stops unprimed flow: 26.3 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 19.4 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.

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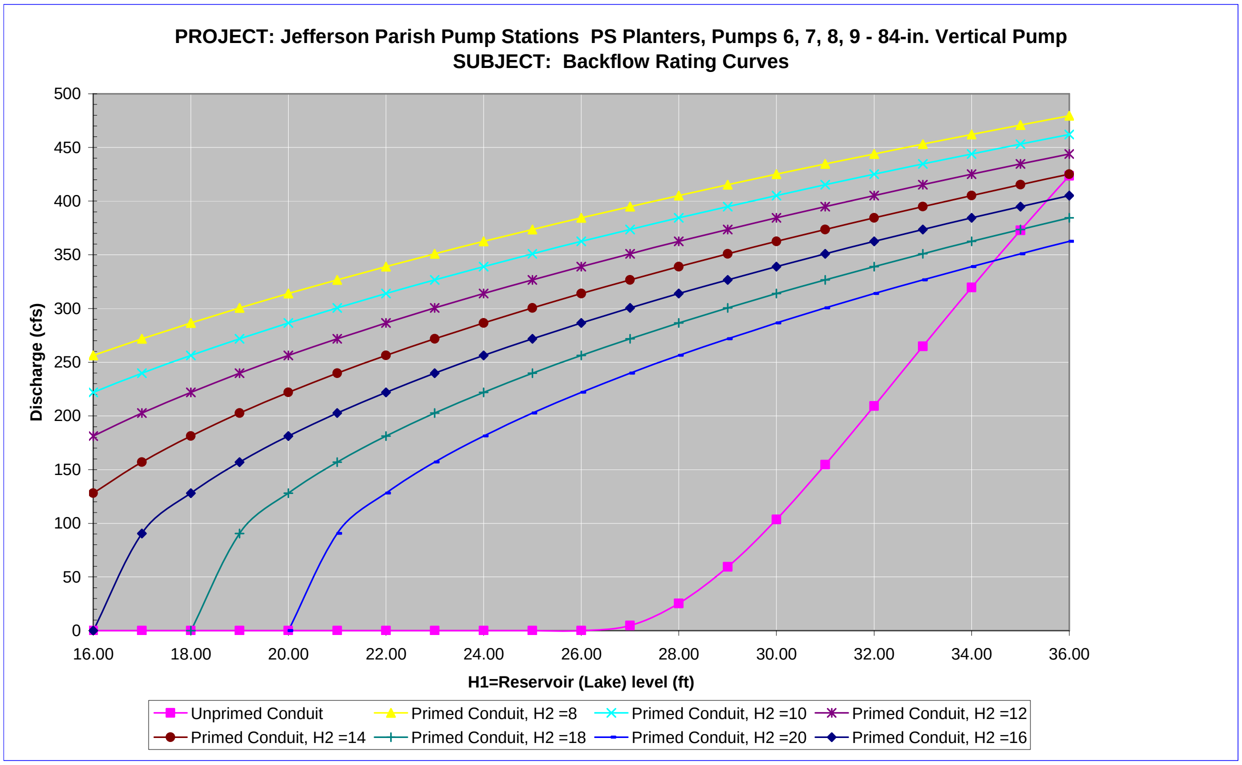

Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	6.50
Intake loss =	0.92
Exit Loss =	1.3

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

All the drawings were used to determine input values.

4 Data Needs or Deficiencies:

None

5 Backflow prevention:

Available:	No backflow prevention system. Mechanism to prevent reverse rotation.
Used:	Operator states no reverse flow occurred.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.1.4.2.8 Fuel Endurance Calculations

Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. To calculate the time, a few assumptions are required. The first assumption is the HHV[143] of diesel fuel being used is 130,000 Btu[144] per gallon of fuel[145]. The second assumption is the diesel engines are at least 35% efficient[146]. This station has 4 diesel driven pumps with the same rated horsepower and 2 diesel generators with the same rated horsepower. The station did not report any issues with running out of fuel. Below are the fuel endurance calculations.

The rated wattage of the diesel generator $G := 2350\text{kW}$ $\text{hp} = 0.746\,\text{kW}$

The rated horsepower of the diesel driver $P := 1262\text{hp}$

The assumed efficiency of the diesels $\varepsilon := 35\%$

The actual power required from the fuel $G_a := \frac{G}{\varepsilon}$ $G_a = 9004.01\,\text{hp}$

$P_a := \frac{P}{\varepsilon}$ $P_a = 3605.71\,\text{hp}$

The higher heating value $\text{HHV} := 130000\frac{\text{BTU}}{\text{gal}}$

$BR_1 := \frac{G_a}{\text{HHV}}$ $BR_1 = 176.231\frac{\text{gal}}{\text{hr}}$

$BR_2 := \frac{P_a}{\text{HHV}}$ $BR_2 = 70.573\frac{\text{gal}}{\text{hr}}$

There are 3-10,000 gallon tanks and 5-380 gallon tanks at this station.

$V_T := (3\cdot 10000 + 5\cdot 380)\text{gal}$

The fuel endurance of the station $FE := \frac{V_T}{BR_1 + 4BR_2}$ $FE = 69.571\,\text{hr}$

$FE = 2.899\,\text{day}$

---

[143] High heating value

[144] British thermal units

[145] http://www.exxon.com/USA-English/GFM/Products_Services/Fuels/Diesel_Fuels_FAQ.asp

[146] Standard Handbook for Mechanical Engineers, Eighth Edition, pg 9-106

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7.6.1.4.3 *Whitney Barataria*

Jefferson Parish – West Bank - East of Harvey Drainage Basin

Engineers Rd
Belle Chasse, LA 70037

Latitude: 29.85655˚ Longitude: -90.02172˚

7.6.1.4.3.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Before Hurricane Katrina: Aerial view of the pump station

After Hurricane Katrina: View from the intake canal

After Hurricane Katrina: Aerial view of the pump station

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.1.4.3.2 Description[147]

Drainage area:	West Bank- East of Harvey
Nominal Capacity:	3750 cfs
Drains water from:	Not available
Discharges water to:	Intracoastal Canal
Owner:	Jefferson Parish Department of Drainage
Number of pumps:	3
Pump orientation:	Not available
Pump driver:	3 electric
Water level to switch pumps on:	10 feet (Cairo)
Water level to switch pumps off:	9 feet (Cairo)
Water level that affects operation:	19.5 feet (Cairo). Water would overtop engine air intake.
Reverse flow protection:	Air suppression

7.6.1.4.3.3 Damages[148]

Estimated cost of repairs:	$13,000[149]
Relative level of damage:	Minor
Severity of circumstances:	Flooding did not reach the operating floor.
Equipment damaged:	No significant equipment damage was recorded.
Building damage:	There was damage to gutters, flashing, and the roof ridge cap.
Misc. damage:	The controller for a generator set, a metal guard for electrical wiring, lightning rods, and the fence were damaged.

---

[147] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[148] Data for damages are taken from the Project Information Report, which can be obtained from the Parish.

[149] This cost only includes repairs to damages due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.1.4.3.4 Katrina Event

Date	Time	Event
8/28/2005	3:00 PM	The survey states that the operators evacuated at 3:00pm
	-	The survey states that the operators pumped down the water in the canal.
8/29/2005	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	-	Flooding did not reach the operating floor.
8/30/2005	3:30 AM	The survey states that the operators returned to find the pumps running. The water was over the canal, but not in the building. They unwatered the canal to elevation 9.5ft. (Cairo Datum)

7.6.1.4.3.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.1.4.3.6 Pump Operational Curves

Operational curves were not developed for Whitney Barataria. The necessary data had been collected and the operational curves will be developed in the future.

7.6.1.4.3.7 Pump Reverse Flow

There are three pumps at this station for which reverse flow rating curves were computed (no pumps were excluded). The reverse flow data and curves are presented in the order of the pump numbering utilized in the summary tables included in this appendix. In cases where there are multiple pumps of equivalent size and system configuration, a single rating curve represents all of them at a unit rate per pump.

Pump No.	**Pump Capacity (cfs)**	**Pump Size (in)**	**Reverse Flow Computed?**		**Rating Curve Ref. No.**
			Yes	**No**	
1	**1250**	**132**	**X**		**1**
2	**1250**	**132**	**X**		**1**
3	**1250**	**132**	**X**		**1**

For a general explanation of reverse flow (terminology, figures, methodology, equations and assumptions), refer to the Reverse Flow Section at the beginning of this appendix. Reverse flow computations for a given pump station do not necessarily imply that reverse flow actually occurred there during the Katrina event. But these curves may instead be used as future tools if further investigations are required based on reverse flow assumptions.

Reverse Flow Rating Curve

PS Whitney Barataria, Pumps 1, 2, 3 - 132 in

Elevation Datum (ft): Cairo

Crest Elevation (ft) = 29.5

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Definition of Flow Regimes:
Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use Q = sqrt((H1-H2)/K')*
K' = *1.23699E-05* sec^2/ft^5

Reverse Flow Trigger Points:
This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:
Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:
The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 29.5 ft
Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 33.3 ft
Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for

minimum H1 elevations for given H2 elevations that would trigger primed flow.

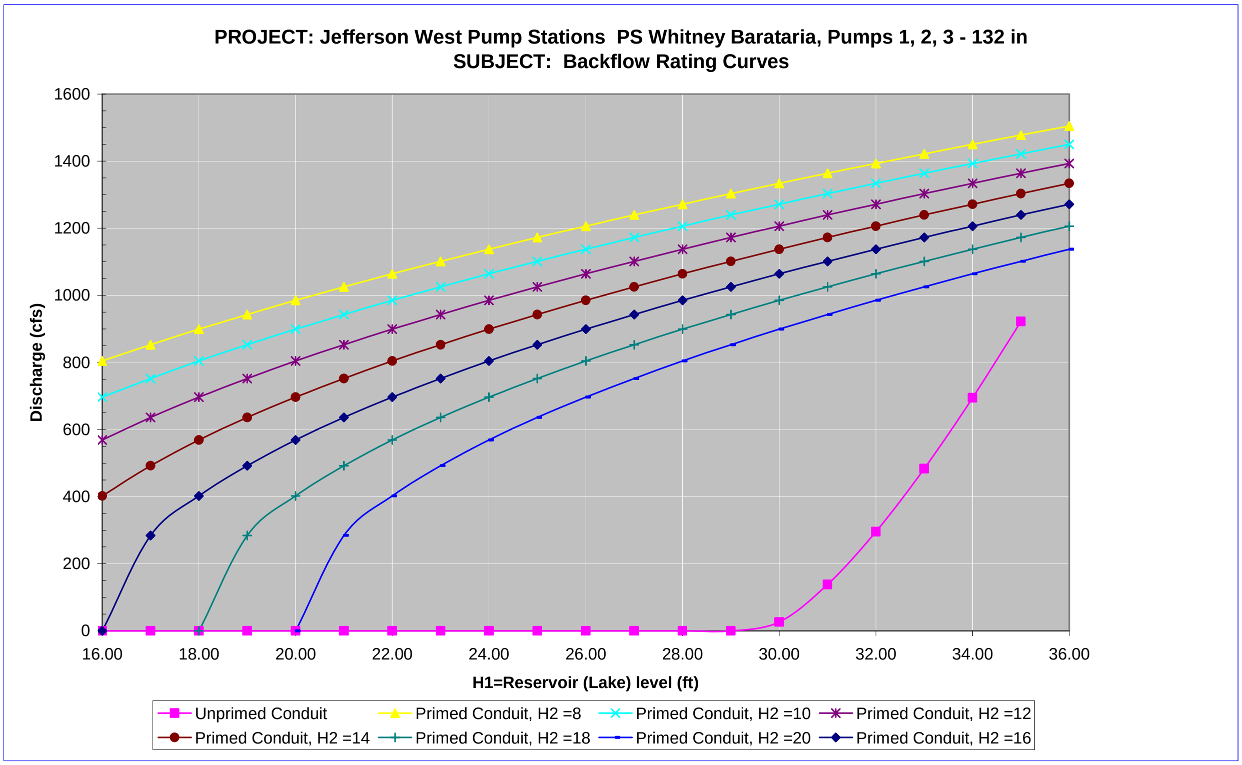
Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.							
H2 =	8.0	10.0	12.0	14.0	16.0	18.0	20.0
H1 >	38	38	37	37	37	36	36

Water elevation (H1) that stops unprimed flow: 29.5 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 13.3 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient = 6.50

Intake loss = 0.5

Exit Loss = 1.0

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Elevations in Cairo Datum

Drawings are accurate and to scale.

4 Data Needs or Deficiencies:

More detailed drawings both plan and profile.

5 Backflow prevention:

Available:	Air suppression backflow prevention system. Backstops installed to prevent reverse rotation.
Used:	Station was evacuated for the storm. Based on high water marks, operators believe reverse flow did not occur.

7.6.1.4.3.8 Fuel Endurance Calculations

We do not have any record of pumps that run on fuel at this pump station.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.2 Orleans Parish Pump Stations

7.6.2.1 New Orleans East Bank Stations

7.6.2.1.1 *OP 1*

Orleans Parish – East Bank Drainage Basin

2501 S. Broad Ave.
New Orleans, LA 70125

Latitude: 29.95185˚ Longitude: -90.09836˚

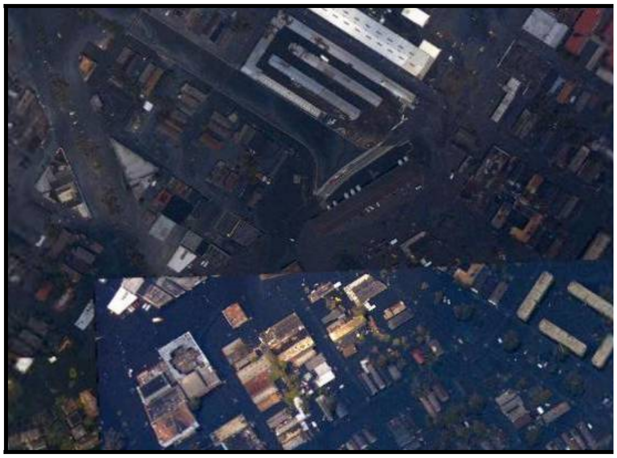
7.6.2.1.1.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Before Hurricane Katrina: Aerial view of the pump station

After Hurricane Katrina: View from the discharge



After Hurricane Katrina: Aerial view of the pump station

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.2.1.1.2 Description[150]

Drainage area:	New Orleans East Bank
Nominal Capacity:	6825 cfs
Drains water from:	Melpomene and Broad Ave. Canals
Discharges water to:	Palmetto Canal
Owner:	New Orleans Sewerage and Water Board
Number of pumps:	11
Pump orientation:	7 horizontal 3 vertical 1 centrifugal
Pump driver:	2 electric 60 Hz motors 9 electric 25 Hz motors
Water level to switch pumps on:	No record
Water level to switch pumps off:	No record
Water level that affects operation:	7.6 feet (NGVD). Water would affect electrical control panels
Reverse flow protection:	None

7.6.2.1.1.3 Damages

Estimated cost of repairs:	The estimated cost of repairs is not yet available.[151]
Relative level of damage:	Substantial
Severity of circumstances:	Flooding occurred approximately 1.5 feet (NGVD) above the operating floor.
Equipment damaged:	Motors B, C, D, and E will need rewinding repairs, Pumps F and G will need inboard bearings replaced.
Building damage:	Roof ridge line flashing needs to be replaced, roll-up-door needs repairs, flooring and the paneling in the control house needs to be replaced.

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[150] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[151] The Project Information Report (PIR) for each parish provides an estimated cost of repairs for the parish's pump stations. At the time this report was written, the Orleans Parish PIR was not yet complete. It should be available through the parish shortly after publication of the IPET Report.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Misc. damage: No significant miscellaneous damage recorded.

7.6.2.1.1.4 Katrina Event

Date	Time	Event
8/28/2005	-	All the pumps were available prior to the hurricane.
	7:20 PM	Pumping began wit pumps V1 and V2 and continued for about 1.5 hours until the intake canal level was at about 8 feet.
8/29/2005	12:02 AM	The operational log indicates a loss of 60 Hz power.
	12:03 AM	The interview form states that pumps F and G were unavailable due to the loss of 60 Hz power.
	2:00 AM	The operational log indicates loss of air pressure (could no longer read the canal discharge elevation).
	2:20 AM	The operational log indicates a loss of the suction recorder (no air pressure and 60 Hz power).
	2:26 AM	The operational log indicates the loss of the 25 cycle booster pump.
	5:41 AM	The operational log indicates that the maximum height of the intake staff gage had been exceeded.
	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	7:39 AM	The operational log indicates that water was coming into the station by booster pump wall.
	-	Water began entering downtown in the evening.
8/30/2005	9:40 AM	The operational log indicates that all the pumps were ordered to stop because the station they were pumping to, Station 6, was shut down.
	12:05 PM	The operational log indicates that a call was made to say that the battery pit was flooded.
	12:26 PM	The operational log indicates that Pump A was started in order to draw down water in the battery pit.
	12:40 PM	The operational log indicates that Pump A started rotating backwards.
	4:40 PM	The operational log indicates that Pump A stopped rotating backwards and that air was pumped into the piping.
8/31/2005	12:01 AM	The operational log indicates that no pumps were running.
	1:10 PM	The operational log indicates that the 25 Hz breakers were opened (This shut down the power to the pumps).
	9:13 PM	The operational log indicates that the crew was rescued by the West Bank supervisor in his personal boat.
9/13/2005	-	The operational log indicates that the crew returned to the station.
9/14/2005	-	The interview form states that Pump G was the only pump used.
9/16/2005	-	The interview form states that the intake canal level was back to the normal operating range.
9/22/2005	4:15 PM	The operational log indicates that the crew left the station for Hurricane Rita.
9/26/2005	8:00 AM	The operational log indicates that the crew returned to the station.

7.6.2.1.1.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.2.1.1.6 Pump Operational Curves

Pump curves are provided for ten[152] OP 1 pumps in 6 different configurations.

- (1) 36” Fairbanks-Morse
- (2) 60” Fairbanks-Morse
- (2) 144” Wood Screw
- (3) 168” Wood Screw
- (2) 168” ITT-AC, 2 configurations

The following pages provide system curves and operational curves for each configuration. Section 7.1.3.5 describes the function of the curves, as well as the processes used to develop the curves. Some details, such as exact dimensions, were not available for all pump systems prior to the calculations. The assumptions made in place of the missing data were based on available known data for similar pumps, and are noted in the “layout” drawings for each pump, as well as in individual pump sections.[153] The accuracy of the calculations directly depends on the amount of information available. When there was not adequate data, the best engineering judgment using other pump station and manufacturer’s data was employed.

7.6.2.1.1.6.1 36” Fairbanks-Morse

No drawings were available for the 36” Fairbanks-Morse. The following resources were used to make the indicated assumptions:[154]

- *Data from similar horizontal pumps* – Modeled was the simplest common system, which included two 45° bends with r/D factors of 1.0, a suction bell with an equivalent circular diameter of 46 inches and a conical transition at an angle of 14°, and a pipe expansion before discharge
- *Operator’s Log* – It was determined that the intake water elevation was 16.4 feet and the discharge water elevation was 26.1 feet.
- *Normal loss coefficients for trash rack and flap valve* – A loss coefficient of 1.0 for the flap valve and trash rack was used.
- *Pictures taken onsite* – Shown was that the pump is the highest point in the piping, and is at an elevation of approximately 20.5 feet.

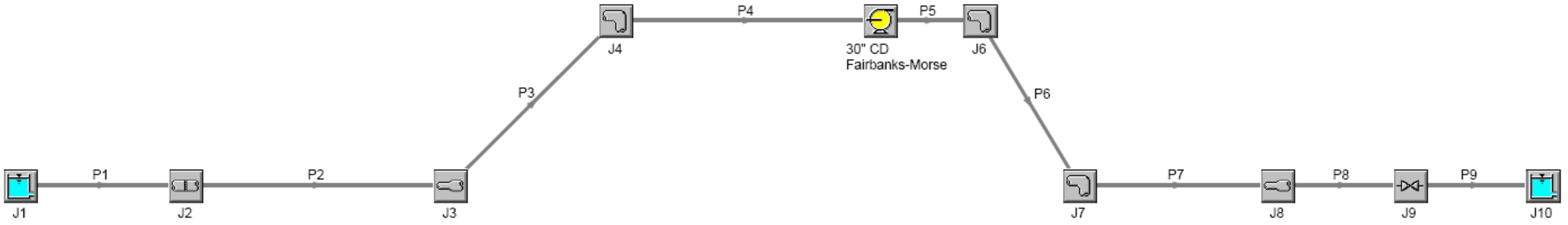
---

[152] OP 1 has a total of 11 pumps; however, not enough data was available to analyze the 36-inch Wood Screw pump within a reasonable accuracy.

[153] Section XXX also contains general assumptions that were consistently made throughout the modeling process, which may or may not be listed as mentioned.

[154] The datum for the listed elevations is not reported. The datum is not needed for modeling pump station capacity in normal operation calculations because only relative elevations affect the calculations.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

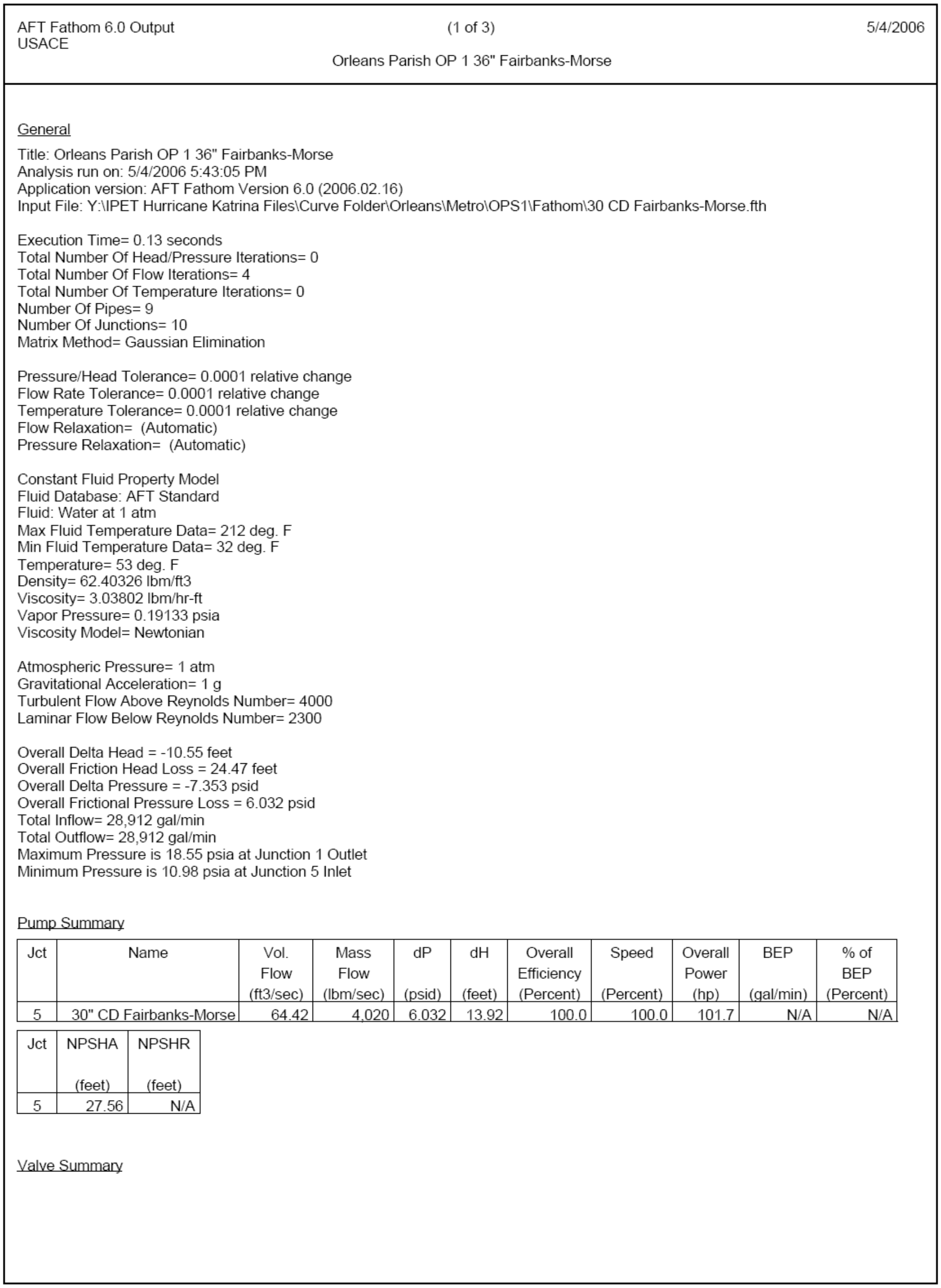


No Drawings to Show

Assumptions:

1. There is one other bends than the two 45 degree bends shown
2. Intake water elevation is 16.4 ft, discharge water elevation is 26.1 ft.
3. Flap valve has a K factor of 1.0
4. Trash Rack has K factor of 1.0
5. Suction and discharge bell has large equivalent diameter of 46 in at angle of 14 degrees
6. Pump elevation is 20.5 ft
7. As there is no drawing, it is assumed that the layout shown is accurate

Layout of 36” Fairbanks-Morse Pump at OP 1



AFT Fathom 6.0 Output (1 of 3) 5/4/2006
USACE
Orleans Parish OP 1 36" Fairbanks-Morse

General

```
Title: Orleans Parish OP 1 36" Fairbanks-Morse
Analysis run on: 5/4/2006 5:43:05 PM
Application version: AFT Fathom Version 6.0 (2006.02.16)
Input File: Y:\IPET Hurricane Katrina Files\Curve Folder\Orleans\Metro\OPS1\Fathom\30 CD Fairbanks-Morse.fth

Execution Time= 0.13 seconds
Total Number Of Head/Pressure Iterations= 0
Total Number Of Flow Iterations= 4
Total Number Of Temperature Iterations= 0
Number Of Pipes= 9
Number Of Junctions= 10
Matrix Method= Gaussian Elimination

Pressure/Head Tolerance= 0.0001 relative change
Flow Rate Tolerance= 0.0001 relative change
Temperature Tolerance= 0.0001 relative change
Flow Relaxation=  (Automatic)
Pressure Relaxation=  (Automatic)

Constant Fluid Property Model
Fluid Database: AFT Standard
Fluid: Water at 1 atm
Max Fluid Temperature Data= 212 deg. F
Min Fluid Temperature Data= 32 deg. F
Temperature= 53 deg. F
Density= 62.40326 lbm/ft3
Viscosity= 3.03802 lbm/hr-ft
Vapor Pressure= 0.19133 psia
Viscosity Model= Newtonian

Atmospheric Pressure= 1 atm
Gravitational Acceleration= 1 g
Turbulent Flow Above Reynolds Number= 4000
Laminar Flow Below Reynolds Number= 2300

Overall Delta Head = -10.55 feet
Overall Friction Head Loss = 24.47 feet
Overall Delta Pressure = -7.353 psid
Overall Frictional Pressure Loss = 6.032 psid
Total Inflow= 28,912 gal/min
Total Outflow= 28,912 gal/min
Maximum Pressure is 18.55 psia at Junction 1 Outlet
Minimum Pressure is 10.98 psia at Junction 5 Inlet
```

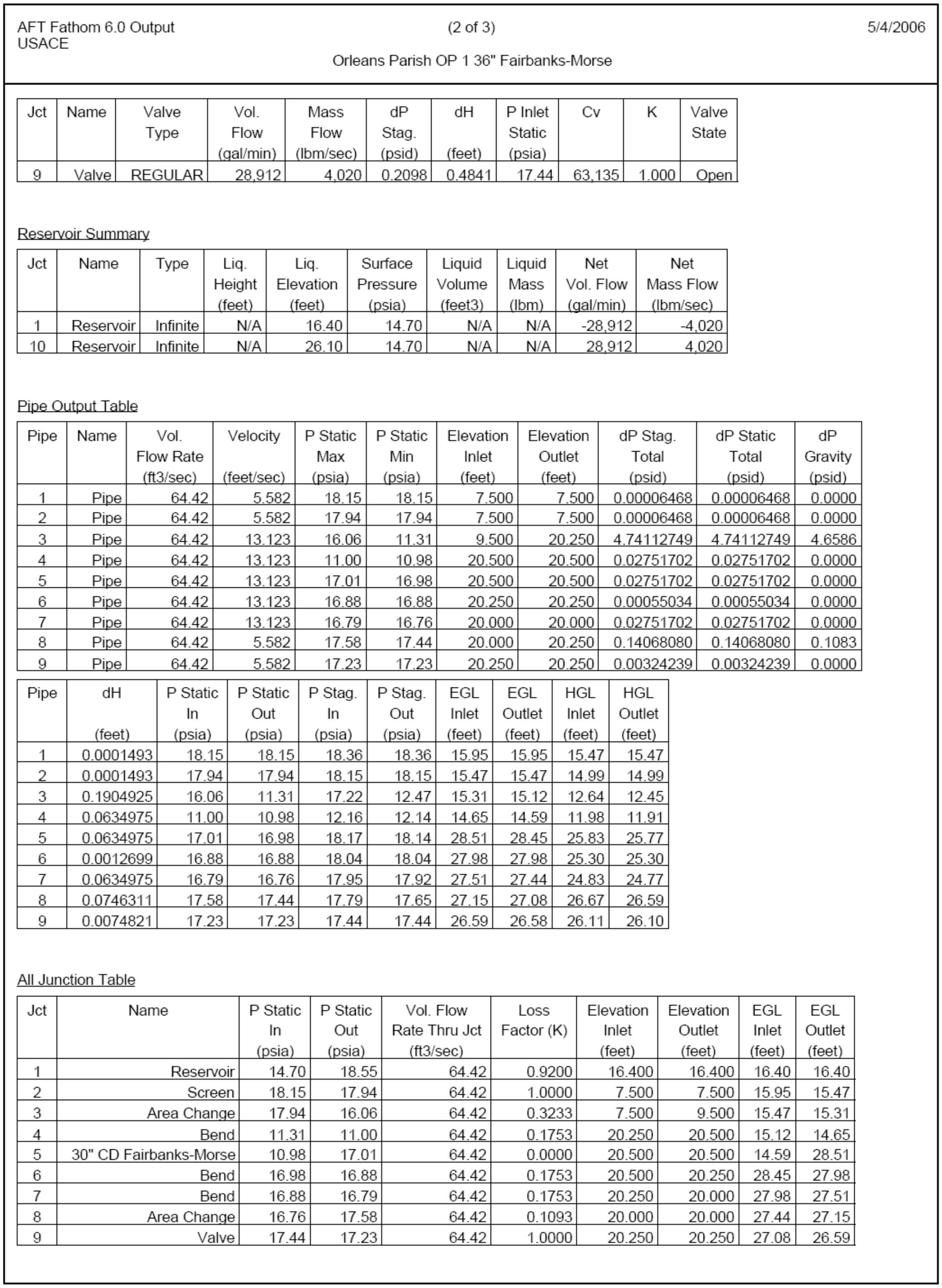
Pump Summary

Jct	Name	Vol. Flow (ft3/sec)	Mass Flow (lbm/sec)	dP (psid)	dH (feet)	Overall Efficiency (Percent)	Speed (Percent)	Overall Power (hp)	BEP (gal/min)	% of BEP (Percent)
5	30" CD Fairbanks-Morse	64.42	4,020	6.032	13.92	100.0	100.0	101.7	N/A	N/A

Jct	NPSHA (feet)	NPSHR (feet)
5	27.56	N/A

Valve Summary

Output from AFT Fathom™ for 36” Fairbanks-Morse, Page 1



AFT Fathom 6.0 Output (2 of 3) 5/4/2006
USACE
Orleans Parish OP 1 36" Fairbanks-Morse

Jct	Name	Valve Type	Vol. Flow (gal/min)	Mass Flow (lbm/sec)	dP Stag. (psid)	dH (feet)	P Inlet Static (psia)	Cv	K	Valve State
9	Valve	REGULAR	28,912	4,020	0.2098	0.4841	17.44	63,135	1.000	Open

Reservoir Summary

Jct	Name	Type	Liq. Height (feet)	Liq. Elevation (feet)	Surface Pressure (psia)	Liquid Volume (feet3)	Liquid Mass (lbm)	Net Vol. Flow (gal/min)	Net Mass Flow (lbm/sec)
1	Reservoir	Infinite	N/A	16.40	14.70	N/A	N/A	-28,912	-4,020
10	Reservoir	Infinite	N/A	26.10	14.70	N/A	N/A	28,912	4,020

Pipe Output Table

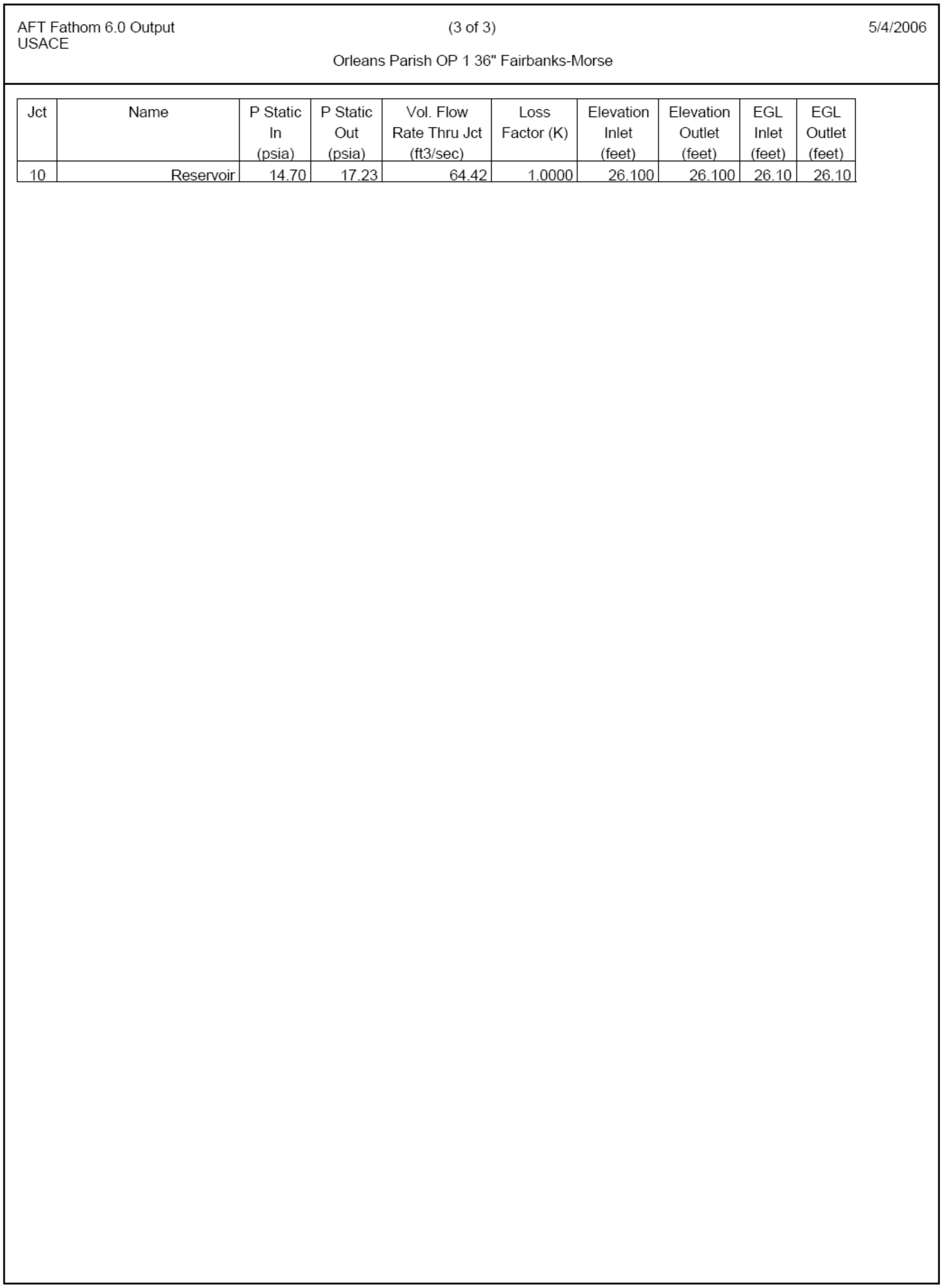
Pipe	Name	Vol. Flow Rate (ft3/sec)	Velocity (feet/sec)	P Static Max (psia)	P Static Min (psia)	Elevation Inlet (feet)	Elevation Outlet (feet)	dP Stag. Total (psid)	dP Static Total (psid)	dP Gravity (psid)
1	Pipe	64.42	5.582	18.15	18.15	7.500	7.500	0.00006468	0.00006468	0.0000
2	Pipe	64.42	5.582	17.94	17.94	7.500	7.500	0.00006468	0.00006468	0.0000
3	Pipe	64.42	13.123	16.06	11.31	9.500	20.250	4.74112749	4.74112749	4.6586
4	Pipe	64.42	13.123	11.00	10.98	20.500	20.500	0.02751702	0.02751702	0.0000
5	Pipe	64.42	13.123	17.01	16.98	20.500	20.500	0.02751702	0.02751702	0.0000
6	Pipe	64.42	13.123	16.88	16.88	20.250	20.250	0.00055034	0.00055034	0.0000
7	Pipe	64.42	13.123	16.79	16.76	20.000	20.000	0.02751702	0.02751702	0.0000
8	Pipe	64.42	5.582	17.58	17.44	20.000	20.250	0.14068080	0.14068080	0.1083
9	Pipe	64.42	5.582	17.23	17.23	20.250	20.250	0.00324239	0.00324239	0.0000

Pipe	dH (feet)	P Static In (psia)	P Static Out (psia)	P Stag. In (psia)	P Stag. Out (psia)	EGL Inlet (feet)	EGL Outlet (feet)	HGL Inlet (feet)	HGL Outlet (feet)
1	0.0001493	18.15	18.15	18.36	18.36	15.95	15.95	15.47	15.47
2	0.0001493	17.94	17.94	18.15	18.15	15.47	15.47	14.99	14.99
3	0.1904925	16.06	11.31	17.22	12.47	15.31	15.12	12.64	12.45
4	0.0634975	11.00	10.98	12.16	12.14	14.65	14.59	11.98	11.91
5	0.0634975	17.01	16.98	18.17	18.14	28.51	28.45	25.83	25.77
6	0.0012699	16.88	16.88	18.04	18.04	27.98	27.98	25.30	25.30
7	0.0634975	16.79	16.76	17.95	17.92	27.51	27.44	24.83	24.77
8	0.0746311	17.58	17.44	17.79	17.65	27.15	27.08	26.67	26.59
9	0.0074821	17.23	17.23	17.44	17.44	26.59	26.58	26.11	26.10

All Junction Table

Jct	Name	P Static In (psia)	P Static Out (psia)	Vol. Flow Rate Thru Jct (ft3/sec)	Loss Factor (K)	Elevation Inlet (feet)	Elevation Outlet (feet)	EGL Inlet (feet)	EGL Outlet (feet)
1	Reservoir	14.70	18.55	64.42	0.9200	16.400	16.400	16.40	16.40
2	Screen	18.15	17.94	64.42	1.0000	7.500	7.500	15.95	15.47
3	Area Change	17.94	16.06	64.42	0.3233	7.500	9.500	15.47	15.31
4	Bend	11.31	11.00	64.42	0.1753	20.250	20.500	15.12	14.65
5	30" CD Fairbanks-Morse	10.98	17.01	64.42	0.0000	20.500	20.500	14.59	28.51
6	Bend	16.98	16.88	64.42	0.1753	20.500	20.250	28.45	27.98
7	Bend	16.88	16.79	64.42	0.1753	20.250	20.000	27.98	27.51
8	Area Change	16.76	17.58	64.42	0.1093	20.000	20.000	27.44	27.15
9	Valve	17.44	17.23	64.42	1.0000	20.250	20.250	27.08	26.59

Output from AFT Fathom™ for 36” Fairbanks-Morse, page 2



AFT Fathom 6.0 Output
USACE

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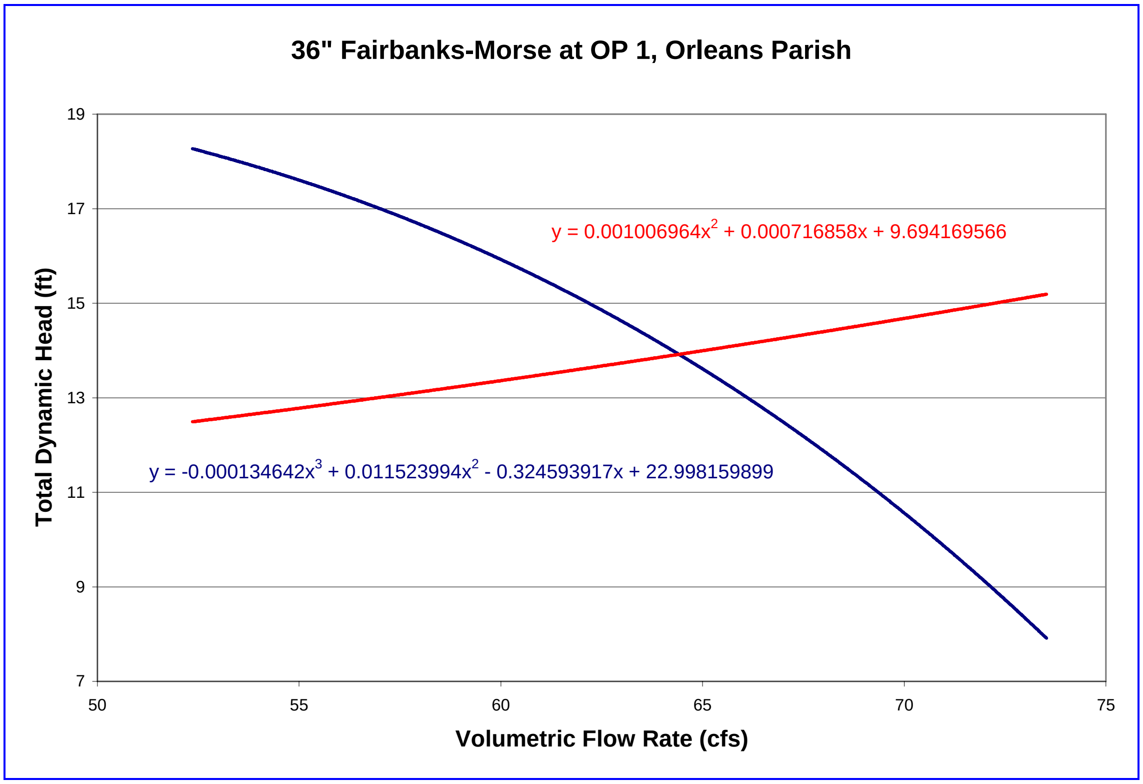
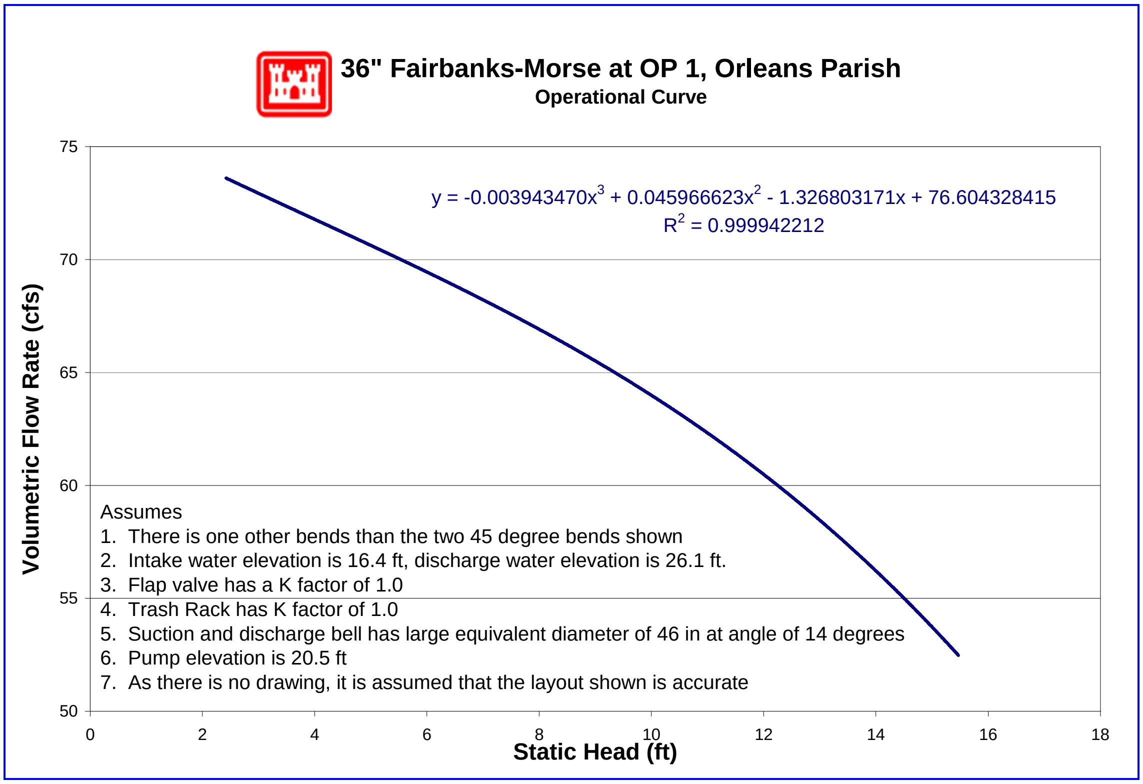
Orleans Parish OP 1 36" Fairbanks-Morse

Jct	Name	P Static In (psia)	P Static Out (psia)	Vol. Flow Rate Thru Jct (ft3/sec)	Loss Factor (K)	Elevation Inlet (feet)	Elevation Outlet (feet)	EGL Inlet (feet)	EGL Outlet (feet)
10	Reservoir	14.70	17.23	64.42	1.0000	26.100	26.100	26.10	26.10

Output from AFT Fathom™ for 36” Fairbanks-Morse, page 3



System Curve of 36” Fairbanks-Morse Pump at OP 1



Assumes
1. There is one other bends than the two 45 degree bends shown
2. Intake water elevation is 16.4 ft, discharge water elevation is 26.1 ft.
3. Flap valve has a K factor of 1.0
4. Trash Rack has K factor of 1.0
5. Suction and discharge bell has large equivalent diameter of 46 in at angle of 14 degrees
6. Pump elevation is 20.5 ft
7. As there is no drawing, it is assumed that the layout shown is accurate

Operational Curve for 36” Fairbanks-Morse Pump at OP 1

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.2.1.1.6.2 60” Fairbanks-Morse

No relevant drawings were available for the 60” Fairbanks-Morse. The following resources were used to make the indicated assumptions:[155]

- *Data from similar vertical pumps* – The simplest common model was used which employed only one 90˚ bend with two 45˚ bends with a maximum elevation of 24 feet. All of the bends had an r/D value of 1.0. Furthermore, suction and discharge bells were taken to have equivalent circular diameters of 80 inches. These bells were also assumed to have a transition angle of 14.5˚. This assumes a complete piping system, but there may be more junctions that are accounted for. With the given information, the best judgment was made.
- *Operator’s Log* – It was determined that the intake water elevation was 16.4 feet and the discharge water elevation was 26.1 feet.
- *Normal loss coefficients for trash rack and flap valve* – A loss coefficient of 1.0 at the flap valve and trash rack was modeled.

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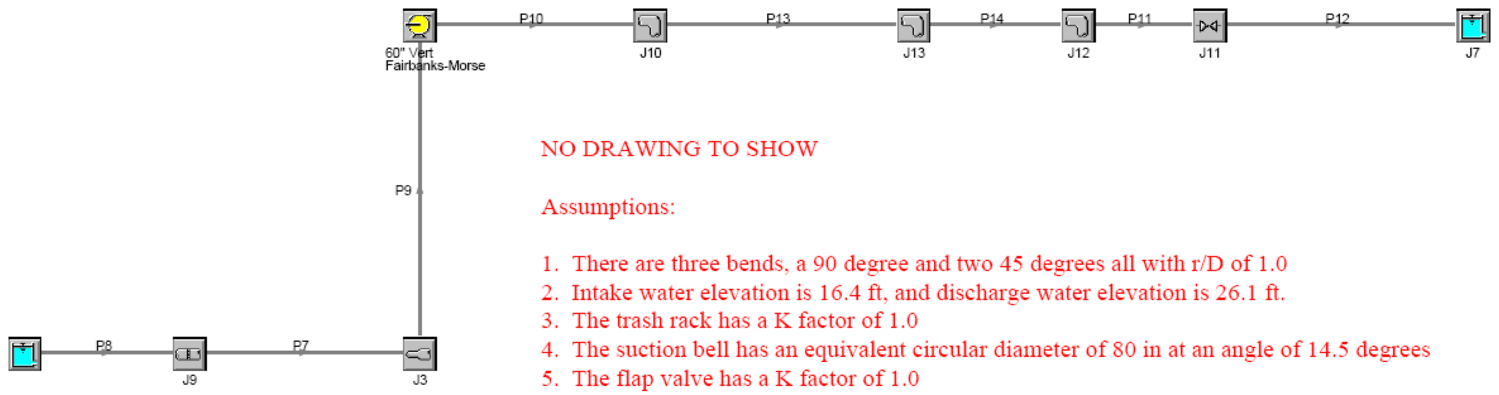
[155] The datum for the listed elevations is not reported. The datum is not needed for modeling pump station capacity in normal operation calculations because only relative elevations affect the calculations.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

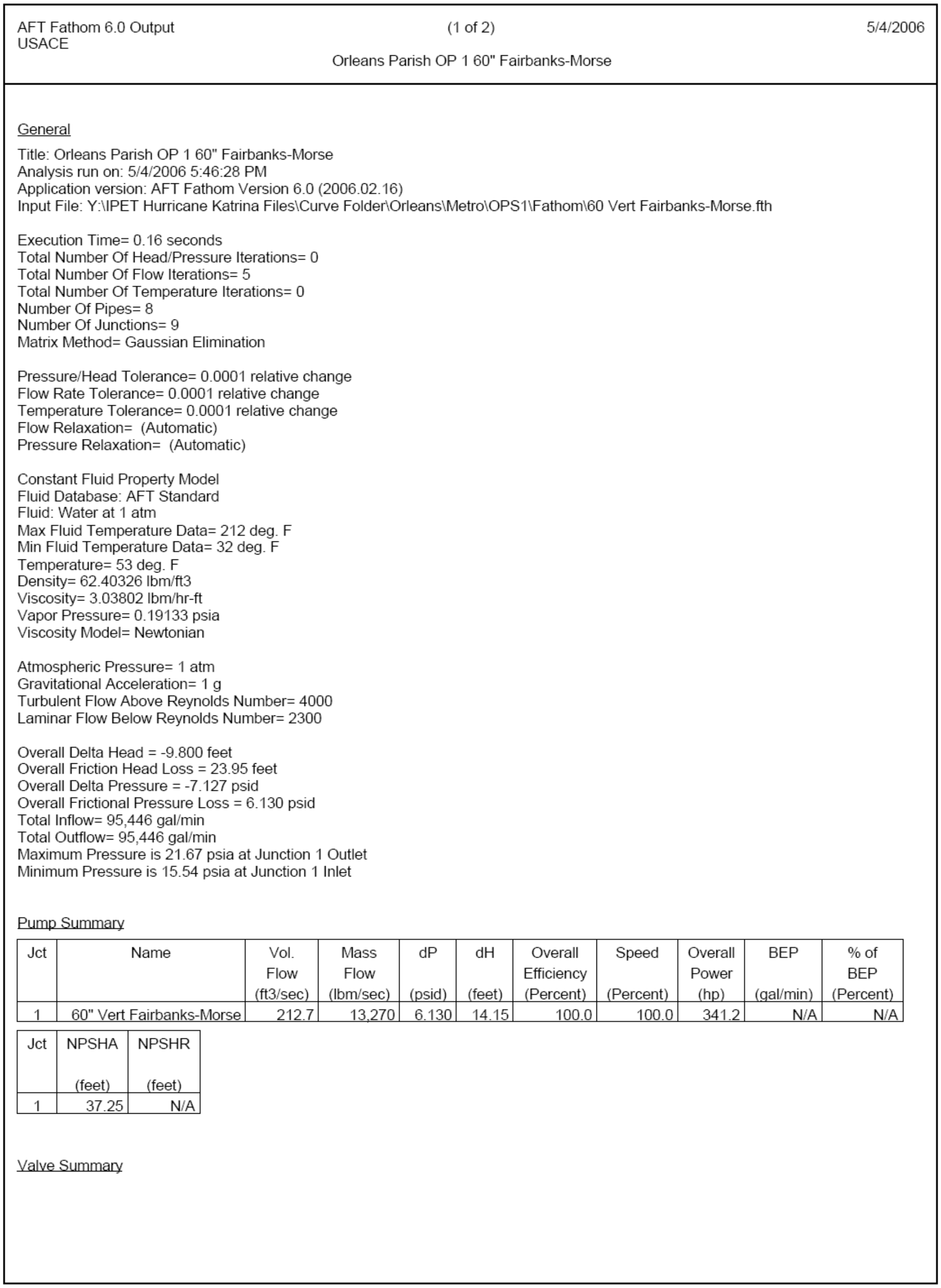


NO DRAWING TO SHOW

Assumptions:

1. There are three bends, a 90 degree and two 45 degrees all with r/D of 1.0
2. Intake water elevation is 16.4 ft, and discharge water elevation is 26.1 ft.
3. The trash rack has a K factor of 1.0
4. The suction bell has an equivalent circular diameter of 80 in at an angle of 14.5 degrees
5. The flap valve has a K factor of 1.0
6. As there is no drawing, it is assumed that model is accurate

Layout of 60” Fairbanks-Morse Pump OP 1



AFT Fathom 6.0 Output (1 of 2) 5/4/2006
USACE
Orleans Parish OP 1 60" Fairbanks-Morse

General

Title: Orleans Parish OP 1 60" Fairbanks-Morse
Analysis run on: 5/4/2006 5:46:28 PM
Application version: AFT Fathom Version 6.0 (2006.02.16)
Input File: Y:\IPET Hurricane Katrina Files\Curve Folder\Orleans\Metro\OPS1\Fathom\60 Vert Fairbanks-Morse.fth

Execution Time= 0.16 seconds
Total Number Of Head/Pressure Iterations= 0
Total Number Of Flow Iterations= 5
Total Number Of Temperature Iterations= 0
Number Of Pipes= 8
Number Of Junctions= 9
Matrix Method= Gaussian Elimination

Pressure/Head Tolerance= 0.0001 relative change
Flow Rate Tolerance= 0.0001 relative change
Temperature Tolerance= 0.0001 relative change
Flow Relaxation= (Automatic)
Pressure Relaxation= (Automatic)

Constant Fluid Property Model
Fluid Database: AFT Standard
Fluid: Water at 1 atm
Max Fluid Temperature Data= 212 deg. F
Min Fluid Temperature Data= 32 deg. F
Temperature= 53 deg. F
Density= 62.40326 lbm/ft3
Viscosity= 3.03802 lbm/hr-ft
Vapor Pressure= 0.19133 psia
Viscosity Model= Newtonian

Atmospheric Pressure= 1 atm
Gravitational Acceleration= 1 g
Turbulent Flow Above Reynolds Number= 4000
Laminar Flow Below Reynolds Number= 2300

Overall Delta Head = -9.800 feet
Overall Friction Head Loss = 23.95 feet
Overall Delta Pressure = -7.127 psid
Overall Frictional Pressure Loss = 6.130 psid
Total Inflow= 95,446 gal/min
Total Outflow= 95,446 gal/min
Maximum Pressure is 21.67 psia at Junction 1 Outlet
Minimum Pressure is 15.54 psia at Junction 1 Inlet

Pump Summary

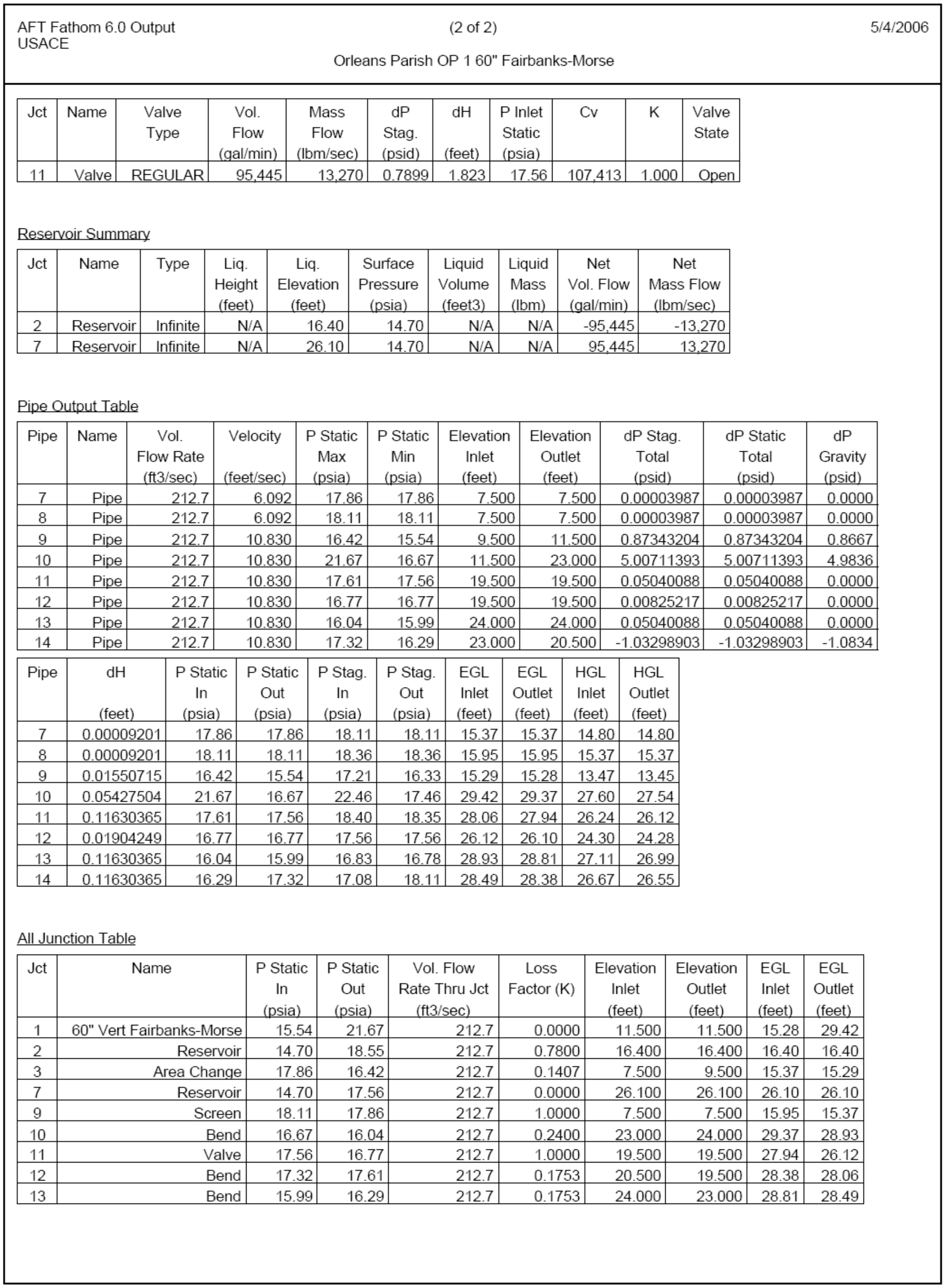
Jct	Name	Vol. Flow (ft3/sec)	Mass Flow (lbm/sec)	dP (psid)	dH (feet)	Overall Efficiency (Percent)	Speed (Percent)	Overall Power (hp)	BEP (gal/min)	% of BEP (Percent)
1	60" Vert Fairbanks-Morse	212.7	13,270	6.130	14.15	100.0	100.0	341.2	N/A	N/A

Jct	NPSHA (feet)	NPSHR (feet)
1	37.25	N/A

Valve Summary

Output from AFT Fathom™ for 60” Fairbanks-Morse, Page 1

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.



AFT Fathom 6.0 Output
USACE

(2 of 2)

5/4/2006

Orleans Parish OP 1 60" Fairbanks-Morse

Jct	Name	Valve Type	Vol. Flow (gal/min)	Mass Flow (lbm/sec)	dP Stag. (psid)	dH (feet)	P Inlet Static (psia)	Cv	K	Valve State
11	Valve	REGULAR	95,445	13,270	0.7899	1.823	17.56	107,413	1.000	Open

Reservoir Summary

Jct	Name	Type	Liq. Height (feet)	Liq. Elevation (feet)	Surface Pressure (psia)	Liquid Volume (feet3)	Liquid Mass (lbm)	Net Vol. Flow (gal/min)	Net Mass Flow (lbm/sec)
2	Reservoir	Infinite	N/A	16.40	14.70	N/A	N/A	-95,445	-13,270
7	Reservoir	Infinite	N/A	26.10	14.70	N/A	N/A	95,445	13,270

Pipe Output Table

Pipe	Name	Vol. Flow Rate (ft3/sec)	Velocity (feet/sec)	P Static Max (psia)	P Static Min (psia)	Elevation Inlet (feet)	Elevation Outlet (feet)	dP Stag. Total (psid)	dP Static Total (psid)	dP Gravity (psid)
7	Pipe	212.7	6.092	17.86	17.86	7.500	7.500	0.00003987	0.00003987	0.0000
8	Pipe	212.7	6.092	18.11	18.11	7.500	7.500	0.00003987	0.00003987	0.0000
9	Pipe	212.7	10.830	16.42	15.54	9.500	11.500	0.87343204	0.87343204	0.8667
10	Pipe	212.7	10.830	21.67	16.67	11.500	23.000	5.00711393	5.00711393	4.9836
11	Pipe	212.7	10.830	17.61	17.56	19.500	19.500	0.05040088	0.05040088	0.0000
12	Pipe	212.7	10.830	16.77	16.77	19.500	19.500	0.00825217	0.00825217	0.0000
13	Pipe	212.7	10.830	16.04	15.99	24.000	24.000	0.05040088	0.05040088	0.0000
14	Pipe	212.7	10.830	17.32	16.29	23.000	20.500	-1.03298903	-1.03298903	-1.0834

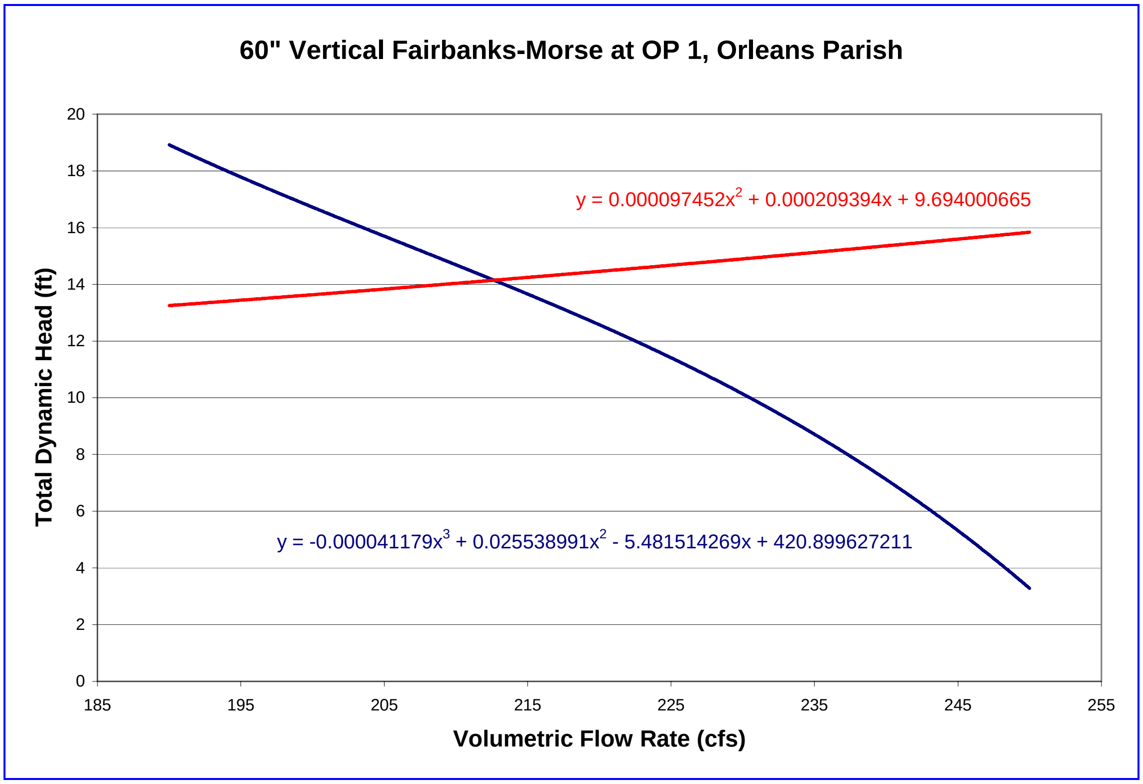
Pipe	dH (feet)	P Static In (psia)	P Static Out (psia)	P Stag. In (psia)	P Stag. Out (psia)	EGL Inlet (feet)	EGL Outlet (feet)	HGL Inlet (feet)	HGL Outlet (feet)
7	0.00009201	17.86	17.86	18.11	18.11	15.37	15.37	14.80	14.80
8	0.00009201	18.11	18.11	18.36	18.36	15.95	15.95	15.37	15.37
9	0.01550715	16.42	15.54	17.21	16.33	15.29	15.28	13.47	13.45
10	0.05427504	21.67	16.67	22.46	17.46	29.42	29.37	27.60	27.54
11	0.11630365	17.61	17.56	18.40	18.35	28.06	27.94	26.24	26.12
12	0.01904249	16.77	16.77	17.56	17.56	26.12	26.10	24.30	24.28
13	0.11630365	16.04	15.99	16.83	16.78	28.93	28.81	27.11	26.99
14	0.11630365	16.29	17.32	17.08	18.11	28.49	28.38	26.67	26.55

All Junction Table

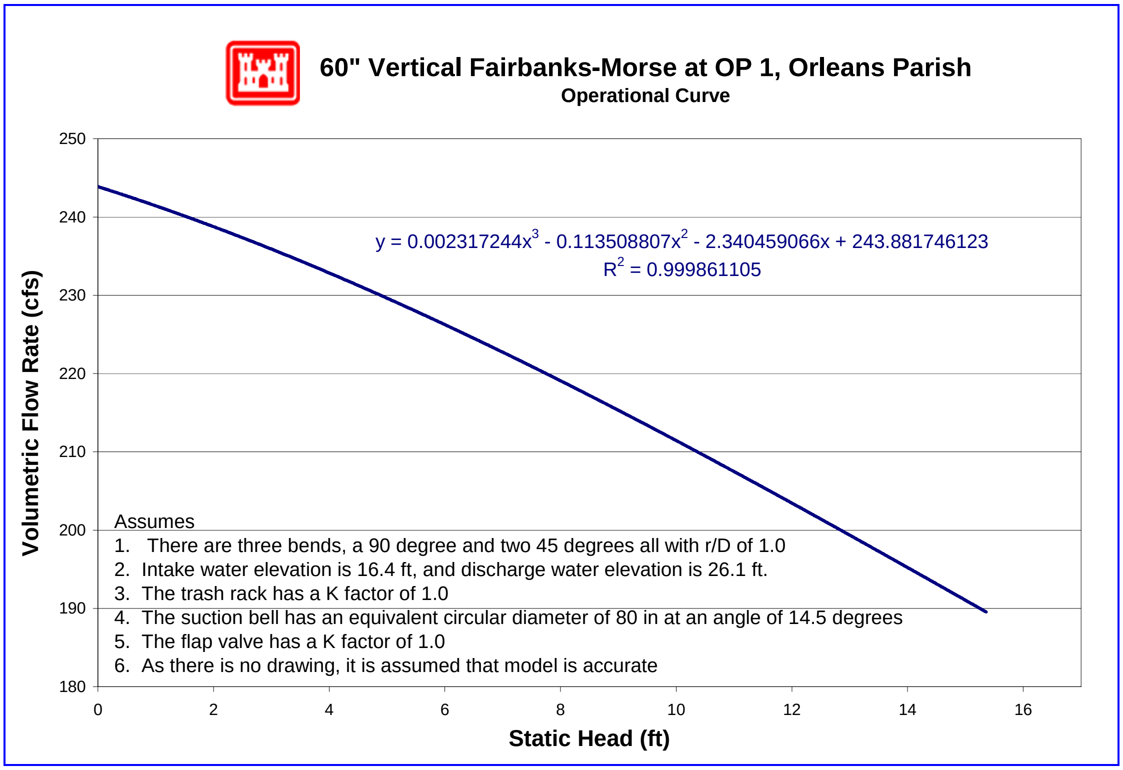
Jct	Name	P Static In (psia)	P Static Out (psia)	Vol. Flow Rate Thru Jct (ft3/sec)	Loss Factor (K)	Elevation Inlet (feet)	Elevation Outlet (feet)	EGL Inlet (feet)	EGL Outlet (feet)
1	60" Vert Fairbanks-Morse	15.54	21.67	212.7	0.0000	11.500	11.500	15.28	29.42
2	Reservoir	14.70	18.55	212.7	0.7800	16.400	16.400	16.40	16.40
3	Area Change	17.86	16.42	212.7	0.1407	7.500	9.500	15.37	15.29
7	Reservoir	14.70	17.56	212.7	0.0000	26.100	26.100	26.10	26.10
9	Screen	18.11	17.86	212.7	1.0000	7.500	7.500	15.95	15.37
10	Bend	16.67	16.04	212.7	0.2400	23.000	24.000	29.37	28.93
11	Valve	17.56	16.77	212.7	1.0000	19.500	19.500	27.94	26.12
12	Bend	17.32	17.61	212.7	0.1753	20.500	19.500	28.38	28.06
13	Bend	15.99	16.29	212.7	0.1753	24.000	23.000	28.81	28.49

Output from AFT Fathom™ for 60" Fairbanks-Morse, Page 2

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.



System Curve of 60” Fairbanks-Morse Pump at OP 1



Assumes

1. There are three bends, a 90 degree and two 45 degrees all with r/D of 1.0
2. Intake water elevation is 16.4 ft, and discharge water elevation is 26.1 ft.
3. The trash rack has a K factor of 1.0
4. The suction bell has an equivalent circular diameter of 80 in at an angle of 14.5 degrees
5. The flap valve has a K factor of 1.0
6. As there is no drawing, it is assumed that model is accurate

Operational Curve for 60” Fairbanks-Morse Pump at OP 1

7.6.2.1.1.6.3 144” Wood Screw

No drawings were available for the 144” Wood Screw. The following resources were used to make the indicated assumptions:[156]

- *Data from similar horizontal pumps* – Modeled were two 45˚ bends with r/D values of 1.0, as well as the suction and discharge bells having equivalent circular hydraulic diameters of 252.5 inches with conical transitions at 28˚.
- *Data from drawing 6760-W-18* – Elevations and other dimensions were taken to be similar for the 168” Wood Screw and for the 144” Wood Screw. Often, this data was developed off of the assumption that the drawing was to scale.
- *Operator's Log* **–** It was determined that the intake water elevation was 16.4 feet and the discharge water elevation was 26.1 feet.
- *An estimated one foot of trash at the intake* – A loss coefficient of 1.0 for the trash rack was utilized.

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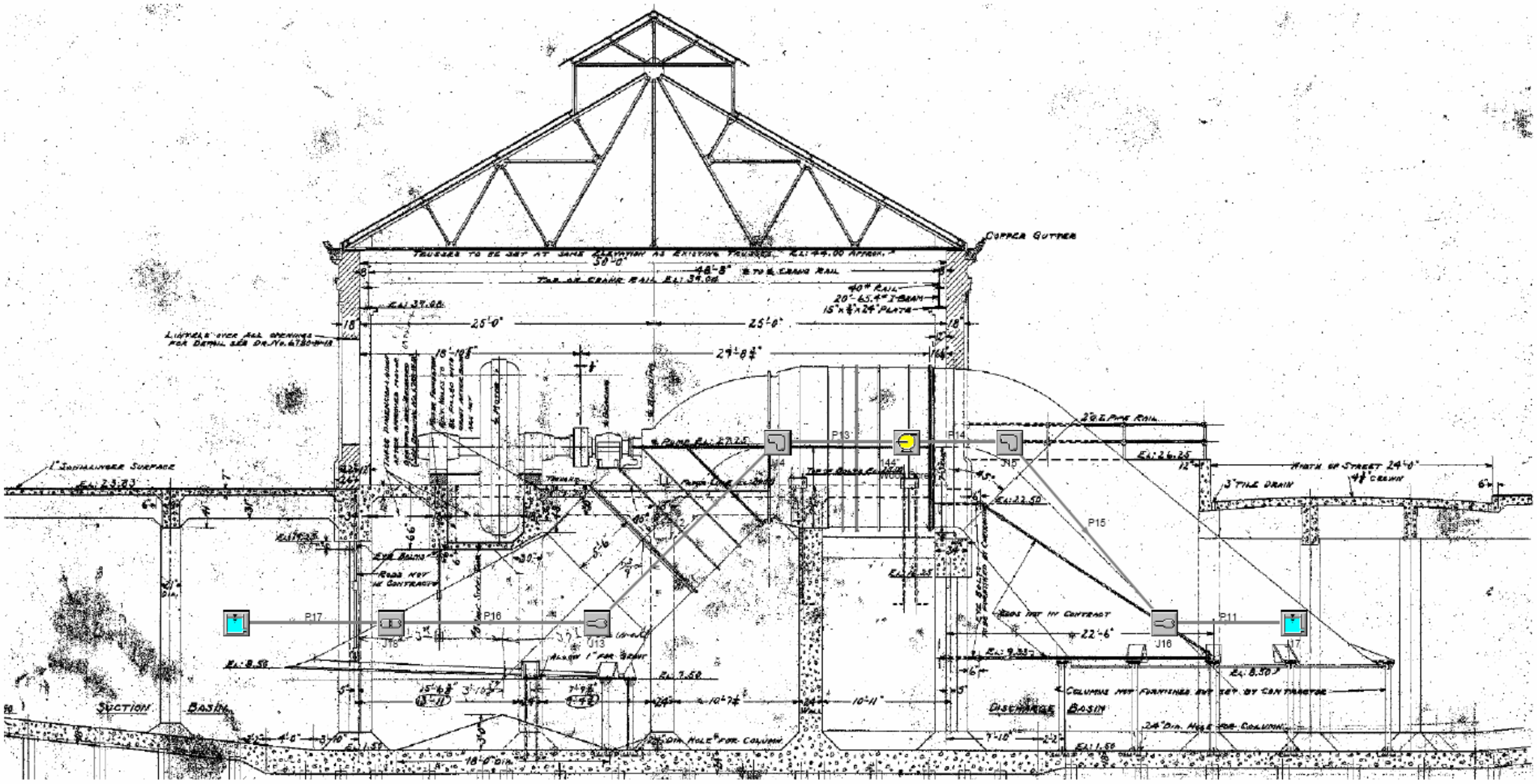
[156] The datum for the listed elevations is not reported. The datum is not needed for modeling pump station capacity in normal operation calculations because only relative elevations affect the calculations.



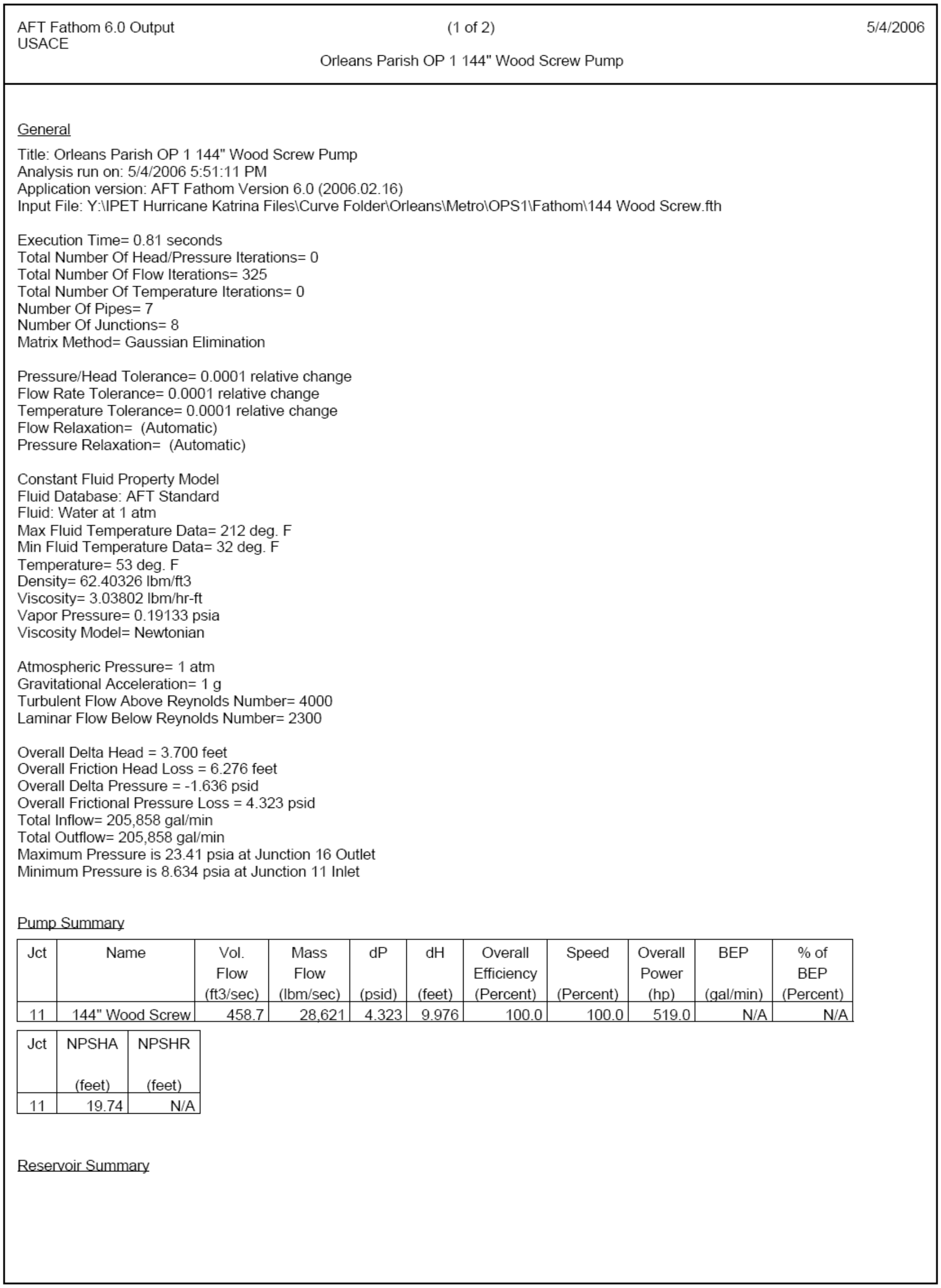
Drawing Shown 6760-W-18

Assumptions:

1. Intake water elevation is 13 ft; discharge water elevation is 26.1 ft
2. Trash rack has K factor of 1.0
3. Suction and discharge bell has equivelant circular diameter of 252.5 in and angle of 28 degrees
4. Pump elevation is same as 168" Wood Screw (drawing shown)
5. Drawings are to scale

Layout of 144" Wood Screw Pump at OP 1

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.



AFT Fathom 6.0 Output (1 of 2) 5/4/2006
USACE
Orleans Parish OP 1 144" Wood Screw Pump

General

Title: Orleans Parish OP 1 144" Wood Screw Pump
Analysis run on: 5/4/2006 5:51:11 PM
Application version: AFT Fathom Version 6.0 (2006.02.16)
Input File: Y:\IPET Hurricane Katrina Files\Curve Folder\Orleans\Metro\OPS1\Fathom\144 Wood Screw.fth

Execution Time= 0.81 seconds
Total Number Of Head/Pressure Iterations= 0
Total Number Of Flow Iterations= 325
Total Number Of Temperature Iterations= 0
Number Of Pipes= 7
Number Of Junctions= 8
Matrix Method= Gaussian Elimination

Pressure/Head Tolerance= 0.0001 relative change
Flow Rate Tolerance= 0.0001 relative change
Temperature Tolerance= 0.0001 relative change
Flow Relaxation= (Automatic)
Pressure Relaxation= (Automatic)

Constant Fluid Property Model
Fluid Database: AFT Standard
Fluid: Water at 1 atm
Max Fluid Temperature Data= 212 deg. F
Min Fluid Temperature Data= 32 deg. F
Temperature= 53 deg. F
Density= 62.40326 lbm/ft3
Viscosity= 3.03802 lbm/hr-ft
Vapor Pressure= 0.19133 psia
Viscosity Model= Newtonian

Atmospheric Pressure= 1 atm
Gravitational Acceleration= 1 g
Turbulent Flow Above Reynolds Number= 4000
Laminar Flow Below Reynolds Number= 2300

Overall Delta Head = 3.700 feet
Overall Friction Head Loss = 6.276 feet
Overall Delta Pressure = -1.636 psid
Overall Frictional Pressure Loss = 4.323 psid
Total Inflow= 205,858 gal/min
Total Outflow= 205,858 gal/min
Maximum Pressure is 23.41 psia at Junction 16 Outlet
Minimum Pressure is 8.634 psia at Junction 11 Inlet

Pump Summary

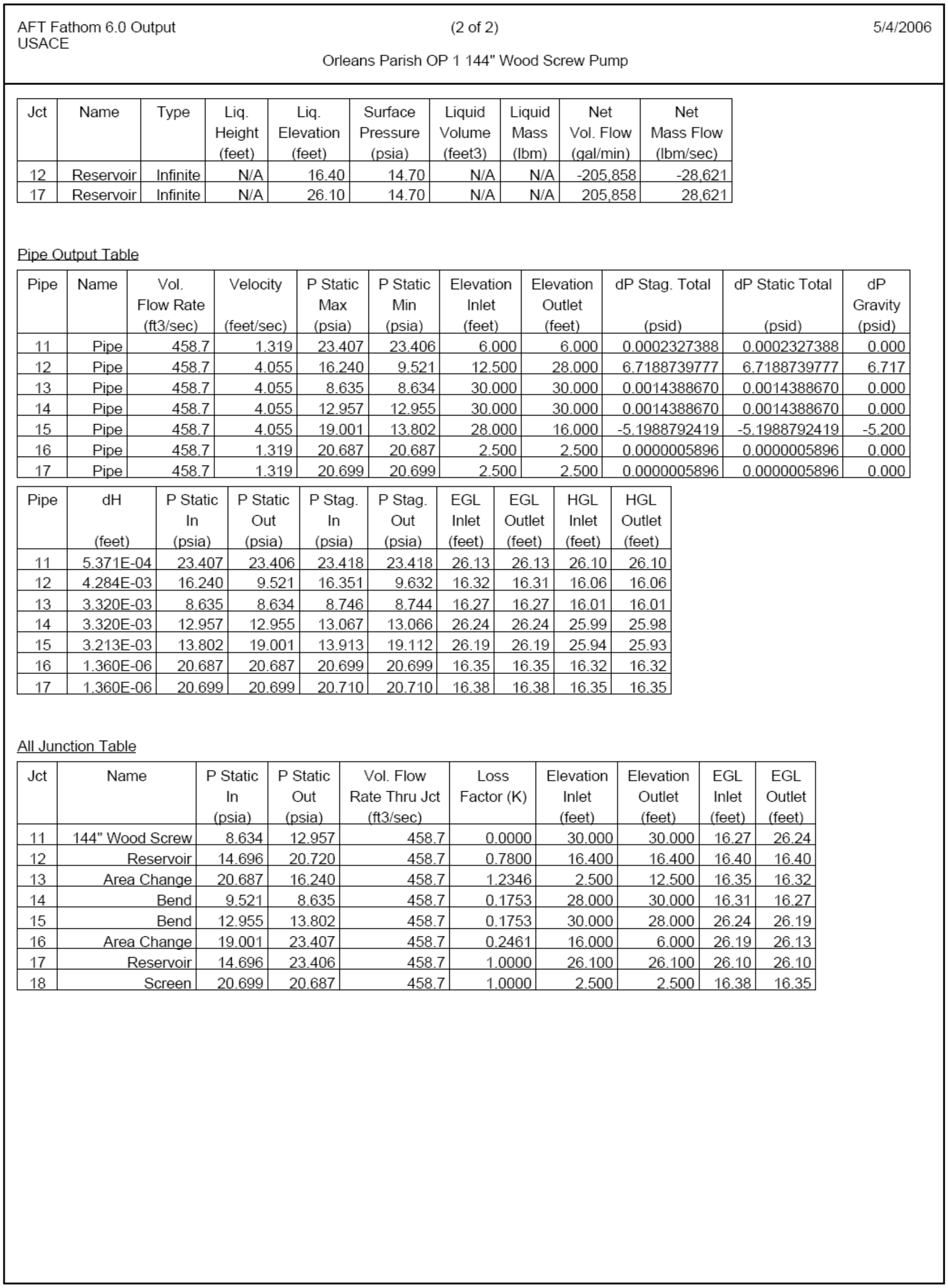
Jct	Name	Vol. Flow (ft3/sec)	Mass Flow (lbm/sec)	dP (psid)	dH (feet)	Overall Efficiency (Percent)	Speed (Percent)	Overall Power (hp)	BEP (gal/min)	% of BEP (Percent)
11	144" Wood Screw	458.7	28,621	4.323	9.976	100.0	100.0	519.0	N/A	N/A

Jct	NPSHA (feet)	NPSHR (feet)
11	19.74	N/A

Reservoir Summary

Output from AFT Fathom™ for 144” Wood Screw, Page 1

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.



AFT Fathom 6.0 Output (2 of 2) 5/4/2006
USACE

Orleans Parish OP 1 144" Wood Screw Pump

Jct	Name	Type	Liq. Height (feet)	Liq. Elevation (feet)	Surface Pressure (psia)	Liquid Volume (feet3)	Liquid Mass (lbm)	Net Vol. Flow (gal/min)	Net Mass Flow (lbm/sec)
12	Reservoir	Infinite	N/A	16.40	14.70	N/A	N/A	-205,858	-28,621
17	Reservoir	Infinite	N/A	26.10	14.70	N/A	N/A	205,858	28,621

Pipe Output Table

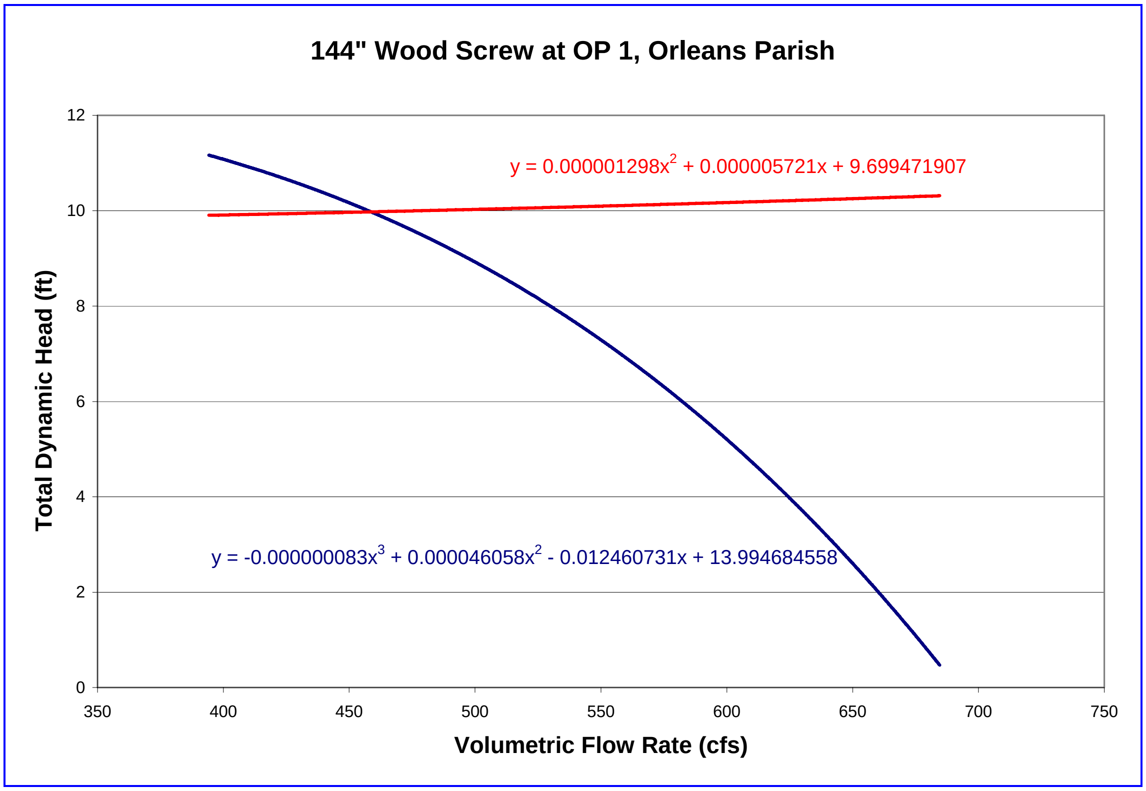
Pipe	Name	Vol. Flow Rate (ft3/sec)	Velocity (feet/sec)	P Static Max (psia)	P Static Min (psia)	Elevation Inlet (feet)	Elevation Outlet (feet)	dP Stag. Total (psid)	dP Static Total (psid)	dP Gravity (psid)
11	Pipe	458.7	1.319	23.407	23.406	6.000	6.000	0.0002327388	0.0002327388	0.000
12	Pipe	458.7	4.055	16.240	9.521	12.500	28.000	6.7188739777	6.7188739777	6.717
13	Pipe	458.7	4.055	8.635	8.634	30.000	30.000	0.0014388670	0.0014388670	0.000
14	Pipe	458.7	4.055	12.957	12.955	30.000	30.000	0.0014388670	0.0014388670	0.000
15	Pipe	458.7	4.055	19.001	13.802	28.000	16.000	-5.1988792419	-5.1988792419	-5.200
16	Pipe	458.7	1.319	20.687	20.687	2.500	2.500	0.0000005896	0.0000005896	0.000
17	Pipe	458.7	1.319	20.699	20.699	2.500	2.500	0.0000005896	0.0000005896	0.000

Pipe	dH (feet)	P Static In (psia)	P Static Out (psia)	P Stag. In (psia)	P Stag. Out (psia)	EGL Inlet (feet)	EGL Outlet (feet)	HGL Inlet (feet)	HGL Outlet (feet)
11	5.371E-04	23.407	23.406	23.418	23.418	26.13	26.13	26.10	26.10
12	4.284E-03	16.240	9.521	16.351	9.632	16.32	16.31	16.06	16.06
13	3.320E-03	8.635	8.634	8.746	8.744	16.27	16.27	16.01	16.01
14	3.320E-03	12.957	12.955	13.067	13.066	26.24	26.24	25.99	25.98
15	3.213E-03	13.802	19.001	13.913	19.112	26.19	26.19	25.94	25.93
16	1.360E-06	20.687	20.687	20.699	20.699	16.35	16.35	16.32	16.32
17	1.360E-06	20.699	20.699	20.710	20.710	16.38	16.38	16.35	16.35

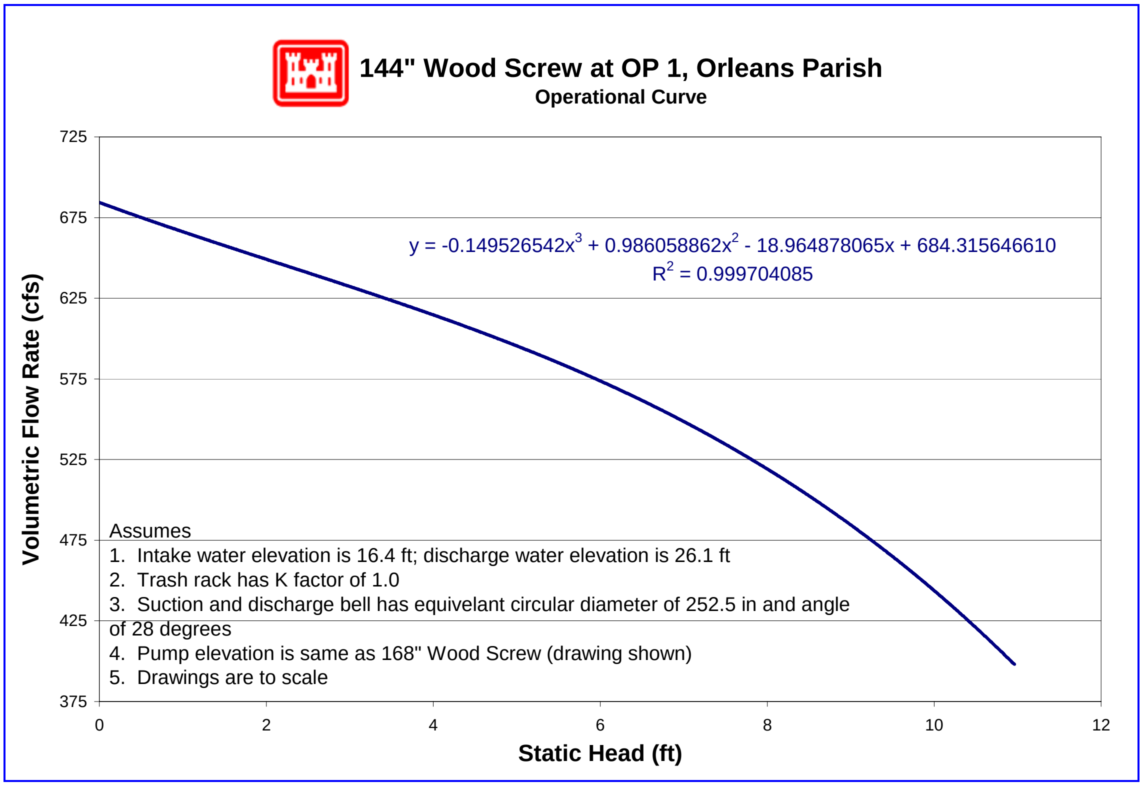
All Junction Table

Jct	Name	P Static In (psia)	P Static Out (psia)	Vol. Flow Rate Thru Jct (ft3/sec)	Loss Factor (K)	Elevation Inlet (feet)	Elevation Outlet (feet)	EGL Inlet (feet)	EGL Outlet (feet)
11	144" Wood Screw	8.634	12.957	458.7	0.0000	30.000	30.000	16.27	26.24
12	Reservoir	14.696	20.720	458.7	0.7800	16.400	16.400	16.40	16.40
13	Area Change	20.687	16.240	458.7	1.2346	2.500	12.500	16.35	16.32
14	Bend	9.521	8.635	458.7	0.1753	28.000	30.000	16.31	16.27
15	Bend	12.955	13.802	458.7	0.1753	30.000	28.000	26.24	26.19
16	Area Change	19.001	23.407	458.7	0.2461	16.000	6.000	26.19	26.13
17	Reservoir	14.696	23.406	458.7	1.0000	26.100	26.100	26.10	26.10
18	Screen	20.699	20.687	458.7	1.0000	2.500	2.500	16.38	16.35

Output from AFT Fathom™ for 144" Wood Screw, Page 2



System Curve of 144” Wood Screw Pump at OP 1



Assumes

1. Intake water elevation is 16.4 ft; discharge water elevation is 26.1 ft
2. Trash rack has K factor of 1.0
3. Suction and discharge bell has equivelant circular diameter of 252.5 in and angle of 28 degrees
4. Pump elevation is same as 168" Wood Screw (drawing shown)
5. Drawings are to scale

Operational Curve for 144” Wood Screw Pump at OP 1

7.6.2.1.1.6.4 168” Wood Screw

Drawing 6760-W-18 provided an elevation view for the 168” Wood Screw. The following resources were used to make the indicated assumptions:[157]

- *Data from 6760-W-18* – Suction and discharge bells were scaled to have an equivalent hydraulic diameter of 264.5 inches with transition angles of 24˚. The angles were determined via scaling to be 45˚ with r/D values of 1.0.
- *Aerial photographs* – It was determined that there were horizontal bends at15˚ with r/D of 1.0
- *An estimated one foot of trash at the intake* – A loss coefficient of 1.0 for the trash rack was modeled.
- *Operator’s Log* – It was determined that the intake water elevation was 16.4 feet and the discharge water elevation was 26.1 feet.

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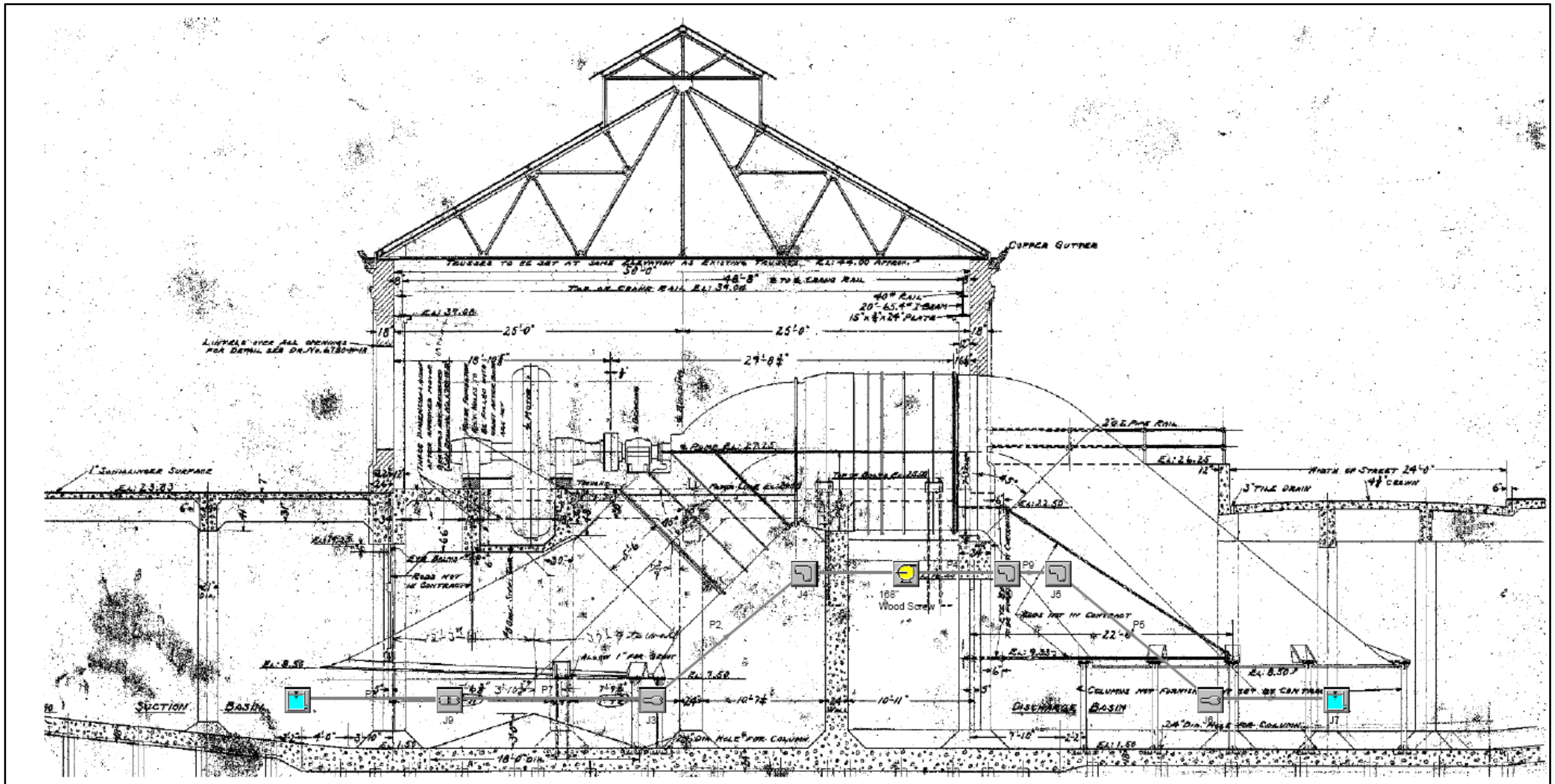
[157] The datum for the listed elevations is not reported. The datum is not needed for modeling pump station capacity in normal operation calculations because only relative elevations affect the calculations.

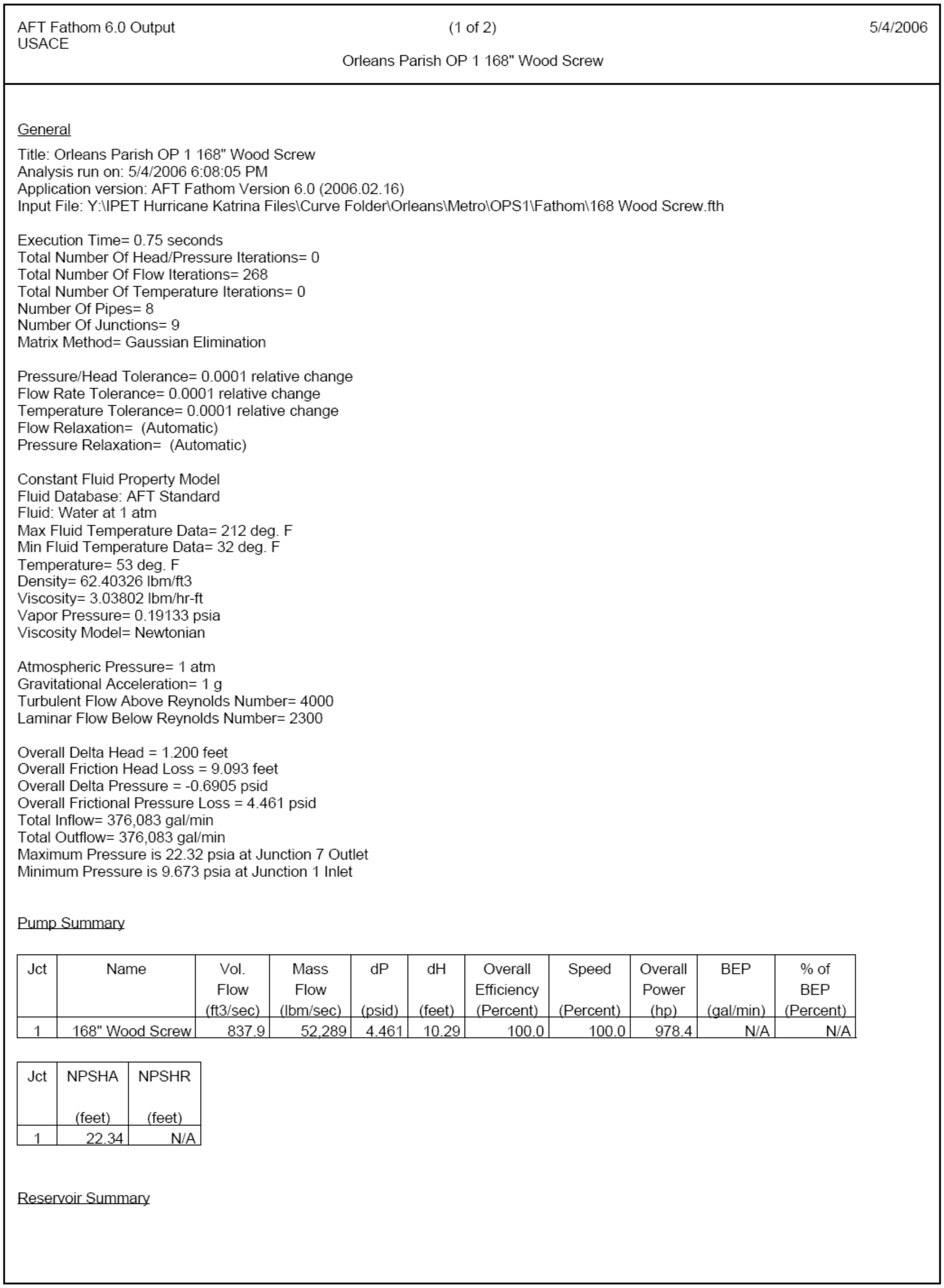


Drawing Shown 6760-W-18

Assumptions:

1. Intake water elevation at 16.4 ft
2. Trash Rack has K factor of 1.0
3. Intake and discharge bell has angle of 24 degrees and equivalent diameter of 264.5 in
4. r/D of curves is 1
5. 45 degree bends
6. Discharge water elevation of 26.1 ft
7. Horizontal bend is at 15 degrees.
8. Drawings are to scale

Layout of 168” Wood Screw Pump at OP 1



AFT Fathom 6.0 Output
USACE

(1 of 2)

5/4/2006

Orleans Parish OP 1 168" Wood Screw

General

Title: Orleans Parish OP 1 168" Wood Screw
Analysis run on: 5/4/2006 6:08:05 PM
Application version: AFT Fathom Version 6.0 (2006.02.16)
Input File: Y:\IPET Hurricane Katrina Files\Curve Folder\Orleans\Metro\OPS1\Fathom\168 Wood Screw.fth

Execution Time= 0.75 seconds
Total Number Of Head/Pressure Iterations= 0
Total Number Of Flow Iterations= 268
Total Number Of Temperature Iterations= 0
Number Of Pipes= 8
Number Of Junctions= 9
Matrix Method= Gaussian Elimination

Pressure/Head Tolerance= 0.0001 relative change
Flow Rate Tolerance= 0.0001 relative change
Temperature Tolerance= 0.0001 relative change
Flow Relaxation= (Automatic)
Pressure Relaxation= (Automatic)

Constant Fluid Property Model
Fluid Database: AFT Standard
Fluid: Water at 1 atm
Max Fluid Temperature Data= 212 deg. F
Min Fluid Temperature Data= 32 deg. F
Temperature= 53 deg. F
Density= 62.40326 lbm/ft3
Viscosity= 3.03802 lbm/hr-ft
Vapor Pressure= 0.19133 psia
Viscosity Model= Newtonian

Atmospheric Pressure= 1 atm
Gravitational Acceleration= 1 g
Turbulent Flow Above Reynolds Number= 4000
Laminar Flow Below Reynolds Number= 2300

Overall Delta Head = 1.200 feet
Overall Friction Head Loss = 9.093 feet
Overall Delta Pressure = -0.6905 psid
Overall Frictional Pressure Loss = 4.461 psid
Total Inflow= 376,083 gal/min
Total Outflow= 376,083 gal/min
Maximum Pressure is 22.32 psia at Junction 7 Outlet
Minimum Pressure is 9.673 psia at Junction 1 Inlet

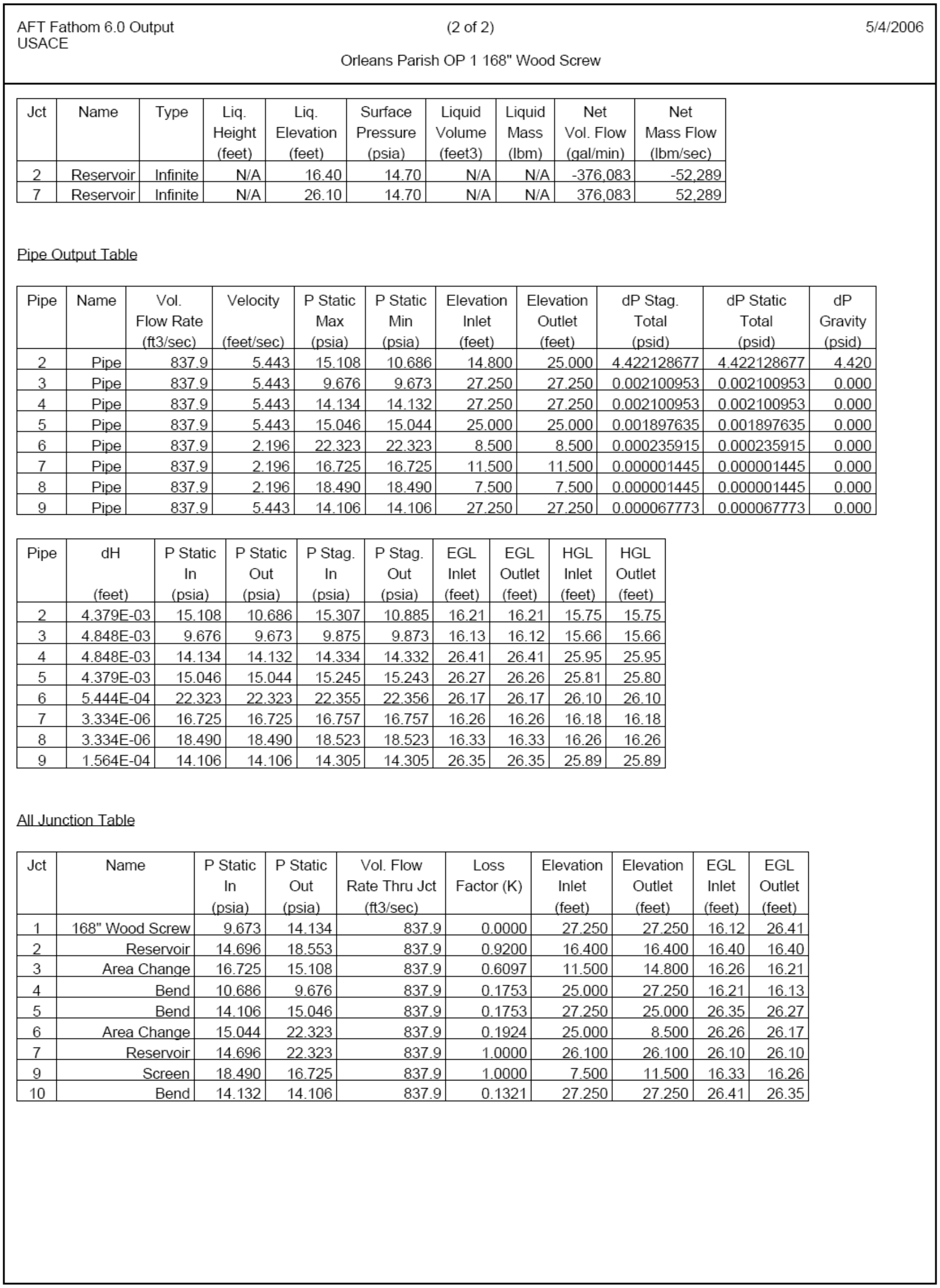
Pump Summary

Jct	Name	Vol. Flow (ft3/sec)	Mass Flow (lbm/sec)	dP (psid)	dH (feet)	Overall Efficiency (Percent)	Speed (Percent)	Overall Power (hp)	BEP (gal/min)	% of BEP (Percent)
1	168" Wood Screw	837.9	52,289	4.461	10.29	100.0	100.0	978.4	N/A	N/A

Jct	NPSHA (feet)	NPSHR (feet)
1	22.34	N/A

Reservoir Summary

Output from AFT Fathom™ for 168” Wood Screw, Page 1



AFT Fathom 6.0 Output (2 of 2) 5/4/2006
USACE

Orleans Parish OP 1 168" Wood Screw

Jct	Name	Type	Liq. Height (feet)	Liq. Elevation (feet)	Surface Pressure (psia)	Liquid Volume (feet3)	Liquid Mass (lbm)	Net Vol. Flow (gal/min)	Net Mass Flow (lbm/sec)
2	Reservoir	Infinite	N/A	16.40	14.70	N/A	N/A	-376,083	-52,289
7	Reservoir	Infinite	N/A	26.10	14.70	N/A	N/A	376,083	52,289

Pipe Output Table

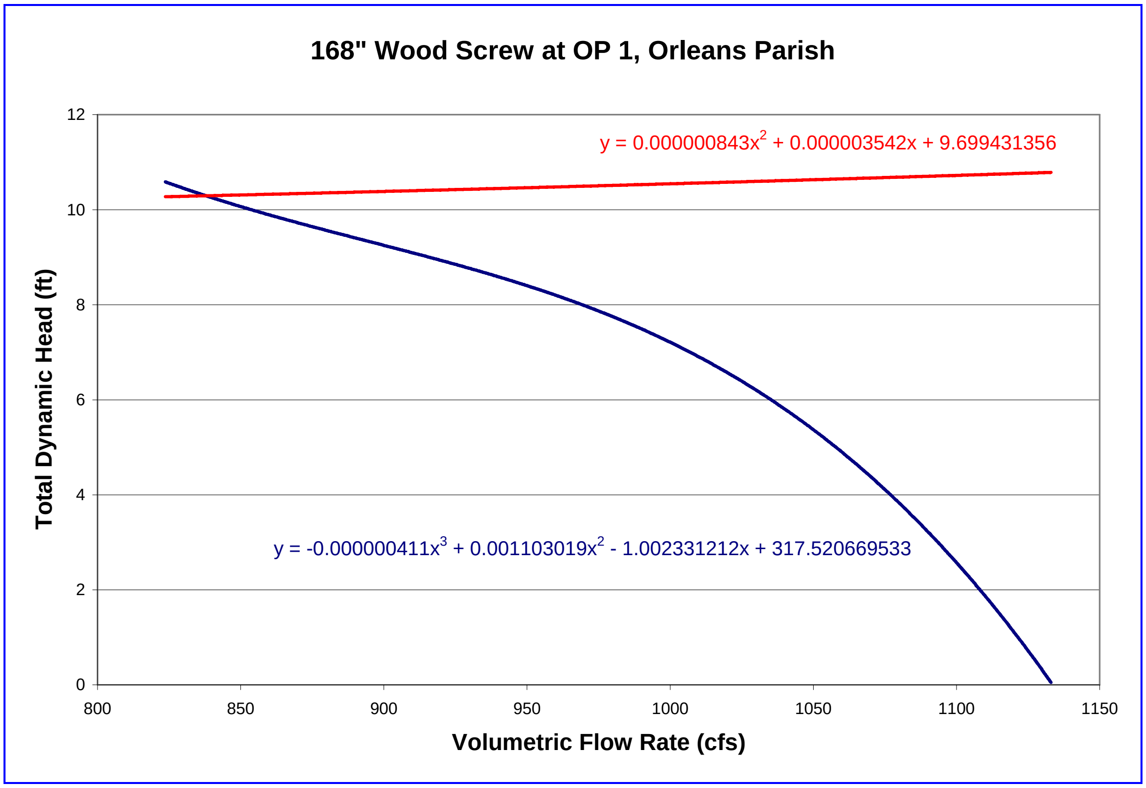
Pipe	Name	Vol. Flow Rate (ft3/sec)	Velocity (feet/sec)	P Static Max (psia)	P Static Min (psia)	Elevation Inlet (feet)	Elevation Outlet (feet)	dP Stag. Total (psid)	dP Static Total (psid)	dP Gravity (psid)
2	Pipe	837.9	5.443	15.108	10.686	14.800	25.000	4.422128677	4.422128677	4.420
3	Pipe	837.9	5.443	9.676	9.673	27.250	27.250	0.002100953	0.002100953	0.000
4	Pipe	837.9	5.443	14.134	14.132	27.250	27.250	0.002100953	0.002100953	0.000
5	Pipe	837.9	5.443	15.046	15.044	25.000	25.000	0.001897635	0.001897635	0.000
6	Pipe	837.9	2.196	22.323	22.323	8.500	8.500	0.000235915	0.000235915	0.000
7	Pipe	837.9	2.196	16.725	16.725	11.500	11.500	0.000001445	0.000001445	0.000
8	Pipe	837.9	2.196	18.490	18.490	7.500	7.500	0.000001445	0.000001445	0.000
9	Pipe	837.9	5.443	14.106	14.106	27.250	27.250	0.000067773	0.000067773	0.000

Pipe	dH (feet)	P Static In (psia)	P Static Out (psia)	P Stag. In (psia)	P Stag. Out (psia)	EGL Inlet (feet)	EGL Outlet (feet)	HGL Inlet (feet)	HGL Outlet (feet)
2	4.379E-03	15.108	10.686	15.307	10.885	16.21	16.21	15.75	15.75
3	4.848E-03	9.676	9.673	9.875	9.873	16.13	16.12	15.66	15.66
4	4.848E-03	14.134	14.132	14.334	14.332	26.41	26.41	25.95	25.95
5	4.379E-03	15.046	15.044	15.245	15.243	26.27	26.26	25.81	25.80
6	5.444E-04	22.323	22.323	22.355	22.356	26.17	26.17	26.10	26.10
7	3.334E-06	16.725	16.725	16.757	16.757	16.26	16.26	16.18	16.18
8	3.334E-06	18.490	18.490	18.523	18.523	16.33	16.33	16.26	16.26
9	1.564E-04	14.106	14.106	14.305	14.305	26.35	26.35	25.89	25.89

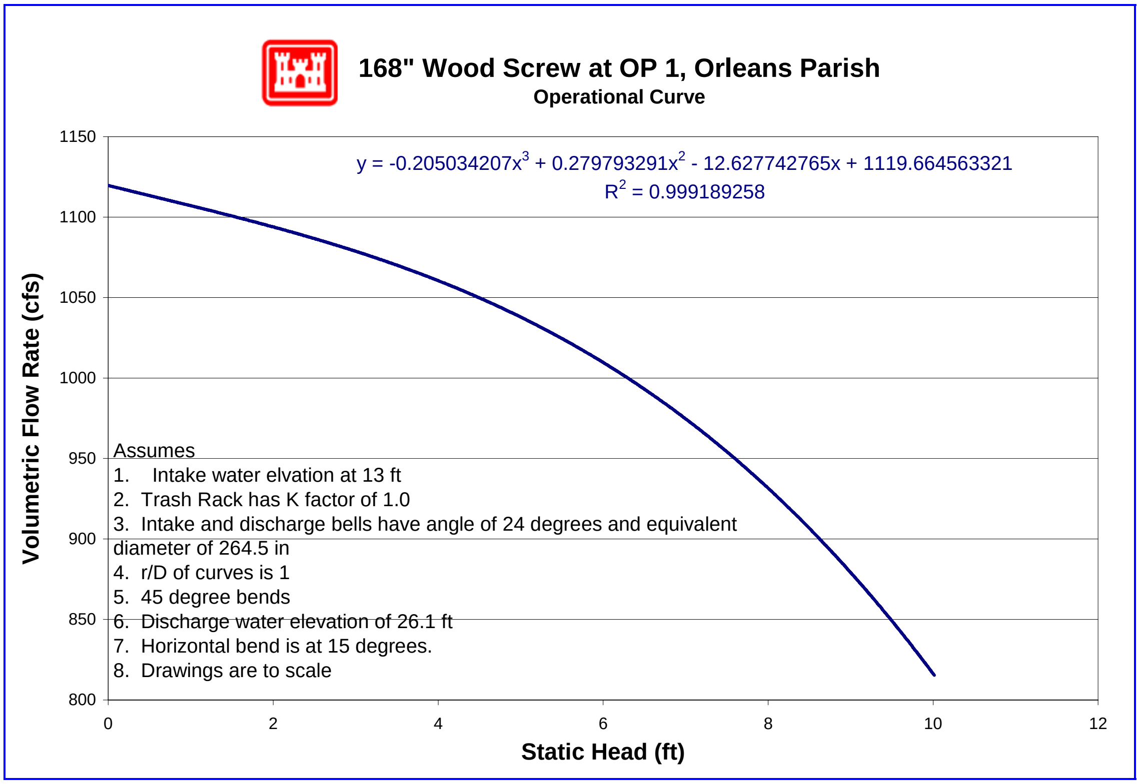
All Junction Table

Jct	Name	P Static In (psia)	P Static Out (psia)	Vol. Flow Rate Thru Jct (ft3/sec)	Loss Factor (K)	Elevation Inlet (feet)	Elevation Outlet (feet)	EGL Inlet (feet)	EGL Outlet (feet)
1	168" Wood Screw	9.673	14.134	837.9	0.0000	27.250	27.250	16.12	26.41
2	Reservoir	14.696	18.553	837.9	0.9200	16.400	16.400	16.40	16.40
3	Area Change	16.725	15.108	837.9	0.6097	11.500	14.800	16.26	16.21
4	Bend	10.686	9.676	837.9	0.1753	25.000	27.250	16.21	16.13
5	Bend	14.106	15.046	837.9	0.1753	27.250	25.000	26.35	26.27
6	Area Change	15.044	22.323	837.9	0.1924	25.000	8.500	26.26	26.17
7	Reservoir	14.696	22.323	837.9	1.0000	26.100	26.100	26.10	26.10
9	Screen	18.490	16.725	837.9	1.0000	7.500	11.500	16.33	16.26
10	Bend	14.132	14.106	837.9	0.1321	27.250	27.250	26.41	26.35

Output from AFT Fathom™ 168" Wood Screw, Page 2



System Curve of 168” Wood Screw Pump at OP 1



Assumes
1. Intake water elvation at 13 ft
2. Trash Rack has K factor of 1.0
3. Intake and discharge bells have angle of 24 degrees and equivalent diameter of 264.5 in
4. r/D of curves is 1
5. 45 degree bends
6. Discharge water elevation of 26.1 ft
7. Horizontal bend is at 15 degrees.
8. Drawings are to scale

Operational Curve for 168” Wood Screw Pump at OP 1

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.2.1.1.6.5 168” ITT-AC “G” (no horizontal bend)

Drawing 11736-W-59 Sheet 18 shows an elevation of the 168” ITT-AC. The following resources were used to make the indicated assumptions:[158]

- *Data from 11736-W-59 Sheet 18* – Modeled were two 45˚ bends with r/D factors of 1.0, as well as a suction bell and a discharge bell with equivalent circular hydraulic diameters of 264.5 inches. The bells had conical transitions at an angle of 24˚. Much of this data came from assuming the drawing to be to scale.
- *Operator’s Log* – It was determined that the intake water elevation was 16.4 feet and the discharge water elevation was 26.1 feet.
- *An estimated one foot of trash at the intake* – A loss coefficient of 1.0 at the trash rack was utilized.

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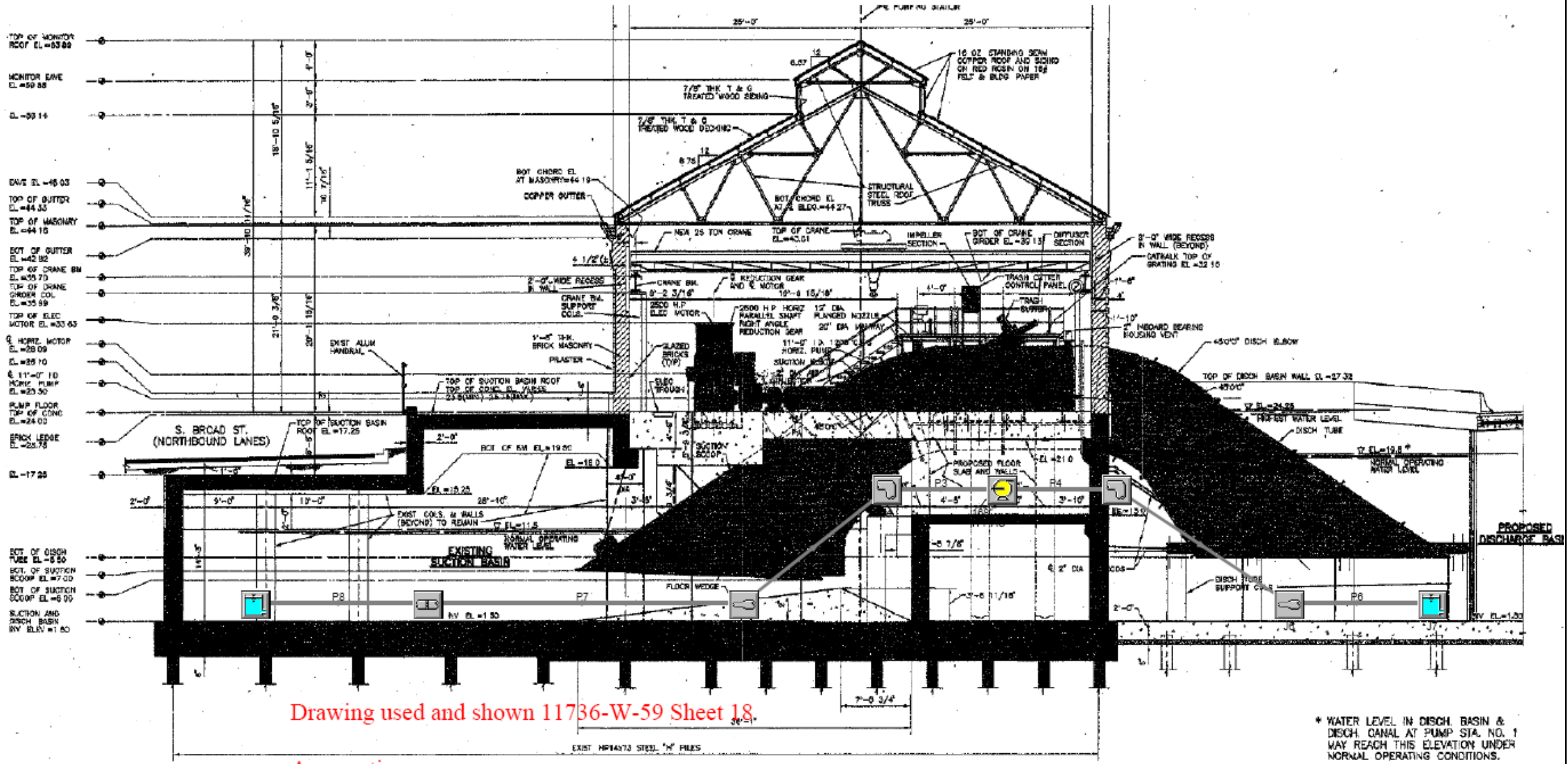
[158] The datum for the listed elevations is not reported. The datum is not needed for modeling pump station capacity in normal operation calculations because only relative elevations affect the calculations.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

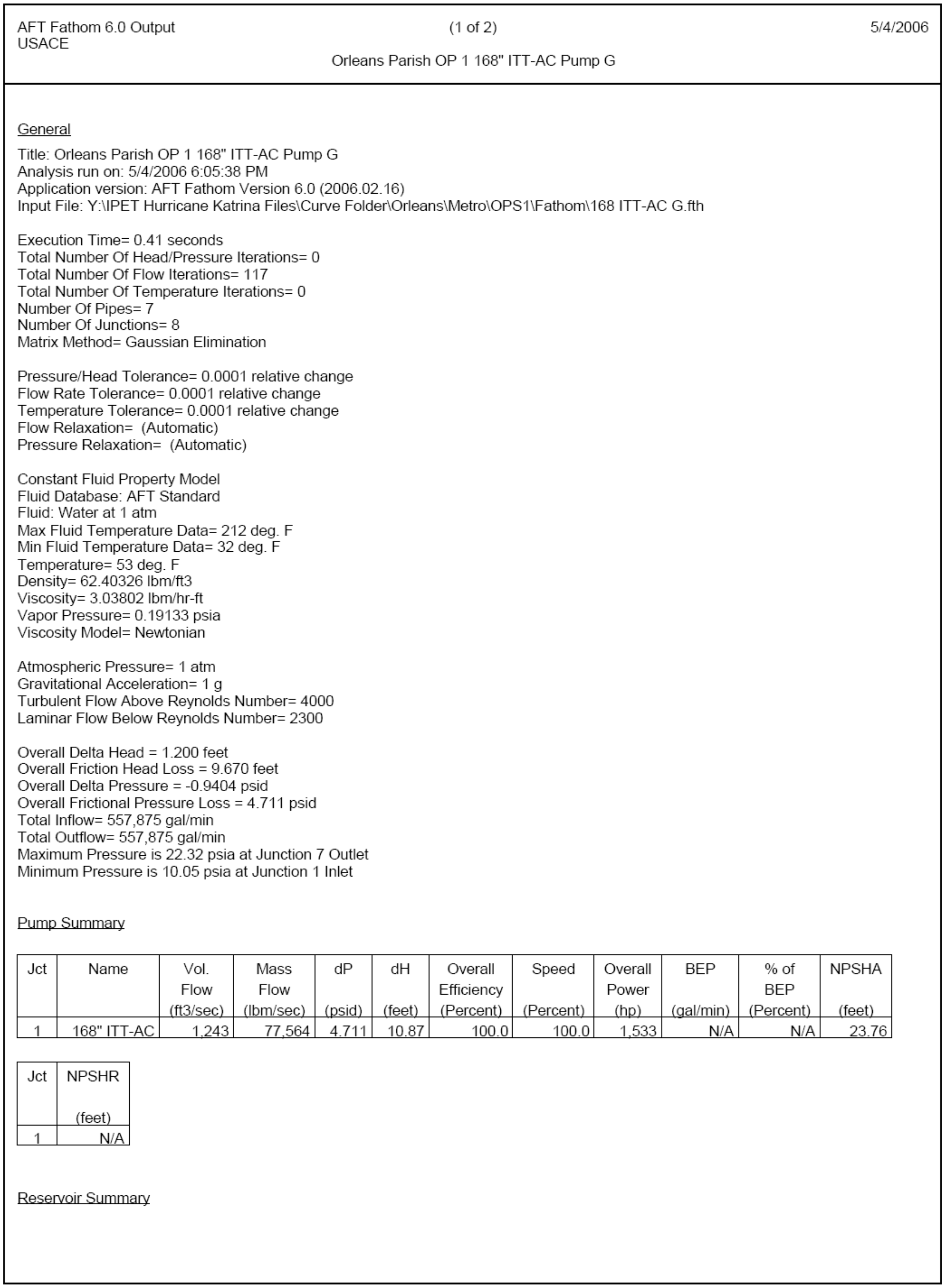


Drawing used and shown 11736-W-59 Sheet 18

Assumptions:

1. Intake water elevation is 16.4 ft
2. Trash rack has K factor of 1.0
3. Suction bell has equivalent diameter of 264.5 in and angle of 24 degrees
4. Bends have r/D of 1 and is 45 degrees
5. Discharge bell has equivalent diameter of 264.5 in and angle of 24 degrees
6. Discharge water elevation is 26.1 ft
7. Drawings are to scale

Layout of 168” ITT-AC Pump at OP 1



AFT Fathom 6.0 Output (1 of 2) 5/4/2006
USACE
Orleans Parish OP 1 168" ITT-AC Pump G

General

Title: Orleans Parish OP 1 168" ITT-AC Pump G
Analysis run on: 5/4/2006 6:05:38 PM
Application version: AFT Fathom Version 6.0 (2006.02.16)
Input File: Y:\IPET Hurricane Katrina Files\Curve Folder\Orleans\Metro\OPS1\Fathom\168 ITT-AC G.fth

Execution Time= 0.41 seconds
Total Number Of Head/Pressure Iterations= 0
Total Number Of Flow Iterations= 117
Total Number Of Temperature Iterations= 0
Number Of Pipes= 7
Number Of Junctions= 8
Matrix Method= Gaussian Elimination

Pressure/Head Tolerance= 0.0001 relative change
Flow Rate Tolerance= 0.0001 relative change
Temperature Tolerance= 0.0001 relative change
Flow Relaxation= (Automatic)
Pressure Relaxation= (Automatic)

Constant Fluid Property Model
Fluid Database: AFT Standard
Fluid: Water at 1 atm
Max Fluid Temperature Data= 212 deg. F
Min Fluid Temperature Data= 32 deg. F
Temperature= 53 deg. F
Density= 62.40326 lbm/ft3
Viscosity= 3.03802 lbm/hr-ft
Vapor Pressure= 0.19133 psia
Viscosity Model= Newtonian

Atmospheric Pressure= 1 atm
Gravitational Acceleration= 1 g
Turbulent Flow Above Reynolds Number= 4000
Laminar Flow Below Reynolds Number= 2300

Overall Delta Head = 1.200 feet
Overall Friction Head Loss = 9.670 feet
Overall Delta Pressure = -0.9404 psid
Overall Frictional Pressure Loss = 4.711 psid
Total Inflow= 557,875 gal/min
Total Outflow= 557,875 gal/min
Maximum Pressure is 22.32 psia at Junction 7 Outlet
Minimum Pressure is 10.05 psia at Junction 1 Inlet

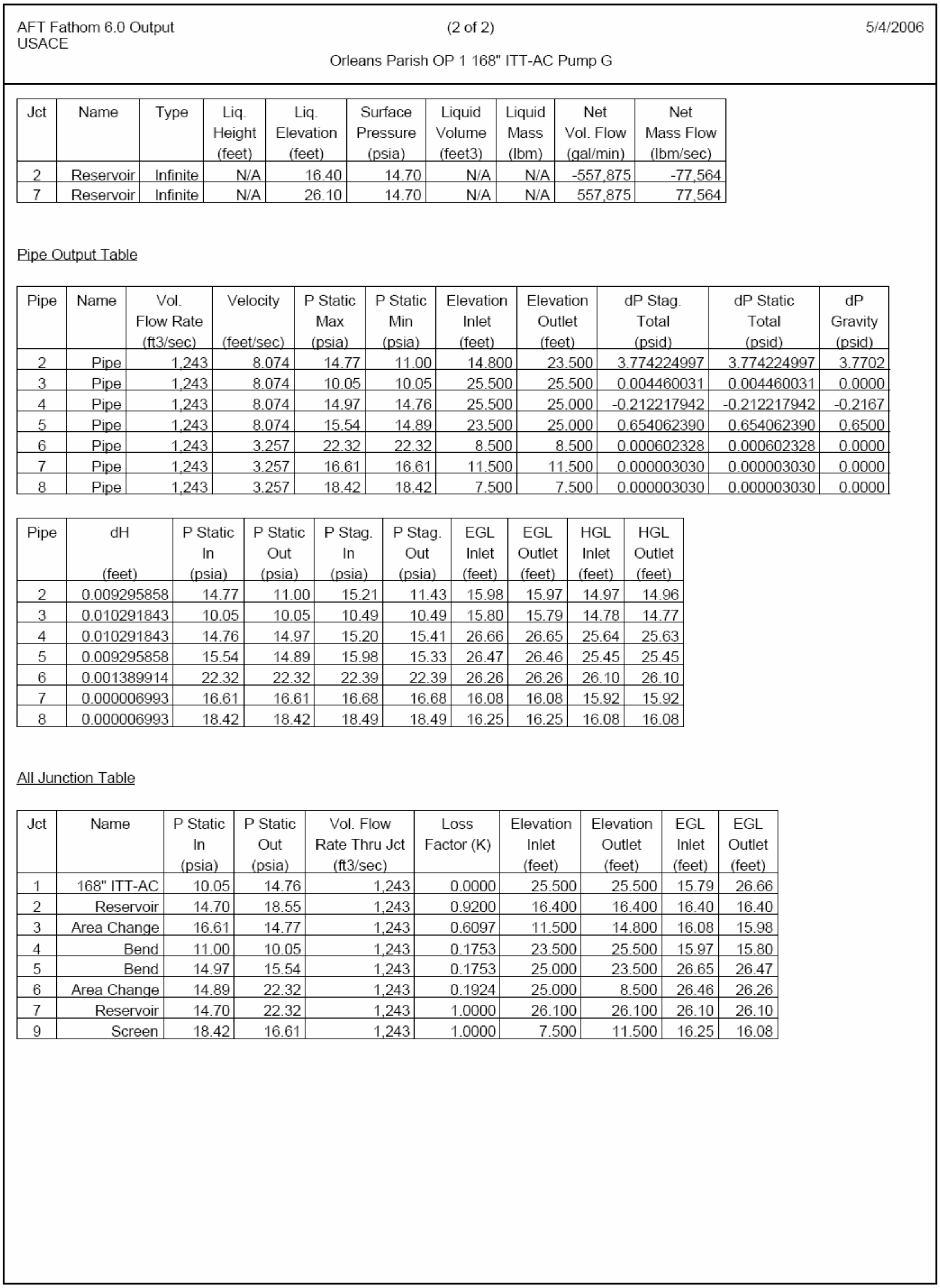
Pump Summary

Jct	Name	Vol. Flow (ft3/sec)	Mass Flow (lbm/sec)	dP (psid)	dH (feet)	Overall Efficiency (Percent)	Speed (Percent)	Overall Power (hp)	BEP (gal/min)	% of BEP (Percent)	NPSHA (feet)
1	168" ITT-AC	1,243	77,564	4.711	10.87	100.0	100.0	1,533	N/A	N/A	23.76

Jct	NPSHR (feet)
1	N/A

Reservoir Summary

Output from AFT Fathom™ for 168" ITT-AC Pump "G", Page 1



AFT Fathom 6.0 Output
USACE

(2 of 2)

5/4/2006

Orleans Parish OP 1 168" ITT-AC Pump G

Jct	Name	Type	Liq. Height (feet)	Liq. Elevation (feet)	Surface Pressure (psia)	Liquid Volume (feet3)	Liquid Mass (lbm)	Net Vol. Flow (gal/min)	Net Mass Flow (lbm/sec)
2	Reservoir	Infinite	N/A	16.40	14.70	N/A	N/A	-557,875	-77,564
7	Reservoir	Infinite	N/A	26.10	14.70	N/A	N/A	557,875	77,564

Pipe Output Table

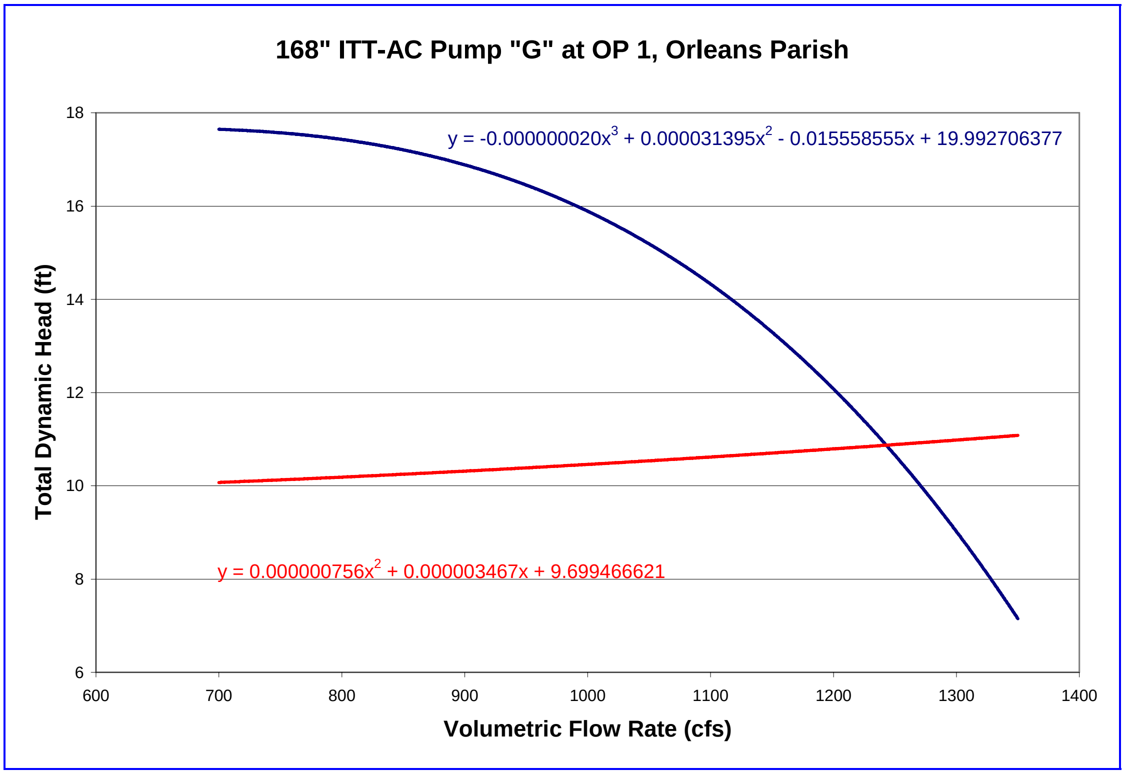
Pipe	Name	Vol. Flow Rate (ft3/sec)	Velocity (feet/sec)	P Static Max (psia)	P Static Min (psia)	Elevation Inlet (feet)	Elevation Outlet (feet)	dP Stag. Total (psid)	dP Static Total (psid)	dP Gravity (psid)
2	Pipe	1,243	8.074	14.77	11.00	14.800	23.500	3.774224997	3.774224997	3.7702
3	Pipe	1,243	8.074	10.05	10.05	25.500	25.500	0.004460031	0.004460031	0.0000
4	Pipe	1,243	8.074	14.97	14.76	25.500	25.000	-0.212217942	-0.212217942	-0.2167
5	Pipe	1,243	8.074	15.54	14.89	23.500	25.000	0.654062390	0.654062390	0.6500
6	Pipe	1,243	3.257	22.32	22.32	8.500	8.500	0.000602328	0.000602328	0.0000
7	Pipe	1,243	3.257	16.61	16.61	11.500	11.500	0.000003030	0.000003030	0.0000
8	Pipe	1,243	3.257	18.42	18.42	7.500	7.500	0.000003030	0.000003030	0.0000

Pipe	dH (feet)	P Static In (psia)	P Static Out (psia)	P Stag. In (psia)	P Stag. Out (psia)	EGL Inlet (feet)	EGL Outlet (feet)	HGL Inlet (feet)	HGL Outlet (feet)
2	0.009295858	14.77	11.00	15.21	11.43	15.98	15.97	14.97	14.96
3	0.010291843	10.05	10.05	10.49	10.49	15.80	15.79	14.78	14.77
4	0.010291843	14.76	14.97	15.20	15.41	26.66	26.65	25.64	25.63
5	0.009295858	15.54	14.89	15.98	15.33	26.47	26.46	25.45	25.45
6	0.001389914	22.32	22.32	22.39	22.39	26.26	26.26	26.10	26.10
7	0.000006993	16.61	16.61	16.68	16.68	16.08	16.08	15.92	15.92
8	0.000006993	18.42	18.42	18.49	18.49	16.25	16.25	16.08	16.08

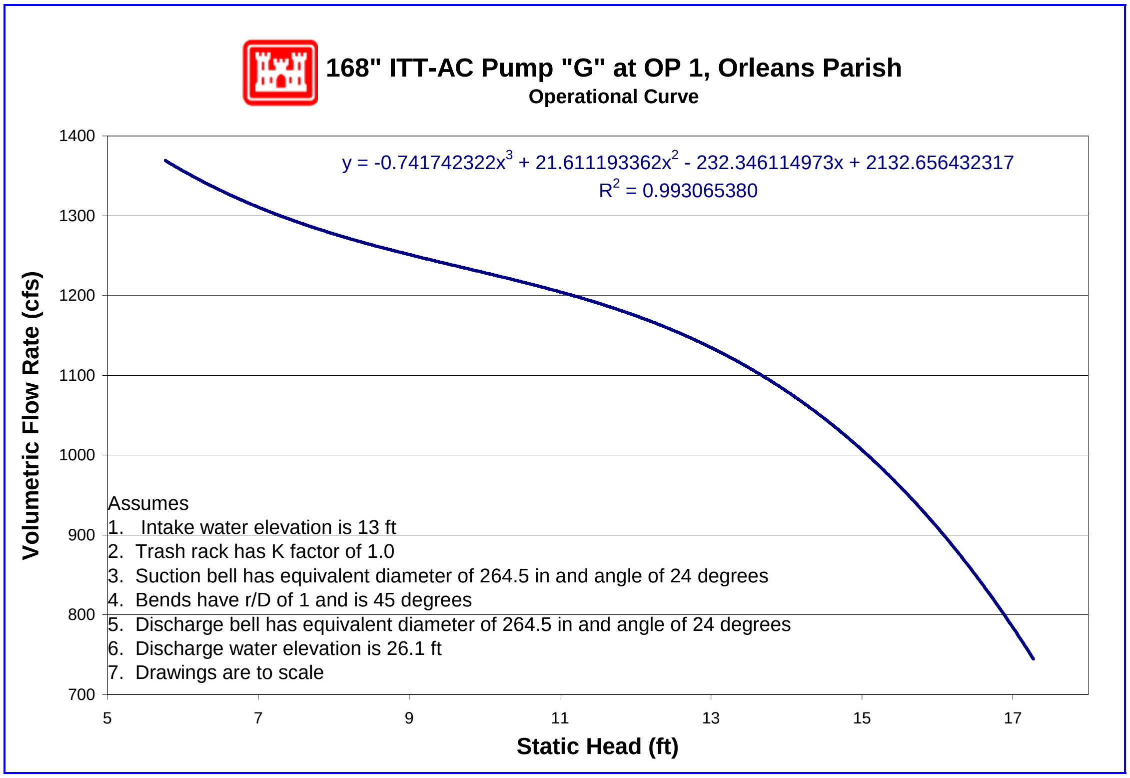
All Junction Table

Jct	Name	P Static In (psia)	P Static Out (psia)	Vol. Flow Rate Thru Jct (ft3/sec)	Loss Factor (K)	Elevation Inlet (feet)	Elevation Outlet (feet)	EGL Inlet (feet)	EGL Outlet (feet)
1	168" ITT-AC	10.05	14.76	1,243	0.0000	25.500	25.500	15.79	26.66
2	Reservoir	14.70	18.55	1,243	0.9200	16.400	16.400	16.40	16.40
3	Area Change	16.61	14.77	1,243	0.6097	11.500	14.800	16.08	15.98
4	Bend	11.00	10.05	1,243	0.1753	23.500	25.500	15.97	15.80
5	Bend	14.97	15.54	1,243	0.1753	25.000	23.500	26.65	26.47
6	Area Change	14.89	22.32	1,243	0.1924	25.000	8.500	26.46	26.26
7	Reservoir	14.70	22.32	1,243	1.0000	26.100	26.100	26.10	26.10
9	Screen	18.42	16.61	1,243	1.0000	7.500	11.500	16.25	16.08

Output from AFT Fathom™ for 168” ITT-AC Pump “G”, Page 2



System Curve of 168” ITT-AC Pump “G” at OP 1



Assumes
1. Intake water elevation is 13 ft
2. Trash rack has K factor of 1.0
3. Suction bell has equivalent diameter of 264.5 in and angle of 24 degrees
4. Bends have r/D of 1 and is 45 degrees
5. Discharge bell has equivalent diameter of 264.5 in and angle of 24 degrees
6. Discharge water elevation is 26.1 ft
7. Drawings are to scale

Operational Curve for 168” ITT-AC Pump “G” at OP 1

7.6.2.1.1.6.6 168” ITT-AC “F”

Drawing 11736-W-59 sheet 18 shows an elevation of the 168” ITT-AC, which generates most inputs into AFT Fathom™. Drawing 11736-W-59 shows the 90˚ horizontal bend. The following resources were used to make the indicated assumptions:[159]

- *Data from 11736-W-59 sheet 18* – Modeled were two 45˚ bends with r/D factors of 1.0, as well as a suction bell and a discharge bell with equivalent circular hydraulic diameters of 264.5 inches. The bells had conical transitions at an angle of 24˚. Much of this data came from assuming the drawing to be to scale.
- *Data from 11736-W-59 sheet A5* – Shown was a 90˚ bend with r/D of 1.0. This data was scaled from drawing.
- *Operator’s Log* – It was determined that the intake water elevation was 16.4 feet and the discharge water elevation was 26.1 feet.
- *An estimated one foot of trash at the intake* – A loss coefficient of 1.0 at the trash rack was employed.

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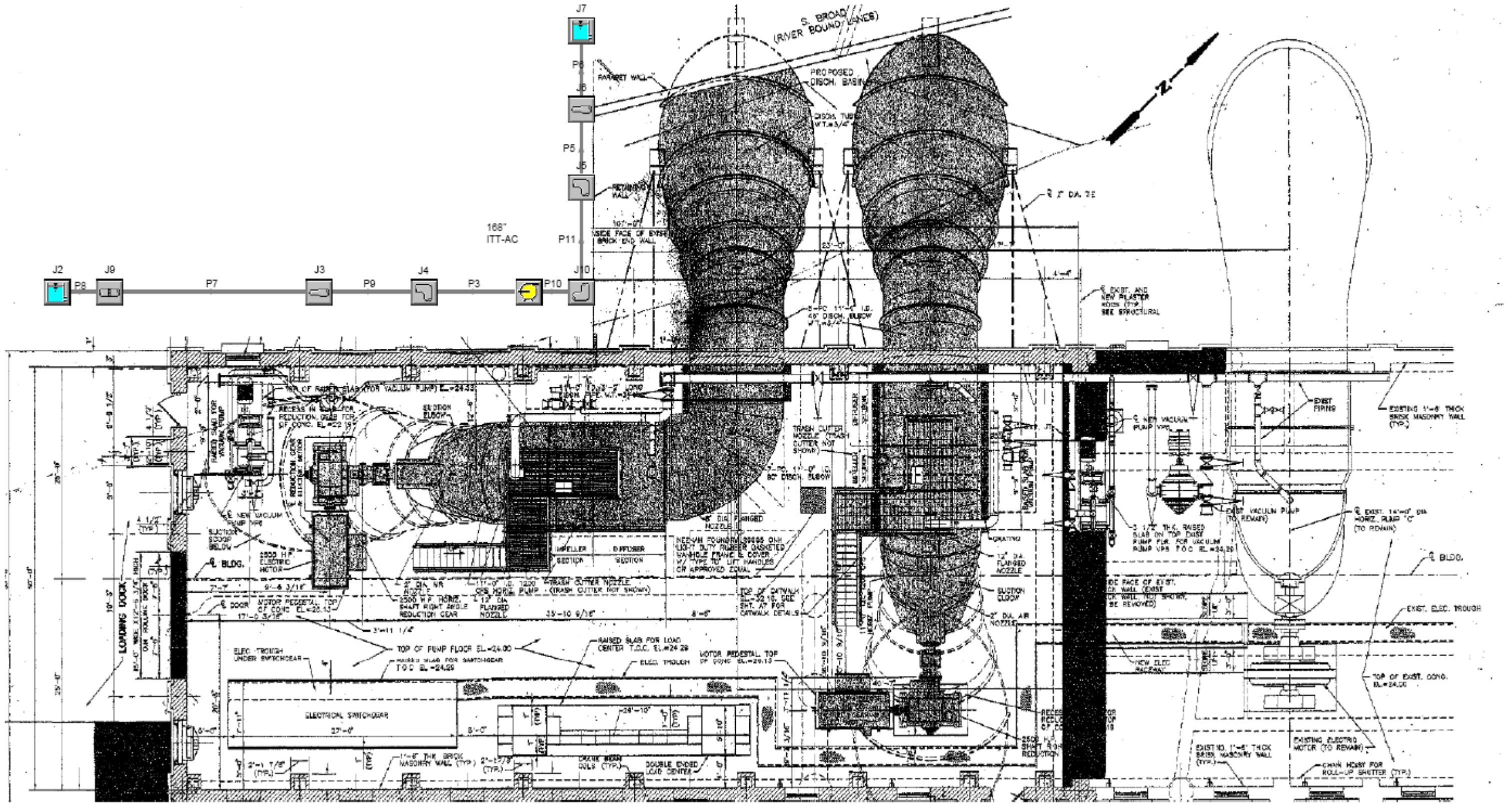
[159] The datum for the listed elevations is not reported. The datum is not needed for modeling pump station capacity in normal operation calculations because only relative elevations affect the calculations.

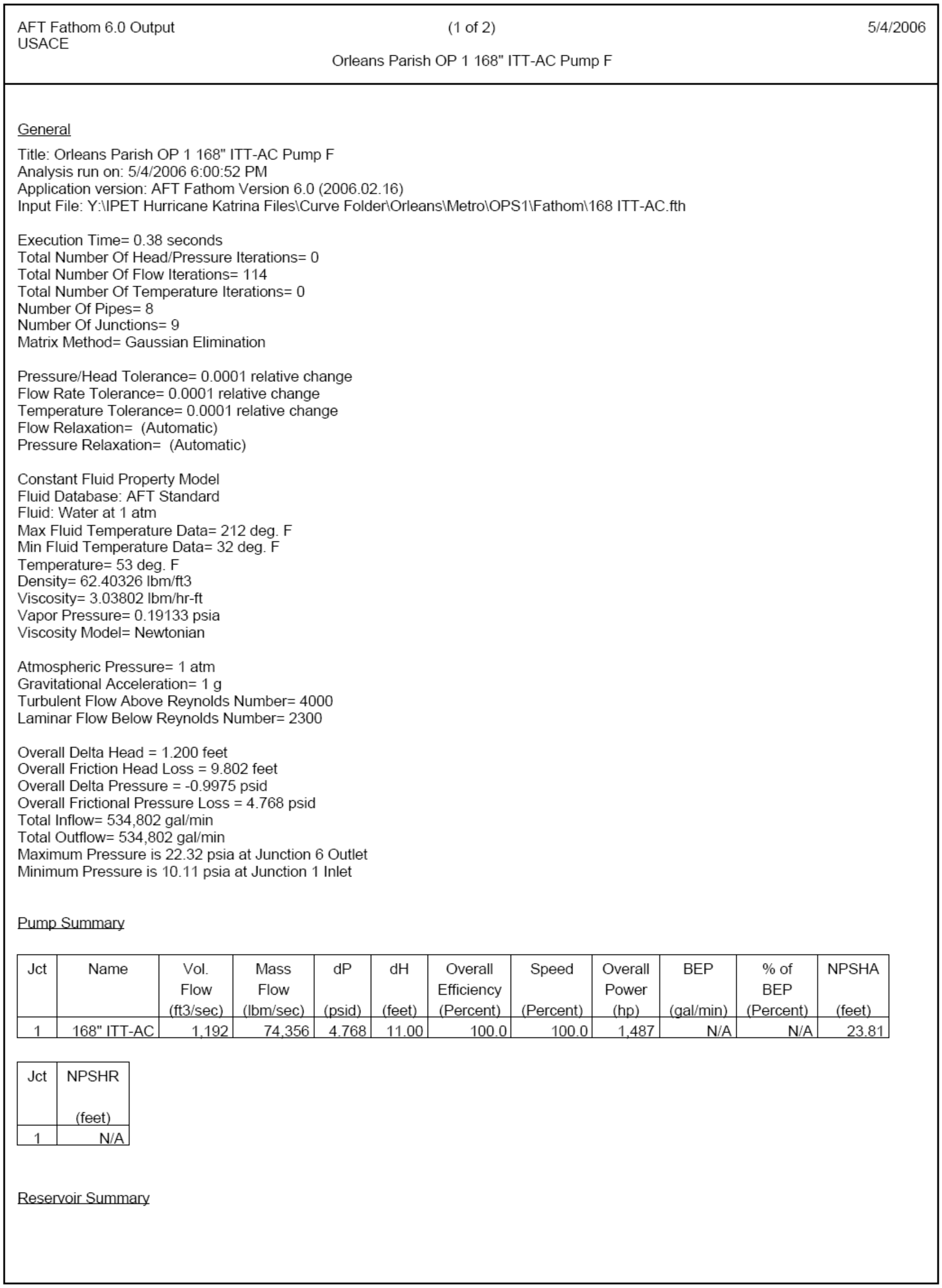
This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.



Drawing Elevations taken from 11736-W-59 Sheet 18
Drawing Shown 11736-W-59 Sheet A5

Assumptions:
1. Intake and discharge water elevation are 16.4 ft and 26.1 ft, respectively
2. Trash rack has a K factor of 1.0
3. Suction bell has equivalent diameter of 264.5 in and angle of 24
4. Bend has r/D value of 1 and is 45 degrees
5. Discharge bell has equivalent diameter of 264.5 and angle of 24
6. Drawings to scale

Layout of 168” ITT-AC Pump “F” at OP 1



AFT Fathom 6.0 Output
USACE

(1 of 2)

5/4/2006

Orleans Parish OP 1 168" ITT-AC Pump F

General

Title: Orleans Parish OP 1 168" ITT-AC Pump F
Analysis run on: 5/4/2006 6:00:52 PM
Application version: AFT Fathom Version 6.0 (2006.02.16)
Input File: Y:\IPET Hurricane Katrina Files\Curve Folder\Orleans\Metro\OPS1\Fathom\168 ITT-AC.fth

Execution Time= 0.38 seconds
Total Number Of Head/Pressure Iterations= 0
Total Number Of Flow Iterations= 114
Total Number Of Temperature Iterations= 0
Number Of Pipes= 8
Number Of Junctions= 9
Matrix Method= Gaussian Elimination

Pressure/Head Tolerance= 0.0001 relative change
Flow Rate Tolerance= 0.0001 relative change
Temperature Tolerance= 0.0001 relative change
Flow Relaxation= (Automatic)
Pressure Relaxation= (Automatic)

Constant Fluid Property Model
Fluid Database: AFT Standard
Fluid: Water at 1 atm
Max Fluid Temperature Data= 212 deg. F
Min Fluid Temperature Data= 32 deg. F
Temperature= 53 deg. F
Density= 62.40326 lbm/ft3
Viscosity= 3.03802 lbm/hr-ft
Vapor Pressure= 0.19133 psia
Viscosity Model= Newtonian

Atmospheric Pressure= 1 atm
Gravitational Acceleration= 1 g
Turbulent Flow Above Reynolds Number= 4000
Laminar Flow Below Reynolds Number= 2300

Overall Delta Head = 1.200 feet
Overall Friction Head Loss = 9.802 feet
Overall Delta Pressure = -0.9975 psid
Overall Frictional Pressure Loss = 4.768 psid
Total Inflow= 534,802 gal/min
Total Outflow= 534,802 gal/min
Maximum Pressure is 22.32 psia at Junction 6 Outlet
Minimum Pressure is 10.11 psia at Junction 1 Inlet

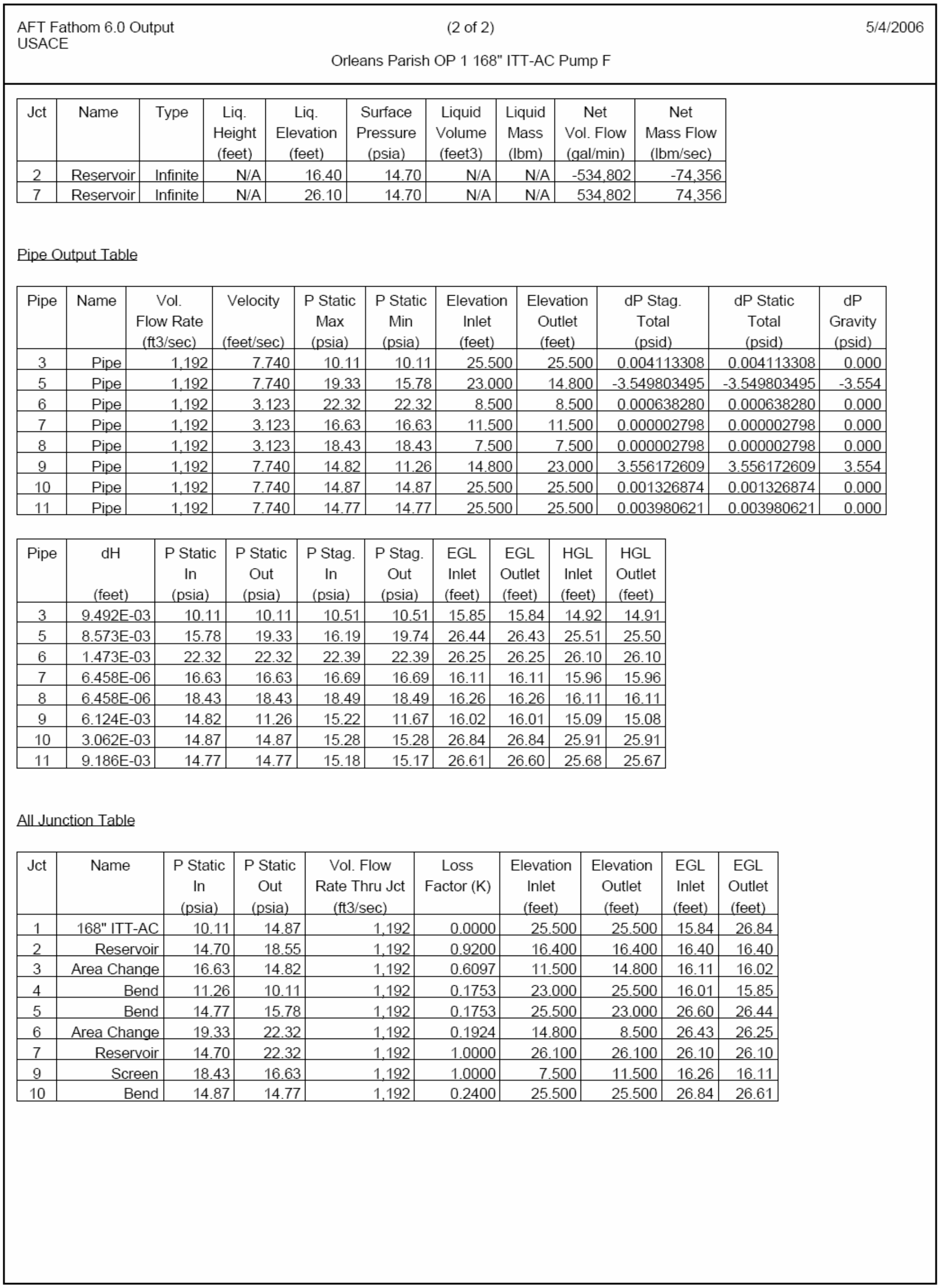
Pump Summary

Jct	Name	Vol. Flow (ft3/sec)	Mass Flow (lbm/sec)	dP (psid)	dH (feet)	Overall Efficiency (Percent)	Speed (Percent)	Overall Power (hp)	BEP (gal/min)	% of BEP (Percent)	NPSHA (feet)
1	168" ITT-AC	1,192	74,356	4.768	11.00	100.0	100.0	1,487	N/A	N/A	23.81

Jct	NPSHR (feet)
1	N/A

Reservoir Summary

Output from AFT Fathom™ for 168” ITT-AC Pump “F”, Page 1



AFT Fathom 6.0 Output (2 of 2) 5/4/2006
USACE
Orleans Parish OP 1 168" ITT-AC Pump F

Jct	Name	Type	Liq. Height (feet)	Liq. Elevation (feet)	Surface Pressure (psia)	Liquid Volume (feet3)	Liquid Mass (lbm)	Net Vol. Flow (gal/min)	Net Mass Flow (lbm/sec)
2	Reservoir	Infinite	N/A	16.40	14.70	N/A	N/A	-534,802	-74,356
7	Reservoir	Infinite	N/A	26.10	14.70	N/A	N/A	534,802	74,356

Pipe Output Table

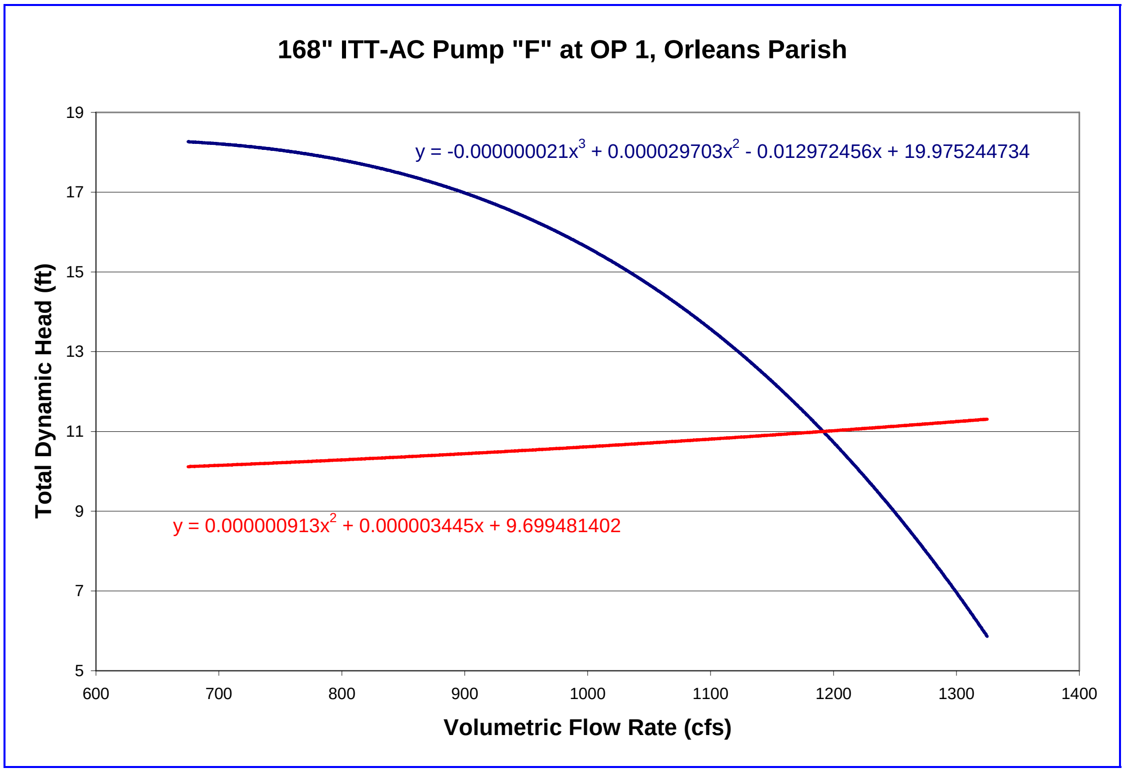
Pipe	Name	Vol. Flow Rate (ft3/sec)	Velocity (feet/sec)	P Static Max (psia)	P Static Min (psia)	Elevation Inlet (feet)	Elevation Outlet (feet)	dP Stag. Total (psid)	dP Static Total (psid)	dP Gravity (psid)
3	Pipe	1,192	7.740	10.11	10.11	25.500	25.500	0.004113308	0.004113308	0.000
5	Pipe	1,192	7.740	19.33	15.78	23.000	14.800	-3.549803495	-3.549803495	-3.554
6	Pipe	1,192	3.123	22.32	22.32	8.500	8.500	0.000638280	0.000638280	0.000
7	Pipe	1,192	3.123	16.63	16.63	11.500	11.500	0.000002798	0.000002798	0.000
8	Pipe	1,192	3.123	18.43	18.43	7.500	7.500	0.000002798	0.000002798	0.000
9	Pipe	1,192	7.740	14.82	11.26	14.800	23.000	3.556172609	3.556172609	3.554
10	Pipe	1,192	7.740	14.87	14.87	25.500	25.500	0.001326874	0.001326874	0.000
11	Pipe	1,192	7.740	14.77	14.77	25.500	25.500	0.003980621	0.003980621	0.000

Pipe	dH (feet)	P Static In (psia)	P Static Out (psia)	P Stag. In (psia)	P Stag. Out (psia)	EGL Inlet (feet)	EGL Outlet (feet)	HGL Inlet (feet)	HGL Outlet (feet)
3	9.492E-03	10.11	10.11	10.51	10.51	15.85	15.84	14.92	14.91
5	8.573E-03	15.78	19.33	16.19	19.74	26.44	26.43	25.51	25.50
6	1.473E-03	22.32	22.32	22.39	22.39	26.25	26.25	26.10	26.10
7	6.458E-06	16.63	16.63	16.69	16.69	16.11	16.11	15.96	15.96
8	6.458E-06	18.43	18.43	18.49	18.49	16.26	16.26	16.11	16.11
9	6.124E-03	14.82	11.26	15.22	11.67	16.02	16.01	15.09	15.08
10	3.062E-03	14.87	14.87	15.28	15.28	26.84	26.84	25.91	25.91
11	9.186E-03	14.77	14.77	15.18	15.17	26.61	26.60	25.68	25.67

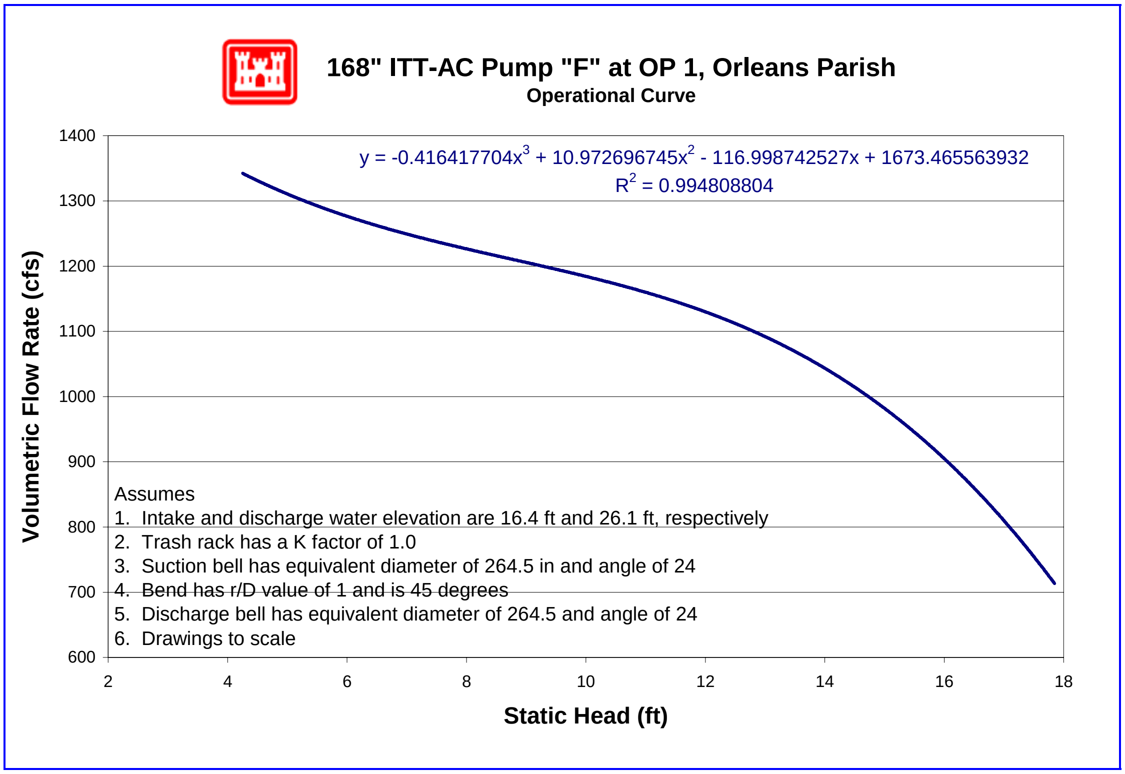
All Junction Table

Jct	Name	P Static In (psia)	P Static Out (psia)	Vol. Flow Rate Thru Jct (ft3/sec)	Loss Factor (K)	Elevation Inlet (feet)	Elevation Outlet (feet)	EGL Inlet (feet)	EGL Outlet (feet)
1	168" ITT-AC	10.11	14.87	1,192	0.0000	25.500	25.500	15.84	26.84
2	Reservoir	14.70	18.55	1,192	0.9200	16.400	16.400	16.40	16.40
3	Area Change	16.63	14.82	1,192	0.6097	11.500	14.800	16.11	16.02
4	Bend	11.26	10.11	1,192	0.1753	23.000	25.500	16.01	15.85
5	Bend	14.77	15.78	1,192	0.1753	25.500	23.000	26.60	26.44
6	Area Change	19.33	22.32	1,192	0.1924	14.800	8.500	26.43	26.25
7	Reservoir	14.70	22.32	1,192	1.0000	26.100	26.100	26.10	26.10
9	Screen	18.43	16.63	1,192	1.0000	7.500	11.500	16.26	16.11
10	Bend	14.87	14.77	1,192	0.2400	25.500	25.500	26.84	26.61

Output from AFT Fathom™ for 168” ITT-AC Pump “F”, Page 2



System Curve of 168” ITT-AC Pump “F” at OP 1



Operational Curve for 168” ITT-AC Pump “F” at OP 1+

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7.6.2.1.1.7 Pump Reverse Flow

There are eleven pumps at this station for which reverse flow rating curves were computed (no pumps were excluded). The reverse flow data and curves are presented in the order of the pump numbering utilized in the summary tables included in this appendix. In cases where there are multiple pumps of equivalent size and system configuration, a single rating curve represents all of them at a unit rate per pump.

Pump No.	Pump Capacity (cfs)	Pump Size (in)	Reverse Flow Computed?		Rating Curve Ref. No.
			Yes	No	
A	550	144	X		1
B	550	144	X		1
C	1000	168	X		2
D	1000	168	X		2
E	1000	168	X		2
F	1215	168	X		3
G	1215	168	X		4
V1	225	60	X		5
V2	225	60	X		5
CD1	60	36	X		6
CD2	15	36	X		7

For a general explanation of reverse flow (terminology, figures, methodology, equations and assumptions), refer to the Reverse Flow Section at the beginning of this appendix. Reverse flow computations for a given pump station do not necessarily imply that reverse flow actually occurred there during the Katrina event. But these curves may instead be used as future tools if further investigations are required based on reverse flow assumptions.

1. Reverse Flow Rating Curve

#1 Pump Station, Pumps # A & B -144-in.

Elevation Datum (ft): Cairo

Crest Elevation (ft) = 20.25

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use* $Q = \mathrm{sqrt}((H1-H2)/K')$

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$K' = \quad 6.80916E\text{-}06 \quad sec^2/ft^5$

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 20.3 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 32.5 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

H2 =	8.0	10.7	13.3	16.0	18.7	21.3	24.0
H1 >	149	137	124	111	98	86	73

Water elevation (H1) that stops unprimed flow: 20.3 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 23.5 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1)

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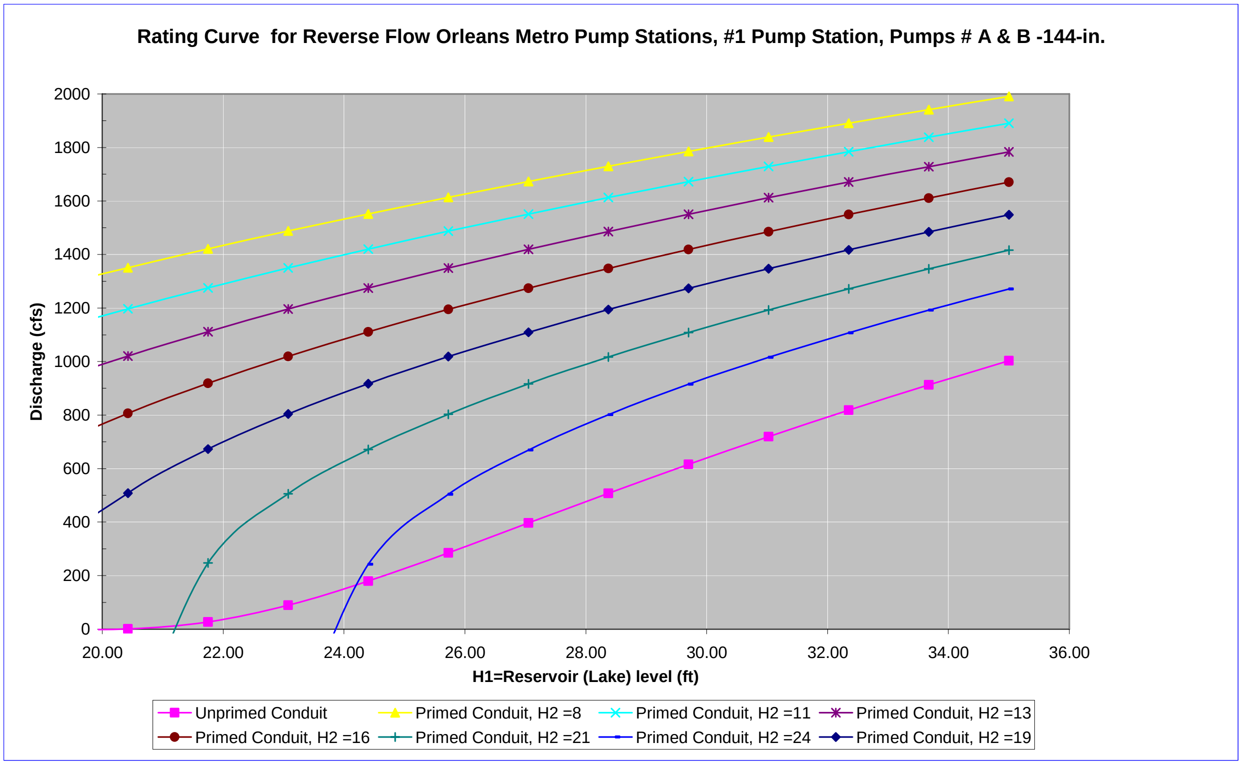
is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	4.90
Intake loss =	0.92
Exit Loss =	1.0

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

No profile drawings for pumps A & B. Assumed the geometry is like pumps C, D, & E.

Elevations in Cairo Datum

All length measurements were center line lengths.

C2 & P1 were the same point. A distance of 0.25 ft was inputted into the table to avoid using 0.

4 Data Needs or Deficiencies:

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Profile drawing of pumps A & B.

5 Backflow prevention:

Available:	Profile drawing of pumps A & B.
Used:	Reverse flow did not occur according to operator. Nothing to stop reverse rotation.

2. Reverse Flow Rating Curve

#1 Pump Station, Pumps # C, D, & E -168-in.

Elevation Datum (ft):	Cairo
Crest Elevation (ft) =	20.25

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: $Q = \mathrm{sqrt}((H1-H2)/K')$ (*Use*)

$K' = 3.89582E-06 \quad sec^2/ft^5$

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the

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discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 20.3 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 34.3 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

H2 =	8.0	10.7	13.3	16.0	18.7	21.3	24.0
H1 >	207	189	172	154	137	119	102

Water elevation (H1) that stops unprimed flow: 20.3 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 25.9 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.

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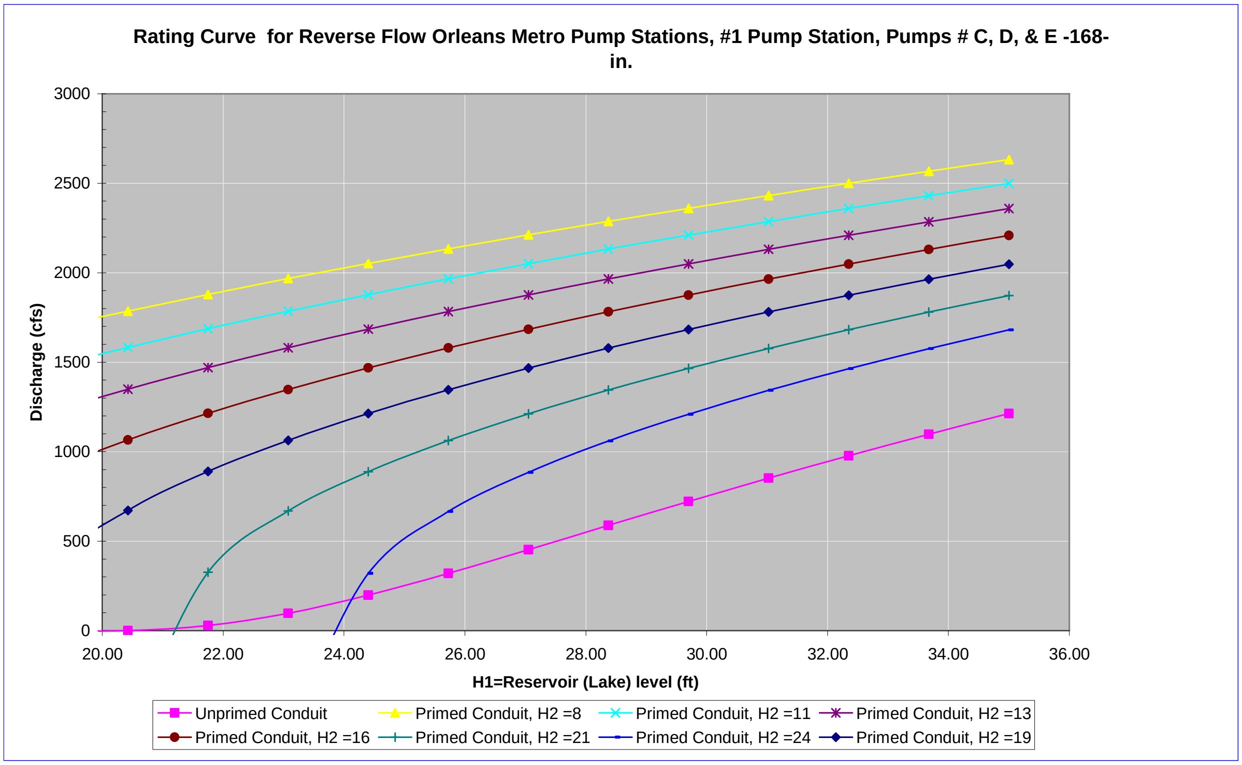

Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	4.50
Intake loss =	0.92
Exit Loss =	1.0

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Pumps C, D, & E are identical in manufacturing & installation.

Elevations in Cairo Datum

Pump flow rates & rated head taken from pump curves.

All length measurements were center line lengths.

C2 & P1 were the same point. A distance of 0.25 ft was inputted into the table to avoid using 0.

4 Data Needs or Deficiencies:

None

5 Backflow prevention:

Available:	No backflow prevention system.
Used:	Reverse flow did not occur according to operator.

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Nothing to stop reverse rotation.

3. Reverse Flow Rating Curve

#1 Pump Station, Pumps # F -168-in.

Elevation Datum (ft):	Cairo
Crest Elevation (ft) =	19.5

H1 = Lake or outlet canal water level (normal pump discharge side)
H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use* $Q = \text{sqrt}((H1-H2)/K')$
$K' =$ 8.36742E-06 sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

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Water elevation (H1) that triggers unprimed flow: 19.5 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 30.9 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.							
H2 =	6.5	9.7	12.8	16.0	19.2	22.3	25.5
H1 >	184	164	144	124	105	85	65

Water elevation (H1) that stops unprimed flow: 19.5 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 23.8 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.

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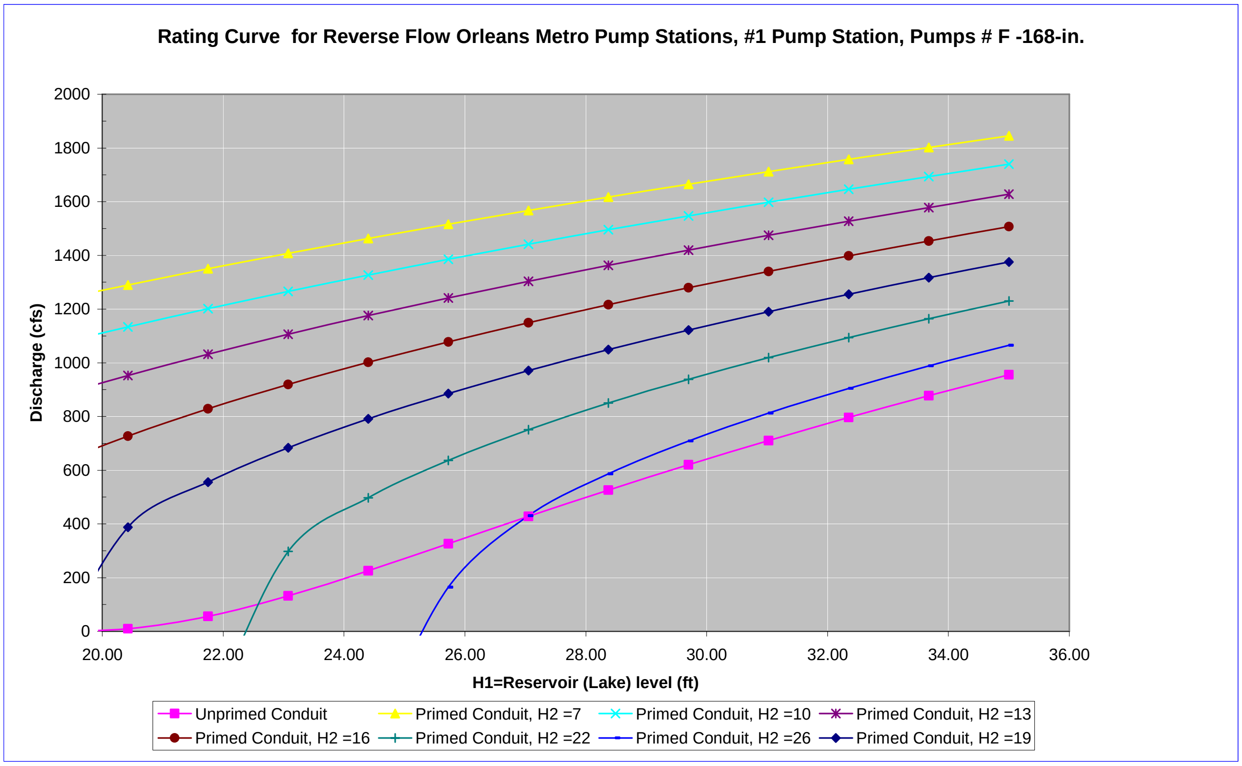

Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient = 4.50
Intake loss = 0.92
Exit Loss = 1.0
Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

No profile drawings of the discharge (our inlet). Assumed to be the same as pump G.

Elevations in Cairo Datum

All measurements were taken from drawings 11736-W-59 (swb_set1 8 & swb_set1 6).

C2 & P1 were the same point. A distance of 0.25 ft was inputted into the table to avoid using 0.

Impeller diameter taken from pump curve.

4 Data Needs or Deficiencies:

Profile drawing of discharge tube (lake side).

5 Backflow prevention:

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Available:	No backflow prevention system.
Used:	Reverse flow did not occur according to operator. Nothing to stop reverse rotation.

4. Reverse Flow Rating Curve

#1 Pump Station, Pumps # G -168-in.

Elevation Datum (ft):	Cairo
Crest Elevation (ft) =	18.5

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use* $Q = \mathrm{sqrt}((H1-H2)/K')$

$K' =$ *8.1822E-06* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling

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limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 18.5 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 29.9 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

H2 =	6.5	9.7	12.8	16.0	19.2	22.3	25.5
H1 >	251	221	191	161	131	101	71

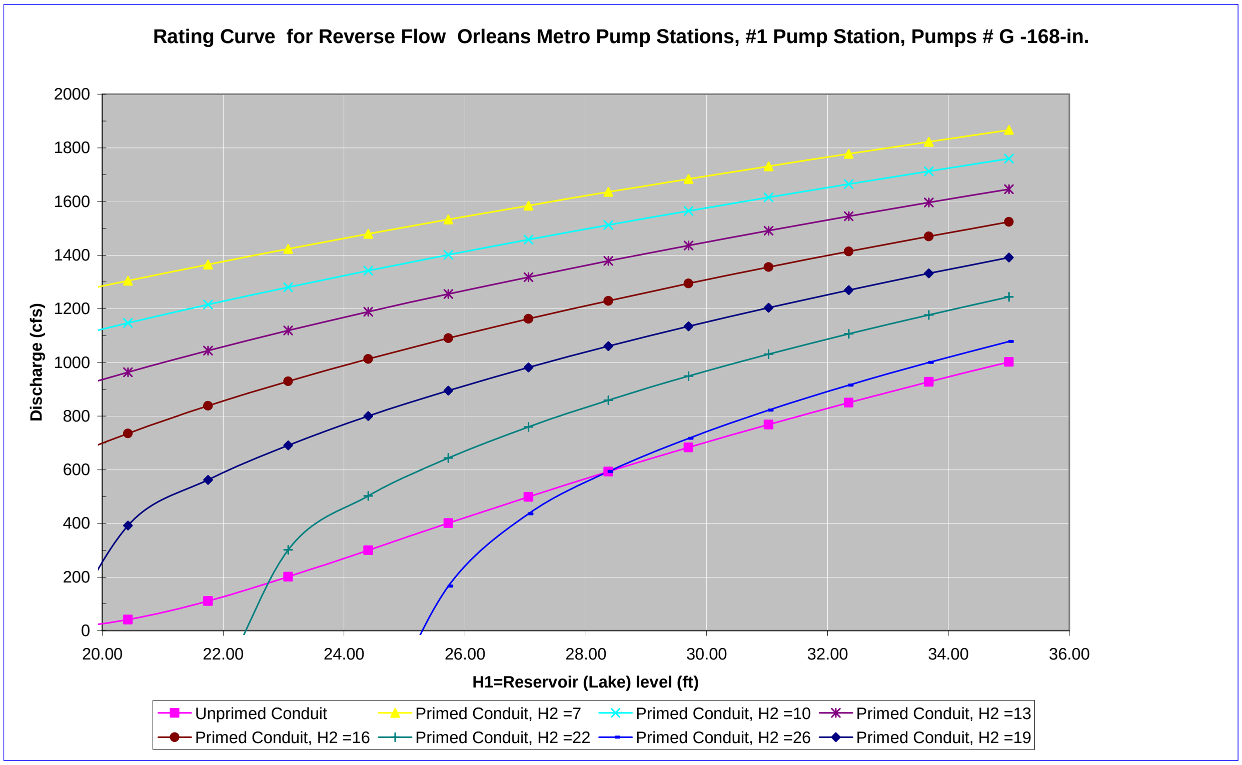
Water elevation (H1) that stops unprimed flow: 18.5 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 23.5 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	4.50
Intake loss =	0.92
Exit Loss =	1.0

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Elevations in Cairo Datum

All length measurements were center line lengths.

All measurements were taken from drawings 11736-W-59 (swb_set1 10 & swb_set1 6).

C2 & P1 were the same point. A distance of 0.25 ft was inputted into the table to avoid using 0.

4 Data Needs or Deficiencies:

None.

5 Backflow prevention:

No backflow prevention system.

Available:

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Used:	Reverse flow did not occur according to operator. Nothing to stop reverse rotation.

5. Reverse Flow Rating Curve

#1 Pump Station, Pumps # V1 & V2 -60-in.

Elevation Datum (ft):	Cairo
Crest Elevation (ft) =	15.75

H1 = Lake or outlet canal water level (normal pump discharge side)
H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: Use $Q = \mathrm{sqrt}((H1-H2)/K')$
$K' =$ 0.000326766 sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Water elevation (H1) that triggers unprimed flow: 15.8 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 20.8 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.							
H2 =	8.0	10.7	13.3	16.0	18.7	21.3	24.0
H1 >	25	24	23	22	22	21	24

Water elevation (H1) that stops unprimed flow: 15.8 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 9.5 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.

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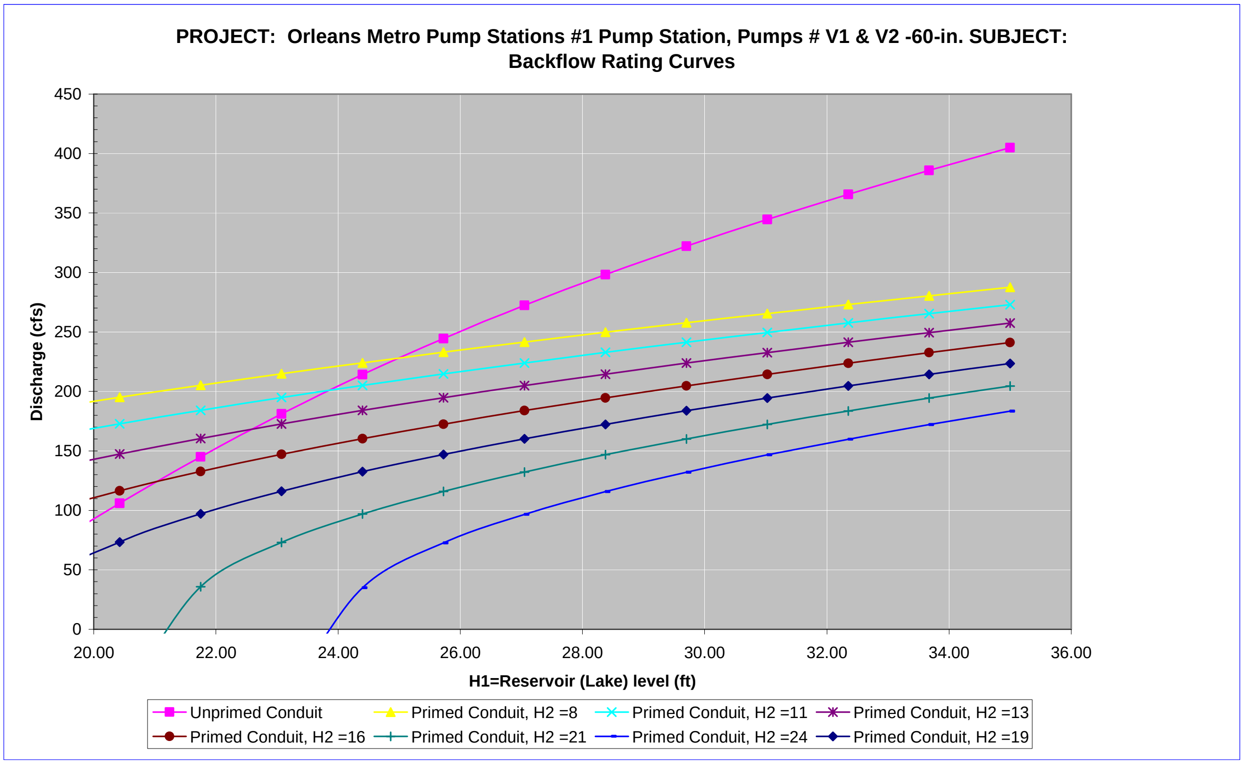

Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	3.50
Intake loss =	0.92
Exit Loss =	1.3

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

No drawings of the pumps or piping. Assumed the layout is similar to vertical pumps 1 - 3 in at PS#10

Assumed that the piping is the same distance off the suction basin floor as the vertical pumps 1 - 3 in PS #10 (Drawing 11521-W-10, Jan. 1984,swb_set2 34).
The discharge exit matches pumps A - G at PS #1.
Based on 2 photos, all piping is below the pump floor (El. 24.0 ft).

Assumed that the piping is the same distance off the suction basin floor as the vertical pumps 1 - 3 in PS #10 (Drawing 11521-W-10, Jan. 1984,swb_set2 34).
Elevations in Cairo Datum

4 Data Needs or Deficiencies:

Drawings of pumps, piping, & piping layout.

5 Backflow prevention:

Available:	No backflow prevention system.
Used:	Reverse flow did not occur according to operator. Nothing to stop reverse rotation.

6. Reverse Flow Rating Curve

#1 Pump Station, Pumps # CD1, 36-in.

Elevation Datum (ft):	Cairo
Crest Elevation (ft) =	15.75

H1 = Lake or outlet canal water level (normal pump discharge side)
H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use* $Q = \mathrm{sqrt}((H1-H2)/K')$

$K' =$ *0.002564414* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 15.8 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 18.8 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.							
H2 =	8.0	10.7	13.3	16.0	18.7	21.3	24.0
H1 >	23	22	21	20	19	21	24

Water elevation (H1) that stops unprimed flow: 15.8 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 9.5 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.

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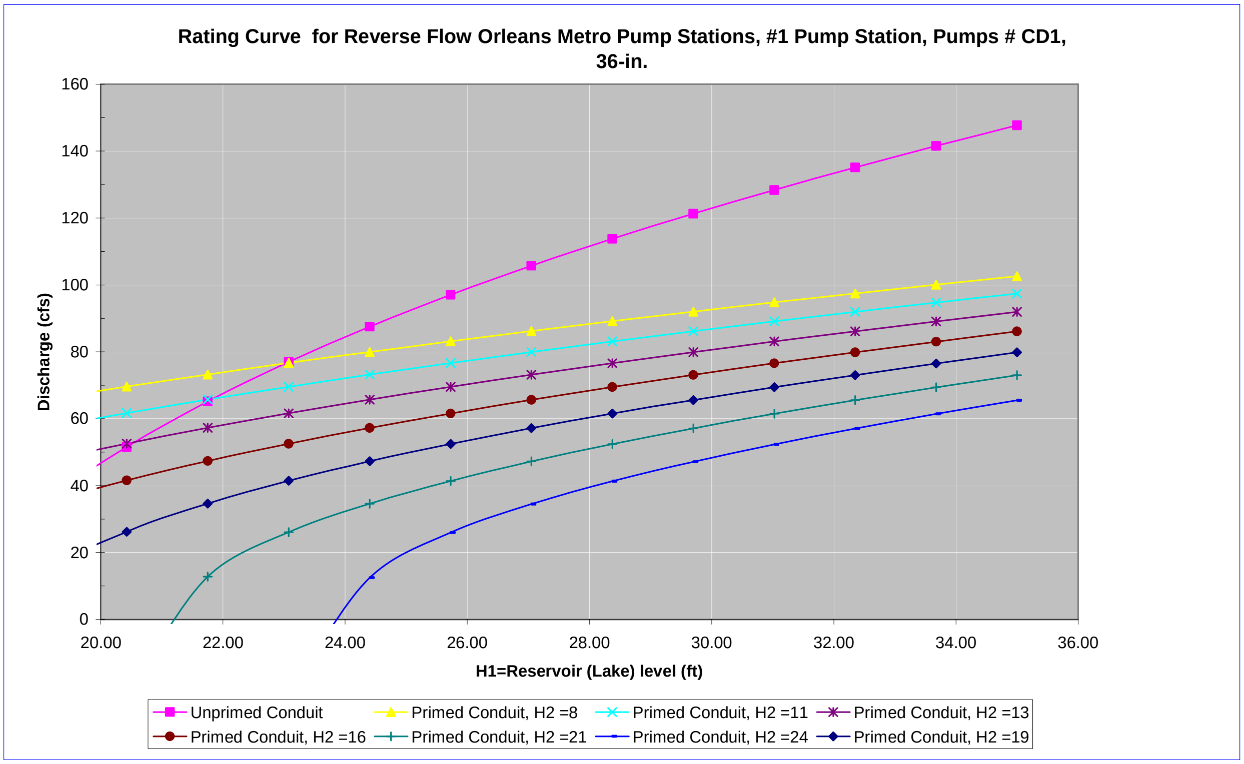

Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	3.50
Intake loss =	0.92
Exit Loss =	1.3

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

No drawings of the pumps or piping. Assumed same layout as pumps V1 & V2 scaled down for the smaller pump.

Drawings 11521-W-10, dated Jan. 1984 (swb_set 2 34).

The discharge exit matches pumps A - G at PS #1.

Assumed piping is the same distance off suction basin floor as the vertical pumps 1-3 in PS #10 (Drawing 11521-W-10, Jan. 1984,swb_set2 34).

Elevations in Cairo Datum

4 Data Needs or Deficiencies:

Drawings of pumps, piping, & piping layout.

5 Backflow prevention:

Available: No backflow prevention system.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Used: Reverse flow did not occur according to operator.
Nothing to stop reverse rotation.

7. Reverse Flow Rating Curve

#1 Pump Station, Pumps # CD2, 36-in.

Elevation Datum (ft):	Cairo
Crest Elevation (ft) =	20.25

H1 = Lake or outlet canal water level (normal pump discharge side)
H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use Q = sqrt((H1-H2)/K')*
K' = *0.002469571* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Water elevation (H1) that triggers unprimed flow: 20.3 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 23.3 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

H2 =	8.0	10.7	13.3	16.0	18.7	21.3	24.0
H1 >	52	47	42	37	32	27	24

Water elevation (H1) that stops unprimed flow: 20.3 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 11.6 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.

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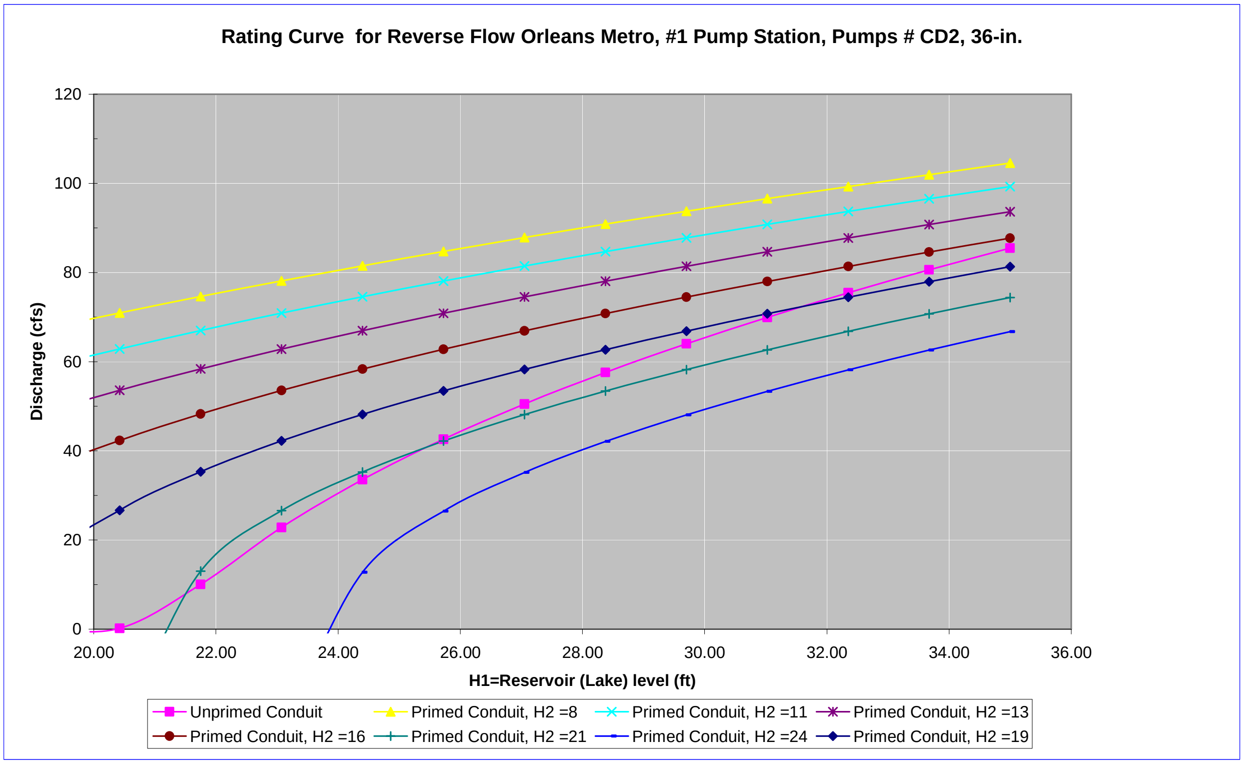

Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	4.50
Intake loss =	0.92
Exit Loss =	1.0

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

No drawings of the pumps or piping. Assumed the layout is the same as wood screw pumps A - G.

Use drawings 6760, Feb. 14, 1929 (swb_set1 3) for configuration. Scaled dimensions down from a 14 ft pipe to a 3 ft pipe.

The suction entrance and discharge exit elevations are the same as pumps A- G.

Elevations in Cairo Datum

4 Data Needs or Deficiencies:

Drawings of pumps, piping, & piping layout.

5 Backflow prevention:

Available: No backflow prevention system.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Used:	Reverse flow did not occur according to operator. Nothing to stop reverse rotation.

7.6.2.1.1.8 Fuel Endurance Calculations

We do not have any record of pumps that run on fuel at this pump station.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.2.1.2 *OP 2*

Orleans Parish – East Bank Drainage Basin

444 N. Broad Ave.
New Orleans, LA 70119

Latitude: 29.96831˚ Longitude: -90.08500˚

7.6.2.1.2.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Before Hurricane Katrina: Aerial view of the pump station

Photo Not Obtained

After Hurricane Katrina

After Hurricane Katrina: Aerial view of the pump station

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.2.1.2.2 Description[160]

Drainage area:	New Orleans East Bank
Nominal Capacity:	3150 cfs
Drains water from:	Broad Street Canal
Discharges water to:	OPS #3 and #7
Owner:	New Orleans Sewerage and Water Board
Number of pumps:	6
Pump orientation:	4 horizontal 2 centrifugal
Pump driver:	6 electric 25 Hz motors
Water level to switch pumps on:	11 feet (NGVD)
Water level to switch pumps off:	12 feet (NGVD)
Water level that affects operation:	-4.4 (NGVD). Electrical control panels are in basement
Reverse flow protection:	Gate valves on only pumps A and B

7.6.2.1.2.3 Damages

Estimated cost of repairs:	The estimated cost of repairs is not yet available.[161]
Relative level of damage:	Substantial
Severity of circumstances:	Flooding occurred approximately 15 inches (NGVD) above the operating floor and about 5 inches above the floor in the control room.
Equipment damaged:	Motors B, C, D, and E will need rewinding repairs, Pumps F and G will need inboard bearings replaced.
Building damage:	The roof ridge line flashing needs to be replaced, in addition to the flooring and paneling in the control house.
Misc. damage:	No significant miscellaneous damage recorded.

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[160] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[161] The Project Information Report (PIR) for each parish provides an estimated cost of repairs for the parish's pump stations. At the time this report was written, the Orleans Parish PIR was not yet complete. It should be available through the parish shortly after publication of the IPET Report.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.2.1.2.4 Katrina Event

Date	Time	Event
8/28/2005	-	The interview form states that the station was pumping and that all of the pumps were available.
8/29/2005	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	-	The interview form states that water entered the building and the operators shut down all of the pumps.
		Flooding reached 1.5 feet above the operating floor.
8/30/2005	-	The interview form states that the pump station was not used during un-watering. The station was in bypass mode (water was flowing backwards to Station 1).

7.6.2.1.2.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.2.1.2.6 Pump Operational Curves

Pump curves are provided for four[162] OP 2 pumps in 3 different configurations.

- (2) 144" Wood Screw, 2 configurations
- (2) 168" Wood Screw

The following pages provide system curves and operational curves for each configuration. Section 7.1.3.5 describes the function of the curves, as well as the processes used to develop the curves. For OP 2, No drawings were available for any of the pumps that had pump curves. Drawing 6039-W-7 had information regarding the constant duty pump. This drawing was used for necessary elevations. Some details, such as exact dimensions, were not available from this drawing which were necessary to the calculations. The assumptions made in place of the missing data were based on available known data for similar pumps, and are noted in the "layout" drawings for each pump, as well as in individual pump sections. The accuracy of the calculations directly depends on the amount of information available. When there was not adequate data, the best engineering judgment using other pump station and manufacturer's data was employed.

7.6.2.1.2.6.1 144" Wood Screw

No specific drawings were available for the 144" Wood Screw. The following resources were used to make the indicated assumptions:[163]

- *Data from similar horizontal pumps* – Modeled was the simplest common system, which included two 45˚ bends with r/D factors of 1.0, a suction bell and a discharge bell

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[162] OP 2 has a total of 6 pumps; however, not enough data was available to analyze the two 42-inch Wood Screw pump within a reasonable accuracy.

[163] The datum for the listed elevations is not reported. The datum is not needed for modeling pump station capacity in normal operation calculations because only relative elevations affect the calculations.

with an equivalent circular diameter of 252.5 inches and a conical transition at an angle of 28˚, and pipe lengths. OP PS1 has a similar pump with a recorded rated head; this rated head was assumed to be similar for this pump station.

- *Operation Log* – The intake water elevation was determined to be 10 feet and the discharge water elevation was determined to be 27.5 feet.
- *An estimated one foot of trash at the intake* – A loss coefficient of 1.0 for the flap valve and trash rack was used.

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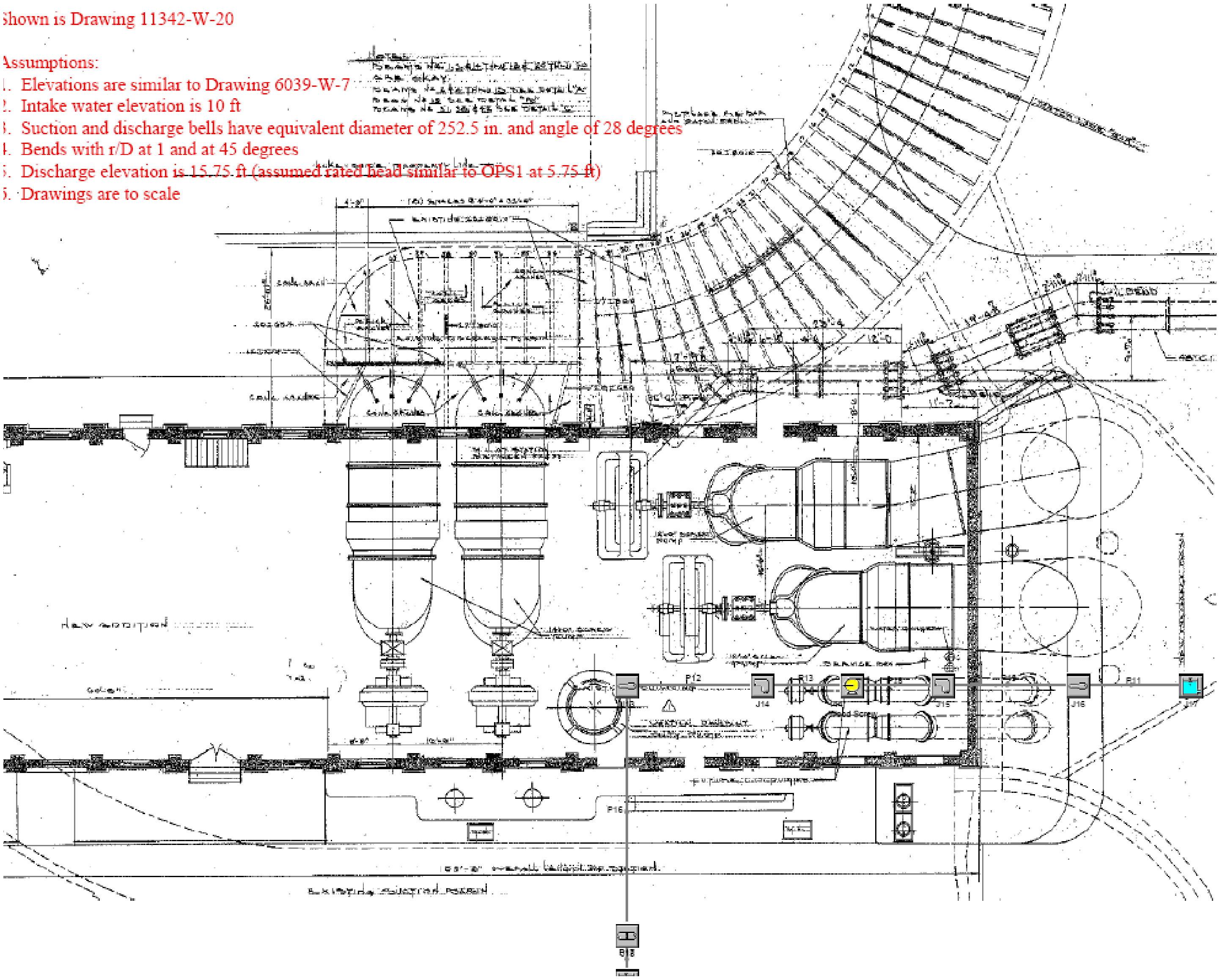


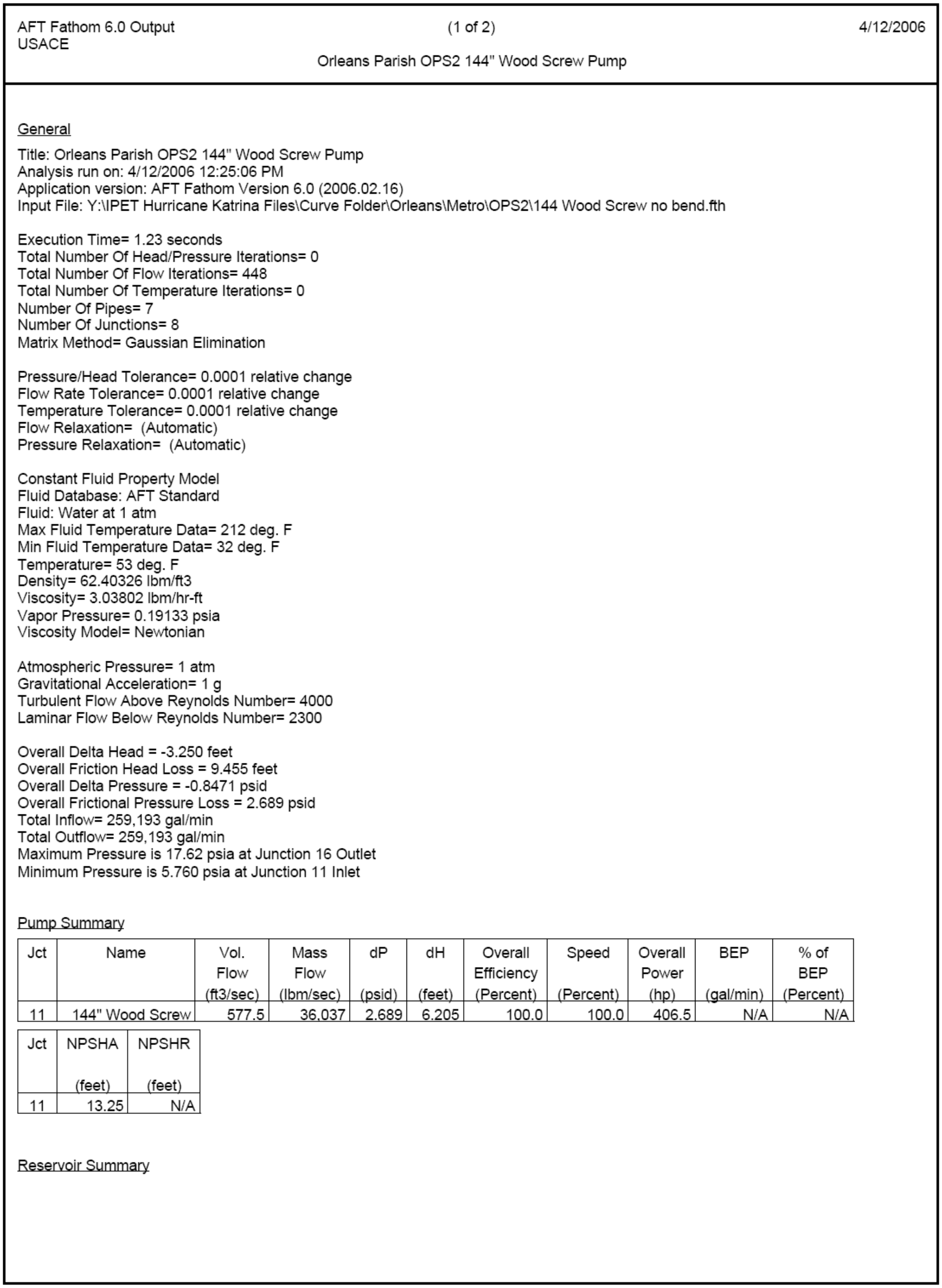
Shown is Drawing 11342-W-20

Assumptions:

1. Elevations are similar to Drawing 6039-W-7
2. Intake water elevation is 10 ft
3. Suction and discharge bells have equivalent diameter of 252.5 in. and angle of 28 degrees
4. Bends with r/D at 1 and at 45 degrees
5. Discharge elevation is 15.75 ft (assumed rated head similar to OPS1 at 5.75 ft)
6. Drawings are to scale

Layout of 144" Wood Screw Pump at OP 2

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.



AFT Fathom 6.0 Output (1 of 2) 4/12/2006
USACE
Orleans Parish OPS2 144" Wood Screw Pump

General

Title: Orleans Parish OPS2 144" Wood Screw Pump
Analysis run on: 4/12/2006 12:25:06 PM
Application version: AFT Fathom Version 6.0 (2006.02.16)
Input File: Y:\IPET Hurricane Katrina Files\Curve Folder\Orleans\Metro\OPS2\144 Wood Screw no bend.fth

Execution Time= 1.23 seconds
Total Number Of Head/Pressure Iterations= 0
Total Number Of Flow Iterations= 448
Total Number Of Temperature Iterations= 0
Number Of Pipes= 7
Number Of Junctions= 8
Matrix Method= Gaussian Elimination

Pressure/Head Tolerance= 0.0001 relative change
Flow Rate Tolerance= 0.0001 relative change
Temperature Tolerance= 0.0001 relative change
Flow Relaxation= (Automatic)
Pressure Relaxation= (Automatic)

Constant Fluid Property Model
Fluid Database: AFT Standard
Fluid: Water at 1 atm
Max Fluid Temperature Data= 212 deg. F
Min Fluid Temperature Data= 32 deg. F
Temperature= 53 deg. F
Density= 62.40326 lbm/ft3
Viscosity= 3.03802 lbm/hr-ft
Vapor Pressure= 0.19133 psia
Viscosity Model= Newtonian

Atmospheric Pressure= 1 atm
Gravitational Acceleration= 1 g
Turbulent Flow Above Reynolds Number= 4000
Laminar Flow Below Reynolds Number= 2300

Overall Delta Head = -3.250 feet
Overall Friction Head Loss = 9.455 feet
Overall Delta Pressure = -0.8471 psid
Overall Frictional Pressure Loss = 2.689 psid
Total Inflow= 259,193 gal/min
Total Outflow= 259,193 gal/min
Maximum Pressure is 17.62 psia at Junction 16 Outlet
Minimum Pressure is 5.760 psia at Junction 11 Inlet

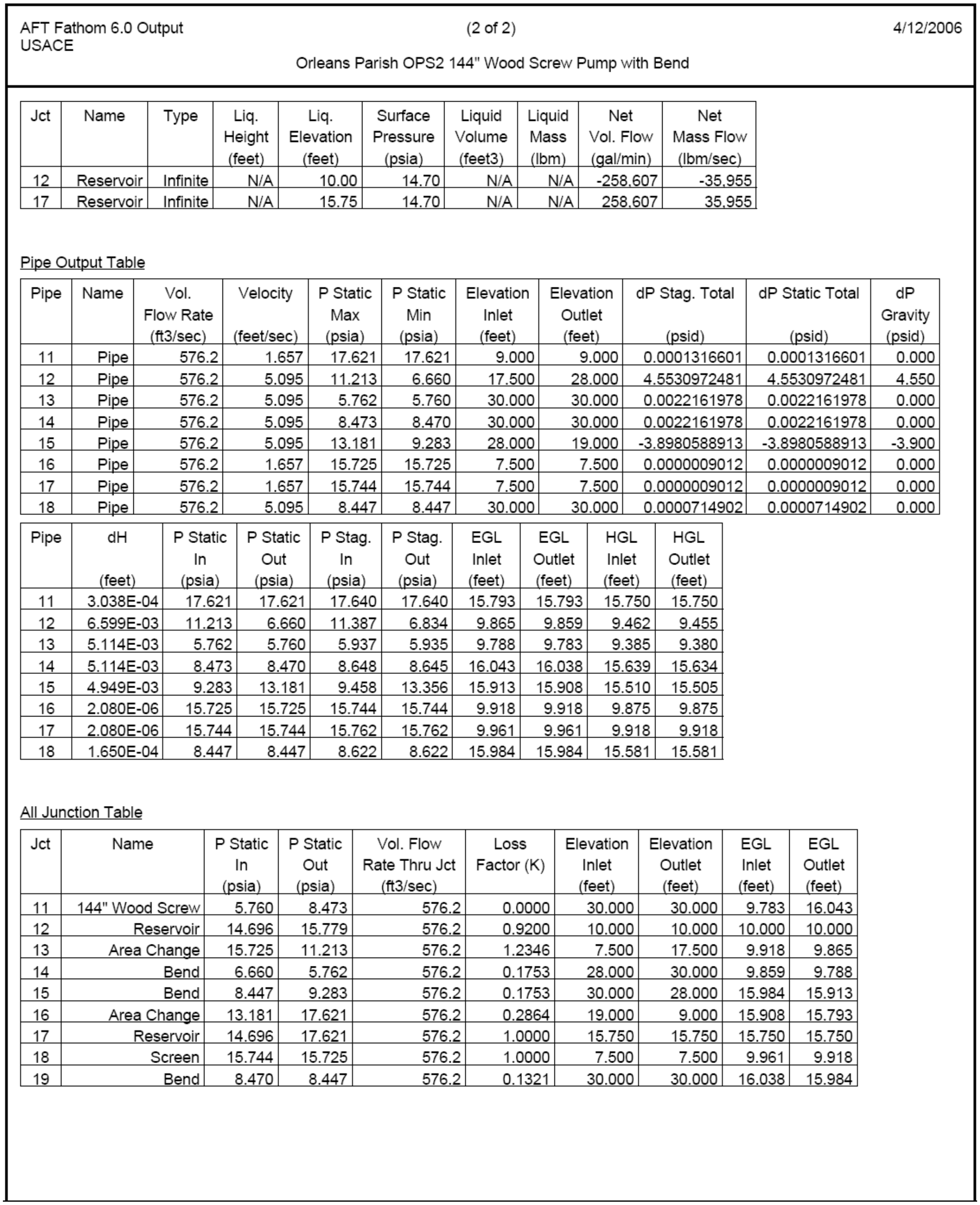
Pump Summary

Jct	Name	Vol. Flow (ft3/sec)	Mass Flow (lbm/sec)	dP (psid)	dH (feet)	Overall Efficiency (Percent)	Speed (Percent)	Overall Power (hp)	BEP (gal/min)	% of BEP (Percent)
11	144" Wood Screw	577.5	36,037	2.689	6.205	100.0	100.0	406.5	N/A	N/A

Jct	NPSHA (feet)	NPSHR (feet)
11	13.25	N/A

Reservoir Summary

Output from AFT Fathom™ for 144" Wood Screw, Page 1



AFT Fathom 6.0 Output (2 of 2) 4/12/2006
USACE
Orleans Parish OPS2 144" Wood Screw Pump with Bend

Jct	Name	Type	Liq. Height (feet)	Liq. Elevation (feet)	Surface Pressure (psia)	Liquid Volume (feet3)	Liquid Mass (lbm)	Net Vol. Flow (gal/min)	Net Mass Flow (lbm/sec)
12	Reservoir	Infinite	N/A	10.00	14.70	N/A	N/A	-258,607	-35,955
17	Reservoir	Infinite	N/A	15.75	14.70	N/A	N/A	258,607	35,955

Pipe Output Table

Pipe	Name	Vol. Flow Rate (ft3/sec)	Velocity (feet/sec)	P Static Max (psia)	P Static Min (psia)	Elevation Inlet (feet)	Elevation Outlet (feet)	dP Stag. Total (psid)	dP Static Total (psid)	dP Gravity (psid)
11	Pipe	576.2	1.657	17.621	17.621	9.000	9.000	0.0001316601	0.0001316601	0.000
12	Pipe	576.2	5.095	11.213	6.660	17.500	28.000	4.5530972481	4.5530972481	4.550
13	Pipe	576.2	5.095	5.762	5.760	30.000	30.000	0.0022161978	0.0022161978	0.000
14	Pipe	576.2	5.095	8.473	8.470	30.000	30.000	0.0022161978	0.0022161978	0.000
15	Pipe	576.2	5.095	13.181	9.283	28.000	19.000	-3.8980588913	-3.8980588913	-3.900
16	Pipe	576.2	1.657	15.725	15.725	7.500	7.500	0.0000009012	0.0000009012	0.000
17	Pipe	576.2	1.657	15.744	15.744	7.500	7.500	0.0000009012	0.0000009012	0.000
18	Pipe	576.2	5.095	8.447	8.447	30.000	30.000	0.0000714902	0.0000714902	0.000

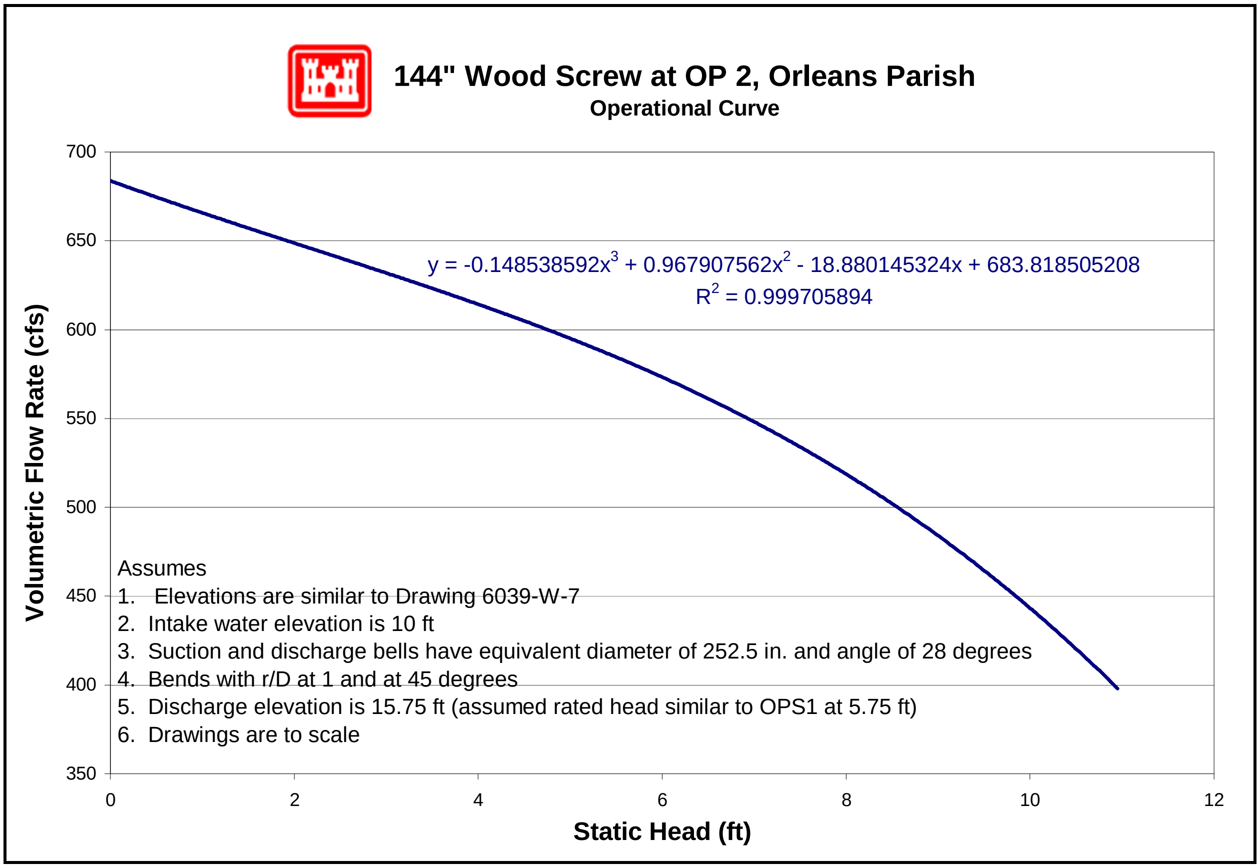
Pipe	dH (feet)	P Static In (psia)	P Static Out (psia)	P Stag. In (psia)	P Stag. Out (psia)	EGL Inlet (feet)	EGL Outlet (feet)	HGL Inlet (feet)	HGL Outlet (feet)
11	3.038E-04	17.621	17.621	17.640	17.640	15.793	15.793	15.750	15.750
12	6.599E-03	11.213	6.660	11.387	6.834	9.865	9.859	9.462	9.455
13	5.114E-03	5.762	5.760	5.937	5.935	9.788	9.783	9.385	9.380
14	5.114E-03	8.473	8.470	8.648	8.645	16.043	16.038	15.639	15.634
15	4.949E-03	9.283	13.181	9.458	13.356	15.913	15.908	15.510	15.505
16	2.080E-06	15.725	15.725	15.744	15.744	9.918	9.918	9.875	9.875
17	2.080E-06	15.744	15.744	15.762	15.762	9.961	9.961	9.918	9.918
18	1.650E-04	8.447	8.447	8.622	8.622	15.984	15.984	15.581	15.581

All Junction Table

Jct	Name	P Static In (psia)	P Static Out (psia)	Vol. Flow Rate Thru Jct (ft3/sec)	Loss Factor (K)	Elevation Inlet (feet)	Elevation Outlet (feet)	EGL Inlet (feet)	EGL Outlet (feet)
11	144" Wood Screw	5.760	8.473	576.2	0.0000	30.000	30.000	9.783	16.043
12	Reservoir	14.696	15.779	576.2	0.9200	10.000	10.000	10.000	10.000
13	Area Change	15.725	11.213	576.2	1.2346	7.500	17.500	9.918	9.865
14	Bend	6.660	5.762	576.2	0.1753	28.000	30.000	9.859	9.788
15	Bend	8.447	9.283	576.2	0.1753	30.000	28.000	15.984	15.913
16	Area Change	13.181	17.621	576.2	0.2864	19.000	9.000	15.908	15.793
17	Reservoir	14.696	17.621	576.2	1.0000	15.750	15.750	15.750	15.750
18	Screen	15.744	15.725	576.2	1.0000	7.500	7.500	9.961	9.918
19	Bend	8.470	8.447	576.2	0.1321	30.000	30.000	16.038	15.984

Output from AFT Fathom™ for 144” Wood Screw, page 2

No system curve is provided because the head experienced during the hurricane exceeded the shutoff head of the pump.



Operational Curve for 144” Wood Screw Pump at OP 2

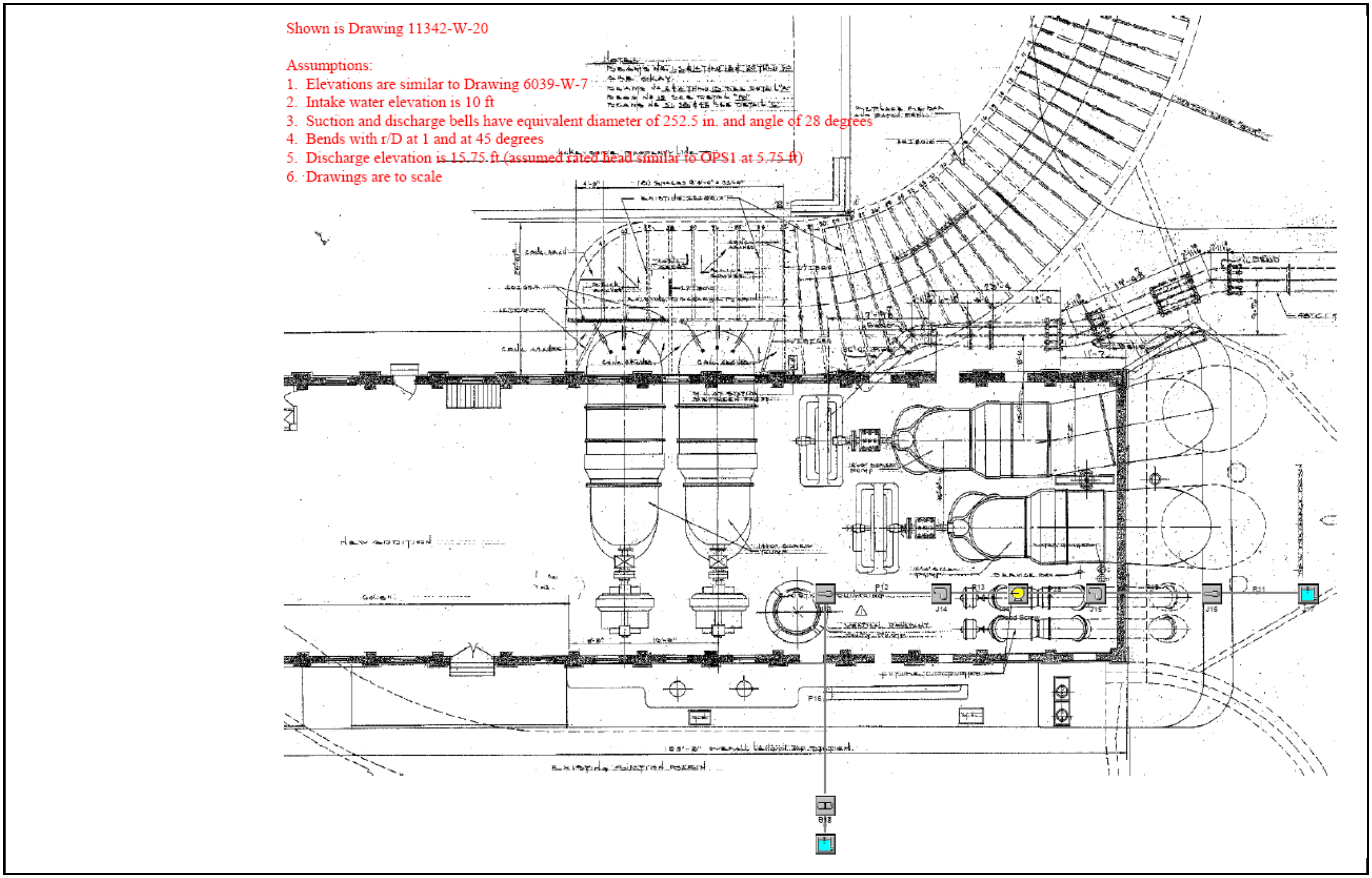
7.6.2.1.2.6.2 144” Wood Screw with a horizontal bend

No specific drawings were available for the 144” Wood Screw. The following resources were used to make the indicated assumptions:[164]

- *Data from similar horizontal pumps* – Modeled was the simplest common system, which included two 45˚ bends with r/D factors of 1.0, a suction bell and a discharge bell with an equivalent circular diameter of 252.5 inches and a conical transition at an angle of 28˚, and pipe lengths. OP PS1 has a similar pump with a recorded rated head; this rated head was assumed to be similar for this pump station.
- *Operation Log* – The intake water elevation was determined to be 10 feet and the discharge water elevation was determined to be 27.5 feet.
- *Drawing 11342-W-20* – The plan view revealed a horizontal bend in one of the 144” Wood Screw pumps. Assuming the drawing to be to scale, a bend was modeled at 15˚ with an r/D value of 1.0.
- *An estimated one foot of trash at the intake* – A loss coefficient of 1.0 for the flap valve and trash rack was employed.

---

[164] The datum for the listed elevations is not reported. The datum is not needed for modeling pump station capacity in normal operation calculations because only relative elevations affect the calculations.



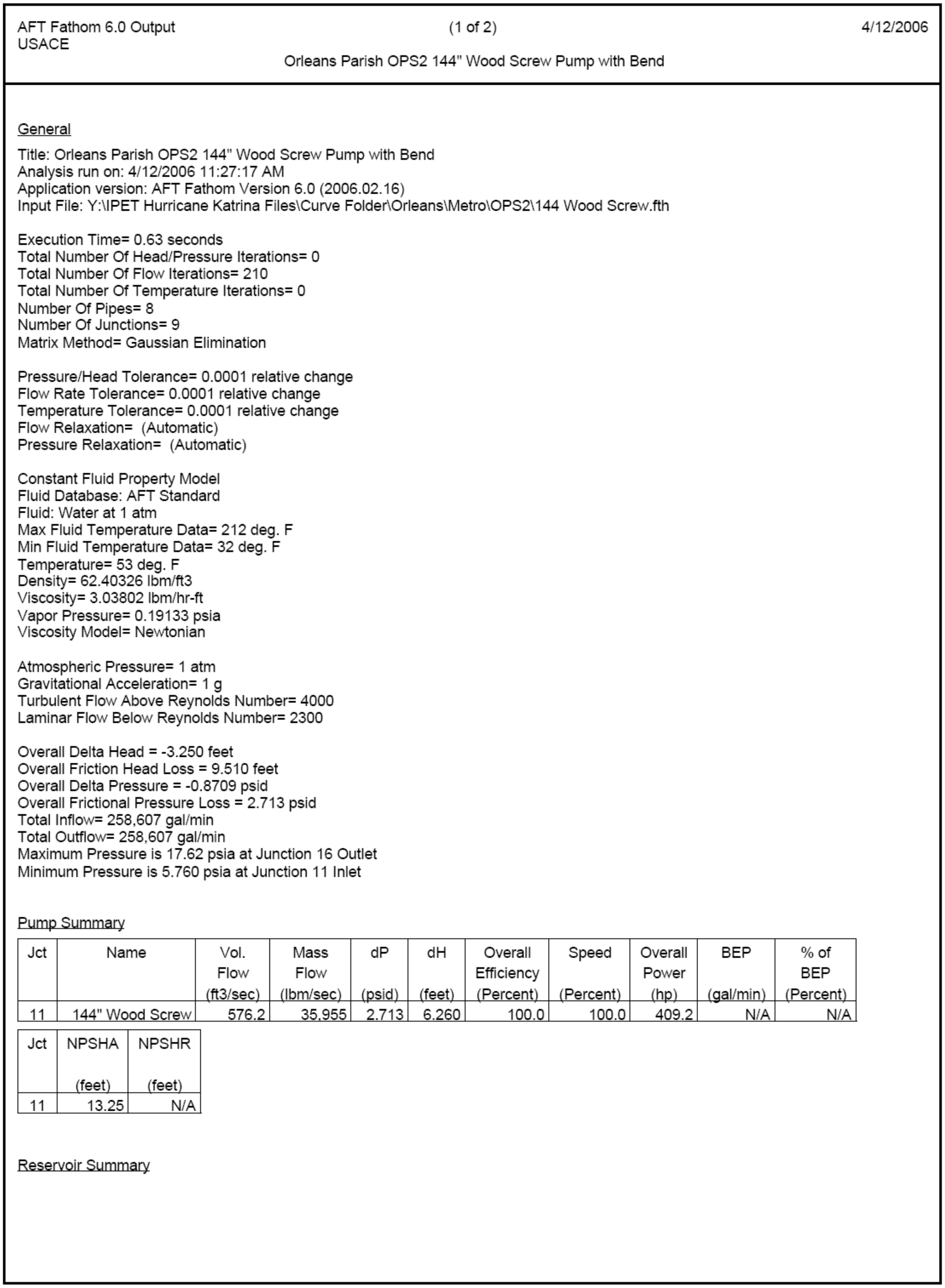
Shown is Drawing 11342-W-20

Assumptions:

1. Elevations are similar to Drawing 6039-W-7
2. Intake water elevation is 10 ft
3. Suction and discharge bells have equivalent diameter of 252.5 in. and angle of 28 degrees
4. Bends with r/D at 1 and at 45 degrees
5. Discharge elevation is 15.75 ft (assumed rated head similar to OPS1 at 5.75 ft)
6. Drawings are to scale

Layout of 144” Wood Screw Pump with Bend at OP 2

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.



AFT Fathom 6.0 Output (1 of 2) 4/12/2006
USACE
Orleans Parish OPS2 144" Wood Screw Pump with Bend

General

Title: Orleans Parish OPS2 144" Wood Screw Pump with Bend
Analysis run on: 4/12/2006 11:27:17 AM
Application version: AFT Fathom Version 6.0 (2006.02.16)
Input File: Y:\IPET Hurricane Katrina Files\Curve Folder\Orleans\Metro\OPS2\144 Wood Screw.fth

Execution Time= 0.63 seconds
Total Number Of Head/Pressure Iterations= 0
Total Number Of Flow Iterations= 210
Total Number Of Temperature Iterations= 0
Number Of Pipes= 8
Number Of Junctions= 9
Matrix Method= Gaussian Elimination

Pressure/Head Tolerance= 0.0001 relative change
Flow Rate Tolerance= 0.0001 relative change
Temperature Tolerance= 0.0001 relative change
Flow Relaxation= (Automatic)
Pressure Relaxation= (Automatic)

Constant Fluid Property Model
Fluid Database: AFT Standard
Fluid: Water at 1 atm
Max Fluid Temperature Data= 212 deg. F
Min Fluid Temperature Data= 32 deg. F
Temperature= 53 deg. F
Density= 62.40326 lbm/ft3
Viscosity= 3.03802 lbm/hr-ft
Vapor Pressure= 0.19133 psia
Viscosity Model= Newtonian

Atmospheric Pressure= 1 atm
Gravitational Acceleration= 1 g
Turbulent Flow Above Reynolds Number= 4000
Laminar Flow Below Reynolds Number= 2300

Overall Delta Head = -3.250 feet
Overall Friction Head Loss = 9.510 feet
Overall Delta Pressure = -0.8709 psid
Overall Frictional Pressure Loss = 2.713 psid
Total Inflow= 258,607 gal/min
Total Outflow= 258,607 gal/min
Maximum Pressure is 17.62 psia at Junction 16 Outlet
Minimum Pressure is 5.760 psia at Junction 11 Inlet

Pump Summary

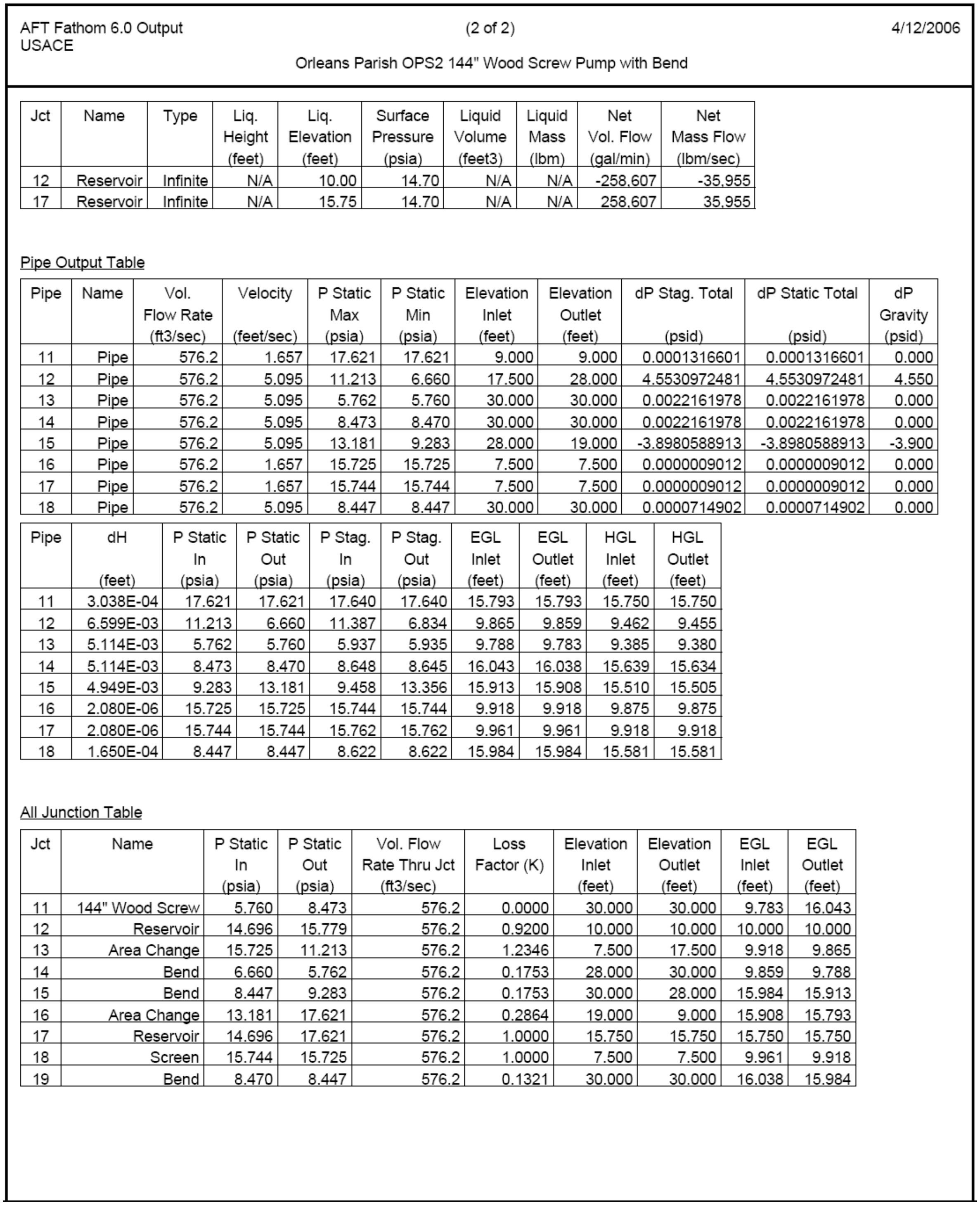
Jct	Name	Vol. Flow (ft3/sec)	Mass Flow (lbm/sec)	dP (psid)	dH (feet)	Overall Efficiency (Percent)	Speed (Percent)	Overall Power (hp)	BEP (gal/min)	% of BEP (Percent)
11	144" Wood Screw	576.2	35,955	2.713	6.260	100.0	100.0	409.2	N/A	N/A

Jct	NPSHA (feet)	NPSHR (feet)
11	13.25	N/A

Reservoir Summary

Output from AFT Fathom™ for 144" Wood Screw with Bend, Page 1

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.



AFT Fathom 6.0 Output (2 of 2) 4/12/2006
USACE

Orleans Parish OPS2 144" Wood Screw Pump with Bend

Jct	Name	Type	Liq. Height (feet)	Liq. Elevation (feet)	Surface Pressure (psia)	Liquid Volume (feet3)	Liquid Mass (lbm)	Net Vol. Flow (gal/min)	Net Mass Flow (lbm/sec)
12	Reservoir	Infinite	N/A	10.00	14.70	N/A	N/A	-258,607	-35,955
17	Reservoir	Infinite	N/A	15.75	14.70	N/A	N/A	258,607	35,955

Pipe Output Table

Pipe	Name	Vol. Flow Rate (ft3/sec)	Velocity (feet/sec)	P Static Max (psia)	P Static Min (psia)	Elevation Inlet (feet)	Elevation Outlet (feet)	dP Stag. Total (psid)	dP Static Total (psid)	dP Gravity (psid)
11	Pipe	576.2	1.657	17.621	17.621	9.000	9.000	0.0001316601	0.0001316601	0.000
12	Pipe	576.2	5.095	11.213	6.660	17.500	28.000	4.5530972481	4.5530972481	4.550
13	Pipe	576.2	5.095	5.762	5.760	30.000	30.000	0.0022161978	0.0022161978	0.000
14	Pipe	576.2	5.095	8.473	8.470	30.000	30.000	0.0022161978	0.0022161978	0.000
15	Pipe	576.2	5.095	13.181	9.283	28.000	19.000	-3.8980588913	-3.8980588913	-3.900
16	Pipe	576.2	1.657	15.725	15.725	7.500	7.500	0.0000009012	0.0000009012	0.000
17	Pipe	576.2	1.657	15.744	15.744	7.500	7.500	0.0000009012	0.0000009012	0.000
18	Pipe	576.2	5.095	8.447	8.447	30.000	30.000	0.0000714902	0.0000714902	0.000

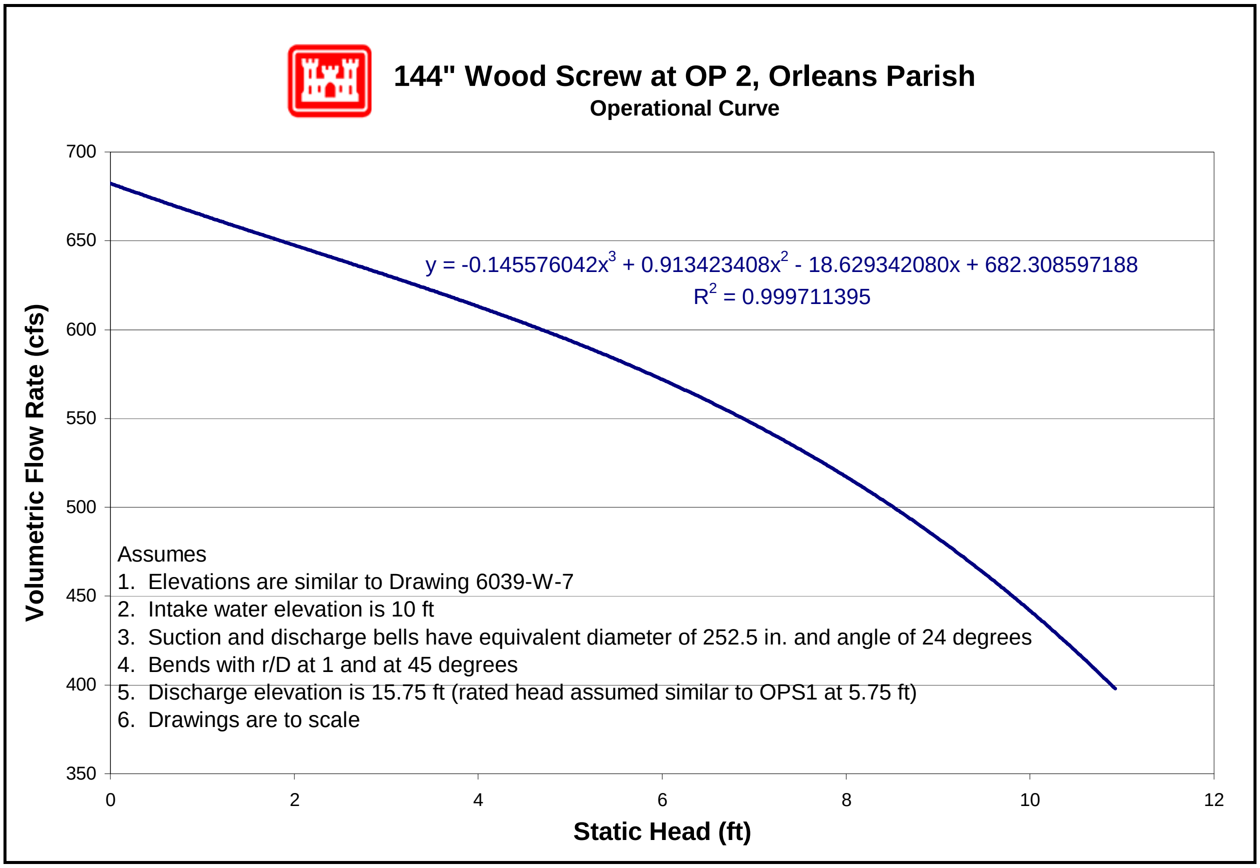
Pipe	dH (feet)	P Static In (psia)	P Static Out (psia)	P Stag. In (psia)	P Stag. Out (psia)	EGL Inlet (feet)	EGL Outlet (feet)	HGL Inlet (feet)	HGL Outlet (feet)
11	3.038E-04	17.621	17.621	17.640	17.640	15.793	15.793	15.750	15.750
12	6.599E-03	11.213	6.660	11.387	6.834	9.865	9.859	9.462	9.455
13	5.114E-03	5.762	5.760	5.937	5.935	9.788	9.783	9.385	9.380
14	5.114E-03	8.473	8.470	8.648	8.645	16.043	16.038	15.639	15.634
15	4.949E-03	9.283	13.181	9.458	13.356	15.913	15.908	15.510	15.505
16	2.080E-06	15.725	15.725	15.744	15.744	9.918	9.918	9.875	9.875
17	2.080E-06	15.744	15.744	15.762	15.762	9.961	9.961	9.918	9.918
18	1.650E-04	8.447	8.447	8.622	8.622	15.984	15.984	15.581	15.581

All Junction Table

Jct	Name	P Static In (psia)	P Static Out (psia)	Vol. Flow Rate Thru Jct (ft3/sec)	Loss Factor (K)	Elevation Inlet (feet)	Elevation Outlet (feet)	EGL Inlet (feet)	EGL Outlet (feet)
11	144" Wood Screw	5.760	8.473	576.2	0.0000	30.000	30.000	9.783	16.043
12	Reservoir	14.696	15.779	576.2	0.9200	10.000	10.000	10.000	10.000
13	Area Change	15.725	11.213	576.2	1.2346	7.500	17.500	9.918	9.865
14	Bend	6.660	5.762	576.2	0.1753	28.000	30.000	9.859	9.788
15	Bend	8.447	9.283	576.2	0.1753	30.000	28.000	15.984	15.913
16	Area Change	13.181	17.621	576.2	0.2864	19.000	9.000	15.908	15.793
17	Reservoir	14.696	17.621	576.2	1.0000	15.750	15.750	15.750	15.750
18	Screen	15.744	15.725	576.2	1.0000	7.500	7.500	9.961	9.918
19	Bend	8.470	8.447	576.2	0.1321	30.000	30.000	16.038	15.984

Output from AFT Fathom™ for 144" Wood Screw with Bend, page 2

No system curve is provided because the head experienced during the hurricane exceeded the shutoff head of the pump.



Assumes
1. Elevations are similar to Drawing 6039-W-7
2. Intake water elevation is 10 ft
3. Suction and discharge bells have equivalent diameter of 252.5 in. and angle of 24 degrees
4. Bends with r/D at 1 and at 45 degrees
5. Discharge elevation is 15.75 ft (rated head assumed similar to OPS1 at 5.75 ft)
6. Drawings are to scale

Operational Curve for 144" Wood Screw Pump at OP 2

7.6.2.1.2.6.3 168" Wood Screw

No specific drawings were available for the 168" Wood Screw. The following resources were used to make the indicated assumptions:[165]

- *Data from similar horizontal pumps* – Modeled was the simplest common system, which included two 45˚ bends with r/D factors of 1.0, a suction bell and a discharge bell with an equivalent circular diameter of 264.5 inches and a conical transition at an angle of 24˚, and pipe lengths. OP PS1 has a similar pump with a recorded rated head; this rated head was assumed to be similar for this pump station.
- *Operation Log* – The intake water elevation was determined to be 10 feet and the discharge water elevation was determined to be 27.5 feet.
- *An estimated one foot of trash at the intake* – A loss coefficient of 1.0 for the flap valve and trash rack was used.

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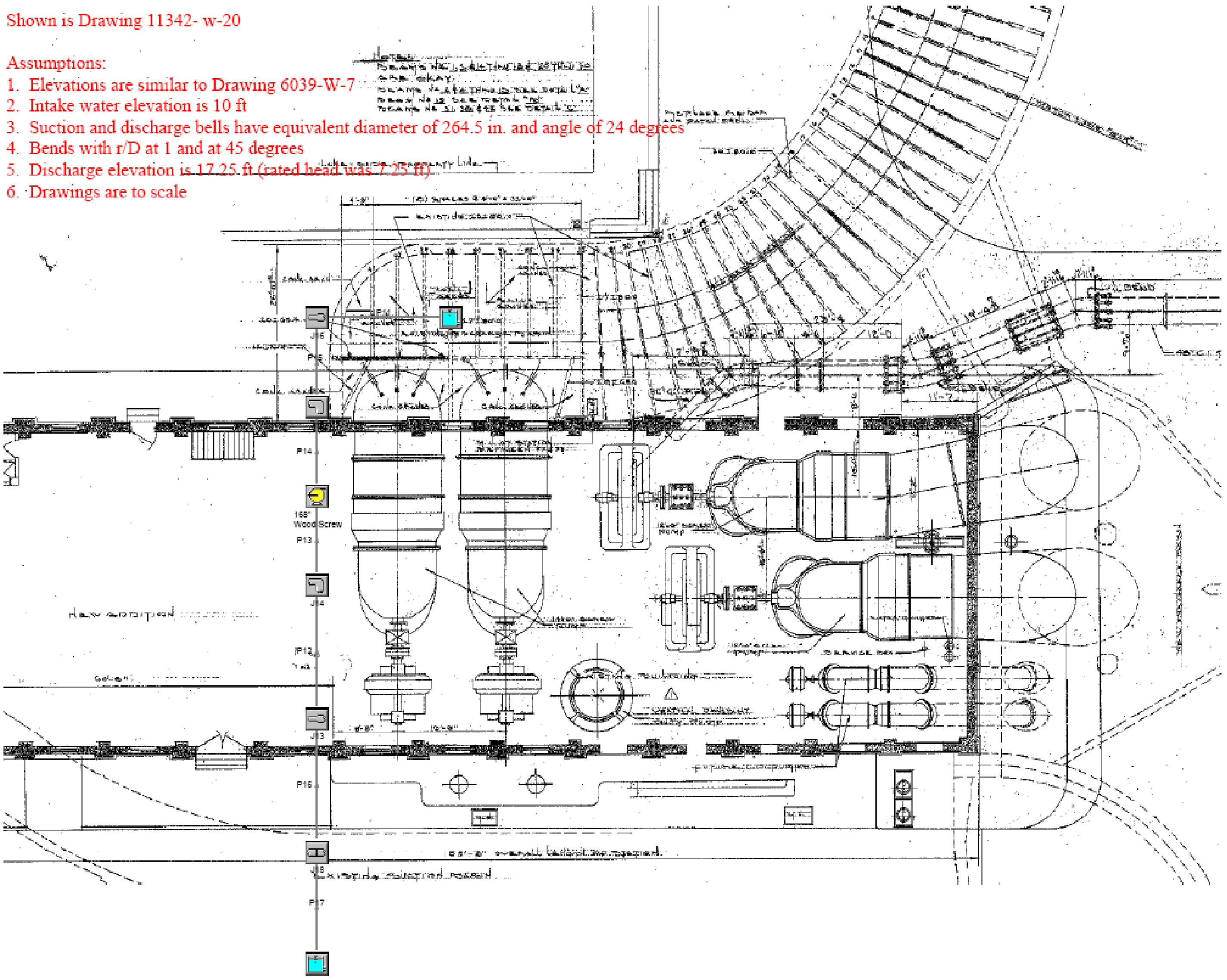
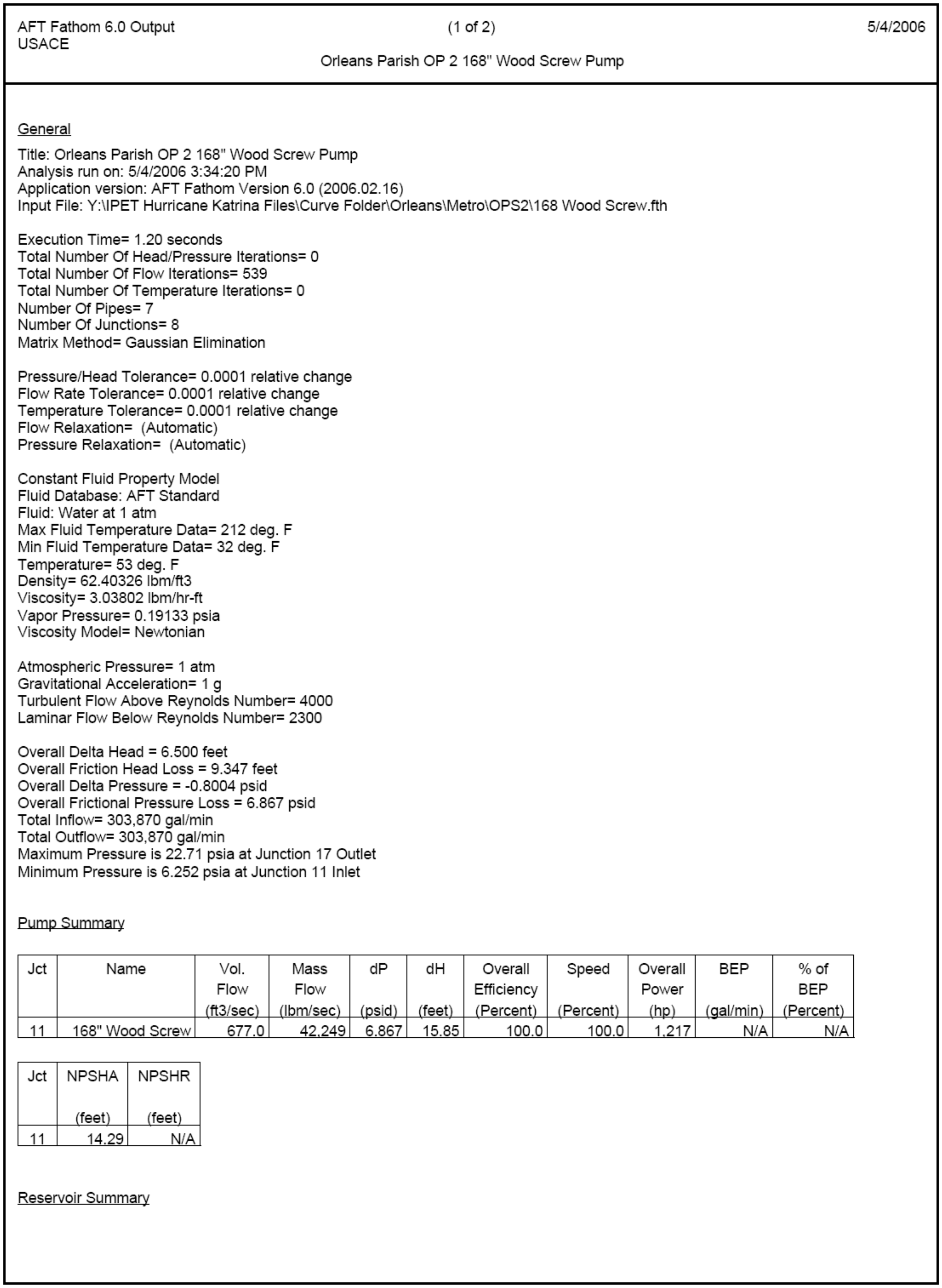
[165] The datum for the listed elevations is not reported. The datum is not needed for modeling pump station capacity in normal operation calculations because only relative elevations affect the calculations.



Shown is Drawing 11342- w-20

Assumptions:
1. Elevations are similar to Drawing 6039-W-7
2. Intake water elevation is 10 ft
3. Suction and discharge bells have equivalent diameter of 264.5 in. and angle of 24 degrees
4. Bends with r/D at 1 and at 45 degrees
5. Discharge elevation is 17.25 ft (rated head was 7.25 ft)
6. Drawings are to scale

Layout of 168" Wood Screw Pump OP 2



AFT Fathom 6.0 Output (1 of 2) 5/4/2006
USACE
Orleans Parish OP 2 168" Wood Screw Pump

General

Title: Orleans Parish OP 2 168" Wood Screw Pump
Analysis run on: 5/4/2006 3:34:20 PM
Application version: AFT Fathom Version 6.0 (2006.02.16)
Input File: Y:\IPET Hurricane Katrina Files\Curve Folder\Orleans\Metro\OPS2\168 Wood Screw.fth

Execution Time= 1.20 seconds
Total Number Of Head/Pressure Iterations= 0
Total Number Of Flow Iterations= 539
Total Number Of Temperature Iterations= 0
Number Of Pipes= 7
Number Of Junctions= 8
Matrix Method= Gaussian Elimination

Pressure/Head Tolerance= 0.0001 relative change
Flow Rate Tolerance= 0.0001 relative change
Temperature Tolerance= 0.0001 relative change
Flow Relaxation= (Automatic)
Pressure Relaxation= (Automatic)

Constant Fluid Property Model
Fluid Database: AFT Standard
Fluid: Water at 1 atm
Max Fluid Temperature Data= 212 deg. F
Min Fluid Temperature Data= 32 deg. F
Temperature= 53 deg. F
Density= 62.40326 lbm/ft3
Viscosity= 3.03802 lbm/hr-ft
Vapor Pressure= 0.19133 psia
Viscosity Model= Newtonian

Atmospheric Pressure= 1 atm
Gravitational Acceleration= 1 g
Turbulent Flow Above Reynolds Number= 4000
Laminar Flow Below Reynolds Number= 2300

Overall Delta Head = 6.500 feet
Overall Friction Head Loss = 9.347 feet
Overall Delta Pressure = -0.8004 psid
Overall Frictional Pressure Loss = 6.867 psid
Total Inflow= 303,870 gal/min
Total Outflow= 303,870 gal/min
Maximum Pressure is 22.71 psia at Junction 17 Outlet
Minimum Pressure is 6.252 psia at Junction 11 Inlet

Pump Summary

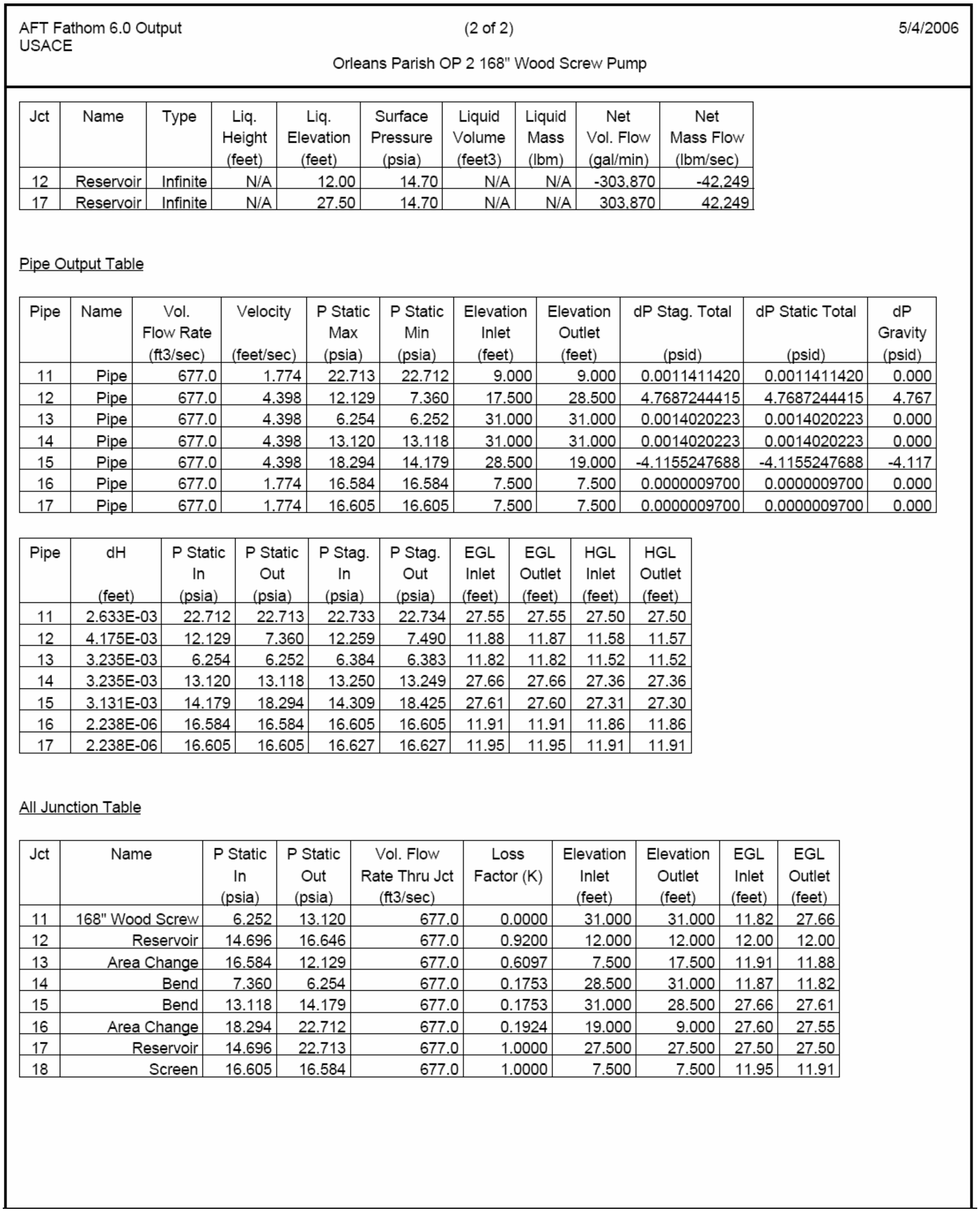
Jct	Name	Vol. Flow (ft3/sec)	Mass Flow (lbm/sec)	dP (psid)	dH (feet)	Overall Efficiency (Percent)	Speed (Percent)	Overall Power (hp)	BEP (gal/min)	% of BEP (Percent)
11	168" Wood Screw	677.0	42,249	6.867	15.85	100.0	100.0	1,217	N/A	N/A

Jct	NPSHA (feet)	NPSHR (feet)
11	14.29	N/A

Reservoir Summary

Output from AFT Fathom™ for 168" Wood Screw, Page 1

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.



AFT Fathom 6.0 Output (2 of 2) 5/4/2006
USACE
Orleans Parish OP 2 168" Wood Screw Pump

Jct	Name	Type	Liq. Height (feet)	Liq. Elevation (feet)	Surface Pressure (psia)	Liquid Volume (feet3)	Liquid Mass (lbm)	Net Vol. Flow (gal/min)	Net Mass Flow (lbm/sec)
12	Reservoir	Infinite	N/A	12.00	14.70	N/A	N/A	-303,870	-42,249
17	Reservoir	Infinite	N/A	27.50	14.70	N/A	N/A	303,870	42,249

Pipe Output Table

Pipe	Name	Vol. Flow Rate (ft3/sec)	Velocity (feet/sec)	P Static Max (psia)	P Static Min (psia)	Elevation Inlet (feet)	Elevation Outlet (feet)	dP Stag. Total (psid)	dP Static Total (psid)	dP Gravity (psid)
11	Pipe	677.0	1.774	22.713	22.712	9.000	9.000	0.0011411420	0.0011411420	0.000
12	Pipe	677.0	4.398	12.129	7.360	17.500	28.500	4.7687244415	4.7687244415	4.767
13	Pipe	677.0	4.398	6.254	6.252	31.000	31.000	0.0014020223	0.0014020223	0.000
14	Pipe	677.0	4.398	13.120	13.118	31.000	31.000	0.0014020223	0.0014020223	0.000
15	Pipe	677.0	4.398	18.294	14.179	28.500	19.000	-4.1155247688	-4.1155247688	-4.117
16	Pipe	677.0	1.774	16.584	16.584	7.500	7.500	0.0000009700	0.0000009700	0.000
17	Pipe	677.0	1.774	16.605	16.605	7.500	7.500	0.0000009700	0.0000009700	0.000

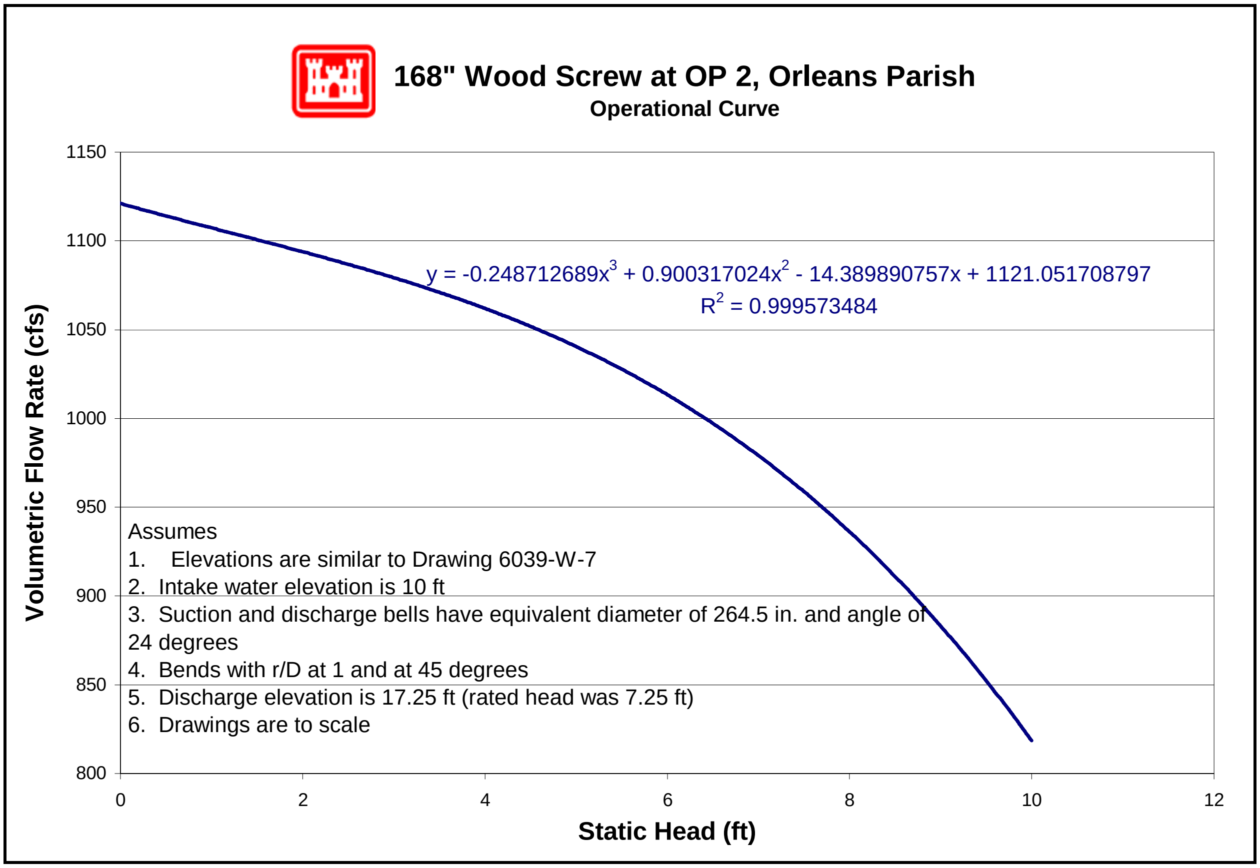
Pipe	dH (feet)	P Static In (psia)	P Static Out (psia)	P Stag. In (psia)	P Stag. Out (psia)	EGL Inlet (feet)	EGL Outlet (feet)	HGL Inlet (feet)	HGL Outlet (feet)
11	2.633E-03	22.712	22.713	22.733	22.734	27.55	27.55	27.50	27.50
12	4.175E-03	12.129	7.360	12.259	7.490	11.88	11.87	11.58	11.57
13	3.235E-03	6.254	6.252	6.384	6.383	11.82	11.82	11.52	11.52
14	3.235E-03	13.120	13.118	13.250	13.249	27.66	27.66	27.36	27.36
15	3.131E-03	14.179	18.294	14.309	18.425	27.61	27.60	27.31	27.30
16	2.238E-06	16.584	16.584	16.605	16.605	11.91	11.91	11.86	11.86
17	2.238E-06	16.605	16.605	16.627	16.627	11.95	11.95	11.91	11.91

All Junction Table

Jct	Name	P Static In (psia)	P Static Out (psia)	Vol. Flow Rate Thru Jct (ft3/sec)	Loss Factor (K)	Elevation Inlet (feet)	Elevation Outlet (feet)	EGL Inlet (feet)	EGL Outlet (feet)
11	168" Wood Screw	6.252	13.120	677.0	0.0000	31.000	31.000	11.82	27.66
12	Reservoir	14.696	16.646	677.0	0.9200	12.000	12.000	12.00	12.00
13	Area Change	16.584	12.129	677.0	0.6097	7.500	17.500	11.91	11.88
14	Bend	7.360	6.254	677.0	0.1753	28.500	31.000	11.87	11.82
15	Bend	13.118	14.179	677.0	0.1753	31.000	28.500	27.66	27.61
16	Area Change	18.294	22.712	677.0	0.1924	19.000	9.000	27.60	27.55
17	Reservoir	14.696	22.713	677.0	1.0000	27.500	27.500	27.50	27.50
18	Screen	16.605	16.584	677.0	1.0000	7.500	7.500	11.95	11.91

Output from AFT Fathom™ for 168" Wood Screw, Page 2

No system curve is provided because the head experienced during the hurricane exceeded the shutoff head of the pump.



Curve for 168” Wood Screw Pump at OP 2

7.6.2.1.2.7 Pump Reverse Flow

There are six pumps at this station for which reverse flow rating curves were computed (no pumps were excluded). The reverse flow data and curves are presented in the order of the pump numbering utilized in the summary tables included in this appendix. In cases where there are multiple pumps of equivalent size and system configuration, a single rating curve represents all of them at a unit rate per pump.

Pump No.	**Pump Capacity (cfs)**	**Pump Size (in)**	**Reverse Flow Computed?**		**Rating Curve Ref. No.**
			Yes	**No**	
A	550	144	X		1
B	550	144	X		2
C	1000	168	X		3
D	1000	168	X		3
CD2	25	42	X		4
CD3	25	42	X		4

For a general explanation of reverse flow (terminology, figures, methodology, equations and assumptions), refer to the Reverse Flow Section at the beginning of this appendix. Reverse flow computations for a given pump station do not necessarily imply that reverse flow actually occurred there during the Katrina event. But these curves may instead be used as future tools if further investigations are required based on reverse flow assumptions.

1. Reverse Flow Rating Curve

#2 Pump Station, Pumps # A -144-in.

Elevation Datum (ft):	Cairo
Crest Elevation (ft) =	21.2

H1 = Lake or outlet canal water level (normal pump discharge side)
H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use* $Q = \mathrm{sqrt}((H1-H2)/K')$
$K' =$ 1.38591E-05 sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Water elevation (H1) that triggers unprimed flow: 21.2 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 31.7 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.							
H2 =	7.0	10.0	13.0	16.0	19.0	22.0	25.0
H1 >	38	37	36	36	35	34	33

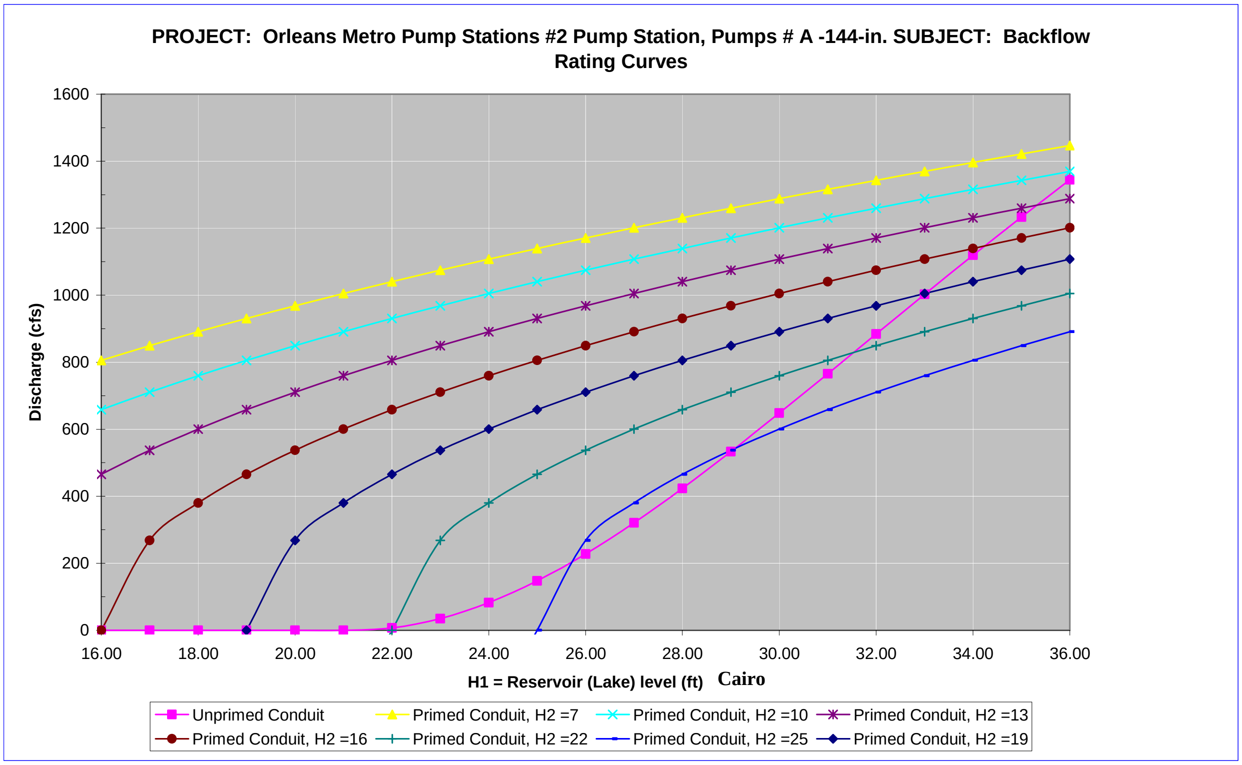
Water elevation (H1) that stops unprimed flow: 21.2 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 13.0 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.


PROJECT: Orleans Metro Pump Stations #2 Pump Station, Pumps # A -144-in. SUBJECT: Backflow Rating Curves

Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	9.00
Intake loss =	0.92
Exit Loss =	1.0

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

No profile drawings for pumps A & B. Assumed the geometry is like pumps C & D.
Elevations in Cairo Datum
All length measurements were center line lengths.
Assumed rated head based on 144” pumps at PS#1
Assumed intake bell diameter proportional to known pump diameter
Assumed reverse rotation did not occur.

4 Data Needs or Deficiencies:

Profile drawing of pumps A & B.

5 Backflow prevention:

Available: No backflow prevention system

Used: Reverse flow did not occur according to operator interview
No comment as to possibility of reverse rotation.

2. Reverse Flow Rating Curve

#2 Pump Station, Pumps # B -144-in.

Elevation Datum (ft): Cairo
Crest Elevation (ft) = 21.2
H1 = Lake or outlet canal water level (normal pump discharge side)
H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use Q = sqrt((H1-H2)/K')*
K' = *1.38149E-05* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Water elevation (H1) that triggers unprimed flow: 21.2 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 31.7 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

H2 =	7.0	10.0	13.0	16.0	19.0	22.0	25.0
H1 >	38	37	36	36	35	34	33

Water elevation (H1) that stops unprimed flow: 21.2 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 13.0 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.

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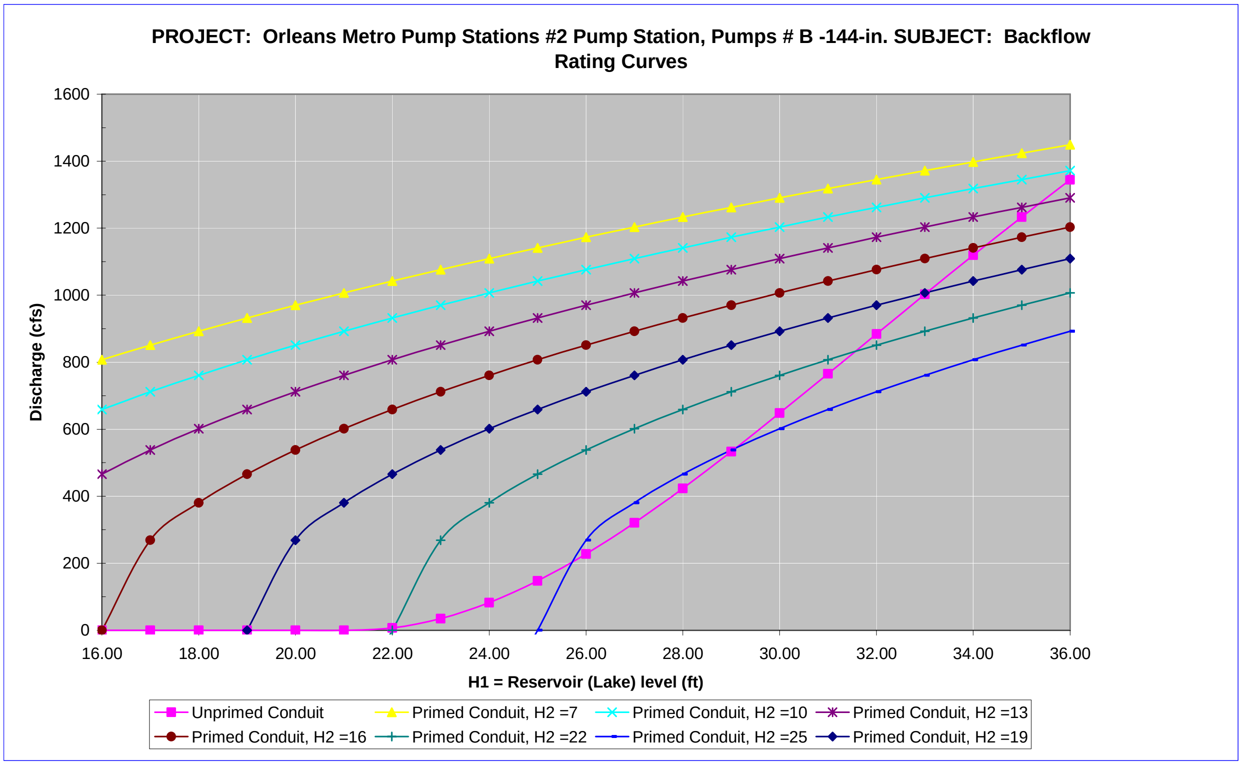

Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	9.00
Intake loss =	0.92
Exit Loss =	1.0

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

No profile drawings for pumps A & B.

Elevations in Cairo Datum

All length measurements were center line lengths.

Assumed rated head based on 144” pumps at PS#1

Assumed invert elevations are the same as pumps C & D.

Assumed intake bell diameter proportional to known pump diameter

4 Data Needs or Deficiencies:

Profile drowning of pumps A & B.

5 Backflow prevention:

Available:	No backflow prevention system
Used:	Reverse flow did not occur according to operator interview

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

No comment as to possibility of reverse rotation.

3. Reverse Flow Rating Curve

#2 Pump Station, Pumps # C, D -168-in.

Elevation Datum (ft):	Cairo
Crest Elevation (ft) =	21.2

H1 = Lake or outlet canal water level (normal pump discharge side)
H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use* $Q = sqrt((H1-H2)/K')$

$K' =$ *7.52286E-06* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

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Water elevation (H1) that triggers unprimed flow: 21.2 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 33.5 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

H2 =	7.0	10.0	13.0	16.0	19.0	22.0	25.0
H1 >	40	39	39	38	37	36	36

Water elevation (H1) that stops unprimed flow: 21.2 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 13.5 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.

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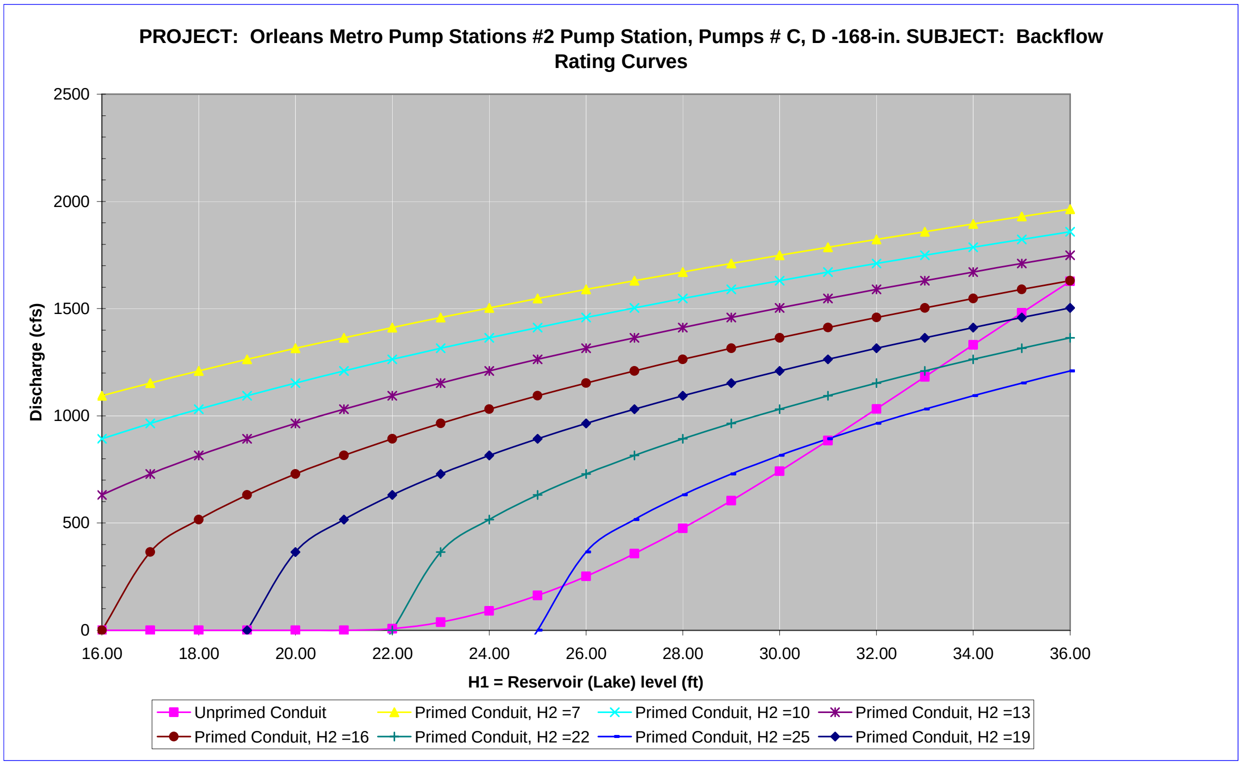

Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	9.00
Intake loss =	0.92
Exit Loss =	1.0

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Pumps C & D are identical in manufacturing and installation

Elevations in Cairo Datum

Length measurements were center line chords lengths

Assumed rated head based on 168" pumps at PS #1

Assumed reverse rotation did not occur.

4 Data Needs or Deficiencies:

None

5 Backflow prevention:

Available:	No backflow prevention system
Used:	Reverse flow did not occur according to operator interview No comment as to possibility of reverse rotation.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

4. Reverse Flow Rating Curve

#2 Pump Station, Pumps CD2 & CD3 - 42-in.

Elevation Datum (ft): Cairo

Crest Elevation (ft) = 34.5

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use Q = sqrt((H1-H2)/K')*

K' = *0.00168028* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 34.5 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal

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reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 37.5 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

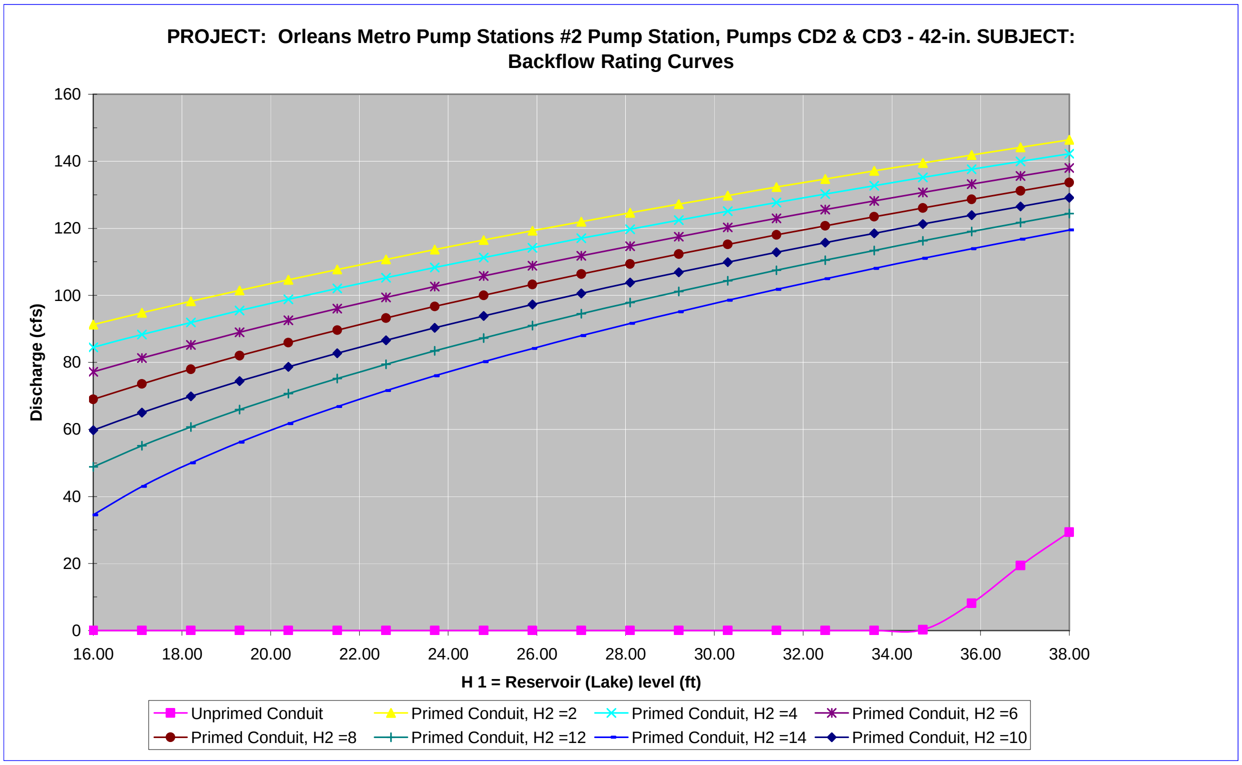
Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.							
H2 =	2.0	4.0	6.0	8.0	10.0	12.0	14.0
H1 >	317	301	285	269	254	238	222

Water elevation (H1) that stops unprimed flow: 34.5 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 28.1 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.



This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	4.50
Intake loss =	0.92
Expansion & Exit Loss =	0.43

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:
Head of 4ft
Cd 2 and 3 share the same design
Drawings to scale
Free rotating impeller Wood Screw pump

4 Data Needs or Deficiencies:
Rated head

5 Backflow prevention:

Available:	No backflow prevention
Used:	Survey states reverse flow did not occur. No reverse rotation mechanism

7.6.2.1.2.8 Fuel Endurance Calculations

We do not have any record of pumps that run on fuel at this pump station.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.2.1.3 *OP 3*

Orleans Parish – East Bank Drainage Basin

2251 N. Broad Ave.
New Orleans, LA 70119

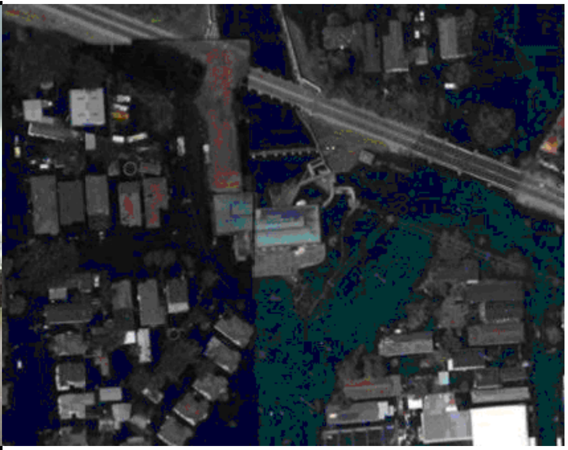
Latitude: 29.98821˚ Longitude: -90.06795˚

7.6.2.1.3.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Before Hurricane Katrina: Aerial view of the pump station



After Hurricane Katrina: View from the inlet canal

After Hurricane Katrina: Aerial view of the pump station

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7.6.2.1.3.2 Description[166]

Drainage area:	New Orleans East Bank
Nominal Capacity:	4340 cfs
Drains water from:	OPS #2
Discharges water to:	London Ave. Canal
Owner:	New Orleans Sewerage and Water Board
Number of pumps:	7
Pump orientation:	5 horizontal 2 centrifugal
Pump driver:	7 electric 25 Hz motors
Water level to switch pumps on:	12 feet (NGVD)
Water level to switch pumps off:	9.5 feet (NGVD)
Water level that affects operation:	0.3 feet (NGVD). Water enters motor pits
Reverse flow protection:	None

7.6.2.1.3.3 Damages

Estimated cost of repairs:	The estimated cost of repairs is not yet available.[167]
Relative level of damage:	Substantial
Severity of circumstances:	Flooding occurred approximately 24 inches above the lower operating floor and 6 inches above the upper operating floor. The control room was flooded 12 inches above the operating floor.
Equipment damaged:	Motors A, B, C, D, and E need rewinding repairs. Pump D will require removing and inspecting before any repairs are performed.
Building damage:	Roof needs repairing along with replacing the flooring and wall panels in the operating room.

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[166] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[167] The Project Information Report (PIR) for each parish provides an estimated cost of repairs for the parish's pump stations. At the time this report was written, the Orleans Parish PIR was not yet complete. It should be available through the parish shortly after publication of the IPET Report.

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Misc. damage:	Fence needs repairing, storage building roof needs repairing, and the site needs cleaning.

7.6.2.1.3.4 Katrina Event

Date	Time	Event
8/28/2005	-	The operation log states that the constant duty pumps 1 and 2 ran all day until the afternoon.
	4:23 PM	The operation log shows that pumping began with pump A, and later with pump B.
	10:00 PM	The operation log shows that the intake canal level was at 9.2 feet.
8/29/2005	-	The operational log indicates that all of the pumps were running in the morning.
	5:38 AM	The operational log indicates a loss of 60 Hz power. The station switched to generator power.
	6:00 AM	First signs of water coming from the Industrial Canal.
	6:28 AM	The operational log states that pump E caught fire.
	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	8:25 AM	The operational log indicates that water was entering station. The operators left the station and entered the auxiliary building (Pump D annex). It is assumed that the pumps were shut down.
9/7/2005	-	The interview form states that the operators returned to the station. The water levels were back to normal upon arrival.

7.6.2.1.3.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.2.1.3.6 Pump Operational Curves

Pump curves are provided for five[168] OP 3 pumps in 2 different configurations.

- (2) 144” Wood Screw
- (3) 168” Wood Screw

The following pages provide system curves and operational curves for each configuration. Section 7.1.3.5 describes the function of the curves, as well as the processes used to develop the curves. Some details, such as exact dimensions, were not available for all pump systems prior to the calculations. The assumptions made in place of the missing data were based on available known data for similar pumps, and are noted in the “layout” drawings for each pump, as well as in individual pump sections.[169] The accuracy of the calculations directly depends on the amount of information available. When there was not adequate data, the best engineering judgment using other pump station and manufacturer’s data was employed.

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[168] OP 3 has a total of 7 pumps; however, not enough data was available to analyze the centrifugal pumps within a reasonable accuracy.

[169] Section 7.1.3.5 also contains general assumptions that were consistently made throughout the modeling process, which may or may not be listed as mentioned.

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7.6.2.1.3.6.1 144” Wood Screw

Drawing 5678-W-4 shows the 144” Wood Screw. The following resources were used to make the indicated assumptions:[170]

- *Data Drawing 5678-W-4* – It was determined that there was two 45˚ bends with r/D factors of 1.0, a suction bell and a discharge bell with equivalent circular diameters of 252.5 inches and a conical transition at an angle of 28˚. Much of this was done assuming the drawing was to scale.
- *Operation Log* – The intake water elevation was determined to be 8.3 feet and the discharge water elevation was determined to be 28.7 feet.
- *An estimated one foot of trash at the intake* – A loss coefficient of 1.0 for the trash rack was utilized.

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[170] The datum for the listed elevations is not reported. The datum is not needed for modeling pump station capacity in normal operation calculations because only relative elevations affect the calculations.

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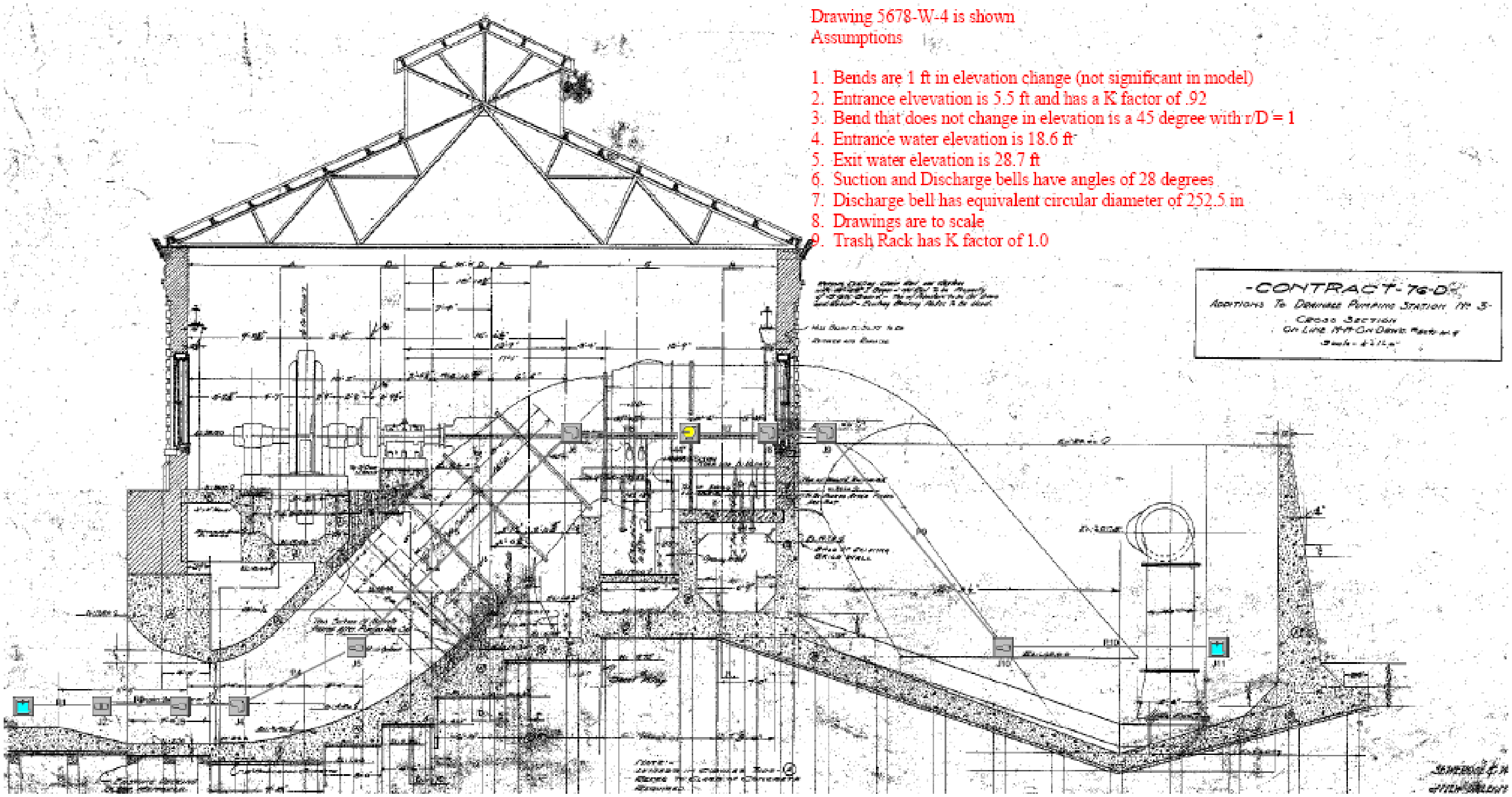

Drawing 5678-W-4 is shown
Assumptions

1. Bends are 1 ft in elevation change (not significant in model)
2. Entrance elvevation is 5.5 ft and has a K factor of .92
3. Bend that does not change in elevation is a 45 degree with r/D = 1
4. Entrance water elevation is 18.6 ft
5. Exit water elevation is 28.7 ft
6. Suction and Discharge bells have angles of 28 degrees
7. Discharge bell has equivalent circular diameter of 252.5 in
8. Drawings are to scale
9. Trash Rack has K factor of 1.0

Layout of 144" Wood Screw Pump at OP 3

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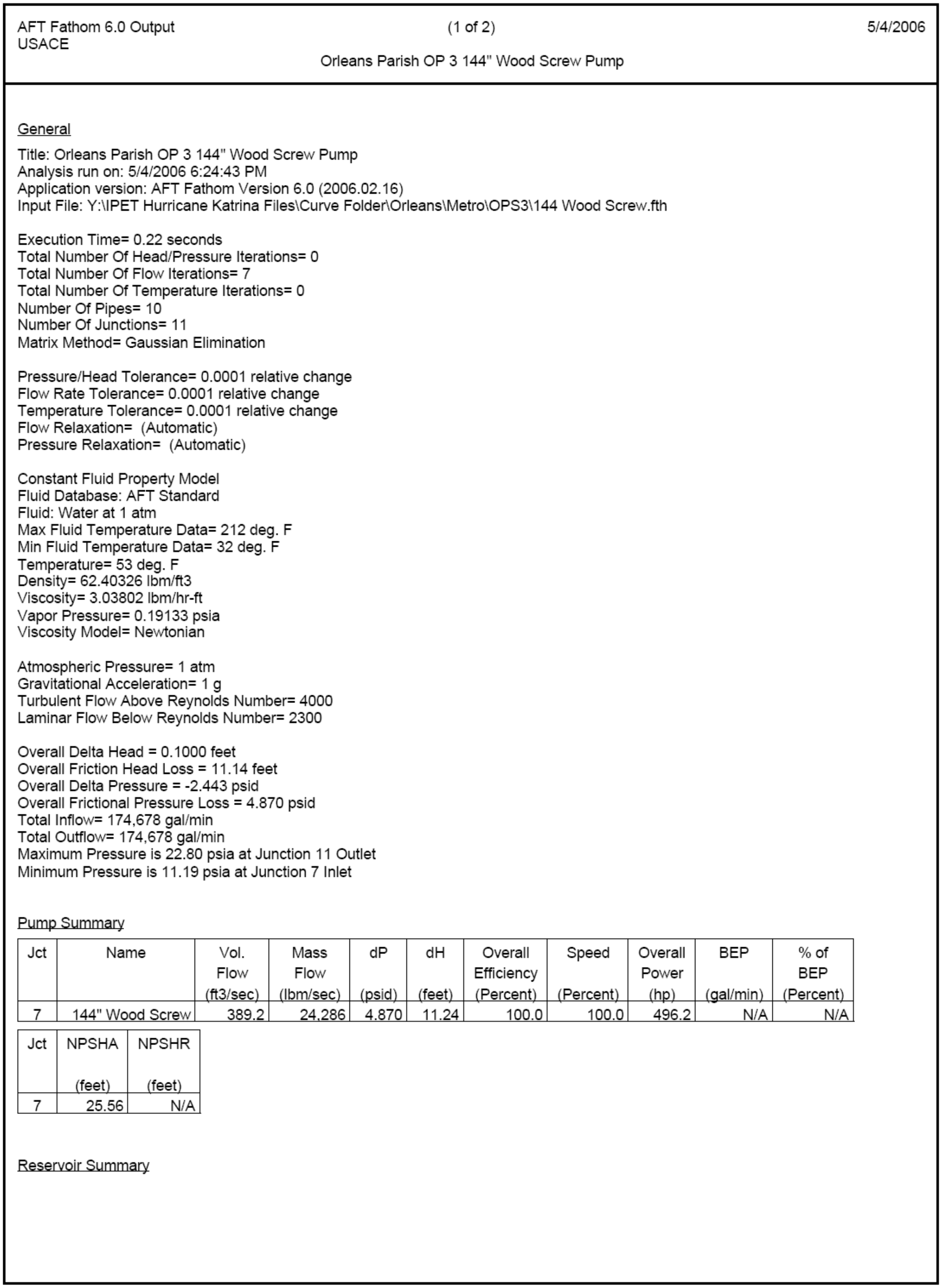

AFT Fathom 6.0 Output (1 of 2) 5/4/2006
USACE
Orleans Parish OP 3 144" Wood Screw Pump

General

Title: Orleans Parish OP 3 144" Wood Screw Pump
Analysis run on: 5/4/2006 6:24:43 PM
Application version: AFT Fathom Version 6.0 (2006.02.16)
Input File: Y:\IPET Hurricane Katrina Files\Curve Folder\Orleans\Metro\OPS3\144 Wood Screw.fth

Execution Time= 0.22 seconds
Total Number Of Head/Pressure Iterations= 0
Total Number Of Flow Iterations= 7
Total Number Of Temperature Iterations= 0
Number Of Pipes= 10
Number Of Junctions= 11
Matrix Method= Gaussian Elimination

Pressure/Head Tolerance= 0.0001 relative change
Flow Rate Tolerance= 0.0001 relative change
Temperature Tolerance= 0.0001 relative change
Flow Relaxation= (Automatic)
Pressure Relaxation= (Automatic)

Constant Fluid Property Model
Fluid Database: AFT Standard
Fluid: Water at 1 atm
Max Fluid Temperature Data= 212 deg. F
Min Fluid Temperature Data= 32 deg. F
Temperature= 53 deg. F
Density= 62.40326 lbm/ft3
Viscosity= 3.03802 lbm/hr-ft
Vapor Pressure= 0.19133 psia
Viscosity Model= Newtonian

Atmospheric Pressure= 1 atm
Gravitational Acceleration= 1 g
Turbulent Flow Above Reynolds Number= 4000
Laminar Flow Below Reynolds Number= 2300

Overall Delta Head = 0.1000 feet
Overall Friction Head Loss = 11.14 feet
Overall Delta Pressure = -2.443 psid
Overall Frictional Pressure Loss = 4.870 psid
Total Inflow= 174,678 gal/min
Total Outflow= 174,678 gal/min
Maximum Pressure is 22.80 psia at Junction 11 Outlet
Minimum Pressure is 11.19 psia at Junction 7 Inlet

Pump Summary

Jct	Name	Vol. Flow (ft3/sec)	Mass Flow (lbm/sec)	dP (psid)	dH (feet)	Overall Efficiency (Percent)	Speed (Percent)	Overall Power (hp)	BEP (gal/min)	% of BEP (Percent)
7	144" Wood Screw	389.2	24,286	4.870	11.24	100.0	100.0	496.2	N/A	N/A

Jct	NPSHA (feet)	NPSHR (feet)
7	25.56	N/A

Reservoir Summary

Output from AFT Fathom™ for 144” Wood Screw, Page 1

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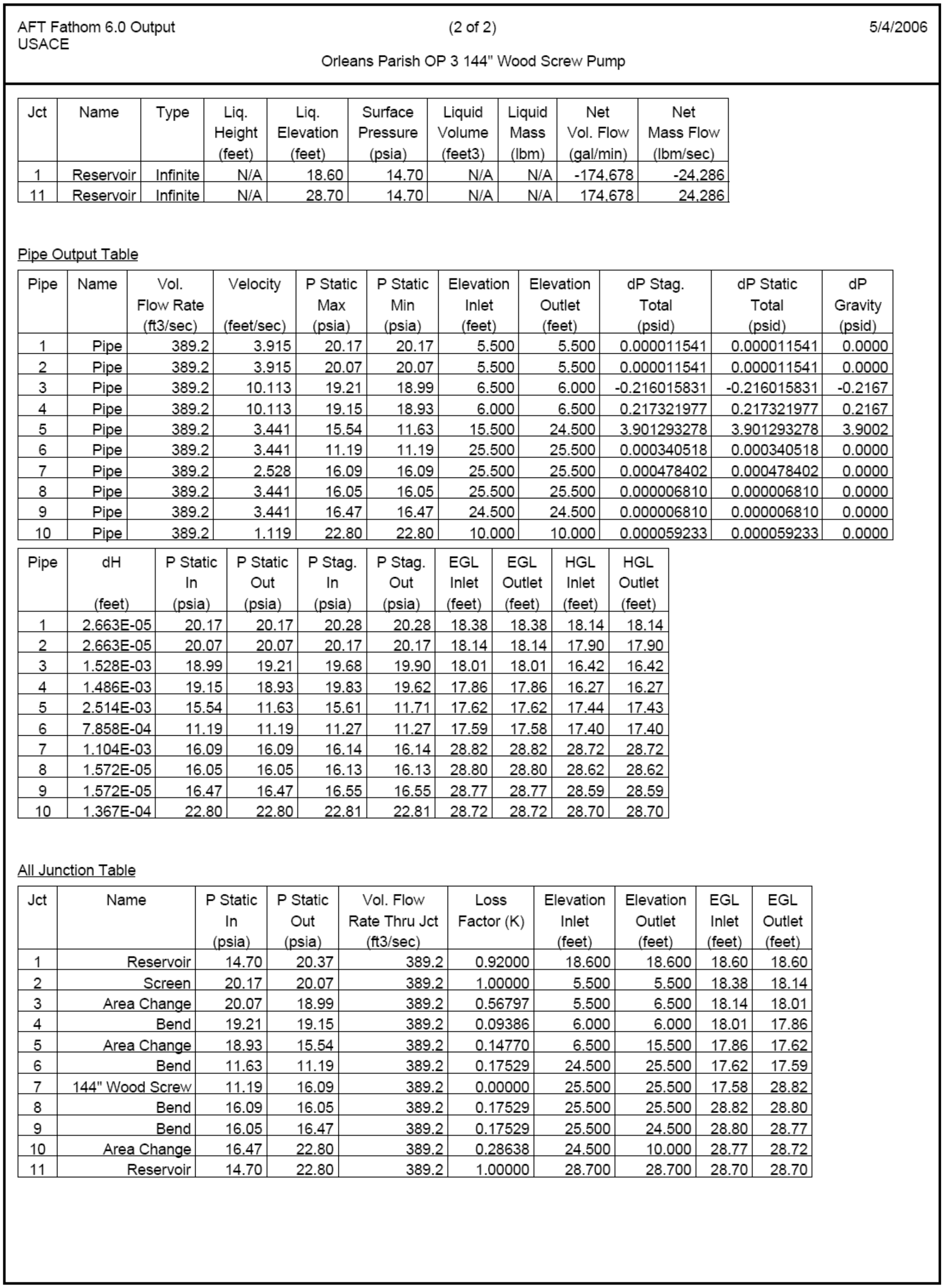


AFT Fathom 6.0 Output (2 of 2) 5/4/2006
USACE
Orleans Parish OP 3 144" Wood Screw Pump

Jct	Name	Type	Liq. Height (feet)	Liq. Elevation (feet)	Surface Pressure (psia)	Liquid Volume (feet3)	Liquid Mass (lbm)	Net Vol. Flow (gal/min)	Net Mass Flow (lbm/sec)
1	Reservoir	Infinite	N/A	18.60	14.70	N/A	N/A	-174,678	-24,286
11	Reservoir	Infinite	N/A	28.70	14.70	N/A	N/A	174,678	24,286

Pipe Output Table

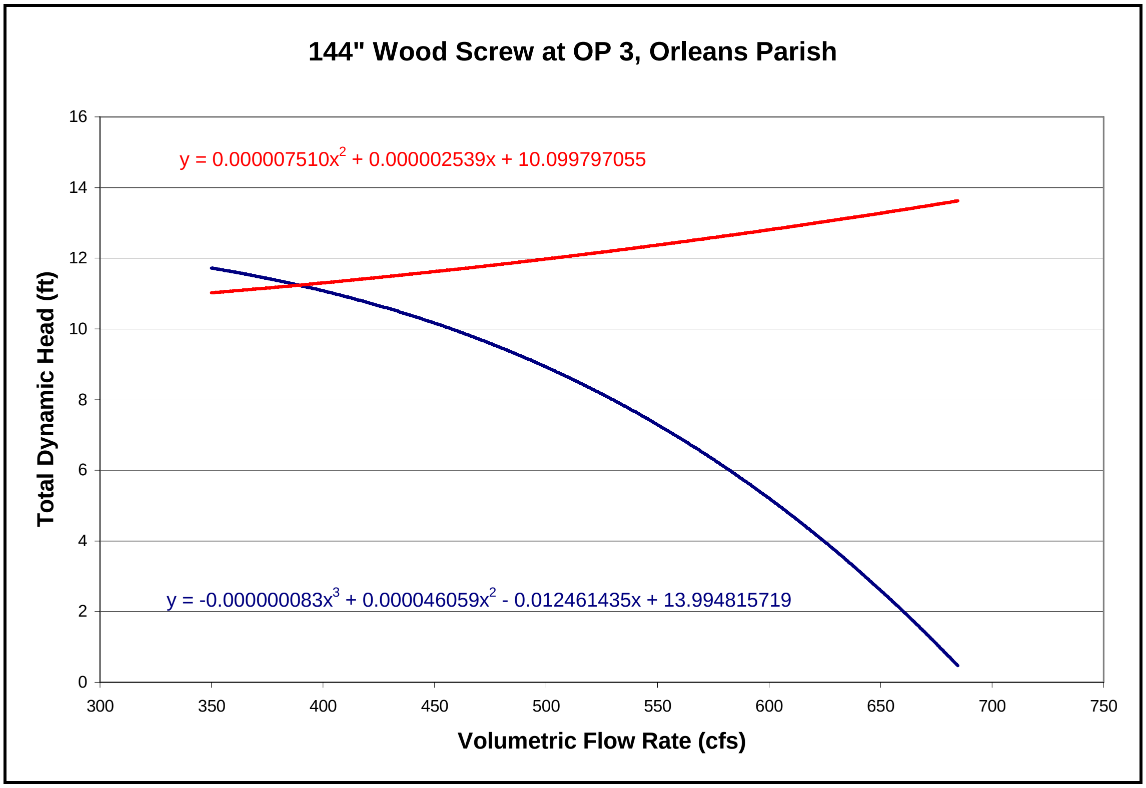
Pipe	Name	Vol. Flow Rate (ft3/sec)	Velocity (feet/sec)	P Static Max (psia)	P Static Min (psia)	Elevation Inlet (feet)	Elevation Outlet (feet)	dP Stag. Total (psid)	dP Static Total (psid)	dP Gravity (psid)
1	Pipe	389.2	3.915	20.17	20.17	5.500	5.500	0.000011541	0.000011541	0.0000
2	Pipe	389.2	3.915	20.07	20.07	5.500	5.500	0.000011541	0.000011541	0.0000
3	Pipe	389.2	10.113	19.21	18.99	6.500	6.000	-0.216015831	-0.216015831	-0.2167
4	Pipe	389.2	10.113	19.15	18.93	6.000	6.500	0.217321977	0.217321977	0.2167
5	Pipe	389.2	3.441	15.54	11.63	15.500	24.500	3.901293278	3.901293278	3.9002
6	Pipe	389.2	3.441	11.19	11.19	25.500	25.500	0.000340518	0.000340518	0.0000
7	Pipe	389.2	2.528	16.09	16.09	25.500	25.500	0.000478402	0.000478402	0.0000
8	Pipe	389.2	3.441	16.05	16.05	25.500	25.500	0.000006810	0.000006810	0.0000
9	Pipe	389.2	3.441	16.47	16.47	24.500	24.500	0.000006810	0.000006810	0.0000
10	Pipe	389.2	1.119	22.80	22.80	10.000	10.000	0.000059233	0.000059233	0.0000

Pipe	dH (feet)	P Static In (psia)	P Static Out (psia)	P Stag. In (psia)	P Stag. Out (psia)	EGL Inlet (feet)	EGL Outlet (feet)	HGL Inlet (feet)	HGL Outlet (feet)
1	2.663E-05	20.17	20.17	20.28	20.28	18.38	18.38	18.14	18.14
2	2.663E-05	20.07	20.07	20.17	20.17	18.14	18.14	17.90	17.90
3	1.528E-03	18.99	19.21	19.68	19.90	18.01	18.01	16.42	16.42
4	1.486E-03	19.15	18.93	19.83	19.62	17.86	17.86	16.27	16.27
5	2.514E-03	15.54	11.63	15.61	11.71	17.62	17.62	17.44	17.43
6	7.858E-04	11.19	11.19	11.27	11.27	17.59	17.58	17.40	17.40
7	1.104E-03	16.09	16.09	16.14	16.14	28.82	28.82	28.72	28.72
8	1.572E-05	16.05	16.05	16.13	16.13	28.80	28.80	28.62	28.62
9	1.572E-05	16.47	16.47	16.55	16.55	28.77	28.77	28.59	28.59
10	1.367E-04	22.80	22.80	22.81	22.81	28.72	28.72	28.70	28.70

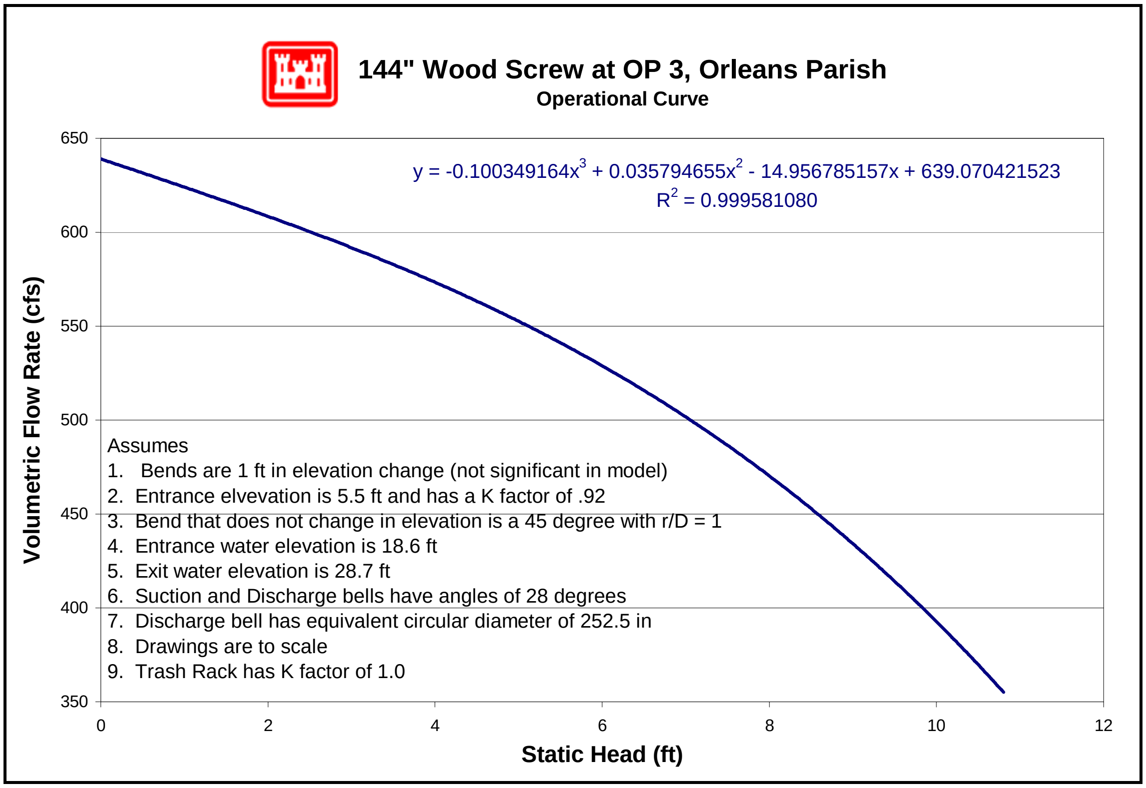
All Junction Table

Jct	Name	P Static In (psia)	P Static Out (psia)	Vol. Flow Rate Thru Jct (ft3/sec)	Loss Factor (K)	Elevation Inlet (feet)	Elevation Outlet (feet)	EGL Inlet (feet)	EGL Outlet (feet)
1	Reservoir	14.70	20.37	389.2	0.92000	18.600	18.600	18.60	18.60
2	Screen	20.17	20.07	389.2	1.00000	5.500	5.500	18.38	18.14
3	Area Change	20.07	18.99	389.2	0.56797	5.500	6.500	18.14	18.01
4	Bend	19.21	19.15	389.2	0.09386	6.000	6.000	18.01	17.86
5	Area Change	18.93	15.54	389.2	0.14770	6.500	15.500	17.86	17.62
6	Bend	11.63	11.19	389.2	0.17529	24.500	25.500	17.62	17.59
7	144" Wood Screw	11.19	16.09	389.2	0.00000	25.500	25.500	17.58	28.82
8	Bend	16.09	16.05	389.2	0.17529	25.500	25.500	28.82	28.80
9	Bend	16.05	16.47	389.2	0.17529	25.500	24.500	28.80	28.77
10	Area Change	16.47	22.80	389.2	0.28638	24.500	10.000	28.77	28.72
11	Reservoir	14.70	22.80	389.2	1.00000	28.700	28.700	28.70	28.70

Output from AFT Fathom™ for 144" Wood Screw, page 2



System Curve of 144” Wood Screw Pump at OP 3



Assumes

1. Bends are 1 ft in elevation change (not significant in model)
2. Entrance elevvation is 5.5 ft and has a K factor of .92
3. Bend that does not change in elevation is a 45 degree with r/D = 1
4. Entrance water elevation is 18.6 ft
5. Exit water elevation is 28.7 ft
6. Suction and Discharge bells have angles of 28 degrees
7. Discharge bell has equivalent circular diameter of 252.5 in
8. Drawings are to scale
9. Trash Rack has K factor of 1.0

Operational Curve for 144” Wood Screw Pump at OP 3

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.2.1.3.6.2 168" Wood Screw

Drawing 7104-W-9 shows the 168" Wood Screw. The following resources were used to make the indicated assumptions:[171]

- *Data Drawing 7104-W-9* – It was determined that there was two 45˚ bends with r/D factors of 1.0, a suction bell and a discharge bell with equivalent circular diameters of 264.5 inches and a conical transition at an angle of 28˚. Much of this was done assuming the drawing was to scale.
- *Operation Log* – The intake water elevation was determined to be 8.3 feet and the discharge water elevation was determined to be 28.7 feet. *An estimated one foot of trash at the intake* – A loss coefficient of 1.0 for the trash rack was utilized.
- *Data from similar horizontal pumps* – As can be seen in Drawing 7104-W-9, the elevation shows a drastic change in the discharge piping. Analysis suggested that if this were a circular pipe, cavitation would likely ensue. Since it is likely that cavitation analysis was done prior to the pump station installation, it was assumed that there was an area change that cannot be seen in the elevation view. It was assumed, therefore, that the tubing was rectangular with the dimensions of 15 feet in width and 82 inches in height. These dimensions were assumed using other horizontal pump configurations. Furthermore, it was assumed that an equivalent hydraulic diameter would better represent the transition in the piping.

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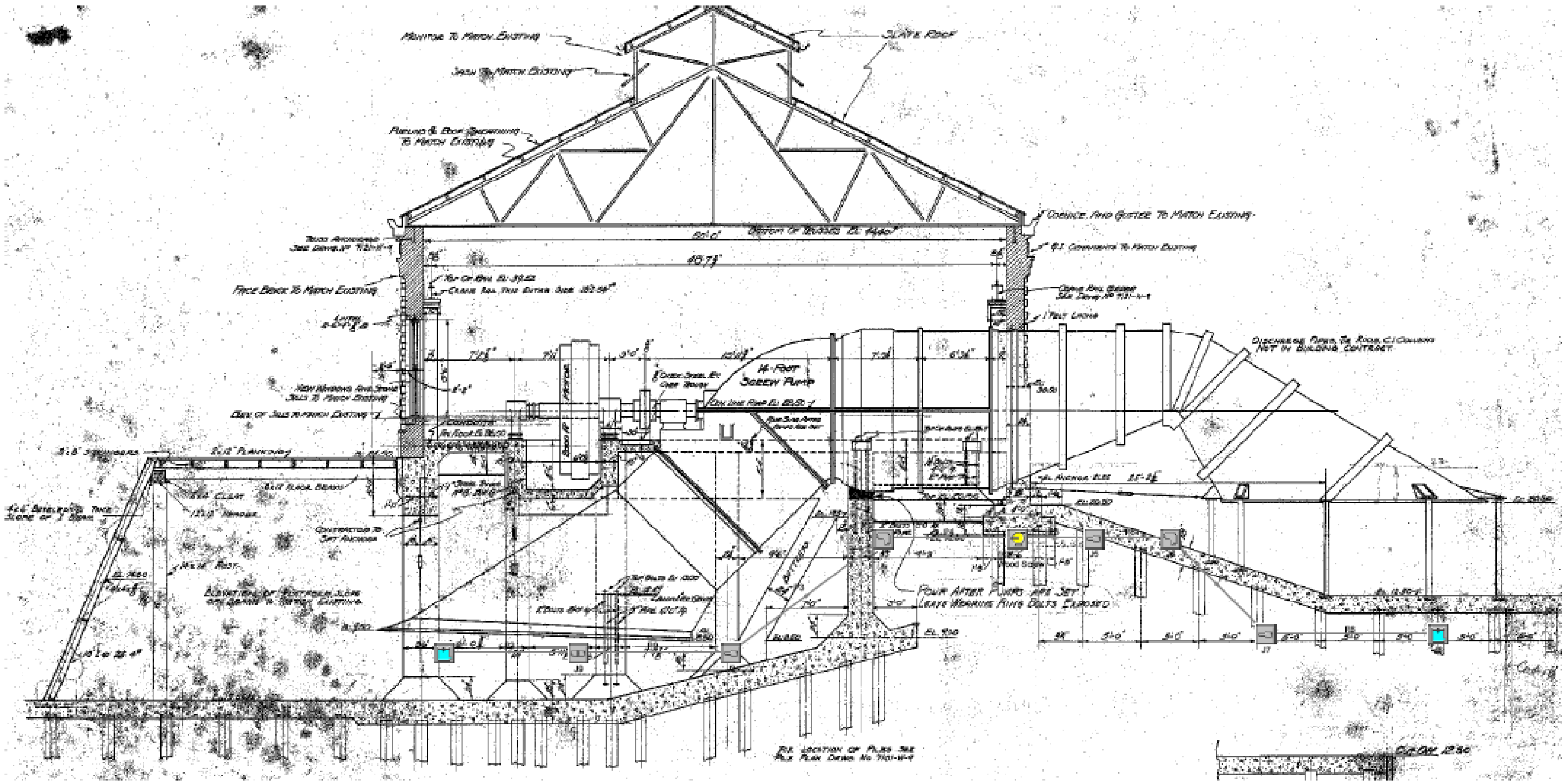
[171] The datum for the listed elevations is not reported. The datum is not needed for modeling pump station capacity in normal operation calculations because only relative elevations affect the calculations.



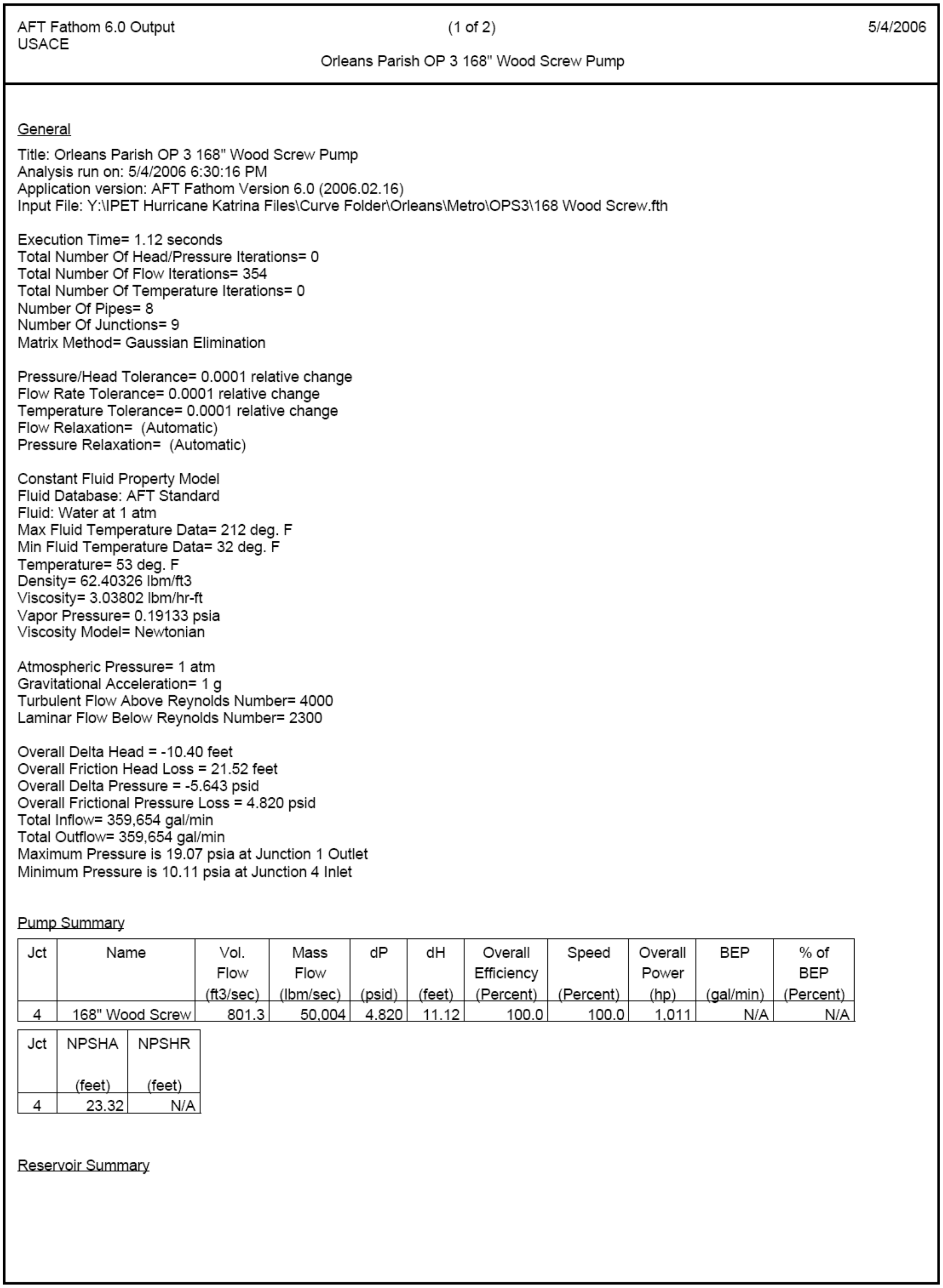
Drawing shown is 7104-W-9

Assumptions:

1. Intake elevation is 18.6 ft
2. Discharge elevation is 28.7 ft
3. Suction and Discharge bells have angles of 28 degrees and equivalent circular diameters of 264.5 in
4. Trash Rack has K factor of 1.0
5. Major area change is a symetric conical shape (modified rectangular pipe with dimensions 15 ft x 82 in to equivalent hydraulic diameter)
6. Drawings are to scale

Layout of 168" Wood Screw Pump OP 3

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.



AFT Fathom 6.0 Output (1 of 2) 5/4/2006
USACE
Orleans Parish OP 3 168" Wood Screw Pump

General

Title: Orleans Parish OP 3 168" Wood Screw Pump
Analysis run on: 5/4/2006 6:30:16 PM
Application version: AFT Fathom Version 6.0 (2006.02.16)
Input File: Y:\IPET Hurricane Katrina Files\Curve Folder\Orleans\Metro\OPS3\168 Wood Screw.fth

Execution Time= 1.12 seconds
Total Number Of Head/Pressure Iterations= 0
Total Number Of Flow Iterations= 354
Total Number Of Temperature Iterations= 0
Number Of Pipes= 8
Number Of Junctions= 9
Matrix Method= Gaussian Elimination

Pressure/Head Tolerance= 0.0001 relative change
Flow Rate Tolerance= 0.0001 relative change
Temperature Tolerance= 0.0001 relative change
Flow Relaxation= (Automatic)
Pressure Relaxation= (Automatic)

Constant Fluid Property Model
Fluid Database: AFT Standard
Fluid: Water at 1 atm
Max Fluid Temperature Data= 212 deg. F
Min Fluid Temperature Data= 32 deg. F
Temperature= 53 deg. F
Density= 62.40326 lbm/ft3
Viscosity= 3.03802 lbm/hr-ft
Vapor Pressure= 0.19133 psia
Viscosity Model= Newtonian

Atmospheric Pressure= 1 atm
Gravitational Acceleration= 1 g
Turbulent Flow Above Reynolds Number= 4000
Laminar Flow Below Reynolds Number= 2300

Overall Delta Head = -10.40 feet
Overall Friction Head Loss = 21.52 feet
Overall Delta Pressure = -5.643 psid
Overall Frictional Pressure Loss = 4.820 psid
Total Inflow= 359,654 gal/min
Total Outflow= 359,654 gal/min
Maximum Pressure is 19.07 psia at Junction 1 Outlet
Minimum Pressure is 10.11 psia at Junction 4 Inlet

Pump Summary

Jct	Name	Vol. Flow (ft3/sec)	Mass Flow (lbm/sec)	dP (psid)	dH (feet)	Overall Efficiency (Percent)	Speed (Percent)	Overall Power (hp)	BEP (gal/min)	% of BEP (Percent)
4	168" Wood Screw	801.3	50,004	4.820	11.12	100.0	100.0	1,011	N/A	N/A

Jct	NPSHA (feet)	NPSHR (feet)
4	23.32	N/A

Reservoir Summary

Output from AFT Fathom™ for 168” Wood Screw, Page 1

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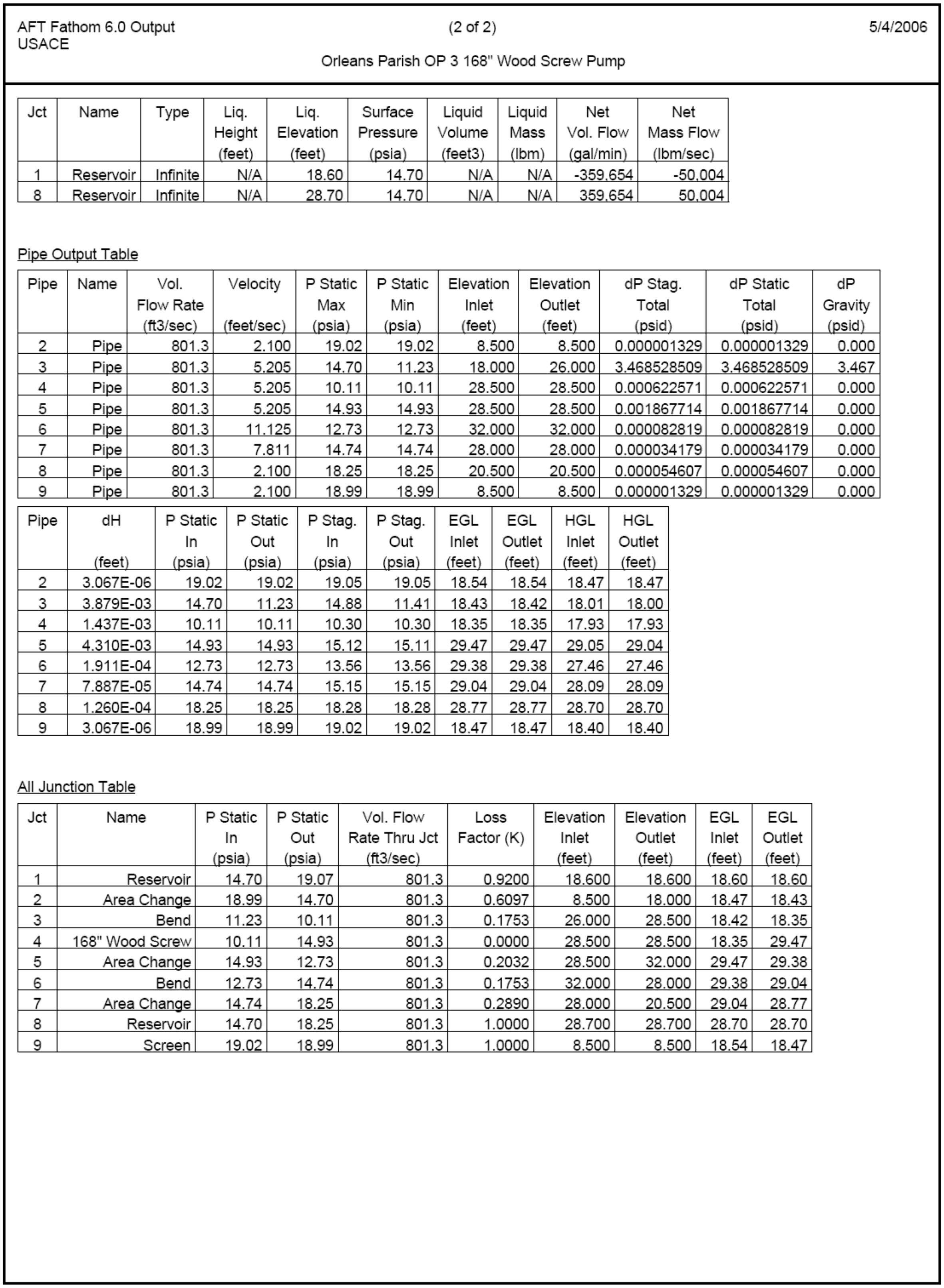

AFT Fathom 6.0 Output
USACE

(2 of 2)

5/4/2006

Orleans Parish OP 3 168" Wood Screw Pump

Jct	Name	Type	Liq. Height (feet)	Liq. Elevation (feet)	Surface Pressure (psia)	Liquid Volume (feet3)	Liquid Mass (lbm)	Net Vol. Flow (gal/min)	Net Mass Flow (lbm/sec)
1	Reservoir	Infinite	N/A	18.60	14.70	N/A	N/A	-359,654	-50,004
8	Reservoir	Infinite	N/A	28.70	14.70	N/A	N/A	359,654	50,004

Pipe Output Table

Pipe	Name	Vol. Flow Rate (ft3/sec)	Velocity (feet/sec)	P Static Max (psia)	P Static Min (psia)	Elevation Inlet (feet)	Elevation Outlet (feet)	dP Stag. Total (psid)	dP Static Total (psid)	dP Gravity (psid)
2	Pipe	801.3	2.100	19.02	19.02	8.500	8.500	0.000001329	0.000001329	0.000
3	Pipe	801.3	5.205	14.70	11.23	18.000	26.000	3.468528509	3.468528509	3.467
4	Pipe	801.3	5.205	10.11	10.11	28.500	28.500	0.000622571	0.000622571	0.000
5	Pipe	801.3	5.205	14.93	14.93	28.500	28.500	0.001867714	0.001867714	0.000
6	Pipe	801.3	11.125	12.73	12.73	32.000	32.000	0.000082819	0.000082819	0.000
7	Pipe	801.3	7.811	14.74	14.74	28.000	28.000	0.000034179	0.000034179	0.000
8	Pipe	801.3	2.100	18.25	18.25	20.500	20.500	0.000054607	0.000054607	0.000
9	Pipe	801.3	2.100	18.99	18.99	8.500	8.500	0.000001329	0.000001329	0.000

Pipe	dH (feet)	P Static In (psia)	P Static Out (psia)	P Stag. In (psia)	P Stag. Out (psia)	EGL Inlet (feet)	EGL Outlet (feet)	HGL Inlet (feet)	HGL Outlet (feet)
2	3.067E-06	19.02	19.02	19.05	19.05	18.54	18.54	18.47	18.47
3	3.879E-03	14.70	11.23	14.88	11.41	18.43	18.42	18.01	18.00
4	1.437E-03	10.11	10.11	10.30	10.30	18.35	18.35	17.93	17.93
5	4.310E-03	14.93	14.93	15.12	15.11	29.47	29.47	29.05	29.04
6	1.911E-04	12.73	12.73	13.56	13.56	29.38	29.38	27.46	27.46
7	7.887E-05	14.74	14.74	15.15	15.15	29.04	29.04	28.09	28.09
8	1.260E-04	18.25	18.25	18.28	18.28	28.77	28.77	28.70	28.70
9	3.067E-06	18.99	18.99	19.02	19.02	18.47	18.47	18.40	18.40

All Junction Table

Jct	Name	P Static In (psia)	P Static Out (psia)	Vol. Flow Rate Thru Jct (ft3/sec)	Loss Factor (K)	Elevation Inlet (feet)	Elevation Outlet (feet)	EGL Inlet (feet)	EGL Outlet (feet)
1	Reservoir	14.70	19.07	801.3	0.9200	18.600	18.600	18.60	18.60
2	Area Change	18.99	14.70	801.3	0.6097	8.500	18.000	18.47	18.43
3	Bend	11.23	10.11	801.3	0.1753	26.000	28.500	18.42	18.35
4	168" Wood Screw	10.11	14.93	801.3	0.0000	28.500	28.500	18.35	29.47
5	Area Change	14.93	12.73	801.3	0.2032	28.500	32.000	29.47	29.38
6	Bend	12.73	14.74	801.3	0.1753	32.000	28.000	29.38	29.04
7	Area Change	14.74	18.25	801.3	0.2890	28.000	20.500	29.04	28.77
8	Reservoir	14.70	18.25	801.3	1.0000	28.700	28.700	28.70	28.70
9	Screen	19.02	18.99	801.3	1.0000	8.500	8.500	18.54	18.47

Output from AFT Fathom™ for 168" Wood Screw, Page 2

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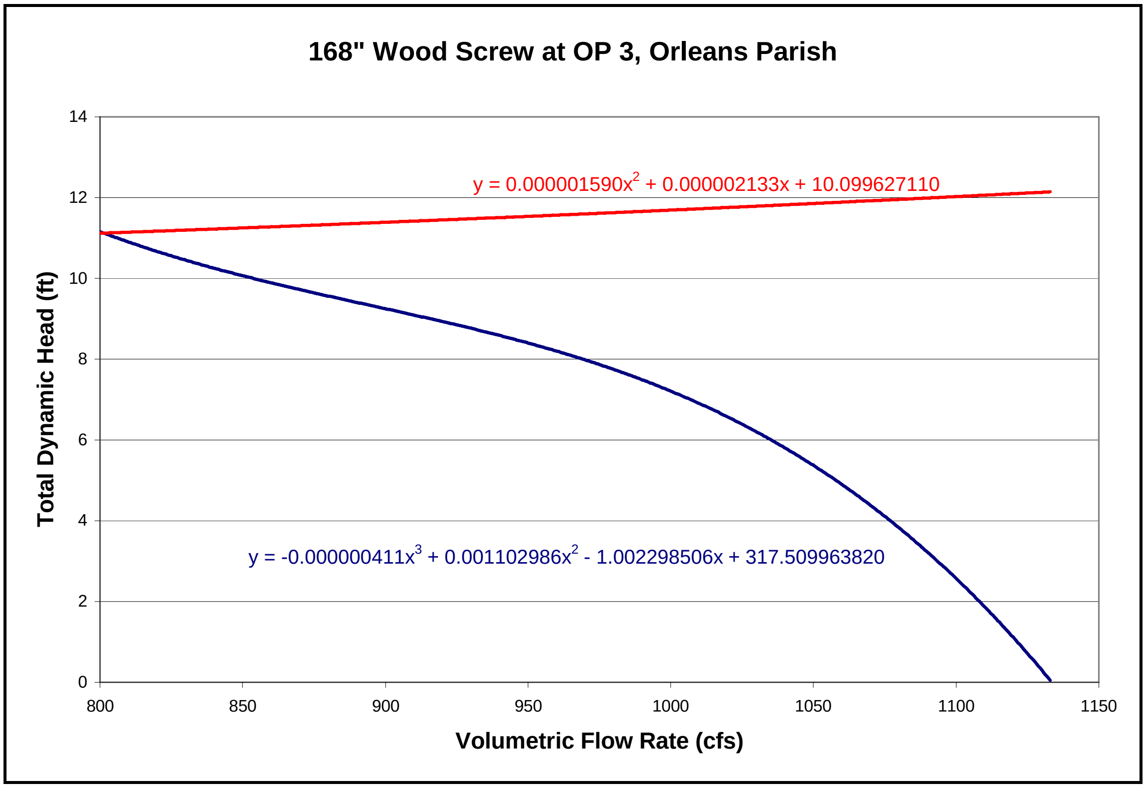
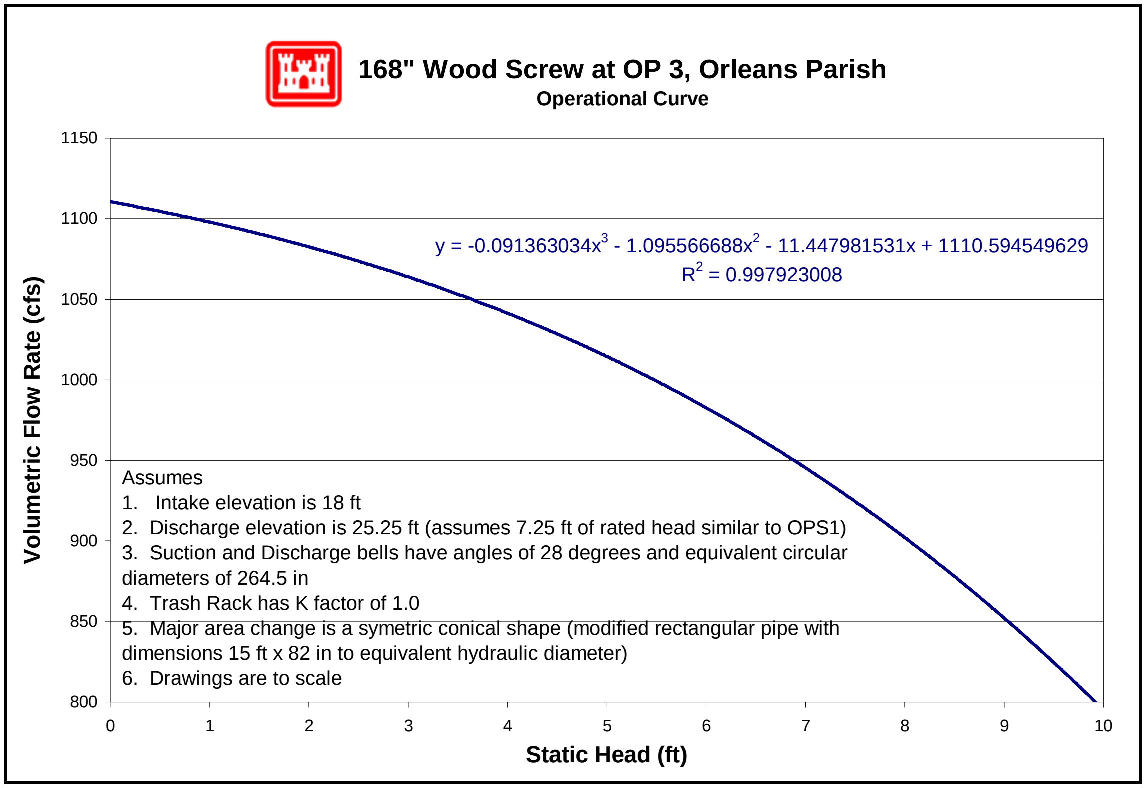


System Curve of 168” Wood Screw Pump at OP 3



Assumes

1. Intake elevation is 18 ft
2. Discharge elevation is 25.25 ft (assumes 7.25 ft of rated head similar to OPS1)
3. Suction and Discharge bells have angles of 28 degrees and equivalent circular diameters of 264.5 in
4. Trash Rack has K factor of 1.0
5. Major area change is a symetric conical shape (modified rectangular pipe with dimensions 15 ft x 82 in to equivalent hydraulic diameter)
6. Drawings are to scale

Curve for 168” Wood Screw Pump at OP 3

7.6.2.1.3.7 Pump Reverse Flow

There are nine pumps at this station for which reverse flow rating curves were computed (no pumps were excluded). The reverse flow data and curves are presented in the order of the pump numbering utilized in the summary tables included in this appendix. In cases where there are multiple pumps of equivalent size and system configuration, a single rating curve represents all of them at a unit rate per pump. Although CD1, CD2, CD3, CD4 have different system configurations, variations in higher flow estimates (drainage area water levels as low as 4 ft.) are within about 10% and a single rating curve (CD2) can be used to represent all of this pump station's lower discharge pumps. Of these four pumps, CD1 will have the highest reverse flow rates and CD4 will have the lowest.

Pump No.	Pump Capacity (cfs)	Pump Size (in)	Reverse Flow Computed?		Rating Curve Ref. No.
			Yes	No	
A	590	144	X		1
B	590	144	X		1
C	1000	168	X		2
D	1000	168	X		2
E	1000	168	X		2
CD1	80	?	X		3
CD2	?	?	X		3
CD3	?	?	X		3
CD4	80	?	X		3

For a general explanation of reverse flow (terminology, figures, methodology, equations and assumptions), refer to the Reverse Flow Section at the beginning of this appendix. Reverse flow computations for a given pump station do not necessarily imply that reverse flow actually occurred there during the Katrina event. But these curves may instead be used as future tools if further investigations are required based on reverse flow assumptions.

1. Reverse Flow Rating Curve

#3 Pump Station, Pumps A & B -144-in.

Elevation Datum (ft): Cairo

Crest Elevation (ft) = 23.3197

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level

(H1) and the drainage area water level (H2):

For primed flow rates: *Use Q = sqrt((H1-H2)/K')*

K' = *1.31981E-05* *sec^2/ft^5*

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 23.3 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 33.8 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

H2 =	2.0	4.0	6.0	8.0	10.0	12.0	14.0
H1 >	378	356	335	313	291	270	248

Water elevation (H1) that stops unprimed flow: 23.3 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

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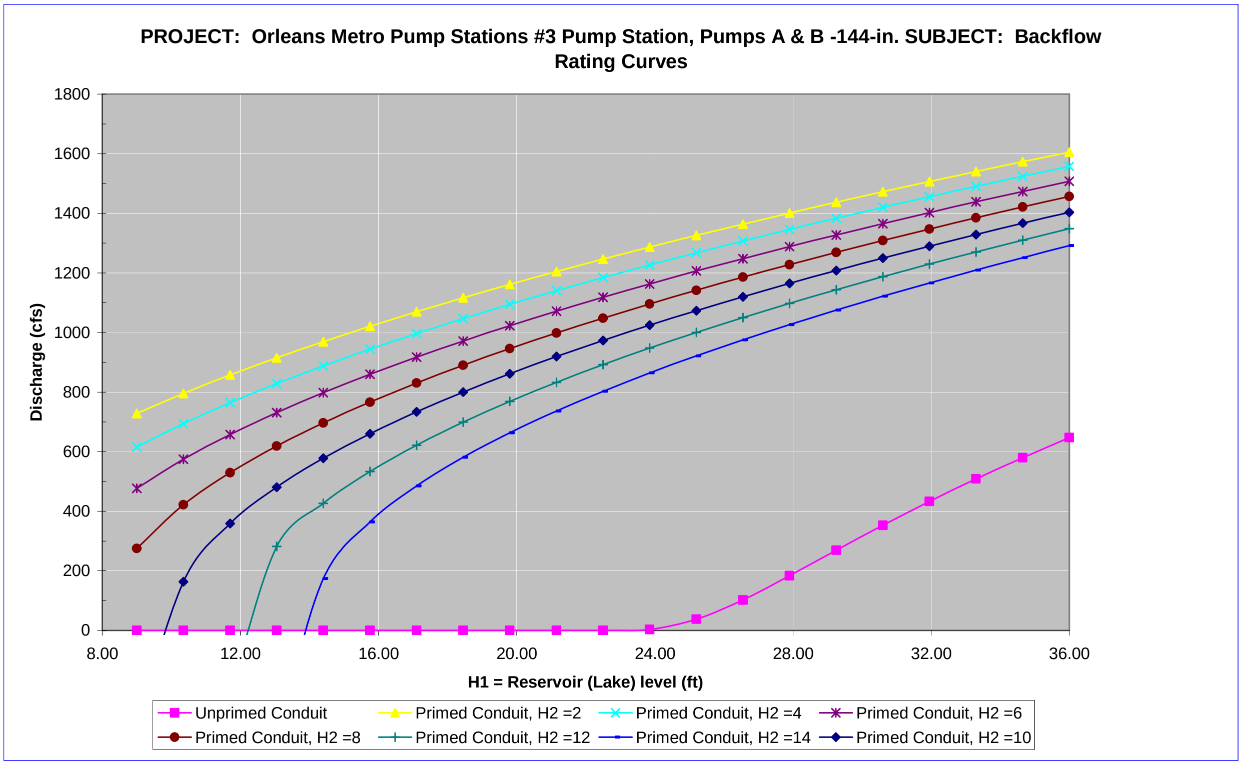
Water elevation (H1) that stops primed conduit flow: 18.4 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient = 9.00
Intake loss = 0.92
Expansion & Exit Loss = 0.55
Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Assume that 1916 drawings apply to A & B.

Assume that A & B have the same design.

Assume that although the first bend is in a different plane than the second, this does not matter due to the pump between the bends.

All pipes are circular.

Elevations in Cairo Datum

Drawings are to scale

0.1 coefficient for all contractions, Expansion and exit loss in incorporated into single term tied to C3.

4 Data Needs or Deficiencies:

Verify that dimensions are as-built

5 Backflow prevention:

Available:	none
Used:	

2. Reverse Flow Rating Curve

#3 Pump Station, Pumps C, D, & E -168-in.

Elevation Datum (ft):	Cairo
Crest Elevation (ft) =	28.041

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: Use $Q = \sqrt{(H1-H2)/K'}$

$K' = 4.57448\text{E-}06 \quad sec^2/ft^5$

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

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Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 28.0 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 34.9 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

H2 =	8.0	11.0	14.0	17.0	20.0	23.0	26.0
H1 >	35	35	35	35	35	35	35

Water elevation (H1) that stops unprimed flow: 28.0 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 23.5 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.

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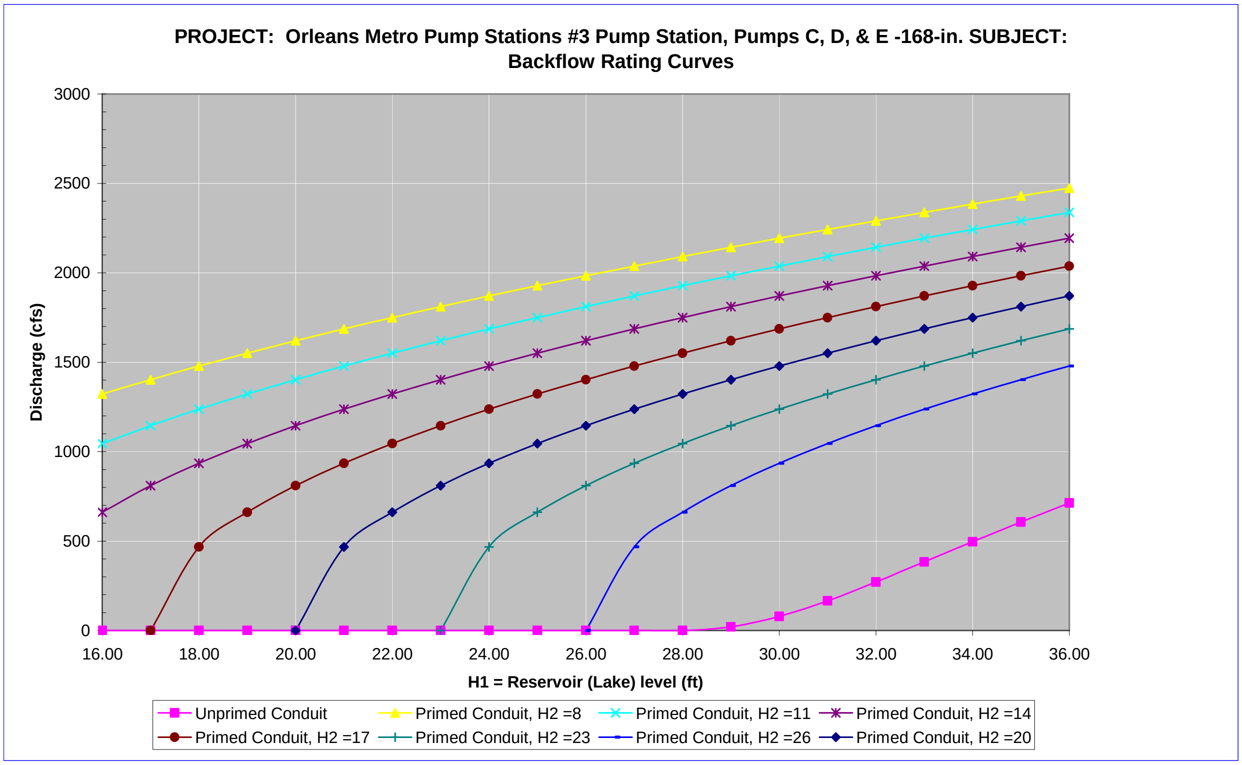

Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	3.50
Intake loss =	0.92
Expansion & Exit Loss =	0.48

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Assumed that Dwg No 114D (11th drawing for PS3) shows C,D,&E.

C,D,& E are the same

Drawings are to scale

Intake Pipes and Pump (P1, P2, C3) are circular

Discharge piping (C1, C2) are elliptical

4 Data Needs or Deficiencies:

Dimensions

5 Backflow prevention:

Available:

Used:

3. Reverse Flow Rating Curve

#3Pump Station, Pump CD1, CD2, CD3, CD4 - 30-in.

Elevation Datum (ft):	Cairo
Crest Elevation (ft) =	19.75

H1 = Lake or outlet canal water level (normal pump discharge side)
H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use Q = sqrt((H1-H2)/K')*
K' = *0.008664321* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 19.8 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated

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unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 21.8 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent. CD1							
H2 =	4.0	6.0	8.0	10.0	12.0	14.0	16.0
H1 >	75	69	63	57	51	45	39

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent. CD2							
H2 =	4.0	6.0	8.0	10.0	12.0	14.0	16.0
H1 >	43	41	38	36	34	31	29

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent. CD3							
H2 =	4.0	6.0	8.0	10.0	12.0	14.0	16.0
H1 >	36	35	33	31	30	28	26

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent. CD4							
H2 =	4.0	6.0	8.0	10.0	12.0	14.0	16.0
H1 >	35	33	32	31	29	28	26

Water elevation (H1) that stops unprimed flow: 19.8 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 6.0 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.

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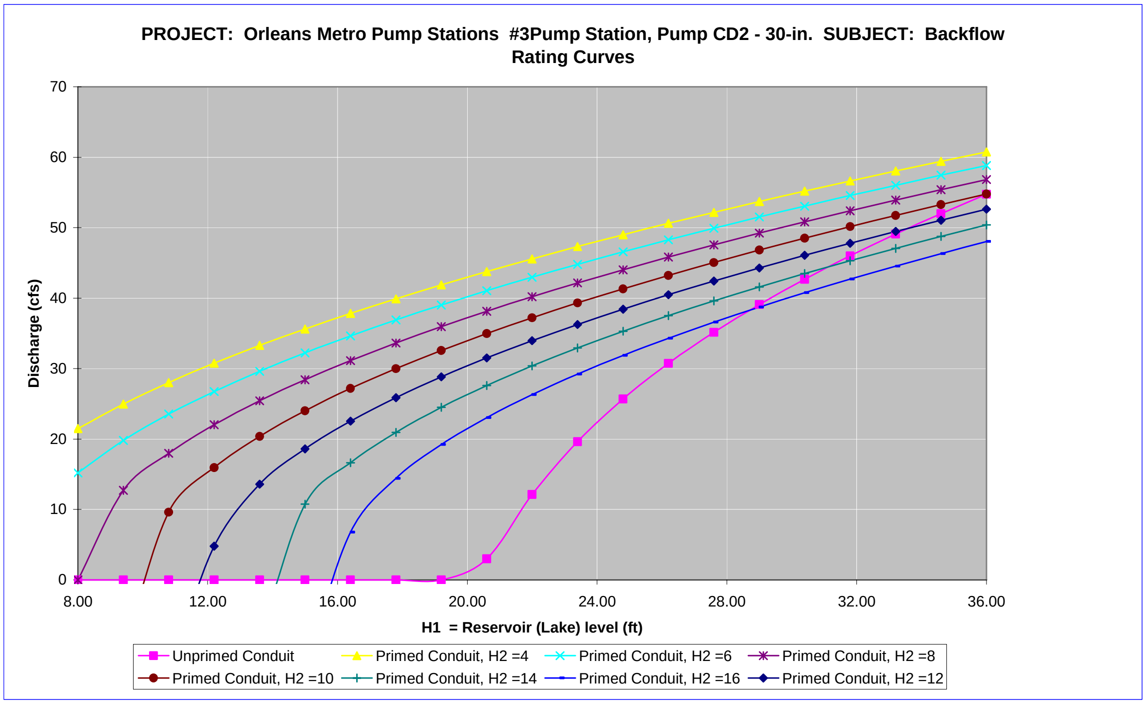

<u>Notes:</u> **<u>CD1</u>**

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	3.50
Intake loss =	0.92
Expansion & Exit Loss =	0.43

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Elevations and head assumed to be similar to pumps A & B.

All pipes are circular and constant diameter.

4 x 40 cfs pumps. Single discharge pipe serves 4 pumps: total discharge pipe area divided by 4 for single pump analyses.

Expansion at outlet similar to CD at PS2.

4 Data Needs or Deficiencies:

Drawings, dimensions, and elevations

Rated head

5 Backflow prevention:

Available:	No backflow prevention Brakes installed to prevent reverse rotation.
Used:	Operator unsure if reverse flow occurred.

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Notes: **CD2**

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	3.50
Intake loss =	0.92
Expansion & Exit Loss =	0.43

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Elevations and head assumed to be similar to pumps A & B.

All pipes are circular and constant diameter

4 x 40 cfs pumps. Single discharge pipe serves 4 pumps:

total discharge pipe area divided by 4 for single pump analyses.

Expansion at outlet similar to CD at PS2.

4 Data Needs or Deficiencies:

Drawings, dimensions, and elevations

Rated head

5 Backflow prevention:

Available:	No backflow prevention Brakes installed to prevent reverse rotation.
Used:	Operator unsure if reverse flow occurred.

Notes: **CD3**

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	6.50
Intake loss =	0.92
Expansion & Exit Loss =	0.43

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Elevations and head assumed to be similar to pumps A & B.

All pipes are circular and constant diameter

4 x 40 cfs pumps. Single discharge pipe serves 4 pumps:

total discharge pipe area divided by 4 for single pump analyses.

Expansion at outlet similar to CD at PS2.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

4 Data Needs or Deficiencies:

Drawings, dimensions, and elevations

Rated head

5 Backflow prevention:

Available: No backflow prevention

Brakes installed to prevent reverse rotation.

Used: Operator unsure if reverse flow occurred.

<u>Notes:</u> **<u>CD4</u>**

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	6.50
Intake loss =	0.92
Expansion & Exit Loss =	0.43

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Elevations and head assumed to be similar to pumps A & B.

All pipes are circular and constant diameter

4 x 40 cfs pumps. Single discharge pipe serves 4 pumps:

total discharge pipe area divided by 4 for single pump analyses.

Expansion at outlet similar to CD at PS2.

4 Data Needs or Deficiencies:

Drawings, dimensions, and elevations

Rated head

5 Backflow prevention:

Available: No backflow prevention

Brakes installed to prevent reverse rotation.

Used: Operator unsure if reverse flow occurred.

7.6.2.1.3.8 Fuel Endurance Calculations

We do not have any record of pumps that run on fuel at this pump station.

7.6.2.1.4 *OP 4*

Orleans Parish – East Bank Drainage Basin

2251 N. Broad Ave.
New Orleans, LA 70119

Latitude: 30.016164˚ Longitude: -90.06959˚

7.6.2.1.4.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Before Hurricane Katrina: Aerial view of the pump station

After Hurricane Katrina: View from the discharge

After Hurricane Katrina: Aerial view of the pump station

7.6.2.1.4.2 Description[172]

Drainage area:	New Orleans East Bank
Nominal Capacity:	3720 cfs
Drains water from:	Prentiss Ave. and St. Anthony
Discharges water to:	London Ave. Canal
Owner:	New Orleans Sewerage and Water Board
Number of pumps:	6
Pump orientation:	3 horizontal 2 centrifugal 1 vertical
Pump driver:	2 electric 60 Hz motors 4 electric 25 Hz motors
Water level to switch pumps on:	10.5 feet (NGVD)
Water level to switch pumps off:	8.5 feet (NGVD)
Water level that affects operation:	5.6 feet (NGVD). Water would damage electrical control panels.
Reverse flow protection:	None

7.6.2.1.4.3 Damages

Estimated cost of repairs:	The estimated cost of repairs is not yet available.[173]
Relative level of damage:	Substantial
Severity of circumstances:	Flooding occurred approximately 12 inches above the operating floor and 9 inches above the control room floor.
Equipment damaged:	Wiring in the basement needs replacing and the inboard bearings for pumps C, D, and E will need replacing too. The motors for the trash racks will require rewinding and the gear boxes replaced.
Building damage:	The metal roof needs to be repaired. The flooring in the control room needs replacing.

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[172] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[173] The Project Information Report (PIR) for each parish provides an estimated cost of repairs for the parish's pump stations. At the time this report was written, the Orleans Parish PIR was not yet complete. It should be available through the parish shortly after publication of the IPET Report.

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Misc. damage: The gate and fence need to be replaced.

7.6.2.1.4.4 Katrina Event

Date	Time	Event
8/28/2005	-	The interview sheet states that all the pumps were available prior to the hurricane.
8/28/2005	4:13 AM	The operational log shows that pumping began with pumps 1 and 2 and continued a little less than 2 hours.
8/29/2005	3:01 AM	The operational log indicates a loss of 60 Hz power.
	3:05 AM	The operational log indicates that the 60 Hz power was back online.
	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	7:30 AM	Estimated time of West and East Canal breaches.
	9:45 AM	The operational log indicates a loss of water pressure. The operators stopped all the pumps, closed the flood gates, and left the station.
	-	The interview form states that the station was flooded to 3 feet above the main slab outside where the equipment is located.
9/19/2005	-	The interview form states that the operators returned to the station. Water levels were back to normal upon their arrival.
10/3/2005	10:40 AM	The operational log indicates that the operators received an order to cease pumping until further notice (no logs were acquired beyond this date).

7.6.2.1.4.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.2.1.4.6 Pump Operational Curves

Operational curves have been developed for OP 4. They are not included in this report at this time, but will be inserted in the future.

7.6.2.1.4.7 Pump Reverse Flow

There are six pumps at this station for which reverse flow rating curves were computed (no pumps were excluded). The reverse flow data and curves are presented in the order of the pump numbering utilized in the summary tables included in this appendix. In cases where there are multiple pumps of equivalent size and system configuration, a single rating curve represents all of them at a unit rate per pump.

Pump No.	Pump Capacity (cfs)	Pump Size (in)	Reverse Flow Computed?		Rating Curve Ref. No.
			Yes	No	
1	300	84	X		1
2	300	84	X		1
C	1000	126	X		2
D	1000	126	X		2
E	1000	126	X		2
CD1	80	30	X		3

For a general explanation of reverse flow (terminology, figures, methodology, equations and assumptions), refer to the Reverse Flow Section at the beginning of this appendix. Reverse flow computations for a given pump station do not necessarily imply that reverse flow actually

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occurred there during the Katrina event. But these curves may instead be used as future tools if further investigations are required based on reverse flow assumptions.

5. Reverse Flow Rating Curve

#4 Pump Station, Pumps 1 & 2 -84-in.

Elevation Datum (ft):	Cairo
Crest Elevation (ft) =	26.5

H1 = Lake or outlet canal water level (normal pump discharge side)
H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: Use $Q = \mathrm{sqrt}((H1-H2)/K')$
$K' =$ 4.70967E-05 sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

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Water elevation (H1) that triggers unprimed flow: 26.5 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 33.5 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.							
H2 =	2.0	5.0	8.0	11.0	14.0	17.0	20.0
H1 >	44	43	42	41	40	39	38

Water elevation (H1) that stops unprimed flow: 26.5 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 20.0 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.

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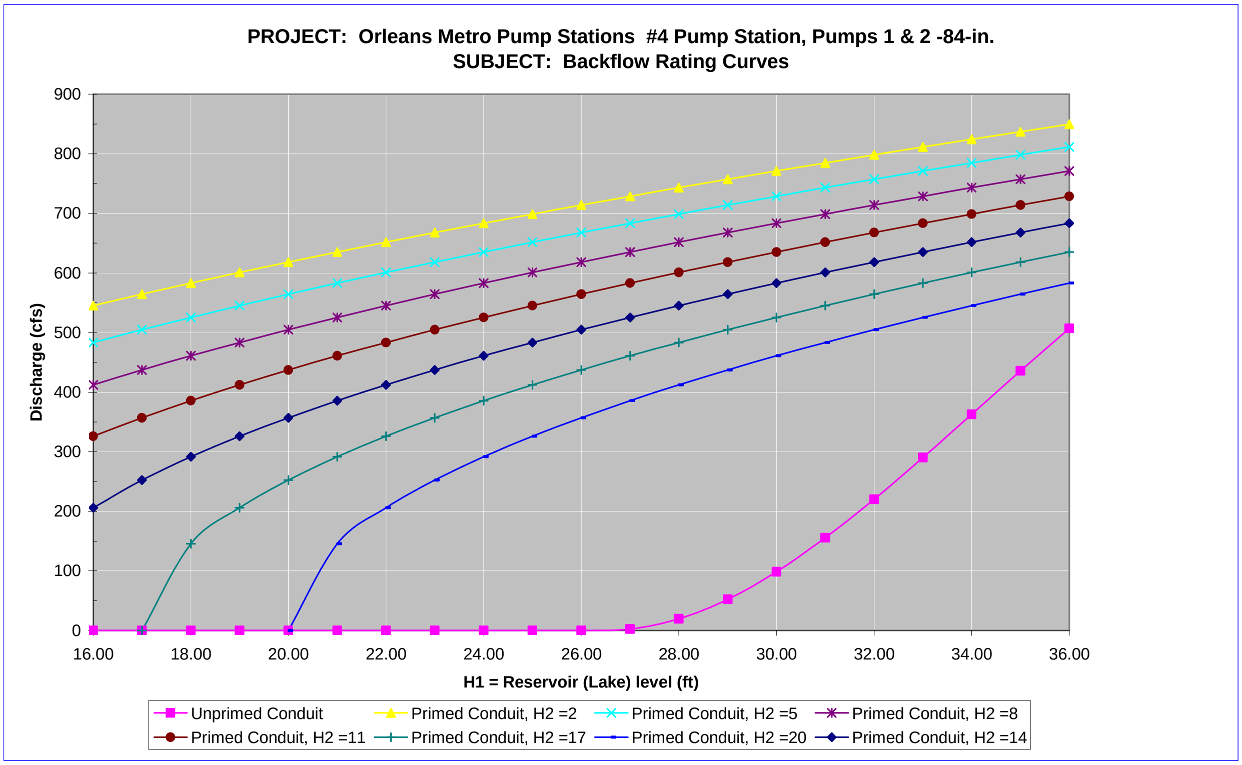

Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	3.50
Intake loss =	0.5
Expansion & Exit Loss =	0.43

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:
Used drawings labels "not used"
Pumps 1 & 2 are the same.
Drawings are to scale
Did not include contraction in pump

4 Data Needs or Deficiencies:
Verify if drawings are correct.

5 Backflow prevention:

Available:	No backflow prevention No brakes for reverse rotation.
Used:	Operator believed reverse flow occurred.

6. Reverse Flow Rating Curve

#4Pump Station, Pumps C, D, E -126-in.

Elevation Datum (ft): Cairo

Crest Elevation (ft) = 28.5

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use Q = sqrt((H1-H2)/K')*

K' = *1.39133E-05* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 28.5 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal

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reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 34.5 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

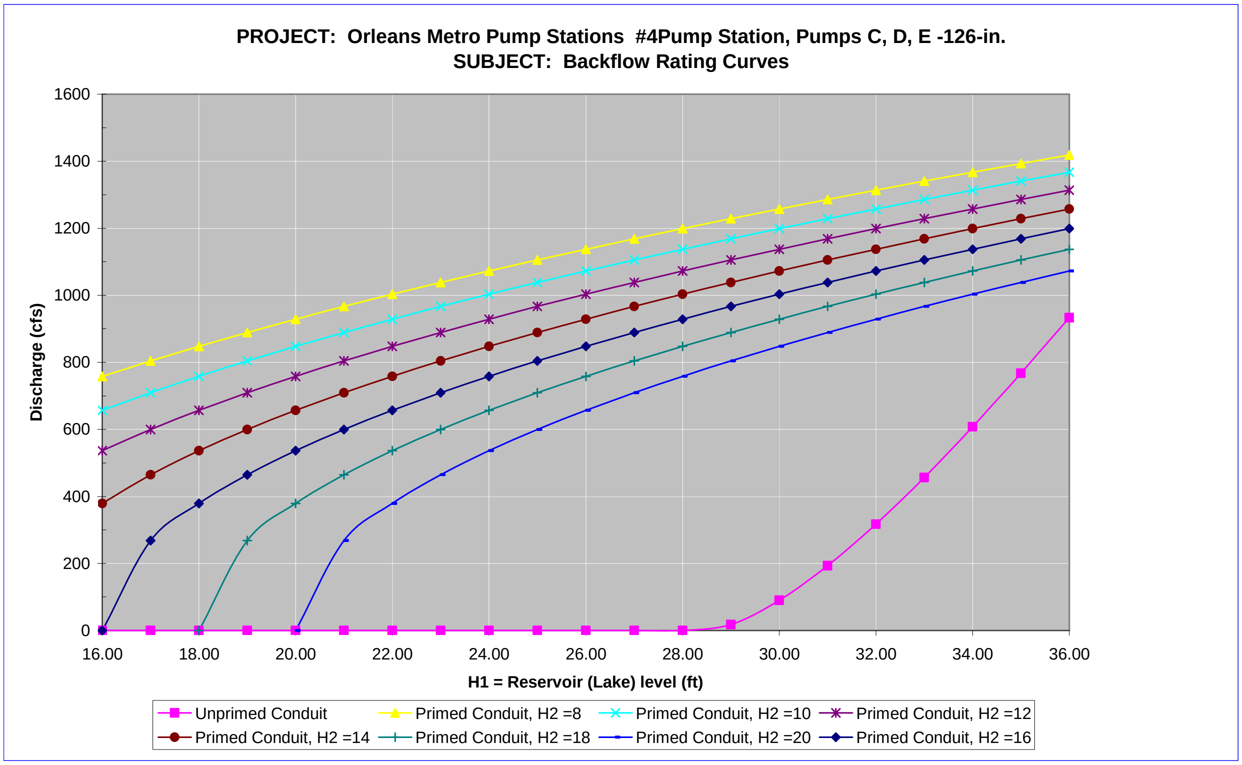
H2 =	8.0	10.0	12.0	14.0	16.0	18.0	20.0
H1 >	39	39	39	38	38	38	37

Water elevation (H1) that stops unprimed flow: 28.5 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 17.0 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	6.50
Intake loss =	0.5
Expansion & Exit Loss =	0.90

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Pumps C, D, and E have the same design.

Crest of discharge tube is rectangular and has same or greater area as cross section of pump.

Drawings are to scale

Used dimensions for swb_set1 41, however, this drawing shows a 14 ft pump. These are 10.5 ft.

swb_set 1 41 shows C,D, E

Discharge exit is rectangular

4 Data Needs or Deficiencies:

Dimensions for pipes and pump, as well as elevation view and plan drawings.

5 Backflow prevention:

Available:	No backflow prevention
Used:	Operator believed reverse flow occurred.

7. Reverse Flow Rating Curve

#4Pump Station, Pumps CD1- 30-in.

Elevation Datum (ft):	Cairo
Crest Elevation (ft) =	22.25

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level

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(H1) and the drainage area water level (H2):

For primed flow rates: *Use Q = sqrt((H1-H2)/K')*

K' = *0.004109065* *sec^2/ft^5*

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 22.3 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 24.8 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.							
H2 =	4.0	6.0	8.0	10.0	12.0	14.0	16.0
H1 >	41	40	38	37	35	33	32

Water elevation (H1) that stops unprimed flow: 22.3 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

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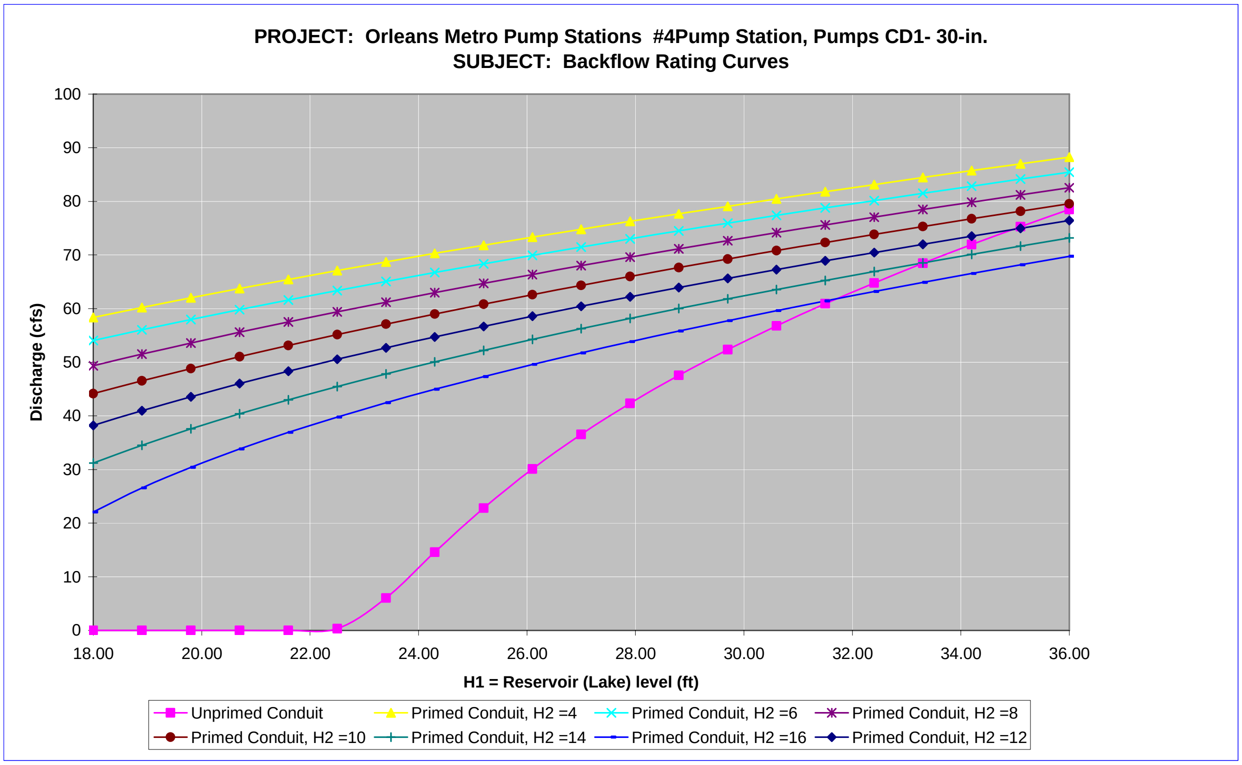
Water elevation (H1) that stops primed conduit flow: 11.0 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	3.50
Intake loss =	0.92
Expansion & Exit Loss =	0.43

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Elevations and head assumed to be similar to pumps C, D, & E.

All pipes are circular and constant diameter

No drawings, image from Google maps

Expansion at outlet similar to CD at PS2

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

4 Data Needs or Deficiencies:
Drawings, dimensions, and elevations
Rated head

5 Backflow prevention:

Available:	No backflow prevention. No brakes to prevent reverse rotation.
Used:	Operator believes reverse flow occurred.

8. Reverse Flow Rating Curve

#2 Pump Station, Pumps CD2 & CD3 - 42-in.

Elevation Datum (ft):	Cairo
Crest Elevation (ft) =	34.5

H1 = Lake or outlet canal water level (normal pump discharge side)
H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use* $Q = \mathrm{sqrt}((H1-H2)/K')$

$K' =$ *0.00168028* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1)

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 34.5 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 37.5 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

H2 =	2.0	4.0	6.0	8.0	10.0	12.0	14.0
H1 >	317	301	285	269	254	238	222

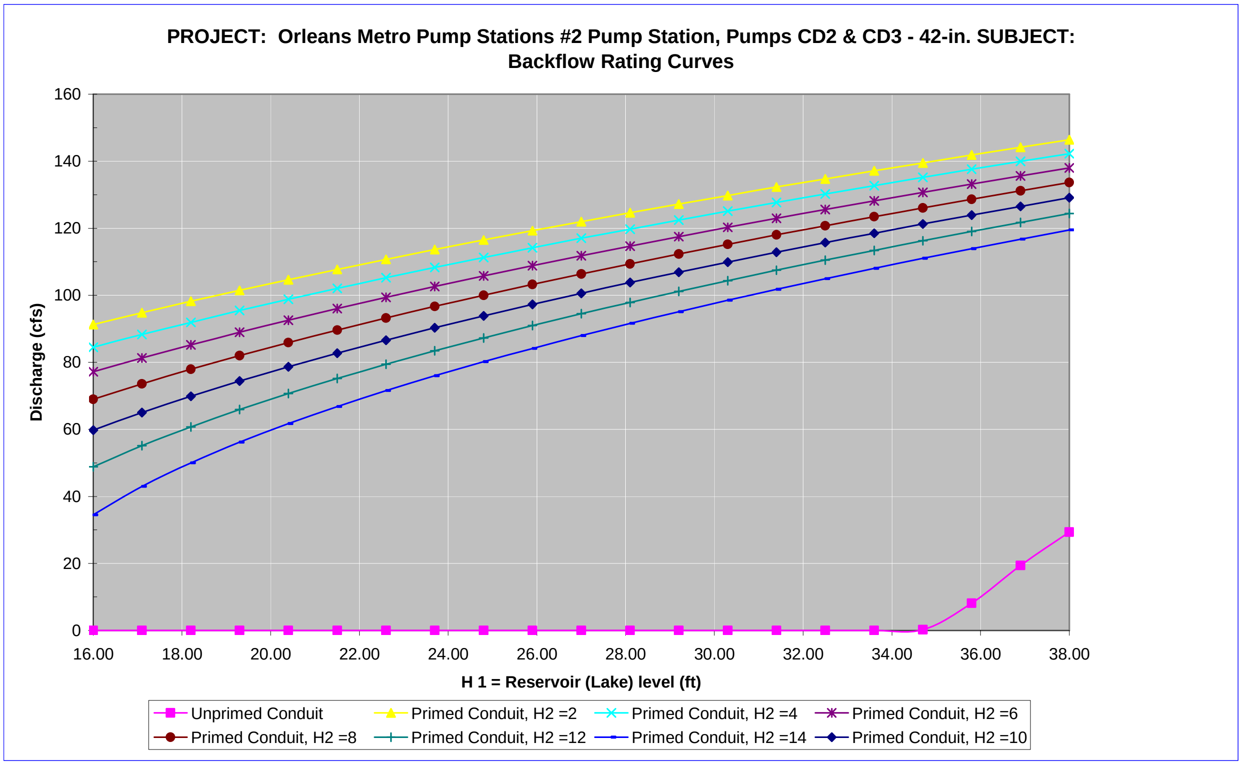
Water elevation (H1) that stops unprimed flow: 34.5 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 28.1 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	4.50
Intake loss =	0.92
Expansion & Exit Loss =	0.43

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:
Head of 4ft
Cd 2 and 3 share the same design
Drawings to scale
Free rotating impeller Wood Screw pump

4 Data Needs or Deficiencies:
Rated head

5 Backflow prevention:

Available:	No backflow prevention
Used:	Survey states reverse flow did not occur. No reverse rotation mechanism

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.2.1.4.8 Fuel Endurance Calculations

We do not have any record of pumps that run on fuel at this pump station.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.2.1.5 *OP 6*

Orleans Parish – East Bank Drainage Basin

345 Orphum Ave.
Metairie, LA 70005

Latitude: 29.98668˚ Longitude: -90.12510˚

7.6.2.1.5.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Before Hurricane Katrina: Aerial view of the pump station

After Hurricane Katrina: View from the discharge

After Hurricane Katrina: Aerial view of the pump station

7.6.2.1.5.2 Description[174]

Drainage area:	New Orleans East Bank
Nominal Capacity:	9480 cfs
Drains water from:	Palmetto Canal
Discharges water to:	17th Street Canal
Owner:	New Orleans Sewerage and Water Board
Number of pumps:	15
Pump orientation:	9 horizontal 6 vertical
Pump driver:	7 electric 25 Hz motors 8 electric 60 Hz motors
Water level to switch pumps on:	10 feet (NGVD)
Water level to switch pumps off:	8 feet (NGVD)
Water level that affects operation:	-6.2 feet (NGVD). Transformers are in basement
Reverse flow protection:	Automatic gate valves

7.6.2.1.5.3 Damages

Estimated cost of repairs:	The estimated cost of repairs is not yet available.[175]
Relative level of damage:	Substantial
Severity of circumstances:	Flood waters reached operating levels and damaged most of the electrical equipment
Equipment damaged:	Pump motors C, D, E, and F were flooded need rewinding repairs. Motors for pumps A and B are currently being rewound by the SWB. Inboard bearings for pumps G, H, and I require replacement
Building damage:	Roof damage requires repair.

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[174] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[175] The Project Information Report (PIR) for each parish provides an estimated cost of repairs for the parish's pump stations. At the time this report was written, the Orleans Parish PIR was not yet complete. It should be available through the parish shortly after publication of the IPET Report.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Misc. damage:	Fence and gate damage require repair. The suction bay has a significant build up of silt and trash and will require clean-up.

7.6.2.1.5.4 Katrina Event

Date	Time	Event
8/28/2005	-	All the pumps were available except for the two constant duty pumps.
8/29/2005	4:00 AM	The operational log states that all of the pumps lost power.
	4:30 AM	The operational log states that the 60 cycle power was lost.
	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	9:00 AM	The operational log states that pumps B, D, G were back in service and pumping.
	9:30 AM	Estimated time of 17th Street Canal Breach
	6:10 PM	The operational log states that water was entering the basement, where the transformers are located. The operators stopped all the pumps and closed all the gates.
	6:20 PM	The operational log states that that all the power was turned off.
	-	Flooding reached 2 feet above the second floor (including the basement) of the station.
8/30/2005	9:45 AM	The operational log states that Station 1 was ordered to stop pumping.
	-	The operational log states that operations were suspended and the employees were awaiting rescue.
	10:00 AM	The operational log indicates that the employees were rescued or left sometime after 10 am.
9/6/2005	11:29 AM	The operational log indicates that the employees returned to the station before 11:30 am.
	3:43 PM	The operational log states that Pump H began pumping.
	4:53 PM	The operational log states that pump H was loaded (pumping).
	5:45 PM	The operational log states that vertical pumps 1, 2, and 4 were loaded (pumping).
9/7/2005	-	The operational log states that vertical pumps 1, 2, and 4 along with pump I were used to pump out the water.
	-	The operational log states that BOH Brothers and Flowserve were working on the sluice gates and pumping out the motor pits.
9/8/2005	-	The operational log states that the pumping continued with vertical pumps 1, 2, and 4 and pump I.
	2:23 PM	The operational log states that pump H was loaded (pumping).
9/9/2005	8:15 AM	The operational log states power was lost for pumps H, I, and verticals pumps 1, 2, and 4.
	10:10 AM	The operational log states that the power was back online.
	4:43 PM	The operational log states that the power was lost at Pump Station 1.
9/10/2005	2:03 AM	The operational log states that the power was back on at Pump Station 1.
	2:08 AM	The operational log states that the power was lost at Pump Station 1.
	6:23 PM	The operational log states that the power was back at Pump Station 1.
9/11/2005	2:02 PM	The operational log states that the station was running a test for Entergy (local power company).
	3:26 PM	The operational log states that the 60 cycle power was back online.
9/15/2005	5:00 PM	The operational log states that pumps A and B were on fire.
	5:30 PM	The operational log states that the fires were extinguished.
9/16/2005	-	The interview form states that the canal levels were back to normal.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.2.1.5.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.2.1.5.6 Pump Operational Curves

Operational curves have been developed for OP 6. They are not included in this report at this time, but will be inserted in the future.

7.6.2.1.5.7 Pump Reverse Flow

No reverse flow curves were developed for this station since all pumps were reported to have gate valves closed during the non-operating period of the storm.

7.6.2.1.5.8 Fuel Endurance Calculations

We do not have any record of pumps that run on fuel at this pump station.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.2.1.6 *OP 7*

Orleans Parish – East Bank Drainage Basin

5741 Orleans Ave.
New Orleans, LA 70124

Latitude: 29.99430˚ Longitude: -90.10064˚

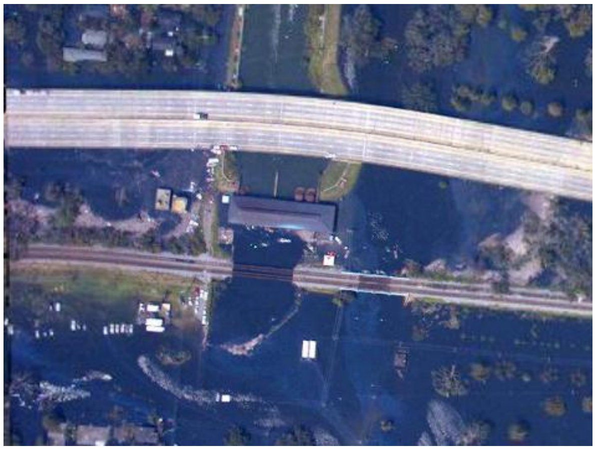
7.6.2.1.6.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Before Hurricane Katrina: Aerial view of the pump station

After Hurricane Katrina: View from the discharge



After Hurricane Katrina: Aerial view of the pump station

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.2.1.6.2 Description[176]

Drainage area:	New Orleans East Bank
Nominal Capacity:	2690 cfs
Drains water from:	OPS #2
Discharges water to:	Lake Canal
Owner:	New Orleans Sewerage and Water Board
Number of pumps:	5
Pump orientation:	3 horizontal 2 vertical
Pump driver:	4 electric 25 Hz motors 1 electric 60 Hz motors
Water level to switch pumps on:	Not Recorded
Water level to switch pumps off:	Not Recorded
Water level that affects operation:	-7.6 feet (NGVD). Transformers in basement
Reverse flow protection:	Gate valves for constant duty pumps

7.6.2.1.6.3 Damages

Estimated cost of repairs:	The estimated cost of repairs is not yet available.[177]
Relative level of damage:	Substantial
Severity of circumstances:	Flooding occurred 28 inches above the operating floor.
Equipment damaged:	Pump motors A and C require complete rewinding.
Building damage:	The station wall is cracked and the control room flooded and requires new paneling and flooring.
Misc. damage:	Some scouring is evident at the northwest corner of the stations. Fence is also damaged. Suction bay contains a significant amount of silt and trash and will require clean-up.

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[176] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[177] The Project Information Report (PIR) for each parish provides an estimated cost of repairs for the parish's pump stations. At the time this report was written, the Orleans Parish PIR was not yet complete. It should be available through the parish shortly after publication of the IPET Report.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.2.1.6.4 Katrina Event

Date	Time	Event
8/28/2005	-	All the pumps were available except constant duty pump 1.
8/29/2005	2:01 AM	The operational log states that the 60 Hz power was lost. Pump D lost power. Operators called the local power company, Entergy. (Pumps A & C continued to run on 25 Hz. power.)
	2:12 AM	The operational log states that the 60 Hz power was back online.
	2:25 AM	The operational log states that the 60 Hz transformer tripped. The operators reset the transformer, turning the 60 Hz power back on.
	2:50 AM	The operational log states that water was entering through the walls and running into the basement, where the transformers are located.
	4:24 AM	The operational log states that the 60 Hz power was lost. Operators called in the loss of power to Entergy.
	5:55 AM	The operational log states that the operators opened all transformers and turned off all the pumps.
	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	9:30 AM	Estimated time of 17th Street Canal Breach
	3:00 PM	The operational log states that water was 3 inches around the office. Operators appear to have left the station at this time.
9/13/2005	7:00 AM	The operational log indicates that the operators were back at the station.

7.6.2.1.6.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.2.1.6.6 Pump Operational Curves

Operational curves have been developed for OP 7. They are not included in this report at this time, but will be inserted in the future.

7.6.2.1.6.7 Pump Reverse Flow

There are seven pumps at this station for which reverse flow rating curves were computed (two pumps were excluded). Reverse flow rating curves were not computed for pumps CD1 and CD2 because the pumps had closed gate valves during the storm. The reverse flow data and curves are presented in the order of the pump numbering utilized in the summary tables included in this appendix. In cases where there are multiple pumps of equivalent size and system configuration, a single rating curve represents all of them at a unit rate per pump.

Pump No.	Pump Capacity (cfs)	Pump Size (in)	Reverse Flow Computed?		Rating Curve Ref. No.
			Yes	No	
A	550	144	X		1
C	1000	168	X		2
D	1000	168	X		3
4	?	42 (est.)	X		4
5	?	42 (est.)	X		4
6	?	42 (est.)	X		4
CD3	?	30 (est.)	X		5
CD1	70	30		X	
CD2	70	30		X	

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For a general explanation of reverse flow (terminology, figures, methodology, equations and assumptions), refer to the Reverse Flow Section at the beginning of this appendix. Reverse flow computations for a given pump station do not necessarily imply that reverse flow actually occurred there during the Katrina event. But these curves may instead be used as future tools if further investigations are required based on reverse flow assumptions.

4. Reverse Flow Rating Curve

#7 Pump Station, Pumps # A -144-in.

Elevation Datum (ft):	Cairo
Crest Elevation (ft) =	23.5

H1 = Lake or outlet canal water level (normal pump discharge side)
H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use* $Q = \mathrm{sqrt}((H1-H2)/K')$
$K' =$ *1.40207E-05* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the

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discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 23.5 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 36.1 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.							
H2 =	1.0	4.5	8.0	11.5	15.0	18.5	22.0
H1 >	176	162	148	134	120	106	92

Water elevation (H1) that stops unprimed flow: 23.5 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 26.3 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.

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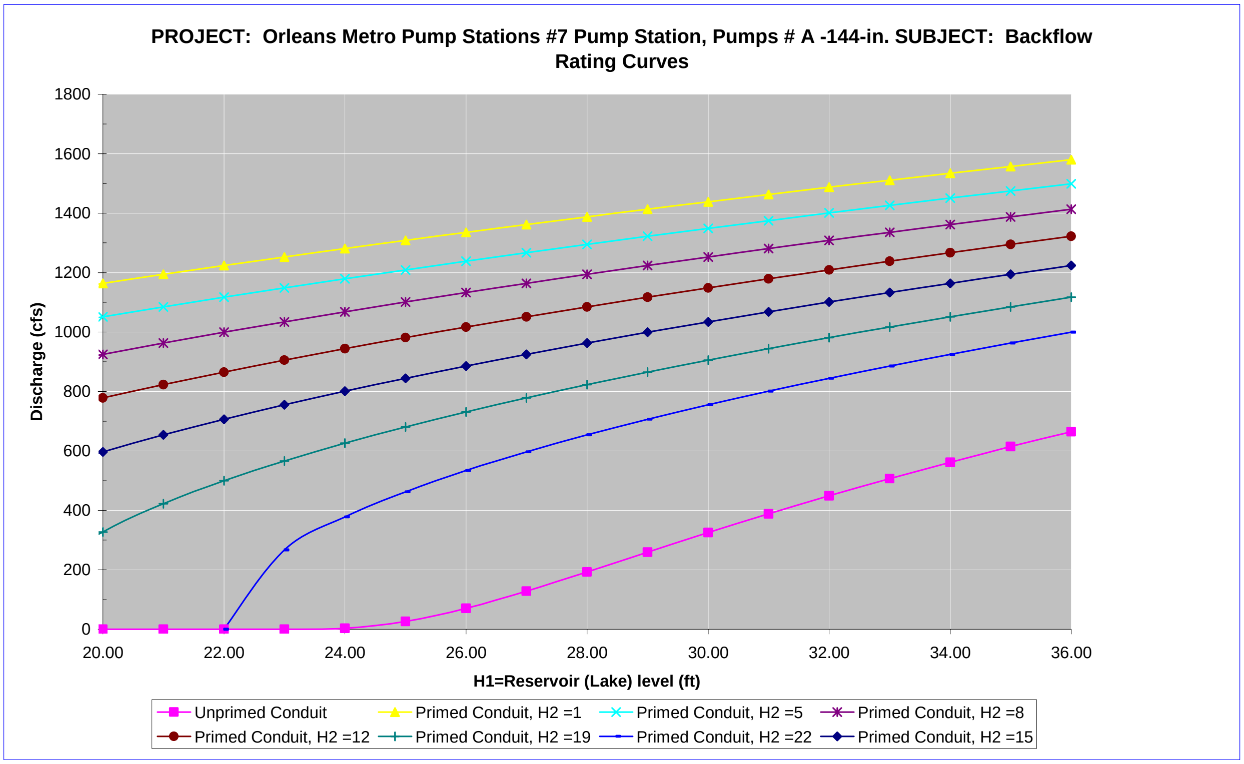

Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	9.00
Intake loss =	0.92
Exit Loss =	1.0

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Elevations in Cairo Datum

Rated head was taken from the pump curve.

All length measurements were center line lengths.

C2 & P2 were the same point. A distance of 0.25 ft was inputted into the table to avoid using 0.

4 Data Needs or Deficiencies:

None.

5 Backflow prevention:

Available:	No backflow prevention system.
Used:	Pump A has brakes.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

5. Reverse Flow Rating Curve

#7 Pump Station, Pump # C -168-in.

Elevation Datum (ft):	Cairo
Crest Elevation (ft) =	23.5

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use* $Q = \mathrm{sqrt}((H1-H2)/K')$

$K' =$ *6.8223E-06* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 23.5 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated

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unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 35.6 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

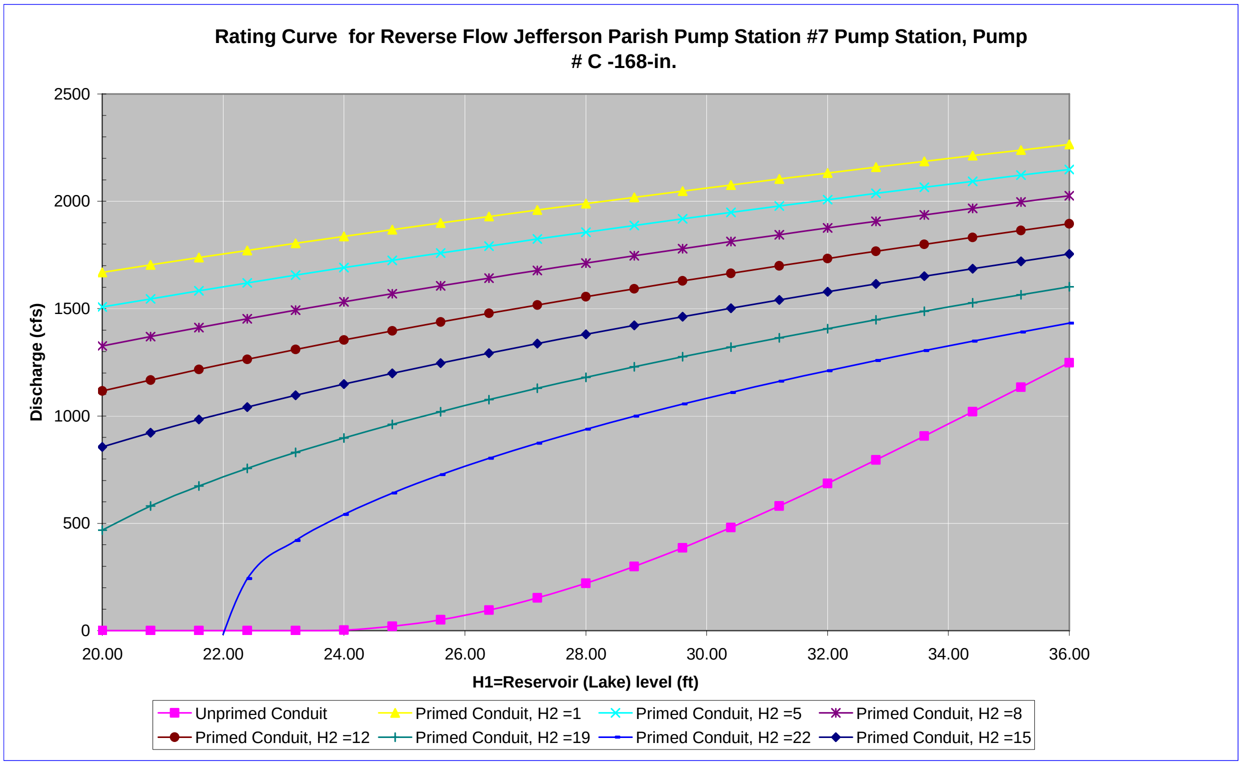
H2 =	1.0	4.5	8.0	11.5	15.0	18.5	22.0
H1 >	47	46	45	43	42	41	40

Water elevation (H1) that stops unprimed flow: 23.5 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 21.0 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.



This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	9.00
Intake loss =	0.92
Exit Loss =	1.0

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

No drawing of pump C. Assumed pump C was identical to pump A, only larger. Use drawing 5747-W9, Mar. 30, 1916 (swb_set2 31) & scaled up to larger pump.

Mar. 30, 1916 (swb_set2 31) & scaled up to larger pump.

Elevations in Cairo Datum

Pump flow rates are taken from survey data sheet. No rated head data was provided.

All length measurements were center line lengths.

C2 & P2 were the same point. A distance of 0.25 ft was inputted into the table to avoid using 0.

4 Data Needs or Deficiencies:

None.

5 Backflow prevention:

Available:	No backflow prevention system. Pump C has brakes for reverse rotation.
Used:	Pump C has brakes.

6. Reverse Flow Rating Curve

#7 Pump Station, Pump # D -168-in.

Elevation Datum (ft): Cairo

Crest Elevation (ft) = 23.5

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Siphon flow is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use $Q = sqrt((H1-H2)/K')$*
K' = *3.87357E-06* *sec^2/ft^5*

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 23.5 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 35.6 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.							
H2 =	1.0	4.5	8.0	11.5	15.0	18.5	22.0
H1 >	62	59	57	54	51	49	46

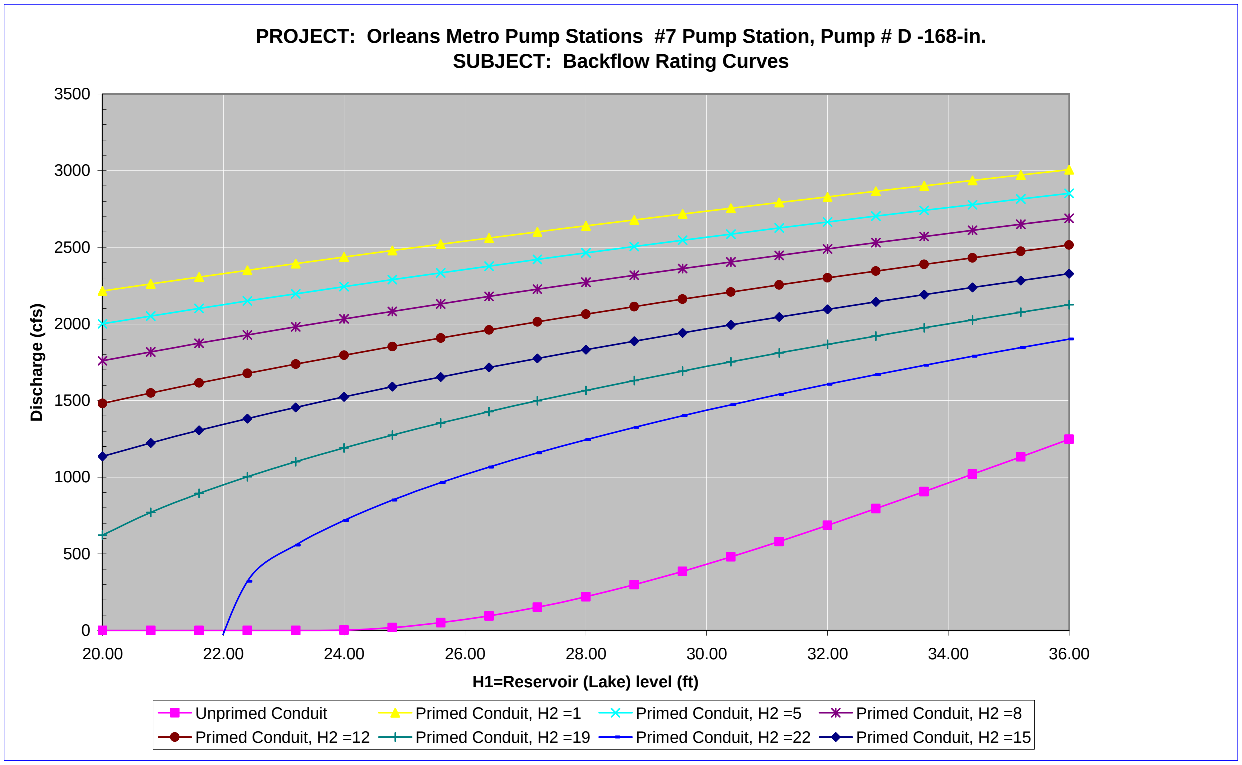
This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Water elevation (H1) that stops unprimed flow: 23.5 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 22.0 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient = 4.50

Intake loss = 0.92

Exit Loss = 1.0

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

No drawing of pump D. Assumed pump D was identical to pump A, only larger. Use drawing 5747-W9, Mar. 30, 1916 (swb_set2 31) & scaled up to larger pump.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Mar. 30, 1916 (swb_set2 31) & scaled up to larger pump.
Elevations in Cairo Datum

Pump flow rates are taken from survey data sheet. No rated head data was provided.
All length measurements were center line lengths.
C2 & P2 were the same point. A distance of 0.25 ft was inputted into the table to avoid using 0.

4 Data Needs or Deficiencies:
None.

5 Backflow prevention:
Available: No backflow prevention system.
Pump D does not have brakes.
Used:

7. Reverse Flow Rating Curve

#7 Pump Station, Pumps # 4, 5, & 6 - 42-in.

Elevation Datum (ft):	Cairo
Crest Elevation (ft) =	25.5

H1 = Lake or outlet canal water level (normal pump discharge side)
H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use* $Q = \mathrm{sqrt}((H1-H2)/K')$
$K' =$ *0.000867873* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 25.5 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 30.7 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

H2 =	1.0	4.5	8.0	11.5	15.0	18.5	22.0
H1 >	33	33	33	32	32	32	31

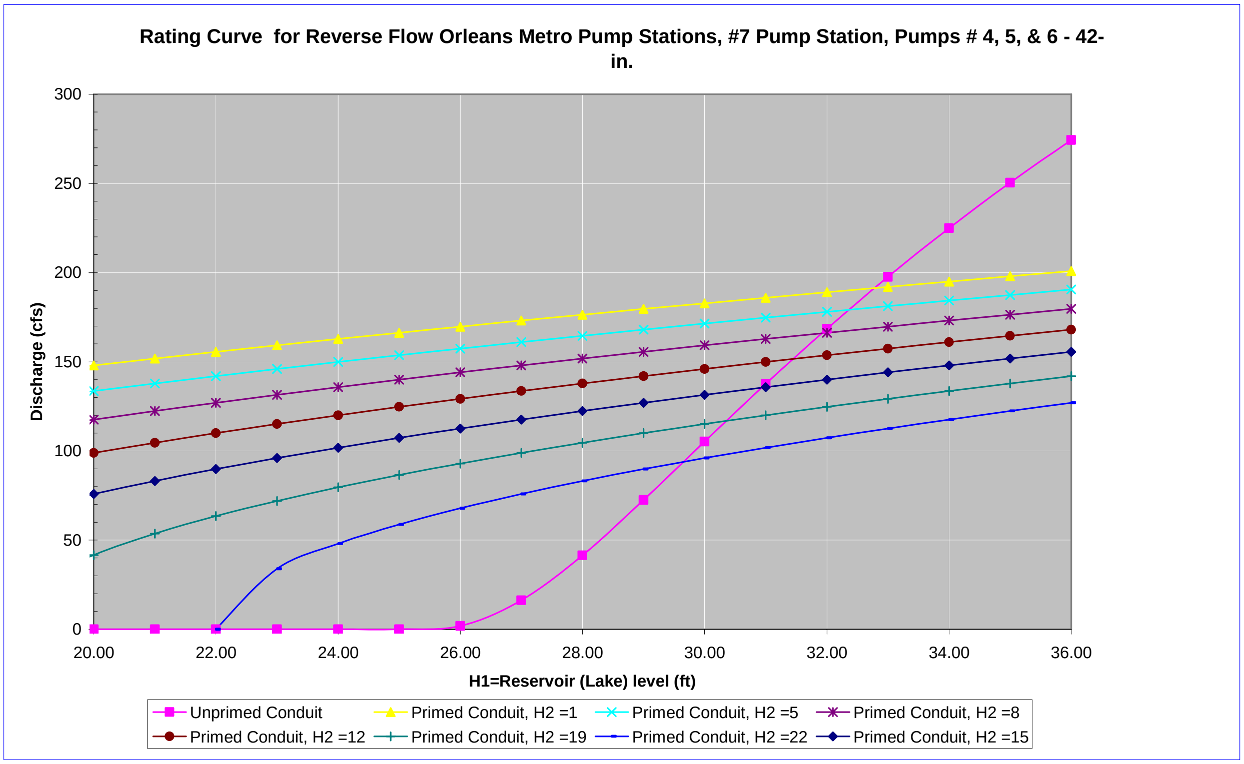
Water elevation (H1) that stops unprimed flow: 25.5 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 21.0 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	6.50
Intake loss =	0.92
Exit Loss =	1.3

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

No drawing of pumps 4, 5, & 6. Assumed pumps layout was identical to pump 1 - 4 at Pump Station #6, only smaller. Use drawing 11578-W-41, June 1985 (swb_set2 28) & 11563-W-41, May 31, 1985 (swb_set2 22) & scaled down to smaller pumps. PS #6 is the closest station to PS #7 with vertical pumps.

Elevations in Cairo Datum

All elevations were assumed to be the same as pumps A, C, & D.

All length measurements were center line lengths.

4 Data Needs or Deficiencies:

Drawings of pumps 4, 5, & 6.

5 Backflow prevention:

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Available:	Unknown. Assumed none or was not used. CD-1 & CD-2 had gate valves. Operators stated that there were no backflow through these pumps.
Used:	Unknown. Assumed none or was not used. CD-1 & CD-2 had gate valves. Operators stated that there were no backflow through these pumps.

8. Reverse Flow Rating Curve

#7 Pump Station, Pumps #CD 3 - 30-in.

Elevation Datum (ft):	Cairo
Crest Elevation (ft) =	25.5

H1 = Lake or outlet canal water level (normal pump discharge side)
H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use* $Q = \mathrm{sqrt}((H1-H2)/K')$
K' = *0.002905494* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger

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points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 25.5 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 29.7 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

H2 =	1.0	4.5	8.0	11.5	15.0	18.5	22.0
H1 >	32	31	31	31	31	30	30

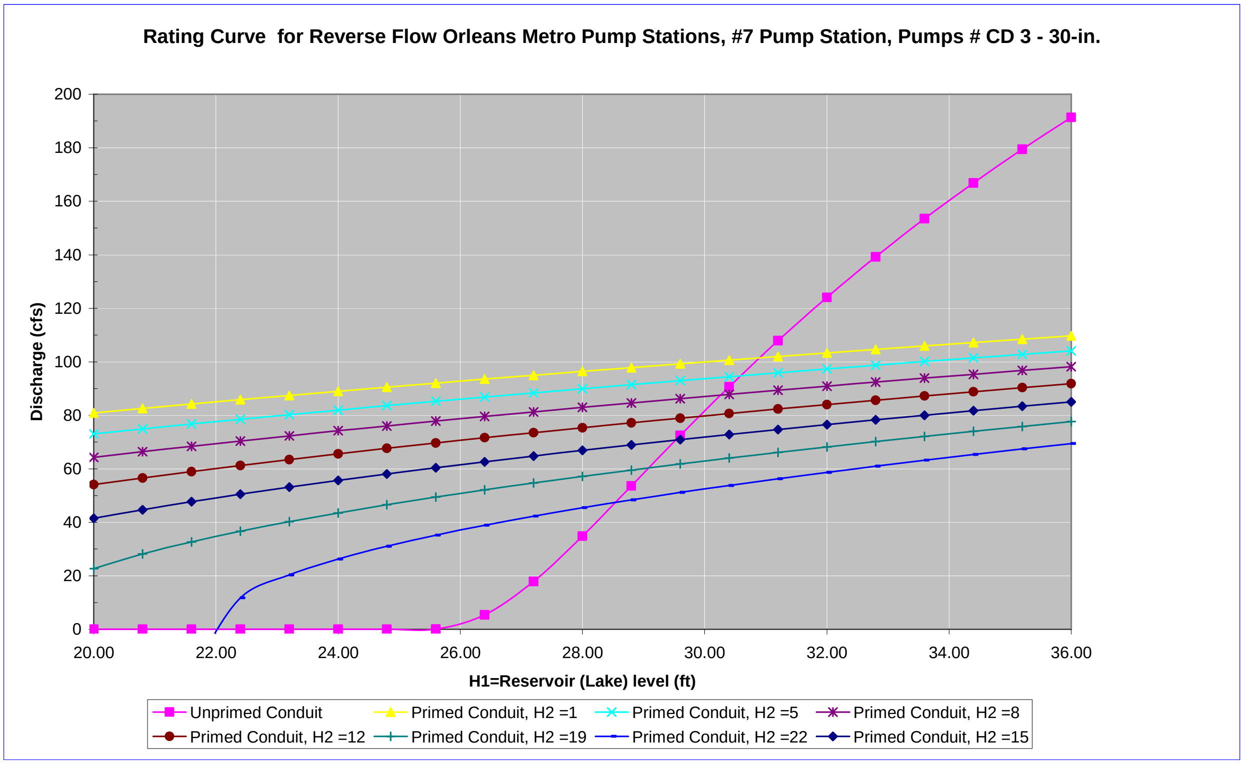
Water elevation (H1) that stops unprimed flow: 25.5 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 21.0 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	0.00
Intake loss =	0.92
Exit Loss =	1.3

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

No drawing of pump CD 3. Assumed pumps layout was identical to pump 1 - 4 at Pump Station #6, only smaller. Use drawing 11578-W-41, June 1985 (swb_set2 28) & 11563-W-41, May 31, 1985 (swb_set2 22) & scaled down to smaller pumps.

Elevations in Cairo Datum

All elevations were assumed to be the same as pumps A, C, & D.

All length measurements were center line lengths.

4 Data Needs or Deficiencies:

Drawings of pump CD 3.

5 Backflow prevention:

Available: Unknown. Assumed none or was not used.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Used: Unknown. Assumed none or was not used.

7.6.2.1.6.8 Fuel Endurance Calculations

We do not have any record of pumps that run on fuel at this pump station.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.2.1.7 *OP 12*

Orleans Parish – East Bank Drainage Basin

7223 Pontchartrain Blvd.
New Orleans, LA 70124

Latitude: 30.02049˚ Longitude: -90.11143˚

7.6.2.1.7.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Before Hurricane Katrina: Aerial view of the pump station

After Hurricane Katrina: View towards the discharge

After Hurricane Katrina: Aerial view of the pump station

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.2.1.7.2 Description[178]

Drainage area:	New Orleans East Bank
Nominal Capacity:	1000 cfs
Drains water from:	Robert E. Lee and Fluer De Lis
Discharges water to:	Lake Pontchartrain
Owner:	New Orleans Sewerage and Water Board
Number of pumps:	1
Pump orientation:	1 horizontal
Pump driver:	1 electric 25 Hz motor
Water level to switch pumps on:	11 feet (Cairo)
Water level to switch pumps off:	9.5 feet (Cairo)
Water level that affects operation:	4.6 feet (NGVD). Water would enter control room
Reverse flow protection:	Floodgate

7.6.2.1.7.3 Damages

Estimated cost of repairs:	The estimated cost of repairs is not yet available.[179]
Relative level of damage:	Substantial
Severity of circumstances:	Flooding occurred 25 inches above the operating floor, while peak levels were significantly higher. The floor level of the building is about 15 inches higher than the exterior slab on grade.
Equipment damaged:	Pump D needs to be inspected and repaired.
Building damage:	The floor, doors, and windows need replacement.
Misc. damage:	No significant miscellaneous damage recorded.

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[178] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[179] The Project Information Report (PIR) for each parish provides an estimated cost of repairs for the parish's pump stations. At the time this report was written, the Orleans Parish PIR was not yet complete. It should be available through the parish shortly after publication of the IPET Report.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.2.1.7.4 Katrina Event

Date	Time	Event
8/28/2005	-	The pump was available and pumping prior to the hurricane.
8/29/2005	5:47 AM	The operational log states that 60 Hz power was lost.
	6:30 AM	Hurricane Katrina made landfall in Louisiana
	6:54 AM	The operational log states that 25 Hz power was lost.
	9:30 AM	Estimated time of 17th Street Canal Breach
9/1/2005	3:05 AM	The operational log states that no 25 Hz or 60 Hz power was available. Water was about a foot high in the station. There was no running water.
9/3/2005	-	The operational log indicates this was the operators' the last day at station.
9/10/2005	7:00 AM	The operational log indicates that the employees were back at the station. The equipment was damaged.

7.6.2.1.7.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.2.1.7.6 Pump Operational Curves

Operational curves have been developed for OP 12. They are not included in this report at this time, but will be inserted in the future.

7.6.2.1.7.7 Pump Reverse Flow

No reverse flow curves were developed for this station since the pump was reported to have a closed gate valve during the non-operating period of the storm.

7.6.2.1.7.8 Fuel Endurance Calculations

We do not have any record of pumps that run on fuel at this pump station.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.2.1.8 *OP 17 (Station D)*

Orleans Parish – East Bank Drainage Basin

7200 Florida Ave.
New Orleans, LA 70125

Latitude: 29.98692˚ Longitude: -90.04520˚

7.6.2.1.8.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Before Hurricane Katrina: Aerial view of the pump station

After Hurricane Katrina: View from the discharge

After Hurricane Katrina: Aerial view of the pump station

7.6.2.1.8.2 Description[180]

Drainage area:	New Orleans East Bank
Nominal Capacity:	160 cfs
Drains water from:	Peoples and Florida Ave. Canals
Discharges water to:	Mississippi River
Owner:	New Orleans Sewerage and Water Board
Number of pumps:	4
Pump orientation:	4 centrifugal
Pump driver:	4 electric 60 Hz motors
Water level to switch pumps on:	8.5 feet (Cairo)
Water level to switch pumps off:	6.0 feet (Cairo)
Water level that affects operation:	5.0 feet (NGVD). Water would flood electric transformers and pumps.
Reverse flow protection:	Manually operated gate valves

7.6.2.1.8.3 Damages

Estimated cost of repairs:	The estimated cost of repairs is not yet available.[181]
Relative level of damage:	Substantial
Severity of circumstances:	Flooding occurred 2 ft. above the operating floor.
Equipment damaged:	The motors for drainage pumps A and D and four motors for frequency changes 3 and 4 were submerged and require rewinding. Medium voltage switchgear was flooded and requires replacement. The vacuum pump and ventilation fan unit was damaged and will require replacement too.
Building damage:	Three rollup doors were damaged and need to be replaced. The control room and restroom flooring and paneling were damaged and need to be replaced also.
Misc. damage:	48-inch discharge line was damaged near Claiborne Ave. and at the river, both will require repairs.

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[180] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[181] The Project Information Report (PIR) for each parish provides an estimated cost of repairs for the parish's pump stations. At the time this report was written, the Orleans Parish PIR was not yet complete. It should be available through the parish shortly after publication of the IPET Report.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.2.1.8.4 Katrina Event

Date	Time	Event
8/29/2005	6:00 AM	The interview form states that there was a loss of 60 Hz power.
	6:30 AM	Hurricane Katrina made landfall in Louisiana.
10/3/2005	-	The interview form states that the 60 Hz power was back online.

7.6.2.1.8.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.2.1.8.6 Pump Operational Curves

Operational curves have been developed for OP 17 (Station D). They are not included in this report at this time, but will be inserted in the future.

7.6.2.1.8.7 Pump Reverse Flow

No reverse flow curves were developed for this station since all pumps were reported to have closed gate valves during the non-operating period of the storm.

7.6.2.1.8.8 Fuel Endurance Calculations

We do not have any record of pumps that run on fuel at this pump station.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.2.1.9 *OP 19*

Orleans Parish – East Bank Drainage Basin

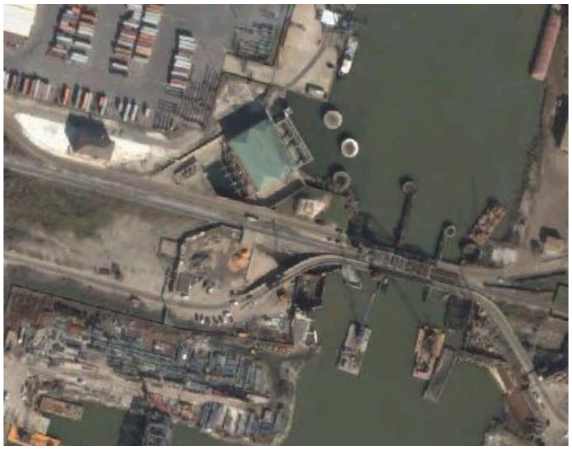
4500 Florida Ave.
New Orleans, LA 70117

Latitude: 29.98206˚ Longitude: -90.023347˚

7.6.2.1.9.1 Before and After Hurricane Katrina Photos

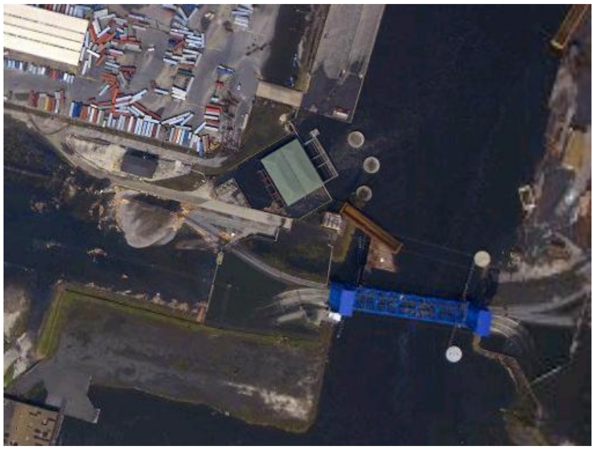
Photo Not Obtained

Before Hurricane Katrina



Before Hurricane Katrina: Aerial view of the pump station

After Hurricane Katrina: View of the station



After Hurricane Katrina: Aerial view of the pump station

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.2.1.9.2 Description[182]

Drainage area:	New Orleans East Bank
Nominal Capacity:	3920 cfs
Drains water from:	Florida Ave. Canal
Discharges water to:	Industrial Canal
Owner:	New Orleans Sewerage and Water Board
Number of pumps:	5
Pump orientation:	3 horizontal 2 vertical
Pump driver:	5 electric 60 Hz motors
Water level to switch pumps on:	8.5 feet (Cairo)
Water level to switch pumps off:	6.0 feet (Cairo)
Water level that affects operation:	13 (NGVD). Water would flood switch gear
Reverse flow protection:	Sluice gates

7.6.2.1.9.3 Damages

Estimated cost of repairs:	The estimated cost of repairs is not yet available.[183]
Relative level of damage:	Substantial
Severity of circumstances:	The station has three levels; ground level, second level, and the control level. Flood waters reached 18 inches above the ground level. Everything at that level will require replacement
Equipment damaged:	The sewer grinder pump and the sump pump require replacement. Pump bearing for vertical pumps 1 and 2 and horizontal pump 2 require replacement. Hydraulic oil system needs to be drained, tested and replaced. One ventilation fan is damaged along with pipe railing around the suction basin.
Building damage:	The roof is leaking.

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[182] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[183] The Project Information Report (PIR) for each parish provides an estimated cost of repairs for the parish's pump stations. At the time this report was written, the Orleans Parish PIR was not yet complete. It should be available through the parish shortly after publication of the IPET Report.

Misc. damage:	The fence needs to be repaired. Erosion around the building is evident requiring fill material and replacement of sidewalks, pavement and curb and gutter.

7.6.2.1.9.4 Katrina Event

Date	Time	Event
8/28/2005	11:26 AM	The station pumped with pumps H1, H2, and H3.
	-	The interview form states that the operators used the three horizontal pumps, as needed, to pump down the water. Pump 2 was down. The remaining 4 pumps were operational.
8/29/2005	4:05 AM	The operational log indicates that there was a loss of 60 Hz power. The station switched to the generator power.
	4:15 AM	The operational log indicates that the sluice gates were closed.
	4:33 AM	The operational log indicates that the sluice gates were opened and the pumping continued.
	6:00 AM	Estimated time of first signs of water coming from the Industrial Canal.
	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	-	Flooding reached 8 feet above the operating floor.
9/3/2005	-	The interview form states that the operators evacuated the station. It is assumed that the pumps were shut down.
9/13/2005	-	The interview form states that the operators returned to station and started pumping out the water.
9/15/2005	-	The interview form states that the water levels were back to their normal operating range.

7.6.2.1.9.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.2.1.9.6 Pump Operational Curves

Operational curves have been developed for Canal Street. They are not included in this report at this time, but will be inserted in the future.

7.6.2.1.9.7 Pump Reverse Flow

No reverse flow curves were developed for this station since all pumps were reported to have closed gate valves during the non-operating period of the storm.

7.6.2.1.9.8 Fuel Endurance Calculations

We do not have any record of pumps that run on fuel at this pump station.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.2.1.10 *OP I 10*

Orleans Parish – East Bank Drainage Basin

1 Academy Dr.
New Orleans, LA 70124

Latitude: 29.99193˚ Longitude: -90.11772˚

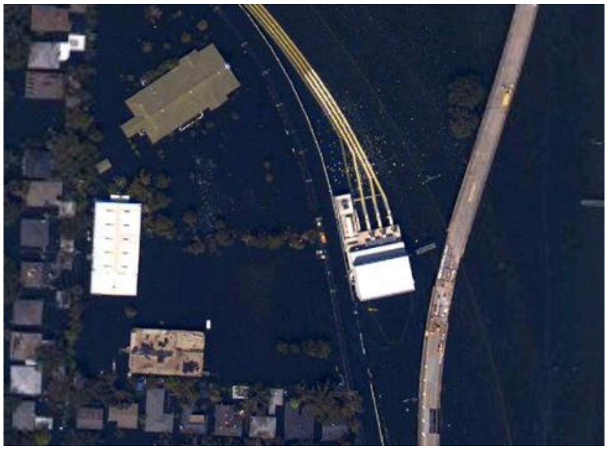
7.6.2.1.10.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Before Hurricane Katrina: Aerial view of the pump station

After Hurricane Katrina: View from the discharge



After Hurricane Katrina: Aerial view of the pump station

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.2.1.10.2 Description[184]

Drainage area:	New Orleans East Bank
Nominal Capacity:	850 cfs
Drains water from:	Not Available
Discharges water to:	17th Street Canal
Owner:	New Orleans Sewerage and Water Board
Number of pumps:	4
Pump orientation:	3 vertical 1 centrifugal
Pump driver:	4 electric 60 Hz motors
Water level to switch pumps on:	1.9 feet (Cairo)
Water level to switch pumps off:	-1.6 feet (Cairo)
Water level that affects operation:	16 feet (NGVD). Water would flood electric switch gear.
Reverse flow protection:	Check valves

7.6.2.1.10.3 Damages

Estimated cost of repairs:	The estimated cost of repairs is not yet available.[185]
Relative level of damage:	Substantial
Severity of circumstances:	Flood waters inundated the first floor; however, the operating flood was not flooded.
Equipment damaged:	Pumps 1, 2, and 3 require bearing replacement due to the raw water that was used to operate the pumps because clean water was not available during the storm. The waste oil system and the sump pump controls were also damaged along with the expansion joint of the 12-inch discharge line.
Building damage:	Consists of roof leaks, ceiling tiles, and doors.

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[184] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[185] The Project Information Report (PIR) for each parish provides an estimated cost of repairs for the parish's pump stations. At the time this report was written, the Orleans Parish PIR was not yet complete. It should be available through the parish shortly after publication of the IPET Report.

Misc. damage: Fence needs to be repaired.

7.6.2.1.10.4 Katrina Event

Date	Time	Event
8/28/2005	-	All the pumps were available prior to the hurricane.
	-	All the pumps were used for pre-Katrina drawdown.
8/29/2005	4:49 AM	The operational log states that there was a loss of 60 Hz power.
	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	-	The flood water reached 7 feet above the lower floor slab.
9/6/2005	-	The operation logs state that the station pumped until this day.

7.6.2.1.10.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.2.1.10.6 Pump Operational Curves

Operational curves have been developed for Canal Street. They are not included in this report at this time, but will be inserted in the future.

7.6.2.1.10.7 Pump Reverse Flow

No reverse flow curves were developed for this station since all pumps were reported to have closed gate valves during the non-operating period of the storm.

7.6.2.1.10.8 Fuel Endurance Calculations

We do not have any record of pumps that run on fuel at this pump station.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.2.1.11 *Prichard*

Orleans Parish – East Bank Drainage Basin

2901 Monticello Ave.
New Orleans, LA 70118

Latitude: 29.96846˚ Longitude: -90.12741˚

7.6.2.1.11.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Before Hurricane Katrina: Aerial view of the pump station

After Hurricane Katrina: View of the station

After Hurricane Katrina: Aerial view of the pump station

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.2.1.11.2 Description[186]

Drainage area:	New Orleans East Bank
Nominal Capacity:	250 cfs
Drains water from:	Carrollton Drainage
Discharges water to:	Monticello Canal
Owner:	New Orleans Sewerage and Water Board
Number of pumps:	3
Pump orientation:	3 vertical
Pump driver:	3 electric 60 Hz motors
Water level to switch pumps on:	10.5 feet (Cairo)
Water level to switch pumps off:	9 feet (Cairo)
Water level that affects operation:	7.6 feet (NGVD). Would flood electrical control panels
Reverse flow protection:	None

7.6.2.1.11.3 Damages

Estimated cost of repairs:	The estimated cost of repairs is not yet available.[187]
Relative level of damage:	Minor
Severity of circumstances:	The building was not flooded. Some wind and water damaged the generator muffler insulation and fuel line.
Equipment damaged:	Wind and water caused minor damage to the generator muffler insulation and fuel line.
Building damage:	Wind damaged the roof.
Misc. damage:	Some scour developed near the discharge line.

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[186] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[187] The Project Information Report (PIR) for each parish provides an estimated cost of repairs for the parish's pump stations. At the time this report was written, the Orleans Parish PIR was not yet complete. It should be available through the parish shortly after publication of the IPET Report.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.2.1.11.4 Katrina Event

Date	Time	Event
8/28/2005	-	Pumps are automatic and run on the preset levels.
8/29/2005	5:15 AM	The operational log states that 60 Hz power was lost.
	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	-	Operators were told to stop pumping because station 6 was shutting down.
9/16/2005	-	Operators returned to the station and the canal levels were back to normal operating levels. The station had no power.

7.6.2.1.11.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.2.1.11.6 Pump Operational Curves

Not enough data was available to analyze Prichard pump station within a reasonable accuracy.

7.6.2.1.11.7 Pump Reverse Flow

There are three pumps at this station for which reverse flow rating curves were computed (no pumps were excluded). The reverse flow data and curves are presented in the order of the pump numbering utilized in the summary tables included in this appendix. In cases where there are multiple pumps of equivalent size and system configuration, a single rating curve represents all of them at a unit rate per pump.

Pump No.	Pump Capacity (cfs)	Pump Size (in)	Reverse Flow Computed?		Rating Curve Ref. No.
			Yes	No	
1	125	48	X		1
2	125	48	X		1
CD1	?	8	X		2

For a general explanation of reverse flow (terminology, figures, methodology, equations and assumptions), refer to the Reverse Flow Section at the beginning of this appendix. Reverse flow computations for a given pump station do not necessarily imply that reverse flow actually occurred there during the Katrina event. But these curves may instead be used as future tools if further investigations are required based on reverse flow assumptions.

9. Reverse Flow Rating Curve

New Orleans Metro Pritchard Pump Station, Pumps 1, 2- 48in.

Elevation Datum (ft): Cairo

Crest Elevation (ft) = 20.66

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

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Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use* $Q = \mathrm{sqrt}((H1-H2)/K')$

K' = *0.000986426* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 20.7 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 24.7 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

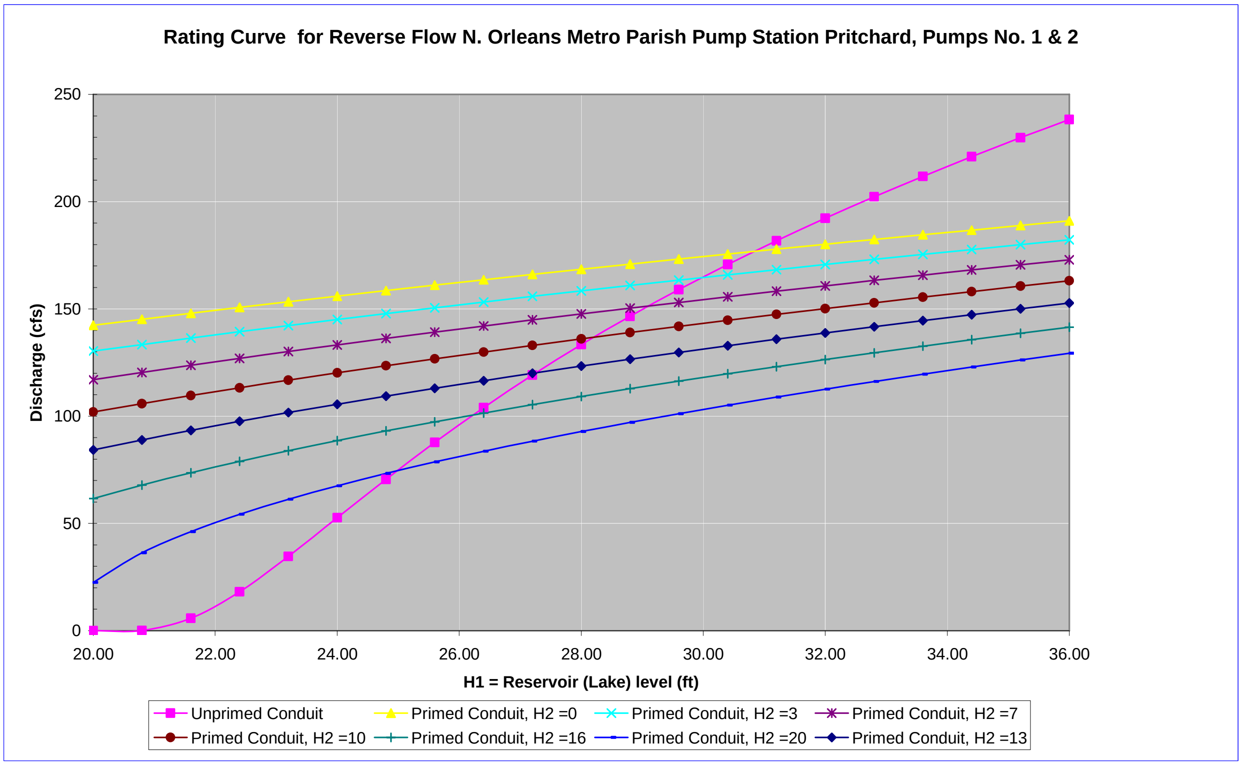
Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.							
H2 =	0.0	3.3	6.5	9.8	13.0	16.3	19.5
H1 >	31	30	29	28	28	27	26

Water elevation (H1) that stops unprimed flow: 20.7 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 20.1 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient = 6.50

Intake loss = 0.92

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Exit Loss = 1.0

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Station discharge piping lies atop a sheet pile wall and appears to be higher than the discharge canal banks.

Pump Station shares a suction basin with Monticello Pump Station located approximately 300 feet away.

4 Data Needs or Deficiencies:

None

5 Backflow prevention:

Available:	Backstops/brakes to prevent reverse rotation of impellers were in place. No gates or valves to prevent backflow.
Used:	Operator believed no reverse flow occurred; water did not enter the pump station.

10. Reverse Flow Rating Curve

New Orleans Metro Pritchard Pump Station, Pump CD1, 1- 48in.

Elevation Datum (ft):	Cairo
Crest Elevation (ft) =	22.33

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: $Q = \mathrm{sqrt}((H1-H2)/K')$ *Use*

$K' = 1.734491229 \quad sec^2/ft^5$

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:
Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:
The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 22.3 ft
Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 23.0 ft
Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

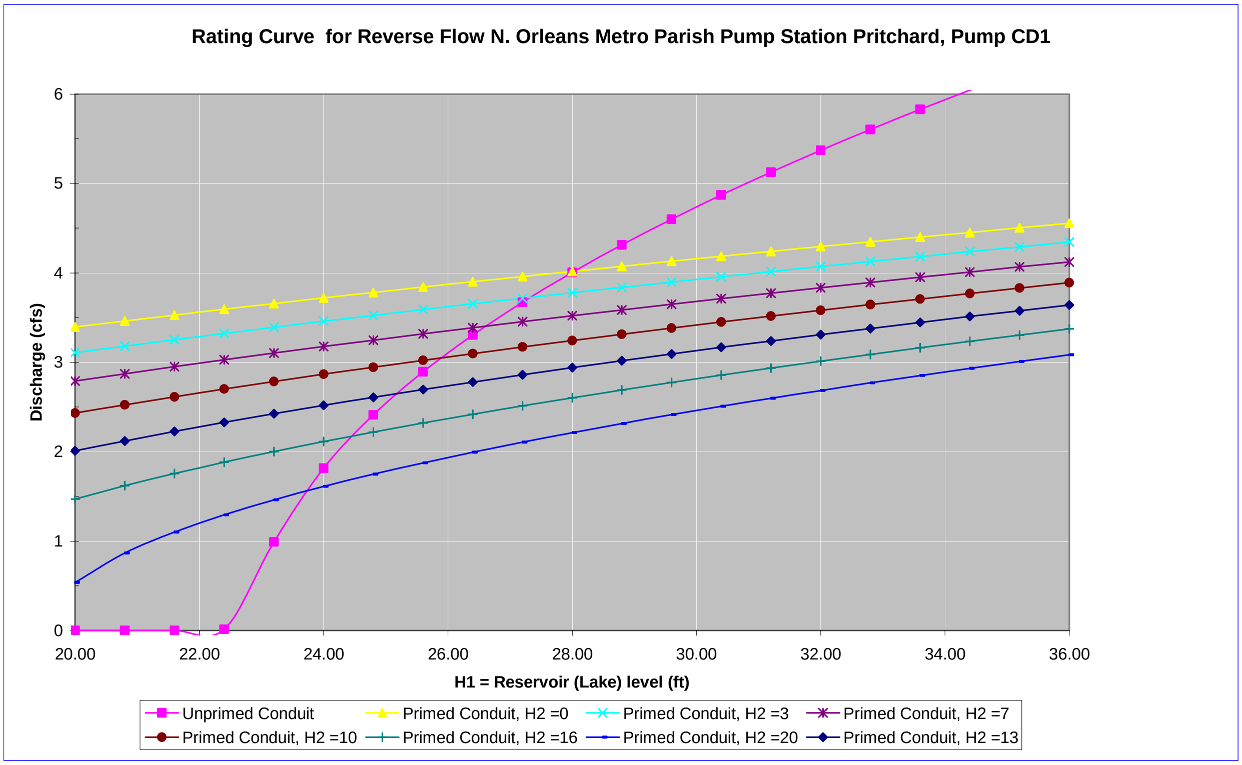
Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

H2 =	0.0	3.3	6.5	9.8	13.0	16.3	19.5
H1 >	28	27	27	26	25	24	24

Water elevation (H1) that stops unprimed flow: 22.3 ft
Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 20.1 ft
Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient = 6.50
Intake loss = 0.92
Exit Loss = 1.0
Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Pump Station shares a suction basin with Monticello Pump Station located approximately 300 feet away.

4 Data Needs or Deficiencies:

The capacity and rated head of pump CD1 are unavailable.

5 Backflow prevention:

Available: Backstops/brakes to prevent reverse rotation of impellers were in place.
No gates or valves to prevent backflow.

Used: Operator believed no reverse flow occurred; water did not enter the pump station.

7.6.2.1.11.8 Fuel Endurance Calculations

We do not have any record of pumps that run on fuel at this pump station.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.2.1.12 *Monticello (Upper Protection)*

Orleans Parish – East Bank Drainage Basin

9400 Oleander St.
New Orleans, LA 70118

Latitude: 29.97106˚ Longitude: -90.12607˚

7.6.2.1.12.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Before Hurricane Katrina: Aerial view of the pump station

After Hurricane Katrina: View of the station

After Hurricane Katrina: Aerial view of the pump station

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.2.1.12.2 Description[188]

Drainage area:	New Orleans East Bank
Nominal Capacity:	210 cfs
Drains water from:	Carrollton Drainage
Discharges water to:	Monticello Canal
Owner:	New Orleans Sewerage and Water Board
Number of pumps:	3
Pump orientation:	3 vertical
Pump driver:	3 electric 60 Hz motors
Water level to switch pumps on:	8.5 feet (Cairo)
Water level to switch pumps off:	7.0 feet (Cairo)
Water level that affects operation:	4.8 feet (NGVD). Electrical control panel and the motors would be flooded.
Reverse flow protection:	None

7.6.2.1.12.3 Damages

Estimated cost of repairs:	The estimated cost of repairs is not yet available.[189]
Relative level of damage:	Substantial
Severity of circumstances:	The building was not flooded; however, there was some minor wind damage.
Equipment damaged:	No substantial equipment damage was recorded.
Building damage:	Some ceramic ridge tiles need replacing.
Misc. damage:	No significant miscellaneous damage was recorded.

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[188] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[189] The Project Information Report (PIR) for each parish provides an estimated cost of repairs for the parish's pump stations. At the time this report was written, the Orleans Parish PIR was not yet complete. It should be available through the parish shortly after publication of the IPET Report.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.2.1.12.4 Katrina Event

Monticello		
Date	**Time**	**Event**
8/28/2005	-	Pumps are automatic and run on the preset levels.
8/29/2005	-	The operational log states that 60 Hz power was lost.
	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	-	Operators were told to stop pumping because station 6 was shutting down.
9/16/2005	-	Operators returned to the station and the canal levels were back to normal operating levels. The station had no power.

7.6.2.1.12.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.2.1.12.6 Pump Operational Curves

Operational curves have been developed for Monticello. They are not included in this report at this time, but will be inserted in the future.

7.6.2.1.12.7 Pump Reverse Flow

A reverse flow rating was computed for this station but is not presented since the discharge pipes cross over the top of the levee wall. Reverse flow becomes irrelevant if it only occurs when the levee is overtopped.

7.6.2.1.12.8 Fuel Endurance Calculations

We do not have any record of pumps that run on fuel at this pump station.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.2.2 Lower Ninth Ward

7.6.2.2.1 *OP 5*

Orleans Parish – Lower Ninth Ward Drainage Basin

4841 Florida Ave.
New Orleans, LA 70117

Latitude: 29.98020˚ Longitude: -90.019428˚

7.6.2.2.1.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Before Hurricane Katrina: Aerial view of the pump station

After Hurricane Katrina: View inside the station

After Hurricane Katrina: Aerial view of the pump station

7.6.2.2.1.2 Description[190]

Drainage area:	Lower Ninth Ward
Nominal Capacity:	1560 cfs
Drains water from:	Florida and Jourdan Ave. Canals
Discharges water to:	Lake Borgne
Owner:	New Orleans Sewerage and Water Board
Number of pumps:	7
Pump orientation:	3 horizontal 4 centrifugal
Pump driver:	7 electric 25 Hz motors
Water level to switch pumps on:	8 feet (NGVD)
Water level to switch pumps off:	5.4 feet (NGVD)
Water level that affects operation:	-5.0 (NGVD). Water would flood motors.
Reverse flow protection:	None

7.6.2.2.1.3 Damages

Estimated cost of repairs:	The estimated cost of repairs is not yet available.[191]
Relative level of damage:	Substantial
Severity of circumstances:	Flooding occurred 12 feet above the operating floor and 4 feet above the operating floor in the electrical equipment room.
Equipment damaged:	Motors A, B, and D need complete rewinding repairs. Pump D will also require the inboard bearings to be replaced. The entire fuel system needs replacing. Motor and gear boxes for the trash racks were also flooded and need replacing. The oil storage building was completely submerged and wood framed roof will require reconstruction along with fascia, soffits, and exterior lighting.

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[190] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[191] The Project Information Report (PIR) for each parish provides an estimated cost of repairs for the parish's pump stations. At the time this report was written, the Orleans Parish PIR was not yet complete. It should be available through the parish shortly after publication of the IPET Report.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Building damage:	The entire asphalt shingled roof was damaged and requires replacement along with the control room flooring, and the doors and windows.
Misc. damage:	All lighting and low voltage wiring below the main floor area and equipment pits were submerged and will require replacement.

7.6.2.2.1.4 Katrina Event

Date	Time	Event
8/28/2005	-	The interview form states that pump 2C was used in the evening.
	-	The interview form states that all of the pumps were available prior to the hurricane.
8/29/2005	-	Pumps 1C, 2C, A, B and D were used before the power was cut.
	6:00 AM	The interview form states that the station lost power and the pumps were shut down.
	5:30 AM	The interview form states that the power to the station was turned off for safety due to high water levels.
	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	7:30 AM	Estimated time floodwater entered the Lower 9th Ward
	-	The interview sheet states that flooding reached 12 feet above the operating floor.
8/30/2005	-	The interview form states that the pump station was flooded and the operators were stranded.
8/31/2005	-	The interview form states that the operators found a boat and evacuated the station.
10/3/2005	-	The station re-gained power.

7.6.2.2.1.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.2.2.1.6 Pump Operational Curves

Operational curves have been developed for OP 5. They are not included in this report at this time, but will be inserted in the future.

7.6.2.2.1.7 Pump Reverse Flow

There are seven pumps at this station for which reverse flow rating curves were computed (no pumps were excluded). The reverse flow data and curves are presented in the order of the pump numbering utilized in the summary tables included in this appendix. In cases where there are multiple pumps of equivalent size and system configuration, a single rating curve represents all of them at a unit rate per pump.

Pump No.	Pump Capacity (cfs)	Pump Size (in)	Reverse Flow Computed?		Rating Curve Ref. No.
			Yes	No	
A	550	126	X		1
B	550	126	X		1
D	590	126	X		2
CD1	50	30	X		3
CD2	50	30	X		3
CD3	50	30	X		3
CD4	50	30	X		3

For a general explanation of reverse flow (terminology, figures, methodology, equations and assumptions), refer to the Reverse Flow Section at the beginning of this appendix. Reverse flow computations for a given pump station do not necessarily imply that reverse flow actually occurred there during the Katrina event. But these curves may instead be used as future tools if further investigations are required based on reverse flow assumptions.

9. Reverse Flow Rating Curve

#5 Pump Station, Pumps A & B -126-in.

Elevation Datum (ft): Cairo

Crest Elevation (ft) = 24.5

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use* $Q = \text{sqrt}((H1-H2)/K')$

$K' =$ *1.08496E-05* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 24.5 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 35.0 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

H2 =	6.0	8.0	10.0	12.0	14.0	16.0	18.0
H1 >	250	235	220	205	191	176	161

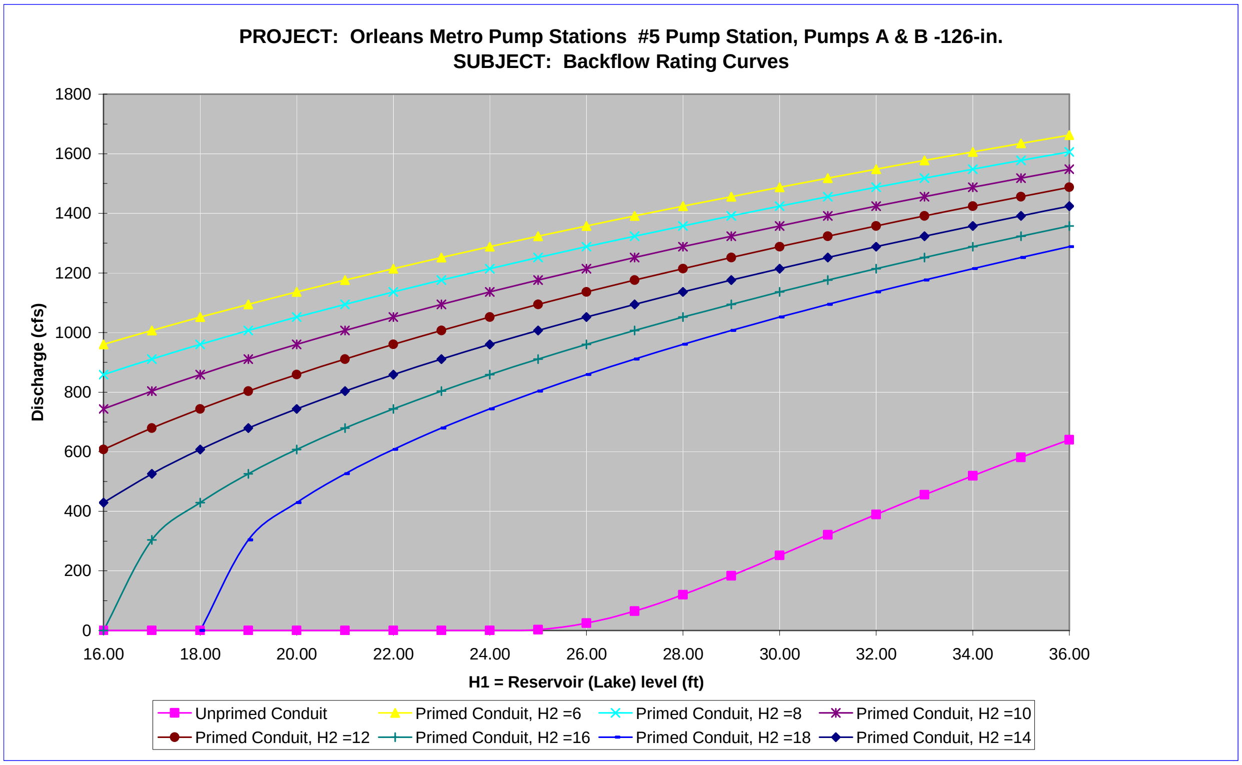
Water elevation (H1) that stops unprimed flow: 24.5 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 22.0 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.



<u>Notes:</u>

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient = 4.50
Intake loss = 0.92
Expansion & Exit Loss = 0.3
Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

A and B the same
Drawing 5292-W-4 (swb_set2 9) 1913 shows A and B
Drawings are to scale
No crest after pump
Pump is slightly smaller than shown in drawing.

4 Data Needs or Deficiencies:

Actual dimensions

5 Backflow prevention:

Available: No backflow prevention
Used: Operator says reverse flow occurred.

10. Reverse Flow Rating Curve

#5 Pump Station, Pump D -144-in.

Elevation Datum (ft):	Cairo
Crest Elevation (ft) =	27.3

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use Q = sqrt((H1-H2)/K')*

K' = *9.78117E-06* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 27.3 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated

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unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 31.1 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

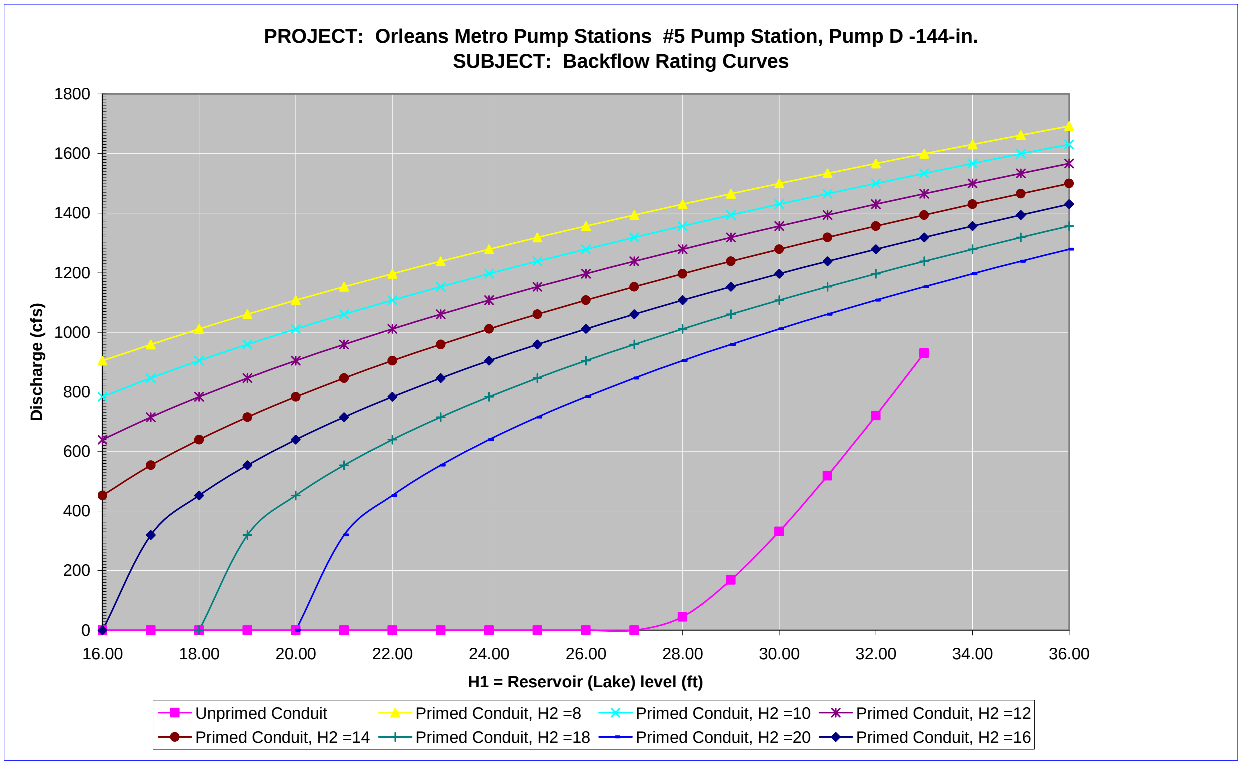
H2 =	8.0	10.0	12.0	14.0	16.0	18.0	20.0
H1 >	38	37	37	36	36	35	34

Water elevation (H1) that stops unprimed flow: 27.3 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 14.8 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	4.50
Intake loss =	0.92
Expansion & Exit Loss =	0.6

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Assumed rated head of 14 ft. This is the rated head for Pumps A and B

Assumed ranges of downstream pool elevations are the same as those of Pumps A and B in Drawing No 5292 W-A (swb_set2 9 of 9 for PS5)

Assumed pipes have same shapes and sizes as those in PS 12

4 Data Needs or Deficiencies:

Dimensions of pipes.

Cross sectional areas of pipes

Rated head

5 Backflow prevention:

Available:	No backflow prevention No brakes for reverse rotation
Used:	Operator says reverse flow occurred.

11. Reverse Flow Rating Curve

#5 Pump Station, Pumps CD1-4 - 30-in.

Elevation Datum (ft): Cairo

Crest Elevation (ft) = 25

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

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For primed flow rates: *Use Q = sqrt((H1-H2)/K')*

$K' =$ *0.003049373* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 25.0 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 27.5 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

H2 =	4.0	7.0	10.0	13.0	16.0	19.0	22.0
H1 >	35	34	33	32	31	30	29

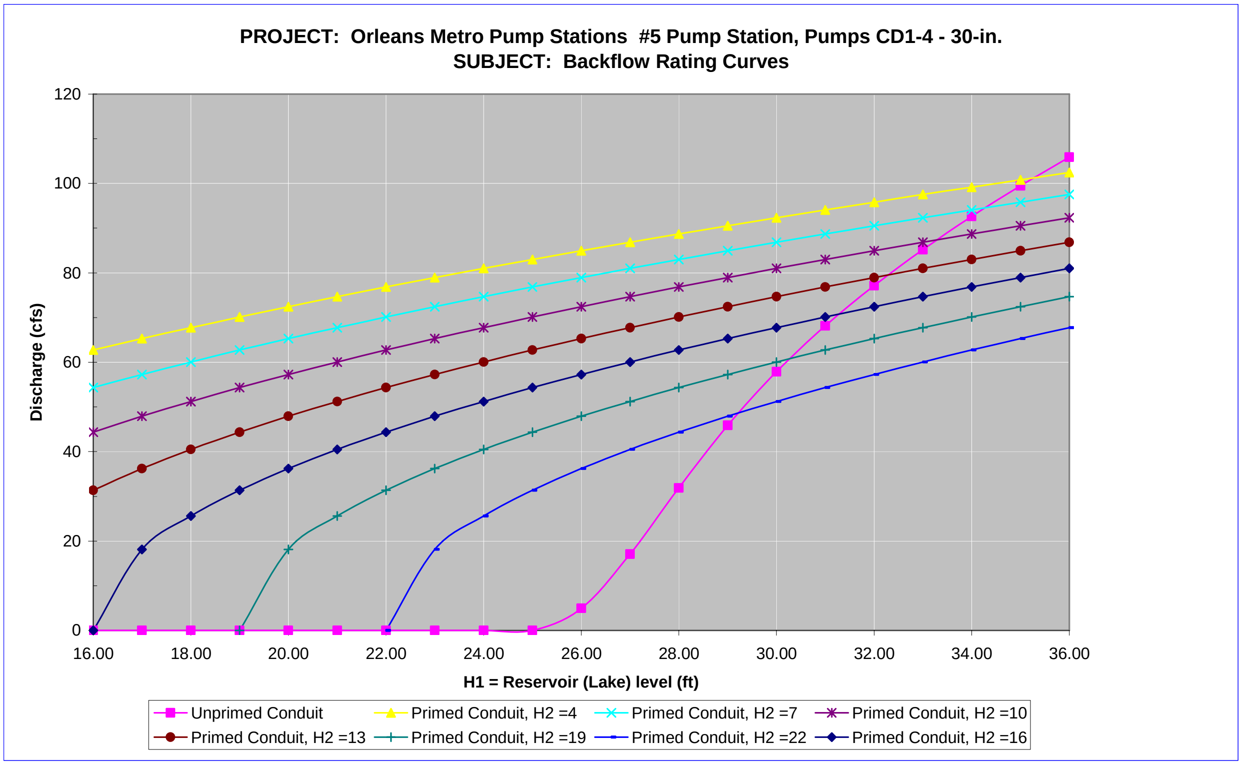
Water elevation (H1) that stops unprimed flow: 25.0 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Water elevation (H1) that stops primed conduit flow: 16.3 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient = 3.50
Intake loss = 0.5
Exit Loss = 1.3
Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Data taken from DWG 5289-W-4, other dimensions assumed to be same as pumps A & B.

Assume 23.5 ft head.

Assume outlet discharges at 45 degrees.

4 Data Needs or Deficiencies:

	Rated head	
5	Backflow prevention:	
	Available:	No backflow prevention. No brakes to prevent reverse rotation.
	Used:	Operator says reverse flow occurred.

7.6.2.2.1.8 Fuel Endurance Calculations

We do not have any record of pumps that run on fuel at this pump station.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.2.3 New Orleans East Stations

7.6.2.3.1 *OP 10 (Citrus)*

Orleans Parish – East Drainage Basin

9600 Hayne Blvd
New Orleans, LA 70127

Latitude: 30.04662˚ Longitude: -89.98818˚

7.6.2.3.1.1 Before and After Hurricane Katrina Photos

Photo Not Obtained	**Photo Not Obtained**
Before Hurricane Katrina	Before Hurricane Katrina

After Hurricane Katrina: View from the intake canal

After Hurricane Katrina: Aerial view of the pump station

7.6.2.3.1.2 Description[192]

Drainage area:	New Orleans East
Nominal Capacity:	1000 cfs
Drains water from:	Citrus Canal
Discharges water to:	Lake Pontchartrain
Owner:	New Orleans Sewerage and Water Board
Number of pumps:	4
Pump orientation:	4 vertical

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[192] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Pump driver:	4 electric 60 Hz motors
Water level to switch pumps on:	10 feet (Cairo)
Water level to switch pumps off:	6.5 feet (Cairo)
Water level that affects operation:	15.75 feet (Cairo). Water would enter control room
Reverse flow protection:	Gate valves

7.6.2.3.1.3 Damages

Estimated cost of repairs:	The estimated cost of repairs is not yet available.[193]
Relative level of damage:	Substantial
Severity of circumstances:	Flood waters did not reach the operating floor of the station; however, 75 percent of the roof was damaged. This allowed rainwater to damage the station.
Equipment damaged:	Switchgear and the motor control centers were damaged and will require repair or replacement. The bearings for pumps 1, 2, 3, and 4 require replacement and the trash screen motors were flooded.
Building damage:	There was damage to the roof, gutters, downspouts, and control room ceiling tiles.
Misc. damage:	The security fence was damaged.

7.6.2.3.1.4 Katrina Event

No record was obtained.

7.6.2.3.1.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.2.3.1.6 Pump Operational Curves

Operational curves have been developed for OP 10 (Citrus). They are not included in this report at this time, but will be inserted in the future.

7.6.2.3.1.7 Pump Reverse Flow

There are four pumps at this station for which reverse flow rating curves were computed (no pumps were excluded). The reverse flow data and curves are presented in the order of the pump numbering utilized in the summary tables included in this appendix. In cases where there are

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[193] The Project Information Report (PIR) for each parish provides an estimated cost of repairs for the parish's pump stations. At the time this report was written, the Orleans Parish PIR was not yet complete. It should be available through the parish shortly after publication of the IPET Report.

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multiple pumps of equivalent size and system configuration, a single rating curve represents all of them at a unit rate per pump.

Pump No.	Pump Capacity (cfs)	Pump Size (in)	Reverse Flow Computed?		Rating Curve Ref. No.
			Yes	No	
1	250	64?	X		1
2	250	64?	X		1
3	250	64?	X		1
4	250	64?	X		1

For a general explanation of reverse flow (terminology, figures, methodology, equations and assumptions), refer to the Reverse Flow Section at the beginning of this appendix. Reverse flow computations for a given pump station do not necessarily imply that reverse flow actually occurred there during the Katrina event. But these curves may instead be used as future tools if further investigations are required based on reverse flow assumptions.

11. Reverse Flow Rating Curve

<u>#10 Pump Station, Pumps 1, 2, 3, &4 -64?-in.</u>

Elevation Datum (ft): Cairo

Crest Elevation (ft) = 27.5

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use* $Q = \mathrm{sqrt}((H1-H2)/K')$

$K' = 0.000229662 \quad sec^2/ft^5$

<u>Reverse Flow Trigger Points:</u>

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:
Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:
The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 27.5 ft
Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 34.5 ft
Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

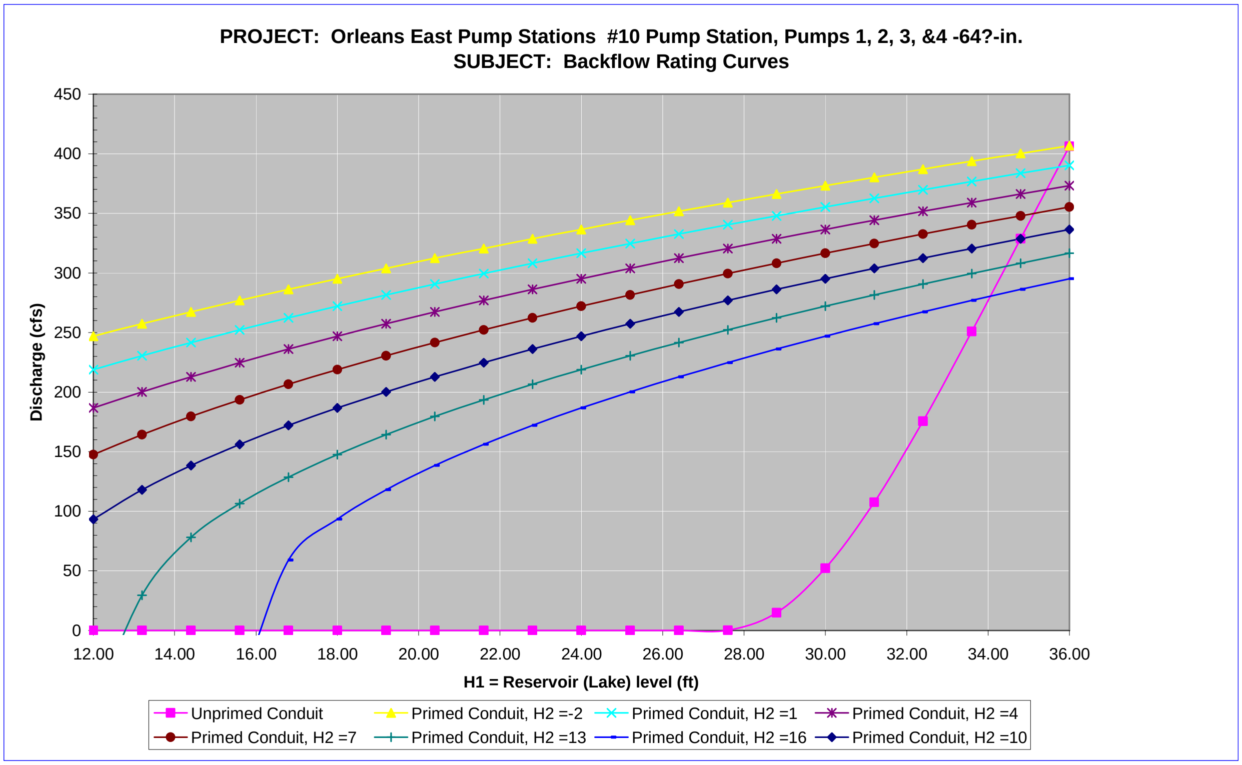
Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

H2 =	-2.0	1.0	4.0	7.0	10.0	13.0	16.0
H1 >	37	37	36	36	36	36	36

Water elevation (H1) that stops unprimed flow: 27.5 ft
Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 13.5 ft
Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	6.50
Intake loss =	0.92
Exit Loss =	1.3

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Pump diameter from scaling DWG 11521-W-10 (swb_set2 34, PS 10, 2 of 5)
Drawings have correct dimensions and are to scale
Pump size taken from Orleans Pump list, and fits with scaling.

4 Data Needs or Deficiencies:
Pump diameter

5 Backflow prevention:
Available: Gate Valve
Brakes to prevent reverse rotation.
Used: Not verified if gate valves were used.
Operator says no reverse flow occurred.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

However, pumping was lost during unmanned operation, which leads to reverse flow if valves do not close automatically.

7.6.2.3.1.8 Fuel Endurance Calculations

We do not have any record of pumps that run on fuel at this pump station.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.2.3.2 *OP 14 (Jahncke)*

Orleans Parish – East Drainage Basin

12200 Haynes Blvd.
New Orleans, LA 70128

Latitude: 30.058333˚ Longitude: -89.96638˚

7.6.2.3.2.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Photo Not Obtained

Before Hurricane Katrina

After Hurricane Katrina: View of the pumps

After Hurricane Katrina: Aerial view of the pump station

7.6.2.3.2.2 Description[194]

Drainage area:	New Orleans East
Nominal Capacity:	1200 cfs
Drains water from:	Morrison and Jahncke Canals
Discharges water to:	Lake Pontchartrain
Owner:	New Orleans Sewerage and Water Board
Number of pumps:	4
Pump orientation:	4 vertical
Pump driver:	4 electric 60 Hz motors

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[194] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Water level to switch pumps on:	10 feet (Cairo)
Water level to switch pumps off:	7 feet (Cairo)
Water level that affects operation:	41 feet (Cairo). Water would enter control room
Reverse flow protection:	Gate valves

7.6.2.3.2.3 Damages

Estimated cost of repairs:	The estimated cost of repairs is not yet available.[195]
Relative level of damage:	Substantial
Severity of circumstances:	The pump motors, diesel generator, and switchgear are on an elevated platform approximately 15 feet above grade and were not flooded.
Equipment damaged:	The control room was damaged by rain water. Pumps 1, 2, 3, and 4 require bearing replacement due to the raw water that ran through them. The vacuum system was damaged from pumps 2 and 4. The trash rack motors were flooded. The motor control center, controls, and sump pump were damaged.
Building damage:	The float house was flooded damaging the low voltage wiring, switches, and lighting. The float house roof was damaged and requires replacement. The entire float built up roof and copper flashing were damaged. The buildings concrete block was damaged structurally too.
Misc. damage:	Wind damaged the fence.

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[195] The Project Information Report (PIR) for each parish provides an estimated cost of repairs for the parish's pump stations. At the time this report was written, the Orleans Parish PIR was not yet complete. It should be available through the parish shortly after publication of the IPET Report.

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7.6.2.3.2.4 Katrina Event

Date	Time	Event
8/28/2005	-	Operators pumped canal down to 6.8ft (Cairo datum)
8/29/2005	7:00 AM	Lost Roof
	7:30 AM	#2 ATF sight glass broken - shut down
	9:00 AM	No water pressure - #1,3 stopped
	1:00 PM	Hooked up contractors pressure washer in attempt to gain back water pressure to run pumps
	1:00 PM	Gearbox Heat exchangers getting hot - shut down pumps
8/31/2005	-	Evacuated
9/1/2005	7AM	Operators resumed pumping.
9/12/2005	-	Canal/station dewatered.

7.6.2.3.2.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.2.3.2.6 Pump Operational Curves

Operational curves have been developed for OP 14 (Jahncke). They are not included in this report at this time, but will be inserted in the future.

7.6.2.3.2.7 Pump Reverse Flow

There are four pumps at this station for which reverse flow rating curves were computed (no pumps were excluded). The reverse flow data and curves are presented in the order of the pump numbering utilized in the summary tables included in this appendix. In cases where there are multiple pumps of equivalent size and system configuration, a single rating curve represents all of them at a unit rate per pump.

Pump No.	**Pump Capacity (cfs)**	**Pump Size (in)**	**Reverse Flow Computed?**		**Rating Curve Ref. No.**
			Yes	**No**	
1	300	84	X		1
2	300	84	X		1
3	300	84	X		1
4	300	84	X		1

For a general explanation of reverse flow (terminology, figures, methodology, equations and assumptions), refer to the Reverse Flow Section at the beginning of this appendix. Reverse flow computations for a given pump station do not necessarily imply that reverse flow actually occurred there during the Katrina event. But these curves may instead be used as future tools if further investigations are required based on reverse flow assumptions.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

12. Reverse Flow Rating Curve

#14 Jahncke Pump Station, Pumps 1 - 4, 84-in.

Elevation Datum (ft): Cairo
Crest Elevation (ft) = 29
H1 = Lake or outlet canal water level (normal pump discharge side)
H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use* $Q = \text{sqrt}((H1-H2)/K')$
$K' =$ *6.15741E-05* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 29.0 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal

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reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 36.1 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

H2 =	2.0	5.0	8.0	11.0	14.0	17.0	20.0
H1 >	45	44	43	43	42	41	40

Water elevation (H1) that stops unprimed flow: 29.0 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 17.2 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.

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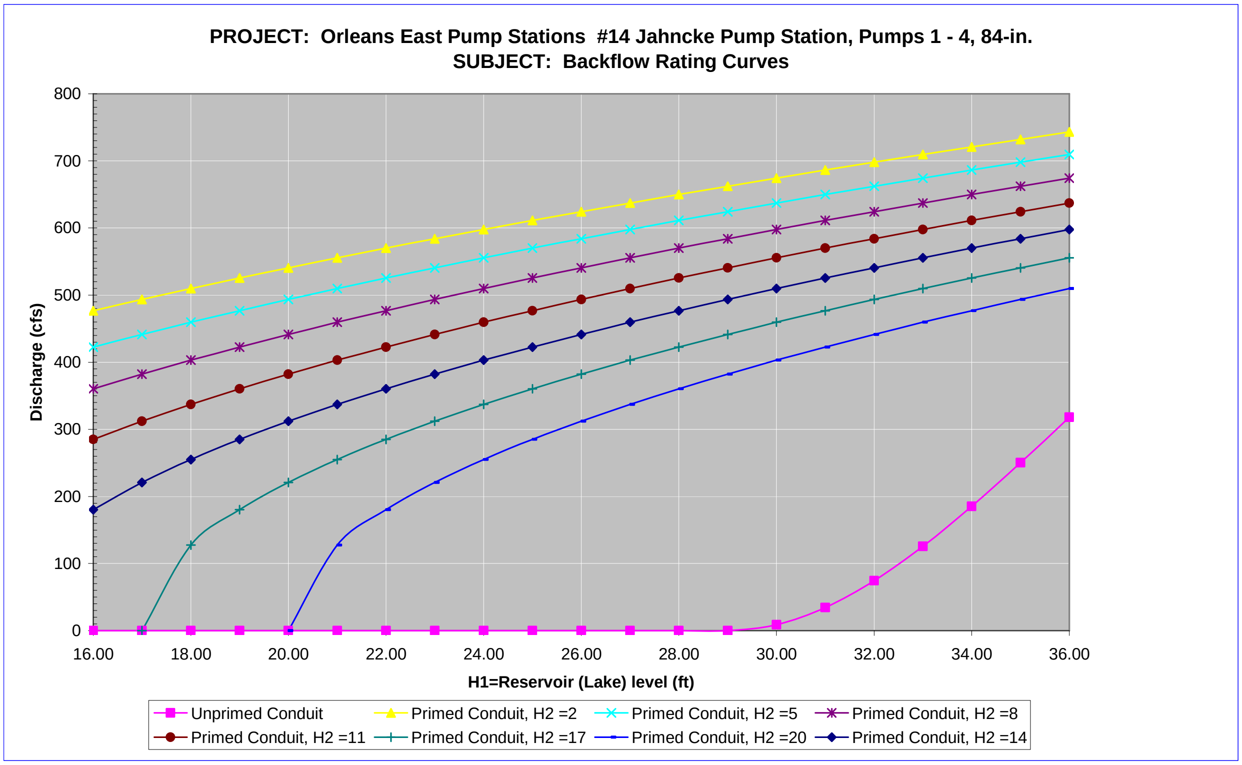


Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	6.50
Intake loss =	0.92
Exit Loss =	1.3

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Incomplete drawings of pump & piping layout. Assumed piping layout & size is like pumps 1-3 at PS #10.

Assumed distances between C2 & C1, P1, P2, & C3 are the same as PS #10.

Elevations in Cairo Datum

Elevations scaled from Photo #1.

Assumed the pumps & layout were the same as PS #10 which is the closest pump station. The pumps look similar based on photos.

4 Data Needs or Deficiencies:

Drawings (w/ elevations) of the piping & pipe layout.

5 Backflow prevention:

Available:	Gate Valves - not known if they were used.
	Brakes to prevent reverse rotation.
Used:	Operator says no reverse flow occurred.

7.6.2.3.2.8 Fuel Endurance Calculations

We do not have any record of pumps that run on fuel at this pump station.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.2.3.3 *OP Dwyer Road*

This station is part of the SELA projects.

7.6.2.3.4 *OP 15*

Orleans Parish – East Drainage Basin

3401 Industrial Pkwy
New Orleans, LA 70129

Latitude: 30.02991˚ Longitude: -89.86809˚

7.6.2.3.4.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Photo Not Obtained

Before Hurricane Katrina

After Hurricane Katrina: View from the discharge

After Hurricane Katrina: Aerial view of the pump station

7.6.2.3.4.2 Description

Drainage area:	New Orleans East
Plant capacity at rated head:	750 cfs
Drains water from:	Maxent Canal
Discharges water to:	Intracoastal Waterway
Owner:	New Orleans Sewerage and Water Board
Number of pumps:	3

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Pump orientation:	3 vertical
Pump driver:	2 electric 60 Hz motors 1 diesel
Water level to switch pumps on:	13.5 feet (Cairo)
Water level to switch pumps off:	12.5 feet (Cairo)
Water level that affects operation:	19.6 feet (NGVD). Would flood electrical control panel.
Reverse flow protection:	None

7.6.2.3.4.3 Damages

7.6.2.3.4.4 Katrina Event

Date	Time	Event
-	-	OP 15 is an automatic station. It operates when water levels reach a preset elevation. The station operated during the storm until 60 Hertz power was lost. As of 6-Feb-2006, no power was restored, and is operating on temporary generator.

7.6.2.3.4.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.2.3.4.6 Pump Operational Curves

Operational curves have been developed for OP 15. They are not included in this report at this time, but will be inserted in the future.

7.6.2.3.4.7 Pump Reverse Flow

There are three pumps at this station for which reverse flow rating curves were computed (no pumps were excluded). The reverse flow data and curves are presented in the order of the pump numbering utilized in the summary tables included in this appendix. In cases where there are multiple pumps of equivalent size and system configuration, a single rating curve represents all of them at a unit rate per pump.

Pump No.	Pump Capacity (cfs)	Pump Size (in)	Reverse Flow Computed?		Rating Curve Ref. No.
			Yes	No	
1	250	72	X		1
2	250	72	X		1
3	250	72	X		1

For a general explanation of reverse flow (terminology, figures, methodology, equations and assumptions), refer to the Reverse Flow Section at the beginning of this appendix. Reverse flow computations for a given pump station do not necessarily imply that reverse flow actually occurred there during the Katrina event. But these curves may instead be used as future tools if further investigations are required based on reverse flow assumptions.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

13. Reverse Flow Rating Curve

Orleans Parish #15 Pump Station, Pumps 1, 2, 3 - 72in. Vertical

Elevation Datum (ft): NGVD
Crest Elevation (ft) = 8.75
H1 = Lake or outlet canal water level (normal pump discharge side)
H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use* $Q = \mathrm{sqrt}((H1-H2)/K')$
$K' =$ *0.00021174* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 8.8 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal

reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 14.8 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

H2 =	-15.0	-11.0	-7.0	-3.0	1.0	5.0	9.0
H1 >	18	18	17	17	16	16	15

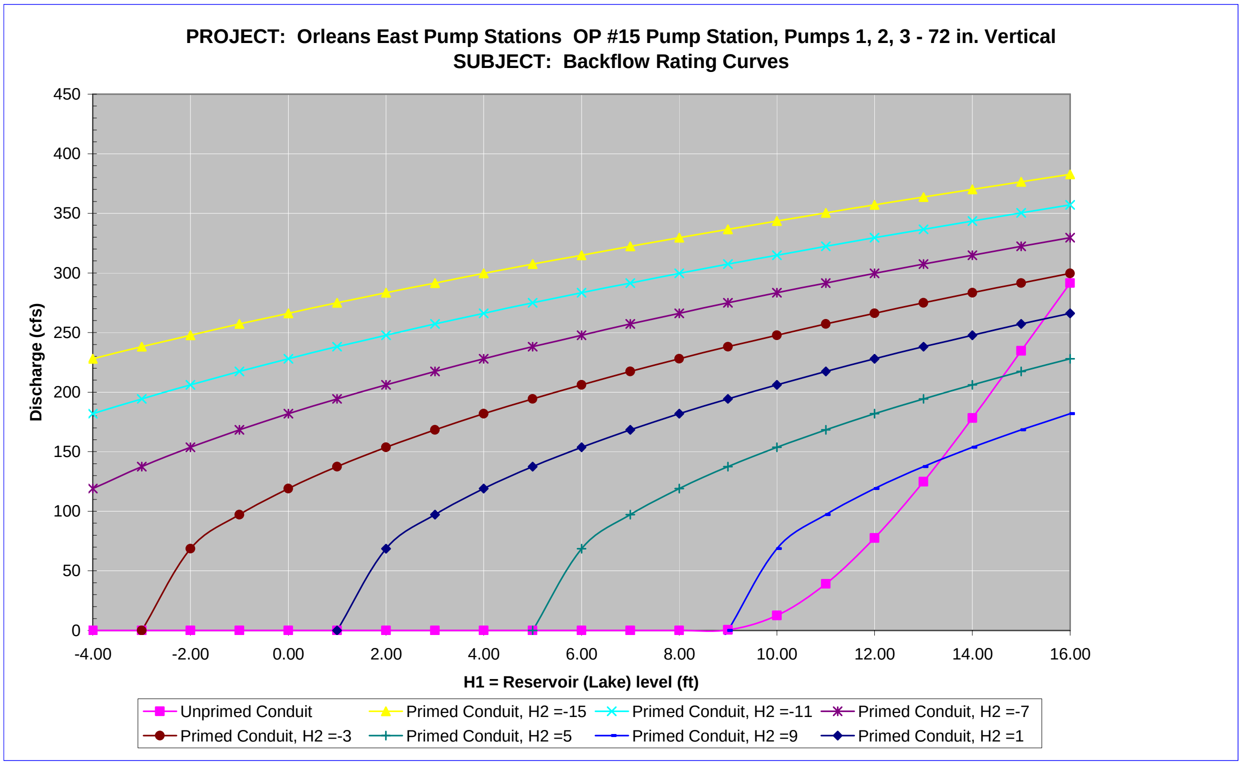
Water elevation (H1) that stops unprimed flow: 8.8 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 3.5 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.


PROJECT: Orleans East Pump Stations OP #15 Pump Station, Pumps 1, 2, 3 - 72 in. Vertical
SUBJECT: Backflow Rating Curves

Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient = 6.50
Intake loss = 0.92
Exit Loss = 1.3
Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Assumed geometry (elevations and lengths) exterior to the pump house.

Drawings have correct dimensions and are to scale.

Datum is in NGVD.

Crest elevation scaled from 3001 geospatial report photo by using invert 1 ft below finished floor # 2 height.

Assumed discharge pipe exit bell was same 5.25 ft radius based on Orleans West #13 Pumps V1 &V2.

4 Data Needs or Deficiencies:

Elevations and plans of discharge tube (reverse flow intake) exterior to the pump house.

5 Backflow prevention:

Available:	No backflow prevention. Equipped with reverse rotation brakes.
Used:	Pump house is automated, pumps shut down when power was lost. Operator unsure if reverse flow occurred.

7.6.2.3.4.8 Fuel Endurance Calculations

We do not have any record of pumps that run on fuel at this pump station.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.2.3.5 *OP 16 (St. Charles)*

Orleans Parish – East Drainage Basin

7200 Wales St
New Orleans, LA 70126

Latitude: 30.0381˚ Longitude: -90.0112˚

7.6.2.3.5.1 Before and After Hurricane Katrina Photos

Photo Not Obtained	**Photo Not Obtained**
Before Hurricane Katrina	Before Hurricane Katrina

After Hurricane Katrina: View from the discharge

After Hurricane Katrina: Aerial view of the pump station

7.6.2.3.5.2 Description[196]

Drainage area:	New Orleans East
Plant capacity at rated head:	1000 cfs
Drains water from:	St. Charles Canal
Discharges water to:	Lake Pontchartrain
Owner:	New Orleans Sewerage and Water Board
Number of pumps:	4
Pump orientation:	4 vertical
Pump driver:	4 electric 60 Hz motors

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[196] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Water level to switch pumps on: 8.5 feet (Cairo)

Water level to switch pumps off: 7.5 feet (Cairo)

Water level that affects operation: 17 feet (NGVD). Water would flood electric switch gear.

Reverse flow protection: Height of pipes designed to prevent reverse flow.

7.6.2.3.5.3 Damages

7.6.2.3.5.4 Katrina Event

Date	Time	Event
8/27/2005	1:00 PM	Operators completed drawdown using the No. 3 and 4.
8/28/2005	7:00 AM	Operators pumped again.
9/18/2005	-	Canal considered un-watered.
9/20/2005	-	Diesel back up generator burned up on 9/20/05

7.6.2.3.5.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.2.3.5.6 Pump Operational Curve

Operational curves have been developed for OP 16. They are not included in this report at this time, but will be inserted in the future.

7.6.2.3.5.7 Pump Reverse Flow

There are four pumps at this station for which reverse flow rating curves were computed (no pumps were excluded). The reverse flow data and curves are presented in the order of the pump numbering utilized in the summary tables included in this appendix. In cases where there are multiple pumps of equivalent size and system configuration, a single rating curve represents all of them at a unit rate per pump.

Pump No.	Pump Capacity (cfs)	Pump Size (in)	Reverse Flow Computed?		Rating Curve Ref. No.
			Yes	No	
1	250	64	X		1
2	250	64	X		1
3	250	64	X		1
4	250	64	X		1

For a general explanation of reverse flow (terminology, figures, methodology, equations and assumptions), refer to the Reverse Flow Section at the beginning of this appendix. Reverse flow computations for a given pump station do not necessarily imply that reverse flow actually occurred there during the Katrina event. But these curves may instead be used as future tools if further investigations are required based on reverse flow assumptions.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

14. Reverse Flow Rating Curve

#16 Pump Station, Pumps 1, 2, 3, &4 64-in.

Elevation Datum (ft): Cairo
Crest Elevation (ft) = 27.5
H1 = Lake or outlet canal water level (normal pump discharge side)
H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use* $Q = \mathrm{sqrt}((H1-H2)/K')$
$K' =$ *0.000228707* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 27.5 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal

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reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 34.5 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.							
H2 =	-2.0	2.0	6.0	10.0	14.0	18.0	22.0
H1 >	37	37	36	36	36	36	35

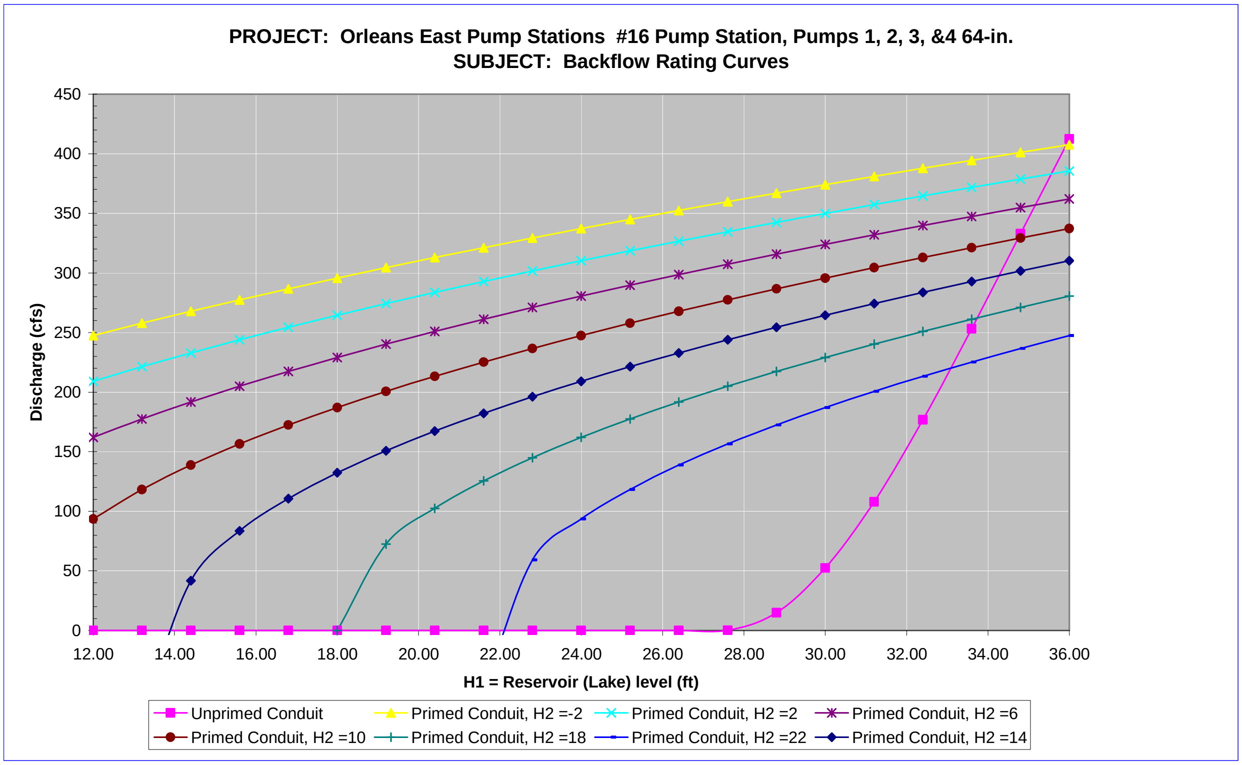
Water elevation (H1) that stops unprimed flow: 27.5 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 16.3 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	6.50
Intake loss =	0.92
Exit Loss =	1.3

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Pump diameter from scaling DWG 11521-W-10DWG 11024-W-14 (swb_set 3 8)

Drawings have correct dimensions and are to scale

Datum is at Cairo.

4 Data Needs or Deficiencies:

Pump size

5 Backflow prevention:

Available: No backflow prevention--Height of conduit intended to prevent backflow.

No brakes to prevent reverse rotation.

Used: Operator says water did not get high enough to cause reverse flow at

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

this location.

7.6.2.3.5.8 Fuel Endurance Calculations

We do not have any record of pumps that run on fuel at this pump station.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.2.3.6 *OP 18 (Maxent)*

Orleans Parish – East Drainage Basin

Michoud Bayou and Levee
New Orleans, LA 70129

Latitude: 30.04205˚ Longitude: -89.90601˚

7.6.2.3.6.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Photo Not Obtained

Before Hurricane Katrina

After Hurricane Katrina: View of the station

After Hurricane Katrina: Aerial view of the pump station

7.6.2.3.6.2 Description[197]

Drainage area:	New Orleans East
Nominal Capacity:	150 cfs
Drains water from:	Village de'l East Lagoon
Discharges water to:	Maxent Canal
Owner:	New Orleans Sewerage and Water Board
Number of pumps:	2
Pump orientation:	2 vertical
Pump driver:	2 electric 60 Hz motors

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[197] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Water level to switch pumps on:	13.5 feet (Cairo)
Water level to switch pumps off:	12.5 feet (Cairo)
Water level that affects operation:	Ground level carries power source.
Reverse flow protection:	None

7.6.2.3.6.3 Damages

Estimated cost of repairs:	The estimated cost of repairs is not yet available.[198]
Relative level of damage:	Minor
Severity of circumstances:	The flood water was below the operating floor.
Equipment damaged:	No substantial equipment damage was recorded.
Building damage:	No substantial building damage was recorded.
Misc. damage:	The chain link fence was damaged.

7.6.2.3.6.4 Katrina Event

Date	Time	Event
-	-	OP 18 (Maxent) is an automatic station. It operates when water levels reach a preset elevation. The station operated during the storm until 60 Hertz power was lost. As of 6-Feb-2006, no power was restored, and is operating on temporary generator.

7.6.2.3.6.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.2.3.6.6 Pump Operational Curves

Operational curves have been developed for OP 18 (Maxent). They are not included in this report at this time, but will be inserted in the future.

7.6.2.3.6.7 Pump Reverse Flow

There are two pumps at this station for which reverse flow rating curves were computed (no pumps were excluded). The reverse flow data and curves are presented in the order of the pump numbering utilized in the summary tables included in this appendix. In cases where there are multiple pumps of equivalent size and system configuration, a single rating curve represents all of them at a unit rate per pump.

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[198] The Project Information Report (PIR) for each parish provides an estimated cost of repairs for the parish's pump stations. At the time this report was written, the Orleans Parish PIR was not yet complete. It should be available through the parish shortly after publication of the IPET Report.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Pump No.	Pump Capacity (cfs)	Pump Size (in)	Reverse Flow Computed?		Rating Curve Ref. No.
			Yes	No	
1	150	72	X		1
2	150	72	X		1

For a general explanation of reverse flow (terminology, figures, methodology, equations and assumptions), refer to the Reverse Flow Section at the beginning of this appendix. Reverse flow computations for a given pump station do not necessarily imply that reverse flow actually occurred there during the Katrina event. But these curves may instead be used as future tools if further investigations are required based on reverse flow assumptions.

15. Reverse Flow Rating Curve

OP East, PS#18 (Maxent), Pump #5 -36-in. Vertical Pump

Elevation Datum (ft): Cairo

Crest Elevation (ft) = 20.1

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use* $Q = \mathrm{sqrt}((H1-H2)/K')$

$K' =$ *0.003455282* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping *operation.*

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 20.1 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 23.1 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

H2 =	9.0	11.0	13.0	15.0	17.0	19.0	21.0
H1 >	30	29	28	27	26	25	24

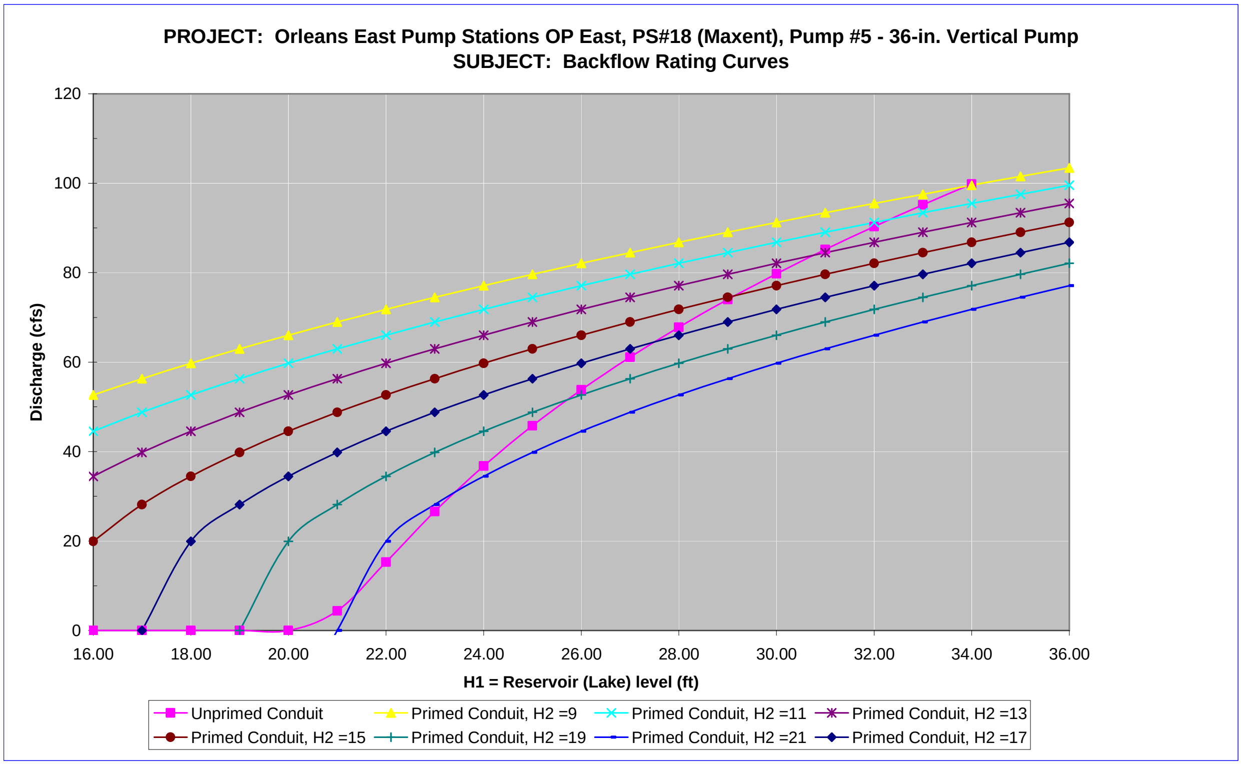
Water elevation (H1) that stops unprimed flow: 20.1 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 18.7 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	3.50
Intake loss =	0.92
Exit Loss =	1.3

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

A straight discharge pipe through the levee.

The assumed sketch is the assumed configuration.

Estimated angles for bends based upon photos.

Estimated lengths based upon photos and aerial imagery.

Estimated elevations based on photos.

Survey sheet indicates a 72" pumps however photos indicate 36" pumps.

4 Data Needs or Deficiencies:

Drawings with dimensions

Key elevations such as: pump intake, entrance, and exit; bends, discharge pipe outlet.

5 Backflow prevention:

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Available: No back flow prevention
No brakes to prevent reverse rotation.
Used: Operator not sure if reverse flow occurred.

7.6.2.3.6.8 Fuel Endurance Calculations

We do not have any record of pumps that run on fuel at this pump station.

7.6.2.3.7 *OP 20 (Amid)*

Orleans Parish – East Drainage Basin

6300 Intracoastal Waterway
New Orleans, LA 70126

Latitude: 29.99267˚ Longitude: -90.0123˚

7.6.2.3.7.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Before Hurricane Katrina: Aerial view of the pump station

After Hurricane Katrina: View from the side

After Hurricane Katrina: Aerial view of the pump station

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.2.3.7.2 Description[199]

Drainage area:	New Orleans East
Nominal Capacity:	500 cfs
Drains water from:	Amid Canal
Discharges water to:	Intracoastal Waterway
Owner:	New Orleans Sewerage and Water Board
Number of pumps:	2
Pump orientation:	2 vertical
Pump driver:	2 electric 60 Hz motors
Water level to switch pumps on:	17.0 feet (Cairo)
Water level to switch pumps off:	14.0 feet (Cairo)
Water level that affects operation:	5.75 feet (NGVD). Backup diesel generators would flood at this level.
Reverse flow protection:	Gate valves

7.6.2.3.7.3 Damages

Estimated cost of repairs:	The estimated cost of repairs is not yet available.[200]
Relative level of damage:	Substantial
Severity of circumstances:	The operating floor is elevated about 15 feet above grade. The underneath portions were flooded with about 7 to 10 feet of water.
Equipment damaged:	The trash rack motors, starters chains, and bars were damaged. The generator was flooded. Pump 2 has damage to the impeller.
Building damage:	One wall of the generator building will require replacement, as will the roof of the office building.

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[199] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[200] The Project Information Report (PIR) for each parish provides an estimated cost of repairs for the parish's pump stations. At the time this report was written, the Orleans Parish PIR was not yet complete. It should be available through the parish shortly after publication of the IPET Report.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Misc. damage:	The chain link fence and light poles were damaged. Scour is evident around the building and the access road and parking lot need fill and aggregate.

7.6.2.3.7.4 Katrina Event

Date	Time	Event
-	-	Station is an automatic station, however there were operators present during hurricane. The pumps were operated at their pre-set levels during the hurricane.
8/29/2005	-	Storm surge came up and flooded the backup diesel generator. Station lost pumping capabilities

7.6.2.3.7.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.2.3.7.6 Pump Operational Curves

Operational curves have been developed for OP 20 (Amid). They are not included in this report at this time, but will be inserted in the future.

7.6.2.3.7.7 Pump Reverse Flow

There are two pumps at this station for which reverse flow rating curves were computed (no pumps were excluded). The reverse flow data and curves are presented in the order of the pump numbering utilized in the summary tables included in this appendix. In cases where there are multiple pumps of equivalent size and system configuration, a single rating curve represents all of them at a unit rate per pump.

Pump No.	Pump Capacity (cfs)	Pump Size (in)	Reverse Flow Computed?		Rating Curve Ref. No.
			Yes	No	
1	250	72	X		1
2	250	72	X		1

For a general explanation of reverse flow (terminology, figures, methodology, equations and assumptions), refer to the Reverse Flow Section at the beginning of this appendix. Reverse flow computations for a given pump station do not necessarily imply that reverse flow actually occurred there during the Katrina event. But these curves may instead be used as future tools if further investigations are required based on reverse flow assumptions.

16. Reverse Flow Rating Curve

#20 Pump Station, Pumps 1 & 2 - 72in.

Elevation Datum (ft):	NGVD
Crest Elevation (ft) =	9

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates:	*Use* $Q = \mathrm{sqrt}((H1-H2)/K')$	
$K' =$	*0.00024316*	sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 9.0 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 15.0 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

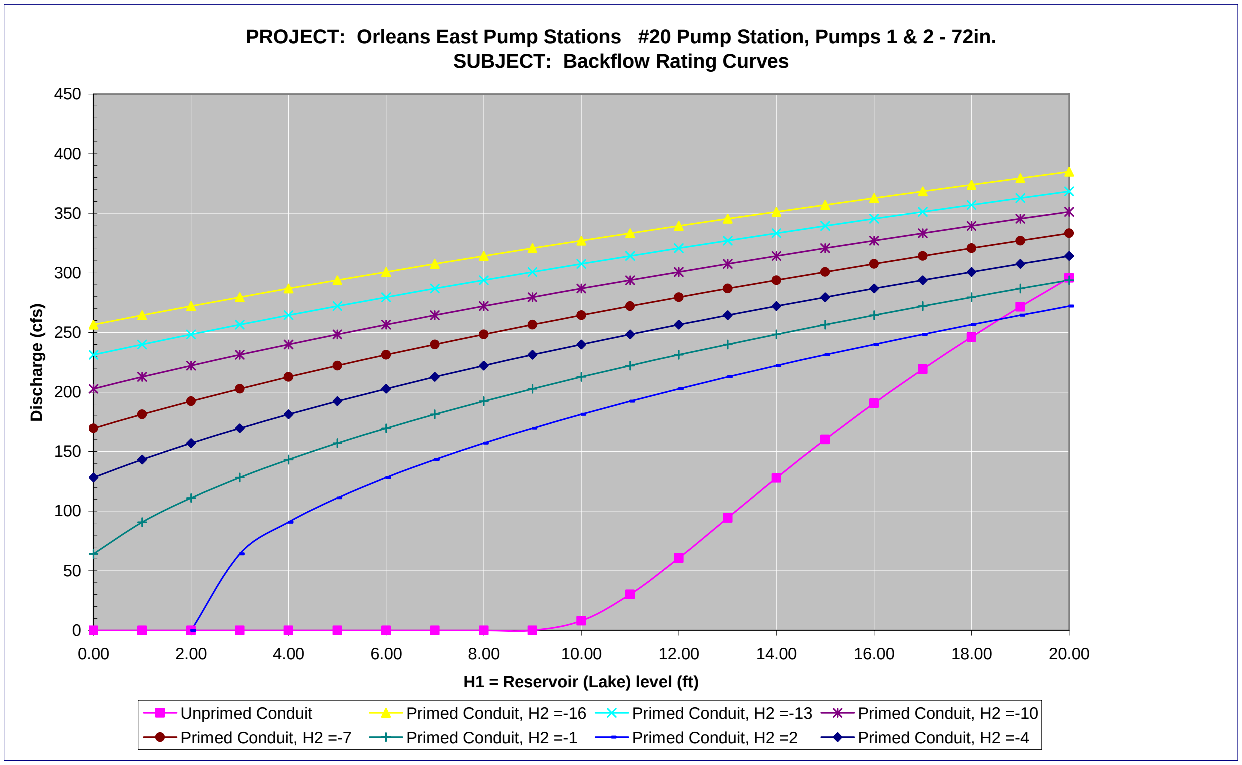
Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.							
H2 =	-16.0	-13.0	-10.0	-7.0	-4.0	-1.0	2.0
H1 >	26	25	24	23	22	21	20

Water elevation (H1) that stops unprimed flow: 9.0 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 1.0 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.



<u>Notes:</u>

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	6.50
Intake loss =	0.92
Exit Loss =	1.3

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:
Drawings are correct and to scale

4 Data Needs or Deficiencies:
If gate valves were used

5 Backflow prevention:

Available:	Gate Valve
Used:	Not verified if gate valves were used.

7.6.2.3.7.8 Fuel Endurance Calculations

We do not have any record of pumps that run on fuel at this pump station.

7.6.2.3.8 *Grant St*

Orleans Parish – East Drainage Basin

3100 Grant St
New Orleans, LA 70126

Latitude: 30.00553˚ Longitude: -89.94933˚

7.6.2.3.8.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Before Hurricane Katrina: Aerial view of the pump station

After Hurricane Katrina: View from the discharge

After Hurricane Katrina: Aerial view of the pump station

7.6.2.3.8.2 Description[201]

Drainage area:	New Orleans East
Nominal Capacity:	172 cfs
Drains water from:	Grant Ave. Canal
Discharges water to:	Intracoastal Waterway
Owner:	New Orleans Sewerage and Water Board
Number of pumps:	6
Pump orientation:	6 vertical
Pump driver:	6 electric 60 Hz motors
Water level to switch pumps on:	18 feet (Cairo)
Water level to switch pumps off:	16 feet (Cairo)
Water level that affects operation:	6.6 feet (NGVD). Electrical control panel would flood
Reverse flow protection:	Gate valves

7.6.2.3.8.3 Damages

Estimated cost of repairs:	The estimated cost of repairs is not yet available.[202]
Relative level of damage:	Substantial
Severity of circumstances:	The station has outdoor pumps 1, 2, 3, and 4 along with pumps 5 and 6 enclosed in a raised pump house. The outdoor pumps are lower than the pump house and were flooded.
Equipment damaged:	The four outdoor pump motors should be rewound. Bearing for the four outdoor pumps require replacement, as do the switchgear and motor controls.
Building damage:	Roof flashing is damaged. All lighting and low voltage power and devices below the platform require replacement.

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[201] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[202] The Project Information Report (PIR) for each parish provides an estimated cost of repairs for the parish's pump stations. At the time this report was written, the Orleans Parish PIR was not yet complete. It should be available through the parish shortly after publication of the IPET Report.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Misc. damage:	Scour is evident at the site. Fill and aggregate are required along with the replacement of pavement. The fencing around the site is also damaged.

7.6.2.3.8.4 Katrina Event

Date	Time	Event
-	-	Grant Street is an automatic station. It operates when water levels reach a preset elevation. The station operated during the storm until 60 Hertz power was lost. As of 6-Feb-2006, no power was restored, and is operating on temporary generator.

7.6.2.3.8.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.2.3.8.6 Pump Operational Curves

Operational curves have been developed for Grant Street. They are not included in this report at this time, but will be inserted in the future.

7.6.2.3.8.7 Pump Reverse Flow

No reverse flow curves were developed for this station since the drawings and photos indicate the discharge pipes cross over the top of the levee wall. Reverse flow becomes irrelevant if it only occurs when the levee is overtopped.

7.6.2.3.8.8 Fuel Endurance Calculations

We do not have any record of pumps that run on fuel at this pump station.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.2.3.9 *Elaine St*

Orleans Parish – East Drainage Basin

3100 Elaine St
New Orleans, LA 70126

Latitude: 30.003˚ Longitude: -89.0115˚

7.6.2.3.9.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Before Hurricane Katrina: Aerial view of the pump station

After Hurricane Katrina: View from the discharge

After Hurricane Katrina: Aerial view of the pump station

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.2.3.9.2 Description[203]

Drainage area:	New Orleans East
Nominal Capacity:	90 cfs
Drains water from:	Elaine St. Canal
Discharges water to:	Intracoastal Waterway
Owner:	New Orleans Sewerage and Water Board
Number of pumps:	2
Pump orientation:	2 vertical
Pump driver:	2 electric 60 Hz motors
Water level to switch pumps on:	Not Recorded
Water level to switch pumps off:	Not Recorded
Water level that affects operation:	1.5 feet (NGVD). The power source housing is at this elevation.
Reverse flow protection:	None

7.6.2.3.9.3 Damages

Estimated cost of repairs:	The estimated cost of repairs is not yet available.[204]
Relative level of damage:	Substantial
Severity of circumstances:	The station's electric pump motors and vacuum pump motors were submerged under 8 feet of water.
Equipment damaged:	The electric pump motors and vacuum pump motors will require replacement. Bearings for both pumps require replacement.
Building damage:	A 12 foot steel support member has collapsed, and a steel door will not open.
Misc. damage:	The site has considerable scour and will require fill material. Tie down straps on the outlet pipes are damaged.

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[203] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[204] The Project Information Report (PIR) for each parish provides an estimated cost of repairs for the parish's pump stations. At the time this report was written, the Orleans Parish PIR was not yet complete. It should be available through the parish shortly after publication of the IPET Report.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.2.3.9.4 Katrina Event

Date	Time	Event
-	-	Elaine Street is an automatic station. It operates when water levels reach a preset elevation. The station operated during the storm until 60 Hertz power was lost. As of 6-Feb-2006, no power was restored.

7.6.2.3.9.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.2.3.9.6 Pump Operational Curves

Operational curves have been developed for Elaine Street. They are not included in this report at this time, but will be inserted in the future.

7.6.2.3.9.7 Pump Reverse Flow

There are two pumps at this station for which reverse flow rating curves were computed (no pumps were excluded). The reverse flow data and curves are presented in the order of the pump numbering utilized in the summary tables included in this appendix. In cases where there are multiple pumps of equivalent size and system configuration, a single rating curve represents all of them at a unit rate per pump.

Pump No.	Pump Capacity (cfs)	Pump Size (in)	Reverse Flow Computed?		Rating Curve Ref. No.
			Yes	No	
1	45	30	X		1
2	45	30	X		1

For a general explanation of reverse flow (terminology, figures, methodology, equations and assumptions), refer to the Reverse Flow Section at the beginning of this appendix. Reverse flow computations for a given pump station do not necessarily imply that reverse flow actually occurred there during the Katrina event. But these curves may instead be used as future tools if further investigations are required based on reverse flow assumptions.

17. Reverse Flow Rating Curve

OP East, Elaine St, Pumps #1 & #2 -30-in. Horizontal Pump

Elevation Datum (ft): Cairo

Crest Elevation (ft) = 30.13

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with

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water. Primed flow is a function of the difference between H1 and H2.

Siphon flow is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: Use Q = sqrt((H1-H2)/K')
K' = 0.005248639 sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 30.1 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 32.6 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

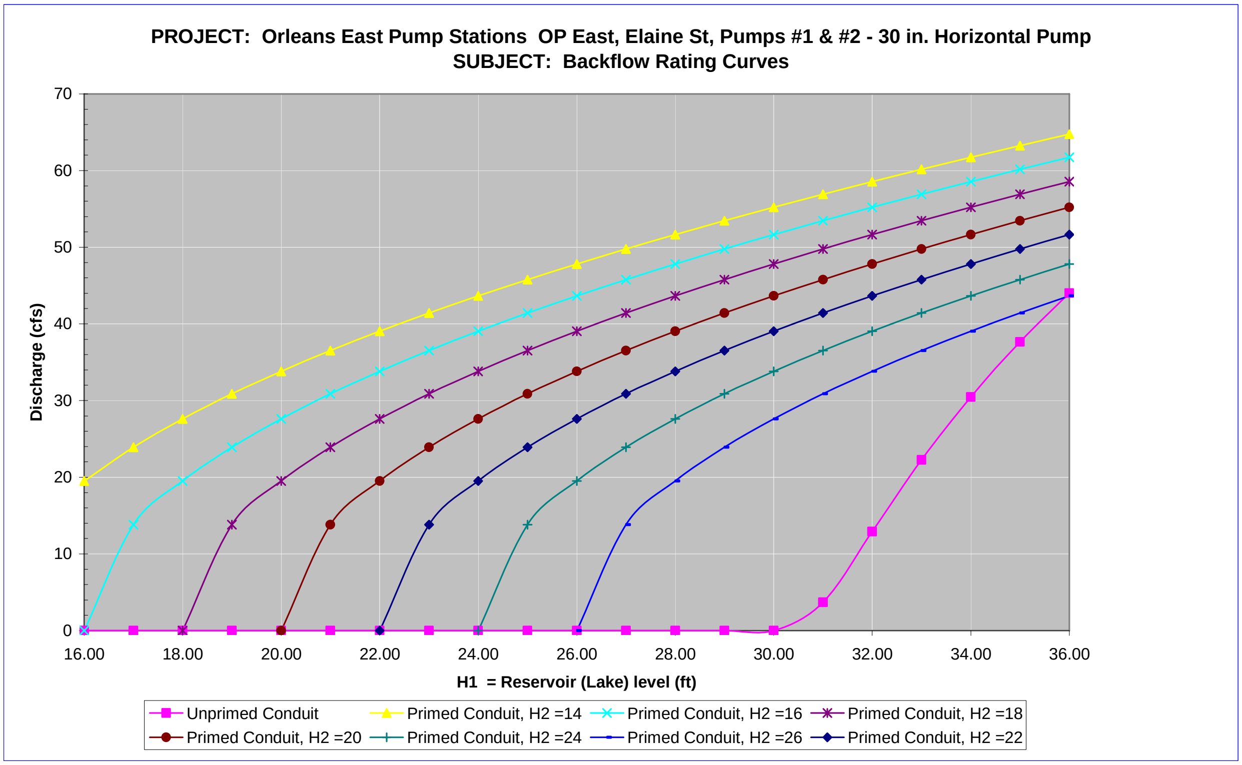
Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.							
H2 =	14.0	16.0	18.0	20.0	22.0	24.0	26.0
H1 >	42	41	40	39	38	37	36

Water elevation (H1) that stops unprimed flow:	30.1	ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow:	22.5	ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	3.50
Intake loss =	0.92
Exit Loss =	1.3

Bend, contraction, and expansion losses also incorporated

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

3 Data Assumptions:

Both pumps were exactly the same.

The entrance loss was approximated as a projecting entrance, sharp edge, and thin wall entrance.

The loss through the pump was a k value of 6.5 based on CENWP-EC-HD Estimates

The outlet loss was a k value of 1.3 based on CENWP-EC-HD estimates.

Radii for composite bends were estimated from drawings.

4 Data Needs or Deficiencies:

None

5 Backflow prevention:

Available:	No backflow prevention. Units have no backstops/brakes installed.
Used:	Operator believed that no reverse flow occurred.

7.6.2.3.9.8 Fuel Endurance Calculations

We do not have any record of pumps that run on fuel at this pump station.

7.6.2.4 West Bank Stations

7.6.2.4.1 *OP 11*

Orleans Parish – West Bank Drainage Basin

5301 E 6th St
New Orleans, LA 70131

Latitude: 29.90961˚ Longitude: -89.97799˚

7.6.2.4.1.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Before Hurricane Katrina: Aerial view of the pump station

After Hurricane Katrina: View from the intake canal

After Hurricane Katrina: Aerial view of the pump station

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.2.4.1.2 Description[205]

Drainage area:	English Turn
Nominal Capacity:	1690 cfs
Drains water from:	Donner Canal
Discharges water to:	Intracoastal Waterway
Owner:	New Orleans Sewerage and Water Board
Number of pumps:	5
Pump orientation:	4 horizontal 1 centrifugal
Pump driver:	2 electric 60 Hz motors 3 electric 25 Hz motors
Water level to switch pumps on:	13 feet (Cairo)
Water level to switch pumps off:	10 feet (Cairo)
Water level that affects operation:	28 feet (Cairo). Switch gear and electrical equipment would be flooded
Reverse flow protection:	None

7.6.2.4.1.3 Damages

Estimated cost of repairs:	The estimated cost of repairs is not yet available.[206]
Relative level of damage:	Substantial
Severity of circumstances:	The station was not flooded.
Equipment damaged:	Rainwater damaged the switchgear and motor control centers and require replacement.
Building damage:	High winds damaged the roof, which requires full replacement. Rainwater damaged the acoustic ceiling in the control house.
Misc. damage:	No significant miscellaneous damage recorded.

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[205] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[206] The Project Information Report (PIR) for each parish provides an estimated cost of repairs for the parish's pump stations. At the time this report was written, the Orleans Parish PIR was not yet complete. It should be available through the parish shortly after publication of the IPET Report.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.2.4.1.4 Katrina Event

Date	Time	Event
8/28/2005	-	Pumped during draw down
8/29/2005	-	4 Pumps were utilized
	-	Lost 60 Hertz power; therefore diesel generators were used.
	-	Roof was extensively damaged. Thus, water entered from above
	-	25 Hertz pumps were used
8/31/2005	-	Canal considered un-watered

7.6.2.4.1.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.2.4.1.6 Pump Operational Curves

Operational curves have been developed for OP 11. They are not included in this report at this time, but will be inserted in the future.

7.6.2.4.1.7 Pump Reverse Flow

There are five pumps at this station for which reverse flow rating curves were computed (no pumps were excluded). The reverse flow data and curves are presented in the order of the pump numbering utilized in the summary tables included in this appendix. In cases where there are multiple pumps of equivalent size and system configuration, a single rating curve represents all of them at a unit rate per pump.

Pump No.	Pump Capacity (cfs)	Pump Size (in)	Reverse Flow Computed?		Rating Curve Ref. No.
			Yes	No	
A	250	96	X		1
B	250	96	X		1
D	570	96	X		2
E	570	96	X		2
CD-3C	50	30	X		3

For a general explanation of reverse flow (terminology, figures, methodology, equations and assumptions), refer to the Reverse Flow Section at the beginning of this appendix. Reverse flow computations for a given pump station do not necessarily imply that reverse flow actually occurred there during the Katrina event. But these curves may instead be used as future tools if further investigations are required based on reverse flow assumptions.

18. Reverse Flow Rating Curve

#11 Pump Station, Pumps A, B - 96-in.

Elevation Datum (ft): Cairo
Crest Elevation (ft) = 28
H1 = Lake or outlet canal water level (normal pump discharge side)
H2 = Drainage area water level (normal pump intake side)

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use* $Q = \mathrm{sqrt}((H1-H2)/K')$

$K' =$ *3.11808E-05* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 28.0 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 36.0 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in

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the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

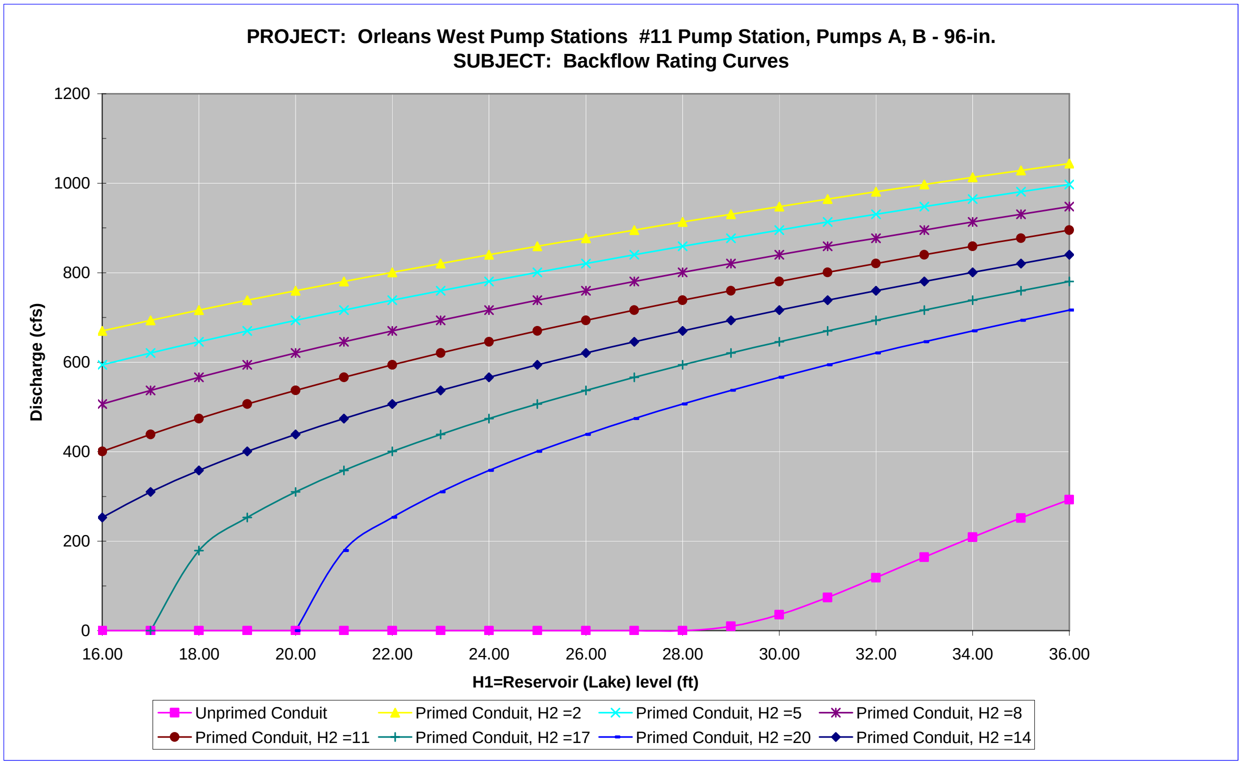
Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.							
H2 =	2.0	5.0	8.0	11.0	14.0	17.0	20.0
H1 >	456	419	382	345	308	270	233

Water elevation (H1) that stops unprimed flow: 28.0 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 27.1 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.



PROJECT: Orleans West Pump Stations #11 Pump Station, Pumps A, B - 96-in.
SUBJECT: Backflow Rating Curves

Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient = 4.50

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Intake loss = 0.5

Exit Loss = 1.0

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

No drawings for pumps A & B but they are the same size as pumps D & E. They appear the same in the photos.

Assumed that pumps A & B were the same as pumps D & E. Survey stated the pumps were the same size.

No drawings or pictures of the inlet or discharge tubes. Assumed rectangle shape because of concrete.

Assumed the inlet tube is the same width as the discharge tube.

Elevations in Cairo Datum.

4 Data Needs or Deficiencies:

Drawings of pumps A & B.

Pictures or drawings of the inlet & discharge tubes.

5 Backflow prevention:

Available: Pumps A & B are filled with air.

Pumps A & B do not have brakes.

Used: Not needed - pumps were always working during the storm.

19. Reverse Flow Rating Curve

#11 Pump Station, Pumps D & E - 96-in.

Elevation Datum (ft): Cairo

Crest Elevation (ft) = 28

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: Use Q = sqrt((H1-H2)/K')

K' = 5.88366E-05 sec^2/ft^5

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 28.0 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 36.0 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.							
H2 =	2.0	5.0	8.0	11.0	14.0	17.0	20.0
H1 >	372	342	313	283	253	224	194

Water elevation (H1) that stops unprimed flow: 28.0 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 26.9 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure

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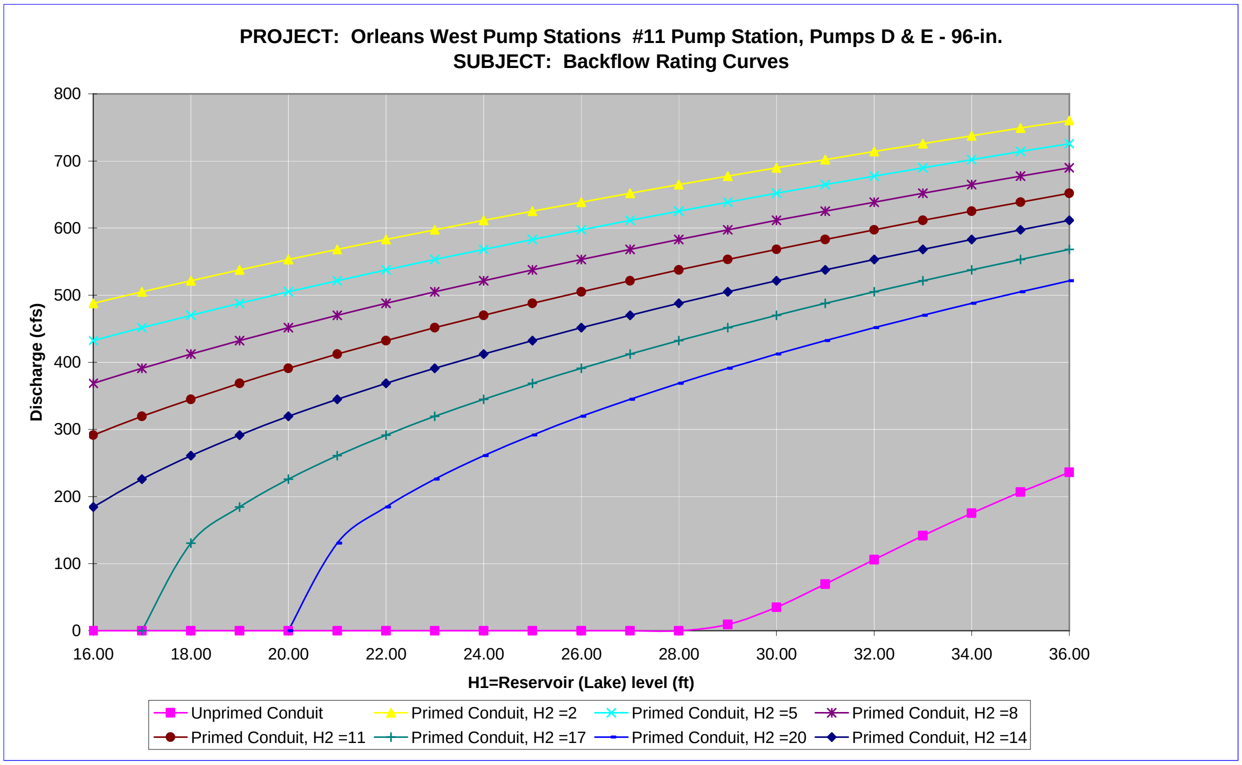
at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	9.00
Intake loss =	0.5
Exit Loss =	1.0

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

No drawings or pictures of the inlet or discharge tubes. Assumed rectangle shape because of concrete.

Assumed the inlet tube is the same width as the discharge tube.

Elevations in Cairo Datum.

4 Data Needs or Deficiencies:

Pictures or drawings of the plan view of the inlet & discharge tubes.

5 Backflow prevention:

Available: Pumps D & E - no backflow prevention

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Pumps D & E have brakes.

Used: Not needed - pumps were always working during the storm.

20. Reverse Flow Rating Curve

OP West, PS#11, Pump # CD-3C -30-in. Centrifugal Pump

Elevation Datum (ft):	Cairo
Crest Elevation (ft) =	28

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use* $Q = \sqrt{(H1-H2)/K'}$

$K' = 0.004427829 \quad sec^2/ft^5$

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Water elevation (H1) that triggers unprimed flow: 28.0 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 30.5 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.							
H2 =	1.8	7.5	13.2	18.9	24.6	30.3	36.0
H1 >	45	42	39	36	33	31	36

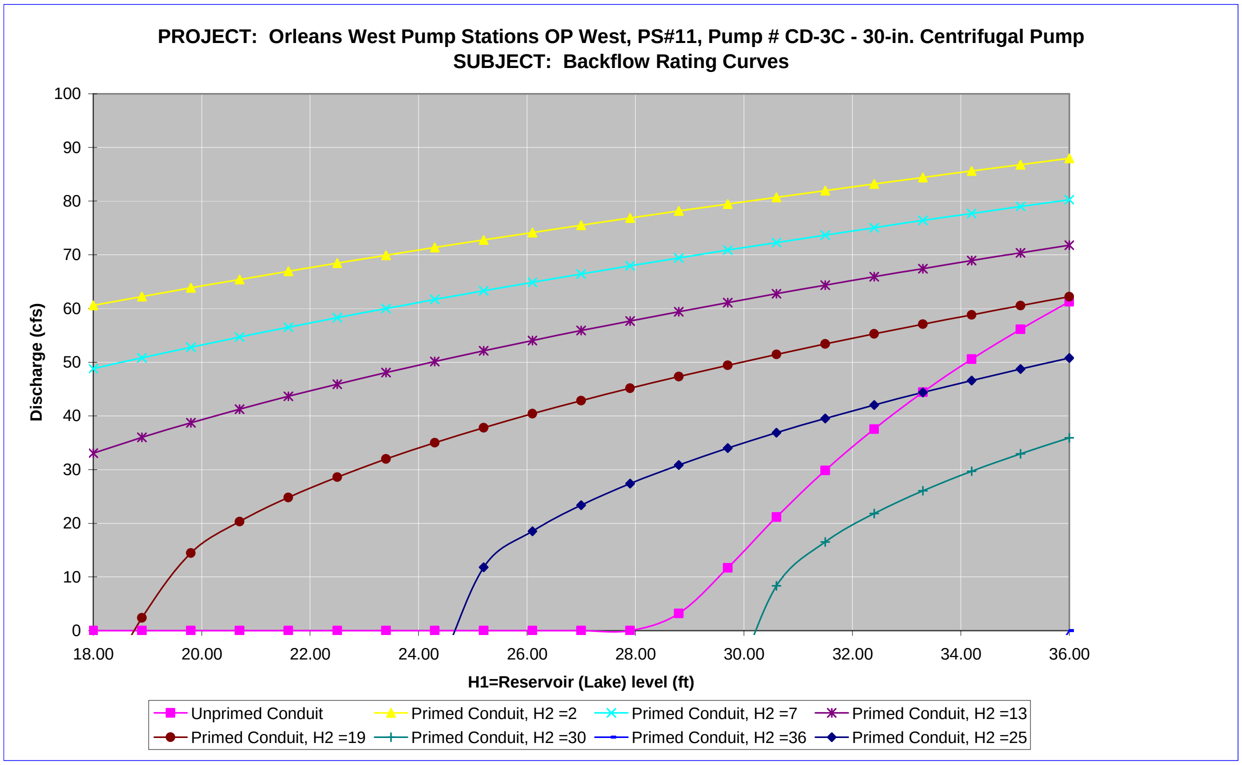
Water elevation (H1) that stops unprimed flow: 28.0 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 15.0 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	3.50
Intake loss =	0.92
Exit Loss =	1.0

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

No drawings for pump CD-3C. Assumed the elevations & layout is similar to pumps D & E.

Assumed the intake & discharge tube is 30 in through the whole layout.

No drawings or pictures of the inlet or discharge tubes. Assumed circular with a 30-in diameter.

Elevations in Cairo Datum.

Used photo for lay out & to estimate unseen layout.

4 Data Needs or Deficiencies:

Drawings of pump CD-3C.

Pictures or drawings of the pipe layout, inlet, & discharge pipes.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

5 Backflow prevention:

Available:	No backflow prevention. No reverse rotation brakes.
Used:	

7.6.2.4.1.8 Fuel Endurance Calculations

We do not have any record of pumps that run on fuel at this pump station.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.2.4.2 *OP 13*

Orleans Parish – West Bank Drainage Basin

4501 Tall Spruce Dr
New Orleans, LA 70131

Latitude: 29.89588˚ Longitude: -89.99775˚

7.6.2.4.2.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina: View from the inlet anal

Before Hurricane Katrina: Aerial view of the pump station

After Hurricane Katrina: View from the side of the intake canal

After Hurricane Katrina: Aerial view of the pump station

7.6.2.4.2.2 Description[207]

Drainage area:	Algiers
Nominal Capacity:	4700 cfs
Drains water from:	Nolan and East Donner Canals
Discharges water to:	Intracoastal Waterway
Owner:	New Orleans Sewerage and Water Board
Number of pumps:	7
Pump orientation:	4 horizontal 3 vertical
Pump driver:	5 electric 60 Hz motors 2 diesels
Water level to switch pumps on:	10 feet (Cairo)
Water level to switch pumps off:	7 feet (Cairo)
Water level that affects operation:	5.6 feet (Cairo). Diesel pump bearings would flood.
Reverse flow protection:	None

7.6.2.4.2.3 Damages

Estimated cost of repairs:	The estimated cost of repairs is not yet available.[208]
Relative level of damage:	
Severity of circumstances:	The basement was flooded, but the operating floor was above the flood waters.
Equipment damaged:	Roof damage allowed rainwater to damage switchgear. Low voltage wiring, switches, and lighting in the sump were damaged along with sump pumps themselves.
Building damage:	Wind damaged the roof, skylights, gutters, and rollup doors.
Misc. damage:	Wind damaged screens, the intake pipe, and vent stakes.

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[207] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[208] The Project Information Report (PIR) for each parish provides an estimated cost of repairs for the parish's pump stations. At the time this report was written, the Orleans Parish PIR was not yet complete. It should be available through the parish shortly after publication of the IPET Report.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.2.4.2.4 Katrina Event

Date	Time	Event
-	-	OP 13 is an automatic station. It operates when water levels reach a preset elevation. The station operated during the storm until 60 Hertz power was lost. As of 6-Feb-2006, no power was restored, and is operating on temporary generator.

7.6.2.4.2.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.2.4.2.6 Pump Operational Curves

Operational curves have been developed for OP 13. They are not included in this report at this time, but will be inserted in the future.

7.6.2.4.2.7 Pump Reverse Flow

There are seven pumps at this station for which reverse flow rating curves were computed (no pumps were excluded). The reverse flow data and curves are presented in the order of the pump numbering utilized in the summary tables included in this appendix. In cases where there are multiple pumps of equivalent size and system configuration, a single rating curve represents all of them at a unit rate per pump.

Pump No.	Pump Capacity (cfs)	Pump Size (in)	Reverse Flow Computed?		Rating Curve Ref. No.
			Yes	No	
V1	250	72	X		1
V2	250	72	X		1
CD3	50	36	X		2
D4	1000	126	X		3
D5	1000	126	X		3
6	1075	126	X		4
7	1075	126	X		4

For a general explanation of reverse flow (terminology, figures, methodology, equations and assumptions), refer to the Reverse Flow Section at the beginning of this appendix. Reverse flow computations for a given pump station do not necessarily imply that reverse flow actually occurred there during the Katrina event. But these curves may instead be used as future tools if further investigations are required based on reverse flow assumptions.

21. Reverse Flow Rating Curve

Orleans West #13 Pump Station, Pumps V1, V2

Elevation Datum (ft): Cairo

Crest Elevation (ft) = 27.31

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use Q = sqrt((H1-H2)/K')*
K' = *0.000108278* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 27.3 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 33.3 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

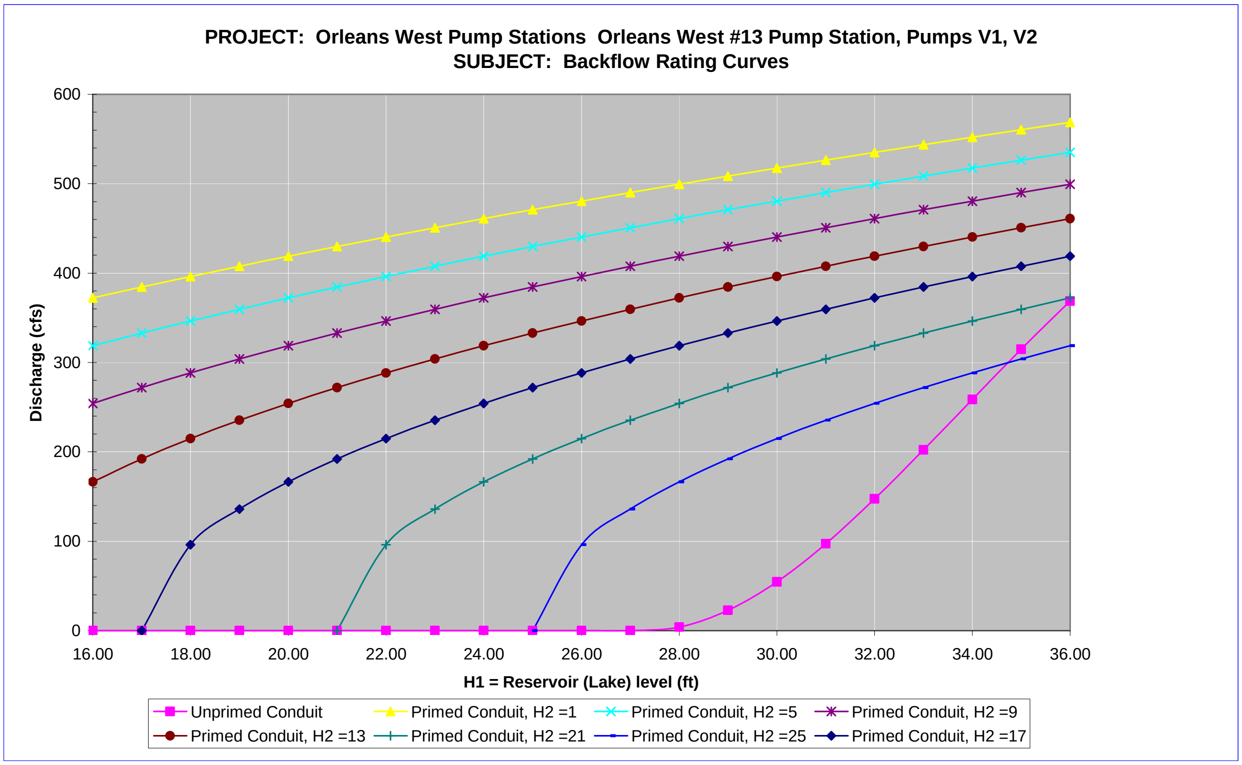
Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.							
H2 =	1.0	5.0	9.0	13.0	17.0	21.0	25.0
H1 >	42	41	40	39	38	36	35

Water elevation (H1) that stops unprimed flow: 27.3 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 14.6 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	3.50
Intake loss =	0.92
Exit Loss =	1.3

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Nominal pump size of 72" assumed to be pump diameter.

Drawings have correct dimensions and are to scale

Datum is at Cairo.

Discharge pipe is steel OD = 72" (swb_set3 39) used 72" as ID

Rated head from TDH pump curve.

Assumed discharge invert at the same elevation as pumps D4 & D5 = 10' (reverse flow inlet)

4 Data Needs or Deficiencies:

Discharge pipe elevations and details (reverse flow inlet)

5 Backflow prevention:

Available: Equipped with vacuum breaker valve.
No reverse rotation brakes installed.

Used: Manned & operating on auxiliary power during hurricane.

22. Reverse Flow Rating Curve

Orleans West #13 Pump Station, Pump CD3

Elevation Datum (ft):	Cairo
Crest Elevation (ft) =	27.31

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: Use $Q = \text{sqrt}((H1-H2)/K')$

$K' =$ 0.001911664 sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:
Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:
The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 27.3 ft
Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 30.3 ft
Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

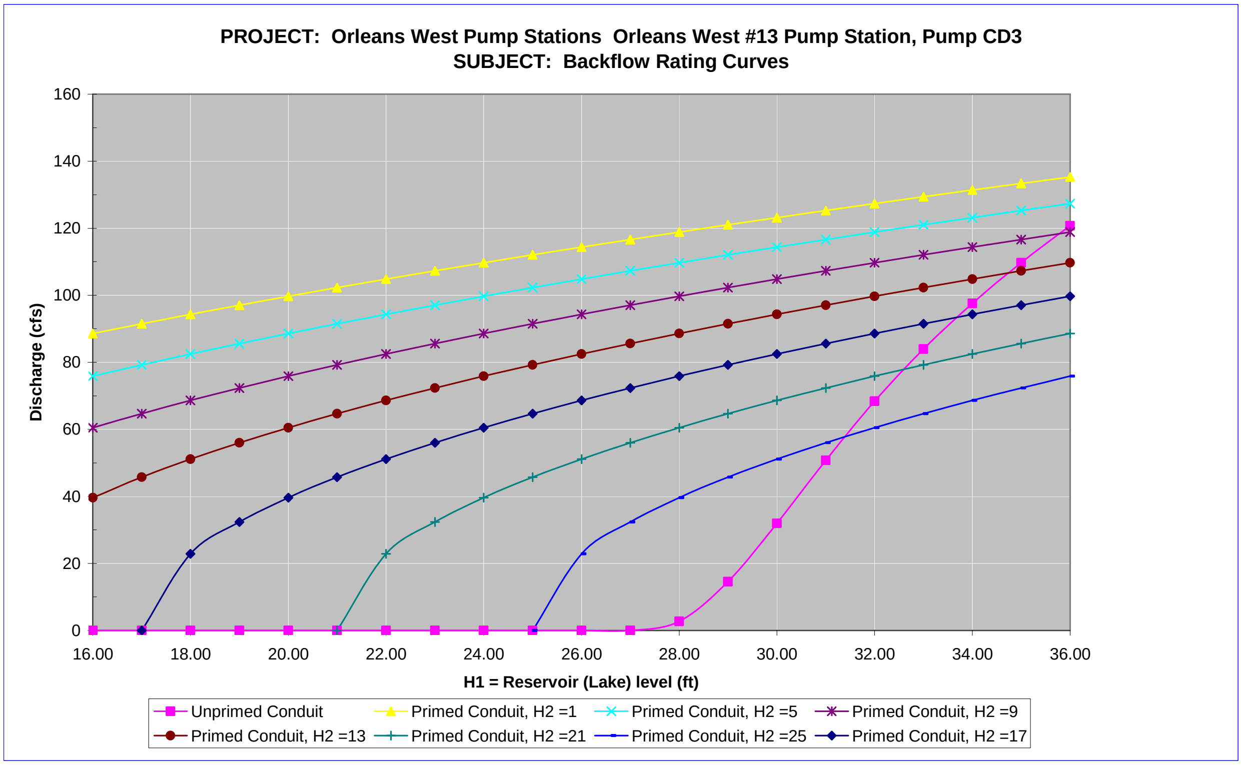
Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

H2 =	1.0	5.0	9.0	13.0	17.0	21.0	25.0
H1 >	38	37	36	35	34	33	32

Water elevation (H1) that stops unprimed flow: 27.3 ft
Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 11.6 ft
Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	3.50
Intake loss =	0.92
Exit Loss =	1.3

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Nominal pump size of 36" assumed to be pump diameter.

Drawings have correct dimensions and are to scale

Datum is at Cairo.

Discharge pipe is steel OD = 36" (swb_set3 39) used 36" as ID

Rated head based on TDH for pumps V1 & V2

Assumed discharge invert at the same elevation as pumps D4 & D5 = 10' (reverse flow inlet)

4 Data Needs or Deficiencies:

Discharge elevation and details (reverse flow inlet)

5 Backflow prevention:

Available: Equipped with vacuum breaker valve

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

No reverse rotation brakes.

Used: Manned and operating on auxiliary power during hurricane.

23. Reverse Flow Rating Curve

Orleans West #13 Pump Station, Pumps D4 & D5 -132-in.

Elevation Datum (ft):	Cairo
Crest Elevation (ft) =	27.31

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use* $Q = \text{sqrt}((H1-H2)/K')$

$K' =$ *7.23214E-06* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Water elevation (H1) that triggers unprimed flow: 27.3 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 31.1 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.							
H2 =	9.0	11.5	14.0	16.5	19.0	21.5	24.0
H1 >	40	39	38	37	36	35	34

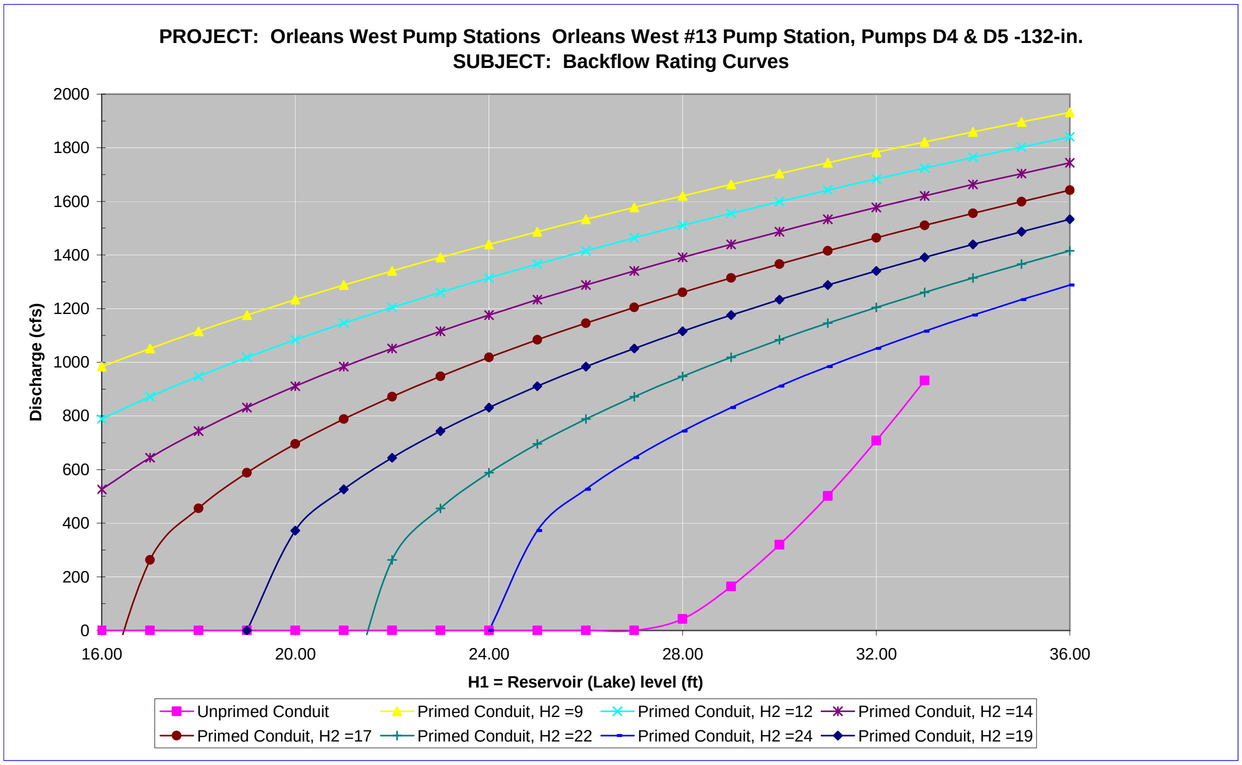
Water elevation (H1) that stops unprimed flow: 27.3 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 14.8 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	3.50
Intake loss =	0.5
Exit Loss =	1.0

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Elevations in Cairo Datum

All length measurements were center line lengths.

Operators interview stated pumps 4 & 5 10.5 ft diameter rated for 1000 cfs @ 12 ft head

Drawings (11242-w-28 (swb-set3_38) clearly indicates 11 ft ID in pump tube….used 11 ft dia.

4 Data Needs or Deficiencies:

Plan view of pump conduit.

5 Backflow prevention:

Available: Equipped with vacuum breaker.
No reverse rotation mechanism.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Used: Manned and operating on auxiliary power during hurricane.

24. Reverse Flow Rating Curve

Orleans West #13 Pump Station, Pumps 6 & 7 -132-in.

Elevation Datum (ft): Cairo
Crest Elevation (ft) = 27.31
H1 = Lake or outlet canal water level (normal pump discharge side)
H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: Use $Q = \mathrm{sqrt}((H1-H2)/K')$
$K' =$ 7.3772E-06 sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Water elevation (H1) that triggers unprimed flow: 27.3 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 31.1 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

H2 =	8.0	10.7	13.3	16.0	18.7	21.3	24.0
H1 >	40	39	38	37	36	35	34

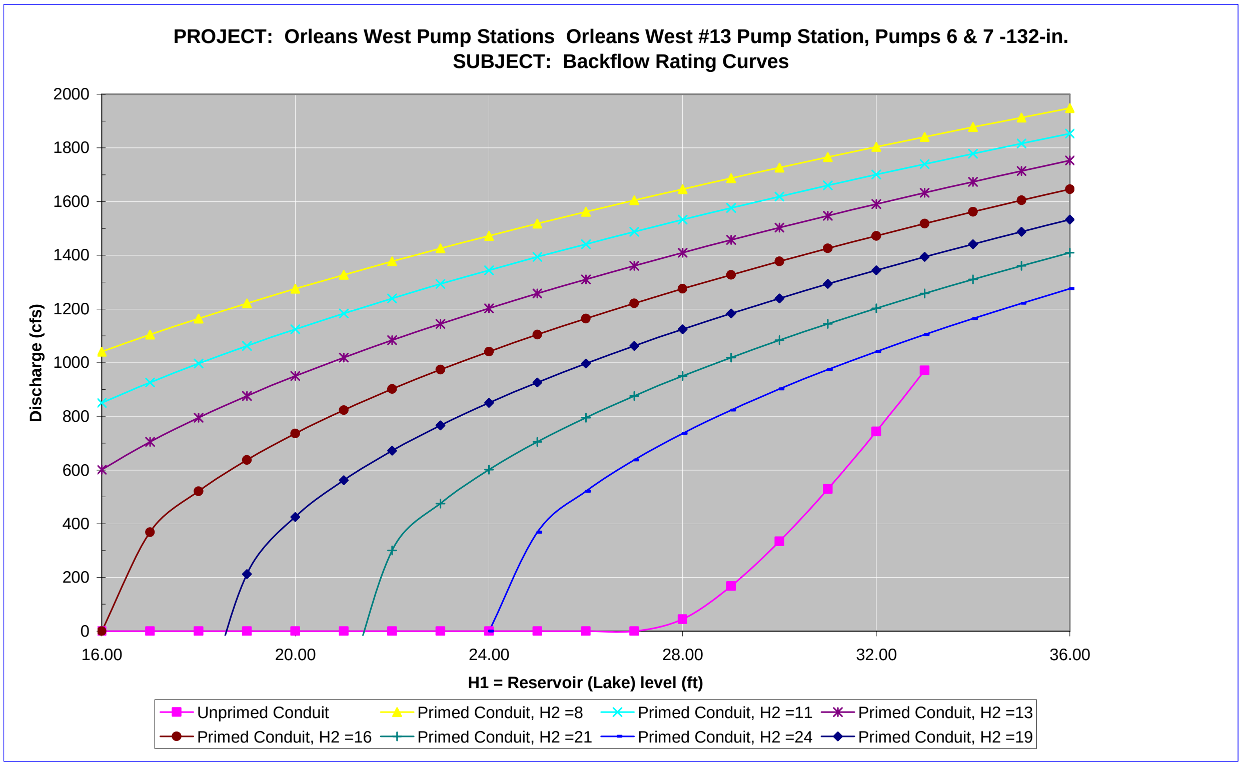
Water elevation (H1) that stops unprimed flow: 27.3 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 14.8 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	3.50
Intake loss =	0.5
Exit Loss =	1.0

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Elevations in Cairo Datum

All length measurements were center line lengths.

No evidence if discharge tube has haunches (Pumps 4 & 5 do)

Operator’s interview stated pumps 6 & 7 10.5 ft diameter rated for 1075 cfs @ 11 ft head.

Drawings (11459-w-28 (swb-set3_31) indicates 1050 CFS and assumed 11 ft pump similar to pump 4 & 5.

4 Data Needs or Deficiencies:

Plan view of pump conduit

5 Backflow prevention:

Available: Equipped with vacuum breaker

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

No reverse rotation mechanism.

Used: Manned and operating on auxiliary power during hurricane.

7.6.2.4.2.8 Fuel Endurance Calculations

We do not have any record of pumps that run on fuel at this pump station.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.3 Plaquemines Parish Pump Stations

7.6.3.1 East Bank Stations

7.6.3.1.1 *Braithwaite*

Plaquemines Parish – Braithwaite Drainage Basin

1155 SR-39
Braithwaite, LA 70040

Latitude 29.850025° Longitude -89.90907°

7.6.3.1.1.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Before Hurricane Katrina: Arial view of the pump station

After Hurricane Katrina: View from the inlet canal

After Hurricane Katrina: Arial view of the pump station

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.3.1.1.2 Description[209]

Drainage area:	East Bank- Braithwaite
Nominal Capacity:	105 cfs
Drains water from:	Braithwaite Pond
Discharges water to:	Marsh
Owner:	Plaquemines Parish Government
Number of pumps:	2
Pump orientation:	2 vertical
Pump driver:	2 diesels
Water level to switch pumps on:	-4.3 feet (NGVD)
Water level to switch pumps off:	-5.0 feet (NGVD)
Water level that affects operation:	13.0 feet (NGVD). Water would enter bearing housing for motor.
Reverse flow protection:	None

7.6.3.1.1.3 Damages

Estimated cost of repairs:	\$101,000[210]
Relative level of damage:	Minor
Severity of circumstances:	Flooding reached 2.5 ft. above the normal operating floor.
Equipment damaged:	Flooding caused non-repairable damages to the stand-by electric generators, air compressors and other auxiliary equipment.
Building damage:	Structure and/or site sustained significant wind and flood damage.
Misc. damage:	No significant miscellaneous damage recorded.

---

[209] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[210] This only includes the costs to repair damage due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

7.6.3.1.1.4 Katrina Event

Date	Time	Event
8/28/2005	-	The interview form states both pumps were operational and used for drawdown.
	10:00 PM	The interview form states that the operator evacuated the station (the pumps were shut down).
8/29/2005	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	-	The interview form states that flooding reached 2.5 feet above the operating floor.
9/3/2005	-	The pumps were restarted for unwatering.
9/13/2005	-	The pumps were turned off.

7.6.3.1.1.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.3.1.1.6 Pump Operational Curves

Operational curves were not developed for Braithwaite. The necessary data had been collected and the operational curves will be developed in the future.

7.6.3.1.1.7 Pump Reverse Flow

Reverse flow curves were not developed for Braithwaite. The necessary data had been collected and the reverse flow curves will be developed in the future.

7.6.3.1.1.8 Fuel Endurance Calculations

Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. To calculate the time, a few assumptions are required. The first assumption is the HHV[211] of diesel fuel being used is 130,000 Btu[212] per gallon of fuel[213]. The second assumption is the diesel engines are at least 35% efficient[214]. This station has 2 diesel driven pumps with different rated horsepower. The station did not report any issues with running out of fuel. Below are the fuel endurance calculations.

---

[211] High heating value

[212] British thermal units

[213] http://www.exxon.com/USA-English/GFM/Products_Services/Fuels/Diesel_Fuels_FAQ.asp

[214] Standard Handbook for Mechanical Engineers, Eighth Edition, pg 9-106

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

The rated horsepower of the diesel drivers $P_1 := 85\text{hp}$ $\quad P_2 := 140\text{hp}$

The assumed efficiency of the diesels $\varepsilon := 35\%$

The actual power required from the fuel $P_{a1} := \frac{P_1}{\varepsilon}$ $\quad P_{a1} = 242.86\,\text{hp}$

$P_{a2} := \frac{P_2}{\varepsilon}$ $\quad P_{a2} = 400\,\text{hp}$

The higher heating value $HHV := 130000\frac{\text{BTU}}{\text{gal}}$

The burn rates $BR_1 := \frac{P_{a1}}{HHV}$ $\quad BR_1 = 4.75\frac{\text{gal}}{\text{hr}}$

$BR_2 := \frac{P_{a2}}{HHV}$ $\quad BR_2 = 7.83\frac{\text{gal}}{\text{hr}}$

There are 1-2,000 gallon tank and 1-500 gallon tank at this station.

Total volume of fuel $V_T := (1\cdot 2000 + 1\cdot 500)\text{gal}$

The fuel endurance of the station $FE := \frac{V_T}{BR_1 + BR_2}$ $\quad FE = 198.69\,\text{hr}$

$FE = 8.28\,\text{day}$

7.6.3.1.2 *Scarsdale*

Plaquemines Parish – Belair/Scarsdale Drainage Basin

822 Scarsdale Rd
Braithwaite, LA 70040

Latitude 29.83266° Longitude -89.95974°

7.6.3.1.2.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Before Hurricane Katrina: Arial view of the pump station

After Hurricane Katrina: View from the side

After Hurricane Katrina: Arial view of the pump station

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.3.1.2.2 Description[215]

Drainage area:	East Bank- Belair/Scarsdale
Nominal Capacity:	1785 cfs
Drains water from:	Scarsdale Drainage Canal
Discharges water to:	Marsh
Owner:	Plaquemines Parish Government
Number of pumps:	4
Pump orientation:	4 horizontal
Pump driver:	4 diesels
Water level to switch pumps on:	-4.4 feet (NGVD)
Water level to switch pumps off:	-5.3 feet (NGVD)
Water level that affects operation:	11.0 feet (NGVD). Fuel pump is overtopped.
Reverse flow protection:	None

7.6.3.1.2.3 Damages

Estimated cost of repairs:	$413,000[216]
Relative level of damage:	Minor
Severity of circumstances:	Flooding reached 6in. above the operating floor.
Equipment damaged:	No significant equipment damage was noted.
Building damage:	Structure and/or site sustained significant wind and flood damage.
Misc. damage:	The trash racks and grease lubricator were damaged.

---

[215] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[216] This only includes the costs to repair damage due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

7.6.3.1.2.4 Katrina Event

Date	Time	Event
8/28/2005	-	The interview form states that all four pumps were operational and used for drawdown.
	10:00 PM	The interview form states that the station was evacuated.
8/29/2005	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	-	The interview form indicates that flooding reached 6 inches above the operating floor.
	-	The interview form states that the operator returned by boat to restart the pumps for unwatering.
9/18/2005	-	The unwatering was complete.

7.6.3.1.2.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.3.1.2.6 Pump Operational Curves

Operational curves were not developed for Scarsdale. The necessary data had been collected and the operational curves will be developed in the future.

7.6.3.1.2.7 Pump Reverse Flow

Reverse flow curves were not developed for Scarsdale. The necessary data had been collected and the reverse flow curves will be developed in the future.

7.6.3.1.2.8 Fuel Endurance Calculations

Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. To calculate the time, a few assumptions are required. The first assumption is the HHV[217] of diesel fuel being used is 130,000 Btu[218] per gallon of fuel[219]. The second assumption is the diesel engines are at least 35% efficient[220]. This station has 4 diesel driven pumps with the same rated horsepower. The station did not report any issues with running out of fuel. Below are the fuel endurance calculations.

---

[217] High heating value
[218] British thermal units
[219] http://www.exxon.com/USA-English/GFM/Products_Services/Fuels/Diesel_Fuels_FAQ.asp
[220] Standard Handbook for Mechanical Engineers, Eighth Edition, pg 9-106

The rated horsepower of the diesel driver $P := 720\text{hp}$

The assumed efficiency of the diesels $\varepsilon := 35\%$

The actual power required from the fuel $P_a := \frac{P}{\varepsilon}$ $P_a = 2057.14\ \text{hp}$

The higher heating value $HHV := 130000\ \frac{\text{BTU}}{\text{gal}}$

The burn rate $BR := \frac{P_a}{HHV}$ $BR = 40.26\ \frac{\text{gal}}{\text{hr}}$

There are 1-10,000 gallon tanks and 4-320 gallon tanks at this station.

Total volume of fuel $V_T := (1 \cdot 10000 + 4 \cdot 320)\text{gal}$

The fuel endurance of the station $FE := \frac{V_T}{4BR}$ $FE = 70.04\ \text{hr}$

$FE = 2.92\ \text{day}$

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.3.1.3 *Belair*

Plaquemines Parish – Belair/Scarsdale Drainage Basin

407 Belair Pump Rd
Braithwaite, LA 70040

Latitude 29.742257° Longitude -89.98725°

7.6.3.1.3.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Before Hurricane Katrina: Arial view of the pump station

After Hurricane Katrina: View from the inlet canal

Photo Not Obtained

After Hurricane Katrina

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.3.1.3.2 Description[221]

Drainage area:	East Bank- Belair/Scarsdale
Nominal Capacity:	130 cfs
Drains water from:	Pointe a La Hache Drainage Canal
Discharges water to:	Marsh
Owner:	Plaquemines Parish Government
Number of pumps:	1
Pump orientation:	Vertical
Pump driver:	Diesel
Water level to switch pumps on:	-3.0 feet (NGVD)
Water level to switch pumps off:	-4.0 feet (NGVD)
Water level that affects operation:	9.5 (NGVD). Water would enter top vent for buried day tank.
Reverse flow protection:	None

7.6.3.1.3.3 Damages

Estimated cost of repairs:	$538,000[222]
Relative level of damage:	Substantial
Severity of circumstances:	Flooding reached 8 ft. above the operating floor.
Equipment damaged:	The flooding submerged the diesel engine air intakes. The salt water damaged the diesel engines beyond normal repair.
Building damage:	Structure and/or site sustained significant wind and flood damage.
Misc. damage:	No significant miscellaneous damage recorded.

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[221] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[222] This only includes the costs to repair damage due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.3.1.3.4 Katrina Event

Date	Time	Event
8/28/2005	-	The interview form indicates that the station was operational prior to the hurricane, but was not used for drawdown.
8/29/2005	-	The interview form states that the station was evacuated prior to the storm (the pumps were not used).
	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	-	The interview form states that flooding reached 8 feet above the operating floor, and that the station was not operable after the hurricane.

7.6.3.1.3.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.3.1.3.6 Pump Operational Curves

Operational curves were not developed for Belair. The necessary data had been collected and the operational curves will be developed in the future.

7.6.3.1.3.7 Pump Reverse Flow

Reverse flow curves were not developed for Belair. The necessary data had been collected and the reverse flow curves will be developed in the future.

7.6.3.1.3.8 Fuel Endurance Calculations

Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. To calculate the time, a few assumptions are required. The first assumption is the HHV[223] of diesel fuel being used is 130,000 Btu[224] per gallon of fuel[225]. The second assumption is the diesel engines are at least 35% efficient[226]. This station has 4 diesel driven pumps with the same rated horsepower. The station did not report any issues with running out of fuel. Below are the fuel endurance calculations.

---

[223] High heating value

[224] British thermal units

[225] http://www.exxon.com/USA-English/GFM/Products_Services/Fuels/Diesel_Fuels_FAQ.asp

[226] Standard Handbook for Mechanical Engineers, Eighth Edition, pg 9-106

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

The rated horsepower of the diesel driver	$P := 225\,hp$	
The assumed efficiency of the diesels	$\varepsilon := 35\%$	
The actual power required from the fuel	$P_a := \frac{P}{\varepsilon}$	$P_a = 642.86\ hp$
The higher heating value	$HHV := 130000\ \frac{BTU}{gal}$	
The burn rate	$BR := \frac{P_a}{HHV}$	$BR = 12.58\ \frac{gal}{hr}$

There are 1-10,000 gallon tank and 1-320 gallon tank at this station.

Total volume of fuel	$V_T := (10000 + 320)\,gal$	
The fuel endurance of the station	$FE := \frac{V_T}{BR}$	$FE = 820.2\ hr$
		$FE = 34.17\ day$

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.3.1.4 *Bellevue*

Plaquemines Parish – Reach C Drainage Basin

14469 SR-39
Braithwaite, LA 70040

Latitude 29.62438° Longitude -89.877686°

7.6.3.1.4.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina: View from the inlet canal

Before Hurricane Katrina: Arial view of the pump station

After Hurricane Katrina: View from the inlet canal

After Hurricane Katrina: Arial view of the pump station

7.6.3.1.4.2 Description[227]

Drainage area:	East Bank- Reach C
Nominal Capacity:	515 cfs
Drains water from:	Pointe A La Hache
Discharges water to:	Over levee into an unnamed marsh
Owner:	Plaquemines Parish Government
Number of pumps:	2
Pump orientation:	2 horizontal
Pump driver:	2 diesels
Water level to switch pumps on:	-3.0 feet (NGVD)
Water level to switch pumps off:	-4.0 feet (NGVD)
Water level that affects operation:	16.5 (NGVD). Water would enter top vent for day tank.
Reverse flow protection:	None

7.6.3.1.4.3 Damages

Estimated cost of repairs:	$281,000[228]
Relative level of damage:	Minor
Severity of circumstances:	Flooding reached 3 ft. above the operating floor.
Equipment damaged:	Flooding caused non-repairable damages to the stand-by electric generators, air compressors and other auxiliary equipment.
Building damage:	Structure and/or site sustained significant wind and flood damage.
Misc. damage:	No significant miscellaneous damage recorded.

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[227] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[228] This only includes the costs to repair damage due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.3.1.4.4 Katrina Event

Date	Time	Event
8/27/2005		The interview form states that both pumps were operational, and used for drawdown.
8/28/2005	12:00 PM	The interview form states that the station was evacuated.
8/29/2005	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	-	The interview form states that the operators returned after the storm, but could not pump due to the levee breaches.

7.6.3.1.4.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.3.1.4.6 Pump Operational Curves

Operational curves were not developed for Bellevue. The necessary data had been collected and the operational curves will be developed in the future.

7.6.3.1.4.7 Pump Reverse Flow

Reverse flow curves were not developed for Bellevue. The necessary data had been collected and the reverse flow curves will be developed in the future.

7.6.3.1.4.8 Fuel Endurance Calculations

Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. To calculate the time, a few assumptions are required. The first assumption is the HHV[229] of diesel fuel being used is 130,000 Btu[230] per gallon of fuel[231]. The second assumption is the diesel engines are at least 35% efficient[232]. This station has 2 diesel driven pumps with the same rated horsepower. The station did not report any issues with running out of fuel. Below are the fuel endurance calculations.

---

[229] High heating value

[230] British thermal units

[231] http://www.exxon.com/USA-English/GFM/Products_Services/Fuels/Diesel_Fuels_FAQ.asp

[232] Standard Handbook for Mechanical Engineers, Eighth Edition, pg 9-106

The rated horsepower of the diesel driver	$P := 360\mathrm{hp}$	
The assumed efficiency of the diesels	$\varepsilon := 35\%$	
The actual power required from the fuel	$P_a := \dfrac{P}{\varepsilon}$	$P_a = 1028.57\,\mathrm{hp}$
The higher heating value	$HHV := 130000\,\dfrac{\mathrm{BTU}}{\mathrm{gal}}$	
The burn rate	$BR := \dfrac{P_a}{HHV}$	$BR = 20.13\,\dfrac{\mathrm{gal}}{\mathrm{hr}}$

There are 1-10,000 gallon tanks and 2-320 gallon tanks at this station.

Total volume of fuel	$V_T := (1 \cdot 10000 + 2 \cdot 320)\mathrm{gal}$	
The fuel endurance of the station	$FE := \dfrac{V_T}{2BR}$	$FE = 264.26\,\mathrm{hr}$
		$FE = 11.01\,\mathrm{day}$

7.6.3.1.5 *Pointe a la Hache (East)*

Plaquemines Parish – Reach C Drainage Basin

17561 SR-39
Braithwaite, LA 70040

Latitude 29.583643° Longitude -89.793133°

7.6.3.1.5.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Before Hurricane Katrina: Arial view of the pump station

After Hurricane Katrina: View from the inlet canal

After Hurricane Katrina: Arial view of the pump station

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.3.1.5.2 Description[233]

Drainage area:	East Bank- Reach C
Nominal Capacity:	580 cfs
Drains water from:	Pointe a La Hache Drainage Canal
Discharges water to:	Marsh
Owner:	Plaquemines Parish Government
Number of pumps:	2
Pump orientation:	2 horizontal
Pump driver:	2 diesels
Water level to switch pumps on:	-1.5 feet (NGVD)
Water level to switch pumps off:	-2.0 feet (NGVD)
Water level that affects operation:	16.5 feet (NGVD) Water would enter the top vents of dry tanks.
Reverse flow protection:	None

7.6.3.1.5.3 Damages

Estimated cost of repairs:	$876,000[234]
Relative level of damage:	Substantial
Severity of circumstances:	Flooding reached over 10 ft. above the operating floor.
Equipment damaged:	The flooding submerged the diesel engine air intakes. The salt water damaged the diesel engines beyond normal repair. Flooding also caused non-repairable damages to the stand-by electric generators, air compressors and other auxiliary equipment
Building damage:	Structure and/or site sustained significant wind and flood damage.
Misc. damage:	No significant miscellaneous damage recorded.

---

[233] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[234] This only includes the costs to repair damage due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.3.1.5.4 Katrina Event

Date	Time	Event
8/28/2005	-	The interview form states that the entire station was used in drawdown prior to Hurricane Katrina
	10:00 PM	The interview form states that the station was evacuated and pumps were shut down.
8/29/2005	6:30 AM	Hurricane Katrina made landfall in Louisiana.
-	-	The interview form states that the station was damaged and rendered un-operational

7.6.3.1.5.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.3.1.5.6 Pump Operational Curves

Operational curves were not developed for Pointe a la Hache (East). The necessary data had been collected and the operational curves will be developed in the future.

7.6.3.1.5.7 Pump Reverse Flow

Reverse flow curves were not developed for Pointe a la Hache (East). The necessary data had been collected and the reverse flow curves will be developed in the future.

7.6.3.1.5.8 Fuel Endurance Calculations

Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. To calculate the time, a few assumptions are required. The first assumption is the HHV[235] of diesel fuel being used is 130,000 Btu[236] per gallon of fuel[237]. The second assumption is the diesel engines are at least 35% efficient[238]. This station has 2 diesel driven pumps with the same rated horsepower. The station reported damage to the fuel system during the hurricane. Below are the fuel endurance calculations.

---

[235] High heating value
[236] British thermal units
[237] http://www.exxon.com/USA-English/GFM/Products_Services/Fuels/Diesel_Fuels_FAQ.asp
[238] Standard Handbook for Mechanical Engineers, Eighth Edition, pg 9-106

The rated horsepower of the diesel driver $P := 305\,\text{hp}$

The assumed efficiency of the diesels $\varepsilon := 35\%$

The actual power required from the fuel $P_a := \frac{P}{\varepsilon}$ $P_a = 871.43\ \text{hp}$

The higher heating value $HHV := 130000\,\frac{\text{BTU}}{\text{gal}}$

The burn rate $BR := \frac{P_a}{HHV}$ $BR = 17.06\,\frac{\text{gal}}{\text{hr}}$

There are 1-5,000 gallon tanks and 2-320 gallon tanks at this station.

Total volume of fuel $V_T := (1 \cdot 5000 + 2 \cdot 320)\text{gal}$

The fuel endurance of the station $FE := \frac{V_T}{2BR}$ $FE = 165.34\ \text{hr}$

$FE = 6.89\ \text{day}$

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.3.2 West Bank Stations

7.6.3.2.1 *Barriere Pond*

Plaquemines Parish – Area 7 Drainage Basin

Pump Station Rd
Belle Chase, LA 70037

Latitude 29.859055° Longitude -90.01495°

7.6.3.2.1.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Before Hurricane Katrina: Arial view of the pump station

After Hurricane Katrina: View from the inlet canal

After Hurricane Katrina: Arial view of the pump station

7.6.3.2.1.2 Description[239]

Drainage area:	West Bank- Area 7 West
Nominal Capacity:	25 cfs
Drains water from:	Barriere Pond
Discharges water to:	Intracoastal Highway
Owner:	Plaquemines Parish Government
Number of pumps:	1
Pump orientation:	Vertical
Pump driver:	Diesel
Water level to switch pumps on:	-8.3 feet (NGVD)
Water level to switch pumps off:	-10.5 feet (NGVD)
Water level that affects operation:	-1.5 feet (NGVD). Water will enter the vent at top of vent.
Reverse flow protection:	None

7.6.3.2.1.3 Damages

Estimated cost of repairs:	$0[240]
Relative level of damage:	None
Severity of circumstances:	Water did not reach the operator floor.
Damage:	No damage recorded.

7.6.3.2.1.4 Katrina Event

Date	Time	Event
8/28/2005	-	Pumps used for drawdown
8/29/2005	6:30 AM	Hurricane Katrina made landfall in Louisiana.
-	-	The interview form states that the pump station was operational, but was not used during Hurricane Katrina nor during unwatering for safety reasons

7.6.3.2.1.5 Repair Status

7.6.3.2.1.6 Pump Operational Curves

Operational curves were not developed for Barriere Pond. The necessary data had been collected and the operational curves will be developed in the future.

---

[239] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[240] This only includes the costs to repair damage due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.3.2.1.7 Pump Reverse Flow

Reverse flow curves were not developed for Barriere Pond. The necessary data had been collected and the reverse flow curves will be developed in the future.

7.6.3.2.1.8 Fuel Endurance Calculations

Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. This station did not have enough information available to perform these calculations.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.3.2.2 *Belle Chasse 1*

Plaquemines Parish – Area 7 Drainage Basin

206 Pump Station Rd
Belle Chasse, LA 70037

Latitude 29.852875° Longitude -90.01895°

7.6.3.2.2.1 Before and After Hurricane Katrina Photos

Before Hurricane Katrina: View from the inlet canal

Before Hurricane Katrina: Arial view of the pump station

After Hurricane Katrina: View from the inlet canal

After Hurricane Katrina: Arial view of the pump station

7.6.3.2.2.2 Description[241]

Drainage area:	West Bank- Area 7 West
Nominal Capacity:	3555 cfs
Drains water from:	Barriere Canal
Discharges water to:	Intracoastal Waterway
Owner:	Plaquemines Parish Government
Number of pumps:	5
Pump orientation:	4 horizontal 1 vertical
Pump driver:	5 diesels
Water level to switch pumps on:	-8.5 feet (NGVD)
Water level to switch pumps off:	-9.5 feet (NGVD)
Water level that affects operation:	10.5 feet (NGVD). Water would enter air intake.
Reverse flow protection:	None

7.6.3.2.2.3 Damages

Estimated cost of repairs:	$6,000[242]
Relative level of damage:	Minor
Severity of circumstances:	Water did not enter the building.
Damage:	No significant damage recorded.

7.6.3.2.2.4 Katrina Event

Date	Time	Event
8/28/2005	-	The interview form states that prior to the storm pump 3 was in-operable. Pumps 1, 2, 4, and 5 were available.
	-	The interview form states that the 4 available pumps were used for drawdown.
8/29/2005	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	-	The interview form states that the pumps were operated through the hurricane and until unwatering was complete.
	-	The interview form states that water did not enter the building.
9/1/2005	-	The interview form states that unwatering was complete.

7.6.3.2.2.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

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[241] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[242] This only includes the costs to repair damage due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

7.6.3.2.2.6 Pump Operational Curves

Operational curves were not developed for Belle Chasse 1. The necessary data had been collected and the operational curves will be developed in the future.

7.6.3.2.2.7 Pump Reverse Flow

Reverse flow curves were not developed for Belle Chasse 1. The necessary data had been collected and the reverse flow curves will be developed in the future.

7.6.3.2.2.8 Fuel Endurance Calculations

Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. To calculate the time, a few assumptions are required. The first assumption is the HHV[243] of diesel fuel being used is 130,000 Btu[244] per gallon of fuel[245]. The second assumption is the diesel engines are at least 35% efficient[246]. This station has 5 diesel driven pumps with different rated horsepower. The station did not report any issues with running out of fuel. Below are the fuel endurance calculations.

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[243] High heating value

[244] British thermal units

[245] http://www.exxon.com/USA-English/GFM/Products_Services/Fuels/Diesel_Fuels_FAQ.asp

[246] Standard Handbook for Mechanical Engineers, Eighth Edition, pg 9-106

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

The rated horsepower of the diesel drivers $P_1 := 1200\,hp \quad P_2 := 240\,hp \quad P_3 := 1440\,hp$

The assumed efficiency of the diesels $\varepsilon := 35\%$

The actual power required from the fuel $P_{a1} := \frac{P_1}{\varepsilon}$ $\quad P_{a1} = 3428.57\ hp$

$P_{a2} := \frac{P_2}{\varepsilon}$ $\quad P_{a2} = 685.71\ hp$

$P_{a3} := \frac{P_3}{\varepsilon}$ $\quad P_{a3} = 4114.29\ hp$

The higher heating value $HHV := 130000\ \frac{BTU}{gal}$

The burn rates $BR_1 := \frac{P_{a1}}{HHV}$ $\quad BR_1 = 67.11\ \frac{gal}{hr}$

$BR_2 := \frac{P_{a2}}{HHV}$ $\quad BR_2 = 13.42\ \frac{gal}{hr}$

$BR_3 := \frac{P_{a3}}{HHV}$ $\quad BR_3 = 80.53\ \frac{gal}{hr}$

There is 1-20,000 gallon tank at this station.

Total volume of fuel $V_T := (1\cdot 20000)\,gal$

The fuel endurance of the station $FE := \frac{V_T}{2BR_1 + BR_2 + 2BR_3}$ $\quad FE = 64.79\ hr$

$FE = 2.7\ day$

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.3.2.3 *Belle Chasse 2*

Plaquemines Parish – Area 7 Drainage Basin

245 Chancellor Dr
Belle Chasse, LA 70037

Latitude 29.884677° Longitude -89.99957°

7.6.3.2.3.1 Before and After Hurricane Katrina Photos

Before Hurricane Katrina: View from the inlet canal

Before Hurricane Katrina: Arial view of the pump station

After Hurricane Katrina: View from the inlet canal

After Hurricane Katrina: Arial view of the pump station

7.6.3.2.3.2 Description[247]

Drainage area:	West Bank- Area 7 West
Nominal Capacity:	1050 cfs
Drains water from:	Pointe a La Hache Drainage Canal
Discharges water to:	Intracoastal Highway
Owner:	Plaquemines Parish Government
Number of pumps:	3
Pump orientation:	3 vertical
Pump driver:	3 diesels
Water level to switch pumps on:	-8.5 feet (NGVD)
Water level to switch pumps off:	-12.0 feet (NGVD)
Water level that affects operation:	14.0 feet (NGVD). Water will enter the top vents of the day tanks.
Reverse flow protection:	None

7.6.3.2.3.3 Damages

Estimated cost of repairs:	$0[248]
Relative level of damage:	None.
Severity of circumstances:	Water did not reach the operator floor.
Damage:	No damage recorded.

7.6.3.2.3.4 Katrina Event

Date	Time	Event
8/28/2005	-	The interview form states that all three pumps were available, and pump 1 was used for drawdown.
8/29/2005	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	-	The interview form states that pumps 1 and 2 were used during the hurricane.
	-	The interview form states that flooding did not reach the operating floor.
9/3/2005	-	The unwatering was complete

7.6.3.2.3.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

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[247] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[248] This only includes the costs to repair damage due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

7.6.3.2.3.6 Pump Operational Curves

Operational curves were not developed for Belle Chasse 2. The necessary data had been collected and the operational curves will be developed in the future.

7.6.3.2.3.7 Pump Reverse Flow

Reverse flow curves were not developed for Belle Chasse 2. The necessary data had been collected and the reverse flow curves will be developed in the future.

7.6.3.2.3.8 Fuel Endurance Calculations

Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. To calculate the time, a few assumptions are required. The first assumption is the HHV[249] of diesel fuel being used is 130,000 Btu[250] per gallon of fuel[251]. The second assumption is the diesel engines are at least 35% efficient[252]. This station has 3 diesel driven pumps with the same rated horsepower. The station did not report any issues with running out of fuel. Below are the fuel endurance calculations.

The rated horsepower of the diesel driver	$P := 1020\text{hp}$	
The assumed efficiency of the diesels	$\varepsilon := 35\%$	
The actual power required from the fuel	$P_a := \dfrac{P}{\varepsilon}$	$P_a = 2914.29\,\text{hp}$
The higher heating value	$HHV := 130000\,\dfrac{\text{BTU}}{\text{gal}}$	
The burn rate	$BR := \dfrac{P_a}{HHV}$	$BR = 57.04\,\dfrac{\text{gal}}{\text{hr}}$

There are 1-12,000 gallon tanks and 3-320 gallon tanks at this station.

Total volume of fuel	$V_T := (1 \cdot 12000 + 3 \cdot 320)\text{gal}$	
The fuel endurance of the station	$FE := \dfrac{V_T}{3BR}$	$FE = 75.74\,\text{hr}$
		$FE = 3.16\,\text{day}$

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[249] High heating value
[250] British thermal units
[251] http://www.exxon.com/USA-English/GFM/Products_Services/Fuels/Diesel_Fuels_FAQ.asp
[252] Standard Handbook for Mechanical Engineers, Eighth Edition, pg 9-106

7.6.3.2.4 *Diamond*

Plaquemines Parish – St Jude to City Price Drainage Basin

24908 SR-23
Port Sulphur, LA 70083

Latitude 29.527753° Longitude -89.762357°

7.6.3.2.4.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Before Hurricane Katrina: Arial view of the pump station

After Hurricane Katrina: View from the inlet canal

After Hurricane Katrina: Arial view of the pump station

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.3.2.4.2 Description[253]

Drainage area:	West Bank- St Jude to City Price
Nominal Capacity:	255 cfs
Drains water from:	Diamond Drainage Canal
Discharges water to:	Marsh
Owner:	Plaquemines Parish Government
Number of pumps:	2
Pump orientation:	2 vertical
Pump driver:	2 diesels
Water level to switch pumps on:	-4.0 feet (NGVD)
Water level to switch pumps off:	-4.5 feet (NGVD)
Water level that affects operation:	14.5 feet (NGVD). Water would enter the top vents of the day tanks.
Reverse flow protection:	None

7.6.3.2.4.3 Damages

Estimated cost of repairs:	$212,000[254]
Relative level of damage:	Minor
Severity of circumstances:	Flooding reached 1 ft. above operating floor.
Equipment damaged:	No significant damage to equipment recorded.
Building damage:	Structure and/or site sustained significant wind and flood damage.
Misc. damage:	No significant miscellaneous damage recorded.

7.6.3.2.4.4 Katrina Event

Date	Time	Event
8/27/2005	-	Pumps 1 and 2 were used for drawdown until evacuation.
8/28/2005	8:00 PM	The station was evacuated (the pumps were shut down).
8/29/2005	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	-	The interview form states that flooding reached 1 foot above the operating floor.
9/1/2005	-	Both pumps were used until unwatering was complete.
9/8/2005	-	The unwatering was complete.

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[253] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[254] This only includes the costs to repair damage due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.3.2.4.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.3.2.4.6 Pump Operational Curves

Operational curves were not developed for Diamond. The necessary data had been collected and the operational curves will be developed in the future.

7.6.3.2.4.7 Pump Reverse Flow

Reverse flow curves were not developed for Diamond. The necessary data had been collected and the reverse flow curves will be developed in the future.

7.6.3.2.4.8 Fuel Endurance Calculations

Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. To calculate the time, a few assumptions are required. The first assumption is the HHV[255] of diesel fuel being used is 130,000 Btu[256] per gallon of fuel[257]. The second assumption is the diesel engines are at least 35% efficient[258]. This station has 2 diesel driven pumps with the same rated horsepower. The station did not report any issues with running out of fuel. Below are the fuel endurance calculations.

The rated horsepower of the diesel driver	$P := 350\text{hp}$	
The assumed efficiency of the diesels	$\varepsilon := 35\%$	
The actual power required from the fuel	$P_a := \frac{P}{\varepsilon}$	$P_a = 1000\,\text{hp}$
The higher heating value	$HHV := 130000\frac{BTU}{gal}$	
The burn rate	$BR := \frac{P_a}{HHV}$	$BR = 19.57\frac{gal}{hr}$

There are 1-10,000 gallon tanks and 2-320 gallon tanks at this station.

Total volume of fuel	$V_T := (1 \cdot 10000 + 2 \cdot 320)\text{gal}$	
The fuel endurance of the station	$FE := \frac{V_T}{2BR}$	$FE = 271.81\,\text{hr}$
		$FE = 11.33\,\text{day}$

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[255] High heating value

[256] British thermal units

[257] http://www.exxon.com/USA-English/GFM/Products_Services/Fuels/Diesel_Fuels_FAQ.asp

[258] Standard Handbook for Mechanical Engineers, Eighth Edition, pg 9-106

7.6.3.2.5 *Duvic (Venice)*

Plaquemines Parish – Reach B-2 Drainage Basin

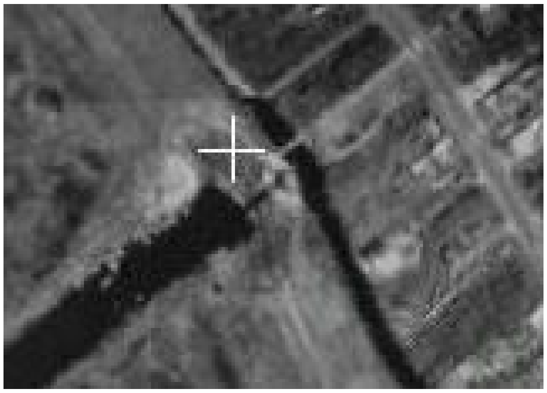
171 Duvic Pump Rd
Buras, LA 70041

Latitude 29.3139205° Longitude -89.38886°

7.6.3.2.5.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina



Before Hurricane Katrina: Arial view of the pump station

After Hurricane Katrina: View from the inlet canal

After Hurricane Katrina: Arial view of the pump station

7.6.3.2.5.2 Description[259]

Drainage area:	West Bank- Reach B-2
Nominal Capacity:	560 cfs
Drains water from:	Venice Drainage Canal
Discharges water to:	Bayou Duvic

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[259] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Owner:	Plaquemines Parish Government
Number of pumps:	2
Pump orientation:	2 vertical
Pump driver:	2 diesels
Water level to switch pumps on:	-8.8 feet (NGVD)
Water level to switch pumps off:	-9.0 feet (NGVD)
Water level that affects operation:	21.5 feet (NGVD) Water will enter the gear box above the pump.
Reverse flow protection:	None

7.6.3.2.5.3 Damages

Estimated cost of repairs:	$144,000[260]
Relative level of damage:	Minor
Severity of circumstances:	Water did not reach the operating floor.
Equipment damaged:	No significant equipment damage recorded.
Building damage:	Structure and/or site sustained significant wind and flood damage.
Misc. damage:	No significant miscellaneous damage recorded.

7.6.3.2.5.4 Katrina Event

Date	Time	Event
8/27/2005	-	Both pumps were operational and were used for drawdown until evacuation.
8/28/2005	8:00 PM	The station was evacuated.
8/29/2005	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	-	The interview form states that flooding did not reach the operating floor.
9/1/2005	-	The crews returned to the station by airboat and ran both pumps continually until after the unwatering of Hurricane Rita.
9/29/2005	-	Hurricane Rita arrived.

7.6.3.2.5.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.3.2.5.6 Pump Operational Curves

Operational curves were not developed for Duvic (Venice). The necessary data had been collected and the operational curves will be developed in the future.

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[260] This only includes the costs to repair damage due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.3.2.5.7 Pump Reverse Flow

Reverse flow curves were not developed for Duvic (Venice). The necessary data had been collected and the reverse flow curves will be developed in the future.

7.6.3.2.5.8 Fuel Endurance Calculations

Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. To calculate the time, a few assumptions are required. The first assumption is the HHV[261] of diesel fuel being used is 130,000 Btu[262] per gallon of fuel[263]. The second assumption is the diesel engines are at least 35% efficient[264]. This station has 2 diesel driven pumps with the same rated horsepower. The station did not report any issues with running out of fuel. Below are the fuel endurance calculations.

The rated horsepower of the diesel driver $P := 1100\text{hp}$

The assumed efficiency of the diesels $\varepsilon := 35\%$

The actual power required from the fuel $P_a := \frac{P}{\varepsilon}$ $P_a = 3142.86\,\text{hp}$

The higher heating value $HHV := 130000\frac{\text{BTU}}{\text{gal}}$

The burn rate $BR := \frac{P_a}{HHV}$ $BR = 61.51\frac{\text{gal}}{\text{hr}}$

There are 1-15,000 gallon tanks and 2-460 gallon tanks at this station.

Total volume of fuel $V_T := (1\cdot 15000 + 2\cdot 460)\text{gal}$

The fuel endurance of the station $FE := \frac{V_T}{2BR}$ $FE = 129.4\,\text{hr}$

$FE = 5.39\,\text{day}$

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[261] High heating value

[262] British thermal units

[263] http://www.exxon.com/USA-English/GFM/Products_Services/Fuels/Diesel_Fuels_FAQ.asp

[264] Standard Handbook for Mechanical Engineers, Eighth Edition, pg 9-106

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.3.2.6 *Gainard Woods 1*

Plaquemines Parish – Reach A Drainage Basin

182 W Paula 1
Port Sulphur, LA 70083

Latitude 29.250074° Longitude -89.649077°

7.6.3.2.6.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Before Hurricane Katrina: Arial view of the pump station

After Hurricane Katrina: View from the inlet canal

After Hurricane Katrina: Arial view of the pump station

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.3.2.6.2 Description[265]

Drainage area:	West Bank- Reach A
Nominal Capacity:	410 cfs
Drains water from:	Gainard Woods Canal
Discharges water to:	Marsh
Owner:	Plaquemines Parish Government
Number of pumps:	2
Pump orientation:	2 vertical
Pump driver:	2 diesels
Water level to switch pumps on:	-6.0 feet (NGVD)
Water level to switch pumps off:	-7.0 feet (NGVD)
Water level that affects operation:	12.5 feet (NGVD) Water would enter bearing housing
Reverse flow protection:	None

7.6.3.2.6.3 Damages[266]

Estimated cost of repairs:	$1,881,000[267]
Relative level of damage:	Substantial
Severity of circumstances:	Flooding reached 9 ft. above operating floor
Equipment damaged:	The flooding submerged the diesel engine air intakes. The salt water damaged the diesel engines beyond normal repair. The flooding also caused non-repairable damages to the stand-by electric generators, air compressors and other auxiliary equipment.
Building damage:	Structure and/or site sustained significant wind and flood damage.
Misc. damage:	No significant miscellaneous damage recorded.

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[265] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[266] This summary incorporates the damages and costs for both Gainard Woods 1 and 2 pump station.

[267] This only includes the costs to repair damage due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.3.2.6.4 Katrina Event

Date	Time	Event
8/28/2005	-	The interview form states that both the pumps were operational prior to the storm, but that the station was not used for drawdown.
	8:00 PM	The interview form states that the station was evacuated. The pumps were shut down.
8/29/2005	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	-	The interview form states that flooding reached 9 inches above the operating floor.
10/2/2005	-	The pumps were started for unwatering. (They were not able to start earlier, due to levee breaches.)
10/6/2005	-	The unwatering was complete.

7.6.3.2.6.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.3.2.6.6 Pump Operational Curves

Operational curves were not developed for Gainard Woods 1. The necessary data had been collected and the operational curves will be developed in the future.

7.6.3.2.6.7 Pump Reverse Flow

Reverse flow curves were not developed for Gainard Woods 1. The necessary data had been collected and the reverse flow curves will be developed in the future.

7.6.3.2.6.8 Fuel Endurance Calculations

Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. To calculate the time, a few assumptions are required. The first assumption is the HHV[268] of diesel fuel being used is 130,000 Btu[269] per gallon of fuel[270]. The second assumption is the diesel engines are at least 35% efficient[271]. This station has 2 diesel driven pumps with the same rated horsepower. The flood waters shift the tanks and damaged the connected piping. Below are the fuel endurance calculations.

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[268] High heating value

[269] British thermal units

[270] http://www.exxon.com/USA-English/GFM/Products_Services/Fuels/Diesel_Fuels_FAQ.asp

[271] Standard Handbook for Mechanical Engineers, Eighth Edition, pg 9-106

The rated horsepower of the diesel driver $P := 300\text{hp}$

The assumed efficiency of the diesels $\varepsilon := 35\%$

The actual power required from the fuel $P_a := \frac{P}{\varepsilon}$ $P_a = 857.14\,\text{hp}$

The higher heating value $HHV := 130000\,\frac{\text{BTU}}{\text{gal}}$

The burn rate $BR := \frac{P_a}{HHV}$ $BR = 16.78\,\frac{\text{gal}}{\text{hr}}$

There are 1-10,000 gallon tanks and 2-320 gallon tanks at this station.

Total volume of fuel $V_T := (1 \cdot 10000 + 2 \cdot 320)\text{gal}$

The fuel endurance of the station $FE := \frac{V_T}{2BR}$ $FE = 317.11\,\text{hr}$

$FE = 13.21\,\text{day}$

7.6.3.2.7 *Gainard Woods 2*

Plaquemines Parish – Reach A Drainage Basin

182 W Paula 1
Port Sculpture, LA 70083

Latitude 29.250074° Longitude -89.649077°

7.6.3.2.7.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Photo Not Obtained

Before Hurricane Katrina

After Hurricane Katrina: View from the inlet canal

After Hurricane Katrina: Arial view of the pump station

7.6.3.2.7.2 Description[272]

Drainage area:	West Bank- Reach A
Nominal Capacity:	570 cfs
Drains water from:	Gainard Woods Canal
Discharges water to:	Marsh
Owner:	Plaquemines Parish Government
Number of pumps:	2
Pump orientation:	2 vertical
Pump driver:	2 diesels
Water level to switch pumps on:	-6.0 feet (NGVD)

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[272] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

Water level to switch pumps off:	-7.0 feet (NGVD)
Water level that affects operation:	4.5 feet (NGVD) Electric pump that transfers fuel from main fuel tank to day tanks would be flooded.
Reverse flow protection:	None

7.6.3.2.7.3 Damages[273]

Estimated cost of repairs:	$1,881,000[274]
Relative level of damage:	Substantial
Severity of circumstances:	Flooding reached 9 ft. above operating floor
Equipment damaged:	The flooding submerged the diesel engine air intakes. The salt water damaged the diesel engines beyond normal repair. The flooding also caused non-repairable damages to the stand-by electric generators, air compressors and other auxiliary equipment.
Building damage:	Structure and/or site sustained significant wind and flood damage.
Misc. damage:	No significant miscellaneous damage recorded.

7.6.3.2.7.4 Katrina Event

Date	Time	Event
8/27/2005	-	The interview form states that both pumps were available and used for drawdown.
8/28/2005	8:00 PM	The interview form states that the station was evacuated. The pumps were shut down.
8/29/2005	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	-	The interview form states that flooding reached 4 feet above the operating floor.
10/2/2005	-	The pumps were started for unwatering. (They were not able to start earlier, due to levee breaches.)
10/6/2005	-	The unwatering was complete.

7.6.3.2.7.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

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[273] This summary incorporates the damages and costs for both Gainard Woods 1 and 2 pump station.

[274] This only includes the costs to repair damage due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

7.6.3.2.7.6 Pump Operational Curves

Operational curves were not developed for Gainard Woods 2. The necessary data had been collected and the operational curves will be developed in the future.

7.6.3.2.7.7 Pump Reverse Flow

Reverse flow curves were not developed for Gainard Woods 2. The necessary data had been collected and the reverse flow curves will be developed in the future.

7.6.3.2.7.8 Fuel Endurance Calculations

Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. To calculate the time, a few assumptions are required. The first assumption is the HHV[275] of diesel fuel being used is 130,000 Btu[276] per gallon of fuel[277]. The second assumption is the diesel engines are at least 35% efficient[278]. This station has 2 diesel driven pumps with the same rated horsepower. The flood waters shifted the fuel tank causing damage to the connected piping. Below are the fuel endurance calculations.

The rated horsepower of the diesel driver $P := 561\,\text{hp}$

The assumed efficiency of the diesels $\varepsilon := 35\%$

The actual power required from the fuel $P_a := \dfrac{P}{\varepsilon}$ $P_a = 1602.86\,\text{hp}$

The higher heating value $HHV := 130000\,\dfrac{BTU}{gal}$

The burn rate $BR := \dfrac{P_a}{HHV}$ $BR = 31.37\,\dfrac{gal}{hr}$

There are 1-10,000 gallon tanks and 2-460 gallon tanks at this station.

Total volume of fuel $V_T := (1 \cdot 10000 + 2 \cdot 460)\,\text{gal}$

The fuel endurance of the station $FE := \dfrac{V_T}{2BR}$ $FE = 174.04\,\text{hr}$

$FE = 7.25\,\text{day}$

---

[275] High heating value

[276] British thermal units

[277] http://www.exxon.com/USA-English/GFM/Products_Services/Fuels/Diesel_Fuels_FAQ.asp

[278] Standard Handbook for Mechanical Engineers, Eighth Edition, pg 9-106

7.6.3.2.8 *Hayes*

Plaquemines Parish – Reach A Drainage Basin

120 West St
Buras, LA 70041

Latitude 29.50054° Longitude -89.72114°

7.6.3.2.8.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Before Hurricane Katrina: Arial view of the pump station

After Hurricane Katrina: View from the inlet canal

After Hurricane Katrina: Arial view of the pump station

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.3.2.8.2 Description[279]

Drainage area:	West Bank- Reach A
Nominal Capacity:	500 cfs
Drains water from:	Hayes Drainage Canal
Discharges water to:	Marsh
Owner:	Plaquemines Parish Government
Number of pumps:	2
Pump orientation:	2 horizontal
Pump driver:	2 diesels
Water level to switch pumps on:	-4.5 feet (NGVD)
Water level to switch pumps off:	-5.5 feet (NGVD)
Water level that affects operation:	12.5 feet (NGVD). Water would enter top vent of dry tanks.
Reverse flow protection:	None

7.6.3.2.8.3 Damages

Estimated cost of repairs:	$1,411,000[280]
Relative level of damage:	Substantial
Severity of circumstances:	Flooding reached 9 ft. above operating floor.
Equipment damaged:	The flooding submerged the diesel engine air intakes. The salt water damaged the diesel engines beyond normal repair. The flooding also caused non-repairable damages to the stand-by electric generators, air compressors and other auxiliary equipment
Building damage:	Structure and/or site sustained significant wind and flood damage.
Misc. damage:	No significant miscellaneous damage recorded.

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[279] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[280] This only includes the costs to repair damage due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.3.2.8.4 Katrina Event

Date	Time	Event
8/27/2005	-	The interview form states that both pumps were operational and were used for drawdown until evacuation.
8/28/2005	8:00 PM	The interview form states that the station was evacuated. (The pumps were shut down).
8/29/2005	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	-	The interview form indicates that flooding reached 9 feet above the operating floor.
9/1/2005	-	Both pumps were restarted for unwatering.

7.6.3.2.8.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.3.2.8.6 Pump Operational Curves

Operational curves were not developed for Hayes. The necessary data had been collected and the operational curves will be developed in the future.

7.6.3.2.8.7 Pump Reverse Flow

Reverse flow curves were not developed for Bellevue. The necessary data had been collected and the reverse flow curves will be developed in the future.

7.6.3.2.8.8 Fuel Endurance Calculations

Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. To calculate the time, a few assumptions are required. The first assumption is the HHV[281] of diesel fuel being used is 130,000 Btu[282] per gallon of fuel[283]. The second assumption is the diesel engines are at least 35% efficient[284]. This station has 2 diesel driven pumps with the same rated horsepower. Flood waters entered the top of the day fuel tanks. Below are the fuel endurance calculations.

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[281] High heating value

[282] British thermal units

[283] http://www.exxon.com/USA-English/GFM/Products_Services/Fuels/Diesel_Fuels_FAQ.asp

[284] Standard Handbook for Mechanical Engineers, Eighth Edition, pg 9-106

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

The rated horsepower of the diesel driver $P := 420\text{hp}$

The assumed efficiency of the diesels $\varepsilon := 35\%$

The actual power required from the fuel $P_a := \frac{P}{\varepsilon}$ $P_a = 1200\,\text{hp}$

The higher heating value $HHV := 130000\,\frac{\text{BTU}}{\text{gal}}$

The burn rate $BR := \frac{P_a}{HHV}$ $BR = 23.49\,\frac{\text{gal}}{\text{hr}}$

There are 1-10,000 gallon tank and 2-320 gallon tanks at this station.

Total volume of fuel $V_T := (1 \cdot 10000 + 2 \cdot 320)\text{gal}$

The fuel endurance of the station $FE := \frac{V_T}{2BR}$ $FE = 226.51\,\text{hr}$

$FE = 9.44\,\text{day}$

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.3.2.9 *Ollie Lower*

Plaquemines Parish – Area 6 Drainage Basin

305 Ollie Dr
Belle Chasse, LA 70037

Latitude 29.7391795° Longitude -89.0221969°

7.6.3.2.9.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Before Hurricane Katrina: Arial view of the pump station

After Hurricane Katrina: View from the inlet canal

Photo Not Obtained

After Hurricane Katrina

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.3.2.9.2 Description[285]

Drainage area:	West Bank- Area 6 West
Nominal Capacity:	440 cfs
Drains water from:	Ollie Canal
Discharges water to:	Ollie Outfall Canal
Owner:	Plaquemines Parish Government
Number of pumps:	3
Pump orientation:	3 vertical
Pump driver:	3 diesels
Water level to switch pumps on:	-4.8 feet (NGVD)
Water level to switch pumps off:	-5.2 feet (NGVD)
Water level that affects operation:	15 feet (NGVD). Water would enter top vents of dry tanks
Reverse flow protection:	None

7.6.3.2.9.3 Damages

Estimated cost of repairs:	$2,000[286]
Relative level of damage:	Minor
Severity of circumstances:	Water did not enter the building.
Damage:	No significant damage recorded.

7.6.3.2.9.4 Katrina Event

Date	Time	Event
8/28/2005	-	All three pumps were available and used for pre-Katrina drawdown.
8/29/2005	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	-	The interview form states that the pumps continued operating through the hurricane and until the unwatering was complete.
	-	The interview form states that water did not enter the building.
9/3/2005	-	The unwatering was complete.

7.6.3.2.9.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

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[285] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[286] This cost includes the damages of Upper, Lower, and New Ollie pump stations. It only includes the costs to repair damage due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.3.2.9.6 Pump Operational Curves

Operational curves were not developed for Ollie Lower. The necessary data had been collected and the operational curves will be developed in the future.

7.6.3.2.9.7 Pump Reverse Flow

Reverse flow curves were not developed for Ollie Lower. The necessary data had been collected and the reverse flow curves will be developed in the future.

7.6.3.2.9.8 Fuel Endurance Calculations

Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. To calculate the time, a few assumptions are required. The first assumption is the HHV[287] of diesel fuel being used is 130,000 Btu[288] per gallon of fuel[289]. The second assumption is the diesel engines are at least 35% efficient[290]. This station has 3 diesel driven pumps with different rated horsepower. The station did not report any issues with running out of fuel. Below are the fuel endurance calculations.

---

[287] High heating value

[288] British thermal units

[289] http://www.exxon.com/USA-English/GFM/Products_Services/Fuels/Diesel_Fuels_FAQ.asp

[290] Standard Handbook for Mechanical Engineers, Eighth Edition, pg 9-106

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

The rated horsepower of the diesel drivers $P_1 := 225\,\text{hp} \quad P_2 := 305\,\text{hp}$

The assumed efficiency of the diesels $\varepsilon := 35\%$

The actual power required from the fuel $P_{a1} := \dfrac{P_1}{\varepsilon}$ $\quad P_{a1} = 642.86\ \text{hp}$

$P_{a2} := \dfrac{P_2}{\varepsilon}$ $\quad P_{a2} = 871.43\ \text{hp}$

The higher heating value $\text{HHV} := 130000\,\dfrac{\text{BTU}}{\text{gal}}$

The burn rates $BR_1 := \dfrac{P_{a1}}{\text{HHV}}$ $\quad BR_1 = 12.58\,\dfrac{\text{gal}}{\text{hr}}$

$BR_2 := \dfrac{P_{a2}}{\text{HHV}}$ $\quad BR_2 = 17.06\,\dfrac{\text{gal}}{\text{hr}}$

There are 1-10,000 gallon tank and 3-320 gallon tanks at this station.

Total volume of fuel $V_T := (1\cdot 10000 + 3\cdot 320)\text{gal}$

The fuel endurance of the station $FE := \dfrac{V_T}{BR_1 + 2BR_2}$ $\quad FE = 234.72\ \text{hr}$

$FE = 9.78\ \text{day}$

7.6.3.2.10 *Ollie Upper*

Plaquemines Parish – Area 6 Drainage Basin

305 Ollie Dr
Belle Chasse, LA 70037

Latitude 29.7391795° Longitude -89.0221969°

7.6.3.2.10.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Before Hurricane Katrina: Arial view of the pump station

After Hurricane Katrina: View from the inlet canal

Photo Not Obtained

After Hurricane Katrina

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.3.2.10.2 Description[291]

Drainage area:	West Bank- Area 6 West
Nominal Capacity:	240 cfs
Drains water from:	Ollie Canal
Discharges water to:	Ollie Outfall Canal
Owner:	Plaquemines Parish Government
Number of pumps:	2
Pump orientation:	2 vertical
Pump driver:	2 diesels
Water level to switch pumps on:	-4.8 feet (NGVD)
Water level to switch pumps off:	-5.2 feet (NGVD)
Water level that affects operation:	7.5 feet (NGVD). Water would enter top vents of dry tanks
Reverse flow protection:	None

7.6.3.2.10.3 Damages

Estimated cost of repairs:	$2,000[292]
Relative level of damage:	Minor
Severity of circumstances:	Water did not enter the building.
Damage:	No significant damage recorded.

7.6.3.2.10.4 Katrina Event

Date	Time	Event
8/28/2005	-	Both pumps were available and used for pre-Katrina drawdown.
8/29/2005	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	-	The interview form states that the pumps continued operating through the hurricane and until the unwatering was complete.
	-	The interview form states that water did not enter the building.
9/3/2005	-	The unwatering was complete.

7.6.3.2.10.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

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[291] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[292] This cost includes the damages of Upper, Lower, and New Ollie pump stations. It only includes the costs to repair damage due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

7.6.3.2.10.6 Pump Operational Curves

Operational curves were not developed for Ollie Upper. The necessary data had been collected and the operational curves will be developed in the future.

7.6.3.2.10.7 Pump Reverse Flow

Reverse flow curves were not developed for Ollie Upper. The necessary data had been collected and the reverse flow curves will be developed in the future.

7.6.3.2.10.8 Fuel Endurance Calculations

Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. To calculate the time, a few assumptions are required. The first assumption is the HHV[293] of diesel fuel being used is 130,000 Btu[294] per gallon of fuel[295]. The second assumption is the diesel engines are at least 35% efficient[296]. This station has 2 diesel driven pumps with different rated horsepower. The station did not report any issues with running out of fuel. Below are the fuel endurance calculations.

---

[293] High heating value

[294] British thermal units

[295] http://www.exxon.com/USA-English/GFM/Products_Services/Fuels/Diesel_Fuels_FAQ.asp

[296] Standard Handbook for Mechanical Engineers, Eighth Edition, pg 9-106

The rated horsepower of the diesel drivers $P_1 := 225\text{hp} \quad P_2 := 300\text{hp}$

The assumed efficiency of the diesels $\varepsilon := 35\%$

The actual power required from the fuel $P_{a1} := \dfrac{P_1}{\varepsilon}$ $\qquad P_{a1} = 642.86\ \text{hp}$

$P_{a2} := \dfrac{P_2}{\varepsilon}$ $\qquad P_{a2} = 857.14\ \text{hp}$

The higher heating value $\text{HHV} := 130000\ \dfrac{\text{BTU}}{\text{gal}}$

The burn rates $BR_1 := \dfrac{P_{a1}}{\text{HHV}}$ $\qquad BR_1 = 12.58\ \dfrac{\text{gal}}{\text{hr}}$

$BR_2 := \dfrac{P_{a2}}{\text{HHV}}$ $\qquad BR_2 = 16.78\ \dfrac{\text{gal}}{\text{hr}}$

There are 1-10,000 gallon tank and 2-320 gallon tanks at this station.

Total volume of fuel $V_T := (1 \cdot 10000 + 2 \cdot 320)\text{gal}$

The fuel endurance of the station $\text{FE} := \dfrac{V_T}{BR_1 + BR_2}$ $\qquad \text{FE} = 362.41\ \text{hr}$

$\text{FE} = 15.1\ \text{day}$

7.6.3.2.11 *Pointe a la Hache (West)*

Plaquemines Parish – St Jude to City Price Drainage Basin

22941 SR-23
Port Sculpture, LA 70083

Latitude 29.569443° Longitude -89.804196°

7.6.3.2.11.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Photo Not Obtained

Before Hurricane Katrina

After Hurricane Katrina: View from the inlet canal

After Hurricane Katrina: Arial view of the pump station

7.6.3.2.11.2 Description[297]

Drainage area:	West Bank- St Jude to City Price
Nominal Capacity:	45 cfs
Drains water from:	West Pointe a La Hache Canal
Discharges water to:	Jefferson Lake Canal
Owner:	Plaquemines Parish Government
Number of pumps:	3
Pump orientation:	3 vertical
Pump driver:	2 diesels 1 electric

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[297] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Water level to switch pumps on:	-1.5 feet (NGVD)
Water level to switch pumps off:	-2.0 feet (NGVD)
Water level that affects operation:	11.5 feet (NGVD).Water would enter top vents of dry tanks
Reverse flow protection:	None

7.6.3.2.11.3 Damages

Estimated cost of repairs:	$121,000[298]
Relative level of damage:	Minor
Severity of circumstances:	Flooding reached 3.5 ft. above operating floor.
Equipment damaged:	Flooding caused non-repairable damages to the stand-by electric generators, air compressors and other auxiliary equipment
Building damage:	Structure and/or site sustained significant wind and flood damage.
Misc. damage:	No significant miscellaneous damage recorded.

7.6.3.2.11.4 Katrina Event

Date	Time	Event
8/27/2005	-	The interview form states that all three pumps were operational and were used for drawdown until evacuation.
8/28/2005	8:00 PM	The interview form states that the station was evacuated. (The pumps were shut down).
8/29/2005	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	-	The interview form indicates that flooding reached 3.5 feet above the operating floor.
	-	Pumps 1 and 2 available after the storm, but were not used for unwatering.

7.6.3.2.11.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.3.2.11.6 Pump Operational Curves

Operational curves were not developed for Pointe a la Hache (West). The necessary data had been collected and the operational curves will be developed in the future.

7.6.3.2.11.7 Pump Reverse Flow

Reverse flow curves were not developed for Pointe a la Hache (West). The necessary data had been collected and the reverse flow curves will be developed in the future.

---

[298] This only includes the costs to repair damage due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

7.6.3.2.11.8 Fuel Endurance Calculations

Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. This station did not have enough information available to perform these calculations.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.3.2.12 *Sunrise 1*

Plaquemines Parish – Reach B-1 Drainage Basin

34358 SR-23
Buras, LA 70041

Latitude 29.362372° Longitude -89.56177°

7.6.3.2.12.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Before Hurricane Katrina: Arial view of the pump station

After Hurricane Katrina: View from the inlet canal

Photo Not Obtained

After Hurricane Katrina

7.6.3.2.12.2 Description[299]

Drainage area:	West Bank- Reach B-1
Nominal Capacity:	180 cfs
Drains water from:	Sunrise Drainage Canal
Discharges water to:	Marsh
Owner:	Plaquemines Parish Government
Number of pumps:	2
Pump orientation:	2 vertical
Pump driver:	2 diesels
Water level to switch pumps on:	-5.7 feet (NGVD)
Water level to switch pumps off:	-7.0 feet (NGVD)
Water level that affects operation:	5 feet (NGVD). Water would enter top vents of dry tanks
Reverse flow protection:	Manually operated gate valve

7.6.3.2.12.3 Damages[300]

Estimated first cost of repairs:	$841,000[301]
Relative level of damage:	Substantial
Severity of circumstances:	Flooding reached 9 ft. above Sunrise 1's operating floor, and 3.5 ft. above Sunrise 2's operating floor.
Equipment damaged:	The flooding submerged the diesel engine air intakes. The salt water damaged the diesel engines beyond normal repair. The flooding also caused non-repairable damages to the stand-by electric generators, air compressors and other auxiliary equipment
Building damage:	Structure and/or site sustained significant wind and flood damage.
Misc. damage:	No significant miscellaneous damage recorded.

---

[299] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[300] This summary incorporates the damages and costs of both Sunrise 1 & 2 pump stations.

[301] This only includes the costs to repair damage due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.3.2.12.4 Katrina Event

Date	Time	Event
8/28/2005	-	The interview form states that the station was available for emergency backup, but was not used for drawdown.
	8:00 PM	The interview form states that the station was evacuated. The pumps were shut down.
8/29/2005	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	-	The interview form states that flooding reached 9 feet above the operating floor.

7.6.3.2.12.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.3.2.12.6 Pump Operational Curves

Operational curves were not developed for Sunrise 1. The necessary data had been collected and the operational curves will be developed in the future.

7.6.3.2.12.7 Pump Reverse Flow

Reverse flow curves were not developed for Sunrise 1. The necessary data had been collected and the reverse flow curves will be developed in the future.

7.6.3.2.12.8 Fuel Endurance Calculations

Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. To calculate the time, a few assumptions are required. The first assumption is the HHV[302] of diesel fuel being used is 130,000 Btu[303] per gallon of fuel[304]. The second assumption is the diesel engines are at least 35% efficient[305]. This station has 2 diesel driven pumps with the same rated horsepower. The station did not report any issues with running out of fuel. Below are the fuel endurance calculations.

---

[302] High heating value

[303] British thermal units

[304] http://www.exxon.com/USA-English/GFM/Products_Services/Fuels/Diesel_Fuels_FAQ.asp

[305] Standard Handbook for Mechanical Engineers, Eighth Edition, pg 9-106

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

The rated horsepower of the diesel driver $P := 150\,hp$

The assumed efficiency of the diesels $\varepsilon := 35\%$

The actual power required from the fuel $P_a := \frac{P}{\varepsilon}$ $P_a = 428.57\ hp$

The higher heating value $HHV := 130000\,\frac{BTU}{gal}$

The burn rate $BR := \frac{P_a}{HHV}$ $BR = 8.39\,\frac{gal}{hr}$

There are 1-5,000 gallon tanks and 2-320 gallon tanks at this station.

Total volume of fuel $V_T := (1 \cdot 5000 + 2 \cdot 320)gal$

The fuel endurance of the station $FE := \frac{V_T}{2BR}$ $FE = 336.18\ hr$

$FE = 14.01\ day$

7.6.3.2.13 *Sunrise 2*

Plaquemines Parish – Reach B-1 Drainage Basin

34358 SR-23
Buras, LA 70041

Latitude 29.362372° Longitude -89.56177°

7.6.3.2.13.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Before Hurricane Katrina: Arial view of the pump station

After Hurricane Katrina: View from the inlet canal

Photo Not Obtained

After Hurricane Katrina

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.3.2.13.2 Description[306]

Drainage area:	West Bank- Reach B-1
Nominal Capacity:	280 cfs
Drains water from:	Sunrise Drainage Canal
Discharges water to:	Marsh
Owner:	Plaquemines Parish Government
Number of pumps:	2
Pump orientation:	2 vertical
Pump driver:	2 diesels
Water level to switch pumps on:	-5.7 feet (NGVD)
Water level to switch pumps off:	-7.0 feet (NGVD)
Water level that affects operation:	15.6 feet (NGVD) Water would enter top vents of dry tanks
Reverse flow protection:	Height of discharge piping

7.6.3.2.13.3 Damages[307]

Estimated first cost of repairs:	$841,000[308]
Relative level of damage:	Substantial
Severity of circumstances:	Flooding reached 9 ft. above Sunrise 1's operating floor, and 3.5 ft. above Sunrise 2's operating floor.
Equipment damaged:	The flooding submerged the diesel engine air intakes. The salt water damaged the diesel engines beyond normal repair. The flooding also caused non-repairable damages to the stand-by electric generators, air compressors and other auxiliary equipment
Building damage:	Structure and/or site sustained significant wind and flood damage.
Misc. damage:	No significant miscellaneous damage recorded.

---

[306] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[307] This summary incorporates the damages and costs of both Sunrise 1 & 2 pump stations.

[308] This only includes the costs to repair damage due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.3.2.13.4 Katrina Event

Date	Time	Event
8/27/2005	-	Both pumps were operational and used for drawdown until evacuation
8/28/2005	8:00 PM	The interview form states that the station was evacuated. The pumps were shut down.
8/29/2005	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	-	The interview form states that flooding reached 3.5 feet above the operating floor.
9/6/2005	-	The interview form states that crews returned to drawdown water.
9/22/2005	-	The dewatering was complete.

7.6.3.2.13.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.3.2.13.6 Pump Operational Curves

Operational curves were not developed for Sunrise 2. The necessary data had been collected and the operational curves will be developed in the future.

7.6.3.2.13.7 Pump Reverse Flow

Reverse flow curves were not developed for Sunrise 2. The necessary data had been collected and the reverse flow curves will be developed in the future.

7.6.3.2.13.8 Fuel Endurance Calculations

Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. To calculate the time, a few assumptions are required. The first assumption is the HHV[309] of diesel fuel being used is 130,000 Btu[310] per gallon of fuel[311]. The second assumption is the diesel engines are at least 35% efficient[312]. This station has 2 diesel driven pumps with the same rated horsepower. The station did not report any issues with running out of fuel. Below are the fuel endurance calculations.

---

[309] High heating value

[310] British thermal units

[311] http://www.exxon.com/USA-English/GFM/Products_Services/Fuels/Diesel_Fuels_FAQ.asp

[312] Standard Handbook for Mechanical Engineers, Eighth Edition, pg 9-106

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

The rated horsepower of the diesel driver $P := 320\text{hp}$

The assumed efficiency of the diesels $\varepsilon := 35\%$

The actual power required from the fuel $P_a := \frac{P}{\varepsilon}$ $P_a = 914.29\,\text{hp}$

The higher heating value $HHV := 130000\,\frac{\text{BTU}}{\text{gal}}$

The burn rate $BR := \frac{P_a}{HHV}$ $BR = 17.89\,\frac{\text{gal}}{\text{hr}}$

There are 1-11,000 gallon tank and 2-460 gallon tanks at this station.

Total volume of fuel $V_T := (1 \cdot 11000 + 2 \cdot 460)\text{gal}$

The fuel endurance of the station $FE := \frac{V_T}{2BR}$ $FE = 333.06\,\text{hr}$

$FE = 13.88\,\text{day}$

7.6.3.2.14 *Grand Liard (Triumph)*

Plaquemines Parish – Reach B-1 Drainage Basin

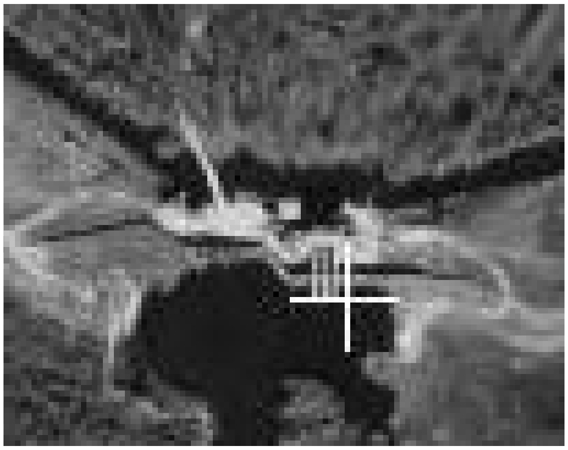
417 Triumph Pump Rd
Buras, LA 70041

Latitude 29.32609° Longitude -89.48063°

7.6.3.2.14.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina



Before Hurricane Katrina: Arial view of the pump station

After Hurricane Katrina: View from the inlet canal

After Hurricane Katrina: Arial view of the pump station

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.3.2.14.2 Description[313]

Drainage area:	West Bank- Reach B-1
Nominal Capacity:	840 cfs
Drains water from:	Bural Drainage Canal
Discharges water to:	Grand Liard Marsh
Owner:	Plaquemines Parish Government
Number of pumps:	3
Pump orientation:	3 vertical
Pump driver:	3 diesels
Water level to switch pumps on:	-8.8 feet (NGVD)
Water level to switch pumps off:	-9.0 feet (NGVD)
Water level that affects operation:	21.5 feet (NGVD) Water would enter gear box above pump
Reverse flow protection:	Height of discharge piping

7.6.3.2.14.3 Damages

7.6.3.2.14.4 Katrina Event

Date	Time	Event
8/27/2005	-	The station was available and used for drawdown until evacuation.
8/28/2005	8:00 PM	The station was evacuated.
8/29/2005	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	-	The interview form states that flooding did not reach the operating floor.
9/15/2005	-	The operators returned and restarted the pumps.
	8:45 PM	The operation log states that pump 1 got damaged from trash in the in-take. The other pumps continued pumping until de-watering was complete.
9/23/2005	-	The unwatering was complete.

7.6.3.2.14.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.3.2.14.6 Pump Operational Curves

Operational curves were not developed for Grand Liard (Triumph). The necessary data had been collected and the operational curves will be developed by in the future.

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[313] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.3.2.14.7 Pump Reverse Flow

Reverse flow curves were not developed for Grand Liard (Triumph). The necessary data had been collected and the reverse flow curves will be developed in the future.

7.6.3.2.14.8 Fuel Endurance Calculations

Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. To calculate the time, a few assumptions are required. The first assumption is the HHV[314] of diesel fuel being used is 130,000 Btu[315] per gallon of fuel[316]. The second assumption is the diesel engines are at least 35% efficient[317]. This station has 3 diesel driven pumps with the same rated horsepower. The station did not report any issues with running out of fuel. Below are the fuel endurance calculations.

The rated horsepower of the diesel driver $P := 1100\text{hp}$

The assumed efficiency of the diesels $\varepsilon := 35\%$

The actual power required from the fuel $P_a := \frac{P}{\varepsilon}$ $P_a = 3142.86\,\text{hp}$

The higher heating value $HHV := 130000\frac{\text{BTU}}{\text{gal}}$

The burn rate $BR := \frac{P_a}{HHV}$ $BR = 61.51\frac{\text{gal}}{\text{hr}}$

There are 2-10,000 gallon tanks and 3-460 gallon tanks at this station.

Total volume of fuel $V_T := (2 \cdot 10000 + 3 \cdot 460)\text{gal}$

The fuel endurance of the station $FE := \frac{V_T}{3BR}$ $FE = 115.85\,\text{hr}$

$FE = 4.83\,\text{day}$

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[314] High heating value

[315] British thermal units

[316] http://www.exxon.com/USA-English/GFM/Products_Services/Fuels/Diesel_Fuels_FAQ.asp

[317] Standard Handbook for Mechanical Engineers, Eighth Edition, pg 9-106

7.6.3.2.15 *Wilkinson Canal (Myrtle Grove) Private Station*

Plaquemines Parish – Area 5 Drainage Basin

17537 SR-23
Belle Chasse, LA 70037

Latitude 29.62197° Longitude -89.95311°

7.6.3.2.15.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Photo Not Obtained

Before Hurricane Katrina

After Hurricane Katrina: View from the inlet canal

Photo Not Obtained

After Hurricane Katrina

7.6.3.2.15.2 Description[318]

Drainage area:	West Bank- Area 5
Nominal Capacity:	980 cfs
Drains water from:	Unnamed Canal
Discharges water to:	Marsh
Owner:	Private Owner
Number of pumps:	4
Pump orientation:	4 vertical
Pump driver:	4 diesels
Water level to switch pumps on:	-4.5 feet (NGVD)

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[318] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Water level to switch pumps off:	-5 feet (NGVD)
Water level that affects operation:	14.0 feet (NGVD). Water would enter motor housing.
Reverse flow protection:	None

7.6.3.2.15.3 Damages

Estimated cost of repairs:	$338,000[319]
Relative level of damage:	Minor
Severity of circumstances:	Water did not reach the operating floor.
Equipment damaged:	An impeller broke and an engine failed.
Building damage:	Structure and/or site sustained significant wind and flood damage.
Misc. damage:	No significant miscellaneous damage recorded.

7.6.3.2.15.4 Katrina Event

Date	Time	Event
8/28/2005	-	The interview form states that all four pumps were operational, but they were not used for drawdown.
	-	The interview form states that the station was evacuated.
8/29/2005	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	-	The interview form states that flooding did not reach the operating floor.
9/5/2005	-	The interview form states that the operator returned by boat and ran all 4 pumps until the dewatering was complete.
9/16/2005	-	The dewatering was complete.
8/28/2005	-	The interview form states that all three pumps were available and used for pre-Katrina drawdown.
8/29/2005	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	-	The interview form states that the pumps continued operating through the hurricane and until the unwatering was complete.
	-	The interview form states that water did not enter the building.
9/3/2005	-	The unwatering was complete.

7.6.3.2.15.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.3.2.15.6 Pump Operational Curves

Operational curves were not developed for Wilkinson Canal (Myrtle Grove). The necessary data had been collected and the operational curves will be developed in the future.

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[319] This only includes the costs to repair damage due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.3.2.15.7 Pump Reverse Flow

Reverse flow curves were not developed for Wilkinson Canal (Myrtle Grove). The necessary data had been collected and the reverse flow curves will be developed in the future.

7.6.3.2.15.8 Fuel Endurance Calculations

Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. This station did not have enough information available to perform these calculations.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.3.2.16 *Pointe Celeste (Private)*

Plaquemines Parish – Area 4 Drainage Basin

17573 SR-23
Belle Chasse, LA 70037

Latitude 29.57922° Longitude -89.857001°

7.6.3.2.16.1 Before and After Hurricane Katrina Photos

Photo Not Obtained

Before Hurricane Katrina

Photo Not Obtained

Before Hurricane Katrina

After Hurricane Katrina

Photo Not Obtained

After Hurricane Katrina

7.6.3.2.16.2 Description[320]

Drainage area: West Bank- Area 4

Nominal Capacity: 890 cfs

Drains water from: Unnamed Canal

Discharges water to: Marsh

Owner: Private Owner

Number of pumps: 4

Pump orientation: 4 vertical

Pump driver: 4 diesels

Water level to switch pumps on: -4.5 feet (NGVD)

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[320] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

Water level to switch pumps off:	-5.0 feet (NGVD)
Water level that affects operation:	8.5 feet (NGVD). Water would move main fuel tanks.
Reverse flow protection:	None

7.6.3.2.16.3 Damages

Estimated cost of repairs:	\$476,000[321]
Relative level of damage:	Minor
Severity of circumstances:	Water did not reach the operating floor.
Equipment damaged:	Two diesel engines had mechanical failures.
Building damage:	Structure and/or site sustained significant wind and flood damage.
Misc. damage:	No significant miscellaneous damage recorded.

7.6.3.2.16.4 Katrina Event

Date	Time	Event
8/28/2005	-	The interview form states that all four pumps are operational prior to the hurricane, but were not used for drawdown.
8/29/2005	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	-	The interview form states that flooding did not reach the operating floor.
	-	A private land owner used a boat to access the station and run it.
9/5/2005	-	The operator returned to the station.

7.6.3.2.16.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.3.2.16.6 Pump Operational Curves

Operational curves were not developed for Pointe Celeste. The necessary data had been collected and the operational curves will be developed in the future.

7.6.3.2.16.7 Pump Reverse Flow

Reverse flow curves were not developed for Pointe Celeste. The necessary data had been collected and the reverse flow curves will be developed in the future.

7.6.3.2.16.8 Fuel Endurance Calculations

Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. This station did not have enough information available to perform these calculations.

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[321] This only includes the costs to repair damage due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

7.6.4 St Bernard Parish Pump Stations

7.6.4.1 East Bank

7.6.4.1.1 *Fortification*

St Bernard Parish – Area 1 Drainage Basin

4200 Jean Lafitte Pkwy
Chalmette, LA 70043

Latitude 29.966557° Longitude -89.975821°

7.6.4.1.1.1 Before and After Hurricane Katrina Photos

Before Hurricane Katrina: View from the inlet canal

Before Hurricane Katrina: Arial view of the pump station

After Hurricane Katrina: View from the inlet canal

After Hurricane Katrina: Arial view of the pump station

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.4.1.1.2 Description[322]

Drainage area:	Area 1
Plant capacity at rated head:	980 cfs
Drains water from:	Florida Walk Forty Arpent Canal
Discharges water to:	Bayou Bienvenue
Owner:	Lake Borgne Levee District
Number of pumps:	3
Pump orientation:	3 vertical
Pump driver:	2 diesels 1 electric 60 Hz motor
Water level to switch pumps on:	-6.0 feet (NGVD)
Water level to switch pumps off:	-6.5 feet (NGVD)
Water level that affects operation:	15 feet (NGVD). Threatens motors and gears.
Reverse flow protection:	Floodgates lowered when discharge elevation is expected to be greater than 3.5 feet (NGVD)

7.6.4.1.1.3 Damages

Estimated cost of repairs:	$150,000[323]
Relative level of damage:	Minor
Severity of circumstances:	Flooding did not reach the operating floor level.
Equipment damaged:	Electric pump motor, generator, trash rack bearing and gear box, lighting, and a bobcat used to remove debris from the trash racks.
Building damage:	Damage to metal siding and roof
Misc. damage:	The diesel engine cooling system developed a leak.

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[322] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[323] This only includes the costs to repair damage due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.4.1.1.4 Katrina Event

Date	Time	Event
8/28/2005	-	The operators pumped the water in the canal down to approximately -8.5 feet.
8/29/2005	1:15	The operators evacuated the pump station.
	6:10	Hurricane Katrina made landfall in Louisiana.
	-	Flooding reached 9 feet above the concrete driveway.
8/30/2005	10:00	The operators returned. Water was at the same elevation on both sides of the pump station.
9/1/2005	-	Two pumps were operating.
	2:55	The operation log states that the fuel line busted on the East engine. The operators shut down the East Pump. The operators closed the flood gate.
	4:00	The operational log states that the diesel compressor repair failed. They were unable to successfully repair it again. This indicates that the diesel pumps were shut down.
	15:30	Operation log states diesel compressor airline broke and tried to repair.
9/2/2005 – 9/4/2005	-	The interview form states that only one pump ran during this period.
9/5/2005	0:00	Operation log states fuel was transferred to Station #6
9/6/2005	6:00	Operation log states fuel was transferred to Station #6 from West engine
The PIR indicates the Center Pump (electric) was inoperable.		

7.6.4.1.1.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.4.1.1.6 Pump Operational Curves

Operational curves have been developed for Fortification. They are not included in this report at this time, but will be inserted in the future.

7.6.4.1.1.7 Pump Reverse Flow

There are three pumps at this station for which reverse flow rating curves were computed (no pumps were excluded). The reverse flow data and curves are presented in the order of the pump numbering utilized in the summary tables included in this appendix. In cases where there are multiple pumps of equivalent size and system configuration, a single rating curve represents all of them at a unit rate per pump.

Pump No.	Pump Capacity (cfs)	Pump Size (in)	Reverse Flow Computed?		Rating Curve Ref. No.
			Yes	No	
1	450	94 x 128	X		1
2	90	42 x 54	X		2
3	450	94 x 128	X		1

For a general explanation of reverse flow (terminology, figures, methodology, equations and assumptions), refer to the Reverse Flow Section at the beginning of this appendix. Reverse flow

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computations for a given pump station do not necessarily imply that reverse flow actually occurred there during the Katrina event. But these curves may instead be used as future tools if further investigations are required based on reverse flow assumptions.

1. Reverse Flow Rating Curve

#1 Fortification Pump Station, Pumps #1 & #3, 94 x 128-in.

Elevation Datum (ft):	NGVD
Crest Elevation (ft) =	3.83

H1 = Lake or outlet canal water level (normal pump discharge side)
H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use Q = sqrt((H1-H2)/K')*
K' = *1.75077E-05* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling

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limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 3.8 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 4.8 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

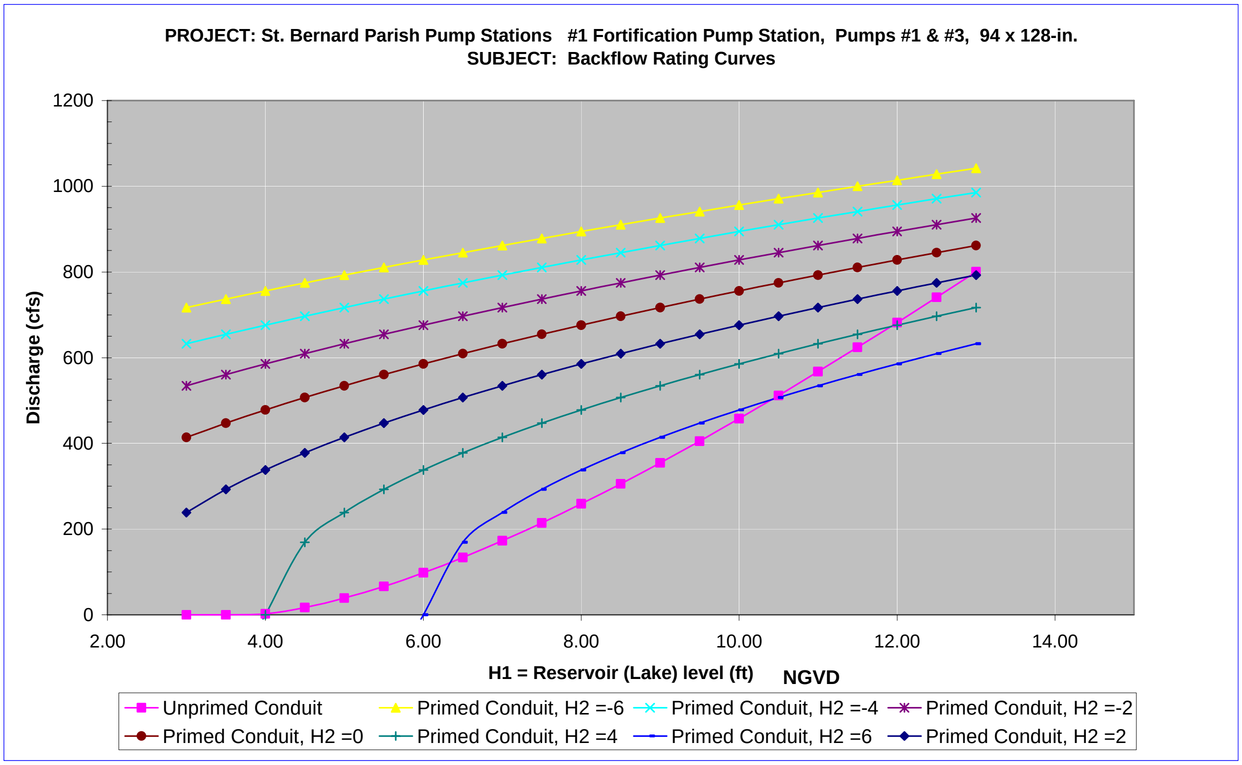
H2 =	-6	-4	-2	0	2	4	6
H1 >	5	5	5	5	5	5	5

Water elevation (H1) that stops unprimed flow: 3.8 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 4.8 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient = 3.5
Intake loss = 0.5
Exit Loss = 1.3
Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Tainter Gate Left open
Discharge gate width = 10 feet

4 Data Needs or Deficiencies:

Discharge gate and channel width
Plan View of Pump Station

5 Backflow prevention:

Available: Tainter Gate for Closure. Floodgates are lowered when Bayou water is expected to exceed 3.5 ft.

No backstops to prevent reverse rotation.

Used: Not sure if reverse flow occurred. Operators evacuated station on 8/29/05 and returned on 8/30/05.

Water was the same elevation on both sides of pump station.

2. Reverse Flow Rating Curve

#1 Fortification Pump Station, Pump #2, 42 x 54-in.

Elevation Datum (ft):	NGVD
Crest Elevation (ft) =	3.83

H1 = Lake or outlet canal water level (normal pump discharge side)
H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use Q = sqrt((H1-H2)/K')*
K' = *0.00033091* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 3.8 ft

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 4.8 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

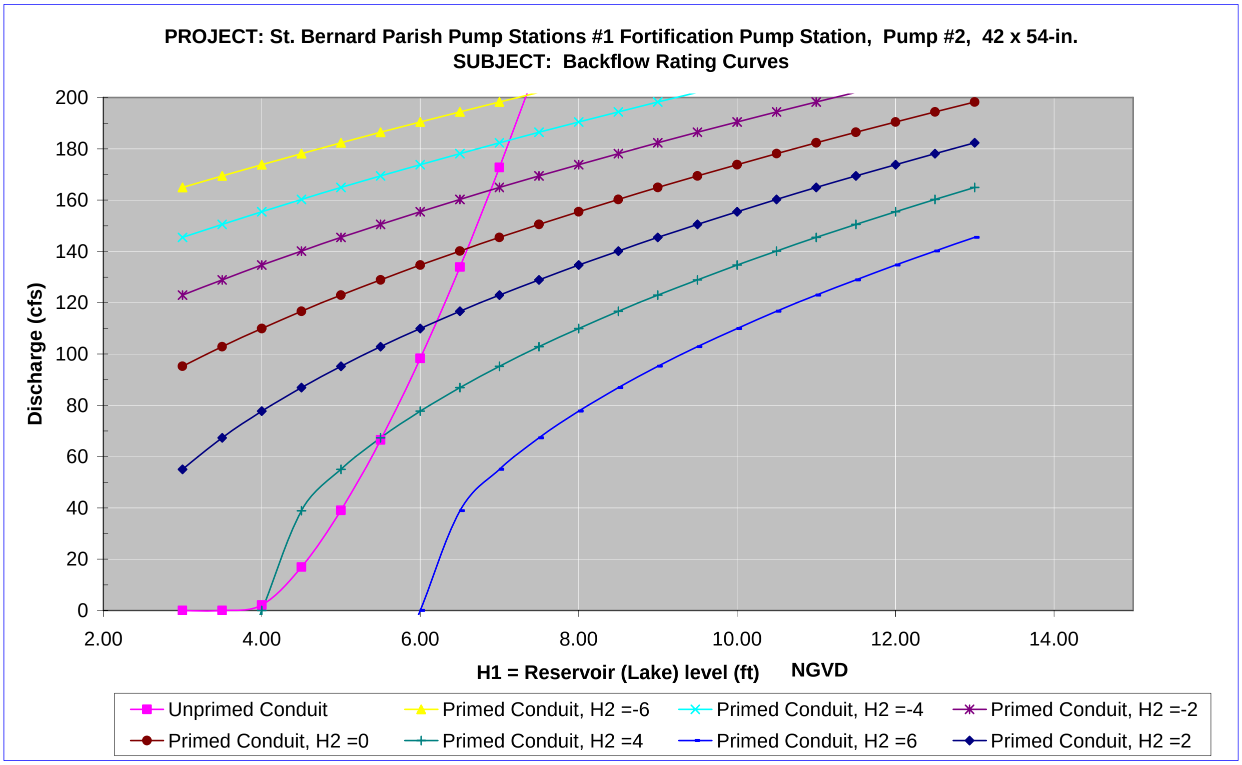
Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.							
H2 =	-6	-4	-2	0	2	4	6
H1 >	5	5	5	5	5	5	5

Water elevation (H1) that stops unprimed flow: 3.8 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 4.8 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	3.5
Intake loss =	0.5
Exit Loss =	1.3

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Tainter Gate Left open

Discharge gate width = 10 feet

4 Data Needs or Deficiencies:

Discharge gate and channel width

Plan View of Pump Station

5 Backflow prevention:

Available:	Tainter Gate for Closure. Floodgates are lowered when Bayou water is expected to exceed 3.5 ft. No backstops to prevent reverse rotation.
Used:	Not sure if reverse flow occurred. Operators evacuated station on 8/29/05 and returned on 8/30/05.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Water was the same elevation on both sides of pump station.

7.6.4.1.1.8 Fuel Endurance Calculation

Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. To calculate the time, a few assumptions are required. The first assumption is the HHV[324] of diesel fuel being used is 130,000 Btu[325] per gallon of fuel[326]. The second assumption is the diesel engines are at least 35% efficient[327]. This station has 2 diesel driven pumps and one electric driven pump. The station did not report any issues with running out of fuel. Below are the fuel endurance calculations.

The rated horsepower of the diesel driver $P := 1200\text{hp}$

The assumed efficiency of the diesels $\varepsilon := 35\%$

The actual power required from the fuel $P_a := \frac{P}{\varepsilon}$ $P_a = 3428.57\,\text{hp}$

The higher heating value $HHV := 130000\,\frac{BTU}{gal}$

The burn rate $BR := \frac{P_a}{HHV}$ $BR = 67.11\,\frac{gal}{hr}$

There are 4-5,000 gallon tanks and 2-110 gallon tanks at this station.

Total volume of fuel $V_T := (4 \cdot 5000 + 2 \cdot 110)\text{gal}$

The fuel endurance of the station $FE := \frac{V_T}{2BR}$ $FE = 150.66\,\text{hr}$

$FE = 6.28\,\text{day}$

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[324] High heating value

[325] British thermal units

[326] http://www.exxon.com/USA-English/GFM/Products_Services/Fuels/Diesel_Fuels_FAQ.asp

[327] Standard Handbook for Mechanical Engineers, Eighth Edition, pg 9-106

7.6.4.1.2 *Guichard*

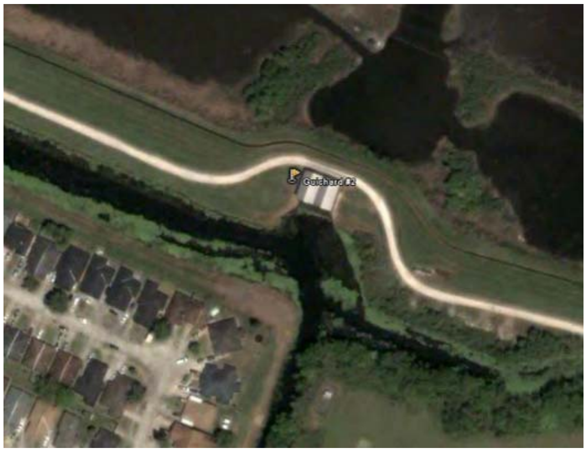
St Bernard Parish – Area 1 Drainage Basin

4201 Jean Lafitte Pkwy
Chalmette, LA 70043

Latitude 29.961649° Longitude -89.964442°

7.6.4.1.2.1 Before and After Hurricane Katrina Photos

Before Hurricane Katrina: View from the inlet canal



Before Hurricane Katrina: Arial view of the pump station

After Hurricane Katrina: View from the inlet canal

After Hurricane Katrina: Arial view of the pump station

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.4.1.2.2 Description[328]

Drainage area:	Area 1
Nominal Capacity:	980 cfs
Drains water from:	Florida Walk Forty Arpent Canal
Discharges water to:	Bayou Bienvenue
Owner:	Lake Borgne Levee District
Number of pumps:	4
Pump orientation:	4 horizontal
Pump driver:	4 diesels
Water level to switch pumps on:	-6.5 feet (NGVD)
Water level to switch pumps off:	-6.0 feet (NGVD)
Water level that affects operation:	4 feet (NGVD) would flood motors.
Reverse flow protection:	None

7.6.4.1.2.3 Damages

Estimated cost of repairs:	$3,886,000[329]
Relative level of damage:	Substantial
Severity of circumstances:	The operating floor was flooded to a depth of 6 to 7 ft.
Equipment damaged:	The four diesel engines were flooded along with control panels, compressors, motors, and vacuum pumps. All exterior and interior lighting was damaged.
Building damage:	Wind and water damaged all four sides and roof.
Misc. damage:	The diesel fuel storage tank was moved off its concrete saddle foundation.

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[328] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[329] This only includes the costs to repair damage due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.4.1.2.4 Katrina Event

Date	Time	Event
8/28/2005	-	The station was available as backup, but not used.
	-	Pump 3 was inoperable due to holes in the intake.
8/29/2005	1:15 AM	The crew evacuated to higher ground.
	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	-	The station was not used during the storm.
	-	The station flooded during the storm and documents were removed for possible restoration.
	-	The interview form states that flooding reached above the motors.
8/30/2005	10:00 AM	The operators returned. Water was at the same elevation on both sides of the pump station.
	-	The interview form states that the pumps would not work due to flooded motors.

7.6.4.1.2.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.4.1.2.6 Pump Operational Curves

Operational curves have been developed for Guichard. They are not included in this report at this time, but will be inserted in the future.

7.6.4.1.2.7 Pump Reverse Flow

There are four pumps at this station. Reverse flow rating curves were computed for three pumps (#1, #2, #4). Reverse flow was not computed for Pump #3 since there was no information available and it was not in service (it is unknown whether it was blocked for reverse flow). The reverse flow data and curves are presented in the order of the pump numbering utilized in the summary tables included in this appendix. In cases where there are multiple pumps of equivalent size and system configuration, a single rating curve represents all of them at a unit rate per pump.

Pump No.	Pump Capacity (cfs)	Pump Size (in)	Reverse Flow Computed?		Rating Curve Ref. No.
			Yes	No	
1	267	60	X		1
2	111	42	X		2
3	?	?		X	
4	267	60	X		2

For a general explanation of reverse flow (terminology, figures, methodology, equations and assumptions), refer to the Reverse Flow Section at the beginning of this appendix. Reverse flow computations for a given pump station do not necessarily imply that reverse flow actually occurred there during the Katrina event. But these curves may instead be used as future tools if further investigations are required based on reverse flow assumptions.

3. Reverse Flow Rating Curve

Guichard #2, Pump #1 42-in.

Elevation Datum (ft):	NGVD
Crest Elevation (ft) =	4

H1 = Lake or outlet canal water level (normal pump discharge side)
H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use* $Q = \mathrm{sqrt}((H1-H2)/K')$
$K' =$ *0.001215452* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 4.0 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal

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reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 7.5 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

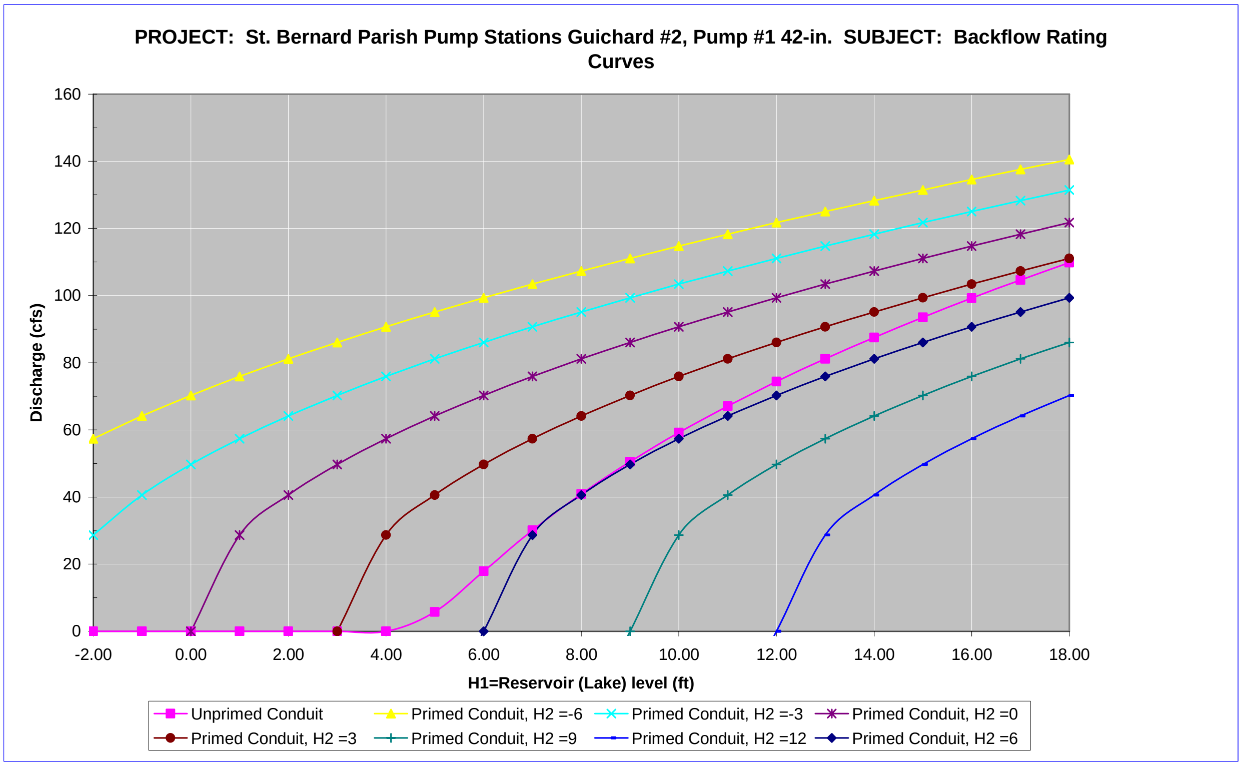
Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.							
H2 =	-6.0	-3.0	0.0	3.0	6.0	9.0	12.0
H1 >	43	35	27	19	11	9	12

Water elevation (H1) that stops unprimed flow: 4.0 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 1.5 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.



This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump head loss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	3.5
Intake loss =	0.5
Exit Loss =	1.3

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Shape/length/angle of: bends, pipes, outlet, intake assumed from Pump info in questionnaire and photos.

Crest elevation assumed at 4ft NGVD based questionnaire statement on flood level that starts impacting motors.

Pump inverts and motors are same elevation from photos.

Also water level reached 8 ft NGVD which exceeds pumps in photos.

Other system elevations based on SBP Pump station #6.

4 Data Needs or Deficiencies:

Shape/length/angle of: bends, pipes, outlet, intake.

Elevations for bends, pipes, pump, outlet, intake etc.

Need pump dia. for pump #3 to estimate backflow curve.

Only info is PS#2 cover sheet indicates pump #3 is 75,000 gpm pump.

5 Backflow prevention:

Available:	No floodgates; No backflow valves No backstops to prevent reverse rotation.
Used:	Not sure if reverse flow occurred. Operators evacuated station at 0115 on 8/29/05 and returned at 1000 on 8/30/05. Water was the same elevation on both sides of pump station.

2. Reverse Flow Rating Curve

Guichard #2, Pumps #2 & #4 -60-in.

Elevation Datum (ft): NGVD

Crest Elevation (ft) = 4

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use Q = sqrt((H1-H2)/K')*
K' = *0.000286911* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 4.0 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 9.0 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

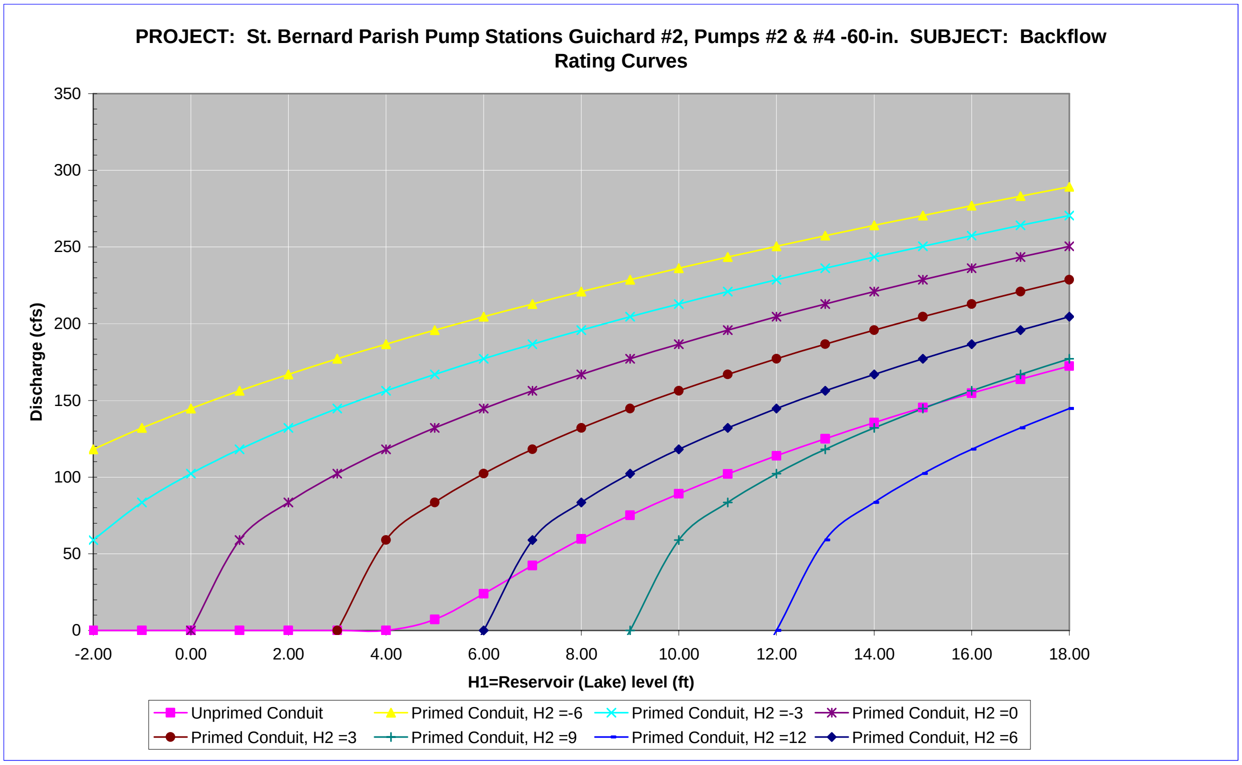
Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.							
H2 =	-6.0	-3.0	0.0	3.0	6.0	9.0	12.0
H1 >	9	9	9	9	9	9	36

Water elevation (H1) that stops unprimed flow: 4.0 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 3.0 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump headloss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient = 3.50
Intake loss = 0.5
Exit Loss = 1.3
Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Shape/length/angle of: bends, pipes, outlet, intake assumed from Pump info in questionnaire and photos.

Crest elevation assumed at 4ft NGVD based on questionnaire statement on flood level that starts impacting motors.

Pump inverts and motors are same elevation from photos.

Also water level reached 8 ft NGVD which exceeds pumps in photos.

Other system elevations based on SBP Pump station #6.

4 Data Needs or Deficiencies:

Shape/length/angle of: bends, pipes, outlet, intake.

Elevations for bends, pipes, pump, outlet, intake etc.

Need pump diam for pump #3 to estimate backflow curve.

Only info is PS#2 cover sheet indicates pump #3 is 75,000 gpm pump.

5 Backflow prevention:

Available:	No floodgates; No backflow valves No backstops to prevent reverse rotation.
Used:	Not sure if reverse flow occurred. Operators evacuated station at 0115 on 8/29/05 and returned at 1000 on 8/30/05. Water was the same elevation on both sides of pump station.

7.6.4.1.2.8 Fuel Endurance Calculation

Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. To calculate the time, a few assumptions are required. The first assumption is the HHV[330] of diesel fuel being used is 130,000 Btu[331] per gallon of fuel[332]. The second assumption is the diesel engines are at least 35% efficient[333]. This station has 4 diesel driven pumps with three different rated horsepower. The station did not report any issues with running out of fuel. Below are the fuel endurance calculations.

---

[330] High heating value

[331] British thermal units

[332] http://www.exxon.com/USA-English/GFM/Products_Services/Fuels/Diesel_Fuels_FAQ.asp

[333] Standard Handbook for Mechanical Engineers, Eighth Edition, pg 9-106

The rated horsepower of the diesel drivers $P_1 := 800\text{hp} \quad P_2 := 335\text{hp} \quad P_3 := 300\text{hp}$

The assumed efficiency of the diesels $\varepsilon := 35\%$

The actual power required from the fuel

$$P_{a1} := \frac{P_1}{\varepsilon} \qquad P_{a1} = 2285.71\ \text{hp}$$

$$P_{a2} := \frac{P_2}{\varepsilon} \qquad P_{a2} = 957.14\ \text{hp}$$

$$P_{a3} := \frac{P_3}{\varepsilon} \qquad P_{a3} = 857.14\ \text{hp}$$

The higher heating value

$$HHV := 130000\,\frac{BTU}{gal}$$

The burn rates

$$BR_1 := \frac{P_{a1}}{HHV} \qquad BR_1 = 44.74\,\frac{gal}{hr}$$

$$BR_2 := \frac{P_{a2}}{HHV} \qquad BR_2 = 18.73\,\frac{gal}{hr}$$

$$BR_3 := \frac{P_{a3}}{HHV} \qquad BR_3 = 16.78\,\frac{gal}{hr}$$

There are 1-5,000 gallon tank and 4-60 gallon tanks at this station.

Total volume of fuel

$$V_T := (1 \cdot 5000 + 4 \cdot 60)\text{gal}$$

The fuel endurance of the station

$$FE := \frac{V_T}{2BR_1 + BR_2 + BR_3} \qquad FE = 41.93\ \text{hr}$$

$$FE = 1.75\ \text{day}$$

7.6.4.1.3 *Bayou Villere*

St Bernard Parish – Area 2 Drainage Basin

3700 Bartolo
Meraux, LA 70075

Latitude 29.951279° Longitude -89.934607°

7.6.4.1.3.1 Before and After Hurricane Katrina Photos

Before Hurricane Katrina: View from the inlet canal

Before Hurricane Katrina: Arial view of the pump station

After Hurricane Katrina: View from the inlet canal

After Hurricane Katrina: Arial view of the pump station

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.4.1.3.2 Description[334]

Drainage area:	Area 2
Nominal Capacity:	825 cfs
Drains water from:	Florida Walk Forty Arpent Canal
Discharges water to:	Bayou Bienvenue
Owner:	Lake Borgne Levee District
Number of pumps:	3
Pump orientation:	3 horizontal
Pump driver:	3 diesels
Water level to switch pumps on:	-6.5 feet (NGVD)
Water level to switch pumps off:	-6.0 feet (NGVD)
Water level that affects operation:	12.5 feet (NGVD). Would flood motors.
Reverse flow protection:	None

7.6.4.1.3.3 Damages

Estimated cost of repairs:	$2,779,000[335]
Relative level of damage:	Substantial
Severity of circumstances:	With its operating floor at or near the natural ground elevation, the pump station was flooded to a depth of 8 ft.
Equipment damaged:	The three diesel engines and hydraulic drives were flooded along with the vacuum pump system and ancillary equipment. All exterior and interior lighting was damaged.
Building damage:	Wind and water damaged all four sides.
Misc. damage:	The diesel fuel storage tank was moved off its foundation.

---

[334] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[335] This only includes the costs to repair damage due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.4.1.3.4 Katrina Event

Before the storm:	The plant was available, but only used as backup. Pump 3 was inoperable due to holes in the intake.
During the storm:	The plant was flooded. Documents were removed for possible restoration. The day fuel tank floated off base. Lines broke. Crew evacuated to higher ground.
After the storm	The station was inoperable due to flooded motors.

7.6.4.1.3.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.4.1.3.6 Pump Operational Curves

Operational curves have been developed for Bayou Villere. They are not included in this report at this time, but will be inserted in the future.

7.6.4.1.3.7 Pump Reverse Flow

There are three pumps at this station for which reverse flow rating curves were computed (no pumps were excluded). The reverse flow data and curves are presented in the order of the pump numbering utilized in the summary tables included in this appendix. In cases where there are multiple pumps of equivalent size and system configuration, a single rating curve represents all of them at a unit rate per pump.

Pump No.	Pump Capacity (cfs)	Pump Size (in)	Reverse Flow Computed?		Rating Curve Ref. No.
			Yes	No	
1	267	60	X		1
2	267	60	X		1
3	267	60	X		1

For a general explanation of reverse flow (terminology, figures, methodology, equations and assumptions), refer to the Reverse Flow Section at the beginning of this appendix. Reverse flow computations for a given pump station do not necessarily imply that reverse flow actually occurred there during the Katrina event. But these curves may instead be used as future tools if further investigations are required based on reverse flow assumptions.

4. Reverse Flow Rating Curve

 # 3 Bayou Villere PS, P1, P2 & P3 - 60-in.

Elevation Datum (ft):	NGVD
Crest Elevation (ft) =	11

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:
Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use* $Q = \mathrm{sqrt}((H1-H2)/K')$
$K' =$ *0.000286911* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 11.0 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 16.0 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge

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lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

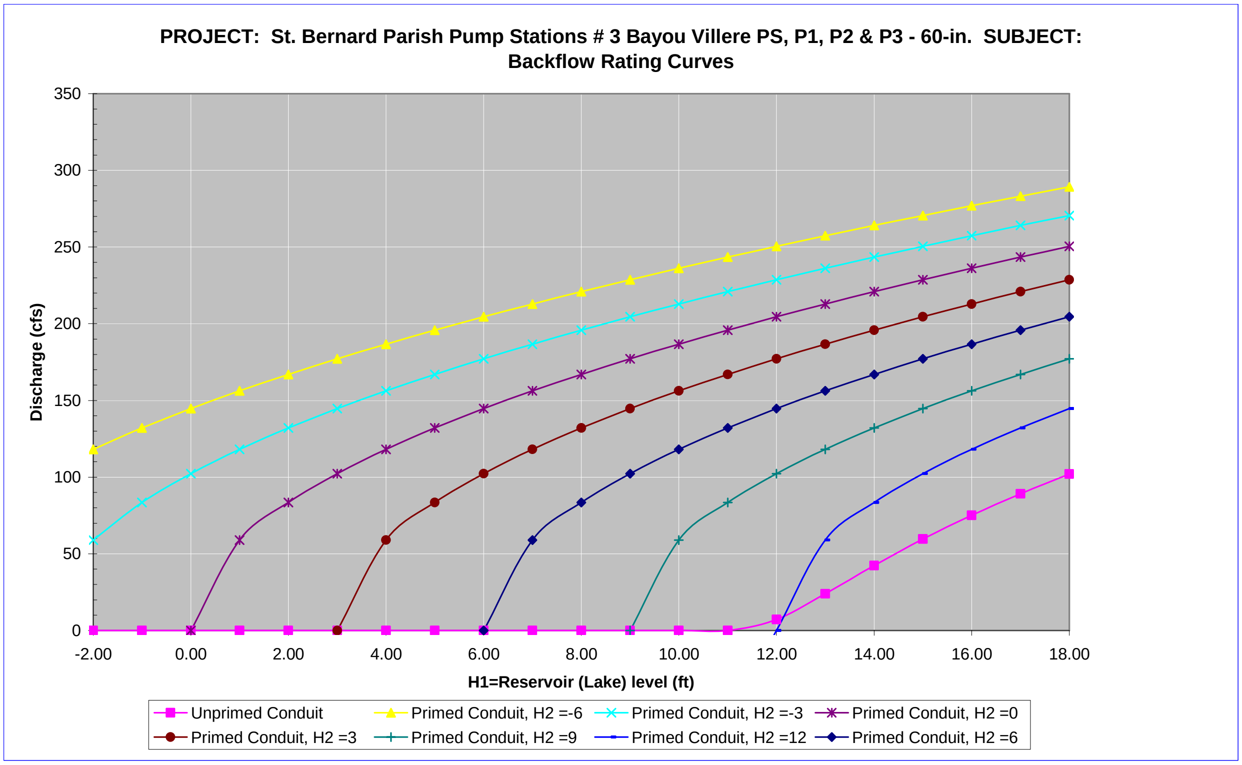
Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.							
H2 =	-6.0	-3.0	0.0	3.0	6.0	9.0	12.0
H1 >	16	16	16	16	16	16	16

Water elevation (H1) that stops unprimed flow: 11.0 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 10.0 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump headloss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient =	3.50
Intake loss =	0.5
Exit Loss =	1.3

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Shape/length/angle of: bends, pipes, outlet, intake assumed from Pump info in questionnaire and photos.

Survey states Slab elevation at 10ft NGVD per COE spreadsheet.

Maximum Ws about 6ft above slab; elevation 16ft NGVD.

Crest elevation assumed to be 11 ft based on assumed invert 1 foot above floor.

Other system elevations based on SBP Pump station #6.

4 Data Needs or Deficiencies:

Shape/length/angle of: bends, pipes, outlet, intake.

Elevations for bends, pipes, pump, outlet, intake etc.

5 Backflow prevention:

Available:	Intake pipes to pumps 1 and 2 have butterfly valves.
	No valve on pump 3.
	No brakes to prevent reverse rotation.
Used:	Not sure if reverse flow occurred.
	Motors overtopped during storm.
	Valves on P1 & P2 probably closed since pumps not used before storm.
	However no statement on whether valves were closed.

7.6.4.1.3.8 Fuel Endurance Calculation

Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. To calculate the time, a few assumptions are required. The first assumption is the HHV[336] of diesel fuel being used is 130,000 Btu[337] per gallon of fuel[338]. The second assumption is the diesel engines are at least 35% efficient[339]. This station has 3 diesel driven pumps with the same rated horsepower. The station did not report any issues with running out of fuel. Below are the fuel endurance calculations.

---

[336] High heating value

[337] British thermal units

[338] http://www.exxon.com/USA-English/GFM/Products_Services/Fuels/Diesel_Fuels_FAQ.asp

[339] Standard Handbook for Mechanical Engineers, Eighth Edition, pg 9-106

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

The rated horsepower of the diesel driver $P := 800\text{hp}$

The assumed efficiency of the diesels $\varepsilon := 35\%$

The actual power required from the fuel $P_a := \frac{P}{\varepsilon}$ $P_a = 2285.71\,\text{hp}$

The higher heating value $HHV := 130000\,\frac{\text{BTU}}{\text{gal}}$

The burn rate $BR := \frac{P_a}{HHV}$ $BR = 44.74\,\frac{\text{gal}}{\text{hr}}$

There are 1-2,500 gallon tank and 3-60 gallon tanks at this station.

Total volume of fuel $V_T := (1\cdot 2500 + 3\cdot 60)\text{gal}$

The fuel endurance of the station $FE := \frac{V_T}{3BR}$ $FE = 19.97\,\text{hr}$

$FE = 0.83\,\text{day}$

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.4.1.4 *Meraux*

St Bernard Parish – Area 2 Drainage Basin

3200 Guerra Dr
Violet, LA 70092

Latitude 29.921331° Longitude -89.891292°

7.6.4.1.4.1 Before and After Hurricane Katrina Photos

Before Hurricane Katrina: View from the inlet canal

Before Hurricane Katrina: Arial view of the pump station

After Hurricane Katrina: View from the inlet canal

After Hurricane Katrina: Arial view of the pump station

7.6.4.1.4.2 Description[340]

Drainage area:	Area 2
Nominal Capacity:	800 cfs
Drains water from:	Florida Forty Arpent Canal
Discharges water to:	Bayou Dupre
Owner:	Lake Borgne Levee District
Number of pumps:	3
Pump orientation:	3 vertical
Pump driver:	2 diesel 1 electric 60 Hz motor
Water level to switch pumps on:	-6.0 feet (NGVD)
Water level to switch pumps off:	-6.5 feet (NGVD)
Water level that affects operation:	15.25 feet (NGVD) Would flood motors and gears.
Reverse flow protection:	3 floodgates

7.6.4.1.4.3 Damages

Estimated cost of repairs:	$464,000[341]
Relative level of damage:	Minor
Severity of circumstances:	Flooding did not reach the operating floor level.
Equipment damaged:	An air compressor, electomode heater, controller for compressed air dryer motor, and generator.
Building damage:	Damage to metal siding and roof
Misc. damage:	One discharge flap gate is not operational.

---

[340] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[341] This only includes the costs to repair damage due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

7.6.4.1.4.4 Katrina Event

Date	Time	Event
8/28/2005	-	The interview form states that the station was available prior to Hurricane Katrina.
	-	The interview form states that the operators pumped the water in the canal down to approximately -8.5 ft NGVD.
8/29/2005	1:15 AM	The interview form states that the operators evacuated the station.
	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	-	The interview form indicates that flooding did not reach the operating floor.

7.6.4.1.4.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.4.1.4.6 Pump Operational Curves

Operational curves have been developed for Meraux. They are not included in this report at this time, but will be inserted in the future.

7.6.4.1.4.7 Pump Reverse Flow

There are three pumps at this station for which reverse flow rating curves were computed (no pumps were excluded). The reverse flow data and curves are presented in the order of the pump numbering utilized in the summary tables included in this appendix. In cases where there are multiple pumps of equivalent size and system configuration, a single rating curve represents all of them at a unit rate per pump.

Pump No.	Pump Capacity (cfs)	Pump Size (in)	Reverse Flow Computed?		Rating Curve Ref. No.
			Yes	No	
1	450	94 x 128	X		1
2	90	42 x 54	X		2
3	450	94 x 128	X		1

For a general explanation of reverse flow (terminology, figures, methodology, equations and assumptions), refer to the Reverse Flow Section at the beginning of this appendix. Reverse flow computations for a given pump station do not necessarily imply that reverse flow actually occurred there during the Katrina event. But these curves may instead be used as future tools if further investigations are required based on reverse flow assumptions.

5. Reverse Flow Rating Curve

#4 Meraux Pump Station, Pumps #1 & #3, 94 x 128-in.

Elevation Datum (ft): NGVD

Crest Elevation (ft) = 3.83

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

> *For primed flow rates:* *Use Q = sqrt((H1-H2)/K')*
> *K' =* *1.75077E-05* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 3.8 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 4.8 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

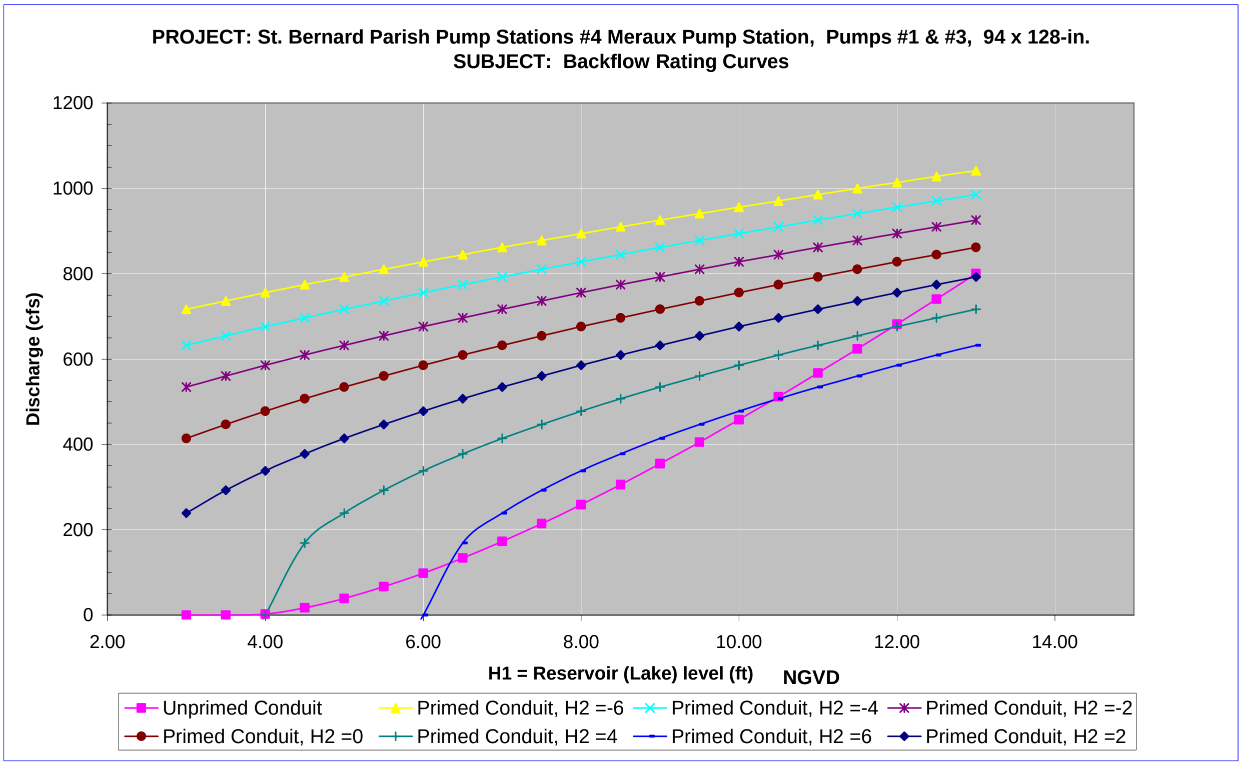
Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.							
H2 =	-6	-4	-2	0	2	4	6
H1 >	5	5	5	5	5	5	5

Water elevation (H1) that stops unprimed flow: 3.8 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 4.8 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.



Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump headloss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient = 3.5

Intake loss = 0.5

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Exit Loss = 1.3

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Tainter Gate Left open

Discharge gate width = 10 feet

4 Data Needs or Deficiencies:

Discharge gate and channel width

Plan View of Pump Station

5 Backflow prevention:

Available:	Tainter Gate for Closure No backstops to prevent reverse rotation.
Used:	Discharge gates closed during pump shutdown, Reversed flow occurred when a gate failed during storm.

6. Reverse Flow Rating Curves

#4 Meraux Pump Station, Pump #2, 42 x 54-in.

Elevation Datum (ft): NGVD

Crest Elevation (ft) = 3.83

H1 = Lake or outlet canal water level (normal pump discharge side)

H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use* $Q = \mathrm{sqrt}((H1-H2)/K')$

$K' =$ *0.000515075* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 3.8 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 4.8 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

H2 =	-6	-4	-2	0	2	4	6
H1 >	5	5	5	5	5	5	5

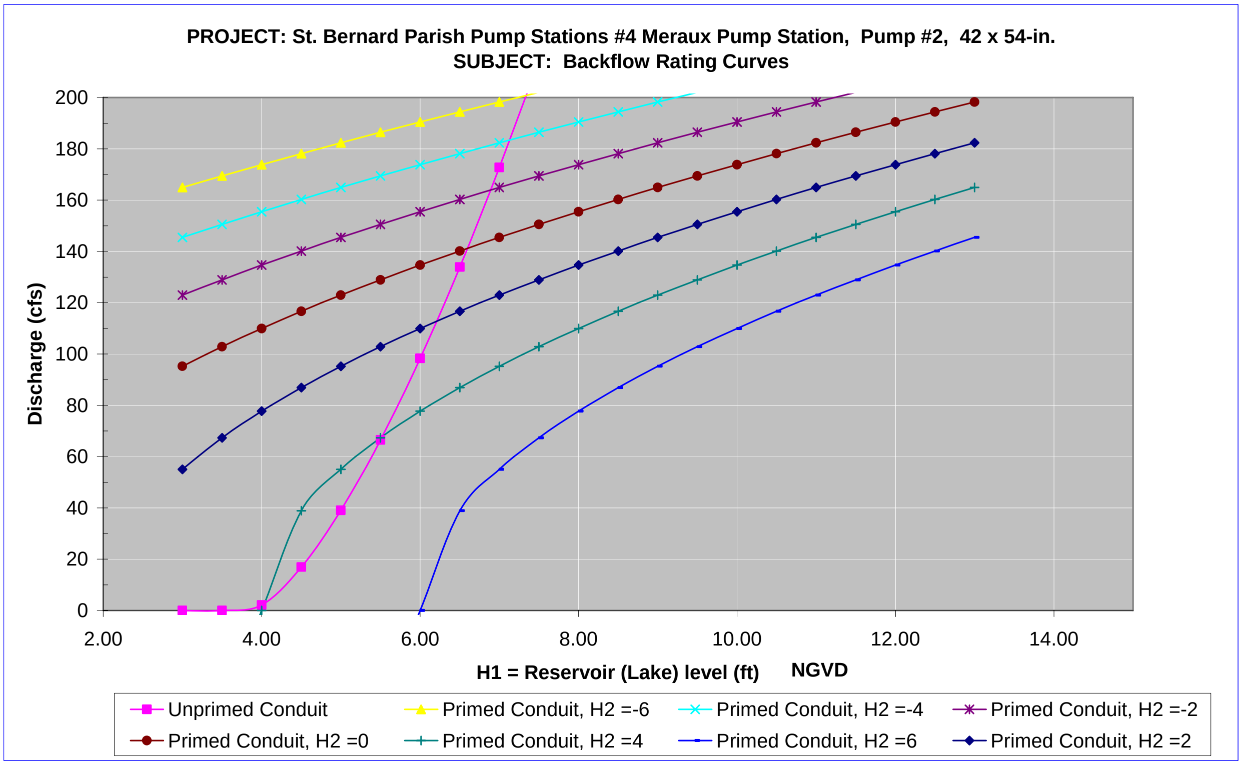
Water elevation (H1) that stops unprimed flow: 3.8 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 4.8 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.



<u>Notes:</u>

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump headloss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:
Pump loss coefficient = 6.50
Intake loss = 0.5
Exit Loss = 1.3
Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:
Tainter Gate Left open
Discharge gate width = 10 feet

4 Data Needs or Deficiencies:
Discharge gate and channel width
Plan View of Pump Station

5 Backflow prevention:
Available: Tainter Gate for Closure
Used: Discharge gates closed during pump shutdown
1 gate failed during storm.

7.6.4.1.4.8 Fuel Endurance Calculation

Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. To calculate the time, a few assumptions are required. The first assumption is the HHV[342] of diesel fuel being used is 130,000 Btu[343] per gallon of fuel[344]. The second assumption is the diesel engines are at least 35% efficient[345]. This station has 2 diesel driven pumps and one electric driven pump. The station did not report any issues with running out of fuel. Below are the fuel endurance calculations.

The rated horsepower of the diesel driver $P := 1200\text{hp}$

The assumed efficiency of the diesels $\varepsilon := 35\%$

The actual power required from the fuel $P_a := \dfrac{P}{\varepsilon}$ $P_a = 3428.57\,\text{hp}$

The higher heating value $HHV := 130000\dfrac{\text{BTU}}{\text{gal}}$

The burn rate $BR := \dfrac{P_a}{HHV}$ $BR = 67.11\,\dfrac{\text{gal}}{\text{hr}}$

There are 4-5,000 gallon tanks and 2-110 gallon tanks at this station.

Total volume of fuel $V_T := (4\cdot 5000 + 2\cdot 110)\text{gal}$

The fuel endurance of the station $FE := \dfrac{V_T}{2BR}$ $FE = 150.66\,\text{hr}$

$FE = 6.28\,\text{day}$

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[342] High heating value

[343] British thermal units

[344] http://www.exxon.com/USA-English/GFM/Products_Services/Fuels/Diesel_Fuels_FAQ.asp

[345] Standard Handbook for Mechanical Engineers, Eighth Edition, pg 9-106

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.4.1.5 *E J Gore*

St Bernard Parish – Area 3 Drainage Basin

7701 East Judge Perez Dr
Violet, LA 70085

Latitude 29.879846° Longitude -89.874986°

7.6.4.1.5.1 Before and After Hurricane Katrina Photos

Before Hurricane Katrina: View from the inlet canal

Before Hurricane Katrina: Arial view of the pump station

After Hurricane Katrina: View from the inlet canal

After Hurricane Katrina: Arial view of the pump station

7.6.4.1.5.2 Description[346]

Drainage area:	Area 3
Nominal Capacity:	665 cfs
Drains water from:	Forty Arpent Canal
Discharges water to:	Bayou Dupre
Owner:	Lake Borgne Levee District
Number of pumps:	6
Pump orientation:	6 horizontal
Pump driver:	6 diesels
Water level to switch pumps on:	0.0 feet (NGVD)
Water level to switch pumps off:	-0.5 feet (NGVD)
Water level that affects operation:	4.0 feet (NGVD) Motors overtopped.
Reverse flow protection:	Flap gates on all pumps

7.6.4.1.5.3 Damages

Estimated cost of repairs:	$2,939,000[347]
Relative level of damage:	Substantial
Severity of circumstances:	With the operating floor at approximately 2 feet N.G.V.D, flood waters within the building reached a height of approximately 6 ft.
Equipment damaged:	The hydraulic driven pumps were damaged along with the six diesel engines. The generator, electric pump motor and controller were flooded.
Building damage:	Damage to the rollup door, roof, building office, and restroom facility.
Misc. damage:	The hydraulic oil tank is not on its foundation. The hydraulic oil tank and fuel system is contaminated with salt water.

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[346] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[347] This only includes the costs to repair damage due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

The trash rack bar screens and the slope pavement adjacent to the discharge pipes are damaged.

7.6.4.1.5.4 Katrina Event

Date	Time	Event
8/28/2005	-	The interview form indicates that operators pumped water into canal approximately -3.0ft. down.
8/29/2005	1:15 AM	The interview form indicated crew evacuated
	-	The interview form indicates that operational logs were destroyed due to flooding. Water levels reached above 6ft. from concrete slab and overtopped the pump motors and pumps.
	-	The interview form states that flooding reached 6 feet over the operating floor.

7.6.4.1.5.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.4.1.5.6 Pump Operational Curves

Operational curves have been developed for E J Gore. They are not included in this report at this time, but will be inserted in the future.

7.6.4.1.5.7 Pump Reverse Flow

No reverse flow curves were developed for this station since all pumps were equipped with flap valves.

7.6.4.1.5.8 Fuel Endurance Calculation

Fuel Endurance Calculation Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. To calculate the time, a few assumptions are required. The first assumption is the HHV[348] of diesel fuel being used is 130,000 Btu[349] per gallon of fuel[350]. The second assumption is the diesel engines are at least 35% efficient[351]. This station has 6 diesel driven pumps with the same rated horsepower. The station did not report any issues with running out of fuel. Below are the fuel endurance calculations.

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[348] High heating value

[349] British thermal units

[350] http://www.exxon.com/USA-English/GFM/Products_Services/Fuels/Diesel_Fuels_FAQ.asp

[351] Standard Handbook for Mechanical Engineers, Eighth Edition, pg 9-106

The rated horsepower of the diesel driver	$P := 335\text{hp}$	
The assumed efficiency of the diesels	$\varepsilon := 35\%$	
The actual power required from the fuel	$P_a := \dfrac{P}{\varepsilon}$	$P_a = 957.14\,\text{hp}$
The higher heating value	$\text{HHV} := 130000\,\dfrac{\text{BTU}}{\text{gal}}$	
The burn rate	$\text{BR} := \dfrac{P_a}{\text{HHV}}$	$\text{BR} = 18.73\,\dfrac{\text{gal}}{\text{hr}}$

There are 1-20,000 gallon tank, 5-50 gallon tanks, and 1-75 gallon tank at this station.

Total volume of fuel	$V_T := (20000 + 5 \cdot 500 + 75)\text{gal}$	
The fuel endurance of the station	$\text{FE} := \dfrac{V_T}{6\text{BR}}$	$\text{FE} = 200.84\,\text{hr}$
		$\text{FE} = 8.37\,\text{day}$

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

7.6.4.1.6 *Jean Lafitte*

St Bernard Parish – Area 1 Drainage Basin

4200 Jean Lafitte Pkwy
Chalmette, LA 70443

Latitude 29.966557° Longitude -89.975821°

7.6.4.1.6.1 Before and After Hurricane Katrina Photos

Before Hurricane Katrina: View from the inlet canal

Before Hurricane Katrina: Arial view of the pump station

After Hurricane Katrina: View from the inlet canal

After Hurricane Katrina: Arial view of the pump station

7.6.4.1.6.2 Description[352]

Drainage area: Area 1

Nominal Capacity: 1000 cfs

Drains water from: Florida Walk Forty Arpent Canal

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[352] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

Discharges water to:	Bayou Bienvenue
Owner:	Lake Borgne Levee District
Number of pumps:	3
Pump orientation:	3 vertical
Pump driver:	3 diesels
Water level to switch pumps on:	-6.0 feet (NGVD)
Water level to switch pumps off:	-6.5 feet (NGVD)
Water level that affects operation:	9.0 feet (NGVD) Water overtops trash rack motors.
Reverse flow protection:	None

7.6.4.1.6.3 Damages

Estimated cost of repairs:	$156,000[353]
Relative level of damage:	Minor
Severity of circumstances:	With the operating floor at approximately 16 feet N.G.V.D, flood waters did not enter the main operating level. Flood waters did enter the lower level causing flooding
Equipment damaged:	Mechanical damage includes damage to the trash rack gear boxes, trash removal equipment, engine exhaust flappers, and sanitation plant. Electrical damage consists of lighting and the remote engine alarm panel.
Building damage:	Building damage consists of damaged roof panels.
Misc. damage:	No significant miscellaneous damage was recorded.

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[353] This only includes the costs to repair damage due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

7.6.4.1.6.4 Katrina Event

Date	Time	Event
8/28/2005	-	The interview form states that the station was available prior to Hurricane Katrina.
	-	The interview form states that the operators pumped water in the canal down to approximately -8.5 feet.
8/29/2005	1:15 AM	The interview form states that the operators evacuated the station.
	6:30 AM	Hurricane Katrina made landfall in Louisiana.
8/30/2005	10:00 AM	The interview form states that the operators returned to the station an the water was the same height on both sides of the levee.
8/31/2005	-	The operators began running pumps 1-3.
9/3/2005	-	Operational log states that the station lost power and fuel to generate both fuel tanks and 1-2-3 engines

7.6.4.1.6.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.4.1.6.6 Pump Operational Curves

Operational curves have been developed for Canal Street. They are not included in this report at this time, but will be inserted in the future.

7.6.4.1.6.7 Pump Reverse Flow

There are three pumps at this station for which reverse flow rating curves were computed (no pumps were excluded). The reverse flow data and curves are presented in the order of the pump numbering utilized in the summary tables included in this appendix. In cases where there are multiple pumps of equivalent size and system configuration, a single rating curve represents all of them at a unit rate per pump.

Pump No.	Pump Capacity (cfs)	Pump Size (in)	Reverse Flow Computed?		Rating Curve Ref. No.
			Yes	No	
1	333	75 x 72	X		1
2	333	75 x 72	X		1
3	333	75 x 72	X		1

For a general explanation of reverse flow (terminology, figures, methodology, equations and assumptions), refer to the Reverse Flow Section at the beginning of this appendix. Reverse flow computations for a given pump station do not necessarily imply that reverse flow actually occurred there during the Katrina event. But these curves may instead be used as future tools if further investigations are required based on reverse flow assumptions.

25. Reverse Flow Rating Curve

<u># 6 Jean Lafitte, P1, P2 & P3 - 75 x 72-in.</u>

Elevation Datum (ft): NGVD

Crest Elevation (ft) = 5

H1 = Lake or outlet canal water level (normal pump discharge side)

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:
Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use* $Q = \mathrm{sqrt}((H1-H2)/K')$
$K' =$ *0.000206663* sec^2/ft^5

<u>Reverse Flow Trigger Points:</u>
This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:
Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

<u>Water elevation trigger points:</u>
The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 5.0 ft
Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 11.0 ft
Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge

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lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

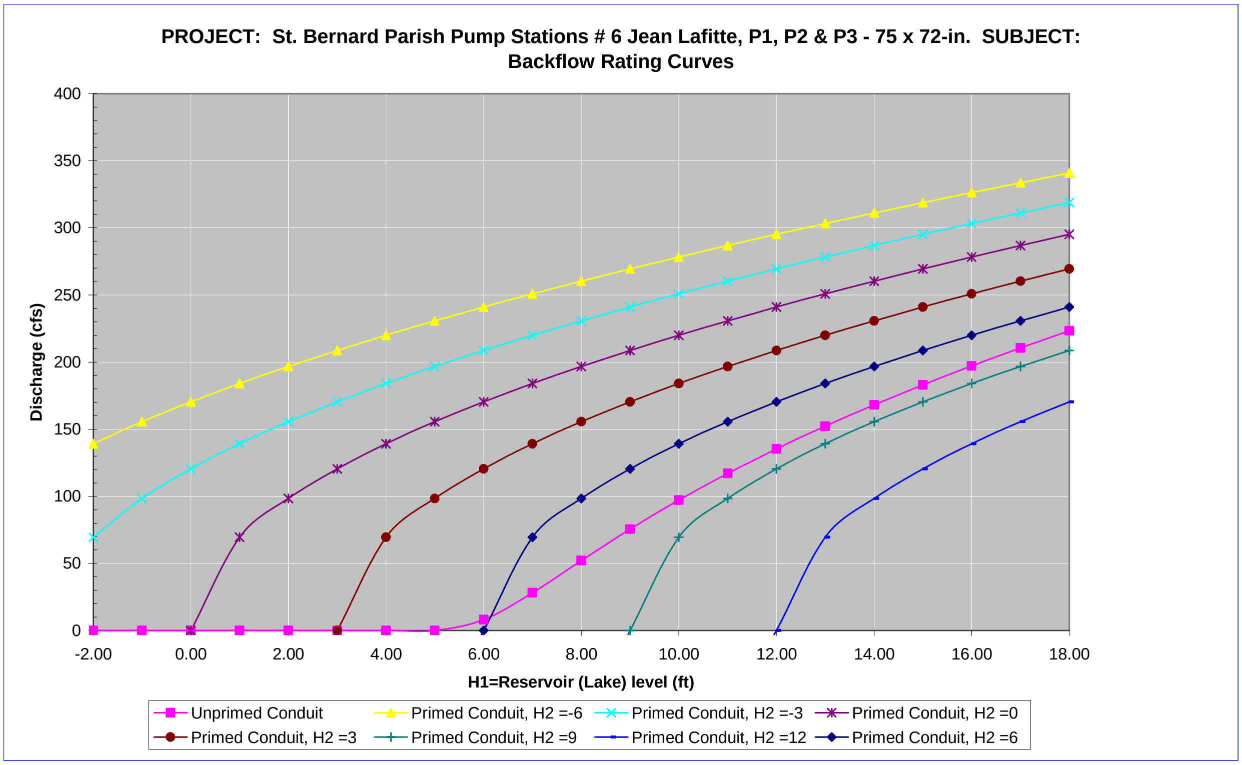
H2 =	-6.0	-3.0	0.0	3.0	6.0	9.0	12.0
H1 >	71	61	50	39	29	18	12

Water elevation (H1) that stops unprimed flow: 5.0 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 0.1 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.



Notes:

1. Full flow rating curve is accurate to within ± 30% due to uncertainty of pump headloss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).
2. Minor Loss Coefficient Assumptions:

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Pump loss coefficient = 6.50
Intake loss = 0.92
Exit Loss = 1.3
Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:
Shape/length/angle of diffuser/baffle based on photos.
Shape/length/angle of 2nd bend based on sketch and photos.
Pipe lengths estimated from photos and 1988 Design Worksheet.
Elevations in msl and NGVD are same.
Pump & Crest invert scaled from drawing = 4 ft NGVD.
Pump Calcs show CL discharge pipe = 8 ft >> invert = 5 ft NGVD.

4 Data Needs or Deficiencies:
Shape/length/angle of diffuser & detail of baffle.
Detail of pumps incl bend to discharge pipe, impeller.

5 Backflow prevention:
Available: No backflow prevention.
Pins can be inserted into hubs to prevent backward rotation of propellers.
Used: Not sure if reverse flow occurred. Operators evacuated station at 0115 on 8/29/05 and returned at 1000 on 8/30/05. Water was the same elevation on both sides of pump station.

7.6.4.1.6.8 Fuel Endurance Calculation

Fuel Endurance Calculation Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. To calculate the time, a few assumptions are required. The first assumption is the HHV[354] of diesel fuel being used is 130,000 Btu[355] per gallon of fuel[356]. The second assumption is the diesel engines are at least 35% efficient[357]. This station has 3 diesel driven pumps with the same rated horsepower. The station did not report any issues with running out of fuel. Below are the fuel endurance calculations.

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[354] High heating value
[355] British thermal units
[356] http://www.exxon.com/USA-English/GFM/Products_Services/Fuels/Diesel_Fuels_FAQ.asp
[357] Standard Handbook for Mechanical Engineers, Eighth Edition, pg 9-106

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

The rated horsepower of the diesel driver $P := 335\text{hp}$

The assumed efficiency of the diesels $\varepsilon := 35\%$

The actual power required from the fuel $P_a := \frac{P}{\varepsilon}$ $P_a = 957.14\,\text{hp}$

The higher heating value $HHV := 130000\,\frac{\text{BTU}}{\text{gal}}$

The burn rate $BR := \frac{P_a}{HHV}$ $BR = 18.73\,\frac{\text{gal}}{\text{hr}}$

There are 2-10,000 gallon tanks and 2-300 gallon tanks at this station.

Total volume of fuel $V_T := (2 \cdot 10000 + 2 \cdot 300)\text{gal}$

The fuel endurance of the station $FE := \frac{V_T}{3BR}$ $FE = 366.54\,\text{hr}$

$FE = 15.27\,\text{day}$

7.6.4.1.7 *Bayou Ducros*

St Bernard Parish – Area 2 Drainage Basin

3701 Bartolo Dr
Meraux, LA 70075

Latitude 29.946969° Longitude -89.922244°

7.6.4.1.7.1 Before and After Hurricane Katrina Photos

Before Hurricane Katrina: View from the inlet canal

Before Hurricane Katrina: Arial view of the pump station

After Hurricane Katrina: View from the inlet canal

After Hurricane Katrina: Arial view of the pump station

7.6.4.1.7.2 Description[358]

Drainage area:	Area 2
Nominal Capacity:	945 cfs
Drains water from:	Florida Walk Forty Arpent Canal
Discharges water to:	Bayou Bienvenue
Owner:	Lake Borgne Levee District
Number of pumps:	3
Pump orientation:	3 vertical
Pump driver:	3 diesels
Water level to switch pumps on:	-6.0 feet (NGVD)
Water level to switch pumps off:	-6.5 feet (NGVD)
Water level that affects operation:	18 feet (NGVD). Water would overtop motors and gears.
Reverse flow protection:	None

7.6.4.1.7.3 Damages

Estimated cost of repairs:	$156,000[359]
Relative level of damage:	Minor
Severity of circumstances:	With the operating floor at approximately 16 feet N.G.V.D, flood waters did not enter the main operating level. Flood waters did enter the lower level causing flooding
Equipment damaged:	Mechanical damage includes damage to the trash rack gear boxes, trash removal equipment, engine exhaust flappers, and sanitation plant. Electrical damage consists of lighting and the remote engine alarm panel.
Building damage:	Building damage consists of damaged roof panels.
Misc. damage:	No significant miscellaneous damage was recorded.

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[358] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[359] This only includes the costs to repair damage due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

7.6.4.1.7.4 Katrina Event

Date	Time	Event
8/28/2005	4:55 PM	The interview form states that the operators pumped the canal down to -8.5 feet NGVD
8/29/2005	1:15 AM	The interview form states that the operators evacuated the pump station.
	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	-	The interview form indicates that flooding did not reach the operating floor.
8/30/2005	10:00 AM	The interview form states that the operators returned to the station and that the water was at the same height on both sides of the levee.
8/31/2005	-	The operators began pumping with pumps 1-3.

7.6.4.1.7.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.4.1.7.6 Pump Operational Curves

Operational curves have been developed for Canal Street. They are not included in this report at this time, but will be inserted in the future.

7.6.4.1.7.7 Pump Reverse Flow

There are three pumps at this station for which reverse flow rating curves were computed (no pumps were excluded). The reverse flow data and curves are presented in the order of the pump numbering utilized in the summary tables included in this appendix. In cases where there are multiple pumps of equivalent size and system configuration, a single rating curve represents all of them at a unit rate per pump.

Pump No.	Pump Capacity (cfs)	Pump Size (in)	Reverse Flow Computed?		Rating Curve Ref. No.
			Yes	No	
1	315	75 x 72	X		1
2	315	75 x 72	X		1
3	315	75 x 72	X		1

For a general explanation of reverse flow (terminology, figures, methodology, equations and assumptions), refer to the Reverse Flow Section at the beginning of this appendix. Reverse flow computations for a given pump station do not necessarily imply that reverse flow actually occurred there during the Katrina event. But these curves may instead be used as future tools if further investigations are required based on reverse flow assumptions.

7. Reverse Flow Rating Curve

 # 7 Bayou Ducros PS, P1, P2 & P3 - 75 x 72-in.

Elevation Datum (ft):	NGVD
Crest Elevation (ft) =	5

H1 = Lake or outlet canal water level (normal pump discharge side)
H2 = Drainage area water level (normal pump intake side)

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use Q = sqrt((H1-H2)/K')*
K' = *0.000206663* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 5.0 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 11.0 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in

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the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

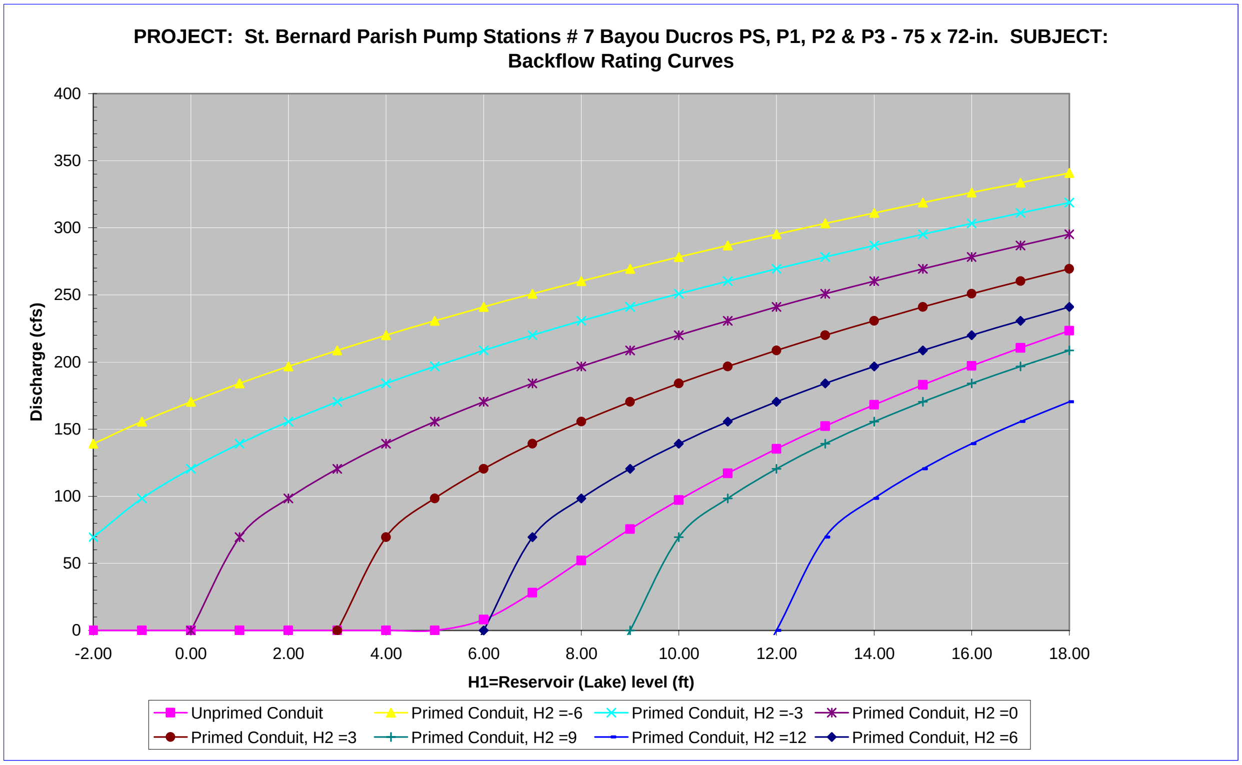
Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.							
H2 =	-6.0	-3.0	0.0	3.0	6.0	9.0	12.0
H1 >	71	61	50	39	29	18	12

Water elevation (H1) that stops unprimed flow: 5.0 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 0.1 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.



<u>**Notes:**</u>

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump headloss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient = 6.50

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Intake loss =	0.92
Exit Loss =	1.3

Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Shape/length/angle of diffuser/baffle based on photos.

Shape/length/angle of 2nd bend based on sketch and photos.

Assume same elevations and dimensions as Pump Station #6.

Pipe lengths estimated from photos and 1988 Design Worksheet.

Elevations in msl and NGVD are same.

4 Data Needs or Deficiencies:

Shape/length/angle of diffuser & detail of baffle.

Detail of pumps incl bend to discharge pipe, impeller.

5 Backflow prevention:

Available:	No backflow prevention. Pins can be inserted into hubs to prevent backward rotation of propellers.
Used:	Not sure if reverse flow occurred. Operators evacuated station at 0115 on 8/29/05 and returned at 1000 on 8/30/05. Water was the same elevation on both sides of levee.

7.6.4.1.7.8 Fuel Endurance Calculation

Fuel Endurance Calculation Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. To calculate the time, a few assumptions are required. The first assumption is the HHV[360] of diesel fuel being used is 130,000 Btu[361] per gallon of fuel[362]. The second assumption is the diesel engines are at least 35% efficient[363]. This station has 3 diesel driven pumps with the same rated horsepower. The station did not report any issues with running out of fuel. Below are the fuel endurance calculations.

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[360] High heating value

[361] British thermal units

[362] http://www.exxon.com/USA-English/GFM/Products_Services/Fuels/Diesel_Fuels_FAQ.asp

[363] Standard Handbook for Mechanical Engineers, Eighth Edition, pg 9-106

This is a preliminary report subject to revision; it does not contain final conclusions of the United States Army Corps of Engineers.

The rated horsepower of the diesel driver $P := 1020\text{hp}$

The assumed efficiency of the diesels $\varepsilon := 35\%$

The actual power required from the fuel $P_a := \frac{P}{\varepsilon}$ $P_a = 2914.29\,\text{hp}$

The higher heating value $HHV := 130000\,\frac{\text{BTU}}{\text{gal}}$

The burn rate $BR := \frac{P_a}{HHV}$ $BR = 57.04\,\frac{\text{gal}}{\text{hr}}$

There are 2-10,000 gallon tanks and 2-300 gallon tanks at this station.

Total volume of fuel $V_T := (2 \cdot 10000 + 2 \cdot 300)\text{gal}$

The fuel endurance of the station $FE := \frac{V_T}{3BR}$ $FE = 120.38\,\text{hr}$

$FE = 5.02\,\text{day}$

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7.6.4.1.8 *St Mary's*

St Bernard Parish – Area 3 Drainage Basin

3616 Bayou Rd
Verret, LA 70085

Latitude 29.854064° Longitude -89.795715

7.6.4.1.8.1 Before Hurricane Katrina Photos (Focused Arial views were not available)

Before Hurricane Katrina: View from the inlet canal

After Hurricane Katrina: View from the inlet canal

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7.6.4.1.8.2 Description[364]

Drainage area:	Area 3
Nominal Capacity:	780 cfs
Drains water from:	Twenty Arpent Canal
Discharges water to:	Lake Lery
Owner:	Lake Borgne Levee District
Number of pumps:	3
Pump orientation:	3 vertical
Pump driver:	3 diesels
Water level to switch pumps on:	0.0 feet (NGVD)
Water level to switch pumps off:	-0.5 feet (NGVD)
Water level that affects operation:	18 feet (NGVD). Water would overtop motors and gears.
Reverse flow protection:	Check valves on discharge pipes

7.6.4.1.8.3 Damages

Estimated cost of repairs:	$130,000[365]
Relative level of damage:	Minor
Severity of circumstances:	With the operating floor at approximately 16 feet N.G.V.D, flood waters did not enter the main operating level. Flooding from the storm flooded the lower level of the station, but the flood waters were approximately 8 ft. below the concrete operating floor level.
Equipment damaged:	Bearing and gears for the trash racks were damaged.
Building damage:	Building damage consists of loose roof panels, scour section near the discharge pipes, light fixtures, and the sewage aerator motor.
Misc. damage:	Auxiliary equipment damage includes a front end loader used to remove debris from the trash racks.

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[364] The Pump Information Table contains more details about the individual pumps and is located in the Parish Summary.

[365] This only includes the costs to repair damage due to Hurricane Katrina. It does not include any costs to improve the station beyond its performance before the hurricane.

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7.6.4.1.8.4 Katrina Event

Date	Time	Event
8/28/2005	-	The interview form states that the operators pumped the canal down to approximately -3.5 feet.
8/29/2005	1:15 AM	The interview form states that the operators evacuated the station.
	6:30 AM	Hurricane Katrina made landfall in Louisiana.
	-	The interview form indicates that flooding reached the first floor, but not the second floor where the motors and gears are located.
9/1/2005	-	The interview form states that the operators began pumping with pumps 1 and 2.
9/3/2005		The log indicates that there was no 24VDC power in the Engine #3 cabinet. The operators drained the rusty water in the conduit under the station and found that wires were broken inside. They cleaned and returned the wires with a wire nut. The power was restored, and pumping resumed.
9/9/2005	9:50 AM	The Army National Guard arrived with 4,000 gallons of diesel fuel for the station.
9/10/2005	5:30 PM	The Army National Guard arrived with 9,000 gallons of diesel fuel for the station.
9/12/2005	5:10 PM	The Army National Guard arrived with 6,400 gallons of diesel fuel for the station.
9/14/2005	6:00 AM	The log states that the pumps shut down. The canal was at - 2.0 feet.

7.6.4.1.8.5 Repair Status

Necessary data concerning current status of the repairs was not available as of April 27, 2006.

7.6.4.1.8.6 Pump Operational Curves

Operational curves have been developed for Canal Street. They are not included in this report at this time, but will be inserted in the future.

7.6.4.1.8.7 Pump Reverse Flow

Operator survey states no reverse flow occurred. Check valves are described as backflow prevention system in questionnaire. However, general summary sheet does not show check valves. Also system includes reverse rotation pins, which appears redundant if automatic check valves are already in place. Reverse flow most likely did not occur here, but the reverse flow ratings curves are shown here due to the discrepancies in information.

There are three pumps at this station for which reverse flow rating curves were computed (no pumps were excluded). The reverse flow data and curves are presented in the order of the pump numbering utilized in the summary tables included in this appendix. In cases where there are multiple pumps of equivalent size and system configuration, a single rating curve represents all of them at a unit rate per pump.

Pump No.	Pump Capacity (cfs)	Pump Size (in)	Reverse Flow Computed?		Rating Curve Ref. No.
			Yes	No	
1	260	108 x 66	X		1
2	260	108 x 66	X		1
3	260	108 x 66	X		1

For a general explanation of reverse flow (terminology, figures, methodology, equations and assumptions), refer to the Reverse Flow Section at the beginning of this appendix. Reverse flow

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computations for a given pump station do not necessarily imply that reverse flow actually occurred there during the Katrina event. But these curves may instead be used as future tools if further investigations are required based on reverse flow assumptions.

8. Reverse Flow Rating Curve

 # 8 St. Mary PS, P1, P2 & P3 - 108 x 66-in.

Elevation Datum (ft):	NGVD
Crest Elevation (ft) =	5

H1 = Lake or outlet canal water level (normal pump discharge side)
H2 = Drainage area water level (normal pump intake side)

Definition of Flow Regimes:

Unprimed flow does not fill the entire conduit and is controlled at the system crest. Unprimed flow is strictly a function of H1.

Primed conduit (or full flow) is a condition in which the pipe or conduit is entirely filled with water. Primed flow is a function of the difference between H1 and H2.

> **Siphon flow** is a subset or special case of primed flow in which the absolute pressure drops below atmospheric pressure inside the conduit.

Primed flow is computed from the difference between the discharge lake/canal water level (H1) and the drainage area water level (H2):

For primed flow rates: *Use* $Q = \mathrm{sqrt}((H1-H2)/K')$
$K' =$ *0.000259888* sec^2/ft^5

Reverse Flow Trigger Points:

This section identifies the conditions which either trigger the initiation of reverse flow, change in flow rates (e.g. from unprimed to primed flow or vice-versa), or flow stoppage. These trigger points can be used to determine which rating curves should be applied in the graph below. The first trigger point listed is not initiated by water elevation, whereas all remaining trigger points are dependent on water elevation (H1).

Pump failure or power failure automatically triggers primed flow:

Primed reverse flow will automatically occur if either a power outage or a pump failure (e.g. due to excessive head) interrupts a pumping operation and there is no automatic check or flap valve to prevent reverse flow. The system conduit is already primed from the pumping operation.

Water elevation trigger points:

The following four trigger points are based on the discharge lake/canal water elevations (H1) that will initiate reverse flow, change the flow rates, or stop flow. The water level trigger points are arranged in an order that follows the pattern of a typical storm hydrograph for the discharge lake/canal level (H1): beginning with a rising limb, followed by a peak and falling

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limb. In an initially primed conduit (i.e. pump failure), only the fourth water level trigger point (siphon breaker) applies.

Water elevation (H1) that triggers unprimed flow: 5.0 ft

Unprimed flow begins when the water level elevation (H1) of the discharge lake or canal reaches the invert elevation of the conduit crest in the pumping system. If the estimated unprimed flow rate exceeds the estimated primed flow rate for a given H1 and H2, then primed flow controls instead of unprimed flow.

Water elevation (H1) that triggers primed flow: 10.5 ft

Primed (or siphon) flow typically begins when the water level elevation (H1) of the discharge lake/canal reaches the elevation of the top (soffit) of the inside conduit at the conduit crest in the pumping system. If there is an open vent in the system, see the following table for minimum H1 elevations for given H2 elevations that would trigger primed flow.

Table for Minimum H1 for Primed Flow if Open Air Valve or Vent.

H2 =	-7.0	-4.0	-1.0	2.0	5.0	8.0	11.0
H1 >	124	105	85	66	46	27	11

Water elevation (H1) that stops unprimed flow: 5.0 ft

Unprimed flow stops at the same H1 that initiates unprimed flow.

Water elevation (H1) that stops primed conduit flow: 0.0 ft

Primed (or siphon) flow stops when the elevation of the discharge lake/canal water level (H1) is lower than the top of the pump system outlet plus ~1 foot drawdown, or when the pressure at the soffit of the crest pipe drops below -9.5 psi gage pressure. Either case is a siphon breaker.

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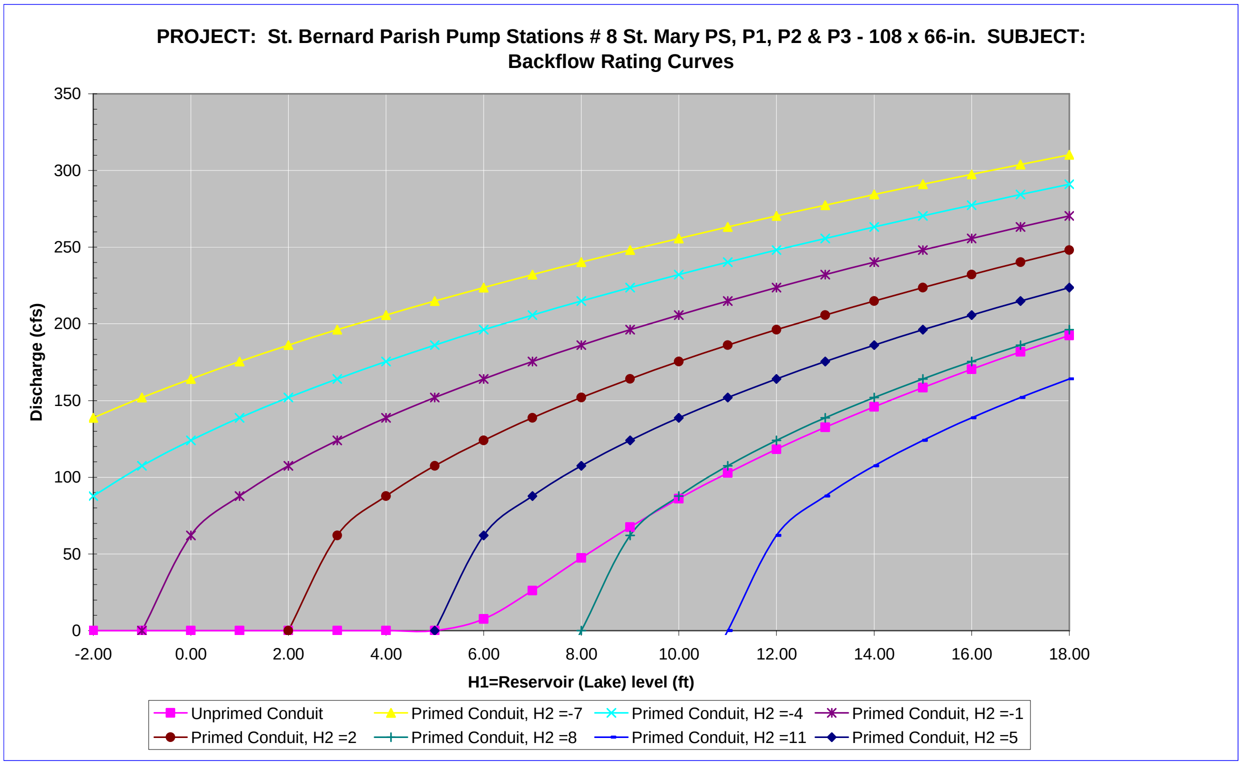
PROJECT: St. Bernard Parish Pump Stations # 8 St. Mary PS, P1, P2 & P3 - 108 x 66-in. SUBJECT: Backflow Rating Curves

Notes:

1 Full flow rating curve is accurate to within ± 30% due to uncertainty of pump headloss coefficients and engineering judgment. Accuracy decreases further based on data deficiencies exist (see below).

2 Minor Loss Coefficient Assumptions:

Pump loss coefficient = 6.50
Intake loss = 0.92
Exit Loss = 1.3
Bend, contraction, and expansion losses also incorporated

3 Data Assumptions:

Shape/length/angle of diffuser/baffle based on photos for PS#6 and PS#8 (similar to PS#6 but longer pipe).

Shape/length/angle of 2nd bend based on 1/2 dwg and photos (assumed similar to PS#6/7).

Pipe lengths estimated from photos and 1988 Design Worksheet for PS#6 and photos for PS#8.

4 Data Needs or Deficiencies:

Plan and profile of system.
Shape/length/angle of diffuser & detail of baffle.
Detail of pumps incl bend to discharge pipe, impeller.

5 Backflow prevention:

Available:	Check valves on discharge pipes. Pins can be inserted into hubs to prevent backward rotation of propellers.
Used:	Operator survey states reverse flow did not occur.

7.6.4.1.8.8 Fuel Endurance Calculation

Fuel Endurance Calculation Fuel endurance is a calculation of how long the station can operate the pumps at rated capacity with its current fuel storage volume. To calculate the time, a few assumptions are required. The first assumption is the HHV[366] of diesel fuel being used is 130,000 Btu[367] per gallon of fuel[368]. The second assumption is the diesel engines are at least 35% efficient[369]. This station has 3 diesel driven pumps with the same rated horsepower. The station did not report any issues with running out of fuel. Below are the fuel endurance calculations.

The rated horsepower of the diesel driver $P := 1020\text{hp}$

The assumed efficiency of the diesels $\varepsilon := 35\%$

The actual power required from the fuel $P_a := \dfrac{P}{\varepsilon}$ $P_a = 2914.29\,\text{hp}$

The higher heating value $HHV := 130000\,\dfrac{\text{BTU}}{\text{gal}}$

The burn rate $BR := \dfrac{P_a}{HHV}$ $BR = 57.04\,\dfrac{\text{gal}}{\text{hr}}$

There are 2-10,000 gallon tanks and 2-300 gallon tanks at this station.

Total volume of fuel $V_T := (2\cdot 10000 + 2\cdot 300)\text{gal}$

The fuel endurance of the station $FE := \dfrac{V_T}{3BR}$ $FE = 120.38\,\text{hr}$

$FE = 5.02\,\text{day}$

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[366] High heating value

[367] British thermal units

[368] http://www.exxon.com/USA-English/GFM/Products_Services/Fuels/Diesel_Fuels_FAQ.asp

[369] Standard Handbook for Mechanical Engineers, Eighth Edition, pg 9-106