Lower Yellowstone Intake Diversion Dam Fish Passage Project, Montana

APPENDIX A – Engineering

Lower Yellowstone Intake Fish Passage EIS

MAY 2016

Engineering Appendix A-1 – Modified Side Channel Alternative

Engineering Appendix A-2 – Multiple Pumping Station Alternative

Engineering Appendix A-3 – Multiple Pumping with Conservation Measures Alternative

Lower Yellowstone Intake Diversion Dam Fish Passage Project, Montana

ENGINEERING APPENDIX A-1

Lower Yellowstone Intake Fish Passage EIS

Modified Side Channel Alternative

MAY 2016

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1.0 Alternative Description

The purpose of the Modified Side Channel Alternative is to provide frequent flow and suitable habitat to support pallid sturgeon migration around the Intake Dam during most years. To accomplish this, an existing high flow channel on the right floodplain of Joe's Island will be modified to connect to the Yellowstone River more frequently and with a larger flow volume.

The existing high flow channel, sometimes referred to as "high flow channel chute", splits from the right bank of the main channel approximately 1.8 miles upstream of the Intake Dam and reconnects with the main channel approximately 1.7 miles downstream of the dam, though its path is approximately 4.5 miles (Figure 1.1). The right bank of the high flow channel is well defined and confined by a shale/siltstone bluff along much of its length. The high flow channel creates an island, referred to as Joe's Island, which is gently sloped and covered by grasses with sparse tree cover (Figure 1.2). Box Elder Creek is the only notable tributary to the high flow channel, joining from the south at about 3 miles downstream of the upstream confluence, or split, from the Yellowstone River. There are two locations where vehicles appear to cross the high flow channel to access Joe's Island. Both crossings are accessible from County Road 303 and require driving through the channel bed. These crossings are used to access the south side of the Intake Diversion Dam for maintenance of the dam including the placement of riprap on an annual basis.

The existing high flow channel provides an unobstructed conveyance around the Intake Dam, albeit a relatively perched or high channel (hence its name) that currently flows when discharge in the Yellowstone exceeds approximately 20,000 to 25,000 (cfs). An exact value for the initiation of flow into the existing high flow channel cannot be determined because the upstream end is influenced by erosion and deposition of material in the high flow channel and by erosion of the Yellowstone River bankline. The flow is, however, nearly an annual occurrence based on open-water (no ice) conditions. Furthermore, at this flow, the depths are typically too shallow for pallid sturgeon passage. In 2014 and 2015, pallid sturgeon were documented to have passed around the Intake Diversion Dam through the high flow channel (Rugg 2014 and 2015) when the peaks flows in the Yellowstone River at the Sidney, Montana (USGS Gage No. 06329500) gage were estimated at approximately 69,800 and 60,500 cfs, respectively.

This document describes the engineering analyses conducted to develop the Modified Side Channel Alternative for the fish passage project at Intake Diversion Dam on the Lower Yellowstone River. The level of design is conceptual to approximately 30-percent detail and the target species is pallid sturgeon, although other fish species are expected to use the Modified Side Channel. Hence the term "fish passage" is used throughout this report, with the primary species of concern being the pallid sturgeon. Analyses presented herein include hydrology, hydraulics, sediment transport, and design of project elements.

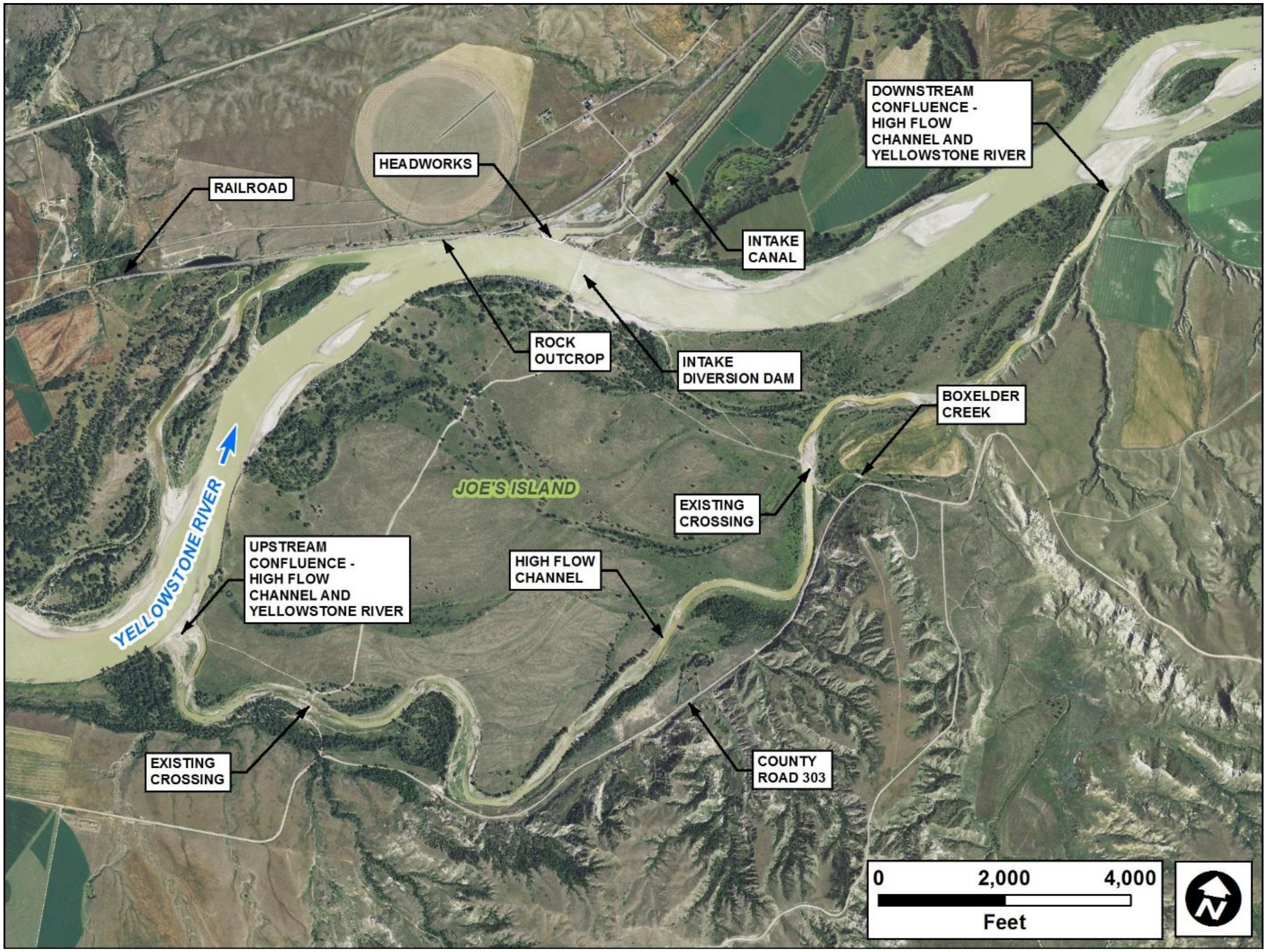


Figure 1.1 Intake Diversion Dam, Potentially Affected Area (Existing Conditions)

Figure 1.2 Panorama of Joe's Island Looking West from County Road 303 with High Flow Channel in Foreground

2.0 Design Guidelines

2.1 Design Criteria

Criteria for the development of the 30-percent design of the Modified Side Channel Alternative is based on guidance from the USFWS and the Biological Review Team (BRT**)**, previously developed for the Bypass Channel Alternative. Two sets of design criteria are recommended; one set applies to discharges in the Yellowstone River that are less than 15,000 cfs and one set that applies to discharges equal to or greater than 15,000 cfs (Table 2.1) (Walsh 2014).

Table 2.1 Summary of Design Criteria for Fish Passage in Bypass Channel Alternative (Walsh 2014)

Discharge at Sidney, Montana USGS Gage	7,000-14,999 cfs	15,000-63,000 cfs
Bypass Channel Flow Split	≥12%	13% to ≥ 15%
Bypass Channel cross-sectional velocities (measured as mean column velocity)*	2.0 - 6.0 ft/s	2.4 - 6.0 ft/s
Bypass Channel Depth (minimum cross-sectional depth for 30 contiguous feet at measured cross-sections)	≥ 4.0 ft	≥ 6.0 ft
Bypass Channel Fish Entrance (measured as mean column velocity)*	2.0 - 6.0 ft/s	2.4-6.0 ft/s
Bypass Channel Fish Exit (measured as mean column velocity)*	≤ 6.0 ft/s	≤ 6.0 ft/s

*The term “measured mean column velocity” is provided by the USFWS and BRT as guidance for design and subsequently for monitoring following construction if the alternative were to be carried forward. The velocities presented in this report and used for design are not based on measurements, but on results of hydraulic models.

In addition to the specific hydraulic criteria in Table 2.1, the USFWS and BRT suggest the Bypass Channel Alternative design also include elements that create variability of flow conditions within or on the margins of the channel without introducing significant turbulence and with depths that exceed one meter.

This criteria is partially addressed in the conceptual design with the creation of backwater habitat as described in the following sections. Additional features such as cover and pools would be included in the preliminary and final designs should this alternative be advanced.

3.0 Engineering Considerations

Hydraulic calculations indicate that under existing conditions, the flow in the high flow channel is significantly less than the recommended values from the USFWS and the BRT. Therefore, modifications are required at the confluence (or channel split) to increase the amount of flow in the modified side channel. This is achieved by lowering the channel inlet of the modified side channel at the upstream confluence with the Yellowstone River by approximately five feet, shortening and steepening the modified side channel, and to a lesser extent, widening of the modified side channel.

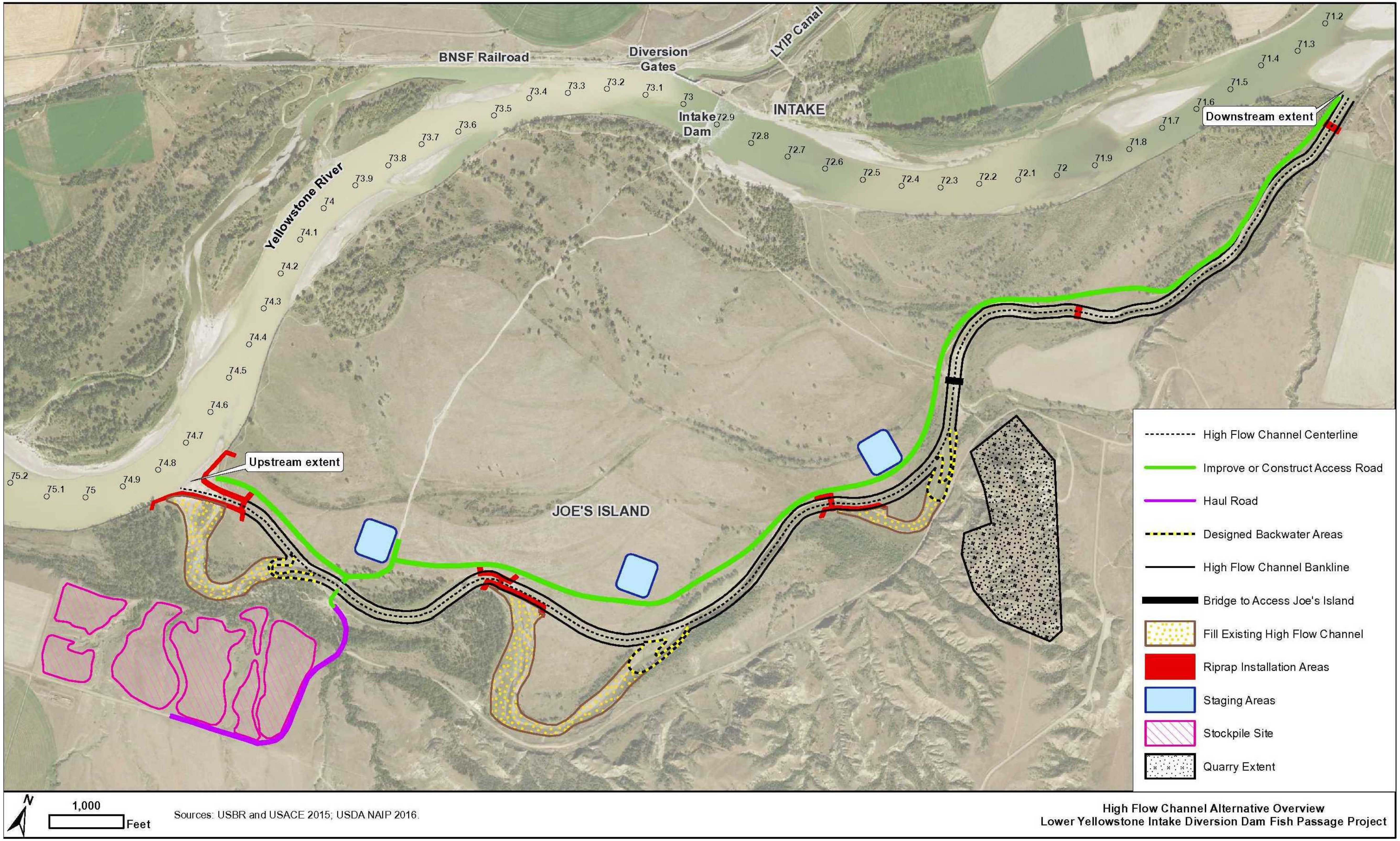
The modified channel would be lowered along its length and at the downstream confluence with the Yellowstone River to ‘daylight’ the lower channel invert, and to improve the attraction to and accessibility of the modified side channel for fish passage.

Between the inlet and outlet, the modified side channel would be realigned in three locations by increasing the radius of curvature creating ‘bend cutoffs.’ These cutoffs provide a slightly shorter channel which would offset the elevation lost by lowering the upstream confluence and provide a channel slope capable of conveying the flows and sediment loads as estimated by the one-dimensional sediment-transport model. Each of the bend cutoffs would include a backwater area for fish refuge and resting. A connected side channel at each of these bend cutoffs was considered but eliminated since the side channel would reduce the depths and flows in the main high flow channel to levels that would no longer meet the USFWS and BRT design criteria. Details of the engineering for the modified side channel are presented in this section. The proposed Modified Side Channel Alternative is shown in Figure 3.1.

3.1 Hydrology

Flow-frequency and flow-duration curves were developed for the project site by both the USGS (Chase 2014) and Corps (Corps 2006). The Corps analyzed the flow records at the Sidney, Montana gage (USGS Gage No. 06329500) located 36 miles downstream of Intake Diversion Dam, and at Glendive, Montana (USGS Gage No. 06327500) located 18 miles upstream of Intake Diversion Dam. Flows at the Sidney gage are affected by operations at Yellowtail Dam, which is located on the Bighorn River in south central Montana, approximately 90 miles upstream of the confluence with the Yellowstone River. Yellowtail Dam regulates approximately 28 percent of the baseflows upstream of Sidney, and reservoir operations can alter the flow regime (Corps 2006). Thus, two periods were assessed: (1) the period of record, Water-Year (WY) 1911-WY2005, and (2) the period following the construction of Yellowtail Dam (WY1967-WY2005).

The USGS analyzed the flow records in the Yellowstone River for two scenarios. The first being ‘unregulated’ streamflow representing flow conditions that might have occurred if there had been no water-resources development in the basin. The second being ‘regulated’ streamflow representing flow conditions if the level of water resources development that existed in 2002 was in place during the entire study period. The period of study was WY1928-WY2002.



Sources: USBR and USACE 2015; USDA NAIP 2016.

High Flow Channel Alternative Overview
Lower Yellowstone Intake Diversion Dam Fish Passage Project

Figure 3.1 Modified Side Channel Alternative

Table 3.1 Annual and Seasonal Flow-Duration Data for the Downstream End of Reach D10 (At Intake Diversion Dam) for Regulated Streamflow Conditions, 1928–2002 (Chase 2014)

Season	Streamflow, in cfs, which was equaled or exceeded for indicated percent of time								
	1%	5%	10%	25%	50%	75%	90%	95%	99%
Annual	56,800	37,000	26,000	12,200	8,000	5,850	4,350	3,530	2,230
Winter (January–March)	32,100	16,200	12,100	8,640	6,670	5,170	4,060	3,480	2,540
Spring (April–June)	67,800	52,000	43,600	27,900	14,600	8,270	5,930	5,150	3,600
Summer (July–September)	54,700	35,300	27,100	14,000	8,540	5,510	3,760	2,840	1,810
Fall (October–December)	13,400	11,300	10,400	8,830	7,370	5,760	4,390	3,530	2,260

This study period was chosen because the Corps desired a 75-year study period and Reclamation depletion data (necessary to estimate unregulated and regulated streamflows) were only available for 1929–2002. The daily streamflows were modified to represent unregulated and regulated streamflow conditions, respectively. Statistical summaries were calculated for each set of conditions.

The Corps used the flow-frequency and flow-duration values for the ‘regulated’ conditions as developed by the USGS (Corps 2015a) for the design and evaluation of the Bypass Channel Alternative. Similarly, the Modified Side Channel Alternative was designed using the USGS flows. Table 3.1 presents the annual and seasonal flow-durations for the Intake Dam, and Table 3.2 presents the instantaneous peak flows with the recommended peak flows. The USGS presents the data results by reaches. The Intake Dam is located at the downstream end of reach D10 (Chase 2014).

Table 3.2 Flow Frequency Values for Intake Diversion Dam (Corps 2015a)

Percent Chance Exceedance	Return Period (years)	Peak Flows[1] (cfs)
0.2	500	156,200
0.5	200	140,200
1	100	128,300
2	50	116,200
10	10	87,600
20	5	74,400
50	2	54,200

[1] Chase (2014)

3.2 Hydraulics

The hydraulic analysis of existing conditions for the high flow channel was conducted using HEC-RAS modeling software version 4.1.0 (Corps 2010). Two HEC-RAS models developed by the Corps for Intake Dam were provided for developing this alternative. The two models included an existing conditions HEC-RAS hydraulic model and the proposed Bypass Channel Alternative HEC-RAS hydraulic model for the 90-percent design (Corps 2015b).

3.2.1 Existing Conditions Hydraulic Modeling

The Corps existing conditions hydraulic model was used to evaluate flow splits between the Yellowstone River and the high flow channel, and to estimate hydraulic conditions in the vicinity of the Intake Diversion Dam. The Corps existing conditions model was slightly modified by replacing the lateral weir connection from the Yellowstone River main channel to the high flow channel with a junction connection. The bed elevation of the upstream cross section was adjusted slightly (increased 1.35 ft) to better match observed flow splits. This amount of variability at the head of the existing high flow channel is reasonable. This model became the basis for evaluating existing conditions and developing the proposed high flow channel alternative. The topography of the high flow channel under existing conditions was provided by the Corps and is based on 2014 LiDAR mapping and supplemental surveys data collected in 2015. HEC-RAS reports for existing conditions are provided in Attachment 1.

Results of the existing conditions hydraulic analysis indicate that the high flow channel diverts flows that are significantly less than the recommended values from the USFWS and the BRT (Table 3.3). These results demonstrate that modifications to the existing high flow channel are required to increase the frequency and rate of flow splits and to create the physical conditions associated with the design criteria outlined by the USFWS and BRT (Table 2.1).

Table 3.3 Summary of Flow Splits to Existing High Flow Channel

Discharge at Sidney, Montana USGS Gage	USFWS and BRT Criteria			Split to High Flow Channel	
	Target Flow (%)	Target Flow (cfs)	Min. Target Depth (ft)	Existing Split (cfs)	Existing Depth (ft)
7000 cfs	≥12%	840	4.0	0	0
15,000 cfs	13% to ≥ 15%	1,950 – 2,250	6.0	0	0
63,000 cfs	13% to ≥ 15%	8,190 – 9,450	6.0	4,470	8.1

3.2.2 Proposed Conditions Hydraulic Modeling

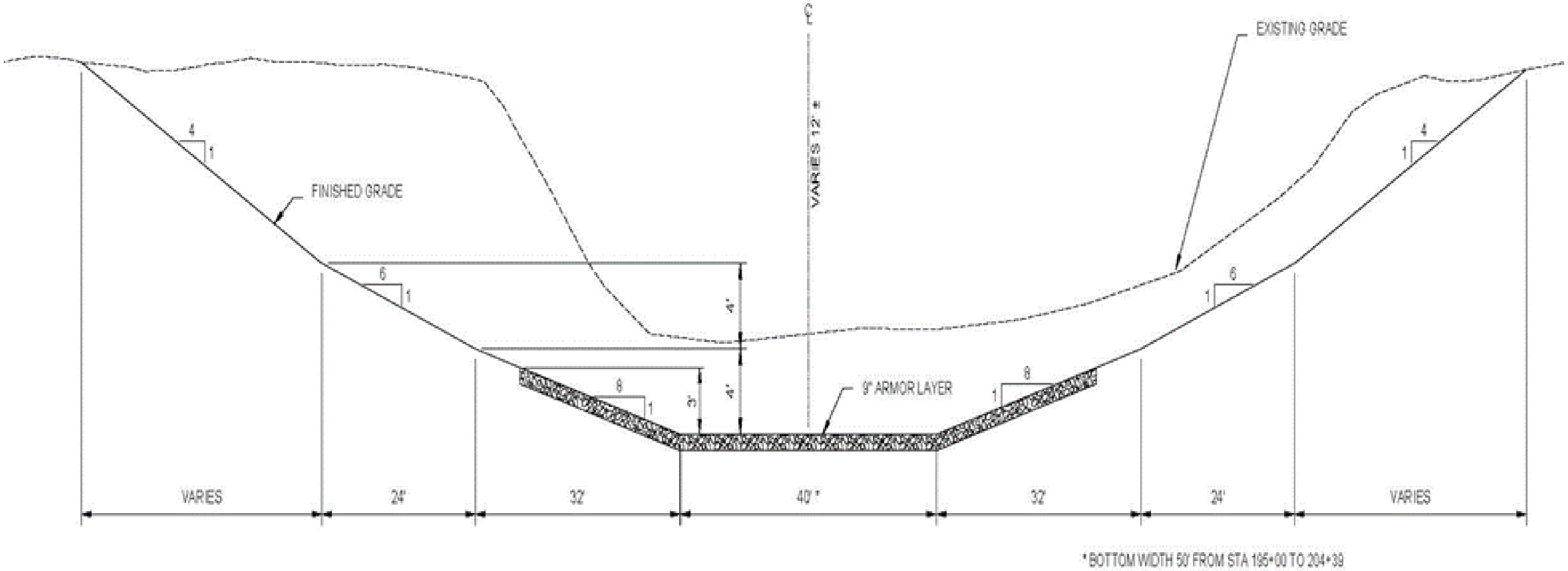
The Proposed Conditions Hydraulic model was developed by modifying the existing conditions model to represent the proposed channel alignment and profile. The channel geometry is generally based on the Bypass Channel Alternative. The Corps evaluated 19 side channels, including the high flow channel as references for physical parameters including top widths, sinuosity, bend radii, energy slope and entrance/exit angles of side channels. The results of this analysis established the basis for, or provided confirmation of, the layout and design of the Bypass Channel Alternative. Similarly, for design of the Modified Side Channel

Alternative, some of the findings are applied including proposed channel geometry, slope, entrance angle, and bend radii as detailed below:

- <u>Cross-section geometry</u>: The Corps evaluated a number of cross-section configurations for the Bypass Channel Alternative, the final being a 40-foot bottom wide channel with 8:1 H:V (horizontal to vertical) side slopes for a 4-foot rise, 6:1 H:V side slopes for a 4-foot rise, and 4:1 side slopes to meet existing conditions (Figure 3.2). For the Modified Side Channel Alternative, the Corps 60% Design cross section was slightly modified at the upstream confluence by widening the bottom width to 50 feet to capture the required flow splits.
- <u>Bed slope</u>: The Corps evaluated bed slope for the Bypass Channel Alternative and concluded a stable bed slope would be between 0.0004 and 0.0007 feet/feet. Likewise a similar analysis and conclusion was conducted for the Modified Side Channel. A constant slope of 0.0006 was used in the layout of the modified side channel. Grade control features would be incorporated into the channel to accommodate potential degradation and adjustment to a flatter slope. The grade control features include a 50-foot long riffle set at 1.0-percent slope for a 6 inch vertical grade differential, and comprised of cobble and small boulders (materials ranging from 2 to 20 inches). When the grade control is exposed, it would function as a riffle. Riffles were not modeled for this study, but were observed in the existing high flow channel during the site visit. Therefore, the grade controls were included at the 1% slope to add a similar variability. If this alternative is selected, the grade controls could be adjusted and other features could be added. A total of five grade controls are included in the design.
- <u>Sinuosity</u>: The sinuosity of the modified side channel is dictated by the alignment of the existing high flow channel with the exception of the two cutoffs to shorten the channel and to slightly increase the channel slope and the sediment transport load. The range of values for sinuosity identified by the Corps was 1.0 to 2.0, with the existing high flow channel at 1.5. Under proposed conditions the modified side channel sinuosity would be 1.3.
- <u>Radius of curvature</u>: The bends in the Bypass Channel alignment are based on a radius of curvature (Rc), of approximately 750 feet. The Corps (Corps 2014) notes that based on the reference and side channels along the Yellowstone River, Rc typically ranges from 812 to 1,136 feet. In the case of the modified side channel, the alignment basically follows the existing channel (with the exception of the three cutoffs), which has a radius of curvature of less than 500 feet. The proposed bends at the cutoffs are designed to fall within the ranges identified by Corps with a radius of curvature of approximately 1,000 feet each.
- <u>Modified side channel entrance</u>: The entrance angle for the modified side channel (26 degrees) is set to match the Bypass Channel Alternative alignment shown in the Corps construction drawings (Figure 3.1).
- <u>Channel-forming discharge</u>: The channel-forming discharge for the modified side channel design would be equal to the 2-year peak flow event. The 2-yr peak flow event in the Yellowstone River is estimated to be 54,200 cfs (Table 3.2). Using the split flow criteria from the USFWS and BRT, a split of 13 to 15 percent of 54,200 cfs is approximately 7,500 cfs.

The resulting modified side channel alignment is shown in Figure 3.1. With the exception of the bend cutoffs, the channel modifications are limited to within the channel banks to lower the channel. The incorporation of features to add diversity in the channel bed and banks would be included during future designs should this alternative be advanced. This would include vegetation to provide cover in the backwaters, the development of riffles and pools with a shifting thalweg (bank to bank), and variability in the channel bottom.

Under the proposed alternative, the modified side channel would be between 2 to 5 feet lower, and would convey flows more frequently than under existing conditions. Therefore, a bridge is proposed to provide access to the island and Intake Diversion Dam from the south. This bridge would be a 150-foot wide single span structure with abutments set at the banks of the channel so as to minimize encroachment into the modified side channel. The bridge would be elevated two feet above the 1% annual flood in conformance with the State of Montana floodplain criteria, which notes that the freeboard is intended to accommodate ice (Figure 3.2). However, previous studies conducted by the Cold Regions Research and Engineering Laboratory (CRREL) (Corps 2014, Attachment 5) for the bypass channel indicate the ice thickness could be as much as 10 feet above the 1% annual flood. To account for this uncertainty the cost for the bridge has been increased by 10% to account for larger abutments and increases to other related elements. Also the possibility of design changes caused by further investigation into ice impacts have been included in the risk analysis and contingency calculations. Should this alternative be advanced, additional analysis would be required.



* BOTTOM WIDTH 50' FROM STA 195+00 TO 204+39

Figure 3.2 Typical Channel Cross Section, Modified Side Channel

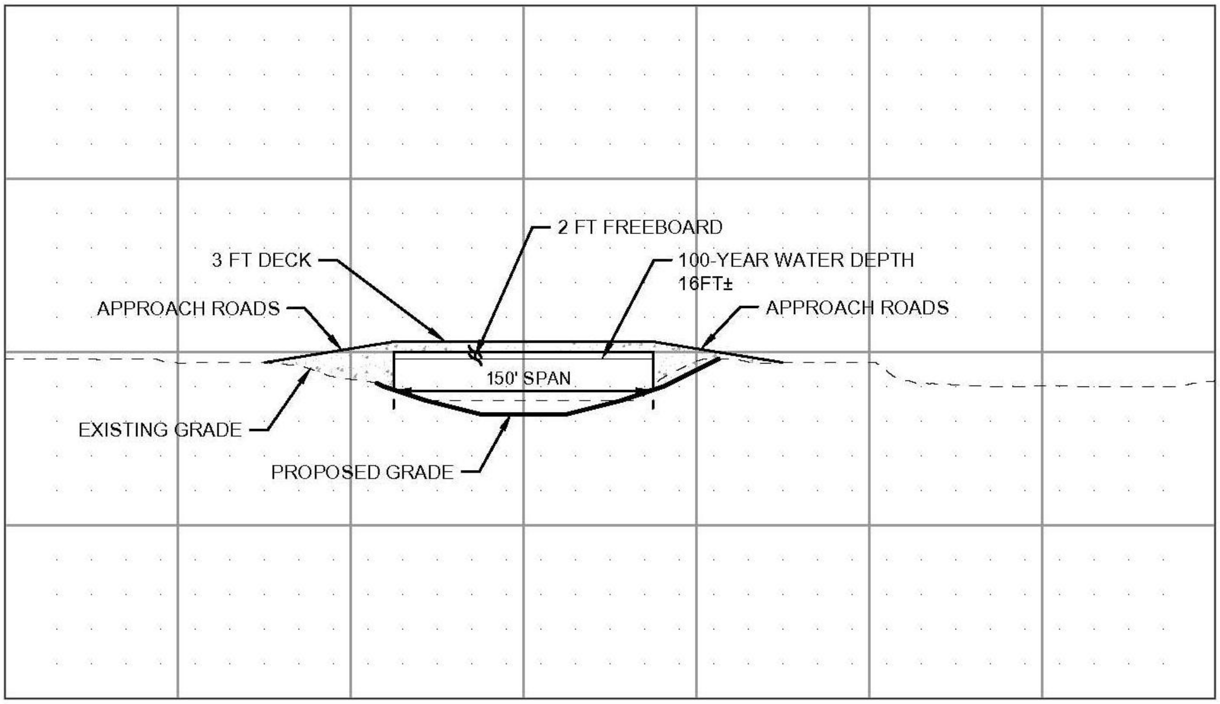


Figure 3.3 Typical Bridge Cross Section

The results of the hydraulic analysis indicated the alternative meets the depth and velocity criteria set by the USFWS and BRT (Table 3.4). The only exception is the velocity at the upstream confluence (the fish exit from the modified side channel) where the average channel velocity was estimated to be 6.7 fps when flows in the Yellowstone River are 63,000 cfs. This velocity is consistent with the average velocities in the Yellowstone River and is likely representative of the main channel as opposed to the modified side channel. Additional design and analyses to further address hydraulic conditions at the fish entrance, particularly a 2-dimensional (2-D) analysis, may be necessary for more detailed design should this alternative be advanced.

Flow splits for a range of conditions were evaluated using this conceptual level channel geometry. The results indicate that for a broad range of flows the USFWS and BRT recommendations for splits, depths and velocities can be achieved (Table 3.5). Table 3.5 also includes the April through June exceedance based on daily flow durations for the months of April through June, the primary months for upstream fish migration. Details of the analyses and results can be found in the proposed conditions HEC-RAS analysis results in Attachment 1.

HEC-RAS model output reports for proposed conditions are provided in Attachment 1. The water surface profiles for a range of flows are shown in Figure 3.4. The profile in Figure 3.4 is the Modified Side Channel reach of a split flow model that includes the Yellowstone River as separate reaches. Therefore, the water surfaces at the upstream and downstream ends of the Modified Side Channel approximately match the water surfaces of the Yellowstone River at the junctions. The slope of the Modified Side Channel was set to provide the desired hydraulic conditions. There is a slight drawdown at the downstream end of the Modified Side Channel at the lowest flows, which would likely result is a slight decrease in the bed elevation at this location. This is not expected to affect the overall hydraulic performance of the side channel.

Figure 3.4 also shows a bridge located at distance 17,500, which is the upper low flow crossing to the island. This bridge has almost no effect on the flow splits into the Modified Side Channel. The preferred bridge location is at the downstream low flow crossing near Boxelder Creek. The lower bridge location would have no effect on the flow splits so the models were not revised.

Table 3.4 Summary of Criteria Versus Modeled Conditions in the Modified Side Channel

Discharge at Sidney, Montana USGS Gage	7,000-14,999 cfs	15,000-63,000 cfs
Channel Flow Split		
Design Criteria	≥12% (840 to1,800 cfs)	13% to ≥ 15% (1,950 cfs to 9,450 cfs)
Modified Side Channel Alternative	1,100 – 1,910 cfs	2,180 to 8,440 cfs
Channel Cross-sectional Velocities (average channel velocity)		
Design Criteria	2.0 - 6.0 ft/s	2.4 - 6.0 ft/s
Modified Side Channel Alternative	2.6 – 3.1 ft/s	3.3 – 5.1 ft/s
Channel Depth (minimum cross-sectional depth for 30 contiguous feet at cross-sections)		
Design Criteria	≥ 4.0 ft	≥ 6.0 ft
Modified Side Channel Alternative	≥ 4.0 ft	≥ 6.0 ft
Channel Fish Entrance Velocity (average channel velocity)		
Design Criteria	2.0 - 6.0 ft/s	2.4-6.0 ft/s
Modified Side Channel Alternative	2.8 – 3.2 ft/s	3.4 – 5.1 ft/s
Channel Fish Exit Velocity (average channel velocity)		
Design Criteria	≤ 6.0 ft/s	≤ 6.0 ft/s
Modified Side Channel Alternative	≤ 5.7 ft/s	≤ 6.7 ft/s

Table 3.5 Hydraulic Conditions for a Range of Flows in the Modified Side Channel

Discharge at Sidney, Montana USGS Gage		Split Flow into Modified Side Channel		Average Velocities in Modified Side Channel (ft/s)	Average Depths in Modified Side Channel (ft)
Flows (cfs)	Percent Exceedance April-June	Flow (cfs)	Percent of Yellowstone River flows		
7,000	83%	1,100	16%	3.1	4.6
15,000	47%	2,180	14%	3.7	6.4
30,000	22%	4,080	14%	4.3	8.8
54,200 (2-yr)	4%	7,160	13%	5.0	11.3
63,000	2%	8,440	13%	5.3	12.2
74,400 (10-yr)	>1%	10,400	14%	5.6	13.2
87,600 (20-yr)	>1%	12,500	14%	5.9	14.3

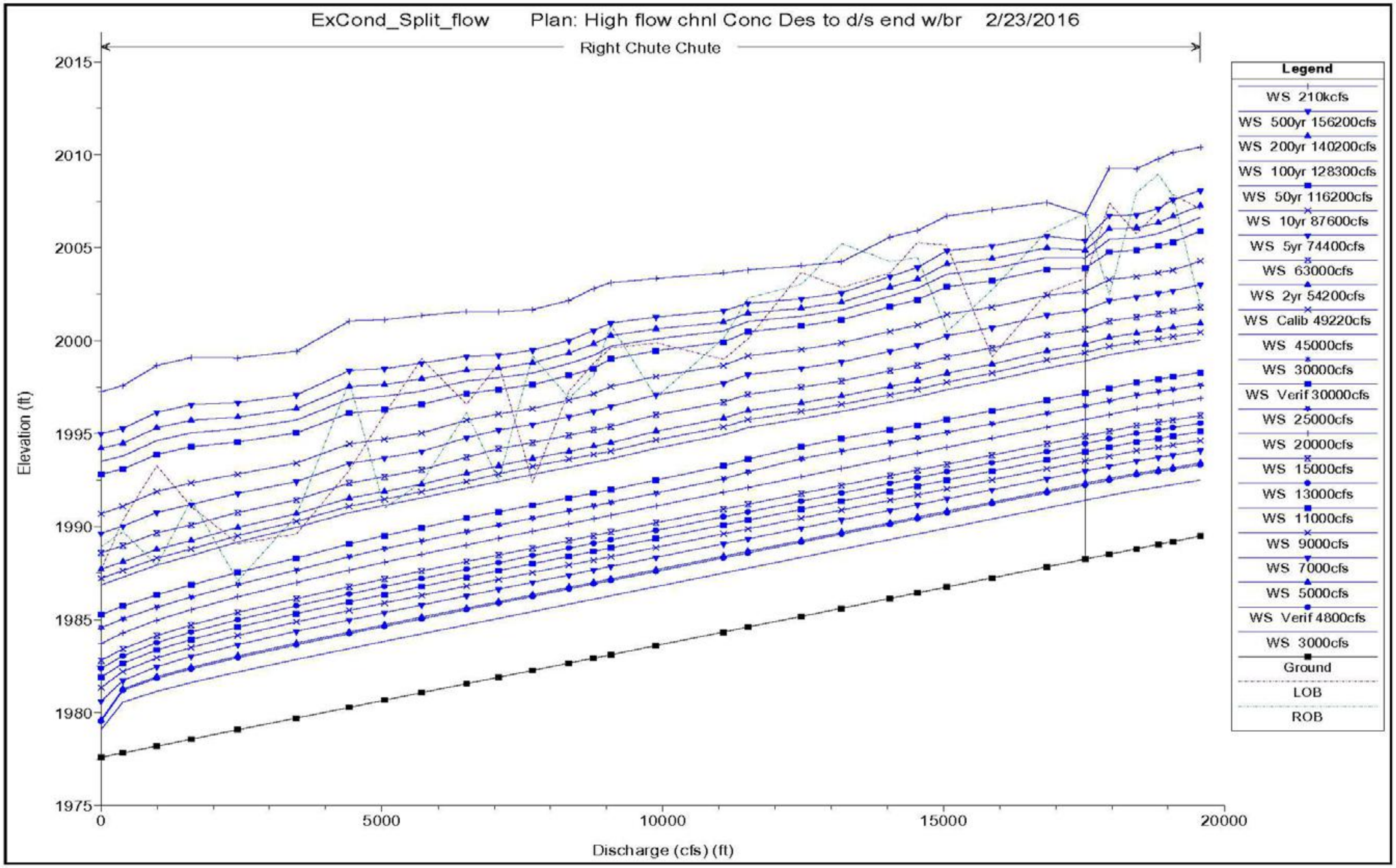


Figure 3.4 Modified Side Channel Water Surface Profiles, 3,000 cfs to 500-Year Peak

3.3 Channel Migration

Channel migration is the change in position of a channel through time. The process involves bankline erosion, which occurs primarily on the outside of bends and is generally accompanied by sediment deposition on the inside of the bend. Channel migration was evaluated as part of the Yellowstone River Cumulative Effects Assessment (YRCEA) (Corps and YRCDC 2015), which concluded that recent migration rates in the vicinity of the project are approximately 5 feet per year. The YRCEA defined a Channel Migration Zone (CMZ) of 1,000 feet along the banklines to accommodate 100 years of migration in areas that are not influenced by bounding bedrock.

3.3.1 Modified Side Channel

Comparisons of the 1950s to recent aerial photography indicate that the channel banklines are relatively stable with little migration except at the high flow channel confluences where the upstream confluence area has migrated approximately 350 to 450 feet downstream since the 1950s, a rate of approximately 8 feet per year. Under proposed conditions, flow into the modified side channel would increase in frequency and magnitude for a given flow in the Yellowstone River (Table 3.6).

Table 3.6 Comparison of Split Flows for High Flow Versus Modified Side Channel

Discharge at Sidney, Montana USGS Gage		Split Flow into Modified Side Channel	
Flows (cfs)	**Percent Exceedance April-June**	**Existing Conditions (cfs)**	**Proposed Conditions (cfs)**
7,000	83%	2	1,100
15,000	47%	70	2,180
30,000	22%	570	4,080
54,200 (2-yr)	4%	2,230	7,160
63,000	2%	4,030	8,440
74,400 (10-yr)	>1%	5,840	10,400
87,600 (20-yr)	>1%	7,480	12,500

Though the right bank of the high flow channel is bounded by bedrock, which prevents downstream bend migration, the downstream confluence of the high flow channel and the main river is active geomorphically. The presence and growth of islands in the main channel has caused the left bank of the Yellowstone River opposite the high flow channel to migrate. The left bank migration may be reduced with the high flow channel modifications due to the increase in the frequency and flow into the high flow channel. Furthermore, is it possible that the Yellowstone River channel braid along the right bank immediately downstream of the high flow channel could deepen and widen with the increase in flow from the modified side channel. When flows are not entering the upstream end of the modified side channel, the downstream end (up to 2,000 feet) is in backwater from the main channel. This complex morphology could be a deterrent to migrating fish particularly in attracting fish into the channel. Further analysis would likely be required if this alternative were to advance, including analysis of alternative locations for the fish entrance. Additional design and analysis may include multi-dimensional hydraulic analyses (2-D and potentially 3-D) for evaluation of the downstream confluence area and the alternative locations, to evaluate not only geomorphologic impacts but also velocities and flow conditions at the fish entrance.

3.3.2 Yellowstone River

The left bankline upstream of the Intake Diversion Dam area exhibits little channel migration due to riprap bank protection. This area also coincides with a high shale and silt stone bluff. The right bank of the Yellowstone River at the diversion dam is the inside of a bend so migration is limited by the opposite bank and by the diversion dam itself. The Intake Diversion Dam has been in place for over 100 years with little to no evidence of vertical or horizontal instability with the exception of a localized scour hole at the downstream end of the existing boulder field. The riprap placed along the railroad bed along the left bank of the channel may be responsible for the deep thalweg where the channel impinges on this lateral constraint. However, the shale/silt stone bluff may also be responsible, or at least contribute to the deepened thalweg at this long this bank. These conditions are not expected to change with the modified side channel alternative.

The outside bank on the upstream bend on the Yellowstone River coincides with the upstream split to the high flow channel. Continued migration of this bend at current rates (approximately 8 feet per year) would not adversely impact the diversion dam or the canal headworks. This area would be protected by riprap to provide a control at the upstream end of this high flow channel.

3.4 Sediment Transport

The sediment-transport analysis follows a similar approach and uses much of the data previously described in the EA appendices (Reclamation and Corps 2015). The Modified Side Channel Alternative was first evaluated hydraulically to provide the desired split flows and hydraulic conditions. This required lowering, shortening, steepening and widening the existing high flow channel. This modified channel was then evaluated for sediment-transport conditions based on the calculated flow splits from the hydraulic analysis and sediment splits determined by Corps for the analysis of the Bypass Channel Alternative. All sediment-transport modeling was conducted using HEC-RAS version 5.0 (Corps 2016) A detailed description of the sediment-transport analysis is provided in Attachment 2. In general, the results of the sediment-transport analyses of the modified side channel alternative are consistent with the Bypass Channel Alternative results (2015).

Prior to running sediment-transport models for the modified channel, two sediment-transport runs were performed for the existing high flow channel. These runs were to test the sediment-transport functions that appeared to be best suited based on the prior work on the EA (Reclamation and Corps 2015). The two selected functions were Laursen (Copeland) and Ackers-White. Because the existing high flow channel is perched relative to the bed of the Yellowstone River, for the existing conditions model, the gravel-size material was excluded from the load. The runs indicated that the existing high flow channel was relatively stable over the 47 year post-Yellowtail Dam flow record of (1967-2014), which is expected due to the persistence of this channel at least since the 1950s. The Laursen (Copeland) run indicated a slight degradation tendency (up to 2 feet over the run), which could be due to the complete exclusion of the gravel fraction. The Ackers-White run tended to be slightly aggradational (up to 2 feet) for the first 40 years then aggraded, approximately 10 feet during a single event at the upstream cross section. This result is very unlikely and is probably due to model instabilities. From these runs, it appears the Laursen (Copeland) sediment-transport function is more reliable than Ackers-White for this condition, but each equation would be used to evaluate the modified side channel alternative.

3.4.1 Modified Side Channel

The sediment-transport model for the Modified Side Channel Alternative followed the same procedure as the EA modeling (Reclamation and Corps 2015) and the analysis of the existing high flow channel with the following differences: (1) The new channel geometry was included; (2) flow splits and associated sediment splits reflected the new conditions; and (3) all sediment sizes, including gravels were included in the sediment split because the design channel invert is relatively close to the Yellowstone River thalweg elevation. The models were run using the Laursen (Copeland) equation as the preferred equation and Ackers-White as a comparison.

The Laursen (Copeland) equation showed general degradation of the channel ranging from approximately 3 feet at the downstream end to approximately 6 feet at the upstream end; the channel slope went from 0.06 to 0.05 percent. Most of the degradation occurred over the first 5 years. Conversely, the Ackers-White equation showed substantial aggradation over the reach with the channel ultimately reaching a 0.1 percent slope. This is consistent with the results of the Bypass Channel Alternative and is likely the result of the Ackers-White equation not transporting gravel as effectively as expected.

The results of the sediment-transport analysis, including a more detailed description of the model setup, are included in Attachment 2. The analysis indicates that use of a coarser armor material and grade control structures are warranted for this design. The armor should inhibit degradation and allow the sediment supply to move through the reach. The armor would not inhibit sediment movement because it guards against a sediment deficient condition where transport capacity exceeds supply. Therefore, the channel hydraulic conditions would convey the supply over the armor and through the length of the Modified Side Channel. If the armor is disturbed in a large event, then the grade-control structure would limit excessive degradation. If the channel flattens to 0.05 percent slope between the structures, then this would tend to lower velocities for fish passage. If, however, what appears to be the less likely outcome occurs and the channel aggrades, then considerable channel maintenance would be required.

Flow splits out of the Yellowstone River into the modified side channel would result in reducing flows by 13 to 16 percent in the Yellowstone River for most flows up to and including the 100-year event. Hydraulic calculations prepared by the Corps for the Bypass Channel Alternative, resulted in similar flow splits (13 to 15 percent reduction in flows the Yellowstone River). Currently under existing conditions the flow splits into the high flow channel range from 0 to 10 percent for flows up to and including the 100-year event. Indicating that with the proposed conditions flow reductions, would likely have a minor to negligible effect to water surface elevations and sediment transport to the Yellowstone River (Corps 2012).

The alignment of the modified side channel also runs roughly parallel to the existing floodplain, which reduces the risk of future migration and is reflected in reduced O&M costs associated with it.

3.5 Floodplain

Implementation of this alternative would modify flood conditions on Joe's Island by increasing flows to the modified side channel. Any change in 100-year flood elevations in the Modified Side Channel is expected to be minor, particularly because the channel would be lower, and the 100-year flood elevation in the Yellowstone River would be very slightly lower than existing conditions. A floodplain map revision (FIRM panel 300140 0009A, Dawson county, MT, effective date April 11, 1978) may be required. The Intake Diversion Dam is currently mapped as Zone A and would be updated to Zone AE.

3.6 Intake Operations

In 2010, a new headworks structure was constructed with fish screens to minimize entrainment of fish greater than 40 mm in length. Water gravity flows through the cylindrical screens from the lower half of the water column, through the gates and into the canal. The removable rotating drums allow each screen unit to be adjusted on a track and be raised above the river when not in use to minimize damage from ice and debris flows. The screen cylinders rotate against fixed brushes to clean and remove debris that could impede flow through the screens.

The new headworks structure requires approximately an additional 0.5 feet of headwater compared to the headwater required prior to the construction of the screens and gates, to maintain a diversion of approximately 1,374 cfs when the Yellowstone River flows are at the extreme operational low flow of 3,000 cfs. To achieve the additional height in water surface elevation at the intake headworks, the Corps proposed improvements to the rock fill timber dam. The most recent design proposed a concrete weir with a trapezoidal notch set at elevation 1,989 feet. The bottom of the notch would be 85 feet wide, side slopes at a 10V:1H up to elevation 1,991 feet for a top width of 125 feet. The concrete weir would then span the remaining width of the river at a consistent elevation of 1,991. The concrete weir was not constructed. The crest of the timber dam is approximately elevation 1989. Rock placement generally adds several additional feet above the existing crest, although it is likely somewhat variable due to the continued rock displacements and replacements.

For the Modified Side Channel Alternative, two hydraulic conditions were assessed to reflect possible conditions at the headworks for the Intake Canal. The first assumed that rather than building a new concrete weir, rock would be added to the existing timber crib diversion structure as needed to create the necessary water elevation for diversion of 1,374 cfs at the extreme low flow of 3,000 cfs. The additional rock would be placed in the spring prior to runoff and create hydraulic conditions similar to the concrete weir modeled for the Bypass Channel Alternative in order to achieve diversions of 1,374cfs for a full range of flow conditions in the Yellowstone River including the extreme low flow of 3,000 cfs.

The second condition assumed that rock would be added to the existing rock fill timber dam generally in conformance with placement practices prior to the construction of the new headworks as described above. The results of the two hydraulic analyses indicate that either rock placement practice will result in split flows, depths, and velocities into the modified side channel that generally meet USFWS and BRT criteria. The only exception is for the second condition (rock placement practices prior to construction of the new headworks), the modified side channel at the upstream confluence with the Yellowstone River must be 55 feet wide to divert the full 12% of the Yellowstone River flows, when the Yellowstone River is flowing above 15,000 cfs. The bottom width of the modified side channel would gradually narrow to 40 feet approximately one mile downstream. The additional earthwork and channel armoring reflect the second conditions (rock placement practices prior to construction of the new headworks) as it conservatively includes slightly higher earthwork and channel armoring costs.

4.0 Design

The 30 Percent Design Drawings for the Modified Side Channel Alternative are provided in Attachment 3. Major site features are described in the following section.

4.1 New Channel, Channel Lowering and Backwater Areas

As previously noted, with the exception of the bend cutoffs, in many portions of the proposed channel, the channel modifications are limited to within the channel banks to lower the channel (Figure 3.2). The bend cutoffs require more substantial excavation of the proposed channel to connect to the upstream and downstream ends of the cutoff. At the intersection of each bend cutoff and the existing side channel, backwaters would be formed.

4.2 Bank Protection and Grade-control Structures

Bank protection using riprap is proposed at three locations: at the upstream confluence or split with the Yellowstone River and at the two bend cutoffs. The configuration of the upstream confluence with the Yellowstone River is critical to maintain the required flows splits. Riprap at the upstream end of the bypass channel would extend in a southwesterly direction as shown on the 30-percent Design Drawings to reduce the risk of flanking. Riprap sizing is based on recommendations from the Corps used for the Bypass Channel construction drawings (Corps 2015c) as the flow regimes would be similar to the proposed Modified Side Channel Alternative. It is possible that additional protection could be required in the future if the initial assessments about channel stability are incorrect and excessive channel migration or degradation begins to impact passage effectiveness.

Riprap banks are also recommended at the bend cutoffs to prevent flows from flanking the channel fill areas. Riprap was not considered for other bends to keep the modified high flow channel as natural as possible and allow for natural channel migration, which is expected to be minor. Additional protection could be required in the future if excessive channel migration occurs.

Grade control structures are recommended to protect against headcutting. Two grade controls would be located near the confluences (upstream and downstream) to maintain the channel bed elevation near the Yellowstone River. The middle three are located in even increments between the upstream and downstream confluences so the estimated degradation at each structure would be at or less than 6 inches.

4.2.1 Bridge

Under existing conditions, vehicle access to Joe’s Island is achieved by driving across the high flow channel bed. This is true not only for dam maintenance traffic, but also recreational traffic. This alternative includes a 150-foot prefabricated clear span truss bridge with abutments set outside of the main channel banks. The new bridge would protect the modified side channel bed and banks from vehicle disturbance caused by the current practice of driving through the channel. It would also provide year-round recreational access to Joe’s Island. As discussed in Section 3.1, the bridge would be elevated two feet above the 1% annual flood in conformance with the State of Montana floodplain criteria, possibly higher pending additional analysis should this alternative be advanced.

4.2.2 Channel Stability Armor Layer

A layer of cobble material is recommended to be placed in the channel bed of the newly excavated modified side channel to provide an armoring layer that might otherwise be found in a channel with the flow regime being introduced into the modified side channel. The armoring layer would be placed across the bottom of the channel and up the side slopes to cover the first three feet of depth. The armoring layer would be generated by screening the channel excavation to provide a well-graded material ranging from 6 to 1 inches in diameter.

4.2.3 LYP Trolley

The continued placement of rock to the existing dam would likely require repair or replacement of the trolley by the Lower Yellowstone Irrigation Project (LYP). The LYP is responsible for diversion dam, headworks and canal O&M costs consistent with the authorizing legislation (Reclamation Act of June 17, 1902, as amended; Water Conservation and Utilization Act of August 11, 1939, as amended), the current O&M contract between Reclamation and the LYP, and Reclamation policy.

5.0 Construction Considerations

5.1 Construction Elements

The major permanent construction elements for the Modified Side Channel Alternative generally include the following:

- Excavation of 1.19 million cubic yards of material for 6,000 feet of new channel at three bend cutoffs and lowering the existing channel;
- Placement of 362,000 cubic yards of material to partially fill the current channel at the three bend cutoffs;
- Haul and place 828,000 cubic yards of material in spoils area, covering approximately 128 acres on the south bluff;
- Construction of one 150-foot single span bridge;
- 5,300 feet of bank protection (16- to 27-inch average diameter riprap) in three locations including the upstream confluence with the Yellowstone and at the bend cutoffs;
- Five grade-control structures; and
- Placement of 50,000 cubic yards of native substrate in the bed of the modified side channel.

5.2 Construction Implementation

Construction related considerations are outlined in this section. These considerations are based on the conceptual design and highlight only the major construction considerations including such items as earthwork and work control with coffer dams.

5.2.1 Earthwork

Excavation is required to construct the three bend cutoffs and to lower and widen the existing channel. An estimated 1.19 million cubic yards would be excavated. Approximately one third of this material would be used as fill of the existing channel at the channel bend cutoffs. One small area on the left bank near Station 65+00 also requires minor fill to elevate the modified side channel banks to contain the maximum of 8,400 cfs as required by the USFWS and BRT design criteria (~15 percent of flow at 63,000 cfs). The remaining material would be disposed of in the spoil area on the upper south bluff as shown in Figure 5.1. This would require a ¾ mile haul route on County Road 303, from Joe’s Island to the upper bluff. Following construction, County Road 303 would likely require reconstruction to return it to current conditions. Erosion and sediment control measures in the spoils area would include silt fencing around the spoils piles adjacent to the drainages and bluff to the north.

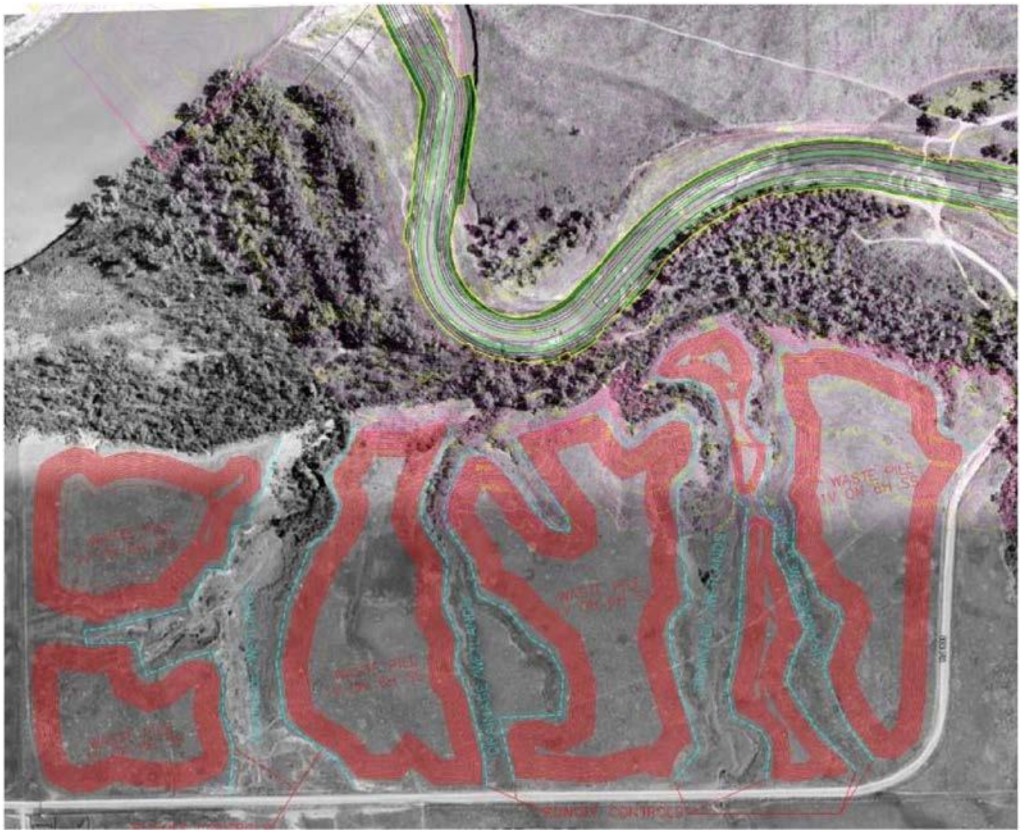


Figure 5.1 Spoil Area

5.2.2 Coffer Dam

A coffer dam would be required at both the upstream and downstream tie-in locations to facilitate channel excavation and would be constructed early in the construction sequence. The coffer dams would consist of sheet piles driven below grade into the coarse alluvium material to reduce seepage into the modified side channel and an earthen embankment with bank protection facing the Yellowstone River.

The coffer dams for the modified side channel would be similar to the coffer dam proposed for the Bypass Channel Alternative, with an earthen embankment running parallel to the river, 20 feet wide, 3H:1V side slopes, and sheet pile, located at the center of the earthen berm driven 10 feet below grade with 2 feet exposed above grade to tie into the earthen berm. The upstream coffer dam would be 600 feet long and the downstream coffer dam 400 feet long. Each coffer dam would consist of native material and have riprap on the river side face.

5.2.3 Staging and Construction Access

Three miles of construction access road and three staging areas, each covering 3.1 acres would be required for construction. The construction access road would be gravel, 24 feet wide. The three staging areas, are each 3.1 acres and also covered with gravel. The construction access road and staging areas would be constructed along the north and east side of the modified side channel to provide access for and staging of heavy equipment (Figure 1.1). The staging areas would be removed at the end of construction and restored to natural conditions. The construction access road would be left in place for future maintenance needs. Following construction, the spoils area would be graded, seeded, mulched and stabilized with an erosion control blanket.

5.2.4 Bank Protection

Riprap with bedding would be installed for bank stabilization at the upstream confluence with the Yellowstone River, and at the three bend cutoffs; and for the construction of five grade-control structures. Approximately 55,000 cubic yards of riprap would be required. The riprap would be purchased from a private source, from a location yet to be identified, hauled onsite, and stockpiled in one of the staging areas until installed.

5.2.5 Bridge

The proposed bridge would be a 150-foot single span truss bridge designed to span the modified side channel. For purposes of this conceptual design it is assumed that the foundation of the bridge would be concrete abutments placed on 10 micro piles. Heavy equipment would be required as well as a possible dewatering pond for the construction of the footings. The dewatering pond would be constructed within the modified side channel, downstream of the bridge. The bridge construction would be phased prior to the channel excavation to facilitate the dewatering needs and to insure that access over the river is in-place as the modified side channel is built.

5.2.6 Disturbance during Construction and Operation

Although much of the channel excavation work and riprap installation can be performed within the limits of the existing channel banks, some disturbance would occur along the channel margins. These areas, along with the bend cutoff fill areas, would be graded, seeded, mulched and stabilized with erosion-control blanket when complete.

5.2.7 Construction Risk

The alternative design presented in this engineering appendix is conceptual and based on limited information and a number of assumptions about the requirements for the final design. The following is a list of the major items which could increase the cost of the final design:

- The upstream end of the modified side channel is influenced by erosion and deposition of material in the modified channel and by erosion of the Yellowstone River bankline. Therefore the split of flows into the modified side channel is dependent on a stable confluence.
- Ice could alter the modified side channel geometry, particularly at the confluence effecting split flows and the conditions in the channel requiring repair.
- Disposal of excess material is assumed to be accomplished south and east of the Yellowstone River, within several miles of the modified side channel. Long or further haul distances could have a significant impact on the length and cost of construction.

- Two coffer dams are proposed to create dry conditions for the construction of the modified side channel. Seeps or groundwater conditions may vary from assumed conditions that could result in additional dewatering requirements.
- Sediment deposition and removal of sediment may be required to maintain the fish entrance and attractive flows.
- All necessary property and rights-of-way is already owned by the US government and/or can be obtained.
- Sufficient quantity of coarse gravel and cobble material is available for the armor layer.
- Based on visual observations it is likely that Box Elder Creek periodically transports and deposits alluvial material at the confluence with the modified side channel. This would be an intermittent issue and likely not with high frequency, however, should this occur it could require sediment removal to maintain capacity in the modified side channel.

6.0 References

Chase, Katherine J. 2014. *Streamflow Statistics for Unregulated and Regulated Conditions for Selected Locations on the Yellowstone, Tongue, and Powder Rivers, Montana, 1928-2002.* Scientific Investigations Report 2013-5173, Version 1.1, U.S. Geological Survey.

Reclamation and U.S. Army Corps of Engineers (Corps). 2015. *Intake Diversion Dam Modification, Lower Yellowstone Project, Montana, Final Supplemental Environmental Assessment.* Report and Appendixes.

Rugg, M. 2014. Lower Yellowstone River Pallid Sturgeon Progress Report. Montana Fish, Wildlife and Parks. Glendive, MT.

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U.S. Army Corps of Engineers (Corps) 2010. *River Analysis System, Version 4.1.0 January 2010*. Hydraulic Engineering Center.

U.S. Army Corps of Engineers (Corps) 2014. *Intake Diversion Dam Modifications, Lower Yellowstone Project, Montana, Bypass Channel 60% Design, Hydraulic Appendix*, Report with Attachments.

U.S. Army Corps of Engineers (Corps) 2015a. *Lower Yellowstone Intake Dam-Model Calibration.* Report.

U.S. Army Corps of Engineers (Corps) 2015b. *Intake Diversion Dam Modifications, Lower Yellowstone, Montana, Bypass Channel 90% Design, Hydraulics Appendix.* Draft Report with Attachments.

U.S. Army Corps of Engineers (Corps) 2015c. *Lower Yellowstone Diversion Dam and Replacement Weir and Fish Passage Channel.* Construction Drawings.

Walsh, Noreen E. 2014. *Bypass Channel Hydraulics and Physical Performance Objectives.* Letter, Denver: USFWS.

Attachment 1
Existing and Proposed Conditions
HEC-RAS Output

Note: the following support calculations refer to this alternative as the *High Flow Channel Alternative*. The name has been revised to *Modified Side Channel Alternative*, however the name on these support calculations still refer to the High Flow Channel. None of the analyses are affected by the name change and all support calculations are applicable to the *Modified Side Channel Alternative*.

HEC-RAS Existing Conditions

```
                         HEC-RAS Version 4.1.0 Jan 2010
                          U.S. Army Corps of Engineers
                         Hydrologic Engineering Center
                               609 Second Street
                               Davis, California

            X     X  XXXXXX    XXXX        XXXX       XX      XXXX
            X     X  X        X    X       X   X     X  X    X
            X     X  X        X            X   X    X    X   X
            XXXXXXX  XXXX     X       XXX  XXXX     XXXXXX    XXXX
            X     X  X        X            X  X     X    X        X
            X     X  X        X    X       X   X    X    X        X
            X     X  XXXXXX    XXXX        X    X   X    X   XXXXX




PROJECT DATA
Project Title: Yellowstone Intake
Project File : YellowstoneIntake.prj
Run Date and Time: 3/14/2016 2:46:33 PM

Project in English units



PLAN DATA

Plan Title: Tt Existing Conditions with Dam Raised
Plan File : s:\Projects\SET-T35234_Intake EIS\06_Hydraulic models\Yellowstone_Intake\YellowstoneIntake.p04

           Geometry Title: Tt ExCond - Dam Raised
           Geometry File : s:\Projects\SET-T35234_Intake EIS\06_Hydraulic
models\Yellowstone_Intake\YellowstoneIntake.g04

           Flow Title    : Tt ExCond & Dam Raised
           Flow File     : s:\Projects\SET-T35234_Intake EIS\06_Hydraulic
models\Yellowstone_Intake\YellowstoneIntake.f03

Plan Description:
The Inline structure at 28022 has been modified to include the rock/concrete
structure from the 90% design model (.p11)

Existing Conditions with right
chute u/s cross section at 24560 raised by 1.35 ft--used for calibration.
```

```
Plan Summary Information:
Number of:  Cross Sections =  232    Multiple Openings  =    0
            Culverts       =    0    Inline Structures  =    1
            Bridges        =    1    Lateral Structures =    1

Computational Information
    Water surface calculation tolerance  =  0.01
    Critical depth calculation tolerance =  0.01
    Maximum number of iterations         =  20
    Maximum difference tolerance         =  0.3
    Flow tolerance factor                =  0.001

Computation Options
    Critical depth computed only where necessary
    Conveyance Calculation Method: At breaks in n values only
    Friction Slope Method:         Average Conveyance
    Computational Flow Regime:     Subcritical Flow




FLOW DATA

Flow Title: Tt ExCond & Dam Raised
Flow File : s:\Projects\SET-T35234_Intake EIS\06_Hydraulic models\Yellowstone_Intake\YellowstoneIntake.f03

Flow Data (cfs)


  River           Reach           RS                3000cfs         5000cfs         7000cfs         9000cfs
      11000cfs        13000cfs        15000cfs        20000cfs
  IrrigCanal      Canal           20523                   1               1               1               1
             1               1               1               1
  Right Chute     Chute           24560                   1               1               1               1
             1               1               1               1
  Yellowstone     US Chute        56000.00             3000            5000            7000            9000
         11000           13000           15000           20000
  Yellowstone     Mid Chute       37074.57             3000            5000            7000            9000
         11000           13000           15000           20000
  Yellowstone     Mid Chute       28203.49             3000            5000            7000            9000
         11000           13000           15000           20000
  Yellowstone     DS Chute        19210.21             3000            5000            7000            9000
         11000           13000           15000           20000
```

```
 River           Reach           RS                 25000cfs        30000cfs        45000cfs    2yr 54200cfs
 5yr 74400cfs   10yr 87600cfs  50yr 116200cfs 100yr 128300cfs
 IrrigCanal      Canal           20523                     1               1               1               1
            1               1               1               1
 Right Chute     Chute           24560                     1               1               1               1
            1               1               1               1
 Yellowstone     US Chute        56000.00              25000           30000           45000           54200
        74400           87600          116200          128300
 Yellowstone     Mid Chute       37074.57              25000           30000           45000           54200
        74400           87600          116200          128300
 Yellowstone     Mid Chute       28203.49              25000           30000           45000           54200
        74400           87600          116200          128300
 Yellowstone     DS Chute        19210.21              25000           30000           45000           54200
        74400           87600          116200          128300



Boundary Conditions

 River           Reach           Profile                        Upstream                   Downstream

 IrrigCanal      Canal           3000cfs                    Normal S = 0.0002          Normal S = 0.0002
 IrrigCanal      Canal           5000cfs                    Normal S = 0.0002          Normal S = 0.0002
 IrrigCanal      Canal           7000cfs                    Normal S = 0.0002          Normal S = 0.0002
 IrrigCanal      Canal           9000cfs                    Normal S = 0.0002          Normal S = 0.0002
 IrrigCanal      Canal           11000cfs                   Normal S = 0.0002          Normal S = 0.0002
 IrrigCanal      Canal           13000cfs                   Normal S = 0.0002          Normal S = 0.0002
 IrrigCanal      Canal           15000cfs                   Normal S = 0.0002          Normal S = 0.0002
 IrrigCanal      Canal           20000cfs                   Normal S = 0.0002          Normal S = 0.0002
 IrrigCanal      Canal           25000cfs                   Normal S = 0.0002          Normal S = 0.0002
 IrrigCanal      Canal           30000cfs                   Normal S = 0.0002          Normal S = 0.0002
 IrrigCanal      Canal           45000cfs                   Normal S = 0.0002          Normal S = 0.0002
 IrrigCanal      Canal           2yr 54200cfs               Normal S = 0.0002          Normal S = 0.0002
 IrrigCanal      Canal           5yr 74400cfs               Normal S = 0.0002          Normal S = 0.0002
 IrrigCanal      Canal           10yr 87600cfs              Normal S = 0.0002          Normal S = 0.0002
 IrrigCanal      Canal           50yr 116200cfs             Normal S = 0.0002          Normal S = 0.0002
 IrrigCanal      Canal           100yr 128300cfs            Normal S = 0.0002          Normal S = 0.0002
 IrrigCanal      Canal           200yr 140200cfs            Normal S = 0.0002          Normal S = 0.0002
 IrrigCanal      Canal           500yr 156200cfs            Normal S = 0.0002          Normal S = 0.0002
 IrrigCanal      Canal           Calib 49220cfs             Normal S = 0.0002          Normal S = 0.0002
 IrrigCanal      Canal           Verif 30000cfs             Normal S = 0.0002          Normal S = 0.0002
 IrrigCanal      Canal           Verif 4800cfs              Normal S = 0.0002          Normal S = 0.0002
 IrrigCanal      Canal           63000cfs                   Normal S = 0.0002          Normal S = 0.0002
 IrrigCanal      Canal           210kcfs                    Normal S = 0.0002          Normal S = 0.0002
 Yellowstone     US Chute        3000cfs                    Normal S = 0.0003
 Yellowstone     US Chute        5000cfs                    Normal S = 0.0003
 Yellowstone     US Chute        7000cfs                    Normal S = 0.0003
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  Yellowstone     US Chute        9000cfs                   Normal S = 0.0003
  Yellowstone     US Chute        11000cfs                  Normal S = 0.0003
  Yellowstone     US Chute        13000cfs                  Normal S = 0.0003
  Yellowstone     US Chute        15000cfs                  Normal S = 0.0003
  Yellowstone     US Chute        20000cfs                  Normal S = 0.0003
  Yellowstone     US Chute        25000cfs                  Normal S = 0.0003
  Yellowstone     US Chute        30000cfs                  Normal S = 0.0003
  Yellowstone     US Chute        45000cfs                  Normal S = 0.0003
  Yellowstone     US Chute        2yr 54200cfs              Normal S = 0.0003
  Yellowstone     US Chute        5yr 74400cfs              Normal S = 0.0003
  Yellowstone     US Chute        10yr 87600cfs             Normal S = 0.0003
  Yellowstone     US Chute        50yr 116200cfs            Normal S = 0.0003
  Yellowstone     US Chute        100yr 128300cfs           Normal S = 0.0003
  Yellowstone     US Chute        200yr 140200cfs           Normal S = 0.0003
  Yellowstone     US Chute        500yr 156200cfs           Normal S = 0.0003
  Yellowstone     US Chute        Calib 49220cfs            Normal S = 0.0003
  Yellowstone     US Chute        Verif 30000cfs            Normal S = 0.0003
  Yellowstone     US Chute        Verif 4800cfs             Normal S = 0.0003
  Yellowstone     US Chute        63000cfs                  Normal S = 0.0003
  Yellowstone     US Chute        210kcfs                   Normal S = 0.0003
  Yellowstone     DS Chute        3000cfs                                            Normal S = 0.0003
  Yellowstone     DS Chute        5000cfs                                            Normal S = 0.0003
  Yellowstone     DS Chute        7000cfs                                            Normal S = 0.0003
  Yellowstone     DS Chute        9000cfs                                            Normal S = 0.0003
  Yellowstone     DS Chute        11000cfs                                           Normal S = 0.0003
  Yellowstone     DS Chute        13000cfs                                           Normal S = 0.0003
  Yellowstone     DS Chute        15000cfs                                           Normal S = 0.0003
  Yellowstone     DS Chute        20000cfs                                           Normal S = 0.0003
  Yellowstone     DS Chute        25000cfs                                           Normal S = 0.0003
  Yellowstone     DS Chute        30000cfs                                           Normal S = 0.0003
  Yellowstone     DS Chute        45000cfs                                           Normal S = 0.0003
  Yellowstone     DS Chute        2yr 54200cfs                                       Normal S = 0.0003
  Yellowstone     DS Chute        5yr 74400cfs                                       Normal S = 0.0003
  Yellowstone     DS Chute        10yr 87600cfs                                      Normal S = 0.0003
  Yellowstone     DS Chute        50yr 116200cfs                                     Normal S = 0.0003
  Yellowstone     DS Chute        100yr 128300cfs                                    Normal S = 0.0003
  Yellowstone     DS Chute        200yr 140200cfs                                    Normal S = 0.0003
  Yellowstone     DS Chute        500yr 156200cfs                                    Normal S = 0.0003
  Yellowstone     DS Chute        Calib 49220cfs                                     Normal S = 0.0003
  Yellowstone     DS Chute        Verif 30000cfs                                     Normal S = 0.0003
  Yellowstone     DS Chute        Verif 4800cfs                                      Normal S = 0.0003
  Yellowstone     DS Chute        63000cfs                                           Normal S = 0.0003
  Yellowstone     DS Chute        210kcfs                                            Normal S = 0.0003


SUMMARY OF MANNING'S N VALUES
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```
River:IrrigCanal

      Reach           River Sta.       n1        n2        n3

 Canal                 20523              .03       .03       .03
 Canal                 20513             .025      .025      .025
 Canal                 20508             .025      .025      .025
 Canal                 20507.5           .025      .025      .025
 Canal                 20494             .025      .025      .025
 Canal                 20493             .025      .025      .025
 Canal                 20492             .025      .025      .025
 Canal                 20490              .05       .05       .05
 Canal                 20430             .034      .034      .034
 Canal                 20420             .034      .034      .034
 Canal                 20400             .034      .034      .034
 Canal                 20380             .034      .034      .034
 Canal                 20370             .034      .034      .034
 Canal                 20360             .034      .034      .034
 Canal                 20340             .034      .034      .034
 Canal                 20330             .034      .034      .034
 Canal                 20320             .034      .034      .034
 Canal                 20300             .034      .034      .034
 Canal                 20280             .034      .034      .034
 Canal                 20250             .034      .034      .034
 Canal                 20230             .034      .034      .034
 Canal                 20190             .034      .034      .034
 Canal                 20130             .034      .034      .034
 Canal                 20060             .034      .034      .034
 Canal                 19990             .034      .034      .034
 Canal                 19890             .034      .034      .034
 Canal                 19830             .034      .034      .034
 Canal                 19780             .034      .034      .034
 Canal                 19720             .034      .034      .034
 Canal                 19680             .034      .034      .034
 Canal                 19630             .034      .034      .034
 Canal                 19600             .034      .034      .034
 Canal                 19530             .034      .034      .034
 Canal                 19480        Bridge
 Canal                 19420             .034      .034      .034
 Canal                 19320             .034      .034      .034
 Canal                 19000             .034      .034      .034
 Canal                 18730.16          .034      .034      .034
 Canal                 18500             .034      .034      .034
 Canal                 18236.73          .034      .034      .034
 Canal                 18000             .034      .034      .034
 Canal                 17734.79          .034      .034      .034
 Canal                 17500             .034      .034      .034
```

```
 Canal                17239.75          .034      .034      .034
 Canal                17000             .034      .034      .034
 Canal                16739.51          .034      .034      .034
 Canal                16500             .034      .034      .034
 Canal                16000             .034      .034      .034
 Canal                15500             .034      .034      .034
 Canal                15000             .034      .034      .034
 Canal                14500             .034      .034      .034
 Canal                14000             .034      .034      .034
 Canal                13500             .034      .034      .034
 Canal                13000             .034      .034      .034
 Canal                12510             .034      .034      .034
 Canal                12000             .034      .034      .034
 Canal                11500             .034      .034      .034
 Canal                11000             .034      .034      .034
 Canal                10510             .034      .034      .034
 Canal                10000             .034      .034      .034
 Canal                9500              .034      .034      .034
 Canal                9000              .034      .034      .034
 Canal                8500              .034      .034      .034
 Canal                8000              .034      .034      .034
 Canal                7500              .034      .034      .034
 Canal                7000              .034      .034      .034
 Canal                6500              .034      .034      .034
 Canal                6000              .034      .034      .034
 Canal                5500              .034      .034      .034
 Canal                5000              .034      .034      .034
 Canal                4500              .034      .034      .034
 Canal                4000              .034      .034      .034
 Canal                3500              .034      .034      .034
 Canal                3000              .034      .034      .034
 Canal                2500              .034      .034      .034
 Canal                2000              .034      .034      .034
 Canal                1500              .034      .034      .034
 Canal                1000              .034      .034      .034
 Canal                500               .034      .034      .034
 Canal                30                .034      .034      .034


River:Right Chute

      Reach          River Sta.       n1        n2        n3

 Chute                24560              .05      .027       .05
 Chute                23960              .05      .027       .05
 Chute                22780.84           .05      .027       .05
 Chute                21990              .05      .027       .05
 Chute                21530              .05      .027       .05
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 Chute                  21109.99            .05       .027        .05
 Chute                  20712.01            .05       .027        .05
 Chute                  20002.85            .05       .027        .05
 Chute                  19020               .05       .027        .05
 Chute                  18233.44            .05       .027        .05
 Chute                  17410               .05       .027        .05
 Chute                  15003.62            .05       .027        .05
 Chute                  14030               .05       .027        .05
 Chute                  13387.50            .05       .027        .05
 Chute                  12441.82            .05       .027        .05
 Chute                  12050               .05       .027        .05
 Chute                  10800               .05       .027        .05
 Chute                  9980                .05       .027        .05
 Chute                  9477.659            .05       .027        .05
 Chute                  8890                .05       .027        .05
 Chute                  8010                .05       .027        .05
 Chute                  7358.393            .05       .027        .05
 Chute                  6770                .05       .027        .05
 Chute                  6017.052            .05       .027        .05
 Chute                  5380                .05       .027        .05
 Chute                  4758.043            .05       .027        .05
 Chute                  3810                .05       .027        .05
 Chute                  2770                .05       .027        .05
 Chute                  1939.394            .05       .027        .05
 Chute                  1360                .05       .027        .05
 Chute                  720                 .05       .027        .05
 Chute                  338.7000            .05       .027        .05


River:Yellowstone

      Reach            River Sta.       n1         n2         n3

 US Chute               56000.00            .05       .024        .05
 US Chute               54003.06            .05       .024        .05
 US Chute               51999.34            .05       .024        .05
 US Chute               50001.19            .05       .024        .05
 US Chute               47994.16            .05       .024        .05
 US Chute               46189.52            .05       .024        .05
 US Chute               43687.06            .05       .024        .05
 US Chute               42707.92            .05       .024        .05
 US Chute               41936.91            .05       .024        .05
 US Chute               40894.62            .05       .024        .05
 US Chute               39877.04            .05       .024        .05
 US Chute               39170.03            .05       .024        .05
 US Chute               38214.43            .05       .024        .05
 Mid Chute              37074.57            .05       .024        .05
 Mid Chute              36104.97            .05       .024        .05
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Mid Chute            35375.29           .05      .024       .05
Mid Chute            34889.88           .05      .024       .05
Mid Chute            34191.19           .05      .024       .05
Mid Chute            33735.56           .05      .024       .05
Mid Chute            33047.64           .05      .024       .05
Mid Chute            32272.67           .05      .024       .05
Mid Chute            31618.85           .05      .024       .05
Mid Chute            30903.05           .05      .024       .05
Mid Chute            30416.56           .05      .024       .05
Mid Chute            29941.29           .05      .024       .05
Mid Chute            29645.16           .05      .024       .05
Mid Chute            29589.64           .05      .024       .05
Mid Chute            29543.81           .05      .024       .05
Mid Chute            29486.53           .05      .024       .05
Mid Chute            29444.45           .05      .024       .05
Mid Chute            29392.44           .05      .024       .05
Mid Chute            29345.32           .05      .024       .05
Mid Chute            29293.13           .05      .024       .05
Mid Chute            29245.19           .05      .024       .05
Mid Chute            29197.49           .05      .024       .05
Mid Chute            29148.45           .05      .024       .05
Mid Chute            29099.87           .05      .024       .05
Mid Chute            29047.75           .05      .024       .05
Mid Chute            28998.60           .05      .024       .05
Mid Chute            28947.07           .05      .024       .05
Mid Chute            28897.52           .05      .024       .05
Mid Chute            28849.13           .05      .024       .05
Mid Chute            28800.76           .05      .024       .05
Mid Chute            28752.58           .05      .024       .05
Mid Chute            28702.18           .05      .024       .05
Mid Chute            28650.25           .05      .024       .05
Mid Chute            28603.39           .05      .024       .05
Mid Chute            28557.23           .05      .024       .05
Mid Chute            28550        Lat Struct
Mid Chute            28510.39           .05      .024       .05
Mid Chute            28406.73           .05      .024       .05
Mid Chute            28203.49           .05      .024       .05
Mid Chute            28062              .05      .024       .05
Mid Chute            28022        Inl Struct
Mid Chute            28012.06           .05      .045       .05
Mid Chute            27912.73           .05      .045       .05
Mid Chute            27778.92           .05      .045       .05
Mid Chute            27597.18           .05      .042       .05
Mid Chute            27550.20           .05       .04       .05
Mid Chute            27498.33           .05      .038       .05
Mid Chute            27447.08           .05      .035       .05
Mid Chute            27398.93           .05      .024       .05
Mid Chute            27348.49           .05      .024       .05
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Mid Chute            27300.85           .05      .024       .05
Mid Chute            27248.50           .05      .024       .05
Mid Chute            27199.15           .05      .024       .05
Mid Chute            27147.30           .05      .024       .05
Mid Chute            27092.77           .05      .024       .05
Mid Chute            27045.05           .05      .024       .05
Mid Chute            26997.92           .05      .024       .05
Mid Chute            26945.88           .05      .024       .05
Mid Chute            26899.79           .05      .024       .05
Mid Chute            26849.79           .05      .024       .05
Mid Chute            26799.33           .05      .024       .05
Mid Chute            26750.78           .05      .024       .05
Mid Chute            26696.93           .05      .024       .05
Mid Chute            26646.45           .05      .024       .05
Mid Chute            26598.26           .05      .024       .05
Mid Chute            26548.87           .05      .024       .05
Mid Chute            26503.32           .05      .024       .05
Mid Chute            26447.30           .05      .024       .05
Mid Chute            26398.50           .05      .024       .05
Mid Chute            26300.47           .05      .024       .05
Mid Chute            26243.25           .05      .024       .05
Mid Chute            26197.23           .05      .024       .05
Mid Chute            26139.58           .05      .024       .05
Mid Chute            26097.74           .05      .024       .05
Mid Chute            26049.91           .05      .024       .05
Mid Chute            26002.24           .05      .024       .05
Mid Chute            25945.89           .05      .024       .05
Mid Chute            25899.95           .05      .024       .05
Mid Chute            25845.58           .05      .024       .05
Mid Chute            25798.14           .05      .024       .05
Mid Chute            25744.07           .05      .024       .05
Mid Chute            25695.91           .05      .024       .05
Mid Chute            25649.82           .05      .024       .05
Mid Chute            25596.44           .05      .024       .05
Mid Chute            25544.84           .05      .024       .05
Mid Chute            25493.87           .05      .024       .05
Mid Chute            25449.23           .05      .024       .05
Mid Chute            25393.35           .05      .024       .05
Mid Chute            25344.31           .05      .024       .05
Mid Chute            25290.78           .05      .024       .05
Mid Chute            25245.25           .05      .024       .05
Mid Chute            25196.84           .05      .024       .05
Mid Chute            25095.44           .05      .024       .05
Mid Chute            25047.96           .05      .024       .05
Mid Chute            25000.14           .05      .024       .05
Mid Chute            24521.01           .05      .024       .05
Mid Chute            23567.89           .05      .024       .05
Mid Chute            22555.07           .05      .024       .05
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 Mid Chute            20556.36           .05      .024       .05
 Mid Chute            19585.36           .05      .024       .05
 DS Chute             19210.21           .05      .024       .05
 DS Chute             18370.67           .05      .024       .05
 DS Chute             17009.26           .05      .024       .05
 DS Chute             16125.84           .05      .024       .05
 DS Chute             14768.24           .05      .024       .05
 DS Chute             12602.25           .05      .024       .05
 DS Chute             7708.504           .05      .024       .05
 DS Chute             5162.571           .05      .024       .05
 DS Chute             3996.727           .05      .024       .05
 DS Chute             2000.000           .05      .024       .05



SUMMARY OF CONTRACTION AND EXPANSION COEFFICIENTS
River: IrrigCanal


      Reach          River Sta.     Contr.    Expan.

 Canal                20523           .2        .4
 Canal                20513           .2        .4
 Canal                20508           .2        .4
 Canal                20507.5         .2        .4
 Canal                20494           .2        .4
 Canal                20493           .2        .4
 Canal                20492           .2        .4
 Canal                20490           .2        .4
 Canal                20430           .2        .4
 Canal                20420           .2        .4
 Canal                20400           .2        .4
 Canal                20380           .2        .4
 Canal                20370           .2        .4
 Canal                20360           .2        .4
 Canal                20340           .2        .4
 Canal                20330           .2        .4
 Canal                20320           .2        .4
 Canal                20300           .2        .4
 Canal                20280           .2        .4
 Canal                20250           .1        .3
 Canal                20230           .1        .3
 Canal                20190           .1        .3
 Canal                20130           .1        .3
 Canal                20060           .1        .3
 Canal                19990           .1        .3
 Canal                19890           .1        .3
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Canal                19830           .1        .3
Canal                19780           .1        .3
Canal                19720           .1        .3
Canal                19680           .1        .3
Canal                19630           .1        .3
Canal                19600           .1        .3
Canal                19530           .1        .3
Canal                19480    Bridge
Canal                19420           .1        .3
Canal                19320           .1        .3
Canal                19000           .1        .3
Canal                18730.16        .1        .3
Canal                18500           .1        .3
Canal                18236.73        .1        .3
Canal                18000           .1        .3
Canal                17734.79        .1        .3
Canal                17500           .1        .3
Canal                17239.75        .1        .3
Canal                17000           .1        .3
Canal                16739.51        .1        .3
Canal                16500           .1        .3
Canal                16000           .1        .3
Canal                15500           .1        .3
Canal                15000           .1        .3
Canal                14500           .1        .3
Canal                14000           .1        .3
Canal                13500           .1        .3
Canal                13000           .1        .3
Canal                12510           .1        .3
Canal                12000           .1        .3
Canal                11500           .1        .3
Canal                11000           .1        .3
Canal                10510           .1        .3
Canal                10000           .1        .3
Canal                9500            .1        .3
Canal                9000            .1        .3
Canal                8500            .1        .3
Canal                8000            .1        .3
Canal                7500            .1        .3
Canal                7000            .1        .3
Canal                6500            .1        .3
Canal                6000            .1        .3
Canal                5500            .1        .3
Canal                5000            .1        .3
Canal                4500            .1        .3
Canal                4000            .1        .3
Canal                3500            .1        .3
Canal                3000            .1        .3
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 Canal                2500            .1         .3
 Canal                2000            .1         .3
 Canal                1500            .1         .3
 Canal                1000            .1         .3
 Canal                500             .1         .3
 Canal                30              .1         .3

River: Right Chute


      Reach          River Sta.     Contr.    Expan.

 Chute                24560           .1         .3
 Chute                23960           .1         .3
 Chute                22780.84        .1         .3
 Chute                21990           .1         .3
 Chute                21530           .1         .3
 Chute                21109.99        .1         .3
 Chute                20712.01        .1         .3
 Chute                20002.85        .1         .3
 Chute                19020           .1         .3
 Chute                18233.44        .1         .3
 Chute                17410           .1         .3
 Chute                15003.62        .1         .3
 Chute                14030           .1         .3
 Chute                13387.50        .1         .3
 Chute                12441.82        .1         .3
 Chute                12050           .1         .3
 Chute                10800           .1         .3
 Chute                9980            .1         .3
 Chute                9477.659        .1         .3
 Chute                8890            .1         .3
 Chute                8010            .1         .3
 Chute                7358.393        .1         .3
 Chute                6770            .1         .3
 Chute                6017.052        .1         .3
 Chute                5380            .1         .3
 Chute                4758.043        .1         .3
 Chute                3810            .1         .3
 Chute                2770            .1         .3
 Chute                1939.394        .1         .3
 Chute                1360            .1         .3
 Chute                720             .1         .3
 Chute                338.7000        .1         .3

River: Yellowstone
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     Reach            River Sta.     Contr.    Expan.

US Chute              56000.00         .1        .3
US Chute              54003.06         .1        .3
US Chute              51999.34         .1        .3
US Chute              50001.19         .1        .3
US Chute              47994.16         .1        .3
US Chute              46189.52         .1        .3
US Chute              43687.06         .1        .3
US Chute              42707.92         .1        .3
US Chute              41936.91         .1        .3
US Chute              40894.62         .1        .3
US Chute              39877.04         .1        .3
US Chute              39170.03         .1        .3
US Chute              38214.43         .1        .3
Mid Chute             37074.57         .1        .3
Mid Chute             36104.97         .1        .3
Mid Chute             35375.29         .1        .3
Mid Chute             34889.88         .1        .3
Mid Chute             34191.19         .1        .3
Mid Chute             33735.56         .1        .3
Mid Chute             33047.64         .1        .3
Mid Chute             32272.67         .1        .3
Mid Chute             31618.85         .1        .3
Mid Chute             30903.05         .1        .3
Mid Chute             30416.56         .1        .3
Mid Chute             29941.29         .1        .3
Mid Chute             29645.16         .1        .3
Mid Chute             29589.64         .1        .3
Mid Chute             29543.81         .1        .3
Mid Chute             29486.53         .1        .3
Mid Chute             29444.45         .1        .3
Mid Chute             29392.44         .1        .3
Mid Chute             29345.32         .1        .3
Mid Chute             29293.13         .1        .3
Mid Chute             29245.19         .1        .3
Mid Chute             29197.49         .1        .3
Mid Chute             29148.45         .1        .3
Mid Chute             29099.87         .1        .3
Mid Chute             29047.75         .1        .3
Mid Chute             28998.60         .1        .3
Mid Chute             28947.07         .1        .3
Mid Chute             28897.52         .1        .3
Mid Chute             28849.13         .1        .3
Mid Chute             28800.76         .1        .3
Mid Chute             28752.58         .1        .3
Mid Chute             28702.18         .1        .3
Mid Chute             28650.25         .1        .3
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Mid Chute            28603.39        .1        .3
Mid Chute            28557.23        .1        .3
Mid Chute            28550    Lat Struct
Mid Chute            28510.39        .1        .3
Mid Chute            28406.73        .1        .3
Mid Chute            28203.49        .1        .3
Mid Chute            28062           .1        .3
Mid Chute            28022    Inl Struct
Mid Chute            28012.06        .1        .3
Mid Chute            27912.73        .1        .3
Mid Chute            27778.92        .1        .3
Mid Chute            27597.18        .1        .3
Mid Chute            27550.20        .1        .3
Mid Chute            27498.33        .1        .3
Mid Chute            27447.08        .1        .3
Mid Chute            27398.93        .1        .3
Mid Chute            27348.49        .1        .3
Mid Chute            27300.85        .1        .3
Mid Chute            27248.50        .1        .3
Mid Chute            27199.15        .1        .3
Mid Chute            27147.30        .1        .3
Mid Chute            27092.77        .1        .3
Mid Chute            27045.05        .1        .3
Mid Chute            26997.92        .1        .3
Mid Chute            26945.88        .1        .3
Mid Chute            26899.79        .1        .3
Mid Chute            26849.79        .1        .3
Mid Chute            26799.33        .1        .3
Mid Chute            26750.78        .1        .3
Mid Chute            26696.93        .1        .3
Mid Chute            26646.45        .1        .3
Mid Chute            26598.26        .1        .3
Mid Chute            26548.87        .1        .3
Mid Chute            26503.32        .1        .3
Mid Chute            26447.30        .1        .3
Mid Chute            26398.50        .1        .3
Mid Chute            26300.47        .1        .3
Mid Chute            26243.25        .1        .3
Mid Chute            26197.23        .1        .3
Mid Chute            26139.58        .1        .3
Mid Chute            26097.74        .1        .3
Mid Chute            26049.91        .1        .3
Mid Chute            26002.24        .1        .3
Mid Chute            25945.89        .1        .3
Mid Chute            25899.95        .1        .3
Mid Chute            25845.58        .1        .3
Mid Chute            25798.14        .1        .3
Mid Chute            25744.07        .1        .3
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Mid Chute           25695.91        .1        .3
Mid Chute           25649.82        .1        .3
Mid Chute           25596.44        .1        .3
Mid Chute           25544.84        .1        .3
Mid Chute           25493.87        .1        .3
Mid Chute           25449.23        .1        .3
Mid Chute           25393.35        .1        .3
Mid Chute           25344.31        .1        .3
Mid Chute           25290.78        .1        .3
Mid Chute           25245.25        .1        .3
Mid Chute           25196.84        .1        .3
Mid Chute           25095.44        .1        .3
Mid Chute           25047.96        .1        .3
Mid Chute           25000.14        .1        .3
Mid Chute           24521.01        .1        .3
Mid Chute           23567.89        .1        .3
Mid Chute           22555.07        .1        .3
Mid Chute           20556.36        .1        .3
Mid Chute           19585.36        .1        .3
DS Chute            19210.21        .1        .3
DS Chute            18370.67        .1        .3
DS Chute            17009.26        .1        .3
DS Chute            16125.84        .1        .3
DS Chute            14768.24        .1        .3
DS Chute            12602.25        .1        .3
DS Chute            7708.504        .1        .3
DS Chute            5162.571        .1        .3
DS Chute            3996.727        .1        .3
DS Chute            2000.000        .1        .3
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HEC-RAS Plan: Tt_ExCond_Dam_Raised

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Yellowstone	US Chute	56000.00	7000cfs	7000.00	1996.00	2001.78	1998.55	2001.89	0.000307	2.65	2640.93	760.08	0.24
Yellowstone	US Chute	56000.00	15000cfs	15000.00	1996.00	2004.01	2000.25	2004.20	0.000315	3.55	4220.06	839.61	0.26
Yellowstone	US Chute	56000.00	30000cfs	30000.00	1996.00	2006.66	2001.84	2007.03	0.000365	4.86	6169.64	902.39	0.30
Yellowstone	US Chute	56000.00	2yr 54200cfs	54200.00	1996.00	2009.58	2003.77	2010.24	0.000439	6.51	8350.76	1477.93	0.34
Yellowstone	US Chute	56000.00	100yr 128300cfs	128300.00	1996.00	2014.70	2008.09	2016.41	0.000699	10.54	12469.11	2440.67	0.46
Yellowstone	US Chute	56000.00	63000cfs	63000.00	1996.00	2010.54	2004.32	2011.29	0.000452	6.97	9092.30	1606.28	0.35
Yellowstone	US Chute	54003.06	7000cfs	7000.00	1995.31	2001.25	1997.86	2001.34	0.000238	2.35	2983.51	791.31	0.21
Yellowstone	US Chute	54003.06	15000cfs	15000.00	1995.31	2003.48	1999.53	2003.64	0.000246	3.17	4736.67	944.94	0.23
Yellowstone	US Chute	54003.06	30000cfs	30000.00	1995.31	2006.05	2001.01	2006.35	0.000301	4.40	6816.59	1075.72	0.27
Yellowstone	US Chute	54003.06	2yr 54200cfs	54200.00	1995.31	2008.84	2002.75	2009.39	0.000378	5.94	9135.55	1200.19	0.32
Yellowstone	US Chute	54003.06	100yr 128300cfs	128300.00	1995.31	2013.49	2006.88	2015.00	0.000657	9.87	13127.81	2828.10	0.44
Yellowstone	US Chute	54003.06	63000cfs	63000.00	1995.31	2009.79	2003.35	2010.42	0.000389	6.36	9932.71	1265.17	0.32
Yellowstone	US Chute	51999.34	7000cfs	7000.00	1994.62	2000.78	1997.96	2000.86	0.000243	2.25	3114.93	873.41	0.21
Yellowstone	US Chute	51999.34	15000cfs	15000.00	1994.62	2002.99	1999.02	2003.11	0.000270	2.84	5285.93	1333.16	0.23
Yellowstone	US Chute	51999.34	30000cfs	30000.00	1994.62	2005.54	2000.50	2005.73	0.000284	3.55	8451.69	1669.52	0.25
Yellowstone	US Chute	51999.34	2yr 54200cfs	54200.00	1994.62	2008.38	2002.31	2008.68	0.000268	4.40	12365.11	2000.31	0.26
Yellowstone	US Chute	51999.34	100yr 128300cfs	128300.00	1994.62	2013.36	2005.83	2013.88	0.000286	6.08	28234.36	4381.81	0.29
Yellowstone	US Chute	51999.34	63000cfs	63000.00	1994.62	2009.37	2002.88	2009.70	0.000256	4.61	13784.85	2152.86	0.26
Yellowstone	US Chute	50001.19	7000cfs	7000.00	1993.93	1999.67	1997.84	2000.00	0.000891	4.75	1678.66	788.86	0.41
Yellowstone	US Chute	50001.19	15000cfs	15000.00	1993.93	2001.37	1999.43	2002.04	0.001390	6.86	2560.33	885.56	0.53
Yellowstone	US Chute	50001.19	30000cfs	30000.00	1993.93	2003.42	2001.68	2004.46	0.002160	8.63	4036.99	1128.89	0.67
Yellowstone	US Chute	50001.19	2yr 54200cfs	54200.00	1993.93	2005.94	2003.87	2007.46	0.001952	10.46	6246.47	1462.73	0.67
Yellowstone	US Chute	50001.19	100yr 128300cfs	128300.00	1993.93	2012.48	2008.34	2013.08	0.000658	6.50	25008.16	4506.15	0.40
Yellowstone	US Chute	50001.19	63000cfs	63000.00	1993.93	2006.86	2004.53	2008.49	0.002074	10.84	7330.88	1622.12	0.69
Yellowstone	US Chute	47994.16	7000cfs	7000.00	1993.23	1997.82	1996.74	1998.01	0.001099	3.49	2005.40	900.94	0.41
Yellowstone	US Chute	47994.16	15000cfs	15000.00	1993.23	1999.57	1997.64	1999.82	0.000843	4.01	3743.31	1119.90	0.39
Yellowstone	US Chute	47994.16	30000cfs	30000.00	1993.23	2002.10	1998.94	2002.39	0.000527	4.31	6966.29	1316.55	0.33
Yellowstone	US Chute	47994.16	2yr 54200cfs	54200.00	1993.23	2005.37	2000.54	2005.73	0.000362	4.78	11370.84	1414.65	0.29
Yellowstone	US Chute	47994.16	100yr 128300cfs	128300.00	1993.23	2011.64	2003.49	2012.16	0.000337	5.86	25472.43	4111.09	0.30
Yellowstone	US Chute	47994.16	63000cfs	63000.00	1993.23	2006.39	2000.94	2006.77	0.000338	4.94	12840.06	1463.21	0.29
Yellowstone	US Chute	46189.52	7000cfs	7000.00	1989.69	1996.20	1994.44	1996.35	0.000643	3.11	2249.13	804.65	0.33
Yellowstone	US Chute	46189.52	15000cfs	15000.00	1989.69	1998.44	1995.60	1998.64	0.000425	3.61	4154.25	871.54	0.29
Yellowstone	US Chute	46189.52	30000cfs	30000.00	1989.69	2001.18	1996.96	2001.50	0.000378	4.58	6552.39	881.69	0.30
Yellowstone	US Chute	46189.52	2yr 54200cfs	54200.00	1989.69	2004.48	1998.63	2004.99	0.000363	5.73	9483.95	928.34	0.31
Yellowstone	US Chute	46189.52	100yr 128300cfs	128300.00	1989.69	2010.30	2002.45	2011.35	0.000438	8.40	19881.26	3209.66	0.36
Yellowstone	US Chute	46189.52	63000cfs	63000.00	1989.69	2005.48	1999.12	2006.05	0.000365	6.09	10375.97	1055.43	0.31
Yellowstone	US Chute	43687.06	7000cfs	7000.00	1983.93	1995.91	1988.88	1995.95	0.000063	1.72	4075.94	621.14	0.12
Yellowstone	US Chute	43687.06	15000cfs	15000.00	1983.93	1997.98	1990.46	1998.10	0.000120	2.76	5446.07	675.59	0.17
Yellowstone	US Chute	43687.06	30000cfs	30000.00	1983.93	2000.55	1992.71	2000.82	0.000194	4.20	7199.28	690.28	0.23
Yellowstone	US Chute	43687.06	2yr 54200cfs	54200.00	1983.93	2003.67	1995.46	2004.20	0.000270	5.88	9426.93	795.10	0.28
Yellowstone	US Chute	43687.06	100yr 128300cfs	128300.00	1983.93	2008.86	2000.34	2010.19	0.000467	9.55	19560.80	3902.35	0.39
Yellowstone	US Chute	43687.06	63000cfs	63000.00	1983.93	2004.59	1996.23	2005.22	0.000294	6.40	10138.80	1027.67	0.29
Yellowstone	US Chute	42707.92	7000cfs	7000.00	1986.56	1995.82	1990.25	1995.88	0.000098	1.95	3598.89	638.01	0.14
Yellowstone	US Chute	42707.92	15000cfs	15000.00	1986.56	1997.82	1991.99	1997.96	0.000185	3.02	4968.36	731.92	0.20
Yellowstone	US Chute	42707.92	30000cfs	30000.00	1986.56	2000.31	1994.06	2000.60	0.000266	4.38	6860.93	773.30	0.26
Yellowstone	US Chute	42707.92	2yr 54200cfs	54200.00	1986.56	2003.38	1996.31	2003.91	0.000326	5.90	9387.25	961.96	0.30
Yellowstone	US Chute	42707.92	100yr 128300cfs	128300.00	1986.56	2008.55	2000.91	2009.68	0.000464	8.91	23740.14	5731.29	0.38
Yellowstone	US Chute	42707.92	63000cfs	63000.00	1986.56	2004.29	1997.06	2004.91	0.000344	6.36	10254.92	1170.83	0.31
Yellowstone	US Chute	41936.91	7000cfs	7000.00	1989.22	1995.65	1992.54	1995.75	0.000298	2.51	2786.35	773.14	0.23
Yellowstone	US Chute	41936.91	15000cfs	15000.00	1989.22	1997.60	1993.89	1997.76	0.000369	3.21	4677.00	1054.79	0.27
Yellowstone	US Chute	41936.91	30000cfs	30000.00	1989.22	2000.10	1995.63	2000.36	0.000334	4.08	7346.36	1069.95	0.27
Yellowstone	US Chute	41936.91	2yr 54200cfs	54200.00	1989.22	2003.22	1997.50	2003.62	0.000313	5.07	10698.79	1360.92	0.28
Yellowstone	US Chute	41936.91	100yr 128300cfs	128300.00	1989.22	2008.55	2000.88	2009.24	0.000339	7.02	28638.42	5801.89	0.32
Yellowstone	US Chute	41936.91	63000cfs	63000.00	1989.22	2004.15	1997.96	2004.60	0.000314	5.39	11702.33	1666.07	0.29
Yellowstone	US Chute	40894.62	7000cfs	7000.00	1989.86	1995.22	1993.36	1995.34	0.000523	2.80	2502.40	900.93	0.30
Yellowstone	US Chute	40894.62	15000cfs	15000.00	1989.86	1997.15	1994.43	1997.34	0.000428	3.47	4319.69	964.97	0.29
Yellowstone	US Chute	40894.62	30000cfs	30000.00	1989.86	1999.67	1995.72	1999.98	0.000391	4.43	6782.57	987.81	0.30
Yellowstone	US Chute	40894.62	2yr 54200cfs	54200.00	1989.86	2002.79	1997.30	2003.26	0.000373	5.50	9914.46	1122.97	0.31
Yellowstone	US Chute	40894.62	100yr 128300cfs	128300.00	1989.86	2008.17	2000.90	2008.83	0.000448	6.94	28894.98	5966.63	0.35
Yellowstone	US Chute	40894.62	63000cfs	63000.00	1989.86	2003.71	1997.79	2004.24	0.000377	5.84	10873.34	1581.33	0.31
Yellowstone	US Chute	39877.04	7000cfs	7000.00	1987.46	1994.56	1992.38	1994.72	0.000721	3.20	2190.05	820.96	0.34
Yellowstone	US Chute	39877.04	15000cfs	15000.00	1987.46	1996.65	1993.95	1996.86	0.000512	3.69	4064.37	949.96	0.31
Yellowstone	US Chute	39877.04	30000cfs	30000.00	1987.46	1999.24	1995.40	1999.56	0.000434	4.51	6667.91	1065.15	0.31
Yellowstone	US Chute	39877.04	2yr 54200cfs	54200.00	1987.46	2002.42	1997.08	2002.88	0.000376	5.47	10110.12	1471.83	0.31
Yellowstone	US Chute	39877.04	100yr 128300cfs	128300.00	1987.46	2007.78	2000.65	2008.45	0.000352	7.09	31182.59	5883.30	0.32
Yellowstone	US Chute	39877.04	63000cfs	63000.00	1987.46	2003.35	1997.59	2003.85	0.000367	5.74	12143.02	2399.37	0.31
Yellowstone	US Chute	39170.03	7000cfs	7000.00	1985.48	1994.39	1989.57	1994.47	0.000179	2.21	3160.68	721.61	0.19
Yellowstone	US Chute	39170.03	15000cfs	15000.00	1985.48	1996.45	1991.39	1996.60	0.000245	3.15	4776.10	822.11	0.23
Yellowstone	US Chute	39170.03	30000cfs	30000.00	1985.48	1999.00	1993.60	1999.30	0.000307	4.34	6936.40	914.22	0.27
Yellowstone	US Chute	39170.03	2yr 54200cfs	54200.00	1985.48	2002.12	1995.74	2002.60	0.000408	5.56	9797.29	1394.12	0.32
Yellowstone	US Chute	39170.03	100yr 128300cfs	128300.00	1985.48	2007.83	1999.88	2008.06	0.000386	3.84	33525.15	6069.18	0.29
Yellowstone	US Chute	39170.03	63000cfs	63000.00	1985.48	2003.04	1996.30	2003.57	0.000437	5.86	10813.87	1970.31	0.33
Yellowstone	US Chute	38214.43	7000cfs	7000.00	1984.11	1994.33	1988.00	1994.37	0.000057	1.67	4184.49	618.01	0.11
Yellowstone	US Chute	38214.43	15000cfs	15000.00	1984.11	1996.32	1989.48	1996.44	0.000112	2.76	5466.35	677.41	0.17
Yellowstone	US Chute	38214.43	30000cfs	30000.00	1984.11	1998.78	1991.33	1999.06	0.000193	4.28	7214.48	789.05	0.23

HEC-RAS Plan: Tt_ExCond_Dam_Raised (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Yellowstone	US Chute	38214.43	2yr 54200cfs	54200.00	1984.11	2001.71	1993.69	2002.27	0.000282	6.05	9619.47	1136.23	0.28
Yellowstone	US Chute	38214.43	100yr 128300cfs	128300.00	1984.11	2006.65	1998.70	2007.62	0.000396	8.76	30554.37	6652.66	0.35
Yellowstone	US Chute	38214.43	63000cfs	63000.00	1984.11	2002.54	1994.45	2003.21	0.000313	6.62	10412.98	1908.30	0.30
Yellowstone	DS Chute	19210.21	7000cfs	5631.56	1974.19	1980.39	1977.94	1980.53	0.000522	2.96	1899.76	625.30	0.30
Yellowstone	DS Chute	19210.21	15000cfs	13631.56	1974.19	1982.37	1979.60	1982.61	0.000682	3.92	3481.46	922.90	0.36
Yellowstone	DS Chute	19210.21	30000cfs	28626.00	1974.19	1984.81	1981.60	1985.16	0.000741	4.72	6063.31	1319.81	0.38
Yellowstone	DS Chute	19210.21	2yr 54200cfs	52827.39	1974.19	1987.76	1983.37	1988.21	0.000499	5.34	9892.73	1485.36	0.34
Yellowstone	DS Chute	19210.21	100yr 128300cfs	126926.40	1974.19	1993.56	1986.83	1994.37	0.000433	7.26	18082.08	4751.35	0.35
Yellowstone	DS Chute	19210.21	63000cfs	61626.35	1974.19	1988.66	1983.94	1989.14	0.000469	5.57	11062.81	1676.89	0.34
Yellowstone	DS Chute	18370.67	7000cfs	5631.56	1975.62	1979.89	1978.49	1980.02	0.000704	2.95	1906.96	790.42	0.34
Yellowstone	DS Chute	18370.67	15000cfs	13631.56	1975.62	1981.82	1979.55	1982.04	0.000656	3.72	3662.91	1017.39	0.35
Yellowstone	DS Chute	18370.67	30000cfs	28626.00	1975.62	1984.30	1981.02	1984.61	0.000549	4.49	6370.19	1174.78	0.34
Yellowstone	DS Chute	18370.67	2yr 54200cfs	52827.39	1975.62	1987.37	1982.65	1987.77	0.000511	5.05	10461.71	1731.62	0.34
Yellowstone	DS Chute	18370.67	100yr 128300cfs	126926.40	1975.62	1993.34	1986.26	1993.99	0.000364	6.46	20106.91	4836.33	0.32
Yellowstone	DS Chute	18370.67	63000cfs	61626.35	1975.62	1988.32	1983.15	1988.73	0.000453	5.18	11903.72	1806.66	0.33
Yellowstone	DS Chute	17009.26	7000cfs	5631.56	1971.03	1979.32	1975.92	1979.41	0.000303	2.30	2444.73	775.00	0.23
Yellowstone	DS Chute	17009.26	15000cfs	13631.56	1971.03	1981.14	1977.79	1981.32	0.000421	3.48	3916.76	855.42	0.29
Yellowstone	DS Chute	17009.26	30000cfs	28626.00	1971.03	1983.56	1979.67	1983.90	0.000503	4.65	6151.77	991.92	0.33
Yellowstone	DS Chute	17009.26	2yr 54200cfs	52827.39	1971.03	1986.58	1981.51	1987.09	0.000474	5.72	9241.27	1189.06	0.34
Yellowstone	DS Chute	17009.26	100yr 128300cfs	126926.40	1971.03	1992.82	1985.42	1993.40	0.000486	6.45	27763.18	5289.45	0.35
Yellowstone	DS Chute	17009.26	63000cfs	61626.35	1971.03	1987.53	1982.10	1988.10	0.000462	6.02	10245.54	1306.90	0.34
Yellowstone	DS Chute	16125.84	7000cfs	5631.56	1973.56	1978.86	1977.24	1979.00	0.000738	3.02	1866.63	774.73	0.34
Yellowstone	DS Chute	16125.84	15000cfs	13631.56	1973.56	1980.54	1978.52	1980.80	0.000877	4.11	3316.05	982.59	0.39
Yellowstone	DS Chute	16125.84	30000cfs	28626.00	1973.56	1983.03	1980.02	1983.38	0.000669	4.80	5958.13	1210.53	0.37
Yellowstone	DS Chute	16125.84	2yr 54200cfs	52827.39	1973.56	1986.20	1981.70	1986.63	0.000510	5.28	10006.00	1577.00	0.34
Yellowstone	DS Chute	16125.84	100yr 128300cfs	126926.40	1973.56	1992.47	1985.29	1993.04	0.000338	6.26	24816.65	3014.71	0.31
Yellowstone	DS Chute	16125.84	63000cfs	61626.35	1973.56	1987.20	1982.19	1987.66	0.000456	5.42	11376.82	1760.47	0.33
Yellowstone	DS Chute	14768.24	7000cfs	5631.56	1972.37	1976.79	1976.31	1977.16	0.003125	4.92	1145.04	675.73	0.67
Yellowstone	DS Chute	14768.24	15000cfs	13631.56	1972.37	1979.23	1977.46	1979.52	0.001002	4.37	3122.51	938.80	0.42
Yellowstone	DS Chute	14768.24	30000cfs	28626.00	1972.37	1982.24	1978.97	1982.59	0.000515	4.76	6109.22	1008.35	0.34
Yellowstone	DS Chute	14768.24	2yr 54200cfs	52827.39	1972.37	1985.48	1980.53	1985.99	0.000431	5.74	9486.07	1099.16	0.33
Yellowstone	DS Chute	14768.24	100yr 128300cfs	126926.40	1972.37	1991.53	1984.16	1992.48	0.000437	8.04	19993.43	3230.24	0.36
Yellowstone	DS Chute	14768.24	63000cfs	61626.35	1972.37	1986.50	1981.05	1987.06	0.000415	6.03	10643.27	1169.14	0.33
Yellowstone	DS Chute	12602.25	7000cfs	5631.56	1969.21	1975.05	1972.26	1975.20	0.000403	3.09	1821.86	464.46	0.28
Yellowstone	DS Chute	12602.25	15000cfs	13631.56	1969.21	1977.81	1973.98	1978.09	0.000468	4.22	3232.43	578.08	0.31
Yellowstone	DS Chute	12602.25	30000cfs	28626.00	1969.21	1980.98	1976.14	1981.40	0.000573	5.26	5445.54	814.15	0.36
Yellowstone	DS Chute	12602.25	2yr 54200cfs	52827.39	1969.21	1984.33	1978.82	1984.96	0.000505	6.40	8367.67	925.06	0.36
Yellowstone	DS Chute	12602.25	100yr 128300cfs	126926.40	1969.21	1990.78	1983.45	1991.55	0.000372	7.68	28632.62	4698.72	0.33
Yellowstone	DS Chute	12602.25	63000cfs	61626.35	1969.21	1985.36	1979.63	1986.07	0.000491	6.74	9379.85	1030.95	0.36
Yellowstone	DS Chute	7708.504	7000cfs	5631.56	1965.57	1973.14	1970.34	1973.25	0.000393	2.71	2077.33	629.56	0.26
Yellowstone	DS Chute	7708.504	15000cfs	13631.56	1965.57	1976.15	1971.97	1976.31	0.000279	3.25	4192.06	746.33	0.24
Yellowstone	DS Chute	7708.504	30000cfs	28626.00	1965.57	1979.01	1973.88	1979.32	0.000319	4.50	6375.79	784.79	0.28
Yellowstone	DS Chute	7708.504	2yr 54200cfs	52827.39	1965.57	1982.36	1975.93	1982.90	0.000349	5.90	9050.94	809.35	0.31
Yellowstone	DS Chute	7708.504	100yr 128300cfs	126926.40	1965.57	1989.53	1980.25	1990.14	0.000254	6.94	27714.38	5153.00	0.28
Yellowstone	DS Chute	7708.504	63000cfs	61626.35	1965.57	1983.39	1976.52	1984.01	0.000357	6.32	9887.53	819.87	0.31
Yellowstone	DS Chute	5162.571	7000cfs	5631.56	1958.27	1972.90	1965.45	1972.94	0.000053	1.49	3775.57	627.98	0.11
Yellowstone	DS Chute	5162.571	15000cfs	13631.56	1958.27	1975.84	1968.45	1975.93	0.000085	2.41	5652.87	646.08	0.14
Yellowstone	DS Chute	5162.571	30000cfs	28626.00	1958.27	1978.51	1970.74	1978.75	0.000157	3.87	7394.78	694.10	0.20
Yellowstone	DS Chute	5162.571	2yr 54200cfs	52827.39	1958.27	1981.68	1972.93	1982.16	0.000236	5.57	9509.18	807.25	0.26
Yellowstone	DS Chute	5162.571	100yr 128300cfs	126926.40	1958.27	1988.09	1977.77	1989.29	0.000373	8.96	16837.62	3617.34	0.35
Yellowstone	DS Chute	5162.571	63000cfs	61626.35	1958.27	1982.65	1973.59	1983.23	0.000257	6.08	10197.64	885.45	0.27
Yellowstone	DS Chute	3996.727	7000cfs	5631.56	1967.58	1972.69	1969.79	1972.80	0.000327	2.62	2148.47	596.79	0.24
Yellowstone	DS Chute	3996.727	15000cfs	13631.56	1967.58	1975.59	1971.51	1975.75	0.000335	3.26	4183.08	854.69	0.26
Yellowstone	DS Chute	3996.727	30000cfs	28626.00	1967.58	1978.16	1973.28	1978.47	0.000365	4.47	6405.45	900.25	0.29
Yellowstone	DS Chute	3996.727	2yr 54200cfs	52827.39	1967.58	1981.29	1975.62	1981.81	0.000383	5.79	9154.83	981.40	0.31
Yellowstone	DS Chute	3996.727	100yr 128300cfs	126926.40	1967.58	1987.88	1979.53	1988.77	0.000372	7.88	23757.93	4557.01	0.34
Yellowstone	DS Chute	3996.727	63000cfs	61626.35	1967.58	1982.27	1976.15	1982.86	0.000387	6.17	10025.16	1047.47	0.32
Yellowstone	DS Chute	2000.000	7000cfs	5631.56	1966.88	1972.08	1969.30	1972.17	0.000301	2.45	2295.58	661.88	0.23
Yellowstone	DS Chute	2000.000	15000cfs	13631.56	1966.88	1974.97	1970.72	1975.11	0.000300	2.94	4628.92	1043.23	0.24
Yellowstone	DS Chute	2000.000	30000cfs	28626.00	1966.88	1977.55	1972.54	1977.79	0.000300	3.95	7253.82	1077.12	0.26
Yellowstone	DS Chute	2000.000	2yr 54200cfs	52827.39	1966.88	1980.70	1974.67	1981.10	0.000300	5.04	10501.32	1125.87	0.28
Yellowstone	DS Chute	2000.000	100yr 128300cfs	126926.40	1966.88	1987.32	1978.29	1988.06	0.000300	7.02	20968.27	1742.61	0.30
Yellowstone	DS Chute	2000.000	63000cfs	61626.35	1966.88	1981.69	1975.28	1982.14	0.000300	5.36	11531.58	1169.22	0.28
Right Chute	Chute	24560	7000cfs	1.58	0.00	1994.21		1994.22	0.000629	0.75	2.09	1.00	0.09
Right Chute	Chute	24560	15000cfs	35.15	1995.47	1995.98	1995.98	1996.22	0.016064	3.92	8.96	21.16	1.06
Right Chute	Chute	24560	30000cfs	483.85	1995.47	1997.86	1997.86	1998.76	0.009311	7.61	63.54	36.47	1.02
Right Chute	Chute	24560	2yr 54200cfs	2231.65	1995.47	2001.14	2001.14	2001.88	0.004116	7.68	483.59	401.98	0.75
Right Chute	Chute	24560	100yr 128300cfs	12380.27	1995.47	2006.92		2007.10	0.000603	5.38	4962.16	1112.82	0.33
Right Chute	Chute	24560	63000cfs	4037.86	1995.47	2002.24		2002.78	0.003270	7.48	1093.14	652.39	0.68
Right Chute	Chute	23960	7000cfs	1.58	0.00	1993.78		1993.80	0.000808	0.84	1.87	1.00	0.11
Right Chute	Chute	23960	15000cfs	35.15	1993.91	1994.51		1994.52	0.000444	0.76	46.21	86.94	0.18
Right Chute	Chute	23960	30000cfs	483.85	1993.91	1996.74		1996.79	0.000362	1.79	270.84	121.02	0.21
Right Chute	Chute	23960	2yr 54200cfs	2231.65	1993.91	2000.07		2000.22	0.000356	3.11	766.50	237.47	0.24
Right Chute	Chute	23960	100yr 128300cfs	12380.27	1993.91	2006.73		2006.88	0.000228	4.18	6833.05	1560.57	0.22
Right Chute	Chute	23960	63000cfs	4037.86	1993.91	2001.97		2002.18	0.000372	3.85	1492.60	616.14	0.26

HEC-RAS Plan: Tt_ExCond_Dam_Raised (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Right Chute	Chute	22780.84	7000cfs	1.58	1992.43	1992.84	1991.55	1992.85	0.000378	0.38	4.20	20.21	0.15
Right Chute	Chute	22780.84	15000cfs	35.15	1992.43	1993.77	1993.09	1993.79	0.000392	0.85	41.24	59.56	0.18
Right Chute	Chute	22780.84	30000cfs	483.85	1992.43	1995.84	1994.36	1995.94	0.000645	2.49	194.57	81.00	0.28
Right Chute	Chute	22780.84	2yr 54200cfs	2231.65	1992.43	1999.03	1996.38	1999.33	0.000729	4.41	560.40	158.44	0.34
Right Chute	Chute	22780.84	100yr 128300cfs	12380.27	1992.43	2005.23	2001.95	2006.08	0.000948	8.48	2296.02	375.90	0.44
Right Chute	Chute	22780.84	63000cfs	4037.86	1992.43	2000.79	1997.76	2001.23	0.000787	5.56	958.45	255.24	0.37
Right Chute	Chute	21990	7000cfs	1.58	1992.18	1992.42		1992.43	0.000802	0.68	2.32	11.95	0.27
Right Chute	Chute	21990	15000cfs	35.15	1992.18	1993.27		1993.29	0.001185	1.29	27.15	47.96	0.30
Right Chute	Chute	21990	30000cfs	483.85	1992.18	1995.22		1995.32	0.000960	2.58	187.30	100.04	0.33
Right Chute	Chute	21990	2yr 54200cfs	2231.65	1992.18	1998.47		1998.67	0.000874	3.61	618.86	189.30	0.35
Right Chute	Chute	21990	100yr 128300cfs	12380.27	1992.18	2005.00		2005.40	0.000522	5.16	2701.61	465.57	0.31
Right Chute	Chute	21990	63000cfs	4037.86	1992.18	2000.28		2000.53	0.000831	3.98	1026.22	264.56	0.35
Right Chute	Chute	21530	7000cfs	1.58	1991.85	1991.97	1990.71	1991.98	0.001199	0.98	1.61	1.59	0.17
Right Chute	Chute	21530	15000cfs	35.15	1991.85	1992.93	1992.50	1992.94	0.000524	0.87	40.30	69.37	0.20
Right Chute	Chute	21530	30000cfs	483.85	1991.85	1994.98	1993.57	1995.03	0.000405	1.74	277.84	139.46	0.22
Right Chute	Chute	21530	2yr 54200cfs	2231.65	1991.85	1998.27	1994.99	1998.38	0.000399	2.66	839.40	220.08	0.24
Right Chute	Chute	21530	100yr 128300cfs	12380.27	1991.85	2004.88	1999.38	2005.18	0.000340	4.47	2987.55	595.61	0.26
Right Chute	Chute	21530	63000cfs	4037.86	1991.85	2000.10	1996.00	2000.24	0.000407	3.03	1336.63	300.81	0.25
Right Chute	Chute	21109.99	7000cfs	1.58	1991.10	1991.59	1990.43	1991.59	0.000726	0.33	4.77	46.04	0.18
Right Chute	Chute	21109.99	15000cfs	35.15	1991.10	1992.89	1991.75	1992.90	0.000039	0.41	86.50	66.97	0.06
Right Chute	Chute	21109.99	30000cfs	483.85	1991.10	1994.78	1992.77	1994.86	0.000402	2.19	221.28	77.71	0.23
Right Chute	Chute	21109.99	2yr 54200cfs	2231.65	1991.10	1997.88	1994.87	1998.15	0.000650	4.29	620.49	203.13	0.32
Right Chute	Chute	21109.99	100yr 128300cfs	12380.27	1991.10	2003.93	2000.52	2004.89	0.001036	8.91	2218.85	579.80	0.46
Right Chute	Chute	21109.99	63000cfs	4037.86	1991.10	1999.58	1996.43	1999.99	0.000731	5.45	991.20	232.11	0.36
Right Chute	Chute	20712.01	7000cfs	1.58	0.00	1991.16	1990.16	1991.18	0.001525	1.11	1.42	1.00	0.16
Right Chute	Chute	20712.01	15000cfs	35.15	1992.24	1992.72	1992.72	1992.83	0.018775	2.64	13.31	64.22	1.02
Right Chute	Chute	20712.01	30000cfs	483.85	1992.24	1994.42	1993.66	1994.54	0.002045	2.85	169.97	138.64	0.45
Right Chute	Chute	20712.01	2yr 54200cfs	2231.65	1992.24	1997.78	1995.23	1997.88	0.000482	2.64	845.39	260.96	0.26
Right Chute	Chute	20712.01	100yr 128300cfs	12380.27	1992.24	2004.16	1998.72	2004.46	0.000365	4.39	2878.01	390.84	0.26
Right Chute	Chute	20712.01	63000cfs	4037.86	1992.24	1999.56	1996.23	1999.70	0.000391	3.01	1340.05	289.81	0.25
Right Chute	Chute	20002.85	7000cfs	1.58	1990.19	1990.72	1989.69	1990.72	0.000349	0.33	4.72	25.28	0.14
Right Chute	Chute	20002.85	15000cfs	35.15	1990.19	1991.57	1990.93	1991.58	0.000306	0.79	44.39	59.23	0.16
Right Chute	Chute	20002.85	30000cfs	483.85	1990.19	1993.69	1992.11	1993.79	0.000634	2.55	189.89	95.47	0.28
Right Chute	Chute	20002.85	2yr 54200cfs	2231.65	1990.19	1997.35	1994.22	1997.49	0.000622	3.08	724.82	213.58	0.29
Right Chute	Chute	20002.85	100yr 128300cfs	12380.27	1990.19	2003.63	1998.69	2004.13	0.000544	5.78	2543.36	553.89	0.33
Right Chute	Chute	20002.85	63000cfs	4037.86	1990.19	1999.19	1995.82	1999.39	0.000478	3.60	1142.08	235.68	0.28
Right Chute	Chute	19020	7000cfs	1.58	0.00	1990.10	1989.03	1990.11	0.001366	1.06	1.49	1.00	0.15
Right Chute	Chute	19020	15000cfs	35.15	1990.19	1990.90	1990.66	1990.93	0.002420	1.46	24.00	60.27	0.41
Right Chute	Chute	19020	30000cfs	483.85	1990.19	1993.03	1991.71	1993.13	0.000725	2.45	197.20	91.81	0.30
Right Chute	Chute	19020	2yr 54200cfs	2231.65	1990.19	1996.58	1993.54	1996.82	0.000747	3.89	573.75	136.26	0.33
Right Chute	Chute	19020	100yr 128300cfs	12380.27	1990.19	2003.05	1998.89	2003.53	0.000676	5.61	2440.60	764.75	0.35
Right Chute	Chute	19020	63000cfs	4037.86	1990.19	1998.45	1994.86	1998.74	0.000922	4.33	932.30	238.23	0.37
Right Chute	Chute	18233.44	7000cfs	1.58	1989.19	1989.46	1988.50	1989.46	0.000547	0.36	4.39	29.74	0.16
Right Chute	Chute	18233.44	15000cfs	35.15	1989.19	1990.14	1989.66	1990.15	0.000529	0.87	40.63	71.78	0.20
Right Chute	Chute	18233.44	30000cfs	483.85	1989.19	1992.73	1990.71	1992.77	0.000284	1.72	281.52	111.06	0.19
Right Chute	Chute	18233.44	2yr 54200cfs	2231.65	1989.19	1996.25	1992.50	1996.37	0.000383	2.82	790.43	185.13	0.24
Right Chute	Chute	18233.44	100yr 128300cfs	12380.27	1989.19	2002.72	1997.34	2003.09	0.000407	5.01	3430.77	1100.50	0.28
Right Chute	Chute	18233.44	63000cfs	4037.86	1989.19	1998.03	1993.74	1998.21	0.000461	3.43	1176.50	237.68	0.27
Right Chute	Chute	17410	7000cfs	1.58	0.00	1988.18		1988.27	0.010153	2.40	0.66	1.00	0.52
Right Chute	Chute	17410	15000cfs	35.15	1988.20	1989.22		1989.29	0.002840	2.03	17.30	29.90	0.47
Right Chute	Chute	17410	30000cfs	483.85	1988.20	1992.31		1992.40	0.000839	2.35	205.47	113.95	0.31
Right Chute	Chute	17410	2yr 54200cfs	2231.65	1988.20	1995.82		1995.98	0.000613	3.17	703.42	196.91	0.30
Right Chute	Chute	17410	100yr 128300cfs	12380.27	1988.20	2002.47		2002.74	0.000372	4.40	4240.41	1227.38	0.27
Right Chute	Chute	17410	63000cfs	4037.86	1988.20	1997.56		1997.78	0.000599	3.73	1083.98	234.54	0.31
Right Chute	Chute	15003.62	7000cfs	1.58	1986.20	1986.73		1986.73	0.000205	0.32	4.92	18.91	0.11
Right Chute	Chute	15003.62	15000cfs	35.15	1986.20	1987.90		1987.92	0.000232	0.85	41.54	40.70	0.15
Right Chute	Chute	15003.62	30000cfs	483.85	1986.20	1990.42		1990.54	0.000717	2.69	179.77	71.74	0.30
Right Chute	Chute	15003.62	2yr 54200cfs	2231.65	1986.20	1994.17		1994.35	0.000748	3.40	655.47	190.04	0.32
Right Chute	Chute	15003.62	100yr 128300cfs	12380.27	1986.20	2001.24		2001.66	0.000528	5.23	2438.01	354.84	0.31
Right Chute	Chute	15003.62	63000cfs	4037.86	1986.20	1996.04		1996.27	0.000651	3.85	1049.53	228.17	0.32
Right Chute	Chute	14030	7000cfs	1.58	1986.23	1986.62		1986.62	0.000074	0.17	9.50	45.77	0.06
Right Chute	Chute	14030	15000cfs	35.15	1986.23	1987.83		1987.83	0.000040	0.35	101.50	102.57	0.06
Right Chute	Chute	14030	30000cfs	483.85	1986.23	1990.25		1990.27	0.000122	1.29	376.46	121.68	0.13
Right Chute	Chute	14030	2yr 54200cfs	2231.65	1986.23	1993.81		1993.90	0.000287	2.37	943.04	232.67	0.21
Right Chute	Chute	14030	100yr 128300cfs	12380.27	1986.23	2000.95		2001.26	0.000282	4.55	2876.82	312.01	0.24
Right Chute	Chute	14030	63000cfs	4037.86	1986.23	1995.73		1995.86	0.000263	2.87	1421.55	258.63	0.21
Right Chute	Chute	13387.50	7000cfs	1.58	1986.23	1986.55		1986.55	0.000222	0.25	6.22	36.06	0.11
Right Chute	Chute	13387.50	15000cfs	35.15	1986.23	1987.80		1987.80	0.000050	0.45	77.83	62.20	0.07
Right Chute	Chute	13387.50	30000cfs	483.85	1986.23	1990.08		1990.15	0.000330	2.01	240.99	83.53	0.21
Right Chute	Chute	13387.50	2yr 54200cfs	2231.65	1986.23	1993.50		1993.64	0.000554	3.04	733.61	201.95	0.28
Right Chute	Chute	13387.50	100yr 128300cfs	12380.27	1986.23	2000.63		2001.01	0.000540	4.99	2480.05	321.65	0.32
Right Chute	Chute	13387.50	63000cfs	4037.86	1986.23	1995.44		1995.63	0.000469	3.52	1147.94	224.06	0.27
Right Chute	Chute	12441.82	7000cfs	1.58	0.00	1986.20	1984.63	1986.21	0.000694	0.79	2.00	1.00	0.10
Right Chute	Chute	12441.82	15000cfs	35.15	1986.89	1987.65	1987.35	1987.67	0.001421	1.11	31.53	79.80	0.31

HEC-RAS Plan: Tt_ExCond_Dam_Raised (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Right Chute	Chute	12441.82	30000cfs	483.85	1986.89	1989.71	1988.27	1989.77	0.000498	1.99	243.25	116.73	0.24
Right Chute	Chute	12441.82	2yr 54200cfs	2231.65	1986.89	1993.07	1989.89	1993.21	0.000373	3.10	839.80	269.86	0.24
Right Chute	Chute	12441.82	100yr 128300cfs	12380.27	1986.89	2000.24	1994.43	2000.59	0.000358	5.47	3716.16	814.99	0.28
Right Chute	Chute	12441.82	63000cfs	4037.86	1986.89	1995.07	1991.00	1995.26	0.000339	3.69	1397.14	285.37	0.25
Right Chute	Chute	12050	7000cfs	1.58	0.00	1985.93	1984.36	1985.94	0.000703	0.79	1.99	1.00	0.10
Right Chute	Chute	12050	15000cfs	35.15	1986.39	1987.47	1986.85	1987.48	0.000235	0.62	57.12	91.46	0.14
Right Chute	Chute	12050	30000cfs	483.85	1986.39	1989.56	1987.82	1989.61	0.000329	1.82	265.55	107.03	0.20
Right Chute	Chute	12050	2yr 54200cfs	2231.65	1986.39	1992.90	1989.45	1993.05	0.000474	3.13	712.43	167.44	0.27
Right Chute	Chute	12050	100yr 128300cfs	12380.27	1986.39	1999.91	1994.30	2000.41	0.000491	5.79	2700.34	1225.05	0.32
Right Chute	Chute	12050	63000cfs	4037.86	1986.39	1994.88	1990.68	1995.10	0.000476	3.77	1072.56	194.78	0.28
Right Chute	Chute	10800	7000cfs	1.58	0.00	1985.00		1985.01	0.000777	0.83	1.91	1.00	0.11
Right Chute	Chute	10800	15000cfs	35.15	1985.51	1986.59	1986.38	1986.68	0.004594	2.46	14.30	26.58	0.59
Right Chute	Chute	10800	30000cfs	483.85	1985.51	1989.06		1989.12	0.000459	1.95	248.49	116.53	0.23
Right Chute	Chute	10800	2yr 54200cfs	2231.65	1985.51	1992.28		1992.46	0.000469	3.37	675.35	167.54	0.27
Right Chute	Chute	10800	100yr 128300cfs	12380.27	1985.51	1999.34		1999.81	0.000464	6.08	3934.21	1374.56	0.31
Right Chute	Chute	10800	63000cfs	4037.86	1985.51	1994.23		1994.50	0.000477	4.22	1053.65	214.12	0.29
Right Chute	Chute	9980	7000cfs	1.58	0.00	1983.04		1983.20	0.021437	3.19	0.49	1.00	0.80
Right Chute	Chute	9980	15000cfs	35.15	1984.26	1986.35		1986.35	0.000126	0.61	57.90	59.24	0.11
Right Chute	Chute	9980	30000cfs	483.85	1984.26	1988.79		1988.84	0.000267	1.71	283.63	107.82	0.19
Right Chute	Chute	9980	2yr 54200cfs	2231.65	1984.26	1991.90		1992.08	0.000443	3.42	676.06	170.70	0.27
Right Chute	Chute	9980	100yr 128300cfs	12380.27	1984.26	1998.97		1999.42	0.000467	6.09	3639.70	1108.00	0.31
Right Chute	Chute	9980	63000cfs	4037.86	1984.26	1993.81		1994.10	0.000495	4.37	1020.11	195.13	0.29
Right Chute	Chute	9477.659	7000cfs	1.58	1982.26	1983.07		1983.08	0.000041	0.19	8.17	20.10	0.05
Right Chute	Chute	9477.659	15000cfs	35.15	1982.26	1986.35		1986.35	0.000003	0.15	228.38	102.13	0.02
Right Chute	Chute	9477.659	30000cfs	483.85	1982.26	1988.76		1988.78	0.000048	0.96	502.87	122.96	0.08
Right Chute	Chute	9477.659	2yr 54200cfs	2231.65	1982.26	1991.83		1991.92	0.000180	2.42	922.73	151.86	0.17
Right Chute	Chute	9477.659	100yr 128300cfs	12380.27	1982.26	1998.81		1999.16	0.000452	4.83	2992.39	921.47	0.29
Right Chute	Chute	9477.659	63000cfs	4037.86	1982.26	1993.71		1993.88	0.000281	3.26	1239.93	182.77	0.22
Right Chute	Chute	8890	7000cfs	1.58	1982.26	1983.05		1983.05	0.000049	0.21	7.66	19.50	0.06
Right Chute	Chute	8890	15000cfs	35.15	1982.26	1986.34		1986.34	0.000003	0.17	212.21	83.51	0.02
Right Chute	Chute	8890	30000cfs	483.85	1982.26	1988.73		1988.75	0.000059	1.10	439.57	102.21	0.09
Right Chute	Chute	8890	2yr 54200cfs	2231.65	1982.26	1991.66		1991.80	0.000231	2.95	760.26	123.19	0.20
Right Chute	Chute	8890	100yr 128300cfs	12380.27	1982.26	1997.98		1998.80	0.000645	7.64	2352.87	661.47	0.37
Right Chute	Chute	8890	63000cfs	4037.86	1982.26	1993.41		1993.68	0.000349	4.23	1000.42	162.59	0.25
Right Chute	Chute	8010	7000cfs	1.58	1982.26	1983.00		1983.00	0.000071	0.24	6.68	18.28	0.07
Right Chute	Chute	8010	15000cfs	35.15	1982.26	1986.34		1986.34	0.000003	0.15	231.21	111.49	0.02
Right Chute	Chute	8010	30000cfs	483.85	1982.26	1988.69		1988.70	0.000046	0.95	510.33	124.91	0.08
Right Chute	Chute	8010	2yr 54200cfs	2231.65	1982.26	1991.50		1991.60	0.000190	2.52	886.65	144.23	0.18
Right Chute	Chute	8010	100yr 128300cfs	12380.27	1982.26	1997.61		1998.22	0.000532	6.44	2302.54	434.66	0.33
Right Chute	Chute	8010	63000cfs	4037.86	1982.26	1993.18		1993.37	0.000301	3.52	1164.21	186.72	0.23
Right Chute	Chute	7358.393	7000cfs	1.58	0.00	1982.89	1981.22	1982.90	0.000627	0.75	2.10	1.00	0.09
Right Chute	Chute	7358.393	15000cfs	35.15	0.00	1985.29	1984.18	1986.24	0.058314	7.80	4.50	1.00	0.65
Right Chute	Chute	7358.393	30000cfs	483.85	1986.40	1988.39	1988.14	1988.58	0.005139	3.53	136.93	183.19	0.67
Right Chute	Chute	7358.393	2yr 54200cfs	2231.65	1986.40	1991.28	1989.31	1991.40	0.000561	2.77	807.89	324.68	0.28
Right Chute	Chute	7358.393	100yr 128300cfs	12380.27	1986.40	1997.51	1992.38	1997.84	0.000391	4.78	3060.52	869.75	0.28
Right Chute	Chute	7358.393	63000cfs	4037.86	1986.40	1992.97	1990.05	1993.13	0.000431	3.22	1301.97	383.58	0.26
Right Chute	Chute	6770	7000cfs	1.58	0.00	1982.52		1982.53	0.000607	0.74	2.13	1.00	0.09
Right Chute	Chute	6770	15000cfs	35.15	1983.67	1985.50		1985.51	0.000213	0.70	50.11	61.30	0.14
Right Chute	Chute	6770	30000cfs	483.85	1983.67	1987.94		1987.99	0.000378	1.86	260.40	112.67	0.22
Right Chute	Chute	6770	2yr 54200cfs	2231.65	1983.67	1990.92		1991.08	0.000527	3.17	704.94	176.03	0.28
Right Chute	Chute	6770	100yr 128300cfs	12380.27	1983.67	1997.13		1997.57	0.000510	5.73	3249.89	861.38	0.32
Right Chute	Chute	6770	63000cfs	4037.86	1983.67	1992.58		1992.83	0.000558	4.01	1014.18	196.94	0.30
Right Chute	Chute	6017.052	7000cfs	1.58	0.00	1982.08	1980.32	1982.09	0.000568	0.72	2.19	1.00	0.09
Right Chute	Chute	6017.052	15000cfs	35.15	1983.67	1985.23	1984.55	1985.25	0.000640	1.20	29.19	36.06	0.24
Right Chute	Chute	6017.052	30000cfs	483.85	1983.67	1987.45	1986.29	1987.53	0.001106	2.26	213.76	154.52	0.34
Right Chute	Chute	6017.052	2yr 54200cfs	2231.65	1983.67	1990.55	1987.94	1990.68	0.000507	2.89	771.01	212.13	0.27
Right Chute	Chute	6017.052	100yr 128300cfs	12380.27	1983.67	1996.98	1991.99	1997.21	0.000319	4.05	4137.51	964.87	0.24
Right Chute	Chute	6017.052	63000cfs	4037.86	1983.67	1992.20	1988.91	1992.37	0.000606	3.38	1208.86	341.14	0.30
Right Chute	Chute	5380	7000cfs	1.58	0.00	1981.73		1981.74	0.000525	0.70	2.27	1.00	0.08
Right Chute	Chute	5380	15000cfs	35.15	1983.96	1985.17		1985.17	0.000049	0.41	85.00	76.06	0.07
Right Chute	Chute	5380	30000cfs	483.85	1983.96	1987.10		1987.16	0.000346	1.97	245.92	91.50	0.21
Right Chute	Chute	5380	2yr 54200cfs	2231.65	1983.96	1990.08		1990.27	0.000803	3.56	634.40	195.72	0.34
Right Chute	Chute	5380	100yr 128300cfs	12380.27	1983.96	1996.60		1996.96	0.000452	5.20	3486.60	989.12	0.30
Right Chute	Chute	5380	63000cfs	4037.86	1983.96	1991.64		1991.92	0.000816	4.28	981.52	260.13	0.35
Right Chute	Chute	4758.043	7000cfs	1.58	0.00	1981.42	1979.48	1981.43	0.000474	0.66	2.37	1.00	0.08
Right Chute	Chute	4758.043	15000cfs	35.15	1984.21	1985.08	1984.69	1985.10	0.000650	0.99	35.62	60.23	0.23
Right Chute	Chute	4758.043	30000cfs	483.85	1984.21	1986.55	1985.79	1986.68	0.002844	2.90	166.64	168.75	0.51
Right Chute	Chute	4758.043	2yr 54200cfs	2231.65	1984.21	1989.77	1987.35	1989.87	0.000464	2.57	869.91	271.93	0.25
Right Chute	Chute	4758.043	100yr 128300cfs	12380.27	1984.21	1996.49	1990.60	1996.69	0.000289	3.60	3574.93	558.99	0.23
Right Chute	Chute	4758.043	63000cfs	4037.86	1984.21	1991.38	1988.19	1991.52	0.000430	3.02	1335.86	308.29	0.26
Right Chute	Chute	3810	7000cfs	1.58	0.00	1981.02		1981.03	0.000386	0.61	2.60	1.00	0.07
Right Chute	Chute	3810	15000cfs	35.15	1982.71	1983.13	1983.12	1983.29	0.021790	3.18	11.06	58.97	1.29
Right Chute	Chute	3810	30000cfs	483.85	1982.71	1985.85		1985.91	0.000365	1.95	247.67	97.06	0.22
Right Chute	Chute	3810	2yr 54200cfs	2231.65	1982.71	1989.19		1989.38	0.000570	3.48	641.23	147.17	0.29
Right Chute	Chute	3810	100yr 128300cfs	12380.27	1982.71	1995.51		1996.22	0.000762	6.89	1976.28	234.32	0.39

HEC-RAS Plan: Tt_ExCond_Dam_Raised (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Right Chute	Chute	3810	63000cfs	4037.86	1982.71	1990.63		1990.96	0.000778	4.63	899.81	200.03	0.35
Right Chute	Chute	2770	7000cfs	1.58	1980.67	1980.67		1980.68	0.000293	0.53	2.95	0.06	0.01
Right Chute	Chute	2770	15000cfs	35.15	1980.67	1982.70		1982.71	0.000152	0.79	44.72	35.39	0.12
Right Chute	Chute	2770	30000cfs	483.85	1980.67	1985.43		1985.48	0.000456	1.79	269.91	141.90	0.23
Right Chute	Chute	2770	2yr 54200cfs	2231.65	1980.67	1988.79		1988.89	0.000357	2.54	887.49	245.57	0.23
Right Chute	Chute	2770	100yr 128300cfs	12380.27	1980.67	1995.19		1995.57	0.000388	5.07	2735.94	346.95	0.28
Right Chute	Chute	2770	63000cfs	4037.86	1980.67	1990.17		1990.34	0.000415	3.35	1255.96	276.12	0.26
Right Chute	Chute	1939.394	7000cfs	1.58	1980.06	1980.61	1977.59	1980.62	0.000033	0.13	11.91	43.77	0.04
Right Chute	Chute	1939.394	15000cfs	35.15	1980.06	1982.69	1980.62	1982.69	0.000006	0.21	164.01	78.08	0.03
Right Chute	Chute	1939.394	30000cfs	483.85	1980.06	1985.32	1981.60	1985.34	0.000079	1.23	394.87	98.16	0.11
Right Chute	Chute	1939.394	2yr 54200cfs	2231.65	1980.06	1988.49	1983.58	1988.63	0.000275	3.02	739.97	240.93	0.21
Right Chute	Chute	1939.394	100yr 128300cfs	12380.27	1980.06	1994.98	1989.40	1995.22	0.000348	4.74	4258.10	676.36	0.26
Right Chute	Chute	1939.394	63000cfs	4037.86	1980.06	1989.59	1985.00	1989.92	0.000580	4.60	877.96	314.73	0.31
Right Chute	Chute	1360	7000cfs	1.58	1980.06	1980.59	1977.20	1980.59	0.000044	0.15	10.39	38.39	0.05
Right Chute	Chute	1360	15000cfs	35.15	1980.06	1982.69	1980.62	1982.69	0.000007	0.23	155.62	82.63	0.03
Right Chute	Chute	1360	30000cfs	483.85	1980.06	1985.28	1981.76	1985.30	0.000084	1.17	413.40	114.95	0.11
Right Chute	Chute	1360	2yr 54200cfs	2231.65	1980.06	1988.36	1983.71	1988.46	0.000246	2.63	967.20	245.57	0.20
Right Chute	Chute	1360	100yr 128300cfs	12380.27	1980.06	1994.57	1989.04	1994.99	0.000425	5.65	3038.82	464.04	0.30
Right Chute	Chute	1360	63000cfs	4037.86	1980.06	1989.37	1985.04	1989.59	0.000452	3.86	1226.48	262.76	0.28
Right Chute	Chute	720	7000cfs	1.58	1978.59	1980.59		1980.59	0.000000	0.02	101.74	78.41	0.00
Right Chute	Chute	720	15000cfs	35.15	1978.59	1982.69		1982.69	0.000001	0.12	290.86	99.30	0.01
Right Chute	Chute	720	30000cfs	483.85	1978.59	1985.25		1985.26	0.000029	0.86	563.84	114.09	0.07
Right Chute	Chute	720	2yr 54200cfs	2231.65	1978.59	1988.25		1988.34	0.000147	2.38	939.22	137.51	0.16
Right Chute	Chute	720	100yr 128300cfs	12380.27	1978.59	1994.00		1994.66	0.000532	6.66	2249.76	332.75	0.34
Right Chute	Chute	720	63000cfs	4037.86	1978.59	1989.11		1989.34	0.000342	3.81	1069.25	166.63	0.25
Right Chute	Chute	338.7000	7000cfs	1.58	1978.09	1980.59	1976.52	1980.59	0.000000	0.01	143.47	87.23	0.00
Right Chute	Chute	338.7000	15000cfs	35.15	1978.09	1982.69	1978.70	1982.69	0.000001	0.10	346.52	103.65	0.01
Right Chute	Chute	338.7000	30000cfs	483.85	1978.09	1985.24	1979.81	1985.25	0.000023	0.75	641.62	130.55	0.06
Right Chute	Chute	338.7000	2yr 54200cfs	2231.65	1978.09	1988.22	1981.73	1988.29	0.000100	2.10	1112.61	181.41	0.13
Right Chute	Chute	338.7000	100yr 128300cfs	12380.27	1978.09	1993.92	1987.00	1994.44	0.000396	6.07	2602.39	317.57	0.29
Right Chute	Chute	338.7000	63000cfs	4037.86	1978.09	1989.04	1982.97	1989.21	0.000230	3.41	1262.36	184.89	0.21

HEC-RAS Plan: Tt_ExCond_Dam_Raised

River	Reach	River Sta	Profile	E.G. Elev	W.S. Elev	Vel Head	Frctn Loss	C & E Loss	Q Left	Q Channel	Q Right	Top Width
				(ft)	(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft)
Yellowstone	US Chute	56000.00	7000cfs	2001.89	2001.78	0.11	0.54	0.01		7000.00		760.08
Yellowstone	US Chute	56000.00	15000cfs	2004.20	2004.01	0.20	0.55	0.01		15000.00		839.61
Yellowstone	US Chute	56000.00	30000cfs	2007.03	2006.66	0.37	0.66	0.02	0.30	29999.37	0.34	902.39
Yellowstone	US Chute	56000.00	2yr 54200cfs	2010.24	2009.58	0.66	0.81	0.03	11.67	54171.21	17.12	1477.93
Yellowstone	US Chute	56000.00	100yr 128300cfs	2016.41	2014.70	1.72	1.35	0.06	86.38	127491.50	722.13	2440.67
Yellowstone	US Chute	56000.00	63000cfs	2011.29	2010.54	0.75	0.84	0.04	19.00	62942.96	38.04	1606.28
Yellowstone	US Chute	54003.06	7000cfs	2001.34	2001.25	0.09	0.48	0.00		7000.00		791.31
Yellowstone	US Chute	54003.06	15000cfs	2003.64	2003.48	0.16	0.52	0.01		15000.00		944.94
Yellowstone	US Chute	54003.06	30000cfs	2006.35	2006.05	0.30	0.59	0.03		30000.00		1075.72
Yellowstone	US Chute	54003.06	2yr 54200cfs	2009.39	2008.84	0.55	0.63	0.07		54187.18	12.82	1200.19
Yellowstone	US Chute	54003.06	100yr 128300cfs	2015.00	2013.49	1.51	0.82	0.30	2.77	128046.50	250.68	2828.10
Yellowstone	US Chute	54003.06	63000cfs	2010.42	2009.79	0.63	0.63	0.09		62970.98	29.02	1265.17
Yellowstone	US Chute	51999.34	7000cfs	2000.86	2000.78	0.08	0.82	0.03		7000.00		873.41
Yellowstone	US Chute	51999.34	15000cfs	2003.11	2002.99	0.13	1.01	0.05		15000.00		1333.16
Yellowstone	US Chute	51999.34	30000cfs	2005.73	2005.54	0.20	1.18	0.08		30000.00		1669.52
Yellowstone	US Chute	51999.34	2yr 54200cfs	2008.68	2008.38	0.30	1.10	0.12	2.97	54173.62	23.41	2000.31
Yellowstone	US Chute	51999.34	100yr 128300cfs	2013.88	2013.36	0.52	0.79	0.01	65.14	115730.10	12504.78	4381.81
Yellowstone	US Chute	51999.34	63000cfs	2009.70	2009.37	0.33	1.09	0.13	7.69	62916.68	75.63	2152.86
Yellowstone	US Chute	50001.19	7000cfs	2000.00	1999.67	0.33	1.96	0.04		6585.31	414.70	788.86
Yellowstone	US Chute	50001.19	15000cfs	2002.04	2001.37	0.67	2.10	0.13		13661.92	1338.08	885.56
Yellowstone	US Chute	50001.19	30000cfs	2004.46	2003.42	1.04	1.84	0.23		26285.58	3714.42	1128.89
Yellowstone	US Chute	50001.19	2yr 54200cfs	2007.46	2005.94	1.52	1.38	0.35		47489.89	6710.11	1462.73
Yellowstone	US Chute	50001.19	100yr 128300cfs	2013.08	2012.48	0.60	0.89	0.02	10.47	116828.00	11461.51	4506.15
Yellowstone	US Chute	50001.19	63000cfs	2008.49	2006.86	1.63	1.34	0.37		55506.88	7493.12	1622.12
Yellowstone	US Chute	47994.16	7000cfs	1998.01	1997.82	0.19	1.65	0.01		7000.00		900.94
Yellowstone	US Chute	47994.16	15000cfs	1999.82	1999.57	0.25	1.16	0.01		15000.00		1119.90
Yellowstone	US Chute	47994.16	30000cfs	2002.39	2002.10	0.29	0.88	0.00	0.00	29999.91	0.09	1316.55
Yellowstone	US Chute	47994.16	2yr 54200cfs	2005.73	2005.37	0.36	0.72	0.02	10.26	54161.10	28.63	1414.65
Yellowstone	US Chute	47994.16	100yr 128300cfs	2012.16	2011.64	0.52	0.76	0.05	153.92	124583.80	3562.25	4111.09
Yellowstone	US Chute	47994.16	63000cfs	2006.77	2006.39	0.38	0.70	0.02	20.03	62918.62	61.35	1463.21
Yellowstone	US Chute	46189.52	7000cfs	1996.35	1996.20	0.15	0.37	0.03		7000.00		804.65
Yellowstone	US Chute	46189.52	15000cfs	1998.64	1998.44	0.20	0.52	0.03		15000.00		871.54
Yellowstone	US Chute	46189.52	30000cfs	2001.50	2001.18	0.33	0.66	0.02		29999.95	0.05	881.69
Yellowstone	US Chute	46189.52	2yr 54200cfs	2004.99	2004.48	0.51	0.78	0.00	9.73	54181.23	9.04	928.34
Yellowstone	US Chute	46189.52	100yr 128300cfs	2011.35	2010.30	1.05	1.13	0.03	1128.97	122590.10	4580.94	3209.66
Yellowstone	US Chute	46189.52	63000cfs	2006.05	2005.48	0.58	0.82	0.01	20.58	62965.47	13.95	1055.43
Yellowstone	US Chute	43687.06	7000cfs	1995.95	1995.91	0.05	0.08	0.00	0.00	7000.00		621.14
Yellowstone	US Chute	43687.06	15000cfs	1998.10	1997.98	0.12	0.14	0.00	6.04	14993.48	0.49	675.59
Yellowstone	US Chute	43687.06	30000cfs	2000.82	2000.55	0.27	0.22	0.00	45.78	29939.01	15.21	690.28
Yellowstone	US Chute	43687.06	2yr 54200cfs	2004.20	2003.67	0.53	0.29	0.00	156.53	53925.21	118.26	795.10
Yellowstone	US Chute	43687.06	100yr 128300cfs	2010.19	2008.86	1.33	0.45	0.06	1145.22	120336.50	6818.31	3902.35
Yellowstone	US Chute	43687.06	63000cfs	2005.22	2004.59	0.63	0.31	0.00	205.94	62609.76	184.30	1027.67
Yellowstone	US Chute	42707.92	7000cfs	1995.88	1995.82	0.06	0.12	0.00		7000.00		638.01
Yellowstone	US Chute	42707.92	15000cfs	1997.96	1997.82	0.14	0.20	0.00	0.02	14999.98		731.92
Yellowstone	US Chute	42707.92	30000cfs	2000.60	2000.31	0.30	0.23	0.01	11.06	29987.59	1.35	773.30
Yellowstone	US Chute	42707.92	2yr 54200cfs	2003.91	2003.38	0.54	0.25	0.04	76.08	54027.10	96.82	961.96
Yellowstone	US Chute	42707.92	100yr 128300cfs	2009.68	2008.55	1.12	0.31	0.13	4671.98	116547.40	7080.64	5731.29
Yellowstone	US Chute	42707.92	63000cfs	2004.91	2004.29	0.62	0.26	0.05	108.07	62629.77	262.16	1170.83
Yellowstone	US Chute	41936.91	7000cfs	1995.75	1995.65	0.10	0.40	0.00		7000.00		773.14
Yellowstone	US Chute	41936.91	15000cfs	1997.76	1997.60	0.16	0.41	0.00		15000.00		1054.79
Yellowstone	US Chute	41936.91	30000cfs	2000.36	2000.10	0.26	0.38	0.00	0.01	29999.98	0.01	1069.95
Yellowstone	US Chute	41936.91	2yr 54200cfs	2003.62	2003.22	0.40	0.36	0.01	5.83	54191.92	2.26	1360.92
Yellowstone	US Chute	41936.91	100yr 128300cfs	2009.24	2008.55	0.69	0.40	0.01	7646.10	114938.60	5715.33	5801.89
Yellowstone	US Chute	41936.91	63000cfs	2004.60	2004.15	0.45	0.36	0.01	11.10	62983.80	5.09	1666.07
Yellowstone	US Chute	40894.62	7000cfs	1995.34	1995.22	0.12	0.62	0.00		7000.00		900.93
Yellowstone	US Chute	40894.62	15000cfs	1997.34	1997.15	0.19	0.48	0.00		15000.00		964.97
Yellowstone	US Chute	40894.62	30000cfs	1999.98	1999.67	0.30	0.42	0.00	5.08	29994.92		987.81
Yellowstone	US Chute	40894.62	2yr 54200cfs	2003.26	2002.79	0.47	0.38	0.00	54.59	54141.84	3.56	1122.97
Yellowstone	US Chute	40894.62	100yr 128300cfs	2008.83	2008.17	0.66	0.38	0.00	14166.94	112447.60	1685.47	5966.63
Yellowstone	US Chute	40894.62	63000cfs	2004.24	2003.71	0.53	0.38	0.01	89.40	62899.66	10.94	1581.33
Yellowstone	US Chute	39877.04	7000cfs	1994.72	1994.56	0.16	0.22	0.02		7000.00		820.96
Yellowstone	US Chute	39877.04	15000cfs	1996.86	1996.65	0.21	0.24	0.02		15000.00		949.96
Yellowstone	US Chute	39877.04	30000cfs	1999.56	1999.24	0.32	0.26	0.01	7.92	29991.58	0.50	1065.15
Yellowstone	US Chute	39877.04	2yr 54200cfs	2002.88	2002.42	0.46	0.28	0.00	253.23	53935.78	11.00	1471.83
Yellowstone	US Chute	39877.04	100yr 128300cfs	2008.45	2007.78	0.66	0.26	0.13	19591.65	108486.70	221.61	5883.30
Yellowstone	US Chute	39877.04	63000cfs	2003.85	2003.35	0.50	0.28	0.00	918.65	62063.79	17.56	2399.37
Yellowstone	US Chute	39170.03	7000cfs	1994.47	1994.39	0.08	0.09	0.01		7000.00		721.61
Yellowstone	US Chute	39170.03	15000cfs	1996.60	1996.45	0.15	0.15	0.01		14994.25	5.75	822.11

HEC-RAS Plan: Tt_ExCond_Dam_Raised (Continued)

River	Reach	River Sta	Profile	E.G. Elev	W.S. Elev	Vel Head	Frctn Loss	C & E Loss	Q Left	Q Channel	Q Right	Top Width
				(ft)	(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft)
Yellowstone	US Chute	39170.03	30000cfs	1999.30	1999.00	0.29	0.23	0.00		29964.23	35.77	914.22
Yellowstone	US Chute	39170.03	2yr 54200cfs	2002.60	2002.12	0.48	0.32	0.01		54085.60	114.40	1394.12
Yellowstone	US Chute	39170.03	100yr 128300cfs	2008.06	2007.83	0.23	0.36	0.07		128117.80	182.25	6069.18
Yellowstone	US Chute	39170.03	63000cfs	2003.57	2003.04	0.53	0.35	0.01		62853.02	146.98	1970.31
Yellowstone	US Chute	38214.43	7000cfs	1994.37	1994.33	0.04	0.14	0.01		6999.99	0.01	618.01
Yellowstone	US Chute	38214.43	15000cfs	1996.44	1996.32	0.12	0.22	0.01	6.17	14992.59	1.23	677.41
Yellowstone	US Chute	38214.43	30000cfs	1999.06	1998.78	0.28	0.30	0.00	139.77	29850.28	9.95	789.05
Yellowstone	US Chute	38214.43	2yr 54200cfs	2002.27	2001.71	0.56	0.35	0.04	810.68	53348.54	40.79	1136.23
Yellowstone	US Chute	38214.43	100yr 128300cfs	2007.62	2006.65	0.97	0.39	0.13	21434.46	104328.30	2537.22	6652.66
Yellowstone	US Chute	38214.43	63000cfs	2003.21	2002.54	0.67	0.36	0.07	1157.74	61785.40	56.87	1908.30
Yellowstone	DS Chute	19210.21	7000cfs	1980.53	1980.39	0.14	0.51	0.00		5631.56		625.30
Yellowstone	DS Chute	19210.21	15000cfs	1982.61	1982.37	0.24	0.56	0.01		13631.56		922.90
Yellowstone	DS Chute	19210.21	30000cfs	1985.16	1984.81	0.35	0.53	0.01		28626.00		1319.81
Yellowstone	DS Chute	19210.21	2yr 54200cfs	1988.21	1987.76	0.44	0.42	0.01	0.27	52827.03	0.10	1485.36
Yellowstone	DS Chute	19210.21	100yr 128300cfs	1994.37	1993.56	0.81	0.33	0.05	337.60	126472.80	116.00	4751.35
Yellowstone	DS Chute	19210.21	63000cfs	1989.14	1988.66	0.48	0.39	0.02	2.15	61622.58	1.61	1676.89
Yellowstone	DS Chute	18370.67	7000cfs	1980.02	1979.89	0.14	0.60	0.02		5631.56		790.42
Yellowstone	DS Chute	18370.67	15000cfs	1982.04	1981.82	0.22	0.71	0.01		13631.56		1017.39
Yellowstone	DS Chute	18370.67	30000cfs	1984.61	1984.30	0.31	0.71	0.00		28626.00		1174.78
Yellowstone	DS Chute	18370.67	2yr 54200cfs	1987.77	1987.37	0.40	0.67	0.01	0.05	52827.34		1731.62
Yellowstone	DS Chute	18370.67	100yr 128300cfs	1993.99	1993.34	0.65	0.57	0.02	441.38	126465.60	19.37	4836.33
Yellowstone	DS Chute	18370.67	63000cfs	1988.73	1988.32	0.42	0.62	0.01	0.78	61625.55	0.01	1806.66
Yellowstone	DS Chute	17009.26	7000cfs	1979.41	1979.32	0.08	0.40	0.01		5631.56		775.00
Yellowstone	DS Chute	17009.26	15000cfs	1981.32	1981.14	0.19	0.52	0.01		13631.56		855.42
Yellowstone	DS Chute	17009.26	30000cfs	1983.90	1983.56	0.34	0.51	0.00		28626.00		991.92
Yellowstone	DS Chute	17009.26	2yr 54200cfs	1987.09	1986.58	0.51	0.43	0.02	0.10	52827.24	0.05	1189.06
Yellowstone	DS Chute	17009.26	100yr 128300cfs	1993.40	1992.82	0.58	0.36	0.00	13241.04	113654.10	31.19	5289.45
Yellowstone	DS Chute	17009.26	63000cfs	1988.10	1987.53	0.56	0.41	0.03	1.02	61624.70	0.64	1306.90
Yellowstone	DS Chute	16125.84	7000cfs	1979.00	1978.86	0.14	1.82	0.02		5631.56		774.73
Yellowstone	DS Chute	16125.84	15000cfs	1980.80	1980.54	0.26	1.27	0.00		13631.56		982.59
Yellowstone	DS Chute	16125.84	30000cfs	1983.38	1983.03	0.36	0.79	0.00		28626.00		1210.53
Yellowstone	DS Chute	16125.84	2yr 54200cfs	1986.63	1986.20	0.43	0.64	0.01	1.36	52822.88	3.16	1577.00
Yellowstone	DS Chute	16125.84	100yr 128300cfs	1993.04	1992.47	0.57	0.52	0.04	8298.34	118540.40	87.58	3014.71
Yellowstone	DS Chute	16125.84	63000cfs	1987.66	1987.20	0.46	0.59	0.01	3.89	61614.53	7.93	1760.47
Yellowstone	DS Chute	14768.24	7000cfs	1977.16	1976.79	0.38	1.89	0.07		5631.56		675.73
Yellowstone	DS Chute	14768.24	15000cfs	1979.52	1979.23	0.30	1.43	0.01		13631.56		938.80
Yellowstone	DS Chute	14768.24	30000cfs	1982.59	1982.24	0.35	1.18	0.01	152.86	28473.14		1008.35
Yellowstone	DS Chute	14768.24	2yr 54200cfs	1985.99	1985.48	0.51	1.01	0.01	539.15	52250.68	37.57	1099.16
Yellowstone	DS Chute	14768.24	100yr 128300cfs	1992.48	1991.53	0.95	0.88	0.06	4914.35	119854.20	2157.81	3230.24
Yellowstone	DS Chute	14768.24	63000cfs	1987.06	1986.50	0.56	0.98	0.01	704.87	60817.93	103.55	1169.14
Yellowstone	DS Chute	12602.25	7000cfs	1975.20	1975.05	0.15	1.95	0.01		5631.56		464.46
Yellowstone	DS Chute	12602.25	15000cfs	1978.09	1977.81	0.28	1.74	0.03		13631.56		578.08
Yellowstone	DS Chute	12602.25	30000cfs	1981.40	1980.98	0.43	2.05	0.03		28626.00		814.15
Yellowstone	DS Chute	12602.25	2yr 54200cfs	1984.96	1984.33	0.63	2.04	0.03	100.29	52724.03	3.08	925.06
Yellowstone	DS Chute	12602.25	100yr 128300cfs	1991.55	1990.78	0.76	1.36	0.05	22201.30	104666.50	58.51	4698.72
Yellowstone	DS Chute	12602.25	63000cfs	1986.07	1985.36	0.70	2.04	0.03	217.36	61401.77	7.21	1030.95
Yellowstone	DS Chute	7708.504	7000cfs	1973.25	1973.14	0.11	0.29	0.02		5631.56		629.56
Yellowstone	DS Chute	7708.504	15000cfs	1976.31	1976.15	0.16	0.36	0.02		13631.56		746.33
Yellowstone	DS Chute	7708.504	30000cfs	1979.32	1979.01	0.31	0.55	0.02		28612.34	13.66	784.79
Yellowstone	DS Chute	7708.504	2yr 54200cfs	1982.90	1982.36	0.54	0.72	0.02	23.90	52680.36	123.14	809.35
Yellowstone	DS Chute	7708.504	100yr 128300cfs	1990.14	1989.53	0.60	0.78	0.06	26283.71	100244.20	398.40	5153.00
Yellowstone	DS Chute	7708.504	63000cfs	1984.01	1983.39	0.62	0.77	0.01	48.73	61403.63	173.99	819.87
Yellowstone	DS Chute	5162.571	7000cfs	1972.94	1972.90	0.03	0.13	0.01		5631.56		627.98
Yellowstone	DS Chute	5162.571	15000cfs	1975.93	1975.84	0.09	0.18	0.01		13631.56		646.08
Yellowstone	DS Chute	5162.571	30000cfs	1978.75	1978.51	0.23	0.27	0.01		28626.00		694.10
Yellowstone	DS Chute	5162.571	2yr 54200cfs	1982.16	1981.68	0.48	0.35	0.00	5.35	52821.05	1.00	807.25
Yellowstone	DS Chute	5162.571	100yr 128300cfs	1989.29	1988.09	1.21	0.43	0.10	3766.69	123093.90	65.75	3617.34
Yellowstone	DS Chute	5162.571	63000cfs	1983.23	1982.65	0.57	0.36	0.00	28.02	61595.14	3.18	885.45
Yellowstone	DS Chute	3996.727	7000cfs	1972.80	1972.69	0.11	0.63	0.00		5631.56		596.79
Yellowstone	DS Chute	3996.727	15000cfs	1975.75	1975.59	0.16	0.63	0.01		13631.57		854.69
Yellowstone	DS Chute	3996.727	30000cfs	1978.47	1978.16	0.31	0.66	0.02	0.10	28625.90		900.25
Yellowstone	DS Chute	3996.727	2yr 54200cfs	1981.81	1981.29	0.52	0.68	0.04	21.49	52804.96	0.96	981.40
Yellowstone	DS Chute	3996.727	100yr 128300cfs	1988.77	1987.88	0.89	0.67	0.05	9666.21	117195.40	64.78	4557.01
Yellowstone	DS Chute	3996.727	63000cfs	1982.86	1982.27	0.59	0.68	0.04	40.86	61582.24	3.25	1047.47
Yellowstone	DS Chute	2000.000	7000cfs	1972.17	1972.08	0.09				5631.56		661.88
Yellowstone	DS Chute	2000.000	15000cfs	1975.11	1974.97	0.13				13631.56		1043.23
Yellowstone	DS Chute	2000.000	30000cfs	1977.79	1977.55	0.24				28626.00		1077.12
Yellowstone	DS Chute	2000.000	2yr 54200cfs	1981.10	1980.70	0.39			4.84	52817.30	5.26	1125.87

HEC-RAS Plan: Tt_ExCond_Dam_Raised (Continued)

River	Reach	River Sta	Profile	E.G. Elev	W.S. Elev	Vel Head	Frctn Loss	C & E Loss	Q Left	Q Channel	Q Right	Top Width
				(ft)	(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft)
Yellowstone	DS Chute	2000.000	100yr 128300cfs	1988.06	1987.32	0.73			5525.68	121279.40	121.25	1742.61
Yellowstone	DS Chute	2000.000	63000cfs	1982.14	1981.69	0.45			14.01	61600.90	11.44	1169.22
Right Chute	Chute	24560	7000cfs	1994.22	1994.21	0.01	0.43	0.00		1.58		1.00
Right Chute	Chute	24560	15000cfs	1996.22	1995.98	0.24	0.78	0.07		35.15		21.16
Right Chute	Chute	24560	30000cfs	1998.76	1997.86	0.90	0.61	0.26		483.85		36.47
Right Chute	Chute	24560	2yr 54200cfs	2001.88	2001.14	0.74	0.51	0.18		1772.83	458.82	401.98
Right Chute	Chute	24560	100yr 128300cfs	2007.10	2006.92	0.19	0.21	0.01	31.13	3986.64	8362.50	1112.82
Right Chute	Chute	24560	63000cfs	2002.78	2002.24	0.54	0.50	0.10		2355.61	1682.24	652.39
Right Chute	Chute	23960	7000cfs	1993.80	1993.78	0.01	0.95	0.00		1.58		1.00
Right Chute	Chute	23960	15000cfs	1994.52	1994.51	0.01	0.74	0.00		35.15		86.94
Right Chute	Chute	23960	30000cfs	1996.79	1996.74	0.05	0.84	0.00		483.85		121.02
Right Chute	Chute	23960	2yr 54200cfs	2000.22	2000.07	0.15	0.88	0.01		2200.12	31.52	237.47
Right Chute	Chute	23960	100yr 128300cfs	2006.88	2006.73	0.16	0.73	0.07	1.11	6826.70	5552.47	1560.57
Right Chute	Chute	23960	63000cfs	2002.18	2001.97	0.21	0.93	0.02		3713.38	324.48	616.14
Right Chute	Chute	22780.84	7000cfs	1992.85	1992.84	0.00	0.42	0.00		1.58		20.21
Right Chute	Chute	22780.84	15000cfs	1993.79	1993.77	0.01	0.50	0.00		35.15		59.56
Right Chute	Chute	22780.84	30000cfs	1995.94	1995.84	0.10	0.62	0.00		483.85		81.00
Right Chute	Chute	22780.84	2yr 54200cfs	1999.33	1999.03	0.29	0.63	0.03	54.27	2167.27	10.10	158.44
Right Chute	Chute	22780.84	100yr 128300cfs	2006.08	2005.23	0.86	0.54	0.14	2836.71	9149.60	393.96	375.90
Right Chute	Chute	22780.84	63000cfs	2001.23	2000.79	0.44	0.64	0.06	339.93	3658.14	39.79	255.24
Right Chute	Chute	21990	7000cfs	1992.43	1992.42	0.01	0.45	0.00		1.58		11.95
Right Chute	Chute	21990	15000cfs	1993.29	1993.27	0.03	0.35	0.00		35.15		47.96
Right Chute	Chute	21990	30000cfs	1995.32	1995.22	0.10	0.27	0.02		483.85		100.04
Right Chute	Chute	21990	2yr 54200cfs	1998.67	1998.47	0.20	0.26	0.03		2231.35	0.29	189.30
Right Chute	Chute	21990	100yr 128300cfs	2005.40	2005.00	0.40	0.19	0.03	249.41	11938.34	192.52	465.57
Right Chute	Chute	21990	63000cfs	2000.53	2000.28	0.24	0.26	0.03		4022.27	15.58	264.56
Right Chute	Chute	21530	7000cfs	1991.98	1991.97	0.01	0.39	0.00		1.58		1.59
Right Chute	Chute	21530	15000cfs	1992.94	1992.93	0.01	0.04	0.00		35.15		69.37
Right Chute	Chute	21530	30000cfs	1995.03	1994.98	0.05	0.17	0.00		483.85		139.46
Right Chute	Chute	21530	2yr 54200cfs	1998.38	1998.27	0.11	0.21	0.02		2231.65		220.08
Right Chute	Chute	21530	100yr 128300cfs	2005.18	2004.88	0.31	0.23	0.07	68.16	12176.30	135.81	595.61
Right Chute	Chute	21530	63000cfs	2000.24	2000.10	0.14	0.22	0.03	0.35	4033.96	3.54	300.81
Right Chute	Chute	21109.99	7000cfs	1991.59	1991.59	0.00	0.40	0.00		1.58		46.04
Right Chute	Chute	21109.99	15000cfs	1992.90	1992.89	0.00	0.06	0.01		35.15		66.97
Right Chute	Chute	21109.99	30000cfs	1994.86	1994.78	0.07	0.31	0.01		483.85		77.71
Right Chute	Chute	21109.99	2yr 54200cfs	1998.15	1997.88	0.27	0.22	0.05	52.41	2131.65	47.58	203.13
Right Chute	Chute	21109.99	100yr 128300cfs	2004.89	2003.93	0.96	0.23	0.20	1343.36	9336.39	1700.52	579.80
Right Chute	Chute	21109.99	63000cfs	1999.99	1999.58	0.41	0.21	0.08	217.78	3550.39	269.69	232.11
Right Chute	Chute	20712.01	7000cfs	1991.18	1991.16	0.02	0.45	0.01		1.58		1.00
Right Chute	Chute	20712.01	15000cfs	1992.83	1992.72	0.11	0.68	0.03		35.15		64.22
Right Chute	Chute	20712.01	30000cfs	1994.54	1994.42	0.13	0.74	0.01		483.85		138.64
Right Chute	Chute	20712.01	2yr 54200cfs	1997.88	1997.78	0.11	0.39	0.00		2231.65		260.96
Right Chute	Chute	20712.01	100yr 128300cfs	2004.46	2004.16	0.30	0.31	0.02	33.48	12343.81	2.98	390.84
Right Chute	Chute	20712.01	63000cfs	1999.70	1999.56	0.14	0.31	0.01		4037.86		289.81
Right Chute	Chute	20002.85	7000cfs	1990.72	1990.72	0.00	0.61	0.00		1.58		25.28
Right Chute	Chute	20002.85	15000cfs	1991.58	1991.57	0.01	0.65	0.00		35.15		59.23
Right Chute	Chute	20002.85	30000cfs	1993.79	1993.69	0.10	0.67	0.00		483.85		95.47
Right Chute	Chute	20002.85	2yr 54200cfs	1997.49	1997.35	0.15	0.67	0.01	0.00	2231.64	0.01	213.58
Right Chute	Chute	20002.85	100yr 128300cfs	2004.13	2003.63	0.50	0.59	0.01	404.23	11913.10	62.95	553.89
Right Chute	Chute	20002.85	63000cfs	1999.39	1999.19	0.20	0.64	0.01	14.99	4020.00	2.87	235.68
Right Chute	Chute	19020	7000cfs	1990.11	1990.10	0.02	0.65	0.00		1.58		1.00
Right Chute	Chute	19020	15000cfs	1990.93	1990.90	0.03	0.77	0.01		35.15		60.27
Right Chute	Chute	19020	30000cfs	1993.13	1993.03	0.09	0.34	0.01		483.85		91.81
Right Chute	Chute	19020	2yr 54200cfs	1996.82	1996.58	0.23	0.41	0.03		2231.65		136.26
Right Chute	Chute	19020	100yr 128300cfs	2003.53	2003.05	0.48	0.41	0.03	217.31	12089.18	73.78	764.75
Right Chute	Chute	19020	63000cfs	1998.74	1998.45	0.29	0.50	0.03		4037.86		238.23
Right Chute	Chute	18233.44	7000cfs	1989.46	1989.46	0.00	1.19	0.01		1.58		29.74
Right Chute	Chute	18233.44	15000cfs	1990.15	1990.14	0.01	0.85	0.01		35.15		71.78
Right Chute	Chute	18233.44	30000cfs	1992.77	1992.73	0.05	0.37	0.00		483.85		111.06
Right Chute	Chute	18233.44	2yr 54200cfs	1996.37	1996.25	0.12	0.39	0.00		2231.65		185.13
Right Chute	Chute	18233.44	100yr 128300cfs	2003.09	2002.72	0.36	0.32	0.03	38.88	11477.26	864.14	1100.50
Right Chute	Chute	18233.44	63000cfs	1998.21	1998.03	0.18	0.43	0.00	0.09	4037.76		237.68
Right Chute	Chute	17410	7000cfs	1988.27	1988.18	0.09	1.52	0.03		1.58		1.00
Right Chute	Chute	17410	15000cfs	1989.29	1989.22	0.06	1.35	0.02		35.15		29.90
Right Chute	Chute	17410	30000cfs	1992.40	1992.31	0.09	1.86	0.00		483.85		113.95
Right Chute	Chute	17410	2yr 54200cfs	1995.98	1995.82	0.16	1.62	0.00		2231.65		196.91
Right Chute	Chute	17410	100yr 128300cfs	2002.74	2002.47	0.26	1.06	0.02	0.80	10757.36	1622.11	1227.38
Right Chute	Chute	17410	63000cfs	1997.78	1997.56	0.22	1.50	0.00		4037.86		234.54

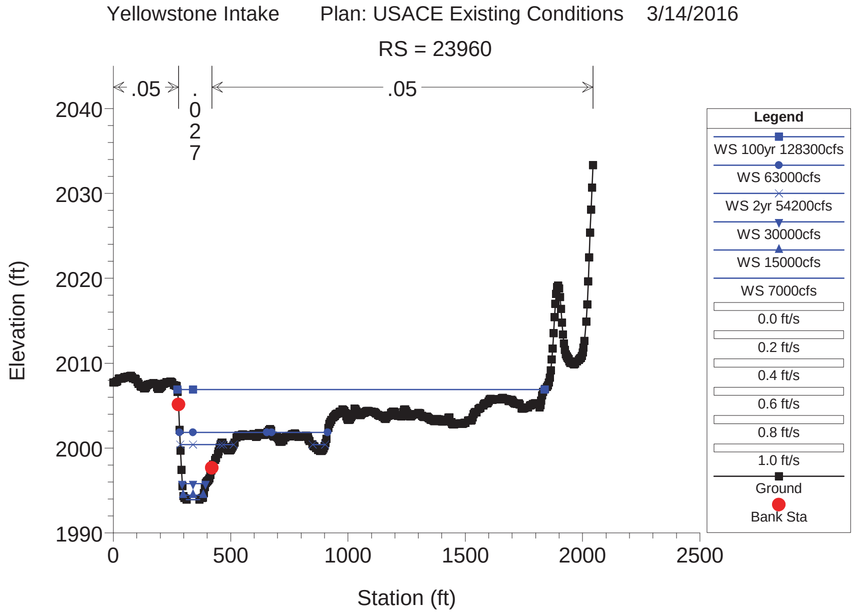
HEC-RAS Plan: Tt_ExCond_Dam_Raised (Continued)

River	Reach	River Sta	Profile	E.G. Elev	W.S. Elev	Vel Head	Frctn Loss	C & E Loss	Q Left	Q Channel	Q Right	Top Width
				(ft)	(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft)
Right Chute	Chute	15003.62	7000cfs	1986.73	1986.73	0.00	0.11	0.00		1.58		18.91
Right Chute	Chute	15003.62	15000cfs	1987.92	1987.90	0.01	0.08	0.00		35.15		40.70
Right Chute	Chute	15003.62	30000cfs	1990.54	1990.42	0.11	0.24	0.03		483.85		71.74
Right Chute	Chute	15003.62	2yr 54200cfs	1994.35	1994.17	0.18	0.43	0.03		2231.65		190.04
Right Chute	Chute	15003.62	100yr 128300cfs	2001.66	2001.24	0.42	0.37	0.03	55.32	12324.95		354.84
Right Chute	Chute	15003.62	63000cfs	1996.27	1996.04	0.23	0.38	0.03		4037.86		228.17
Right Chute	Chute	14030	7000cfs	1986.62	1986.62	0.00	0.08	0.00		1.58		45.77
Right Chute	Chute	14030	15000cfs	1987.83	1987.83	0.00	0.03	0.00		35.15		102.57
Right Chute	Chute	14030	30000cfs	1990.27	1990.25	0.03	0.12	0.00		483.85		121.68
Right Chute	Chute	14030	2yr 54200cfs	1993.90	1993.81	0.09	0.25	0.01		2231.53	0.12	232.67
Right Chute	Chute	14030	100yr 128300cfs	2001.26	2000.95	0.32	0.24	0.01	152.02	12153.06	75.19	312.01
Right Chute	Chute	14030	63000cfs	1995.86	1995.73	0.13	0.22	0.01	3.13	4030.84	3.89	258.63
Right Chute	Chute	13387.50	7000cfs	1986.55	1986.55	0.00	0.34	0.00		1.58		36.06
Right Chute	Chute	13387.50	15000cfs	1987.80	1987.80	0.00	0.14	0.00		35.15		62.20
Right Chute	Chute	13387.50	30000cfs	1990.15	1990.08	0.06	0.38	0.00		483.85		83.53
Right Chute	Chute	13387.50	2yr 54200cfs	1993.64	1993.50	0.14	0.43	0.00		2231.65		201.95
Right Chute	Chute	13387.50	100yr 128300cfs	2001.01	2000.63	0.39	0.41	0.01	0.01	12380.27		321.65
Right Chute	Chute	13387.50	63000cfs	1995.63	1995.44	0.19	0.37	0.00		4037.86		224.06
Right Chute	Chute	12441.82	7000cfs	1986.21	1986.20	0.01	0.27	0.00		1.58		1.00
Right Chute	Chute	12441.82	15000cfs	1987.67	1987.65	0.02	0.19	0.00		35.15		79.80
Right Chute	Chute	12441.82	30000cfs	1989.77	1989.71	0.06	0.16	0.00		483.85		116.73
Right Chute	Chute	12441.82	2yr 54200cfs	1993.21	1993.07	0.14	0.16	0.00	89.84	2138.30	3.51	269.86
Right Chute	Chute	12441.82	100yr 128300cfs	2000.59	2000.24	0.35	0.16	0.01	2997.77	9141.51	241.00	814.99
Right Chute	Chute	12441.82	63000cfs	1995.26	1995.07	0.19	0.16	0.00	453.04	3555.69	29.12	285.37
Right Chute	Chute	12050	7000cfs	1985.94	1985.93	0.01	0.92	0.00		1.58		1.00
Right Chute	Chute	12050	15000cfs	1987.48	1987.47	0.01	0.78	0.01		35.15		91.46
Right Chute	Chute	12050	30000cfs	1989.61	1989.56	0.05	0.48	0.00		483.85		107.03
Right Chute	Chute	12050	2yr 54200cfs	1993.05	1992.90	0.15	0.59	0.00		2231.65		167.44
Right Chute	Chute	12050	100yr 128300cfs	2000.41	1999.91	0.50	0.60	0.01	417.34	11944.22	18.72	1225.05
Right Chute	Chute	12050	63000cfs	1995.10	1994.88	0.22	0.60	0.00	0.47	4037.39		194.78
Right Chute	Chute	10800	7000cfs	1985.01	1985.00	0.01	1.80	0.01		1.58		1.00
Right Chute	Chute	10800	15000cfs	1986.68	1986.59	0.09	0.30	0.03		35.15		26.58
Right Chute	Chute	10800	30000cfs	1989.12	1989.06	0.06	0.28	0.00		483.85		116.53
Right Chute	Chute	10800	2yr 54200cfs	1992.46	1992.28	0.18	0.37	0.00		2225.43	6.22	167.54
Right Chute	Chute	10800	100yr 128300cfs	1999.81	1999.34	0.47	0.38	0.00	150.19	10004.64	2225.44	1374.56
Right Chute	Chute	10800	63000cfs	1994.50	1994.23	0.27	0.40	0.00	0.19	3925.36	112.31	214.12
Right Chute	Chute	9980	7000cfs	1983.20	1983.04	0.16	0.08	0.05		1.58		1.00
Right Chute	Chute	9980	15000cfs	1986.35	1986.35	0.01	0.00	0.00		35.15		59.24
Right Chute	Chute	9980	30000cfs	1988.84	1988.79	0.05	0.05	0.01		483.85		107.82
Right Chute	Chute	9980	2yr 54200cfs	1992.08	1991.90	0.18	0.13	0.03		2219.55	12.09	170.70
Right Chute	Chute	9980	100yr 128300cfs	1999.42	1998.97	0.45	0.23	0.03	75.12	9638.43	2666.72	1108.00
Right Chute	Chute	9980	63000cfs	1994.10	1993.81	0.29	0.18	0.04		3908.60	129.26	195.13
Right Chute	Chute	9477.659	7000cfs	1983.08	1983.07	0.00	0.03	0.00		1.58		20.10
Right Chute	Chute	9477.659	15000cfs	1986.35	1986.35	0.00	0.00	0.00		35.15		102.13
Right Chute	Chute	9477.659	30000cfs	1988.78	1988.76	0.01	0.03	0.00		483.85		122.96
Right Chute	Chute	9477.659	2yr 54200cfs	1991.92	1991.83	0.09	0.12	0.00		2231.65		151.86
Right Chute	Chute	9477.659	100yr 128300cfs	1999.16	1998.81	0.35	0.31	0.05	303.48	12076.79		921.47
Right Chute	Chute	9477.659	63000cfs	1993.88	1993.71	0.16	0.18	0.01		4037.86		182.77
Right Chute	Chute	8890	7000cfs	1983.05	1983.05	0.00	0.05	0.00		1.58		19.50
Right Chute	Chute	8890	15000cfs	1986.34	1986.34	0.00	0.00	0.00		35.15		83.51
Right Chute	Chute	8890	30000cfs	1988.75	1988.73	0.02	0.05	0.00		483.85		102.21
Right Chute	Chute	8890	2yr 54200cfs	1991.80	1991.66	0.14	0.18	0.01	0.91	2230.28	0.46	123.19
Right Chute	Chute	8890	100yr 128300cfs	1998.80	1997.98	0.82	0.51	0.06	1216.39	11100.09	63.79	661.47
Right Chute	Chute	8890	63000cfs	1993.68	1993.41	0.28	0.29	0.02	28.22	4005.15	4.49	162.59
Right Chute	Chute	8010	7000cfs	1983.00	1983.00	0.00	0.10	0.00		1.58		18.28
Right Chute	Chute	8010	15000cfs	1986.34	1986.34	0.00	0.01	0.09		35.15		111.49
Right Chute	Chute	8010	30000cfs	1988.70	1988.69	0.01	0.10	0.02		483.85		124.91
Right Chute	Chute	8010	2yr 54200cfs	1991.60	1991.50	0.10	0.20	0.00		2231.65		144.23
Right Chute	Chute	8010	100yr 128300cfs	1998.22	1997.61	0.62	0.30	0.09	438.64	11892.47	49.16	434.66
Right Chute	Chute	8010	63000cfs	1993.37	1993.18	0.19	0.23	0.01	8.78	4029.02	0.06	186.72
Right Chute	Chute	7358.393	7000cfs	1982.90	1982.89	0.01	0.36	0.00		1.58		1.00
Right Chute	Chute	7358.393	15000cfs	1986.24	1985.29	0.95	0.45	0.28		35.15		1.00
Right Chute	Chute	7358.393	30000cfs	1988.58	1988.39	0.19	0.55	0.04		483.85		183.19
Right Chute	Chute	7358.393	2yr 54200cfs	1991.40	1991.28	0.12	0.32	0.00	0.14	2230.70	0.82	324.68
Right Chute	Chute	7358.393	100yr 128300cfs	1997.84	1997.51	0.33	0.26	0.01	356.07	11590.94	433.25	869.75
Right Chute	Chute	7358.393	63000cfs	1993.13	1992.97	0.16	0.29	0.01	6.67	3995.51	35.68	383.58
Right Chute	Chute	6770	7000cfs	1982.53	1982.52	0.01	0.44	0.00		1.58		1.00

HEC-RAS Plan: Tt_ExCond_Dam_Raised (Continued)

River	Reach	River Sta	Profile	E.G. Elev	W.S. Elev	Vel Head	Frctn Loss	C & E Loss	Q Left	Q Channel	Q Right	Top Width
				(ft)	(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft)
Right Chute	Chute	6770	15000cfs	1985.51	1985.50	0.01	0.26	0.00		35.15		61.30
Right Chute	Chute	6770	30000cfs	1987.99	1987.94	0.05	0.45	0.00		483.85		112.67
Right Chute	Chute	6770	2yr 54200cfs	1991.08	1990.92	0.16	0.39	0.01	0.00	2231.65		176.03
Right Chute	Chute	6770	100yr 128300cfs	1997.57	1997.13	0.44	0.30	0.06	90.33	10583.24	1706.71	861.38
Right Chute	Chute	6770	63000cfs	1992.83	1992.58	0.25	0.44	0.02	3.18	4033.97	0.70	196.94
Right Chute	Chute	6017.052	7000cfs	1982.09	1982.08	0.01	0.35	0.00		1.58		1.00
Right Chute	Chute	6017.052	15000cfs	1985.25	1985.23	0.02	0.08	0.01		35.15		36.06
Right Chute	Chute	6017.052	30000cfs	1987.53	1987.45	0.08	0.36	0.01		483.85		154.52
Right Chute	Chute	6017.052	2yr 54200cfs	1990.68	1990.55	0.13	0.40	0.01		2231.65		212.13
Right Chute	Chute	6017.052	100yr 128300cfs	1997.21	1996.98	0.23	0.24	0.01	40.52	10894.65	1445.11	964.87
Right Chute	Chute	6017.052	63000cfs	1992.37	1992.20	0.18	0.45	0.01		4032.52	5.34	341.14
Right Chute	Chute	5380	7000cfs	1981.74	1981.73	0.01	0.31	0.00		1.58		1.00
Right Chute	Chute	5380	15000cfs	1985.17	1985.17	0.00	0.07	0.00		35.15		76.06
Right Chute	Chute	5380	30000cfs	1987.16	1987.10	0.06	0.47	0.01		483.85		91.50
Right Chute	Chute	5380	2yr 54200cfs	1990.27	1990.08	0.20	0.37	0.03		2226.57	5.08	195.72
Right Chute	Chute	5380	100yr 128300cfs	1996.96	1996.60	0.35	0.22	0.05	75.23	10207.15	2097.90	989.12
Right Chute	Chute	5380	63000cfs	1991.92	1991.64	0.28	0.36	0.04		3984.55	53.31	260.13
Right Chute	Chute	4758.043	7000cfs	1981.43	1981.42	0.01	0.40	0.00		1.58		1.00
Right Chute	Chute	4758.043	15000cfs	1985.10	1985.08	0.02	1.79	0.01		35.15		60.23
Right Chute	Chute	4758.043	30000cfs	1986.68	1986.55	0.13	0.75	0.02		483.85		168.75
Right Chute	Chute	4758.043	2yr 54200cfs	1989.87	1989.77	0.10	0.49	0.01		2231.65		271.93
Right Chute	Chute	4758.043	100yr 128300cfs	1996.69	1996.49	0.20	0.42	0.05	113.01	12267.26		558.99
Right Chute	Chute	4758.043	63000cfs	1991.52	1991.38	0.14	0.54	0.02		4037.86		308.29
Right Chute	Chute	3810	7000cfs	1981.03	1981.02	0.01	0.35	0.00		1.58		1.00
Right Chute	Chute	3810	15000cfs	1983.29	1983.13	0.16	0.54	0.04		35.15		58.97
Right Chute	Chute	3810	30000cfs	1985.91	1985.85	0.06	0.42	0.00		483.85		97.06
Right Chute	Chute	3810	2yr 54200cfs	1989.38	1989.19	0.19	0.46	0.03		2231.65		147.17
Right Chute	Chute	3810	100yr 128300cfs	1996.22	1995.51	0.71	0.55	0.10	600.62	11769.11	10.54	234.32
Right Chute	Chute	3810	63000cfs	1990.96	1990.63	0.33	0.58	0.05	25.78	4012.07		200.03
Right Chute	Chute	2770	7000cfs	1980.68	1980.67	0.00	0.06	0.00		1.58		0.06
Right Chute	Chute	2770	15000cfs	1982.71	1982.70	0.01	0.01	0.00		35.15		35.39
Right Chute	Chute	2770	30000cfs	1985.48	1985.43	0.05	0.13	0.01		483.85		141.90
Right Chute	Chute	2770	2yr 54200cfs	1988.89	1988.79	0.10	0.26	0.00	3.40	2228.24		245.57
Right Chute	Chute	2770	100yr 128300cfs	1995.57	1995.19	0.38	0.30	0.04	482.27	11874.28	23.73	346.95
Right Chute	Chute	2770	63000cfs	1990.34	1990.17	0.17	0.41	0.02	46.61	3991.14	0.11	276.12
Right Chute	Chute	1939.394	7000cfs	1980.62	1980.61	0.00	0.02	0.00		1.58		43.77
Right Chute	Chute	1939.394	15000cfs	1982.69	1982.69	0.00	0.00	0.00		35.15		78.08
Right Chute	Chute	1939.394	30000cfs	1985.34	1985.32	0.02	0.05	0.00		483.85		98.16
Right Chute	Chute	1939.394	2yr 54200cfs	1988.63	1988.49	0.14	0.15	0.01		2231.65		240.93
Right Chute	Chute	1939.394	100yr 128300cfs	1995.22	1994.98	0.25	0.22	0.02	2168.25	8379.47	1832.55	676.36
Right Chute	Chute	1939.394	63000cfs	1989.92	1989.59	0.33	0.30	0.03		4037.86		314.73
Right Chute	Chute	1360	7000cfs	1980.59	1980.59	0.00	0.00	0.00		1.58		38.39
Right Chute	Chute	1360	15000cfs	1982.69	1982.69	0.00	0.00	0.00		35.15		82.63
Right Chute	Chute	1360	30000cfs	1985.30	1985.28	0.02	0.03	0.00		483.85		114.95
Right Chute	Chute	1360	2yr 54200cfs	1988.46	1988.36	0.10	0.12	0.00	0.08	2129.21	102.36	245.57
Right Chute	Chute	1360	100yr 128300cfs	1994.99	1994.57	0.42	0.30	0.02	75.04	10134.61	2170.62	464.04
Right Chute	Chute	1360	63000cfs	1989.59	1989.37	0.22	0.25	0.00	0.97	3738.15	298.73	262.76
Right Chute	Chute	720	7000cfs	1980.59	1980.59	0.00	0.00	0.00		1.58		78.41
Right Chute	Chute	720	15000cfs	1982.69	1982.69	0.00	0.00	0.00		35.15		99.30
Right Chute	Chute	720	30000cfs	1985.26	1985.25	0.01	0.01	0.00		483.85		114.09
Right Chute	Chute	720	2yr 54200cfs	1988.34	1988.25	0.09	0.05	0.01		2231.65	0.00	137.51
Right Chute	Chute	720	100yr 128300cfs	1994.66	1994.00	0.66	0.17	0.04	547.12	11759.60	73.55	332.75
Right Chute	Chute	720	63000cfs	1989.34	1989.11	0.22	0.11	0.01	2.40	4035.14	0.31	166.63
Right Chute	Chute	338.7000	7000cfs	1980.59	1980.59	0.00	0.05	0.01		1.58		87.23
Right Chute	Chute	338.7000	15000cfs	1982.69	1982.69	0.00	0.06	0.02		35.15		103.65
Right Chute	Chute	338.7000	30000cfs	1985.25	1985.24	0.01	0.06	0.03		483.85		130.55
Right Chute	Chute	338.7000	2yr 54200cfs	1988.29	1988.22	0.07	0.05	0.04	22.77	2207.71	1.17	181.41
Right Chute	Chute	338.7000	100yr 128300cfs	1994.44	1993.92	0.52	0.04	0.03	1103.43	11186.65	90.20	317.57
Right Chute	Chute	338.7000	63000cfs	1989.21	1989.04	0.18	0.04	0.03	68.80	3964.29	4.76	184.89

High Flow Channel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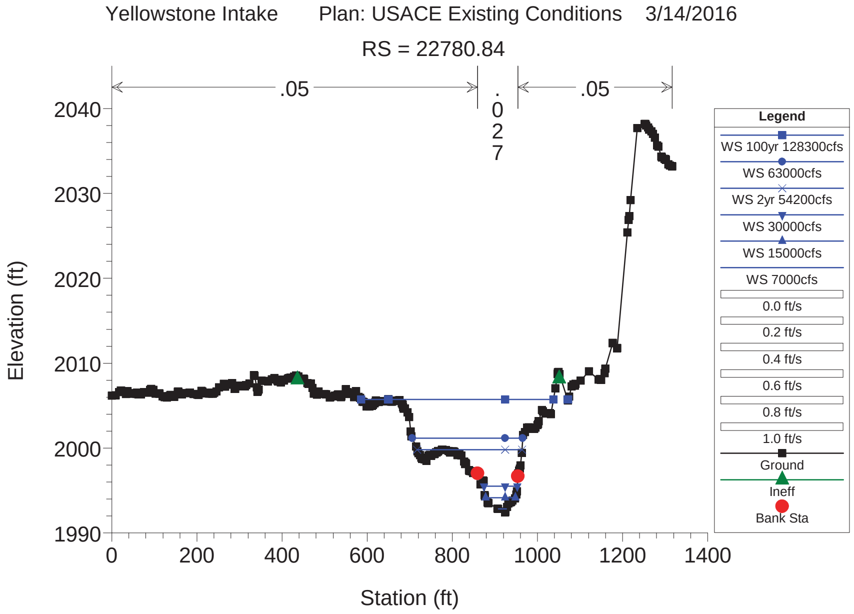
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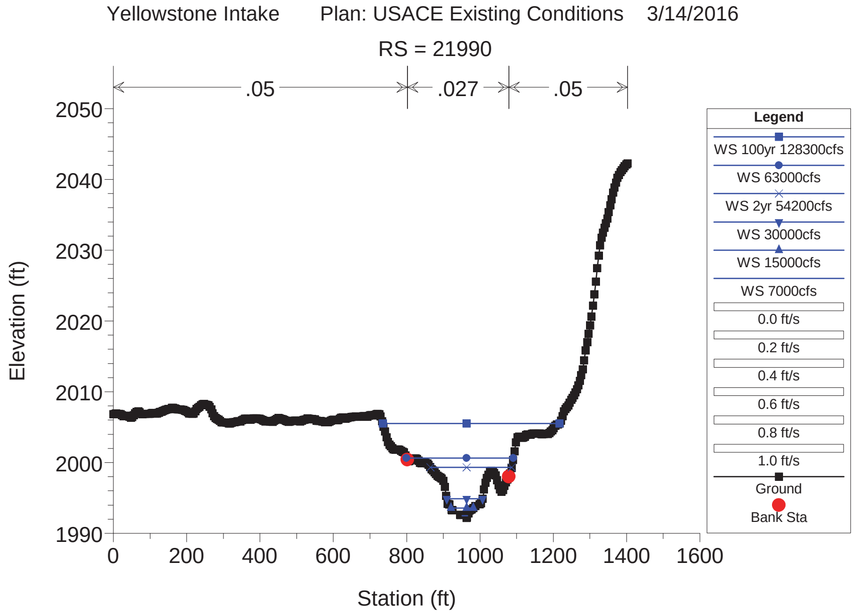
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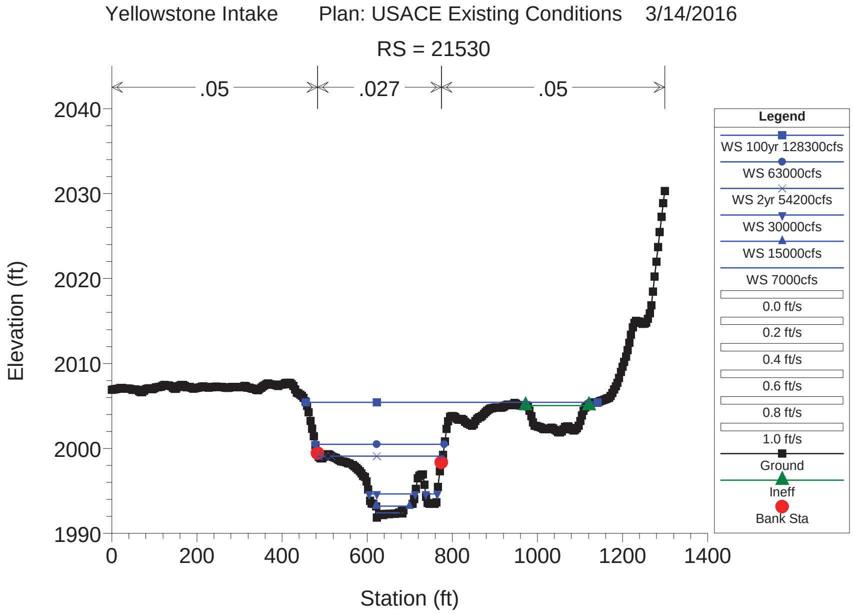
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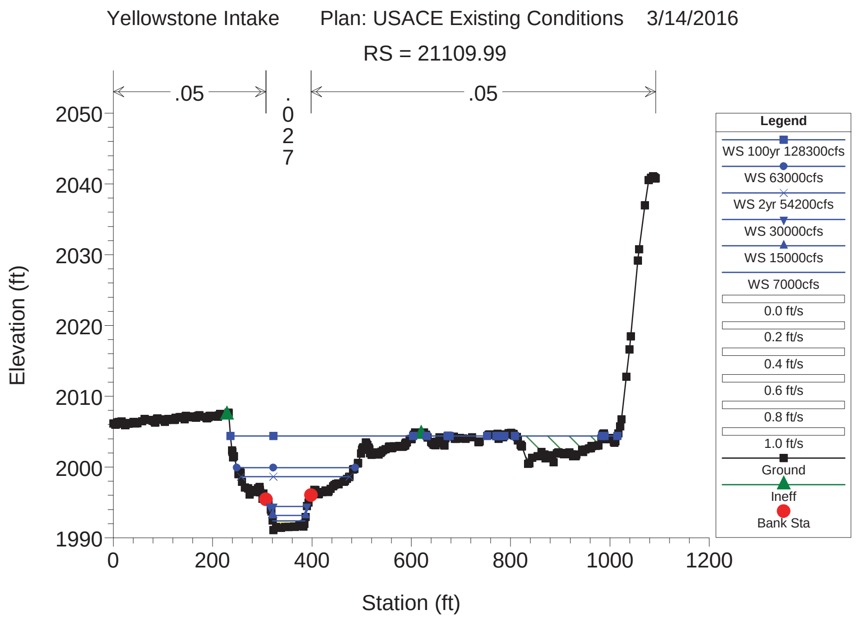

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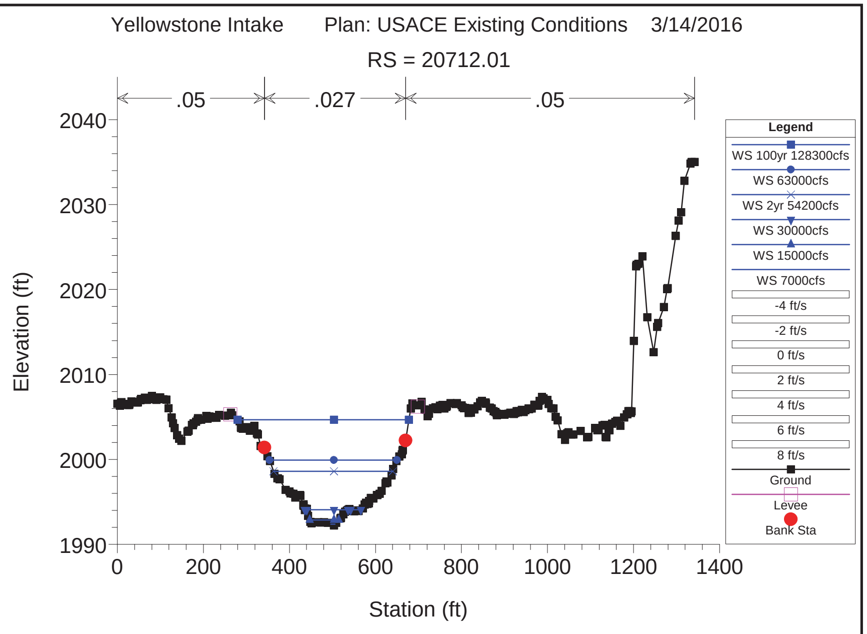

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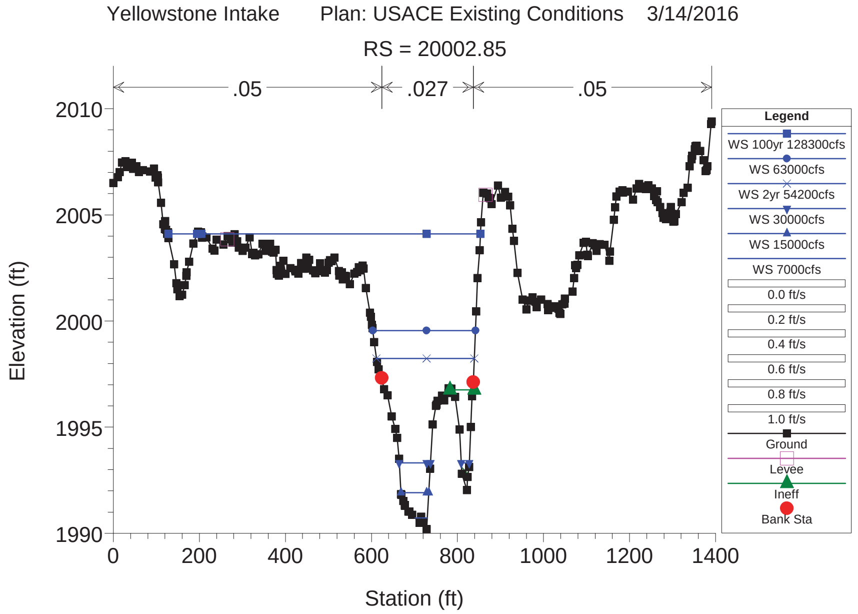

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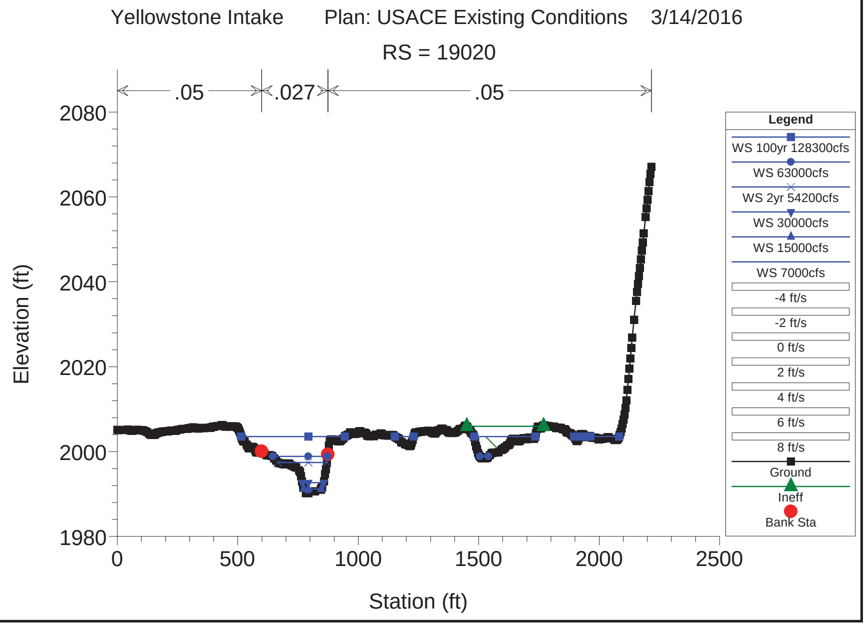

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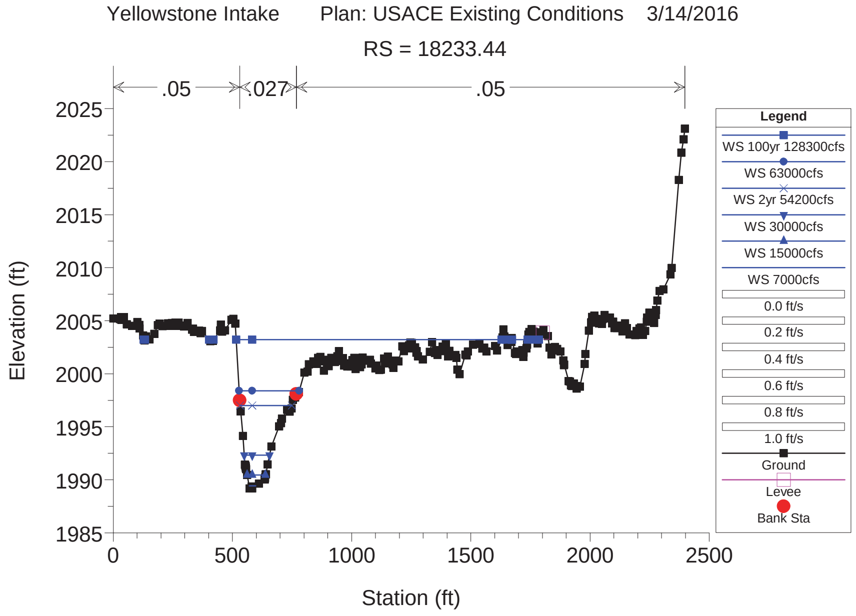
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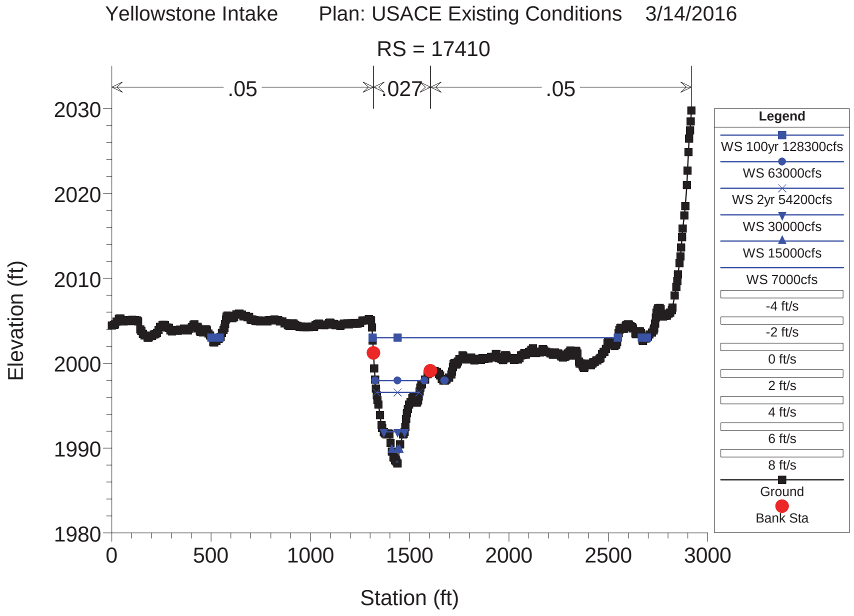
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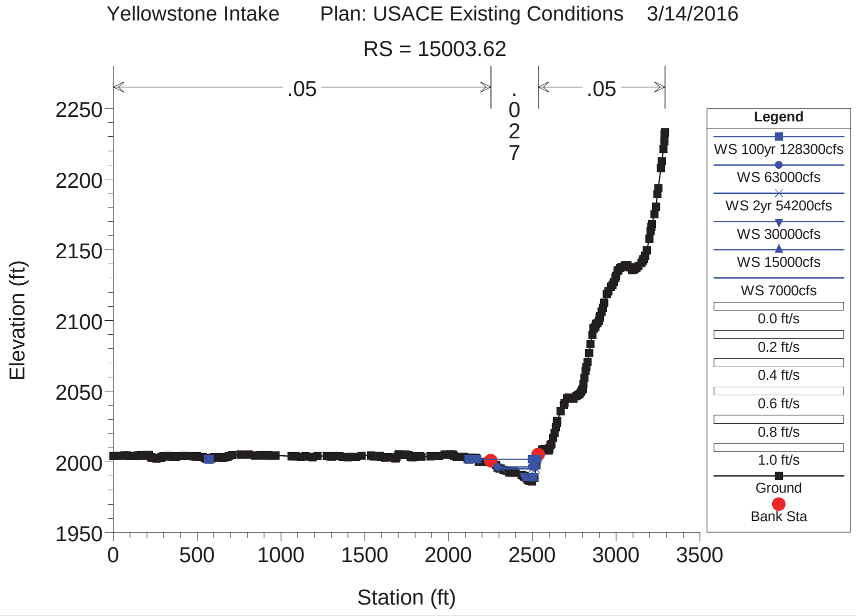
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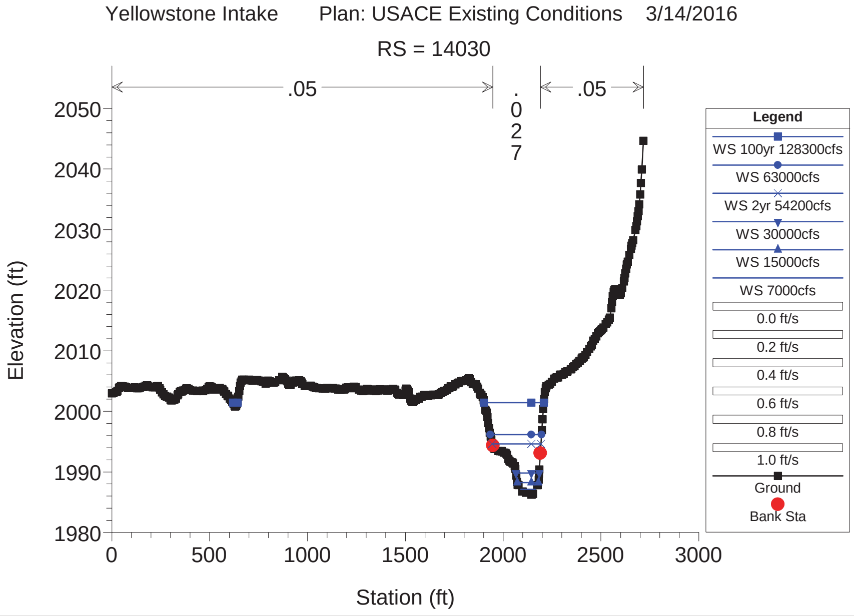
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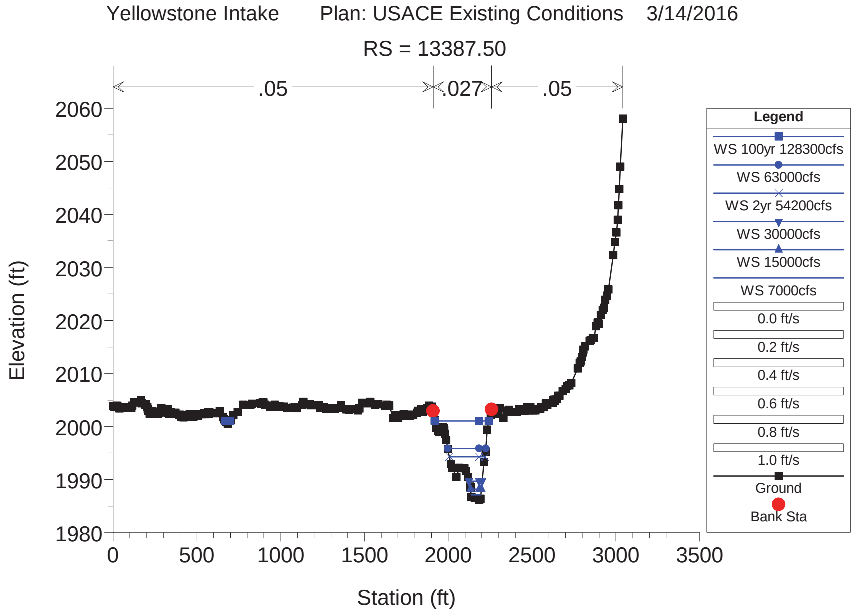
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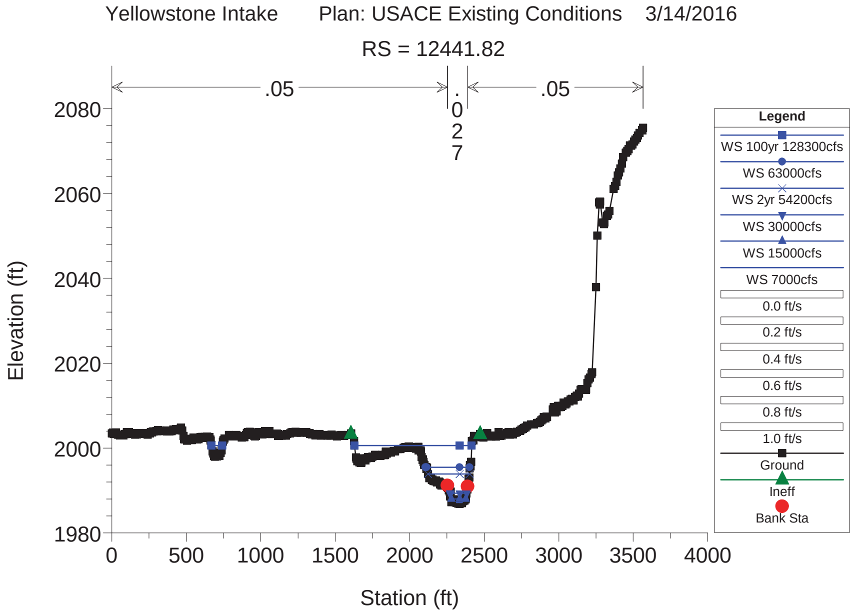
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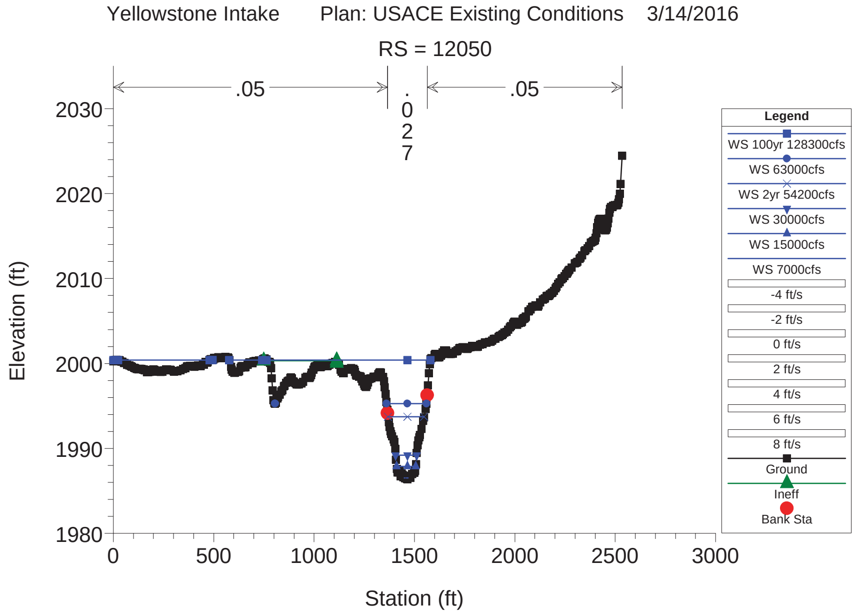
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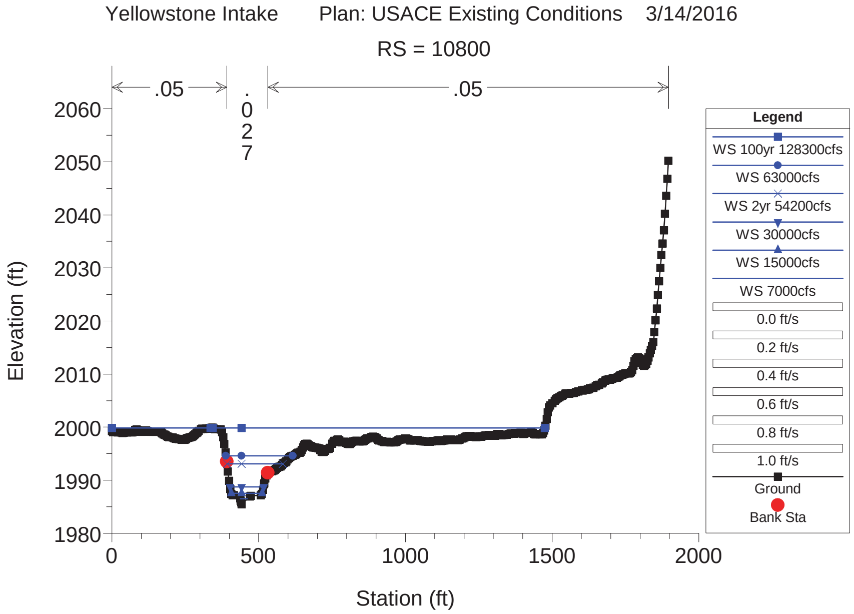
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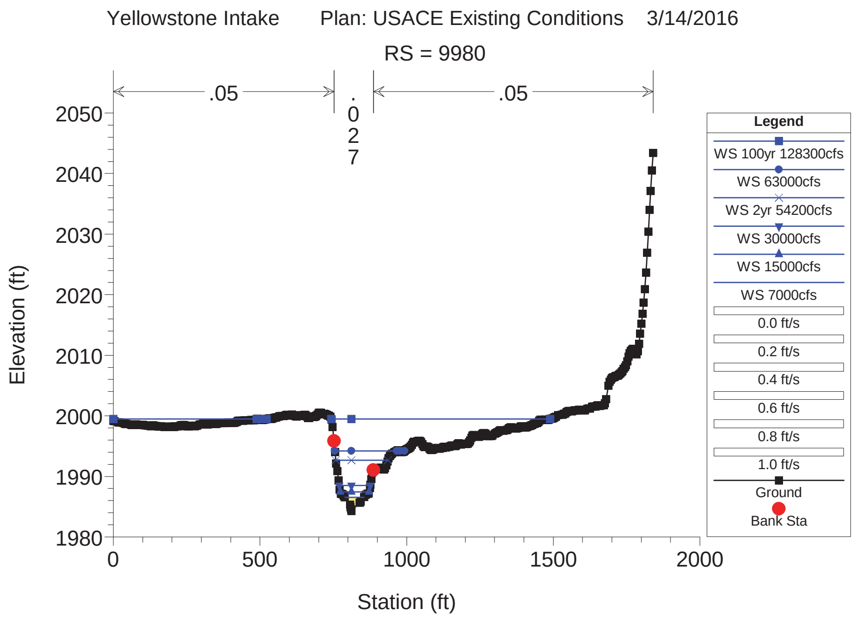
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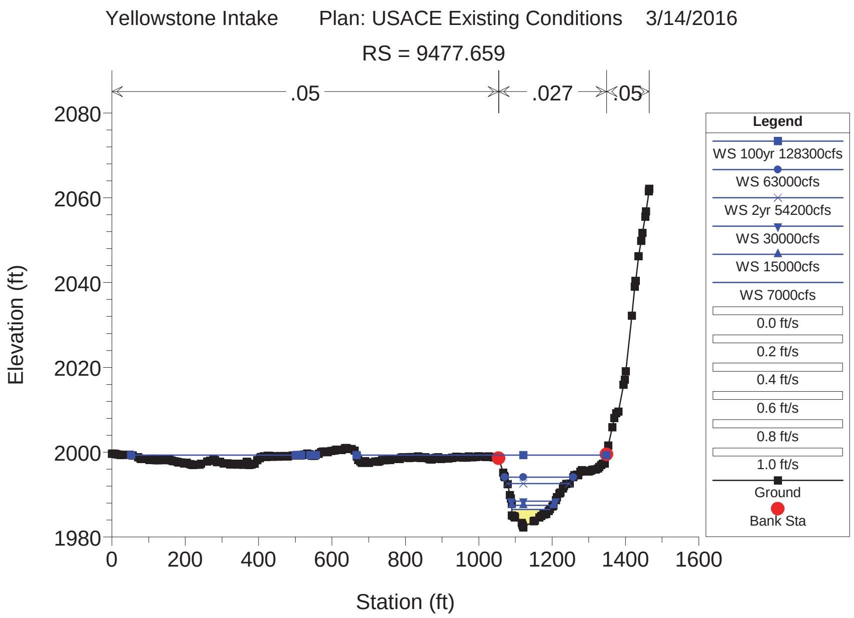
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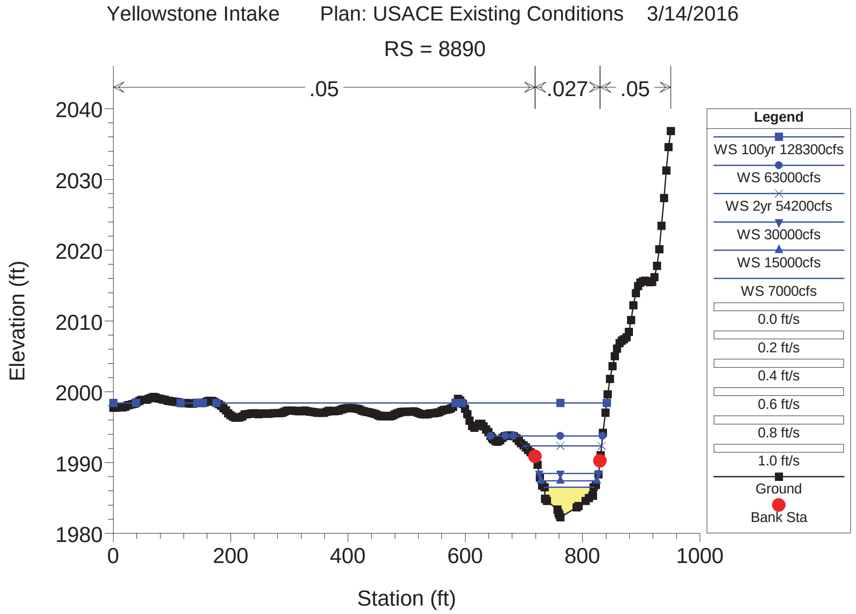
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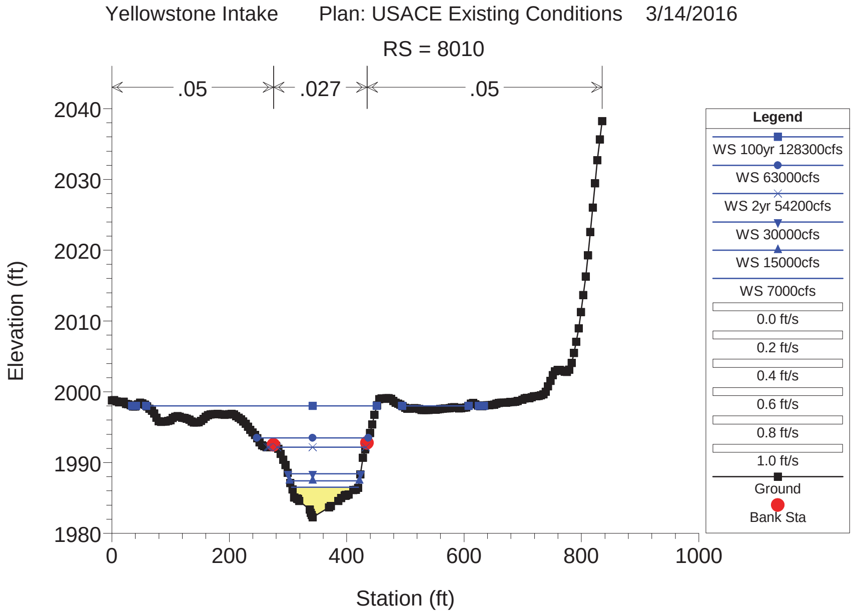
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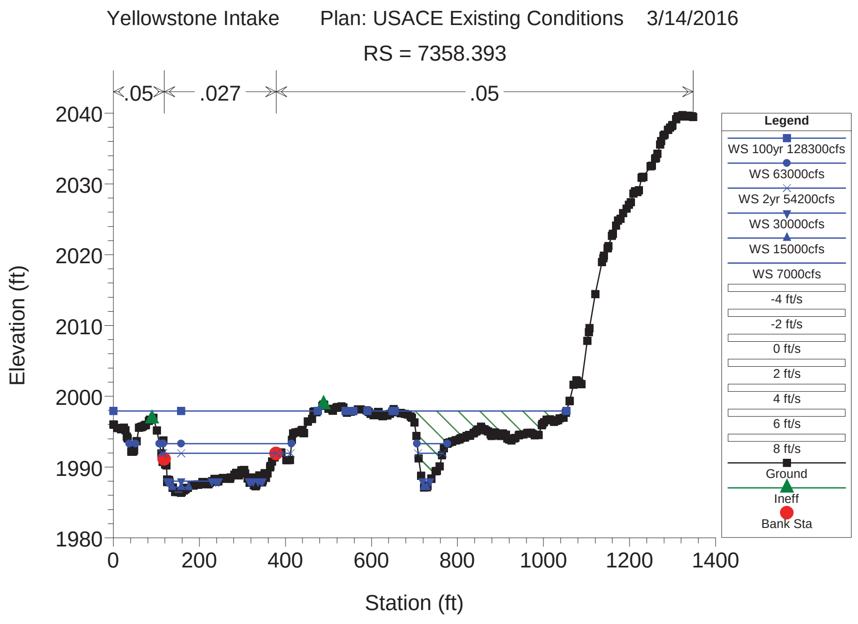
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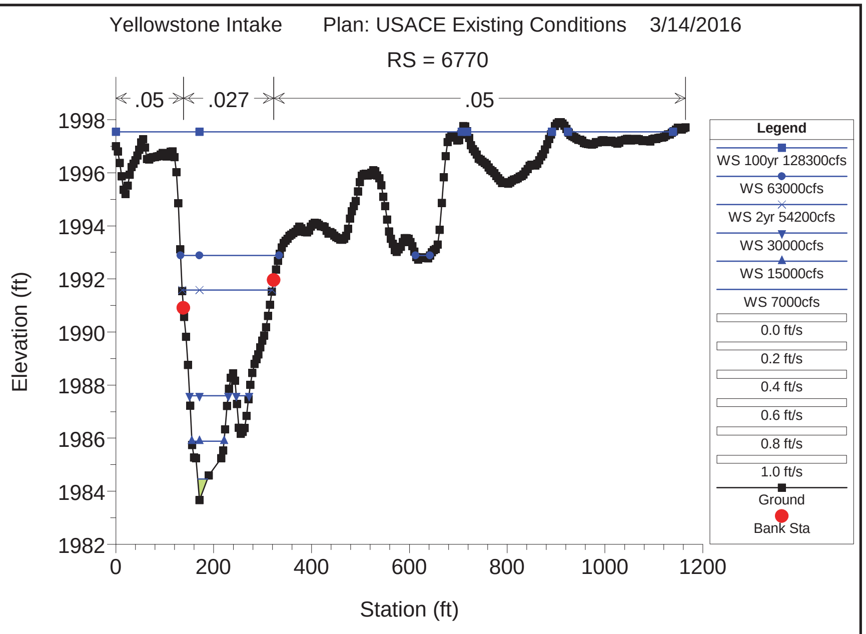
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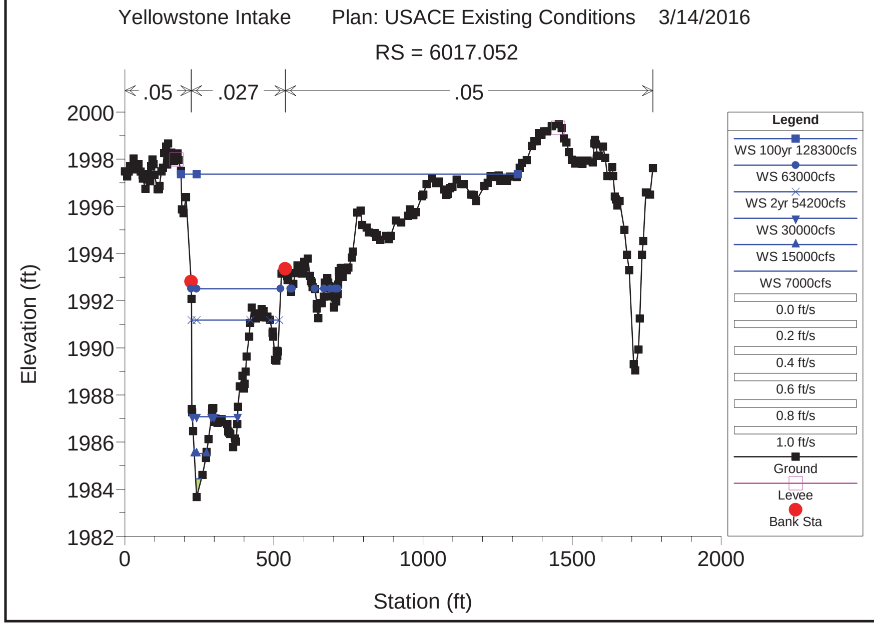
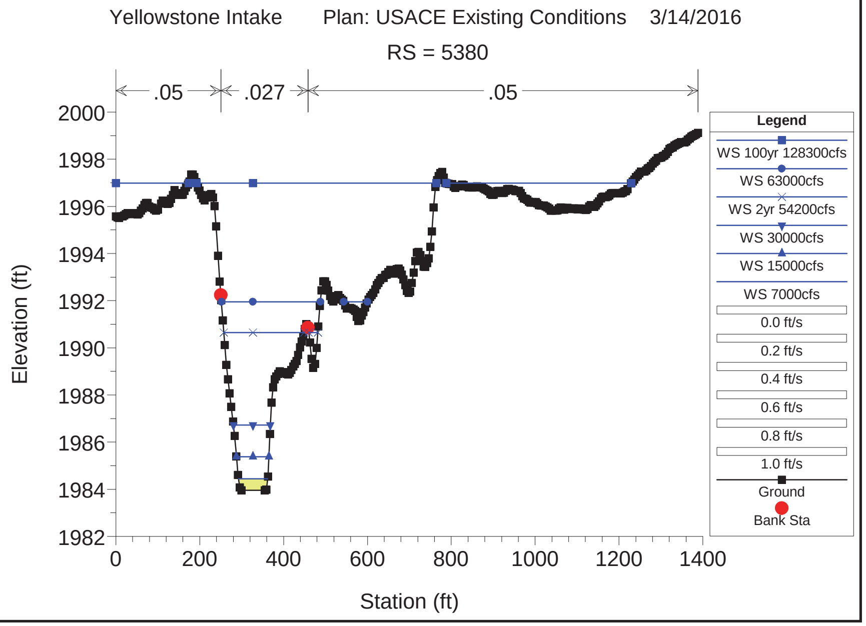
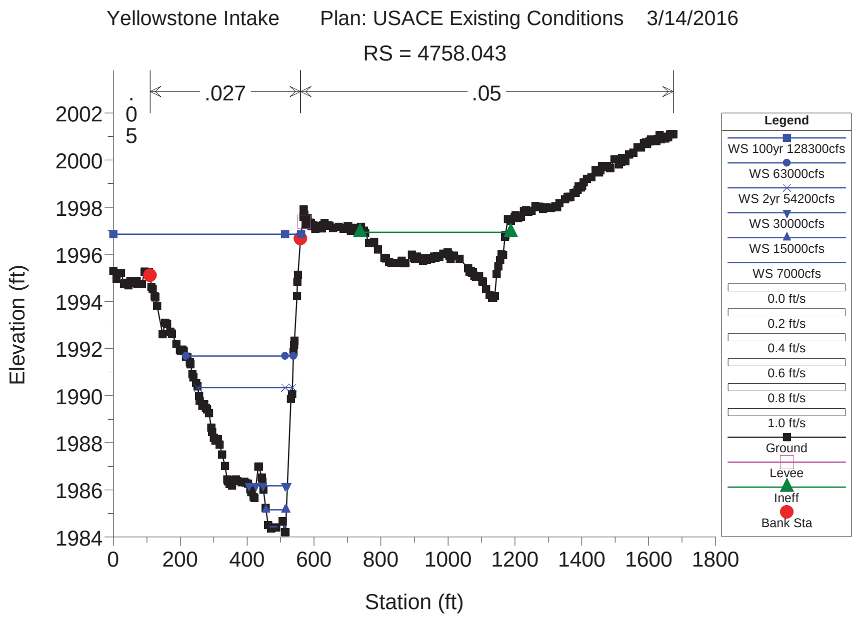

Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

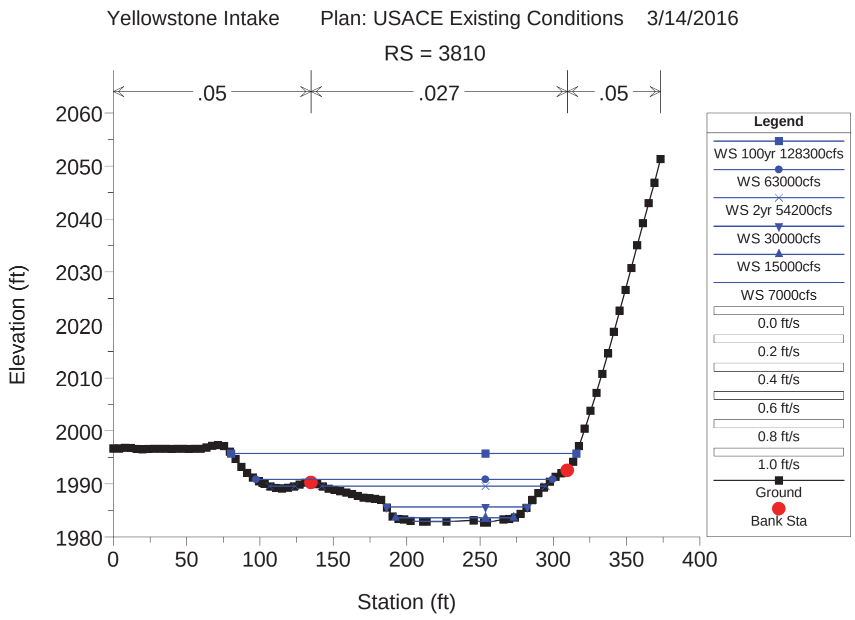
RS = 6017.052


Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

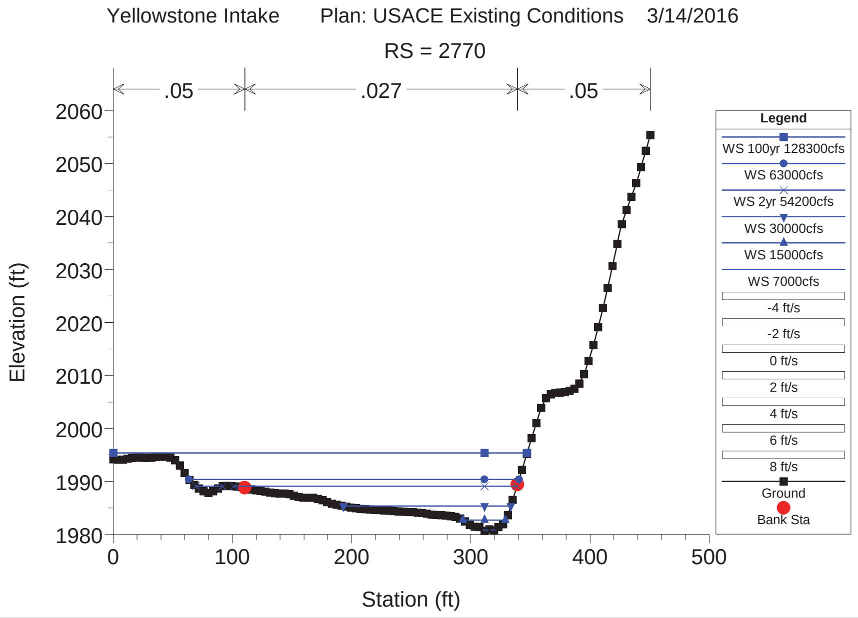
RS = 5380


Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

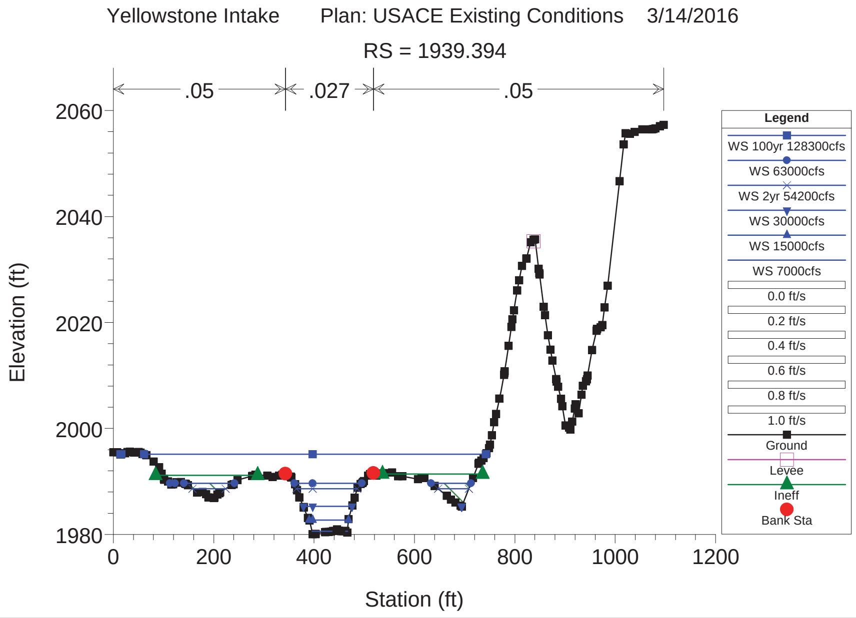
RS = 4758.043


Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

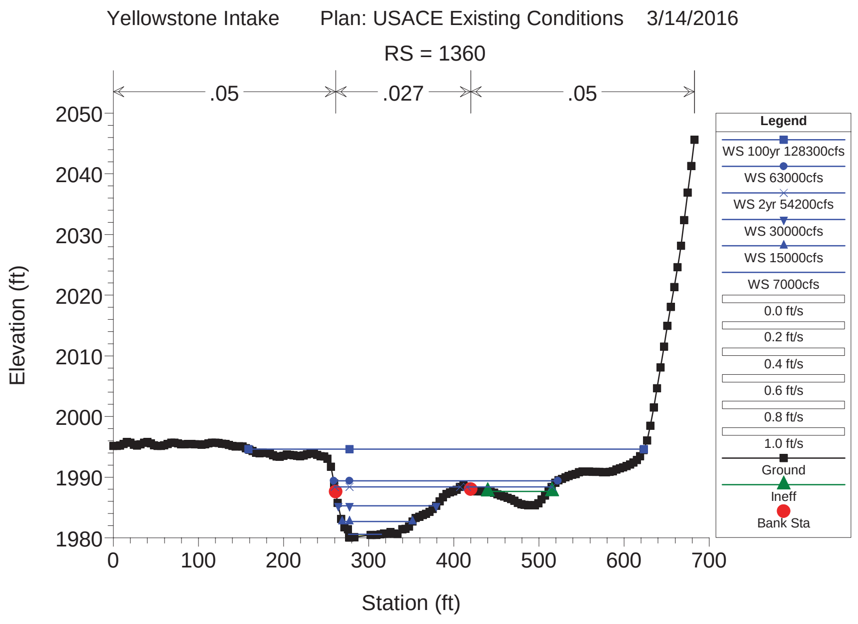
RS = 3810

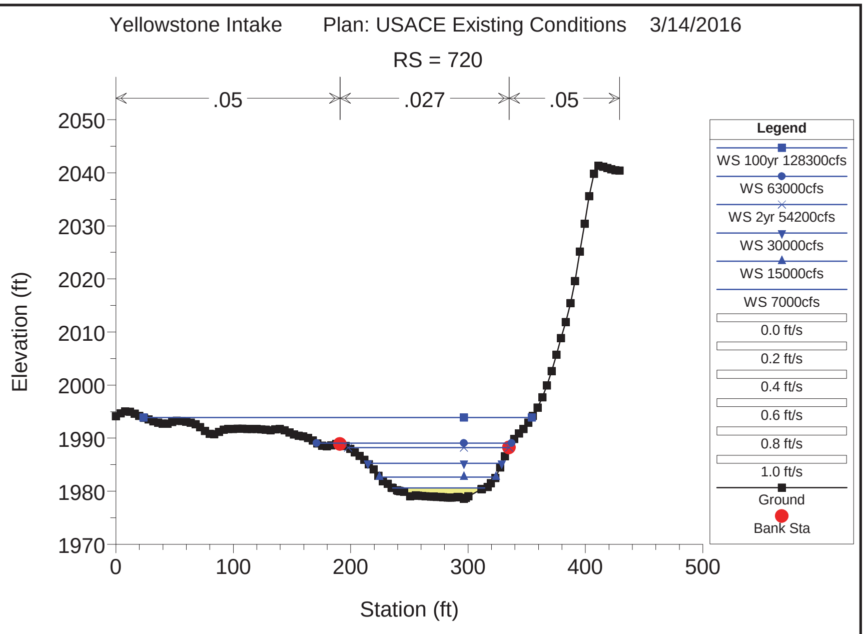

Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

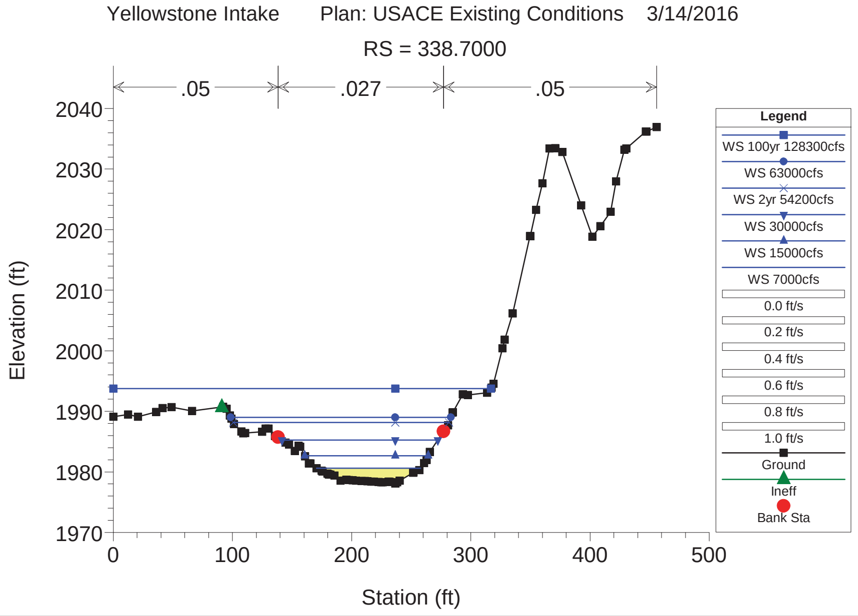
RS = 2770

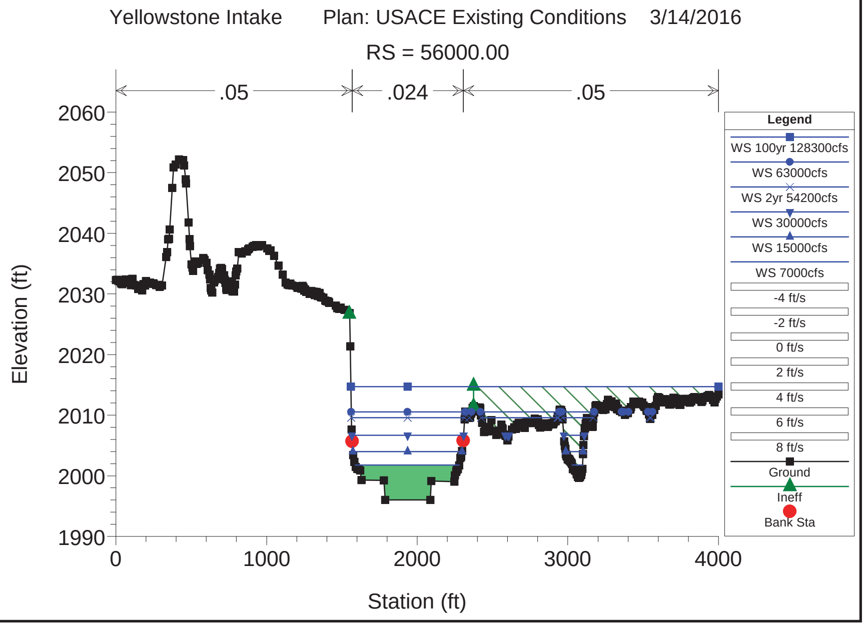

Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

RS = 1939.394

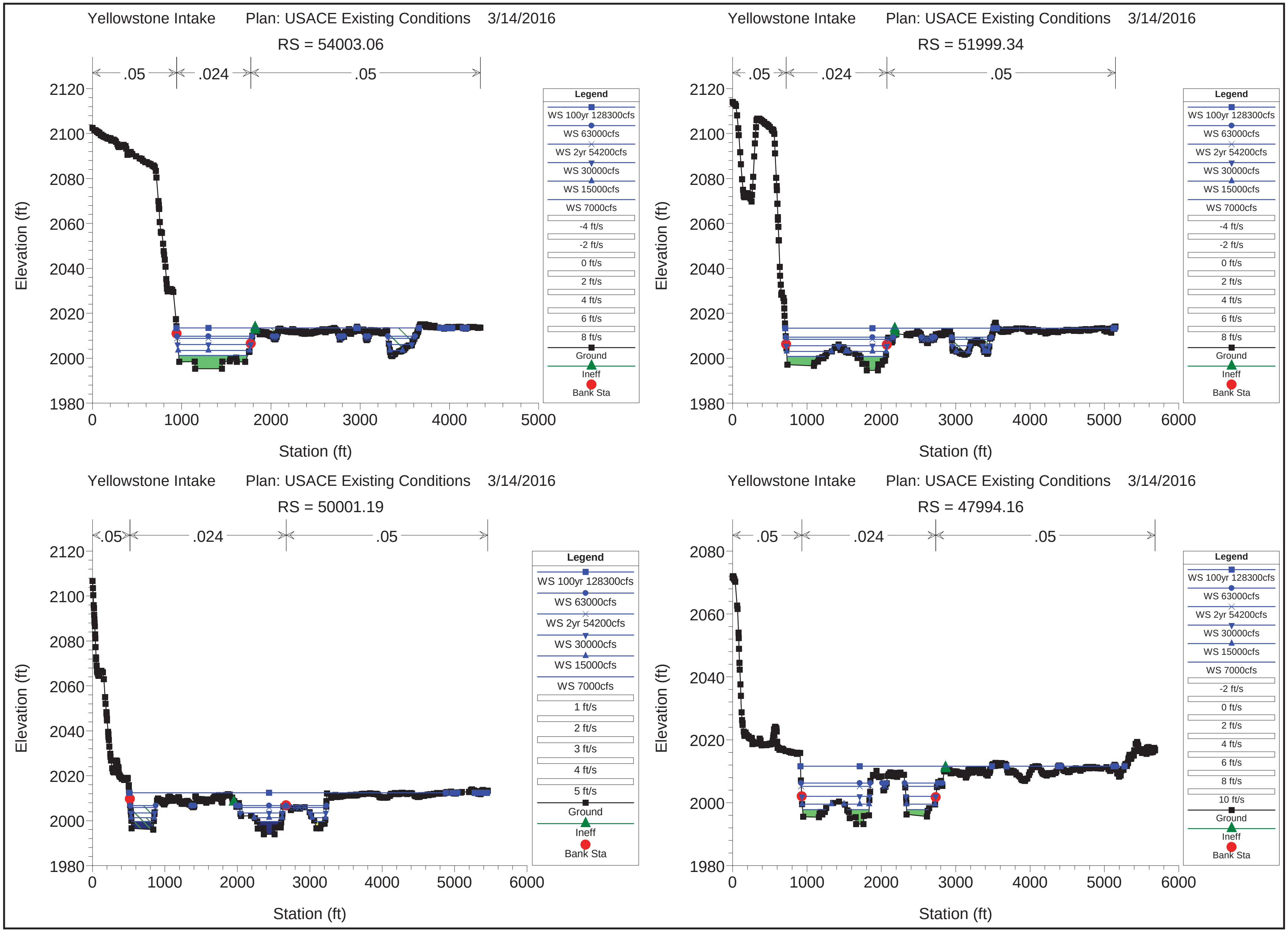

Yellowstone Intake
Plan: USACE Existing Conditions
3/14/2016
RS = 1360
.05
.027
.05
Elevation (ft)
1980
1990
2000
2010
2020
2030
2040
2050
Station (ft)
0
100
200
300
400
500
600
700
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.0 ft/s
0.2 ft/s
0.4 ft/s
0.6 ft/s
0.8 ft/s
1.0 ft/s
Ground
Ineff
Bank Sta


Yellowstone Intake
Plan: USACE Existing Conditions
3/14/2016
RS = 720
.05
.027
.05
Elevation (ft)
1970
1980
1990
2000
2010
2020
2030
2040
2050
Station (ft)
0
100
200
300
400
500
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.0 ft/s
0.2 ft/s
0.4 ft/s
0.6 ft/s
0.8 ft/s
1.0 ft/s
Ground
Bank Sta


Yellowstone Intake
Plan: USACE Existing Conditions
3/14/2016
RS = 338.7000
.05
.027
.05
Elevation (ft)
1970
1980
1990
2000
2010
2020
2030
2040
Station (ft)
0
100
200
300
400
500
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.0 ft/s
0.2 ft/s
0.4 ft/s
0.6 ft/s
0.8 ft/s
1.0 ft/s
Ground
Ineff
Bank Sta

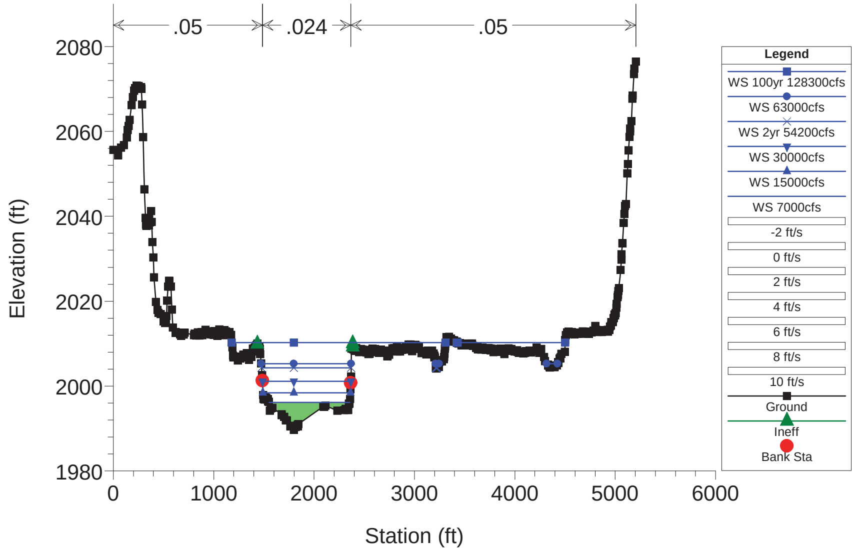

Yellowstone Intake
Plan: USACE Existing Conditions
3/14/2016
RS = 56000.00
.05
.024
.05
Elevation (ft)
1990
2000
2010
2020
2030
2040
2050
2060
Station (ft)
0
1000
2000
3000
4000
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
-4 ft/s
-2 ft/s
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
Ground
Ineff
Bank Sta

Yellowstone River



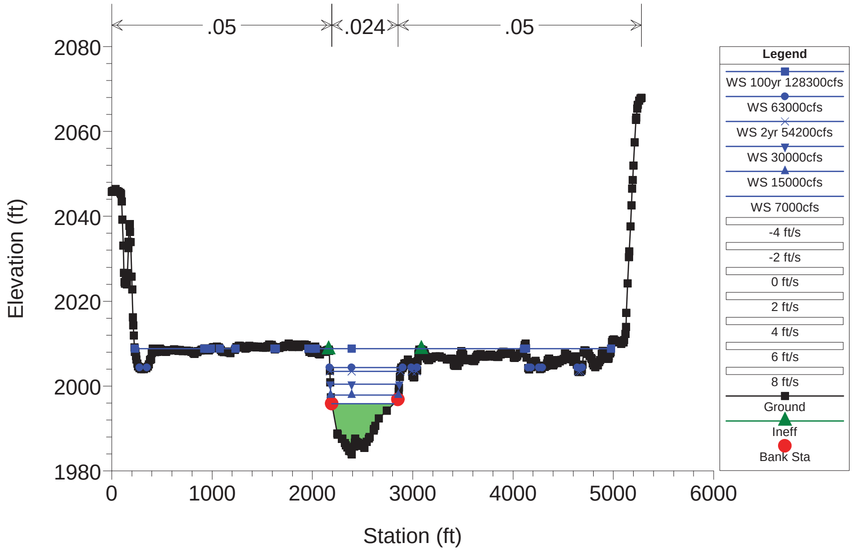
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

RS = 46189.52



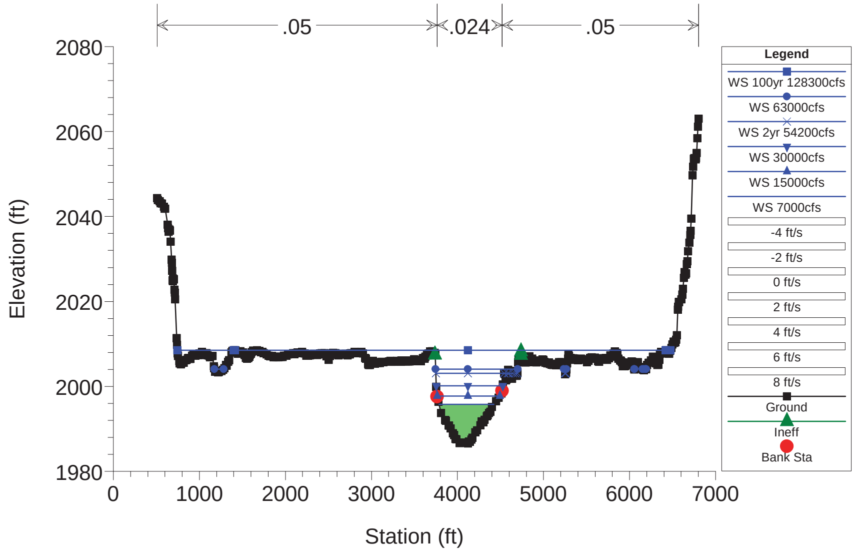
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

RS = 43687.06



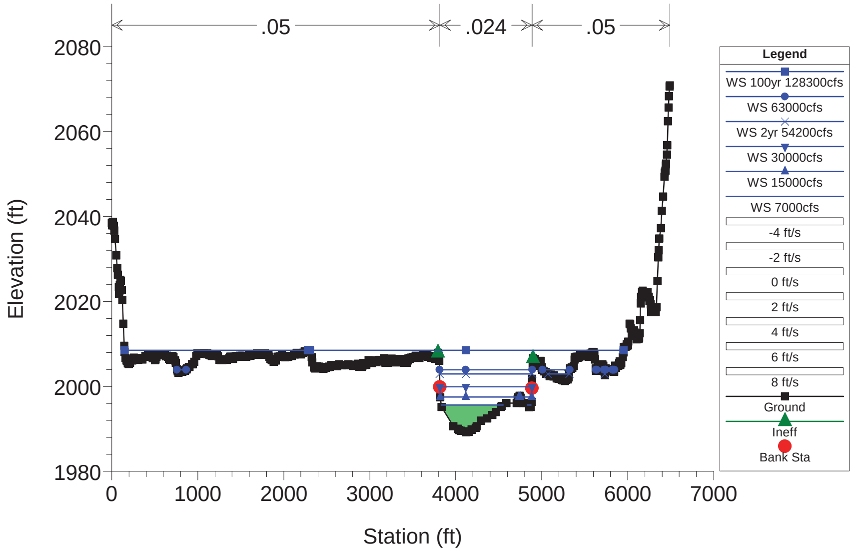
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

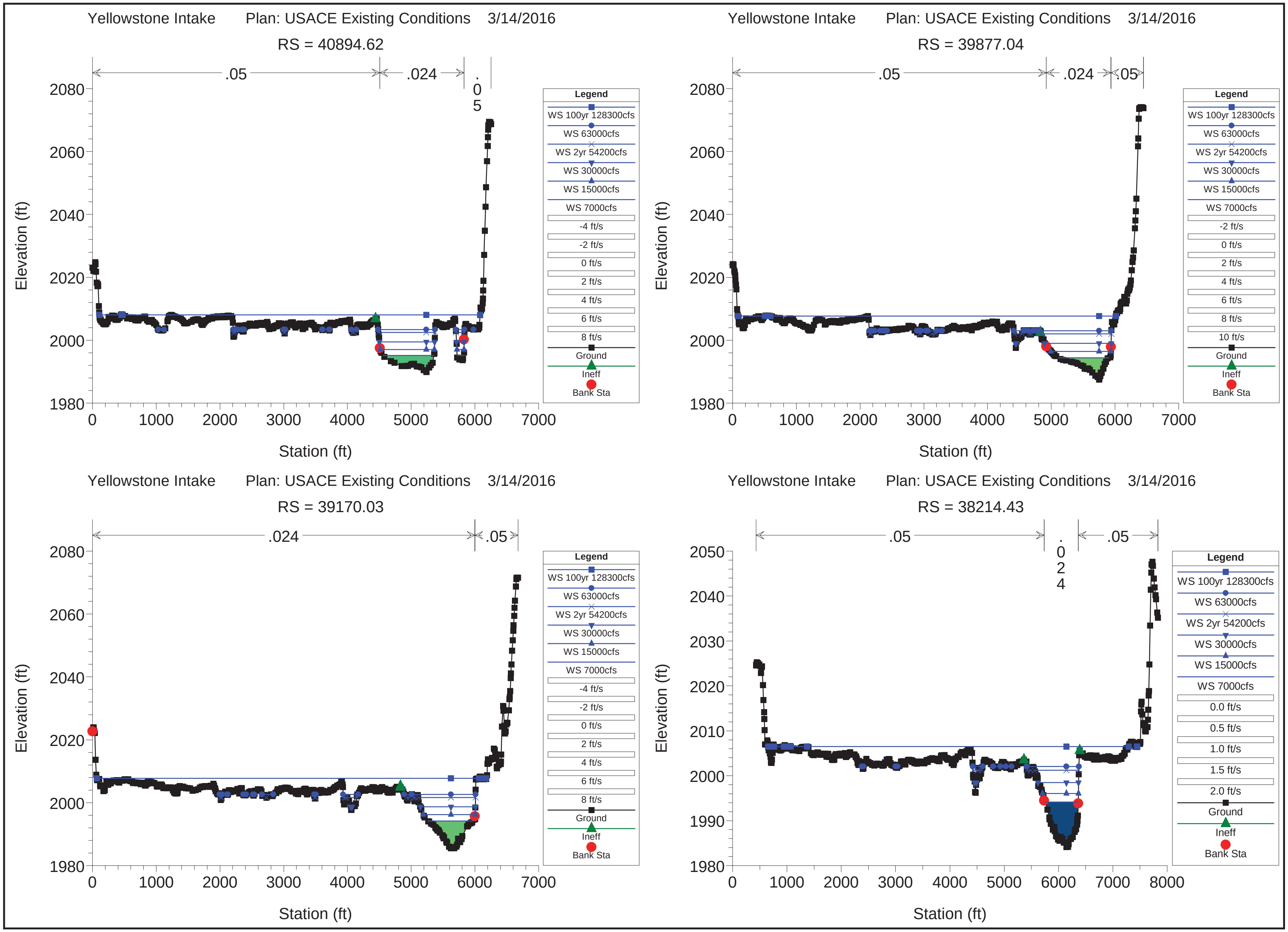
RS = 42707.92



Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

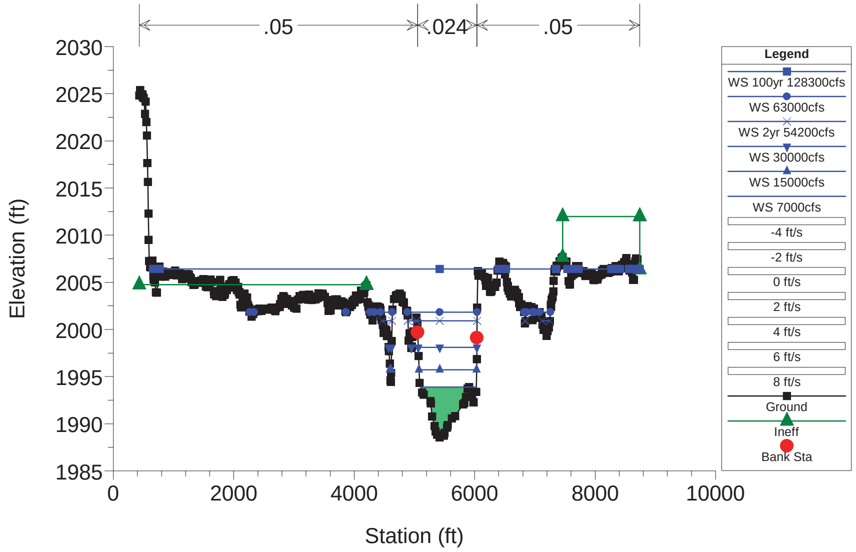
RS = 41936.91




Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 40894.62
.05
.024
.05
Elevation (ft)
Station (ft)
2080
2060
2040
2020
2000
1980
0
1000
2000
3000
4000
5000
6000
7000
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
-4 ft/s
-2 ft/s
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
Ground
Ineff
Bank Sta
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 39877.04
.05
.024
.05
Elevation (ft)
Station (ft)
2080
2060
2040
2020
2000
1980
0
1000
2000
3000
4000
5000
6000
7000
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
-2 ft/s
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
10 ft/s
Ground
Ineff
Bank Sta
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 39170.03
.024
.05
Elevation (ft)
Station (ft)
2080
2060
2040
2020
2000
1980
0
1000
2000
3000
4000
5000
6000
7000
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
-4 ft/s
-2 ft/s
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
Ground
Ineff
Bank Sta
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 38214.43
.05
.024
.05
Elevation (ft)
Station (ft)
2050
2040
2030
2020
2010
2000
1990
1980
0
1000
2000
3000
4000
5000
6000
7000
8000
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.0 ft/s
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
Ground
Ineff
Bank Sta

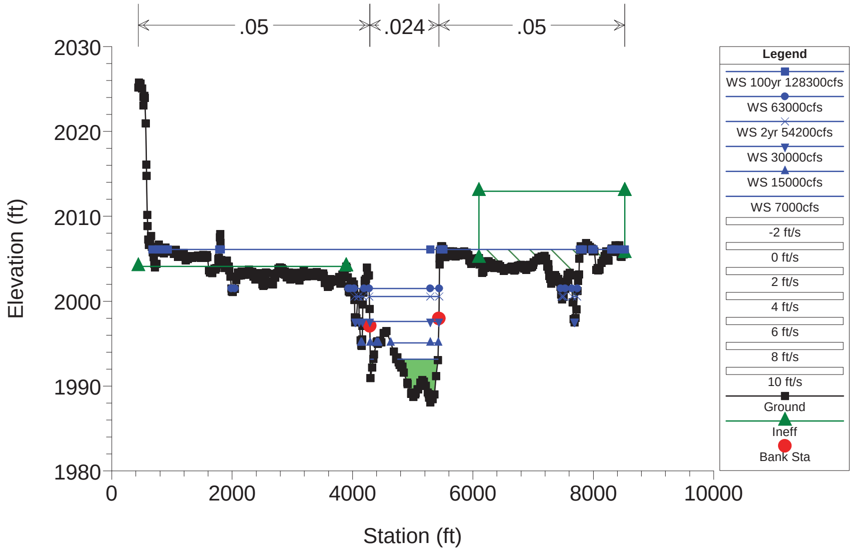
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

RS = 37074.57



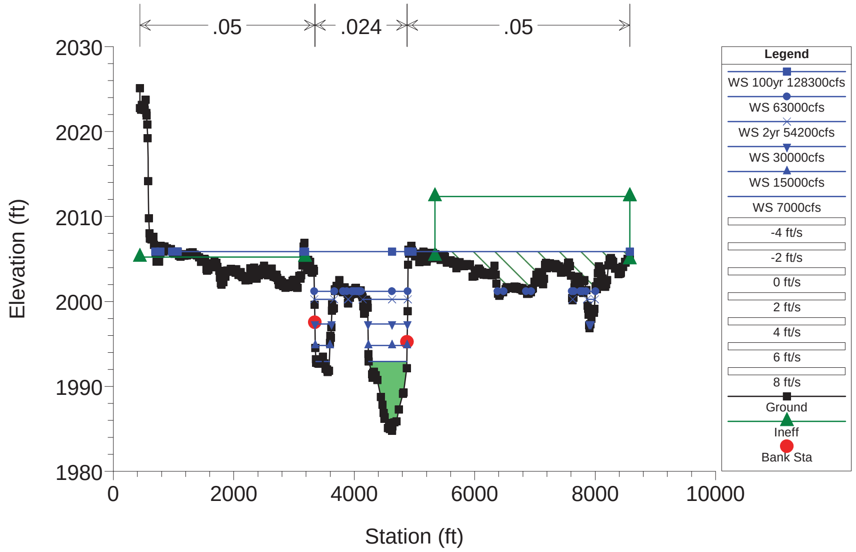
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

RS = 36104.97



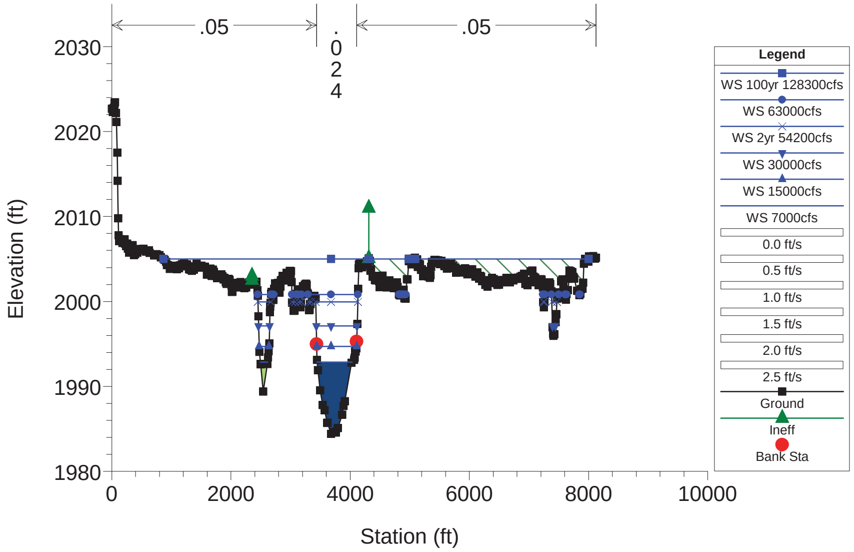
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

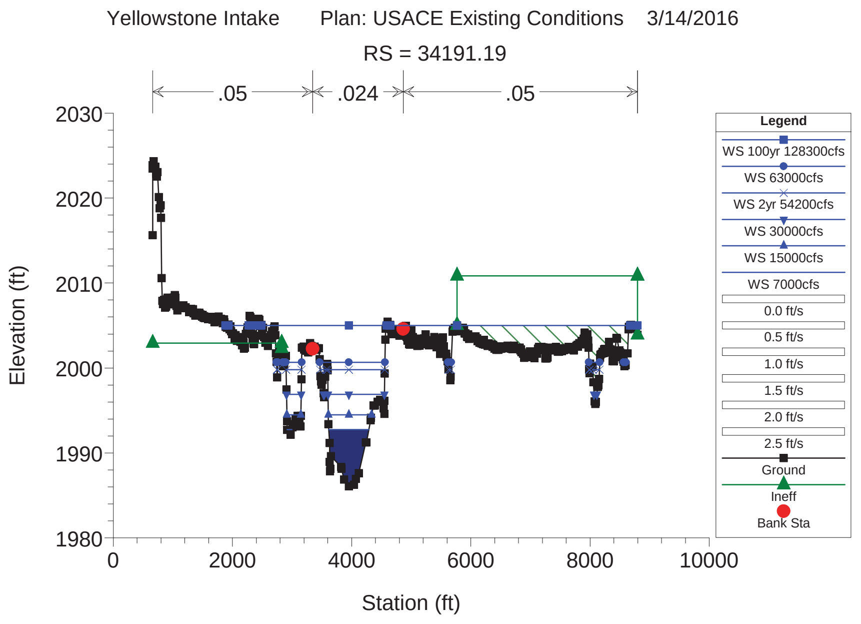
RS = 35375.29

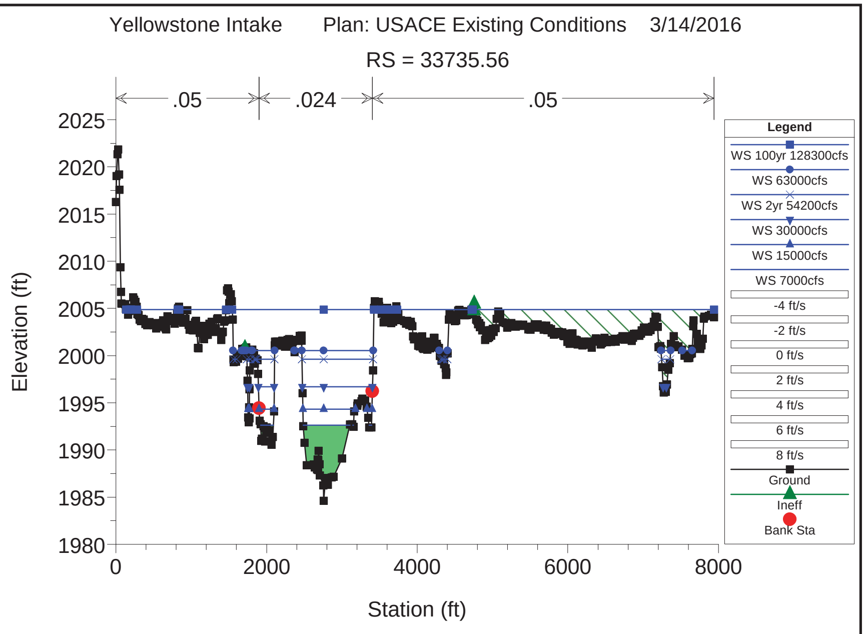


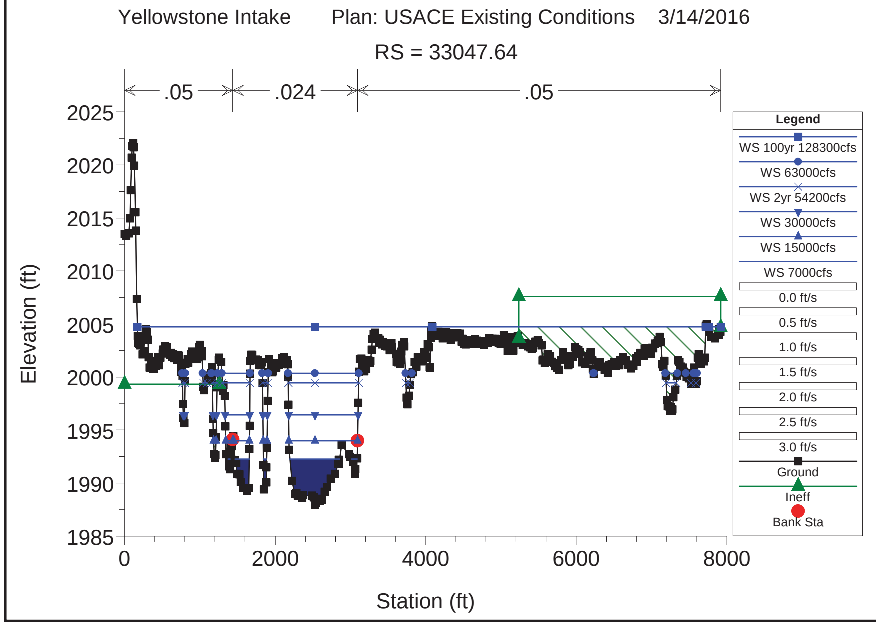
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

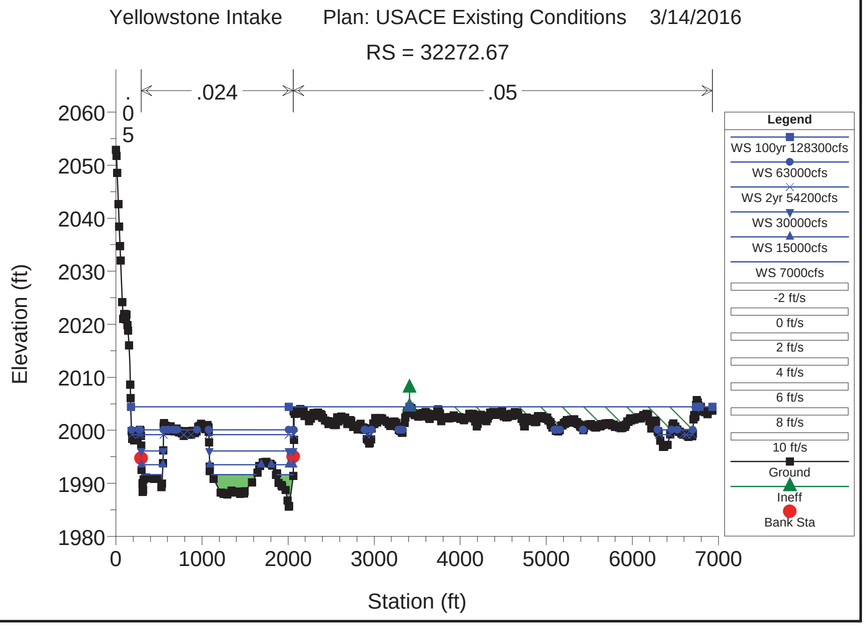
RS = 34889.88

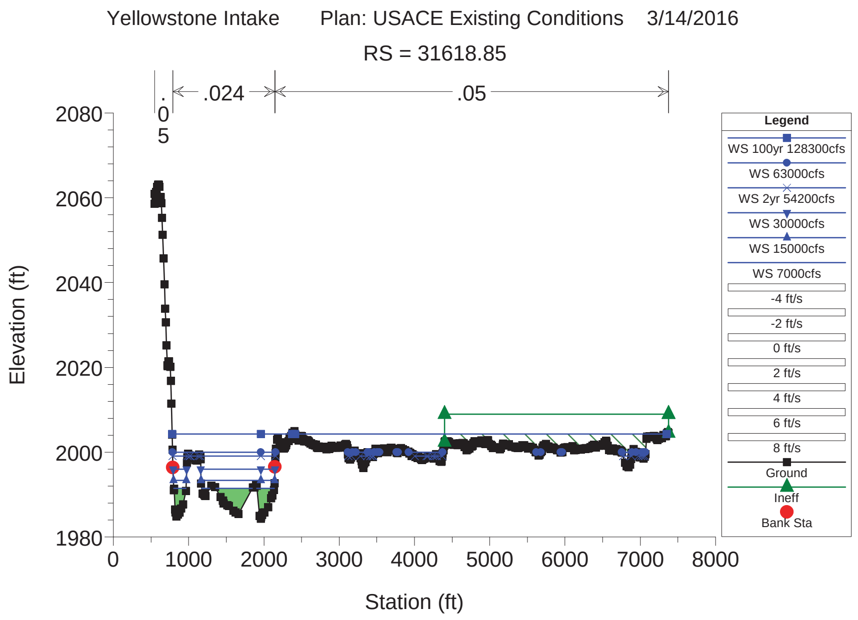


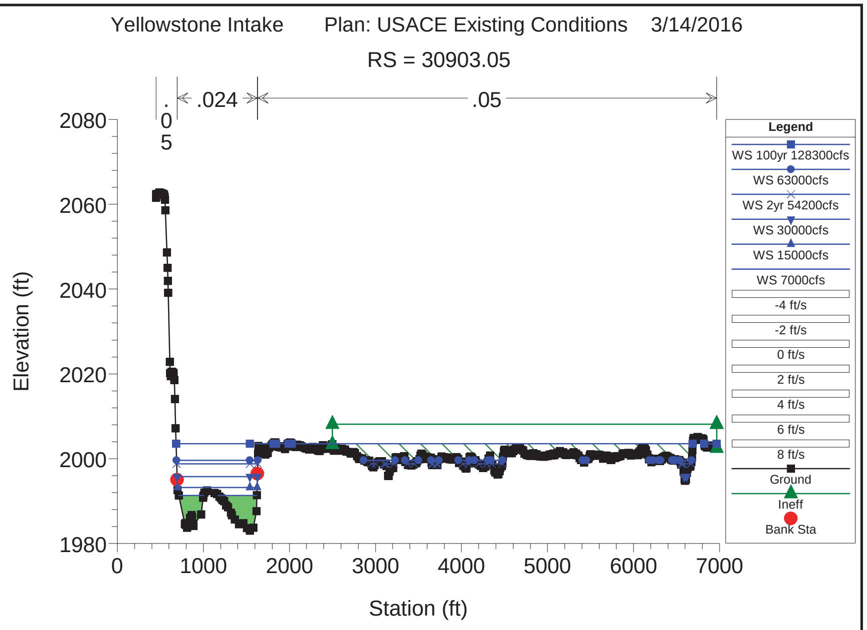

Yellowstone Intake
Plan: USACE Existing Conditions
3/14/2016
RS = 34191.19
.05
.024
.05
2030
2020
2010
2000
1990
1980
Elevation (ft)
0
2000
4000
6000
8000
10000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.0 ft/s
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
Ground
Ineff
Bank Sta

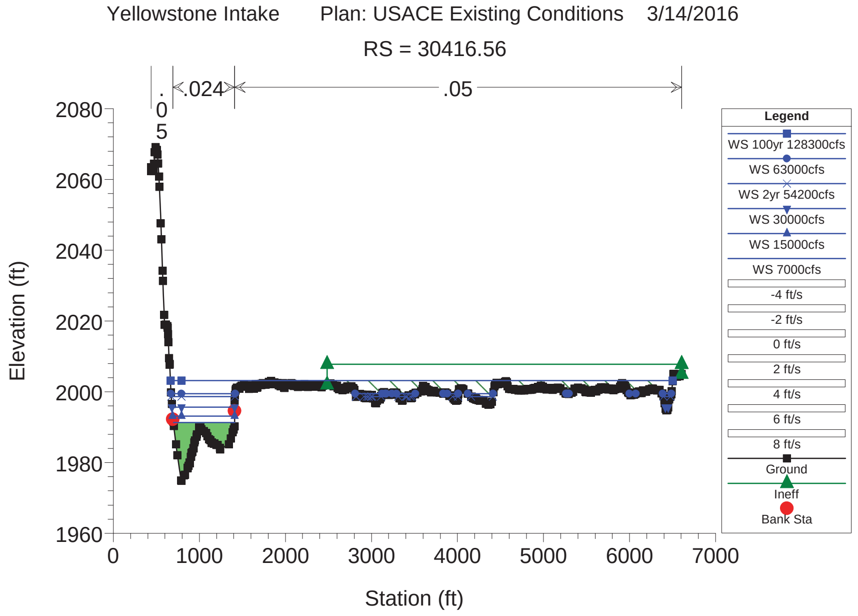

Yellowstone Intake
Plan: USACE Existing Conditions
3/14/2016
RS = 33735.56
.05
.024
.05
2025
2020
2015
2010
2005
2000
1995
1990
1985
1980
Elevation (ft)
0
2000
4000
6000
8000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
-4 ft/s
-2 ft/s
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
Ground
Ineff
Bank Sta

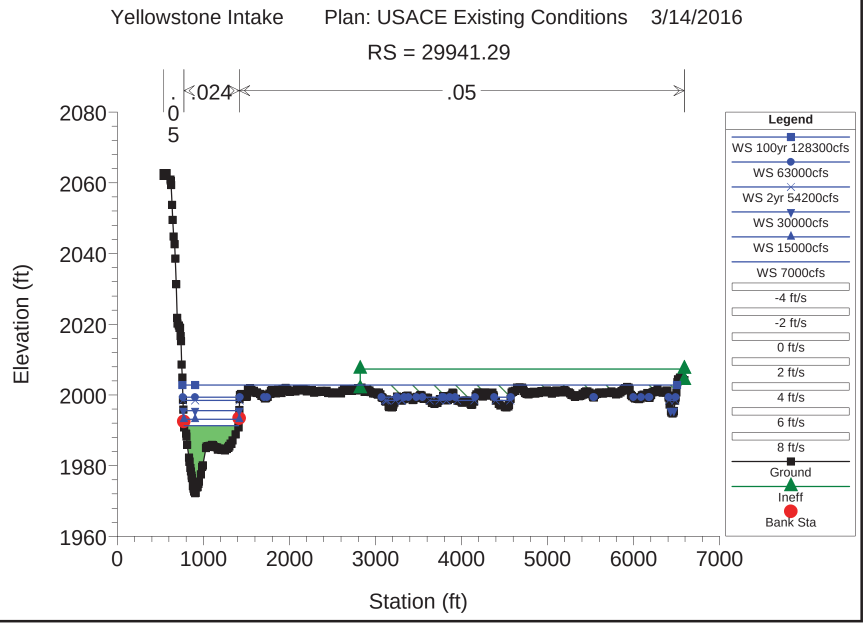

Yellowstone Intake
Plan: USACE Existing Conditions
3/14/2016
RS = 33047.64
.05
.024
.05
2025
2020
2015
2010
2005
2000
1995
1990
1985
Elevation (ft)
0
2000
4000
6000
8000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.0 ft/s
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
Ground
Ineff
Bank Sta

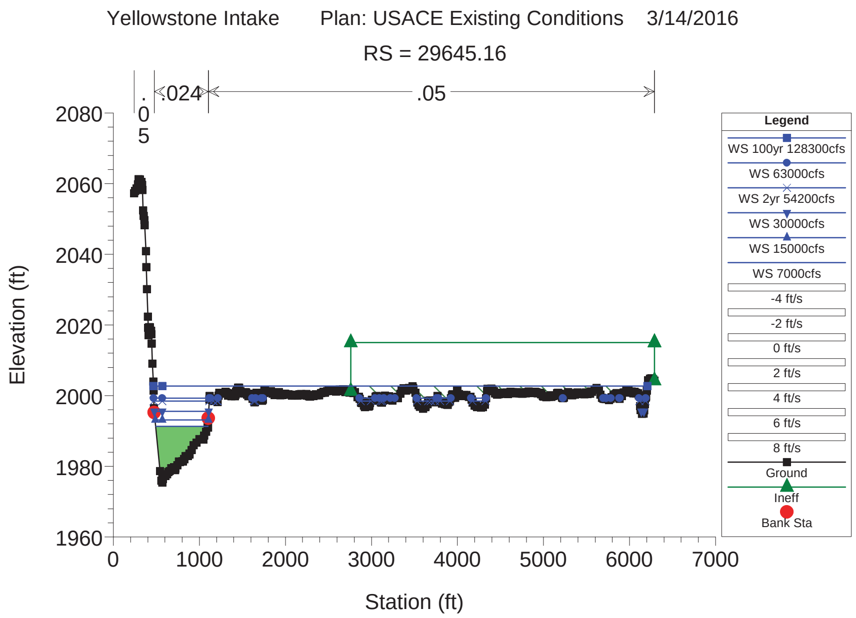

Yellowstone Intake
Plan: USACE Existing Conditions
3/14/2016
RS = 32272.67
.05
.024
.05
2060
2050
2040
2030
2020
2010
2000
1990
1980
Elevation (ft)
0
1000
2000
3000
4000
5000
6000
7000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
-2 ft/s
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
10 ft/s
Ground
Ineff
Bank Sta


Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 31618.85
.05
.024
.05
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
-4 ft/s
-2 ft/s
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
Ground
Ineff
Bank Sta
Elevation (ft)
2080
2060
2040
2020
2000
1980
0
1000
2000
3000
4000
5000
6000
7000
8000
Station (ft)

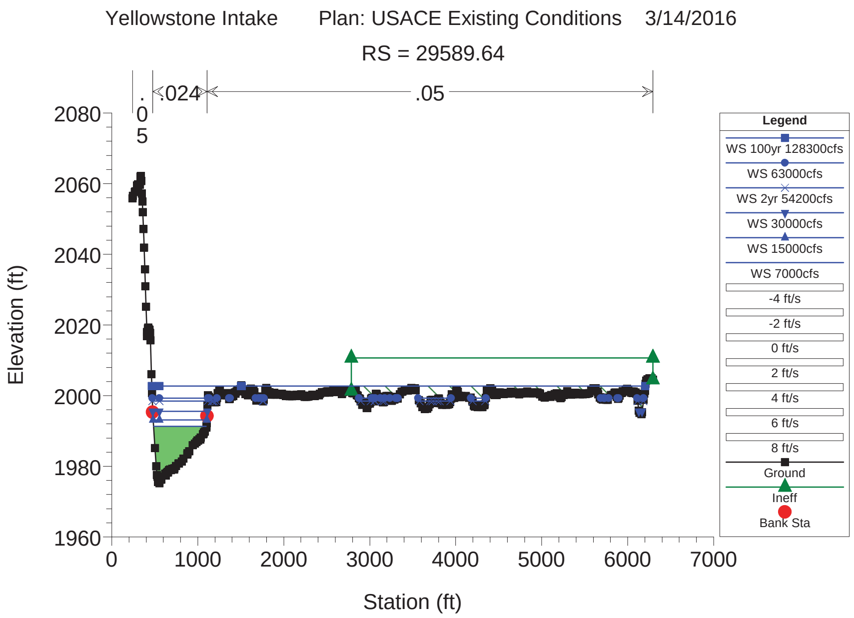

Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 30903.05
.05
.024
.05
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
-4 ft/s
-2 ft/s
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
Ground
Ineff
Bank Sta
Elevation (ft)
2080
2060
2040
2020
2000
1980
0
1000
2000
3000
4000
5000
6000
7000
Station (ft)


Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 30416.56
.05
.024
.05
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
-4 ft/s
-2 ft/s
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
Ground
Ineff
Bank Sta
Elevation (ft)
2080
2060
2040
2020
2000
1980
1960
0
1000
2000
3000
4000
5000
6000
7000
Station (ft)

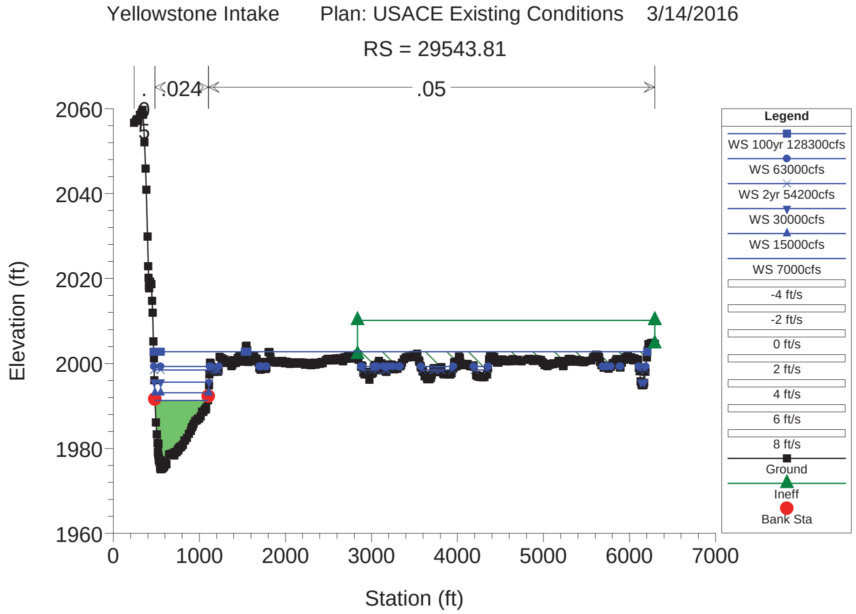

Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 29941.29
.05
.024
.05
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
-4 ft/s
-2 ft/s
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
Ground
Ineff
Bank Sta
Elevation (ft)
2080
2060
2040
2020
2000
1980
1960
0
1000
2000
3000
4000
5000
6000
7000
Station (ft)


Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

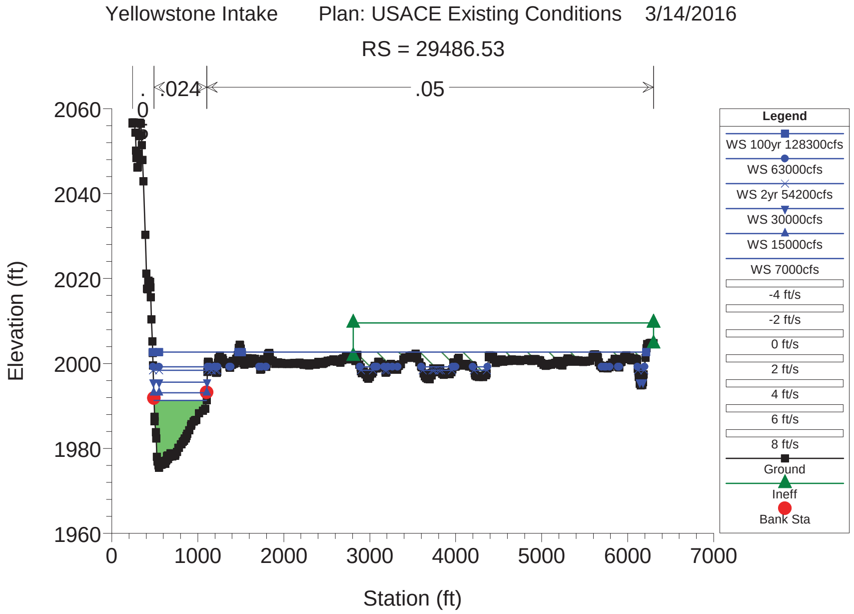
RS = 29645.16


Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

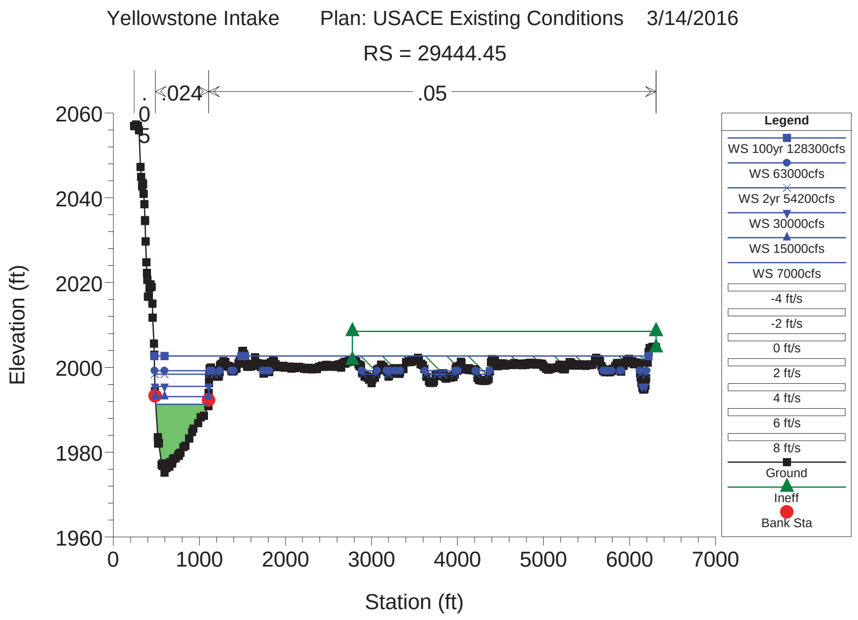
RS = 29589.64

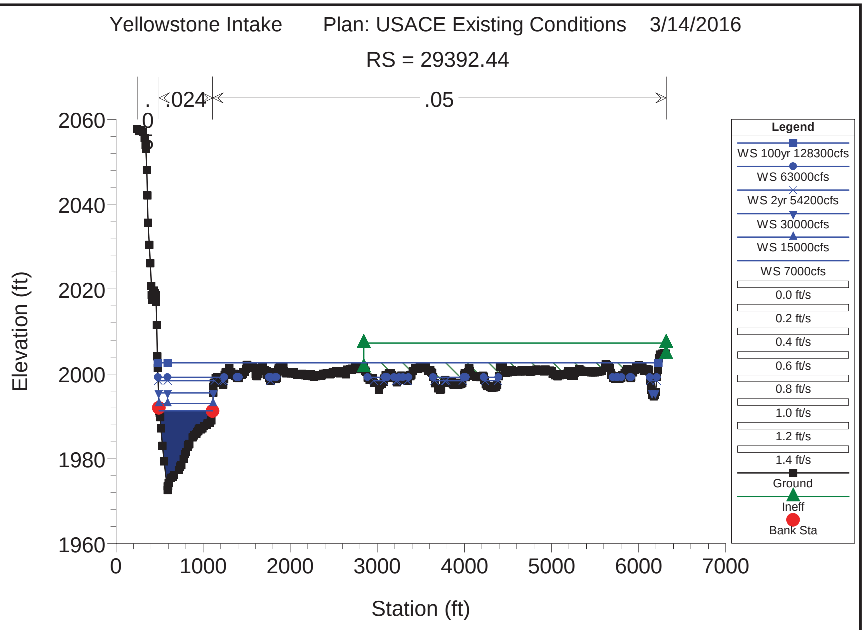

Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

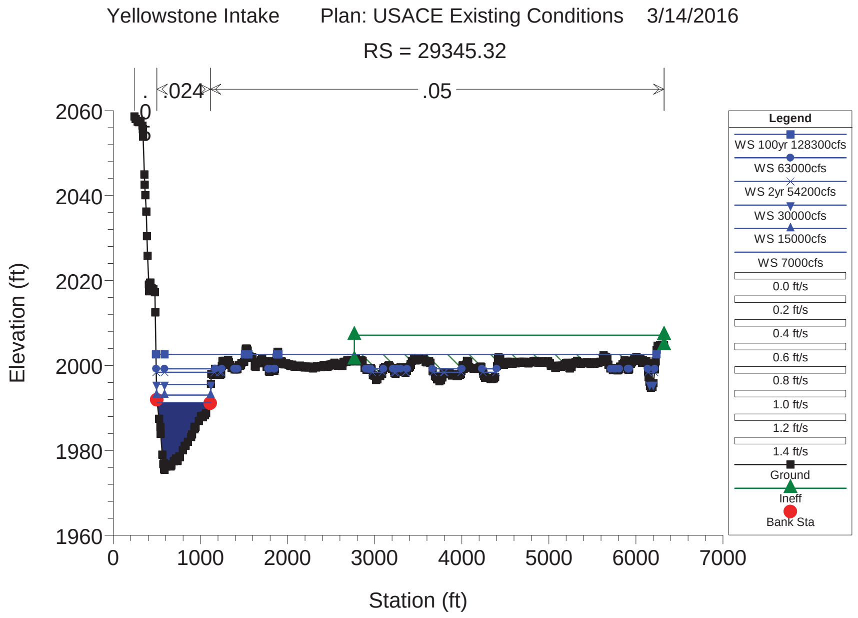
RS = 29543.81

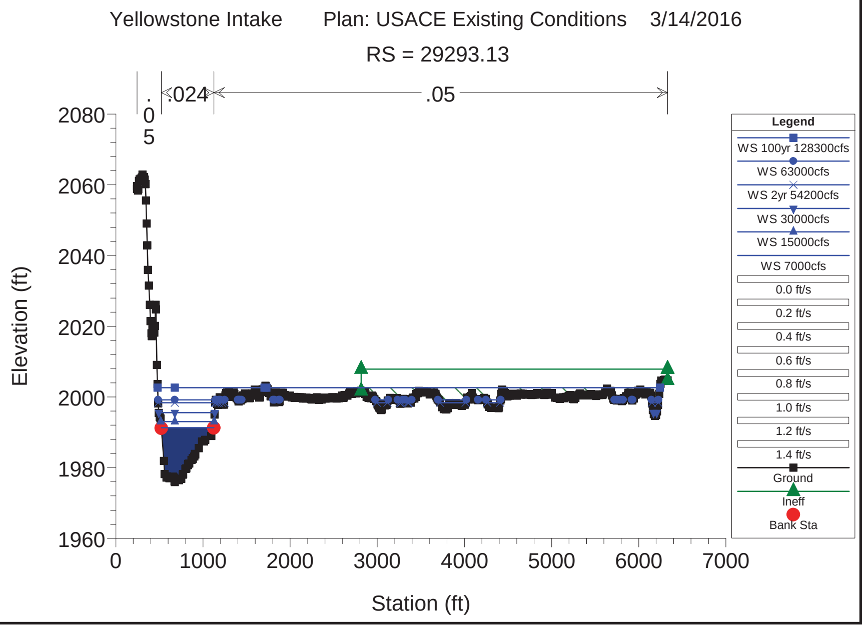

Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

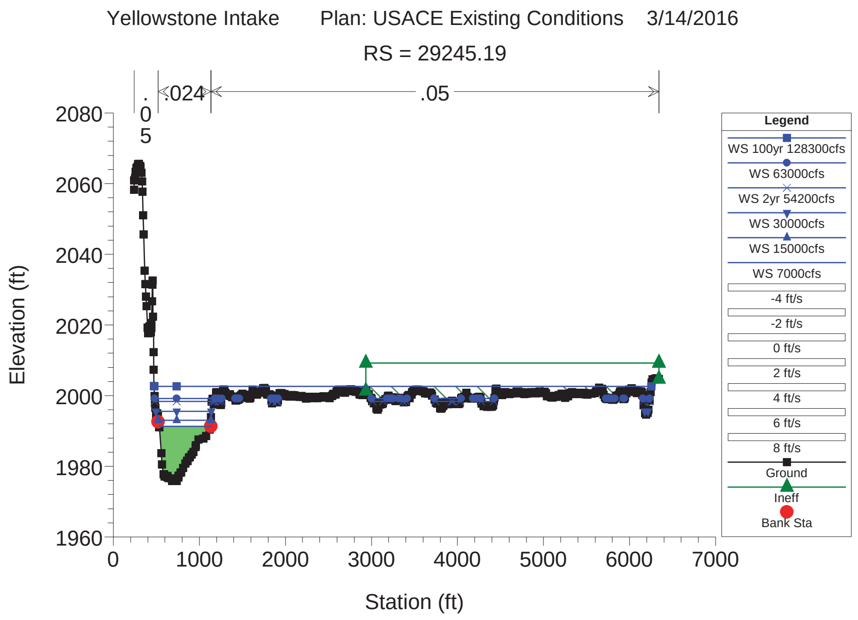
RS = 29486.53

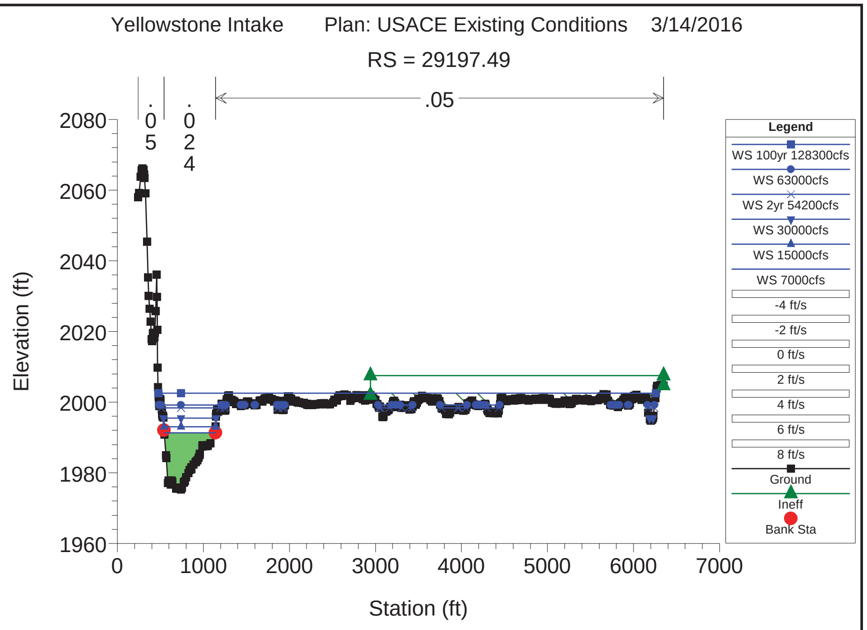

Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 29444.45
.05
.024
.05
Elevation (ft)
2060
2040
2020
2000
1980
1960
0
1000
2000
3000
4000
5000
6000
7000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
-4 ft/s
-2 ft/s
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
Ground
Ineff
Bank Sta

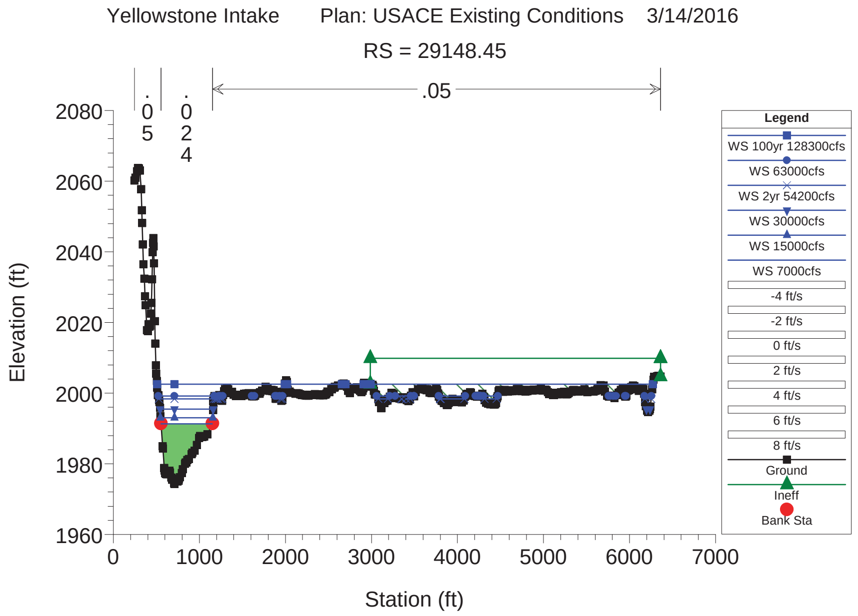

Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 29392.44
.05
.024
.05
Elevation (ft)
2060
2040
2020
2000
1980
1960
0
1000
2000
3000
4000
5000
6000
7000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.0 ft/s
0.2 ft/s
0.4 ft/s
0.6 ft/s
0.8 ft/s
1.0 ft/s
1.2 ft/s
1.4 ft/s
Ground
Ineff
Bank Sta

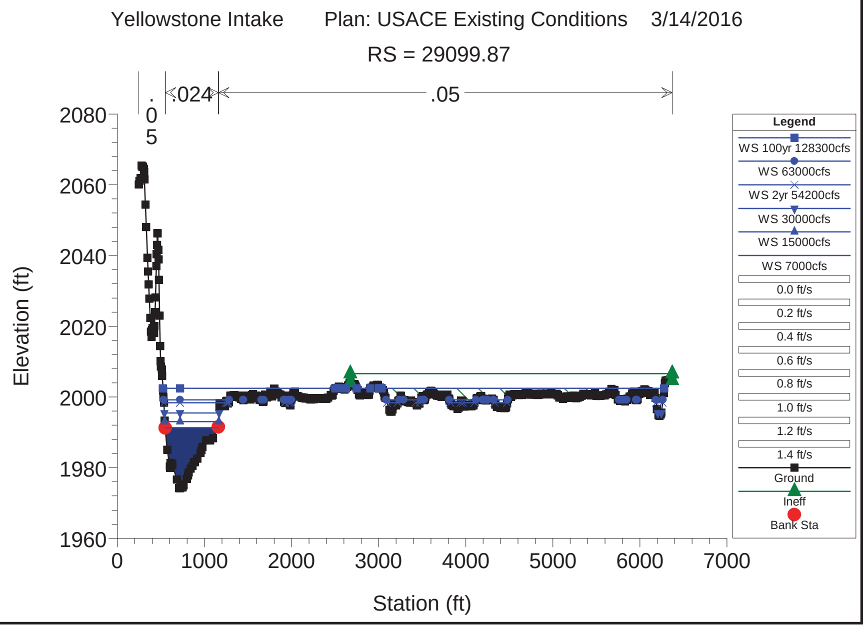

Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 29345.32
.05
.024
.05
Elevation (ft)
2060
2040
2020
2000
1980
1960
0
1000
2000
3000
4000
5000
6000
7000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.0 ft/s
0.2 ft/s
0.4 ft/s
0.6 ft/s
0.8 ft/s
1.0 ft/s
1.2 ft/s
1.4 ft/s
Ground
Ineff
Bank Sta


Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 29293.13
.05
.024
.05
Elevation (ft)
2080
2060
2040
2020
2000
1980
1960
0
1000
2000
3000
4000
5000
6000
7000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.0 ft/s
0.2 ft/s
0.4 ft/s
0.6 ft/s
0.8 ft/s
1.0 ft/s
1.2 ft/s
1.4 ft/s
Ground
Ineff
Bank Sta


Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 29245.19
.05
.024
.05
Elevation (ft)
2080
2060
2040
2020
2000
1980
1960
Station (ft)
0
1000
2000
3000
4000
5000
6000
7000
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
-4 ft/s
-2 ft/s
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
Ground
Ineff
Bank Sta

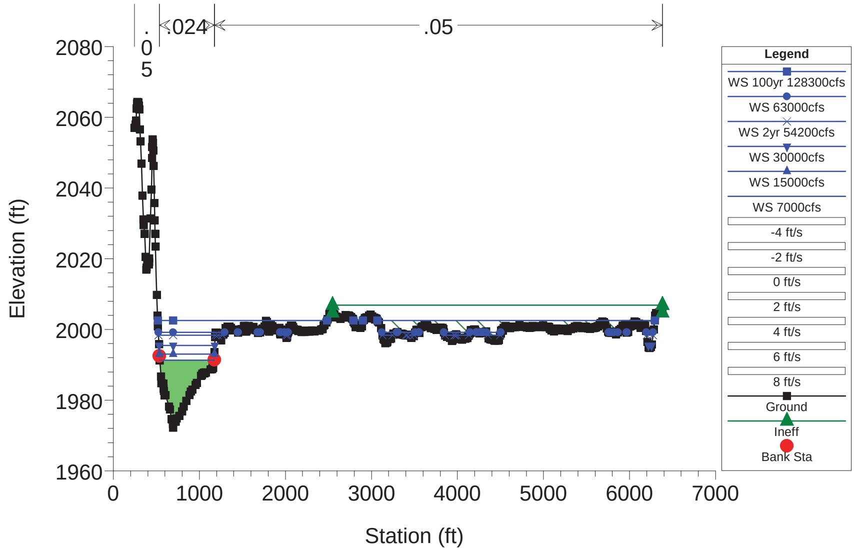

Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 29197.49
.05
.024
.05
Elevation (ft)
2080
2060
2040
2020
2000
1980
1960
Station (ft)
0
1000
2000
3000
4000
5000
6000
7000
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
-4 ft/s
-2 ft/s
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
Ground
Ineff
Bank Sta


Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 29148.45
.05
.024
.05
Elevation (ft)
2080
2060
2040
2020
2000
1980
1960
Station (ft)
0
1000
2000
3000
4000
5000
6000
7000
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
-4 ft/s
-2 ft/s
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
Ground
Ineff
Bank Sta


Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 29099.87
.05
.024
.05
Elevation (ft)
2080
2060
2040
2020
2000
1980
1960
Station (ft)
0
1000
2000
3000
4000
5000
6000
7000
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.0 ft/s
0.2 ft/s
0.4 ft/s
0.6 ft/s
0.8 ft/s
1.0 ft/s
1.2 ft/s
1.4 ft/s
Ground
Ineff
Bank Sta

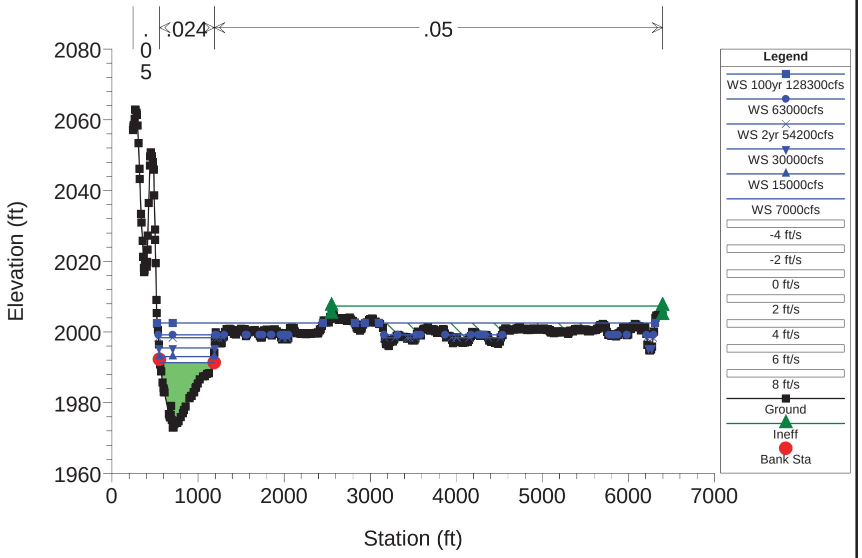
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

RS = 29047.75



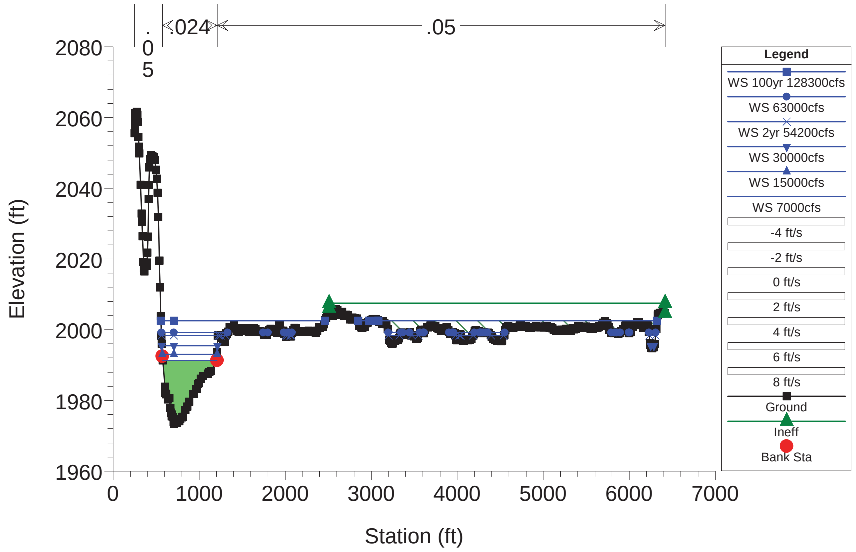
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

RS = 28998.60



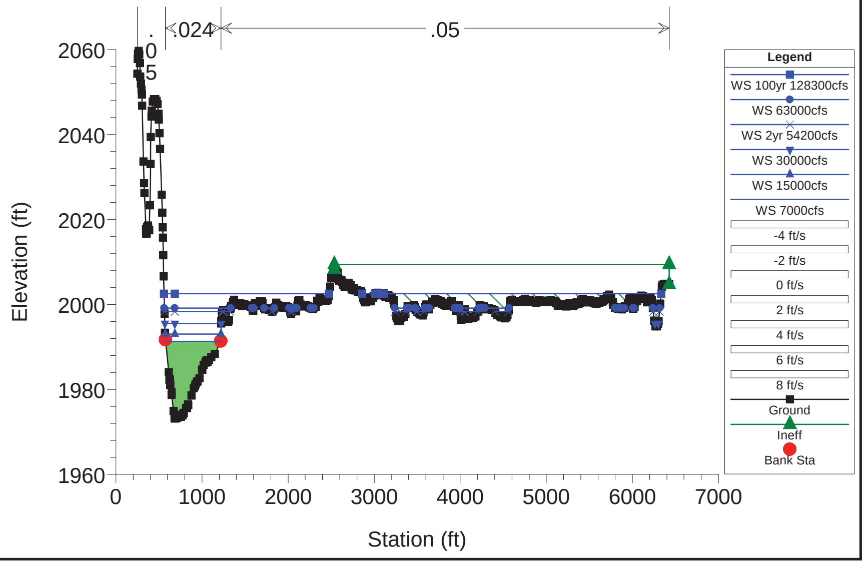
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

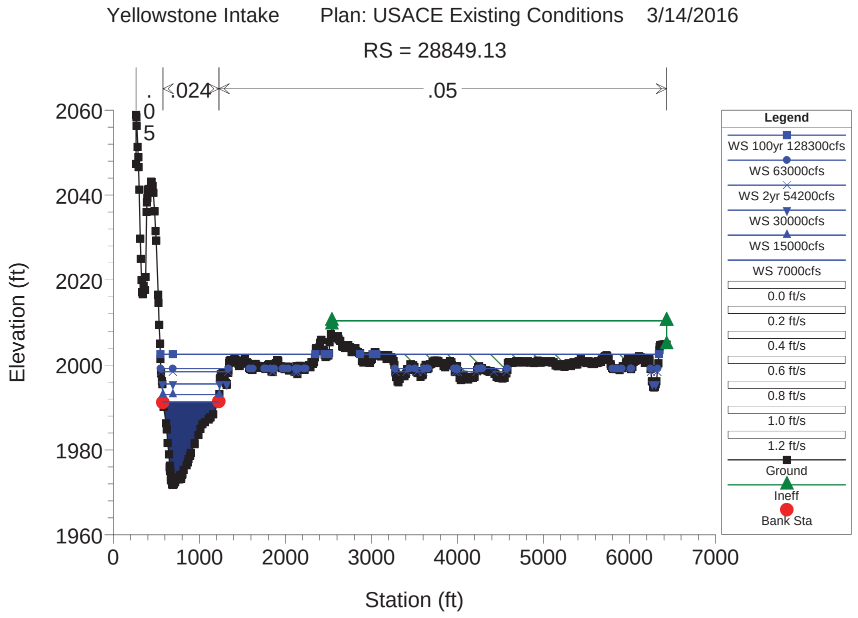
RS = 28947.07

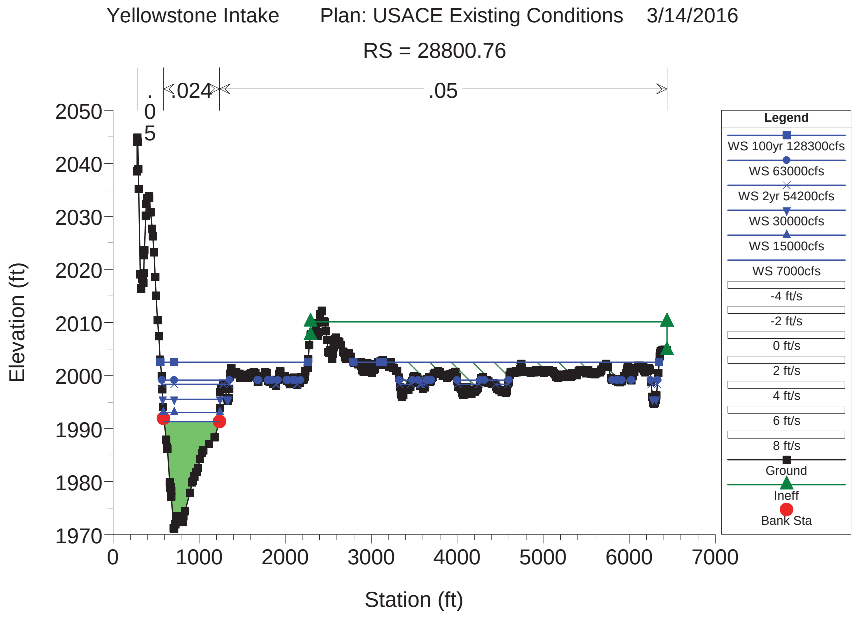


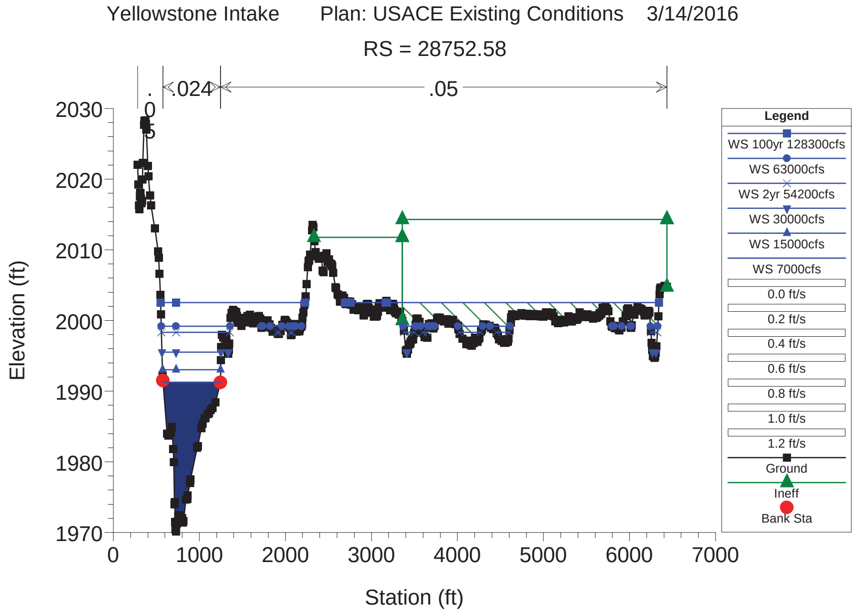
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

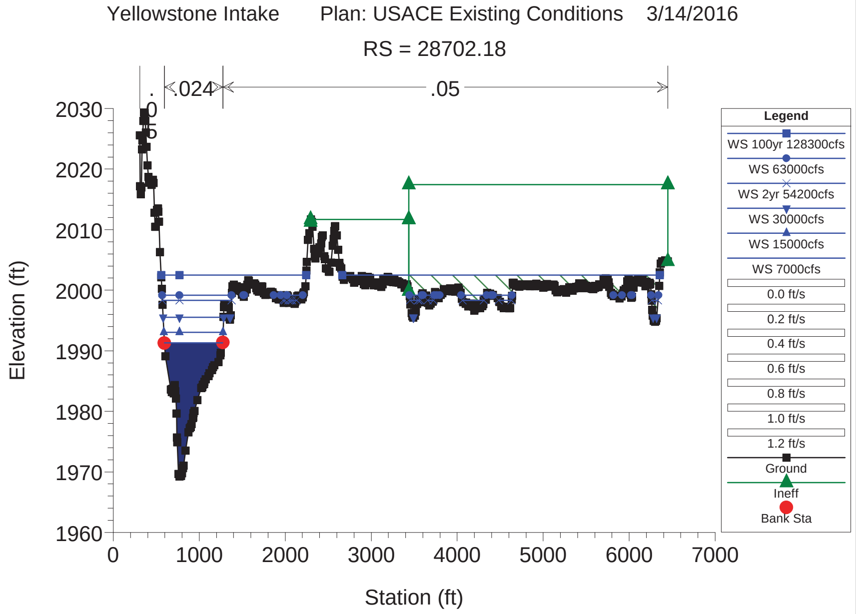
RS = 28897.52

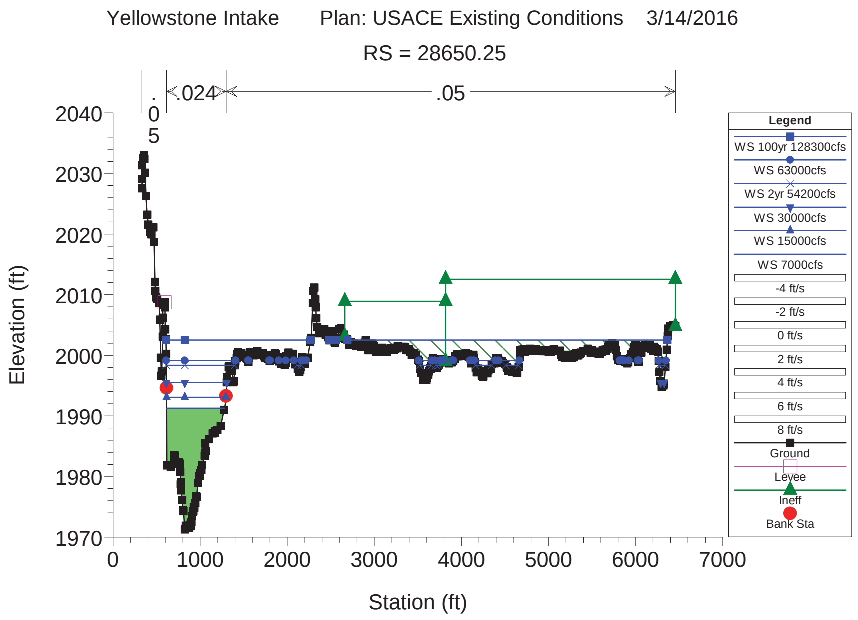


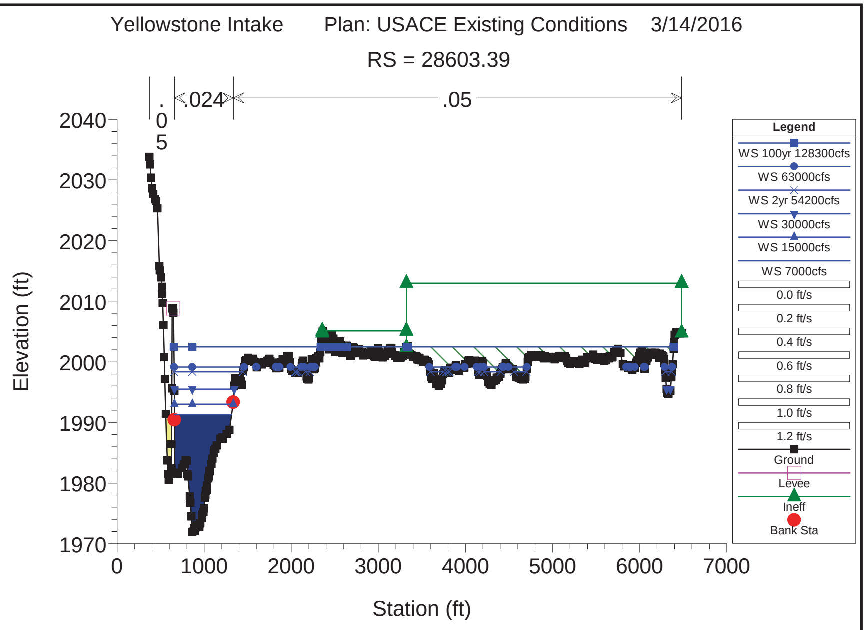

Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 28849.13
.05
.024
.05
Elevation (ft)
2060
2040
2020
2000
1980
1960
0
1000
2000
3000
4000
5000
6000
7000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.0 ft/s
0.2 ft/s
0.4 ft/s
0.6 ft/s
0.8 ft/s
1.0 ft/s
1.2 ft/s
Ground
Ineff
Bank Sta

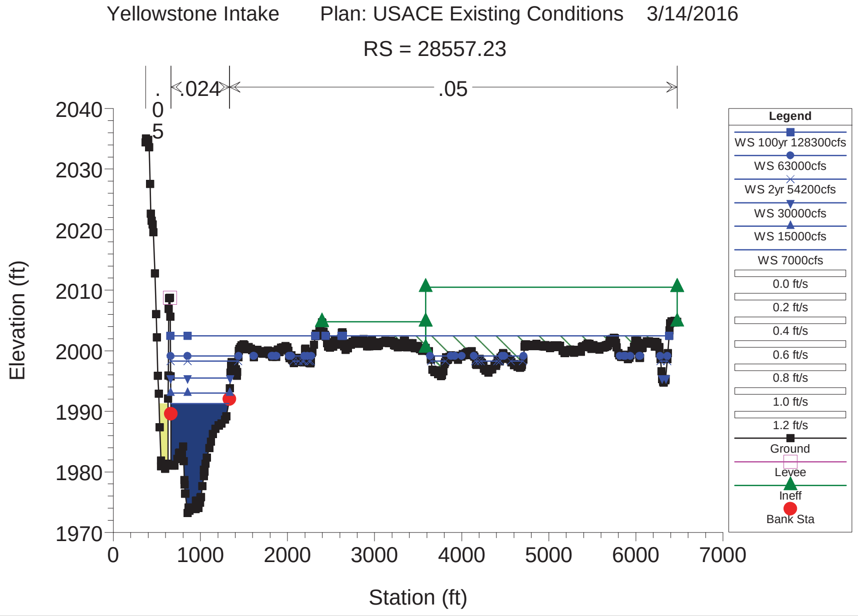

Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 28800.76
.05
.024
.05
Elevation (ft)
2050
2040
2030
2020
2010
2000
1990
1980
1970
0
1000
2000
3000
4000
5000
6000
7000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
-4 ft/s
-2 ft/s
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
Ground
Ineff
Bank Sta

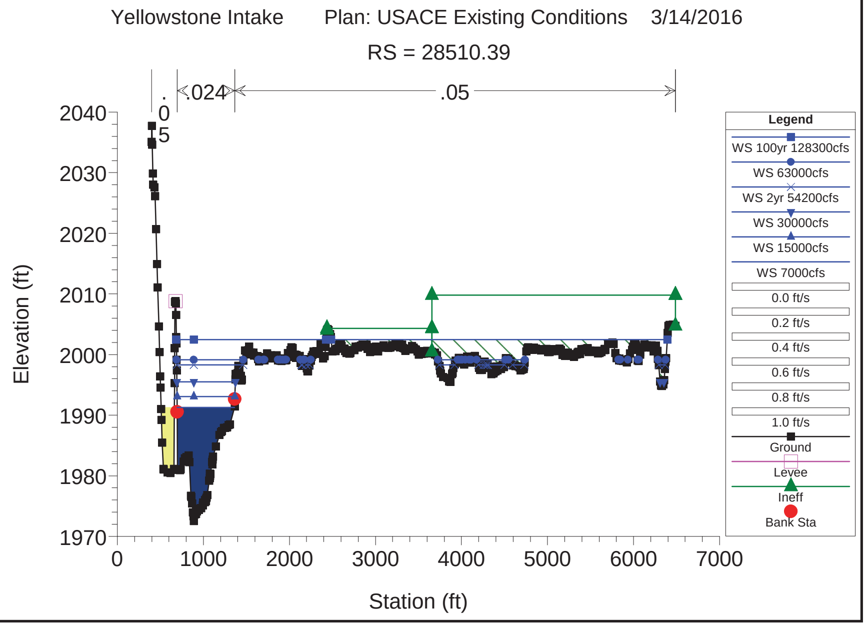

Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 28752.58
.05
.024
.05
Elevation (ft)
2030
2020
2010
2000
1990
1980
1970
0
1000
2000
3000
4000
5000
6000
7000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.0 ft/s
0.2 ft/s
0.4 ft/s
0.6 ft/s
0.8 ft/s
1.0 ft/s
1.2 ft/s
Ground
Ineff
Bank Sta

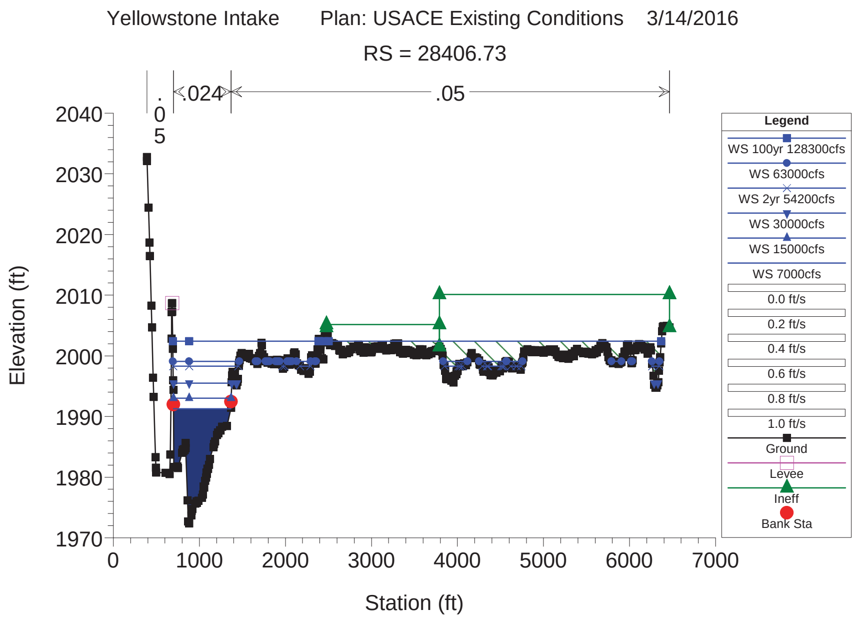

Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 28702.18
.05
.024
.05
Elevation (ft)
2030
2020
2010
2000
1990
1980
1970
1960
0
1000
2000
3000
4000
5000
6000
7000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.0 ft/s
0.2 ft/s
0.4 ft/s
0.6 ft/s
0.8 ft/s
1.0 ft/s
1.2 ft/s
Ground
Ineff
Bank Sta


Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 28650.25
.05
.024
.05
2040
2030
2020
2010
2000
1990
1980
1970
Elevation (ft)
0
1000
2000
3000
4000
5000
6000
7000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
-4 ft/s
-2 ft/s
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
Ground
Levee
Ineff
Bank Sta


Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 28603.39
.05
.024
.05
2040
2030
2020
2010
2000
1990
1980
1970
Elevation (ft)
0
1000
2000
3000
4000
5000
6000
7000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.0 ft/s
0.2 ft/s
0.4 ft/s
0.6 ft/s
0.8 ft/s
1.0 ft/s
1.2 ft/s
Ground
Levee
Ineff
Bank Sta

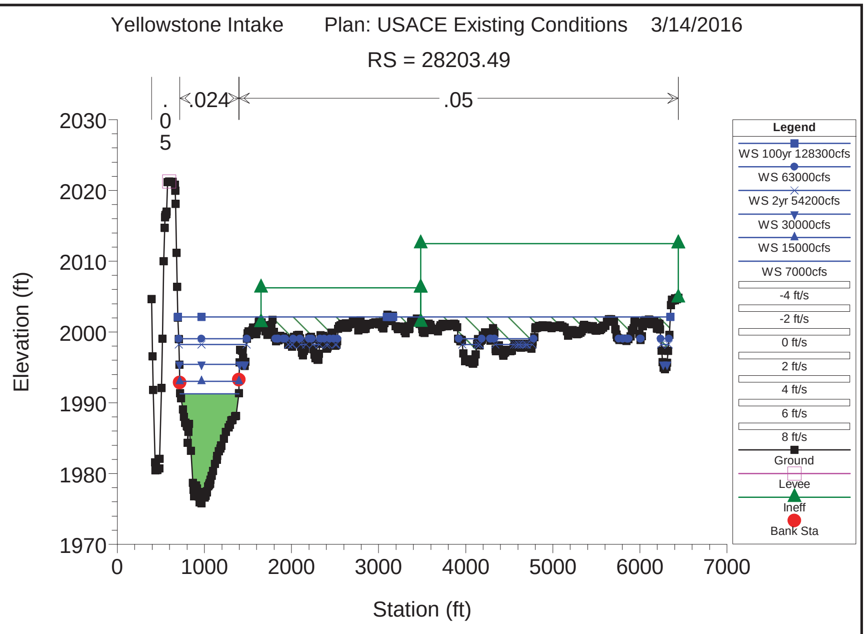

Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 28557.23
.05
.024
.05
2040
2030
2020
2010
2000
1990
1980
1970
Elevation (ft)
0
1000
2000
3000
4000
5000
6000
7000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.0 ft/s
0.2 ft/s
0.4 ft/s
0.6 ft/s
0.8 ft/s
1.0 ft/s
1.2 ft/s
Ground
Levee
Ineff
Bank Sta


Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 28510.39
.05
.024
.05
2040
2030
2020
2010
2000
1990
1980
1970
Elevation (ft)
0
1000
2000
3000
4000
5000
6000
7000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.0 ft/s
0.2 ft/s
0.4 ft/s
0.6 ft/s
0.8 ft/s
1.0 ft/s
Ground
Levee
Ineff
Bank Sta



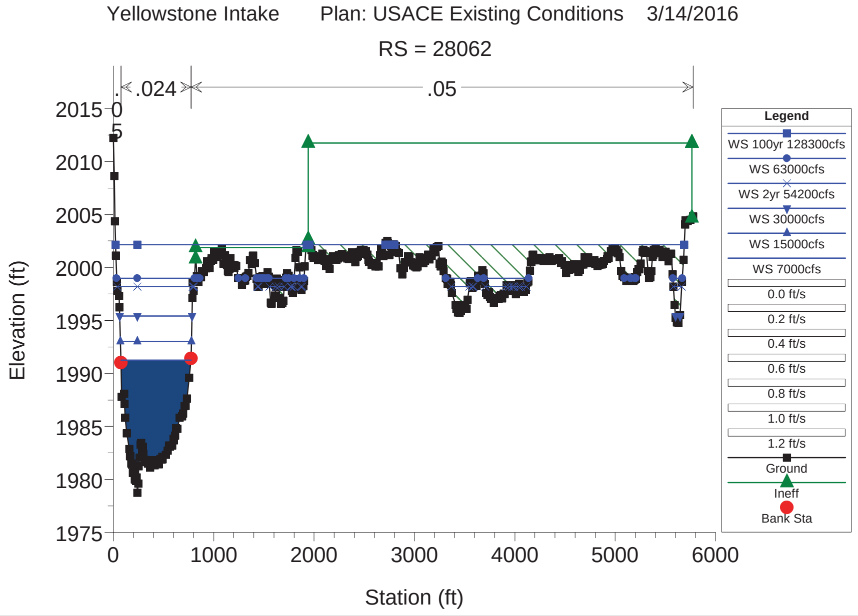
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

RS = 28406.73



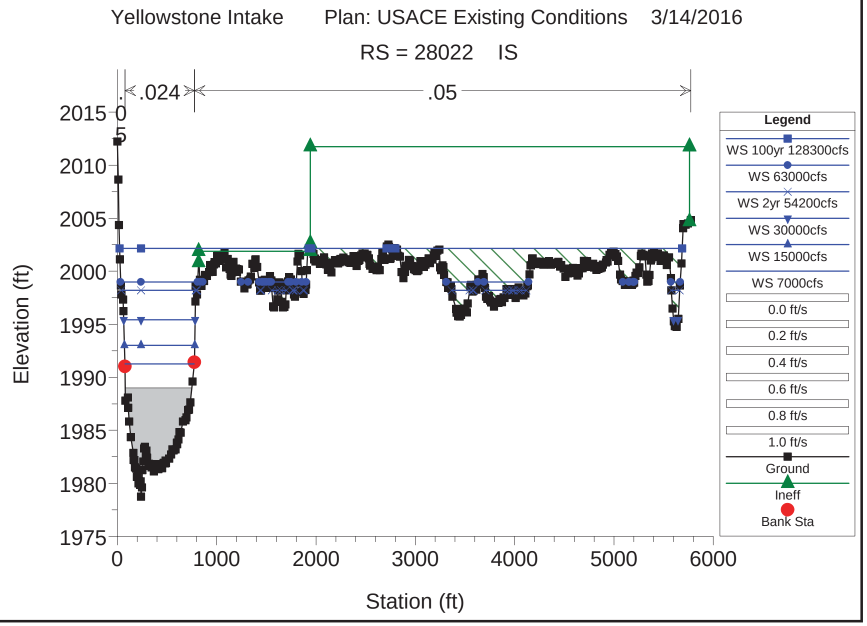
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

RS = 28203.49



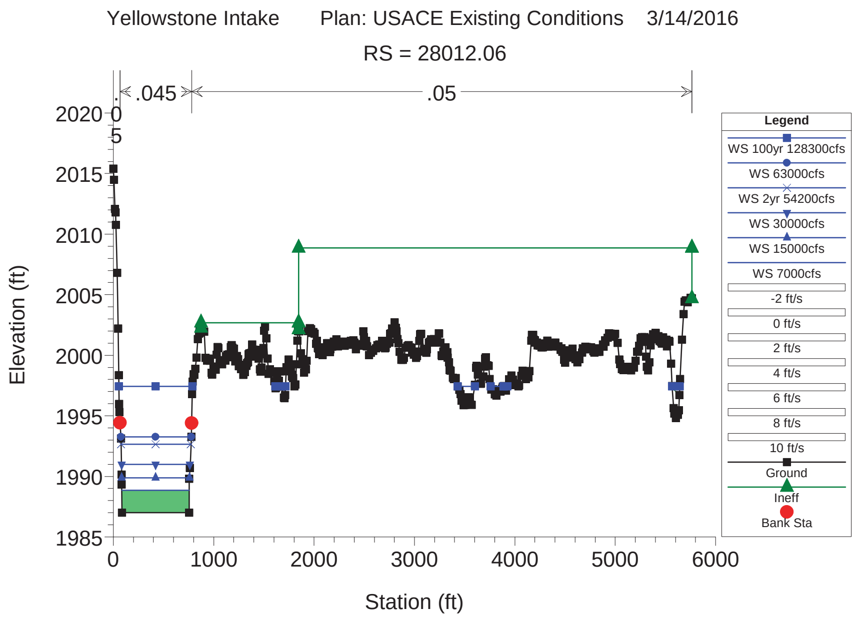
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

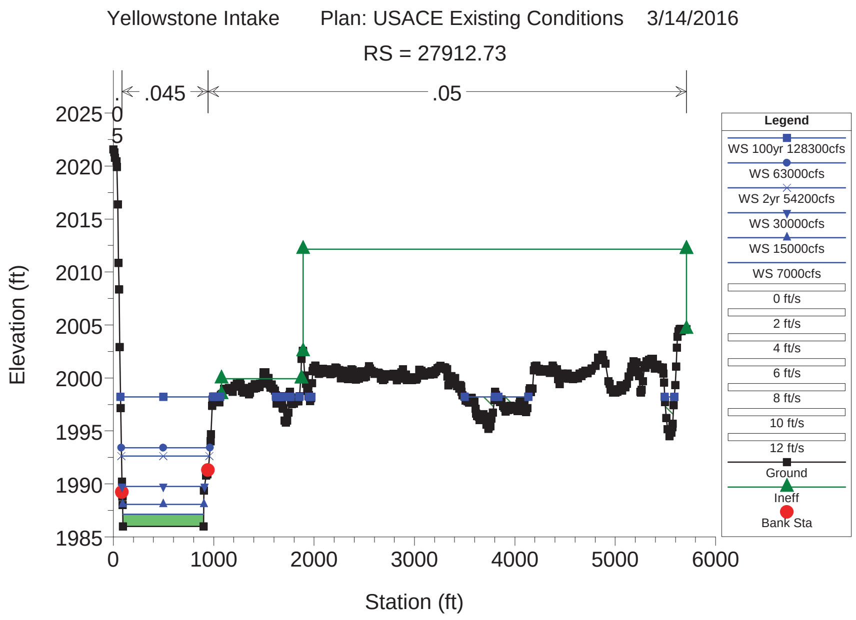
RS = 28062

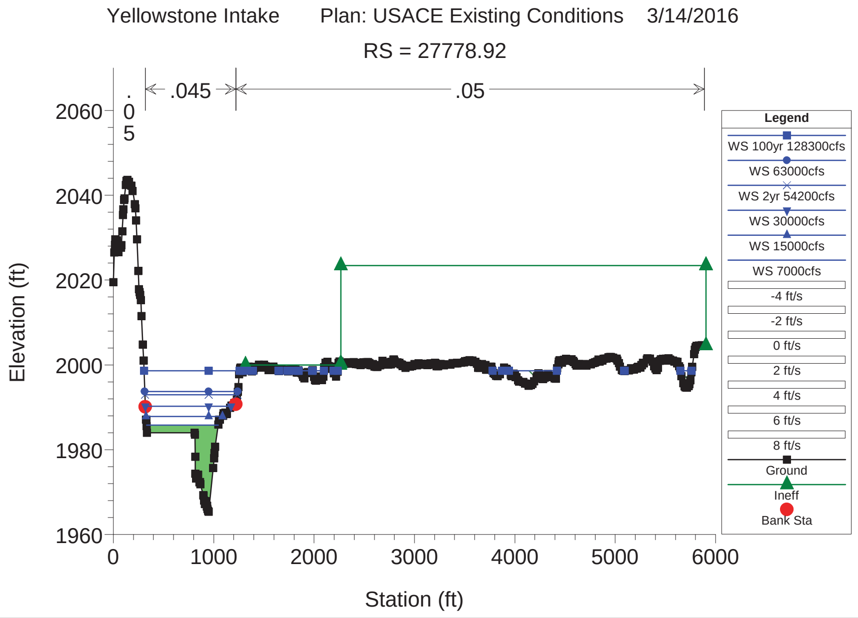


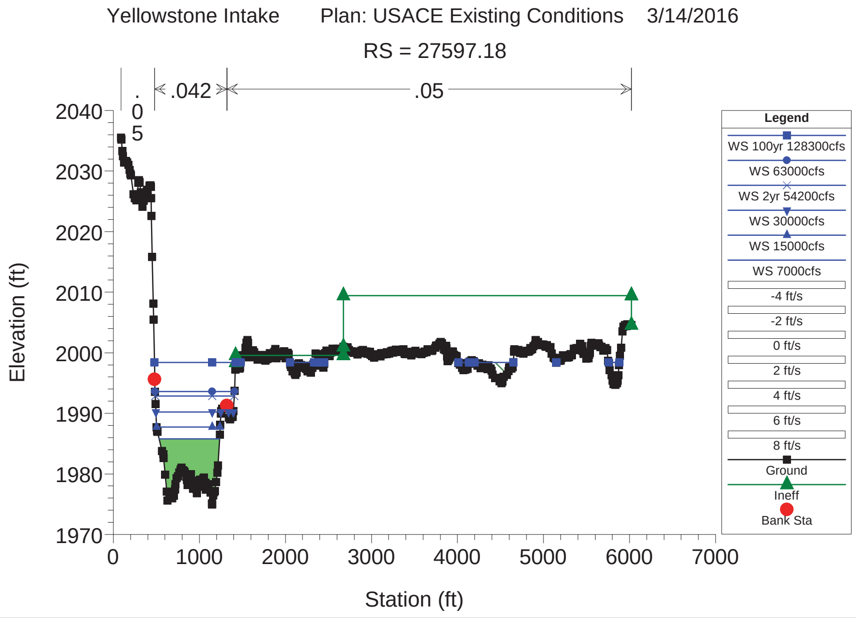
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

RS = 28022 IS


Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 28012.06
.05
.045
.05
Elevation (ft)
2020
2015
2010
2005
2000
1995
1990
1985
0
1000
2000
3000
4000
5000
6000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
-2 ft/s
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
10 ft/s
Ground
Ineff
Bank Sta

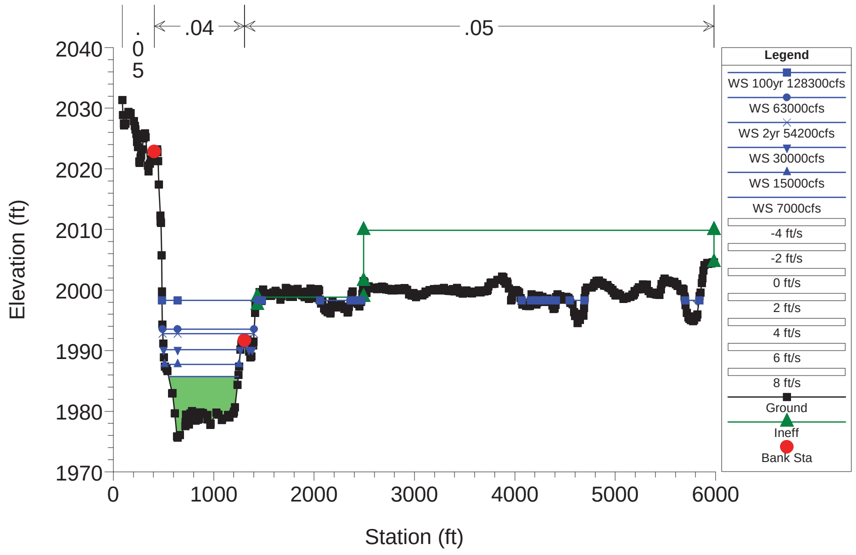

Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 27912.73
.05
.045
.05
Elevation (ft)
2025
2020
2015
2010
2005
2000
1995
1990
1985
0
1000
2000
3000
4000
5000
6000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
10 ft/s
12 ft/s
Ground
Ineff
Bank Sta


Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 27778.92
.05
.045
.05
Elevation (ft)
2060
2040
2020
2000
1980
1960
0
1000
2000
3000
4000
5000
6000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
-4 ft/s
-2 ft/s
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
Ground
Ineff
Bank Sta


Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 27597.18
.05
.042
.05
Elevation (ft)
2040
2030
2020
2010
2000
1990
1980
1970
0
1000
2000
3000
4000
5000
6000
7000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
-4 ft/s
-2 ft/s
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
Ground
Ineff
Bank Sta

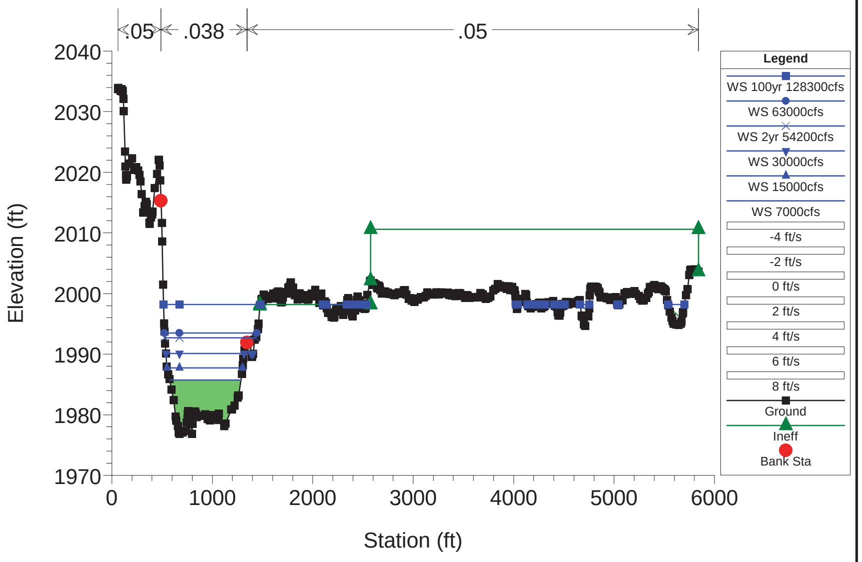
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

RS = 27550.20



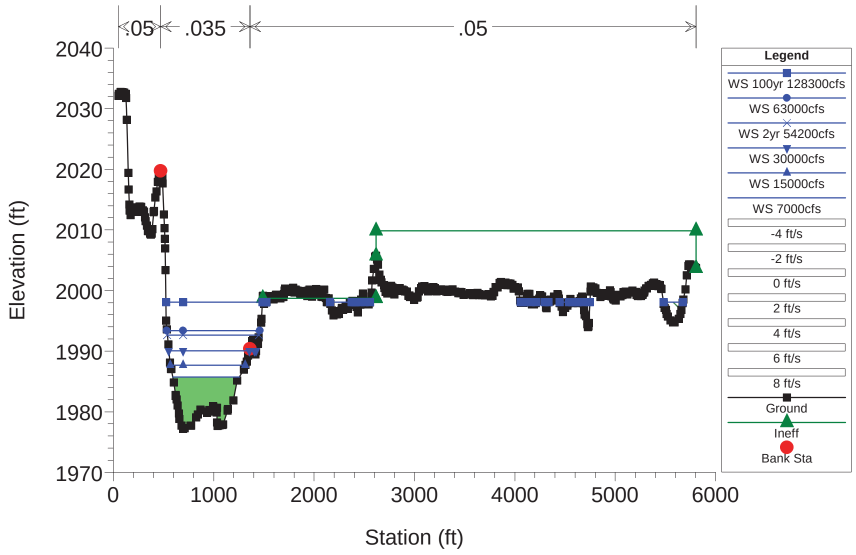
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

RS = 27498.33



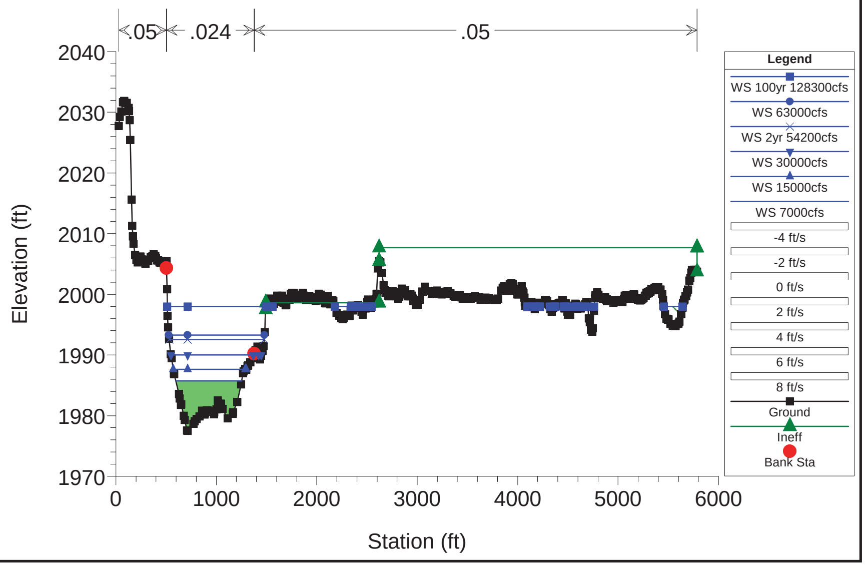
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

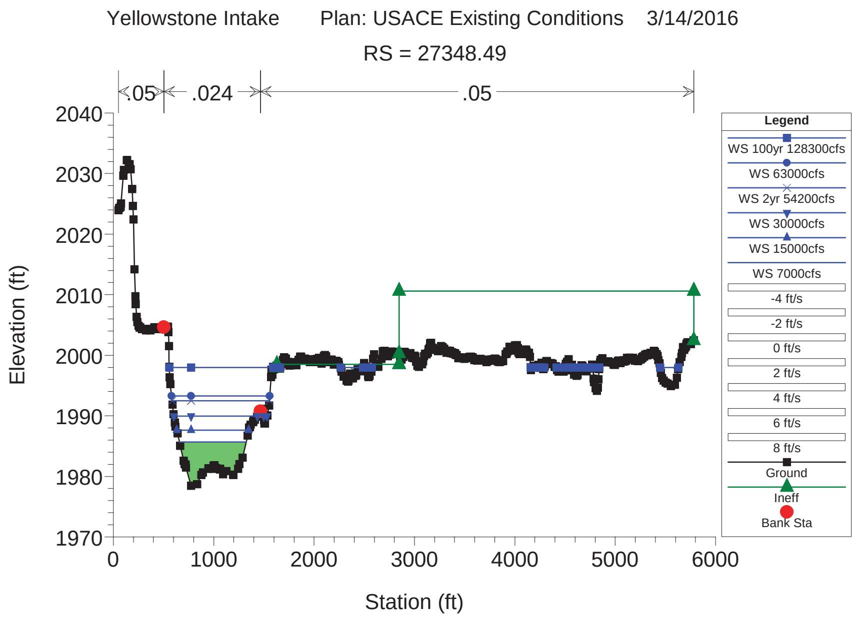
RS = 27447.08

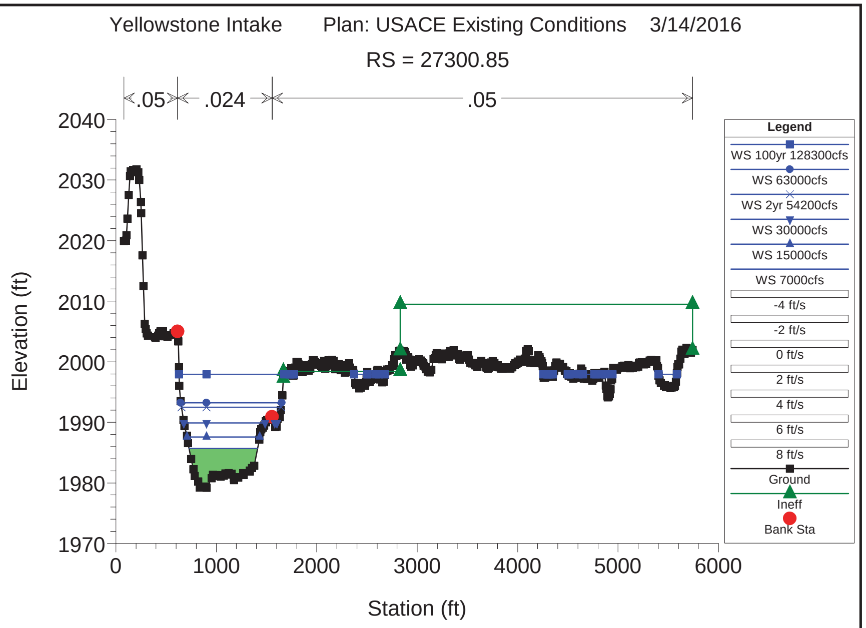


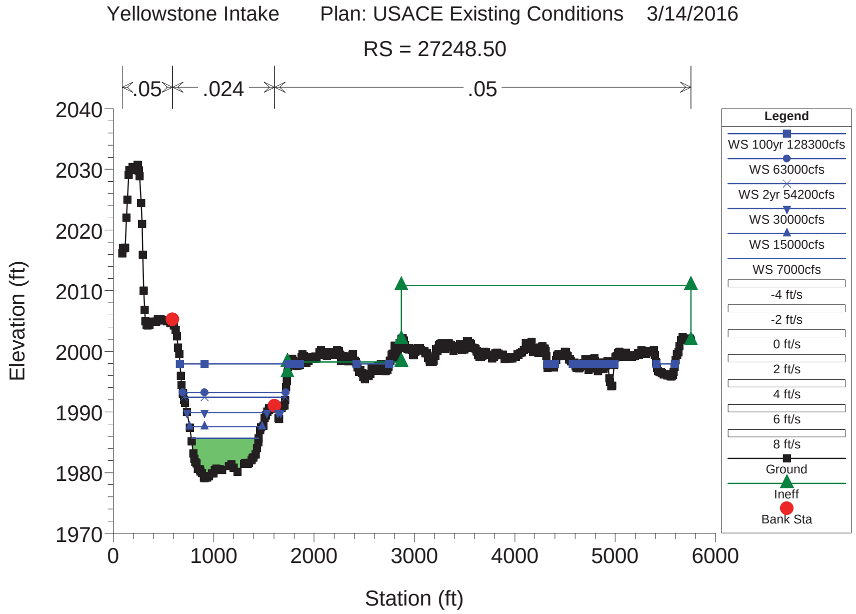
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

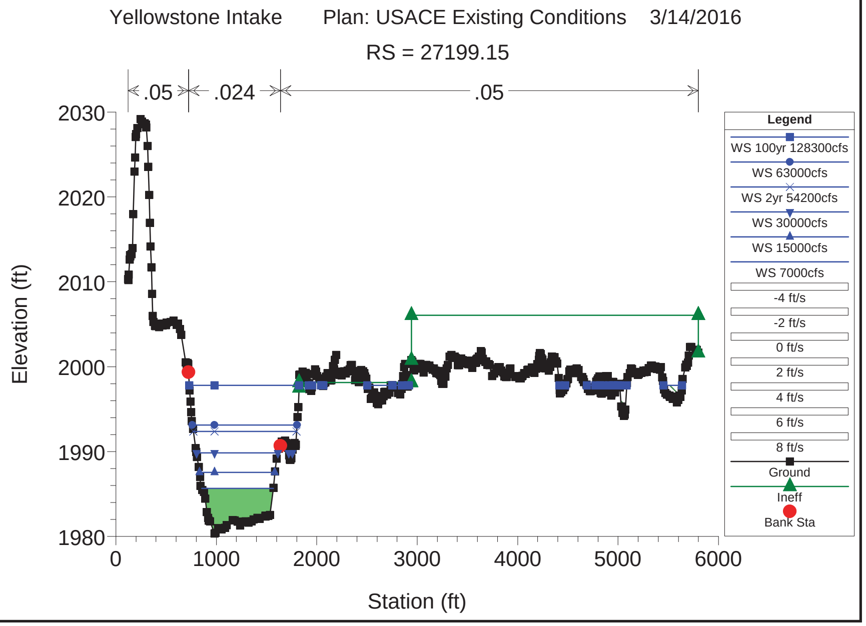
RS = 27398.93




Yellowstone Intake
Plan: USACE Existing Conditions
3/14/2016
RS = 27348.49
.05
.024
.05
Elevation (ft)
Station (ft)
2040
2030
2020
2010
2000
1990
1980
1970
0
1000
2000
3000
4000
5000
6000
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
-4 ft/s
-2 ft/s
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
Ground
Ineff
Bank Sta

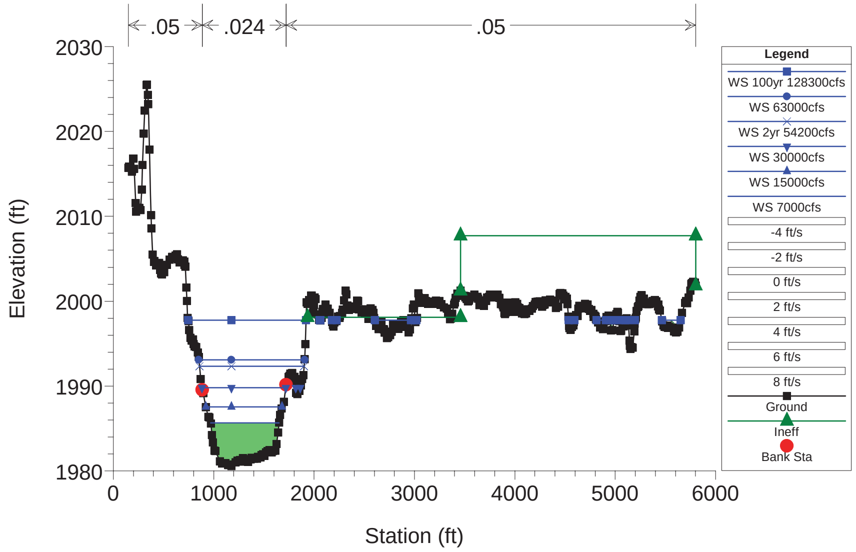

Yellowstone Intake
Plan: USACE Existing Conditions
3/14/2016
RS = 27300.85
.05
.024
.05
Elevation (ft)
Station (ft)
2040
2030
2020
2010
2000
1990
1980
1970
0
1000
2000
3000
4000
5000
6000
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
-4 ft/s
-2 ft/s
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
Ground
Ineff
Bank Sta


Yellowstone Intake
Plan: USACE Existing Conditions
3/14/2016
RS = 27248.50
.05
.024
.05
Elevation (ft)
Station (ft)
2040
2030
2020
2010
2000
1990
1980
1970
0
1000
2000
3000
4000
5000
6000
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
-4 ft/s
-2 ft/s
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
Ground
Ineff
Bank Sta


Yellowstone Intake
Plan: USACE Existing Conditions
3/14/2016
RS = 27199.15
.05
.024
.05
Elevation (ft)
Station (ft)
2030
2020
2010
2000
1990
1980
0
1000
2000
3000
4000
5000
6000
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
-4 ft/s
-2 ft/s
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
Ground
Ineff
Bank Sta

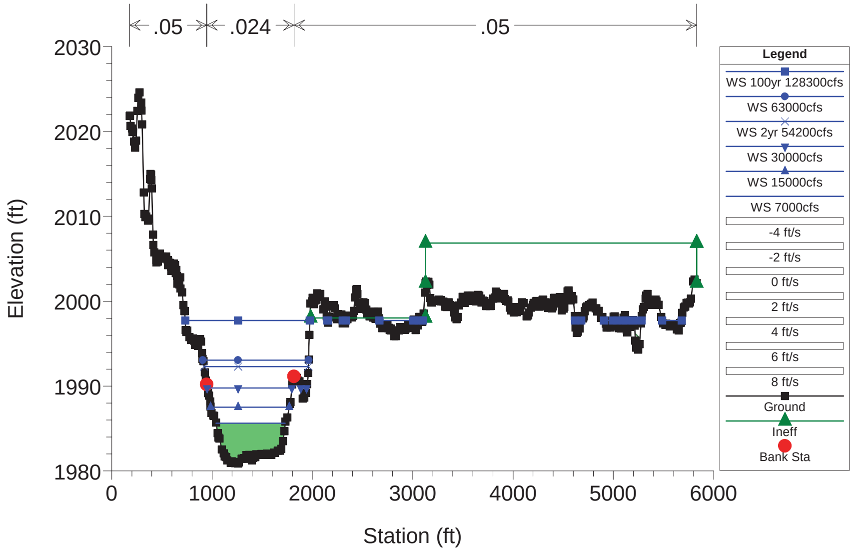
Yellowstone Intake   Plan: USACE Existing Conditions   3/14/2016

RS = 27147.30



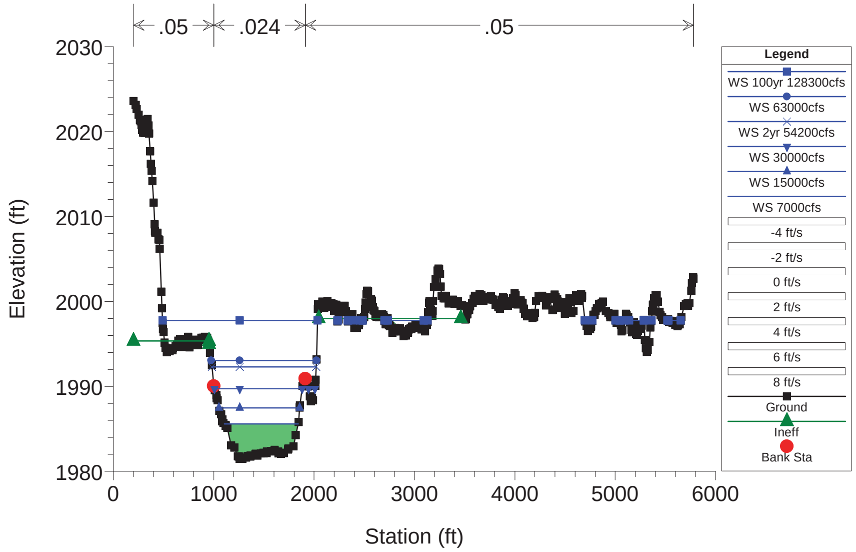
Yellowstone Intake   Plan: USACE Existing Conditions   3/14/2016

RS = 27092.77



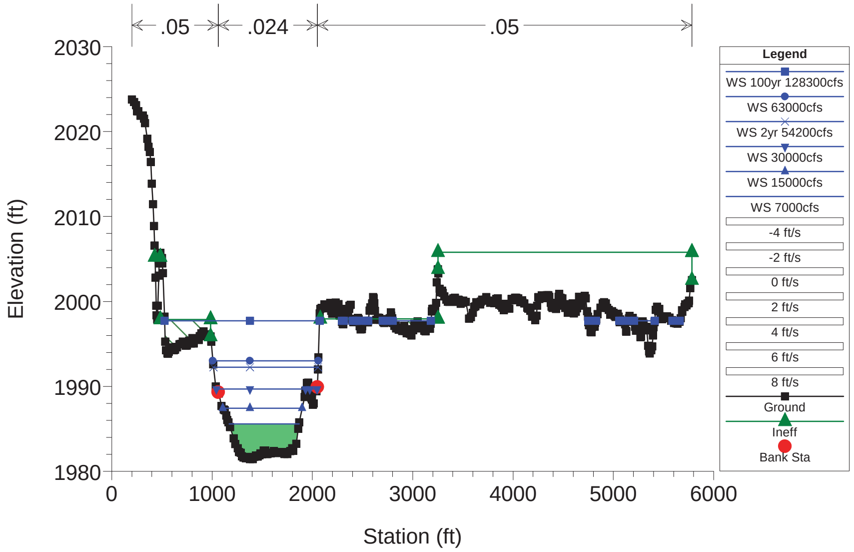
Yellowstone Intake   Plan: USACE Existing Conditions   3/14/2016

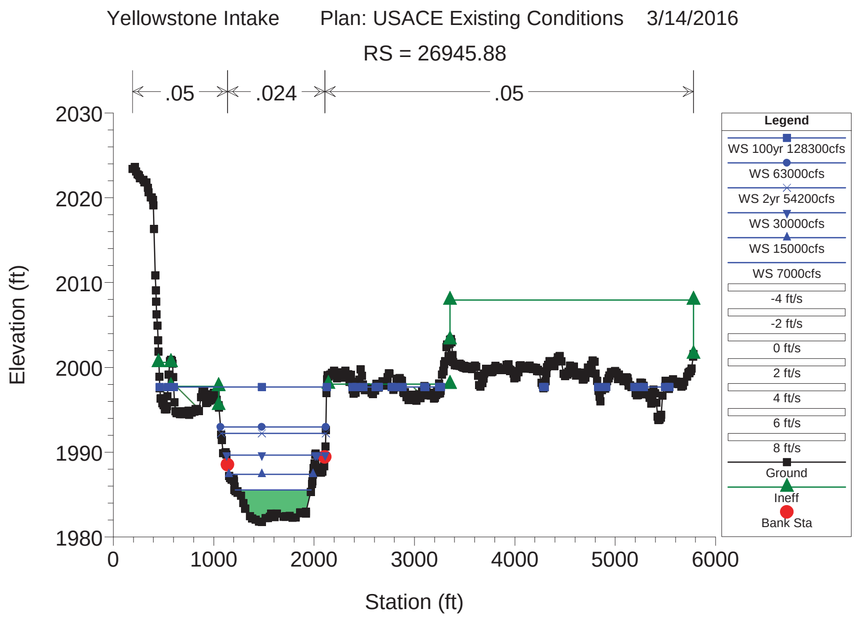
RS = 27045.05



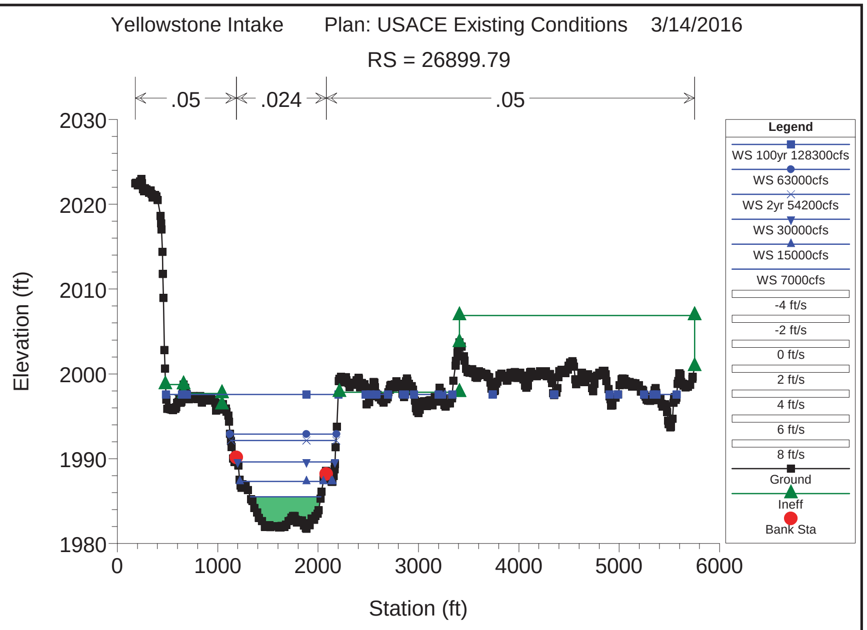
Yellowstone Intake   Plan: USACE Existing Conditions   3/14/2016

RS = 26997.92

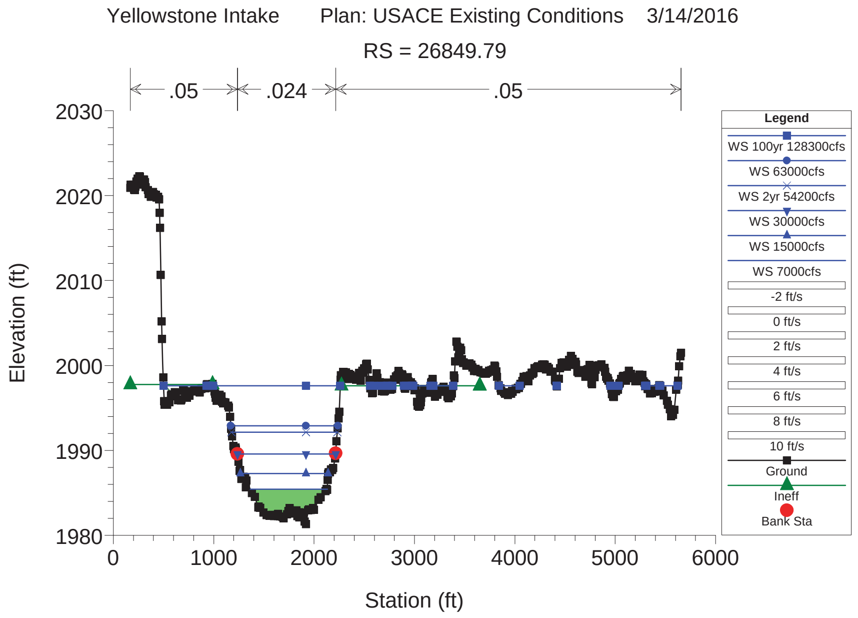



Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

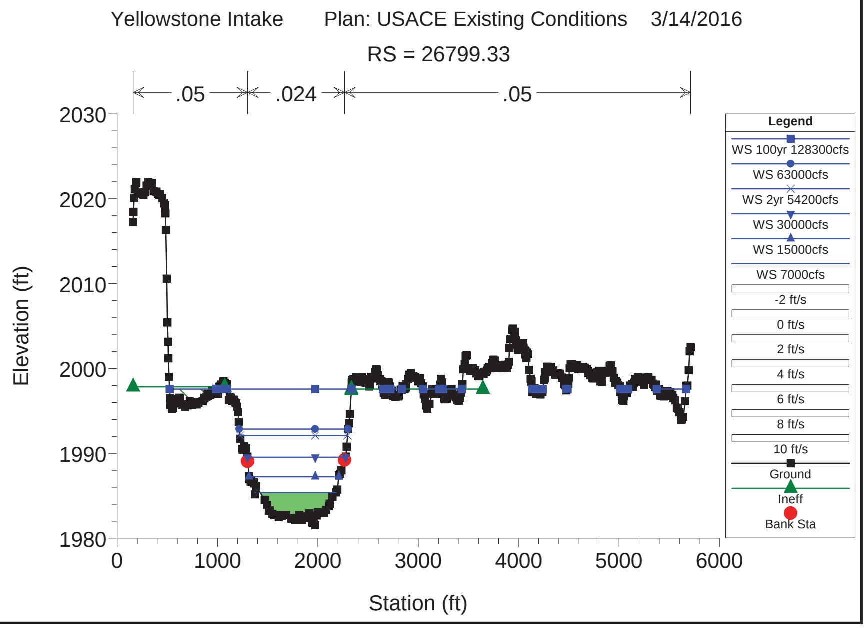
RS = 26945.88


Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

RS = 26899.79


Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

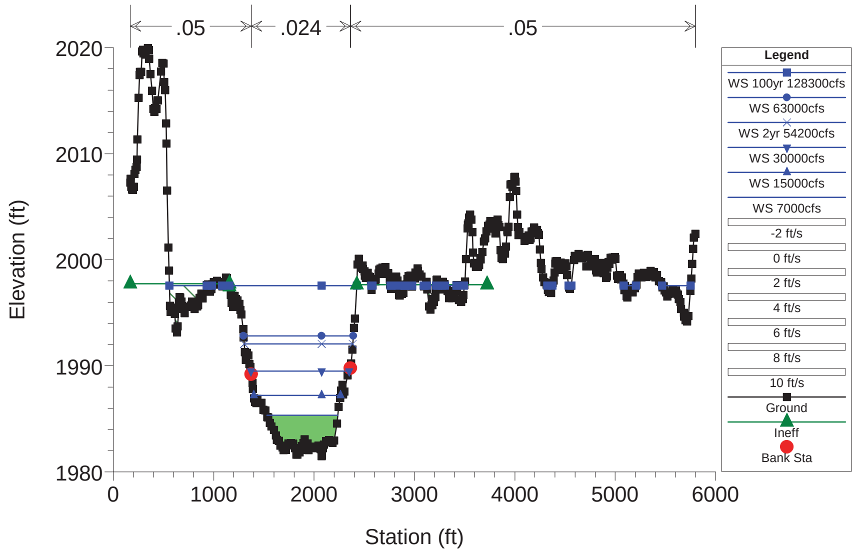
RS = 26849.79


Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

RS = 26799.33

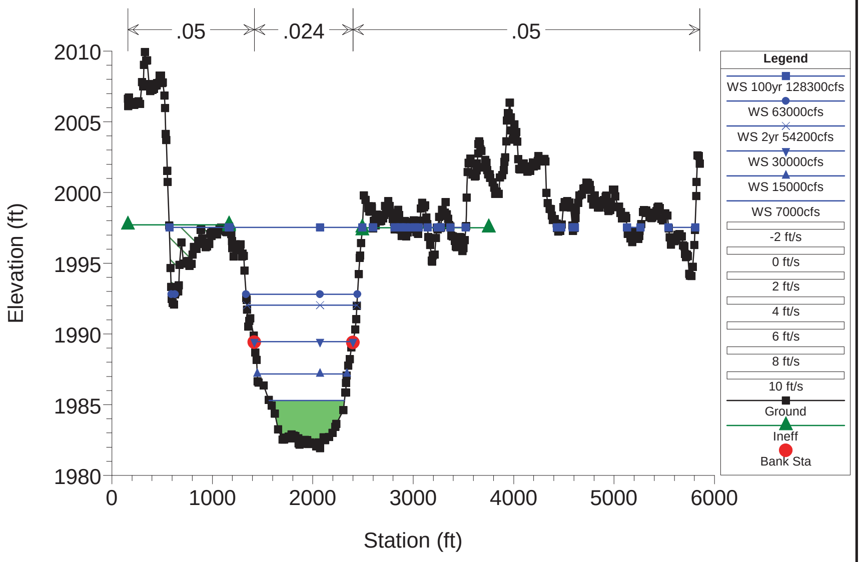
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

RS = 26750.78



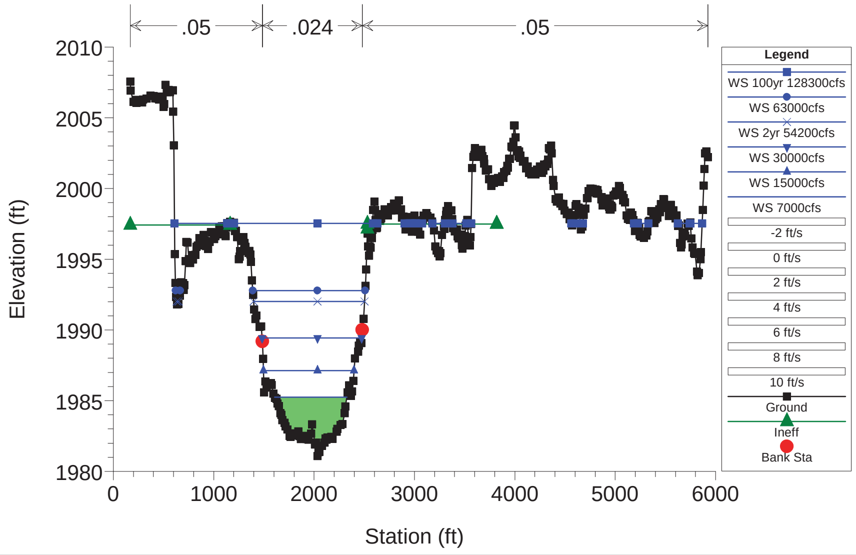
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

RS = 26696.93



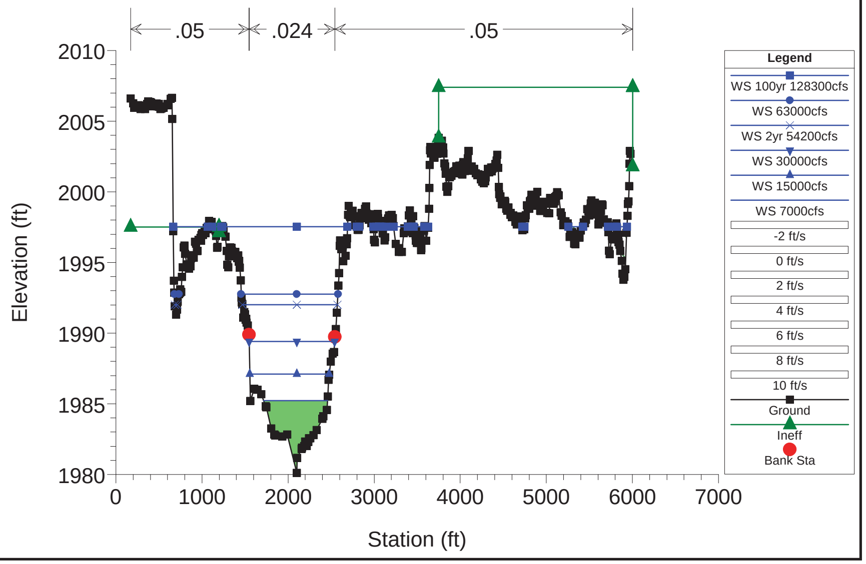
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

RS = 26646.45



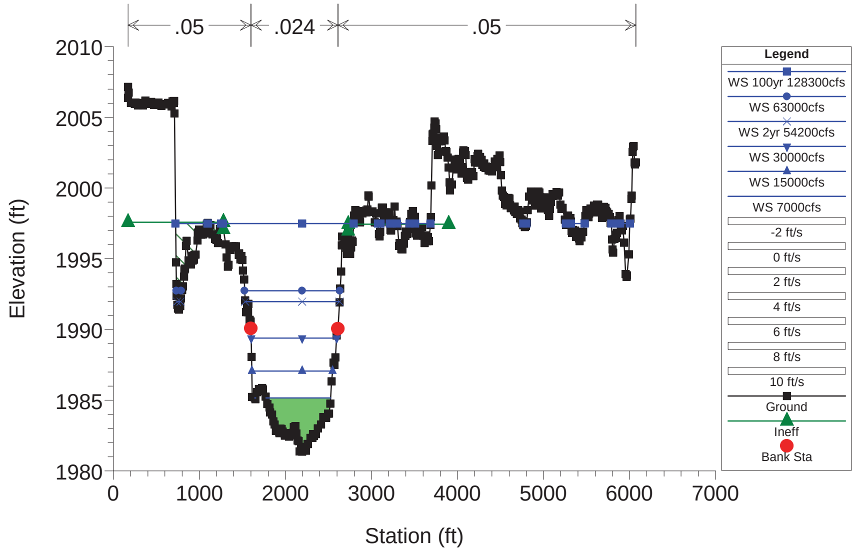
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

RS = 26598.26



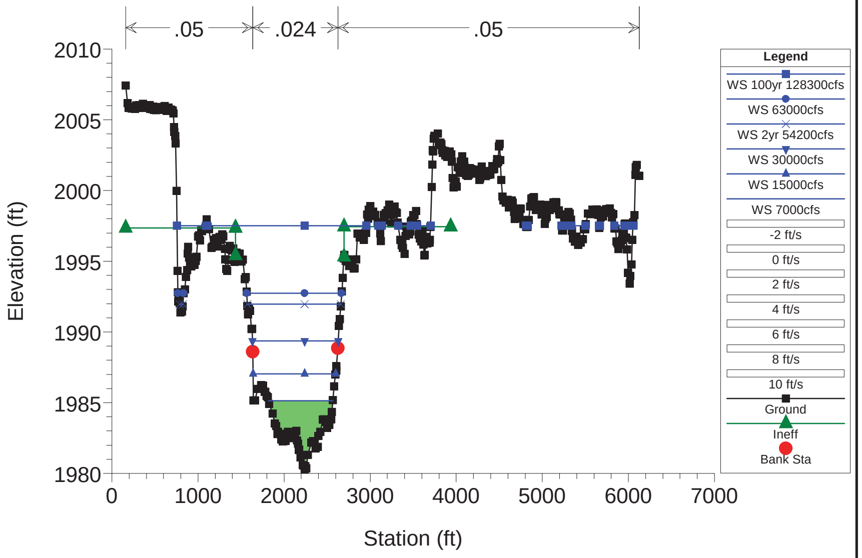
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

RS = 26548.87



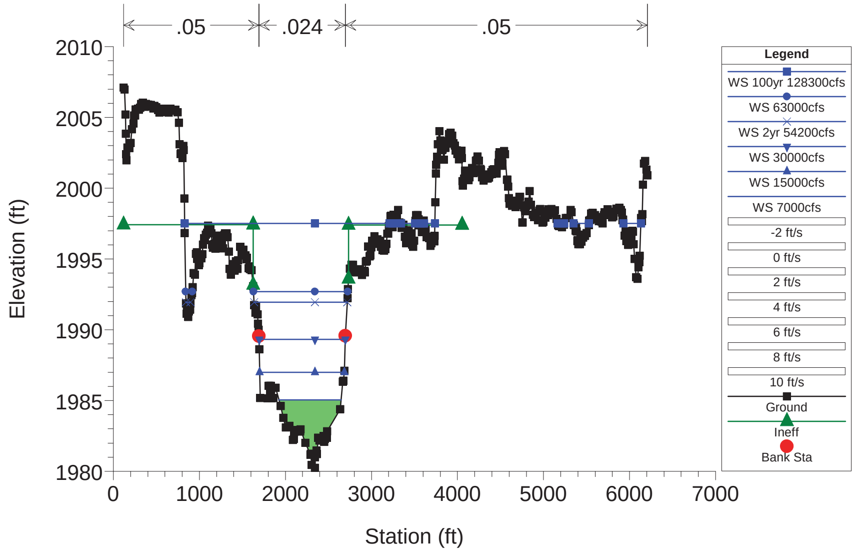
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

RS = 26503.32



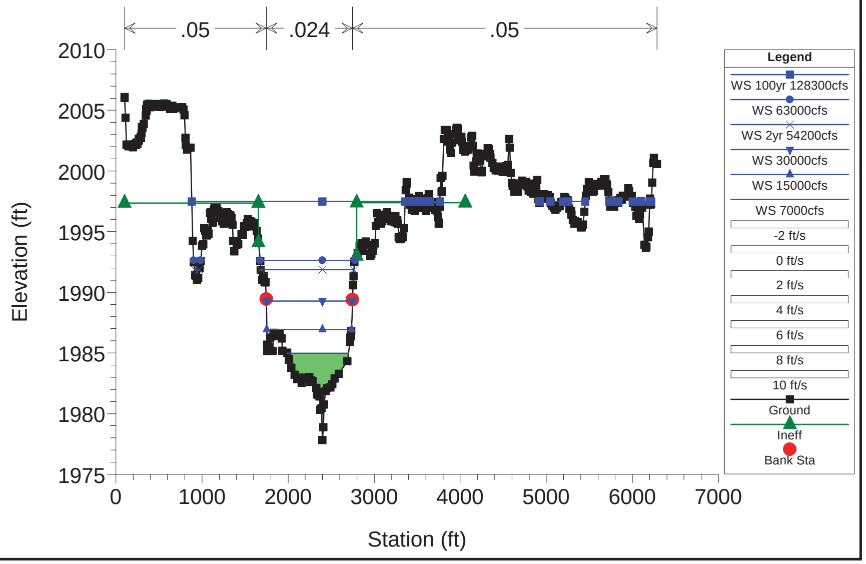
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

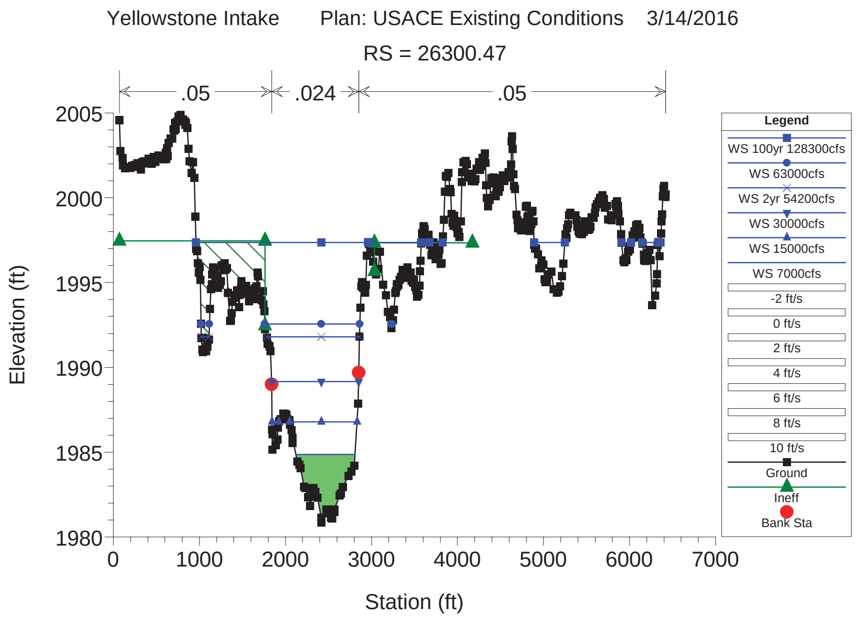
RS = 26447.30

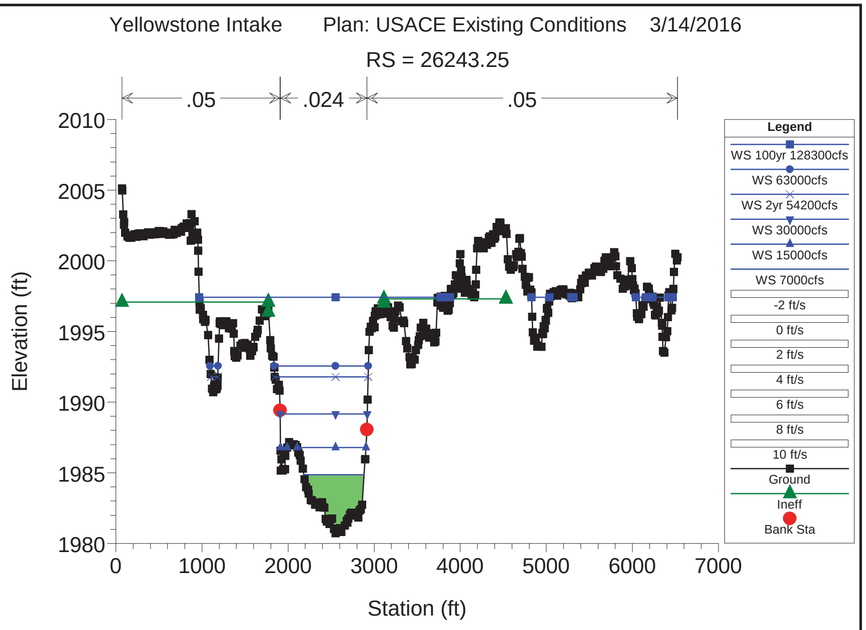


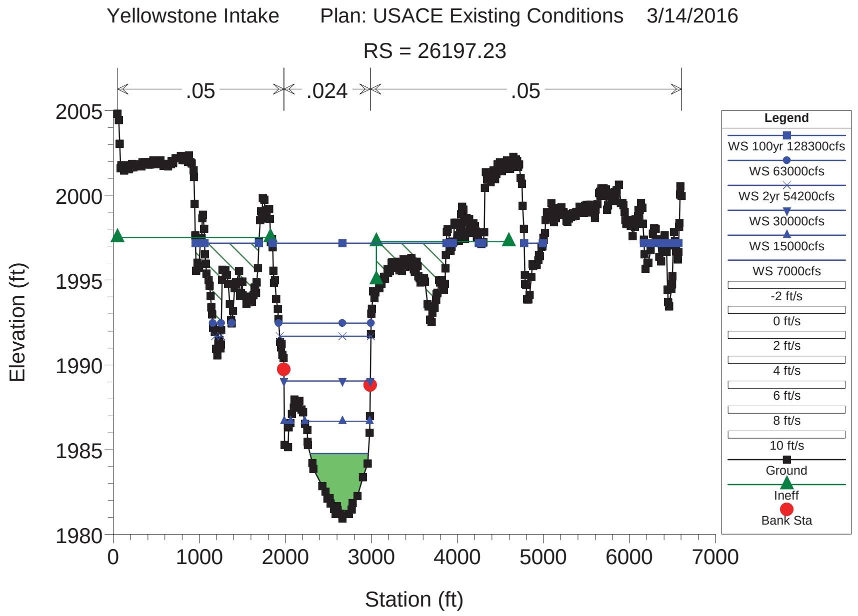
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

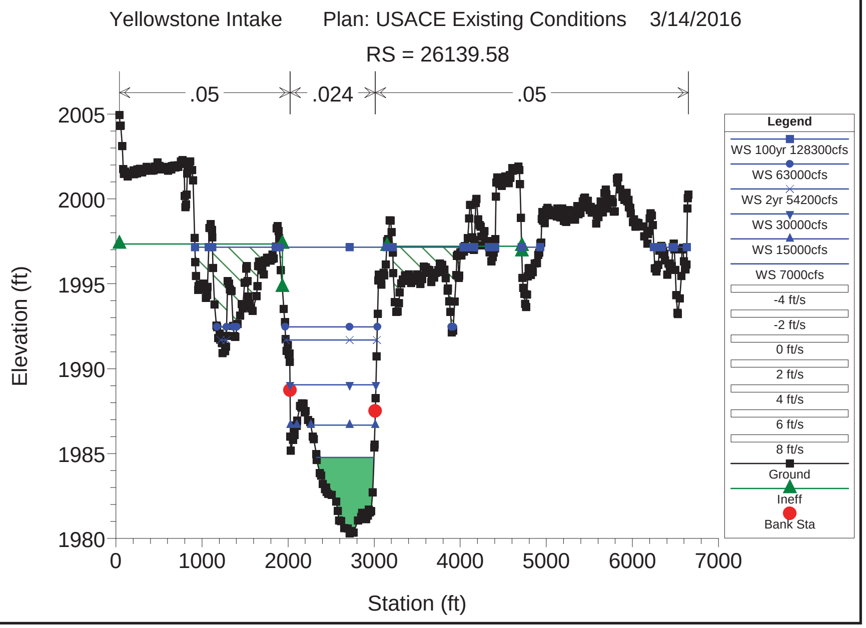
RS = 26398.50




Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 26300.47
.05
.024
.05
Elevation (ft)
2005
2000
1995
1990
1985
1980
Station (ft)
0
1000
2000
3000
4000
5000
6000
7000
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
-2 ft/s
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
10 ft/s
Ground
Ineff
Bank Sta

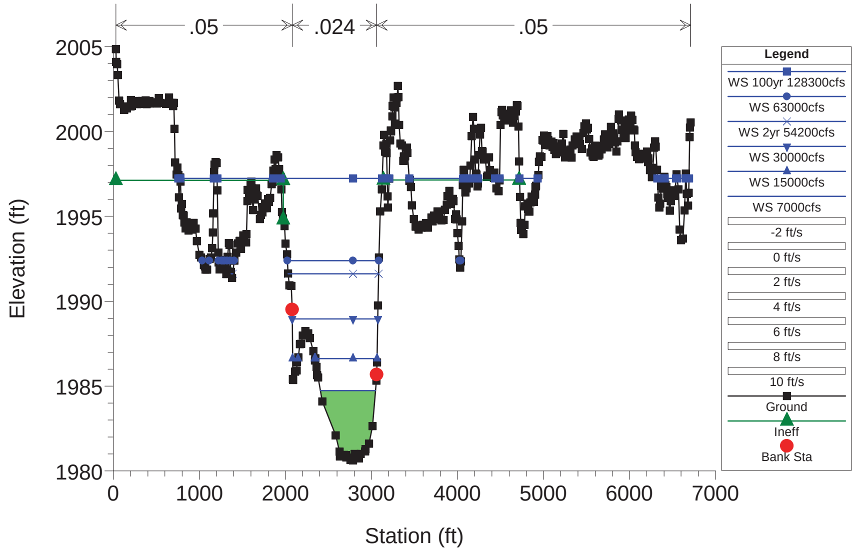

Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 26243.25
.05
.024
.05
Elevation (ft)
2010
2005
2000
1995
1990
1985
1980
Station (ft)
0
1000
2000
3000
4000
5000
6000
7000
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
-2 ft/s
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
10 ft/s
Ground
Ineff
Bank Sta


Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 26197.23
.05
.024
.05
Elevation (ft)
2005
2000
1995
1990
1985
1980
Station (ft)
0
1000
2000
3000
4000
5000
6000
7000
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
-2 ft/s
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
10 ft/s
Ground
Ineff
Bank Sta


Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 26139.58
.05
.024
.05
Elevation (ft)
2005
2000
1995
1990
1985
1980
Station (ft)
0
1000
2000
3000
4000
5000
6000
7000
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
-4 ft/s
-2 ft/s
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
Ground
Ineff
Bank Sta

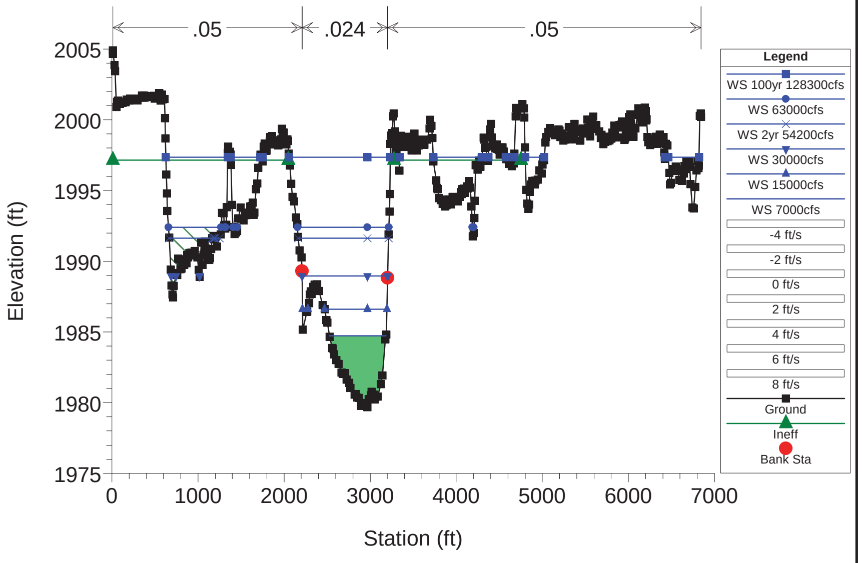
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

RS = 26097.74



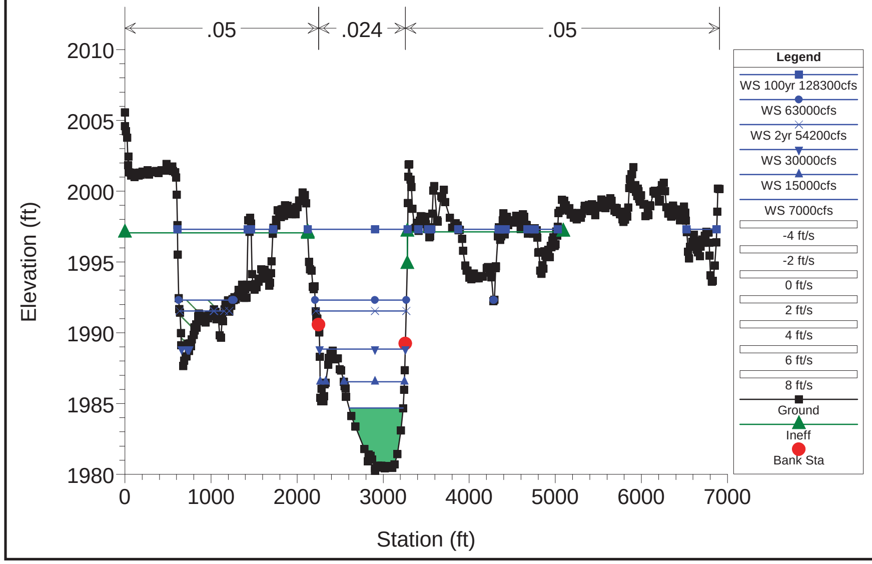
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

RS = 26049.91



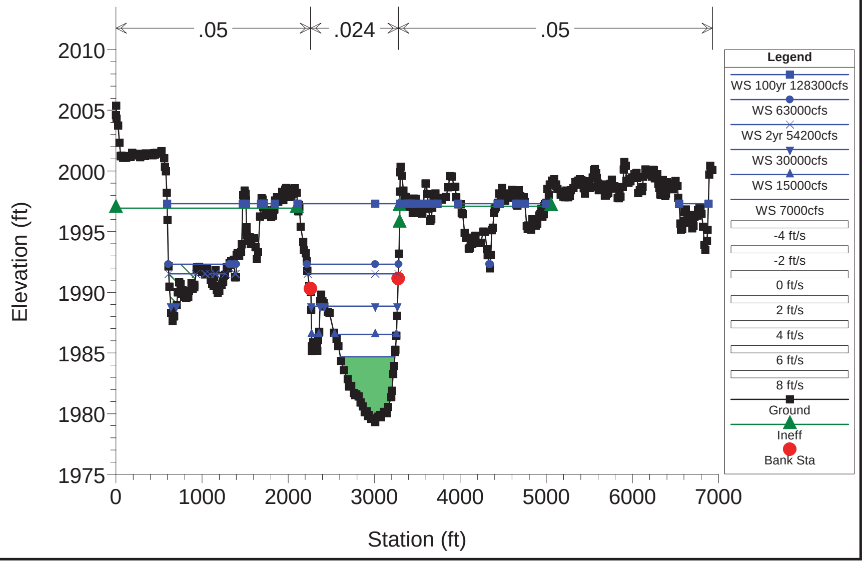
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

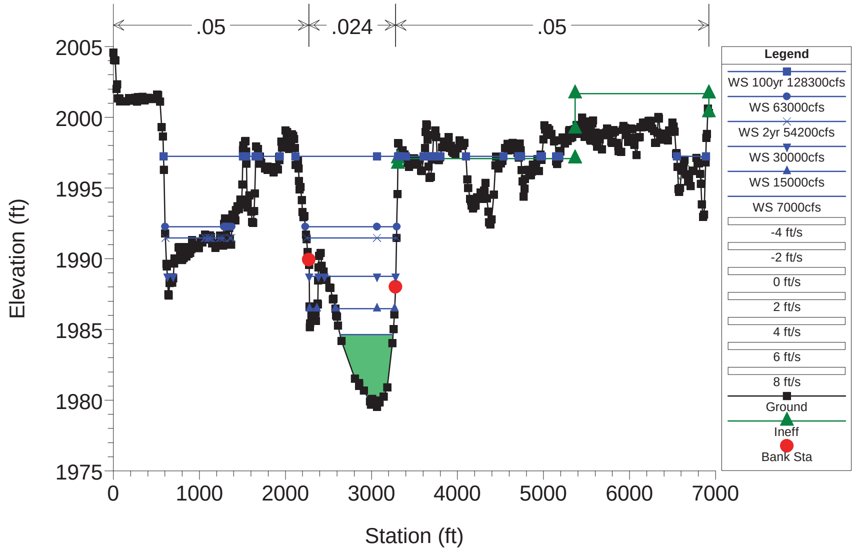
RS = 26002.24



Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

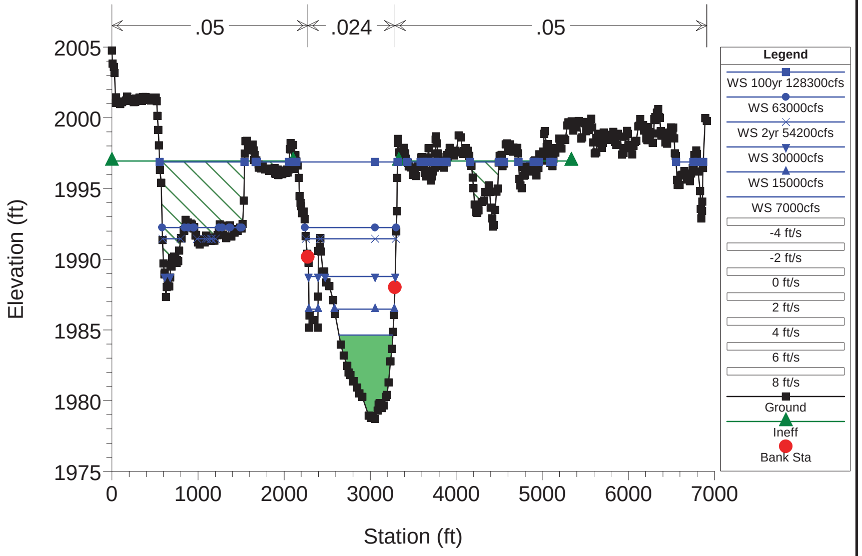
RS = 25945.89





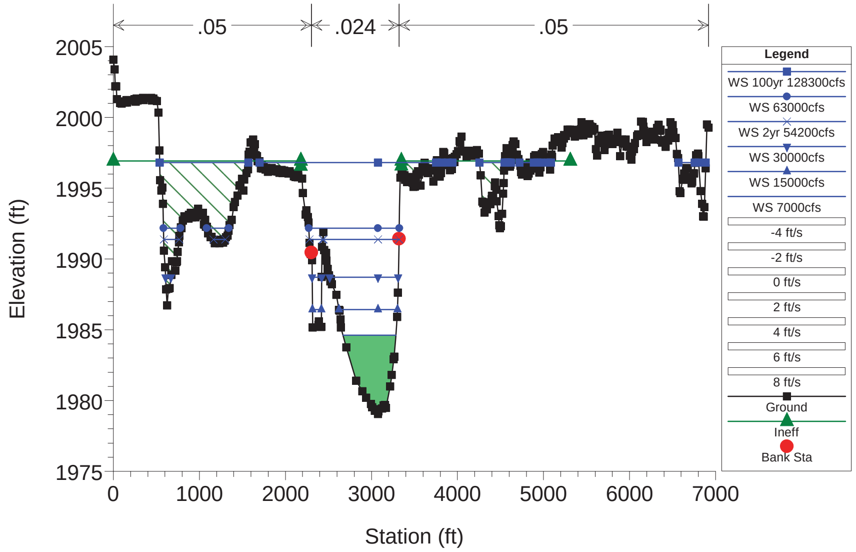
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

RS = 25899.95



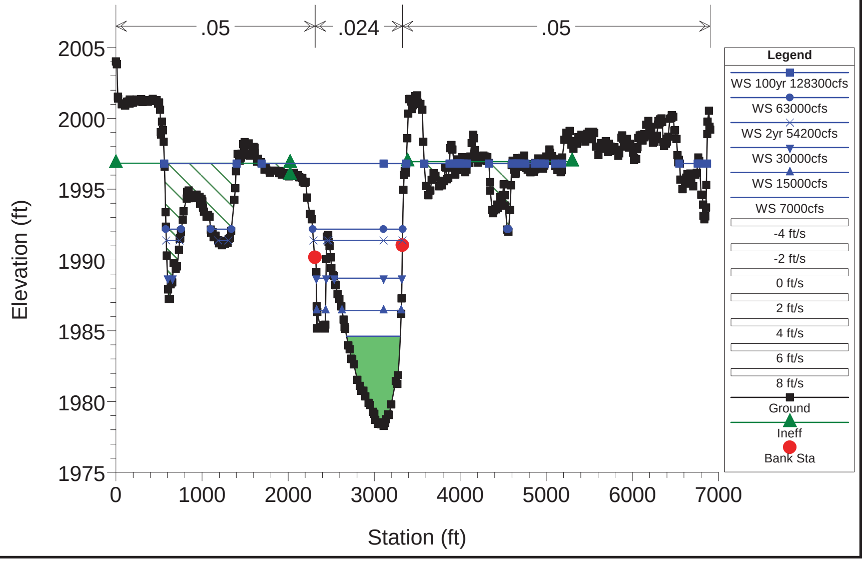
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

RS = 25845.58



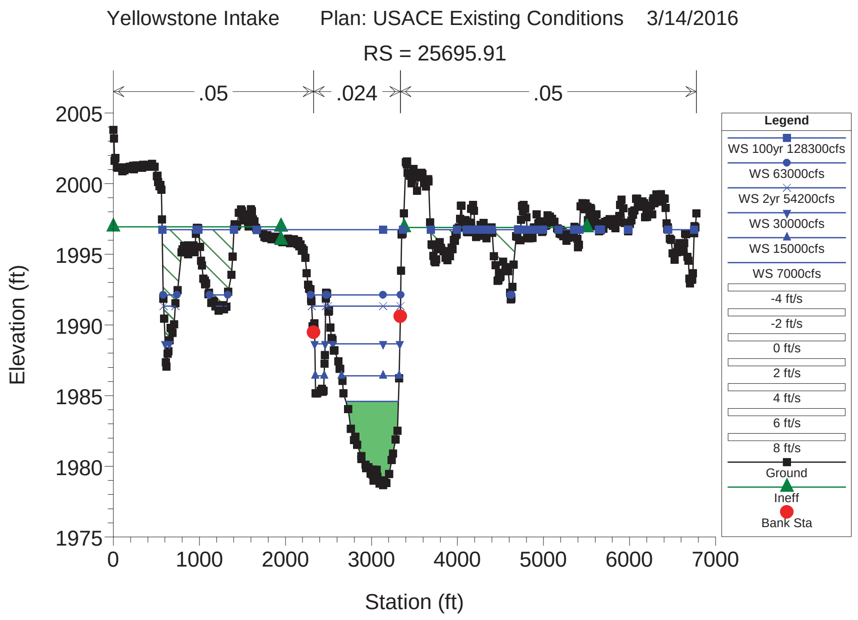
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

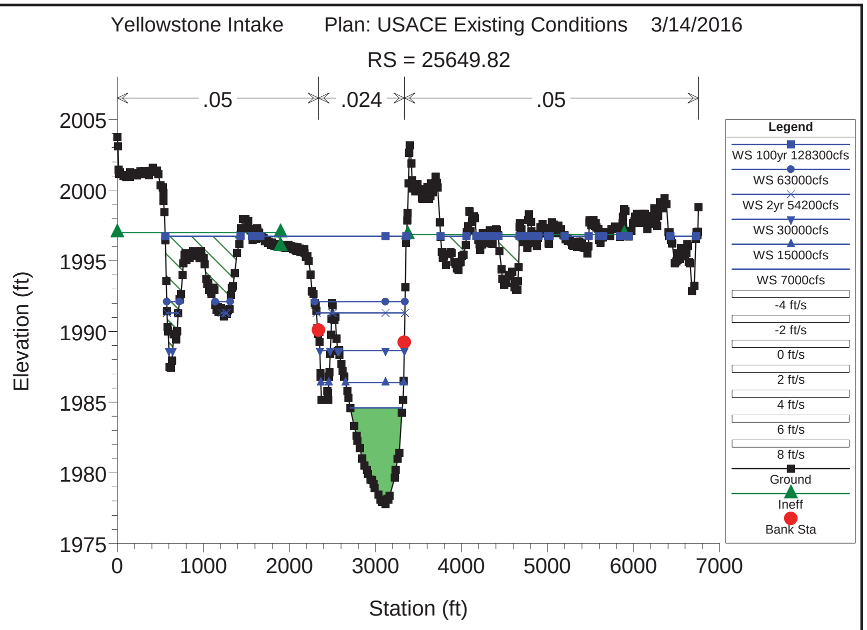
RS = 25798.14

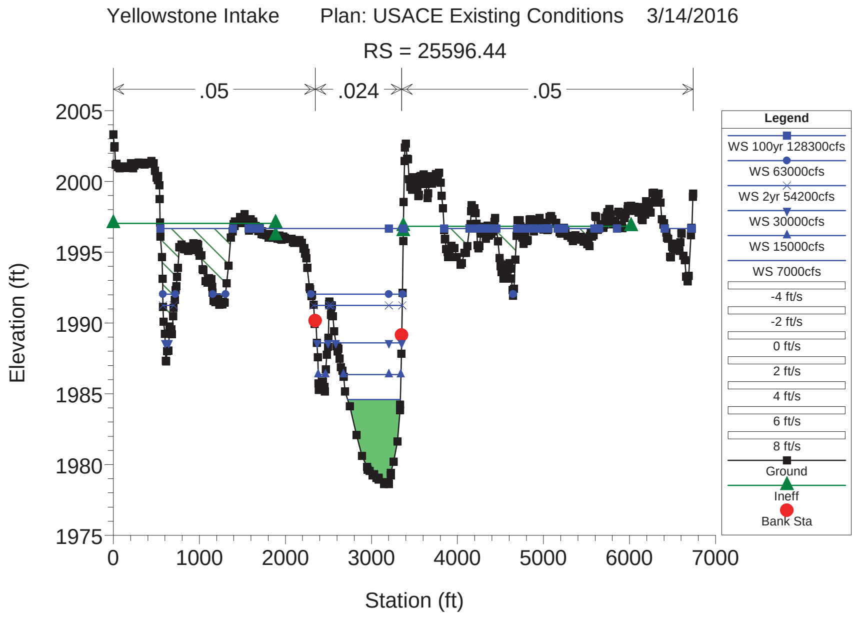


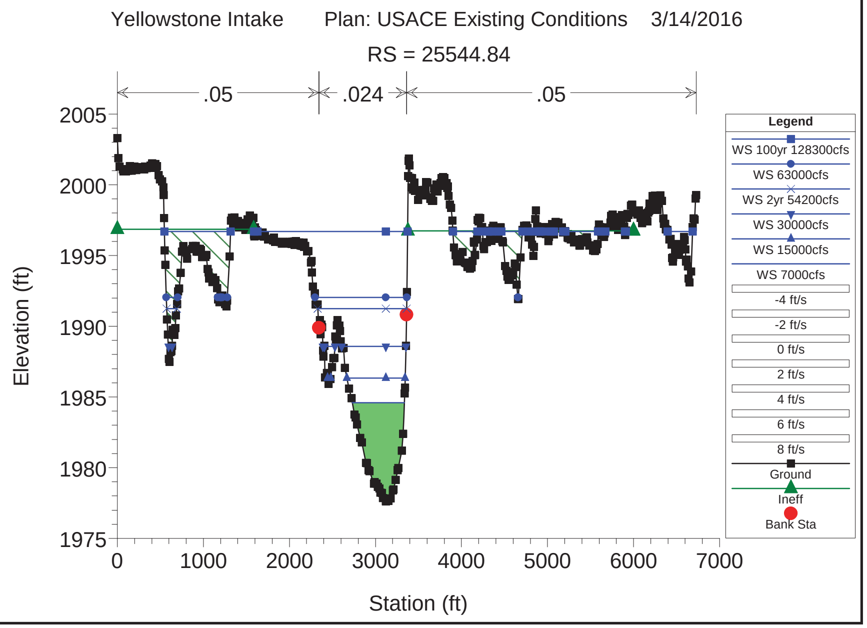
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

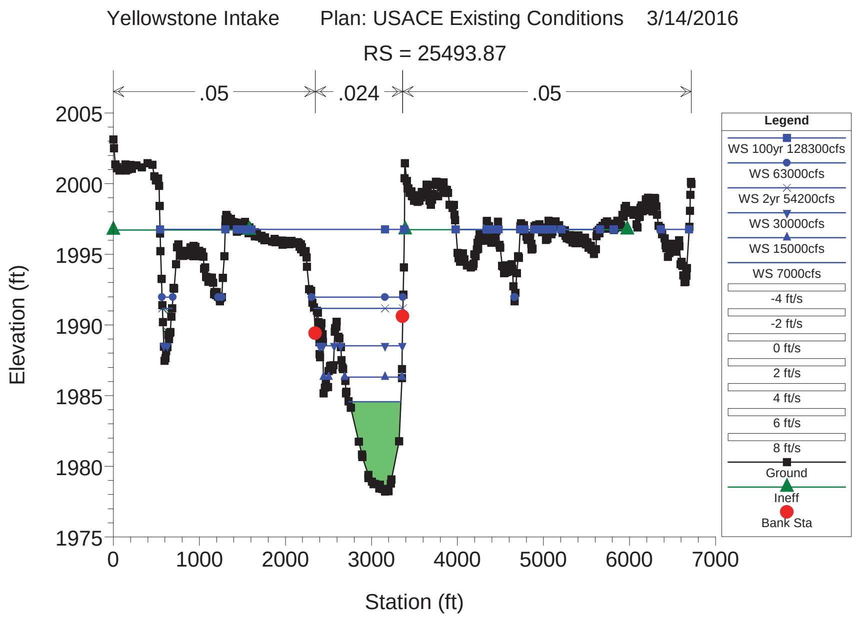
RS = 25744.07


Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 25695.91
.05
.024
.05
Elevation (ft)
Station (ft)
2005
2000
1995
1990
1985
1980
1975
0
1000
2000
3000
4000
5000
6000
7000
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
-4 ft/s
-2 ft/s
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
Ground
Ineff
Bank Sta

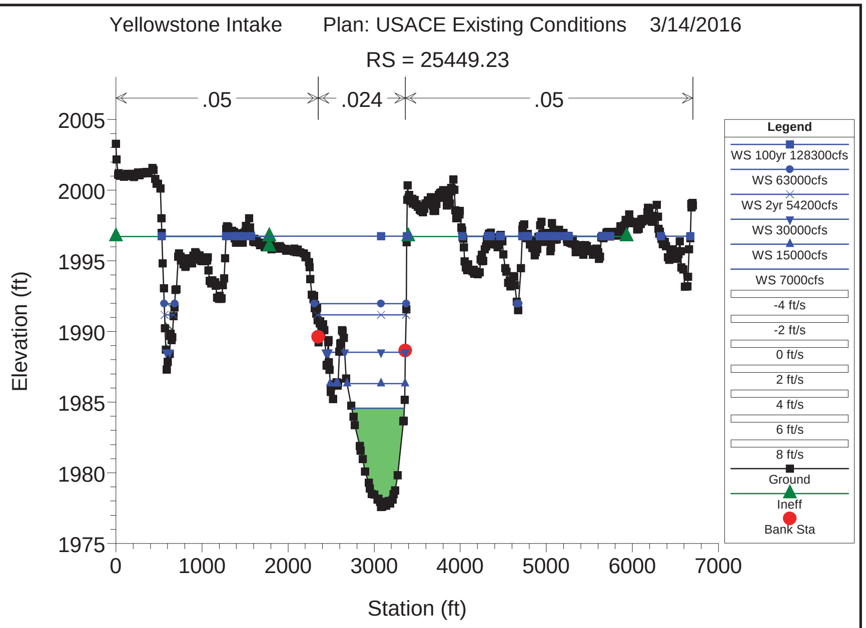

Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 25649.82
.05
.024
.05
Elevation (ft)
Station (ft)
2005
2000
1995
1990
1985
1980
1975
0
1000
2000
3000
4000
5000
6000
7000
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
-4 ft/s
-2 ft/s
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
Ground
Ineff
Bank Sta


Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 25596.44
.05
.024
.05
Elevation (ft)
Station (ft)
2005
2000
1995
1990
1985
1980
1975
0
1000
2000
3000
4000
5000
6000
7000
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
-4 ft/s
-2 ft/s
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
Ground
Ineff
Bank Sta

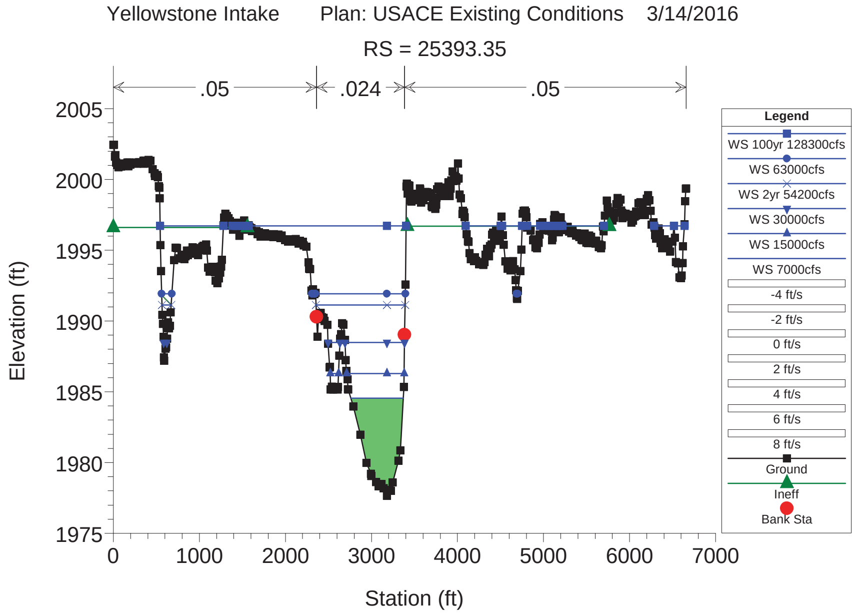

Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 25544.84
.05
.024
.05
Elevation (ft)
Station (ft)
2005
2000
1995
1990
1985
1980
1975
0
1000
2000
3000
4000
5000
6000
7000
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
-4 ft/s
-2 ft/s
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
Ground
Ineff
Bank Sta



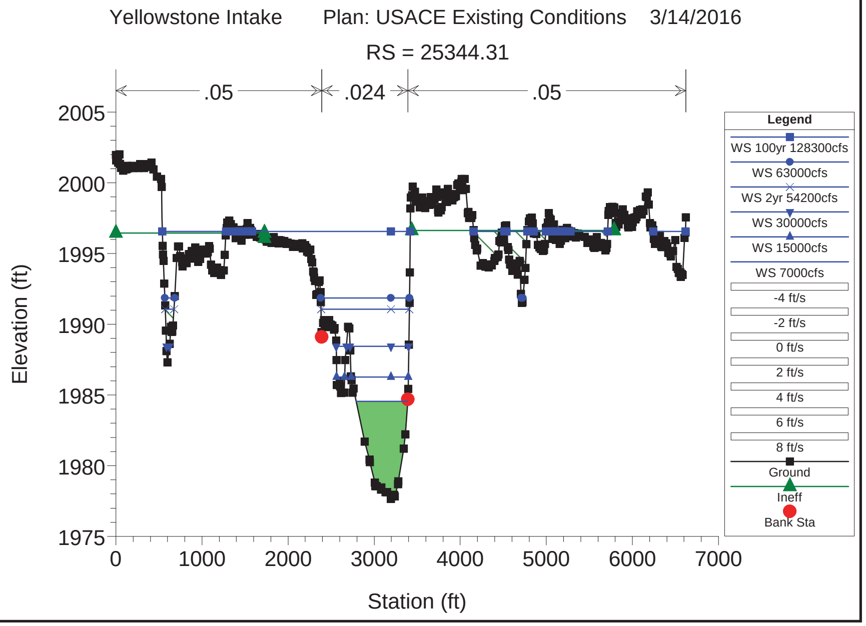
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 25493.87
.05
.024
.05
Elevation (ft)
2005
2000
1995
1990
1985
1980
1975
0
1000
2000
3000
4000
5000
6000
7000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
-4 ft/s
-2 ft/s
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
Ground
Ineff
Bank Sta



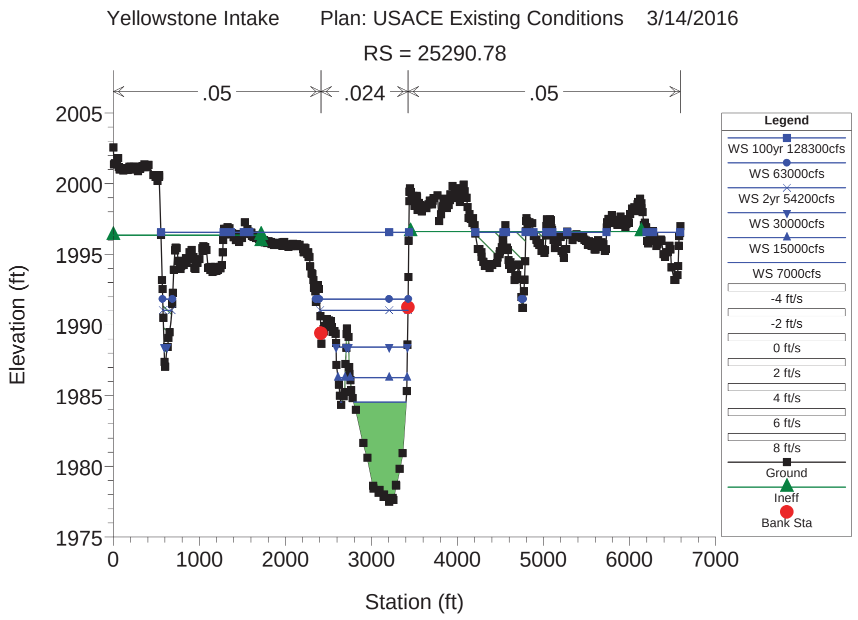
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 25449.23
.05
.024
.05
Elevation (ft)
2005
2000
1995
1990
1985
1980
1975
0
1000
2000
3000
4000
5000
6000
7000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
-4 ft/s
-2 ft/s
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
Ground
Ineff
Bank Sta

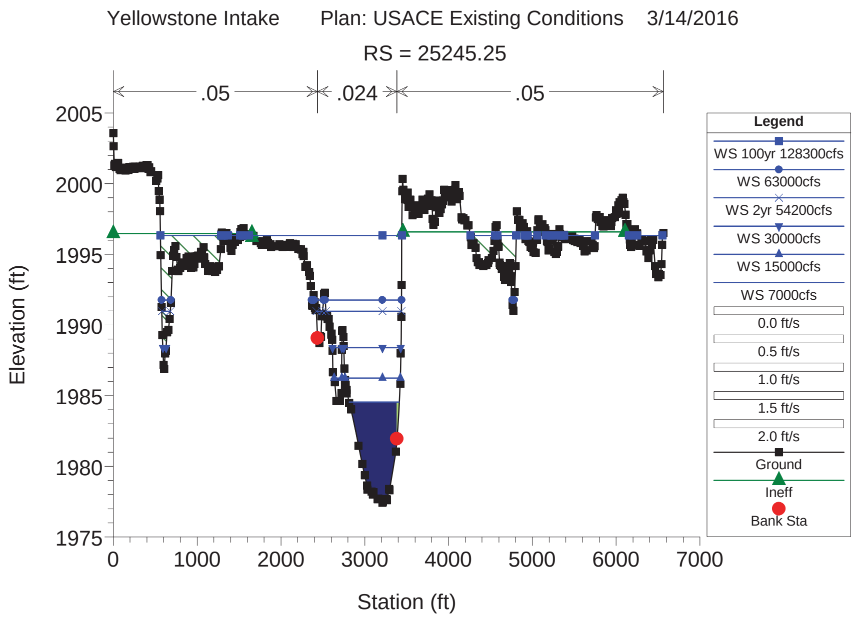


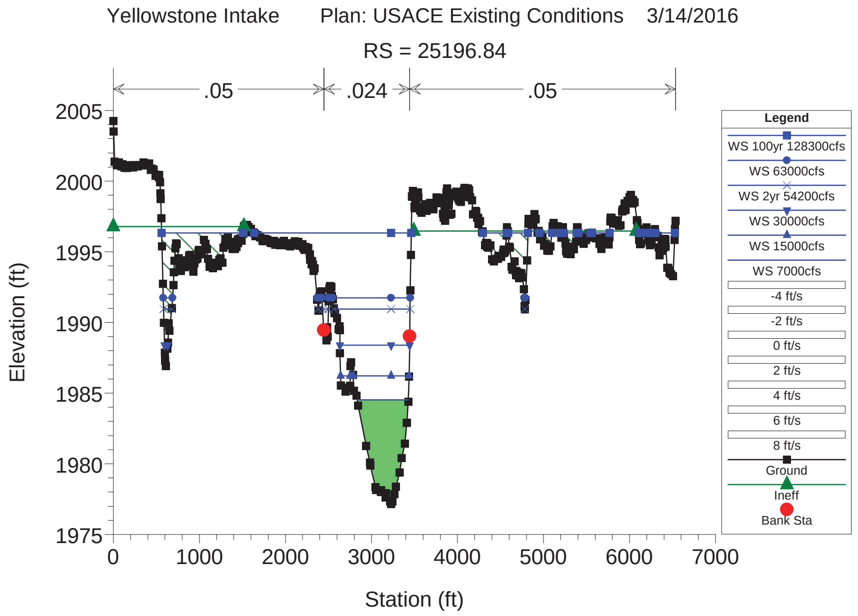
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 25393.35
.05
.024
.05
Elevation (ft)
2005
2000
1995
1990
1985
1980
1975
0
1000
2000
3000
4000
5000
6000
7000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
-4 ft/s
-2 ft/s
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
Ground
Ineff
Bank Sta

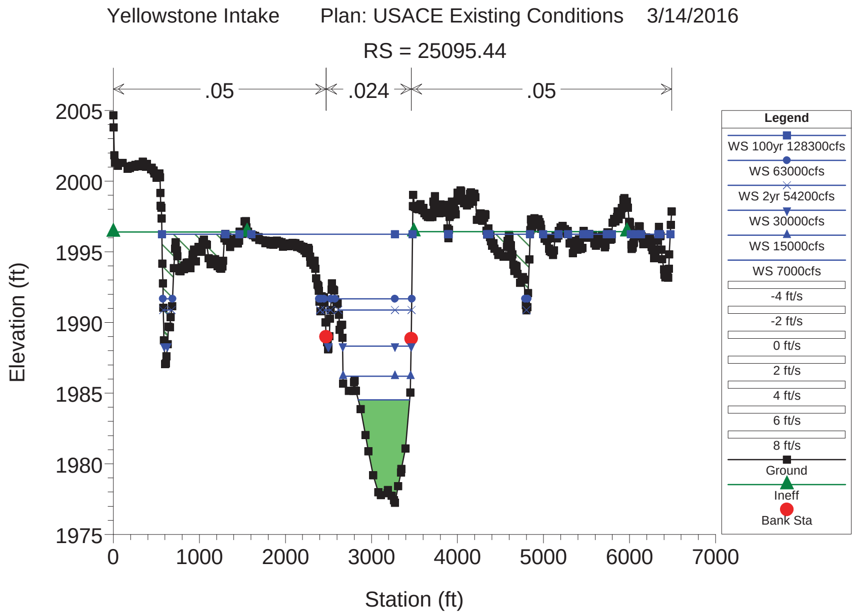


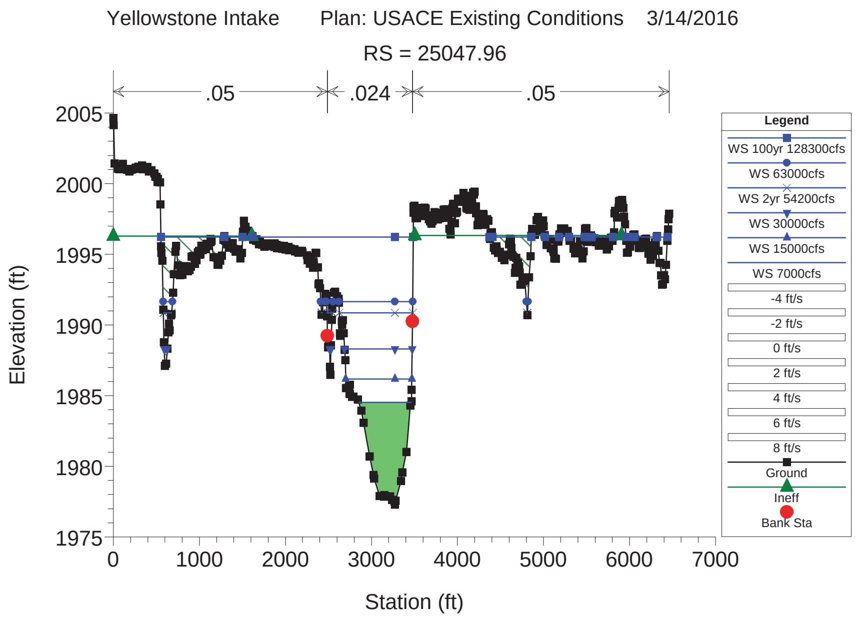
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 25344.31
.05
.024
.05
Elevation (ft)
2005
2000
1995
1990
1985
1980
1975
0
1000
2000
3000
4000
5000
6000
7000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
-4 ft/s
-2 ft/s
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
Ground
Ineff
Bank Sta


Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 25290.78
.05
.024
.05
Elevation (ft)
Station (ft)
2005
2000
1995
1990
1985
1980
1975
0
1000
2000
3000
4000
5000
6000
7000
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
-4 ft/s
-2 ft/s
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
Ground
Ineff
Bank Sta

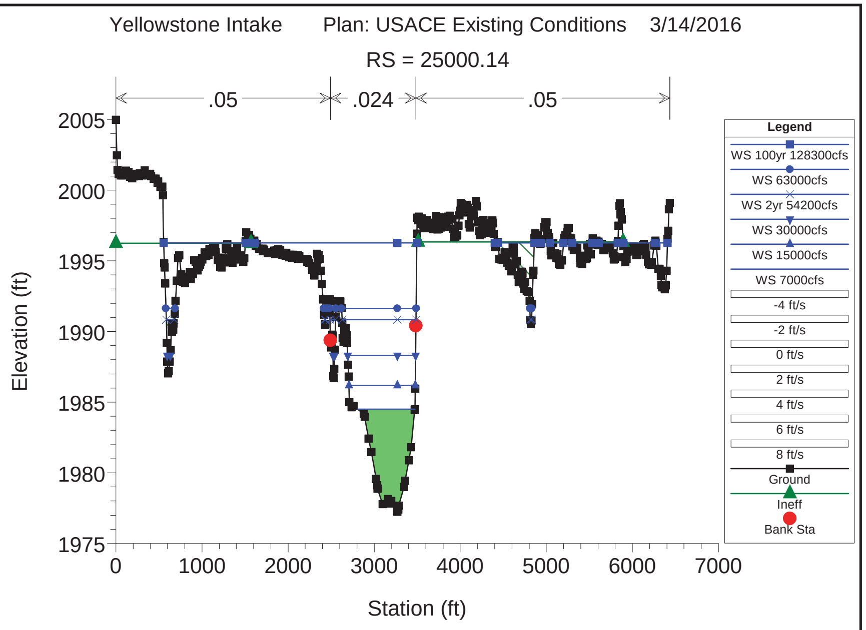

Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 25245.25
.05
.024
.05
Elevation (ft)
Station (ft)
2005
2000
1995
1990
1985
1980
1975
0
1000
2000
3000
4000
5000
6000
7000
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.0 ft/s
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
Ground
Ineff
Bank Sta


Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 25196.84
.05
.024
.05
Elevation (ft)
Station (ft)
2005
2000
1995
1990
1985
1980
1975
0
1000
2000
3000
4000
5000
6000
7000
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
-4 ft/s
-2 ft/s
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
Ground
Ineff
Bank Sta

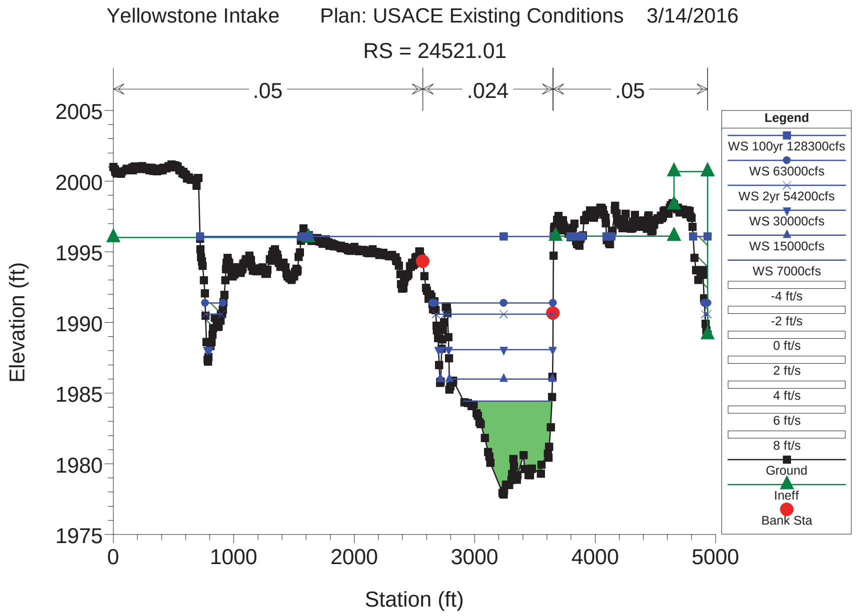

Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 25095.44
.05
.024
.05
Elevation (ft)
Station (ft)
2005
2000
1995
1990
1985
1980
1975
0
1000
2000
3000
4000
5000
6000
7000
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
-4 ft/s
-2 ft/s
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
Ground
Ineff
Bank Sta


Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

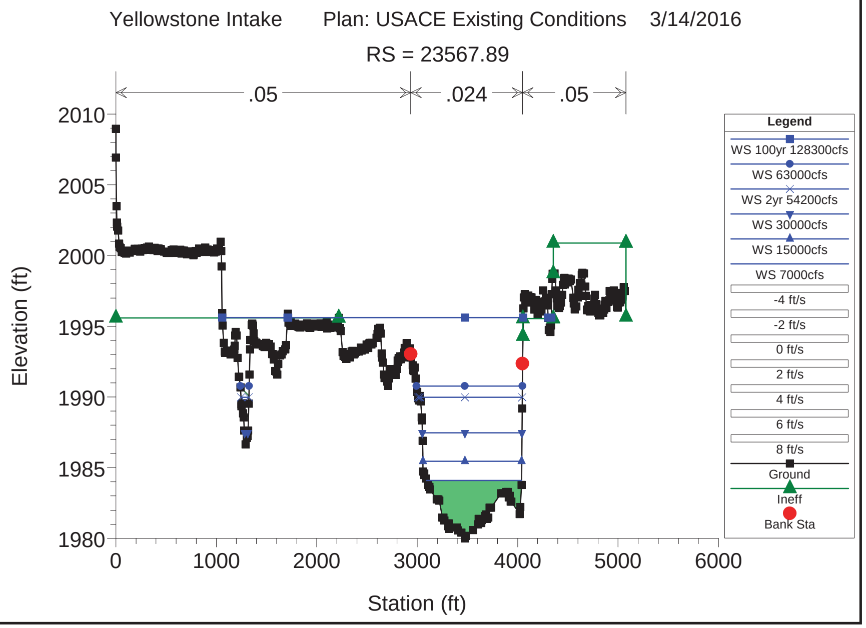
RS = 25047.96


Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

RS = 25000.14


Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

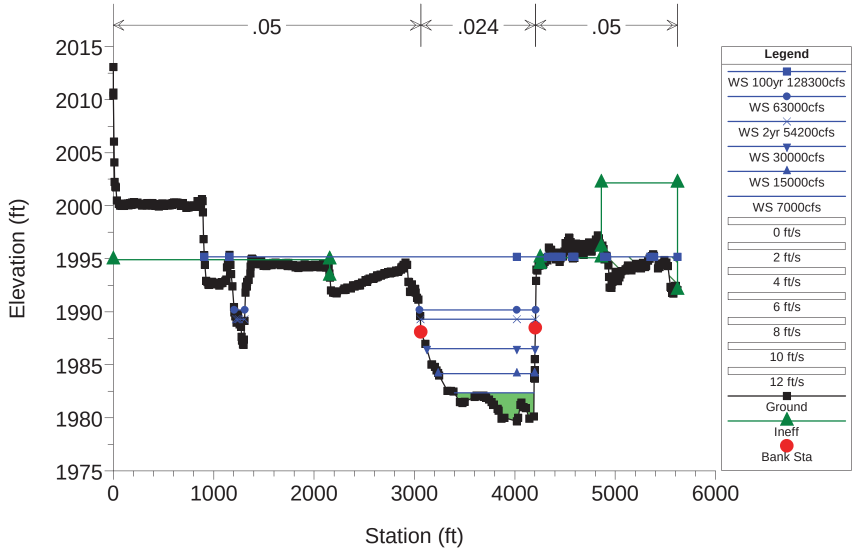
RS = 24521.01


Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

RS = 23567.89

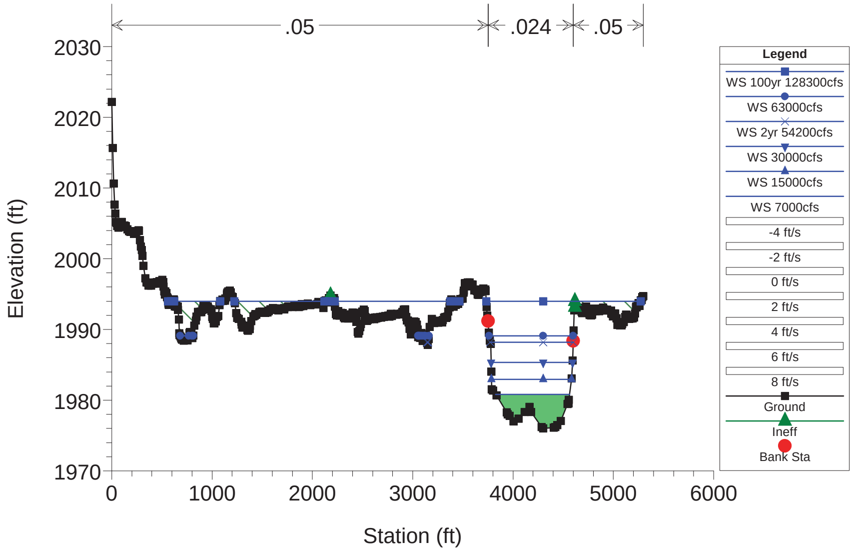
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

RS = 22555.07



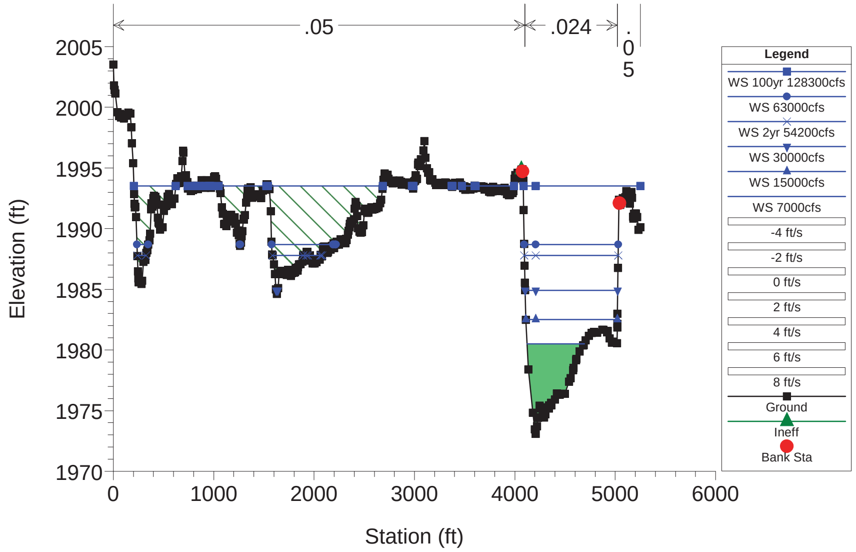
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

RS = 20556.36



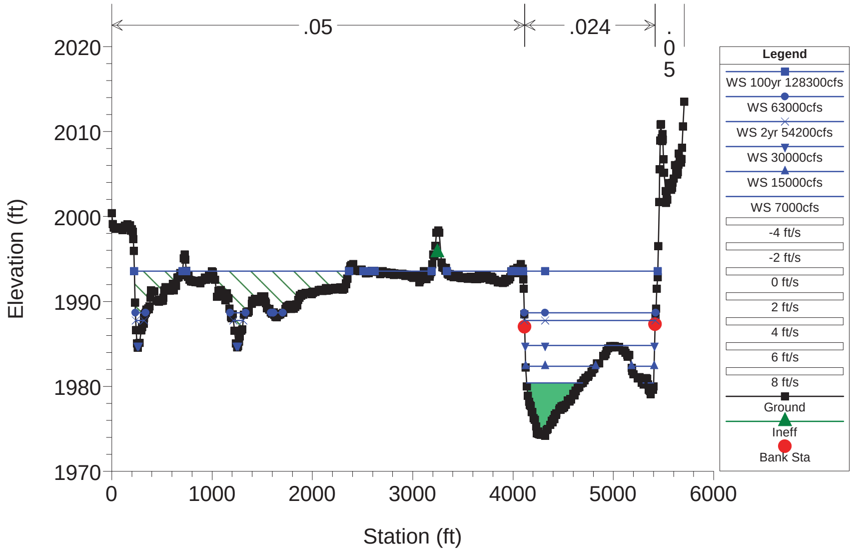
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

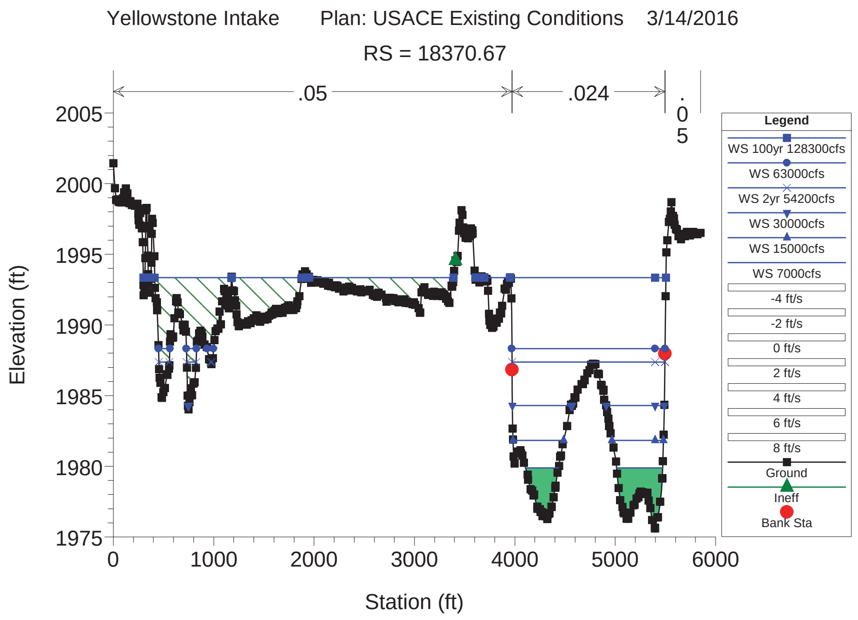
RS = 19585.36

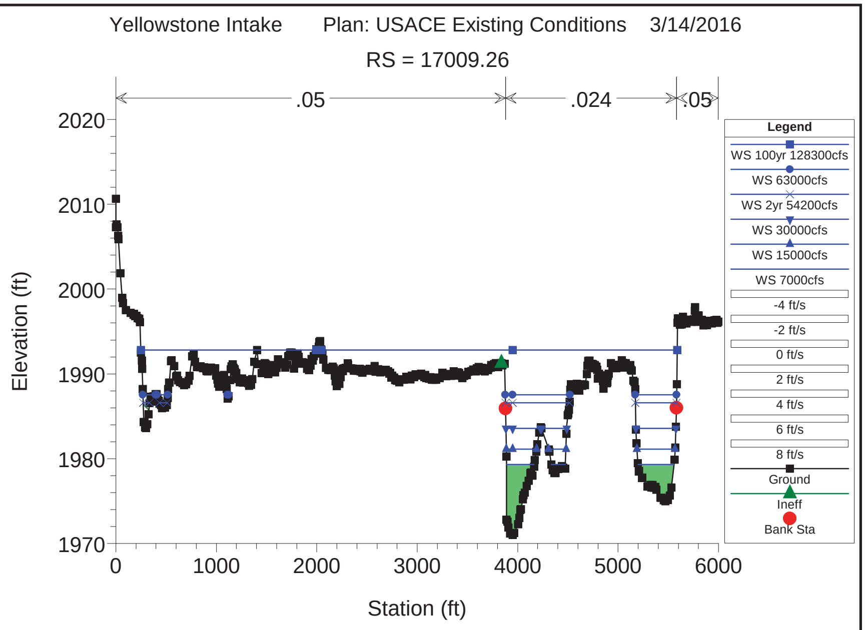


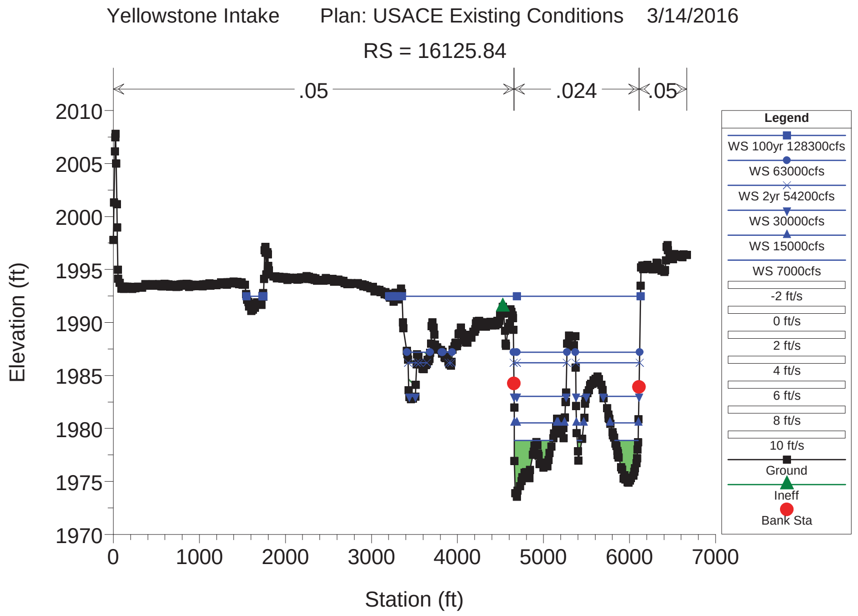
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

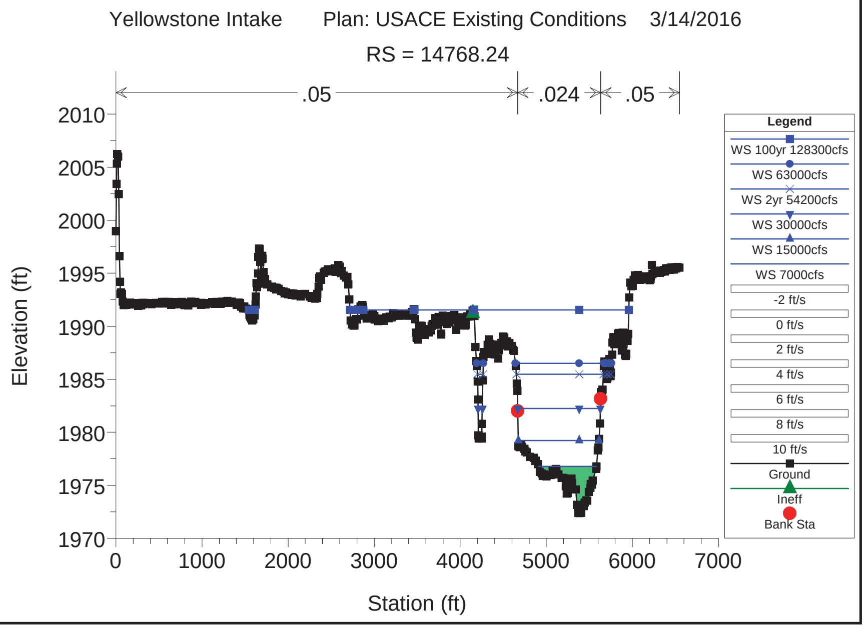
RS = 19210.21




Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 18370.67
.05
.024
.05
Elevation (ft)
2005
2000
1995
1990
1985
1980
1975
0
1000
2000
3000
4000
5000
6000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
-4 ft/s
-2 ft/s
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
Ground
Ineff
Bank Sta

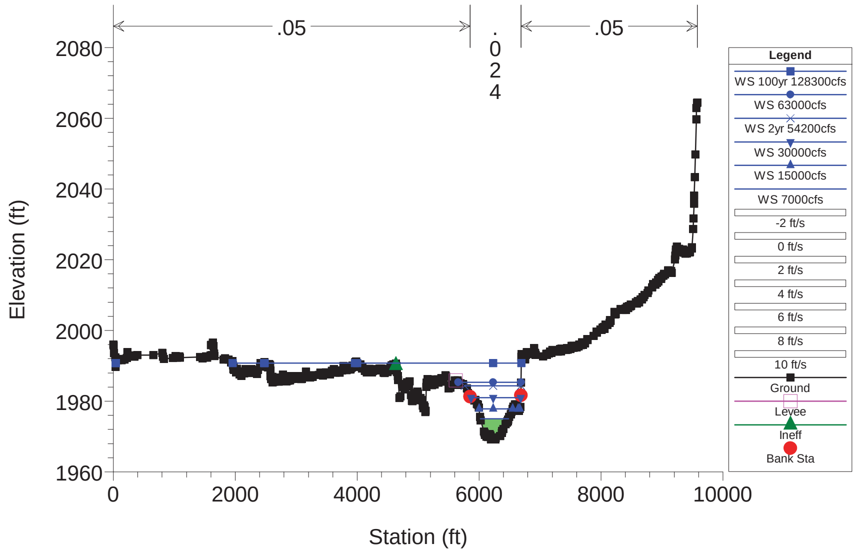

Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 17009.26
.05
.024
.05
Elevation (ft)
2020
2010
2000
1990
1980
1970
0
1000
2000
3000
4000
5000
6000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
-4 ft/s
-2 ft/s
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
Ground
Ineff
Bank Sta


Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 16125.84
.05
.024
.05
Elevation (ft)
2010
2005
2000
1995
1990
1985
1980
1975
1970
0
1000
2000
3000
4000
5000
6000
7000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
-2 ft/s
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
10 ft/s
Ground
Ineff
Bank Sta


Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016
RS = 14768.24
.05
.024
.05
Elevation (ft)
2010
2005
2000
1995
1990
1985
1980
1975
1970
0
1000
2000
3000
4000
5000
6000
7000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
-2 ft/s
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
10 ft/s
Ground
Ineff
Bank Sta

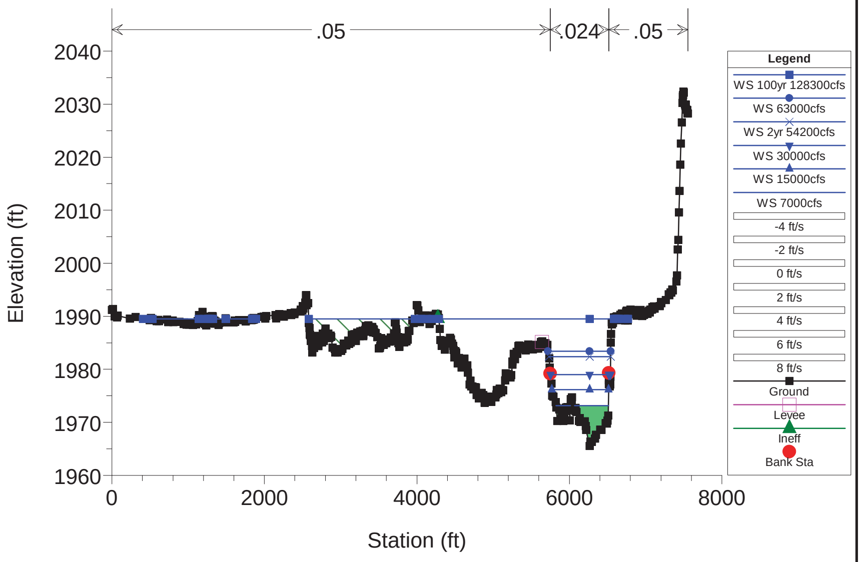
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

RS = 12602.25



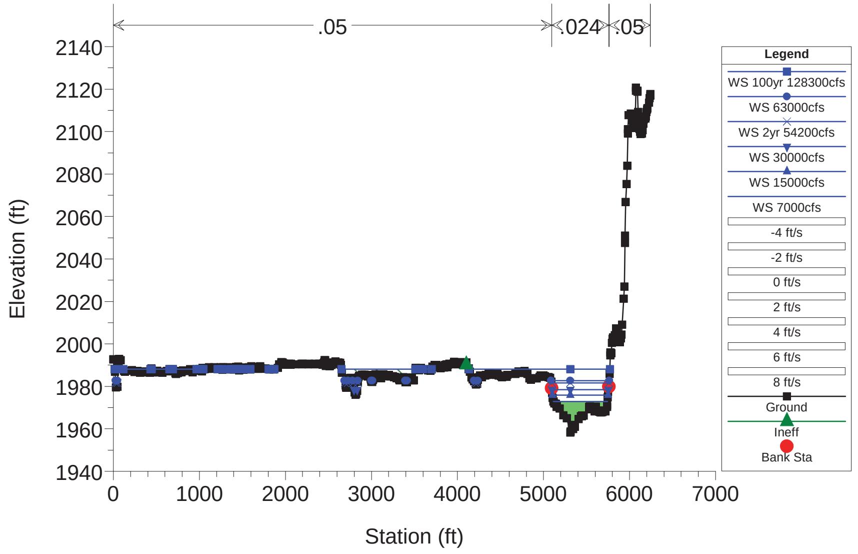
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

RS = 7708.504



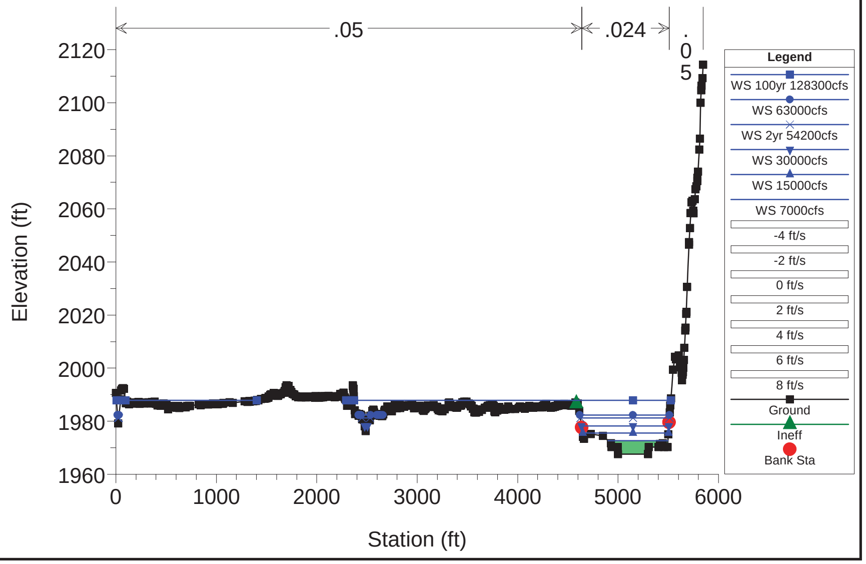
Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

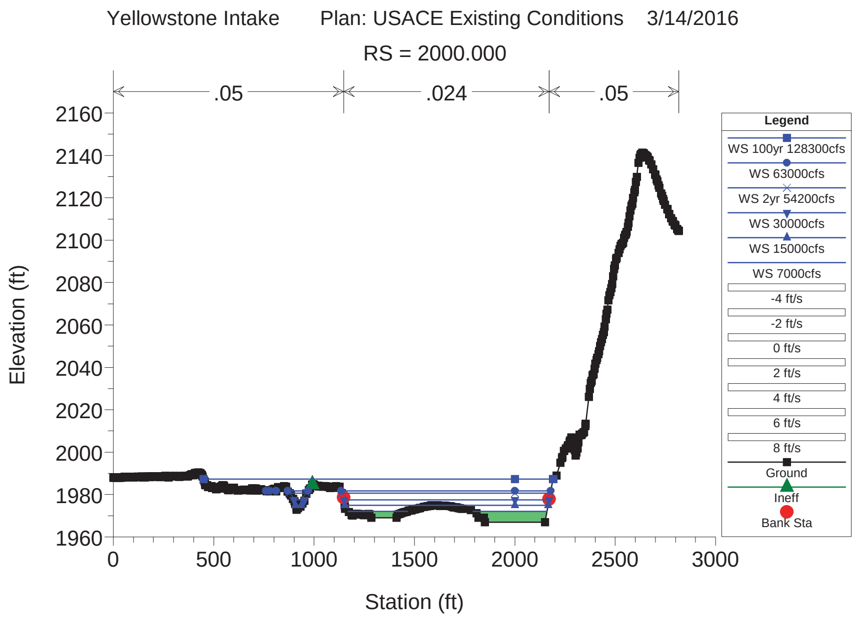
RS = 5162.571



Yellowstone Intake Plan: USACE Existing Conditions 3/14/2016

RS = 3996.727





Yellowstone Intake
Plan: USACE Existing Conditions
3/14/2016
RS = 2000.000
.05
.024
.05
Elevation (ft)
2160
2140
2120
2100
2080
2060
2040
2020
2000
1980
1960
0
500
1000
1500
2000
2500
3000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
-4 ft/s
-2 ft/s
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
Ground
Ineff
Bank Sta

HEC-RAS Proposed Conditions

```
                         HEC-RAS Version 4.1.0 Jan 2010
                          U.S. Army Corps of Engineers
                         Hydrologic Engineering Center
                               609 Second Street
                               Davis, California


            X     X  XXXXXX    XXXX        XXXX       XX      XXXX
            X     X  X        X    X       X   X     X  X    X
            X     X  X        X            X   X    X    X   X
            XXXXXXX  XXXX     X       XXX  XXXX     XXXXXX    XXXX
            X     X  X        X            X  X     X    X        X
            X     X  X        X    X       X   X    X    X        X
            X     X  XXXXXX    XXXX        X    X   X    X   XXXXX




PROJECT DATA
Project Title: Yellowstone Intake
Project File : YellowstoneIntake.prj
Run Date and Time: 3/15/2016 11:02:59 AM

Project in English units



PLAN DATA

Plan Title: Tt High Flow Chnl with Bridge
Plan File : s:\Projects\SET-T35234_Intake EIS\06_Hydraulic models\Yellowstone_Intake\YellowstoneIntake.p05

           Geometry Title: Tt High Flow Channel Alt w/Bridge
           Geometry File : s:\Projects\SET-T35234_Intake EIS\06_Hydraulic
models\Yellowstone_Intake\YellowstoneIntake.g05

           Flow Title    : Tt High Flow Channel Alt
           Flow File     : s:\Projects\SET-T35234_Intake EIS\06_Hydraulic
models\Yellowstone_Intake\YellowstoneIntake.f04

Plan Description:
The design channel width of the channel is increased to 50 ft for the first
four cross sections. The remaining channel cross sections have a bottom width
of 40 ft.  The side slopes are the same as the USACE design in all cross
sections.  The design channel in this plan extends for the entire length of the
side channel.
```

```
Plan Summary Information:
Number of:  Cross Sections =  231    Multiple Openings  =    0
            Culverts       =    0    Inline Structures  =    1
            Bridges        =    1    Lateral Structures =    1

Computational Information
    Water surface calculation tolerance  =  0.01
    Critical depth calculation tolerance =  0.01
    Maximum number of iterations         =  20
    Maximum difference tolerance         =  0.3
    Flow tolerance factor                =  0.001

Computation Options
    Critical depth computed only where necessary
    Conveyance Calculation Method: At breaks in n values only
    Friction Slope Method:         Average Conveyance
    Computational Flow Regime:     Subcritical Flow



FLOW DATA

Flow Title: Tt High Flow Channel Alt
Flow File : s:\Projects\SET-T35234_Intake EIS\06_Hydraulic models\Yellowstone_Intake\YellowstoneIntake.f04

Flow Data (cfs)


  River           Reach           RS                 3000cfs         5000cfs         7000cfs         9000cfs
       11000cfs        13000cfs        15000cfs        20000cfs
  IrrigCanal      Canal           20523                    1               1               1               1
              1               1               1               1
  Right Chute     Chute           19860                    1               1               1               1
              1               1               1               1
  Yellowstone     US Chute        56000.00              3000            5000            7000            9000
          11000           13000           15000           20000
  Yellowstone     Mid Chute       37074.57              3000            5000            7000            9000
          11000           13000           15000           20000
  Yellowstone     Mid Chute       28203.49              3000            5000            7000            9000
          11000           13000           15000           20000
  Yellowstone     DS Chute        19210.21              3000            5000            7000            9000
          11000           13000           15000           20000
```

```
 River           Reach            RS                 25000cfs         30000cfs         45000cfs    2yr 54200cfs
 5yr 74400cfs   10yr 87600cfs   50yr 116200cfs 100yr 128300cfs
 IrrigCanal      Canal            20523                     1                1                1               1
            1                1                1                1
 Right Chute     Chute            19860                     1                1                1               1
            1                1                1                1
 Yellowstone     US Chute         56000.00              25000            30000            45000           54200
        74400            87600           116200           128300
 Yellowstone     Mid Chute        37074.57              25000            30000            45000           54200
        74400            87600           116200           128300
 Yellowstone     Mid Chute        28203.49              25000            30000            45000           54200
        74400            87600           116200           128300
 Yellowstone     DS Chute         19210.21              25000            30000            45000           54200
        74400            87600           116200           128300
```

```
Boundary Conditions

 River           Reach            Profile                         Upstream                  Downstream

 IrrigCanal      Canal            3000cfs                    Normal S = 0.0002         Normal S = 0.0002
 IrrigCanal      Canal            5000cfs                    Normal S = 0.0002         Normal S = 0.0002
 IrrigCanal      Canal            7000cfs                    Normal S = 0.0002         Normal S = 0.0002
 IrrigCanal      Canal            9000cfs                    Normal S = 0.0002         Normal S = 0.0002
 IrrigCanal      Canal            11000cfs                   Normal S = 0.0002         Normal S = 0.0002
 IrrigCanal      Canal            13000cfs                   Normal S = 0.0002         Normal S = 0.0002
 IrrigCanal      Canal            15000cfs                   Normal S = 0.0002         Normal S = 0.0002
 IrrigCanal      Canal            20000cfs                   Normal S = 0.0002         Normal S = 0.0002
 IrrigCanal      Canal            25000cfs                   Normal S = 0.0002         Normal S = 0.0002
 IrrigCanal      Canal            30000cfs                   Normal S = 0.0002         Normal S = 0.0002
 IrrigCanal      Canal            45000cfs                   Normal S = 0.0002         Normal S = 0.0002
 IrrigCanal      Canal            2yr 54200cfs               Normal S = 0.0002         Normal S = 0.0002
 IrrigCanal      Canal            5yr 74400cfs               Normal S = 0.0002         Normal S = 0.0002
 IrrigCanal      Canal            10yr 87600cfs              Normal S = 0.0002         Normal S = 0.0002
 IrrigCanal      Canal            50yr 116200cfs             Normal S = 0.0002         Normal S = 0.0002
 IrrigCanal      Canal            100yr 128300cfs            Normal S = 0.0002         Normal S = 0.0002
 IrrigCanal      Canal            200yr 140200cfs            Normal S = 0.0002         Normal S = 0.0002
 IrrigCanal      Canal            500yr 156200cfs            Normal S = 0.0002         Normal S = 0.0002
 IrrigCanal      Canal            Calib 49220cfs             Normal S = 0.0002         Normal S = 0.0002
 IrrigCanal      Canal            Verif 30000cfs             Normal S = 0.0002         Normal S = 0.0002
 IrrigCanal      Canal            Verif 4800cfs              Normal S = 0.0002         Normal S = 0.0002
 IrrigCanal      Canal            63000cfs                   Normal S = 0.0002         Normal S = 0.0002
 IrrigCanal      Canal            210kcfs                    Normal S = 0.0002         Normal S = 0.0002
 Yellowstone     US Chute         3000cfs                    Normal S = 0.0003
 Yellowstone     US Chute         5000cfs                    Normal S = 0.0003
 Yellowstone     US Chute         7000cfs                    Normal S = 0.0003
 Yellowstone     US Chute         9000cfs                    Normal S = 0.0003
```

```
  Yellowstone     US Chute        11000cfs                  Normal S = 0.0003
  Yellowstone     US Chute        13000cfs                  Normal S = 0.0003
  Yellowstone     US Chute        15000cfs                  Normal S = 0.0003
  Yellowstone     US Chute        20000cfs                  Normal S = 0.0003
  Yellowstone     US Chute        25000cfs                  Normal S = 0.0003
  Yellowstone     US Chute        30000cfs                  Normal S = 0.0003
  Yellowstone     US Chute        45000cfs                  Normal S = 0.0003
  Yellowstone     US Chute        2yr 54200cfs              Normal S = 0.0003
  Yellowstone     US Chute        5yr 74400cfs              Normal S = 0.0003
  Yellowstone     US Chute        10yr 87600cfs             Normal S = 0.0003
  Yellowstone     US Chute        50yr 116200cfs            Normal S = 0.0003
  Yellowstone     US Chute        100yr 128300cfs           Normal S = 0.0003
  Yellowstone     US Chute        200yr 140200cfs           Normal S = 0.0003
  Yellowstone     US Chute        500yr 156200cfs           Normal S = 0.0003
  Yellowstone     US Chute        Calib 49220cfs            Normal S = 0.0003
  Yellowstone     US Chute        Verif 30000cfs            Normal S = 0.0003
  Yellowstone     US Chute        Verif 4800cfs             Normal S = 0.0003
  Yellowstone     US Chute        63000cfs                  Normal S = 0.0003
  Yellowstone     US Chute        210kcfs                   Normal S = 0.0003
  Yellowstone     DS Chute        3000cfs                                            Normal S = 0.0003
  Yellowstone     DS Chute        5000cfs                                            Normal S = 0.0003
  Yellowstone     DS Chute        7000cfs                                            Normal S = 0.0003
  Yellowstone     DS Chute        9000cfs                                            Normal S = 0.0003
  Yellowstone     DS Chute        11000cfs                                           Normal S = 0.0003
  Yellowstone     DS Chute        13000cfs                                           Normal S = 0.0003
  Yellowstone     DS Chute        15000cfs                                           Normal S = 0.0003
  Yellowstone     DS Chute        20000cfs                                           Normal S = 0.0003
  Yellowstone     DS Chute        25000cfs                                           Normal S = 0.0003
  Yellowstone     DS Chute        30000cfs                                           Normal S = 0.0003
  Yellowstone     DS Chute        45000cfs                                           Normal S = 0.0003
  Yellowstone     DS Chute        2yr 54200cfs                                       Normal S = 0.0003
  Yellowstone     DS Chute        5yr 74400cfs                                       Normal S = 0.0003
  Yellowstone     DS Chute        10yr 87600cfs                                      Normal S = 0.0003
  Yellowstone     DS Chute        50yr 116200cfs                                     Normal S = 0.0003
  Yellowstone     DS Chute        100yr 128300cfs                                    Normal S = 0.0003
  Yellowstone     DS Chute        200yr 140200cfs                                    Normal S = 0.0003
  Yellowstone     DS Chute        500yr 156200cfs                                    Normal S = 0.0003
  Yellowstone     DS Chute        Calib 49220cfs                                     Normal S = 0.0003
  Yellowstone     DS Chute        Verif 30000cfs                                     Normal S = 0.0003
  Yellowstone     DS Chute        Verif 4800cfs                                      Normal S = 0.0003
  Yellowstone     DS Chute        63000cfs                                           Normal S = 0.0003
  Yellowstone     DS Chute        210kcfs                                            Normal S = 0.0003


SUMMARY OF MANNING'S N VALUES
```

```
River:IrrigCanal

      Reach          River Sta.       n1        n2        n3

 Canal                20523              .03       .03       .03
 Canal                20513             .025      .025      .025
 Canal                20508             .025      .025      .025
 Canal                20507.5           .025      .025      .025
 Canal                20494             .025      .025      .025
 Canal                20493             .025      .025      .025
 Canal                20492             .025      .025      .025
 Canal                20490              .05       .05       .05
 Canal                20430             .034      .034      .034
 Canal                20420             .034      .034      .034
 Canal                20400             .034      .034      .034
 Canal                20380             .034      .034      .034
 Canal                20370             .034      .034      .034
 Canal                20360             .034      .034      .034
 Canal                20340             .034      .034      .034
 Canal                20330             .034      .034      .034
 Canal                20320             .034      .034      .034
 Canal                20300             .034      .034      .034
 Canal                20280             .034      .034      .034
 Canal                20250             .034      .034      .034
 Canal                20230             .034      .034      .034
 Canal                20190             .034      .034      .034
 Canal                20130             .034      .034      .034
 Canal                20060             .034      .034      .034
 Canal                19990             .034      .034      .034
 Canal                19890             .034      .034      .034
 Canal                19830             .034      .034      .034
 Canal                19780             .034      .034      .034
 Canal                19720             .034      .034      .034
 Canal                19680             .034      .034      .034
 Canal                19630             .034      .034      .034
 Canal                19600             .034      .034      .034
 Canal                19530             .034      .034      .034
 Canal                19480        Bridge
 Canal                19420             .034      .034      .034
 Canal                19320             .034      .034      .034
 Canal                19000             .034      .034      .034
 Canal                18730.16          .034      .034      .034
 Canal                18500             .034      .034      .034
 Canal                18236.73          .034      .034      .034
 Canal                18000             .034      .034      .034
 Canal                17734.79          .034      .034      .034
 Canal                17500             .034      .034      .034
 Canal                17239.75          .034      .034      .034
```

```
 Canal                  17000            .034      .034      .034
 Canal                  16739.51         .034      .034      .034
 Canal                  16500            .034      .034      .034
 Canal                  16000            .034      .034      .034
 Canal                  15500            .034      .034      .034
 Canal                  15000            .034      .034      .034
 Canal                  14500            .034      .034      .034
 Canal                  14000            .034      .034      .034
 Canal                  13500            .034      .034      .034
 Canal                  13000            .034      .034      .034
 Canal                  12510            .034      .034      .034
 Canal                  12000            .034      .034      .034
 Canal                  11500            .034      .034      .034
 Canal                  11000            .034      .034      .034
 Canal                  10510            .034      .034      .034
 Canal                  10000            .034      .034      .034
 Canal                  9500             .034      .034      .034
 Canal                  9000             .034      .034      .034
 Canal                  8500             .034      .034      .034
 Canal                  8000             .034      .034      .034
 Canal                  7500             .034      .034      .034
 Canal                  7000             .034      .034      .034
 Canal                  6500             .034      .034      .034
 Canal                  6000             .034      .034      .034
 Canal                  5500             .034      .034      .034
 Canal                  5000             .034      .034      .034
 Canal                  4500             .034      .034      .034
 Canal                  4000             .034      .034      .034
 Canal                  3500             .034      .034      .034
 Canal                  3000             .034      .034      .034
 Canal                  2500             .034      .034      .034
 Canal                  2000             .034      .034      .034
 Canal                  1500             .034      .034      .034
 Canal                  1000             .034      .034      .034
 Canal                  500              .034      .034      .034
 Canal                  30               .034      .034      .034


River:Right Chute

      Reach            River Sta.       n1        n2        n3

 Chute                  19860             .05      .027       .05
 Chute                  19371             .05      .027       .05
 Chute                  19112             .05      .027       .05
 Chute                  18723             .05      .027       .05
 Chute                  18236             .05      .027       .05
 Chute                  17811             .05      .027       .05
```

```
 Chute               17128               .05      .027       .05
 Chute               16148               .05      .027       .05
 Chute               15352               .05      .027       .05
 Chute               14824               .05      .027       .05
 Chute               14335               .05      .027       .05
 Chute               13471               .05      .027       .05
 Chute               12752               .05      .027       .05
 Chute               11805               .05      .027       .05
 Chute               11368               .05      .027       .05
 Chute               10169               .05      .027       .05
 Chute               9362                .05      .027       .05
 Chute               9056                .05      .027       .05
 Chute               8620                .05      .027       .05
 Chute               7967                .05      .027       .05
 Chute               7364                .05      .027       .05
 Chute               6795                .05      .027       .05
 Chute               5997                .05      .027       .05
 Chute               5332                .05      .027       .05
 Chute               4706                .05      .027       .05
 Chute               3764                .05      .027       .05
 Chute               2720                .05      .027       .05
 Chute               1889                .05      .027       .05
 Chute               1277                .05      .027       .05
 Chute               675                 .05      .027       .05
 Chute               286                 .05      .027       .05


River:Yellowstone

      Reach           River Sta.       n1        n2        n3

 US Chute            56000.00            .05      .024       .05
 US Chute            54003.06            .05      .024       .05
 US Chute            51999.34            .05      .024       .05
 US Chute            50001.19            .05      .024       .05
 US Chute            47994.16            .05      .024       .05
 US Chute            46189.52            .05      .024       .05
 US Chute            43687.06            .05      .024       .05
 US Chute            42707.92            .05      .024       .05
 US Chute            41936.91            .05      .024       .05
 US Chute            40894.62            .05      .024       .05
 US Chute            39877.04            .05      .024       .05
 US Chute            39170.03            .05      .024       .05
 US Chute            38214.43            .05      .024       .05
 Mid Chute           37074.57            .05      .024       .05
 Mid Chute           36104.97            .05      .024       .05
 Mid Chute           35375.29            .05      .024       .05
 Mid Chute           34889.88            .05      .024       .05
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Mid Chute            34191.19           .05      .024       .05
Mid Chute            33735.56           .05      .024       .05
Mid Chute            33047.64           .05      .024       .05
Mid Chute            32272.67           .05      .024       .05
Mid Chute            31618.85           .05      .024       .05
Mid Chute            30903.05           .05      .024       .05
Mid Chute            30416.56           .05      .024       .05
Mid Chute            29941.29           .05      .024       .05
Mid Chute            29645.16           .05      .024       .05
Mid Chute            29589.64           .05      .024       .05
Mid Chute            29543.81           .05      .024       .05
Mid Chute            29486.53           .05      .024       .05
Mid Chute            29444.45           .05      .024       .05
Mid Chute            29392.44           .05      .024       .05
Mid Chute            29345.32           .05      .024       .05
Mid Chute            29293.13           .05      .024       .05
Mid Chute            29245.19           .05      .024       .05
Mid Chute            29197.49           .05      .024       .05
Mid Chute            29148.45           .05      .024       .05
Mid Chute            29099.87           .05      .024       .05
Mid Chute            29047.75           .05      .024       .05
Mid Chute            28998.60           .05      .024       .05
Mid Chute            28947.07           .05      .024       .05
Mid Chute            28897.52           .05      .024       .05
Mid Chute            28849.13           .05      .024       .05
Mid Chute            28800.76           .05      .024       .05
Mid Chute            28752.58           .05      .024       .05
Mid Chute            28702.18           .05      .024       .05
Mid Chute            28650.25           .05      .024       .05
Mid Chute            28603.39           .05      .024       .05
Mid Chute            28557.23           .05      .024       .05
Mid Chute            28550        Lat Struct
Mid Chute            28510.39           .05      .024       .05
Mid Chute            28406.73           .05      .024       .05
Mid Chute            28203.49           .05      .024       .05
Mid Chute            28062              .05      .024       .05
Mid Chute            28022        Inl Struct
Mid Chute            28012.06           .05      .045       .05
Mid Chute            27912.73           .05      .045       .05
Mid Chute            27778.92           .05      .045       .05
Mid Chute            27597.18           .05      .042       .05
Mid Chute            27550.20           .05       .04       .05
Mid Chute            27498.33           .05      .038       .05
Mid Chute            27447.08           .05      .035       .05
Mid Chute            27398.93           .05      .024       .05
Mid Chute            27348.49           .05      .024       .05
Mid Chute            27300.85           .05      .024       .05
Mid Chute            27248.50           .05      .024       .05
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Mid Chute           27199.15          .05      .024        .05
Mid Chute           27147.30          .05      .024        .05
Mid Chute           27092.77          .05      .024        .05
Mid Chute           27045.05          .05      .024        .05
Mid Chute           26997.92          .05      .024        .05
Mid Chute           26945.88          .05      .024        .05
Mid Chute           26899.79          .05      .024        .05
Mid Chute           26849.79          .05      .024        .05
Mid Chute           26799.33          .05      .024        .05
Mid Chute           26750.78          .05      .024        .05
Mid Chute           26696.93          .05      .024        .05
Mid Chute           26646.45          .05      .024        .05
Mid Chute           26598.26          .05      .024        .05
Mid Chute           26548.87          .05      .024        .05
Mid Chute           26503.32          .05      .024        .05
Mid Chute           26447.30          .05      .024        .05
Mid Chute           26398.50          .05      .024        .05
Mid Chute           26300.47          .05      .024        .05
Mid Chute           26243.25          .05      .024        .05
Mid Chute           26197.23          .05      .024        .05
Mid Chute           26139.58          .05      .024        .05
Mid Chute           26097.74          .05      .024        .05
Mid Chute           26049.91          .05      .024        .05
Mid Chute           26002.24          .05      .024        .05
Mid Chute           25945.89          .05      .024        .05
Mid Chute           25899.95          .05      .024        .05
Mid Chute           25845.58          .05      .024        .05
Mid Chute           25798.14          .05      .024        .05
Mid Chute           25744.07          .05      .024        .05
Mid Chute           25695.91          .05      .024        .05
Mid Chute           25649.82          .05      .024        .05
Mid Chute           25596.44          .05      .024        .05
Mid Chute           25544.84          .05      .024        .05
Mid Chute           25493.87          .05      .024        .05
Mid Chute           25449.23          .05      .024        .05
Mid Chute           25393.35          .05      .024        .05
Mid Chute           25344.31          .05      .024        .05
Mid Chute           25290.78          .05      .024        .05
Mid Chute           25245.25          .05      .024        .05
Mid Chute           25196.84          .05      .024        .05
Mid Chute           25095.44          .05      .024        .05
Mid Chute           25047.96          .05      .024        .05
Mid Chute           25000.14          .05      .024        .05
Mid Chute           24521.01          .05      .024        .05
Mid Chute           23567.89          .05      .024        .05
Mid Chute           22555.07          .05      .024        .05
Mid Chute           20556.36          .05      .024        .05
Mid Chute           19585.36          .05      .024        .05
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 DS Chute             19210.21            .05      .024       .05
 DS Chute             18370.67            .05      .024       .05
 DS Chute             17009.26            .05      .024       .05
 DS Chute             16125.84            .05      .024       .05
 DS Chute             14768.24            .05      .024       .05
 DS Chute             12602.25            .05      .024       .05
 DS Chute             7708.504            .05      .024       .05
 DS Chute             5162.571            .05      .024       .05
 DS Chute             3996.727            .05      .024       .05
 DS Chute             2000.000            .05      .024       .05



SUMMARY OF CONTRACTION AND EXPANSION COEFFICIENTS
River: IrrigCanal


      Reach          River Sta.     Contr.    Expan.

 Canal                20523           .2        .4
 Canal                20513           .2        .4
 Canal                20508           .2        .4
 Canal                20507.5         .2        .4
 Canal                20494           .2        .4
 Canal                20493           .2        .4
 Canal                20492           .2        .4
 Canal                20490           .2        .4
 Canal                20430           .2        .4
 Canal                20420           .2        .4
 Canal                20400           .2        .4
 Canal                20380           .2        .4
 Canal                20370           .2        .4
 Canal                20360           .2        .4
 Canal                20340           .2        .4
 Canal                20330           .2        .4
 Canal                20320           .2        .4
 Canal                20300           .2        .4
 Canal                20280           .2        .4
 Canal                20250           .1        .3
 Canal                20230           .1        .3
 Canal                20190           .1        .3
 Canal                20130           .1        .3
 Canal                20060           .1        .3
 Canal                19990           .1        .3
 Canal                19890           .1        .3
 Canal                19830           .1        .3
 Canal                19780           .1        .3
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Canal                19720           .1        .3
Canal                19680           .1        .3
Canal                19630           .1        .3
Canal                19600           .1        .3
Canal                19530           .1        .3
Canal                19480    Bridge
Canal                19420           .1        .3
Canal                19320           .1        .3
Canal                19000           .1        .3
Canal                18730.16        .1        .3
Canal                18500           .1        .3
Canal                18236.73        .1        .3
Canal                18000           .1        .3
Canal                17734.79        .1        .3
Canal                17500           .1        .3
Canal                17239.75        .1        .3
Canal                17000           .1        .3
Canal                16739.51        .1        .3
Canal                16500           .1        .3
Canal                16000           .1        .3
Canal                15500           .1        .3
Canal                15000           .1        .3
Canal                14500           .1        .3
Canal                14000           .1        .3
Canal                13500           .1        .3
Canal                13000           .1        .3
Canal                12510           .1        .3
Canal                12000           .1        .3
Canal                11500           .1        .3
Canal                11000           .1        .3
Canal                10510           .1        .3
Canal                10000           .1        .3
Canal                9500            .1        .3
Canal                9000            .1        .3
Canal                8500            .1        .3
Canal                8000            .1        .3
Canal                7500            .1        .3
Canal                7000            .1        .3
Canal                6500            .1        .3
Canal                6000            .1        .3
Canal                5500            .1        .3
Canal                5000            .1        .3
Canal                4500            .1        .3
Canal                4000            .1        .3
Canal                3500            .1        .3
Canal                3000            .1        .3
Canal                2500            .1        .3
Canal                2000            .1        .3
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 Canal                1500           .1        .3
 Canal                1000           .1        .3
 Canal                500            .1        .3
 Canal                30             .1        .3

River: Right Chute


      Reach          River Sta.     Contr.    Expan.

 Chute                19860          .1        .3
 Chute                19371          .1        .3
 Chute                19112          .1        .3
 Chute                18723          .1        .3
 Chute                18236          .1        .3
 Chute                17811          .1        .3
 Chute                17128          .1        .3
 Chute                16148          .1        .3
 Chute                15352          .1        .3
 Chute                14824          .1        .3
 Chute                14335          .1        .3
 Chute                13471          .1        .3
 Chute                12752          .1        .3
 Chute                11805          .1        .3
 Chute                11368          .1        .3
 Chute                10169          .1        .3
 Chute                9362           .1        .3
 Chute                9056           .1        .3
 Chute                8620           .1        .3
 Chute                7967           .1        .3
 Chute                7364           .1        .3
 Chute                6795           .1        .3
 Chute                5997           .1        .3
 Chute                5332           .1        .3
 Chute                4706           .1        .3
 Chute                3764           .1        .3
 Chute                2720           .1        .3
 Chute                1889           .1        .3
 Chute                1277           .1        .3
 Chute                675            .1        .3
 Chute                286            .1        .3

River: Yellowstone


      Reach          River Sta.     Contr.    Expan.

 US Chute             56000.00       .1        .3
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US Chute             54003.06        .1        .3
US Chute             51999.34        .1        .3
US Chute             50001.19        .1        .3
US Chute             47994.16        .1        .3
US Chute             46189.52        .1        .3
US Chute             43687.06        .1        .3
US Chute             42707.92        .1        .3
US Chute             41936.91        .1        .3
US Chute             40894.62        .1        .3
US Chute             39877.04        .1        .3
US Chute             39170.03        .1        .3
US Chute             38214.43        .1        .3
Mid Chute            37074.57        .1        .3
Mid Chute            36104.97        .1        .3
Mid Chute            35375.29        .1        .3
Mid Chute            34889.88        .1        .3
Mid Chute            34191.19        .1        .3
Mid Chute            33735.56        .1        .3
Mid Chute            33047.64        .1        .3
Mid Chute            32272.67        .1        .3
Mid Chute            31618.85        .1        .3
Mid Chute            30903.05        .1        .3
Mid Chute            30416.56        .1        .3
Mid Chute            29941.29        .1        .3
Mid Chute            29645.16        .1        .3
Mid Chute            29589.64        .1        .3
Mid Chute            29543.81        .1        .3
Mid Chute            29486.53        .1        .3
Mid Chute            29444.45        .1        .3
Mid Chute            29392.44        .1        .3
Mid Chute            29345.32        .1        .3
Mid Chute            29293.13        .1        .3
Mid Chute            29245.19        .1        .3
Mid Chute            29197.49        .1        .3
Mid Chute            29148.45        .1        .3
Mid Chute            29099.87        .1        .3
Mid Chute            29047.75        .1        .3
Mid Chute            28998.60        .1        .3
Mid Chute            28947.07        .1        .3
Mid Chute            28897.52        .1        .3
Mid Chute            28849.13        .1        .3
Mid Chute            28800.76        .1        .3
Mid Chute            28752.58        .1        .3
Mid Chute            28702.18        .1        .3
Mid Chute            28650.25        .1        .3
Mid Chute            28603.39        .1        .3
Mid Chute            28557.23        .1        .3
Mid Chute            28550    Lat Struct
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Mid Chute            28510.39        .1        .3
Mid Chute            28406.73        .1        .3
Mid Chute            28203.49        .1        .3
Mid Chute            28062           .1        .3
Mid Chute            28022    Inl Struct
Mid Chute            28012.06        .1        .3
Mid Chute            27912.73        .1        .3
Mid Chute            27778.92        .1        .3
Mid Chute            27597.18        .1        .3
Mid Chute            27550.20        .1        .3
Mid Chute            27498.33        .1        .3
Mid Chute            27447.08        .1        .3
Mid Chute            27398.93        .1        .3
Mid Chute            27348.49        .1        .3
Mid Chute            27300.85        .1        .3
Mid Chute            27248.50        .1        .3
Mid Chute            27199.15        .1        .3
Mid Chute            27147.30        .1        .3
Mid Chute            27092.77        .1        .3
Mid Chute            27045.05        .1        .3
Mid Chute            26997.92        .1        .3
Mid Chute            26945.88        .1        .3
Mid Chute            26899.79        .1        .3
Mid Chute            26849.79        .1        .3
Mid Chute            26799.33        .1        .3
Mid Chute            26750.78        .1        .3
Mid Chute            26696.93        .1        .3
Mid Chute            26646.45        .1        .3
Mid Chute            26598.26        .1        .3
Mid Chute            26548.87        .1        .3
Mid Chute            26503.32        .1        .3
Mid Chute            26447.30        .1        .3
Mid Chute            26398.50        .1        .3
Mid Chute            26300.47        .1        .3
Mid Chute            26243.25        .1        .3
Mid Chute            26197.23        .1        .3
Mid Chute            26139.58        .1        .3
Mid Chute            26097.74        .1        .3
Mid Chute            26049.91        .1        .3
Mid Chute            26002.24        .1        .3
Mid Chute            25945.89        .1        .3
Mid Chute            25899.95        .1        .3
Mid Chute            25845.58        .1        .3
Mid Chute            25798.14        .1        .3
Mid Chute            25744.07        .1        .3
Mid Chute            25695.91        .1        .3
Mid Chute            25649.82        .1        .3
Mid Chute            25596.44        .1        .3
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Mid Chute            25544.84        .1        .3
Mid Chute            25493.87        .1        .3
Mid Chute            25449.23        .1        .3
Mid Chute            25393.35        .1        .3
Mid Chute            25344.31        .1        .3
Mid Chute            25290.78        .1        .3
Mid Chute            25245.25        .1        .3
Mid Chute            25196.84        .1        .3
Mid Chute            25095.44        .1        .3
Mid Chute            25047.96        .1        .3
Mid Chute            25000.14        .1        .3
Mid Chute            24521.01        .1        .3
Mid Chute            23567.89        .1        .3
Mid Chute            22555.07        .1        .3
Mid Chute            20556.36        .1        .3
Mid Chute            19585.36        .1        .3
DS Chute             19210.21        .1        .3
DS Chute             18370.67        .1        .3
DS Chute             17009.26        .1        .3
DS Chute             16125.84        .1        .3
DS Chute             14768.24        .1        .3
DS Chute             12602.25        .1        .3
DS Chute             7708.504        .1        .3
DS Chute             5162.571        .1        .3
DS Chute             3996.727        .1        .3
DS Chute             2000.000        .1        .3
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HEC-RAS Plan: Tt_High_flow_w_Bridge

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Yellowstone	US Chute	56000.00	7000cfs	7000.00	1996.00	2001.78	1998.55	2001.89	0.000307	2.65	2640.93	760.08	0.24
Yellowstone	US Chute	56000.00	15000cfs	15000.00	1996.00	2004.01	2000.25	2004.20	0.000315	3.55	4220.23	839.62	0.26
Yellowstone	US Chute	56000.00	30000cfs	30000.00	1996.00	2006.66	2001.84	2007.03	0.000366	4.87	6168.01	902.21	0.30
Yellowstone	US Chute	56000.00	2yr 54200cfs	54200.00	1996.00	2009.55	2003.77	2010.22	0.000443	6.53	8331.80	1474.23	0.34
Yellowstone	US Chute	56000.00	100yr 128300cfs	128300.00	1996.00	2014.68	2008.09	2016.40	0.000702	10.55	12455.48	2440.66	0.46
Yellowstone	US Chute	56000.00	63000cfs	63000.00	1996.00	2010.52	2004.32	2011.28	0.000454	6.98	9078.18	1602.51	0.35
Yellowstone	US Chute	54003.06	7000cfs	7000.00	1995.31	2001.25	1997.86	2001.34	0.000238	2.35	2983.42	791.30	0.21
Yellowstone	US Chute	54003.06	15000cfs	15000.00	1995.31	2003.48	1999.53	2003.64	0.000246	3.17	4737.06	944.96	0.23
Yellowstone	US Chute	54003.06	30000cfs	30000.00	1995.31	2006.05	2001.01	2006.35	0.000302	4.40	6814.39	1075.67	0.27
Yellowstone	US Chute	54003.06	2yr 54200cfs	54200.00	1995.31	2008.81	2002.75	2009.36	0.000382	5.96	9108.51	1197.90	0.32
Yellowstone	US Chute	54003.06	100yr 128300cfs	128300.00	1995.31	2013.46	2006.88	2014.98	0.000660	9.89	13107.68	2820.00	0.44
Yellowstone	US Chute	54003.06	63000cfs	63000.00	1995.31	2009.77	2003.35	2010.40	0.000392	6.37	9913.64	1263.45	0.33
Yellowstone	US Chute	51999.34	7000cfs	7000.00	1994.62	2000.78	1997.96	2000.86	0.000243	2.25	3114.61	873.38	0.21
Yellowstone	US Chute	51999.34	15000cfs	15000.00	1994.62	2002.99	1999.02	2003.11	0.000270	2.84	5286.76	1333.36	0.23
Yellowstone	US Chute	51999.34	30000cfs	30000.00	1994.62	2005.53	2000.50	2005.73	0.000284	3.55	8447.10	1669.35	0.25
Yellowstone	US Chute	51999.34	2yr 54200cfs	54200.00	1994.62	2008.34	2002.31	2008.65	0.000272	4.42	12308.94	1993.38	0.26
Yellowstone	US Chute	51999.34	100yr 128300cfs	128300.00	1994.62	2013.33	2005.83	2013.85	0.000288	6.09	28114.03	4380.65	0.29
Yellowstone	US Chute	51999.34	63000cfs	63000.00	1994.62	2009.35	2002.88	2009.68	0.000259	4.62	13745.62	2151.32	0.26
Yellowstone	US Chute	50001.19	7000cfs	7000.00	1993.93	1999.67	1997.84	2000.00	0.000892	4.75	1678.31	788.83	0.41
Yellowstone	US Chute	50001.19	15000cfs	15000.00	1993.93	2001.37	1999.43	2002.04	0.001389	6.86	2561.37	885.73	0.53
Yellowstone	US Chute	50001.19	30000cfs	30000.00	1993.93	2003.41	2001.68	2004.46	0.002175	8.65	4027.97	1128.57	0.67
Yellowstone	US Chute	50001.19	2yr 54200cfs	54200.00	1993.93	2005.81	2003.87	2007.39	0.002064	10.65	6107.66	1412.08	0.69
Yellowstone	US Chute	50001.19	100yr 128300cfs	128300.00	1993.93	2012.44	2008.34	2013.05	0.000671	6.54	24809.41	4491.99	0.40
Yellowstone	US Chute	50001.19	63000cfs	63000.00	1993.93	2006.73	2004.53	2008.43	0.002176	11.07	7168.13	1605.13	0.71
Yellowstone	US Chute	47994.16	7000cfs	7000.00	1993.23	1997.82	1996.74	1998.01	0.001091	3.48	2010.13	901.25	0.41
Yellowstone	US Chute	47994.16	15000cfs	15000.00	1993.23	1999.54	1997.64	1999.79	0.000865	4.05	3707.29	1115.00	0.39
Yellowstone	US Chute	47994.16	30000cfs	30000.00	1993.23	2002.01	1998.94	2002.31	0.000559	4.38	6842.28	1315.22	0.34
Yellowstone	US Chute	47994.16	2yr 54200cfs	54200.00	1993.23	2005.18	2000.54	2005.55	0.000387	4.90	11102.36	1391.03	0.30
Yellowstone	US Chute	47994.16	100yr 128300cfs	128300.00	1993.23	2011.58	2003.49	2012.11	0.000343	5.90	25218.38	4098.71	0.30
Yellowstone	US Chute	47994.16	63000cfs	63000.00	1993.23	2006.22	2000.94	2006.62	0.000359	5.03	12592.19	1456.36	0.30
Yellowstone	US Chute	46189.52	7000cfs	7000.00	1989.69	1996.15	1994.44	1996.31	0.000684	3.17	2206.52	804.12	0.34
Yellowstone	US Chute	46189.52	15000cfs	15000.00	1989.69	1998.35	1995.60	1998.56	0.000454	3.68	4073.72	871.29	0.30
Yellowstone	US Chute	46189.52	30000cfs	30000.00	1989.69	2001.02	1996.96	2001.36	0.000406	4.68	6412.63	881.05	0.31
Yellowstone	US Chute	46189.52	2yr 54200cfs	54200.00	1989.69	2004.22	1998.63	2004.76	0.000393	5.87	9255.16	898.08	0.32
Yellowstone	US Chute	46189.52	100yr 128300cfs	128300.00	1989.69	2010.21	2002.45	2011.28	0.000449	8.47	19586.59	3201.57	0.37
Yellowstone	US Chute	46189.52	63000cfs	63000.00	1989.69	2005.25	1999.12	2005.85	0.000389	6.21	10175.54	1039.82	0.32
Yellowstone	US Chute	43687.06	7000cfs	7000.00	1983.93	1995.85	1988.88	1995.89	0.000064	1.73	4037.29	617.99	0.12

HEC-RAS Plan: Tt_High_flow_w_Bridge (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Yellowstone	US Chute	43687.06	15000cfs	15000.00	1983.93	1997.87	1990.46	1997.99	0.000126	2.80	5366.44	675.02	0.17
Yellowstone	US Chute	43687.06	30000cfs	30000.00	1983.93	2000.35	1992.71	2000.63	0.000206	4.29	7060.09	689.31	0.23
Yellowstone	US Chute	43687.06	2yr 54200cfs	54200.00	1983.93	2003.35	1995.46	2003.91	0.000292	6.02	9183.82	765.54	0.29
Yellowstone	US Chute	43687.06	100yr 128300cfs	128300.00	1983.93	2008.73	2000.34	2010.09	0.000479	9.63	19076.68	3834.30	0.39
Yellowstone	US Chute	43687.06	63000cfs	63000.00	1983.93	2004.31	1996.23	2004.97	0.000313	6.52	9918.51	952.45	0.30
Yellowstone	US Chute	42707.92	7000cfs	7000.00	1986.56	1995.75	1990.25	1995.81	0.000102	1.97	3557.40	635.10	0.15
Yellowstone	US Chute	42707.92	15000cfs	15000.00	1986.56	1997.69	1991.99	1997.84	0.000195	3.08	4875.39	727.13	0.21
Yellowstone	US Chute	42707.92	30000cfs	30000.00	1986.56	2000.08	1994.06	2000.40	0.000290	4.50	6688.42	772.10	0.27
Yellowstone	US Chute	42707.92	2yr 54200cfs	54200.00	1986.56	2003.02	1996.31	2003.59	0.000361	6.08	9060.44	902.42	0.31
Yellowstone	US Chute	42707.92	100yr 128300cfs	128300.00	1986.56	2008.40	2000.91	2009.57	0.000484	9.05	22870.13	5648.32	0.39
Yellowstone	US Chute	42707.92	63000cfs	63000.00	1986.56	2003.98	1997.06	2004.64	0.000374	6.52	9959.36	1102.90	0.32
Yellowstone	US Chute	41936.91	7000cfs	7000.00	1989.22	1995.58	1992.54	1995.68	0.000314	2.56	2730.26	763.61	0.24
Yellowstone	US Chute	41936.91	15000cfs	15000.00	1989.22	1997.45	1993.89	1997.62	0.000410	3.32	4519.80	1047.69	0.28
Yellowstone	US Chute	41936.91	30000cfs	30000.00	1989.22	1999.85	1995.63	2000.13	0.000378	4.24	7076.98	1069.43	0.29
Yellowstone	US Chute	41936.91	2yr 54200cfs	54200.00	1989.22	2002.84	1997.50	2003.27	0.000357	5.28	10280.66	1323.41	0.30
Yellowstone	US Chute	41936.91	100yr 128300cfs	128300.00	1989.22	2008.39	2000.88	2009.11	0.000356	7.15	27722.44	5783.96	0.32
Yellowstone	US Chute	41936.91	63000cfs	63000.00	1989.22	2003.82	1997.96	2004.30	0.000348	5.56	11344.24	1603.22	0.30
Yellowstone	US Chute	40894.62	7000cfs	7000.00	1989.86	1995.10	1993.36	1995.24	0.000598	2.92	2397.39	894.98	0.31
Yellowstone	US Chute	40894.62	15000cfs	15000.00	1989.86	1996.94	1994.43	1997.14	0.000502	3.65	4111.31	961.68	0.31
Yellowstone	US Chute	40894.62	30000cfs	30000.00	1989.86	1999.36	1995.72	1999.69	0.000456	4.64	6467.92	985.10	0.32
Yellowstone	US Chute	40894.62	2yr 54200cfs	54200.00	1989.86	2002.33	1997.30	2002.85	0.000436	5.76	9446.84	1045.74	0.33
Yellowstone	US Chute	40894.62	100yr 128300cfs	128300.00	1989.86	2007.98	2000.90	2008.68	0.000481	7.12	27766.46	5930.60	0.36
Yellowstone	US Chute	40894.62	63000cfs	63000.00	1989.86	2003.32	1997.79	2003.89	0.000425	6.06	10461.09	1310.31	0.33
Yellowstone	US Chute	39877.04	7000cfs	7000.00	1987.46	1994.29	1992.38	1994.49	0.000921	3.54	1976.53	763.40	0.39
Yellowstone	US Chute	39877.04	15000cfs	15000.00	1987.46	1996.30	1993.95	1996.55	0.000666	4.01	3736.28	937.10	0.35
Yellowstone	US Chute	39877.04	30000cfs	30000.00	1987.46	1998.82	1995.40	1999.18	0.000541	4.82	6228.47	1047.68	0.34
Yellowstone	US Chute	39877.04	2yr 54200cfs	54200.00	1987.46	2001.88	1997.08	2002.40	0.000456	5.79	9513.65	1267.19	0.34
Yellowstone	US Chute	39877.04	100yr 128300cfs	128300.00	1987.46	2007.59	2000.65	2008.27	0.000366	7.17	30061.73	5801.53	0.33
Yellowstone	US Chute	39877.04	63000cfs	63000.00	1987.46	2002.91	1997.59	2003.46	0.000425	6.00	11228.12	1747.56	0.33
Yellowstone	US Chute	39170.03	7000cfs	7000.00	1985.48	1994.09	1989.57	1994.18	0.000213	2.38	2946.99	690.66	0.20
Yellowstone	US Chute	39170.03	15000cfs	15000.00	1985.48	1996.05	1991.39	1996.23	0.000307	3.38	4447.05	814.04	0.25
Yellowstone	US Chute	39170.03	30000cfs	30000.00	1985.48	1998.53	1993.60	1998.86	0.000368	4.61	6526.75	876.57	0.29
Yellowstone	US Chute	39170.03	2yr 54200cfs	54200.00	1985.48	2001.53	1995.74	2002.08	0.000442	5.91	9211.43	1167.93	0.33
Yellowstone	US Chute	39170.03	100yr 128300cfs	128300.00	1985.48	2007.61	1999.88	2007.86	0.000439	3.99	32213.80	6005.31	0.30
Yellowstone	US Chute	39170.03	63000cfs	63000.00	1985.48	2002.53	1996.30	2003.13	0.000515	6.18	10247.04	1641.80	0.36
Yellowstone	US Chute	38214.43	7000cfs	7000.00	1984.11	1994.02	1988.00	1994.06	0.000065	1.75	3994.47	607.20	0.12
Yellowstone	US Chute	38214.43	15000cfs	15000.00	1984.11	1995.90	1989.48	1996.03	0.000132	2.90	5183.62	653.45	0.18

HEC-RAS Plan: Tt_High_flow_w_Bridge (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Yellowstone	US Chute	38214.43	30000cfs	30000.00	1984.11	1998.27	1991.33	1998.58	0.000226	4.49	6833.52	776.81	0.24
Yellowstone	US Chute	38214.43	2yr 54200cfs	54200.00	1984.11	2001.09	1993.69	2001.71	0.000331	6.35	9052.39	1034.29	0.31
Yellowstone	US Chute	38214.43	100yr 128300cfs	128300.00	1984.11	2006.30	1998.70	2007.37	0.000438	9.10	28267.70	6377.74	0.37
Yellowstone	US Chute	38214.43	63000cfs	63000.00	1984.11	2001.97	1994.45	2002.70	0.000359	6.91	9867.86	1385.66	0.32
Yellowstone	DS Chute	19210.21	7000cfs	5626.17	1974.19	1980.39	1977.95	1980.53	0.000521	2.96	1898.61	624.77	0.30
Yellowstone	DS Chute	19210.21	15000cfs	13626.17	1974.19	1982.37	1979.63	1982.60	0.000682	3.92	3480.45	922.83	0.36
Yellowstone	DS Chute	19210.21	30000cfs	28626.09	1974.19	1984.81	1981.60	1985.16	0.000741	4.72	6063.31	1319.81	0.38
Yellowstone	DS Chute	19210.21	2yr 54200cfs	52826.09	1974.19	1987.76	1983.37	1988.21	0.000499	5.34	9892.56	1485.35	0.34
Yellowstone	DS Chute	19210.21	100yr 128300cfs	126926.20	1974.19	1993.56	1986.83	1994.37	0.000433	7.26	18082.08	4751.35	0.35
Yellowstone	DS Chute	19210.21	63000cfs	61626.09	1974.19	1988.66	1983.94	1989.14	0.000469	5.57	11062.81	1676.89	0.34
Yellowstone	DS Chute	18370.67	7000cfs	5626.17	1975.62	1979.89	1978.49	1980.02	0.000704	2.95	1905.61	790.27	0.34
Yellowstone	DS Chute	18370.67	15000cfs	13626.17	1975.62	1981.82	1979.55	1982.04	0.000656	3.72	3661.79	1017.31	0.35
Yellowstone	DS Chute	18370.67	30000cfs	28626.09	1975.62	1984.30	1981.02	1984.61	0.000549	4.49	6370.19	1174.78	0.34
Yellowstone	DS Chute	18370.67	2yr 54200cfs	52826.09	1975.62	1987.37	1982.65	1987.77	0.000511	5.05	10461.34	1731.59	0.34
Yellowstone	DS Chute	18370.67	100yr 128300cfs	126926.20	1975.62	1993.34	1986.26	1993.99	0.000364	6.46	20106.91	4836.33	0.32
Yellowstone	DS Chute	18370.67	63000cfs	61626.09	1975.62	1988.32	1983.14	1988.73	0.000453	5.18	11903.72	1806.66	0.33
Yellowstone	DS Chute	17009.26	7000cfs	5626.17	1971.03	1979.32	1975.90	1979.41	0.000303	2.30	2443.50	774.92	0.23
Yellowstone	DS Chute	17009.26	15000cfs	13626.17	1971.03	1981.14	1977.79	1981.32	0.000421	3.48	3915.92	855.37	0.29
Yellowstone	DS Chute	17009.26	30000cfs	28626.09	1971.03	1983.56	1979.68	1983.90	0.000503	4.65	6151.77	991.92	0.33
Yellowstone	DS Chute	17009.26	2yr 54200cfs	52826.09	1971.03	1986.58	1981.51	1987.09	0.000474	5.72	9241.02	1189.05	0.34
Yellowstone	DS Chute	17009.26	100yr 128300cfs	126926.20	1971.03	1992.82	1985.42	1993.40	0.000486	6.45	27763.18	5289.45	0.35
Yellowstone	DS Chute	17009.26	63000cfs	61626.09	1971.03	1987.53	1982.08	1988.10	0.000462	6.02	10245.41	1306.90	0.34
Yellowstone	DS Chute	16125.84	7000cfs	5626.17	1973.56	1978.86	1977.25	1979.00	0.000738	3.02	1865.69	774.63	0.34
Yellowstone	DS Chute	16125.84	15000cfs	13626.17	1973.56	1980.53	1978.53	1980.80	0.000877	4.11	3315.09	982.52	0.39
Yellowstone	DS Chute	16125.84	30000cfs	28626.09	1973.56	1983.03	1980.02	1983.38	0.000669	4.80	5958.13	1210.53	0.37
Yellowstone	DS Chute	16125.84	2yr 54200cfs	52826.09	1973.56	1986.20	1981.70	1986.63	0.000510	5.28	10005.67	1576.96	0.34
Yellowstone	DS Chute	16125.84	100yr 128300cfs	126926.20	1973.56	1992.47	1985.28	1993.04	0.000338	6.26	24816.65	3014.71	0.31
Yellowstone	DS Chute	16125.84	63000cfs	61626.09	1973.56	1987.20	1982.20	1987.66	0.000456	5.42	11376.66	1760.44	0.33
Yellowstone	DS Chute	14768.24	7000cfs	5626.17	1972.37	1976.78	1976.31	1977.16	0.003131	4.92	1143.72	675.65	0.67
Yellowstone	DS Chute	14768.24	15000cfs	13626.17	1972.37	1979.22	1977.45	1979.52	0.001003	4.37	3121.37	938.78	0.42
Yellowstone	DS Chute	14768.24	30000cfs	28626.09	1972.37	1982.24	1978.97	1982.59	0.000515	4.76	6109.22	1008.35	0.34
Yellowstone	DS Chute	14768.24	2yr 54200cfs	52826.09	1972.37	1985.48	1980.53	1985.99	0.000431	5.74	9485.80	1099.14	0.33
Yellowstone	DS Chute	14768.24	100yr 128300cfs	126926.20	1972.37	1991.53	1984.17	1992.48	0.000437	8.04	19993.43	3230.24	0.36
Yellowstone	DS Chute	14768.24	63000cfs	61626.09	1972.37	1986.50	1981.05	1987.06	0.000415	6.03	10643.13	1169.12	0.33
Yellowstone	DS Chute	12602.25	7000cfs	5626.17	1969.21	1975.05	1972.26	1975.20	0.000403	3.09	1820.84	464.39	0.27
Yellowstone	DS Chute	12602.25	15000cfs	13626.17	1969.21	1977.81	1973.99	1978.08	0.000468	4.22	3231.58	577.96	0.31
Yellowstone	DS Chute	12602.25	30000cfs	28626.09	1969.21	1980.98	1976.13	1981.40	0.000573	5.26	5445.54	814.15	0.36

HEC-RAS Plan: Tt_High_flow_w_Bridge (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Yellowstone	DS Chute	12602.25	2yr 54200cfs	52826.09	1969.21	1984.33	1978.81	1984.96	0.000505	6.40	8367.45	925.05	0.36
Yellowstone	DS Chute	12602.25	100yr 128300cfs	126926.20	1969.21	1990.78	1983.45	1991.55	0.000372	7.68	28632.62	4698.72	0.33
Yellowstone	DS Chute	12602.25	63000cfs	61626.09	1969.21	1985.36	1979.63	1986.07	0.000491	6.74	9379.72	1030.95	0.36
Yellowstone	DS Chute	7708.504	7000cfs	5626.17	1965.57	1973.13	1970.33	1973.25	0.000392	2.71	2076.33	629.50	0.26
Yellowstone	DS Chute	7708.504	15000cfs	13626.17	1965.57	1976.15	1971.95	1976.31	0.000279	3.25	4190.97	746.32	0.24
Yellowstone	DS Chute	7708.504	30000cfs	28626.09	1965.57	1979.01	1973.87	1979.32	0.000319	4.50	6375.79	784.79	0.28
Yellowstone	DS Chute	7708.504	2yr 54200cfs	52826.09	1965.57	1982.36	1975.90	1982.90	0.000349	5.90	9050.75	809.35	0.31
Yellowstone	DS Chute	7708.504	100yr 128300cfs	126926.20	1965.57	1989.53	1980.23	1990.14	0.000254	6.94	27714.38	5153.00	0.28
Yellowstone	DS Chute	7708.504	63000cfs	61626.09	1965.57	1983.39	1976.50	1984.01	0.000357	6.32	9887.43	819.87	0.31
Yellowstone	DS Chute	5162.571	7000cfs	5626.17	1958.27	1972.90	1965.45	1972.93	0.000053	1.49	3774.65	627.97	0.11
Yellowstone	DS Chute	5162.571	15000cfs	13626.17	1958.27	1975.84	1968.45	1975.93	0.000085	2.41	5652.08	646.07	0.14
Yellowstone	DS Chute	5162.571	30000cfs	28626.09	1958.27	1978.51	1970.74	1978.75	0.000157	3.87	7394.78	694.10	0.20
Yellowstone	DS Chute	5162.571	2yr 54200cfs	52826.09	1958.27	1981.68	1972.92	1982.16	0.000236	5.57	9509.09	807.25	0.26
Yellowstone	DS Chute	5162.571	100yr 128300cfs	126926.20	1958.27	1988.09	1977.75	1989.29	0.000373	8.96	16837.62	3617.34	0.35
Yellowstone	DS Chute	5162.571	63000cfs	61626.09	1958.27	1982.65	1973.60	1983.23	0.000257	6.08	10197.64	885.45	0.27
Yellowstone	DS Chute	3996.727	7000cfs	5626.17	1967.58	1972.69	1969.79	1972.80	0.000326	2.62	2147.74	596.75	0.24
Yellowstone	DS Chute	3996.727	15000cfs	13626.17	1967.58	1975.58	1971.51	1975.75	0.000335	3.26	4182.15	854.69	0.26
Yellowstone	DS Chute	3996.727	30000cfs	28626.09	1967.58	1978.16	1973.28	1978.47	0.000365	4.47	6405.45	900.25	0.29
Yellowstone	DS Chute	3996.727	2yr 54200cfs	52826.09	1967.58	1981.29	1975.62	1981.81	0.000383	5.79	9154.72	981.40	0.31
Yellowstone	DS Chute	3996.727	100yr 128300cfs	126926.20	1967.58	1987.88	1979.54	1988.77	0.000372	7.88	23757.93	4557.01	0.34
Yellowstone	DS Chute	3996.727	63000cfs	61626.09	1967.58	1982.27	1976.16	1982.86	0.000387	6.17	10025.16	1047.47	0.32
Yellowstone	DS Chute	2000.000	7000cfs	5626.17	1966.88	1972.08	1969.29	1972.17	0.000300	2.45	2295.41	661.87	0.23
Yellowstone	DS Chute	2000.000	15000cfs	13626.17	1966.88	1974.97	1970.74	1975.11	0.000300	2.94	4627.68	1043.22	0.24
Yellowstone	DS Chute	2000.000	30000cfs	28626.09	1966.88	1977.55	1972.54	1977.79	0.000300	3.95	7253.82	1077.12	0.26
Yellowstone	DS Chute	2000.000	2yr 54200cfs	52826.09	1966.88	1980.70	1974.66	1981.10	0.000300	5.04	10501.19	1125.87	0.28
Yellowstone	DS Chute	2000.000	100yr 128300cfs	126926.20	1966.88	1987.32	1978.29	1988.06	0.000300	7.02	20968.27	1742.61	0.30
Yellowstone	DS Chute	2000.000	63000cfs	61626.09	1966.88	1981.69	1975.28	1982.14	0.000300	5.36	11531.58	1169.22	0.28
Right Chute	Chute	19860	7000cfs	969.07	1989.49	1993.81		1993.92	0.000520	2.66	364.64	117.79	0.27
Right Chute	Chute	19860	15000cfs	1964.83	1989.49	1995.64		1995.80	0.000510	3.27	600.39	139.76	0.28
Right Chute	Chute	19860	30000cfs	3814.31	1989.49	1998.01		1998.25	0.000499	3.95	964.98	166.14	0.29
Right Chute	Chute	19860	2yr 54200cfs	7052.45	1989.49	2000.90		2001.26	0.000490	4.77	1479.71	189.29	0.30
Right Chute	Chute	19860	100yr 128300cfs	17371.82	1989.49	2006.60		2006.77	0.000199	4.09	8431.02	1609.88	0.21
Right Chute	Chute	19860	63000cfs	8388.27	1989.49	2001.82		2002.21	0.000502	5.07	1655.43	196.57	0.31
Right Chute	Chute	19371	7000cfs	969.07	1989.19	1993.56		1993.67	0.000494	2.61	371.12	118.45	0.26
Right Chute	Chute	19371	15000cfs	1964.83	1989.19	1995.40		1995.56	0.000491	3.23	608.55	140.46	0.27
Right Chute	Chute	19371	30000cfs	3814.31	1989.19	1997.77		1998.01	0.000483	3.91	975.54	166.65	0.28
Right Chute	Chute	19371	2yr 54200cfs	7052.45	1989.19	2000.67		2001.02	0.000478	4.73	1492.55	189.84	0.30

HEC-RAS Plan: Tt_High_flow_w_Bridge (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Right Chute	Chute	19371	100yr 128300cfs	17371.82	1989.19	2006.01		2006.59	0.000524	6.27	3600.92	890.26	0.33
Right Chute	Chute	19371	63000cfs	8388.27	1989.19	2001.58		2001.97	0.000492	5.03	1667.46	197.07	0.30
Right Chute	Chute	19112	7000cfs	969.07	1989.04	1993.44		1993.54	0.000483	2.59	374.06	118.75	0.26
Right Chute	Chute	19112	15000cfs	1964.83	1989.04	1995.27		1995.43	0.000483	3.21	612.07	140.76	0.27
Right Chute	Chute	19112	30000cfs	3814.31	1989.04	1997.65		1997.88	0.000477	3.89	980.04	166.87	0.28
Right Chute	Chute	19112	2yr 54200cfs	7052.45	1989.04	2000.55		2000.90	0.000473	4.71	1497.99	190.09	0.30
Right Chute	Chute	19112	100yr 128300cfs	17371.82	1989.04	2005.74		2006.43	0.000604	6.70	2608.93	361.16	0.35
Right Chute	Chute	19112	63000cfs	8388.27	1989.04	2001.45		2001.84	0.000488	5.02	1672.36	197.29	0.30
Right Chute	Chute	18723	7000cfs	969.07	1988.80	1993.26		1993.36	0.000457	2.54	381.18	119.47	0.25
Right Chute	Chute	18723	15000cfs	1964.83	1988.80	1995.09		1995.24	0.000465	3.17	620.31	141.46	0.27
Right Chute	Chute	18723	30000cfs	3814.31	1988.80	1997.47		1997.70	0.000463	3.85	990.14	167.35	0.28
Right Chute	Chute	18723	2yr 54200cfs	7052.45	1988.80	2000.37		2000.71	0.000463	4.67	1509.65	190.57	0.29
Right Chute	Chute	18723	100yr 128300cfs	17371.82	1988.80	2005.50		2006.20	0.000603	6.70	2592.28	231.59	0.35
Right Chute	Chute	18723	63000cfs	8388.27	1988.80	2001.27		2001.65	0.000479	4.98	1683.22	197.72	0.30
Right Chute	Chute	18236	7000cfs	969.07	1988.50	1992.97		1993.10	0.000607	2.86	338.30	109.65	0.29
Right Chute	Chute	18236	15000cfs	1964.83	1988.50	1994.79		1994.98	0.000602	3.52	557.82	131.50	0.30
Right Chute	Chute	18236	30000cfs	3814.31	1988.50	1997.16		1997.43	0.000679	4.17	915.30	183.44	0.33
Right Chute	Chute	18236	2yr 54200cfs	7052.45	1988.50	2000.14		2000.46	0.000553	4.49	1571.05	241.52	0.31
Right Chute	Chute	18236	100yr 128300cfs	17371.82	1988.50	2005.43		2005.88	0.000431	5.52	3951.28	766.21	0.30
Right Chute	Chute	18236	63000cfs	8388.27	1988.50	2001.05		2001.39	0.000532	4.67	1795.57	252.41	0.31
Right Chute	Chute	17811	7000cfs	969.07	1988.24	1992.71	1990.48	1992.84	0.000606	2.86	338.52	109.67	0.29
Right Chute	Chute	17811	15000cfs	1964.83	1988.24	1994.53	1991.60	1994.72	0.000630	3.50	560.70	137.75	0.31
Right Chute	Chute	17811	30000cfs	3814.31	1988.24	1996.89	1993.02	1997.16	0.000560	4.23	901.04	150.00	0.30
Right Chute	Chute	17811	2yr 54200cfs	7052.45	1988.24	1999.78	1994.82	2000.21	0.000542	5.28	1335.21	150.00	0.31
Right Chute	Chute	17811	100yr 128300cfs	17371.82	1988.24	2004.42	1998.37	2005.56	0.000875	8.55	2031.68	150.00	0.41
Right Chute	Chute	17811	63000cfs	8388.27	1988.24	2000.63	1995.39	2001.14	0.000574	5.73	1462.74	150.00	0.32
Right Chute	Chute	17128	7000cfs	969.07	1987.83	1992.30		1992.43	0.000609	2.87	337.91	109.61	0.29
Right Chute	Chute	17128	15000cfs	1964.83	1987.83	1994.10		1994.30	0.000609	3.54	555.53	131.29	0.30
Right Chute	Chute	17128	30000cfs	3814.31	1987.83	1996.50		1996.77	0.000579	4.22	903.15	157.35	0.31
Right Chute	Chute	17128	2yr 54200cfs	7052.45	1987.83	1999.41		1999.77	0.000714	4.77	1479.56	251.76	0.35
Right Chute	Chute	17128	100yr 128300cfs	17371.82	1987.83	2004.46		2004.91	0.000493	5.65	4117.11	957.49	0.31
Right Chute	Chute	17128	63000cfs	8388.27	1987.83	2000.31		2000.68	0.000646	4.91	1707.81	257.23	0.34
Right Chute	Chute	16148	7000cfs	969.07	1987.23	1991.70		1991.83	0.000606	2.86	338.55	109.68	0.29
Right Chute	Chute	16148	15000cfs	1964.83	1987.23	1993.51		1993.70	0.000607	3.53	556.23	131.35	0.30
Right Chute	Chute	16148	30000cfs	3814.31	1987.23	1995.94		1996.21	0.000568	4.19	909.55	157.66	0.31
Right Chute	Chute	16148	2yr 54200cfs	7052.45	1987.23	1998.70		1999.11	0.000625	5.10	1388.28	221.76	0.33
Right Chute	Chute	16148	100yr 128300cfs	17371.82	1987.23	2003.85		2004.41	0.000525	6.33	3922.24	1001.74	0.33

HEC-RAS Plan: Tt_High_flow_w_Bridge (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Right Chute	Chute	16148	63000cfs	8388.27	1987.23	1999.61		2000.05	0.000630	5.34	1622.92	296.38	0.34
Right Chute	Chute	15352	7000cfs	969.07	1986.75	1991.22		1991.35	0.000608	2.87	338.20	109.64	0.29
Right Chute	Chute	15352	15000cfs	1964.83	1986.75	1993.03		1993.22	0.000608	3.54	555.75	131.31	0.30
Right Chute	Chute	15352	30000cfs	3814.31	1986.75	1995.48		1995.76	0.000577	4.17	914.54	161.99	0.31
Right Chute	Chute	15352	2yr 54200cfs	7052.45	1986.75	1998.21		1998.57	0.000692	4.80	1469.19	241.63	0.34
Right Chute	Chute	15352	100yr 128300cfs	17371.82	1986.75	2003.56		2003.98	0.000468	5.40	4009.14	1508.11	0.30
Right Chute	Chute	15352	63000cfs	8388.27	1986.75	1999.13		1999.51	0.000686	4.92	1706.47	301.62	0.34
Right Chute	Chute	14824	7000cfs	969.07	1986.43	1990.90		1991.03	0.000609	2.87	338.03	109.62	0.29
Right Chute	Chute	14824	15000cfs	1964.83	1986.43	1992.70		1992.90	0.000609	3.54	555.53	131.29	0.30
Right Chute	Chute	14824	30000cfs	3814.31	1986.43	1995.19		1995.46	0.000554	4.16	917.31	158.06	0.30
Right Chute	Chute	14824	2yr 54200cfs	7052.45	1986.43	1997.80		1998.22	0.000606	5.19	1358.02	178.99	0.33
Right Chute	Chute	14824	100yr 128300cfs	17371.82	1986.43	2002.80		2003.63	0.000767	7.35	2452.76	326.52	0.40
Right Chute	Chute	14824	63000cfs	8388.27	1986.43	1998.68		1999.15	0.000623	5.52	1518.29	186.02	0.34
Right Chute	Chute	14335	7000cfs	969.07	1986.13	1990.60		1990.73	0.000607	2.86	338.43	109.66	0.29
Right Chute	Chute	14335	15000cfs	1964.83	1986.13	1992.41		1992.60	0.000608	3.53	555.96	131.33	0.30
Right Chute	Chute	14335	30000cfs	3814.31	1986.13	1994.92		1995.19	0.000544	4.13	922.70	158.32	0.30
Right Chute	Chute	14335	2yr 54200cfs	7052.45	1986.13	1997.51		1997.93	0.000605	5.19	1358.77	179.00	0.33
Right Chute	Chute	14335	100yr 128300cfs	17371.82	1986.13	2002.38		2003.25	0.000798	7.46	2343.19	279.49	0.40
Right Chute	Chute	14335	63000cfs	8388.27	1986.13	1998.38		1998.85	0.000624	5.53	1517.23	185.95	0.34
Right Chute	Chute	13471	7000cfs	969.07	1985.61	1990.08		1990.20	0.000610	2.87	337.71	109.59	0.29
Right Chute	Chute	13471	15000cfs	1964.83	1985.61	1991.88		1992.08	0.000610	3.54	555.03	131.24	0.30
Right Chute	Chute	13471	30000cfs	3814.31	1985.61	1994.46		1994.72	0.000528	4.09	932.30	158.81	0.30
Right Chute	Chute	13471	2yr 54200cfs	7052.45	1985.61	1996.98		1997.40	0.000606	5.19	1358.09	178.98	0.33
Right Chute	Chute	13471	100yr 128300cfs	17371.82	1985.61	2001.63		2002.53	0.000849	7.63	2290.82	247.16	0.41
Right Chute	Chute	13471	63000cfs	8388.27	1985.61	1997.83		1998.31	0.000630	5.55	1512.66	185.77	0.34
Right Chute	Chute	12752	7000cfs	969.07	1985.17	1989.64		1989.77	0.000609	2.87	337.97	109.61	0.29
Right Chute	Chute	12752	15000cfs	1964.83	1985.17	1991.44		1991.64	0.000610	3.54	555.30	131.27	0.30
Right Chute	Chute	12752	30000cfs	3814.31	1985.17	1994.05		1994.29	0.000665	4.00	954.34	200.63	0.32
Right Chute	Chute	12752	2yr 54200cfs	7052.45	1985.17	1996.62		1996.95	0.000587	4.60	1534.25	237.96	0.32
Right Chute	Chute	12752	100yr 128300cfs	17371.82	1985.17	2001.30		2001.88	0.000703	6.11	2850.17	357.60	0.37
Right Chute	Chute	12752	63000cfs	8388.27	1985.17	1997.49		1997.85	0.000563	4.81	1743.69	244.36	0.32
Right Chute	Chute	11805	7000cfs	969.07	1984.59	1989.06		1989.19	0.000606	2.86	338.62	109.69	0.29
Right Chute	Chute	11805	15000cfs	1964.83	1984.59	1990.87		1991.06	0.000608	3.54	555.80	131.31	0.30
Right Chute	Chute	11805	30000cfs	3814.31	1984.59	1993.36		1993.58	0.000831	3.78	1010.38	273.96	0.35
Right Chute	Chute	11805	2yr 54200cfs	7052.45	1984.59	1996.20		1996.43	0.000459	3.85	1832.84	308.59	0.28
Right Chute	Chute	11805	100yr 128300cfs	17371.82	1984.59	2001.01		2001.33	0.000377	4.65	4617.17	862.35	0.27
Right Chute	Chute	11805	63000cfs	8388.27	1984.59	1997.11		1997.35	0.000420	3.95	2136.59	363.44	0.27

HEC-RAS Plan: Tt_High_flow_w_Bridge (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Right Chute	Chute	11368	7000cfs	969.07	1984.33	1988.80		1988.93	0.000609	2.87	338.00	109.62	0.29
Right Chute	Chute	11368	15000cfs	1964.83	1984.33	1990.60		1990.79	0.000611	3.54	554.94	131.23	0.30
Right Chute	Chute	11368	30000cfs	3814.31	1984.33	1992.99		1993.27	0.000610	4.21	906.77	165.18	0.32
Right Chute	Chute	11368	2yr 54200cfs	7052.45	1984.33	1995.79		1996.18	0.000588	5.01	1412.68	210.73	0.33
Right Chute	Chute	11368	100yr 128300cfs	17371.82	1984.33	2000.50		2001.09	0.000618	6.48	4147.47	1527.66	0.35
Right Chute	Chute	11368	63000cfs	8388.27	1984.33	1996.68		1997.12	0.000592	5.30	1616.96	247.71	0.33
Right Chute	Chute	10169	7000cfs	969.07	1983.60	1988.07		1988.20	0.000609	2.87	337.97	109.61	0.29
Right Chute	Chute	10169	15000cfs	1964.83	1983.60	1989.87		1990.06	0.000612	3.54	554.50	131.19	0.30
Right Chute	Chute	10169	30000cfs	3814.31	1983.60	1992.23		1992.50	0.000667	4.22	903.68	175.41	0.33
Right Chute	Chute	10169	2yr 54200cfs	7052.45	1983.60	1995.08		1995.41	0.000673	4.62	1527.23	260.76	0.34
Right Chute	Chute	10169	100yr 128300cfs	17371.82	1983.60	2000.08		2000.42	0.000407	5.00	5359.78	1477.85	0.28
Right Chute	Chute	10169	63000cfs	8388.27	1983.60	1996.01		1996.36	0.000633	4.70	1800.16	333.37	0.33
Right Chute	Chute	9362	7000cfs	969.07	1983.11	1987.58		1987.70	0.000610	2.87	337.73	109.59	0.29
Right Chute	Chute	9362	15000cfs	1964.83	1983.11	1989.37		1989.57	0.000614	3.55	553.85	131.13	0.30
Right Chute	Chute	9362	30000cfs	3814.31	1983.11	1991.71		1991.99	0.000600	4.27	892.37	156.79	0.32
Right Chute	Chute	9362	2yr 54200cfs	7052.45	1983.11	1994.47		1994.89	0.000610	5.20	1357.22	193.93	0.33
Right Chute	Chute	9362	100yr 128300cfs	17371.82	1983.11	1999.68		2000.08	0.000448	5.67	5398.63	1456.23	0.30
Right Chute	Chute	9362	63000cfs	8388.27	1983.11	1995.37		1995.84	0.000616	5.50	1585.54	318.88	0.34
Right Chute	Chute	9056	7000cfs	969.07	1982.92	1987.39		1987.52	0.000608	2.87	338.15	109.63	0.29
Right Chute	Chute	9056	15000cfs	1964.83	1982.92	1989.18		1989.38	0.000613	3.55	554.15	131.16	0.30
Right Chute	Chute	9056	30000cfs	3814.31	1982.92	1991.53		1991.81	0.000598	4.27	893.44	156.84	0.32
Right Chute	Chute	9056	2yr 54200cfs	7052.45	1982.92	1994.28		1994.70	0.000609	5.20	1355.87	178.86	0.33
Right Chute	Chute	9056	100yr 128300cfs	17371.82	1982.92	1999.19		1999.88	0.000668	6.89	3693.84	1285.20	0.37
Right Chute	Chute	9056	63000cfs	8388.27	1982.92	1995.18		1995.65	0.000622	5.52	1519.24	186.02	0.34
Right Chute	Chute	8620	7000cfs	969.07	1982.66	1987.12		1987.25	0.000612	2.87	337.41	109.55	0.29
Right Chute	Chute	8620	15000cfs	1964.83	1982.66	1988.91		1989.11	0.000617	3.55	552.95	131.05	0.30
Right Chute	Chute	8620	30000cfs	3814.31	1982.66	1991.26		1991.55	0.000598	4.27	893.27	156.83	0.32
Right Chute	Chute	8620	2yr 54200cfs	7052.45	1982.66	1994.01		1994.44	0.000610	5.21	1354.82	178.84	0.33
Right Chute	Chute	8620	100yr 128300cfs	17371.82	1982.66	1998.76		1999.56	0.000721	7.34	2906.46	684.97	0.39
Right Chute	Chute	8620	63000cfs	8388.27	1982.66	1994.90		1995.38	0.000624	5.53	1516.98	185.96	0.34
Right Chute	Chute	7967	7000cfs	969.07	1982.26	1986.72		1986.85	0.000611	2.87	337.53	109.57	0.29
Right Chute	Chute	7967	15000cfs	1964.83	1982.26	1988.51		1988.71	0.000618	3.56	552.55	131.02	0.31
Right Chute	Chute	7967	30000cfs	3814.31	1982.26	1990.88		1991.16	0.000595	4.26	895.08	156.92	0.31
Right Chute	Chute	7967	2yr 54200cfs	7052.45	1982.26	1993.63		1994.04	0.000585	5.19	1382.25	198.50	0.33
Right Chute	Chute	7967	100yr 128300cfs	17371.82	1982.26	1998.24		1999.08	0.000739	7.53	2810.69	581.68	0.39
Right Chute	Chute	7967	63000cfs	8388.27	1982.26	1994.51		1994.98	0.000589	5.52	1564.23	212.75	0.33

HEC-RAS Plan: Tt_High_flow_w_Bridge (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Right Chute	Chute	7364	7000cfs	969.07	1981.89	1986.36		1986.48	0.000610	2.87	337.79	109.59	0.29
Right Chute	Chute	7364	15000cfs	1964.83	1981.89	1988.14		1988.34	0.000619	3.56	552.12	130.98	0.31
Right Chute	Chute	7364	30000cfs	3814.31	1981.89	1990.52		1990.80	0.000591	4.25	897.25	204.94	0.31
Right Chute	Chute	7364	2yr 54200cfs	7052.45	1981.89	1993.24		1993.63	0.000788	4.98	1460.97	363.69	0.36
Right Chute	Chute	7364	100yr 128300cfs	17371.82	1981.89	1997.99		1998.60	0.000637	6.40	3085.24	972.26	0.36
Right Chute	Chute	7364	63000cfs	8388.27	1981.89	1994.19		1994.58	0.000680	5.06	1734.55	465.39	0.35
Right Chute	Chute	6795	7000cfs	969.07	1981.55	1986.01		1986.14	0.000616	2.88	336.72	109.48	0.29
Right Chute	Chute	6795	15000cfs	1964.83	1981.55	1987.78		1987.98	0.000626	3.57	550.01	130.78	0.31
Right Chute	Chute	6795	30000cfs	3814.31	1981.55	1990.17		1990.45	0.000646	4.23	901.64	190.99	0.32
Right Chute	Chute	6795	2yr 54200cfs	7052.45	1981.55	1992.82		1993.22	0.000655	5.05	1398.47	290.08	0.34
Right Chute	Chute	6795	100yr 128300cfs	17371.82	1981.55	1997.82		1998.19	0.000574	5.10	4356.92	1374.85	0.32
Right Chute	Chute	6795	63000cfs	8388.27	1981.55	1993.72		1994.14	0.000864	5.21	1667.67	480.21	0.38
Right Chute	Chute	5997	7000cfs	969.07	1981.06	1985.52		1985.64	0.000617	2.88	336.53	109.46	0.29
Right Chute	Chute	5997	15000cfs	1964.83	1981.06	1987.28		1987.48	0.000632	3.58	548.27	130.62	0.31
Right Chute	Chute	5997	30000cfs	3814.31	1981.06	1989.67		1989.95	0.000597	4.27	894.00	171.79	0.31
Right Chute	Chute	5997	2yr 54200cfs	7052.45	1981.06	1992.25		1992.69	0.000671	5.29	1371.62	337.27	0.35
Right Chute	Chute	5997	100yr 128300cfs	17371.82	1981.06	1997.26		1997.76	0.000520	6.19	4643.48	1266.06	0.33
Right Chute	Chute	5997	63000cfs	8388.27	1981.06	1993.05		1993.53	0.000685	5.56	1671.90	457.81	0.35
Right Chute	Chute	5332	7000cfs	969.07	1980.66	1985.10		1985.23	0.000624	2.89	335.08	109.30	0.29
Right Chute	Chute	5332	15000cfs	1964.83	1980.66	1986.85		1987.05	0.000643	3.61	544.83	130.31	0.31
Right Chute	Chute	5332	30000cfs	3814.31	1980.66	1989.23		1989.52	0.000719	4.26	895.52	187.01	0.34
Right Chute	Chute	5332	2yr 54200cfs	7052.45	1980.66	1991.86		1992.23	0.000646	4.88	1509.49	301.48	0.34
Right Chute	Chute	5332	100yr 128300cfs	17371.82	1980.66	1997.00		1997.43	0.000433	5.66	4458.22	1168.42	0.30
Right Chute	Chute	5332	63000cfs	8388.27	1980.66	1992.67		1993.07	0.000618	5.11	1794.90	397.87	0.33
Right Chute	Chute	4706	7000cfs	969.07	1980.28	1984.71		1984.84	0.000633	2.91	333.57	109.13	0.29
Right Chute	Chute	4706	15000cfs	1964.83	1980.28	1986.44		1986.65	0.000656	3.63	541.07	129.97	0.31
Right Chute	Chute	4706	30000cfs	3814.31	1980.28	1988.77		1989.04	0.000795	4.18	913.15	205.68	0.35
Right Chute	Chute	4706	2yr 54200cfs	7052.45	1980.28	1991.50		1991.79	0.000689	4.33	1628.29	312.17	0.33
Right Chute	Chute	4706	100yr 128300cfs	17371.82	1980.28	1996.85		1997.15	0.000351	4.51	4680.24	1027.38	0.26
Right Chute	Chute	4706	63000cfs	8388.27	1980.28	1992.34		1992.64	0.000683	4.41	1903.74	353.58	0.33
Right Chute	Chute	3764	7000cfs	969.07	1979.70	1984.10		1984.24	0.000647	2.93	330.92	108.84	0.30
Right Chute	Chute	3764	15000cfs	1964.83	1979.70	1985.81		1986.02	0.000681	3.68	533.95	129.30	0.32
Right Chute	Chute	3764	30000cfs	3814.31	1979.70	1988.02		1988.34	0.000695	4.49	849.77	154.91	0.34
Right Chute	Chute	3764	2yr 54200cfs	7052.45	1979.70	1990.66		1991.12	0.000687	5.47	1314.76	198.90	0.35
Right Chute	Chute	3764	100yr 128300cfs	17371.82	1979.70	1995.72		1996.64	0.000701	7.80	2427.73	235.60	0.39
Right Chute	Chute	3764	63000cfs	8388.27	1979.70	1991.43		1991.97	0.000695	5.88	1471.13	206.26	0.36
Right Chute	Chute	2720	7000cfs	969.07	1979.07	1983.40		1983.54	0.000696	3.00	322.76	107.94	0.31

HEC-RAS Plan: Tt_High_flow_w_Bridge (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Right Chute	Chute	2720	15000cfs	1964.83	1979.07	1985.05		1985.28	0.000743	3.80	517.69	127.78	0.33
Right Chute	Chute	2720	30000cfs	3814.31	1979.07	1987.24		1987.57	0.000778	4.61	826.61	158.08	0.35
Right Chute	Chute	2720	2yr 54200cfs	7052.45	1979.07	1989.93		1990.34	0.000783	5.16	1408.63	257.47	0.37
Right Chute	Chute	2720	100yr 128300cfs	17371.82	1979.07	1995.24		1995.90	0.000569	6.65	2912.00	338.69	0.35
Right Chute	Chute	2720	63000cfs	8388.27	1979.07	1990.75		1991.20	0.000723	5.39	1622.77	263.60	0.36
Right Chute	Chute	1889	7000cfs	969.07	1978.56	1982.78		1982.93	0.000777	3.12	310.66	106.58	0.32
Right Chute	Chute	1889	15000cfs	1964.83	1978.56	1984.38		1984.62	0.000835	3.96	496.75	125.80	0.35
Right Chute	Chute	1889	30000cfs	3814.31	1978.56	1986.54		1986.90	0.000836	4.78	800.19	162.19	0.37
Right Chute	Chute	1889	2yr 54200cfs	7052.45	1978.56	1989.23		1989.70	0.000758	5.57	1407.97	294.48	0.37
Right Chute	Chute	1889	100yr 128300cfs	17371.82	1978.56	1995.04		1995.43	0.000399	5.68	4688.58	668.39	0.29
Right Chute	Chute	1889	63000cfs	8388.27	1978.56	1990.09		1990.59	0.000739	5.79	1693.36	383.52	0.37
Right Chute	Chute	1277	7000cfs	969.07	1978.19	1982.24		1982.41	0.000920	3.31	293.02	104.58	0.35
Right Chute	Chute	1277	15000cfs	1964.83	1978.19	1983.80		1984.07	0.000974	4.18	470.34	123.26	0.38
Right Chute	Chute	1277	30000cfs	3814.31	1978.19	1985.97		1986.36	0.000926	4.96	781.99	181.90	0.39
Right Chute	Chute	1277	2yr 54200cfs	7052.45	1978.19	1988.76		1989.21	0.000813	5.47	1428.71	276.86	0.38
Right Chute	Chute	1277	100yr 128300cfs	17371.82	1978.19	1994.62		1995.15	0.000501	6.22	3584.63	461.83	0.32
Right Chute	Chute	1277	63000cfs	8388.27	1978.19	1989.66		1990.13	0.000745	5.64	1680.20	286.05	0.37
Right Chute	Chute	675	7000cfs	969.07	1977.83	1981.52		1981.74	0.001340	3.79	256.02	98.96	0.41
Right Chute	Chute	675	15000cfs	1964.83	1977.83	1983.05		1983.38	0.001312	4.64	423.59	118.62	0.43
Right Chute	Chute	675	30000cfs	3814.31	1977.83	1985.31		1985.74	0.001099	5.28	722.63	145.76	0.42
Right Chute	Chute	675	2yr 54200cfs	7052.45	1977.83	1988.11		1988.68	0.000923	6.07	1161.71	165.93	0.40
Right Chute	Chute	675	100yr 128300cfs	17371.82	1977.83	1993.80		1994.74	0.000745	7.88	2451.40	330.13	0.40
Right Chute	Chute	675	63000cfs	8388.27	1977.83	1988.97		1989.61	0.000919	6.41	1307.94	171.21	0.41
Right Chute	Chute	286	7000cfs	969.07	1977.59	1980.11		1980.74	0.005836	6.40	151.40	80.28	0.82
Right Chute	Chute	286	15000cfs	1964.83	1977.59	1982.29		1982.75	0.002023	5.40	364.01	112.43	0.53
Right Chute	Chute	286	30000cfs	3814.31	1977.59	1984.79		1985.28	0.001290	5.59	682.32	142.41	0.45
Right Chute	Chute	286	2yr 54200cfs	7052.45	1977.59	1987.71		1988.31	0.000979	6.22	1134.40	168.30	0.42
Right Chute	Chute	286	100yr 128300cfs	17371.82	1977.59	1993.52		1994.45	0.000719	7.94	2543.78	314.15	0.39
Right Chute	Chute	286	63000cfs	8388.27	1977.59	1988.58		1989.25	0.000944	6.56	1285.47	176.93	0.42

HEC-RAS Plan: Tt_High_flow_w_Bridge

River	Reach	River Sta	Profile	E.G. Elev	W.S. Elev	Vel Head	Frctn Loss	C & E Loss	Q Left	Q Channel	Q Right	Top Width
				(ft)	(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft)
Yellowstone	US Chute	56000.00	7000cfs	2001.89	2001.78	0.11	0.54	0.01		7000.00		760.08
Yellowstone	US Chute	56000.00	15000cfs	2004.20	2004.01	0.20	0.55	0.01		15000.00		839.62
Yellowstone	US Chute	56000.00	30000cfs	2007.03	2006.66	0.37	0.66	0.02	0.29	29999.37	0.33	902.21
Yellowstone	US Chute	56000.00	2yr 54200cfs	2010.22	2009.55	0.66	0.82	0.03	11.55	54171.56	16.89	1474.23
Yellowstone	US Chute	56000.00	100yr 128300cfs	2016.40	2014.68	1.72	1.36	0.06	86.19	127494.70	719.14	2440.66
Yellowstone	US Chute	56000.00	63000cfs	2011.28	2010.52	0.76	0.84	0.04	18.90	62943.66	37.44	1602.51
Yellowstone	US Chute	54003.06	7000cfs	2001.34	2001.25	0.09	0.48	0.00		7000.00		791.30
Yellowstone	US Chute	54003.06	15000cfs	2003.64	2003.48	0.16	0.52	0.01		15000.00		944.96
Yellowstone	US Chute	54003.06	30000cfs	2006.35	2006.05	0.30	0.59	0.03		30000.00		1075.67
Yellowstone	US Chute	54003.06	2yr 54200cfs	2009.36	2008.81	0.55	0.64	0.07		54187.54	12.46	1197.90
Yellowstone	US Chute	54003.06	100yr 128300cfs	2014.98	2013.46	1.51	0.83	0.30	2.71	128049.00	248.31	2820.00
Yellowstone	US Chute	54003.06	63000cfs	2010.40	2009.77	0.63	0.63	0.09		62971.34	28.65	1263.45
Yellowstone	US Chute	51999.34	7000cfs	2000.86	2000.78	0.08	0.83	0.03		7000.00		873.38
Yellowstone	US Chute	51999.34	15000cfs	2003.11	2002.99	0.13	1.01	0.05		15000.00		1333.36
Yellowstone	US Chute	51999.34	30000cfs	2005.73	2005.53	0.20	1.19	0.08		30000.00		1669.35
Yellowstone	US Chute	51999.34	2yr 54200cfs	2008.65	2008.34	0.30	1.13	0.13	2.85	54175.08	22.07	1993.38
Yellowstone	US Chute	51999.34	100yr 128300cfs	2013.85	2013.33	0.52	0.80	0.01	64.80	115814.50	12420.75	4380.65
Yellowstone	US Chute	51999.34	63000cfs	2009.68	2009.35	0.33	1.11	0.14	7.56	62918.72	73.73	2151.32
Yellowstone	US Chute	50001.19	7000cfs	2000.00	1999.67	0.33	1.95	0.04		6585.42	414.58	788.83
Yellowstone	US Chute	50001.19	15000cfs	2002.04	2001.37	0.67	2.13	0.13		13661.40	1338.59	885.73
Yellowstone	US Chute	50001.19	30000cfs	2004.46	2003.41	1.04	1.92	0.22		26286.24	3713.75	1128.57
Yellowstone	US Chute	50001.19	2yr 54200cfs	2007.39	2005.81	1.57	1.47	0.36		47516.71	6683.29	1412.08
Yellowstone	US Chute	50001.19	100yr 128300cfs	2013.05	2012.44	0.61	0.91	0.02	10.10	116977.60	11312.30	4491.99
Yellowstone	US Chute	50001.19	63000cfs	2008.43	2006.73	1.71	1.42	0.39		55735.17	7264.83	1605.13
Yellowstone	US Chute	47994.16	7000cfs	1998.01	1997.82	0.19	1.70	0.01		7000.00		901.25
Yellowstone	US Chute	47994.16	15000cfs	1999.79	1999.54	0.25	1.22	0.01		15000.00		1115.00
Yellowstone	US Chute	47994.16	30000cfs	2002.31	2002.01	0.30	0.94	0.00	0.00	29999.96	0.04	1315.22
Yellowstone	US Chute	47994.16	2yr 54200cfs	2005.55	2005.18	0.37	0.78	0.02	9.08	54164.87	26.05	1391.03
Yellowstone	US Chute	47994.16	100yr 128300cfs	2012.11	2011.58	0.53	0.78	0.05	153.07	124723.30	3423.60	4098.71
Yellowstone	US Chute	47994.16	63000cfs	2006.62	2006.22	0.39	0.74	0.02	18.59	62926.01	55.41	1456.36
Yellowstone	US Chute	46189.52	7000cfs	1996.31	1996.15	0.16	0.38	0.03		7000.00		804.12
Yellowstone	US Chute	46189.52	15000cfs	1998.56	1998.35	0.21	0.54	0.03		15000.00		871.29
Yellowstone	US Chute	46189.52	30000cfs	2001.36	2001.02	0.34	0.71	0.02		29999.98	0.02	881.05
Yellowstone	US Chute	46189.52	2yr 54200cfs	2004.76	2004.22	0.53	0.85	0.00	8.02	54183.75	8.23	898.08
Yellowstone	US Chute	46189.52	100yr 128300cfs	2011.28	2010.21	1.07	1.16	0.03	1084.20	122888.10	4327.70	3201.57
Yellowstone	US Chute	46189.52	63000cfs	2005.85	2005.25	0.60	0.88	0.01	18.42	62968.38	13.21	1039.82
Yellowstone	US Chute	43687.06	7000cfs	1995.89	1995.85	0.05	0.08	0.00		7000.00		617.99
Yellowstone	US Chute	43687.06	15000cfs	1997.99	1997.87	0.12	0.15	0.00	5.34	14994.28	0.38	675.02
Yellowstone	US Chute	43687.06	30000cfs	2000.63	2000.35	0.28	0.23	0.00	43.07	29943.59	13.34	689.31
Yellowstone	US Chute	43687.06	2yr 54200cfs	2003.91	2003.35	0.56	0.31	0.00	149.31	53949.79	100.90	765.54
Yellowstone	US Chute	43687.06	100yr 128300cfs	2010.09	2008.73	1.35	0.47	0.06	1390.56	120533.40	6376.04	3834.30
Yellowstone	US Chute	43687.06	63000cfs	2004.97	2004.31	0.66	0.33	0.00	198.76	62622.79	178.44	952.45
Yellowstone	US Chute	42707.92	7000cfs	1995.81	1995.75	0.06	0.13	0.00		7000.00		635.10
Yellowstone	US Chute	42707.92	15000cfs	1997.84	1997.69	0.15	0.21	0.00	0.00	15000.00		727.13
Yellowstone	US Chute	42707.92	30000cfs	2000.40	2000.08	0.31	0.26	0.01	9.04	29990.07	0.89	772.10
Yellowstone	US Chute	42707.92	2yr 54200cfs	2003.59	2003.02	0.57	0.28	0.04	69.39	54062.02	68.60	902.42
Yellowstone	US Chute	42707.92	100yr 128300cfs	2009.57	2008.40	1.17	0.32	0.13	4289.85	117319.00	6691.16	5648.32
Yellowstone	US Chute	42707.92	63000cfs	2004.64	2003.98	0.66	0.28	0.05	101.46	62698.71	199.83	1102.90
Yellowstone	US Chute	41936.91	7000cfs	1995.68	1995.58	0.10	0.44	0.00		7000.00		763.61
Yellowstone	US Chute	41936.91	15000cfs	1997.62	1997.45	0.17	0.47	0.00		15000.00		1047.69
Yellowstone	US Chute	41936.91	30000cfs	2000.13	1999.85	0.28	0.43	0.01	0.00	30000.00	0.00	1069.43
Yellowstone	US Chute	41936.91	2yr 54200cfs	2003.27	2002.84	0.43	0.41	0.01	4.51	54193.88	1.62	1323.41
Yellowstone	US Chute	41936.91	100yr 128300cfs	2009.11	2008.39	0.72	0.43	0.01	6997.81	115826.60	5475.60	5783.96
Yellowstone	US Chute	41936.91	63000cfs	2004.30	2003.82	0.48	0.40	0.01	9.46	62986.44	4.10	1603.22
Yellowstone	US Chute	40894.62	7000cfs	1995.24	1995.10	0.13	0.75	0.01		7000.00		894.98
Yellowstone	US Chute	40894.62	15000cfs	1997.14	1996.94	0.21	0.59	0.00		15000.00		961.68
Yellowstone	US Chute	40894.62	30000cfs	1999.69	1999.36	0.33	0.50	0.00	3.60	29996.39		985.10
Yellowstone	US Chute	40894.62	2yr 54200cfs	2002.85	2002.33	0.52	0.45	0.00	44.83	54152.81	2.36	1045.74
Yellowstone	US Chute	40894.62	100yr 128300cfs	2008.68	2007.98	0.70	0.40	0.01	13163.73	113517.50	1618.79	5930.60
Yellowstone	US Chute	40894.62	63000cfs	2003.89	2003.32	0.57	0.43	0.01	77.87	62915.69	6.45	1310.31
Yellowstone	US Chute	39877.04	7000cfs	1994.49	1994.29	0.19	0.27	0.03		7000.00		763.40
Yellowstone	US Chute	39877.04	15000cfs	1996.55	1996.30	0.25	0.31	0.02		15000.00		937.10
Yellowstone	US Chute	39877.04	30000cfs	1999.18	1998.82	0.36	0.31	0.01	2.61	29997.18	0.21	1047.68
Yellowstone	US Chute	39877.04	2yr 54200cfs	2002.40	2001.88	0.52	0.32	0.00	196.98	53994.36	8.66	1267.19
Yellowstone	US Chute	39877.04	100yr 128300cfs	2008.27	2007.59	0.68	0.28	0.13	19772.80	108323.90	203.29	5801.53
Yellowstone	US Chute	39877.04	63000cfs	2003.46	2002.91	0.55	0.33	0.00	786.27	62198.39	15.33	1747.56
Yellowstone	US Chute	39170.03	7000cfs	1994.18	1994.09	0.09	0.10	0.01		7000.00		690.66
Yellowstone	US Chute	39170.03	15000cfs	1996.23	1996.05	0.18	0.18	0.01		14996.18	3.82	814.04

HEC-RAS Plan: Tt_High_flow_w_Bridge (Continued)

River	Reach	River Sta	Profile	E.G. Elev	W.S. Elev	Vel Head	Frctn Loss	C & E Loss	Q Left	Q Channel	Q Right	Top Width
				(ft)	(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft)
Yellowstone	US Chute	39170.03	30000cfs	1998.86	1998.53	0.33	0.27	0.01		29968.65	31.35	876.57
Yellowstone	US Chute	39170.03	2yr 54200cfs	2002.08	2001.53	0.54	0.36	0.01		54097.82	102.18	1167.93
Yellowstone	US Chute	39170.03	100yr 128300cfs	2007.86	2007.61	0.25	0.41	0.08		128015.50	284.54	6005.31
Yellowstone	US Chute	39170.03	63000cfs	2003.13	2002.53	0.59	0.41	0.01		62857.98	142.02	1641.80
Yellowstone	US Chute	38214.43	7000cfs	1994.06	1994.02	0.05	0.15	0.01		7000.00	0.00	607.20
Yellowstone	US Chute	38214.43	15000cfs	1996.03	1995.90	0.13	0.23	0.00	2.81	14996.37	0.81	653.45
Yellowstone	US Chute	38214.43	30000cfs	1998.58	1998.27	0.31	0.32	0.01	92.52	29899.40	8.08	776.81
Yellowstone	US Chute	38214.43	2yr 54200cfs	2001.71	2001.09	0.62	0.39	0.07	641.25	53523.39	35.36	1034.29
Yellowstone	US Chute	38214.43	100yr 128300cfs	2007.37	2006.30	1.07	0.41	0.16	19784.07	106409.80	2106.09	6377.74
Yellowstone	US Chute	38214.43	63000cfs	2002.70	2001.97	0.73	0.40	0.09	898.98	62050.63	50.38	1385.66
Yellowstone	DS Chute	19210.21	7000cfs	1980.53	1980.39	0.14	0.51	0.00		5626.17		624.77
Yellowstone	DS Chute	19210.21	15000cfs	1982.60	1982.37	0.24	0.56	0.01		13626.17		922.83
Yellowstone	DS Chute	19210.21	30000cfs	1985.16	1984.81	0.35	0.53	0.01		28626.09		1319.81
Yellowstone	DS Chute	19210.21	2yr 54200cfs	1988.21	1987.76	0.44	0.42	0.01	0.27	52825.72	0.10	1485.35
Yellowstone	DS Chute	19210.21	100yr 128300cfs	1994.37	1993.56	0.81	0.33	0.05	337.60	126472.60	116.00	4751.35
Yellowstone	DS Chute	19210.21	63000cfs	1989.14	1988.66	0.48	0.39	0.02	2.15	61622.32	1.61	1676.89
Yellowstone	DS Chute	18370.67	7000cfs	1980.02	1979.89	0.14	0.60	0.02		5626.17		790.27
Yellowstone	DS Chute	18370.67	15000cfs	1982.04	1981.82	0.22	0.71	0.01		13626.17		1017.31
Yellowstone	DS Chute	18370.67	30000cfs	1984.61	1984.30	0.31	0.71	0.00		28626.09		1174.78
Yellowstone	DS Chute	18370.67	2yr 54200cfs	1987.77	1987.37	0.40	0.67	0.01	0.05	52826.03		1731.59
Yellowstone	DS Chute	18370.67	100yr 128300cfs	1993.99	1993.34	0.65	0.57	0.02	441.38	126465.40	19.37	4836.33
Yellowstone	DS Chute	18370.67	63000cfs	1988.73	1988.32	0.42	0.62	0.01	0.78	61625.29	0.01	1806.66
Yellowstone	DS Chute	17009.26	7000cfs	1979.41	1979.32	0.08	0.40	0.01		5626.17		774.92
Yellowstone	DS Chute	17009.26	15000cfs	1981.32	1981.14	0.19	0.52	0.01		13626.17		855.37
Yellowstone	DS Chute	17009.26	30000cfs	1983.90	1983.56	0.34	0.51	0.00		28626.09		991.92
Yellowstone	DS Chute	17009.26	2yr 54200cfs	1987.09	1986.58	0.51	0.43	0.02	0.10	52825.93	0.05	1189.05
Yellowstone	DS Chute	17009.26	100yr 128300cfs	1993.40	1992.82	0.58	0.36	0.00	13241.02	113654.00	31.19	5289.45
Yellowstone	DS Chute	17009.26	63000cfs	1988.10	1987.53	0.56	0.41	0.03	1.02	61624.43	0.64	1306.90
Yellowstone	DS Chute	16125.84	7000cfs	1979.00	1978.86	0.14	1.82	0.02		5626.17		774.63
Yellowstone	DS Chute	16125.84	15000cfs	1980.80	1980.53	0.26	1.27	0.00		13626.17		982.52
Yellowstone	DS Chute	16125.84	30000cfs	1983.38	1983.03	0.36	0.79	0.00		28626.09		1210.53
Yellowstone	DS Chute	16125.84	2yr 54200cfs	1986.63	1986.20	0.43	0.64	0.01	1.36	52821.57	3.16	1576.96
Yellowstone	DS Chute	16125.84	100yr 128300cfs	1993.04	1992.47	0.57	0.52	0.04	8298.33	118540.30	87.58	3014.71
Yellowstone	DS Chute	16125.84	63000cfs	1987.66	1987.20	0.46	0.59	0.01	3.89	61614.27	7.93	1760.44
Yellowstone	DS Chute	14768.24	7000cfs	1977.16	1976.78	0.38	1.89	0.07		5626.17		675.65
Yellowstone	DS Chute	14768.24	15000cfs	1979.52	1979.22	0.30	1.43	0.01		13626.17		938.78
Yellowstone	DS Chute	14768.24	30000cfs	1982.59	1982.24	0.35	1.18	0.01	152.86	28473.23		1008.35
Yellowstone	DS Chute	14768.24	2yr 54200cfs	1985.99	1985.48	0.51	1.01	0.01	539.12	52249.41	37.56	1099.14
Yellowstone	DS Chute	14768.24	100yr 128300cfs	1992.48	1991.53	0.95	0.88	0.06	4914.34	119854.00	2157.81	3230.24
Yellowstone	DS Chute	14768.24	63000cfs	1987.06	1986.50	0.56	0.98	0.01	704.86	60817.68	103.54	1169.12
Yellowstone	DS Chute	12602.25	7000cfs	1975.20	1975.05	0.15	1.95	0.01		5626.17		464.39
Yellowstone	DS Chute	12602.25	15000cfs	1978.08	1977.81	0.28	1.74	0.03		13626.17		577.96
Yellowstone	DS Chute	12602.25	30000cfs	1981.40	1980.98	0.43	2.05	0.03		28626.09		814.15
Yellowstone	DS Chute	12602.25	2yr 54200cfs	1984.96	1984.33	0.63	2.04	0.03	100.27	52722.74	3.08	925.05
Yellowstone	DS Chute	12602.25	100yr 128300cfs	1991.55	1990.78	0.76	1.36	0.05	22201.27	104666.40	58.51	4698.72
Yellowstone	DS Chute	12602.25	63000cfs	1986.07	1985.36	0.70	2.04	0.03	217.33	61401.55	7.21	1030.95
Yellowstone	DS Chute	7708.504	7000cfs	1973.25	1973.13	0.11	0.29	0.02		5626.17		629.50
Yellowstone	DS Chute	7708.504	15000cfs	1976.31	1976.15	0.16	0.36	0.02		13626.17		746.32
Yellowstone	DS Chute	7708.504	30000cfs	1979.32	1979.01	0.31	0.55	0.02		28612.43	13.66	784.79
Yellowstone	DS Chute	7708.504	2yr 54200cfs	1982.90	1982.36	0.54	0.72	0.02	23.89	52679.06	123.13	809.35
Yellowstone	DS Chute	7708.504	100yr 128300cfs	1990.14	1989.53	0.60	0.78	0.06	26283.67	100244.10	398.40	5153.00
Yellowstone	DS Chute	7708.504	63000cfs	1984.01	1983.39	0.62	0.77	0.01	48.72	61403.37	173.99	819.87
Yellowstone	DS Chute	5162.571	7000cfs	1972.93	1972.90	0.03	0.13	0.01		5626.17		627.97
Yellowstone	DS Chute	5162.571	15000cfs	1975.93	1975.84	0.09	0.18	0.01		13626.17		646.07
Yellowstone	DS Chute	5162.571	30000cfs	1978.75	1978.51	0.23	0.27	0.01		28626.09		694.10
Yellowstone	DS Chute	5162.571	2yr 54200cfs	1982.16	1981.68	0.48	0.35	0.00	5.34	52819.75	1.00	807.25
Yellowstone	DS Chute	5162.571	100yr 128300cfs	1989.29	1988.09	1.21	0.43	0.10	3766.69	123093.70	65.75	3617.34
Yellowstone	DS Chute	5162.571	63000cfs	1983.23	1982.65	0.57	0.36	0.00	28.02	61594.88	3.18	885.45
Yellowstone	DS Chute	3996.727	7000cfs	1972.80	1972.69	0.11	0.62	0.00		5626.17		596.75
Yellowstone	DS Chute	3996.727	15000cfs	1975.75	1975.58	0.16	0.63	0.01		13626.17		854.69
Yellowstone	DS Chute	3996.727	30000cfs	1978.47	1978.16	0.31	0.66	0.02	0.10	28625.98		900.25
Yellowstone	DS Chute	3996.727	2yr 54200cfs	1981.81	1981.29	0.52	0.68	0.04	21.48	52803.64	0.96	981.40
Yellowstone	DS Chute	3996.727	100yr 128300cfs	1988.77	1987.88	0.89	0.67	0.05	9666.19	117195.20	64.78	4557.01
Yellowstone	DS Chute	3996.727	63000cfs	1982.86	1982.27	0.59	0.68	0.04	40.86	61581.98	3.25	1047.47
Yellowstone	DS Chute	2000.000	7000cfs	1972.17	1972.08	0.09				5626.17		661.87
Yellowstone	DS Chute	2000.000	15000cfs	1975.11	1974.97	0.13				13626.17		1043.22
Yellowstone	DS Chute	2000.000	30000cfs	1977.79	1977.55	0.24				28626.09		1077.12
Yellowstone	DS Chute	2000.000	2yr 54200cfs	1981.10	1980.70	0.39			4.84	52815.98	5.26	1125.87

HEC-RAS Plan: Tt_High_flow_w_Bridge (Continued)

River	Reach	River Sta	Profile	E.G. Elev	W.S. Elev	Vel Head	Frctn Loss	C & E Loss	Q Left	Q Channel	Q Right	Top Width
				(ft)	(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft)
Yellowstone	DS Chute	2000.000	100yr 128300cfs	1988.06	1987.32	0.73			5525.68	121279.20	121.25	1742.61
Yellowstone	DS Chute	2000.000	63000cfs	1982.14	1981.69	0.45			14.01	61600.64	11.44	1169.22
Right Chute	Chute	19860	7000cfs	1993.92	1993.81	0.11	0.25	0.00		969.07		117.79
Right Chute	Chute	19860	15000cfs	1995.80	1995.64	0.17	0.24	0.00		1964.83		139.76
Right Chute	Chute	19860	30000cfs	1998.25	1998.01	0.24	0.24	0.00		3814.31		166.14
Right Chute	Chute	19860	2yr 54200cfs	2001.26	2000.90	0.35	0.24	0.00		7052.45		189.29
Right Chute	Chute	19860	100yr 128300cfs	2006.77	2006.60	0.17	0.14	0.04	10.77	10819.63	6541.42	1609.88
Right Chute	Chute	19860	63000cfs	2002.21	2001.82	0.40	0.24	0.00		8388.27		196.57
Right Chute	Chute	19371	7000cfs	1993.67	1993.56	0.11	0.13	0.00		969.07		118.45
Right Chute	Chute	19371	15000cfs	1995.56	1995.40	0.16	0.13	0.00		1964.83		140.46
Right Chute	Chute	19371	30000cfs	1998.01	1997.77	0.24	0.12	0.00		3814.31		166.65
Right Chute	Chute	19371	2yr 54200cfs	2001.02	2000.67	0.35	0.12	0.00		7052.45		189.84
Right Chute	Chute	19371	100yr 128300cfs	2006.59	2006.01	0.58	0.14	0.01		16434.99	936.83	890.26
Right Chute	Chute	19371	63000cfs	2001.97	2001.58	0.39	0.13	0.00		8388.27		197.07
Right Chute	Chute	19112	7000cfs	1993.54	1993.44	0.10	0.18	0.00		969.07		118.75
Right Chute	Chute	19112	15000cfs	1995.43	1995.27	0.16	0.18	0.00		1964.83		140.76
Right Chute	Chute	19112	30000cfs	1997.88	1997.65	0.24	0.18	0.00		3814.31		166.87
Right Chute	Chute	19112	2yr 54200cfs	2000.90	2000.55	0.34	0.18	0.00		7052.45		190.09
Right Chute	Chute	19112	100yr 128300cfs	2006.43	2005.74	0.70	0.24	0.00	1.10	17367.98	2.74	361.16
Right Chute	Chute	19112	63000cfs	2001.84	2001.45	0.39	0.19	0.00		8388.27		197.29
Right Chute	Chute	18723	7000cfs	1993.36	1993.26	0.10	0.26	0.00		969.07		119.47
Right Chute	Chute	18723	15000cfs	1995.24	1995.09	0.16	0.26	0.00		1964.83		141.46
Right Chute	Chute	18723	30000cfs	1997.70	1997.47	0.23	0.27	0.00		3814.31		167.35
Right Chute	Chute	18723	2yr 54200cfs	2000.71	2000.37	0.34	0.25	0.01		7052.45		190.57
Right Chute	Chute	18723	100yr 128300cfs	2006.20	2005.50	0.70	0.25	0.07		17371.82		231.59
Right Chute	Chute	18723	63000cfs	2001.65	2001.27	0.39	0.25	0.01		8388.27		197.72
Right Chute	Chute	18236	7000cfs	1993.10	1992.97	0.13	0.26	0.00		969.07		109.65
Right Chute	Chute	18236	15000cfs	1994.98	1994.79	0.19	0.26	0.00		1964.83		131.50
Right Chute	Chute	18236	30000cfs	1997.43	1997.16	0.27	0.26	0.00		3814.31		183.44
Right Chute	Chute	18236	2yr 54200cfs	2000.46	2000.14	0.31	0.23	0.01		7052.45		241.52
Right Chute	Chute	18236	100yr 128300cfs	2005.88	2005.43	0.45	0.25	0.07		16387.33	984.50	766.21
Right Chute	Chute	18236	63000cfs	2001.39	2001.05	0.34	0.24	0.02		8388.27		252.41
Right Chute	Chute	17811	7000cfs	1992.84	1992.71	0.13	0.42	0.00		969.07		109.67
Right Chute	Chute	17811	15000cfs	1994.72	1994.53	0.19	0.42	0.00		1964.83		137.75
Right Chute	Chute	17811	30000cfs	1997.16	1996.89	0.28	0.39	0.00		3814.31		150.00
Right Chute	Chute	17811	2yr 54200cfs	2000.21	1999.78	0.43	0.42	0.02		7052.45		150.00
Right Chute	Chute	17811	100yr 128300cfs	2005.56	2004.42	1.14	0.44	0.20		17371.82		150.00
Right Chute	Chute	17811	63000cfs	2001.14	2000.63	0.51	0.42	0.04		8388.27		150.00
Right Chute	Chute	17128	7000cfs	1992.43	1992.30	0.13	0.60	0.00		969.07		109.61
Right Chute	Chute	17128	15000cfs	1994.30	1994.10	0.19	0.60	0.00		1964.83		131.29
Right Chute	Chute	17128	30000cfs	1996.77	1996.50	0.28	0.56	0.00		3814.31		157.35
Right Chute	Chute	17128	2yr 54200cfs	1999.77	1999.41	0.35	0.65	0.01		7052.45		251.76
Right Chute	Chute	17128	100yr 128300cfs	2004.91	2004.46	0.46	0.49	0.01	569.89	16009.46	792.47	957.49
Right Chute	Chute	17128	63000cfs	2000.68	2000.31	0.37	0.63	0.01		8388.27		257.23
Right Chute	Chute	16148	7000cfs	1991.83	1991.70	0.13	0.48	0.00		969.07		109.68
Right Chute	Chute	16148	15000cfs	1993.70	1993.51	0.19	0.48	0.00		1964.83		131.35
Right Chute	Chute	16148	30000cfs	1996.21	1995.94	0.27	0.46	0.00		3814.31		157.66
Right Chute	Chute	16148	2yr 54200cfs	1999.11	1998.70	0.40	0.52	0.01		7050.70	1.75	221.76
Right Chute	Chute	16148	100yr 128300cfs	2004.41	2003.85	0.56	0.39	0.04	610.05	15574.65	1187.12	1001.74
Right Chute	Chute	16148	63000cfs	2000.05	1999.61	0.44	0.52	0.02	5.26	8351.99	31.03	296.38
Right Chute	Chute	15352	7000cfs	1991.35	1991.22	0.13	0.32	0.00		969.07		109.64
Right Chute	Chute	15352	15000cfs	1993.22	1993.03	0.19	0.32	0.00		1964.83		131.31
Right Chute	Chute	15352	30000cfs	1995.76	1995.48	0.27	0.30	0.00		3814.31		161.99
Right Chute	Chute	15352	2yr 54200cfs	1998.57	1998.21	0.36	0.34	0.01		7052.45		241.63
Right Chute	Chute	15352	100yr 128300cfs	2003.98	2003.56	0.43	0.31	0.04	2.10	16312.52	1057.20	1508.11
Right Chute	Chute	15352	63000cfs	1999.51	1999.13	0.38	0.35	0.01		8388.27		301.62
Right Chute	Chute	14824	7000cfs	1991.03	1990.90	0.13	0.30	0.00		969.07		109.62
Right Chute	Chute	14824	15000cfs	1992.90	1992.70	0.19	0.30	0.00		1964.83		131.29
Right Chute	Chute	14824	30000cfs	1995.46	1995.19	0.27	0.27	0.00		3814.31		158.06
Right Chute	Chute	14824	2yr 54200cfs	1998.22	1997.80	0.42	0.30	0.00		7052.45		178.99
Right Chute	Chute	14824	100yr 128300cfs	2003.63	2002.80	0.83	0.38	0.00	5.64	17286.01	80.17	326.52
Right Chute	Chute	14824	63000cfs	1999.15	1998.68	0.47	0.30	0.00		8388.27		186.02
Right Chute	Chute	14335	7000cfs	1990.73	1990.60	0.13	0.53	0.00		969.07		109.66
Right Chute	Chute	14335	15000cfs	1992.60	1992.41	0.19	0.53	0.00		1964.83		131.33
Right Chute	Chute	14335	30000cfs	1995.19	1994.92	0.27	0.46	0.00		3814.31		158.32
Right Chute	Chute	14335	2yr 54200cfs	1997.93	1997.51	0.42	0.52	0.00		7052.45		179.00
Right Chute	Chute	14335	100yr 128300cfs	2003.25	2002.38	0.86	0.71	0.00	2.21	17365.60	4.02	279.49
Right Chute	Chute	14335	63000cfs	1998.85	1998.38	0.47	0.54	0.00		8388.27		185.95

HEC-RAS Plan: Tt_High_flow_w_Bridge (Continued)

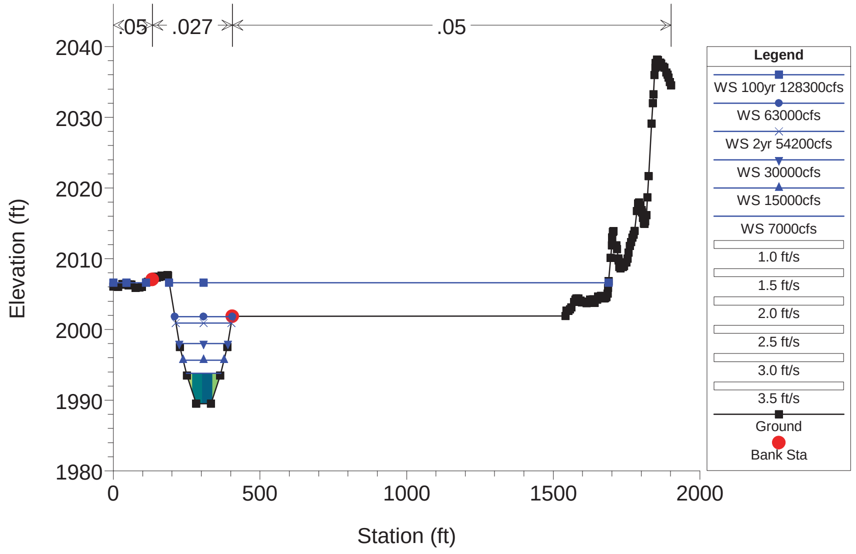
River	Reach	River Sta	Profile	E.G. Elev	W.S. Elev	Vel Head	Frctn Loss	C & E Loss	Q Left	Q Channel	Q Right	Top Width
				(ft)	(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft)
Right Chute	Chute	13471	7000cfs	1990.20	1990.08	0.13	0.44	0.00		969.07		109.59
Right Chute	Chute	13471	15000cfs	1992.08	1991.88	0.19	0.44	0.00		1964.83		131.24
Right Chute	Chute	13471	30000cfs	1994.72	1994.46	0.26	0.42	0.00		3814.31		158.81
Right Chute	Chute	13471	2yr 54200cfs	1997.40	1996.98	0.42	0.43	0.03		7052.45		178.98
Right Chute	Chute	13471	100yr 128300cfs	2002.53	2001.63	0.90	0.55	0.10	8.20	17363.62		247.16
Right Chute	Chute	13471	63000cfs	1998.31	1997.83	0.48	0.43	0.04		8388.27		185.77
Right Chute	Chute	12752	7000cfs	1989.77	1989.64	0.13	0.58	0.00		969.07		109.61
Right Chute	Chute	12752	15000cfs	1991.64	1991.44	0.19	0.58	0.00		1964.83		131.27
Right Chute	Chute	12752	30000cfs	1994.29	1994.05	0.25	0.70	0.01		3814.31		200.63
Right Chute	Chute	12752	2yr 54200cfs	1996.95	1996.62	0.33	0.49	0.03		7052.45		237.96
Right Chute	Chute	12752	100yr 128300cfs	2001.88	2001.30	0.58	0.47	0.08	3.26	17368.56		357.60
Right Chute	Chute	12752	63000cfs	1997.85	1997.49	0.36	0.46	0.04		8388.27		244.36
Right Chute	Chute	11805	7000cfs	1989.19	1989.06	0.13	0.27	0.00		969.07		109.69
Right Chute	Chute	11805	15000cfs	1991.06	1990.87	0.19	0.27	0.00		1964.83		131.31
Right Chute	Chute	11805	30000cfs	1993.58	1993.36	0.22	0.31	0.01		3814.31		273.96
Right Chute	Chute	11805	2yr 54200cfs	1996.43	1996.20	0.23	0.23	0.02		7052.45		308.59
Right Chute	Chute	11805	100yr 128300cfs	2001.33	2001.01	0.31	0.21	0.03	1148.86	16222.96		862.35
Right Chute	Chute	11805	63000cfs	1997.35	1997.11	0.24	0.22	0.02	4.99	8383.29		363.44
Right Chute	Chute	11368	7000cfs	1988.93	1988.80	0.13	0.73	0.00		969.07		109.62
Right Chute	Chute	11368	15000cfs	1990.79	1990.60	0.19	0.73	0.00		1964.83		131.23
Right Chute	Chute	11368	30000cfs	1993.27	1992.99	0.27	0.76	0.00		3814.31		165.18
Right Chute	Chute	11368	2yr 54200cfs	1996.18	1995.79	0.39	0.75	0.02	2.18	7050.27		210.73
Right Chute	Chute	11368	100yr 128300cfs	2001.09	2000.50	0.59	0.59	0.08	1711.45	15655.00	5.37	1527.66
Right Chute	Chute	11368	63000cfs	1997.12	1996.68	0.43	0.73	0.03	22.56	8365.72		247.71
Right Chute	Chute	10169	7000cfs	1988.20	1988.07	0.13	0.49	0.00		969.07		109.61
Right Chute	Chute	10169	15000cfs	1990.06	1989.87	0.19	0.49	0.00		1964.83		131.19
Right Chute	Chute	10169	30000cfs	1992.50	1992.23	0.28	0.51	0.00		3814.31		175.41
Right Chute	Chute	10169	2yr 54200cfs	1995.41	1995.08	0.33	0.52	0.01		7052.45		260.76
Right Chute	Chute	10169	100yr 128300cfs	2000.42	2000.08	0.34	0.34	0.01	291.09	15031.27	2049.46	1477.85
Right Chute	Chute	10169	63000cfs	1996.36	1996.01	0.34	0.50	0.01		8381.19	7.08	333.37
Right Chute	Chute	9362	7000cfs	1987.70	1987.58	0.13	0.19	0.00		969.07		109.59
Right Chute	Chute	9362	15000cfs	1989.57	1989.37	0.20	0.19	0.00		1964.83		131.13
Right Chute	Chute	9362	30000cfs	1991.99	1991.71	0.28	0.18	0.00		3814.31		156.79
Right Chute	Chute	9362	2yr 54200cfs	1994.89	1994.47	0.42	0.19	0.00		7052.09	0.36	193.93
Right Chute	Chute	9362	100yr 128300cfs	2000.08	1999.68	0.40	0.17	0.03	330.58	13577.05	3464.19	1456.23
Right Chute	Chute	9362	63000cfs	1995.84	1995.37	0.47	0.19	0.00		8358.32	29.96	318.88
Right Chute	Chute	9056	7000cfs	1987.52	1987.39	0.13	0.27	0.00		969.07		109.63
Right Chute	Chute	9056	15000cfs	1989.38	1989.18	0.20	0.27	0.00		1964.83		131.16
Right Chute	Chute	9056	30000cfs	1991.81	1991.53	0.28	0.26	0.00		3814.31		156.84
Right Chute	Chute	9056	2yr 54200cfs	1994.70	1994.28	0.42	0.27	0.00		7052.45		178.86
Right Chute	Chute	9056	100yr 128300cfs	1999.88	1999.19	0.68	0.30	0.01	575.55	16078.64	717.62	1285.20
Right Chute	Chute	9056	63000cfs	1995.65	1995.18	0.47	0.27	0.00		8388.27		186.02
Right Chute	Chute	8620	7000cfs	1987.25	1987.12	0.13	0.40	0.00		969.07		109.55
Right Chute	Chute	8620	15000cfs	1989.11	1988.91	0.20	0.40	0.00		1964.83		131.05
Right Chute	Chute	8620	30000cfs	1991.55	1991.26	0.28	0.39	0.00		3814.31		156.83
Right Chute	Chute	8620	2yr 54200cfs	1994.44	1994.01	0.42	0.39	0.00		7052.45		178.84
Right Chute	Chute	8620	100yr 128300cfs	1999.56	1998.76	0.81	0.48	0.00	189.14	16736.38	446.30	684.97
Right Chute	Chute	8620	63000cfs	1995.38	1994.90	0.47	0.40	0.00		8388.27		185.96
Right Chute	Chute	7967	7000cfs	1986.85	1986.72	0.13	0.37	0.00		969.07		109.57
Right Chute	Chute	7967	15000cfs	1988.71	1988.51	0.20	0.37	0.00		1964.83		131.02
Right Chute	Chute	7967	30000cfs	1991.16	1990.88	0.28	0.36	0.00		3814.31		156.92
Right Chute	Chute	7967	2yr 54200cfs	1994.04	1993.63	0.42	0.41	0.01	22.31	7030.13		198.50
Right Chute	Chute	7967	100yr 128300cfs	1999.08	1998.24	0.84	0.41	0.07	776.37	16554.65	40.80	581.68
Right Chute	Chute	7967	63000cfs	1994.98	1994.51	0.47	0.38	0.02	53.12	8335.15		212.75
Right Chute	Chute	7364	7000cfs	1986.48	1986.36	0.13	0.35	0.00		969.07		109.59
Right Chute	Chute	7364	15000cfs	1988.34	1988.14	0.20	0.35	0.00		1964.83		130.98
Right Chute	Chute	7364	30000cfs	1990.80	1990.52	0.28	0.35	0.00		3814.31		204.94
Right Chute	Chute	7364	2yr 54200cfs	1993.63	1993.24	0.38	0.41	0.00		6999.12	53.33	363.69
Right Chute	Chute	7364	100yr 128300cfs	1998.60	1997.99	0.61	0.34	0.07	107.32	16606.94	657.57	972.26
Right Chute	Chute	7364	63000cfs	1994.58	1994.19	0.39	0.43	0.00		8269.96	118.32	465.39
Right Chute	Chute	6795	7000cfs	1986.14	1986.01	0.13	0.49	0.00		969.07		109.48
Right Chute	Chute	6795	15000cfs	1987.98	1987.78	0.20	0.50	0.00		1964.83		130.78
Right Chute	Chute	6795	30000cfs	1990.45	1990.17	0.28	0.50	0.00		3814.31		190.99
Right Chute	Chute	6795	2yr 54200cfs	1993.22	1992.82	0.40	0.53	0.00		7052.12	0.33	290.08
Right Chute	Chute	6795	100yr 128300cfs	1998.19	1997.82	0.37	0.41	0.01	176.56	15972.95	1222.32	1374.85
Right Chute	Chute	6795	63000cfs	1994.14	1993.72	0.42	0.61	0.01		8344.35	43.92	480.21
Right Chute	Chute	5997	7000cfs	1985.64	1985.52	0.13	0.41	0.00		969.07		109.46

HEC-RAS Plan: Tt_High_flow_w_Bridge (Continued)

River	Reach	River Sta	Profile	E.G. Elev	W.S. Elev	Vel Head	Frctn Loss	C & E Loss	Q Left	Q Channel	Q Right	Top Width
				(ft)	(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft)
Right Chute	Chute	5997	15000cfs	1987.48	1987.28	0.20	0.42	0.00		1964.83		130.62
Right Chute	Chute	5997	30000cfs	1989.95	1989.67	0.28	0.43	0.00		3814.31		171.79
Right Chute	Chute	5997	2yr 54200cfs	1992.69	1992.25	0.43	0.44	0.02		7028.76	23.69	337.27
Right Chute	Chute	5997	100yr 128300cfs	1997.76	1997.26	0.50	0.31	0.02	0.97	14444.95	2925.90	1266.06
Right Chute	Chute	5997	63000cfs	1993.53	1993.05	0.47	0.43	0.02		8247.92	140.35	457.81
Right Chute	Chute	5332	7000cfs	1985.23	1985.10	0.13	0.39	0.00		969.07		109.30
Right Chute	Chute	5332	15000cfs	1987.05	1986.85	0.20	0.41	0.00		1964.83		130.31
Right Chute	Chute	5332	30000cfs	1989.52	1989.23	0.28	0.47	0.00		3814.23	0.08	187.01
Right Chute	Chute	5332	2yr 54200cfs	1992.23	1991.86	0.37	0.42	0.02		6981.62	70.83	301.48
Right Chute	Chute	5332	100yr 128300cfs	1997.43	1997.00	0.43	0.24	0.04	112.99	14740.94	2517.89	1168.42
Right Chute	Chute	5332	63000cfs	1993.07	1992.67	0.40	0.41	0.03		8224.04	164.23	397.87
Right Chute	Chute	4706	7000cfs	1984.84	1984.71	0.13	0.60	0.00		969.07		109.13
Right Chute	Chute	4706	15000cfs	1986.65	1986.44	0.20	0.63	0.00		1964.83		129.97
Right Chute	Chute	4706	30000cfs	1989.04	1988.77	0.27	0.70	0.00		3814.31		205.68
Right Chute	Chute	4706	2yr 54200cfs	1991.79	1991.50	0.29	0.65	0.02		7052.45		312.17
Right Chute	Chute	4706	100yr 128300cfs	1997.15	1996.85	0.30	0.45	0.06	368.19	16554.52	449.12	1027.38
Right Chute	Chute	4706	63000cfs	1992.64	1992.34	0.30	0.65	0.02		8388.27		353.58
Right Chute	Chute	3764	7000cfs	1984.24	1984.10	0.13	0.70	0.00		969.07		108.84
Right Chute	Chute	3764	15000cfs	1986.02	1985.81	0.21	0.74	0.00		1964.83		129.30
Right Chute	Chute	3764	30000cfs	1988.34	1988.02	0.31	0.77	0.00		3814.31		154.91
Right Chute	Chute	3764	2yr 54200cfs	1991.12	1990.66	0.46	0.76	0.02	26.66	7025.79	0.00	198.90
Right Chute	Chute	3764	100yr 128300cfs	1996.64	1995.72	0.92	0.66	0.08	482.49	16799.99	89.34	235.60
Right Chute	Chute	3764	63000cfs	1991.97	1991.43	0.53	0.74	0.03	60.00	8327.75	0.52	206.26
Right Chute	Chute	2720	7000cfs	1983.54	1983.40	0.14	0.61	0.00		969.07		107.94
Right Chute	Chute	2720	15000cfs	1985.28	1985.05	0.22	0.65	0.00		1964.83		127.78
Right Chute	Chute	2720	30000cfs	1987.57	1987.24	0.33	0.67	0.00		3814.31	0.01	158.08
Right Chute	Chute	2720	2yr 54200cfs	1990.34	1989.93	0.41	0.64	0.01	38.68	6996.81	16.96	257.47
Right Chute	Chute	2720	100yr 128300cfs	1995.90	1995.24	0.66	0.39	0.08	375.67	16759.27	236.88	338.69
Right Chute	Chute	2720	63000cfs	1991.20	1990.75	0.45	0.61	0.01	77.37	8278.96	31.94	263.60
Right Chute	Chute	1889	7000cfs	1982.93	1982.78	0.15	0.52	0.00		969.07		106.58
Right Chute	Chute	1889	15000cfs	1984.62	1984.38	0.24	0.55	0.00		1964.83		125.80
Right Chute	Chute	1889	30000cfs	1986.90	1986.54	0.36	0.54	0.00		3813.06	1.25	162.19
Right Chute	Chute	1889	2yr 54200cfs	1989.70	1989.23	0.47	0.48	0.01	68.23	6870.63	113.59	294.48
Right Chute	Chute	1889	100yr 128300cfs	1995.43	1995.04	0.40	0.27	0.01	2264.15	13336.82	1770.85	668.39
Right Chute	Chute	1889	63000cfs	1990.59	1990.09	0.50	0.45	0.01	149.00	8021.65	217.63	383.52
Right Chute	Chute	1277	7000cfs	1982.41	1982.24	0.17	0.66	0.01		969.07		104.58
Right Chute	Chute	1277	15000cfs	1984.07	1983.80	0.27	0.68	0.01		1964.83		123.26
Right Chute	Chute	1277	30000cfs	1986.36	1985.97	0.38	0.61	0.01		3806.54	7.78	181.90
Right Chute	Chute	1277	2yr 54200cfs	1989.21	1988.76	0.45	0.52	0.01		6787.36	265.09	276.86
Right Chute	Chute	1277	100yr 128300cfs	1995.15	1994.62	0.53	0.37	0.04	28.59	15023.36	2319.87	461.83
Right Chute	Chute	1277	63000cfs	1990.13	1989.66	0.47	0.50	0.02		7946.21	442.06	286.05
Right Chute	Chute	675	7000cfs	1981.74	1981.52	0.22	0.95	0.04		969.07		98.96
Right Chute	Chute	675	15000cfs	1983.38	1983.05	0.33	0.63	0.01		1964.83		118.62
Right Chute	Chute	675	30000cfs	1985.74	1985.31	0.43	0.46	0.01		3814.31		145.76
Right Chute	Chute	675	2yr 54200cfs	1988.68	1988.11	0.57	0.37	0.00		7052.45		165.93
Right Chute	Chute	675	100yr 128300cfs	1994.74	1993.80	0.94	0.28	0.00	317.83	17007.06	46.93	330.13
Right Chute	Chute	675	63000cfs	1989.61	1988.97	0.64	0.36	0.00		8388.27		171.21
Right Chute	Chute	286	7000cfs	1980.74	1980.11	0.64	0.06	0.15		969.07		80.28
Right Chute	Chute	286	15000cfs	1982.75	1982.29	0.45	0.08	0.06		1964.83		112.43
Right Chute	Chute	286	30000cfs	1985.28	1984.79	0.49	0.08	0.04		3814.31		142.41
Right Chute	Chute	286	2yr 54200cfs	1988.31	1987.71	0.60	0.05	0.05	0.04	7052.40		168.30
Right Chute	Chute	286	100yr 128300cfs	1994.45	1993.52	0.94	0.05	0.04	632.45	16621.57	117.80	314.15
Right Chute	Chute	286	63000cfs	1989.25	1988.58	0.67	0.05	0.06	5.80	8382.48		176.93

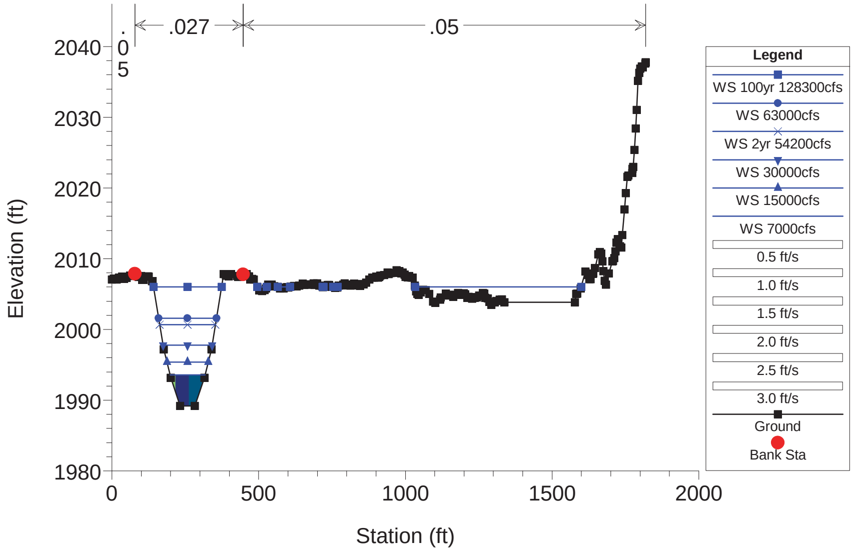
Yellowstone Intake   Plan: Tt High Flow Chnl with Bridge   3/15/2016

RS = 19860



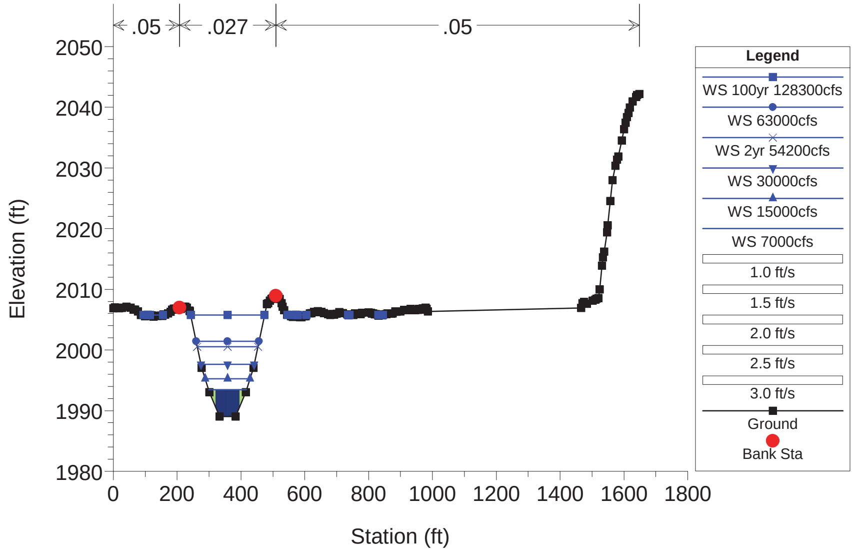
Yellowstone Intake   Plan: Tt High Flow Chnl with Bridge   3/15/2016

RS = 19371



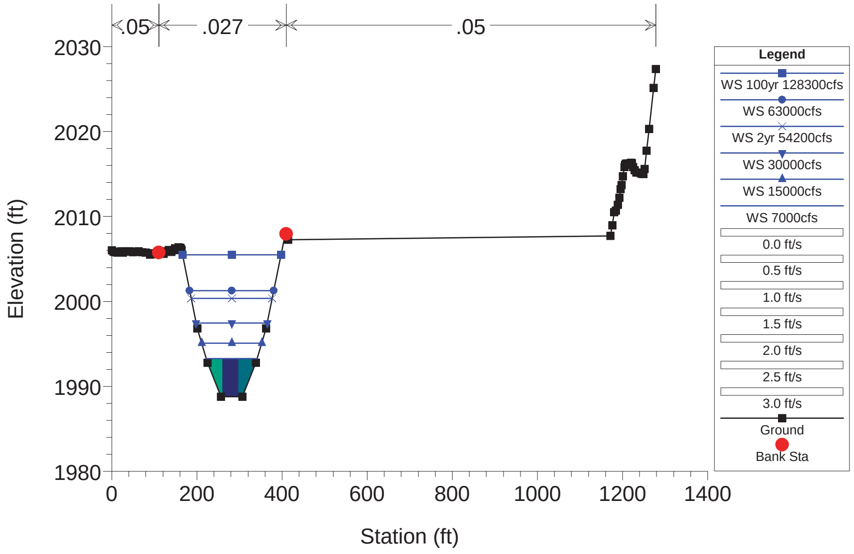
Yellowstone Intake   Plan: Tt High Flow Chnl with Bridge   3/15/2016

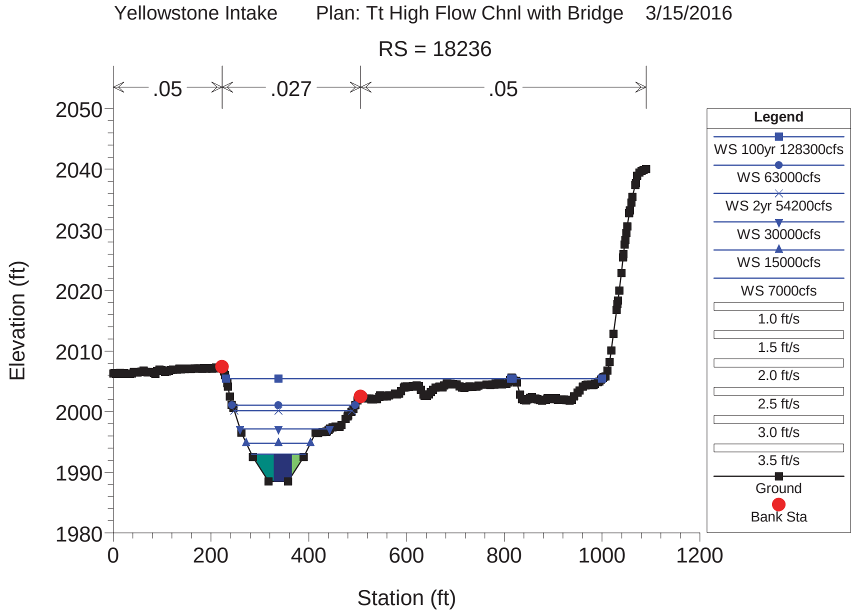
RS = 19112



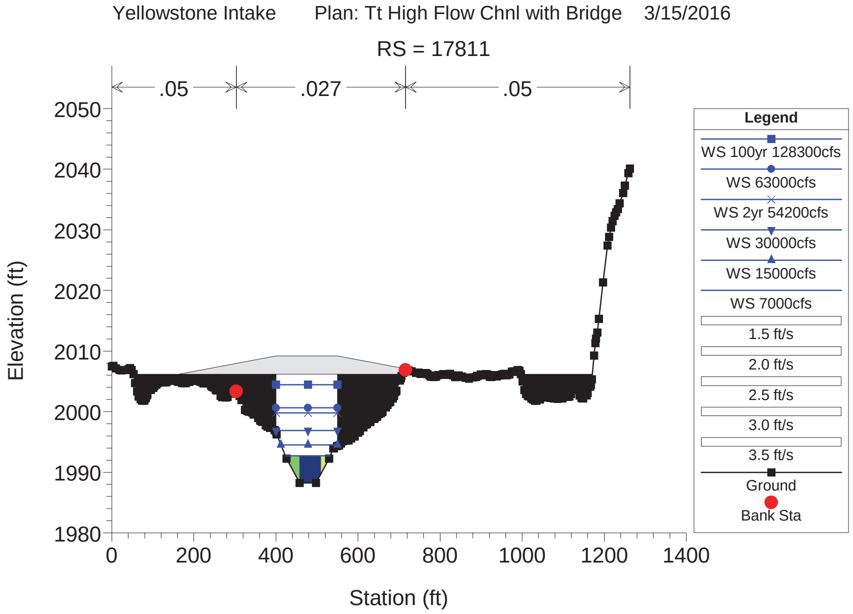
Yellowstone Intake   Plan: Tt High Flow Chnl with Bridge   3/15/2016

RS = 18723

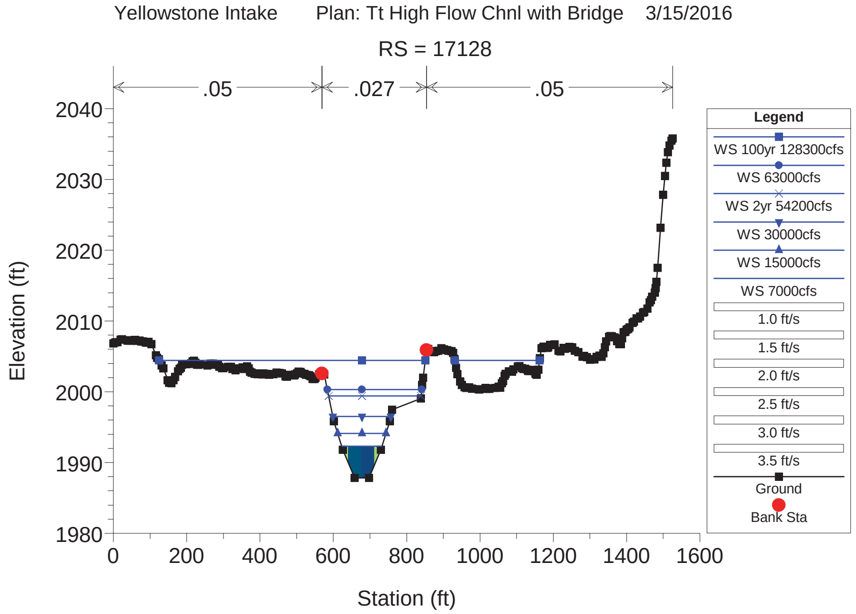



Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

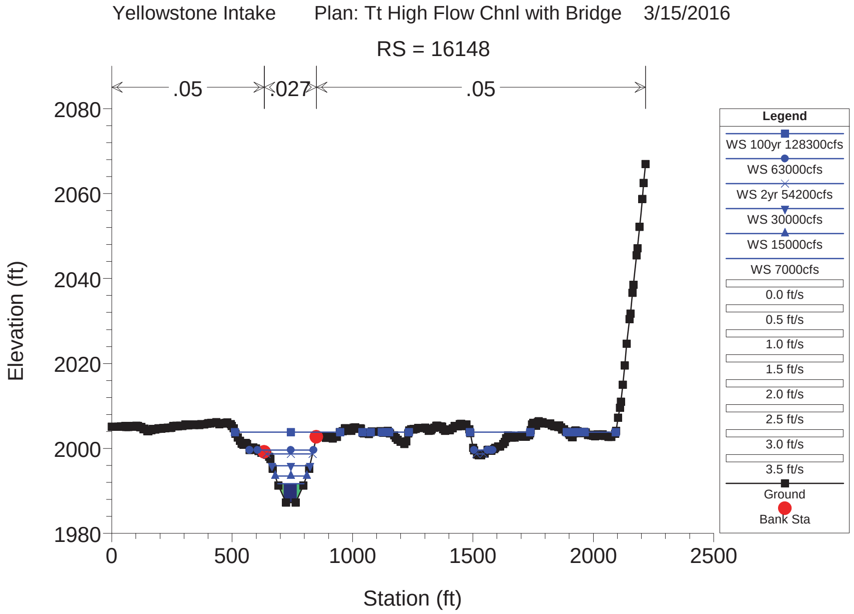
RS = 18236


Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

RS = 17811


Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

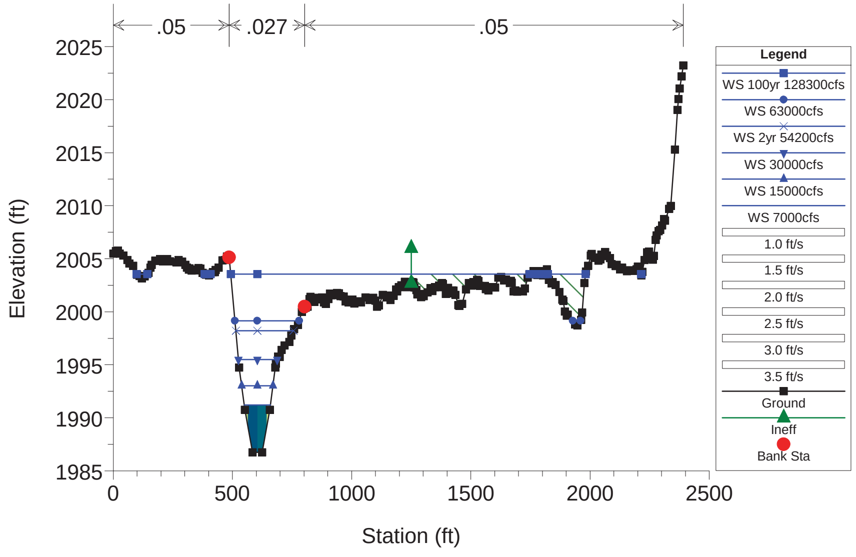
RS = 17128


Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

RS = 16148

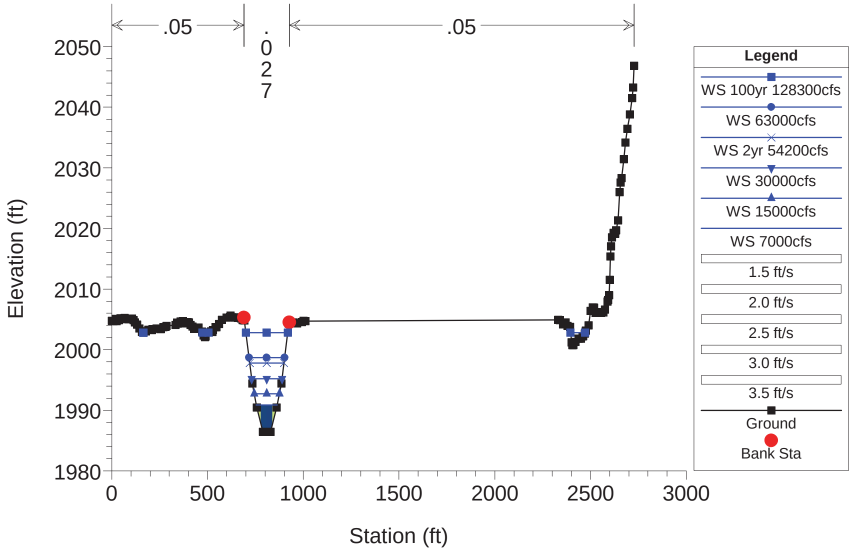
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

RS = 15352



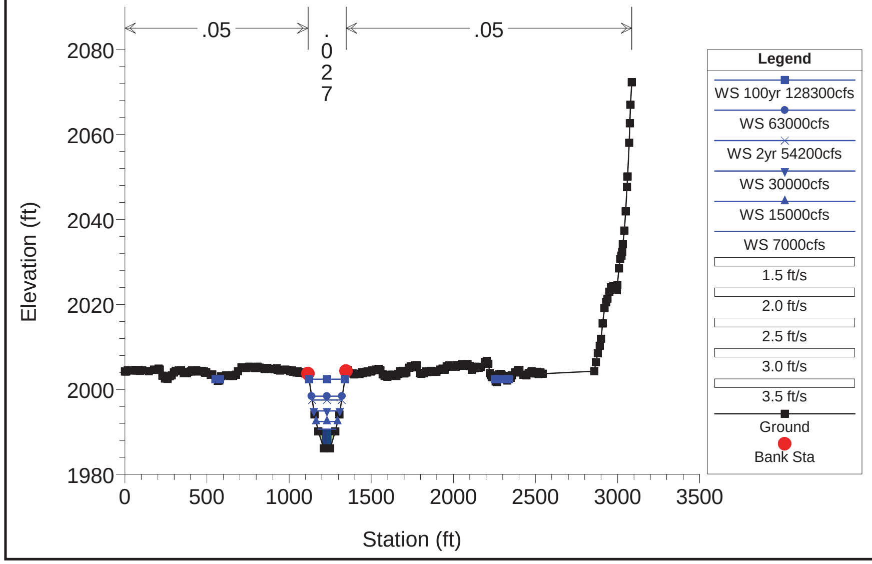
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

RS = 14824



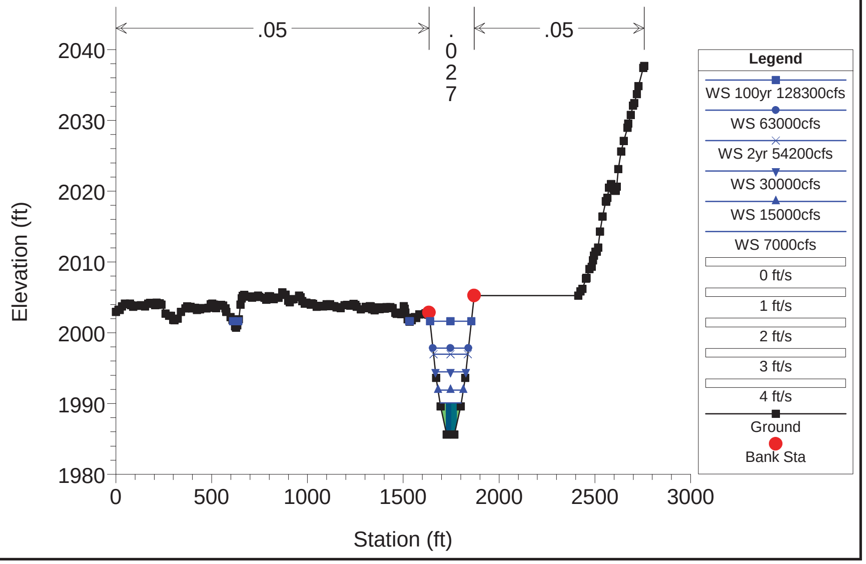
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

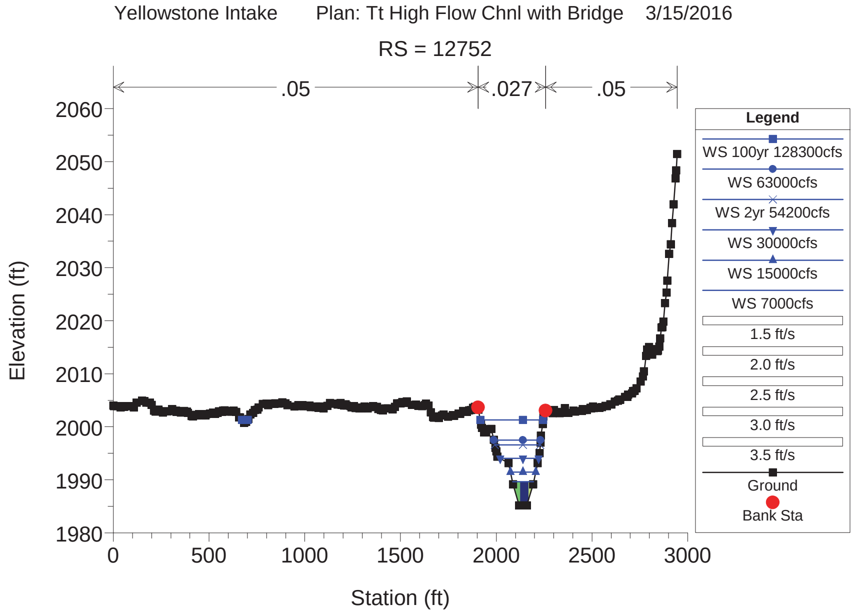
RS = 14335

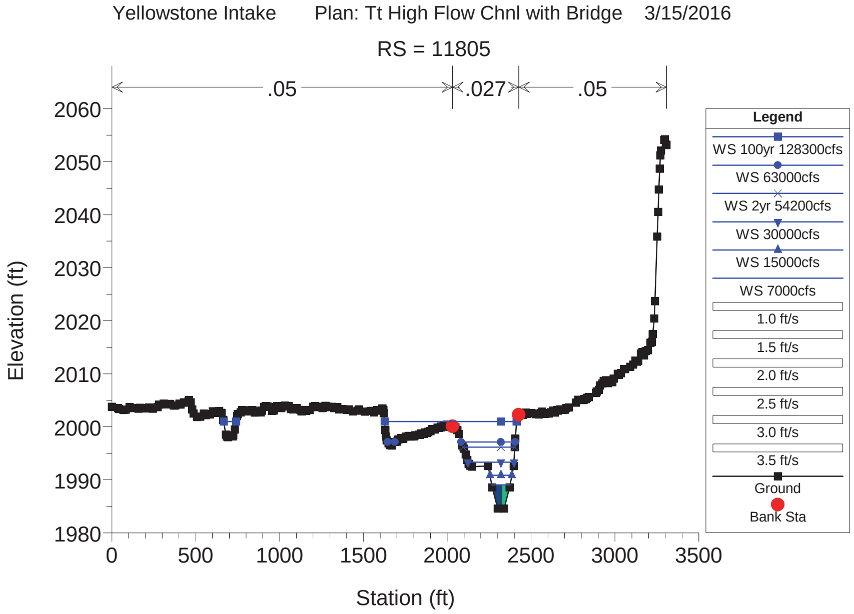


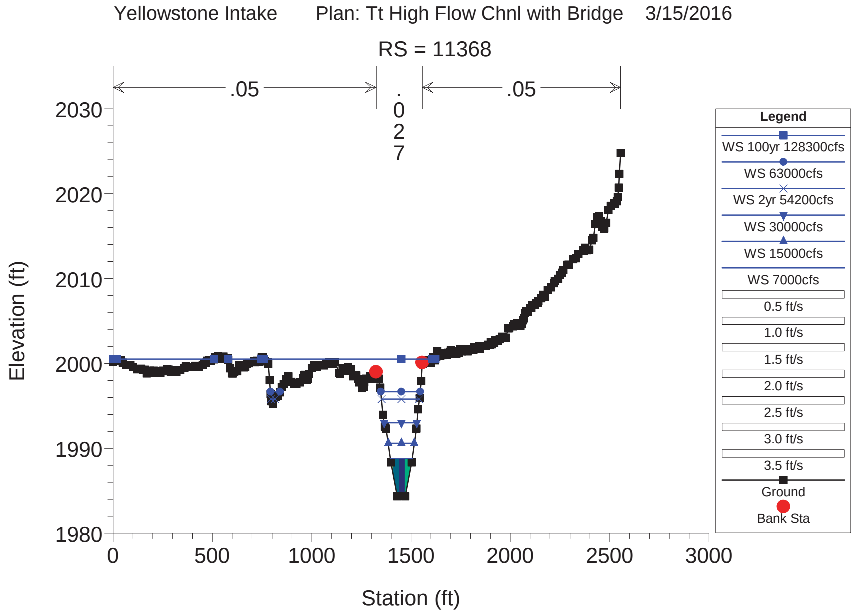
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

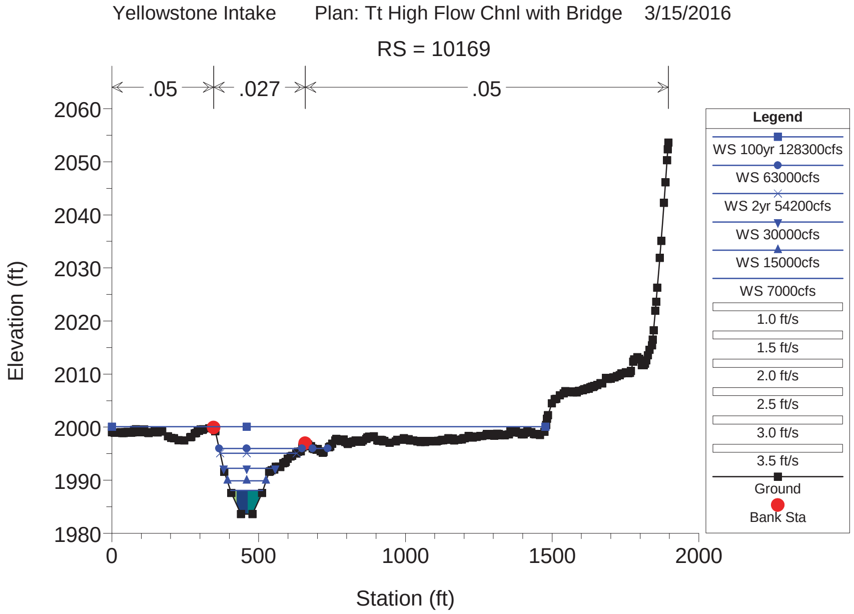
RS = 13471

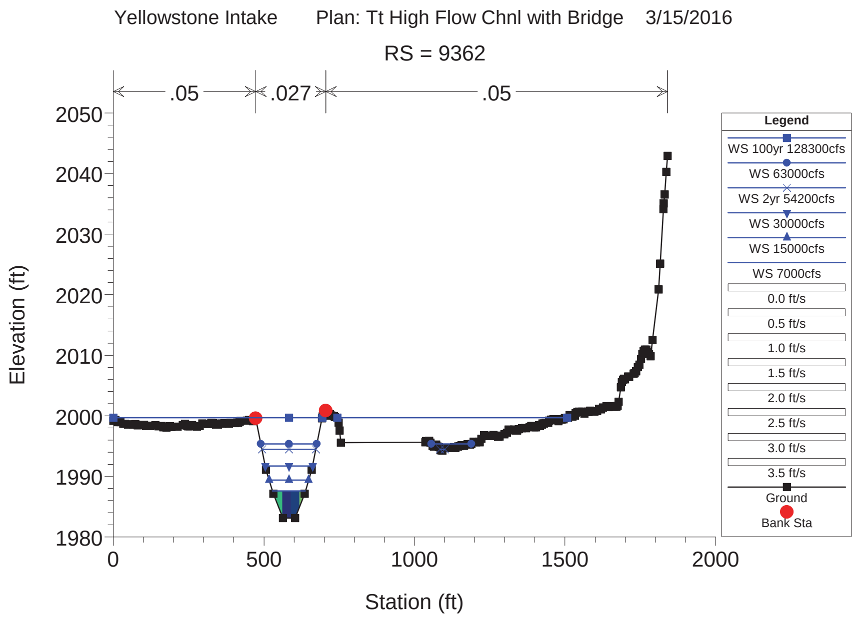


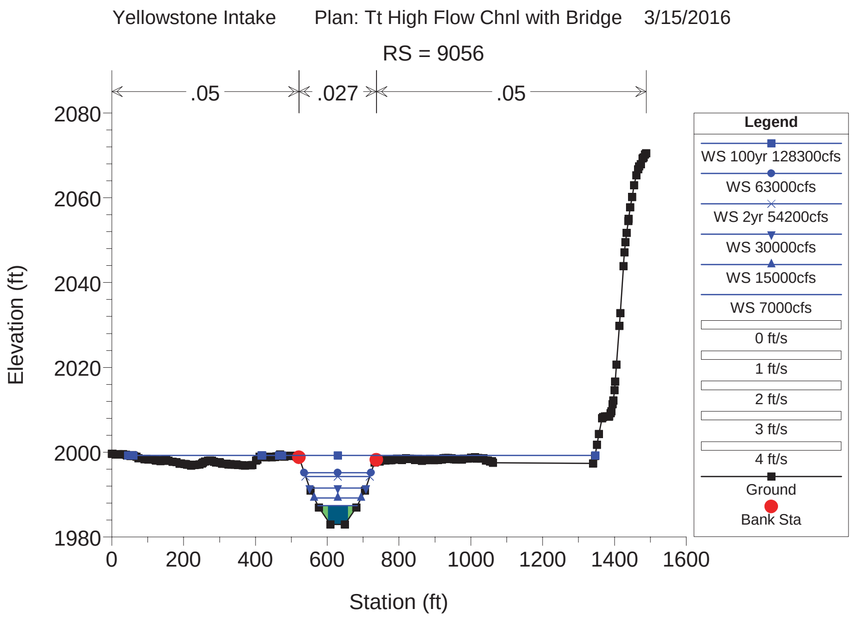

Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 12752
.05
.027
.05
Elevation (ft)
2060
2050
2040
2030
2020
2010
2000
1990
1980
0
500
1000
1500
2000
2500
3000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
3.5 ft/s
Ground
Bank Sta

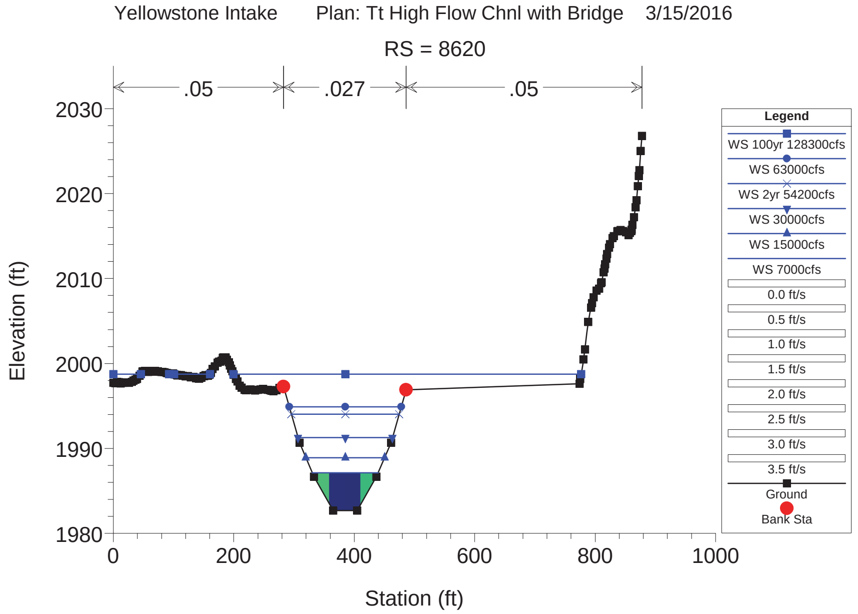

Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 11805
.05
.027
.05
Elevation (ft)
2060
2050
2040
2030
2020
2010
2000
1990
1980
0
500
1000
1500
2000
2500
3000
3500
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
3.5 ft/s
Ground
Bank Sta

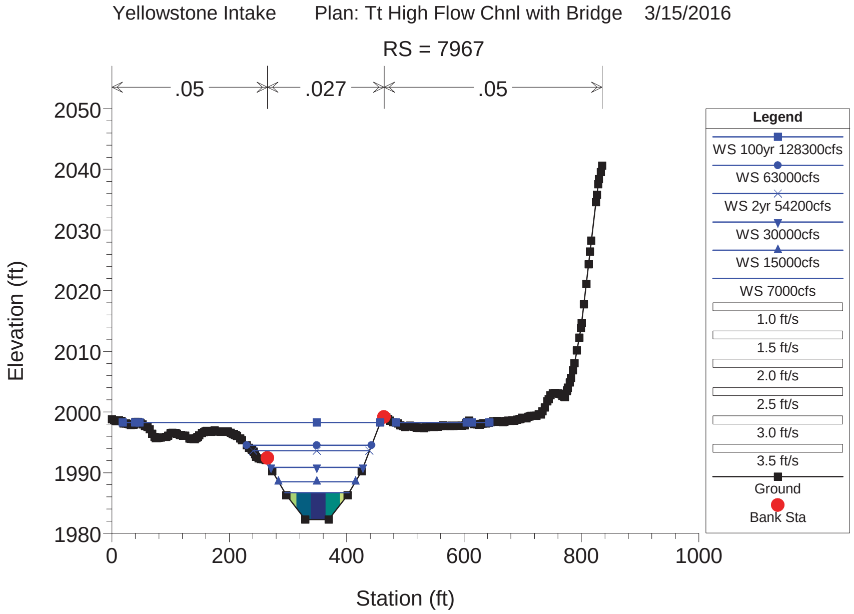

Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 11368
.05
.027
.05
Elevation (ft)
2030
2020
2010
2000
1990
1980
0
500
1000
1500
2000
2500
3000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
3.5 ft/s
Ground
Bank Sta


Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 10169
.05
.027
.05
Elevation (ft)
2060
2050
2040
2030
2020
2010
2000
1990
1980
0
500
1000
1500
2000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
3.5 ft/s
Ground
Bank Sta


Yellowstone Intake
Plan: Tt High Flow Chnl with Bridge
3/15/2016
RS = 9362
.05
.027
.05
Elevation (ft)
2050
2040
2030
2020
2010
2000
1990
1980
0
500
1000
1500
2000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.0 ft/s
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
3.5 ft/s
Ground
Bank Sta

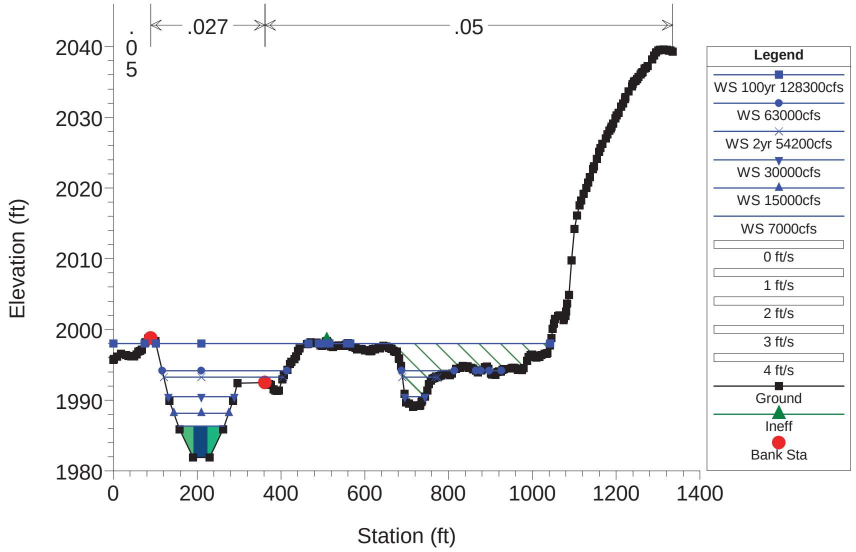

Yellowstone Intake
Plan: Tt High Flow Chnl with Bridge
3/15/2016
RS = 9056
.05
.027
.05
Elevation (ft)
2080
2060
2040
2020
2000
1980
0
200
400
600
800
1000
1200
1400
1600
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0 ft/s
1 ft/s
2 ft/s
3 ft/s
4 ft/s
Ground
Bank Sta


Yellowstone Intake
Plan: Tt High Flow Chnl with Bridge
3/15/2016
RS = 8620
.05
.027
.05
Elevation (ft)
2030
2020
2010
2000
1990
1980
0
200
400
600
800
1000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.0 ft/s
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
3.5 ft/s
Ground
Bank Sta


Yellowstone Intake
Plan: Tt High Flow Chnl with Bridge
3/15/2016
RS = 7967
.05
.027
.05
Elevation (ft)
2050
2040
2030
2020
2010
2000
1990
1980
0
200
400
600
800
1000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
3.5 ft/s
Ground
Bank Sta

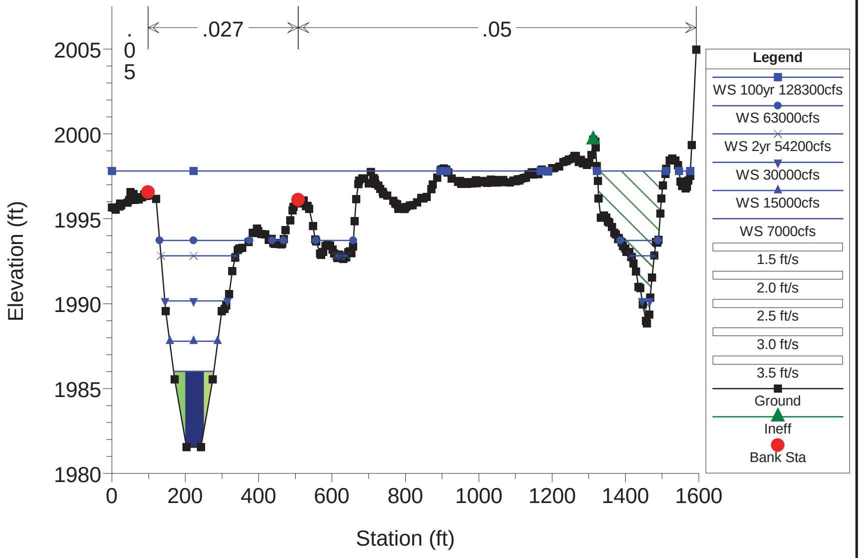
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

RS = 7364



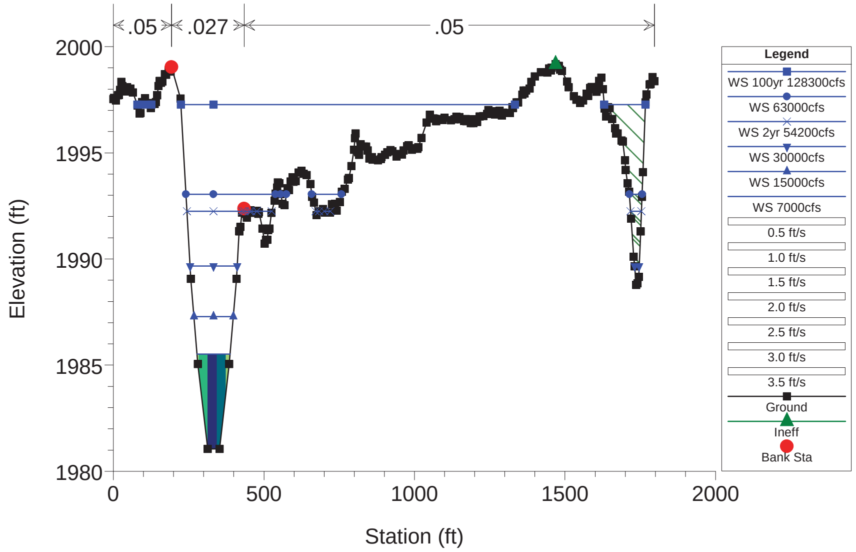
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

RS = 6795



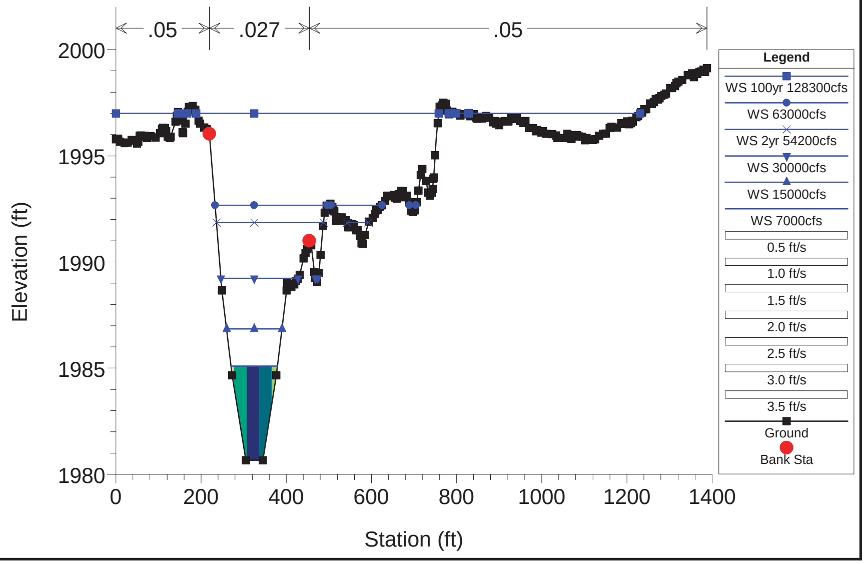
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

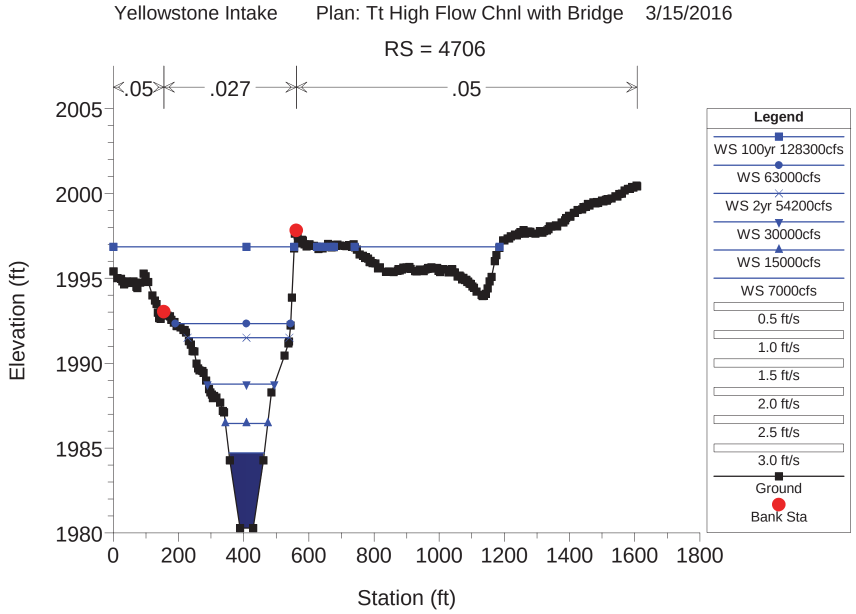
RS = 5997



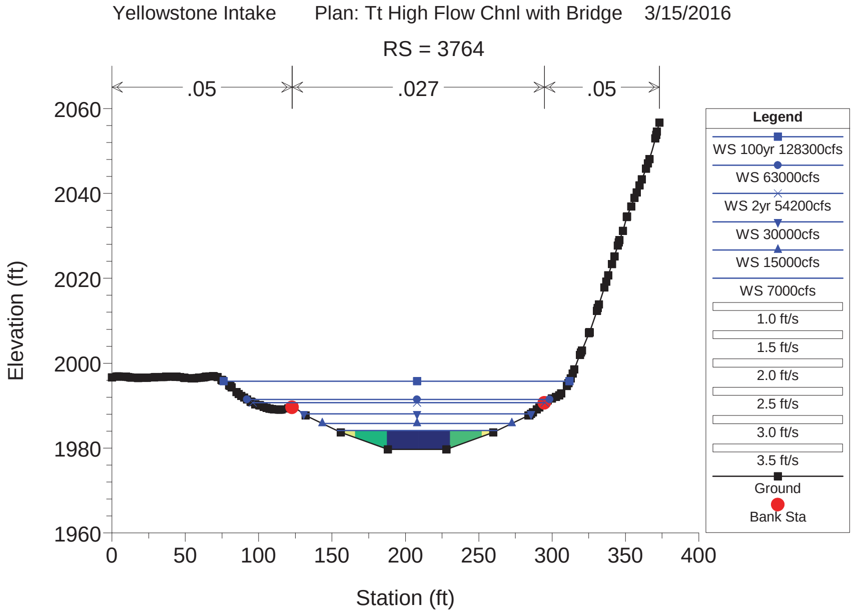
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

RS = 5332

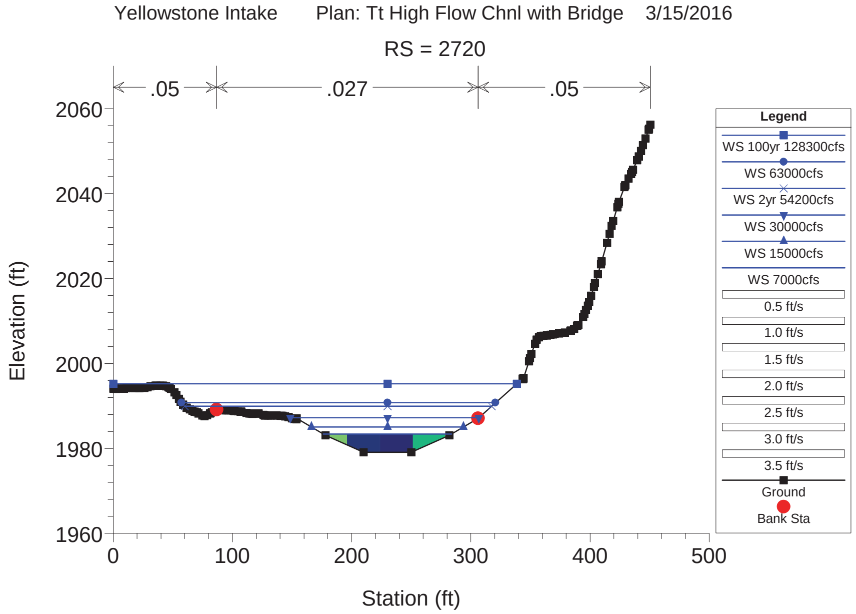



Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

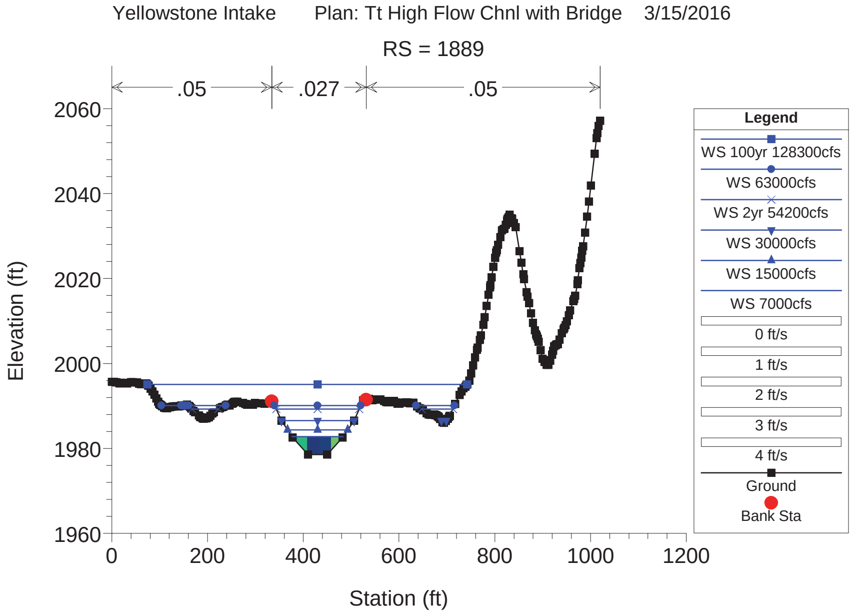
RS = 4706


Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

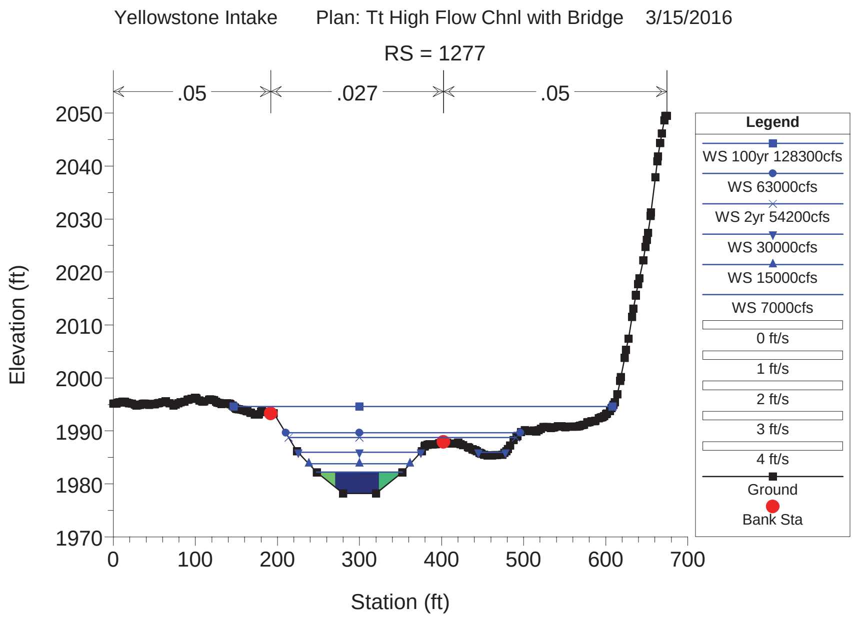
RS = 3764

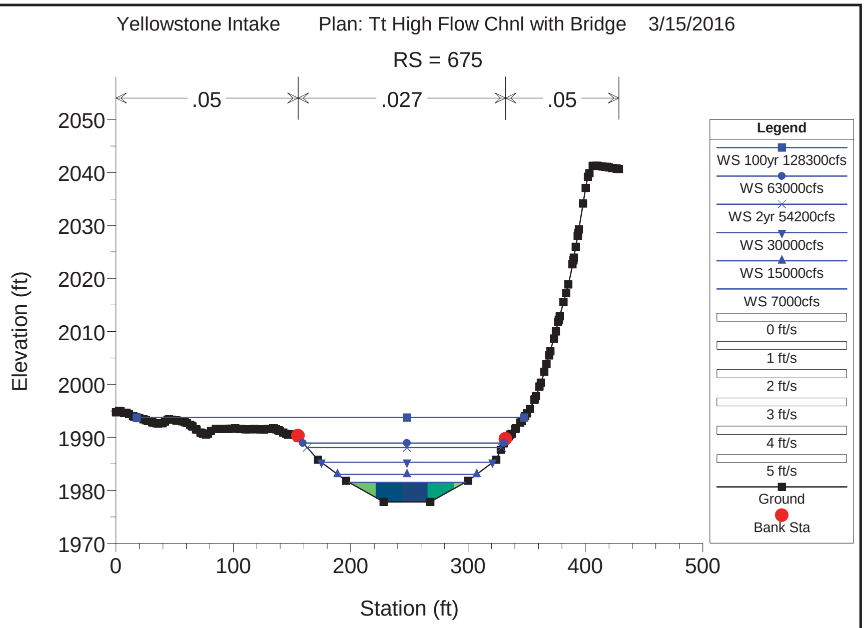

Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

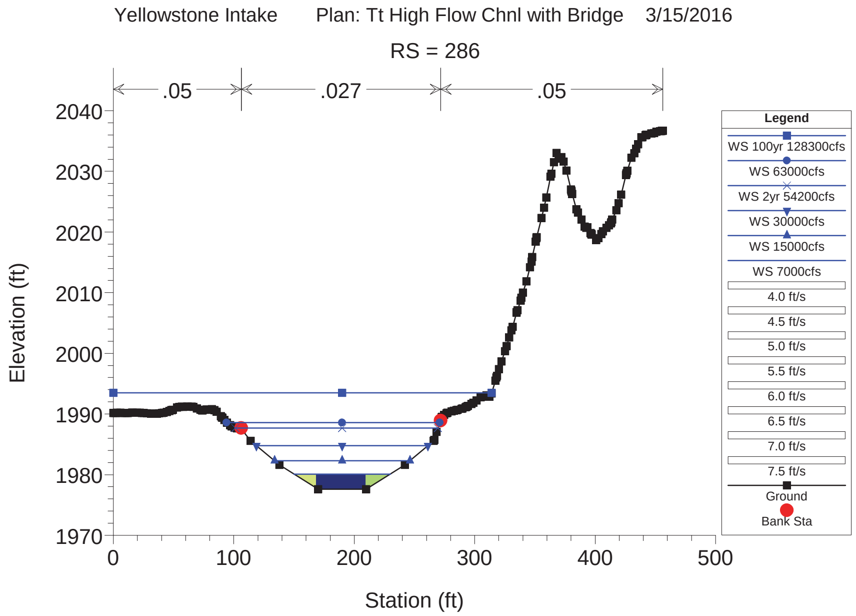
RS = 2720

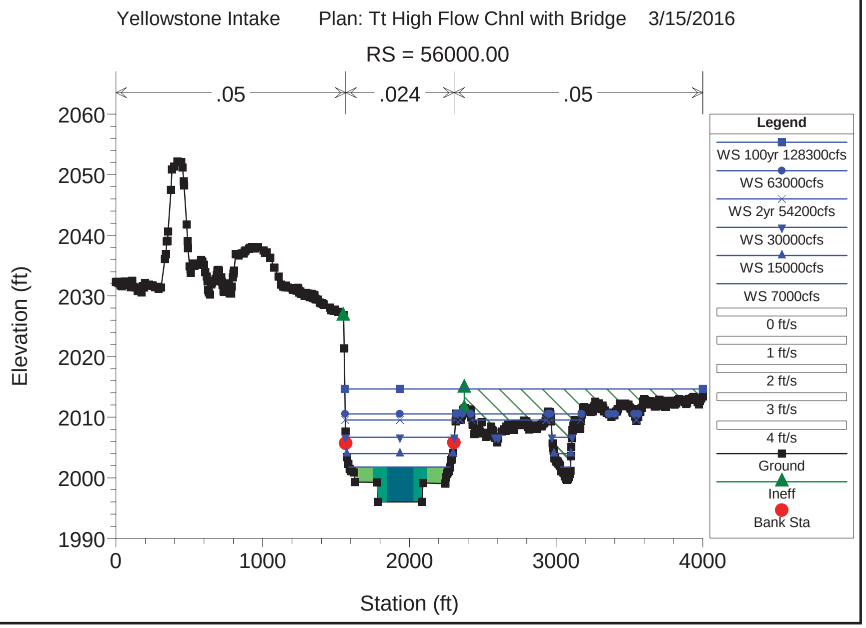

Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

RS = 1889


Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 1277
.05
.027
.05
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0 ft/s
1 ft/s
2 ft/s
3 ft/s
4 ft/s
Ground
Bank Sta
Elevation (ft)
1970
1980
1990
2000
2010
2020
2030
2040
2050
Station (ft)
0
100
200
300
400
500
600
700

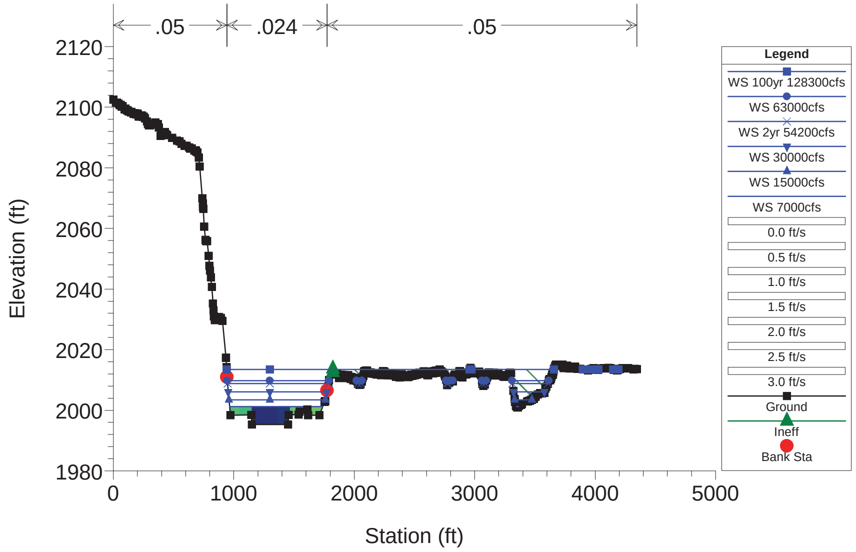

Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 675
.05
.027
.05
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0 ft/s
1 ft/s
2 ft/s
3 ft/s
4 ft/s
5 ft/s
Ground
Bank Sta
Elevation (ft)
1970
1980
1990
2000
2010
2020
2030
2040
2050
Station (ft)
0
100
200
300
400
500


Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 286
.05
.027
.05
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
4.0 ft/s
4.5 ft/s
5.0 ft/s
5.5 ft/s
6.0 ft/s
6.5 ft/s
7.0 ft/s
7.5 ft/s
Ground
Bank Sta
Elevation (ft)
1970
1980
1990
2000
2010
2020
2030
2040
Station (ft)
0
100
200
300
400
500


Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 56000.00
.05
.024
.05
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0 ft/s
1 ft/s
2 ft/s
3 ft/s
4 ft/s
Ground
Ineff
Bank Sta
Elevation (ft)
1990
2000
2010
2020
2030
2040
2050
2060
Station (ft)
0
1000
2000
3000
4000

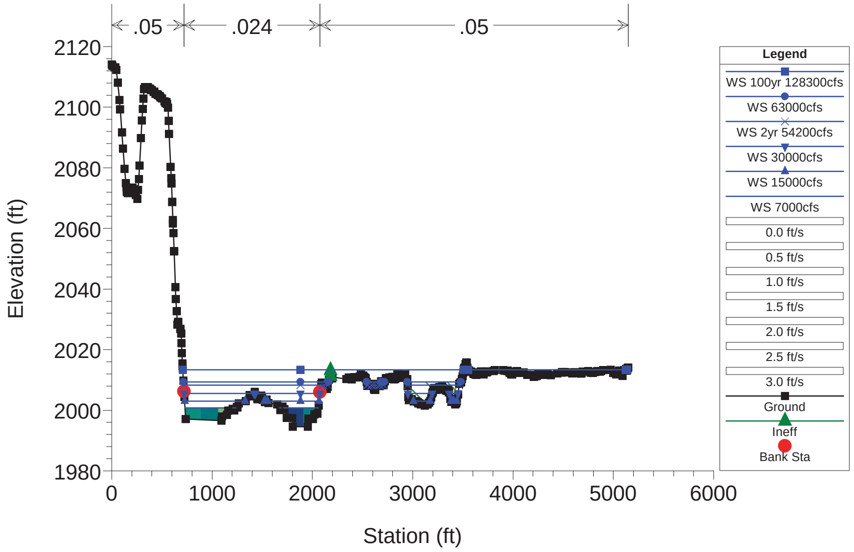
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

RS = 54003.06



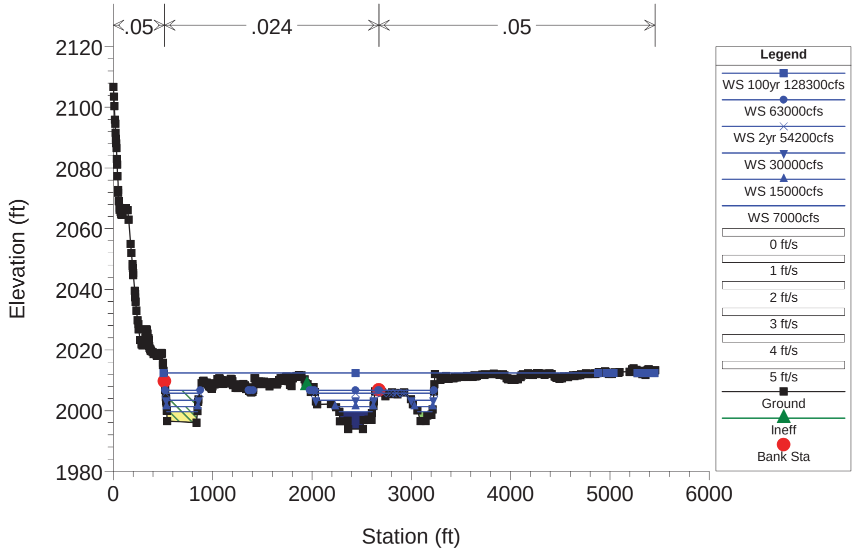
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

RS = 51999.34



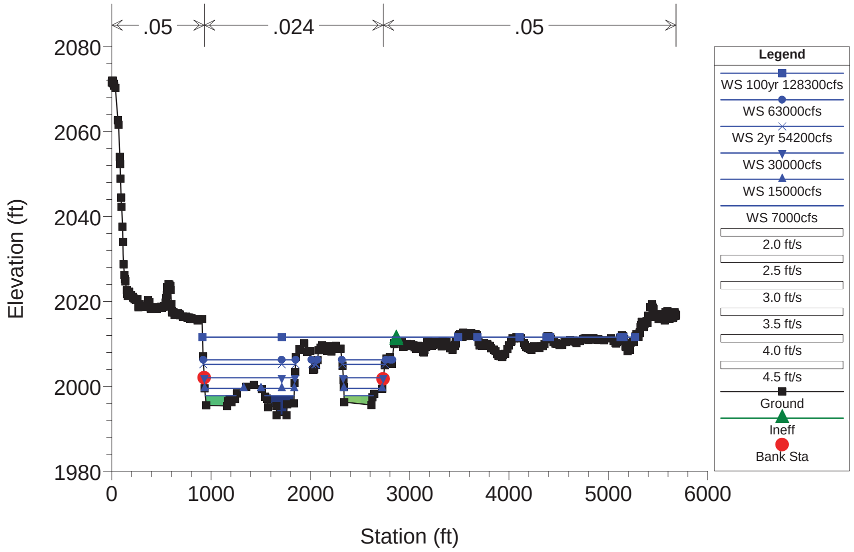
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

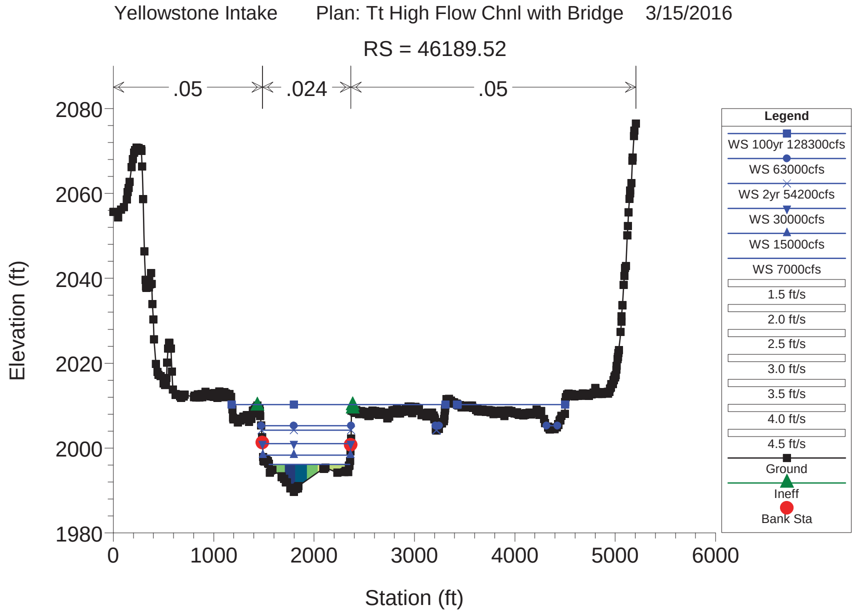
RS = 50001.19

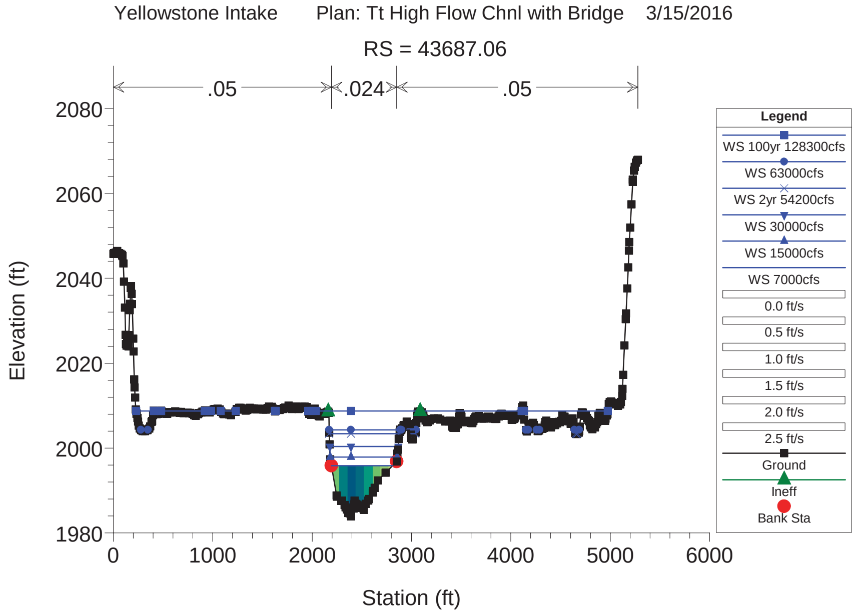


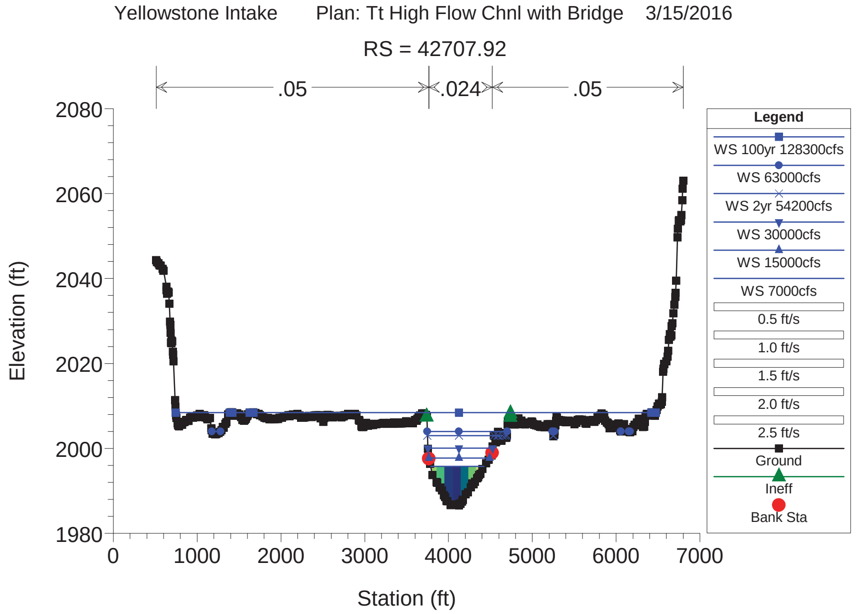
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

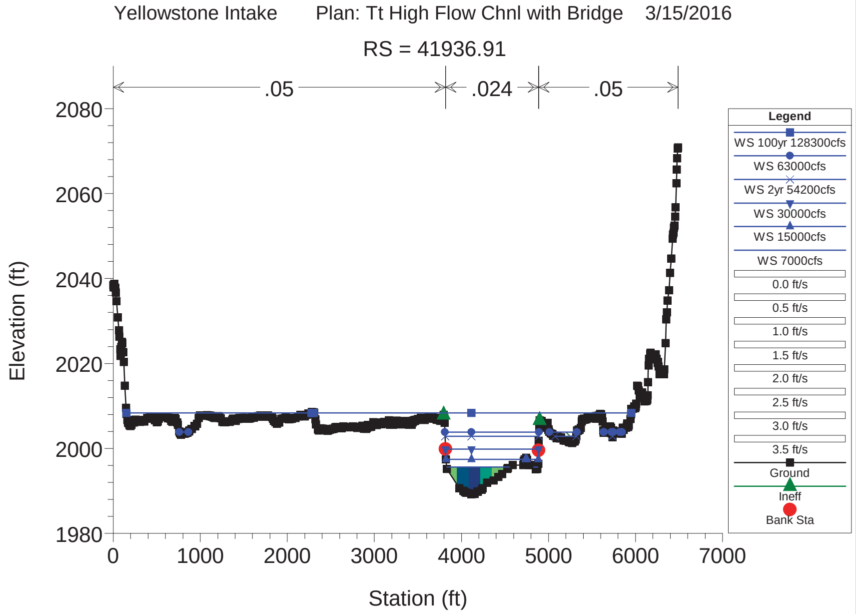
RS = 47994.16

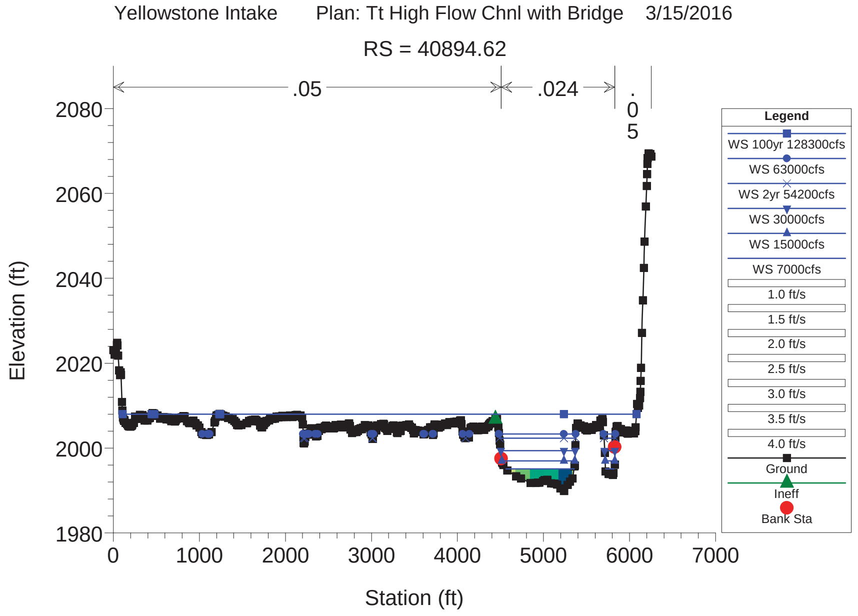



Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 46189.52
.05
.024
.05
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
3.5 ft/s
4.0 ft/s
4.5 ft/s
Ground
Ineff
Bank Sta
Elevation (ft)
2080
2060
2040
2020
2000
1980
0
1000
2000
3000
4000
5000
6000
Station (ft)

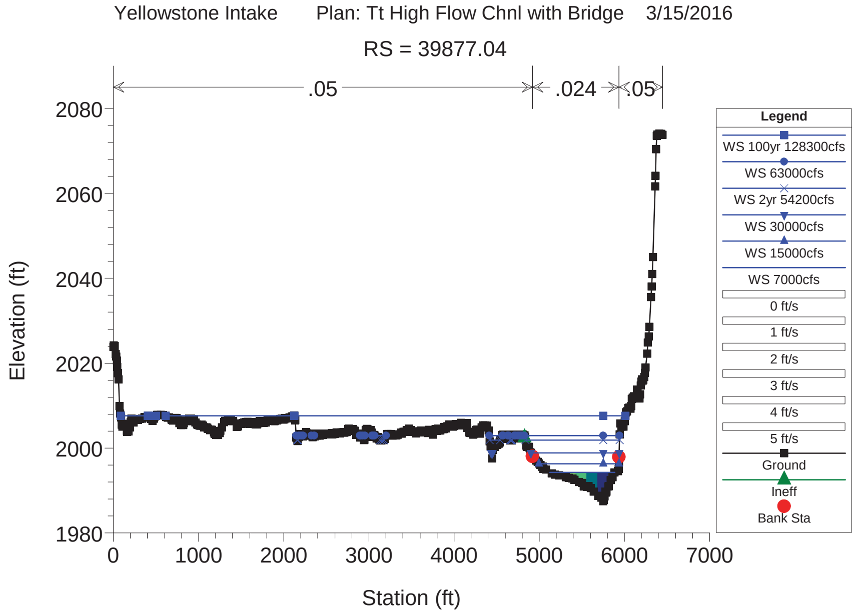

Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 43687.06
.05
.024
.05
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.0 ft/s
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
Ground
Ineff
Bank Sta
Elevation (ft)
2080
2060
2040
2020
2000
1980
0
1000
2000
3000
4000
5000
6000
Station (ft)


Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 42707.92
.05
.024
.05
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
Ground
Ineff
Bank Sta
Elevation (ft)
2080
2060
2040
2020
2000
1980
0
1000
2000
3000
4000
5000
6000
7000
Station (ft)

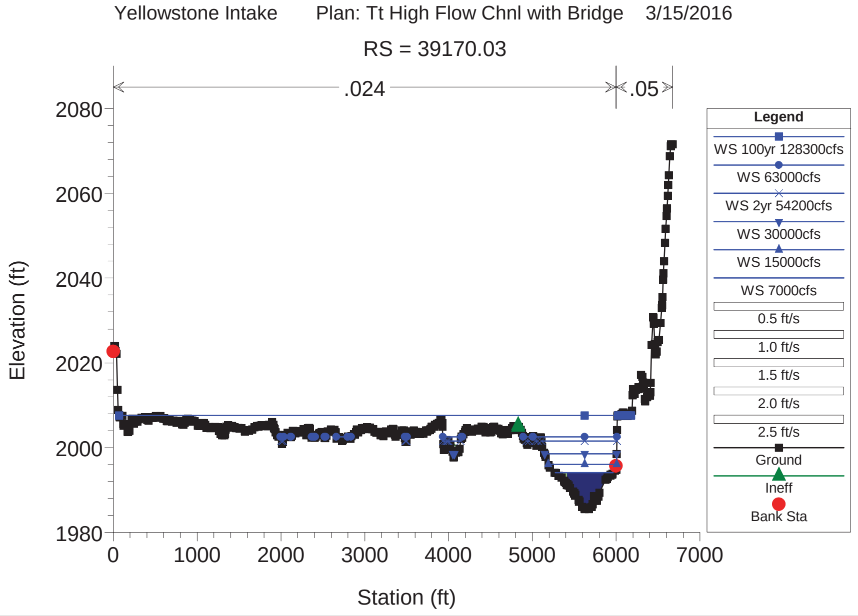

Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 41936.91
.05
.024
.05
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.0 ft/s
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
3.5 ft/s
Ground
Ineff
Bank Sta
Elevation (ft)
2080
2060
2040
2020
2000
1980
0
1000
2000
3000
4000
5000
6000
7000
Station (ft)


Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

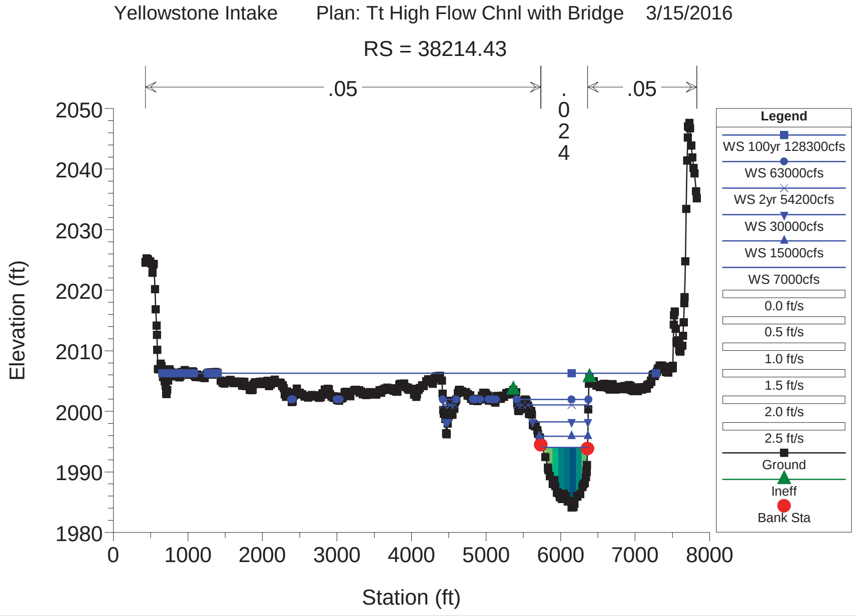
RS = 40894.62


Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

RS = 39877.04


Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

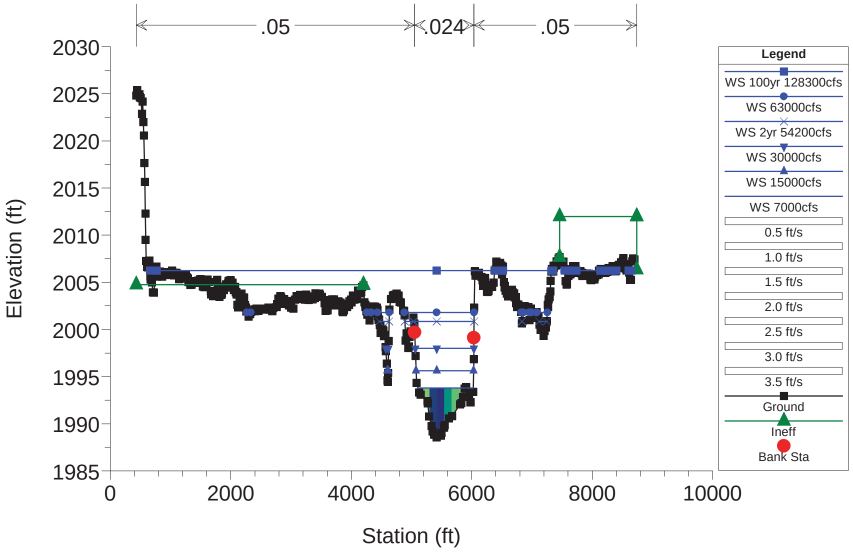
RS = 39170.03


Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

RS = 38214.43

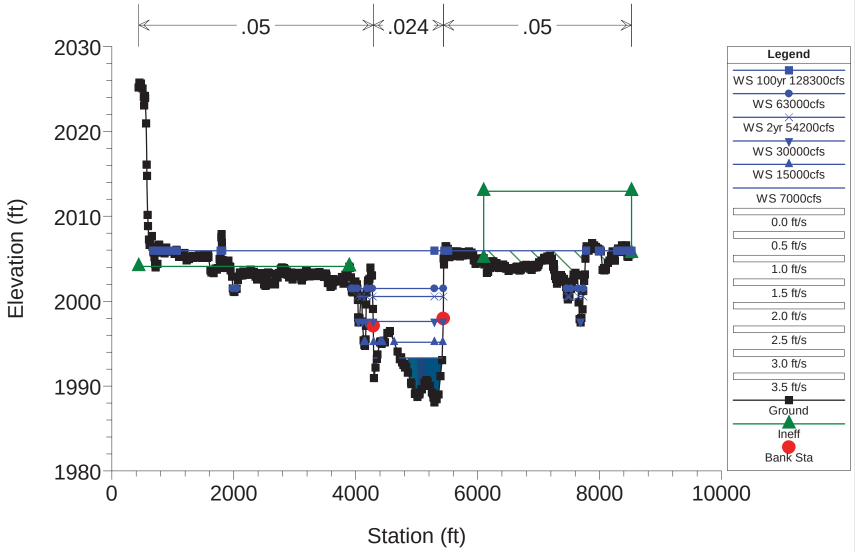
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

RS = 37074.57



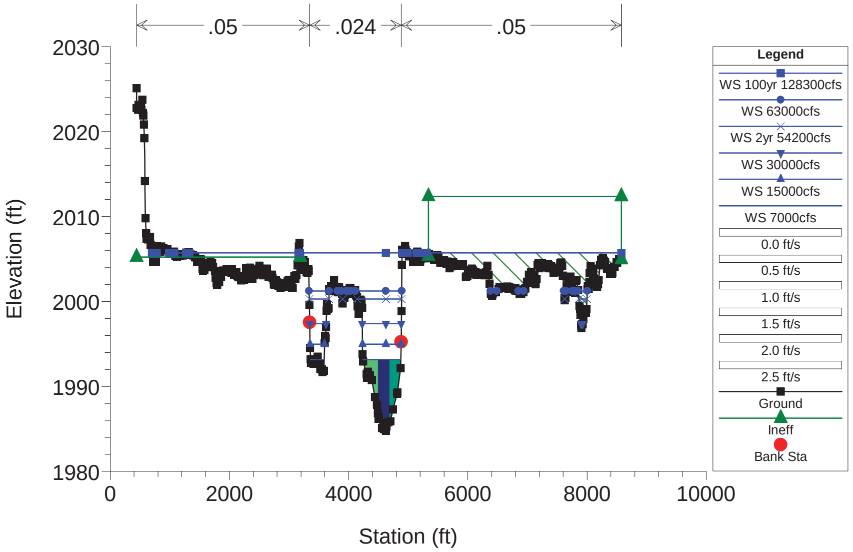
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

RS = 36104.97



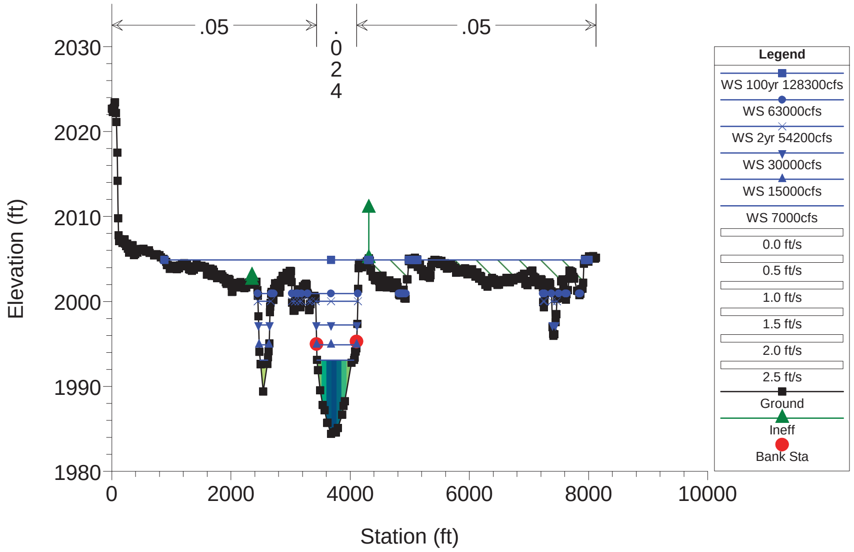
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

RS = 35375.29



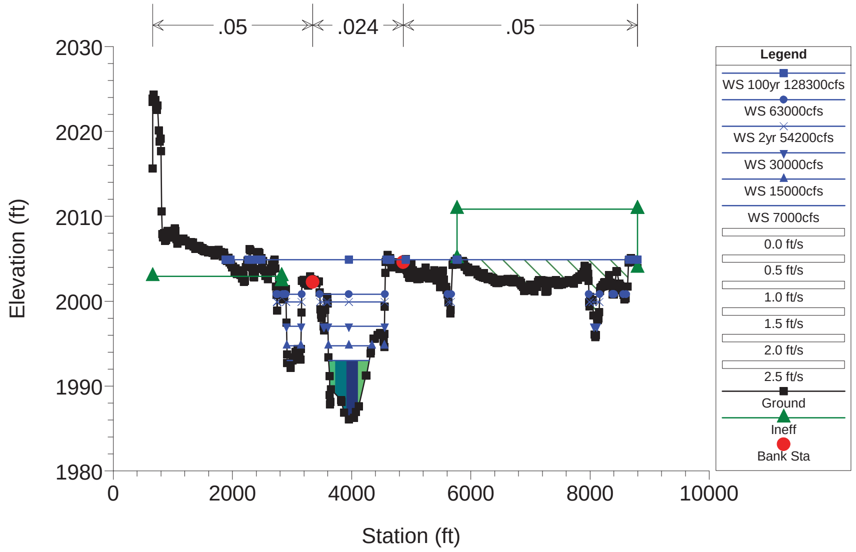
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

RS = 34889.88



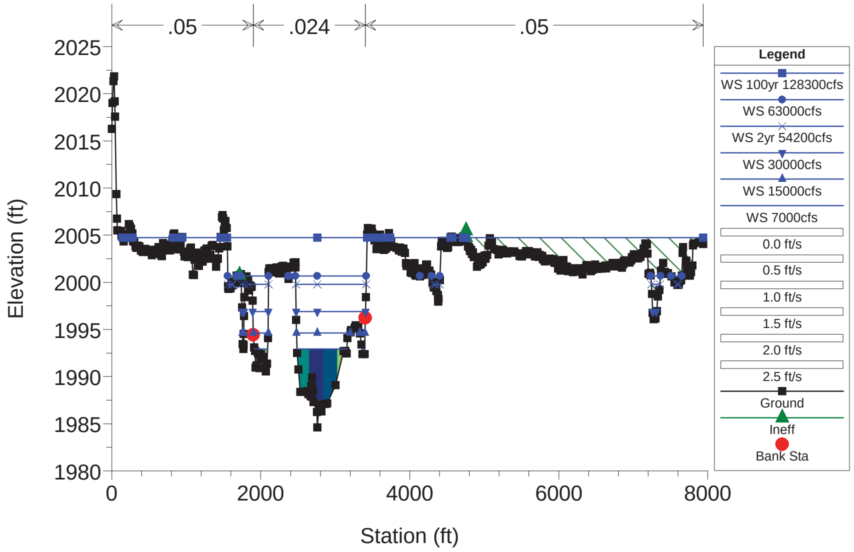
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

RS = 34191.19



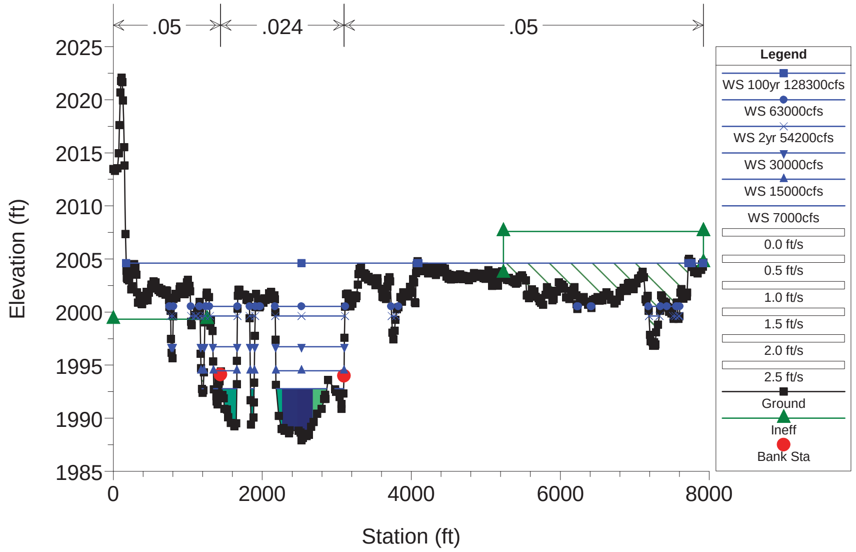
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

RS = 33735.56



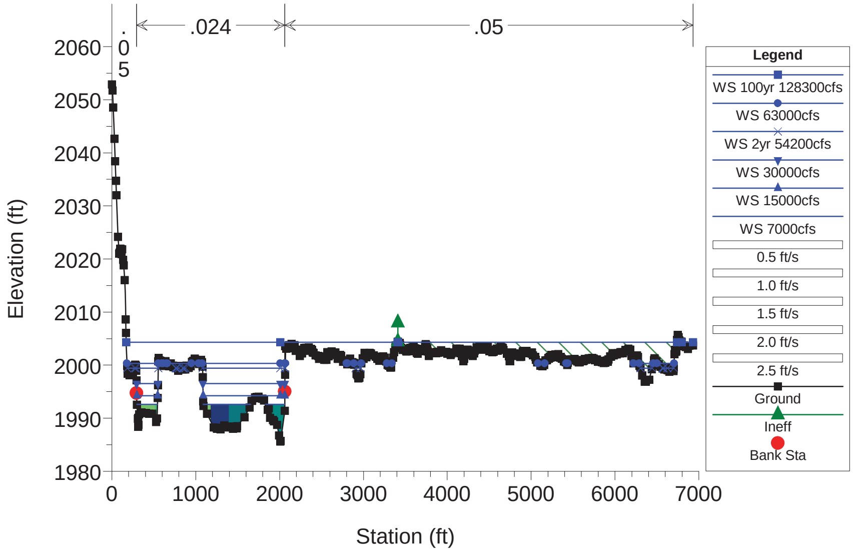
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

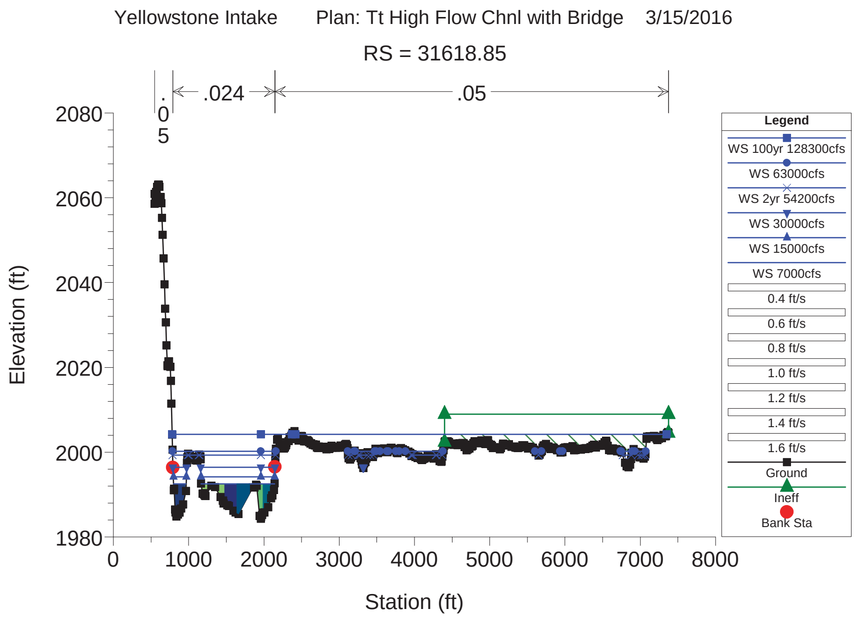
RS = 33047.64



Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

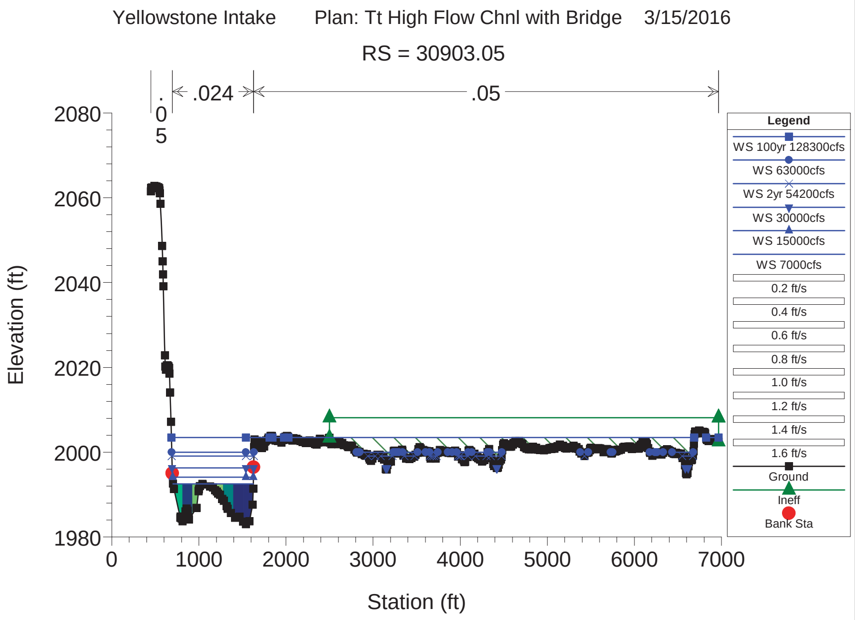
RS = 32272.67





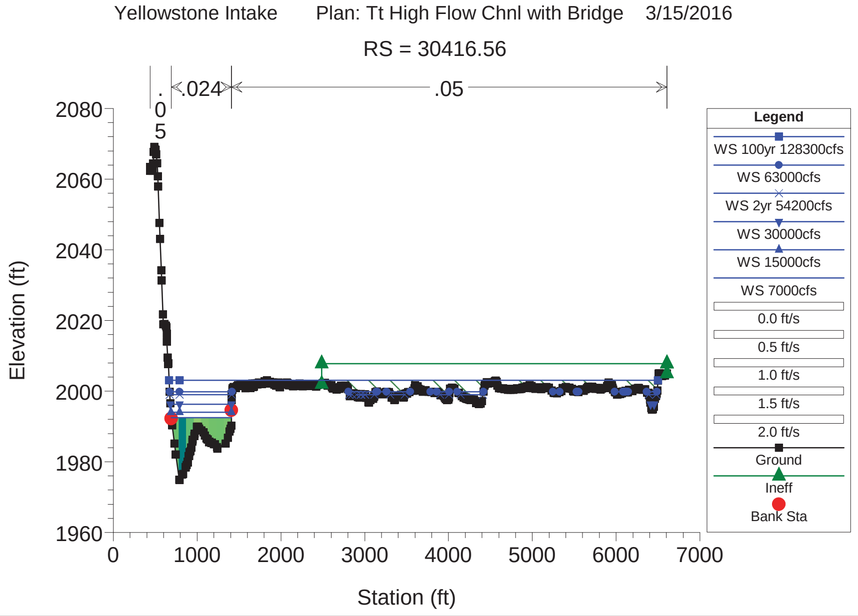
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

RS = 31618.85



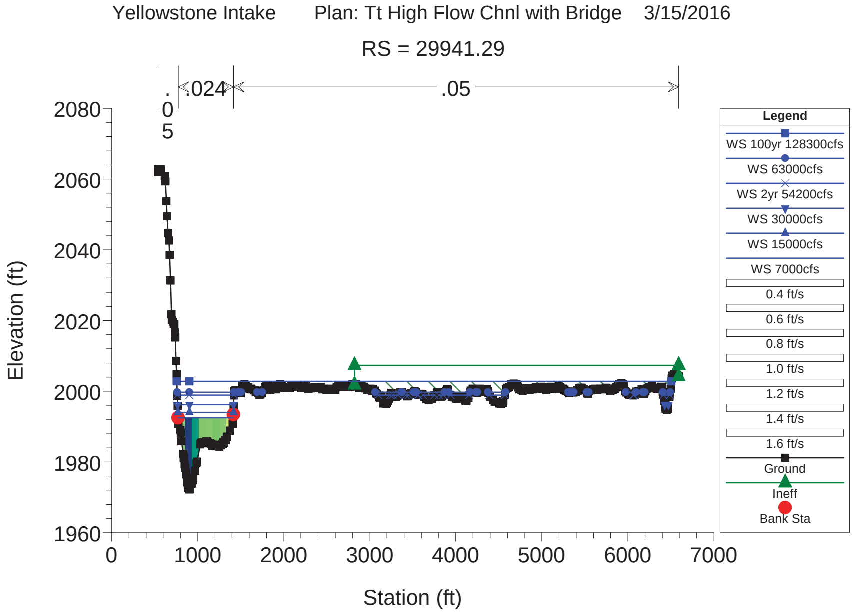
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

RS = 30903.05



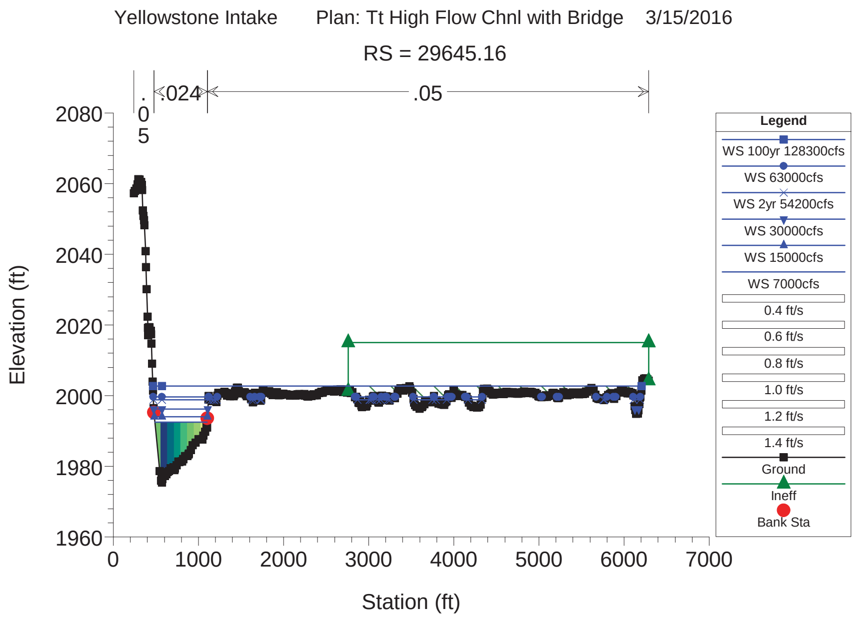
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

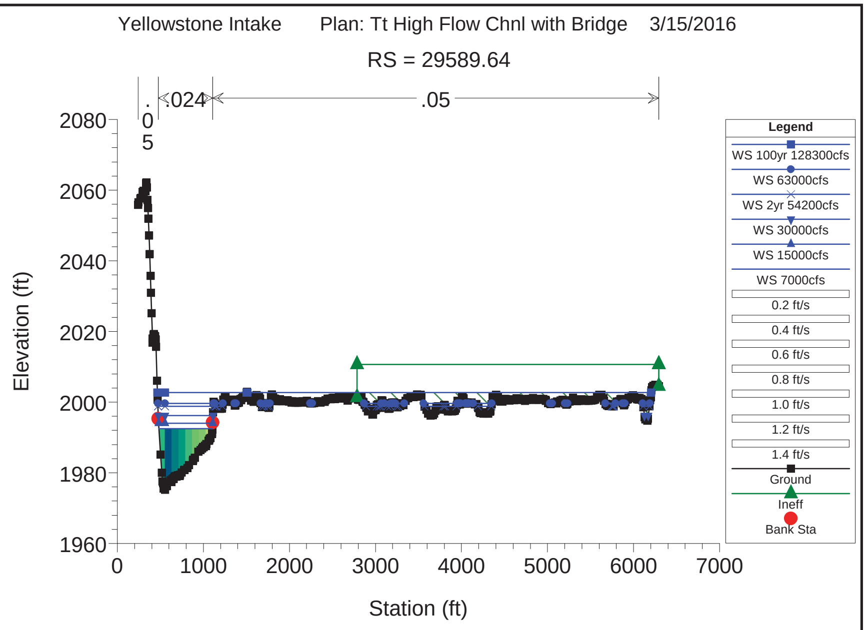
RS = 30416.56

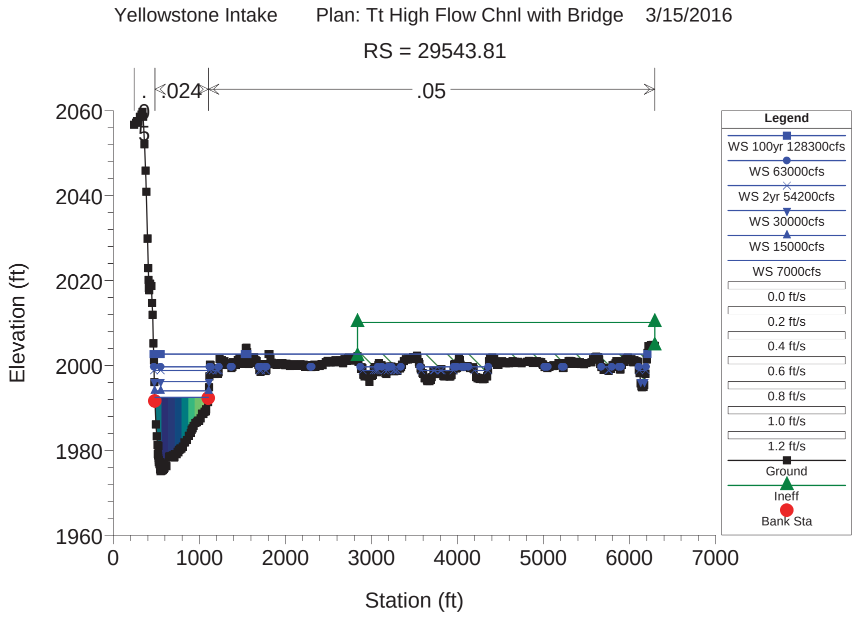


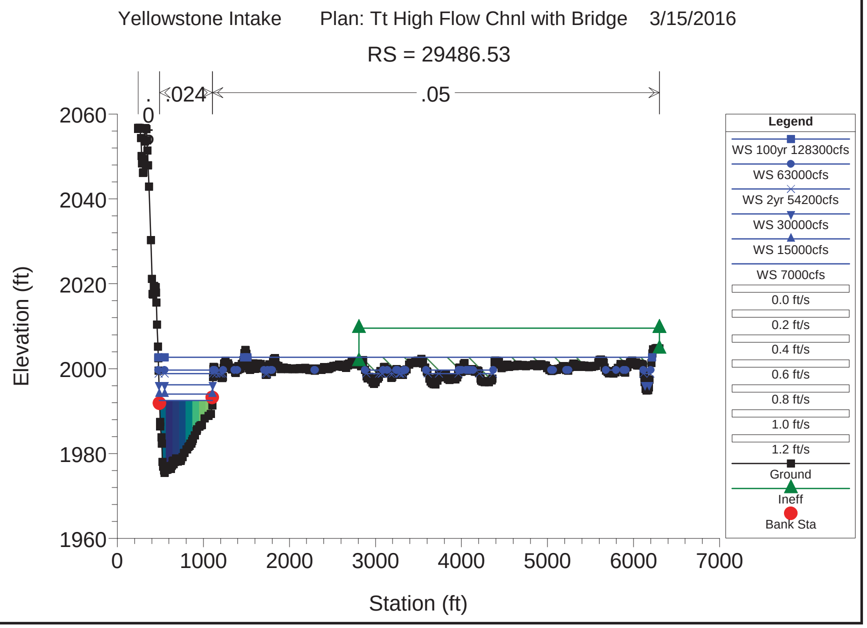
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

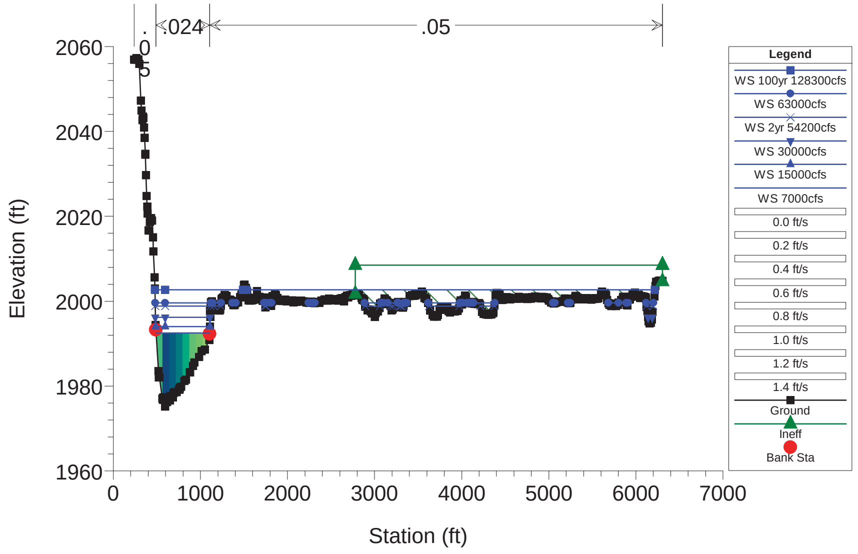
RS = 29941.29


Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 29645.16
.05
.024
.05
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.4 ft/s
0.6 ft/s
0.8 ft/s
1.0 ft/s
1.2 ft/s
1.4 ft/s
Ground
Ineff
Bank Sta
Elevation (ft)
2080
2060
2040
2020
2000
1980
1960
Station (ft)
0
1000
2000
3000
4000
5000
6000
7000


Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 29589.64
.05
.024
.05
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.2 ft/s
0.4 ft/s
0.6 ft/s
0.8 ft/s
1.0 ft/s
1.2 ft/s
1.4 ft/s
Ground
Ineff
Bank Sta
Elevation (ft)
2080
2060
2040
2020
2000
1980
1960
Station (ft)
0
1000
2000
3000
4000
5000
6000
7000

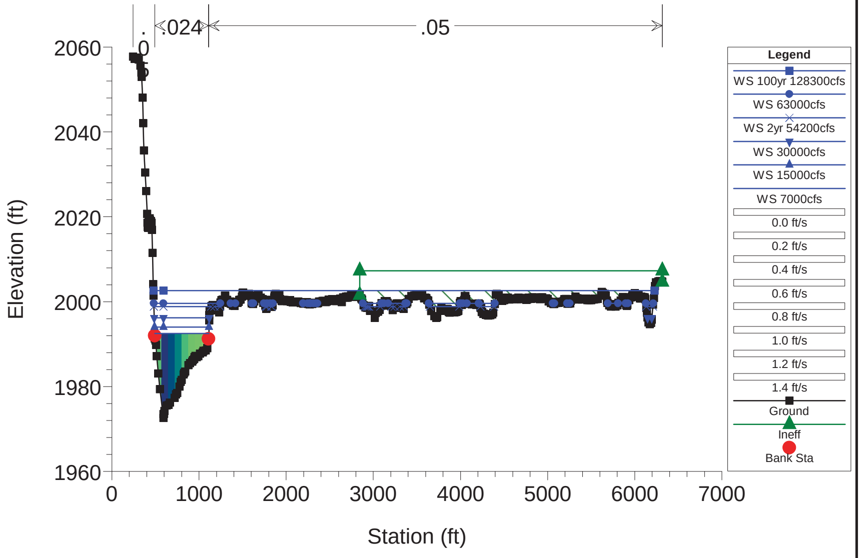

Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 29543.81
.05
.024
.05
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.0 ft/s
0.2 ft/s
0.4 ft/s
0.6 ft/s
0.8 ft/s
1.0 ft/s
1.2 ft/s
Ground
Ineff
Bank Sta
Elevation (ft)
2060
2040
2020
2000
1980
1960
Station (ft)
0
1000
2000
3000
4000
5000
6000
7000


Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 29486.53
.05
.024
.05
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.0 ft/s
0.2 ft/s
0.4 ft/s
0.6 ft/s
0.8 ft/s
1.0 ft/s
1.2 ft/s
Ground
Ineff
Bank Sta
Elevation (ft)
2060
2040
2020
2000
1980
1960
Station (ft)
0
1000
2000
3000
4000
5000
6000
7000



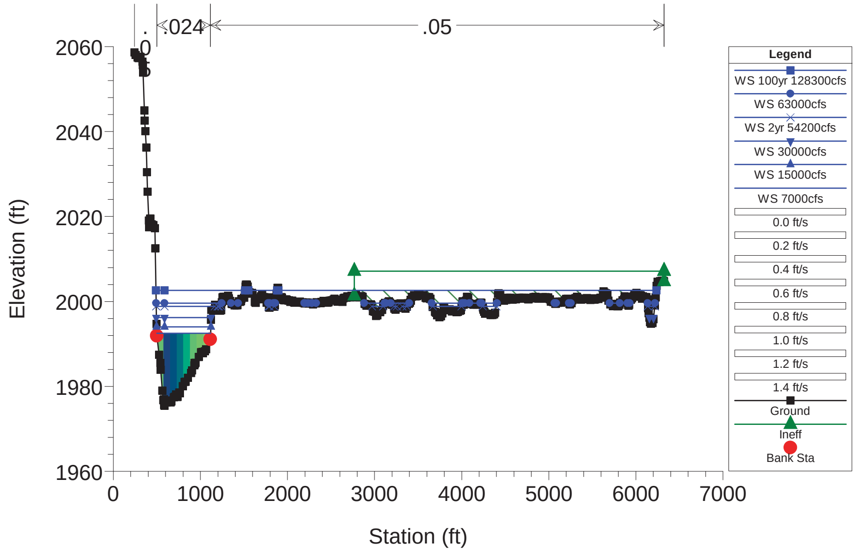
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

RS = 29444.45



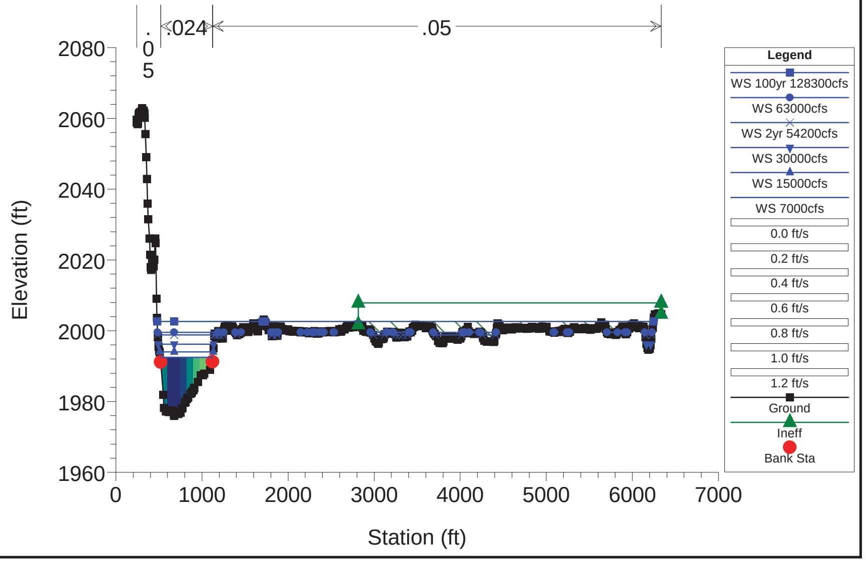
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

RS = 29392.44



Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

RS = 29345.32

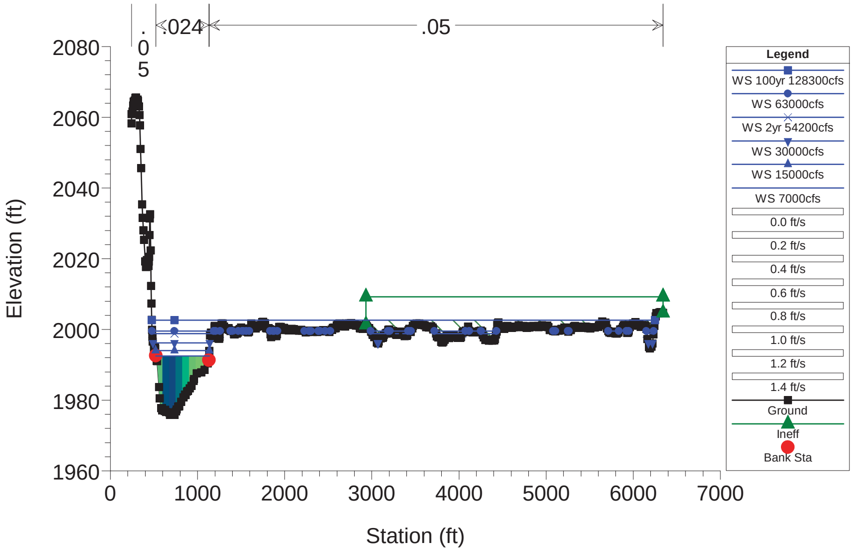


Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

RS = 29293.13

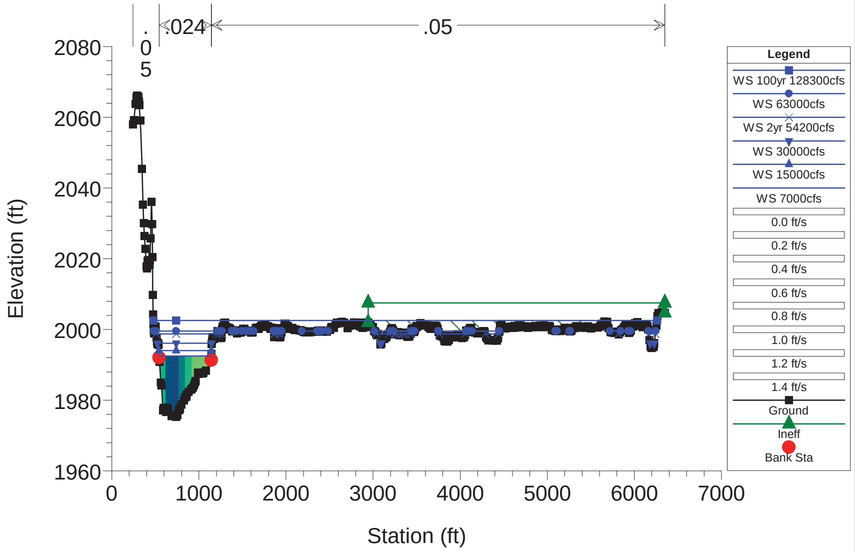
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

RS = 29245.19



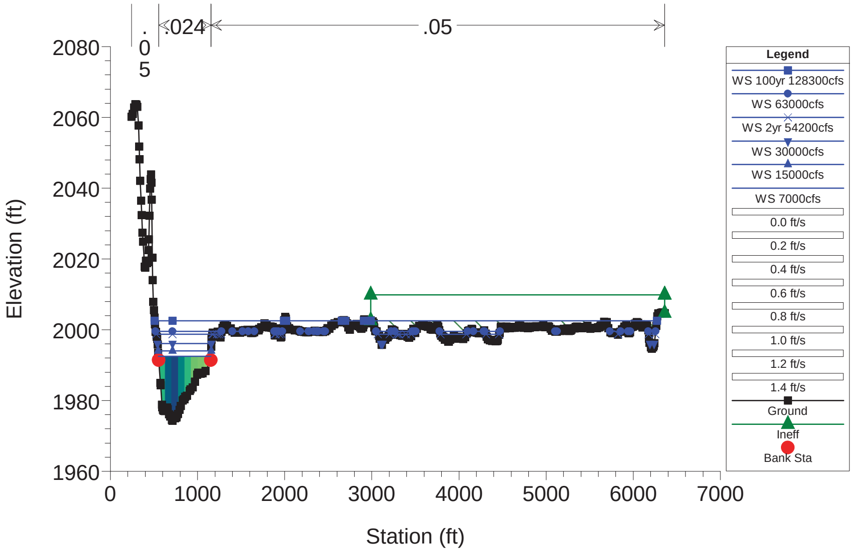
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

RS = 29197.49



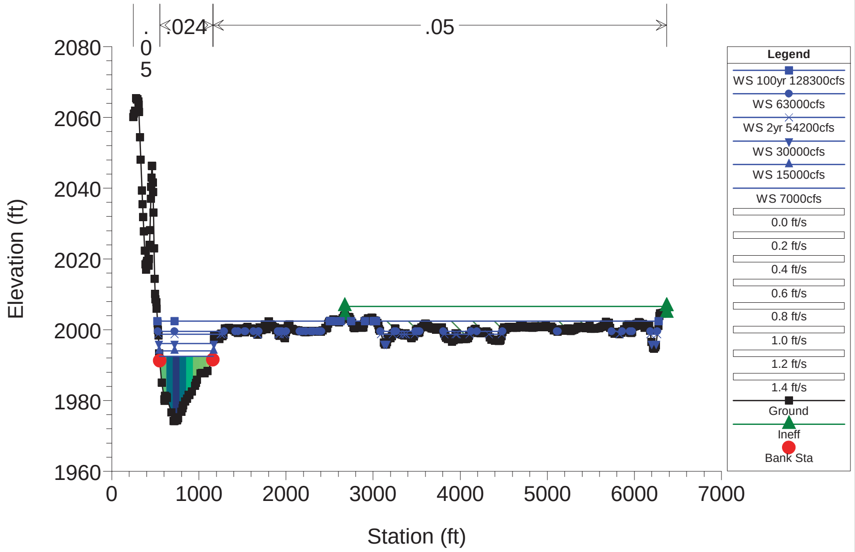
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

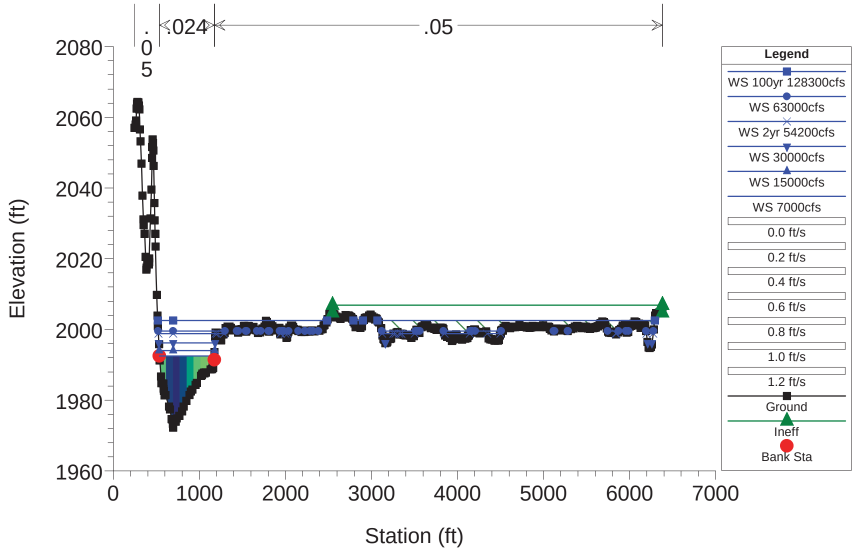
RS = 29148.45



Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

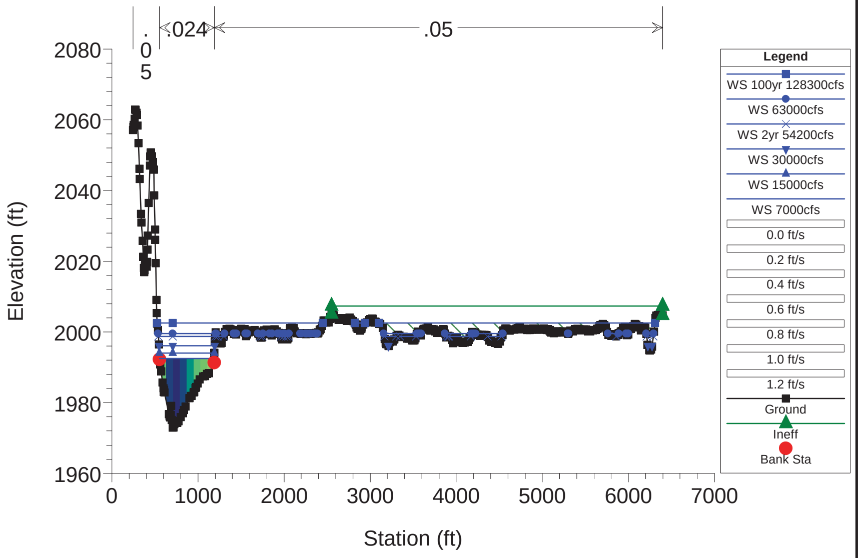
RS = 29099.87





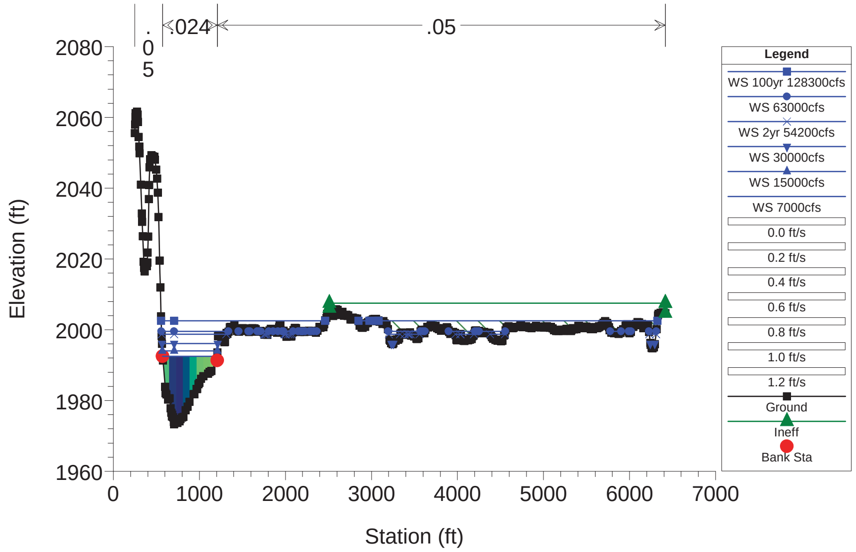
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

RS = 29047.75



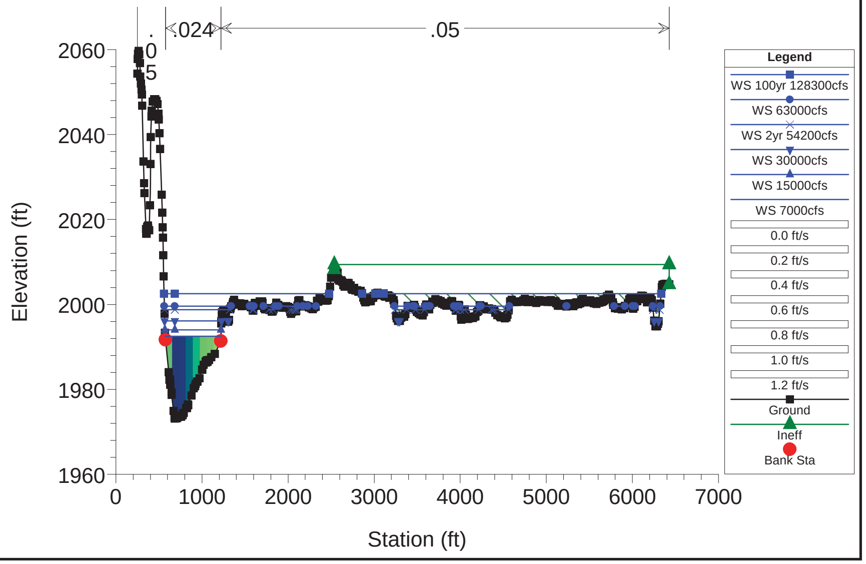
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

RS = 28998.60



Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

RS = 28947.07

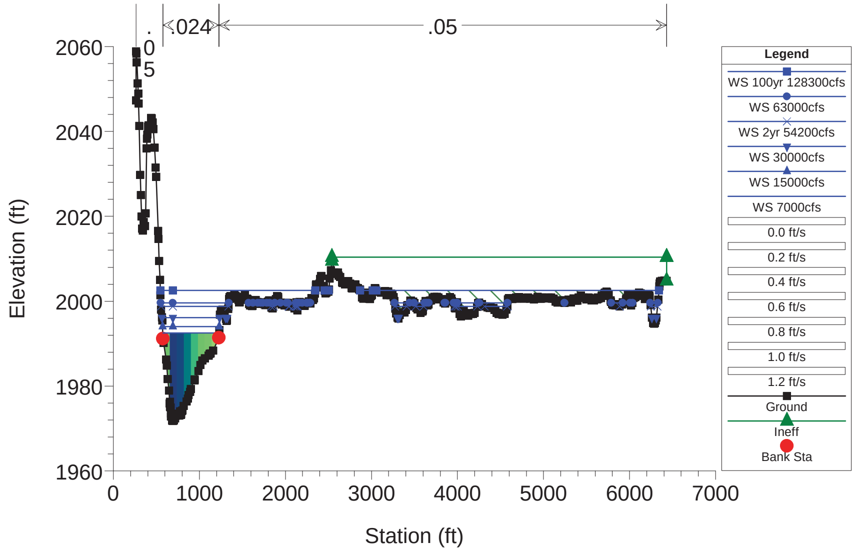


Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

RS = 28897.52

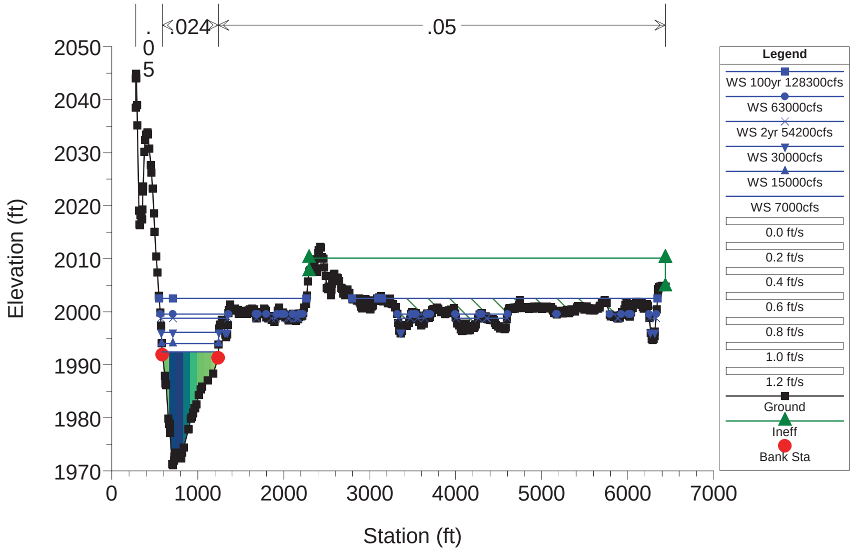
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

RS = 28849.13



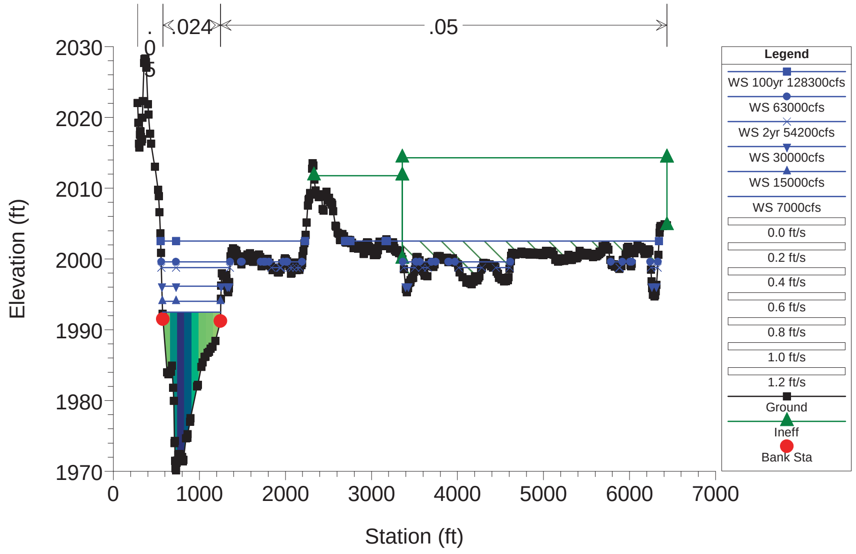
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

RS = 28800.76



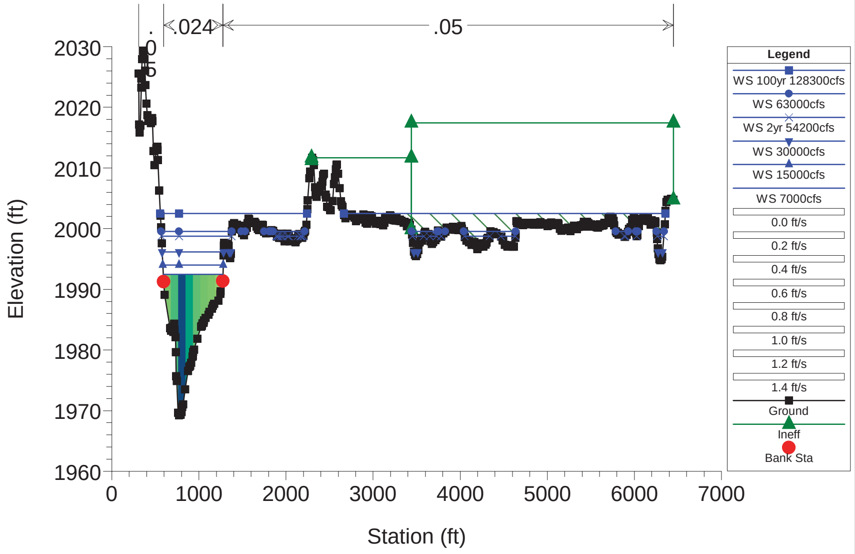
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

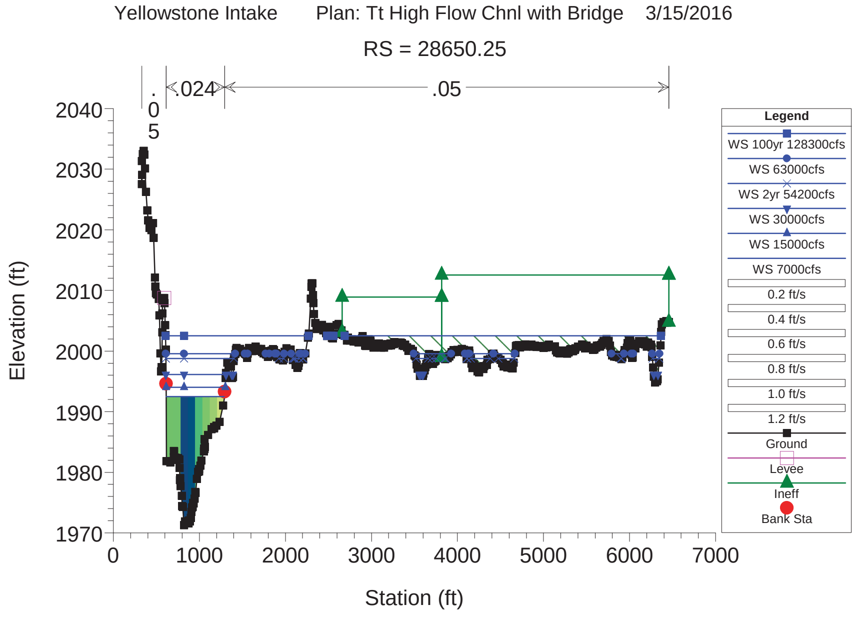
RS = 28752.58

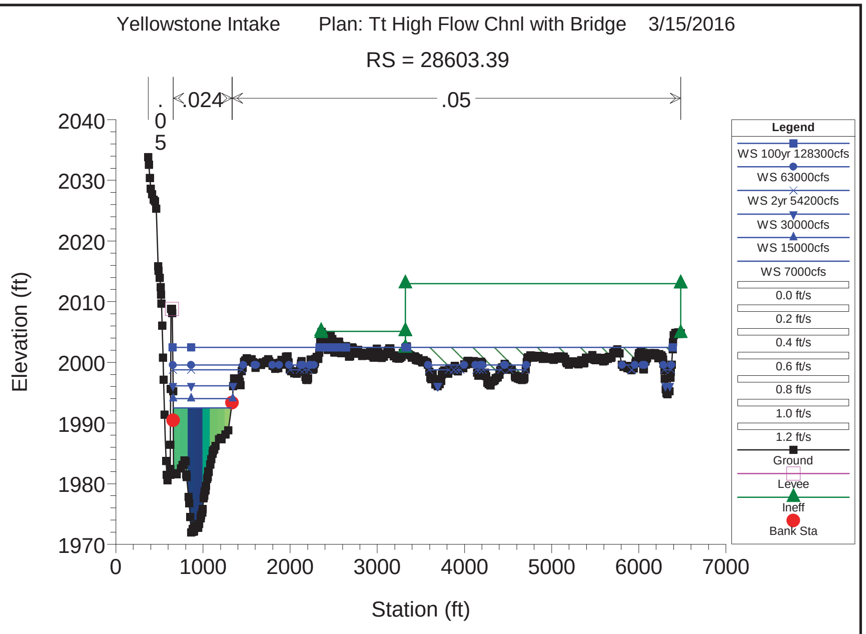


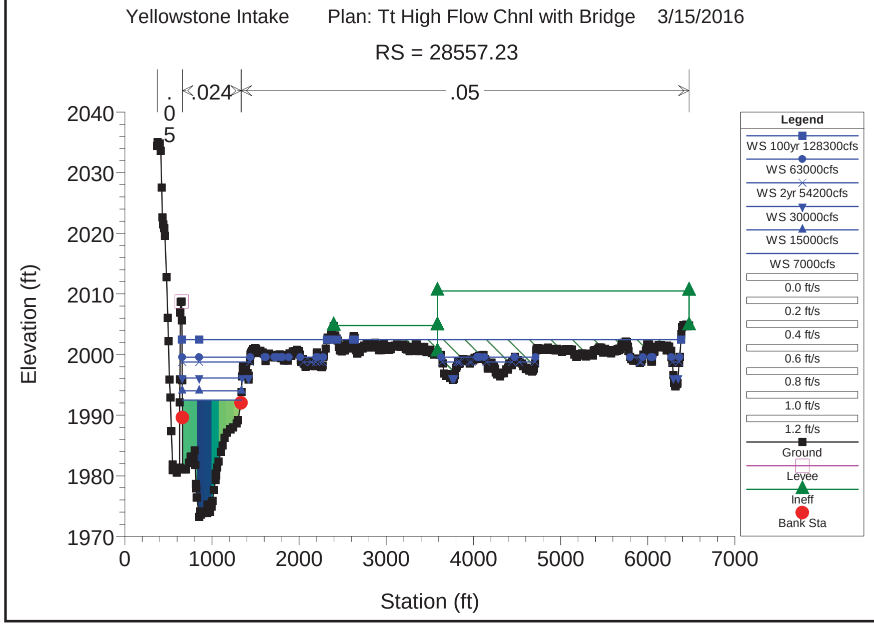
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

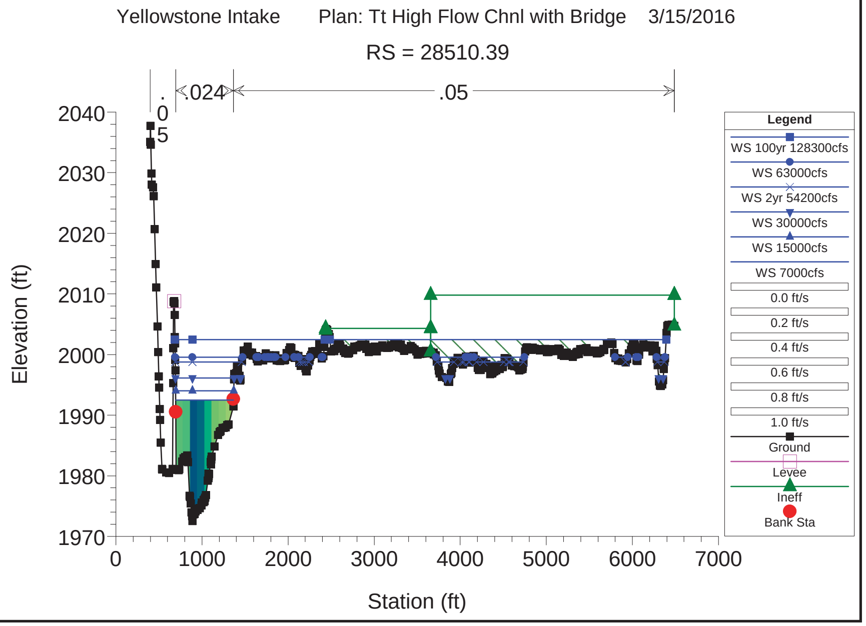
RS = 28702.18

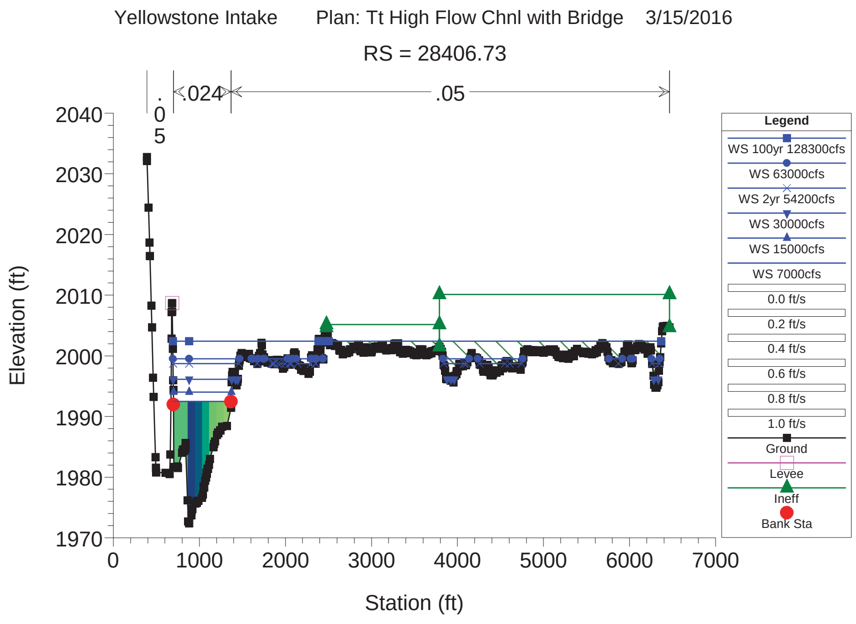


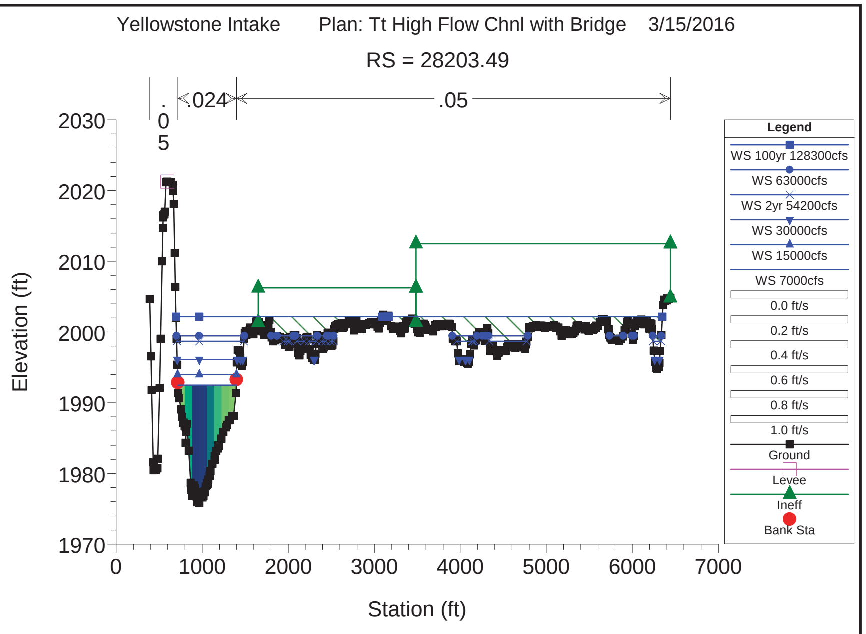

Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 28650.25
.05
.024
.05
Elevation (ft)
Station (ft)
2040
2030
2020
2010
2000
1990
1980
1970
0
1000
2000
3000
4000
5000
6000
7000
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.2 ft/s
0.4 ft/s
0.6 ft/s
0.8 ft/s
1.0 ft/s
1.2 ft/s
Ground
Levee
Ineff
Bank Sta

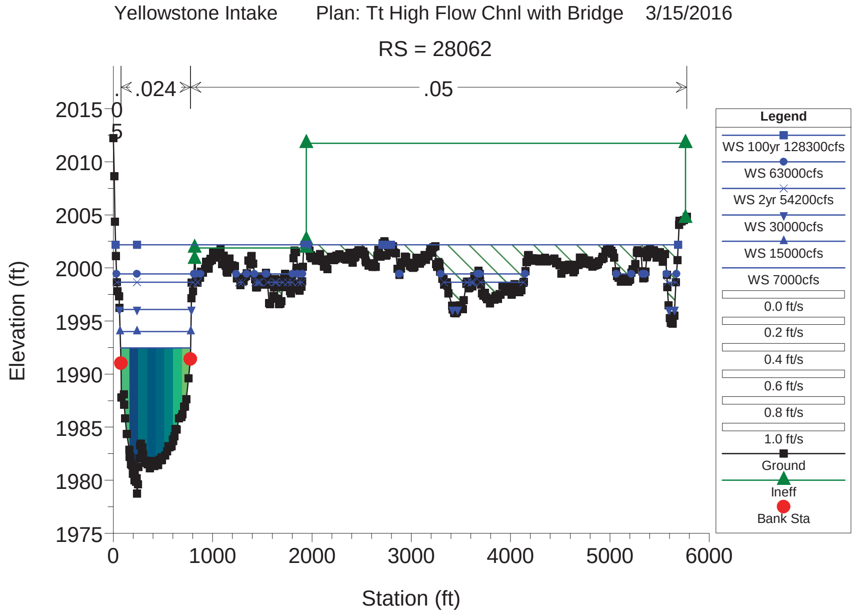

Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 28603.39
.05
.024
.05
Elevation (ft)
Station (ft)
2040
2030
2020
2010
2000
1990
1980
1970
0
1000
2000
3000
4000
5000
6000
7000
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.0 ft/s
0.2 ft/s
0.4 ft/s
0.6 ft/s
0.8 ft/s
1.0 ft/s
1.2 ft/s
Ground
Levee
Ineff
Bank Sta

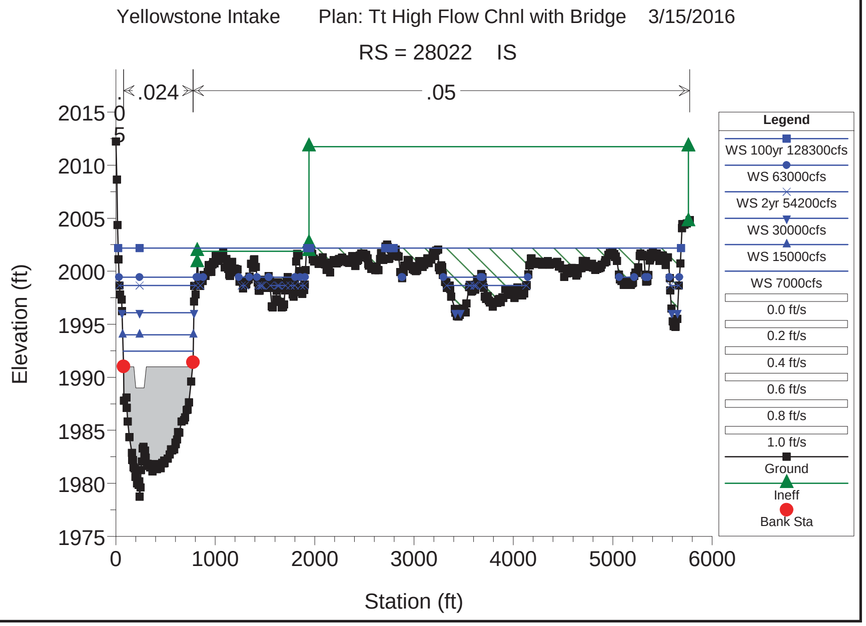

Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 28557.23
.05
.024
.05
Elevation (ft)
Station (ft)
2040
2030
2020
2010
2000
1990
1980
1970
0
1000
2000
3000
4000
5000
6000
7000
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.0 ft/s
0.2 ft/s
0.4 ft/s
0.6 ft/s
0.8 ft/s
1.0 ft/s
1.2 ft/s
Ground
Levee
Ineff
Bank Sta


Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 28510.39
.05
.024
.05
Elevation (ft)
Station (ft)
2040
2030
2020
2010
2000
1990
1980
1970
0
1000
2000
3000
4000
5000
6000
7000
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.0 ft/s
0.2 ft/s
0.4 ft/s
0.6 ft/s
0.8 ft/s
1.0 ft/s
Ground
Levee
Ineff
Bank Sta


Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 28406.73
.05
.024
.05
Elevation (ft)
Station (ft)
2040
2030
2020
2010
2000
1990
1980
1970
0
1000
2000
3000
4000
5000
6000
7000
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.0 ft/s
0.2 ft/s
0.4 ft/s
0.6 ft/s
0.8 ft/s
1.0 ft/s
Ground
Levee
Ineff
Bank Sta

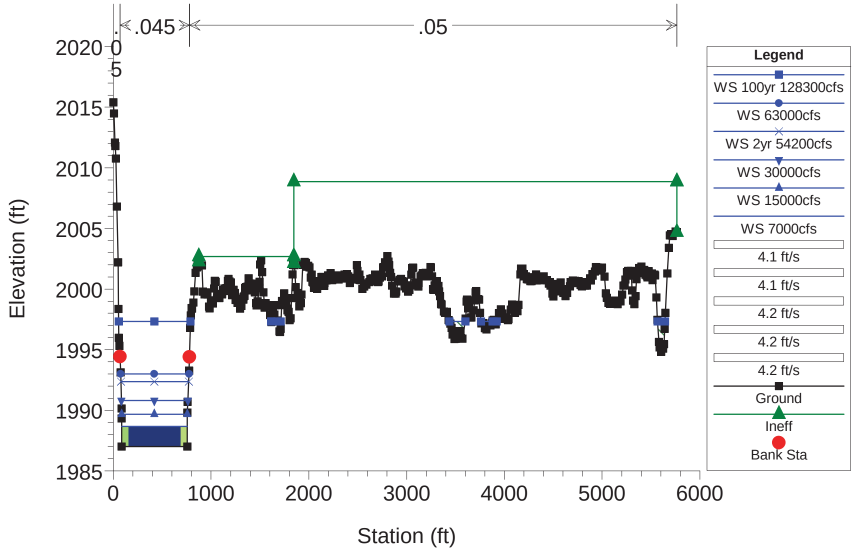

Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 28203.49
.05
.024
.05
Elevation (ft)
Station (ft)
2030
2020
2010
2000
1990
1980
1970
0
1000
2000
3000
4000
5000
6000
7000
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.0 ft/s
0.2 ft/s
0.4 ft/s
0.6 ft/s
0.8 ft/s
1.0 ft/s
Ground
Levee
Ineff
Bank Sta


Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 28062
.05
.024
.05
Elevation (ft)
Station (ft)
2015
2010
2005
2000
1995
1990
1985
1980
1975
0
1000
2000
3000
4000
5000
6000
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.0 ft/s
0.2 ft/s
0.4 ft/s
0.6 ft/s
0.8 ft/s
1.0 ft/s
Ground
Ineff
Bank Sta


Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 28022 IS
.05
.024
.05
Elevation (ft)
Station (ft)
2015
2010
2005
2000
1995
1990
1985
1980
1975
0
1000
2000
3000
4000
5000
6000
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.0 ft/s
0.2 ft/s
0.4 ft/s
0.6 ft/s
0.8 ft/s
1.0 ft/s
Ground
Ineff
Bank Sta

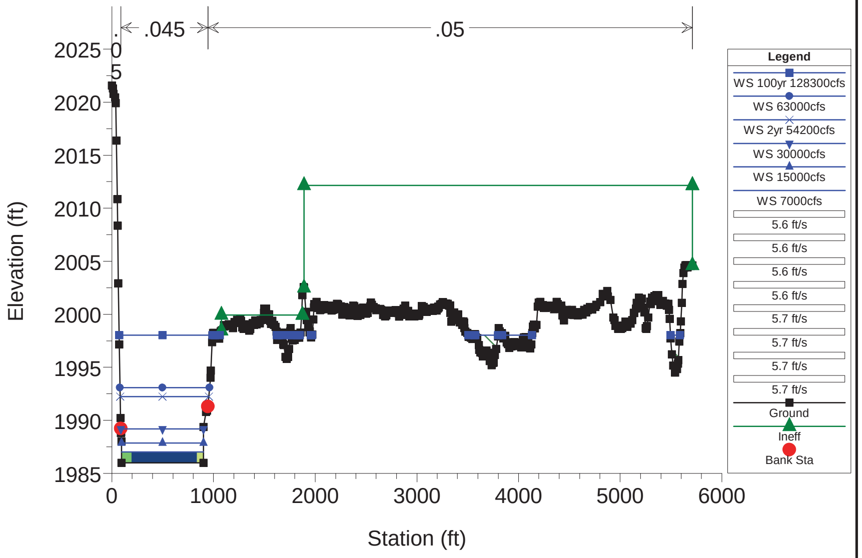
Yellowstone Intake   Plan: Tt High Flow Chnl with Bridge   3/15/2016

RS = 28012.06



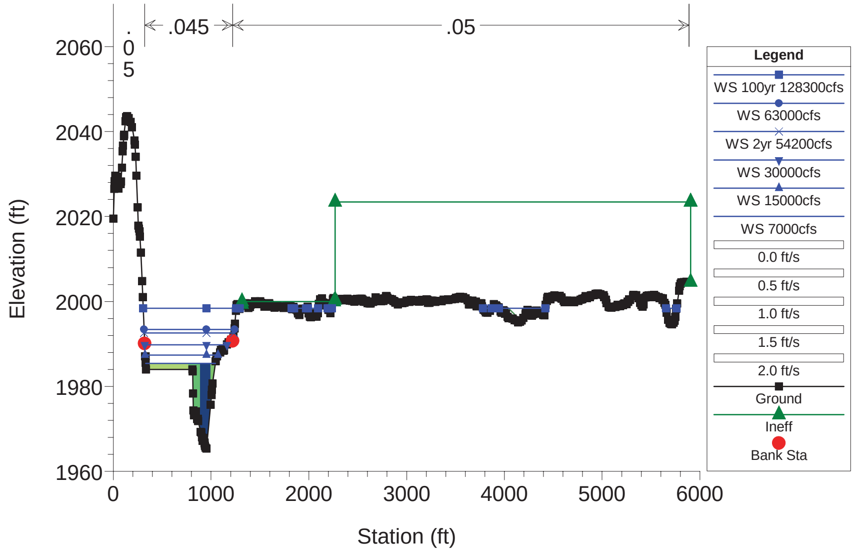
Yellowstone Intake   Plan: Tt High Flow Chnl with Bridge   3/15/2016

RS = 27912.73



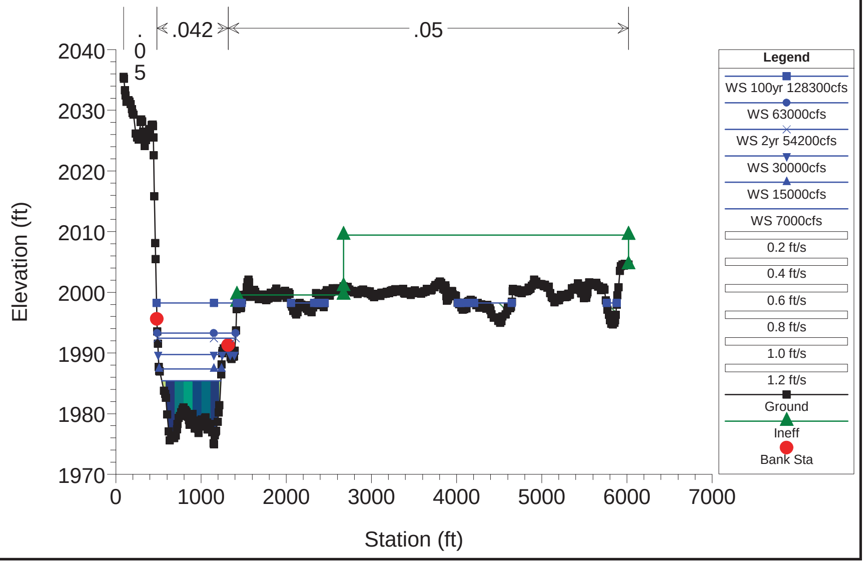
Yellowstone Intake   Plan: Tt High Flow Chnl with Bridge   3/15/2016

RS = 27778.92



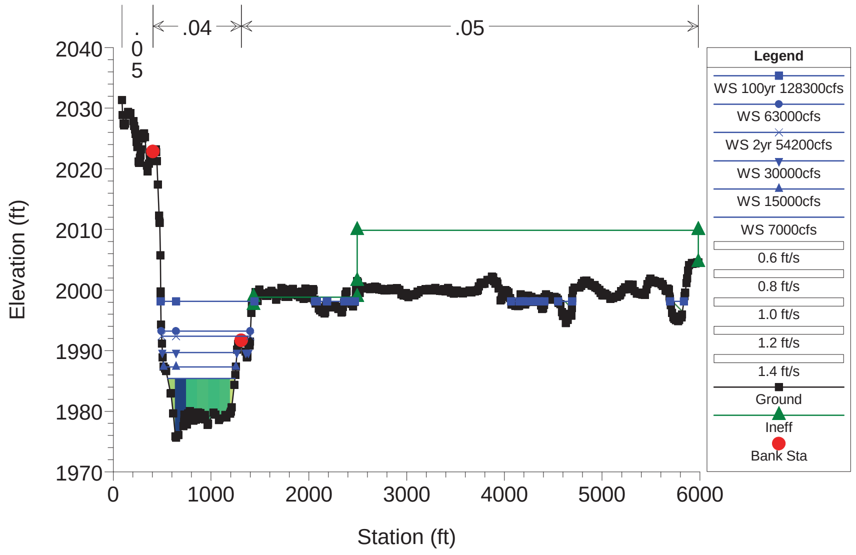
Yellowstone Intake   Plan: Tt High Flow Chnl with Bridge   3/15/2016

RS = 27597.18



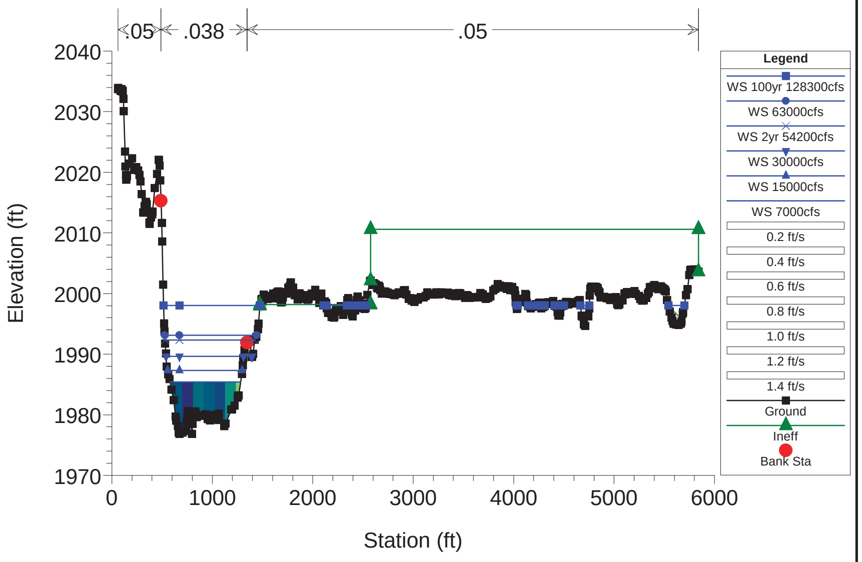
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

RS = 27550.20



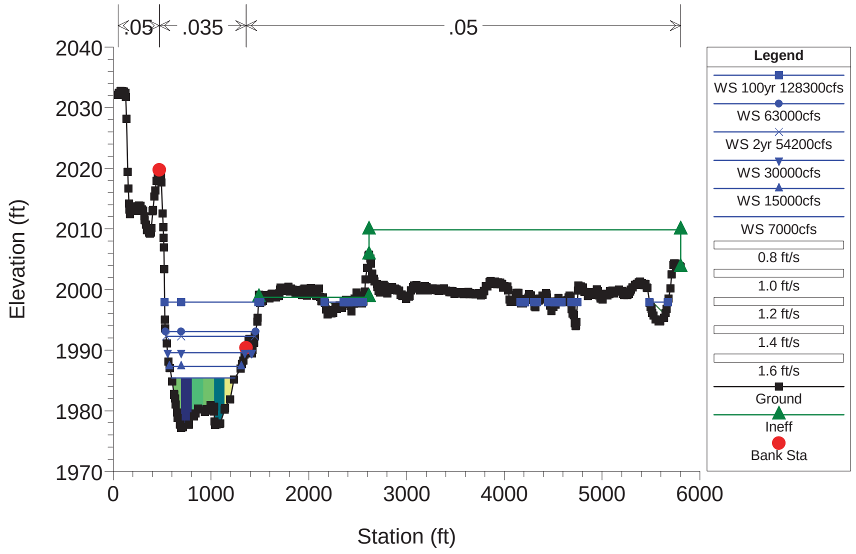
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

RS = 27498.33



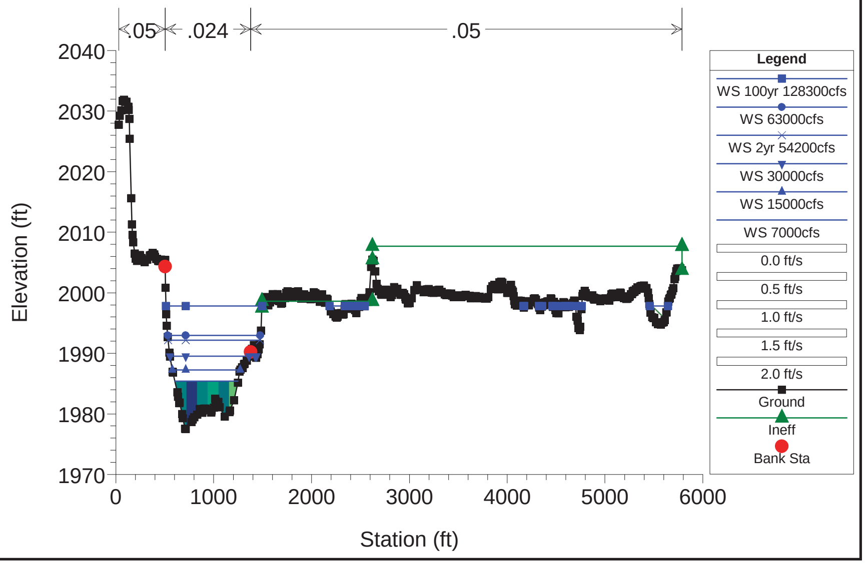
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

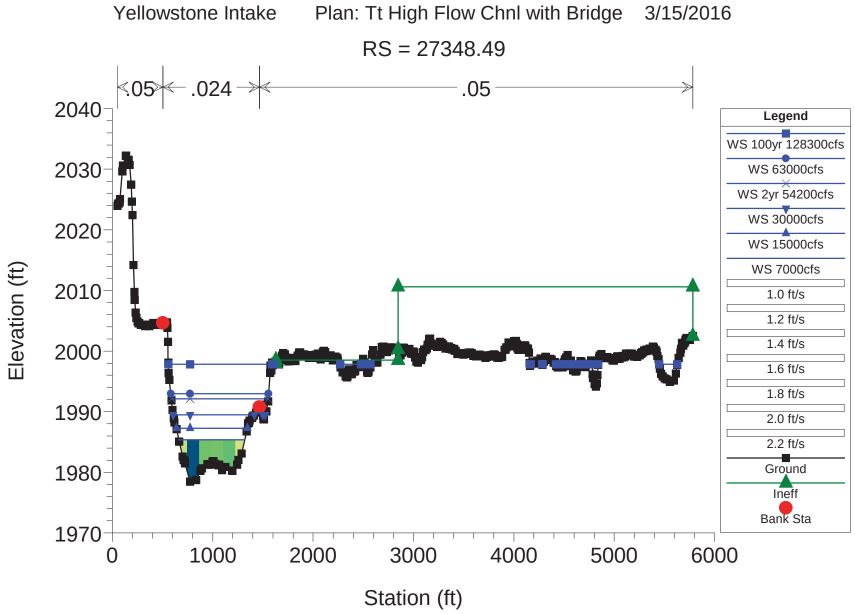
RS = 27447.08

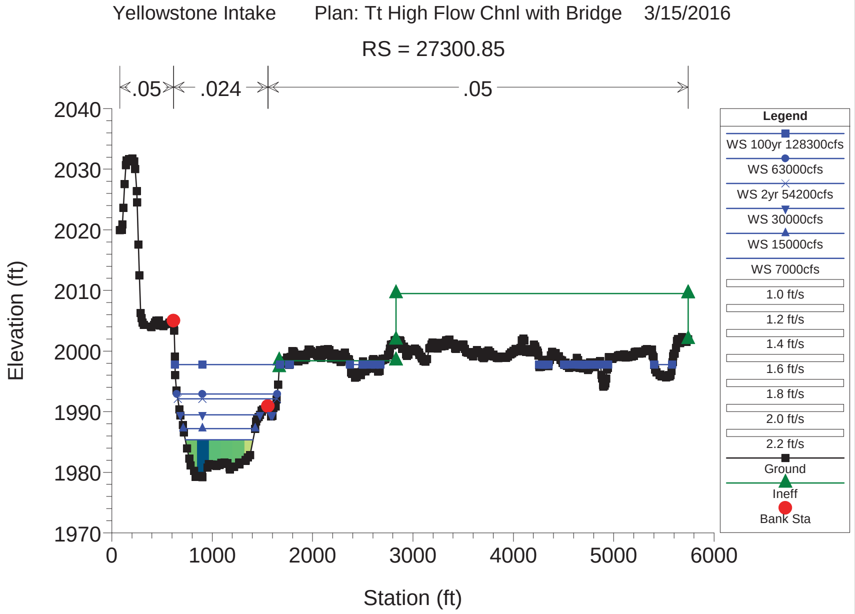


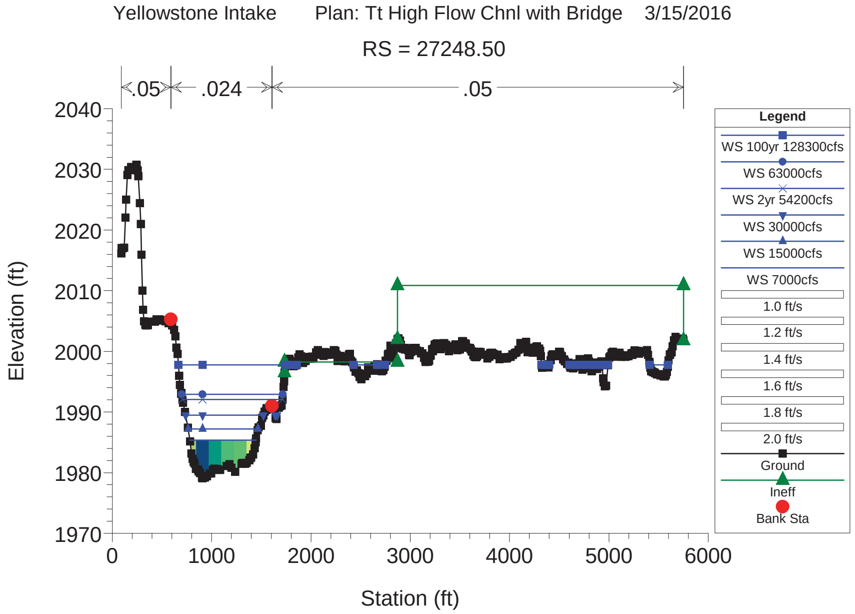
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

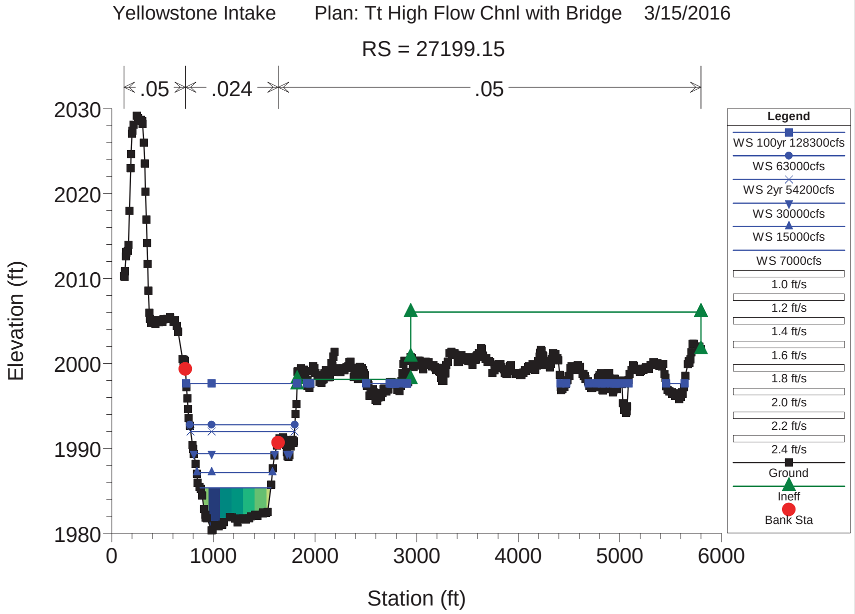
RS = 27398.93

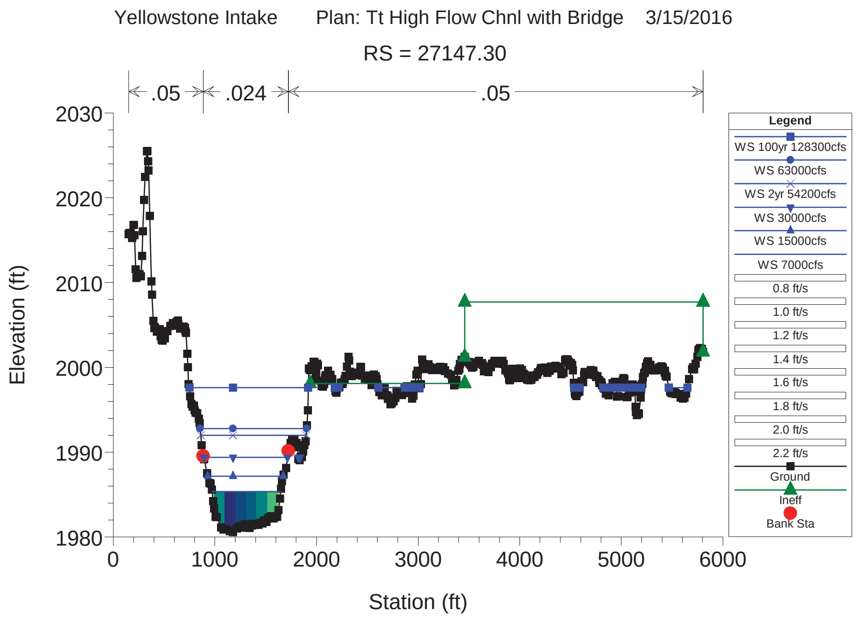


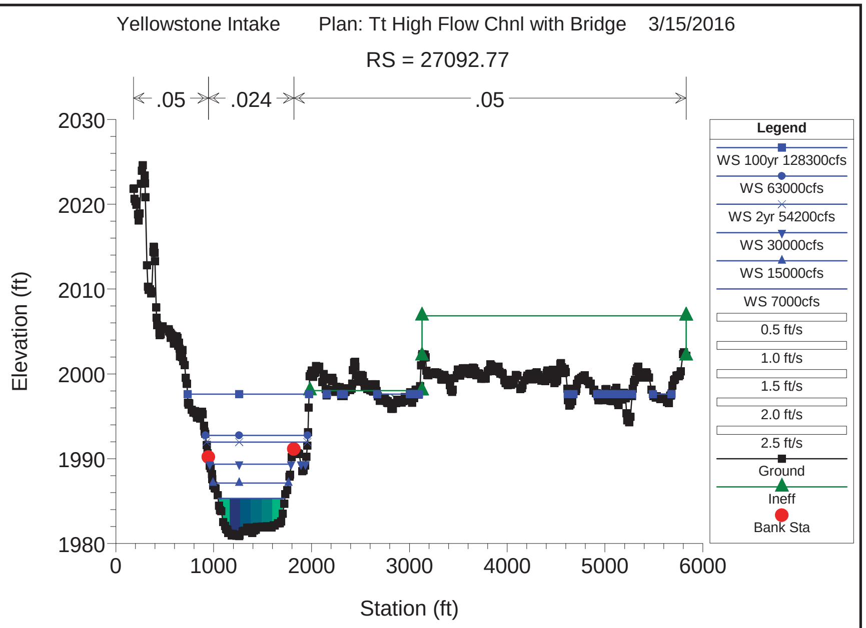

Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 27348.49
.05
.024
.05
Elevation (ft)
2040
2030
2020
2010
2000
1990
1980
1970
0
1000
2000
3000
4000
5000
6000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
1.0 ft/s
1.2 ft/s
1.4 ft/s
1.6 ft/s
1.8 ft/s
2.0 ft/s
2.2 ft/s
Ground
Ineff
Bank Sta

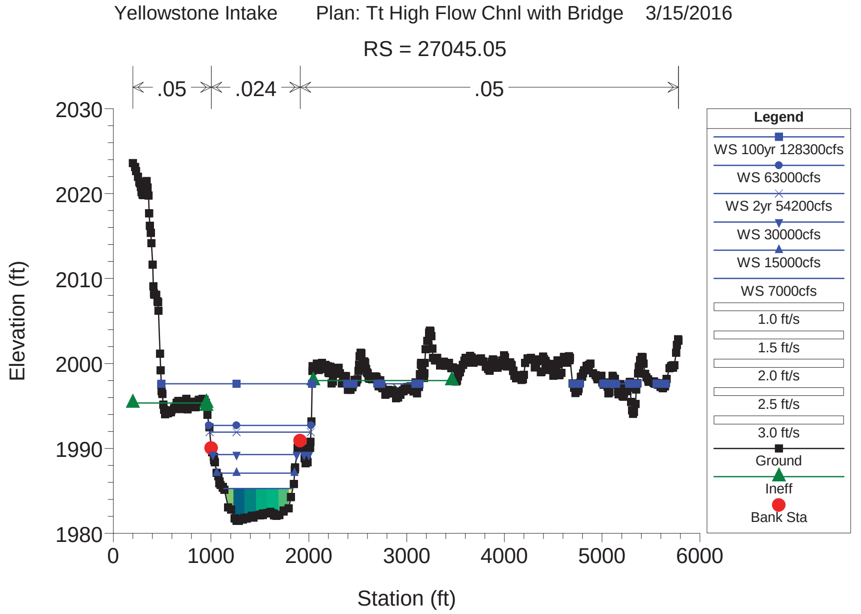

Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 27300.85
.05
.024
.05
Elevation (ft)
2040
2030
2020
2010
2000
1990
1980
1970
0
1000
2000
3000
4000
5000
6000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
1.0 ft/s
1.2 ft/s
1.4 ft/s
1.6 ft/s
1.8 ft/s
2.0 ft/s
2.2 ft/s
Ground
Ineff
Bank Sta

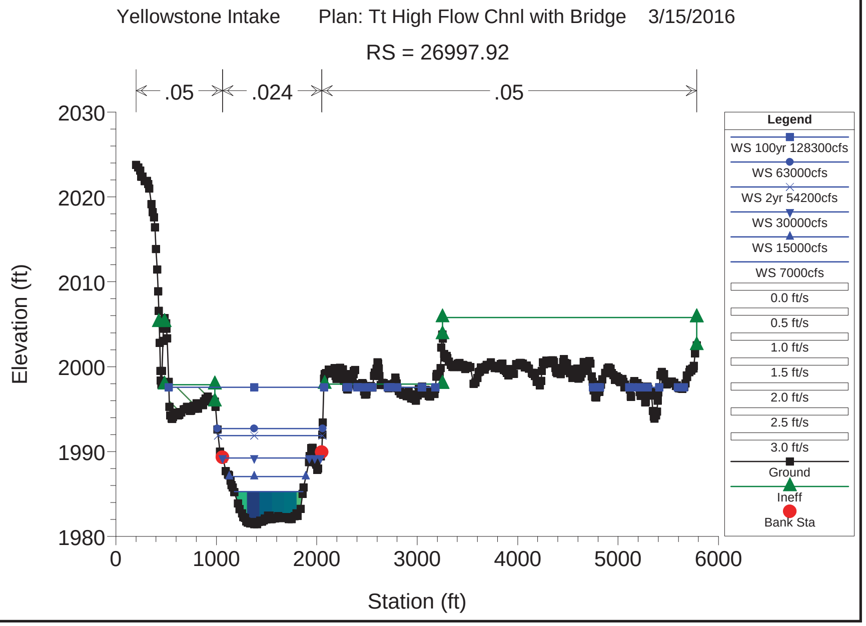

Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 27248.50
.05
.024
.05
Elevation (ft)
2040
2030
2020
2010
2000
1990
1980
1970
0
1000
2000
3000
4000
5000
6000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
1.0 ft/s
1.2 ft/s
1.4 ft/s
1.6 ft/s
1.8 ft/s
2.0 ft/s
Ground
Ineff
Bank Sta

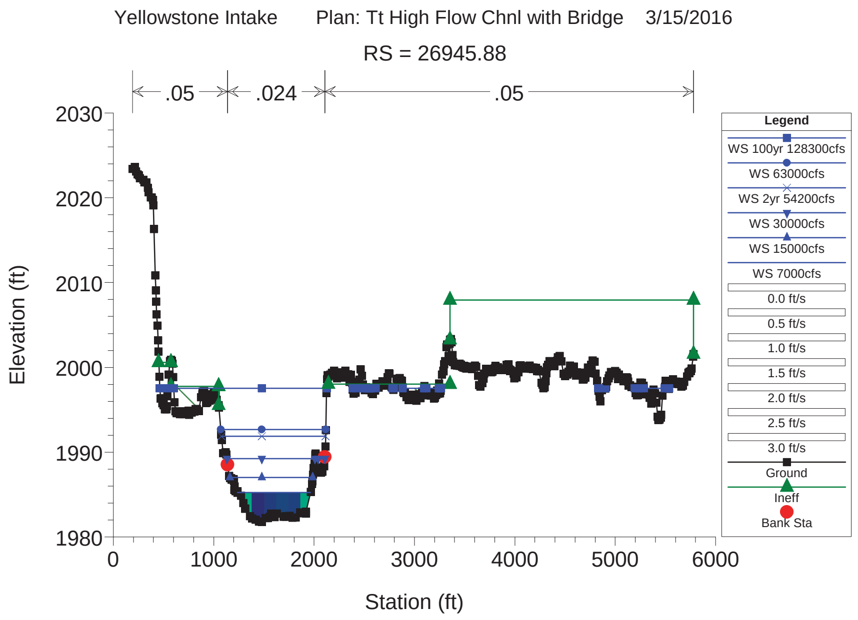

Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 27199.15
.05
.024
.05
Elevation (ft)
2030
2020
2010
2000
1990
1980
0
1000
2000
3000
4000
5000
6000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
1.0 ft/s
1.2 ft/s
1.4 ft/s
1.6 ft/s
1.8 ft/s
2.0 ft/s
2.2 ft/s
2.4 ft/s
Ground
Ineff
Bank Sta


Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 27147.30
.05
.024
.05
Elevation (ft)
2030
2020
2010
2000
1990
1980
0
1000
2000
3000
4000
5000
6000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.8 ft/s
1.0 ft/s
1.2 ft/s
1.4 ft/s
1.6 ft/s
1.8 ft/s
2.0 ft/s
2.2 ft/s
Ground
Ineff
Bank Sta

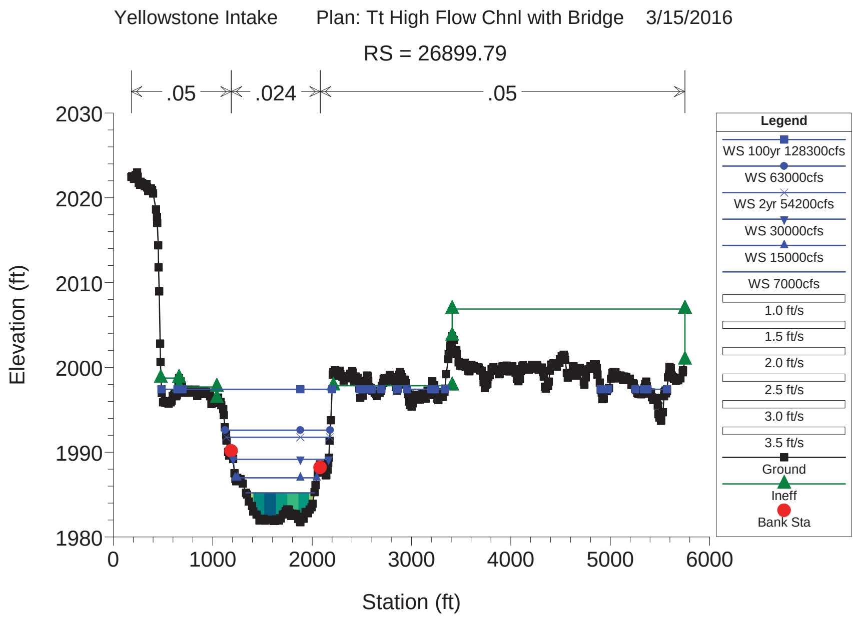

Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 27092.77
.05
.024
.05
Elevation (ft)
2030
2020
2010
2000
1990
1980
0
1000
2000
3000
4000
5000
6000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
Ground
Ineff
Bank Sta


Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 27045.05
.05
.024
.05
Elevation (ft)
2030
2020
2010
2000
1990
1980
0
1000
2000
3000
4000
5000
6000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
Ground
Ineff
Bank Sta

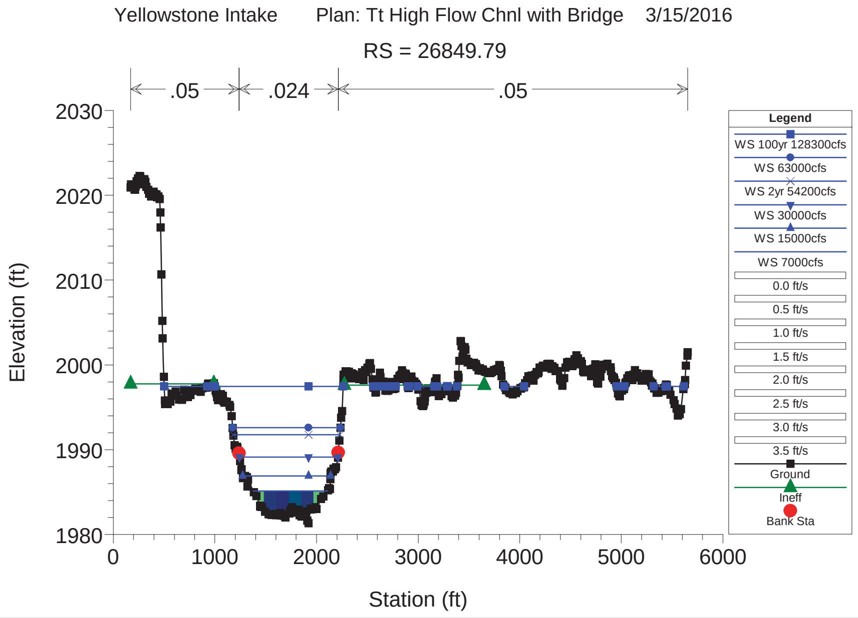

Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 26997.92
.05
.024
.05
Elevation (ft)
2030
2020
2010
2000
1990
1980
0
1000
2000
3000
4000
5000
6000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.0 ft/s
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
Ground
Ineff
Bank Sta



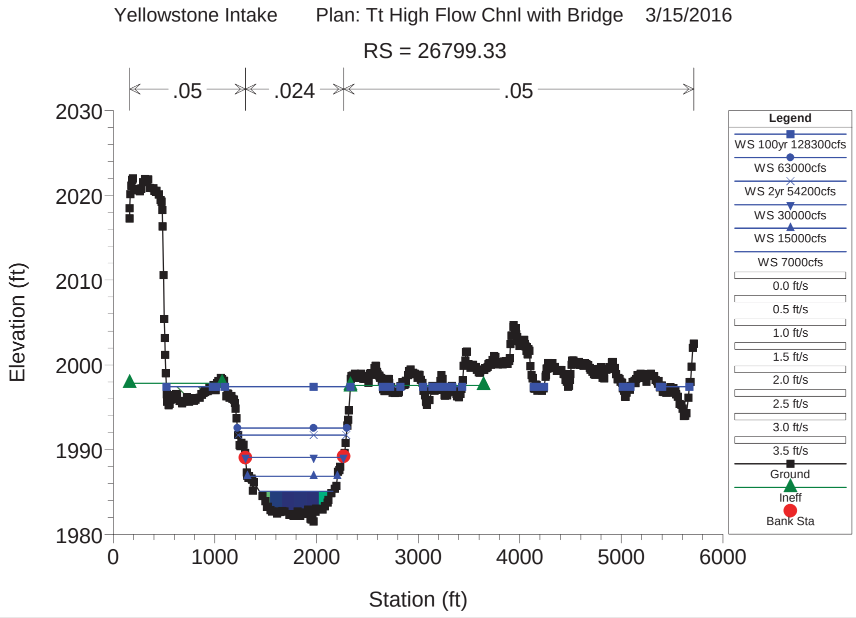
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 26945.88
.05
.024
.05
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.0 ft/s
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
Ground
Ineff
Bank Sta
Elevation (ft)
2030
2020
2010
2000
1990
1980
0
1000
2000
3000
4000
5000
6000
Station (ft)



Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 26899.79
.05
.024
.05
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
3.5 ft/s
Ground
Ineff
Bank Sta
Elevation (ft)
2030
2020
2010
2000
1990
1980
0
1000
2000
3000
4000
5000
6000
Station (ft)



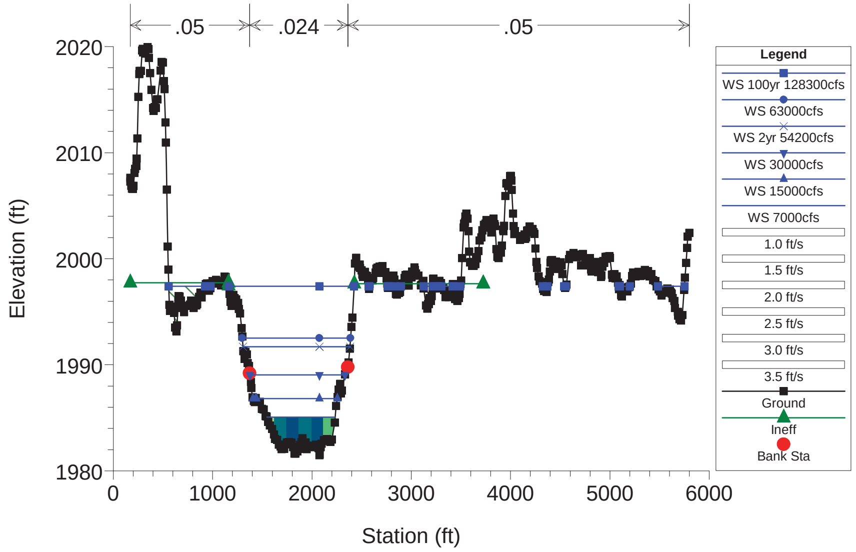
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 26849.79
.05
.024
.05
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.0 ft/s
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
3.5 ft/s
Ground
Ineff
Bank Sta
Elevation (ft)
2030
2020
2010
2000
1990
1980
0
1000
2000
3000
4000
5000
6000
Station (ft)



Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 26799.33
.05
.024
.05
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.0 ft/s
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
3.5 ft/s
Ground
Ineff
Bank Sta
Elevation (ft)
2030
2020
2010
2000
1990
1980
0
1000
2000
3000
4000
5000
6000
Station (ft)

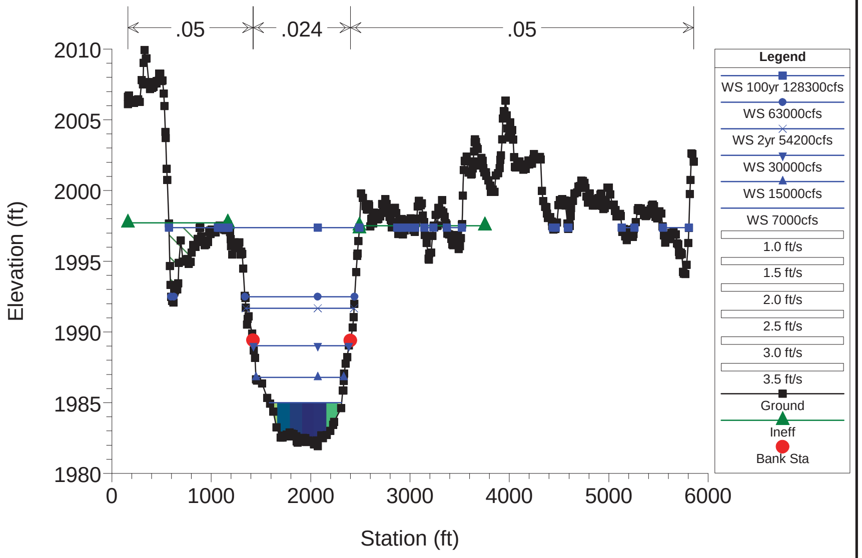
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

RS = 26750.78



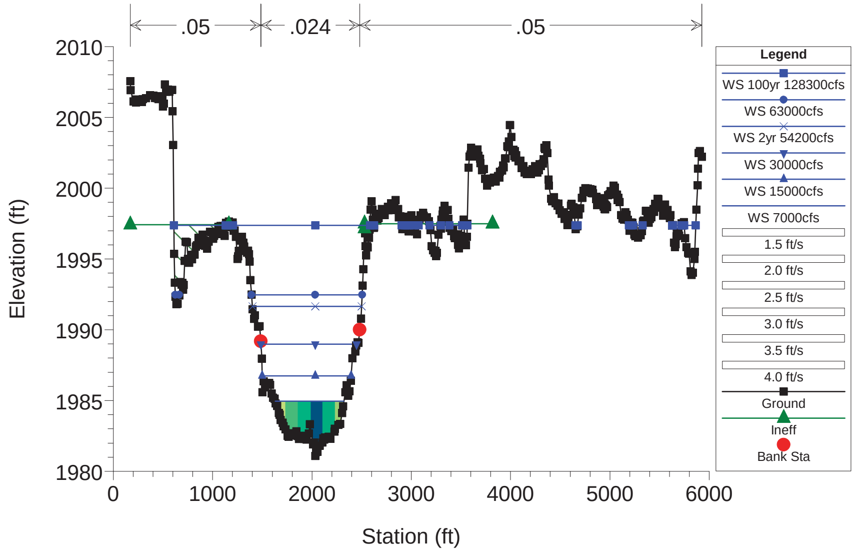
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

RS = 26696.93



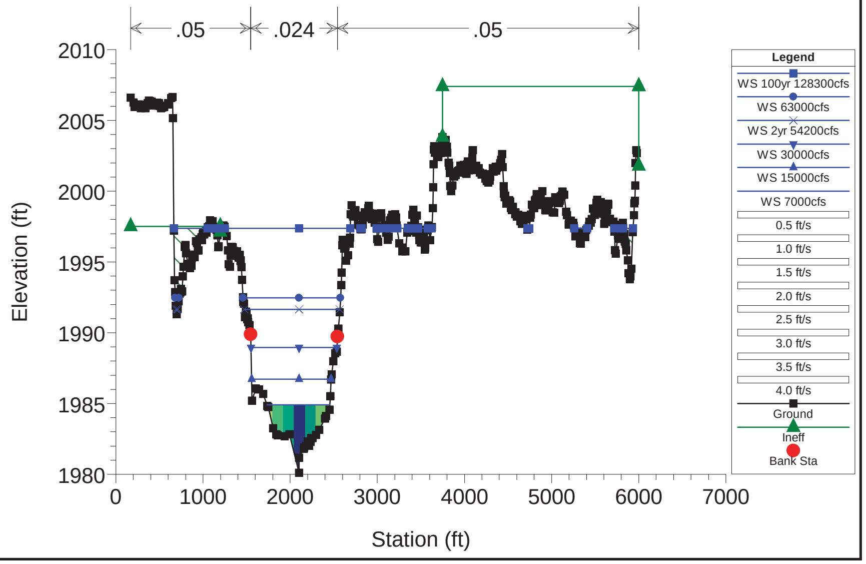
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

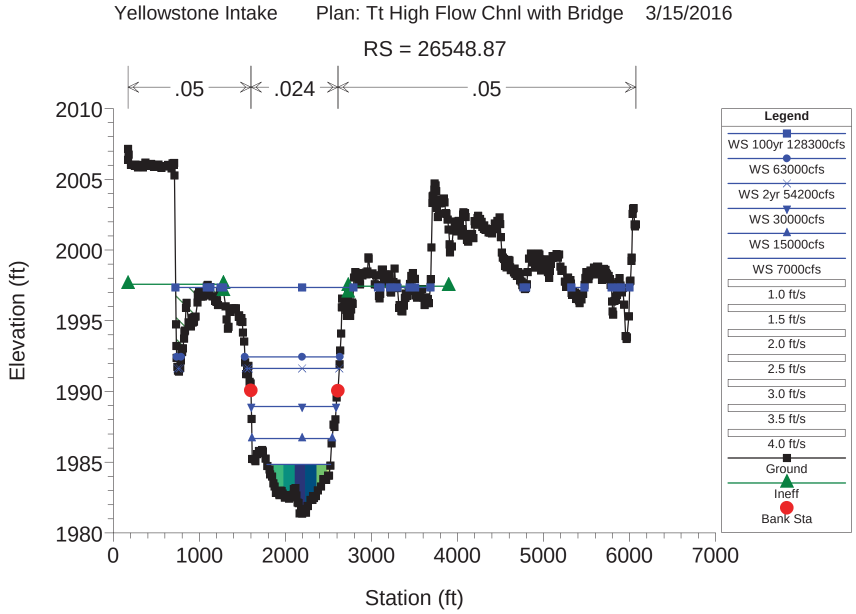
RS = 26646.45



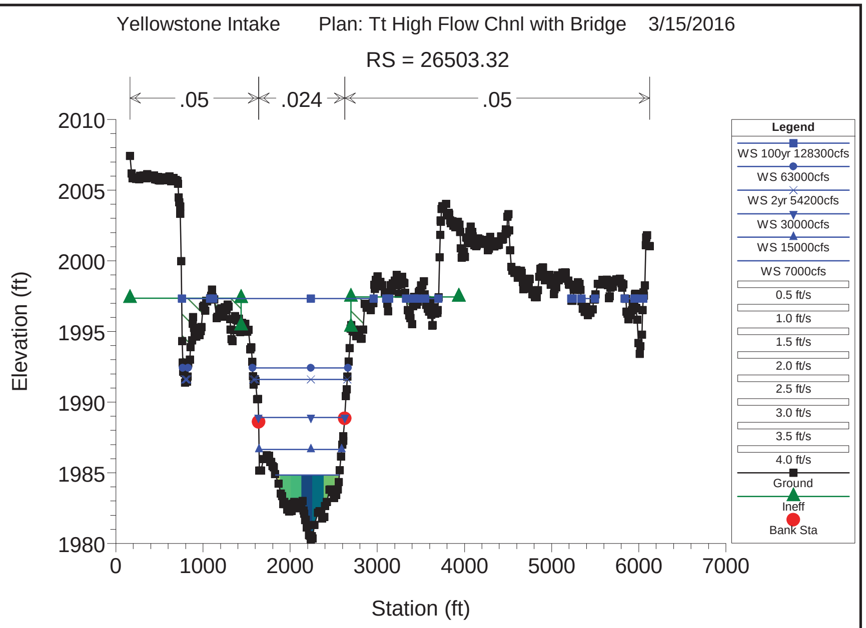
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

RS = 26598.26

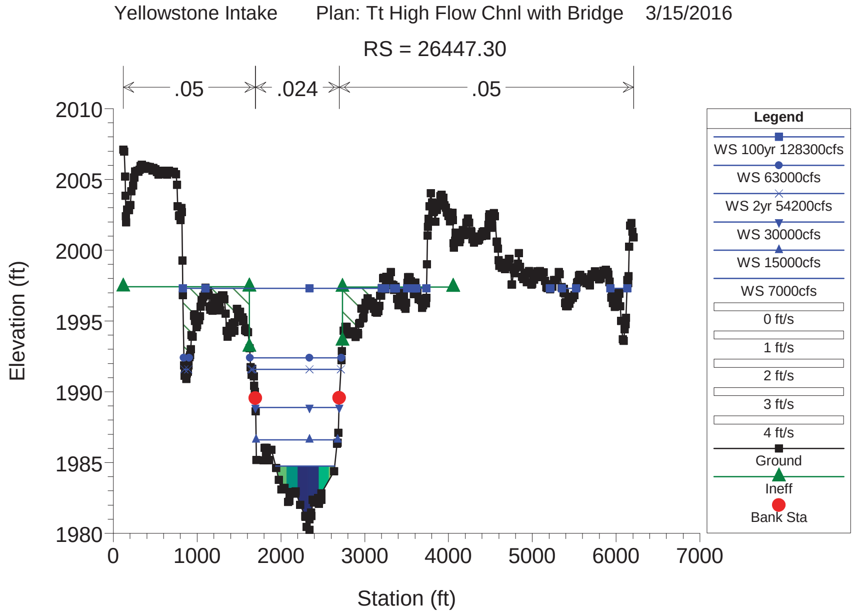



Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

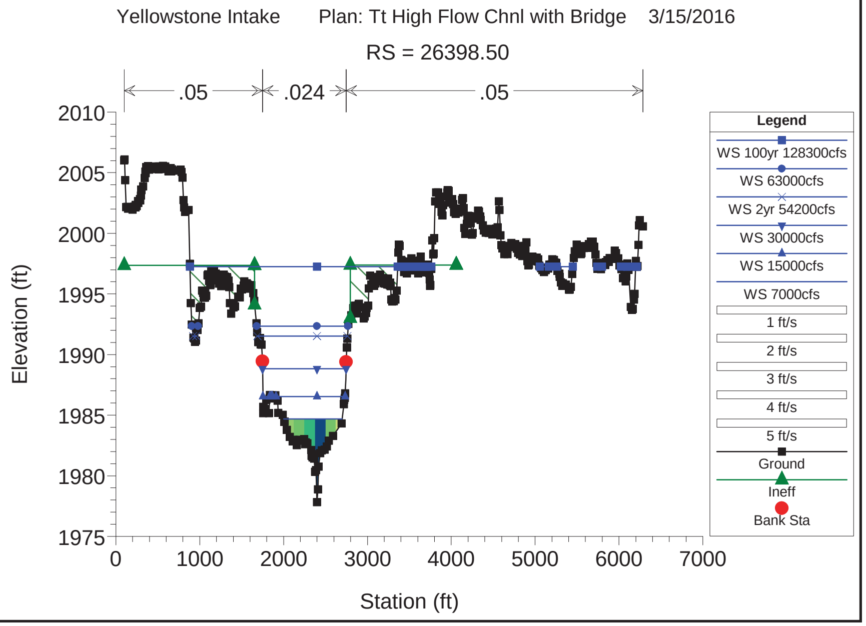
RS = 26548.87


Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

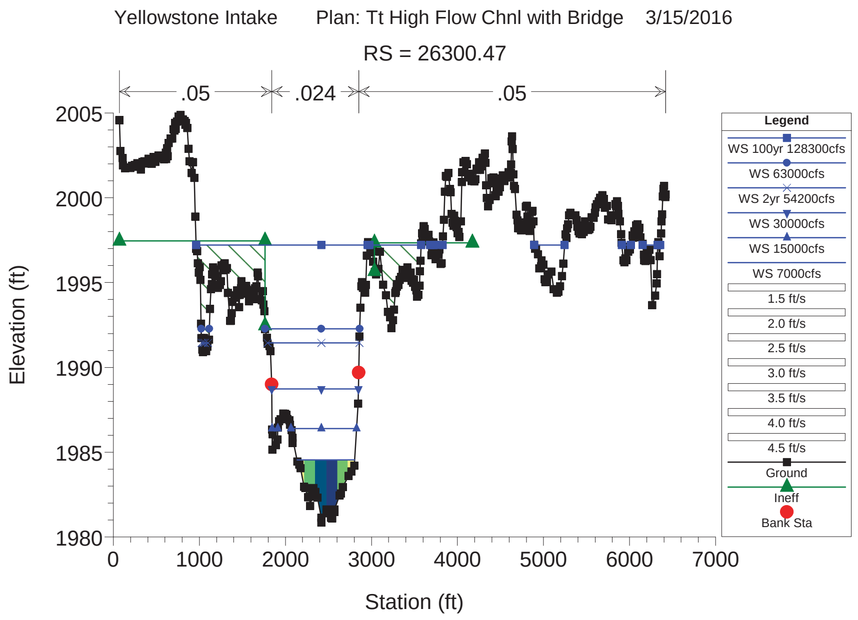
RS = 26503.32


Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

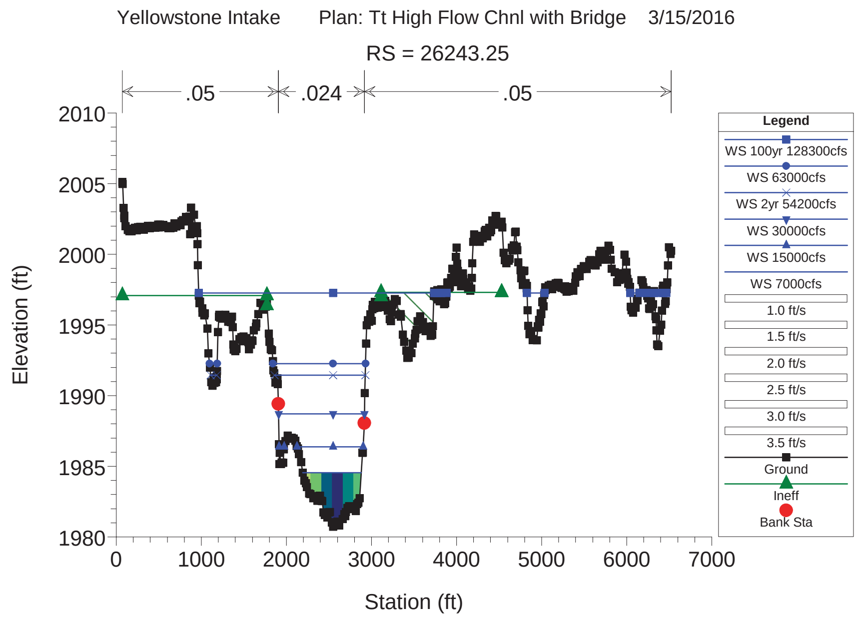
RS = 26447.30


Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

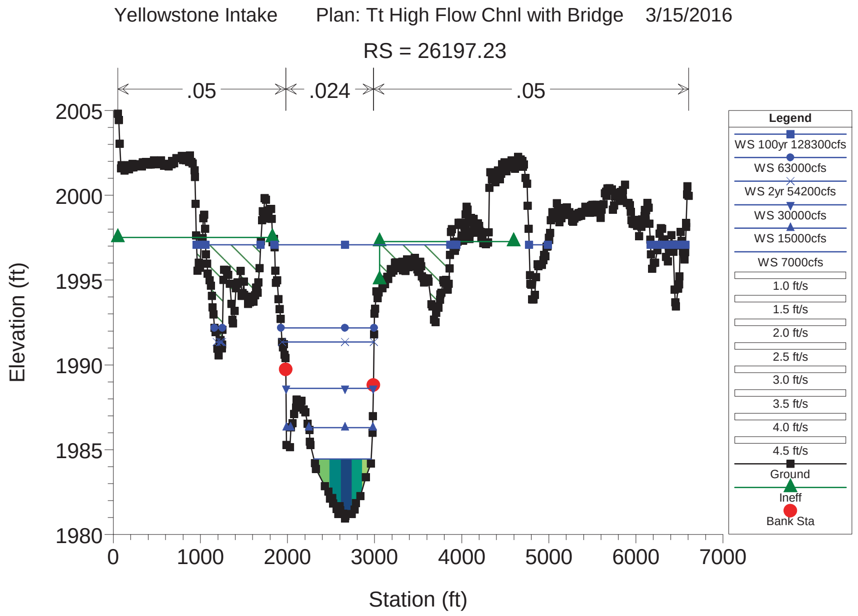
RS = 26398.50


Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

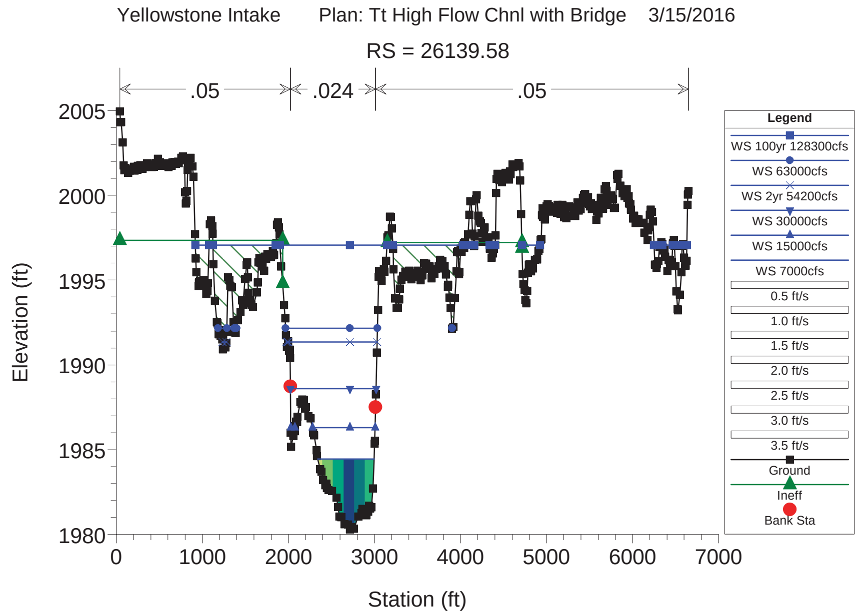
RS = 26300.47


Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

RS = 26243.25


Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

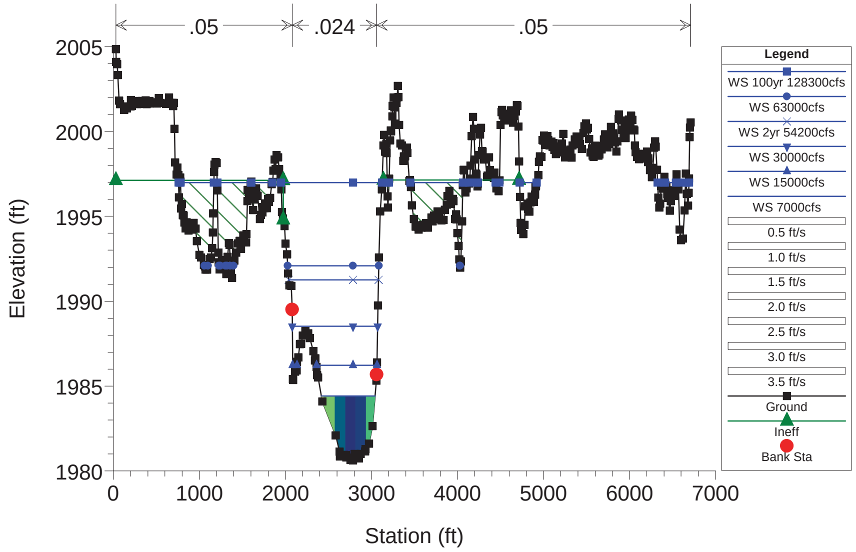
RS = 26197.23


Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

RS = 26139.58

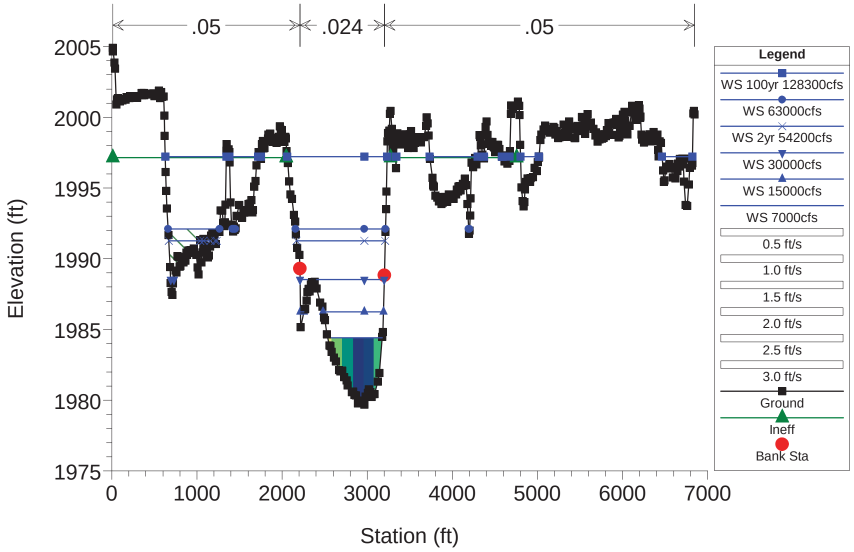
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

RS = 26097.74



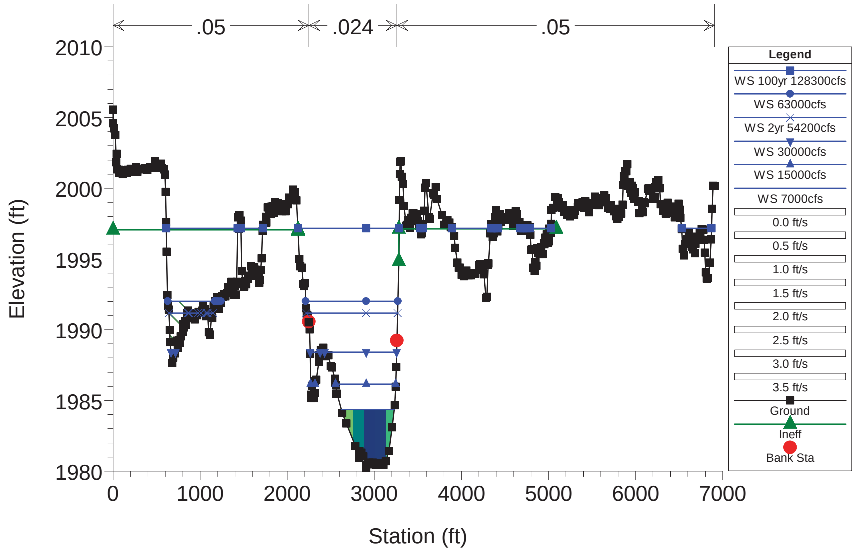
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

RS = 26049.91



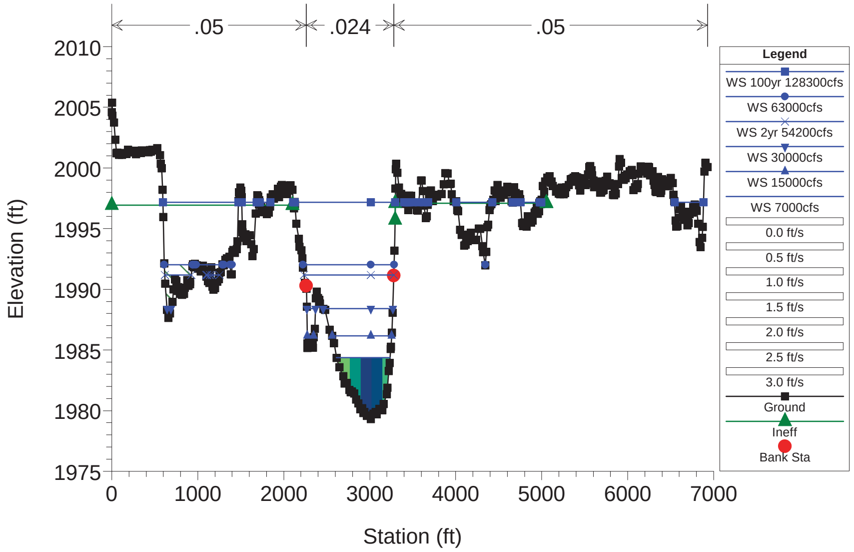
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

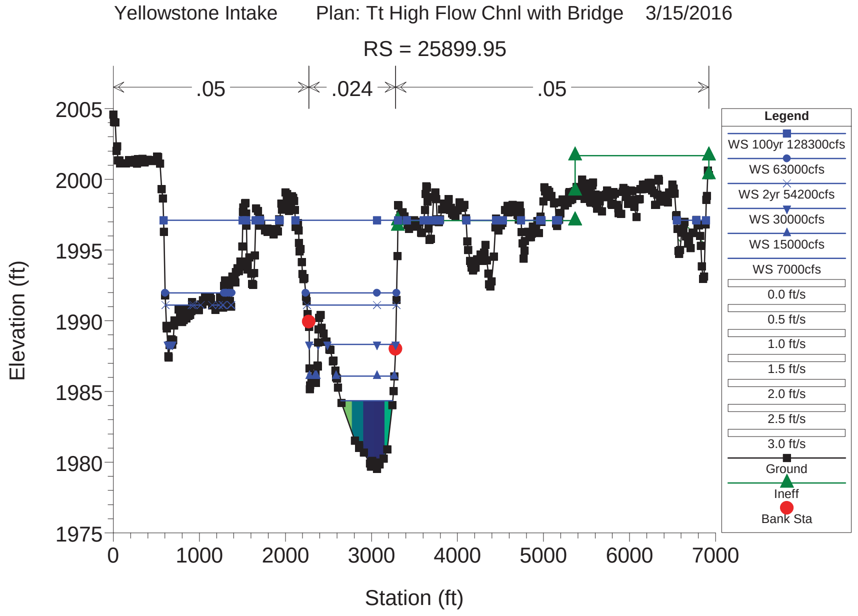
RS = 26002.24

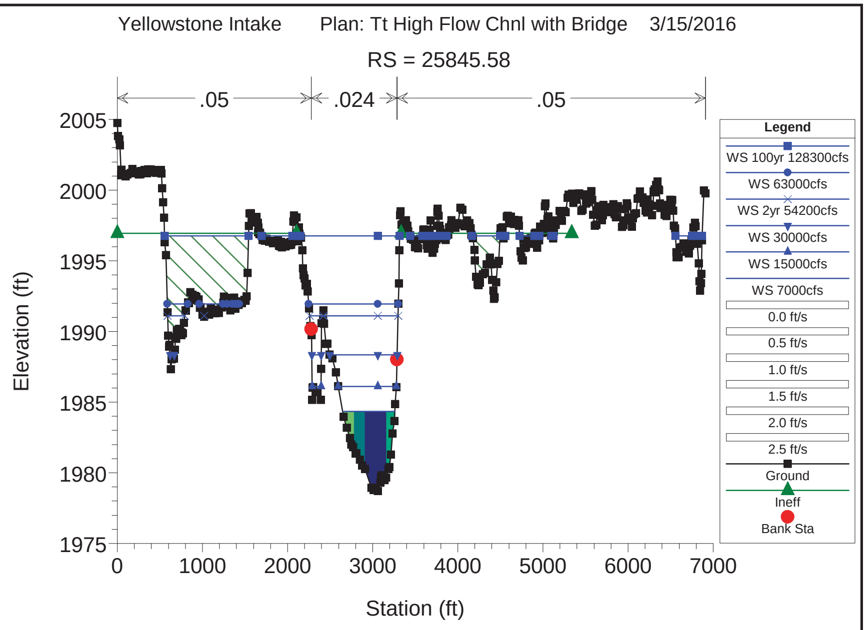


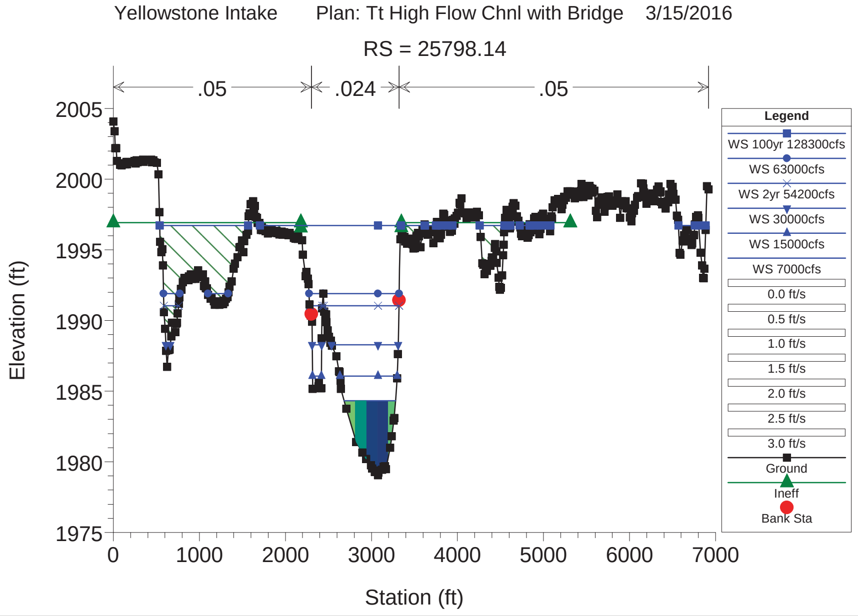
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

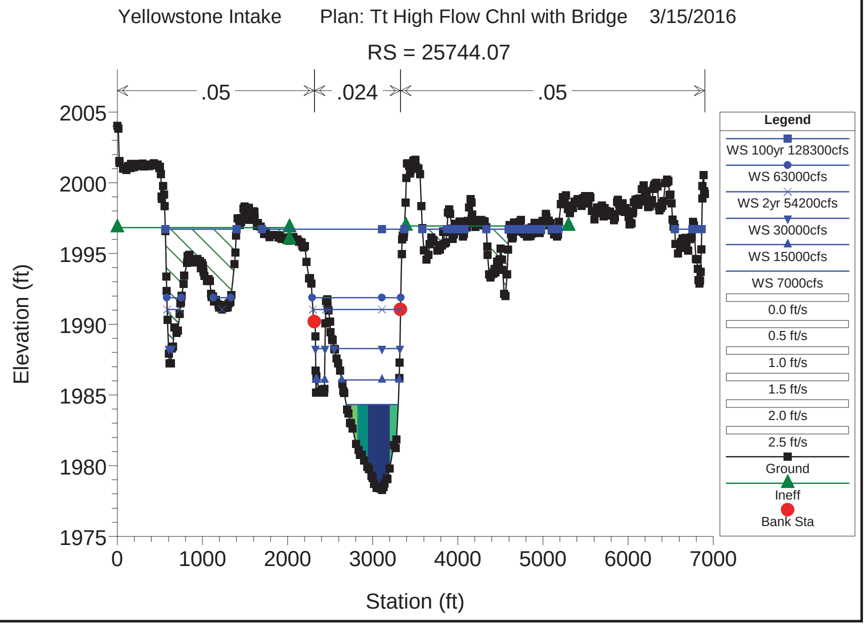
RS = 25945.89

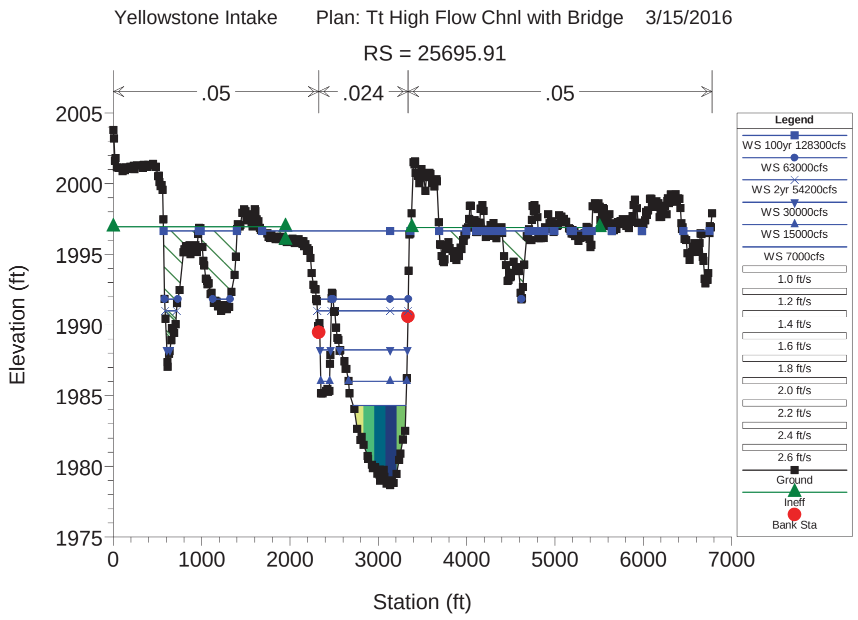


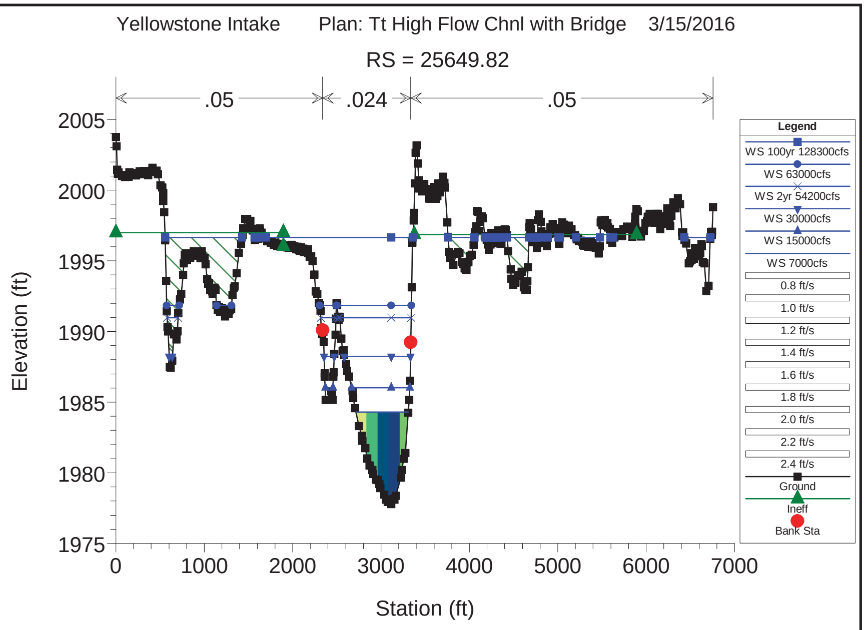

Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 25899.95
.05
.024
.05
Elevation (ft)
2005
2000
1995
1990
1985
1980
1975
0
1000
2000
3000
4000
5000
6000
7000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.0 ft/s
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
Ground
Ineff
Bank Sta

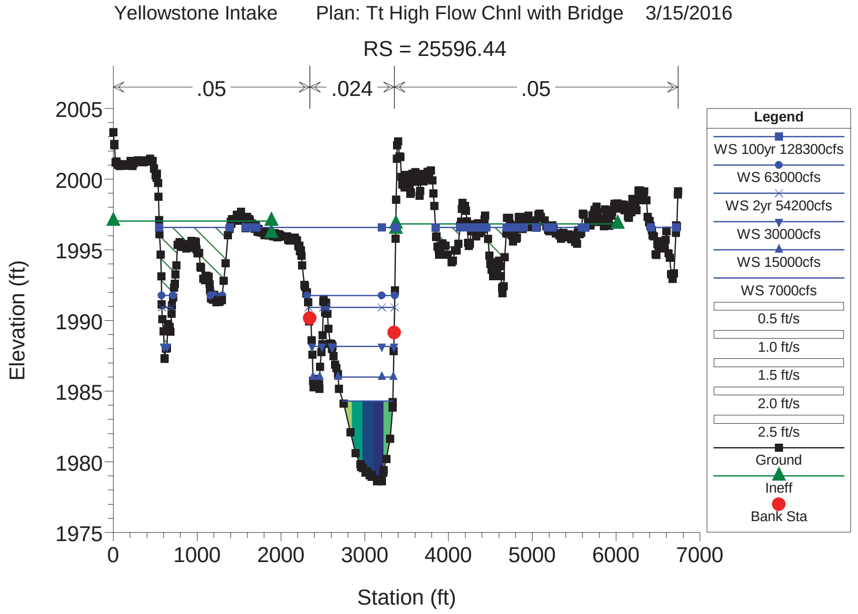

Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 25845.58
.05
.024
.05
Elevation (ft)
2005
2000
1995
1990
1985
1980
1975
0
1000
2000
3000
4000
5000
6000
7000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.0 ft/s
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
Ground
Ineff
Bank Sta

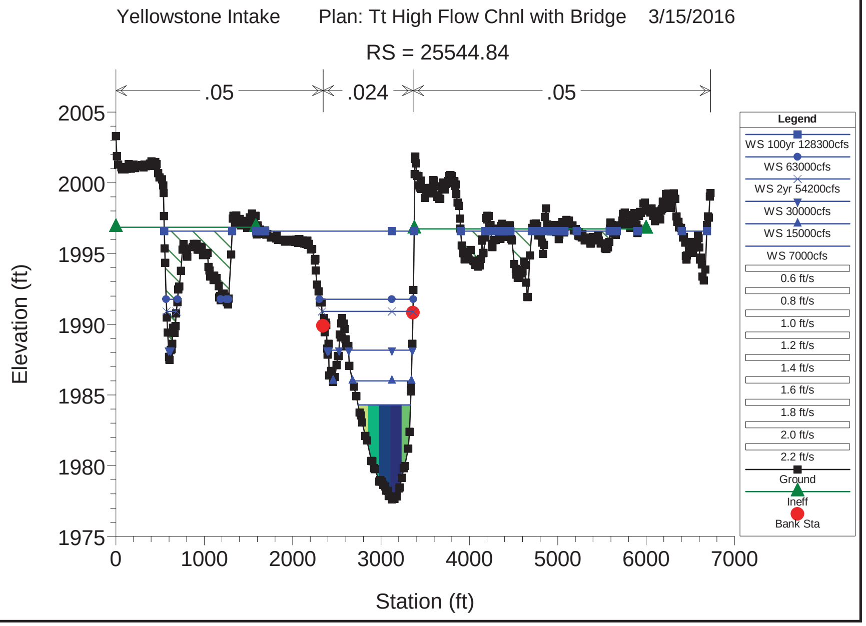

Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 25798.14
.05
.024
.05
Elevation (ft)
2005
2000
1995
1990
1985
1980
1975
0
1000
2000
3000
4000
5000
6000
7000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.0 ft/s
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
Ground
Ineff
Bank Sta

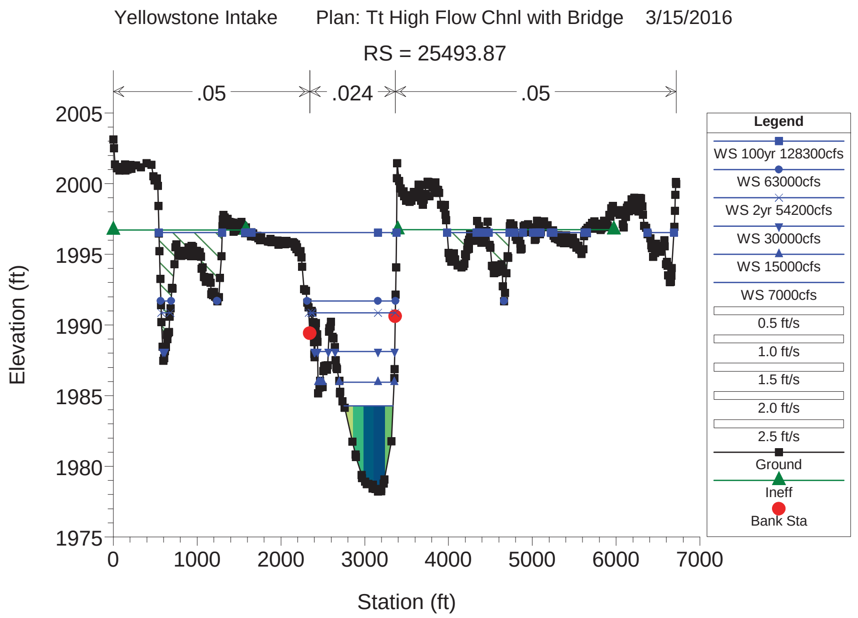

Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 25744.07
.05
.024
.05
Elevation (ft)
2005
2000
1995
1990
1985
1980
1975
0
1000
2000
3000
4000
5000
6000
7000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.0 ft/s
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
Ground
Ineff
Bank Sta

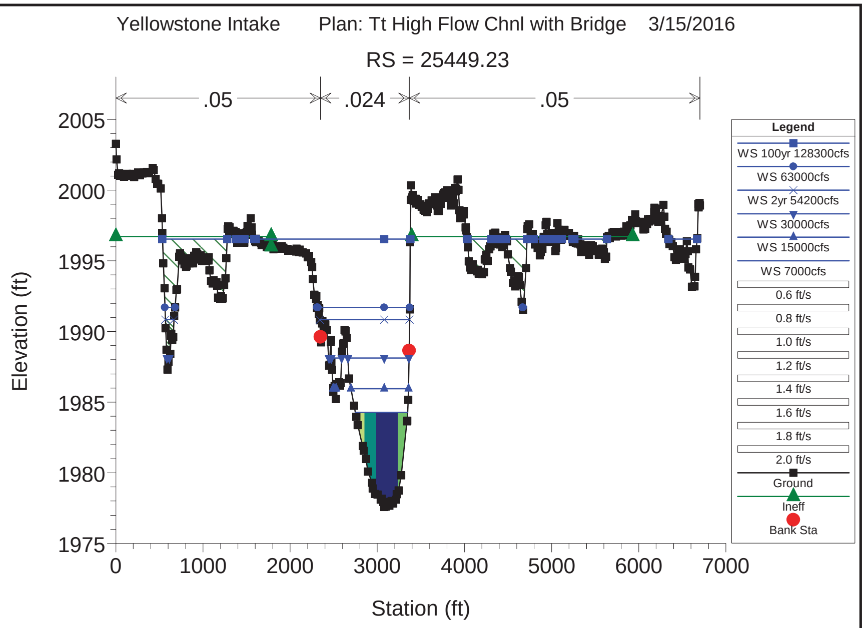

Yellowstone Intake
Plan: Tt High Flow Chnl with Bridge
3/15/2016
RS = 25695.91
.05
.024
.05
Elevation (ft)
Station (ft)
2005
2000
1995
1990
1985
1980
1975
0
1000
2000
3000
4000
5000
6000
7000
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
1.0 ft/s
1.2 ft/s
1.4 ft/s
1.6 ft/s
1.8 ft/s
2.0 ft/s
2.2 ft/s
2.4 ft/s
2.6 ft/s
Ground
Ineff
Bank Sta

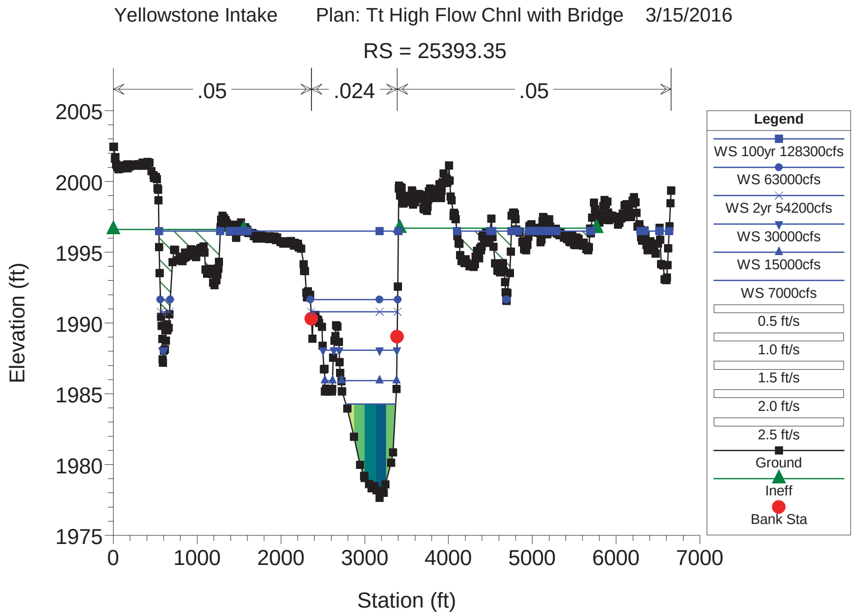

Yellowstone Intake
Plan: Tt High Flow Chnl with Bridge
3/15/2016
RS = 25649.82
.05
.024
.05
Elevation (ft)
Station (ft)
2005
2000
1995
1990
1985
1980
1975
0
1000
2000
3000
4000
5000
6000
7000
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.8 ft/s
1.0 ft/s
1.2 ft/s
1.4 ft/s
1.6 ft/s
1.8 ft/s
2.0 ft/s
2.2 ft/s
2.4 ft/s
Ground
Ineff
Bank Sta

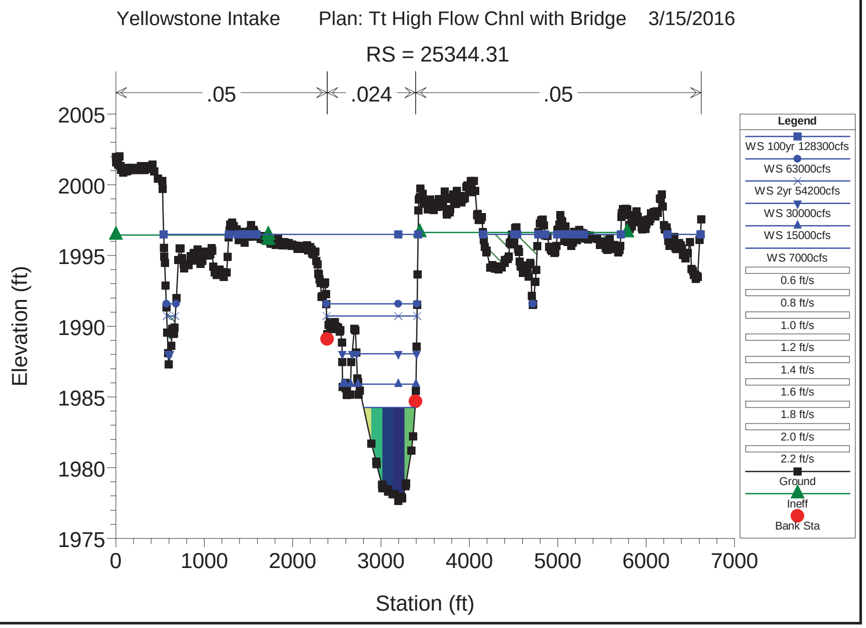

Yellowstone Intake
Plan: Tt High Flow Chnl with Bridge
3/15/2016
RS = 25596.44
.05
.024
.05
Elevation (ft)
Station (ft)
2005
2000
1995
1990
1985
1980
1975
0
1000
2000
3000
4000
5000
6000
7000
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
Ground
Ineff
Bank Sta


Yellowstone Intake
Plan: Tt High Flow Chnl with Bridge
3/15/2016
RS = 25544.84
.05
.024
.05
Elevation (ft)
Station (ft)
2005
2000
1995
1990
1985
1980
1975
0
1000
2000
3000
4000
5000
6000
7000
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.6 ft/s
0.8 ft/s
1.0 ft/s
1.2 ft/s
1.4 ft/s
1.6 ft/s
1.8 ft/s
2.0 ft/s
2.2 ft/s
Ground
Ineff
Bank Sta


Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 25493.87
.05
.024
.05
Elevation (ft)
2005
2000
1995
1990
1985
1980
1975
0
1000
2000
3000
4000
5000
6000
7000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
Ground
Ineff
Bank Sta

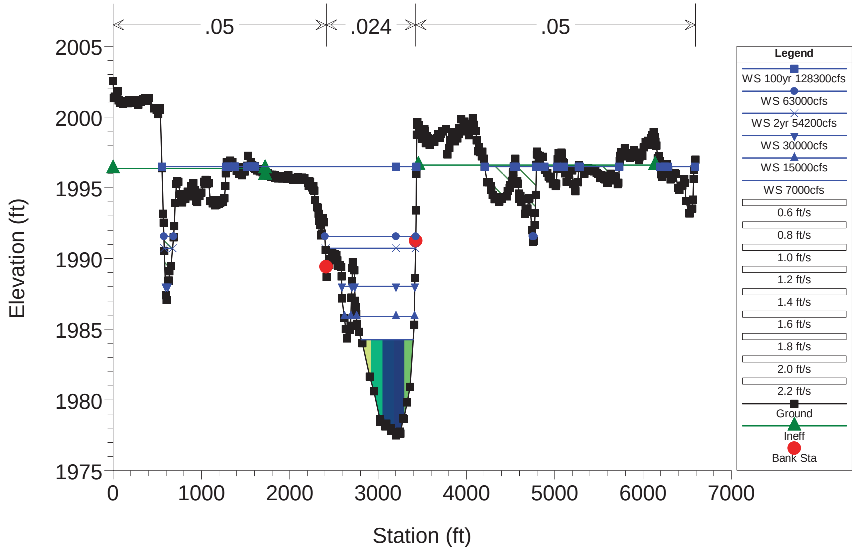

Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 25449.23
.05
.024
.05
Elevation (ft)
2005
2000
1995
1990
1985
1980
1975
0
1000
2000
3000
4000
5000
6000
7000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.6 ft/s
0.8 ft/s
1.0 ft/s
1.2 ft/s
1.4 ft/s
1.6 ft/s
1.8 ft/s
2.0 ft/s
Ground
Ineff
Bank Sta


Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 25393.35
.05
.024
.05
Elevation (ft)
2005
2000
1995
1990
1985
1980
1975
0
1000
2000
3000
4000
5000
6000
7000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
Ground
Ineff
Bank Sta


Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 25344.31
.05
.024
.05
Elevation (ft)
2005
2000
1995
1990
1985
1980
1975
0
1000
2000
3000
4000
5000
6000
7000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.6 ft/s
0.8 ft/s
1.0 ft/s
1.2 ft/s
1.4 ft/s
1.6 ft/s
1.8 ft/s
2.0 ft/s
2.2 ft/s
Ground
Ineff
Bank Sta

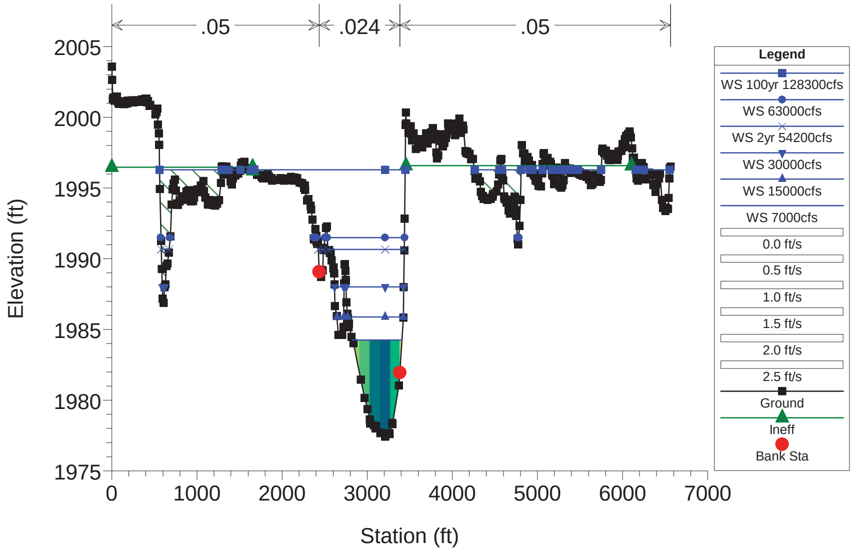
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

RS = 25290.78



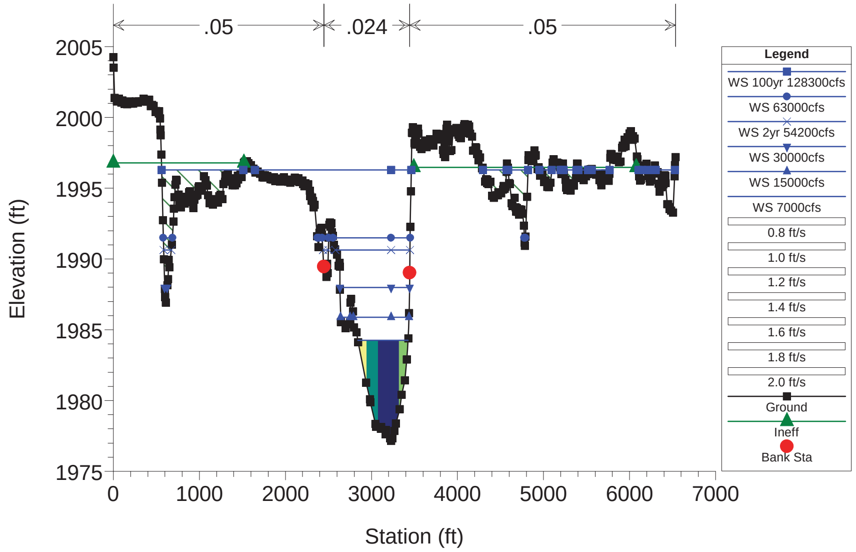
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

RS = 25245.25



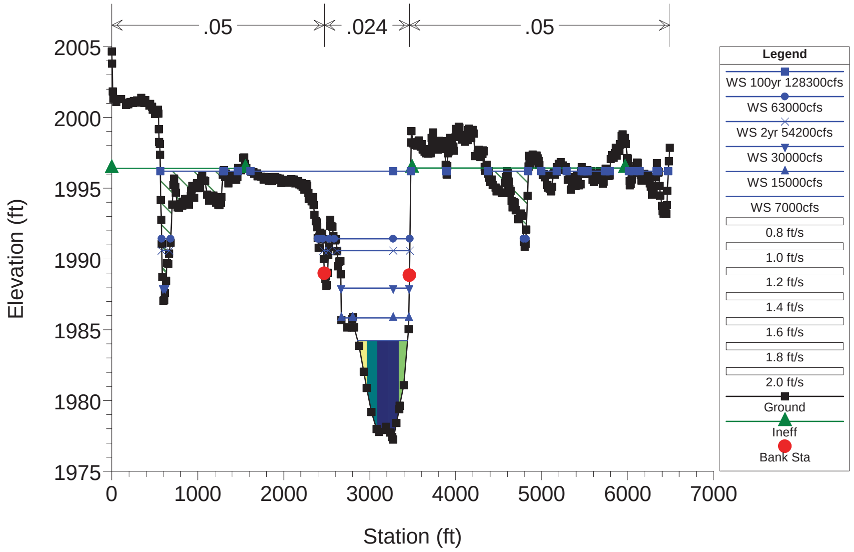
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

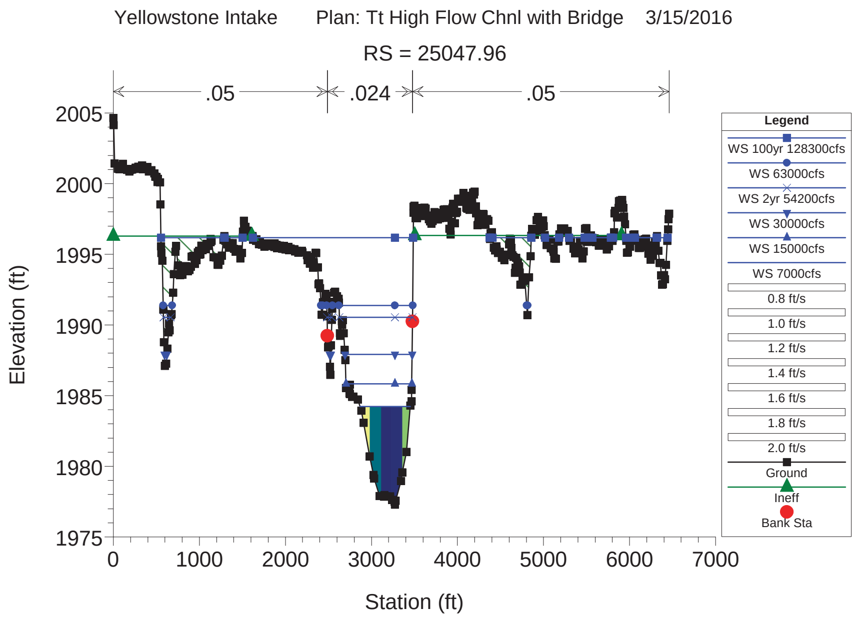
RS = 25196.84

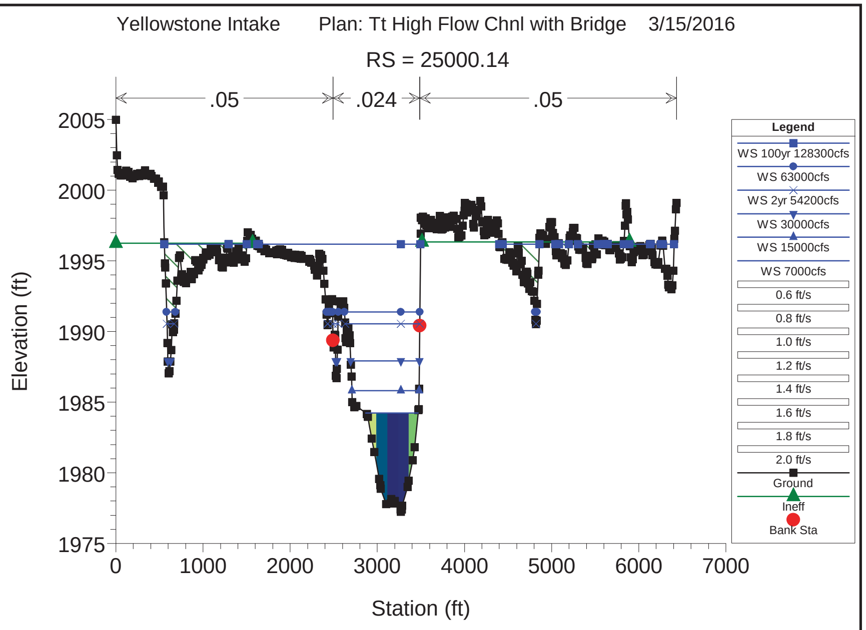


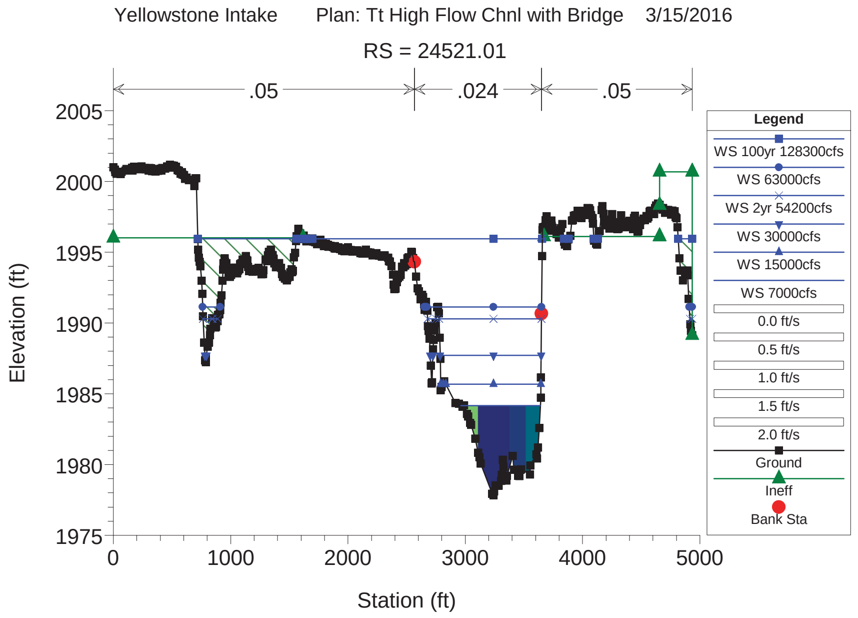
Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016

RS = 25095.44




Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 25047.96
.05
.024
.05
Elevation (ft)
Station (ft)
2005
2000
1995
1990
1985
1980
1975
0
1000
2000
3000
4000
5000
6000
7000
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.8 ft/s
1.0 ft/s
1.2 ft/s
1.4 ft/s
1.6 ft/s
1.8 ft/s
2.0 ft/s
Ground
Ineff
Bank Sta


Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 25000.14
.05
.024
.05
Elevation (ft)
Station (ft)
2005
2000
1995
1990
1985
1980
1975
0
1000
2000
3000
4000
5000
6000
7000
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.6 ft/s
0.8 ft/s
1.0 ft/s
1.2 ft/s
1.4 ft/s
1.6 ft/s
1.8 ft/s
2.0 ft/s
Ground
Ineff
Bank Sta


Yellowstone Intake Plan: Tt High Flow Chnl with Bridge 3/15/2016
RS = 24521.01
.05
.024
.05
Elevation (ft)
Station (ft)
2005
2000
1995
1990
1985
1980
1975
0
1000
2000
3000
4000
5000
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
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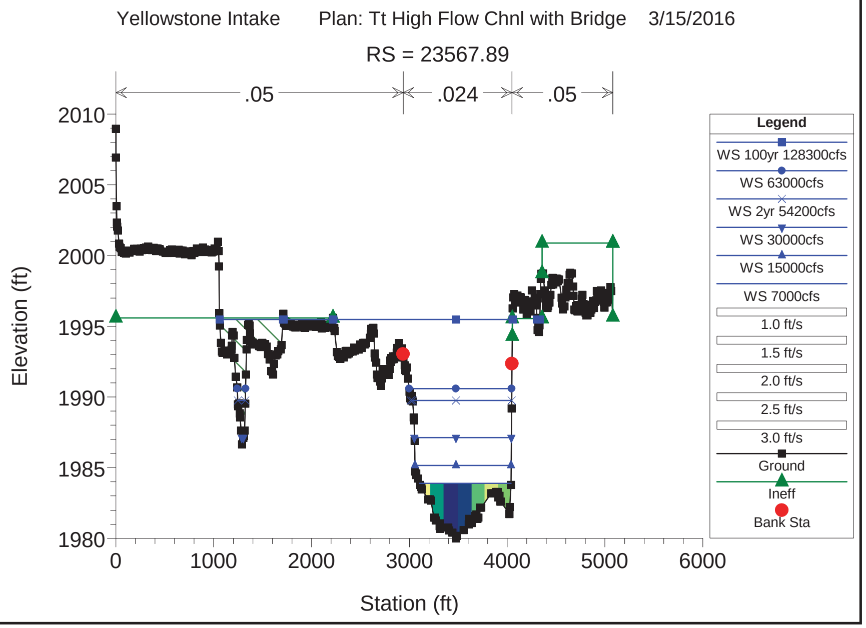
Ineff
Bank Sta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Station (ft)
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2005
2000
1995
1990
1985
1980
0
1000
2000
3000
4000
5000
6000
Legend
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WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
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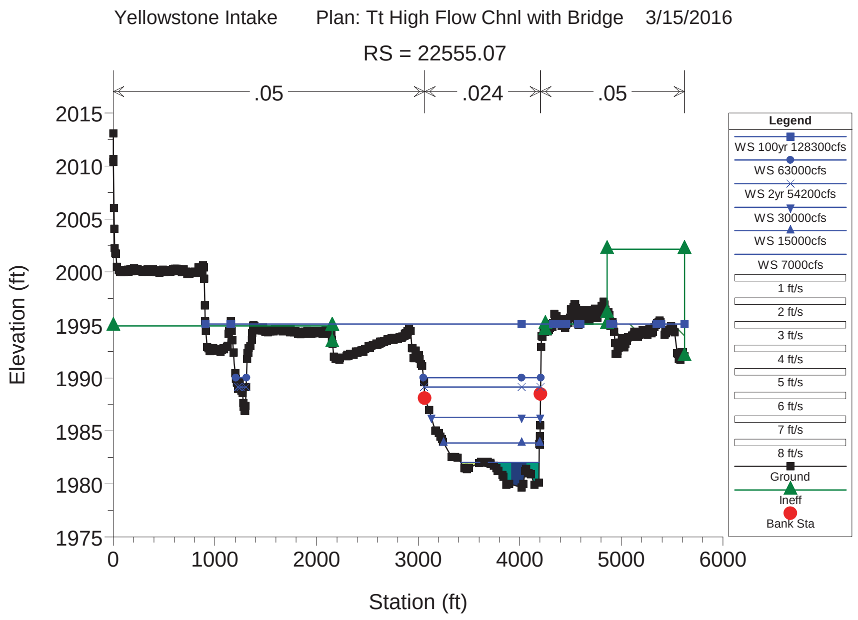
Ineff
Bank Sta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2000
1995
1990
1985
1980
1975
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3000
4000
5000
6000
Station (ft)
Legend
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WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
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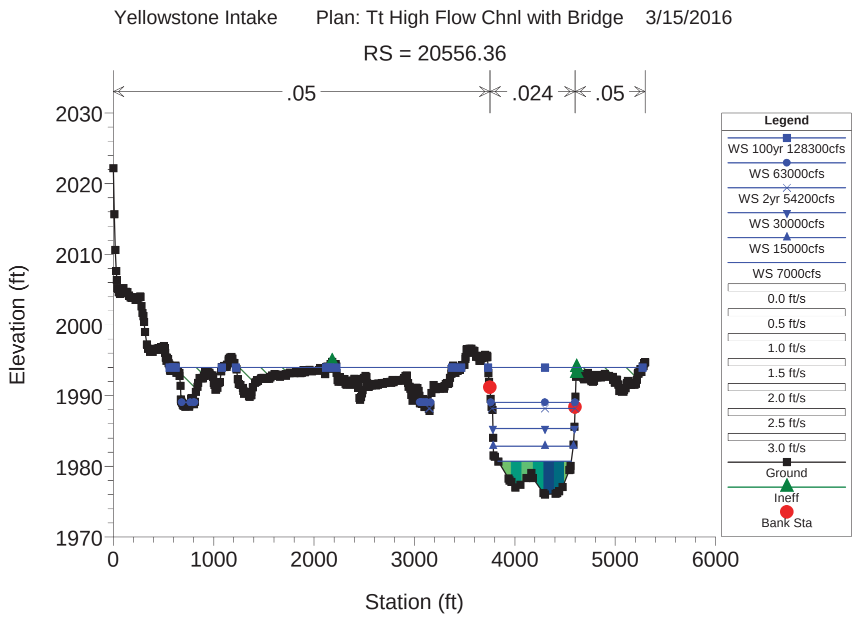
3 ft/s
4 ft/s
5 ft/s
6 ft/s
7 ft/s
8 ft/s
Ground
Ineff
Bank Sta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2010
2000
1990
1980
1970
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3000
4000
5000
6000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.0 ft/s
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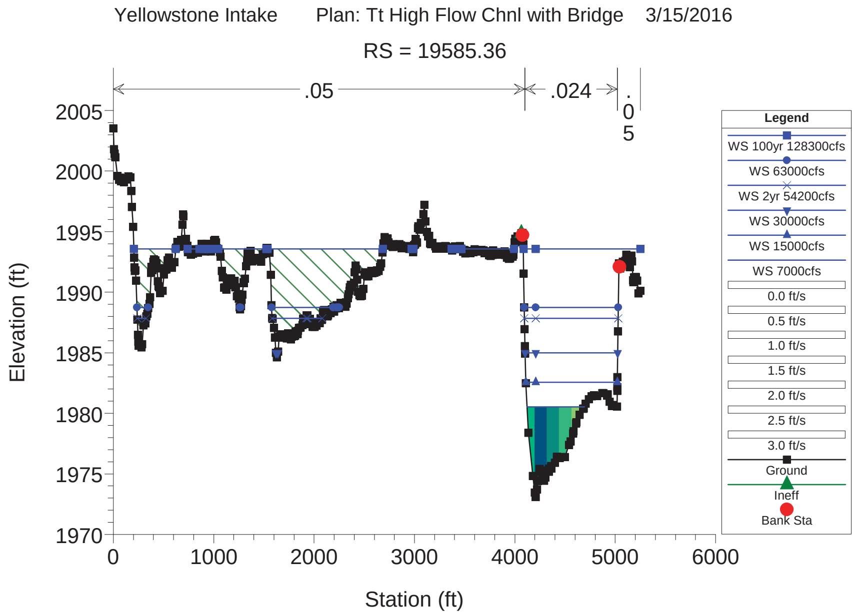
3.0 ft/s
Ground
Ineff
Bank Sta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1990
1985
1980
1975
1970
0
1000
2000
3000
4000
5000
6000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
0.0 ft/s
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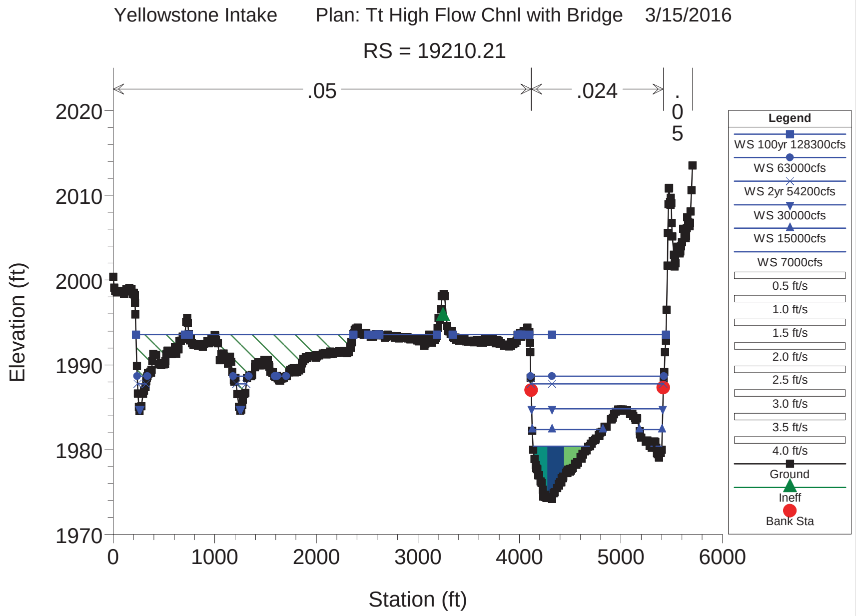
Ground
Ineff
Bank Sta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2000
3000
4000
5000
6000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
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1.0 ft/s
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Ground
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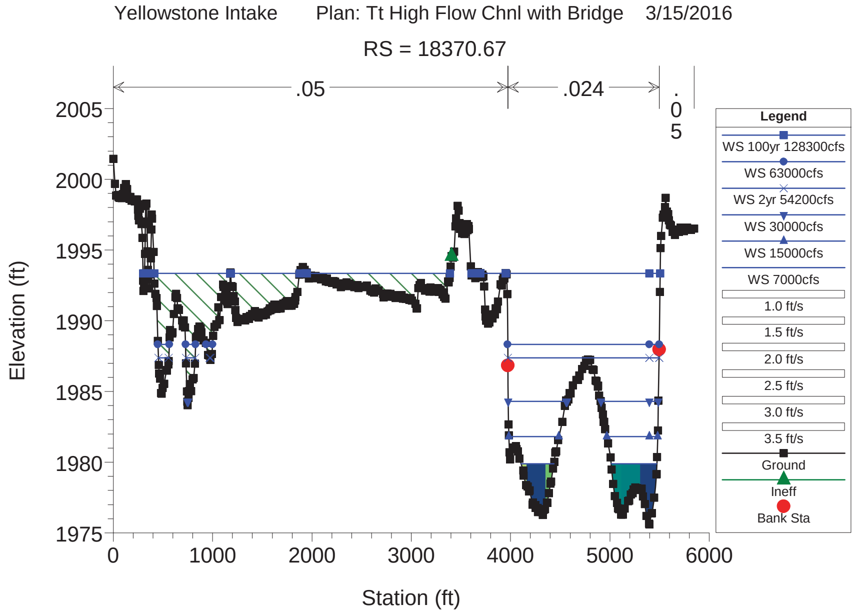
Bank Sta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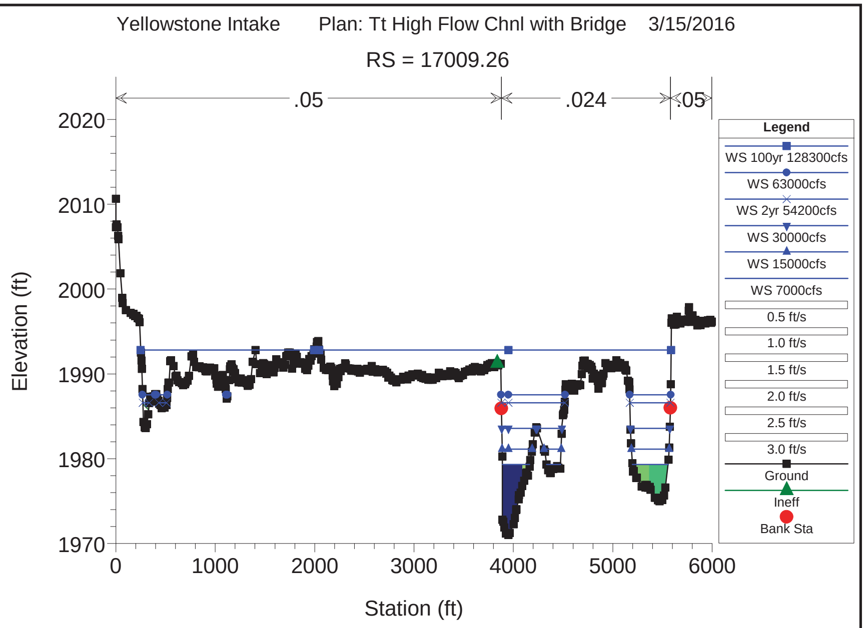
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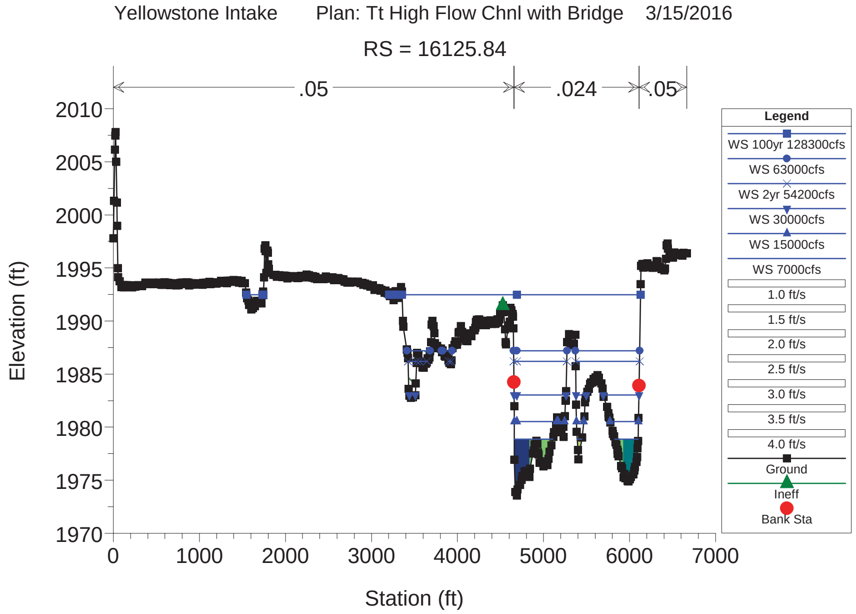
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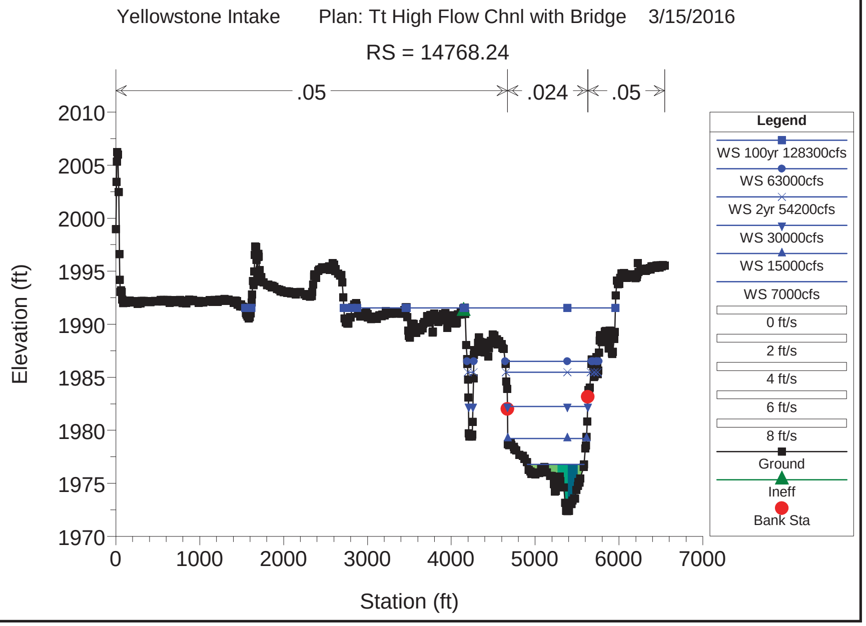
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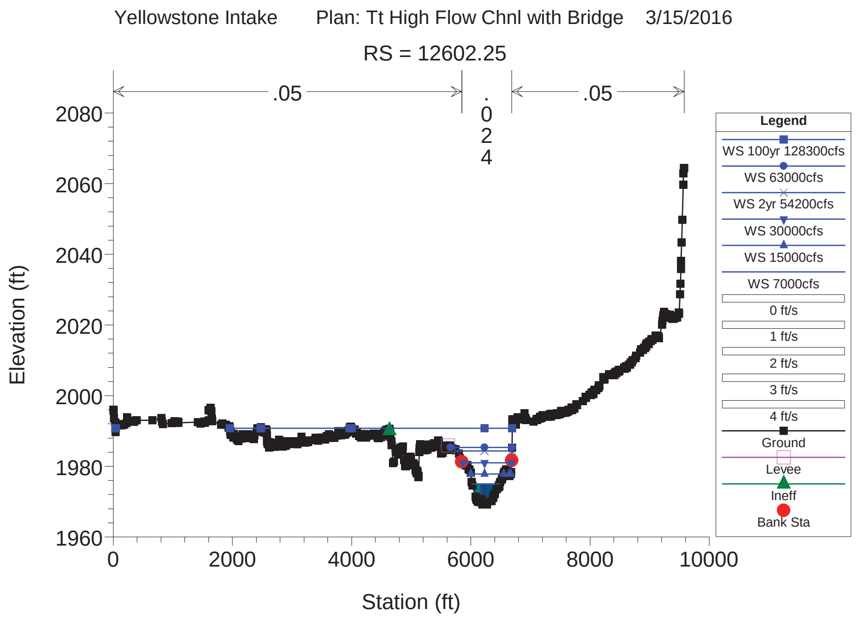
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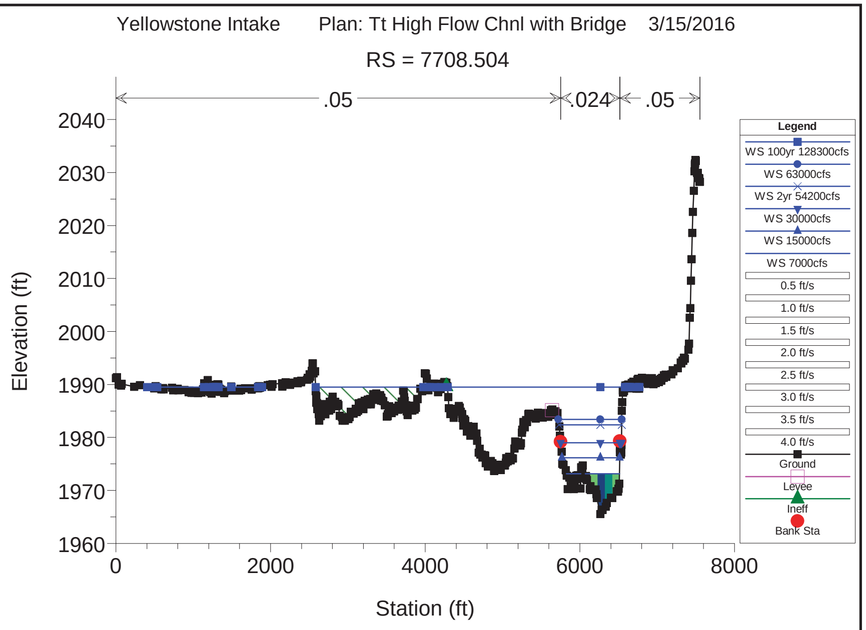
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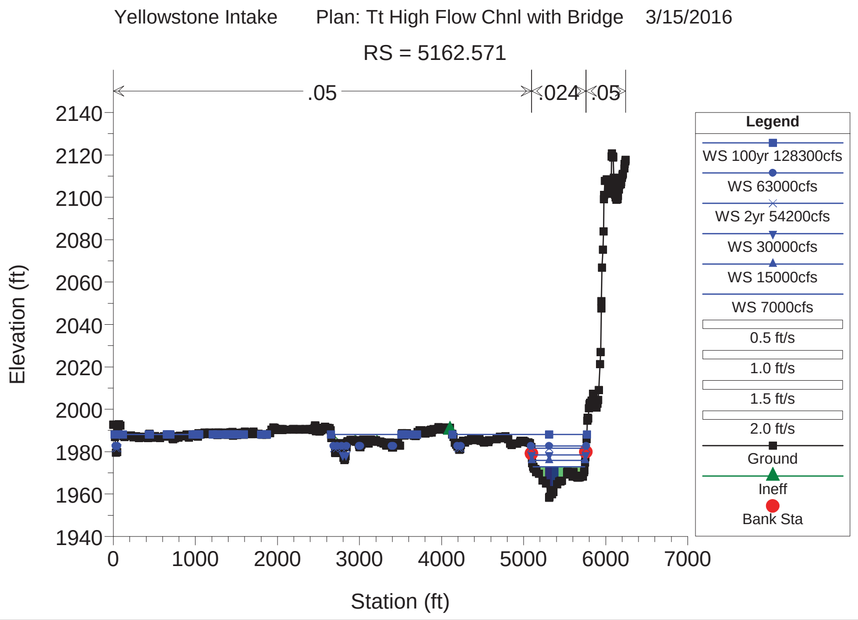
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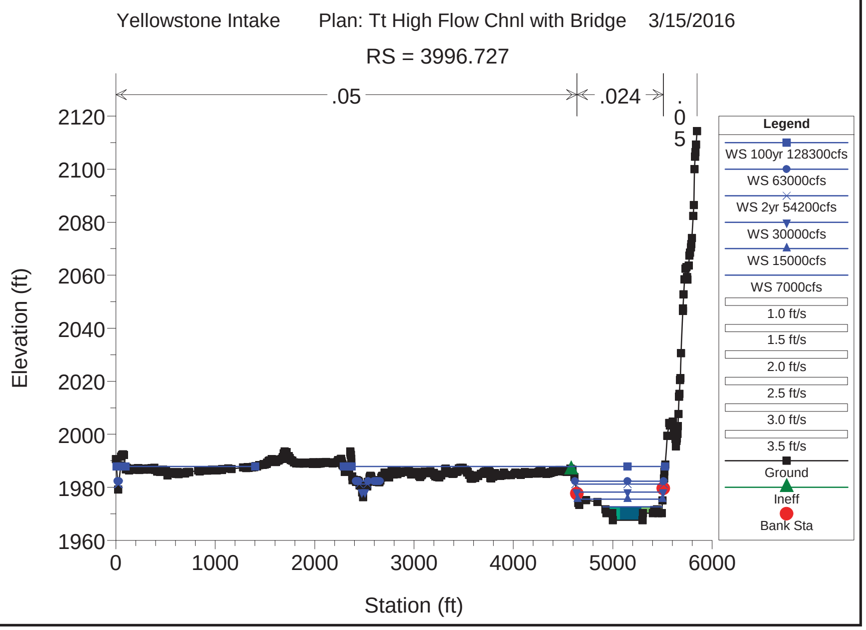
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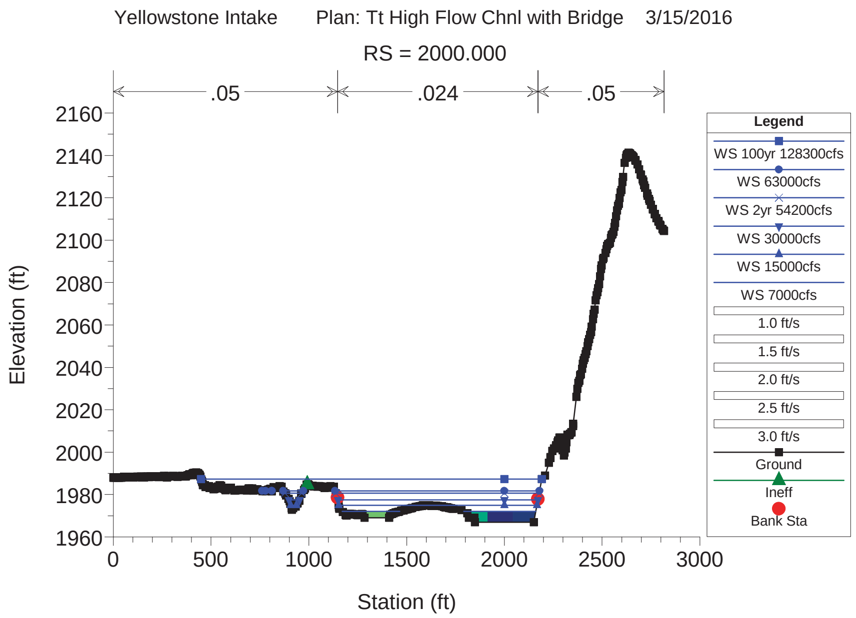
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.024
.05
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1500
2000
2500
3000
Station (ft)
Legend
WS 100yr 128300cfs
WS 63000cfs
WS 2yr 54200cfs
WS 30000cfs
WS 15000cfs
WS 7000cfs
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
Ground
Ineff
Bank Sta

Attachment 2
Sediment Transport Analysis

Note: the following support calculations refer to this alternative as the *High Flow Channel Alternative*. The name has been revised to *Modified Side Channel Alternative,* however the name on these support calculations still refer to the High Flow Channel. None of the analyses are affected by the name change and all support calculations are applicable to the *Modified Side Channel Alternative*.

1.1 Sediment Transport

The sediment-transport analysis follows a similar approach and uses much of the data previously described in the EA appendices (Reclamation and Corps 2015). All sediment- transport modeling was conducted using HEC-RAS version 5.0 (Corps 2016). The Modified Side Channel sediment transport analysis was performed in the following two general steps. First, perform a sediment transport analysis for the existing high flow channel. This was done to evaluate whether the boundary conditions and selected sediment transport functions generally produce a relatively stable condition for the existing channel. Because the existing high flow has persisted since at least the 1950s, it is likely that this channel is relatively stable and the modeling should reflect this. This approach was selected because there are no data to otherwise calibrate the sediment transport model. Second, using the hydraulic model that includes the geometry of the Modified Side Channel Alternative, perform a sediment transport analysis using hydraulic and sediment boundary conditions that reflect the target split flows.

For each of these simulations the following data and information were used:

- Channel geometry was based on the HEC-RAS models for the existing conditions high flow channel and the Modified Side Channel Alternative.
- Flow splits from the Yellowstone River were determined from the hydraulic models.
- Sediment splits from the Yellowstone River were based on the Corps Chute Channel Alternative model as shown in Table 1. Because the existing high flow channel is perched relative to the thalweg of the Yellowstone River, gravel sizes were excluded for these runs. Gravel sizes were included for the Modified Side Channel Alternative because the invert of this alternative is close to the thalweg of the Yellowstone River.
- Bed material for the high flow channel was based on bar samples as described in the EA appendices (Reclamation and Corps 2015).
- The downstream boundary condition was based on the water surface elevations of the Yellowstone River at the downstream confluence of the high flow channel and the Yellowstone River.
- Each model was run for the Post-Yellowtail Dam hydrologic record from 1967 to 2014 on a daily flow time step.

The Corps performed a sensitivity analysis that included four transport equations in HEC-RAS; Laursen (Copeland), Yang, Toffaleti, and Ackers-White. They found that Laursen (Copeland) was the only equation that did not produce unrealistic amounts of aggradation in the designed chute channel, although Ackers-White produced more reasonable results than Yang or Toffaleti, and that by excluding medium gravel from the sediment supply that Ackers-White also produced reasonable results. Therefore, the Laursen (Copeland) and Ackers-White sediment transport functions were used for these analyses.

Table 1. Sediment Loads for high flow channel

Split flow, cfs	10	75	2,000	3,000	10,000	25,000
Total Load, tons/day	0.5	6	2,897	6,031	90,405	510,775
Sediment size class	Percent of total load in each size class					
Clay (0.002-0.004 mm)	80	86.57	67.9	42.75	32.9	23.25
VFM (0.004-0.008 mm) (very fine silt)	10	6.97	7.76	6.65	5.64	6.51
FM (0.008-0.016 mm) (fine silt)	10	4.98	4.85	7.61	8.47	7.45
MM (0.016-0.032 mm) (medium silt)		1	4.88	9.54	9.45	9.36
CM (0.032-0.0625 mm) (coarse silt)		0.03	5.03	9.8	11.64	9.72
VFS (0.0625-0.125 mm) (very fine sand)		0.05	5.18	9.98	13.73	11.83
FS (0.125-0.25 mm) (fine sand)		0.01	1.95	5.77	7.61	11.27
MS (0.25-0.5 mm) (medium sand)		0.01	0.06	2	2.94	7.58
CS (0.5-1.0 mm) (coarse sand)		0.03	0.15	2.15	3.12	7.79
VCS (1.0-2.0 mm) (very coarse sand)		0.06	0.36	0.6	0.72	0.84
VFG (2.0-4.0 mm) (very fine gravel)		0.09	0.54	0.9	1.08	1.26
FG (4.0-8.0 mm) (fine gravel)		0.11	0.66	1.1	1.32	1.54
MG (8.0-16.0 mm) (medium gravel)		0.11	0.69	1.15	1.38	1.61

1.1.1 Existing High Flow Channel

Figure 1 shows the thalweg elevation of the 47-year simulation for the Laursen (Copeland) equation. Results are at approximate 5 year intervals and indicate a slight degradation tendency (up to 2 feet over the run. This could be due to the complete exclusion of the gravel fraction. The Ackers-White run (Figure 2) tended to be slightly aggradational (up to 2 feet) for the first 40 years then aggraded approximately 10 feet during a single event at the upstream cross section. This sudden aggradation is very unlikely and is probably due to model instabilities or limitations of the Ackers-White function. From these runs, it appears the Laursen (Copeland) sediment-transport function is more reliable than Ackers-White for this condition. Overall, the results indicate that these functions are generally applicable to the existing high flow channel because the bed is relatively stable over the simulation period.

1.1.2 Modified Side Channel Alternative

The sediment transport model for the Modified Side Channel Alternative followed the same procedure as existing high flow channel with the following differences: (1) The new channel geometry was included, (2) flow splits and associated sediment splits reflected the new conditions, and (3) all sediment sizes, including gravels were included in the sediment split because the design channel invert is relatively close to the Yellowstone River thalweg elevation. The models were run using the Laursen (Copeland) equation as the preferred equation and Ackers-White as a comparison.

Figure 3 shows the thalweg profiles at approximate 5-year intervals for the Laursen (Copeland) simulation. General degradation occurs in the channel ranging from approximately 3 feet at the downstream end to approximately 6 feet at the upstream end. The channel slope flattened from 0.06 to 0.05 percent. Most of the degradation occurred over the first 5 years. Conversely, the Ackers-White equation (Figure 4) showed substantial aggradation over the reach with the channel ultimately reaching a 0.1 percent. This is consistent with the Corps results of the Bypass Channel Alternative and is likely the result of the Ackers-White equation not transporting gravel as effectively as expected. It does, however, suggest that some deposition is possible at the upstream end of the designed Modified Side Channel.

1.1.3 Discussion

These analyses indicates that use of a coarser armor material and grade control structures (riffles) are warranted for this design. The armor should inhibit degradation and allow the sediment supply to move through the reach. If the armor is disturbed in a large event, the grade control structure would limit excessive degradation. If the channel flattens to 0.05 percent between the structures this would tend to lower velocities for fish passage. What appears to be the less likely outcome is channel aggradation. If it does occur, however, then considerable channel maintenance would be required.

In general, the results of the sediment transport analyses of the high flow channel alternative are consistent with the results presented in Reclamation and Corps (2015). Boxelder Creek, which enters the high flow channel at approximately station 7,000 ft was not included as a water or sediment sources part of this analysis. This location shows as a higher bed elevation in the initial profile of the existing conditions runs. This tributary source would be and intermittent source of water and sediment. Although it would affect the form and hydraulics of design high flow channel over time, it would probably not form a barrier as the channel would likely erode through or shift around any fan that is produced by this tributary.

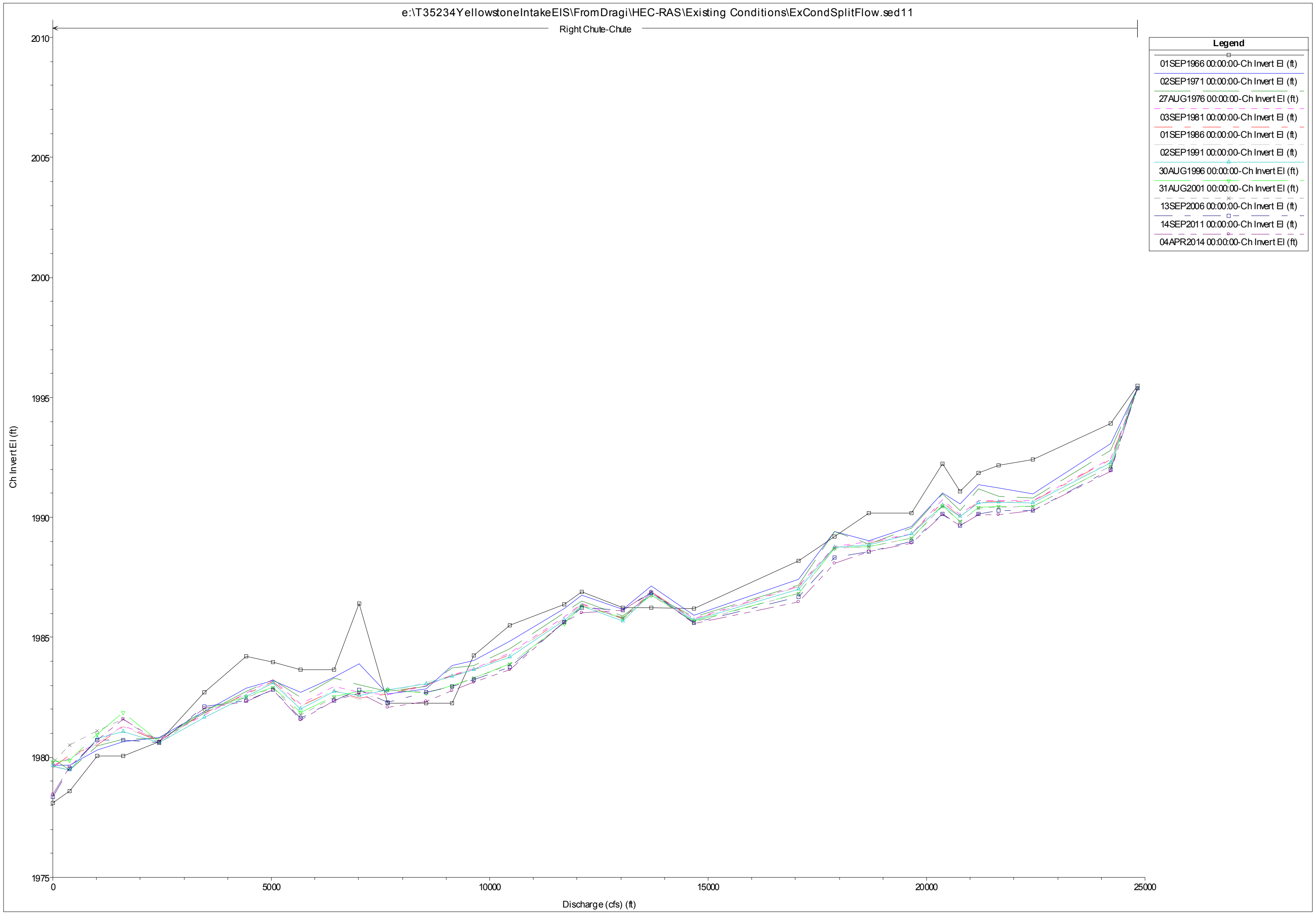

Figure 1. Thalweg profiles over time for the existing high flow channel using Laursen (Copland) sediment transport function.

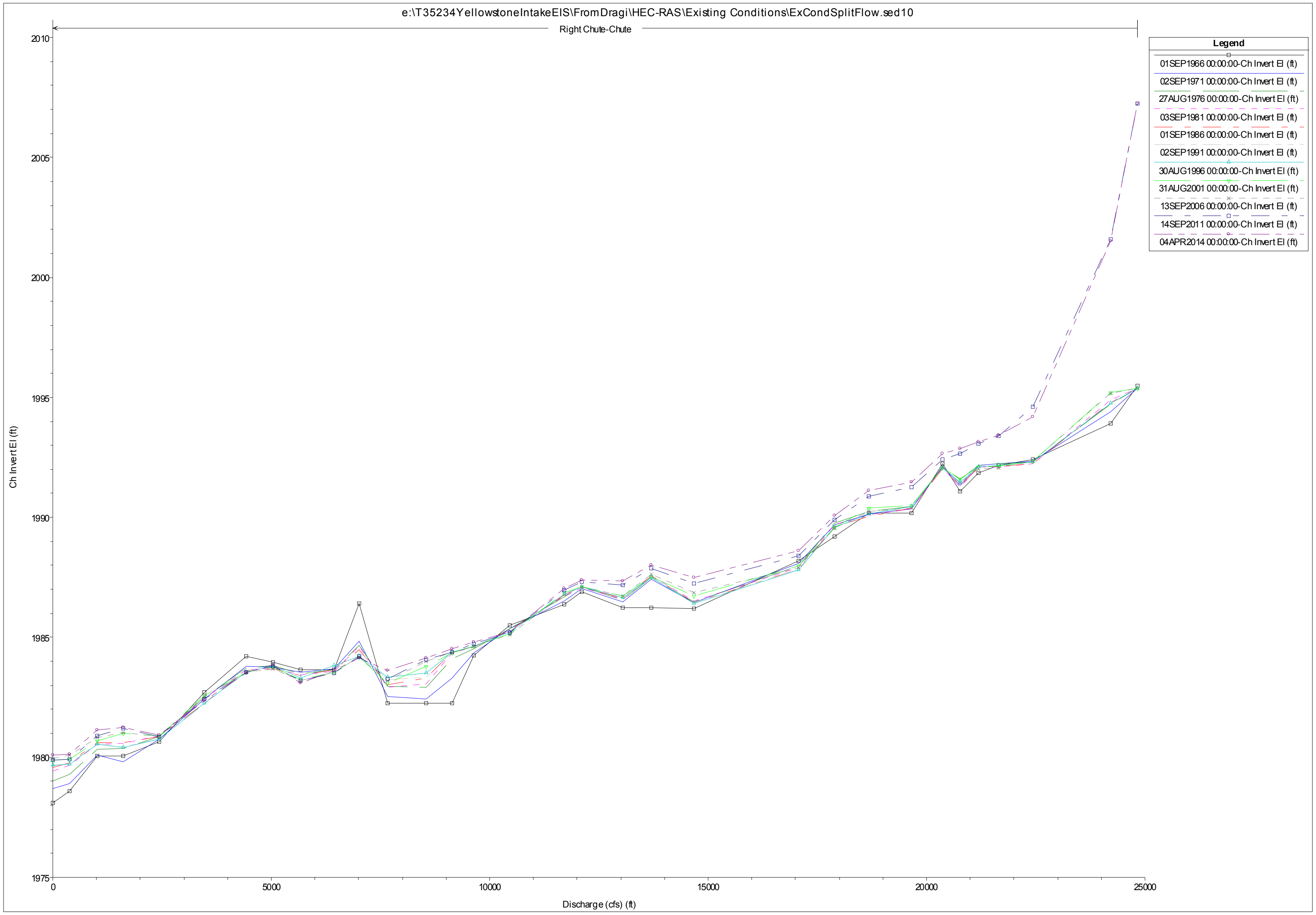

Figure 2. Thalweg profiles over time for the existing high flow channel using Ackers-White sediment transport function.

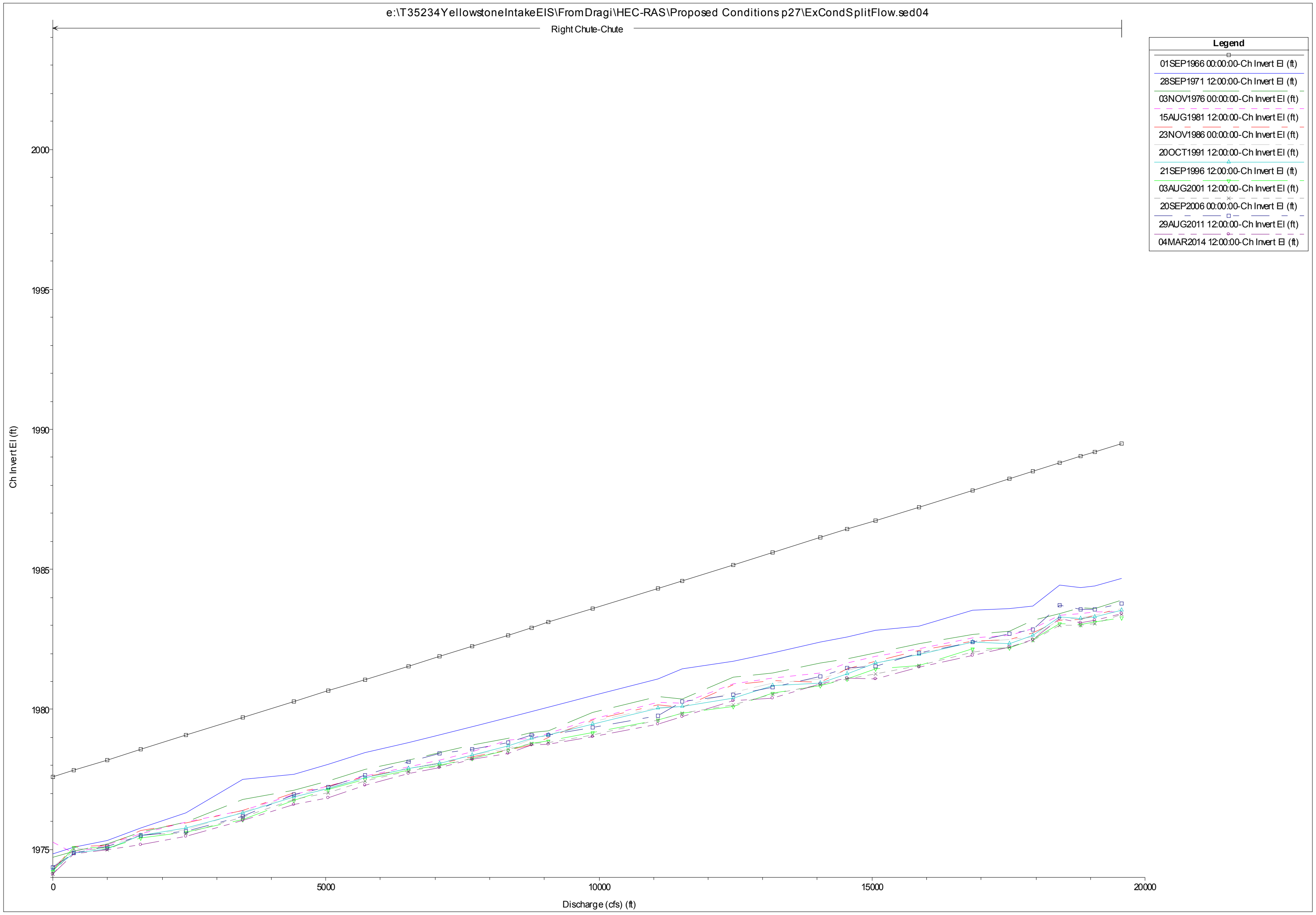

Figure 3. Thalweg profiles over time for the designed modified side channel using Laursen (Copeland) sediment transport function.

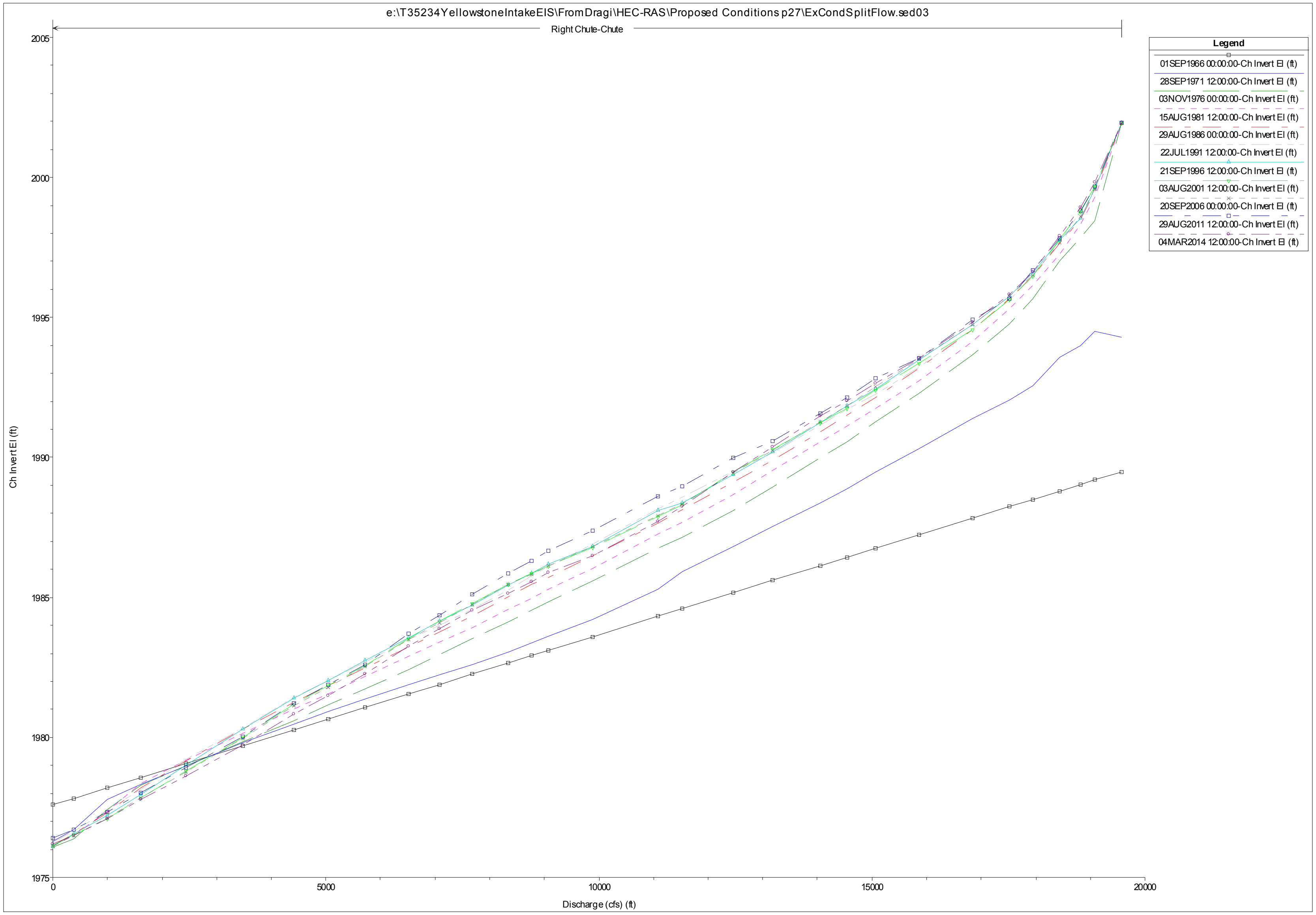

Figure 4. Thalweg profiles over time for the designed modified side channel using Ackers-White sediment transport function.

Attachment 3
30% Design Drawings

Note: the following support calculations refer to this alternative as the *High Flow Channel Alternative*. The name has been revised to *Modified Side Channel Alternative*, however the name on these support calculations still refer to the High Flow Channel. None of the analyses are affected by the name change and all support calculations are applicable to the *Modified Side Channel Alternative*.

US ARMY CORPS
OF ENGINEERS
OMAHA DISTRICT

MARK	DESCRIPTION	DATE	APPR

MARK	DESCRIPTION	DATE	APPR

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS

TETRA TECH

DESIGNED BY: P. BAILEY		DATE:
DWN BY: BKT	CKD BY: PB	SOLICITATION NO.: W9128F–0X–X–00XX
SUBMITTED BY:		CONTRACT NO.: W9128F–0X–C–00XX
FILE NAME: AS SHOWN		FILE NUMBER:
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LOWER YELLOWSTONE PROJECT, MONTANA
YELLOWSTONE INTAKE

HIGH FLOW CHANNEL

SHEET
IDENTIFICATION
NUMBER
C-101

US ARMY CORPS
OF ENGINEERS
OMAHA DISTRICT

MARK	DESCRIPTION	DATE	APPR

MARK	DESCRIPTION	DATE	APPR

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS

TETRA TECH

DESIGNED BY: P. BAILEY
DWN BY: BKT
CKD BY: PB
DATE:
SOLICITATION NO.: W9128F–0X–X–00XX
SUBMITTED BY:
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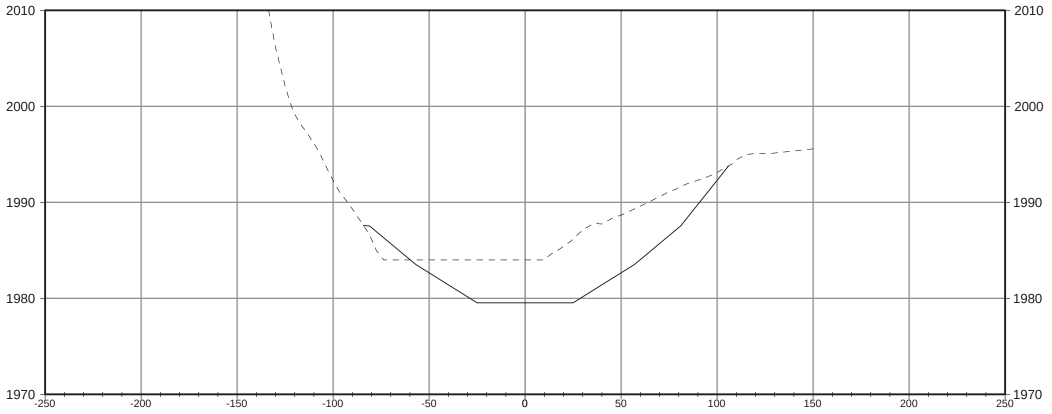
LOWER YELLOWSTONE PROJECT, MONTANA
YELLOWSTONE INTAKE

HIGHFLOW CHANNEL

SHEET
IDENTIFICATION
NUMBER
C-102

35+00



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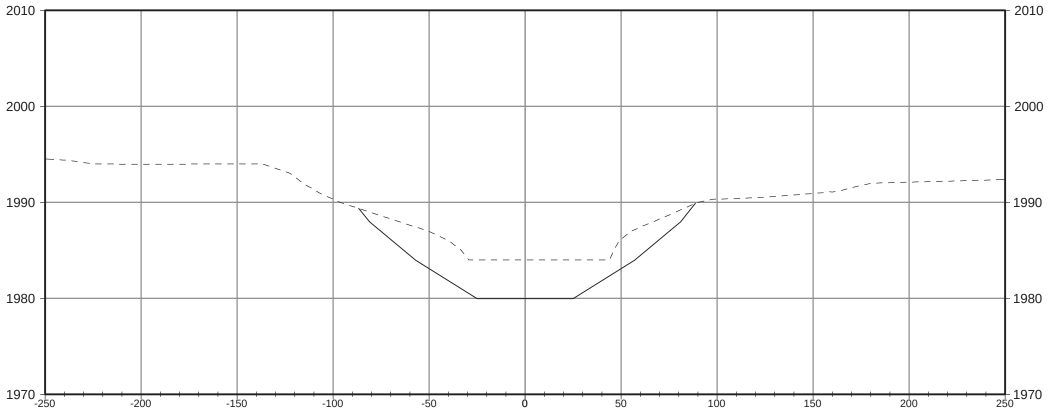

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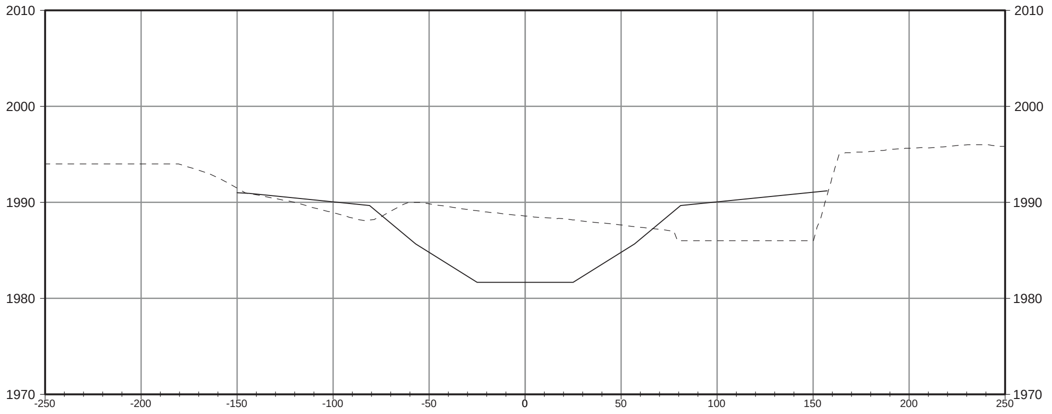

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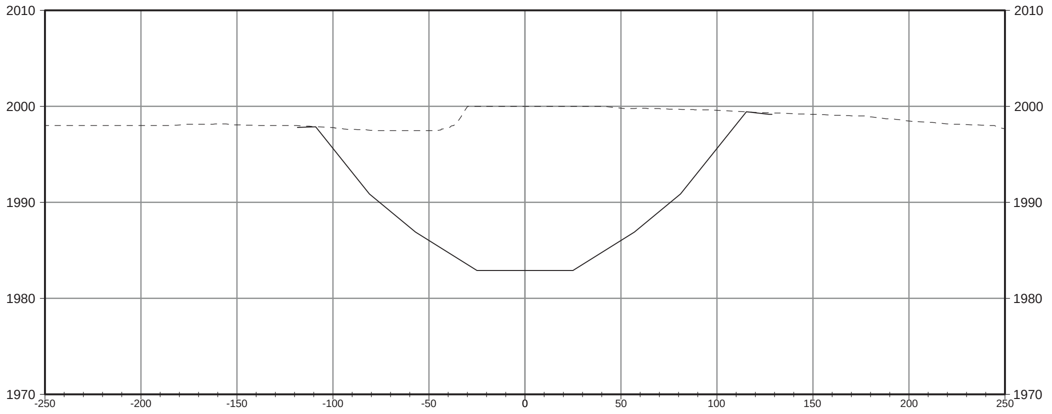

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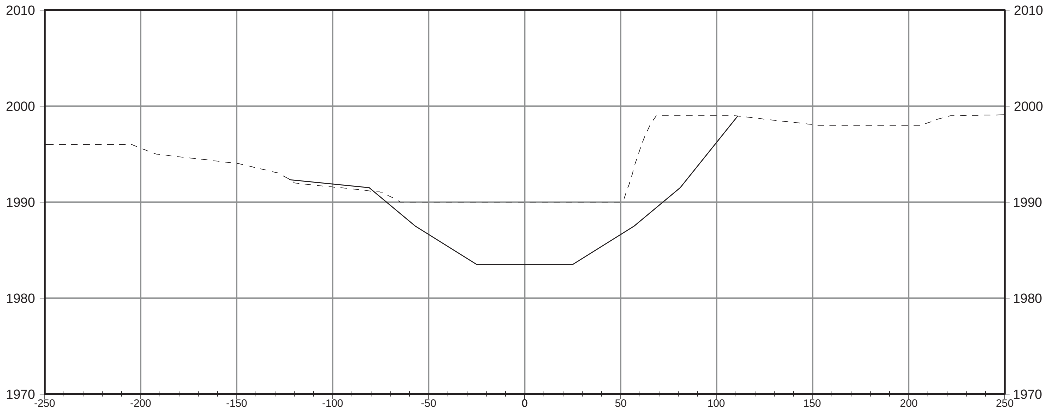

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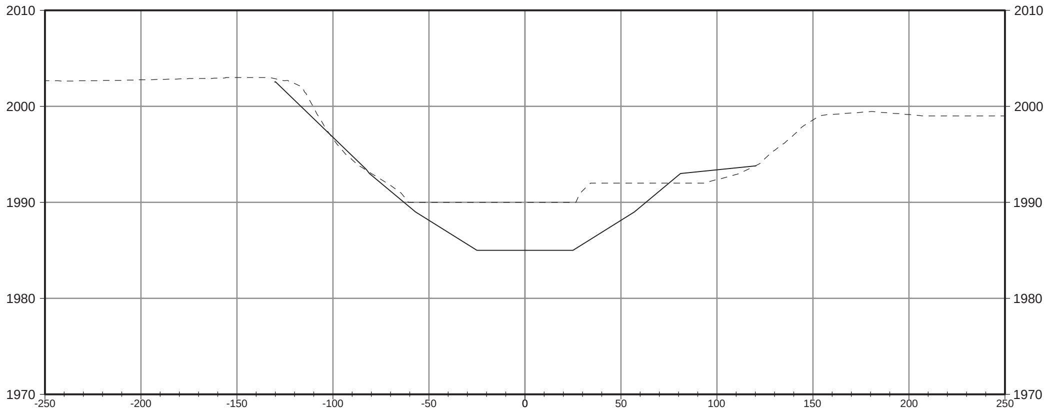

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US Army Corps
of Engineers®
Omaha District

MARK	DESCRIPTION	DATE	APPR

MARK	DESCRIPTION	DATE	APPR

U.S. ARMY CORPS OF ENGINEERS
OMAHA DISTRICT
OMAHA, NE

TETRA TECH

DESIGNED BY:
P. BAILEY

DATE:

DWN BY:
BKT

CKD BY:
PB

SOLICITATION NO.:

SUBMITTED BY:

CONTRACT NO.:

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LOWER YELLOWSTONE PROJECT, MONTANA
YELLOWSTONE INTAKE

HIGH FLOW CHANNEL
SECTIONS

SHEET
IDENTIFICATION
C-401

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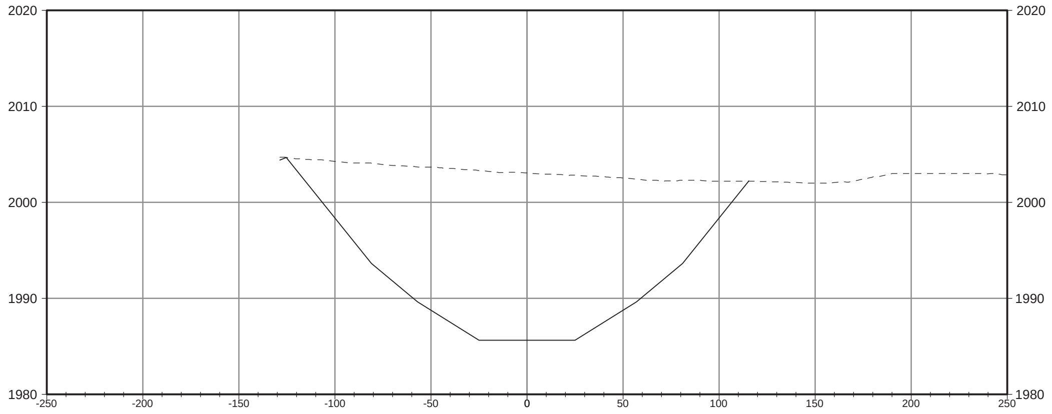

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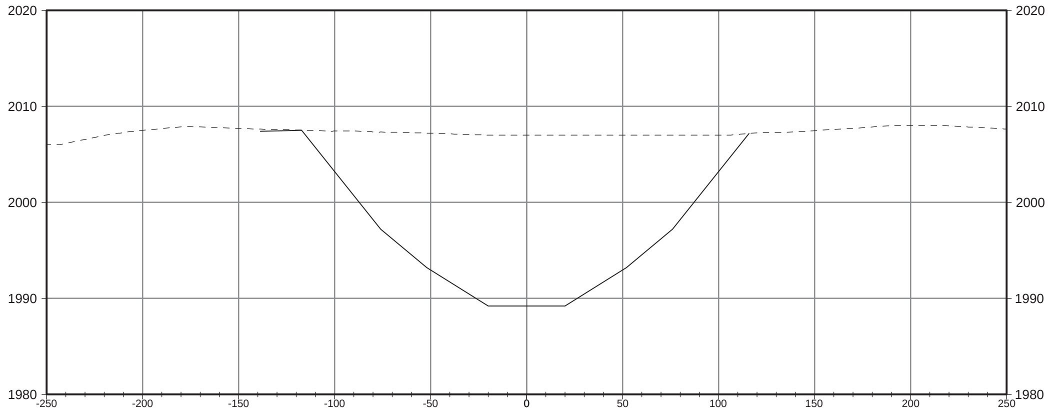

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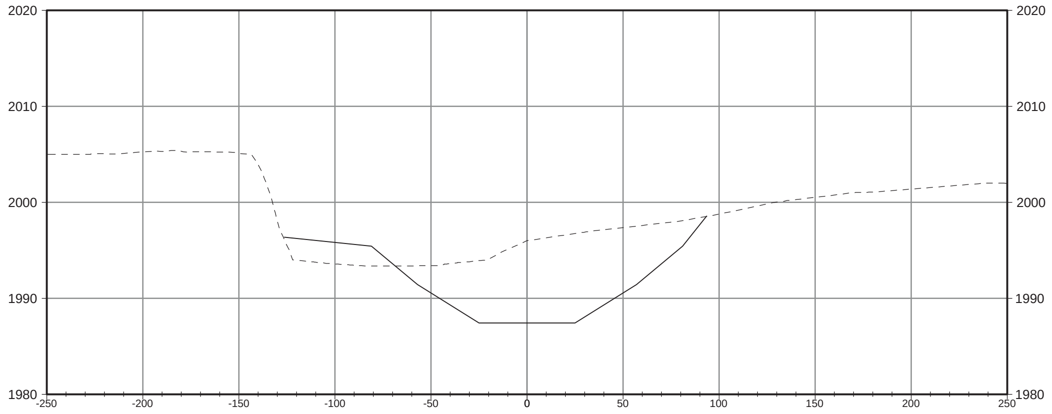

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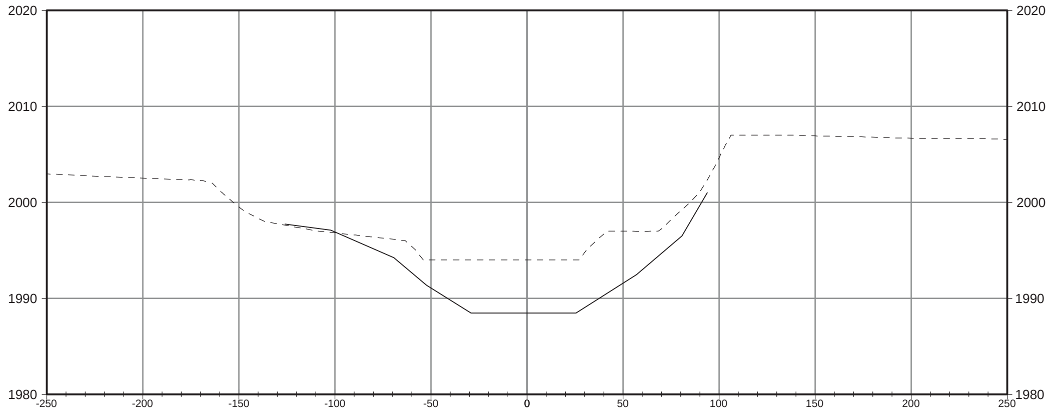

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US Army Corps
of Engineers®
Omaha District

MARK	DESCRIPTION	DATE	APPR

MARK	DESCRIPTION	DATE	APPR

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P. BAILEY
DWN BY:
BKT
CKD BY:
PB
SUBMITTED BY:
PLOT SCALE:
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PLOT DATE:
SIZE:
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CONTRACT NO.:
FILE NUMBER:

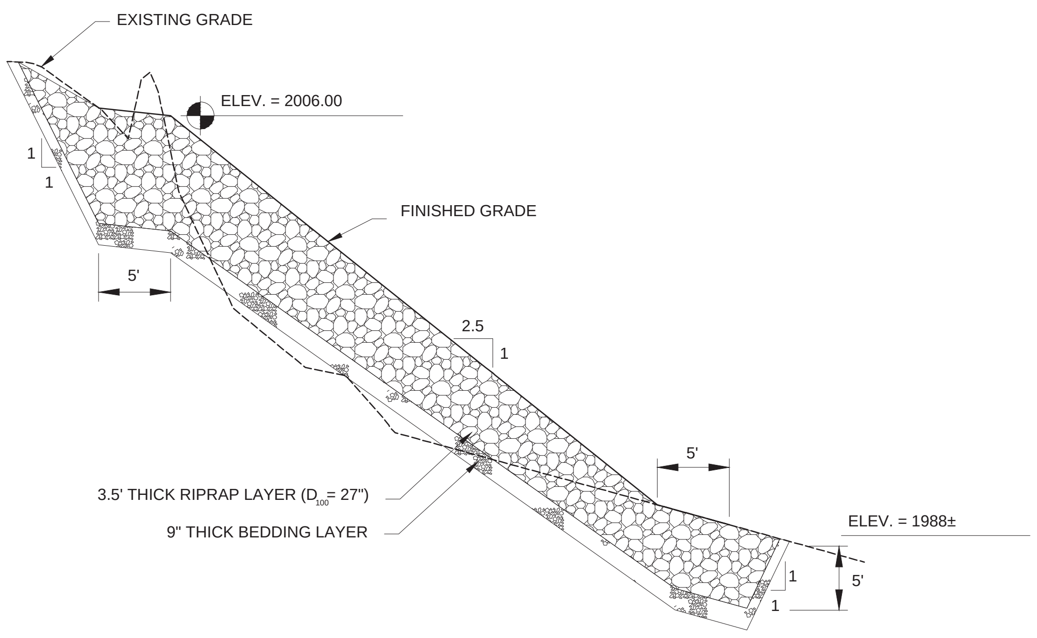
U.S. ARMY CORPS OF ENGINEERS
OMAHA DISTRICT
OMAHA, NE

TETRA TECH

LOWER YELLOWSTONE PROJECT, MONTANA
YELLOWSTONE INTAKE

HIGH FLOW CHANNEL
SECTIONS

SHEET
IDENTIFICATION
C-402



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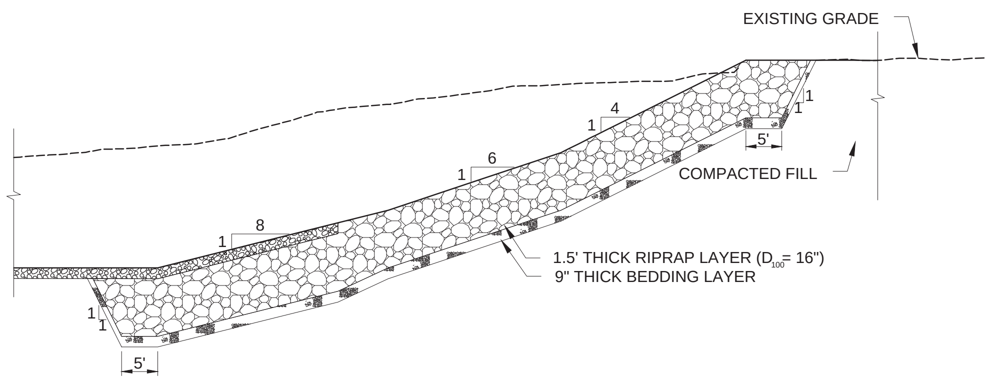

HIGH FLOW CHANNEL BANK PROTECTION DETAIL AT DESIGNATED LOCATIONS BETWEEN STA 0+00 TO 195+00*

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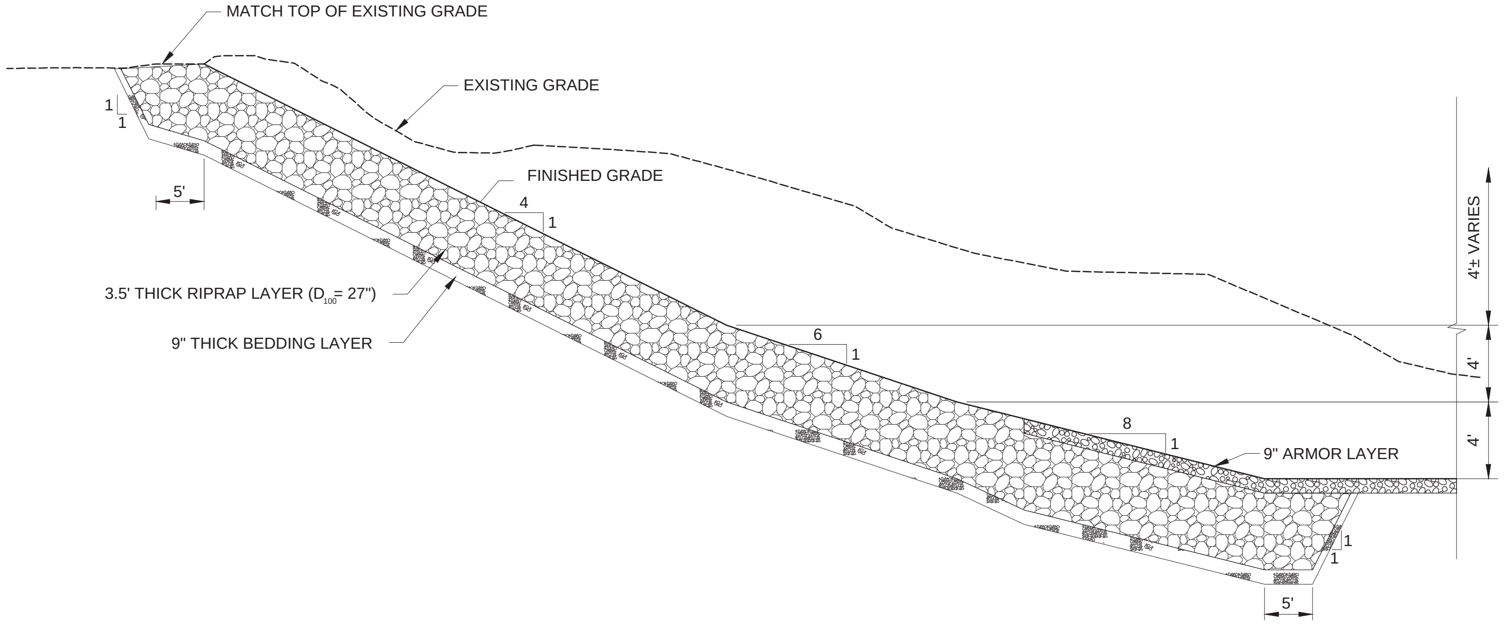

HIGH FLOW CHANNEL BANK PROTECTION DETAIL STA 195+00 TO 204+39

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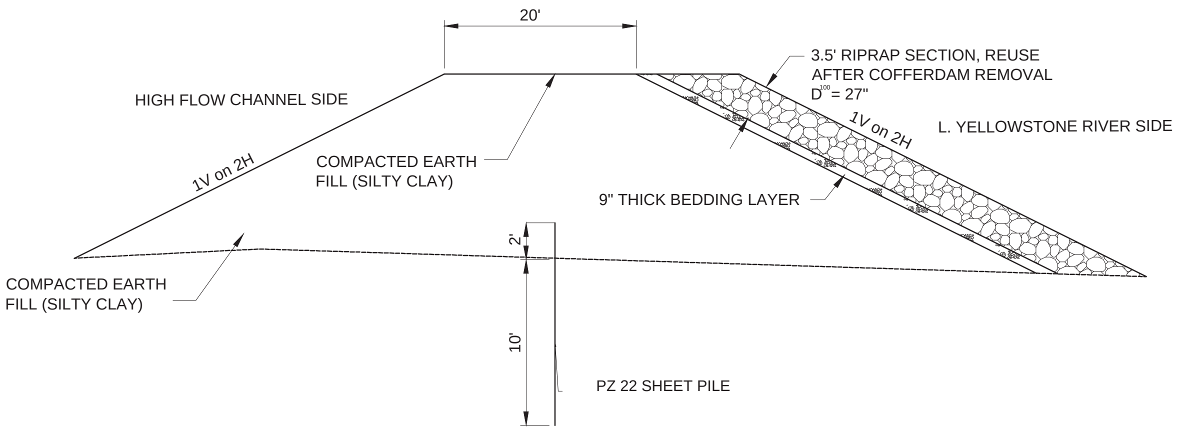

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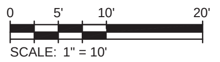


SCALE: 1" = 10'

US Army Corps
of Engineers®
Omaha District

MARK	DESCRIPTION	DATE	APPR

MARK	DESCRIPTION	DATE	APPR

U.S. ARMY CORPS OF ENGINEERS
OMAHA DISTRICT
OMAHA, NE

TETRA TECH

DESIGNED BY:
P. BAILEY

DWN BY:
BKT

CKD BY:
PB

SUBMITTED BY:

PLOT SCALE:
AS SHOWN

PLOT DATE:

SIZE:
D

FILE NAME:
C-500 DETAILS.DWG

DATE:

SOLICITATION NO.:

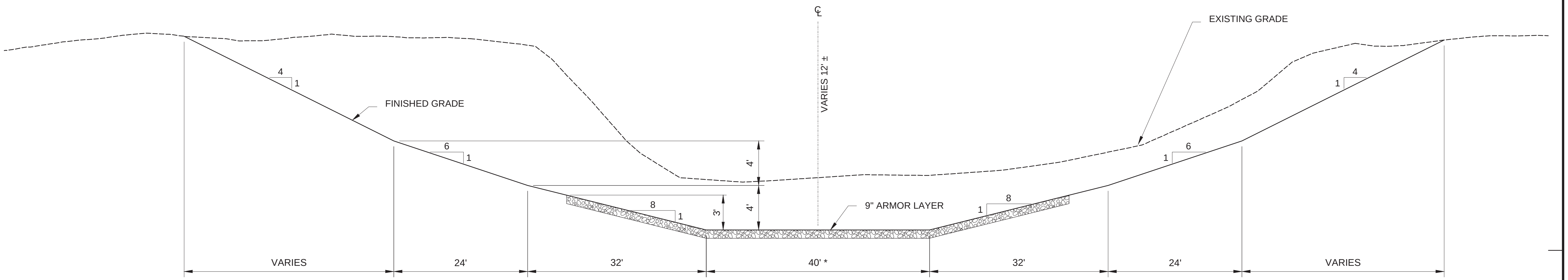
CONTRACT NO.:

FILE NUMBER:

LOWER YELLOWSTONE PROJECT, MONTANA
YELLOWSTONE INTAKE

HIGH FLOW CHANNEL
DETAILS

SHEET
IDENTIFICATION
C-501



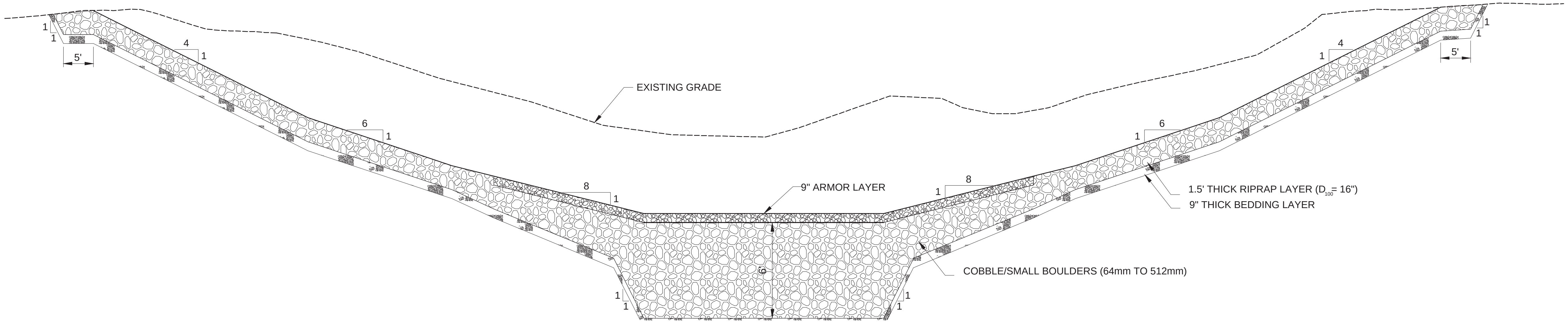
FISH BYPASS CHANNEL SECTION

A

NO SCALE

SEE TABLE ON SHEET CG701

* BOTTOM WIDTH 55' FROM STA 195+00 TO 203+55
45' FROM STA 150+00 TO 195+00
40' FROM STA 0+00 TO 150+00



GRADE CONTROL STRUCTURE

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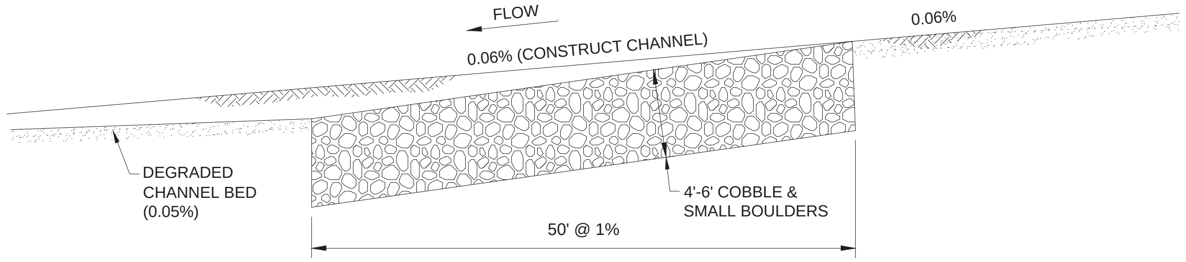

GRADE CONTROL STRUCTURE PROFILE

NO SCALE

0 5' 10' 20'
SCALE: 1" = 10'

US ARMY CORPS
OF ENGINEERS
OMAHA DISTRICT

MARK	DESCRIPTION	DATE	APPR

MARK	DESCRIPTION	DATE	APPR

DESIGNED BY:
P. BAILEY
DWN BY:
BKT
CKD BY:
PB
SUBMITTED BY:
FILE NAME:
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PLOT SCALE:
DATE:
SOLICITATION NO.:
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W9128F–0X–C–00XX
FILE NUMBER:
PLOT DATE:

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS

TETRA TECH

LOWER YELLOWSTONE PROJECT, MONTANA
YELLOWSTONE INTAKE

HIGH FLOW CHANNEL
DETAILS

SHEET
IDENTIFICATION
NUMBER
C-502

Lower Yellowstone Intake Diversion Dam Fish Passage Project, Montana

ENGINEERING APPENDIX A-2

Lower Yellowstone Intake Fish Passage EIS

Multiple Pumping Station Alternative

MAY 2016

Contents

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ATTACHMENTS

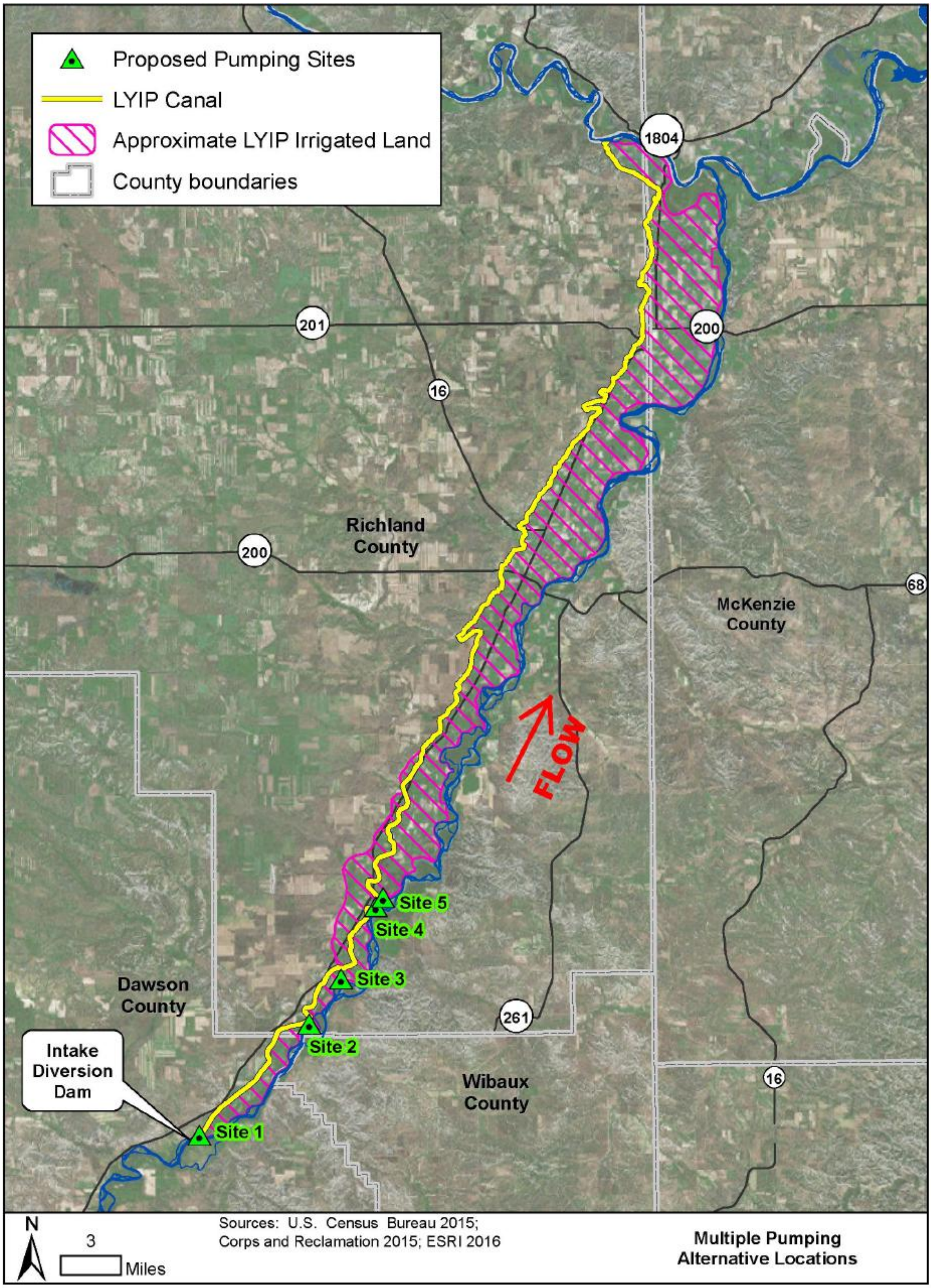
1.0 Alternative Description

The multiple pumping station alternative proposes removing the Intake Diversion Dam, using the existing headworks when there is sufficient flow in the Yellowstone River to gravity divert the required flows, and constructing five pumping stations along the banks of the Yellowstone River to deliver water to the Lower Yellowstone Project when gravity flows are insufficient. The pumping plants would be constructed at various locations along the Lower Yellowstone Project between Intake Dam and Savage. The intakes would be screened to minimize fish entrainment and would discharge into existing canals to supply the irrigation districts. Because the irrigation canal system was designed for gravity flow of water primarily from a single water source at Intake, this alternative would require some restructuring of the Lower Yellowstone Project canal system to accommodate a water supply from multiple points along the canal.

The pumping stations are designed for a total diversion capacity of 1,374 cfs when the flow in the Yellowstone River is 3,000 cfs at the upper most point of diversion. Each of the five pumping stations is designed for a capacity of 275 cfs. Water would be drawn from the river through a feeder canal to a fish screen structure, located at the edge of the channel migration zone. The motors and electrical equipment in both the fish screen structure and the pump station would be located above the 100-year flood elevation. Fish would be screened out and returned to the river through a fish return pipe and irrigation water would pass through the fish screen and flow into the pumping station. Discharge pipes would convey the irrigation water to the main irrigation canal.

The design features are shown and described in Section 4 of this appendix and conceptual design drawings are included in Attachment 1.

The locations of the five proposed pumping stations are shown in Figure 1.1, below.



Sources: U.S. Census Bureau 2015; Corps and Reclamation 2015; ESRI 2016

Figure 1.1 Multiple Pumping Station Locations

2.0 Design Guidelines

2.1 Design Criteria

The pumping stations are designed for a total diversion capacity of 1,374 cfs when the flow in the Yellowstone River is 3,000 cfs at the upper most point of diversion (located near Intake Dam), as specified by the Corps.

The proposed pumping stations should be located outside of the channel migration zone (CMZ) if possible, or as far from the riverbank as practical to minimize the need for riverbank protection.

The proposed typical fish screen is designed according to criteria stated in the NMFS Anadromous Salmonid Passage Facility Design guide (NMFS, 2011).

The mechanical design of the proposed pumping stations are based on EM 1110-2-3105, "Mechanical and Electrical Design of Pumping Stations" (Corps, 1999). The structural design of the proposed pumping stations are based on EM 1110-2-2100, "Stability Analysis of Concrete Structures" (Corps, 2005).

The proposed concrete outlet structures are designed according to "Design of Small Canal Structures" by Reclamation (Reclamation, 1978).

The removal of the existing intake diversion dam should include constructing a continuous river geometry through the dam location to provide fish passage to native fishes. This would require removal of any obstruction at the dam site to the adjacent river bottom elevation (1982 feet±).

2.2 Assumptions

The follow assumptions were made in the preparation of this conceptual design:

- The design flow rate in the Yellowstone River decreases downstream by the quantity of each diversion without additional losses or recharge.
- Bathymetric data in the Yellowstone River was not available, except at the Intake Dam location. Channel elevation and depth data at the pumping station sites was taken from the Yellowstone River Corridor Study hydraulic model.
- Topographic surveys of the proposed sites were not available. Elevations and geometry of pump stations and conveyance structures are estimated based on LIDAR and GIS data available on the Montana.Gov Geographic Information Clearinghouse at: http://geoinfo.msl.mt.gov/Home/data/yellowstone_river_corridor_resource_clearinghouse.
- A fish handling pump would be permitted to operate the fish return pipes.
- Cost estimates of some fish screen mechanical equipment are based on previous studies.

- Fish screen and pumping station design are the same for all five sites, although it is recognized the final designs would show some variations.
- Soil parameters and groundwater elevation at each site are assumed to be the same.
- Hydraulic analysis indicates that gravity diversions from the existing headworks could occur concurrently with pumping when the three most downstream pumping stations are brought online, without producing a higher tailwater elevation at the main canal headworks. It was assumed that no gravity diversion could occur when the upper two pumping stations are brought online.
- Irrigation water would be delivered to the existing irrigation canal, not to individual laterals or farms. Potentially connecting individual laterals or farms would be considered during site-specific design, if this alternative is selected.
- The necessary land rights could be obtained for the pumping stations, feeder canals, pipelines, and other design features. Land ownership was not assessed.
- Discharge pipelines would be installed with a typical cover depth of 2-3 feet. Conflicts with existing features along the proposed pipeline alignments were assessed based on existing GIS data and aerial photos, but the alignments have not been field-verified.
- Access roads to the pumping stations would be cut by an average depth of 2 feet for half of their length and filled by an average depth of 2 feet for the other half. Grading design has not been performed for the conceptual design.
- Average annual estimated energy consumption assumes that the average historical diversion rate (1,100 cfs) would be delivered to the irrigation canal on each day from May 1 to September 30. Gravity diversions would be used to supply some or all of this quantity, when possible.

3.0 Engineering Considerations

3.1 Hydrology and Hydraulics

3.1.1 Modeling

Three hydraulic models were developed related to this alternative. Each was performed using HEC-RAS version 5.0 (Corps 2010). The first included modeling of the Yellowstone River to provide water surface elevations at the pumping sites. The second involved removal of Intake Dam and upstream sediment wedge from the existing conditions model to evaluate potential for gravity diversion without the presence of the diversion dam. The third included modeling of the irrigation canal to evaluate canal hydraulics under a range of pumping conditions.

3.1.1.1 Yellowstone River Water Depth Model

Water depth in the Yellowstone River was taken from the Yellowstone River Corridor Study hydraulic model (Corps, 2014). The hydraulic modeling was conducted using HEC-RAS (Corps, 2010). The model was constructed using cross sections with an assumed trapezoidal geometry, due to the lack of bathymetry in most of the river. Because of this limitation, depths obtained from the model represent only an average depth across the river. Maximum depths are likely greater than the average depth, likely by several feet. Results from the model were taken for conditions when the flow in the river is 3,000 cfs at Intake Dam and decreases downstream by the quantity of each diversion. The water depths calculated at Sites 1 - 5 are shown in Table 3.1, below.

Additional data collection, modeling, and analysis would be required to confirm the suitability of each site and the likely water depths, geomorphic conditions, intake canal conditions, screening requirements, and other considerations if this alternative is selected as the preferred alternative for further design.

Table 3.1 Yellowstone River Depth at Sites 1 - 5

Site	Location	Diversion Rate (cfs)	Yellowstone River Flow (cfs)	Average River Depth[a] (feet)	Yellowstone River WSEL[b] (feet)
Site 1 / Existing Intake	RM 72.8	275	3000	2.9	1985.1
Site 2	RM 64.3	275	2725	2.1	1957.7
Site 3	RM 60.6	275	2450	3.3	1949.6
Site 4	RM 54.8	275	2176	2.6	1935.7
Site 5	RM 54.1	275	1901	1.8	1933.6

[a] Maximum depth will be greater than the reported average depth

[b] Yellowstone River Water Surface Elevation (WSEL) is in the NAVD88 datum.

3.1.1.2 Intake Dam Removal Model

The hydraulic modeling of the removal of Intake Dam focused on evaluating the potential for gravity diversion with the diversion dam and downstream rock down to the prevailing natural bed elevations removed. The existing conditions HEC-RAS model provided by the Corps was the starting point for the modeling. The analysis was conducted in a two-step process with the first version of the “no-dam” model, consisting of simply removing the cross sections representing the dam crest, downstream existing rock, and the scour hole at the downstream end of the rock. The model was run for the 2-year discharge to assess whether upstream deposition has occurred over the life of the dam. Figure 3.1 shows the channel bed and 2-year water surface profiles of the with-dam and first version of the no-dam models. Removal of the dam lowers the water surface immediately upstream of the dam by approximately 6 feet for the 2-year flow, but there is also a convexity in the 2-year water surface that likely indicates the presence of a wedge of sediment that has collected during the life of the dam.

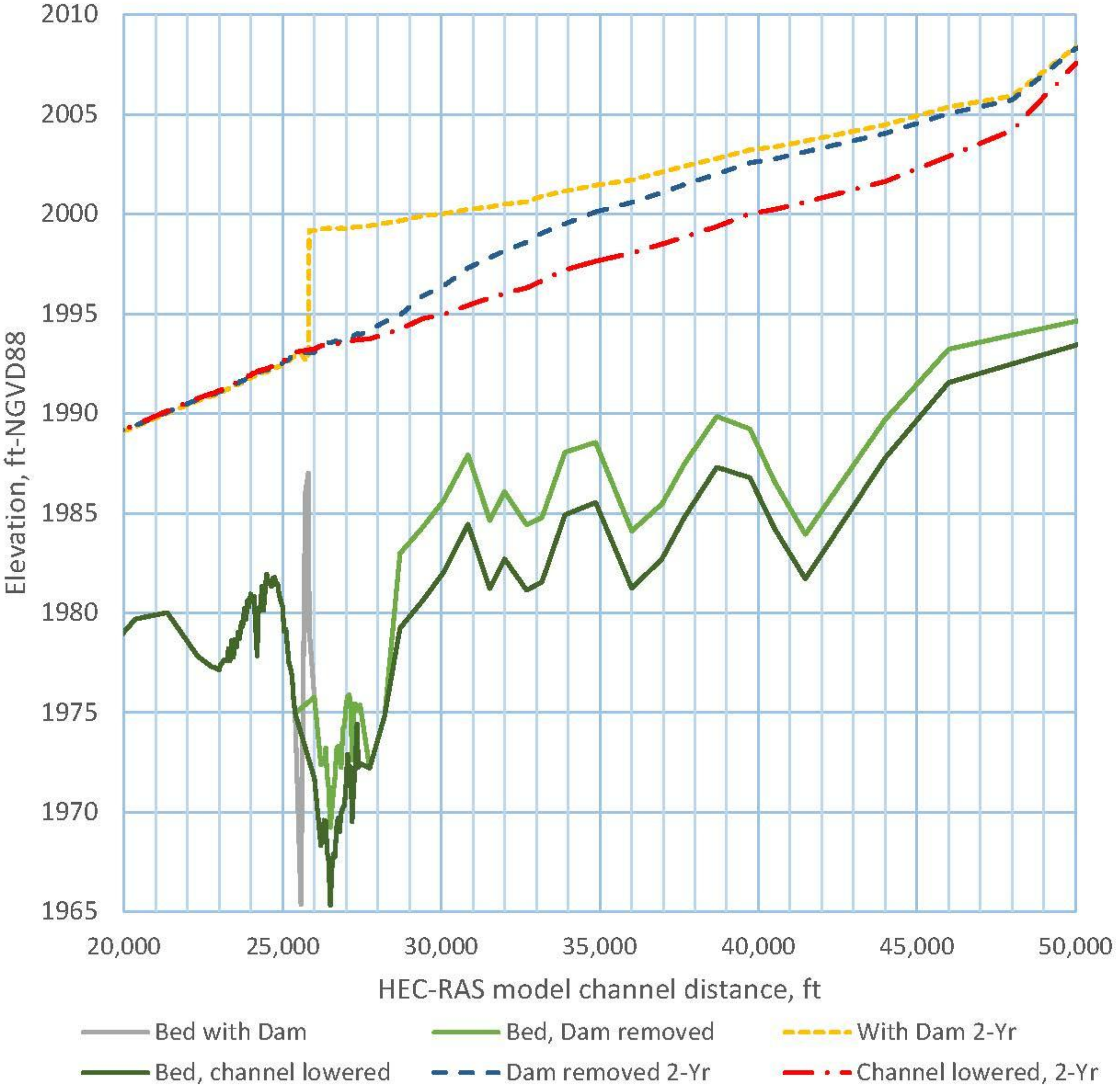


Figure 3.1 Yellowstone River Profiles for Existing and After Dam Removal

The second version of the no-dam model represents an estimate of the future channel condition after the Yellowstone River has adjusted to the removal of the structure and rock. The sediment wedge is considered to be approximately 4 feet thick at the dam and tapers to zero feet at the upstream end of the model. The downstream channel was left unchanged assuming that over several years the sediment released from the wedge would distribute downstream and would have an indiscernible impact. The second version of the model shows no convexity in the water surface profile, so no further adjustments were made. This final model also includes a lateral structure representing the fish screens and gates. The lateral structure incorporates a stage-discharge rating curve for the canal that is offset assuming 1-ft of head loss across the screens and gates to estimate the required stage on the Yellowstone River to determine the potential gravity diversion flow.

When this model is run for a range of flows, the potential gravity diversion for the non-weir alternative is computed. Table 3.2 shows the potential gravity diversion-flow duration curves based on the Yellowstone River flow-duration curves for Sydney Gage (USGS gage #06329500) (Corps 2006). The gravity diversion of 1,374 cfs could be met approximately 17 percent of the 5-month irrigation season based on 30,000 cfs in the Yellowstone River, but almost never occurs during August and September, which are historically low flow periods.

Table 3.2 Flow Duration of Potential Diversions Based on 1 Foot Head Loss

Percent time exceeded	Diversion potential based on Yellowstone River flow duration, cfs					
	May	June	July	August	Sept	5 months
0.01	1,374	1,374	1,374	1,374	1,374	1,374
0.05	1,374	1,374	1,374	1,374	1,374	1,374
0.1	1,374	1,374	1,374	1,374	1,374	1,374
0.2	1,374	1,374	1,374	1,374	1,331	1,374
0.5	1,374	1,374	1,374	1,302	1,095	1,374
1	1,374	1,374	1,374	1,214	946	1,374
2	1,374	1,374	1,374	1,116	847	1,374
5	1,374	1,374	1,374	904	748	1,374
10	1,374	1,374	1,374	790	692	1,374
15	1,269	1,374	1,374	731	647	1,374
20	1,141	1,374	1,374	692	612	1,282
30	1,002	1,374	1,245	620	569	1,035
40	908	1,374	1,088	544	525	853
50	828	1,374	916	491	472	724
60	765	1,262	801	442	427	620
70	692	1,120	674	379	387	527
80	614	977	523	334	352	443
85	554	908	474	308	331	400
90	513	832	428	267	314	356
95	452	731	385	215	286	307
98	403	625	331	192	247	245
99	364	559	314	187	231	210
99.5	277	521	289	182	203	194
99.8	250	492	254	177	192	186
99.9	231	466	249	174	188	182
99.95	229	464	246	172	186	177
99.99	227	464	240	167	181	169

3.1.1.3 Irrigation Canal Model

A HEC-RAS hydraulic model of the main irrigation canal was developed to assess both existing conditions within the canal and changes in water surface elevation resulting from the pumping alternative. The model geometry was derived from a number of sources. Irrigation canal geometry for the upstream most four miles of the canal were extracted from a previous HEC-RAS model of the Yellowstone River covering the general location of Intake Dam (Corps, 2015). Seven cross sections representing typical irrigation canal geometry were surveyed in 2016 between canal miles 6.3 and 22.7, inclusive. The surveyed cross sections were used to represent irrigation canal geometry from canal mile 6.3 to canal mile 47.0. Structures including the Burns Creek and Peabody Coulee Creek overchutes, and Prevost Check, NN Check and Gauge, and Crane Check and Gauge were also surveyed and included in the HEC-RAS model. Historical design drawings were then used to represent the irrigation canal geometry for the remainder of the canal, from canal mile 47.0 to the terminal end of the canal at the confluence with the Missouri River. Roughness coefficients were adjusted to best match high water marks collected at the time of the 2016 survey. The lower portion of the model was not calibrated, and slightly higher roughness values were used to reflect the smaller downstream channel.

The HEC-RAS model was used to model several flow scenarios within the main irrigation canal. It was assumed that gravity diversion of flows from the Yellowstone River at the headworks would be utilized concurrently with pumping until no longer feasible. Water surface elevation profiles were modeled for scenarios where gravity diversion provided all demand within the canal. As flows lessen in the Yellowstone River, gravity inflow at the headworks was reduced as each pump was turned on commensurate with the flows provided by each pump. Observed flows from July 6, 2012 which had a peak inflow of 1,355 cfs at the headworks were also modeled to provide a comparison with expected maximum water surface elevations within the canal as part of the evaluation of canal operations.

Figure 3.2 shows the results of the upper 20 miles of the HEC-RAS model developed for the LYP main canal. This figure includes water surface profiles from complete gravity diversion, and from various pumping sites with the remaining flow assumed to be providing the remaining flow needed for a total of 1,374 cfs. For example, the “WS Pump 5” profile assumes pumping station 5 is at its maximum capacity (275 cfs) and the remainder of the flow is diverted by gravity. Table 3.3 shows the gravity and pumping discharges used to develop the profiles in Figure 3.2. This figure illustrates the issues of operating a canal under combined pumping and gravity. Below station 280,000, the profiles are unchanged because the same amount of water has been supplied. When pumping is required, the areas upstream of the Burns Creek Overchute would either require additional control structures or pumping from the irrigation canal to the laterals, but below this point, minimal modification would be required. Pumping from the irrigation canal is probably preferable because pumping a small amount of water from the canal at laterals AA, BB, CC, DD, and FF is less costly than raising the water level and eliminating a much larger gravity-diverted flow which would require the flow to be replaced by pumping from the Yellowstone River.

Table 3.3 Gravity and Pumping Discharges

	Discharge (cfs)						
Profile	**Gravity**	**Pump 1**	**Pump 2**	**Pump 3**	**Pump 4**	**Pump 5**	**Total**
Pump 5	1,100	0	0	0	0	274	1,374
Pumps 4&5	825	0	0	0	275	274	1,374
Pumps 3-5	550	0	0	275	275	274	1,374
Pumps 2-5	275	0	275	275	275	274	1,374
Pumps 1-5	0	275	275	275	275	274	1,374
06Jul2012	1,355	n/a	n/a	n/a	n/a	n/a	1,355

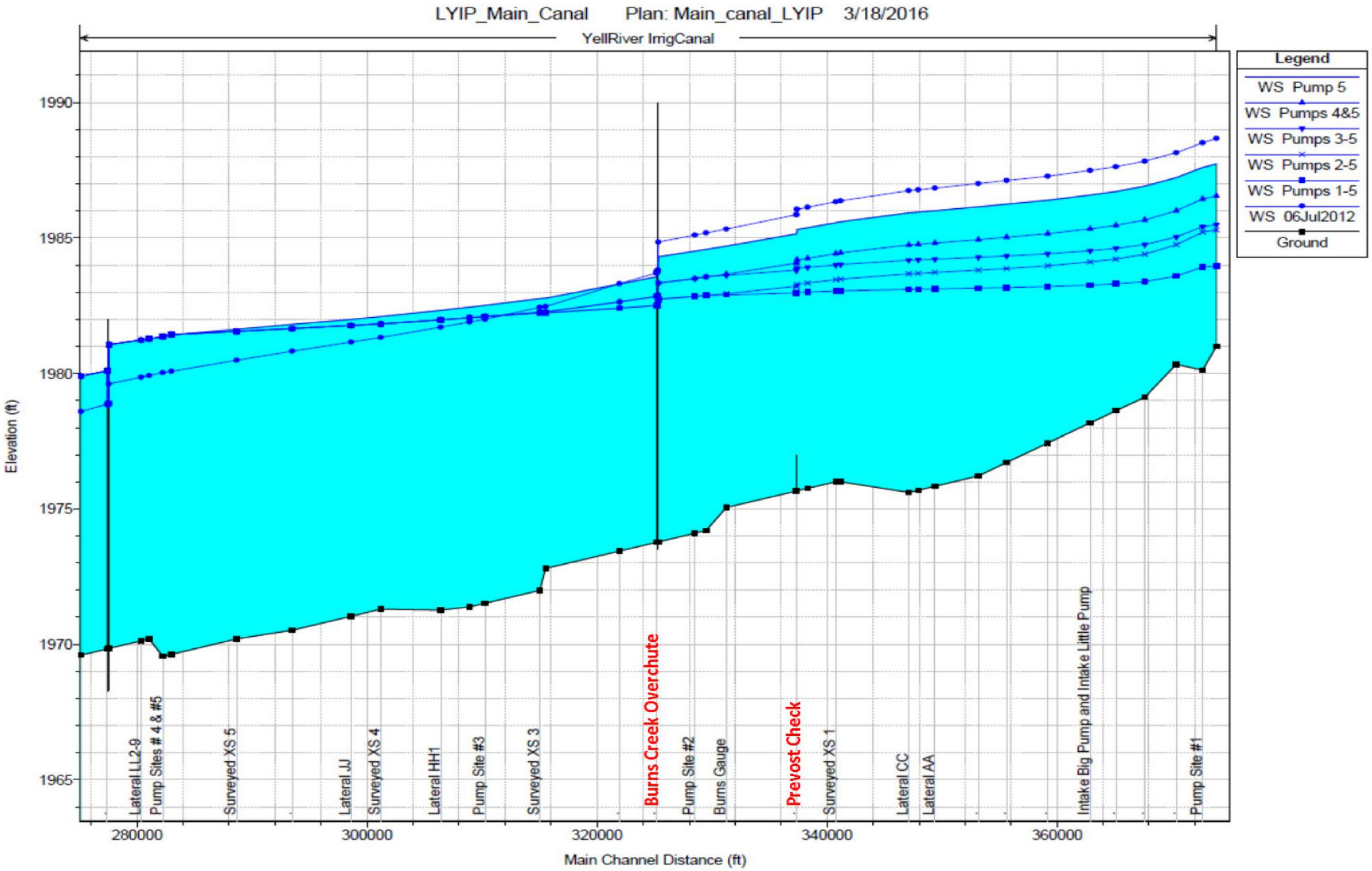


Figure 3.2 LYP Main Canal Water Surface Profiles

3.1.2 Groundwater

The existing and future groundwater elevation at the pumping station sites is unknown and is expected to vary at each of the proposed locations. Structural dimensions for the pumping station foundation and fish screen structure walls were estimated assuming the groundwater at the pumping station sites is 6 feet lower than the design water surface elevation in the river, or 25 feet below the finished floor elevation of the pumping station's equipment room.

3.1.3 Ice

Ice formation on the Yellowstone River has been identified as a challenge for any in-channel features. Previous studies on ice formation in the river at the Intake Dam location found that ice jams up to 8 feet in depth may occur, and an ice load of 2,000 pounds per square foot may occur on the upstream faces of in-channel features (Final Supplemental EA, Appendix A2, Attachment 5, Corps, 2015).

The fish screen structures and pumping stations proposed by this alternative are located in an off-channel location to minimize the impact of river ice flows on them. Additionally, an ice protection berm is provided on the upstream side of each facility (relative to the river flow) to provide additional protection against damage due to river ice. The fish screen structures are designed to be dewatered during the non-irrigation season and the fish screen panels could be removed in the winter, if necessary. More information about proposed O&M activities is included in Appendix B.

3.1.4 Channel Migration

The Yellowstone River Cumulative Effects Assessment (YRCEA) (Corps and YRCDC, 2015) describes geomorphic trends primarily occurring after 1950 with a focus on analysis of GIS data to describe the spatial distribution and temporal shifts of overall channel planform and associated complexity. The analysis included degree of braiding, extent and blockage of side channels, bankfull channel area, floodplain turnover and channel migration, and bank armoring. The YRCEA indicated the reach that includes Intake Dam has average migration rates of around 5 feet per year, which is a reduction from historical rates of around 7 to 8 feet per year. The right bank of the bend at the head of the high flow channel shows migration of approximately 400 feet in approximately 60 years. If this rate of migration continues for at least 100 years at this location, there would be no expected adverse impact on the gravity flow diversion potential.

Channel migration at the Intake Dam location is not a concern because the channel location has persisted throughout the life of the diversion project. The left bank of the Yellowstone River is against a bedrock outcrop consisting of shale and siltstone. This is also the location of a railroad alignment where riprap bank protection is present.

Channel migration has been previously identified in the segment of the Yellowstone River where pumping sites would be located, particularly relative to the deepest channel locations where a surface intake would need to be located to divert at flows down to 3,000 cfs. Areas where channel migration is expected to possibly occur over the next 100 years were previously identified as the Channel Migration Zone (CMZ) in this segment of the Yellowstone River (DTM Consulting & AGI, 2009). The CMZ study identified floodplain areas along the river where the channel may migrate over the next 100 years, based primarily upon historical channel migration rates. The CMZ often extends approximately 1,000 feet from the banks of the Yellowstone River but was evaluated on river-reach basis. The migration rates of the CMZ may vary; in some locations the migration rate may be higher or lower, but the CMZ is meant to be a reasonable and conservative estimate of 100-year migration potential. All of the pumping facility locations are at or outside the CMZ. Therefore, although channel migration would affect the feeder canals, the pumping facilities are not expected to be affected.

3.1.5 Sediment Transport

Sediment transport analyses of the Yellowstone River were not conducted in relation to this alternative. As discussed above, sediment transport on the Yellowstone River is assumed to be only locally affected in approximately the first 5 miles upstream of Intake Dam and removal of the dam was evaluated based on removing the sediment wedge from the upstream channel in this reach. Operation of the pumping sites may be affected by sedimentation in the feeder canals leading to the pumps. Assuming that complete gravity diversion occurs for Yellowstone River flows exceeding 30,000 cfs and any lower flows require pumping, a conservative estimate is that 2,800 cubic yards of material may collect in each feeder canals on average annually. This estimate is based on the sediment concentrations of the Yellowstone River for flows less than 30,000 cfs and the assumption that only sand size and larger particles would deposit in the feeder canals. Because more sediment would deposit when the Yellowstone River is high (near 30,000 cfs), some amount of sediment removal may be required to operate the pumps as flow recedes in July and August. This is because high flows on the Yellowstone have the highest sediment concentration but velocities in the feeder canal are the lowest under this condition. The amount of flow diverted by the pumping stations would have a negligible effect on sediment transport rates of the Yellowstone River. This is because the low flow conditions when pumping would be highest are very low sediment transport conditions on the Yellowstone River. Sediment loads in the river vary; however, designs should include features to allow for sediment deposits to be removed during maintenance operations that may be necessary on an annual basis or more frequently, as described in Appendix B.

3.2 Fish Entrainment

The proposed alternative includes a fish screen structure to minimize fish entrainment into the irrigation system, with a fish return pipe to return any fish that are entrained back to the Yellowstone River. A fish handling pump is required to operate the fish return pipe, due to the flat slope of the Yellowstone River in this region.

The proposed fish screen structure and fish return system are described in Section 4.3.2 of this appendix.

3.3 Intake Selection

A preliminary analysis and comparison of four multiple pump station conceptual intake alternatives was performed, as documented in the technical memorandum which is included in Attachment 2. The conceptual intake alternatives evaluated are the Ranney well alternative and three different types of surface water intake alternatives.

Each conceptual alternative was evaluated using 9 criteria including harm to fish, water supply reliability, and cost. The surface water intake with an off-river fish screen design concept ranked highest based on a subjective analysis of four alternatives, and is presented here. A summary of the results of this preliminary analysis is shown in Table 3.4, below.

The technical memo describing this preliminary analysis is included in Attachment 2, which provides more information regarding this comparison.

Table 3.4 Intake Type Selection Summary

Evaluation Criteria	Ranney Wells Intake Alternative	Surface Water Intake Alternative		
		Off-River Flat Plate Screens	In-River Cone Screens	On-Bank Flat Plate Screens
Fish Entrainment / Harm to Fish	4	2	1	3
Maintenance Requirements	4	3	1	2
Potential for Ice Damage	4	3	1	1
Potential for Channel Migration Damage	3	4	1	1
Disturbance during Construction and Operation	1	4	2	3
Construction Risk	1	4	1	2
Operability/Reliability	2	3	1	2
Power Requirements	1	2	2	2
Capital Costs	1	4	3	3
TOTAL SCORE:	**21**	**29**	**13**	**19**

Scores are ranked from worst to best with 4 being the best in a given category.

3.4 Compatibility with Existing Intake

As described in Section 3.1.1, some level of combined pumping and gravity diversion are feasible if pumping occurs at downstream sites and control structures are not used in the upper portion of the canal. For Yellowstone River flows in excess of 30,000 cfs, the analysis indicates that the full 1,374 cfs diversion can be accomplished using gravity. At lower flows, pumping sites must be brought online. For these conditions it appears that the optimal operation would be to maximize gravity diversion and pump water from the main irrigation canal into a small number of laterals rather than attempt to gravity divert into the laterals. If canal control structures are used to divert flow into the laterals, the resulting tailwater on the diversion structure could reduce or eliminate gravity diversion into the main canal. Because the laterals require less than 50 cfs, it is better to pump into the laterals than gravity divert into the laterals and pump 275 cfs from pump site 1. Therefore, above Burns Creek Overchute, diversion into laterals should be done with pumping rather than gravity for any condition that would impede gravity diversion into the main canal.

The proposed modifications to the existing irrigation canal are described in Section 4.3.7 of this appendix.

3.5 Operability/Reliability

The multiple pumping station design includes several features to improve the overall reliability of the system. Each pumping station includes one redundant pump which would be used when one of the pumps or motors is shut down for maintenance without affecting the capacity of the system. Additionally, there are five pumping stations in the design, therefore a portion of the full water right could be supplied if one of the pumping stations is completely shut down. A standby generator at each pumping station site would allow operation during a temporary power outage.

Siltation of the feeder canals is expected to require routine annual maintenance and should be monitored during the irrigation season, but is not expected to significantly affect the daily reliability of the system. The condition most likely to diminish pumping reliability is when pumping has occurred during river flows between 20,000 and 30,000 cfs, which are likely to create sedimentation in the feeder canal, that is followed by lower flows and the deposition blocks the feeder canal entrance. Under these conditions some sediment removal may be required to reconnect the river with the feeder canal and pumping facility. Another condition that may require occasional maintenance is river channel shifting increasing bed elevations at the canal entrance. This could result in full or partial blockages of the canal entrance that would require excavation.

Siltation of the feeder canals is expected to require routine annual maintenance and should be monitored during the irrigation season, but is not expected to effect the daily reliability of the system.

3.6 Power Consumption

This design alternative would consume approximately 10 Gigawatt hours of power in a typical year. This estimate assumes an average diversion rate of 1,100 cfs continuously throughout the irrigation season. This estimated diversion rate is based on the average annual diversion rate noted in the EA (Corps 2010) of 327,046 acre feet over a 5 month irrigation season, which results in an average flow rate of 1,078 cfs. This diversion rate was confirmed using the 2000 and 2012 evaporation and seepage analyses provided by the irrigation district, in which the average diversion rates were 1,094 and 1,097 cfs, respectively.

The existing headworks would be used to divert water by gravity when the Yellowstone River water level is high enough to permit gravity diversions to take place, and the pumping stations would be used when they are not. Due to backwater effects between the pumped inflows and gravity diversions, the downstream pumping stations are assumed to be used first (pumping stations 5 and 4). When pumping stations 1 and 2 are required, the headworks would be closed and all irrigation water would be diverted by pumping.

A summary of the operation and power demand of each pumping station is shown in Table 3.5, below.

Table 3.5 Typical Operation and Power Demand at Each Pumping Station

Pumping Station Sites in Use	Power Demand[a] (kW)	Time Operating in this Mode[b]	Days Operating in this Mode[b]	Energy Consumption (GWH)
None	0	27%	42	0.0
Site 5 Only	1750	15%	22	0.9
Sites 4 & 5	3450	25%	39	3.2
Sites 3-5	4850	29%	44	5.1
All Sites	6250	3%	5	0.8
Total	-	100%		**10.1**

Notes:

a) Power demand shown includes irrigation pumps, fish return pumps, and lateral pumps.

b) Estimated time in each operating mode is based on the analysis of the existing headworks, as described in Section 3.1.1, assuming a diversion rate of 1100 cfs.

The average annual energy consumption calculation is included in Attachment 7.

4.0 Design

This alternative proposes removing the existing Intake Dam and constructing five pumping stations on the Yellowstone River to deliver water to the Lower Yellowstone Project. The conceptual design features of the proposed alternative are described, below.

4.1 Alternative Design Overview

The multiple pumping station alternative is made up of eight design features, each of which is described in more detail in this Section. These features are:

- a feeder canal which conveys water from the river to a stable location outside the channel migration zone;
- a fish screen structure which uses flat fish screen plates to remove fish and return them to the river in a return pipe;
- a pumping station structure which houses three irrigation pumps and a fourth irrigation pump which is provided for redundancy;
- discharge pipelines which convey the irrigation water to the irrigation canal;
- concrete outlet structures located where each discharge pipeline enters the irrigation canal;
- uprating of the existing electrical system to provide the electrical power required, and a standby generator for use during power outages;
- modifications to the existing irrigation canal; and
- removal of the existing Intake Dam, which is described in Section A-3 of this appendix.

These features are identified in Figure 4.1, below.

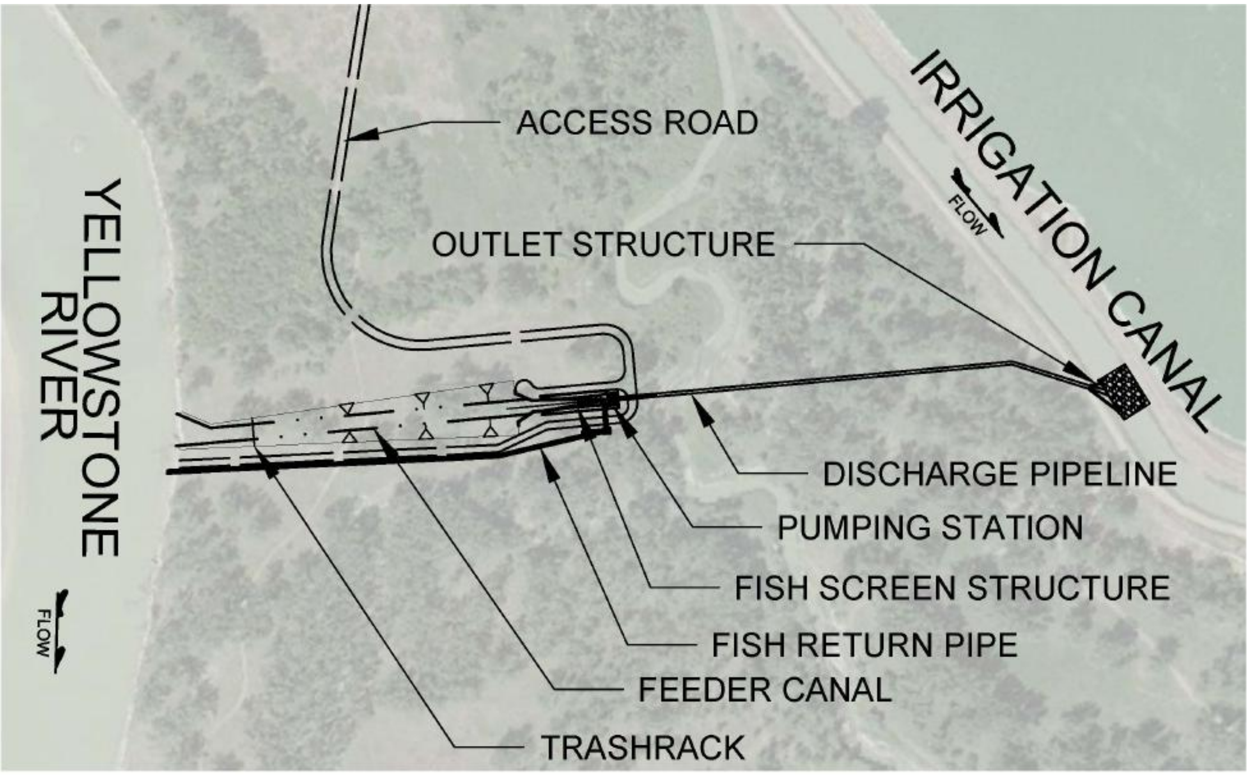


Figure 4.1 Features of the Multiple Pumping Station Alternative

(Shown at Site 2. Design features are similar at all sites)

4.2 Site Selection

The five pumping stations would be constructed at various locations along the Lower Yellowstone Project between Intake Dam and Savage, as shown in Figure 1.1 previously and on the site plans included in Attachment 1. The five sites shown were selected on the outside of meander bends to minimize the chances they would be blocked by bar formation and maximize the depth of flow in the Yellowstone River. Both of these factors contribute to the reliability of the diversion and reduce maintenance associated with sediment removal. The downside is that the outside of the bends are the most likely to erode in the immediate future. To minimize this potential, two additional factors were accounted for in siting the pumping stations; the bends were reviewed and the stations were sited at the more stable bends and the pumping stations were set back approximately 1,000 feet from the channel bank where possible. This placed them at or just inside the outer edge of the CMZ (DTM Consulting & AGI, 2009). Stability of the bends was assessed by reviewing historical channel locations (DTM Consulting, 2009) to determine how much the channel had shifted over the last 60-70 years. The five selected locations have been numbered from upstream to downstream along the river and are generally located as described in Table 4.1, below.

Table 4.1 Multiple Pump Station Locations

Site	River Mile	Approximate Location
Site 1	72.8	Near Intake Dam
Site 2	64.3	8 miles downstream from Site 1
Site 3	60.6	3 miles downstream from Site 2
Site 4	54.8	0.2 miles upstream of Savage
Site 5	54.1	0.3 miles downstream of Savage

4.3 Design Features

4.3.1 Feeder Canals

A feeder canal would be constructed at each site between the river and the location of the fish screen. A trash rack would be constructed in each feeder canal to prevent debris from entering the system and reduce the number of adult fish entering the system.

4.3.1.1 Description

A feeder canal would be constructed at each site with a trapezoidal section, sloping downward at a 0.1% slope from the river to the fish screen structure. The bottom of the typical feeder canal would be 32’ wide with an elevation as close as practical to the thalweg of the river to maximize the flow depth into the feeder canal under low flow conditions. Under low flow conditions, the target depth in the intake feeder canal would be 2.5’ deep with an average velocity of 3.1 feet / second at the connection to the existing river bottom, increasing to a depth of 5’ at the entrance to the fish screen structure. Under higher flow conditions, the depth in the feeder canal could be much greater and average velocities in the feeder canal may be approximately 1 feet / second or less. Typical depths and velocities in the feeder canals ranging from the low flow condition up to a discharge of 30,000 cfs in the Yellowstone River are shown in Table 4.2, below. It should be noted that when main channel discharges exceed 30,000 cfs, the full 1,374 cfs diversion can be accomplished by gravity at the canal headworks and the pumping sites will not be operating.

A trash rack with 1” openings would be constructed in each feeder canal to prevent adult fish entrainment.

Table 4.2 Typical Feeder Canal Depth and Velocity

Main Channel Discharge (cfs)	Feeder Canal Depth (feet)	Feeder Canal Velocity (feet/sec)
3,000	2.5	3.1
5,000	4.0	1.8
10,000	6.1	1.1
15,000	7.7	0.78
20,000	8.9	0.65
25,000	9.8	0.57
30,000	10.7	0.50

Sedimentation in the proposed feeder canals is expected to require annual cleaning during the non-irrigation season and may require additional cleaning as described in Appendix B. The feeder canals would be cleaned from the access road with an excavator or small dragline. Material, which would consist of sand, gravel and silt, could be temporarily stockpiled, then hauled off to a disposal site.

Site specific design of the feeder canals has not been performed at this time. If this alternative is selected for detailed design, a bathymetric and topographic survey of each site would be produced and grading design for each site would be performed.

More information about the feeder canals is provided in Attachment 3.

4.3.1.2 Quantities

The quantity of excavation required to construct the proposed feeder canals was estimated by comparing the invert elevation of the proposed canals to the existing ground elevation at each site, as shown on existing LIDAR maps. The average cut depth at each site was calculated and used to estimate the quantity of excavation required for the feeder canals. Five percent of this gross excavation quantity was estimated to be underwater during excavation.

The estimated excavation quantities are shown in Table 4.3, below.

Table 4.3 Feeder Canal Dimensions and Quantities

Site	Length (feet)	Average Depth Below Existing (feet)	In-Channel (Wet) Excavation Volume (CY)	Excavation Volume on Land (CY)
Site 1	300	17	600	12,000
Site 2	1000	17	2,100	40,000
Site 3	1100	17	2,300	44,000
Site 4	500	17	1,100	20,000
Site 5	900	17	1,900	35,000

4.3.1.3 Drawings

The proposed feeder canals are shown on drawings C-001 to C-005, included in Attachment 1.

4.3.2 Fish Screen Structure

A fish screen structure would be constructed at the downstream end of each feeder canal with a V-shaped vertical fish screen configuration. The typical fish screen structure design is described below. Site specific design would be performed at each of the pumping station locations if this alternative is selected.

4.3.2.1 Description

The typical fish screen structure is composed of two vertical fish screens, arranged in a V-shaped configuration. The fish screens would be designed according to the NMFS Anadromous Salmonid Passage Facility Design guide (NMFS, 2011), using screens with an opening width of 1.75 mm, a maximum approach velocity of 0.4 feet/second, and a sweeping velocity which exceeds the approach velocity. Two wedge-wire fish screen panels would be installed in a V-shaped configuration, each of which is 96’ long and 4’ high for a gross screen area of 768 square feet or a net screen area of 691 square feet, assuming 10% blockage for supports. A travelling screen cleaner would be installed to remove debris and silt from the screens and a 1’ deep sill below the fish screens would provide space for silt to collect between cleanings.

The slope of the Yellowstone River is too flat to permit the use of a fish return channel or pipe that operates by gravity; therefore, a fish handling pump is provided downstream of the fish screen to return the juveniles to the river. The Aqua-Life BP120 fish handling pump was selected as the design reference pump based on the recommendation of the vendor. The BP120 pump is a centrifugal style pump with no exposed edges for fish to come in contact with. It is operated off of a hydraulic power unit and is made of 356 Aluminum Alloy. Product data sheets for the proposed fish handling pump are included in Attachment 4.

Under the design condition, the depth in the fish screen structure will be 5’ and the screens will have a sweeping velocity of 2.8 feet/second and a travel time of 33 seconds. If this alternative is selected for detailed design, then an analysis of the fish screen performance at each site would be performed under higher flow conditions up to the 5% exceedance level in the Yellowstone River during the irrigation period. The results will vary at each site, but additional fishway exits or an intake control gate may be required at some locations.

An ice protection berm is provided at each fish screen and pumping station facility, located on the upstream side of the facility (relative to the Yellowstone River flow) to intercept river ice and direct it away from the facilities during breakup. A typical ice protection berm is shown on the preliminary design drawings, with a top elevation 2’ above the 100-year flood level and a top width of 15’ (approximately 2 times the berm height). A smaller ice protection berm is also provided on the downstream side of each facility to provide further protection against river ice. If this alternative is selected for further analysis then site specific designs of the ice protection berms would be produced for each of the five sites.

Design calculations for the fish screen structure are provided in Attachment 4.

Plan and section views of the typical fish screen structure are shown in Figure 4.2 and Figure 4.3 below.

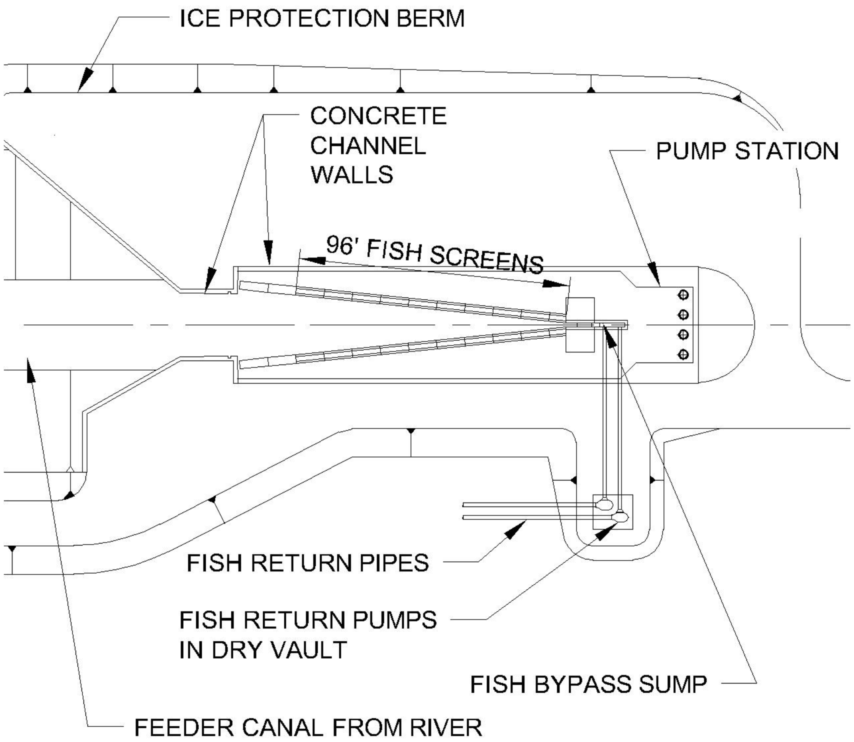


Figure 4.2 Typical Fish Screen Structure (Plan View)

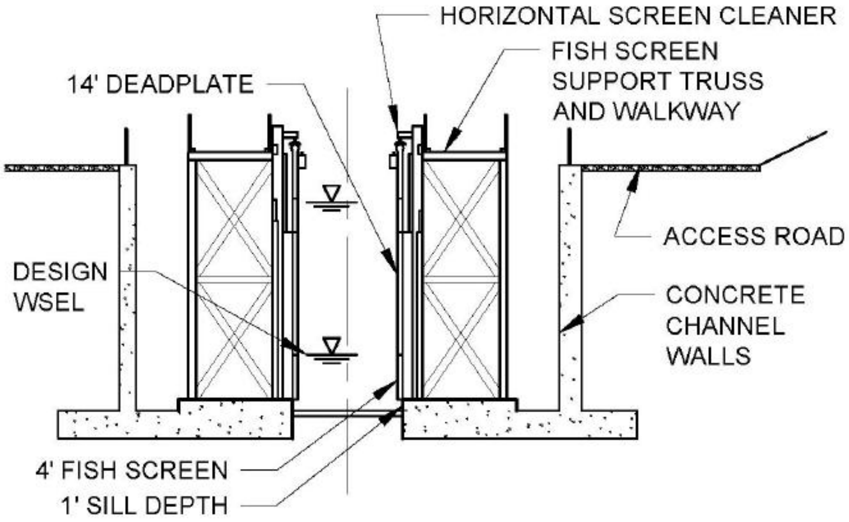


Figure 4.3 Typical Fish Screen Structure (Section View)

4.3.2.2 Quantities

Construction quantities for the fish screen structure were estimated based on the typical fish screen structure shown on drawing M-002, which was assumed to be similar at all five sites. Excavation quantities were estimated based on an assumed existing ground elevation at each site.

Concrete quantities were estimated for the reinforced concrete retaining walls and fish screen foundations shown in the figures above, which were assumed to be moderately reinforced.

A rough budgetary cost estimate of $300/square foot was obtained from a vendor for the fish screens and deadplates. The cost of the fish screen cleaners and steel support trusses for the fish screens were estimated based on inflation adjustment of the cost estimates provided in the Fish Protection and Passage Concept Study Report II (Reclamation, 2004).

4.3.2.3 Drawings

The conceptual design of the typical fish screen structure is shown on drawing M-002, included in Attachment 1.

4.3.3 Pumping Station

A pumping station would be constructed downstream of each of the fish screen structures, as described below.

4.3.3.1 Description

Irrigation water would leave the fish screens and flow into the pumping station structure. A concrete wet well would be constructed at each site to provide the submergence depth required by the irrigation pumps. Three vertical impeller pumps would be installed in each wet well with a total capacity of 275 cfs, with one additional pump provided at each pumping station for redundancy. A prefabricated steel building would be constructed over each wet well to house the motors and control. The pumps would be operated by 480V motors and standby generators would be provided at each site as a backup power source during any power outage. The finished floor elevation of the pumping station would be located 1’ above the 100 year floodplain elevation. The required height varies at each site depending on the difference between the 100 year floodplain elevation and the required submergence depth in the wet well.

A summary of the irrigation pump requirements is shown in Table 4.4, below. The head required at the five sites increases as they move downstream because the river slopes more steeply than the irrigation canal.

A plan and section view of a typical pump station is shown in Figure 4.4 and Figure 4.5, below, showing the dimensions required at the largest of the 5 pumping stations. If this alternative is selected then a site specific design of each pumping station would be performed.

Design calculations for the typical pumping station design are included in Attachment 5.

Table 4.4 Irrigation Pump Sizes Required

Site	Total Flow Rate (cfs)	Flow Rate per Pump (cfs)	Static Head (feet)	Total Dynamic Head (feet)	Pump Motor Power (HP)
Site 1	275	92	-1	7	107
Site 2	275	92	25	34	408
Site 3	275	92	33	47	564
Site 4	275	92	46	58	703
Site 5	275	92	48	58	703

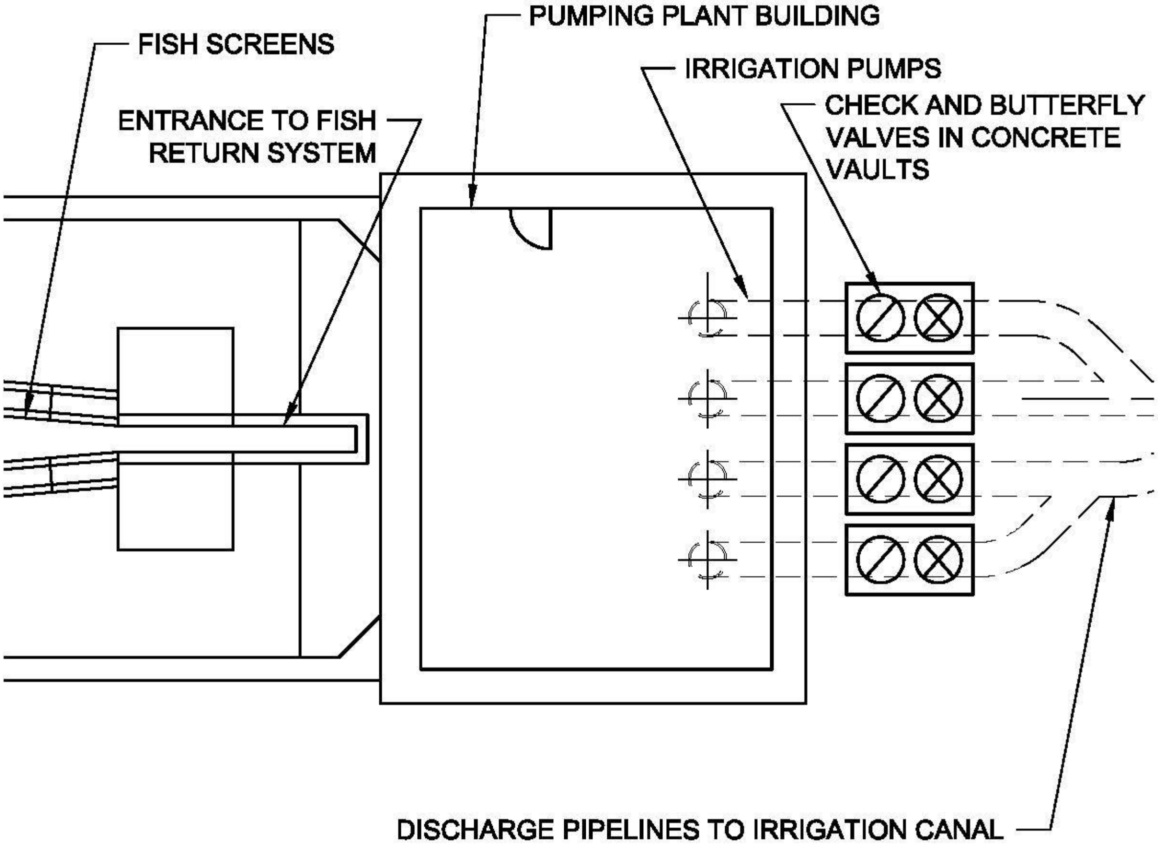


Figure 4.4 Typical Pump Station (Plan View)

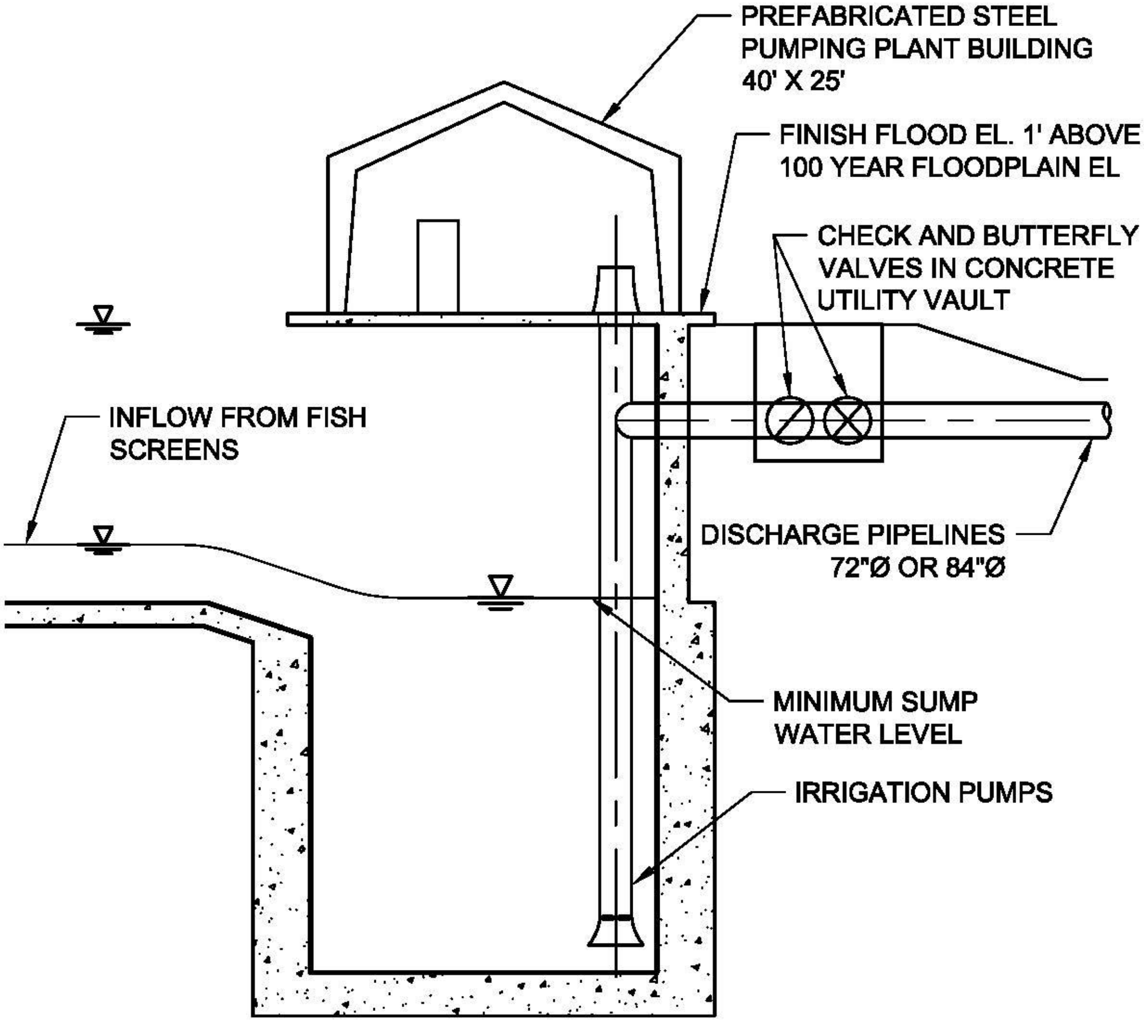


Figure 4.5 Typical Pump Station (Section)

4.3.3.2 Quantities

Construction quantities were produced for the typical proposed pumping station structure and assumed to be similar for all five sites. Cost estimates for the proposed pumps and motors required at each site were obtained from pump vendors.

4.3.3.3 Drawings

The conceptual design of the typical pump station is shown on drawing M-001, included in Attachment 1.

4.3.4 Discharge Pipelines

Discharge pipelines, which are 6’-7’ in diameter, would convey irrigation water from each of the pumping stations to the irrigation canal. A concrete outlet structure would be designed and constructed at the downstream end of each discharge pipeline, as described in Section 4.3.5, below.

4.3.4.1 Description

The discharge pipelines vary in length at each site from 300’ to 5,600’. Steel pipes with a 7’ diameter are proposed to reduce head losses and energy costs, except at site 1 where a 6’ diameter is acceptable due to the short pipeline length and low total head at this site. Each discharge pipeline would terminate in the irrigation canal.

Existing crossings were evaluated based on features which were visible on aerial photos. Road crossings will be required at most sites. The discharge pipelines at sites 2, 4, and 5 would cross existing irrigation laterals. The discharge pipelines are assumed to cross under these existing irrigation laterals at these locations. The discharge pipeline at site 3 would cross the existing BNSF railroad tracks at the location of an existing road crossing.

A site survey of each proposed alignment would be performed if this alternative is selected, and other potential conflicts might be identified at that time.

The possibility of feeding some laterals and farms directly from the discharge pipelines would also be evaluated during site specific design, if this alternative is selected.

A summary of the discharge pipeline requirements is shown in Table 4.5, below.

Table 4.5 Discharge Pipeline Requirements

Site	Length (feet)	Diameter (feet)	Velocity (feet/sec)
Site 1	300	6	9.7
Site 2	1,000	7	7.1
Site 3	5,600	7	7.1
Site 4	4,100	7	7.1
Site 5	1,800	7	7.1

Friction loss calculations and other design calculations for the discharge pipelines are included in Attachment 5.

4.3.4.2 Quantities

Construction quantities for the proposed pipelines were estimated, assuming that each pipeline will be constructed with a 2’ – 3’ cover depth.

4.3.4.3 Drawings

The conceptual design of the discharge pipelines is shown on drawings C-001 to C-005, included in Attachment 1.

4.3.5 Outlet Structures

A concrete outlet structure would be constructed at the outlet of each discharge pipeline into the irrigation canal to reduce the risk of erosion to the irrigation canal at these locations.

4.3.5.1 Description

A concrete outlet structure would be designed and constructed at the outlet of each discharge pipeline into the irrigation canal. The concrete outlet structures would be similar to a Reclamation Type 1 concrete transition, with a concrete headwall, concrete wing walls, and a concrete floor, as shown in Figure 4.6 and Figure 4.7, below. The dimensions of each outlet structure vary at each site depending on the angle of the discharge pipeline to the existing irrigation canal and the canal depth. Riprap lining would be placed downstream of each concrete outlet structure.

If this alternative is selected, then survey data would be collected at each location and site specific designs of each outlet structure would be produced.

Design calculations for the outlet structures is provided in Attachment 6.

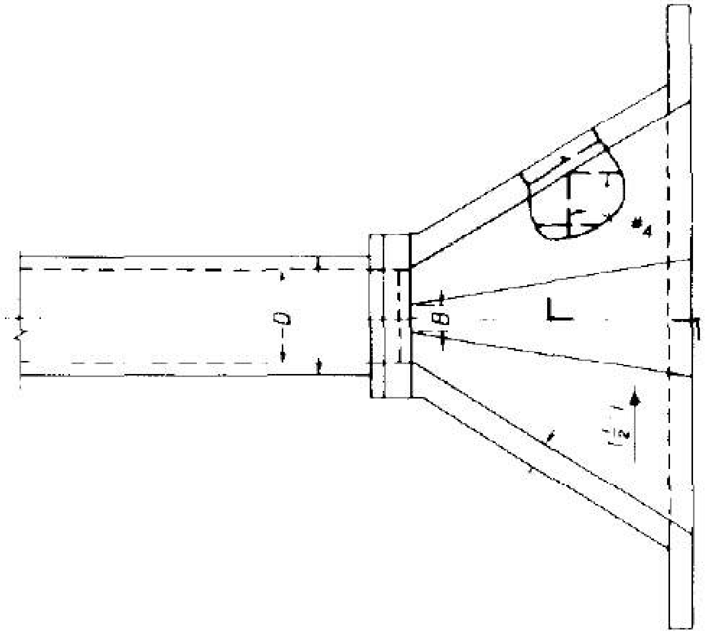


Figure 4.6 Typical Concrete Outlet Structure (Plan)

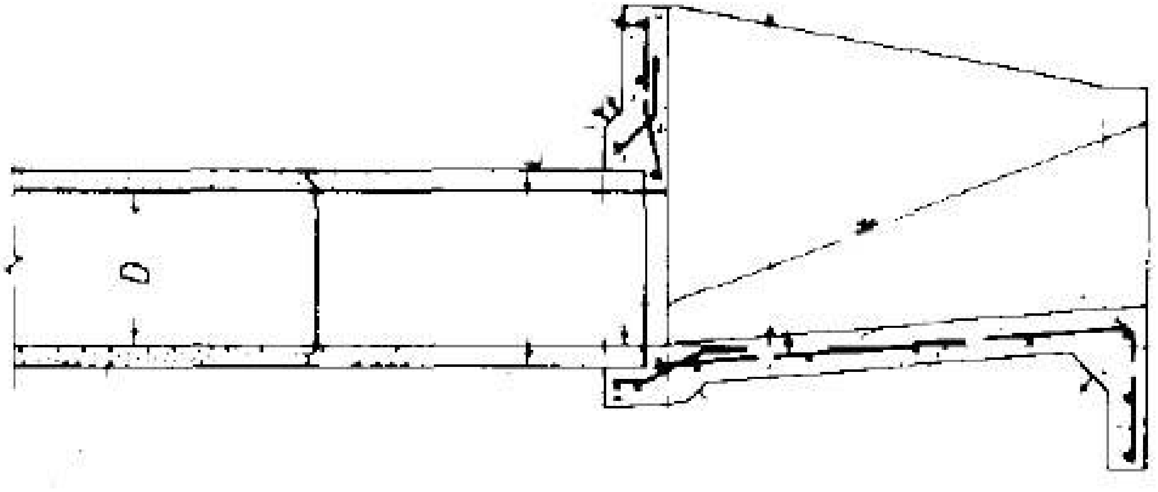


Figure 4.7 Typical Concrete Outlet Structure (Section)

4.3.5.2 Quantities

Construction quantities for the concrete outlet structures were estimated for each site assuming the outlet structures are 14’ high and the outlet structure walls are 18” thick. The concrete outlet structure is assumed to be moderately reinforced.

4.3.5.3 Drawings

The outlet structures are shown on drawings C-001 to C-005, included in Attachment 1.

4.3.6 Electrical System

The power demand for the pumps would exceed the capacity of the existing power system in this area. The estimated power demand for each site was discussed with Montana-Dakota Utilities (MDU) and MDU provided quantity and cost estimates for the powerline reconductoring required, and a cost estimate for the substation replacement required, as described below.

A standby generator is also provided at each of the pumping station sites to improve reliability of the pumping stations. The standby generators are also described, below.

The average annual energy consumption for the multiple pumping station alternative was also estimated, as described in Section 3.6 of this appendix.

4.3.6.1 Description

Power System Uprating

The power demand for the irrigation pumps would exceed the capacity of the existing power system in this area, requiring uprating of existing powerlines and the extension of existing powerlines to provide 3-phase, 480 volt power to each of the sites. New powerlines would be constructed underground with 4/0 conductors. Existing sub-stations would also be uprated to meet the power demands required.

A summary of the estimated power demand at each site and power system uprating required is shown in Table 4.6, below. More information about the power system uprating recommended by MDU is provided in Attachment 7.

Table 4.6 Estimated Power Demands and Power System Uprating

Site	Total Power Demand (kW)	Length of New Conductors[a] (feet)	Length of New Power Lines[b] (feet)	New Sub-Station Required?
Site 1	400	None - All New	6,600	No
Site 2	1,000	None - All New	6,000	Yes
Site 3	1,400	None - All New	16,000	Yes
Site 4	1,700	5,000	1,500	Yes
Site 5	1,700	(Included in Site 4)		

Notes:
a) New conductors to be constructed on existing poles.
b) Power lines to be constructed on a new alignment.

Standby Generators

A diesel standby generator would be provided at each site to provide backup power during an outage. The generators vary in size from 500 kW to 2000 kW. Each generator would be in a weatherproof housing with minimal sound deadening, and would have a 48 hour fuel supply.

4.3.6.2 Quantities

Construction quantities and a cost estimate for the power system uprating were provided by MDU and are provided in Attachment 7.

A cost estimate for the standby generators was provided by Cummins and is provided in Attachment 7.

4.3.6.3 Drawings

Conceptual drawings of the reconductoring recommended by MDU are provided in Attachment 7.

4.3.7 Irrigation Canal Modifications

The irrigation canal system was designed for gravity flow of water primarily from the upstream end at Intake, therefore this alternative would require some restructuring of the Lower Yellowstone Project canal system to accommodate a water supply from multiple points along the canal between Intake and Savage. The primary change is anticipated to be the addition of small pumping diversion facilities at laterals AA, BB, CC, DD, and FF. The need for any additional check structures or pumping into additional laterals would need to be considered if this alternative were selected.

4.3.7.1 Description

The reduced water surface elevation would require the construction of small pumping diversion facilities between the main irrigation canal and laterals AA, BB, CC, DD, and FF. These pumping facilities would be sized to match the existing flow rates into each lateral, which are estimated based on historical data provided by the irrigation district. The estimated head required at each pump station is calculated based on the difference in the irrigation canal's water surface elevation in its existing condition and after the implementation of this alternative.

A summary of the flow and head requirements at each small pumping diversion facility is provided in Table 4.7, below.

Table 4.7 Small Pumping Diversion Facility Requirements

Lateral	Flow Rate (cfs)	Existing WSEL[a] (feet)	Proposed WSEL[b] (feet)	Static Head (feet)	Friction Losses[c] (feet)	Total Head (feet)
AA	6	1985.8	1983.1	2.7	10.9	13.6
BB	6	1985.7	1983.1	2.6	10.9	13.5
CC	9	1985.7	1983.1	2.6	9.3	11.9
DD	12.5	1985.4	1983.1	2.3	8.2	10.5
FF	8	1985.1	1983.0	2.1	7.3	9.4

Notes:
a) Existing water surface elevation in the irrigation canal is calculated assuming the flow in the canal is 1100 cfs.
b) Proposed water surface elevation in the irrigation canal is calculated assuming no gravity diversions are being made.
c) Pipe friction losses assume 300' of pipe flowing at approximately 7 feet per second, including typical valves, checks, and bends.

4.3.8 Intake Dam Removal

The existing intake diversion dam near RM 72 would be removed as a part of this design alternative to improve fish passage at the site.

The proposed dam removal is described in Section A-3 of this appendix.

4.4 Further Design Considerations/Next Steps

The alternative design presented in this engineering appendix is conceptual. If this alternative is selected for further consideration, then the following steps are recommended:

- Bathymetric and topographic surveys would be performed at each of the proposed sites.
- A survey of the existing irrigation canal, including check structures, culverts, and lateral inverts would be performed to develop a more refined hydraulic analysis.

- A geotechnical investigation would be performed at each of the proposed sites to determine soil properties for permeability and structural design.
- The Yellowstone River Corridor Study HEC-RAS model would be updated with the new bathymetric data at each of the sites.
- Channel stability would be analyzed at each of the pumping station sites to determine if riverbank protection measures are required.
- Site specific designs of the feeder canals would be produced.
- An analysis of river ice would be performed at each location and used to design ice protection berms at each site.
- A flood flow analysis would be performed to determine whether the proposed ice protection berms would impact the 100 year flood elevation at each site.
- The groundwater levels and anticipated fluctuations in the project area would be evaluated to determine the effect of the modifications to the existing irrigation canal on existing wells or wetland areas.
- Sedimentation would be analyzed in the fish screens, feeder canals, and the river channel near each of the feeder canals.
- Design criteria for the fish screens would be established in cooperation with the U.S. Fish and Wildlife Service, Montana Fish Wildlife and Parks (FWP), and other agencies. The screens installed at the Intake headworks were based on design criteria for salmonids as there are not established criteria for sturgeon larvae and other larval fish. Based on the results of monitoring the screens at Intake, design criteria could be modified to be more appropriate for larval fish.
- Use of a fish handling pump to return fish to the river would be evaluated and discussed with these same agencies.
- A hydraulic analysis of the flow through each fish screen and pumping station would be performed to verify the design dimensions shown.
- Use of a sloping or screened floor in the fish screen structure would be considered based on anticipated sedimentation loads and input from the agencies.
- Site specific designs for the fish screens at each site would be produced.
- The water surface elevation in the Yellowstone River and the irrigation canal would be determined based on the updated models.
- Use of SCADA or other remote operation and monitoring system would be discussed with the irrigation district.
- Use of VFD controlled pumps or medium voltage power systems would be considered.
- Site specific designs for the pumping stations would be produced.
- The alignments of the discharge pipelines would be assessed in the field and modified, where necessary.
- Discharge pipeline profiles would be designed.
- The railroad crossing for the discharge pipeline at site 3 would be negotiated with the Burlington Northern Santa Fe Railway and a pipeline crossing would be designed at this location.
- The most economical pipeline diameter for each of the sites would be evaluated, considering the construction and energy costs.

- Outlet structures would be designed at each point where the discharge pipelines enter the irrigation canal.
- Access road alignments to each of the sites would be assessed in the field and the access roads would be designed.
- Land ownership and easement requirements would be determined.
- The diversion pump stations which are required between the main irrigation canal and several of the upstream laterals would be designed.
- Topographic and bathymetric surveys of Intake Dam would be performed including the dam, boulder field, and collected sediments around the dam would be performed for the dam removal.
- A geotechnical investigation of Intake Dam would be performed including the rock fill, the dam foundation, the boulder field, and sediments collected around the dam.
- A stability analysis of the existing Intake Dam foundation would be performed.
- Channel stability and sedimentation transport would be analyzed for the during-construction and post-construction conditions of the dam removal.
- Temporary coffer dams for the Intake Dam removal would be designed.
- A more detailed energy estimate would be prepared accounting for monthly variations in historical demand rates and Yellowstone River water surface elevations.

5.0 Construction Considerations

5.1 Construction Risk

The alternative design presented in this engineering appendix is conceptual and based on limited information and a number of assumptions about the requirements for the final design. The following is a list of the major items which could increase the cost of the final design:

- Bathymetry at the pumping station sites was assumed. Actual river bathymetry could require modifications to the feeder canals, bank protection at the pumping station sites, and/or relocating some of the pumping stations.
- Topographic data at the pumping station sites was taken from existing LIDAR data which has not been confirmed in the field. Differing existing ground elevations may require modification of the site layout designs, and/or modify the estimated earthwork quantities shown.
- One typical conceptual design of the pumping station was assumed for all five sites and could require modification during site specific design.
- Soil properties and groundwater elevations at the pumping station sites were assumed based on typical values. Actual soil properties and groundwater elevations may vary and require modification of the pumping station designs.
- Use of the off-river fish screen design proposed assumes that a fish handling pump would be permitted for the fish return system at these sites. If a fish handling pump were not permitted, then either an on-river fish screen system or a groundwater intake source would be required.
- Further optimization of the fish screen design may require that additional exits be provided, which could increase the cost of the fish screen structure and the fish handling pumps.
- The existing dam removal is conceptual and based on limited information and a number of assumptions, as described in Section A-3 of this appendix. Geotechnical or structural analysis as well as field survey to be performed for the construction-level design may affect the design details shown in this report and may increase the project costs.
- It was assumed that the coffer dams needed for the feeder canal construction would not require deep cutoffs. If deep cutoffs are required, this will increase the cost of the coffer dams.

5.2 Disturbance during Construction and Operation

Approximately 41 acres would be disturbed during construction, including approximately 1 acre in the Yellowstone River, 18 acres for temporary stockpiles, and 22 acres for the proposed facilities.

The proposed facilities would occupy an area of approximately 22 acres after construction.

6.0 References

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Attachment 1
Design Drawings

US Army Corps
of Engineers®
Omaha District

MARK	DESCRIPTION	DATE	APPR.

MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
OMAHA DISTRICT
OMAHA, NE

TETRA TECH
400 112TH AVE NE, SUITE 400
BELLEVUE, WA 98004

DESIGNED BY: K. AXT		DATE: $$Date$$
DWN BY: V. ROUSE	CKD BY: J. PHILLIPS	SOLICITATION NO.:
SUBMITTED BY: D. THOMPSON		CONTRACT NO.:
PLOT SCALE: AS SHOWN	PLOT DATE: $$Date$$	FILE NUMBER:
SIZE: ANSI D	FILE NAME: ANSI_D_nonPW.dgn	

LOWER YELLOWSTONE RIVER
ALTERNATIVE DESIGN

SITE 1

SHEET
IDENTIFICATION
C-001
SHEET X OF Y

LEGEND

- ——► VEHICLE ROUTE FROM HIGHWAY 16
- —— — —— EXISTING SURFACE WATER CENTERLINE
- ——► CANAL FLOW DIRECTION

PUMP SITE PLAN

1" = 200'

0 200' 400'

SCALE: 1" = 200'

US Army Corps
of Engineers®
Omaha District

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
OMAHA DISTRICT
OMAHA, NE

TETRA TECH
400 112TH AVE NE, SUITE 400
BELLEVUE, WA 98004

DESIGNED BY: K. AXT
DWN BY: V. ROUSE
CKD BY: J. PHILLIPS
SUBMITTED BY: D. THOMPSON
PLOT SCALE: AS SHOWN
PLOT DATE: $$Date$$
SIZE: ANSI D
FILE NAME: ANSI_D_nonPW.dgn
DATE: $$Date$$
SOLICITATION NO.:
CONTRACT NO.:
FILE NUMBER:

LOWER YELLOWSTONE RIVER
ALTERNATIVE DESIGN

SITE 2

SHEET IDENTIFICATION
C-002
SHEET X OF Y

LEGEND

- ⟶ VEHICLE ROUTE FROM HIGHWAY 16
- — — EXISTING SURFACE WATER CENTERLINE
- ⅄ GRADING
- ⟶ CANAL FLOW DIRECTION

PUMP SITE PLAN

1" = 200'

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SCALE:1"=200'

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SUBMITTED BY: D. THOMPSON		CONTRACT NO.:
PLOT SCALE: AS SHOWN	PLOT DATE: $$Date$$	FILE NUMBER:
SIZE: ANSI D	FILE NAME: ANSI_D_nonPW.dgn	

LOWER YELLOWSTONE RIVER
ALTERNATIVE DESIGN

SITE 3

SHEET
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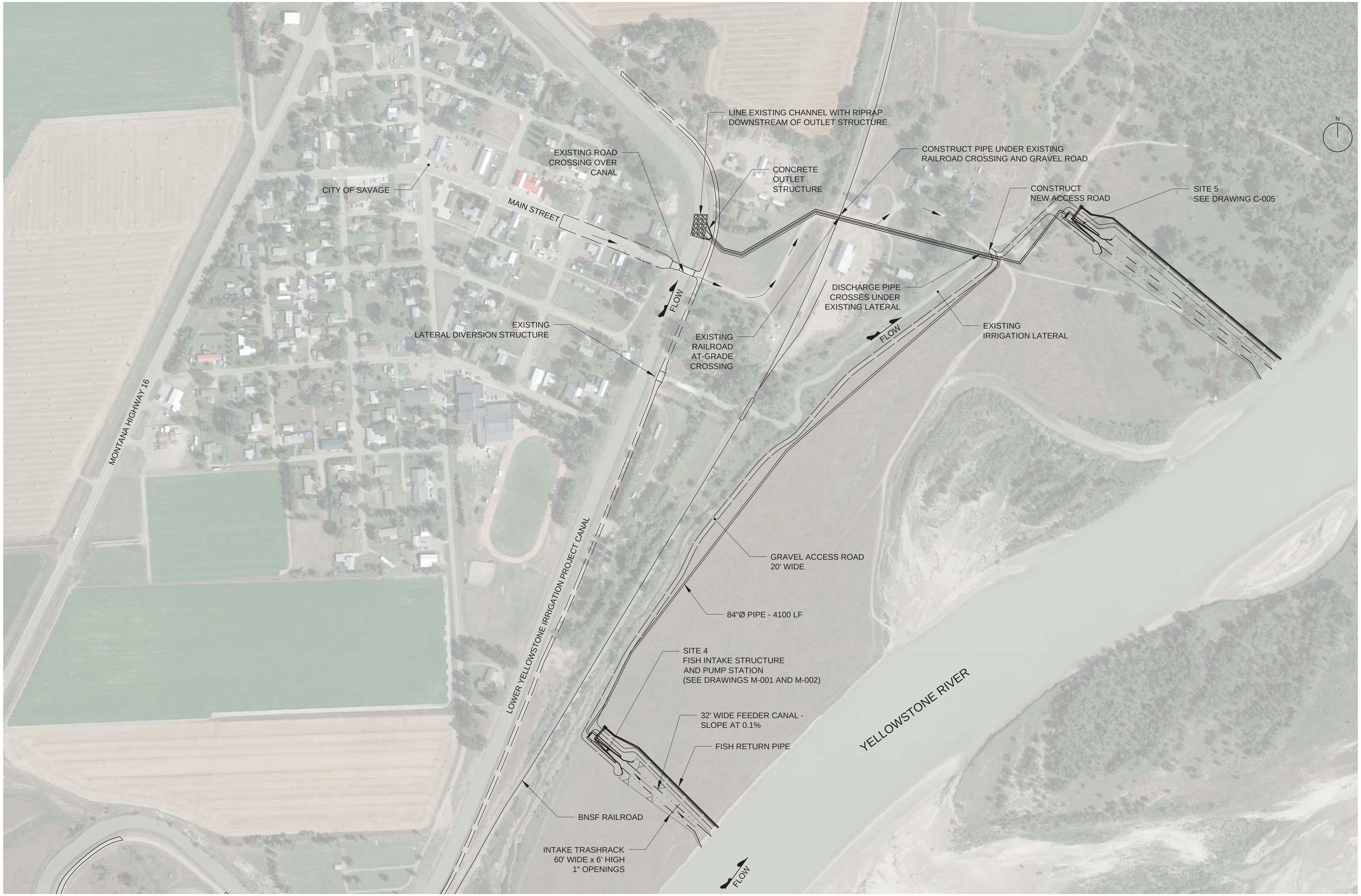
C-003
SHEET X OF Y



LEGEND

⟶ VEHICLE ROUTE FROM HIGHWAY 16	⩓ GRADING
— — — EXISTING SURFACE WATER CENTERLINE	⟶ CANAL FLOW DIRECTION

PUMP SITE PLAN

1" = 200'

0 200' 400'

SCALE:1"=200'

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OMAHA, NE

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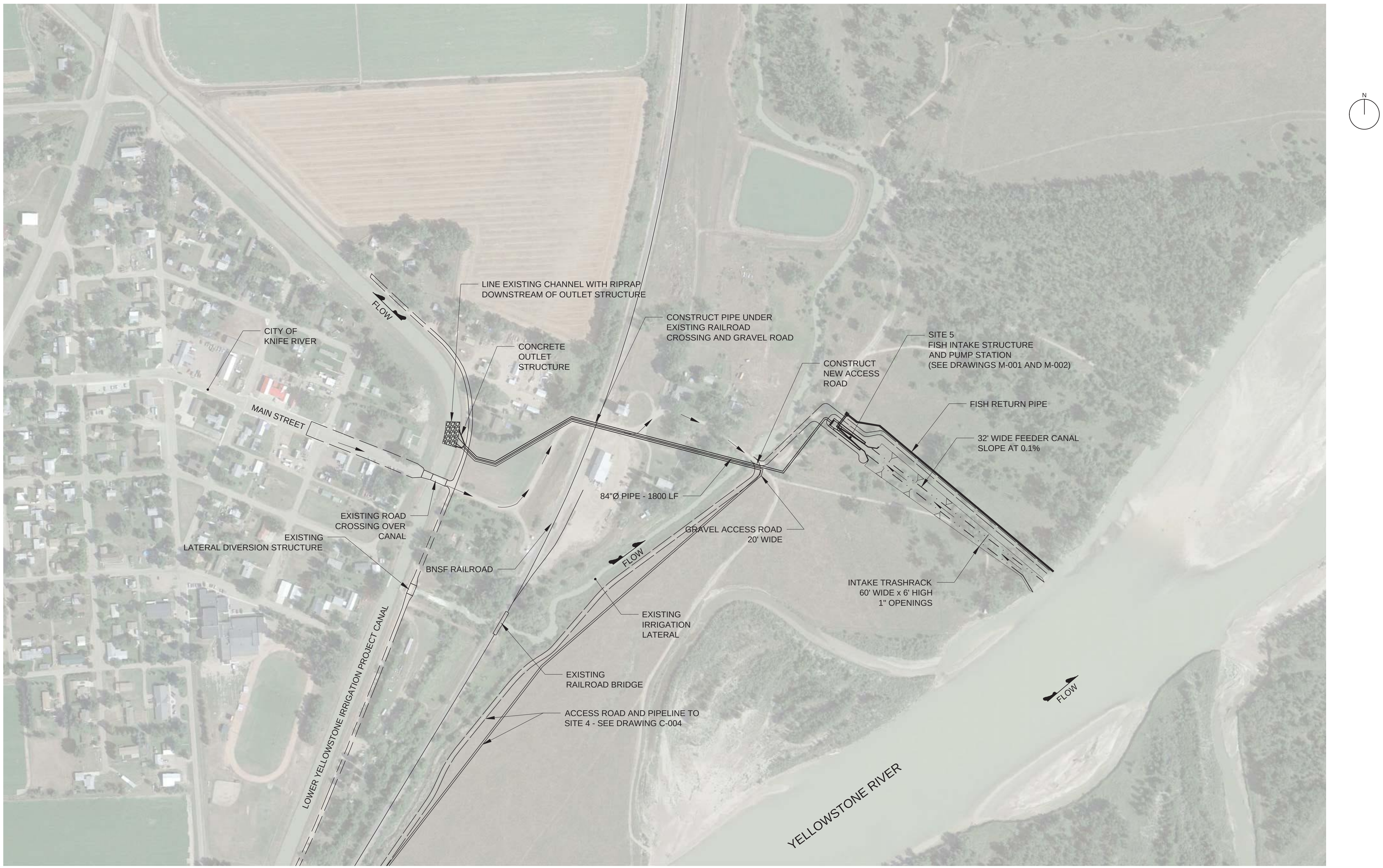
DESIGNED BY: K. AXT		DATE: $$Date$$
DWN BY: V. ROUSE	CKD BY: J. PHILLIPS	SOLICITATION NO.:
SUBMITTED BY: D. THOMPSON		CONTRACT NO.:
PLOT SCALE: AS SHOWN	PLOT DATE: $$Date$$	FILE NUMBER:
SIZE: ANSI D	FILE NAME: ANSI_D_nonPW.dgn	

LOWER YELLOWSTONE RIVER
ALTERNATIVE DESIGN

SITE 4

SHEET IDENTIFICATION
C-004
SHEET



LEGEND

- ——▶ VEHICLE ROUTE FROM HIGHWAY 16
- — — — EXISTING SURFACE WATER CENTERLINE
- ⧍ GRADING
- ——➤ CANAL FLOW DIRECTION

PUMP SITE PLAN

1" = 200'

0 200' 400'

SCALE:1"=200'

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MARK	DESCRIPTION	DATE	APPR

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OMAHA, NE

TETRA TECH
400 112TH AVE NE, SUITE 400
BELLEVUE, WA 98004

DESIGNED BY: K. AXT		DATE: $$Date$$
DWN BY: V. ROUSE	CKD BY: J. PHILLIPS	SOLICITATION NO.:
SUBMITTED BY: D. THOMPSON		CONTRACT NO.:
PLOT SCALE: AS SHOWN	PLOT DATE: $$Date$$	FILE NUMBER:
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LOWER YELLOWSTONE RIVER
ALTERNATIVE DESIGN

SITE 5

SHEET
IDENTIFICATION
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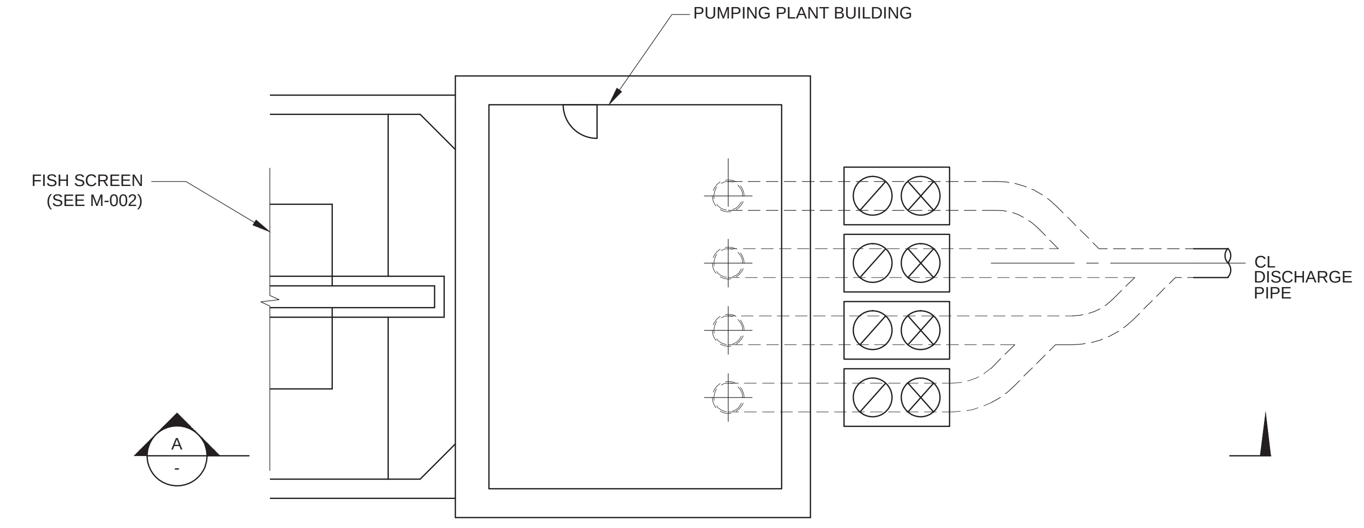
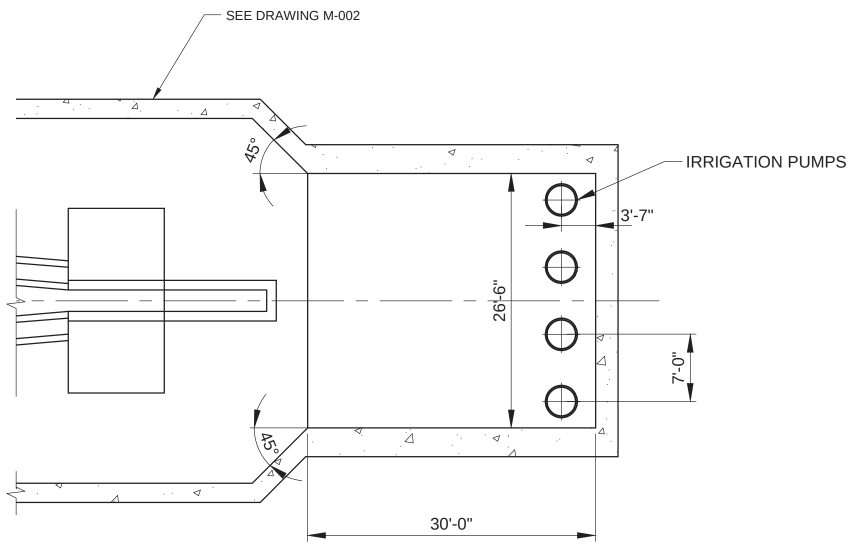
SHEET X OF Y



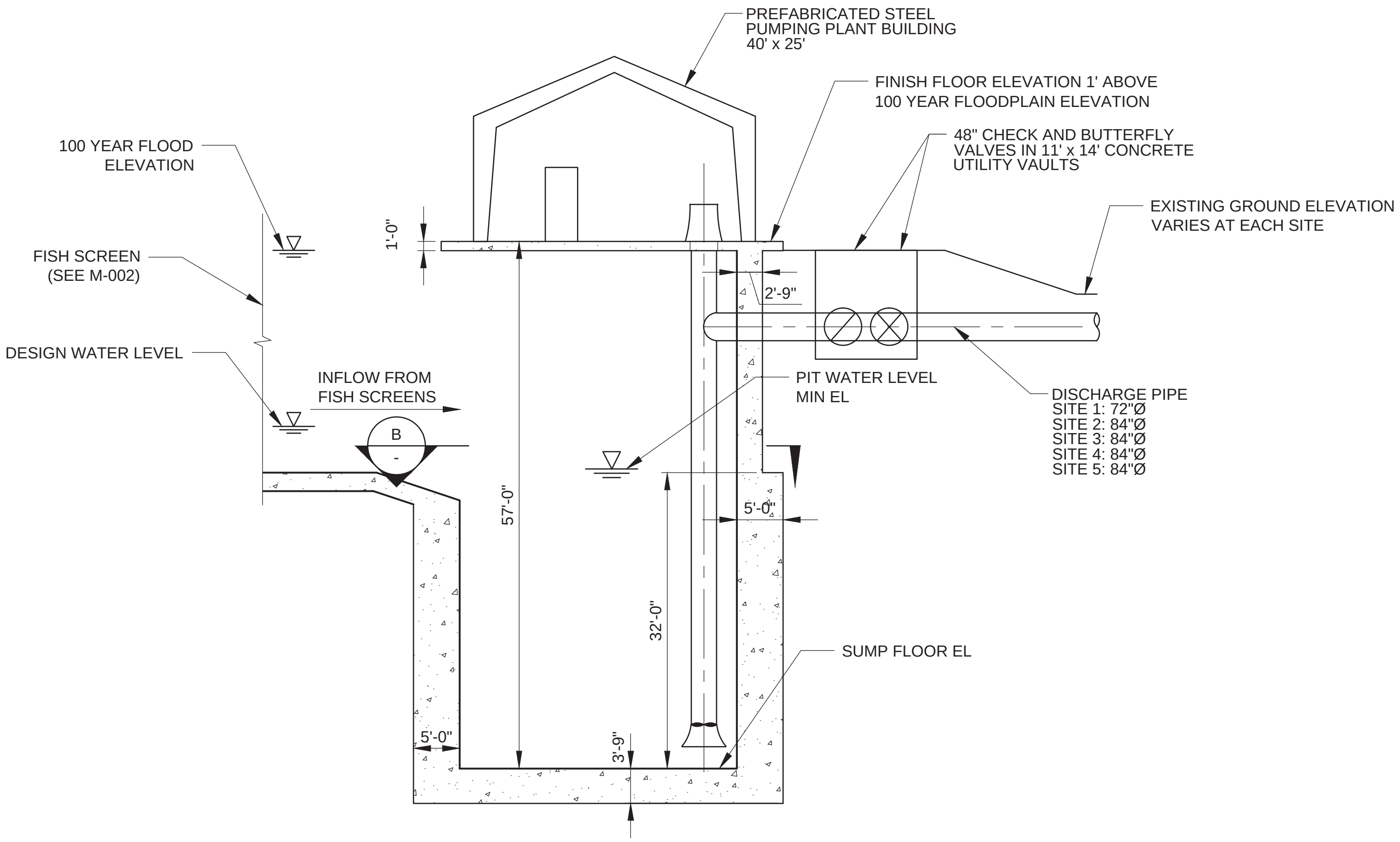
PLAN

SCALE: 1"=10'



SECTION B -

SCALE: 1"=10'



SECTION A -

SCALE: 1"=10'

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MARK	DESCRIPTION	DATE	APPR

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OMAHA, NE

TETRA TECH
400 112TH AVE NE, SUITE 400
BELLEVUE, WA 98004

DESIGNED BY:
F. BATRACK

DWN BY:
V. ROUSE

CKD BY:
J. PHILLIPS

SUBMITTED BY:
D. THOMPSON

PLOT SCALE:
AS SHOWN

PLOT DATE:
$$Date$$

SIZE:
ANSI D

FILE NAME:
ANSI_D_nonPW.dgn

DATE:
$$Date$$

SOLICITATION NO.:

CONTRACT NO.:

FILE NUMBER:

LOWER YELLOWSTONE RIVER
ALTERNATIVE DESIGN

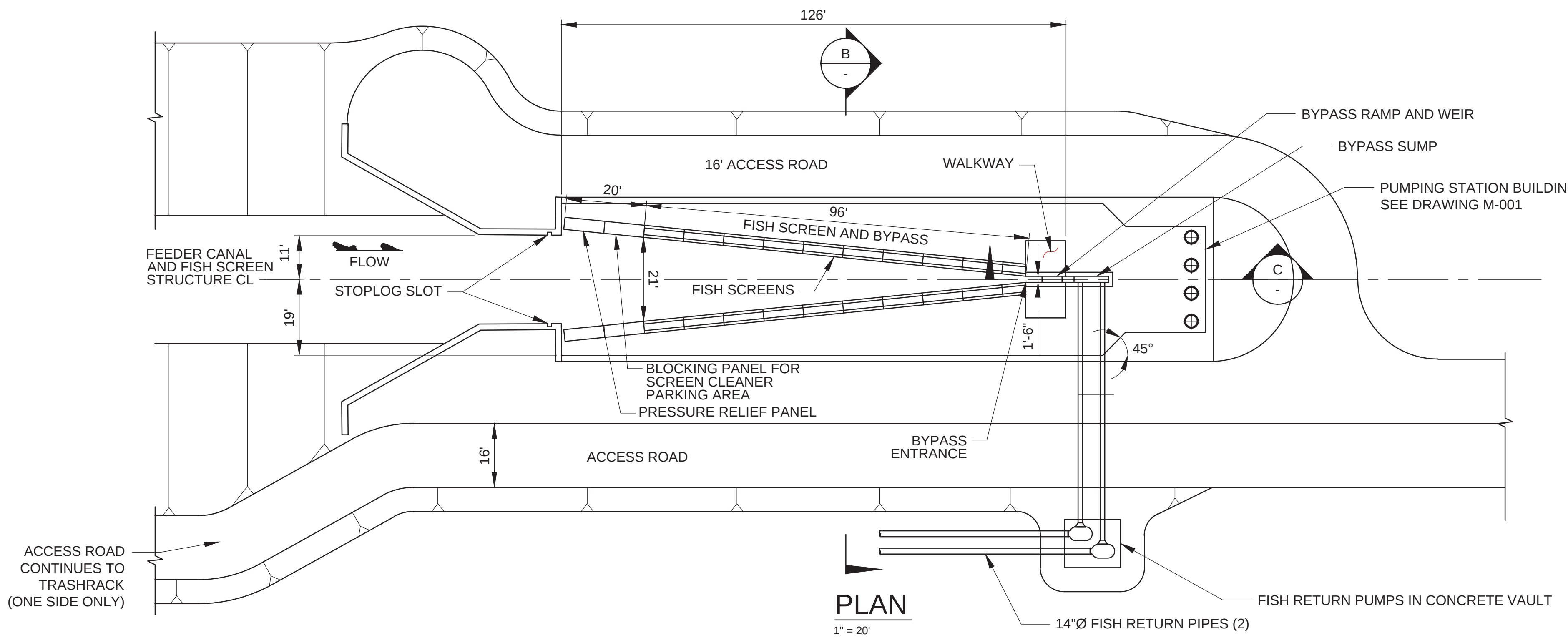
PUMP STATION
PLAN AND SECTION

SHEET
IDENTIFICATION
M-001
SHEET X OF Y

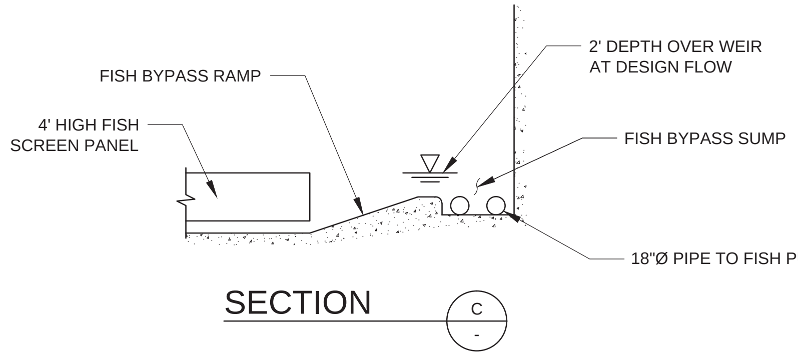
FISH SCREEN CONCEPTUAL DESIGN DATA

DESIGN RIVER FLOW RATE	3000 CFS
DESIGN RIVER FLOW DEPTH	2.5'
SCREEN FLOW RATE	275 CFS
DESIGN WATER DEPTH ON SCREENS	4 FT
SCREEN LENGTH	96 FT
SCREEN GROSS AREA	768 SQ FT
SCREEN NET AREA (10% BLOCKAGE)	691 SQ FT
APPROACH VELOCITY	0.4 FT/S
SCREEN ANGLE	5°
SWEEPING VELOCITY	2.1 FT/S
BYPASS FLOW RATE	16 CFS
SCREEN PASSAGE TIME	38 SECONDS

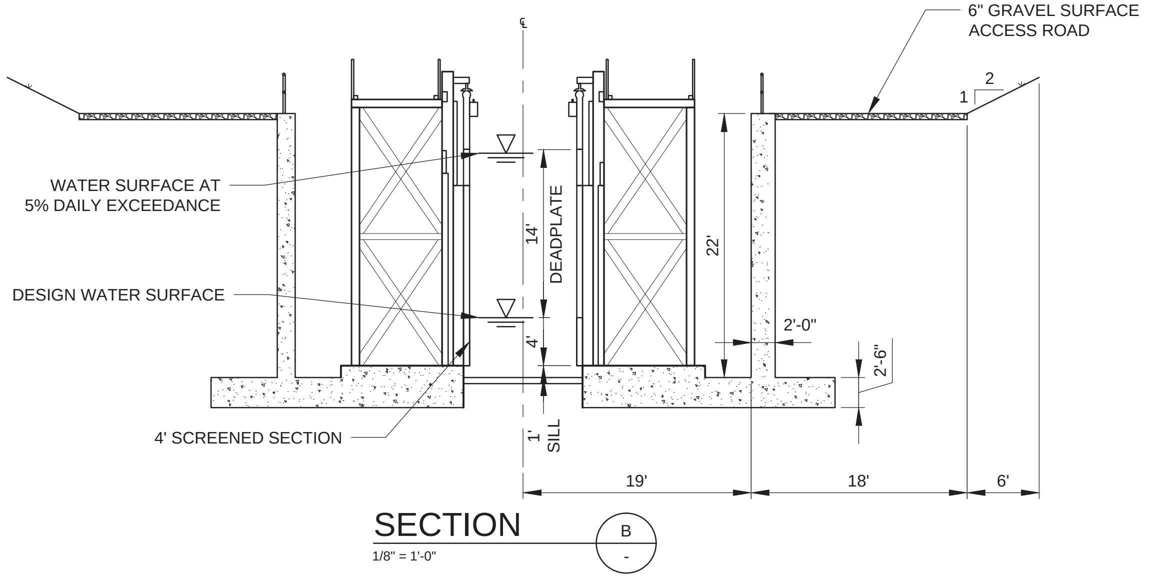
NOTE: DESIGN RIVER FLOW RATE AND DEPTH VARY BY SITE. VALUES SHOWN ARE TYPICAL.



PLAN
1" = 20'



SECTION C



SECTION B
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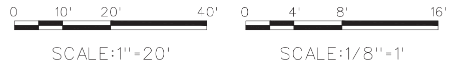

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LOWER YELLOWSTONE RIVER
ALTERNATIVE DESIGN

FISH SCREEN FACILITY
PLAN AND SECTIONS

SHEET
IDENTIFICATION
M-002
SHEET X OF Y

Attachment 2
Intake Selection

Lower Yellowstone Intake Diversion Dam Fish Passage Project, Environmental Impact Statement

DRAFT

February 2016

Preliminary Analysis of Multiple Pump Station Alternatives

Submitted by:
Tetra Tech, Inc.

Date: February 25, 2016

To: Tiffany Vanosdall (Corps), David Trimpe (Reclamation)

From : Scott Estergard (Tetra Tech)

Subject: Lower Yellowstone Intake Diversion Dam Fish Passage Project,
Multiple Pump Station Intake Alternative Selection (Draft)

INTRODUCTION

This technical memorandum documents a preliminary analysis and comparison of two multiple pump station conceptual alternatives. This analysis was conducted to inform the selection of one multiple pump station alternative for further detailed analysis in the Lower Yellowstone Intake Diversion Dam Fish Passage Project Environmental Impact Statement (EIS). The two conceptual alternatives evaluated are the Ranney Wells Alternative and the Surface Water Intake Alternative, both previously identified in the 2015 Final Supplement to the 2010 Final Environmental Assessment (EA) for the project as "Alternatives Considered but Not Analyzed in Detail" (Bureau of Reclamation and US Army Corps of Engineers, 2015).

The two multiple pump station alternatives differ primarily in the number of pump stations required and by the type and configuration of the intake structures. The Ranney Wells alternative intake structure pumps groundwater and the Surface Water Intake alternative pumps surface water and requires fish screening. Each alternative is configured to provide a target flow capacity of 1,374 cfs based on the existing water right for the Lower Yellowstone Irrigation Project (LYIP) (Bureau of Reclamation and US Army Corps of Engineers, 2015).

EVALUATION OF ALTERNATIVES

This section serves to document design and evaluation considerations of the two multiple pump station intake alternatives.

RANNEY WELLS INTAKE ALTERNATIVE

The Ranney Wells Alternative includes removal of the existing Intake Diversion Dam and construction of a series of Ranney well chambers to produce groundwater for discharge into existing irrigation canal infrastructure to supply water to the LYIP (Note: the existing Intake headworks could still be used during periods of high Yellowstone River flow to divert water into the LYIP). Each Ranney Well would include sections of screened pipe/chamber buried adjacent to the river to collect water from below/adjacent to the river channel and direct it into a pumping plant. The number of Ranney wells and associated pumping plants required to meet the target flow capacity of 1,374 cfs would depend on the potential yield of water that could be obtained from the shallow aquifer associated with the Yellowstone River. A typical Ranney well is a reinforced concrete caisson, 10 feet to 20 feet inside diameter, sunk from grade to a confining layer or bedrock. Horizontal well screen laterals are projected into the alluvial aquifer a distance of 100 to

250'. The caisson becomes the foundation of a pumping station. Plan and section views of a typical Ranney well structure are shown in Figures 1 and 2.

The Ranney well alternative was discussed in an alternatives analysis from 2013 (Bureau of Reclamation, 2013) and in the 2015 EA (Bureau of Reclamation and US Army Corps of Engineers, 2015). The Ranney well alternative described in 2013 called for the installation of Ranney wells at seven sites along the Yellowstone River with a total combined capacity of 1,374 cfs. The 2013 alternative analysis was based on the assumption that Ranney wells capable of producing 200 cfs each could be constructed at each site. Soils and aquifer characteristics were not were not considered in the 2013 analysis. More information about the previous analysis of Ranney wells is included in Attachment A.

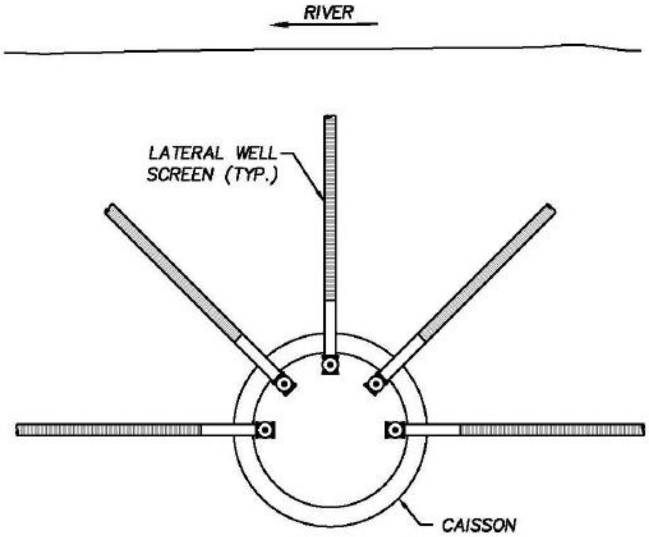

Figure 1 - Typical Ranney Well (Plan View)

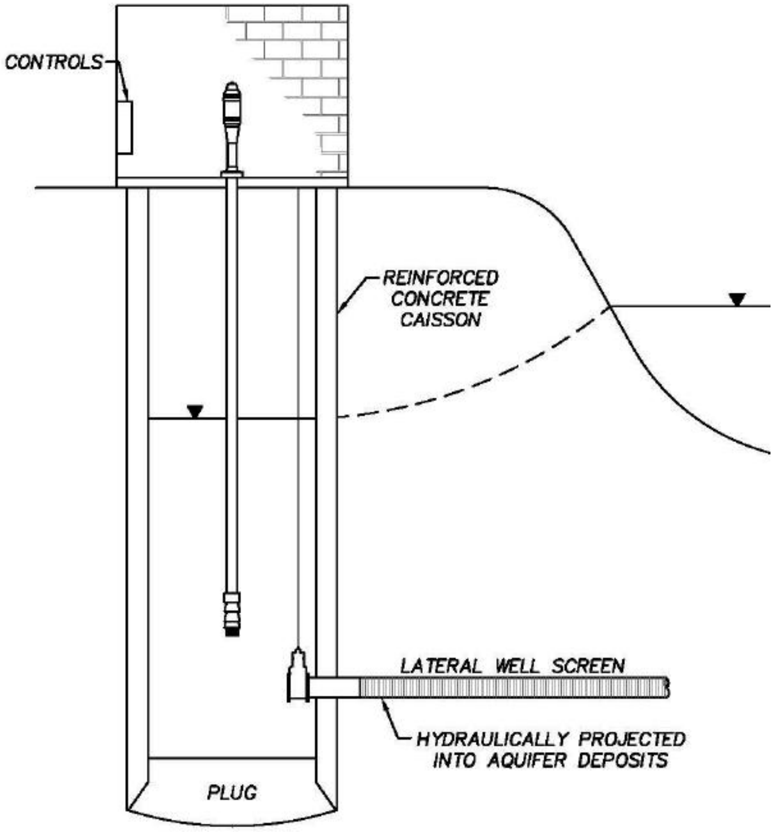

Figure 2 - Typical Ranney Well (Section View)

Design and Evaluation Considerations

Five primary design and evaluation considerations were identified for the Ranney wells intake alternative: estimated yield, construction cost, maintenance, compatibility with the existing intake and canal system, and groundwater level impacts. These considerations are discussed in the following paragraphs.

Estimated Yield

For the current analysis, a desktop review of existing well log data and published literature of aquifer characteristics was performed to provide a better understanding of the potential production characteristics of Ranney wells in the project area. The desktop review determined that each Ranney well would likely yield approximately 5 to 17 cfs, with the most productive wells located in the Sidney area where aquifer transmissivity is expected to be greatest. This estimated range is based on existing well log data in the vicinity of the project (Tetra Tech 2016, Attachment A). Site specific pump tests at each proposed well location would be required to verify site specific conditions and hydraulic conductivity rates. Based on the potential yield identified in the desktop review, it is estimated that between 80 and 270 Ranney wells would be required to provide the 1,374 cfs flow capacity. The production capacity of Ranney well systems installed at some sites has been shown to degrade over time due to fine materials clogging the pore spaces in the soils (Chou Cha Personal Communication, 2016).

Preliminary Construction Cost

The analysis also included a discussion of the technical feasibility and estimated cost of Ranney wells with Layne Construction, a contractor who constructs Ranney wells in eastern Montana (Attachment A). The purpose of these efforts was to evaluate whether Ranney wells are a technically feasible option, and to collect enough information to compare the Ranney well alternative to the surface water pumping alternative. Layne Construction provided a conceptual level cost estimate indicating each Ranney well is expected to cost $4 - 5 million to construct. This cost estimate only includes the construction of the well and the installation of the pumping equipment in the wells. The cost for site development, pipe system construction, and power system upgrades are not included in this estimate. A potential range of Ranney Wells Intake construction cost is provided in Table 1 based upon above noted yield assumptions.

TABLE 1 - RANNEY WELL OPTION SUMMARY

Case	Well Production[a] (cfs)	Number of Wells[b]	Total Well Cost (Million $)[c]
Best Case	17	80	360
Average Case	11	120	540
Worst Case	5	270	1220

a. Note that the estimated well production rates shown are based on existing well test data in the vicinity of the project. Site specific tests would be required to determine the production rate at each well site.

b. Estimated number of wells required to produce a total of 1374 cfs.

c. Well cost is based on conceptual level cost estimate data provided by Layne Construction. Cost shown includes only the Ranney well and basic pumping equipment. Site development, pipe network, power system, and additional pump station costs are not included. Maintenance not included.

Maintenance

Each well should be inspected using divers every 5 - 10 years to verify the condition of the major structural components. Maintenance needs vary depending on water quality and the pumping schedule, but major maintenance of the pumps and motors would typically be required within 10 - 20 years of installation.

Compatibility with Existing Intake

The existing intake cannot be used simultaneously with the pumped water supplies; however, it could be maintained in place to reduce power costs, when the river elevation is high enough to divert the full 1374 cfs at the intake.

Groundwater Levels

The groundwater level is expected to decrease throughout the project area after the installation and operation of the Ranney well system being described. This effect might dewater wetland areas and impact some existing wells. Further evaluation would be required to determine the extent of this possible effect, possibly including pump drawdown testing to determine site-specific soil permeability factors at and between the proposed well sites, an analysis of the post-construction groundwater level, a survey of wells and wetlands areas within the groundwater-affected area, and an analysis of how those wells and wetland areas might be affected by the reduced groundwater level.

SURFACE WATER INTAKE ALTERNATIVE

The Surface Water Intake Alternative includes removal of the existing Intake Diversion Dam, and construction of five surface water pumping stations on the Yellowstone River to deliver water to the LYIP (Note: the existing Intake headworks could still be used during periods of high Yellowstone River flow to divert water into the LYIP). The pumping plants would be constructed at suitable locations along the LYIP. The pumps would be screened to minimize fish entrainment and would discharge into existing irrigation canal infrastructure to supply water to the Lower Yellowstone Irrigation Districts. The canal infrastructure may require modification to allow pumping from multiple locations, which will need to be determined during design. Power lines, roads, and pipelines would also be required for construction of this alternative.

Design and Evaluation Considerations

Five primary design considerations were identified for the surface water intake alternative: fish entrainment, water depth, ice formation, sedimentation, and compatibility with the existing intake and canal system. These considerations are discussed in the following paragraphs.

Fish Entrainment

A major consideration for a surface water intake system is the need for screening to avoid entrainment of fish. At each surface pump location, a positive barrier screen would be provided that reduces entrainment and is designed to be fish friendly to minimize impingement. Using the NOAA fish screen design criteria (NOAA, 2011) that was similarly used for the design of the existing screens at the headworks, requires screens with a 1.75mm opening size, a maximum approach velocity of 0.4 feet per second and a sweeping velocity of 2.0 to 2.5 feet per second. These are widely adopted requirements for actively cleaned screens, although they are designed primarily for salmonids and cannot likely exclude fish smaller than 1.6 inches in length. If an active cleaning system is not installed then the approach velocity may need to be reduced to minimize collection of debris or fish on the face of the screens.

Water Depth

Water depth in the Yellowstone River was taken from Yellowstone River Corridor Study hydraulic model (USACE, 2014). The hydraulic modeling was conducted using HEC-RAS (USACE, 2010). The model was constructed using cross sections with an assumed trapezoidal geometry, due to the lack of bathymetry in most of the river. Because of this limitation, depths obtained from the model represent only an average depth across the river. Maximum depths are likely greater than the average depth, likely by several feet. Results from the model were taken for conditions when the flow in the river is 3000 cfs at Intake Dam and decreases downstream by the quantity of each diversion. The water depths calculated at Sites 1 - 5 are shown in Table 2.

TABLE 2 - YELLOWSTONE RIVER DEPTH AT SITES 1 - 5

Site	Location	Diversion Rate (cfs)	Yellowstone River Flow (cfs)	Average River Depth, (Feet)
Site 1 / Existing Intake	RM 72.8	275	3000	6.7
Site 2	RM 64.3	275	2725	2.1
Site 3	RM 60.6	275	2450	3.3
Site 4	RM 54.8	275	2176	2.6
Site 5	RM 54.1	275	1901	1.8

[1] Maximum depth will be greater than the reported average depth, see "Water Depth" section for more details

Additional data collection, modeling, and analysis would be required to confirm the suitability of each site and the likely water depths, geomorphic conditions, intake canal conditions, screening requirements, and other considerations if this alternative was selected as the preferred alternative for further design.

Ice

Ice formation on the Yellowstone River has been identified as a challenge for any in-channel features. Previous studies on ice formation in the river at the Intake Dam location found that ice jams up to 8 feet in depth may occur, and an ice load of 2,000 pounds per square foot may occur on the upstream faces of in-channel features. Due to these tremendous pressures that could damage a pumping station located in the river, various off-channel pumping options were considered.

Sedimentation

Sedimentation and channel migration are also known challenges in this segment of the river. Sediment loads in the river vary; however designs should include features to allow for sediment deposits to be removed during maintenance operations that may be necessary on an annual basis or more frequently. Channel migration has also been previously identified in this segment of the Yellowstone River, particularly relative to the deepest channel locations where a surface intake would need to be located to divert at flows down to 3,000 cfs.

Compatibility with Existing Intake

The existing intake cannot be used simultaneously with the pumped water supplies, however it would be maintained in place to reduce power costs, when the river elevation is high enough to divert the full 1,374 cfs.

Design Options

Three surface water intake design options were investigated.

1. The first option is an off-river intake structure fed by a diversion channel. This configuration minimizes problems associated with ice jams in the river and channel migration, but requires special considerations to return fish that enter the diversion channel back to the river. Because of the dead end nature of this option, though screened, it may entrain fish.

2. The second option is an in channel intake located in the thalweg of the channel. This option eliminates considerations to return fish to the river, but exposes the intakes and associated screens to debris and ice and may entrain larval fish.
3. The third option is an intake located along the channel bank. This option would be easier to protect from ice than the intake located in the thalweg, but would be subject to channel migration concerns and may entrain larval fish.

Each of the surface water intake design options includes intakes and pump stations at five locations on the Yellowstone River, each with an intake capacity of ~275 cfs for a total pumped capacity of 1,374 cfs.

Surface Water Intake Design Option 1: Off-River Intake with Flat Plate Screen

An off-river flat plate screen involves the use of a series of flat wedge-wire screen panels installed in a concrete structure located off the main river channel and typically has the top slab elevated above the 100-year flood elevation. Flat plate screens are typically installed in either a diagonal or "V" configuration. Both of these configurations orient the screen at an angle to the flow to create uniform approach velocity and proper sweeping velocity. Water is diverted from the river into an intake channel flowing to a concrete structure housing the fish screens. This concept is similar to the one shown in the 2010 Final EA, Appendix A1, as shown in Figure 3 (Bureau of Reclamation, 2010). Design considerations are discussed below Figure 3.

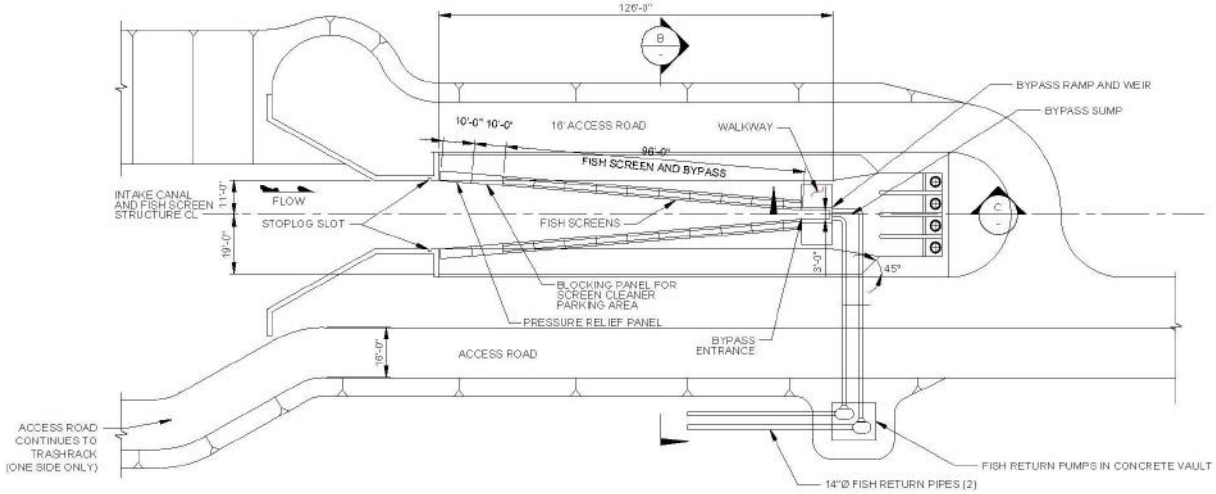

Figure 3 - Off-River Intake with Flat Plate Screen - Conceptual Plan

Trash Rack: Installation off the main river channel often requires a trash rack upstream of the fish screen at the river where water is diverted. Trash rack slot velocities are typically 1 foot per second resulting in a 135 foot wide trash rack assuming a water depth of 2.1 feet. The trash rack openings would be sized to exclude adult sturgeon and other large fish.

Ice Protection: The fish screen structure is located off the river and would not be subject to the large ice flows which occur in the main channel. The trash rack could be removed for the winter with minimal difficulty.

Fish Screen: Downstream from the trash rack, flat fish screen panels are installed in a concrete structure. Fish screen panels with a gross screen area of approximately 800 square feet will provide the required approach velocity of 0.4 feet per second at a design flow rate of 275 cfs.

Sedimentation and Channel Migration: The pumping stations will be generally located outside of the channel migration zone (DTM/AGI, 2009), typically approximately 1,000 feet from the current river bank. It is initially planned that the channel bank will not be protected until channel migration would bring the river bank to within a pre-specified distance of the pump station (a value such as 300 feet seems reasonable). The canal will likely need to have sediment removed from it on an annual or possibly more frequent basis. This is particularly true of the entrance areas and the river immediately in front of the canal entrance.

Sediment Trap: A sediment trap is provided under the screens to remove collected sediments, which will require seasonal maintenance. Siltation may require that the intake channel be maintained on an annual or semi-annual basis.

Fish Return System: The Yellowstone River slopes down at approximately 2.0’ - 2.5’ per mile at the pump station locations. This relatively flat slope makes a gravity-fed fish return system technically infeasible and a pumped fish return system is required. The pumped fish return system uses a fish-friendly pump design; however it is expected that some fish would be injured or killed from being pumped back to the river.

Surface Water Intake Design Option 2: In-River intake with Cone Screen

A surface water intake located out from the bank of the river in the thalweg would use cone screens to prevent fish entrainment. The cone screens are installed on a concrete foundation located in the river channel. The shallow water depth at the intake sites, ranging from 2.1’ - 2.9’, requires the cone screens to be placed in the deepest part of the river channel. Pipes are installed underneath the concrete slab to draw water in to the pump station wet well, which will have a top slab and pumps elevated above the 100-year flood elevation. Figure 4 provides a conceptual layout of a typical cone screen in-river intake structure. Design considerations are discussed below Figure 4.

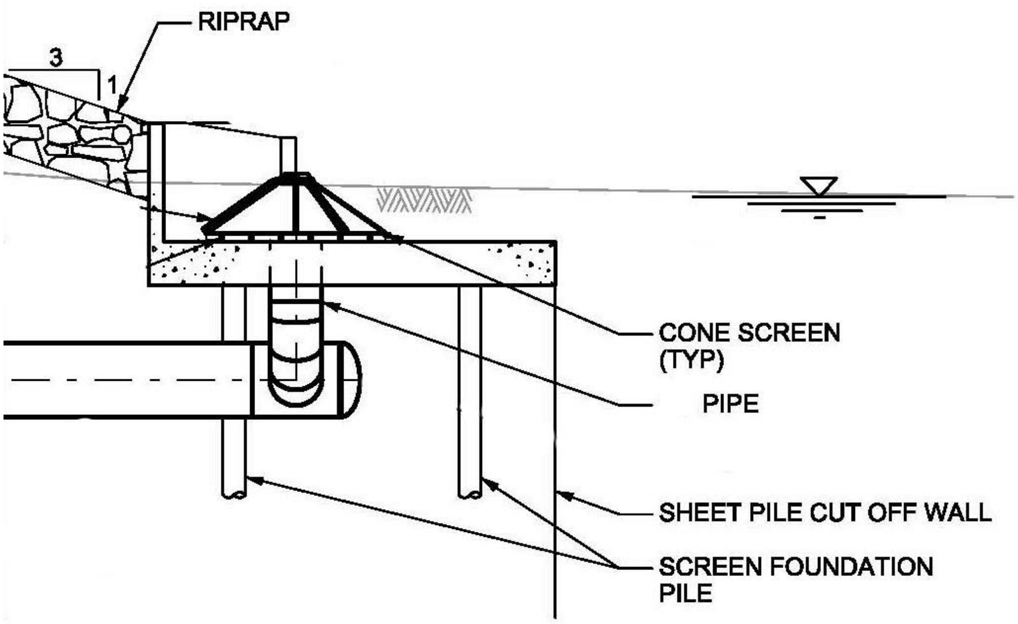

Figure 4 - In-River Intake with Cone Screen - Conceptual Section

Fish Screen: The proposed fish screen for the in-river intake structure is a cone screen. Cone screens are a type of actively cleaned cylindrical wedge wire screen that is configured in a cone shape making it better suited for shallower water depths. Other configurations of cylindrical screens include vertical and horizontal drums. Any of the three configurations may be suitable for the project, but the cone screens are considered for this application because of superior performance in shallow river depth. The cone screen being evaluated is a fabricated unit that is actively cleaned with external brushes. The proposed cone screens are 8' in diameter and 2' high with an approach velocity of 0.4 feet per second. Each screen has a capacity of 21.9 cubic feet per second. Fourteen cone screens are provided at each of the pump station sites, with a total capacity of 275 cfs at each site, including one spare cone screen for use during maintenance. A typical cone screen is presented in Figure 5. Because the screens would be located in the thalweg of the river, where sturgeon and paddlefish free embryos would likely be drifting, the risk of entraining fish into the pumps or impinging them on the screens would be quite high.

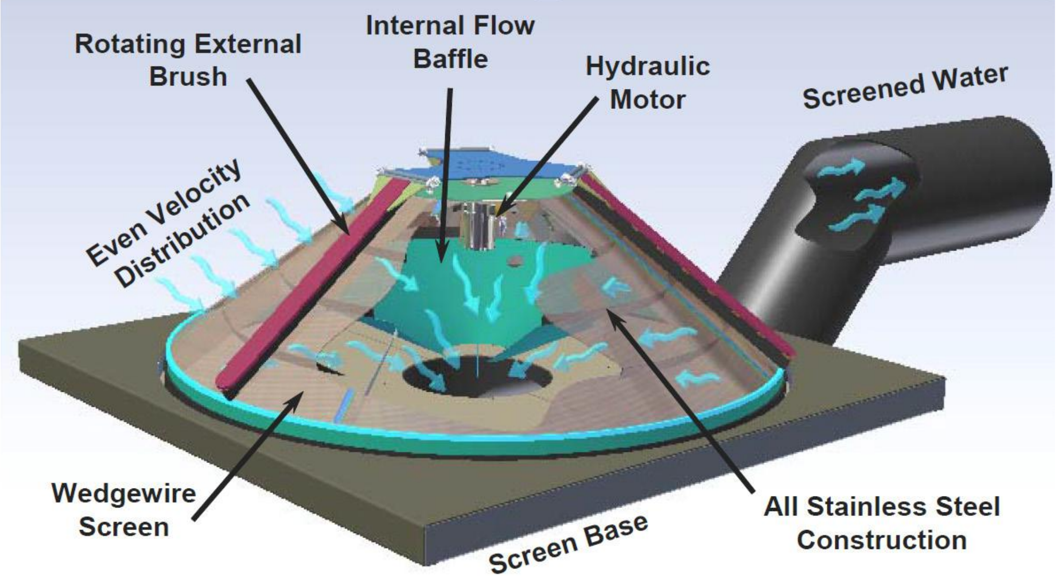

Figure 5 – Typical Cone Screened Intake

Ice Protection: The concrete foundation for the 14 cone screens at each of the five stations would be approximately 160 feet long by 30 feet wide with sufficiently rugged construction to withstand the ice flows on the river. Ice flows on the river will require that the cone screens be removed and the intake pipes covered every winter. Mounting hardware for the cone screens is recessed into the concrete foundations to protect it from ice damage and covered with a steel lid during the non-irrigation season to prevent damage to the mounting hardware. Assuming an average river flow rate in April and October when the cone screens would be installed and removed, the maximum river depth is 5 - 6 feet and the average velocity in the river is 2 - 4 feet per second. As described in the "Water Depth" section, the depth is calculated by the HEC-RAS model using an assumed trapezoidal river channel (USACE, 2010). In reality, the channel bathymetry is more variable, and the maximum depth will be greater than the reported average depth by up to several feet. The mounting hardware would be designed to simplify installation and removal of the cone screens, however it is anticipated that divers would be required.

Channel Migration and Sedimentation: Channel migration and sedimentation will likely require annual or more frequent channel excavation to maintain access to the cone screen foundation and permit re-installation of the cone screens. Sedimentation around the screens during the irrigation season might also cause reliability issues if the water depth became too shallow to effectively pump the required volume.

Sediment Trap: Sand and finer sediment will pass into the intake and be entrained in the system. There will need to be considerations to either provide sediment traps or provide designs that keep sediment, particularly the sand sized, in suspension throughout the pumping and delivery system to the LYIP canal.

Surface Water Intake Design Option 3: River Bank Diversion with Flat Plate Screen

A diversion along the river bank involves the use of a series of flat wedge-wire screen panels installed in a concrete structure located at the edge of the main river channel in a section of the river that is deep enough to maintain minimum screen submergence. The screens fit into slots in a concrete intake structure which directs flow into the pump station wet well through an internal channel structure. A plan and section view of this conceptual design is shown in Figures 6 and 7, below. Design considerations are provided below the figures.

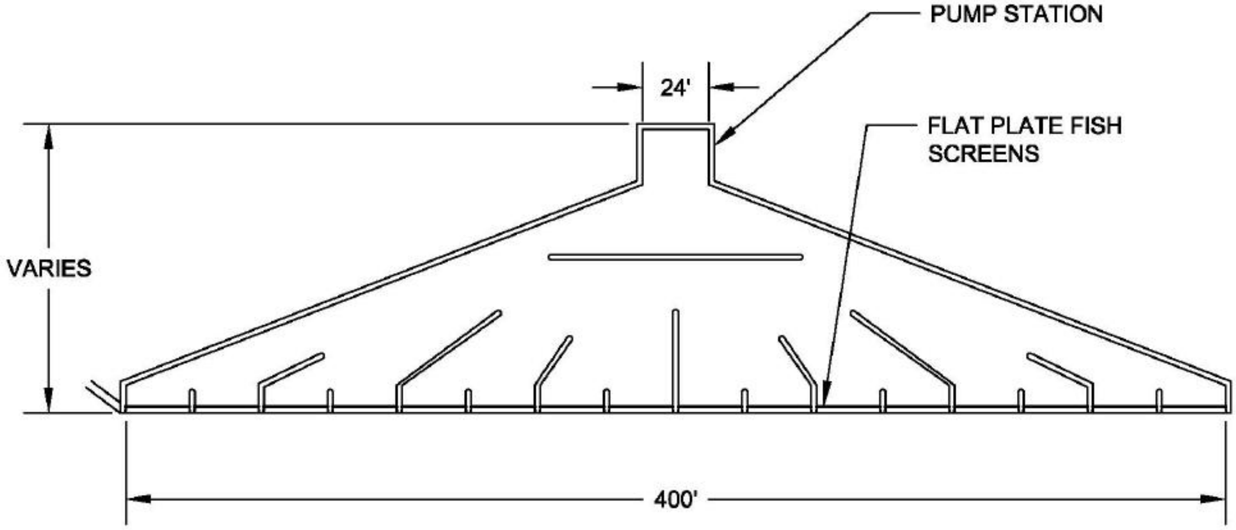

Figure 6 - River Bank Diversion with Flat Plate Screen - Conceptual Plan

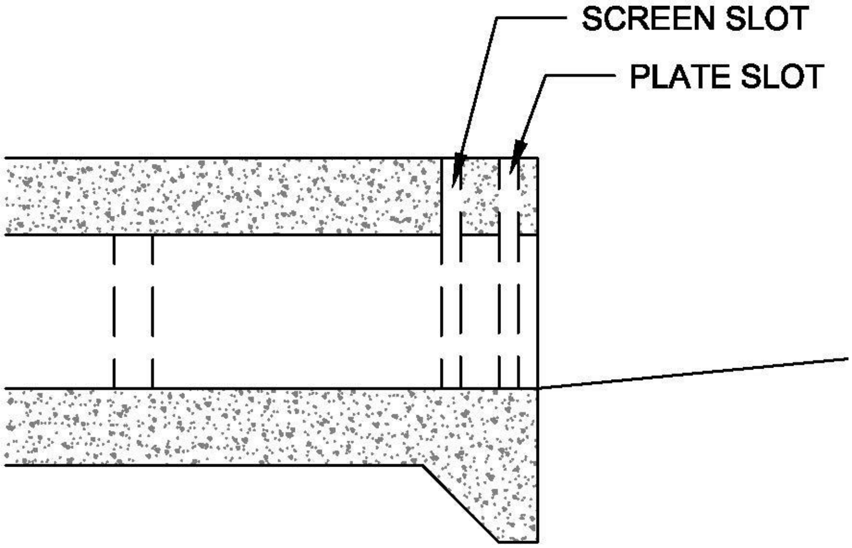

Figure 7 - River Bank Diversion with Flat Plate Screen - Conceptual Section

Fish Screen: Each intake site requires a total of 19 flat plate screens, each of which is 20' in length, providing the required approach velocity of 0.4 feet per second. This sizing assumes the river depth is 2.1 feet at 3,000 cfs and no accommodation has been made for holding the screens off the bottom of the river to account for sedimentation, which may be required depending on siting and hydrology. Overall, each concrete intake structure is approximately 400' wide. Baffles or porosity plates located within the concrete intake structure and directly behind the screens would be required to create uniform velocity across the screen minimizing "hot spots". An active screen cleaning system is required and could consist of a removable brush cleaning system or water backwash system to clean the flat plate screens. Because the pumps and screens would be located at a site with the deepest water possible against the bank (i.e. the outside of a bend), where the majority of sturgeon and paddlefish free embryos would be drifting, the risk of entraining or impinging fish is quite high.

Ice Protection: A slot would be provided upstream of each of these flat screens to allow the placement of a steel bulkhead to protect the screens from ice damage during the non-irrigation season. Removable guide posts which fit into holes in the concrete intake can be provided to simplify the placement of the steel bulkheads without the use of divers. Gates behind each screen plate system would also be required to allow the screens to be maintained while the facility is operating.

Channel Migration and Sedimentation: Channel migration and sedimentation may require annual or possibly more frequent channel excavation to maintain flow into the intake during the low flow periods. Sediment buildup in front of the screens during the irrigation season might cause reliability issues while they are in use.

Sediment Trap: Sand and finer sediment will pass into the intake and be entrained in the system. There will need to be considerations to either provide sediment traps or provide designs that keep sediment, particularly the sand sized, in suspension throughout the pumping and delivery system to the LYIP canal.

COMPARISON OF ALTERNATIVE INTAKE CONCEPTS

Two primary types of multiple pump station structures were evaluated: the Ranney Wells Intake Alternative and the Surface Water Intake Alternative. For the Surface Water Intake Alternative, three options were evaluated. Each of the intake concepts was evaluated based on its relative ability to protect fish, reliability in providing the required water, O&M requirements, and anticipated construction cost. The advantages and disadvantages of each approach relative to these categories were identified and are summarized in Table 3.

TABLE 3 – SURFACE WATER INTAKE OPTION SUMMARY

Intake Concept	Advantages	Disadvantages
Off-River Intake with Flat Plate Screens	• Slightly lower potential for encountering fish • Lowest maintenance requirements • Lowest cost • Protected from ice damage • Moderate potential for damage or interruption in service due to channel migration and sedimentation	• May not meet fish screening criteria due to limited sweeping velocity • Vulnerable to sedimentation in the intake channel, and likely to require annual or more frequent sediment removal • Fish return via pumps could cause additional injury or mortality
In-River Intake with Cone Screens	• Operate in shallow water	• May not meet fish screen criteria due to high velocities • Highest annual maintenance costs, due to annual removal to avoid ice damage • Risk of damage from river debris • Difficult to access during operation • Expected to require bank protection and possibly periodic channel maintenance to prevent or mitigate for channel migration • Vulnerable to sedimentation and may require regular cleaning while in use to maintain operation

Intake Concept	**Advantages**	**Disadvantages**
On-Bank Intake with Flat Plate Screens	• Most likely to consistently meet fish screen criteria • Good protection from debris and ice damage • Moderate potential for damage or interruption in service due to channel migration and sedimentation	• High construction cost • Significant annual maintenance costs • Large construction footprint on the riverbank • Regular adjustment to meet uniform screen velocity and consistently protect fish without ongoing maintenance during the operation season • Performance is dependent on river stage • Expected to require bank protection and possibly periodic channel maintenance to prevent or mitigate for channel migration • Vulnerable to sedimentation and may require regular cleaning while in use to maintain operation
Ranney Wells	• Avoids risk of entraining fish as all water is pumped from groundwater • Minimizes visual impact • Protected from ice damage as wells are located away from the river	• Highest construction cost • Highest power demand • Reduced local groundwater levels may affect wells and wetlands • Large construction footprint • Vulnerable to loss of long term performance due to plugging with fine sediment • Moderate potential for damage or interruption in service due to channel migration

The advantages and disadvantages of each concept were used to inform ranking scores for nine evaluation criteria. The scores for each criterion were ranked from 1 to 4, with the lower scores indicating higher cost and or risk associated with that criterion. Thus higher scores are preferable to lower scores. The criteria and resultant ranking scores for each intake option are summarized in Table 4.

TABLE 4 - MULTIPLE PUMP STATION RANKING SCORES

Evaluation Criteria	Ranney Wells Intake Alternative	Surface Water Intake Alternative		
		Off-River Flat Plate Screens	In-River Cone Screens	On-Bank Flat Plate Screens
Fish Entrainment / Harm to Fish	**4**	**2**	**1**	**3**
Maintenance Requirements	**4**	**3**	**1**	**2**
Potential for Ice Damage	**4**	**3**	**1**	**1**
Potential for Channel Migration Damage	**3**	**4**	**1**	**1**
Disturbance during Construction and Operation	**1**	**4**	**2**	**3**
Construction Risk	**1**	**4**	**1**	**2**
Operability/Reliability	**2**	**3**	**1**	**2**
Power Requirements	**1**	**2**	**2**	**2**
Capital Costs	**1**	**4**	**3**	**3**
TOTAL SCORE:	**21**	**29**	**13**	**19**
Scores are ranked from worst to best with 4 being the best in a given category.				

RECOMMENDATION

Based on this evaluation of multiple pump station intake alternatives, the recommended alternative is the Surface Water Intake Alternative with Off-River Flat Plate Screens. It has the highest total ranking score in Table 5. This option is located off-channel, so would have a lower risk of debris, ice, or channel migration although still has a risk of entrainment. The other two surface water intake options evaluated (In-River Cone Screens and On-Bank Flat Plate Screens) were identified to have significantly greater risk of being technically infeasible at these sites. This is primarily due to concern that shallow water depth and sediment load in the river would make these options unreliable.

The Ranney Well Intake Alternative essentially eliminates concerns about entraining fish, however the number of wells to be installed adjacent to the river has a large construction footprint, potentially susceptible to channel migration, and is expected to have the greatest capital cost and the greatest power demand. This alternative would require locating 80 - 270 sites with acceptable hydraulic conditions along the Yellowstone River. The access roads, pipelines, and power supply to these wells will have a large construction footprint and associated environmental impacts. The lifespan of these wells is unknown based on existing available data, however it is expected that that some of them could fail over time due to amount of fine materials in the soils. The effect of this alternative on the local groundwater is also unknown, however it is expected that implementation of this option could result in dewatering some wetland areas and could cutoff some nearby wells.

Based upon these considerations and findings, a surface water intake with an off-river fish screen is the preferred design concept available for the multiple pump station intake, and is recommended for the further development and evaluation in the EIS.

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ATTACHMENT A - PRIOR RANNEY WELL ANALYSES

TETRA TECH

MEMO

To:	Tiffany Vanosdall (Corps) and David Trimpe (Reclamation)
Cc:	
From:	Scott Estergard (Tetra Tech)
Date:	January 27, 2016
Subject:	Revised Review of Collection Well Assumptions Yellowstone River Diversion Desktop Hydrogeologic Review (Project# 100-SET-T35234)

INTRODUCTION

This memorandum is a follow up to the January 15 memo in which we summarized the findings pertaining to hydraulic conductivity as it relates to Ranney wells. The objective of this review is to evaluate whether hydrogeologic conditions are suitable to support large scale production of water (i.e., 1,374 cubic feet per second) from Ranney® Wells at multiple locations within this reach of the Yellowstone River valley. The trademark name Ranney Well® is owned by Layne, Inc., however, the term "collector well" is typically used in the literature. The two terms are used interchangeably in the document depending on the source of the information.

Tetra Tech (Helena) reviewed the January 5, 2016, email from Mr. Henry Hunt of Layne Inc. to Joshua Phillips of Tetra Tech, regarding the Lower Yellowstone Ranney Well® Alternative. We agree with Mr. Hunt's observations that the previous technical memorandum findings were restricted to small capacity or domestic wells along the river corridor and that the available drawdown (saturated thickness) in portions of the study area warrants further investigation. We further agree with his statement that "there is a great deal of variation in collector well yields that is related to hydraulic conductivity, recharge, available drawdown and configuration." Within this email Mr. Hunt presented a typical scenario of specific capacity for a collector well (200 gpm/foot of screen) and available drawdown (50 feet) necessary for a collector well to produce 10,000 gallons per minute (gpm). Mr. Hunt estimated, a series of 60 collector wells yielding 10,000 gpm each would be necessary to supply adequate water for the canal. Those wells would need to have 50 feet or more of available drawdown.

Upon further discussion with Mr. Hunt, he provided data from an aquifer test they conducted for a client along the Yellowstone River near the North Dakota/Montana border (email dated January 20, 2016). The test results have not been published, however, they were submitted to the North Dakota State Water Commission and are in the public domain. The test evaluated the feasibility of constructing a collector well near the downstream edge of the study area. The test consisted of a 72 hour constant rate aquifer test with water level monitoring from six wells and a staff gauge in the river. The test well was in close proximity to the river and was in the alluvial aquifer evaluated in this document, hence, we believe the findings are relevant to this analysis. The site encountered 56 feet of saturated alluvial aquifer and they estimated the average hydraulic conductivity at 4000 gallons/day/foot^2 (535 feet/day). Using a typical configuration for a collector well and analytical methods developed by Hantush and Papadopulos (1962), Layne, Inc. estimated a well would produce approximately 7,500 gallons per minute (16.7 cfs). Their analysis indicates a series of 82 collector wells yielding over 7,500 gallons per minute would be necessary to supply adequate water for the canal. This assumes that at least 45 feet of available drawdown would be available at each location.

A paper titled “A Modeling Frame Work for the Design of Collector Wells” published in the Journal of Ground Water (Moore et al. 2012) was reviewed to provide further comparison of the likely ability of collector wells. The hydrogeologic setting described in this article is similar to that present within our study area. The author’s conducted a numerical groundwater modeling exercise using both 2 dimensional and 3 dimensional models to evaluate the likely production from two separate collector wells along the Des Moines River in Iowa. The authors assumed a saturated thickness of approximately 50 feet, approximately 30 feet of available drawdown and hydraulic conductivities of 165 and 286 feet/day at the two locations. The modeling results indicated a combined production capacity averaging approximately 5,000 gpm (11.1 cfs) for the two wells, and a specific capacity of approximately 150 gpm/foot of screen. Two collector wells were subsequently constructed based upon the analysis and actual production rates were similar to the predicted values.

Further evaluation was deemed necessary to identify whether aquifer properties in these case studies are similar to those throughout the study area.

METHODS

Two approaches were taken to obtain ranges of hydraulic conductivity likely present in close proximity to the Yellowstone River within the study area. Well logs in close proximity to the river and area hydrologic studies were reviewed to determine dominant grainsize classifications present. These size classifications were then compared to published literature values to obtain hydraulic conductivity ranges. Additionally, an expanded search of Montana databases was conducted to identify high capacity wells completed in alluvium within the river valley that have undergone aquifer testing. The results are discussed below.

GRAINSIZE REVIEW

Torrey and Kohout (1956) indicate the flood plain lithology within the study area is “alluvium consisting largely of medium to fine sand, silt, and clay. In places small amounts of gravel are scattered along the river bank.” Geotechnical borings performed in 2010 within the river channel, as documented within the 2015 EA Supplement Final Appendix C in the vicinity of the diversion, indicate materials to be primarily silty or sandy clays, sands, and gravels with occasional fat clays. Review of selected well logs indicate the dominant alluvial grainsize to be silty or sandy clay with mixed gravels.

In general, available grainsize descriptions available indicate the grainsize in the immediate vicinity of the river channel to be relatively fine grained silt, sand, and clays with occasional gravels. The following table presents published hydraulic conductivity ranges based on the grainsize descriptions available.

Based on available grainsize information and corresponding literature values summarized above, it is likely that hydraulic conductivities in the study area range from 10^{-3} to 10 feet/day.

Hydraulic Conductivity (feet/day)	Lithology	Source
10^{-3} to 10^{-1}	Silt, sandy silt clayey sand	Fetter 1994
10^{-2} to 10	Silty sand, fine sand	Fetter 1994
10^{-3} to 10	Fine sand, silt, clay, sand-silt-clay mix	Todd 1980
10^{-2} to 10	Silt fine to coarse sand	Driscoll 1986
10^{-2} to 10^{2}	Fine to coarse sand, gravel	Driscoll 1986
2.3 to 75	Alluvial slug test data	Smith et al 2000

STUDY AREA HIGH CAPACITY AQUIFER TESTING

Montana's Ground Water Information Center (GWIC) online database and The Montana Department of Natural Resources and Conservation Water Right Query System were reviewed to identify high production alluvial wells (i.e., greater than 100 gpm) located within the Yellowstone River valley. Four wells with these criteria were found to be on file within the study area. All four wells are located north or northwest of Sidney, Montana, which is at the downstream edge of the study area. All four locations are between two and four miles west of the current river channel and are screened in relatively clean gravels. The following is a summary of their location and aquifer characteristics.

DATA SUMMARY FOR HIGH PRODUCTION WELLS IN STUDY AREA

GWIC #	Lat	Long	Lithology	Total Depth/ Saturated Thickness (feet)	Discharge (gpm)	Drawdown (feet)	Specific Capacity (gpm/foot of screen)	Hydraulic Conductivity (feet/day)
262846	47.73972	104.13111	Gravel with clay layers	70 / 65	180 363	10 44	18 8	122 72
251850	47.73986	104.13143	Course sand med gravel	102 / 92	570	19	30	121
269247	47.739722	104.13167	Sand and gravel	72 / 66	600 365	40 32.6	15 11	106 87
274100	47.732516	104.17181	Gravel	75 / 54	100	10	10	99

Note: Multiple values in discharge column indicate multiple aquifer tests completed.

Available aquifer test data for the four large production wells on record suggest hydraulic conductivities within the study area are approximately 80 to 125 feet/day.

DISCUSSION

Although literature and well logs suggest the presence of an alluvial aquifer with up to 80 feet of available drawdown, these conditions do not appear to be ubiquitous along the river and they appear to be more prevalent in the lower stretches of the study area near Sidney.

Review of available well logs and literature presented suggest the presence of a low to moderate transmissivity alluvial aquifer in proximity to the river. Wells present adjacent to the current river channel are dominantly low producing domestic or stock wells. Lithology is dominated by relatively fine grained silt, sand, and clays with occasional gravels with literature hydraulic conductivities of less than 100 feet/day.

A few select locations to the north of Sidney have been developed with production wells yielding greater than 100 gpm. These locations are two to four miles to the west of the current river channel and appear to encounter relatively clean gravels likely of a buried river channel. Aquifer tests completed on these high production wells suggest estimated hydraulic conductivities in the range of 80 to 125 feet/day.

The test conducted by Layne, Inc. near Cartwright, North Dakota estimated hydraulic conductivities of 535 feet/day in close proximity to the Yellowstone River, which resulted in estimated collector well production of 16.7 cfs.

Hydraulic conductivities estimated from literature searches were 80-125 feet/day, which are approximately half the values used by Moore et al. The collector wells constructed by Moore et. al. exhibited an average production capacity of approximately 5,000 gpm (11.1 cfs) each. Using a simple linear interpolation, a collector well in a setting with hydraulic conductivity values one half the values used by Moore, would likely produce half the production or 2,500 gpm (5.6 cfs) each. Under this scenario, approximately 250 collector wells would be needed to supply the indicated demand of 1,374 cubic feet per second.

SUMMARY OF HYDRAULIC CONDUCTIVITIES AND ESTIMATE COLLECTOR WELL PRODUCTION RATES

DATA SOURCE OF AQUIFER CHARACTERISTICS	AQUIFER OR WELL CHARACTERISTICS	ESTIMATED PRODUCTION FROM A COLLECTOR WELL	ESTIMATED NUMBER OF WELLS TO PRODUCE 1374 CFS
Henry Hunt calculations using industry averages for collector well yields.	Well specific capacity of 200 gpm/foot of screen	22.3 cfs	62
Estimates resulting from Layne, Inc. aquifer test near Cartwright, North Dakota	535 feet/day	16.7 cfs	82
Literature values and pump test results from water supply wells near Sidney	80-125 feet/day	5.6 cfs (average when correlated to Moore, et al. example)	250

It is our professional opinion this alluvial aquifer is primarily suitable for low-density, low to moderate-yield irrigation or water supply wells with a few areas suitable for high-yield production wells. The largest yield wells would most likely be possible in the Sidney area where aquifer thicknesses are greatest. Based on the range of hydraulic conductivities that were identified by this desktop evaluation, it appears that between 62 and 250 collector wells would be necessary to meet the canal flow volume. Site specific testing would be necessary to identify how many specific locations can be found where suitable aquifer conditions exist adjacent to the river to allow construction of the higher capacity collector wells, such as observed near Cartwright, North Dakota. The literature and water supply well values may be more indicative of the average conditions throughout the study area.

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Date: January 15, 2016

To: Tiffany Vanosdall, USACE Omaha District

From : Joshua Phillips, Tetra Tech

Subject: Ranney Well Preliminary Design Review

Design criteria for the project calls for the intakes to supply 1374 CFS to the canal when the Yellowstone River is flowing at 3000 CFS or greater. One intake alternative which was considered in previous studies is the use of Ranney wells. Ranney wells are a type of riverbank filtration intake which relies on river water infiltrating through the soils under the riverbed and collecting it in screened pipes located underground. The purpose of this technical memo is to summarize available information regarding the potential use of Ranney wells based on available information on aquifer characteristics.

PRIOR ANALYSES

The Ranney well intake alternative was discussed in an alternatives analysis from 2013, as shown in Attachment 1. The Ranney well alternative described in 2013 calls for the installation of Ranney wells at seven sites along the Yellowstone River with a total capacity of 1,374 CFS. The 2013 alternative analysis was based on the assumption that Ranney wells which would produce 200 CFS could be constructed at each site. Aquifer characteristics were not available and were not considered at that time to determine if production of 200 CFS from a single Ranney well was realistic.

ADDITIONAL ANALYSES PERFORMED

Tetra Tech performed an initial desktop review of existing well log data and published literature in December of 2015, as shown in Attachment 2. The purpose of this review was to estimate aquifer parameters for the potential use of Ranney wells based on existing information. The desktop review determined that the alluvial thickness through the project area is most likely to be 30 - 80 feet, with a saturated aquifer thickness of 20 - 50 feet. These alluvial materials are most likely composed of sands and gravels with some clay. An estimate of hydraulic conductivity was not made.

Henry Hunt with Layne Construction provided an opinion regarding the potential use of Ranney wells in this area based on the results of the 2015 desktop review, as shown in Attachment 3. Mr. Hunt indicated that in an alluvial layer with 40 - 50 feet of available drawdown, a typical Ranney well would produce 8,000 - 10,000 gpm (18 - 22 CFS) and that 60 - 80 Ranney wells would be required to produce 1,374 CFS. He noted that this is based on a specific capacity of 200 gpm per foot of drawdown depth which is typical, but that the specific capacity of previously constructed wells have varied.

In a subsequent phone conversation, Mr. Hunt provided a rough budgetary estimate that each well would cost approximately $4 million to construct, not including piping, site development, or any other non-downhole costs.

Tetra Tech performed a review of the Layne Construction capacity estimate and a more detailed desktop review of existing aquifer parameters in January of 2016. The purpose of this review was to determine whether other existing information might be available which would more accurately define the typical values used by Layne Construction in their estimate. During this second review, four high production alluvial wells were located within 2 - 4 miles of the project area. Based on this additional information, the hydraulic conductivity was estimated to be in the range of 80 to 125 feet / day.

It is expected that this estimated hydraulic conductivity rate will reduce the specific capacity of the Ranney wells below the 200 gpm / foot rate which was assumed in Mr. Hunt's estimate, and increase the number of Ranney wells that are required. However an updated quantitative analysis to has not been completed at this time.

Note that the aquifer thickness, saturated aquifer depth, and hydraulic conductivity estimates stated above are based on existing well log data in the vicinity of the project. Site specific tests of each proposed well location would be required to verify site specific conditions and hydraulic conductivity rates.

ATTACHMENTS

Attachments:

1. US Bureau of Reclamation, 2013. "Alternatives Analysis, Alternative Theme A".
2. Tetra Tech, December 2015. "Draft Desktop Hydrogeologic Review".
3. Henry Hunt, Layne Construction, January 5, 2016. Email to Josh Phillips, Tetra Tech.
4. Josh Phillips, Tetra Tech, January 8, 2016. Telephone record with Henry Hunt, Layne Construction.

Attachments were included with original and are not repeated here.

TETRA TECH

MEMO

To:	Mr. Scott Estergard – Senior Project Manager/Water Resource Planner – Tetra Tech DIV
Cc:	Joshua Phillips
From:	Kirk Miller and Jim Maus – Tetra Tech MMI - Helena MT
Date:	December 18, 2015
Subject:	DRAFT Yellowstone River Diversion Desktop Hydrogeologic Review (Project# 100-SET-T35234)

INTRODUCTION

Tetra Tech MMI – Helena performed a desktop review of hydrogeologic conditions along the Yellowstone River from the Yellowstone River Diversion Intake (Approximately 15 miles downstream of Glendive MT) to a predetermined location approximately 7.5 miles downstream of Sidney, MT. The objective of the review is to evaluate whether hydrogeologic conditions are suitable to support large scale production of water from Ranney Wells® at multiple locations within this reach of the Yellowstone River valley. The nature of the proposed project and details on Ranney Wells® were obtained by reviewing Alternative Theme A: Open Channel with Multiple Ranney Wells®. The purpose of this memorandum is to summarize methods, information sources and findings of this brief desktop review.

METHODS

Two approaches were taken to obtain data and information relative to hydrogeologic conditions in close proximity to the Yellowstone River within the study area. A well records search was conducted and a literature search was conducted. The methods and results are discussed below.

WELL RECORD SEARCH

The initial step involved viewing the predetermined seven sites using satellite imagery available through Google Earth software. Imagery dates viewed were August 18, 2013, September 11, 2013, and September 24, 2014. The objective of viewing imagery was to identify any significant geologic structural controls to the river valley system that may have resulted in different depositional environments. Due to relatively similar conditions throughout the study reach, two sites (Site #2 and Site #5) were chosen at random for further evaluation. The Township, Range, and Section (TRS) for these locations were identified using Montana's Cadastral mapping program. A search for well logs within Montana's Ground Water Information Center (GWIC) online database using the TRS was conducted on December 14 and December 16, 2015. Due to relatively minimal well logs being available, the search was expanded to surrounding sections as needed. A summary of database entries for the selected sections is attached. Selected well logs believed to be representative of both the alluvial and deeper bedrock system were then retrieved. These well logs are also attached.

Review of well logs in the vicinity of Site #2 and Site #5 suggested a relatively shallow low yielding aquifer system. Due to concern that these may be localized characteristics, three additional sites were chosen (Site #1, Site #4, and Site #6). Review of available well logs suggests relatively thin alluvial material overlies a low production bedrock formation. Wells within this bedrock system are generally completed at depths greater than 500 feet. As mentioned, well logs selected as representative of proposed locations are attached. The following table summarizes key findings by site.

	Site #1	Site #2	Site #4	Site #5	Site #6
Township, Range, Section	18N,57E,25	19N,57E,35	20N,58E,33	21N58E34	22N,59E,19
Approximate Alluvial Thickness	No Data Available	30 feet	80 feet	55 feet	60 feet
Alluvial Composition		Sands & mixed gravel	Sand & gravel w/ clay layers	Mixed fine sand to coarse gravel	Sand some gravel
Static Water Level		7-10 feet BGS	25-30 feet BGS	15-20 feet BGS	15 feet BGS
Saturated Thickness		20 feet	50 feet	35 feet	45 feet
% Drawdown During Pumping		50 %	No data	40 %	67 %
Pumping Rate		10-20 gpm	25 gpm	15 gpm	10 gpm

LITERATURE SEARCH

Readily available published literature from the Montana Bureau of Mines and Geology (MBMG) and the US Geological Survey (USGS) were perused to identify information on the thickness of unconsolidated sediments in the Yellowstone River valley and their hydrologic properties.

A number of studies have been conducted by the MBMG and the USGS relative to water resources in the lower Yellowstone River basin. These studies have typically focused on bedrock aquifers since they are more prevalent across the basin and typically more productive for large scale agricultural or industrial uses, however, they also address unconsolidated deposits. The unconsolidated deposits include both flood plain level deposits (hereinafter called alluvial deposits), the multiple terraces that stair step up from the river, and deposits in small tributary streams and glacial tills that exist on some of the upland areas.

A key question is whether there exists adequate thickness of coarse alluvial materials beneath the active river channel that can be utilized for development of a Ranney Well®, which is designed to have lateral perforated pipes that actually extend beneath the river bed. In most locations within the lower Yellowstone study area, beneath the alluvial materials is assumed to be the Fort Union Formation. The Tertiary Fort Union Formation, which is a mixture of fine-grained sandstone, silt stone, mudstone and shales. The Fort Union typically has relative low permeabilities relative to the alluvial materials, would preclude their adequately supplying 200 cfs to a Ranney Well®.

Smith (1998) evaluated the thickness of unconsolidated sediments in the lower Yellowstone River watershed and his results are shown on Attachment 1. It appears that there are significant areas where there are 20 ft or less of unconsolidated sediments along the Yellowstone River floodplain (shown in yellow on map). Assuming that the river is incised below the floodplain by at least 10 feet and likely up to 20 ft in some locations, the materials within the <20 feet unit are not saturated. Hence, area areas on Attachment 1 that are in yellow appear to be unsuitable for large volume water production from a Ranney Well.

The next map unit displays areas where there are 20 to 50 ft of unconsolidated sediments (light green on map). Using the same parameters as stated above, the 20 to 50 ft map unit areas may have 10 to 30 ft of unconsolidated sediments between the base of the river channel and bedrock. Where these materials are thickest, this area provides a reasonable thickness of saturated alluvial material to be developed by a Ranney Well®. However, the thinner portions of this map unit would likely have limited materials below the river channel. A significant portion of the materials in the active river channel are likely disturbed during flood events, which would seem to preclude construction of Ranney Well® laterals beneath the river where there is 10 ft or less of alluvial material . We did not evaluate typical bed movement depths beneath the river. Perhaps this value could be refined if it has been evaluated by others for the Yellowstone River within the study area. This could change the area within the 20 to 50 unit that is suitable for Ranney Wells®.

The next two map units display areas where there are 50 to 100 ft or more of unconsolidated sediments (blue green shades on map). Using the same conditions as stated above, these areas may have 30 to 80 ft or more of unconsolidated sediments between the base of the river channel and bedrock. These areas would seem to have 30 ft or more of saturated alluvium between the base of the river channel and bedrock, which should be adequate for construction and operation of Ranney Well® laterals beneath the river. It is important to note that along the boundaries of the Yellowstone valley floor there are colluvial deposits that extend out over the alluvial deposits, which were included in Smith's measurements. This could misrepresent the actual thicknesses of saturated alluvium available. In addition, these thickness only exist in limited narrow zones and in the upper stretches of the study area these conditions do not exist adjacent to the river, where the Ranney Wells® would be constructed, hence, the large source of recharge offered by the river would not be available. These thick alluvial sediments are in proximity to the river near Sidney and to the northeast, however, their downriver extent is not known because this is the eastern edge of Smith's map.

Smith, et al (2000) evaluated three primary sources of groundwater in the Lower Yellowstone area; a Shallow Hydrologic Unit (SHU) which includes aquifers within 200 ft of the land surface (the shallowest portion of which is of primary interest to this analysis) and two deeper bedrock units, located 200 ft or more below the land surface.

Smith, et al.'s findings relative to development of large Ranney Wells® in close proximity to the Yellowstone River are summarized below:

- Average well yields within the SHU are 35 gallons per minute, which although these are typically smaller diameter wells for residential or small agricultural use, they still indicate limited potential for large groundwater production from the alluvial aquifer.
- Groundwater use in the Lower Yellowstone area is only 1.7% of the total water used in the basin. Surface water constitutes the overwhelming majority of water resources in the area, which has likely occurred because limited groundwater resources are available.
- Long-term water level trends in most SHU groundwater wells follow climatic trends more than short term precipitation events, indicating that shallow unconsolidated materials are of relatively low permeability, which slows percolation from the surface. This supports the observation of low productivity from SHU wells.
- The median specific capacity of wells in the SHU is approximately 2.5 gpm/foot. This is a relatively low number relative to the large quantities of groundwater production required to supply a Ranney Well®.
- Aquifer testing conducted in shallow unconsolidated materials near the Yellowstone River were limited to slug tests. The two tests reported Hydraulic Conductivity (K) values of 2.23 and 75.60 ft/day. These

values are of limited value since they are derived from slug tests, however, they do give a rough range of possible K values in the alluvial materials adjacent to the river.

DISCUSSION

Review of available well logs suggest the presence of a low to moderate transmissivity alluvial aquifer in proximity to the river. Relatively low pumping rates of 10-20 gpm for less than eight continuous hours result in consumption of approximately 50% of available drawdown. It is our professional opinion this alluvial aquifer is suitable only for low density low yield domestic use and is not suitable for high yield production wells. Hence, it is necessary for the Ranney Well® to be located in close proximity to the river and its abundant potential for recharge.

We subsequently focused our analysis on finding 20 ft or greater thicknesses of saturated gravels and coarse sands in close proximity to the river (either laterally adjacent or vertically beneath the river channel). This is based on the assumption that a Ranney Well® producing 200 cubic feet per second or more needs to have laterals either very near to or beneath the river channel. We also focused on locations in close proximity to the river, since the well records search indicated that the only significant groundwater resources available at distances away from the river are from deep bedrock aquifers.

There are alluvial materials in close proximity to the river at depths of 20 feet or more below the base of the river channel, at select locations within the study area. These conditions are in no way ubiquitous along the river and they appear to be more prevalent in the lower stretches of the study area near Sidney. Adequate thicknesses of saturated alluvial materials are possibly scarce in the upper portion of the study area. To evaluate the likelihood that there are multiple locations which could supply the desired quantity of water for the entire project would require site specific analysis.

SOURCES

Montana Cadastral Mapping Program December 14 and 16, 2015 - http://svc.mt.gov/msl/mtcadastral/

Montana Groundwater Information Center December 14 and 16, 2015 - http://mbmggwic.mtech.edu/

Smith, Larry N., 1998. Thickness of Unconsolidated Deposits, Lower Yellowstone River Area; Dawson, Fallon, Prairie, Richland and Wibaux Counties, Montana. Montana Ground-Water Assessment Atlas No. 1, Part B, Map 2, December 17, 1998

Smith, L.N., LaFave, J. I., Patton, T. W., Rose, J.C. and McKenna, D.P., 2000. Ground-water Resources of the Lower Yellowstone Dawson, Fallon, Prairie, Richland and Wibaux Counties, Montana. Part A-Descriptive Overview and Basic Data. Montana Bureau of Mines and Geology, Montana Ground-Water Assessment Atlas No. 1.

Enclosures:

Well logs

Smith, 1998 Map 1

From: Henry Hunt
To: Phillips, Joshua
Cc: Estergard, Scott
Subject: RE: Lower Yellowstone Ranney Well alternative
Date: Tuesday, January 05, 2016 9:35:15 AM
Attachments: Collector Schematic.pdf
Plan & Section - RBF - horiz.pdf
SurfaceWaterIntakes.pdf

Joshua, sorry for the delayed response, I have been away from the office and traveling yesterday.

The information you sent was helpful, but has some limitations, as you might expect as most (if not all) of the well log information is related to private residential wells or smaller agricultural wells. Limitations include: smaller diameter wells; likely not developed very thoroughly; likely limited screen lengths; typically smaller wells like this would be drilled deep enough to get the water needed for a house and may not fully explore the available depth; the flow rates or “well yields” may reflect what flow was needed rather than what flow might be possible from the well; etc.

All that being said the general alluvial aquifer shows good sand and gravel deposits. The actual thickness of the alluvial deposits and available saturated thickness is not known at all the sites as most of the borings did not reach bedrock or an underlying confining layer that would define the available aquifer conditions.

For the indicated demand (1374 cfs), that is a lot of water. Collector wells typically have shown specific capacities ranging from about 100 gpm per foot of drawdown to about 2000. We have shallow collector wells that can produce in excess of 15 mgd from an aquifer less than 50 feet deep that have good hydraulic conductivity, but have collector wells 70-100 feet deep than only produce 3-4-5 mgd each, so there is a great deal of variation in yields that is related to hydraulic conductivity, recharge and available drawdown.

If you take a typical scenario and assume you have 50 feet of available drawdown and can generate a specific capacity of 200 gpm per foot of drawdown, you might expect a collector well to produce 10,000 gpm or about 15 mgd each. You might need 60 collector wells to get your target demand of 1374 cfs. if the available drawdown was less, maybe 40 feet, this would equate to a yield of about 8,000 gpm (11.5 mgd) per collector well, requiring maybe 77 collector wells.

These wells could be installed along the river, at appropriate spacings, to possibly lessen the impacts at a given spot. Of course, extracting the water as naturally filtered water recharged from the river, this would lessen the impacts on local aquatic life as fish and other aquatic organisms would have no direct contact with the well screens. The water quality should be very consistent and should be free of turbidity as the sediment in the river would typically be filtered naturally during the slow infiltration process as recharge to the aquifer. I don’t know if they have to provide any treatment to the surface water they use presently to manage the suspended solids (e.g. turbidity), but that may factor into the cost evaluation if they will have to treat the river water prior to use, or if they have operational costs to maintain the pumps and piping of river water.

As I mentioned previously, we also build a passive intake structure that uses fish-friendly intake screens to bring in river water if they are interested in taking river water from new intake sites. These intakes are constructed using trenchless methods to minimize environmental impacts, which can simplify permitting.

I hope this gives you a starting place. Please let us know if you have any further questions in this regard. I attached a couple of typical schematics for your reference.

Thank you for your interest in collector wells.

Henry

Henry C. Hunt
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From: Phillips, Joshua [mailto:Joshua.Phillips@tetratech.com]
Sent: Tuesday, December 22, 2015 1:27 PM
To: Henry Hunt
Cc: Estergard, Scott
Subject: Lower Yellowstone Ranney Well alternative

Henry,

I'm writing to send you some information related to the lower Yellowstone intake project that we spoke about previously. We are working for USACE and attempting to determine whether Ranney wells could be used to replace the existing surface water intake, which is located at Intake Dam. The conceptual plan would be to construct Ranney wells at 7 locations along the river (as shown on the attached vicinity map) with a total capacity of 1374 CFS.

I've attached the information that I have about the existing soils and hydrogeology at the sites. These documents are confidential and not for distribution.

Please let me know if you have any questions.

Thank you,

Joshua Phillips | Civil Engineer

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From: Henry Hunt
To: Phillips, Joshua
Cc: Miller, Kirk
Subject: RE: Test data from the site near Sydney
Date: Wednesday, January 20, 2016 11:36:05 AM
Attachments: Hantush-example.pdf
H & P 1962.pdf

Joshua, thanks for your and Kirk's time also.

Looking at a collector well, I think the estimates we provided previously are in the right range, maybe $ 3-4 million for the well and maybe $ 1 million or so for the pumps, controls, piping, etc.

Typically, we might expect to have to perform maintenance on each well within 10-20 years of installation, but the actual time will depend on water quality and pumping schedule during that time. We also recommend inspecting the well (using a diver for photographs, video, flow measurements, etc.) every 5-10 years during the well life. The inspection forms the basis for monitoring the well performance and predicting maintenance needs and scheduling.

I'm not sure we can release the document yet, but the information below was developed using the aquifer properties shown. We developed those by conducting a 72 hour constant rate test with a pumping rate of 880 gpm with six monitoring wells and a staff gauge.

Collector Well Option - Low River Stage

Location	Assumed Ground Elevation (feet)	Assumed Aquifer Bottom Elevation (feet)	Assumed Static Water Elevation (feet)	Saturated Aquifer Thickness (feet)	Average Aquifer Hydraulic Conductivity (gpd/ft^2)	Average Transmissivity (gpd/ft)	Assumed Effective Distance to Recharge (feet)	Assumed Elevation of Laterals (feet)	Estimated Collector Well Yield (MGD)	Percentage of Pumping from Surface Water(1)
Cartwright, ND	1890	1811	1867	56	4000	224,000	700	1821	10.9	71(2)

Assumptions:

Caisson Radius	6.5	feet
Lateral Radius	0.5	feet
Number of Laterals	8	
Average Lateral Length	175	feet
Caisson Distance from Edge of Terrace	100	feet

(1) Percentage assumes ambient daily discharge to river is 183,000 gallons per 100 feet of shore - calculated using aquifer transmissivity of 224,000 gpd/ft2 and gradient of 0.0071 (measured during non-pumping field activities).
(2) Precentage assumes a 10.9 mgd collector well will capture water from 2000 feet of river length.

I have also attached an excerpt from another report and an excerpt from the publication that discusses the equations used to calculate collector well yields. I hope this all is helpful.

Please let us know if you have any further questions at this time.

Thanks for your interest in collector wells.

Henry

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Henry.Hunt@Layne.com | **Layne.com**

From: Phillips, Joshua [mailto:Joshua.Phillips@tetratech.com]
Sent: Tuesday, January 19, 2016 5:48 PM
To: Henry Hunt
Subject: Test data from the site near Sydney

Henry,

It was good talking with you today.

Do you think you can send that test data from the site near Sydney in the next couple of days? I ask because we need it to finalize our opinion about Ranney wells for USACE, so the sooner we can get it the better.

Thank you again for your help!

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Attachment 3
Feeder Canal Design

Feeder Canal Feasibility Analysis

Date: May 17, 2016

The feasibility of pump site feeder canals and feasibility level dimensioning was performed utilizing assumed Yellowstone River water depths for the low flow design period. The low flow design period assumes a constant 3,000 cubic feet per second (cfs) occurring at the upstream most pump site (Pump Site 1), and accounts for incremental withdrawals at each subsequent downstream pump site. Each pump supplies the irrigation canal with an inflow of 275 cfs and requires an additional 16 cfs for fish return flows to the river. Therefore the required feeder canal flow is 291 cfs. With the exception of pump site 1, where the estimated water depths during the low flow period are 13.4 feet, the assumed water depths at the junction between the Yellowstone River and each feeder canal were estimated as the difference between the United States Army Corps of Engineers provided HEC-RAS model calculated water surface elevations and the thalweg elevation at the nearest cross section to the junction. At pump site 1, the initial assumed water depth was determined from the normal depth calculator to provide the required feeder canal flow. The upstream invert elevation for each feeder canal is assumed to be the same as this corresponding thalweg elevation.

Feasibility level canal dimensions were determined for the required capacity of 291 cfs by normal depth calculations using canal design guidance documents prepared by Reclamation and the Channel Analysis calculator available in the Federal Highway Administration Hydraulic Toolbox. Each canal is assumed to be approximately 1,000 feet long and have an along canal downward slope towards the pump of 1 foot vertical change per 1,000 feet horizontal change (0.001 feet/feet). The canals were assumed to have a Manning's roughness coefficient value of 0.025 based on the values used in the provided HEC-RAS model and are typical of excavated artificial channels. Canal sideslopes were set at 2 feet horizontal to 1 foot vertical (2:1). The canal bottom widths were then varied to achieve the desired capacity of 291 cfs at each canal junction. The initial results for these normal depth calculations are provided in Table 1.

A feasibility level typical feeder canal cross section was developed by generalizing the initial canal dimensions, and also included a canal flow depth of 2.5 feet.

A summary of the typical feeder canal cross section dimensions and available flow are provided in Table 2.

Table 1. Initial feeder canal dimensions determined to flow to pump sites.

Site	Yellowstone River Water Surface Elevation (Feet NAVD88)	Feeder Canal Upstream Invert Elevation (Feet NAVD88)	Depth[1] (Feet)	Bottom Width (Feet)	Available Flow[2] (CFS)
Pump Site 1	1985.1	1981.9	3.2	20	291
Pump Site 2	1957.7	1955.6	2.1	44	291
Pump Site 3	1949.6	1946.3	3.3	19	291
Pump Site 4	1935.7	1933.2	2.5	32	291
Pump Site 5	1933.6	1931.9	1.7	60	291

Notes

1. Depth based on difference between assumed Yellowstone River water surface elevation at each pump location during the low flow design period and the thalweg elevation obtained from the Corps provided HEC-RAS cross sections. Design low flows at each pump location assume 3,000 CFS available at Pump Site 1 and incremental pump withdrawals of 275 CFS.

2. Pump sites are assumed to require a minimum of 291 CFS, including 16 CFS for pump fish bypass flows and 275 CFS delivered to the irrigation canal.

Table 2. Summary of generalized typical feeder canal dimensions and estimated available flows for the low flow (3,000 CFS) design period.

Parameter	Value
Feeder Canal Depth (Feet)	2.5
Side Slopes (Horizontal : Vertical)	2:1
Bottom Width (Feet)	32
Freeboard (Feet)	1.5
Berm Top Width (Feet)	12
Available Flow (CFS)	291

Attachment 4
Fish Screen Design Calculations

TETRA TECH

Job No.: 100-SET-T35234

Project: Lower Yellowstone River
Subject: Multiple Pump Station Alternative
Design Topic: Fish Screen Conceptual Design
Made By: JPP **Date:** 1-Mar-16 **Chk'd By:** Darrel Nice **Date:** 3-Mar-16

1.0 ISSUE BEING ADDRESSED

Calculate the approach and sweeping velocities for the fish screen.

2.0 APPROACH

The required screen area is calculated based on the maximum approach velocity. The sweeping velocity is then calculated using the velocity component which is parallel to the face of the fish screens. The ratio of sweeping velocity to approach velocity is calculated to verify that the sweeping velocity is greater than the approach velocity.

3.0 REFERENCES

References used in this calculation are as follows:

1) USDA Fish Screening Design Guide, Technical Supplement 14N, August 2007.
2) Anadromous Salmonid Passage Facility Design. NMFS. 2011

4.0 ASSUMPTIONS

1) 10% of fish screen area is blocked by screen supports.
2) The maximum allowable approach velocity is 0.4 feet / second, similar to NMFS criteria for salmonids.

5.0 CALCULATIONS

1) Calculate the minimum screen area.

			Reference / Formula
Design irrigation flow rate (Q)	275	cfs	*[Design Q into the irrigation canal per site]*
Maximum Approach Velocity	0.4	feet / second	*[Assumed per Ref 1 (see assumptions above)]*
Minimum Screen Area (total)	688	square feet	*[Q / Approach Velocity]*
	344	square feet (per side)	
Blocked Screen Area	10%		*[Assumed to be 10% of gross screen area]*
Minimum Gross Screen Area	756	square feet	*[Minimum Screen Area * (1+Blocked Screen Area)]*

2) Calculate the fish screen angle to the water.

			Reference / Formula
Width at inlet (Win)	21	feet	
Width at outlet (Wout)	1.5	feet	
Net Width of Screen, 1 side	9.75	feet	*[(Win - Wout) / 2]*
Screen Length (with blocking)	116	feet	
Screen Length (screens only)	96	feet	
Screen Angle to Flow (α)	4.8	degrees	*[ASin(Net Width / Length)]*

TETRA TECH

Job No.: 100-SET-T35234

Project: Lower Yellowstone River
Subject: Multiple Pump Station Alternative
Design Topic: Fish Screen Conceptual Design
Made By: JPP **Date:** 1-Mar-16 **Chk'd By:** Darrel Nice **Date:** 3-Mar-16

3) Calculate the sweeping velocity and approach velocity at the entrance, middle, and exit of the screen at the design depth.

	Entrance	Middle	Exit	Reference / Formula
Flow Rate	291	154	16	*[Flow rate between the screens]*
Design Depth	5	5	5	
Width	21	11	1.5	*[Width between screens]*
Flow Area	105	56.25	7.5	*[Width * Depth]*
Flow Velocity (V)	2.8	2.7	2.1	*[Flow / Area]*
Sweeping Vel. (Vs)	2.8	2.7	2.1	*[V * Cos(α)]*
Screen Height	4	4	4	
Approach Vel. (Va)	0.4	0.4	0.4	*[Irrigation Flow Rate / Screen Area]*
Vs / Va	6.9	6.8	5.3	*[Vs / Va > 1]*
Travel Time			38	*[Screen Length / Flow Velocity]*

4) Calculate head loss across the fish screens.

			Reference / Formula
Irrigation Water Flow Rate (Q)	275	cfs	
Gross Screen Area (Agross)	768	square feet, both sides	
Blocked Screen Area	10%		
Net Screen Area	691	square feet, both sides	*[Gross Area - Blocked Screen Area]*
Screen Size Ratio	50%		*[Opening Area / Screen Area]*
Screen Opening Area (Ascreen)	346	square feet	*[Net Area * Screen Size Ratio, both sides]*
C factor for fish screen	0.6		*[per Ref 1]*
Head Loss	0.03	feet	*[1/(2*g) * (Q/(C*Ascreen))^2, per Ref 1]*

Actual head loss will be greater due to baffles required to equalize flow velocity across the screens. Assume 0.5' for pump sizing calculations.

5) Calculate the sweeping velocity and approach velocity at the entrance, middle, and exit of the screen at the largest 5% exceedance depth occurring at any of the 5 sites.

	Entrance	Middle	Exit	Reference / Formula
Flow Rate	291	154	16	*[Flow rate between the screens]*
Depth	18.7	18.7	18.7	
Width	21	11	1.5	*[Width between screens]*
Flow Area	392.7	210.375	28.05	*[Width * Depth]*
Flow Velocity (V)	0.7	0.7	0.6	*[Flow / Area]*
Sweeping Vel. (Vs)	0.7	0.7	0.6	*[V * Cos(α)]*
Screen Height	4	4	4	
Approach Vel. (Va)	0.4	0.4	0.4	*[Irrigation Flow Rate / Screen Area]*
Vs / Va	1.8	1.8	1.4	*[Vs / Va > 1]*
Travel Time			141.1	*[Screen Length / Flow Velocity]*

The 5% exceedance depth and the fish screen design will vary at each site. Additional fish exits or upstream control gates may be required, to be determined during site specific design at each site.

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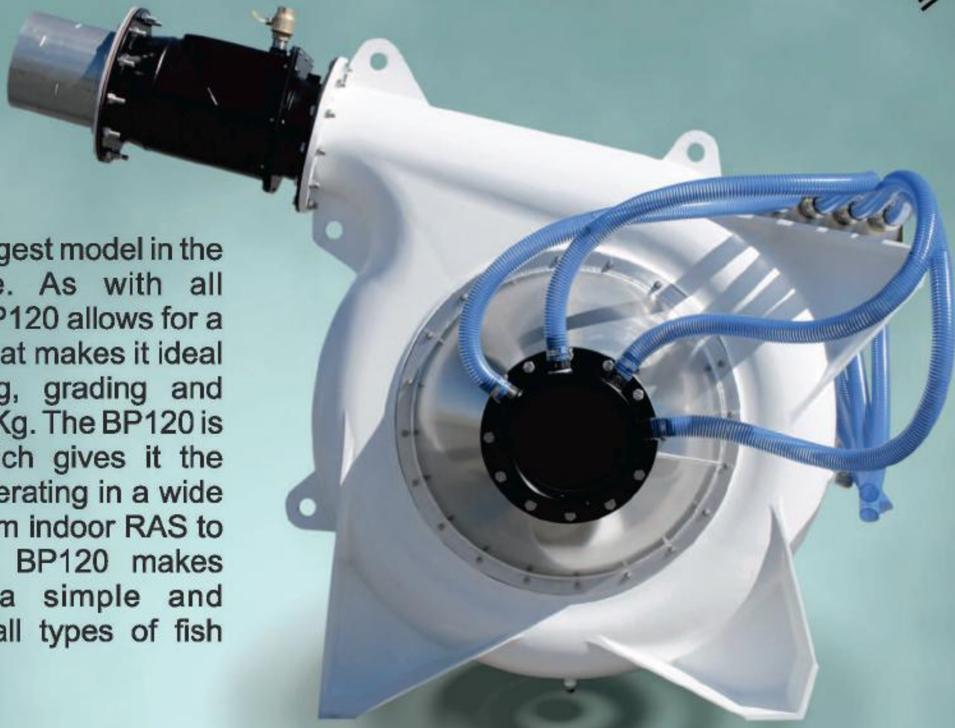

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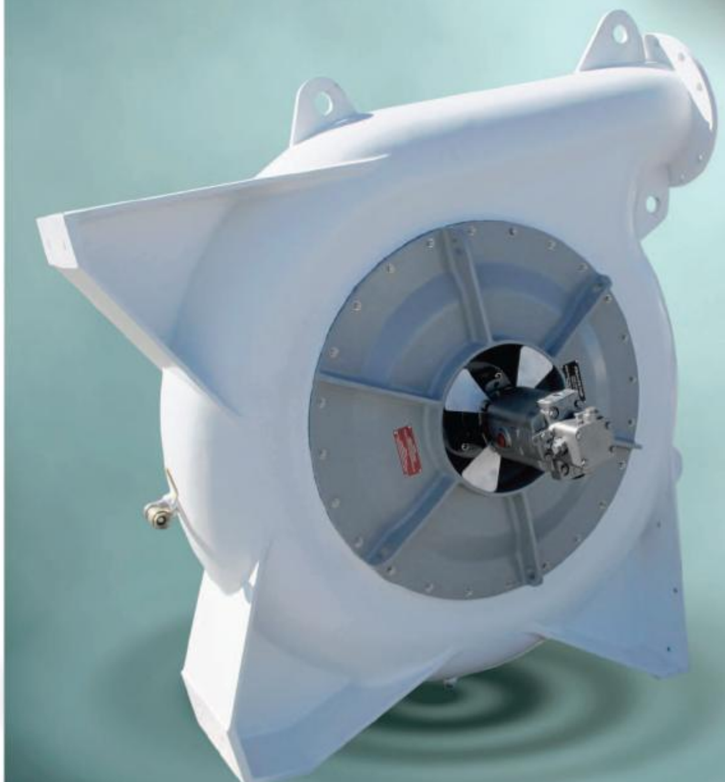

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Applications

Top: BP120 being used to transfer and count large 3Kg-4Kg Trout, at a cage pen operation in Scotland.The BP120 and AquaScan CSF counter are pkg. together on a specially designed skid to facilitate loading and unloading of the system from boats and barges.

Intel/ Outlet Size	*Main Pump Drive*	*Fish Pumping cap.*	*Pump Output Max.*	*Maximum Head*	*Maximum Distance*	*Maximum Fish Size*
12 in (305mm)	75 HP	150 t/h	800-4800 gpm	8 m	1500m	6 kg

Bottom: BP120 shown transferring Atlanta Salmon to grader at a RAS facility in British Columbia. All transfer lines, suction devises, and misc. items used in the fish handling system were designed and built by Aqua-Life.

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Attachment 5

Pumping Station and Pipeline Design

TETRA TECH

Job No.: 100-SET-T35234

Project: Lower Yellowstone River
Subject: Multiple Pump Station Alternative
Design Topic: Pump Station Hydraulics
Made By: JPP **Date:** 9-Feb-16 **Chk'd By:** EF **Date:** 2/11/16

1.0 ISSUE BEING ADDRESSED

Calculate the required flow rate and static head at each of the pump stations.

2.0 APPROACH

Pump stations are proposed at Sites 1 - 5, designed for a total flow rate of 1374 cfs. Static head is calculated using the WSEL in the Yellowstone River taken from the Yellowstone River Corridor Study HEC-RAS model and the existing irrigation canal, as shown on existing drawings.

3.0 REFERENCES

References used in this calculation are as follows:

1) Yellowstone River Corridor Study HEC-RAS model (USACE 2010)
2) Lower Yellowstone Project, Canal System and Operating Maps (US Dept. of Interior, 1923)
3) AWWA, M-11 Manual, "Steel Water Pipe-A Guide for Design and Installation"

4.0 ASSUMPTIONS

1) Total design flow rate for all pump stations is 1374 cfs, delivered to the irrigation canal.
2) The existing headworks cannot always be used at the same time that the pumped intakes are in use.
3) The Yellowstone River flow rate upstream of the first diversion is 3000 cfs and decreases linearly by the quantity of each diversion.
4) WSEL in the existing irrigation canal was derived from a 1-D HEC-RAS hydraulic model of the irrigation canal calibrated using surveyed high water marks.
5) All elevations are shown in NAVD88 format.

5.0 CALCULATIONS

1) Calculate the design flow rate at each pump station site

Site	**Design Flow Rate (cfs)**
Site 1	275
Site 2	275
Site 3	275
Site 4	275
Site 5	275
Total	1374

TETRA TECH **Job No.:** 100-SET-T35234

Project: Lower Yellowstone River
Subject: Multiple Pump Station Alternative
Design Topic: Pump Station Hydraulics
Made By: JPP **Date:** 9-Feb-16 **Chk'd By:** EF **Date:** 2/11/16

2) Calculate the static head at each site, based on WSEL in the Yellowstone River and in the canal [Ref 1 and 2]

Site	River Flow (cfs)	River WSEL (feet)	Canal WSEL (feet)	Static Head (feet)
Site 1	3000	1985.1	1983.9	-1.1
Site 2	2725	1957.7	1982.9	25.2
Site 3	2450	1949.6	1982.1	32.5
Site 4	2176	1935.7	1981.4	45.7
Site 5	1901	1933.6	1981.4	47.8
Remainder:	1626			

3) Calculate the head losses upstream of the wet well

Site	Canal Length (feet)	Canal HL (feet)	Trashrack HL (feet)	Fish Screen (feet)	Total Upstream HL (feet)
Site 1	300	0.3	0.5	0.5	1.3
Site 2	1000	1.0	0.5	0.5	2.0
Site 3	1100	1.1	0.5	0.5	2.1
Site 4	500	0.5	0.5	0.5	1.5
Site 5	900	0.9	0.5	0.5	1.9

4) Calculate the head losses in the discharge pipe system from the pump to the irrigation canal

Head losses calculated using the Darcy-Weisbach formula.

Site	Pipe Len. (feet)	Pipe Dia.[a] (feet)	Pipe Vel. (ft/sec)	Minor HL 'k' value	Major HL[b] (feet)	Minor HL[b] (feet)	Total HL (feet)
Site 1	300	6	9.7	6.8	0.8	5.6	6.4
Site 2	1000	7	7.1	6.8	1.2	5.6	6.9
Site 3	5600	7	7.1	6.8	7.0	5.6	12.6
Site 4	4100	7	7.1	6.8	5.1	5.6	10.7
Site 5	1800	7	7.1	6.8	2.2	5.6	7.8

a) Discharge Pipe Diameters chosen to produce flow velocities in the discharge pipes less than 10 FPS and to avoid excessive head losses for longer pipe runs.
b) Head losses calculated using the Darcy-Weisbach formula.

TETRA TECH **Job No.:** 100-SET-T35234

Project: Lower Yellowstone River
Subject: Multiple Pump Station Alternative
Design Topic: Pump Station Hydraulics
Made By: JPP **Date:** 9-Feb-16 **Chk'd By:** EF **Date:** 2/11/16

Typical fittings for 'k' value shown:

Feature	Qty	Unit k-value[Ref 3]	k-value
Entrance Losses	1	1	1
45° Bend	1	0.3	0.3
90° Bend	1	1.2	1.2
Wye	2	1.3	2.6
Check Valve	1	1.5	1.5
Gate Valve	1	0.2	0.2
Total K:			**6.8**

5) Calculate the total dynamic head required at each pump station

Site	Stat. Head (feet)	Upstream HL (feet)	Pipeline HL (feet)	Total HL (feet)	TDH (feet)
Site 1	-1.1	1.3	6.4	7.7	7
Site 2	25.2	2.0	6.9	8.9	34
Site 3	32.5	2.1	12.6	14.7	47
Site 4	45.7	1.5	10.7	12.2	58
Site 5	47.8	1.9	7.8	9.7	58

INPUT	OUTPUT

TETRA TECH

Job No.: 100-SET-T35234

Project: Lower Yellowstone River
Subject: Multiple Pump Station Alternative
Design Topic: Sizing Pumps
Made By: FMB **Date:** 16-Feb-16 **Chk'd By:** JPP **Date:** 2-Mar-16

1.0 ISSUE BEING ADDRESSED

Given the flow rate required, river elevations, canal elevations and maximum flow speeds, the pumps need to be sized.

2.0 APPROACH

The pump will be sized using the information from Reference 2 and calculating the net positive suction head available per site as per EM 1110-2-3105 Appendix B.

3.0 REFERENCES

References used in this calculation are as follows:

1) Existing Techinical Info - 2010 Intake Final EA Appendixes
2) Pump Station Hydraulics Calculation by Tetra Tech
3) USACE EM 1110-2-3105 Appendix B
4) Patterson Pump Data Sheets

4.0 ASSUMPTIONS

Assumptions used in this calculation are as follows:

1) Elevations, Pipe Lengths, Head [Ref 2]

	Operating Pipe Length	River WS Elevation	Canal WS Elevation	Total Dynamic Head	No of Pumps	Discharge Pipe Dia.
Station 1	300 ft	EL. 1985.1	EL. 1983.9	7 ft	3	6 ft
Station 2	1000 ft	EL. 1957.7	EL. 1982.9	34 ft	3	7 ft
Station 3	5600 ft	EL. 1949.6	EL. 1982.1	47 ft	3	7 ft
Station 4	4100 ft	EL. 1935.7	EL. 1981.4	58 ft	3	7 ft
Station 5	1800 ft	EL. 1933.6	EL. 1981.4	58 ft	3	7 ft

INPUT	OUTPUT

TETRA TECH

Job No.: 100-SET-T35234

Project: Lower Yellowstone River
Subject: Multiple Pump Station Alternative
Design Topic: Sizing Pumps
Made By: FMB **Date:** 16-Feb-16 **Chk'd By:** JPP **Date:** 2-Mar-16

5.0 CALCULATIONS

	NPSHr [Ref4]	Bowl Dia [Ref4]	Intake Losses [Ref2]
Station 1	12.5 ft	2.8 ft	1.5 ft
Station 2	12.5 ft	2.8 ft	2.0 ft
Station 3	31.0 ft	2.8 ft	2.1 ft
Station 4	32.6 ft	2.8 ft	1.5 ft
Station 5	31.0 ft	2.8 ft	1.9 ft

	River El	Pit Max Water El	Pit Min Water El	Bell El	Sump Floor El	Building Floor El	Sump Depth
Station 1	EL. 1985.1	EL. 1983.6	EL. 1980.6	EL. 1968.1	EL. 1966.7	EL. 1999.7	33.0 ft
Station 2	EL. 1957.7	EL. 1955.7	EL. 1952.7	EL. 1940.2	EL. 1938.9	EL. 1976.7	37.8 ft
Station 3	EL. 1949.6	EL. 1947.5	EL. 1944.5	EL. 1913.5	EL. 1912.1	EL. 1966.6	54.5 ft
Station 4	EL. 1935.7	EL. 1934.2	EL. 1931.2	EL. 1898.6	EL. 1897.3	EL. 1951.0	53.7 ft
Station 5	EL. 1933.6	EL. 1931.7	EL. 1928.7	EL. 1897.7	EL. 1896.4	EL. 1949.9	53.6 ft

Where,
[Pit Max Water El] = [River El] - [Intake Losses]
[Pit Min Water El] = [Pit Max Water El] - [3 ft]
[Bell El] = [Pit Min Water El] - [NPSHr]
[Sump Floor El] = [Bell El] - (0.5*[Bowl Dia])
[Building Floor El] = [100 year flood El] + [1 ft]
[Sump Depth] = [Building Floor El] - [Sump Floor El]

	Motor HP (each)	Motor KW (each)	Fish Pump KW	Total KW	Rounded for Design (KW)
Station 1	107	80	60	300	400
Station 2	408	304	60	973	1000
Station 3	564	421	60	1322	1400
Station 4	703	524	60	1632	1700
Station 5	703	524	60	1632	1700

Where,
[Motor HP] was calculated based on adjusting the vendor pump curves to actual head.
[Motor KW] = Motor HP * 0.7457
[Fish Pump KW] is from vendor information for an Aqualife Model BP120 pump
[Total KW] = [Motor KW] * 3 motors + [Fish Pump KW]
[Rounded for Design] = [Total KW] rounded up to the nearest 100 KW for conductor sizing.

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Yellowstone Pump House Foundation Walls - Design Loads

Wall Properties

	Driving	Resisting
Base of Wall Elev	0.00	
Soil Elev for Horiz Loads	57.00	
Groundwater EL	32.00	
Max Pumphouse Water Elev	32.00	

Material Properties
Soil Properties

γ_{sat}	125.00	pcf
γ_{moist}	120.00	pcf
γ_b	62.60	pcf
ϕ	0.56	rad
β	0.00	rad
ϕ	32.00	deg
β	0.00	deg

Water Properties

γ_{water}	62.40	pcf

Seismic
Loading Information

PGA (L1)	0.031	g	PER USGS
$k_{h, L1}$	0.021	g	

Soil Pressure Constants

	c1	c2	α active	Ka	Kab	α pass.	Kp	Kpb	Ko
Level 1	1.19	0.95	1.05	0.31	0.31	0.50	3.25	3.25	0.47
	(Eq. G-14) EM 1110-2-2100	(Eq. G-15)	(Eq. G-13)	(Eq. G-11)		(Eq. G-16)	(Eq. G-34)	(Eq. G-35)	(Eq. 3-4) EM 1110-2-2502

Load Factors

#	Name	Hf	D	L	H	E	Type	Notes	
1	LC1	1.00	1.20	1.60				ASCE7	
2	LC2	1.00	1.20		1.60	1.00		ASCE7	
3	LC3	1.00	1.00	1.00	1.00	1.25	Unusual	EM 2104	1.3Hf not included
4									
5									
6									
7									
8									
9									

Template Created: 21-May-10
Pump House Foundation Analysis.xlsm

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Yellowstone Pump House Foundation Walls - Design Loads

Horizontal Force Totals

Units: lb/ft, lb-ft/ft UON

			Driving Side					**Resisting Side**				
					Soil Static					**Soil Static**		
LC	**Live Load Surcharge**	**Pumphouse Water EL**	**GW EL**	**Hydro-static P_{ws}**	Above GW	Below GW (Uniform)	Below GW (Varying)	**GW EL**	**Hydro-static Press**	Above GW	Below GW (Uniform)	Below GW (Varying)
LC1	0	32.00	32.00	31949	17628	45128	15067					
LC2	0	32.00	32.00	31949	17628	45128	15067					
LC3	0	32.00	32.00	31949	17628	45128	15067					
0	0	32.00	32.00	31949	17628	45128	15067					
0	0	32.00	32.00	31949	17628	45128	15067					
0												
0												
0												
0												

	Seismic Soil Active Force					**Seismic Soil Passive Force**					**Inertial Loads**	**Sum of Forces**
	EM 1110-2-2100					EM 1110-2-2100						
		Eqn G-26		Eqn. G-28			Eqn G-30		Eqn. G-32			
LC	**Pa1**	**Pa2 (U)**	**Pa2 (T)**	**ΔPae1**	**ΔPae2**	**Pp1**	**Pp2 (U)**	**Pp2 (T)**	**ΔPpe1**	**ΔPpe2**	**Foundation Wall**	**P_{AE}**
LC1	11514	29477	9841	2314	30							162948
LC2	11514	29477	9841	2314	30							162948
LC3	11514	29477	9841	2314	30							162948
0	11514	29477	9841	2314	30							162948
0	11514	29477	9841	2314	30							162948
0												0
0												0
0												0
0												0

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Yellowstone Pump House Foundation Walls - Design Loads

Horizontal Force Totals Eccentricity

Units: ft UON

			Driving Side					Resisting Side				
				Hydro-static	Soil Static				Hydro-static	Soil Static		
LC	**Live Load Surcharge**	**Pumphouse Water EL**	**GW EL**	**P_{ws}**	Above GW	Below GW (Uniform)	Below GW (Varying)	**GW EL**	**Press**	Above GW	Below GW (Uniform)	Below GW (Varying)
LC1		10.67	10.67	10.67	40.33	16.00	10.67					
LC2		10.67	10.67	10.67	40.33	16.00	10.67					
LC3		10.67	10.67	10.67	40.33	16.00	10.67					
0		10.67	10.67	10.67	40.33	16.00	10.67					
0		10.67	10.67	10.67	40.33	16.00	10.67					
0												
0												
0												
0												

	Seismic Soil Active Force					Seismic Soil Passive Force					Inertial Loads
	EM 1110-2-2100					EM 1110-2-2100					
	Eqn G-26			Eqn. G-28		Eqn G-30			Eqn. G-32		
LC	**Pa1**	**Pa2 (U)**	**Pa2 (T)**	**ΔPae1**	**ΔPae2**	**Pp1**	**Pp2 (U)**	**Pp2 (T)**	**ΔPpe1**	**ΔPpe2**	**Foundation Wall**
LC1	40.33	16.00	10.67	38.00	21.33						
LC2	40.33	16.00	10.67	38.00	21.33						
LC3	40.33	16.00	10.67	38.00	21.33						
0	40.33	16.00	10.67	38.00	21.33						
0	40.33	16.00	10.67	38.00	21.33						
0											
0											
0											
0											

	Σ Horizontal Forces				Σ Horizontal Forces Factored				Load Combinations Total Load		
LC	**D**	**L**	**H+W**	**E**	**D**	**L**	**H+W**	**E**	**LC**	**Total (lbs/ft)**	(Includes H_f factor)
LC1	0	0	31949	53176.65	0	0	0	0.0	LC1	**0.0**	
LC2	0	0	31949	53176.65	0	0	51118	53176.6	LC2	**104294.7**	
LC3	0	0	31949	53176.65	0	0	31949	66470.8	LC3	**98419.6**	
0	0	0	31949	53176.65	0	0	0	0.0	0	**0.0**	
0	0	0	31949	53176.65	0	0	0	0.0	0	**0.0**	
0	0	0	0	0	0	0	0	0.0	0	**0.0**	
0	0	0	0	0	0	0	0	0.0	0	**0.0**	
0	0	0	0	0	0	0	0	0.0	0	**0.0**	
0	0	0	0	0	0	0	0	0.0	0	**0.0**	

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Yellowstone Pump House Foundation Walls - Design Loads

Horizontal Forces At Base of Wall

Units: lb/ft, lb-ft/ft UON

			Driving Side					Resisting Side				
				Hydro-static	Soil Static				Hydro-static	Soil Static		
LC	**Live Load Surcharge**	**Pumphouse Water EL**	**GW EL**	**P_{WS}**	Above GW	Below GW (Uniform)	Below GW (Varying)	**GW EL**	**Press**	Above GW	Below GW (Uniform)	Below GW (Varying)
LC1	0	32.00	32.00	1997	0	1410	471					
LC2	0	32.00	32.00	1997	0	1410	471					
LC3	0	32.00	32.00	1997	0	1410	471					
0	0	32.00	32.00	1997	0	1410	471					
0	0	32.00	32.00	1997	0	1410	471					
0												
0												
0												
0												

	Seismic Soil Active Force					Seismic Soil Passive Force					Inertial Loads	Sum of Forces
	EM 1110-2-2100					EM 1110-2-2100						
		Eqn G-26		Eqn. G-28			Eqn G-30		Eqn. G-32			
LC	**Pa1**	**Pa2 (U)**	**Pa2 (T)**	**ΔPae1**	**ΔPae2**	**Pp1**	**Pp2 (U)**	**Pp2 (T)**	**ΔPpe1**	**ΔPpe2**	**Foundation Wall**	**P_{AE}**
LC1	0	921	615	0	0							5414
LC2	0	921	615	0	0							5414
LC3	0	921	615	0	0							5414
0	0	921	615	0	0							5414
0	0	921	615	0	0							5414
0												0
0												0
0												0
0												0

	Σ Horizontal Forces at base of wall				Σ Horizontal Forces Factored				Load Combinations at Base of Wall		
LC	**D**	**L**	**H+W**	**E**	**D**	**L**	**H+W**	**E**	**LC**	**Total (psf)**	(Includes H_f factor)
LC1	0	0	1997	1536.2	0	0	0	0.0	LC1	**0.0**	
LC2	0	0	1997	1536.2	0	0	3195	1536.2	LC2	**4731.1**	
LC3	0	0	1997	1536.2	0	0	1997	1920.3	LC3	**3917.1**	
0	0	0	1997	1536.2	0	0	0	0.0	0	**0.0**	
0	0	0	1997	1536.2	0	0	0	0.0	0	**0.0**	
0	0	0	0	0.0	0	0	0	0.0	0	**0.0**	
0	0	0	0	0.0	0	0	0	0.0	0	**0.0**	
0	0	0	0	0.0	0	0	0	0.0	0	**0.0**	
0	0	0	0	0.0	0	0	0	0.0	0	**0.0**	

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Yellowstone Pump House Foundation Walls - Design Loads

Horizontal Forces At Groundwater Elevation

Units: lb/ft, lb-ft/ft UON

			Driving Side					Resisting Side				
				Hydro-static	Soil Static				Hydro-static	Soil Static		
LC	**Live Load Surcharge**	**Pumphouse Water EL**	**GW EL**	**P_{WS}**	Above GW	Below GW (Uniform)	Below GW (Varying)	**GW EL**	**Press**	Above GW	Below GW (Uniform)	Below GW (Varying)
LC1	0	32.00	32.00	0	1410	1410	0					
LC2	0	32.00	32.00	0	1410	1410	0					
LC3	0	32.00	32.00	0	1410	1410	0					
0	0	32.00	32.00	0	1410	1410	0					
0	0	32.00	32.00	0	1410	1410	0					
0												
0												
0												
0												

	Seismic Soil Active Force					Seismic Soil Passive Force					Inertial Loads	Sum of Forces
	EM 1110-2-2100					EM 1110-2-2100						
		Eqn G-26		Eqn. G-28			Eqn G-30		Eqn. G-32			
LC	**Pa1**	**Pa2 (U)**	**Pa2 (T)**	**ΔPae1**	**ΔPae2**	**Pp1**	**Pp2 (U)**	**Pp2 (T)**	**ΔPpe1**	**ΔPpe2**	**Foundation Wall**	**P_{AE}**
LC1	921	921	0	45.58	1.90							4710
LC2	921	921	0	45.58	1.90							4710
LC3	921	921	0	45.58	1.90							4710
0	921	921	0	45.58	1.90							4710
0	921	921	0	45.58	1.90							4710
0												0
0												0
0												0
0												0

	Σ Horizontal Forces at groundwater EL				Σ Horizontal Forces Factored				Load Combinations at Groundwater EL		
LC	**D**	**L**	**H+W**	**E**	**D**	**L**	**H+W**	**E**	**LC**	**Total (psf)**	(Includes H_f factor)
LC1	0	0	0	1889.8	0	0	0	0.0	LC1	**0.0**	
LC2	0	0	0	1889.8	0	0	0	1889.8	LC2	**1889.8**	
LC3	0	0	0	1889.8	0	0	0	2362.2	LC3	**2362.2**	
0	0	0	0	1889.8	0	0	0	0.0	0	**0.0**	
0	0	0	0	1889.8	0	0	0	0.0	0	**0.0**	
0	0	0	0	0.0	0	0	0	0.0	0	**0.0**	
0	0	0	0	0.0	0	0	0	0.0	0	**0.0**	
0	0	0	0	0.0	0	0	0	0.0	0	**0.0**	
0	0	0	0	0.0	0	0	0	0.0	0	**0.0**	

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Yellowstone Pump House 30ft Foundation Walls Design

Wall Properties

	Driving	Resisting
Base of Wall Elev	0	
Soil Elev for Horiz Loads	57	
Groundwater EL	32	
Max Pumphouse Water Elev	32	

Material Properties

Soil Properties

γ_{sat}	125.00	pcf
γ_{moist}	120.00	pcf
γ_{b}	62.60	pcf
ϕ	0.56	rad
β	0.00	rad
ϕ	32.00	deg
β	0.00	deg

Water Properties

γ_{water}	62.40	pcf

Seismic

Loading Information

PGA (L1)	0.031	g
$k_{h, L1}$	0.021	g

Structure Properties

fy	60	ksi	
d @ base	94	in	8' wall
d @ groundwater	46	in	4' wall
f'c	5	ksi	
beff	12	in	
ϕ flexure	0.9		
ϕ shear	0.75		
Wall Length	30	ft	

Pump Pit Foundation Wall Design - Assume Wall Spans Horizontally

Wall at Base of Pit

Controlling Factored Load	Pu	4731.1	lbs/ft	
Wall Length Horizontal	l	30.00	ft	
Wall Positive Design Moment	Mu	425800	lb-ft	At mid span, assume wl^2/10 - This is conservative for partial fixity at the ends
	Mu	5109602	lb-in	
	Mu	5110	k-in	
Wall Negative Design Moment	Mu	425800	lb-ft	At supports, assume wl^2/10 - This is conservative for partial fixity
	Mu	5109602	lb-in	
	Mu	5110	k-in	
Wall Shear At Supports	Vu	70967	lbs/ft	
	Vu	71	kips/ft	

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Yellowstone Pump House 30ft Foundation Walls Design

Wall Horiz Flexure Reinforcing Design

I.F. Bar Spacing	6	in	
As	1	in^2	
As tot	2	in^2/ft	
ϕMn	10025	k-in	
CHECK ϕMn>Mu	**OK**		So, #9 Bars at 6in OC, I.F.
O.F. Bar Spacing	6	in	
As	1	in^2	
As tot	2	in^2/ft	
ϕMn	10025	k-in	
CHECK ϕMn>Mu	**OK**		So, #9 Bars at 6in OC, O.F.

Check I.F. Minimum Flexural Steel

A_{smin}	3.99	in^2/ft	ACI 318-11 (10-3)
CHECK As>=Asmin	**NG**		
CHECK As>=(4/3)AsREQUIRED	**OK**		ACI 318-11 10.5.3

Check O.F. Minimum Flexural Steel

A_{smin}	3.99	in^2/ft	ACI 318-11 (10-3)
CHECK As>=Asmin	**NG**		
CHECK As>=(4/3)AsREQUIRED	**OK**		ACI 318-11 10.5.3

Wall Vert Flexure Reinforcing Design

Provide Min Flexure Steel in Vert Direction
#9 at 12" Each Face
Additional #9 at 6" Outside Face at Top and Bottom Slabs

Wall Shear Reinforcing Design

Vc	159523.3	lbs/ft	
	159.5	kips/ft	
CHECK ϕ.5Vc>= Vu	**OK**		So shear steel not required

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Yellowstone Pump House 30ft Foundation Walls Design

Wall at Groundwater Elevation

Controlling Factored Load	Pu	2362.22	lbs/ft	
Wall Length Horizontal	l	30.00	ft	
Wall Positive Design Moment	Mu	212600	lb-ft	At mid span, assume wl^2/10 - This is conservative for partial fixity at the ends
	Mu	2551199	lb-in	
	Mu	2551	k-in	
Wall Negative Design Moment	Mu	212600	lb-ft	At supports, assume wl^2/10 - This is conservative for partial fixity
	Mu	2551199	lb-in	
	Mu	2551	k-in	
Wall Shear At Supports	Vu	35433	lbs/ft	
	Vu	35	kips/ft	

Wall Horiz Flexure Reinforcing Design

I.F. Bar Spacing	6	in	
As	1	in^2	
As tot	2	in^2/ft	
ϕMn	4841	k-in	
CHECK ϕMn>Mu	**OK**		So, #9 Bars at 6in OC, I.F.
O.F. Bar Spacing	6	in	
As	1	in^2	
As tot	2	in^2/ft	
ϕMn	4841	k-in	
CHECK ϕMn>Mu	**OK**		So, #9 Bars at 6in OC, O.F.

Check I.F. Minimum Flexural Steel

A_{smin}	1.95	in^2/ft	ACI 318-11 (10-3)
CHECK As>=Asmin	**OK**		
CHECK As>=(4/3)AsREQUIRED	**OK**		ACI 318-11 10.5.3

Check O.F. Minimum Flexural Steel

A_{smin}	1.95	in^2/ft	ACI 318-11 (10-3)
CHECK As>=Asmin	**OK**		
CHECK As>=(4/3)AsREQUIRED	**OK**		ACI 318-11 10.5.3

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Yellowstone Pump House 30ft Foundation Walls Design

Wall Vert Flexure Reinforcing Design

Provide Min Flexure Steel in Vert Direction

#9 at 12" Each Face
Additional #9x8ft at 6" Outside Face at Top and Bottom Slabs

Wall Shear Reinforcing Design

Vc	78064.6	lbs/ft
	78.1	kips/ft
CHECK ϕ.5Vc>= Vu	**OK**	

So shear steel not required

Project: *Yellowstone*		**Sheet:** 10	**of** 29 -
Description: *Yellowstone Pump House 20ft Foundation Walls Design*		**Date:** *03/14/16*	
		Computed: *MGH*	**Chkd:** *LT*
Document No.		**Backchecked:**	**Date:** *3/17/16*

Yellowstone Pump House 20ft Foundation Walls Design

Wall Properties

	Driving	Resisting
Base of Wall Elev	0	
Soil Elev for Horiz Loads	57	
Groundwater EL	32	
Max Pumphouse Water Elev	32	

Material Properties

Soil Properties

γ_{sat}	125.00	pcf
γ_{moist}	120.00	pcf
γ_b	62.60	pcf
ϕ	0.56	rad
β	0.00	rad
ϕ	32.00	deg
β	0.00	deg

Water Properties

γ_{water}	62.40	pcf

Seismic

Loading Information

PGA (L1)	0.031	g
$k_{h, L1}$	0.021	g

Structure Properties

fy	60	ksi	
d @ base	58	in	5' wall
d @ groundwater	31	in	2' 9" wall
f'c	5	ksi	
beff	12	in	
ϕ flexure	0.9		
ϕ shear	0.75		
Wall Length	20	ft	

Pump Pit Foundation Wall Design - Assume Wall Spans Horizontally

Wall at Base of Pit

Controlling Factored Load	Pu	4731.1	lbs/ft	
Wall Length Horizontal	l	20.00	ft	
Wall Positive Design Moment	Mu	189245	lb-ft	At mid span, assume wl^2/10 - This is conservative for partial fixity at the ends
	Mu	2270934	lb-in	
	Mu	2271	k-in	
Wall Negative Design Moment	Mu	189245	lb-ft	At supports, assume wl^2/10 - This is conservative for partial fixity
	Mu	2270934	lb-in	
	Mu	2271	k-in	
Wall Shear At Supports	Vu	47311	lbs/ft	
	Vu	47	kips/ft	

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Pump House Foundation Analysis.xlsm

Project: *Yellowstone*

Description:

Yellowstone Pump House 20ft Foundation Walls Design

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Computed: *MGH* **Chkd:** *LT*

Backchecked: **Date:** *3/17/16*

Yellowstone Pump House 20ft Foundation Walls Design

Wall Flexure Reinforcing Design

I.F. Bar Spacing	6	in	
As	1	in^2	
As tot	2	in^2/ft	
ϕMn	6137	k-in	
CHECK ϕMn>Mu	**OK**		So, #9 Bars at 6in OC, I.F.
O.F. Bar Spacing	6	in	
As	1	in^2	
As tot	2	in^2/ft	
ϕMn	6137	k-in	
CHECK ϕMn>Mu	**OK**		So, #9 Bars at 6in OC, O.F.

Check I.F. Minimum Flexural Steel

A_{smin}	2.46	in^2/ft	ACI 318-11 (10-3)
CHECK As>=Asmin	**NG**		
CHECK As>=(4/3)AsREQUIRED	**OK**		ACI 318-11 10.5.3

Check O.F. Minimum Flexural Steel

A_{smin}	2.46	in^2/ft	ACI 318-11 (10-3)
CHECK As>=Asmin	**NG**		
CHECK As>=(4/3)AsREQUIRED	**OK**		ACI 318-11 10.5.3

Wall Vert Flexure Reinforcing Design

Provide Min Flexure Steel in Vert Direction

#9 at 12" Each Face
Additional #9x8ft at 6" Outside Face at Top and Bottom Slabs

Wall Shear Reinforcing Design

Vc	98429.3	lbs/ft	
Vc	98.4	kips/ft	
CHECK ϕ.5Vc>= Vu	**OK**		So shear steel NOT required

Project:	*Yellowstone*	**Sheet:**	12	**of**	29 -
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	Yellowstone Pump House 20ft Foundation Walls Design				
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Yellowstone Pump House 20ft Foundation Walls Design

Wall at Groundwater Elevation

Controlling Factored Load	Pu	2362.22	lbs/ft	
Wall Length Horizontal	l	20.00	ft	
Wall Positive Design Moment	Mu	94489	lb-ft	At mid span, assume wl^2/10 - This is conservative for partial fixity at the ends
	Mu	1133866	lb-in	
	Mu	1134	k-in	
Wall Negative Design Moment	Mu	94489	lb-ft	At supports, assume wl^2/10 - This is conservative for partial fixity
	Mu	1133866	lb-in	
	Mu	1134	k-in	
Wall Shear At Supports	Vu	23622	lbs/ft	
	Vu	24	kips/ft	

Wall Flexure Reinforcing Design

I.F. Bar Spacing	12	in	
As	1	in^2	
As tot	1	in^2/ft	
ϕMn	1642	k-in	
CHECK ϕMn>Mu	**OK**		So, #9 Bars at 12in OC, I.F.
O.F. Bar Spacing	12	in	
As	1	in^2	
As tot	1	in^2/ft	
ϕMn	1642	k-in	
CHECK ϕMn>Mu	**OK**		So, #9 Bars at 12in OC, O.F.

Check I.F. Minimum Flexural Steel

A_{smin}	1.32	in^2/ft	ACI 318-11 (10-3)
CHECK As>=Asmin	**NG**		
CHECK As>=(4/3)AsREQUIRED	**OK**		ACI 318-11 10.5.3

Check O.F. Minimum Flexural Steel

A_{smin}	1.32	in^2/ft	ACI 318-11 (10-3)
CHECK As>=Asmin	**NG**		
CHECK As>=(4/3)AsREQUIRED	**OK**		ACI 318-11 10.5.3

Wall Shear Reinforcing Design

Vc	52608.7	lbs/ft	
	52.6	kips/ft	
CHECK ϕ.5Vc>= Vu	**OK**		So shear steel NOT required

Project: *Yellowstone* **Sheet:** 13 **of** 29 -

Description: *Yellowstone Pump House Foundation Base Slab Design* **Date:** *03/14/16*

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Document No. **Backchecked:** **Date:** *3/17/16*

Yellowstone Pump House Foundation Base Slab Design

Wall Properties

	Driving	**Resisting**
Base of Wall Elev	0	
Soil Elev for Horiz Loads	57	
Groundwater EL	32	
Max Pumphouse Water Elev	32	

Material Properties

Soil Properties

γ_{sat}	125.00	pcf
γ_{moist}	120.00	pcf
γ_{b}	62.60	pcf
ϕ	0.56	rad
β	0.00	rad
ϕ	32.00	deg
β	0.00	deg

Water Properties

γ_{water}	62.40	pcf

Seismic

Loading Information

PGA (L1)	0.031	g
$k_{h,\ L1}$	0.021	g

Structure Properties

fy	60	ksi	
d @ base	28	in	2' 6" Slab
f'c	5	ksi	
beff	12	in	
ϕ flexure	0.9		
ϕ shear	0.75		
Foundation Slab Length	20	ft	

Pump Pit Foundation Slab Design - Assume Slab Spans Transversely to Direction of Flow

Foundation Slab at Base of Pit

Controlling Factored Load	Pu	1996.8	lbs/ft	Hydrostatic Uplift
Foundation Slab Length Horizontal	l	20.00	ft	
Slab Positive Design Moment	Mu	79872	lb-ft	At mid span, assume wl^2/10 - This is conservative for partial fixity at the ends
	Mu	958464	lb-in	
	Mu	958	k-in	
Wall Negative Design Moment	Mu	79872	lb-ft	At supports, assume wl^2/10 - This is conservative for partial fixity
	Mu	958464	lb-in	
	Mu	958	k-in	
Slab Shear At Supports	Vu	19968	lbs/ft	
	Vu	20	kips/ft	

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Pump House Foundation Analysis.xlsm

CALCULATIONS

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Yellowstone Pump House Foundation Base Slab Design
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Yellowstone Pump House Foundation Base Slab Design

Foundation Slab Flexure Reinforcing Design

TOP Bar Spacing	12	in	
As	1	in^2	
As tot	1	in^2/ft	
ϕMn	1480	k-in	
CHECK ϕMn>Mu	**OK**		So, #9 Bars at 12in OC, TOP EACH WAY
BOT Bar Spacing	12	in	
As	1	in^2	
As tot	1.000	in^2/ft	
ϕMn	1480	k-in	
CHECK ϕMn>Mu	**OK**		So, #9 Bars at 12in OC, BOT EACH WAY

Check TOP Minimum Flexural Steel

A_{smin}	1.19	in^2/ft	ACI 318-11 (10-3)
CHECK As>=Asmin	**NG**		
CHECK As>=(4/3)AsREQUIRED	**OK**		ACI 318-11 10.5.3

Check BOT Minimum Flexural Steel

A_{smin}	1.19	in^2/ft	ACI 318-11 (10-3)
CHECK As>=Asmin	**NG**		
CHECK As>=(4/3)AsREQUIRED	**OK**		ACI 318-11 10.5.3

Foundation Slab Shear Reinforcing Design

Vc	47517.6	lbs/ft	
	47.5	kips/ft	
CHECK ϕ.5Vc>= Vu	**OK**		So Shear Steel Not Required

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Pump House Foundation Analysis.xlsm

Project: *Yellowstone*
Description:
Yellowstone Pump House Top Slab Design
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Computed: *MGH* **Chkd:** *LT*
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Yellowstone Pump House Top Slab Design

Wall Properties

	Driving	**Resisting**
Base of Wall Elev	0	
Soil Elev for Horiz Loads	57	
Groundwater EL	32	
Max Pumphouse Water Elev	32	

Material Properties

Soil Properties

γ_{sat}	125.00	pcf
γ_{moist}	120.00	pcf
γ_{b}	62.60	pcf
ϕ	0.56	rad
β	0.00	rad
ϕ	32.00	deg
β	0.00	deg

Water Properties

γ_{water}	62.40	pcf

Seismic

Loading Information

PGA (L1)	0.031	g
$k_{h, L1}$	0.021	g

Structure Properties

fy	60	ksi	
d	10	in	1' slab
Slab Thickness	12	in	
f'c	5	ksi	
beff	12	in	
ϕ flexure	0.9		
ϕ shear	0.75		
Foundation Slab Length	20	ft	
Concrete Weight	150	pcf	
Pump Floor Live Load	150	psf	
Pump Floor Dead Load	180.0	psf	

Load Factors

#	Name	Hf	D	L	H	E	Type	Notes	
1	LC2	1.00	1.20	1.60				ASCE7	
2	LC3	1.00	1.20		1.60	1.00		ASCE7	
3	LC4	1.30	0.75	0.75	0.75	0.94	Unusual	EM 2104	Includes 1.3Hf
4									
5									
6									
7									
8									
9									

CALCULATIONS

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Yellowstone Pump House Top Slab Design

Pump Pit Top Floor Slab Design - Assume Slab Spans Transversely to Direction of Flow

Top Floor Slab

Controlling Factored Load	Pu	456.0	lbs/ft	Dead + Live Load on Floor (includes Hf)
Foundation Slab Length Horizontal	l	20.00	ft	
Slab Positive Design Moment	Mu	18240	lb-ft	At mid span, assume wl^2/10 - This is conservative for partial fixity at the ends
	Mu	218880	lb-in	
	Mu	219	k-in	
Wall Negative Design Moment	Mu	18240	lb-ft	At supports, assume wl^2/10 - This is conservative for partial fixity
	Mu	218880	lb-in	
	Mu	219	k-in	
Wall Shear At Supports	Vu	4560	lbs/ft	
	Vu	5	kips/ft	

Flexure Reinforcing Design

BOT Bar Spacing	9	in	
As	0.44	in^2	
As tot	0.58666667	in^2/ft	
ϕMn	306	k-in	
CHECK ϕMn>Mu	**OK**		So, #6 Bars at 9in OC, BOT EACH WAY
TOP Bar Spacing	12	in	
As	0.44	in^2	
As tot	0.440	in^2/ft	
ϕMn	231	k-in	
CHECK ϕMn>Mu	**OK**		So, #6 Bars at 12in OC, TOP EACH WAY

Check TOP Minimum Flexural Steel

A_{smin}	0.42	in^2/ft	ACI 318-11 (10-3)
CHECK As>=Asmin	**OK**		
CHECK As>=(4/3)AsREQUIRED	**OK**		ACI 318-11 10.5.3

Check BOT Minimum Flexural Steel

A_{smin}	0.42	in^2/ft	ACI 318-11 (10-3)
CHECK As>=Asmin	**OK**		
CHECK As>=(4/3)AsREQUIRED	**NG**		ACI 318-11 10.5.3

CALCULATIONS

Project: *Yellowstone*
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Yellowstone Pump House Top Slab Design
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Yellowstone Pump House Top Slab Design

Shear Reinforcing Design

Vc	16970.6	lbs/ft
	17.0	kips/ft
CHECK ϕ.5Vc>= Vu	**OK**	

So Shear Steel NOT Required

Project: *Yellowstone*

Description: *Yellowstone Wing Wall - Design Loads*

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Computed: *MGH* **Chkd:** *LT*

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Yellowstone Wing Wall - Design Loads

Wall Properties

	Driving	**Resisting**
Base of Wall Elev	32.00	
Soil Elev for Horiz Loads	54.00	
Groundwater EL	32.00	
Max Pumphouse Water Elev	32.00	

Material Properties

Soil Properties

γ_{sat}	125.00	pcf
γ_{moist}	120.00	pcf
γ_b	62.60	pcf
ϕ	0.56	rad
β	0.00	rad
ϕ	32.00	deg
β	0.00	deg

Water Properties

γ_{water}	62.40	pcf

Seismic

Loading Information

PGA (L1)	0.031	g	Per USGS
$k_{h, L1}$	0.021	g	

Soil Pressure Constants

	c1	c2	α active	Ka	Kab	α pass.	Kp	Kpb	Ko
Level 1	1.19	0.95	1.05	0.31	0.31	0.50	3.25	3.25	0.47
	(Eq. G-14) EM 1110-2-2100	(Eq. G-15)	(Eq. G-13)	(Eq. G-11)		(Eq. G-16)	(Eq. G-34)	(Eq. G-35)	(Eq. 3-4) EM 1110-2-2502

Load Factors

#	Name	Hf	D	L	H	E	Type	Notes	
1	LC1	1.00	1.20	1.60				ASCE7	
2	LC2	1.00	1.20		1.60	1.00		ASCE7	
3	LC3	1.00	1.00	1.00	1.00	1.25	Unusual	EM 2104	1.3Hf not included
4									
5									
6									
7									
8									
9									

Template Created: 21-May-10

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Project: *Yellowstone*
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Yellowstone Wing Wall - Design Loads
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Yellowstone Wing Wall - Design Loads

Horizontal Force Totals

Units: lb/ft, lb-ft/ft UON

		Driving Side					Resisting Side				
				Soil Static					Soil Static		
LC	**Live Load Surcharge**	**GW EL**	**Hydro-static P_{ws}**	Above GW	Below GW (Uniform)	Below GW (Varying)	**GW EL**	**Hydro-static Press**	Above GW	Below GW (Uniform)	Below GW (Varying)
LC1	0	32.00	0	13651	0	0					
LC2	0	32.00	0	13651	0	0					
LC3	0	32.00	0	13651	0	0					
0	0	32.00	0	13651	0	0					
0	0	32.00	0	13651	0	0					
0											
0											
0											
0											

	Seismic Soil Active Force					Seismic Soil Passive Force					Inertial Loads	Sum of Forces
	EM 1110-2-2100					EM 1110-2-2100						
		Eqn G-26		Eqn. G-28			Eqn G-30		Eqn. G-32			
LC	**Pa1**	**Pa2 (U)**	**Pa2 (T)**	**ΔPae1**	**ΔPae2**	**Pp1**	**Pp2 (U)**	**Pp2 (T)**	**ΔPpe1**	**ΔPpe2**	**Foundation Wall**	**P_{AE}**
LC1	8917	0	0	345	0							22913
LC2	8917	0	0	345	0							22913
LC3	8917	0	0	345	0							22913
0	8917	0	0	345	0							22913
0	8917	0	0	345	0							22913
0												0
0												0
0												0
0												0

Project:	*Yellowstone*	**Sheet:**	20 **of** 29 -
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	Yellowstone Wing Wall - Design Loads		
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Yellowstone Wing Wall - Design Loads

Horizontal Force Eccentricity (Distance Above Base of Wall)

Units: ft UON

			Driving Side					**Resisting Side**				
				Hydro-static	**Soil Static**				**Hydro-static**	**Soil Static**		
LC	**Live Load Surcharge**	**Pumphouse Water EL**	**GW EL**	**P_{ws}**	Above GW	Below GW (Uniform)	Below GW (Varying)	**GW EL**	**Press**	Above GW	Below GW (Uniform)	Below GW (Varying)
LC1		0.00	0.00	0.00	7.33	0.00	0.00					
LC2		0.00	0.00	0.00	7.33	0.00	0.00					
LC3		0.00	0.00	0.00	7.33	0.00	0.00					
0		0.00	0.00	0.00	7.33	0.00	0.00					
0		0.00	0.00	0.00	7.33	0.00	0.00					
0												
0												
0												
0												

	Seismic Soil Active Force					**Seismic Soil Passive Force**					**Inertial Loads**	
	EM 1110-2-2100					EM 1110-2-2100						
LC	Eqn G-26 **Pa1**	**Pa2 (U)**	**Pa2 (T)**	Eqn. G-28 **ΔPae1**	**ΔPae2**	Eqn G-30 **Pp1**	**Pp2 (U)**	**Pp2 (T)**	Eqn. G-32 **ΔPpe1**	**ΔPpe2**	**Foundation Wall**	
LC1	7.33	0.00	0.00	14.67	0.00							
LC2	7.33	0.00	0.00	14.67	0.00							
LC3	7.33	0.00	0.00	14.67	0.00							
0	7.33	0.00	0.00	14.67	0.00							
0	7.33	0.00	0.00	14.67	0.00							
0												
0												
0												
0												

	Σ Horizontal Forces				**Σ Horizontal Forces Factored**				**Load Combinations Total Load**		
LC	**D**	**L**	**H+W**	**E**	**D**	**L**	**H+W**	**E**	**LC**	**Total (lbs/ft)**	(Includes H_f factor)
LC1	0	0	0	9261.412	0	0	0	0.0	LC1	**0.0**	
LC2	0	0	0	9261.412	0	0	0	9261.4	LC2	**9261.4**	
LC3	0	0	0	9261.412	0	0	0	11576.8	LC3	**11576.8**	
0	0	0	0	9261.412	0	0	0	0.0	0	**0.0**	
0	0	0	0	9261.412	0	0	0	0.0	0	**0.0**	
0	0	0	0	0	0	0	0	0.0	0	**0.0**	
0	0	0	0	0	0	0	0	0.0	0	**0.0**	
0	0	0	0	0	0	0	0	0.0	0	**0.0**	
0	0	0	0	0	0	0	0	0.0	0	**0.0**	

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Description:

Date: *03/14/16*

Yellowstone Wing Wall - Design Loads

Computed: *MGH* **Chkd:** *LT*

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Backchecked: **Date:** *3/17/16*

Yellowstone Wing Wall - Design Loads

Horizontal Moments About The Base of Wall

Units: lb-ft UON

			Driving Side					Resisting Side				
					Soil Static					Soil Static		
LC	**Live Load Surcharge**	**Pumphouse Water EL**	**GW EL**	**Hydro-static P_{ws}**	Above GW	Below GW (Uniform)	Below GW (Varying)	**GW EL**	**Hydro-static Press**	Above GW	Below GW (Uniform)	Below GW (Varying)
LC1			0.00	0.00	100108.39	0.00	0.00					
LC2			0.00	0.00	100108.39	0.00	0.00					
LC3			0.00	0.00	100108.39	0.00	0.00					
0			0.00	0.00	100108.39	0.00	0.00					
0			0.00	0.00	100108.39	0.00	0.00					
0												
0												
0												
0												

	Seismic Soil Active Force					Seismic Soil Passive Force					Inertial Loads
	EM 1110-2-2100					EM 1110-2-2100					
	Eqn G-26			Eqn. G-28		Eqn G-30			Eqn. G-32		
LC	**Pa1**	**Pa2 (U)**	**Pa2 (T)**	**ΔPae1**	**ΔPae2**	**Pp1**	**Pp2 (U)**	**Pp2 (T)**	**ΔPpe1**	**ΔPpe2**	**Foundation Wall**
LC1	65389.40	0.00	0.00	5055.24	0.00						
LC2	65389.40	0.00	0.00	5055.24	0.00						
LC3	65389.40	0.00	0.00	5055.24	0.00						
0	65389.40	0.00	0.00	5055.24	0.00						
0	65389.40	0.00	0.00	5055.24	0.00						
0											
0											
0											
0											

	Σ Horizontal Moments				Σ Horizontal Moments Factored				Load Combinations Total Moments	
LC	**D**	**L**	**H+W**	**E**	**D**	**L**	**H+W**	**E**	**LC**	**Total (lbs-ft)** (Includes H_f factor)
LC1	0	0	0	70444.64	0	0	0	0.0	LC1	**0.0**
LC2	0	0	0	70444.64	0	0	0	70444.6	LC2	**70444.6**
LC3	0	0	0	70444.64	0	0	0	88055.8	LC3	**88055.8**
0	0	0	0	70444.64	0	0	0	0.0	0	**0.0**
0	0	0	0	70444.64	0	0	0	0.0	0	**0.0**
0	0	0	0	0	0	0	0	0.0	0	**0.0**
0	0	0	0	0	0	0	0	0.0	0	**0.0**
0	0	0	0	0	0	0	0	0.0	0	**0.0**
0	0	0	0	0	0	0	0	0.0	0	**0.0**

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Yellowstone Wing Wall - Design Loads

Wall Properties

	Driving	Resisting
Base of Wall Elev	32.00	
Soil Elev for Horiz Loads	54.00	
Groundwater EL	32.00	
Max Pumphouse Water Elev	32.00	

Material Properties

Soil Properties

γ_{sat}	125.00	pcf
γ_{moist}	120.00	pcf
γ_{b}	62.60	pcf
ϕ	0.56	rad
β	0.00	rad
ϕ	32.00	deg
β	0.00	deg

Water Properties

γ_{water}	62.40	pcf

Seismic

Loading Information

PGA (L1)	0.031	g	Per USGS
$k_{h,\ L1}$	0.021	g	

Soil Pressure Constants

	c1	c2	α active	Ka	Kab	α pass.	Kp	Kpb	Ko
Level 1	1.19	0.95	1.05	0.31	0.31	0.50	3.25	3.25	0.47
	(Eq. G-14) EM 1110-2-2100	(Eq. G-15)	(Eq. G-13)	(Eq. G-11)		(Eq. G-16)	(Eq. G-34)	(Eq. G-35)	(Eq. 3-4) EM 1110-2-2502

Load Factors

#	Name	Hf	D	L	H	E	Type	Notes	
1	LC1	1.00	1.20	1.60				ASCE7	
2	LC2	1.00	1.20		1.60	1.00		ASCE7	
3	LC3	1.00	1.00	1.00	1.00	1.25	Unusual	EM 2104	1.3Hf not included
4									
5									
6									
7									
8									
9									

Project: *Yellowstone*
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Date: *03/14/16*
Computed: *MGH* **Chkd:** *LT*
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Backchecked: **Date:** *3/17/16*

Yellowstone Wing Wall - Design Loads

Horizontal Force Totals

Units: lb/ft, lb-ft/ft UON

		Driving Side					Resisting Side				
			Hydro-static	Soil Static				Hydro-static	Soil Static		
LC	**Live Load Surcharge**	**GW EL**	**P_{WS}**	Above GW	Below GW (Uniform)	Below GW (Varying)	**GW EL**	**Press**	Above GW	Below GW (Uniform)	Below GW (Varying)
LC1	0	32.00	0	13651	0	0					
LC2	0	32.00	0	13651	0	0					
LC3	0	32.00	0	13651	0	0					
0	0	32.00	0	13651	0	0					
0	0	32.00	0	13651	0	0					
0											
0											
0											
0											

	Seismic Soil Active Force					Seismic Soil Passive Force					Inertial Loads	Sum of Forces
	EM 1110-2-2100					EM 1110-2-2100						
		Eqn G-26		Eqn. G-28			Eqn G-30		Eqn. G-32			
LC	**Pa1**	**Pa2 (U)**	**Pa2 (T)**	**ΔPae1**	**ΔPae2**	**Pp1**	**Pp2 (U)**	**Pp2 (T)**	**ΔPpe1**	**ΔPpe2**	**Foundation Wall**	**P_{AE}**
LC1												13651
LC2												13651
LC3												13651
0												13651
0												13651
0												0
0												0
0												0
0												0

CALCULATIONS

Project:	*Yellowstone*	**Sheet:**	24 **of** 29 -
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	Yellowstone Wing Wall - Design Loads		
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Yellowstone Wing Wall - Design Loads

Horizontal Force Eccentricity (Distance Above Base of Wall)

Units: ft UON

			Driving Side					Resisting Side				
				Hydro-static	Soil Static				Hydro-static	Soil Static		
LC	**Live Load Surcharge**	**Pumphouse Water EL**	**GW EL**	**P_{ws}**	Above GW	Below GW (Uniform)	Below GW (Varying)	**GW EL**	**Press**	Above GW	Below GW (Uniform)	Below GW (Varying)
LC1		0.00	0.00	0.00	7.33	0.00	0.00					
LC2		0.00	0.00	0.00	7.33	0.00	0.00					
LC3		0.00	0.00	0.00	7.33	0.00	0.00					
0		0.00	0.00	0.00	7.33	0.00	0.00					
0		0.00	0.00	0.00	7.33	0.00	0.00					
0												
0												
0												
0												

	Seismic Soil Active Force					Seismic Soil Passive Force					Inertial Loads	
	EM 1110-2-2100					EM 1110-2-2100						
	Eqn G-26			Eqn. G-28		Eqn G-30			Eqn. G-32			
LC	**Pa1**	**Pa2 (U)**	**Pa2 (T)**	**ΔPae1**	**ΔPae2**	**Pp1**	**Pp2 (U)**	**Pp2 (T)**	**ΔPpe1**	**ΔPpe2**	**Foundation Wall**	
LC1	7.33	0.00	0.00	14.67	0.00							
LC2	7.33	0.00	0.00	14.67	0.00							
LC3	7.33	0.00	0.00	14.67	0.00							
0	7.33	0.00	0.00	14.67	0.00							
0	7.33	0.00	0.00	14.67	0.00							
0												
0												
0												
0												

	Σ Horizontal Forces				Σ Horizontal Forces Factored				Load Combinations Total Load		
LC	**D**	**L**	**H+W**	**E**	**D**	**L**	**H+W**	**E**	**LC**	**Total (lbs/ft)**	(Includes H_f factor)
LC1	0	0	13651	0	0	0	0	0.0	LC1	**0.0**	
LC2	0	0	13651	0	0	0	21842	0.0	LC2	**21841.8**	
LC3	0	0	13651	0	0	0	13651	0.0	LC3	**13651.1**	
0	0	0	13651	0	0	0	0	0.0	0	**0.0**	
0	0	0	13651	0	0	0	0	0.0	0	**0.0**	
0	0	0	0	0	0	0	0	0.0	0	**0.0**	
0	0	0	0	0	0	0	0	0.0	0	**0.0**	
0	0	0	0	0	0	0	0	0.0	0	**0.0**	
0	0	0	0	0	0	0	0	0.0	0	**0.0**	

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Yellowstone Wing Wall - Design Loads

Horizontal Moments About The Base of Wall

Units: lb-ft UON

			Driving Side					Resisting Side				
					Soil Static					Soil Static		
LC	**Live Load Surcharge**	**Pumphouse Water EL**	**GW EL**	**Hydro-static P_{WS}**	Above GW	Below GW (Uniform)	Below GW (Varying)	**GW EL**	**Hydro-static Press**	Above GW	Below GW (Uniform)	Below GW (Varying)
LC1			0.00	0.00	100108.39	0.00	0.00					
LC2			0.00	0.00	100108.39	0.00	0.00					
LC3			0.00	0.00	100108.39	0.00	0.00					
0			0.00	0.00	100108.39	0.00	0.00					
0			0.00	0.00	100108.39	0.00	0.00					
0												
0												
0												
0												

	Seismic Soil Active Force					Seismic Soil Passive Force					Inertial Loads	
	EM 1110-2-2100					EM 1110-2-2100						
	Eqn G-26			Eqn. G-28		Eqn G-30			Eqn. G-32			
LC	**Pa1**	**Pa2 (U)**	**Pa2 (T)**	**ΔPae1**	**ΔPae2**	**Pp1**	**Pp2 (U)**	**Pp2 (T)**	**ΔPpe1**	**ΔPpe2**	**Foundation Wall**	
LC1												
LC2												
LC3												
0												
0												
0												
0												
0												
0												

	Σ Horizontal Moments				Σ Horizontal Moments Factored				Load Combinations Total Moments		
LC	**D**	**L**	**H+W**	**E**	**D**	**L**	**H+W**	**E**	**LC**	**Total (lbs-ft)**	(Includes H_f factor)
LC1	0	0	100108	0	0	0	0	0.0	LC1	**0.0**	
LC2	0	0	100108	0	0	0	160173	0.0	LC2	**160173.4**	
LC3	0	0	100108	0	0	0	100108	0.0	LC3	**100108.4**	
0	0	0	100108	0	0	0	0	0.0	0	**0.0**	
0	0	0	100108	0	0	0	0	0.0	0	**0.0**	
0	0	0	0	0	0	0	0	0.0	0	**0.0**	
0	0	0	0	0	0	0	0	0.0	0	**0.0**	
0	0	0	0	0	0	0	0	0.0	0	**0.0**	
0	0	0	0	0	0	0	0	0.0	0	**0.0**	

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Yellowstone Pump House Wing Walls Design

Wall Properties

	Driving	Resisting
Base of Wall Elev	32.00	
Soil Elev for Horiz Loads	54.00	
Groundwater EL	32.00	
Max Pumphouse Water Elev	32.00	

Material Properties
Soil Properties

γ_{sat}	125.00	pcf
γ_{moist}	120.00	pcf
γ_b	62.60	pcf
ϕ	0.56	rad
β	0.00	rad
ϕ	32.00	deg
β	0.00	deg

Water Properties

γ_{water}	62.40	pcf

Seismic
Loading Information

PGA (L1)	0.031	g
$k_{h,\ L1}$	0.021	g

Structure Properties

fy	60	ksi	
d @ base	22	in	2' wall
f'c	5	ksi	
beff	12	in	
ϕ flexure	0.9		
ϕ shear	0.75		
Wall Height	22	ft	

Pump Pit Foundation Wall Design - Assume Wall Spans Horizontally

Wall at Base of Pit

Wall Height	l	22.00	ft	
Wall Positive Design Moment	Mu	88056	lb-ft	Bending About Base of Wall
	Mu	1056670	lb-in	
	Mu	1057	k-in	
Wall Negative Design Moment	Mu	88056	lb-ft	Set Negative moment same as positive moment, to be conservative
	Mu	1056670	lb-in	
	Mu	1057	k-in	
Wall Shear At Base	Vu	11577	lbs/ft	
	Vu	12	kips/ft	

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Yellowstone Pump House Wing Walls Design

Wall Flexure Reinforcing Design

I.F. Bar Spacing	6	in
As	0.6	in^2
As tot	1.2	in^2/ft
ϕMn	1380	k-in
CHECK ϕMn>Mu	**OK**	So, #7 Bars at 6in OC, I.F.

O.F. Bar Spacing	6	in
As	0.6	in^2
As tot	1.2	in^2/ft
ϕMn	1380	k-in
CHECK ϕMn>Mu	**OK**	So, #7 Bars at 6in OC, O.F.

Check I.F. Minimum Flexural Steel

A_{smin}	0.93	in^2/ft
CHECK As>=Asmin	**OK**	
CHECK As>=(4/3)AsREQUIRED	**NG**	ACI 318-11 10.5.3

Check O.F. Minimum Flexural Steel

A_{smin}	0.93	in^2/ft
CHECK As>=Asmin	**OK**	
CHECK As>=(4/3)AsREQUIRED	**NG**	ACI 318-11 10.5.3

Wall Vert Flexure Reinforcing Design

Provide Min Flexure Steel in Horiz Direction #6 at 12" Each Face

Wall Shear Reinforcing Design

Vc	37335.2	lbs/ft
Vc	37.3	kips/ft
CHECK ϕ.5Vc>= Vu	**OK**	So shear steel required

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Yellowstone Pump House Wing Walls Design			
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Yellowstone Pump House Wing Walls Design

Wall Properties

	Driving	Resisting
Base of Wall Elev	32.00	
Soil Elev for Horiz Loads	54.00	
Groundwater EL	32.00	
Max Pumphouse Water Elev	32.00	

Material Properties

Soil Properties

γ_{sat}	125.00	pcf
γ_{moist}	120.00	pcf
γ_b	62.60	pcf
ϕ	0.56	rad
β	0.00	rad
ϕ	32.00	deg
β	0.00	deg

Water Properties

γ_{water}	62.40	pcf

Seismic

Loading Information

PGA (L1)	0.031	g
$k_{h,\ L1}$	0.021	g

Structure Properties

fy	60	ksi	
d @ base	28	in	2' 6" wall
f'c	5	ksi	
beff	12	in	
ϕ flexure	0.9		
ϕ shear	0.75		
Wall Height	22	ft	

Pump Pit Foundation Wall Design - Assume Wall Spans Horizontally

Wall at Base of Pit

Wall Height	l	22.00	ft	
Wall Positive Design Moment	Mu	160173	lb-ft	Bending About Base of Wall
	Mu	1922081	lb-in	
	Mu	1922	k-in	
Wall Negative Design Moment	Mu	160173	lb-ft	Set Negative moment same as positive moment, to be conservative
	Mu	1922081	lb-in	
	Mu	1922	k-in	
Wall Shear At Base	Vu	21842	lbs/ft	
	Vu	22	kips/ft	

Template Created: 21-May-10
Pump House Foundation Analysis.xlsm

CALCULATIONS

Project:	*Yellowstone*	**Sheet:**	29	**of**	29
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Document No.		**Backchecked:**		**Date:**	*3/17/16*

Yellowstone Pump House Wing Walls Design

Wall Flexure Reinforcing Design

I.F. Bar Spacing	9	in	
As	1	in^2	
As tot	1.33333333	in^2/ft	
ϕMn	1960	k-in	
CHECK ϕMn>Mu	**OK**		So, #7 Bars at 6in OC, I.F.
O.F. Bar Spacing	9	in	
As	1	in^2	
As tot	1.33333333	in^2/ft	
ϕMn	1960	k-in	
CHECK ϕMn>Mu	**OK**		So, #7 Bars at 6in OC, O.F.

Check I.F. Minimum Flexural Steel

A_{smin}	1.19	in^2/ft	
CHECK As>=Asmin	**OK**		
CHECK As>=(4/3)AsREQUIRED	**NG**		ACI 318-11 10.5.3

Check O.F. Minimum Flexural Steel

A_{smin}	1.19	in^2/ft	
CHECK As>=Asmin	**OK**		
CHECK As>=(4/3)AsREQUIRED	**NG**		ACI 318-11 10.5.3

Wall Vert Flexure Reinforcing Design

Provide Min Flexure Steel in Horiz Direction — #6 at 12" Each Face

Wall Shear Reinforcing Design

Vc	47517.6	lbs/ft
Vc	47.5	kips/ft
CHECK ϕ.5Vc>= Vu	**OK**	

INPUT	OUTPUT

TETRA TECH

Job No.: 100-SET-T35234

Project: Lower Yellowstone River
Subject: Multiple Pump Station Alternative
Design Topic: Inverted Siphon Design across Site 3 Intake Canal
Made By: JPP **Date:** 12-Feb-16 **Chk'd By:** FMB **Date:** 3/1/16

1.0 ISSUE BEING ADDRESSED

The intake canal to the pump station at Site 3 crosses Lateral HH.

2.0 APPROACH

Provide the conceptual design of an inverted siphon to pass Lateral HH underneath the intake canal to Site 3.

3.0 REFERENCES

References used in this calculation are as follows:

1) Design of Small Canal Structures, USBR, 1978

4.0 ASSUMPTIONS

1) The invert of the intake canal is 8.7' below the existing ground at the crossing.
2) Lateral HH is flowing 1.5' deep, carrying 5.0 cfs at the crossing. The invert of lateral HH is 2.5' below the existing ground elevation.

5.0 CALCULATIONS

1) Calculate the approximate elevations of the crossing features.

Distance from riverbank	600	feet
EG Elevation at riverbank	1949.6	feet
EG Slope from riverbank	1.46%	
EG El. at crossing	1958.4	feet
Intake canal depth at river	2.5	feet
Intake canal slope	0.10%	
Intake canal IE at crossing	1946.5	feet
Lateral HH depth (from existing)	2.5	
Lateral HH IE at crossing	1955.9	feet

2) Calculate the allowable head loss through the siphon.

Siphon Distance	200	feet
Lateral HH slope	0.08%	
Allowable head loss	0.160	feet

3) Calculate head losses in the siphon.

Lateral flow rate	5	cfs	
Siphon diameter	2.0	feet	
Siphon area	3.14	SF	
Siphon velocity	1.59	ft/s	
Inlet loss coefficient	0.40		
Inlet head loss	0.02	feet	
Siphon pipe length	200	feet	
manning loss coefficient (n)	0.013		
Pipe friction losses	0.10	feet	(calculated by Manning equation)
Bend losses for 2-22.5° bends	0.01	feet	
Outlet loss coefficient	0.70		
Outlet head loss	0.03	feet	
Total head loss	0.15	feet	
Allowable head loss / total head loss	109%		

Attachment 6
Outlet Structure Design

				Job No.:	100-SET-T35234		
Project:	Lower Yellowstone River						
Subject:	Multiple Pump Station Alternative						
Design Topic:	Discharge Pipeline Outlet Structures						
Made By:	JPP	**Date:**	22-Feb-16	**Chk'd By:**	FMB	**Date:**	3/1/16

1.0 ISSUE BEING ADDRESSED

Calculate the size and type of concrete outlet structures required for the discharge pipelines.

2.0 APPROACH

Use criteria in USBR's Design of Small Canals and provide a conceptual design dimensions for a concrete outlet structure, using criteria stated in Chapter 7.

3.0 REFERENCES

References used in this calculation are as follows:

1) Design of Small Canals, USBR, 1978
2) Lower Yellowstone Project, Canal System and Operating Maps, USBR, 1923

4.0 ASSUMPTIONS

1) Water depth in the irrigation canal will be as shown on the existing design drawings, listed as reference 2.
2) Wall thickness is approximated for conceptual design by extrapolating values listed in reference 1.
3) All dimensions are shown in feet.
4) The outlet is at a 22.5° angle to the water surface in the canal.

5.0 CALCULATIONS

1) Recommend that a Type 1 transition be used. Velocity in the discharge pipelines is between 3.5 - 10 ft/s, and the outlet pipe will be close to horizontal at discharge.[Ref 1]

2) Determine the approximate water depth at each discharge point, as shown on existing design drawings.
[Ref 2]

Site	Canal Depth	Canal WSEL	Canal IE
Site 1	10	1988.5	1978.5
Site 2	10	1984.4	1974.4
Site 3	10	1981.5	1971.5
Site 4	10	1979.5	1969.5
Site 5	10	1979.3	1969.3

TETRA TECH **Job No.:** 100-SET-T35234

Project: Lower Yellowstone River
Subject: Multiple Pump Station Alternative
Design Topic: Discharge Pipeline Outlet Structures
Made By: JPP **Date:** 22-Feb-16 **Chk'd By:** FMB **Date:** 3/1/16

3) Calculate the minimum dimensions of the concrete outlet structure. [Ref 1]

	Site 1	Site 2	Site 3	Site 4	Site 5	Formula
Pipe Dia (D)	6.0	7.0	7.0	7.0	7.0	Design value
Length (L)	18.0	21.0	21.0	21.0	21.0	L = 3*D
Invert Width (B)	1.8	2.1	2.1	2.1	2.1	B = 0.303 * D
Base Width (C)	3.0	3.5	3.5	3.5	3.5	C = 0.5 * D
Canal Depth (d)	10.0	10.0	10.0	10.0	10.0	Existing [Ref 1]
Freeboard (FB)	3.8	3.8	3.8	3.8	3.8	Ref 2, Figure 1-9
Depth+FB (y)	13.8	13.8	13.8	13.8	13.8	y = d + FB
Side Width (SW)	20.0	20.0	20.0	20.0	20.0	1.5*(y-0.5)
Outlet Width (OW)	42.9	43.4	43.4	43.4	43.4	OW = C + 2*SW
Wall Ht	13.8	13.8	13.8	13.8	13.8	d + FB
Wall thickness (tw)	1.5	1.5	1.5	1.5	1.5	tw = 8" * 14'/6'
Cutoff depth (e)	3.0	3.0	3.0	3.0	3.0	e = 3' where d > 6'.

4) Provide erosion protection downstream of each structure. [Ref 1]

Use Type 4 (18" riprap protection on 6" band and gravel bedding) for pipe diameter over 3.5'.
Minimum Length is 2.5 * canal depth (25'), adjust per site geometry.

Attachment 7
Electrical Design

TETRA TECH

Job No.: 100-SET-T35234

Project: Lower Yellowstone River
Subject: Multiple Pump Station Alternative
Design Topic: Average Annual Energy Consumption
Made By: JPP **Date:** 18-Mar-16 **Chk'd By:** FMB **Date:** 21-Mar-16

1.0 ISSUE BEING ADDRESSED

Calculate the average estimated annual power consumption for the multiple pump station alternative.

2.0 APPROACH

Calculate the average number of days per year when gravity diversions permit the use of 1, 2, and 3 pump stations based on results of the gravity flow potential model. Then calculate the power demand in each mode based on the number of days the pumping stations are in that mode and the power demand in that mode.

3.0 REFERENCES

References used in this calculation are as follows:

1) Gravity flow potential technical memo, TetraTech, 2016
2) Pump sizing calculations, TetraTech, 2016.

4.0 ASSUMPTIONS

1) A total diversion of 1100 cfs is required at all times during the irrigation season.
2) Pumped inflows from pumping stations 1 and 2 cannot be used simultaneously with gravity inflow from the existing headworks due to backwater effects. Pumping stations 3-5 can be used simultaneously, provided the most downstream station is used first.
3) Variation in the pump flow rates due to changes in the river WSEL will be small and can be ignored.

5.0 CALCULATIONS

Number of days in irrigation period (May - September)	152	
Power demand at each pumping station[Ref 2]:		
Site 1	400	kW
Site 2	1000	kW
Site 3	1400	kW
Site 4	1700	kW
Site 5	1700	kW
Lateral Diversion Pumping Stations (total)	50	kW

Pump Stations in Use:	**None**	**Site 5 Only**	**Sites 4 & 5**	**Sites 3-5**	**All Sites**
Pumped Diversion Flow Rate (cfs)	0	275	550	825	1100
Gravity Diversion Flow Rate, Qg (cfs)	1100	825	550	275	0
Days when gravity could supply Qg[Ref 1, Table 3]	27%	42%	68%	97%	100%
Days operated in only this mode	27%	15%	25%	29%	3%
Number of days in this mode per year	42	22	39	44	5
Power Demand (kW)	0	1750	3450	4850	6250
Energy consumed (GigaWatt hours)	0.0	0.9	3.2	5.1	0.8

Average Annual Energy Consumption: **10.1 Gigawatt hours per year**

Gravity Diversion Potential without Intake Diversion Dam

Date: 2016-05-17

1.1 Purpose

The purpose of this analysis is to expand on the preliminary analysis of gravity diversion potential without the presence of the Intake Diversion Dam (Corps, 2010). Flow duration curves were evaluated on a monthly basis from May through September to provide additional detail on potential pumping requirements. Flow duration tables were developed for each of the months and for the 5-month irrigation season. The feasibility of partially diverting a portion of the canal supply requirement when the river stage is below that required for the maximum diversion rate depends on whether the intake gates need to be shut to prevent reverse flow in the canal, which is not accounted for in the analysis presented in this attachment. The hydraulic model of the canal was used to evaluate the potential for reverse flow and could result in greatly restricting or eliminating the ability to simultaneously supply the canal with both gravity diversion from the intake and pumping from downstream points.

1.1.1 Background and Methodology

Preliminary analysis by the Corps indicated that 1,374 cfs could be diverted at the Intake Diversion Dam site when flow at that location exceeded 25,000 cfs at the Sydney Gage. Based on the flow duration curves for the Sydney Gage from May through September, the required flow to divert 1,374 cfs is exceeded approximately 23 percent of the time.

The calculations are based on four types of information, which include a flow versus stage rating curve for the Yellowstone River at the Intake Diversion Dam site without the influence of the dam, a flow versus stage rating curve for the upstream end of the diversion canal, head-loss across the intake screens and gates between the Yellowstone River and the canal, and flow duration curves for the Sydney gage (USGS #06329500). The first three pieces of information are combined to develop a rating curve of flow in the Yellowstone River versus potential diversion flow into the canal. Since the flow at the diversion point is required input, the flow duration curves at the Sydney gage are augmented by an average diversion discharge of 1,100 cfs. The 1,100 cfs represents the average diversion of 327,000 ac-ft (Reclamation and Corps, 2010) over the 5 month diversion period from May through September.

The primary difference between this analysis and the preliminary analysis by the Corps is in the details associated with removal of the influence of the diversion dam from the HEC-RAS model. Both models removed the dam, rock ramp downstream of the dam, the scour hole at the downstream end of the rock ramp, and generally lowered bed elevations upstream of the dam to represent mobilization of deposited sediment. This analysis maintained the pools and riffles (crossings) where the Corps model generally filled the pools. This difference lowers the water surface at the diversion point for a given discharge and slightly reduces the potential gravity flow for the analysis presented in this TM compared with the analysis conducted by the Corps.

As a final step, a hydraulic model of the canal was used to simulate a range of pumping conditions. This model was used to assess whether the pumped flows would backwater the canal inlet structure and limit or eliminate gravity diversions.

1.1.2 Results

Figure 1 shows the rating curve of stage versus discharge in the canal. From this starting point the stage in the Yellowstone River required to divert the canal discharge based only on gravity was estimated based on between 0.7 and 1.0 feet of head loss through the canal and gates. No flow can be diverted below elevation 1983.4, which is the sill elevation of the gates and the bottom elevation of the cylindrical screens (Corps, 2010). Also shown on Figure 1 is the discharge that would be allowable for three operations that do not exceed 0.4 fps through the screens (all 12 screens with the screen velocity of 0.34 fps, 11 screens operating at 0.37 fps, and 12 screens with a maximum velocity of 0.4 fps). For any diversion discharge the required water surface in the Yellowstone River is higher than the water surface based on limiting screen velocity. Therefore, the rating curves based on the head loss assumption control gravity flow into the canal. Note that this analysis indicates that a water surface elevation of 1989.5 ft NAVD88 in the Yellowstone River is required to limit fish screen velocity to 0.4 fps at a discharge of 1,374 cfs, which is based on the screen configuration by the Corps (Corps, 2010). An earlier analysis (Corps, 2009) had indicated that the full 1,374 cfs diversion could be made at a lower elevation of 1987 ft NAVD88, but this was for a different alternative of screen size, number of screens, screen elevations.

The hydraulic modeling of the removal of Intake Diversion Dam focused on the gravity diversion potential assuming the complete removal of the diversion dam and downstream rock down to the prevailing natural bed elevations. The existing conditions HEC-RAS model was the starting point for the modeling. The first version of the “no-dam” model simply removed the cross sections representing the dam crest, downstream existing rock, and the scour hole at the downstream end of the rock. The model was run for the 2-year discharge to assess whether upstream deposition has occurred over the life of the dam. Figure 1 shows the channel bed and 2-year water surface profiles of the with-dam and first version of the no-dam models. Removal of the dam lowers the water surface immediately upstream of the dam by approximately 6 feet for the 2-year flow, but there is also a convexity in the 2-year water surface that likely indicates the presence of a wedge of sediment that has collected during the life of the dam.

The second version of the no-dam model represents an estimate of the future channel condition after the Yellowstone River has adjusted to the removal of the structure and rock. Based on the amount of convexity in the water surface profile, the sediment wedge was estimated be approximately 4 feet thick at the dam and tapering to zero feet at the upstream end of the model. The downstream channel was left unchanged assuming that over several years the sediment released from the wedge would distribute downstream and would have an indiscernible impact. The second version of the model shows no convexity in the water surface profile, so no further adjustments were made. This final model also includes a lateral structure representing the fish screens and gates. The lateral structure incorporates a stage-discharge rating curve for the canal that is offset assuming 1-ft of head loss across the screens and gates to estimate the required stage on the Yellowstone River to determine the potential gravity diversion flow.

When this model is run for a range of flows, the potential gravity diversion for the non-weir alternative is computed. Table 1 shows the flow duration values for the Yellowstone River at Sydney Gage (USGS gage # 06329500) (Corps 2006). Table 2 shows an estimate of the flow duration values upstream of Intake Diversion Dam by adding the average diversion of 1,100 cfs to the values at Sydney Gage. Table 3 shows the potential gravity diversion-flow duration curves based on the HEC-RAS modeling. The gravity diversion of 1,374 cfs could occur approximately 17 percent of the 5-month irrigation season based on 30,000 cfs in the Yellowstone River at Sidney, or approximately 31,400 cfs upstream of the canal headworks. Note that 30,000 cfs almost never occurs at the Sydney gage during August and September, which are historically low flow periods.

Figure 3 shows rating curves for a range of weir removal elevations and the preliminary complete dam removal analysis by the USACE. The Tetra Tech HEC-RAS model for complete dam removal results in lower water surface elevations at the diversion, so higher flows are required to divert the same flow into the canal, but are similar and confirm the general validity of USACE analysis. To divert the complete 1,374 cfs water right, the Corps analysis indicates that 25,000 cfs is required in the Yellowstone River, where the Tetra Tech analysis indicates that between 29,000 and 31,400 cfs are required, depending on the head loss assumption at the screens and gates (0.7 and 1.0 feet total head loss, respectively).

Table 3 and Figure 4 show the potential diversion based on the 1 ft head loss and flow duration curves for each month and the irrigation season over the entire range of flows included in the Yellowstone River flow duration curves. The complete curves can be used to estimate the amount of time that Yellowstone River flows would be adequate to provide gravity-only diversion and potential supplemental pumping requirements. The supplemental pumping would also affect canal hydraulics and potentially interfere with gravity flows as discussed in the next section.

1.1.3 Canal Hydraulics with Combined Pumping and Gravity Diversion

A HEC-RAS hydraulic model of the main irrigation canal was also developed to assess both existing conditions within the canal and changes in water surface elevation resulting from the pumping alternative. The model geometry was derived from a number of sources. Canal geometry for the upstream most four miles of the canal were extracted from a previous HEC-RAS model of the Yellowstone River covering the general location of the Intake Dam. Seven cross sections representing typical canal geometry were surveyed between canal miles 6.3 and 22.7, inclusive. The surveyed cross sections used to represent canal geometry from canal mile 6.3 to canal mile 47.0. Structures including the Burns Creek and Peabody Coulee Creek overchutes, and Prevost Check, NN Check and Gauge, and Crane Check and Gauge were also surveyed and included in the HEC-RAS model. Historical design drawings were then used to represent canal geometry for the remainder of the canal, from canal mile 47.0 to the terminal end of the canal at the confluence with the Missouri River. Roughness coefficients were adjusted to best match high water marks collected at the time of the survey.

The HEC-RAS model was used to model several flow scenarios within the main canal. It was assumed that gravity diversion of flows from the Yellowstone River at the headworks would be utilized concurrently with pumping until no longer feasible. Water surface elevations profiles were obtained for scenarios where gravity diversion provided all demand within the canal, and then gravity inflow at the headworks was reduced as each pump was turned on commensurate with the flows provided by each pump. Observed flows from July 6, 2012 which had a peak inflow of 1355 cfs at the headworks were also modeled to provide a comparison with expected maximum water surface elevations within the canal.

Figure 5 shows the results of the upper 20 miles of the HEC-RAS model developed for the LYIP main canal. This figure includes water surface profiles from complete gravity diversion, and various pumping sites with the remaining flow assumed to be providing the remaining flow needed for a total of 1,374 cfs. For example, the “WS Pump 5” profile assumes 1,110 cfs gravity and 274 cfs at pump 5. This figure illustrates the issues of operating a canal under combined pumping and gravity. Below station 280,000 the profiles are unchanged because the same amount of water has been supplied. When pumping is required, the areas upstream of Burns Creek Overchute would either require additional control structures or pumping from the channel, but below this point minimal modification would be required. Pumping from the canal is probably preferable because pumping a small amount of water from the canal at laterals AA, BB, CC, DD and FF is less costly than raising the water level and eliminating a much larger gravity-diverted flow.

Based on the water surface profiles and the water surface elevations at the upstream end of the canal for the various pumping scenarios, it appears that gravity diversion and pumping are compatible when the downstream pumping sites (3, 4 and 5) are operating, but when site 2 is added that there may not be sufficient head in the Yellowstone River for continued gravity diversion. Therefore, it is assumed that when pump site 2 is brought online then the head gates would be closed, gravity diversion would cease, and pump site 1 would also be brought online.

References:

Corps 2006, Lower Yellowstone Project Fish Passage and Screening Preliminary Design Report for Intake Diversion Dam, Appendix B, Hydrology.

Corps 2009, Lower Yellowstone Project Fish Passage and Screening Preliminary Design Report, Appendix A-2 Hydraulics, Draft Report.

Corps 2010, Rating Curves-Intake Screens/Gates, memorandum.

Reclamation 2013, Lower Yellowstone Fish Passage Alternatives Planning Study.

Reclamation and Corps. 2010. Intake Diversion Dam Modification, Lower Yellowstone Project, Montana, Final Environmental Assessment. Report and Appendixes.

Table 1. Flow duration for Sydney Gage (Corps, 2006)

Percent time exceeded	Diversion potential based on Yellowstone River flow duration, cfs					
	May	June	July	August	Sept	5 months
0.01	104,000	142,000	112,000	38,000	39,000	138,111
0.05	104,000	134,000	106,000	38,000	37,800	119,831
0.1	87,500	127,000	101,000	37,000	33,700	109,633
0.2	82,900	121,000	85,000	34,000	29,000	98,448
0.5	61,900	108,000	80,000	28,000	22,000	83,942
1	53,200	93,000	73,200	25,400	17,900	72,147
2	48,000	84,600	66,900	22,600	15,300	58,575
5	35,900	59,900	44,000	16,800	12,800	47,299
10	31,100	54,700	37,500	13,800	11,500	37,534
15	27,000	49,900	33,500	12,400	10,500	31,687
20	23,300	46,200	30,300	11,500	9,710	27,478
30	19,400	40,500	26,300	9,890	8,780	20,331
40	16,900	35,400	21,800	8,230	7,820	15,441
50	14,800	30,700	17,100	7,080	6,660	12,241
60	13,200	26,800	14,100	6,010	5,710	9,889
70	11,500	22,700	11,100	4,810	4,970	7,872
80	9,770	18,700	7,780	3,980	4,320	6,052
85	8,450	16,900	6,700	3,490	3,910	5,204
90	7,560	14,900	5,730	2,710	3,600	4,378
95	6,230	12,400	4,930	1,770	3,060	3,455
98	5,260	10,000	3,910	1,470	2,330	2,298
99	4,530	8,570	3,590	1,390	2,020	1,703
99.5	2,900	7,730	3,130	1,330	1,610	1,490
99.8	2,380	7,090	2,460	1,260	1,460	1,381
99.9	2,030	6,530	2,370	1,220	1,410	1,324
99.95	1,980	6,500	2,310	1,190	1,380	1,270
99.99	1,940	6,480	2,190	1,130	1,320	1,150

Table 2. Approximate flow duration above Intake Diversion Dam (Tetra Tech, 2016)

Percent time exceeded	Diversion potential based on Yellowstone River flow duration, cfs					
	May	June	July	August	Sept	5 months
0.01	105,100	143,100	113,100	39,100	40,100	139,211
0.05	105,100	135,100	107,100	39,100	38,900	120,931
0.1	88,600	128,100	102,100	38,100	34,800	110,733
0.2	84,000	122,100	86,100	35,100	30,100	99,548
0.5	63,000	109,100	81,100	29,100	23,100	85,042
1	54,300	94,100	74,300	26,500	19,000	73,247
2	49,100	85,700	68,000	23,700	16,400	59,675
5	37,000	61,000	45,100	17,900	13,900	48,399
10	32,200	55,800	38,600	14,900	12,600	38,634
15	28,100	51,000	34,600	13,500	11,600	32,787
20	24,400	47,300	31,400	12,600	10,810	28,578
30	20,500	41,600	27,400	10,990	9,880	21,431
40	18,000	36,500	22,900	9,330	8,920	16,541
50	15,900	31,800	18,200	8,180	7,760	13,341
60	14,300	27,900	15,200	7,110	6,810	10,989
70	12,600	23,800	12,200	5,910	6,070	8,972
80	10,870	19,800	8,880	5,080	5,420	7,152
85	9,550	18,000	7,800	4,590	5,010	6,304
90	8,660	16,000	6,830	3,810	4,700	5,478
95	7,330	13,500	6,030	2,870	4,160	4,555
98	6,360	11,100	5,010	2,570	3,430	3,398
99	5,630	9,670	4,690	2,490	3,120	2,803
99.5	4,000	8,830	4,230	2,430	2,710	2,590
99.8	3,480	8,190	3,560	2,360	2,560	2,481
99.9	3,130	7,630	3,470	2,320	2,510	2,424
99.95	3,080	7,600	3,410	2,290	2,480	2,370
99.99	3,040	7,580	3,290	2,230	2,420	2,250

Table 3. Flow duration of potential gravity diversions based on 1 foot head loss (Tetra Tech, 2016)

Percent time exceeded	Diversion potential based on Yellowstone River flow duration, cfs					
	May	June	July	August	Sept	5 months
0.01	1,374	1,374	1,374	1,374	1,374	1,374
0.05	1,374	1,374	1,374	1,374	1,374	1,374
0.1	1,374	1,374	1,374	1,374	1,374	1,374
0.2	1,374	1,374	1,374	1,374	1,331	1,374
0.5	1,374	1,374	1,374	1,302	1,095	1,374
1	1,374	1,374	1,374	1,214	946	1,374
2	1,374	1,374	1,374	1,116	847	1,374
5	1,374	1,374	1,374	904	748	1,374
10	1,374	1,374	1,374	790	692	1,374
15	1,269	1,374	1,374	731	647	1,374
20	1,141	1,374	1,374	692	612	1,282
30	1,002	1,374	1,245	620	569	1,035
40	908	1,374	1,088	544	525	853
50	828	1,374	916	491	472	724
60	765	1,262	801	442	427	620
70	692	1,120	674	379	387	527
80	614	977	523	334	352	443
85	554	908	474	308	331	400
90	513	832	428	267	314	356
95	452	731	385	215	286	307
98	403	625	331	192	247	245
99	364	559	314	187	231	210
99.5	277	521	289	182	203	194
99.8	250	492	254	177	192	186
99.9	231	466	249	174	188	182
99.95	229	464	246	172	186	177
99.99	227	464	240	167	181	169

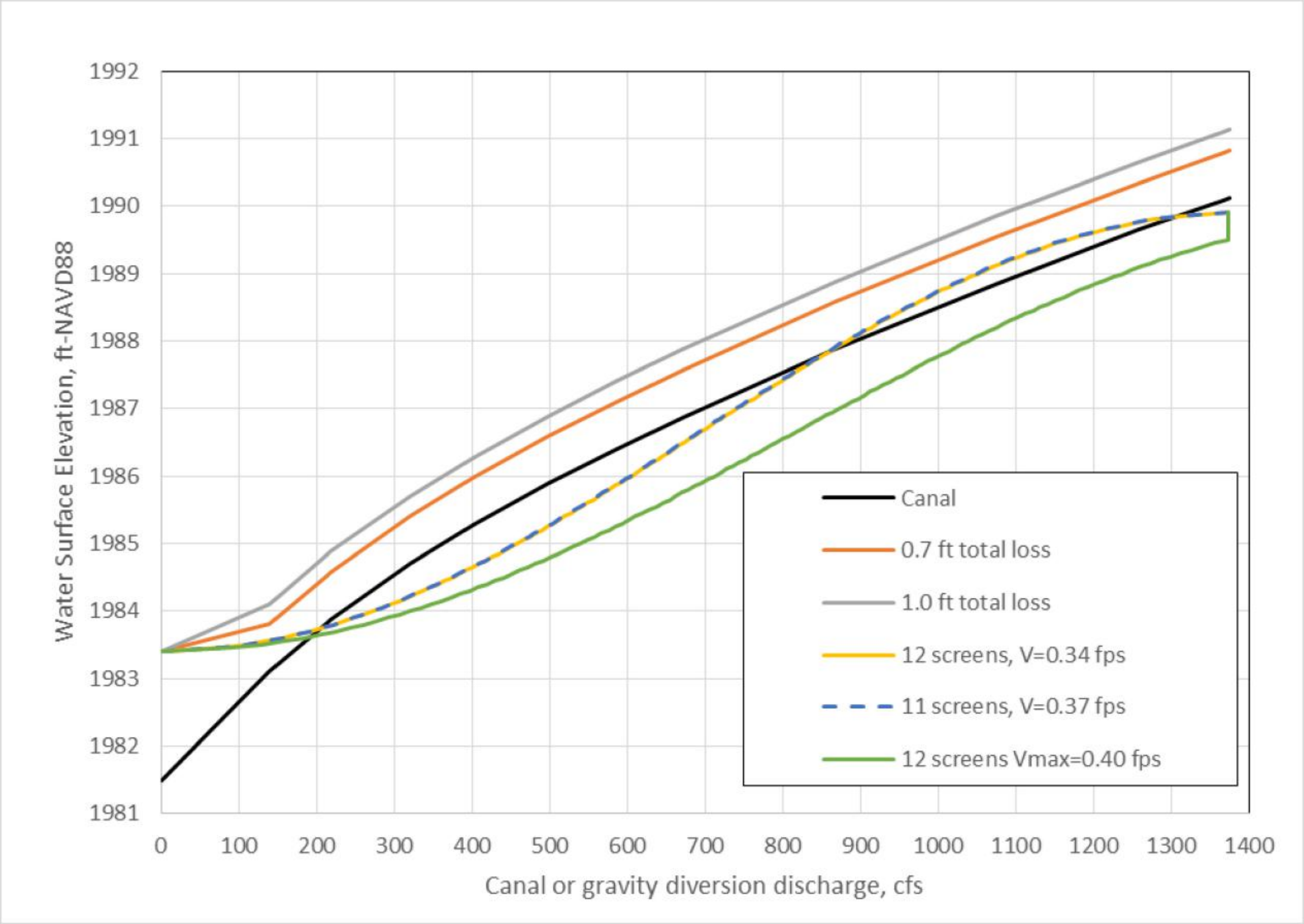


Figure 1. Stage-Discharge Rating Curves for Canal and Yellowstone River (Tetra Tech, 2016)

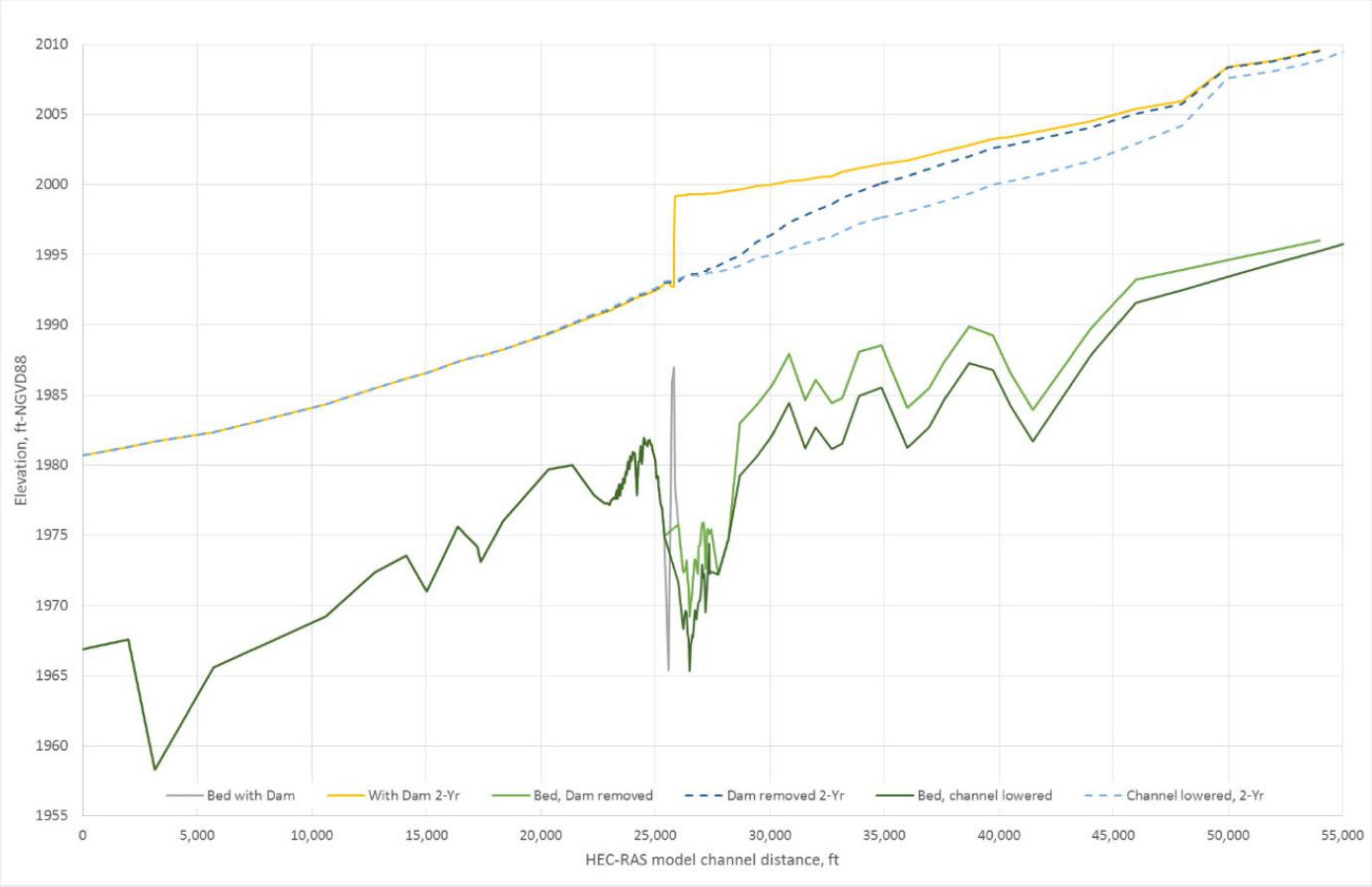
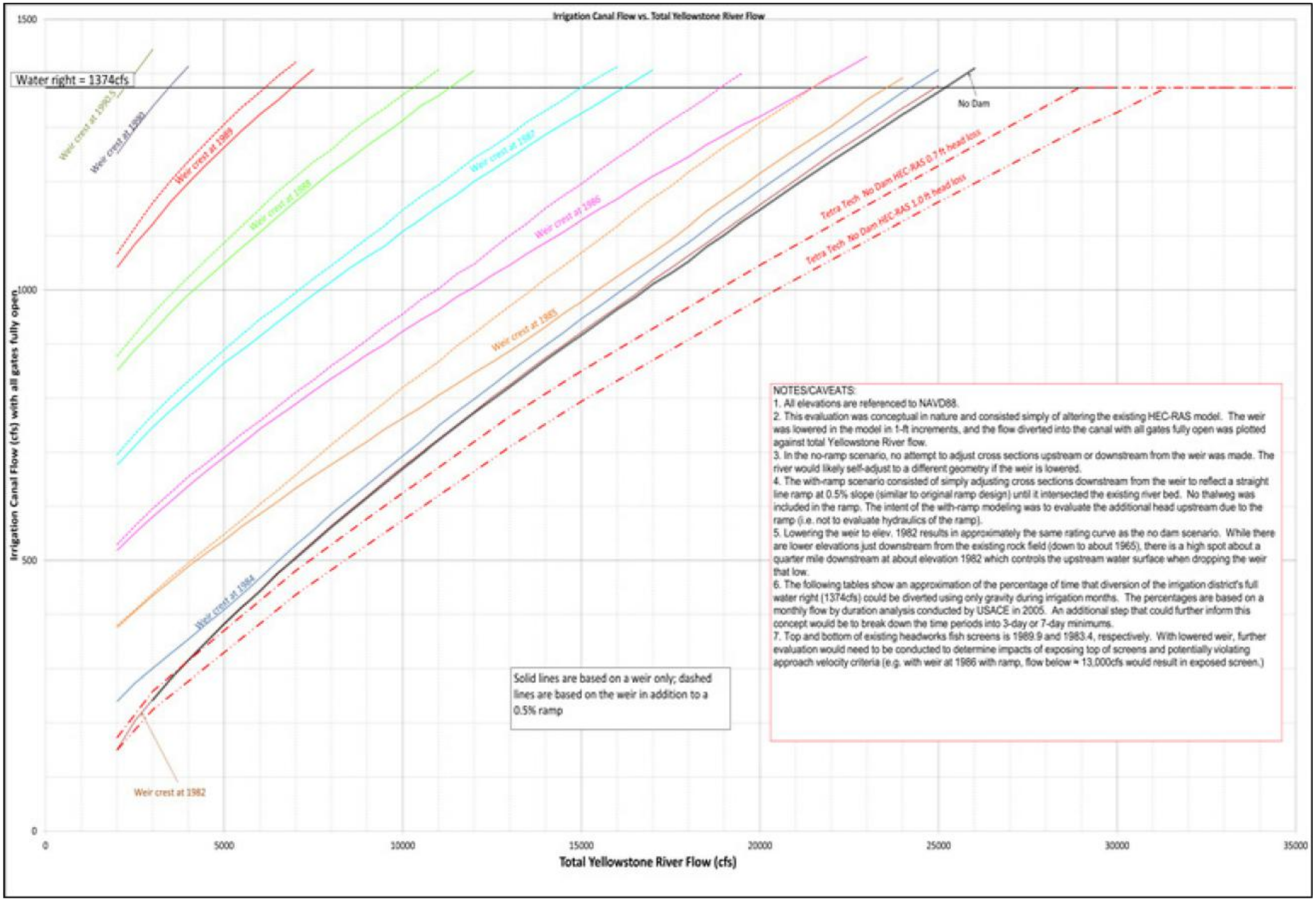


Figure 2. Yellowstone River profiles for existing conditions and dam removal (Tetra Tech, 2016)



Solid lines are based on a weir only; dashed lines are based on the weir in addition to a 0.5% ramp

NOTES/CAVEATS:
1. All elevations are referenced to NAVD88.
2. This evaluation was conceptual in nature and consisted simply of altering the existing HEC-RAS model. The weir was lowered in the model in 1-ft increments, and the flow diverted into the canal with all gates fully open was plotted against total Yellowstone River flow.
3. In the no-ramp scenario, no attempt to adjust cross sections upstream or downstream from the weir was made. The river would likely self-adjust to a different geometry if the weir is lowered.
4. The with-ramp scenario consisted of simply adjusting cross sections downstream from the weir to reflect a straight line ramp at 0.5% slope (similar to original ramp design) until it intersected the existing river bed. No thalweg was included in the ramp. The intent of the with-ramp modeling was to evaluate the additional head upstream due to the ramp (i.e. not to evaluate hydraulics of the ramp).
5. Lowering the weir to elev. 1982 results in approximately the same rating curve as the no dam scenario. While there are lower elevations just downstream from the existing rock field (down to about 1965), there is a high spot about a quarter mile downstream at about elevation 1982 which controls the upstream water surface when dropping the weir that low.
6. The following tables show an approximation of the percentage of time that diversion of the irrigation district's full water right (1374cfs) could be diverted using only gravity during irrigation months. The percentages are based on a monthly flow by duration analysis conducted by USACE in 2005. An additional step that could further inform this concept would be to break down the time periods into 3-day or 7-day minimums.
7. Top and bottom of existing headworks fish screens is 1989.9 and 1983.4, respectively. With lowered weir, further evaluation would need to be conducted to determine impacts of exposing top of screens and potentially violating approach velocity criteria (e.g. with weir at 1986 with ramp, flow below ≈ 13,000cfs would result in exposed screen.)

Figure 3. Yellowstone River flow versus potential canal flow (Tetra Tech 2016, adapted from Reclamation, 2013)

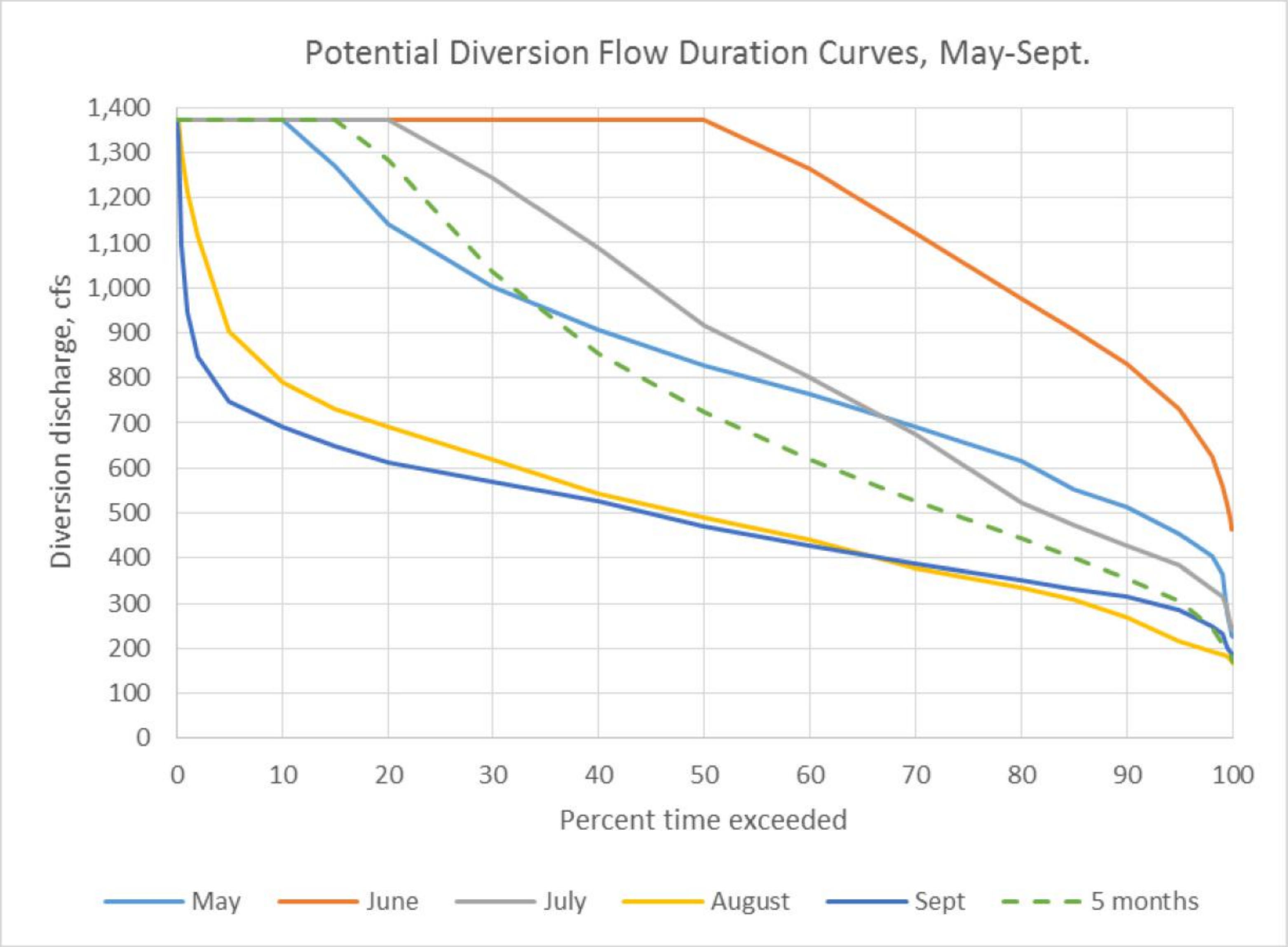


Figure 4. Potential diversion flow duration curves based on Tetra Tech hydraulic model and 1.0 feet of head loss across screens.

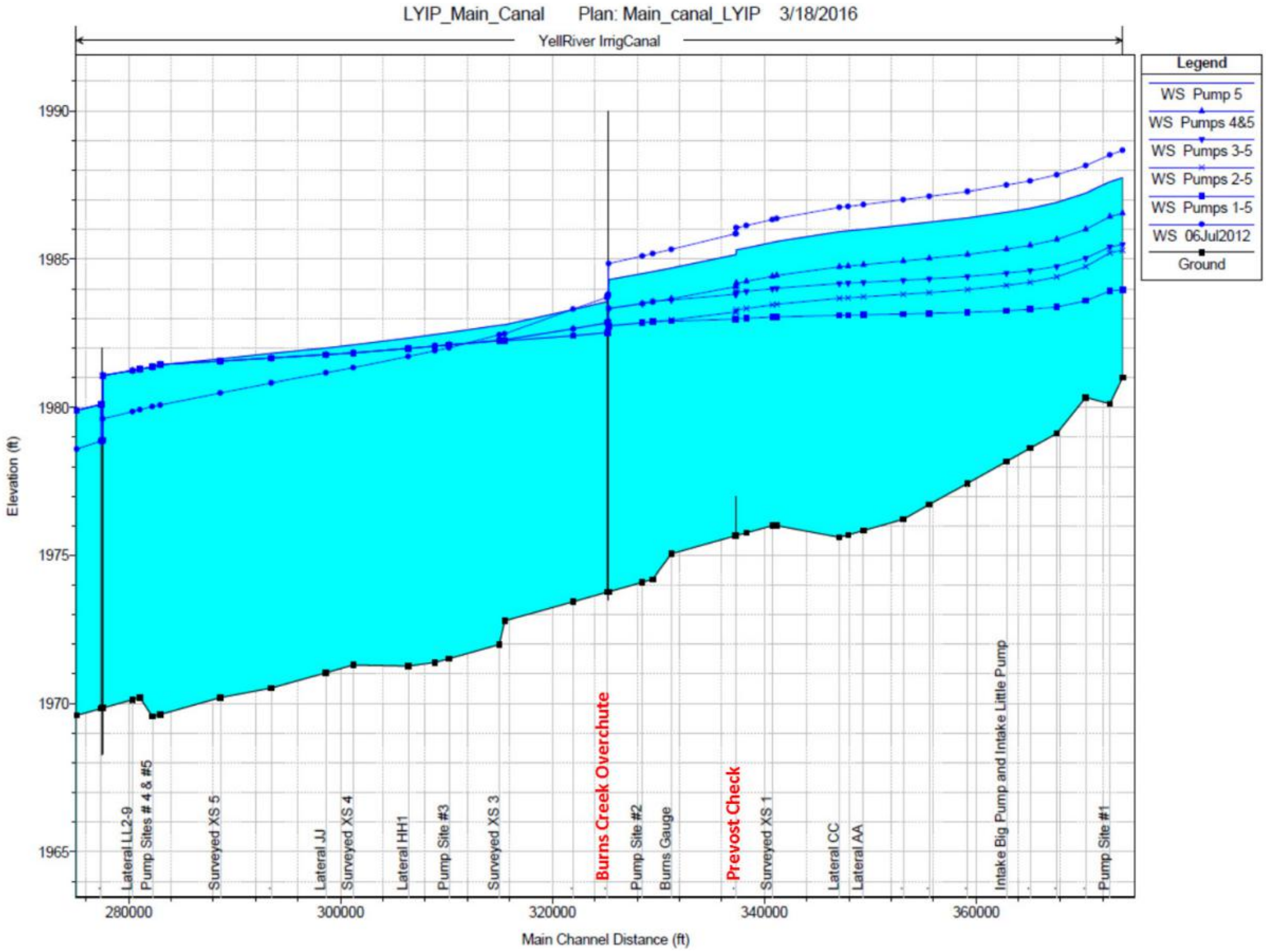


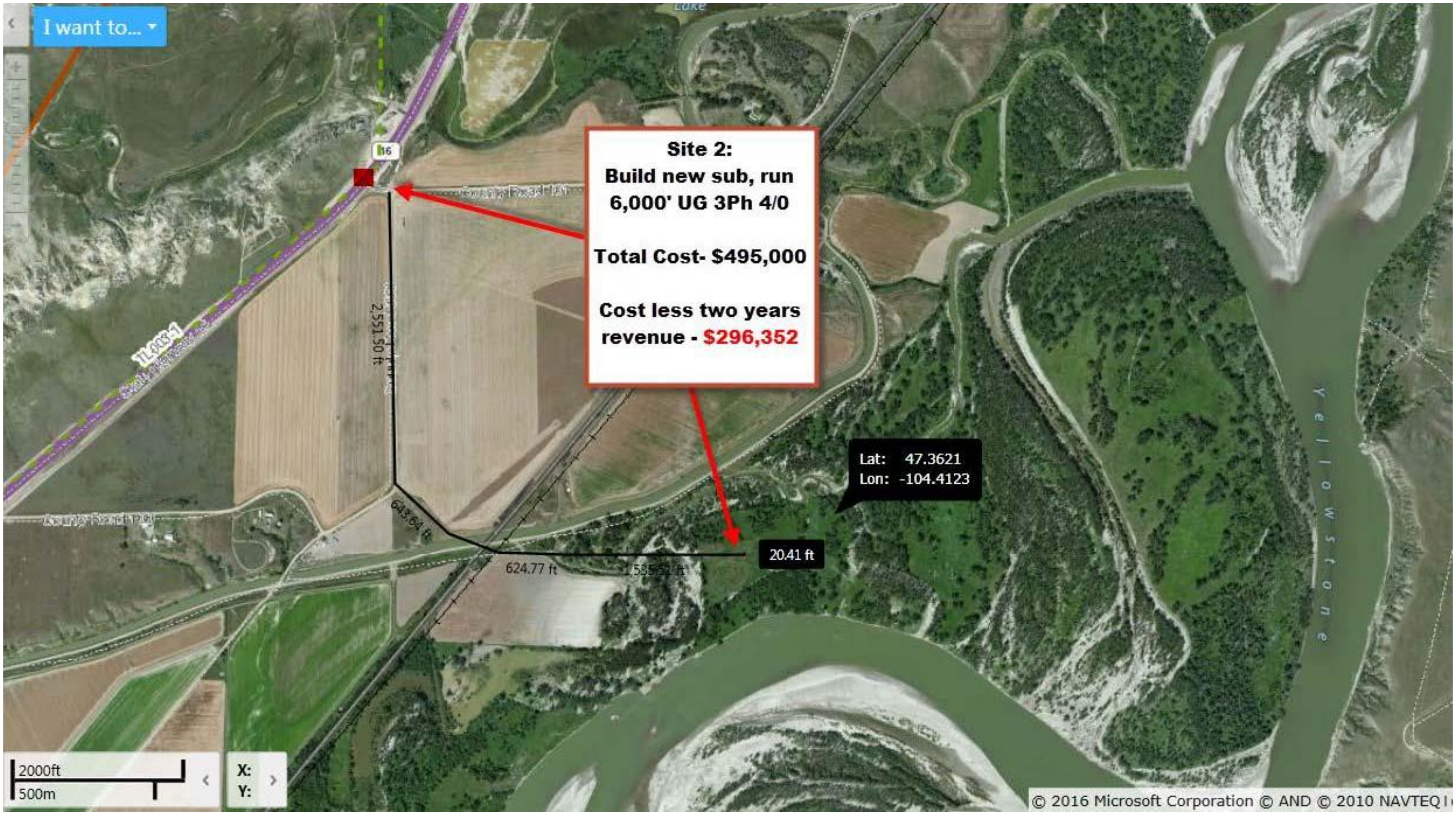
Figure 5. LYIP Main Canal water surface profiles (Tetra Tech, 2016)

Site 1:
Run 6,600' UG 3Ph
4/0 primary

Total Cost- $133,071

Cost less two years revenue - $12,535

Site 1 - Power System Uprating Estimate from MDU

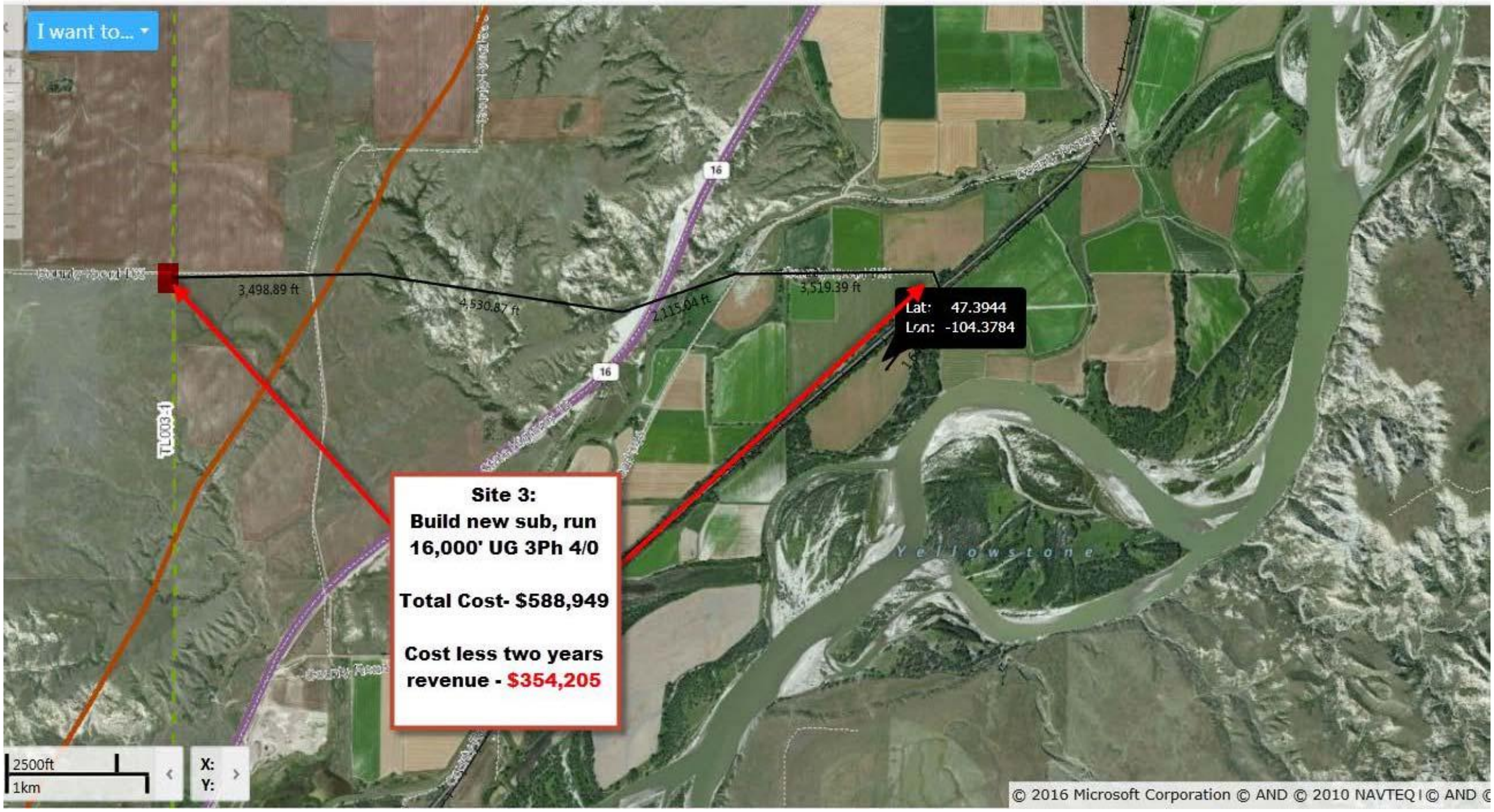


Site 2:
Build new sub, run 6,000' UG 3Ph 4/0

Total Cost- $495,000

Cost less two years revenue - $296,352

Site 2 - Power System Uprating Estimate from MDU

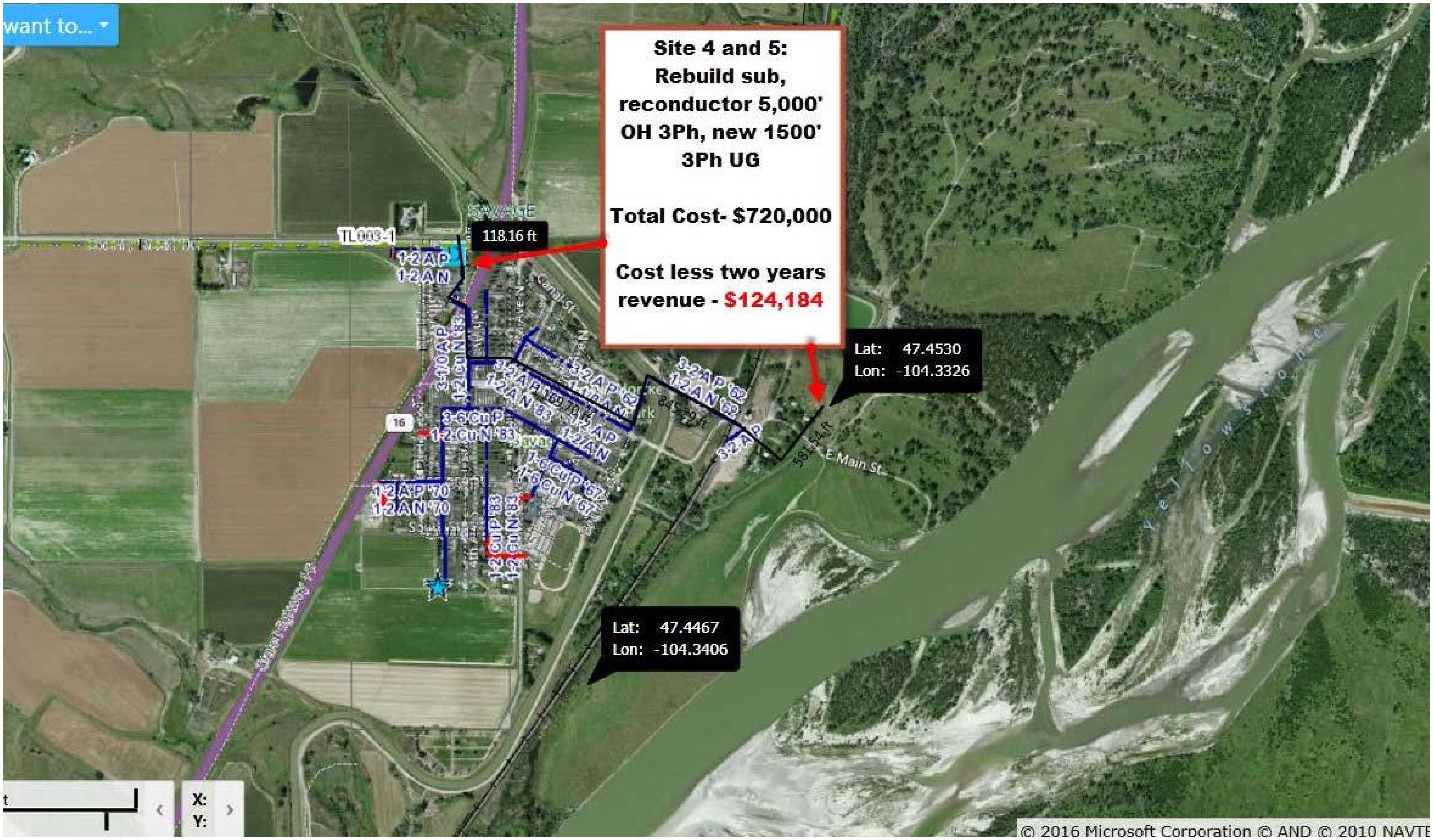


Site 3:
Build new sub, run 16,000' UG 3Ph 4/0

Total Cost- $588,949

Cost less two years revenue - $354,205

Site 3 - Power System Uprating Estimate from MDU



Site 4 and 5:
Rebuild sub, reconductor 5,000' OH 3Ph, new 1500' 3Ph UG

Total Cost- $720,000

Cost less two years revenue - $124,184

Lat: 47.4530
Lon: -104.3326

Lat: 47.4467
Lon: -104.3406

Sites 4 and 5 - Power System Uprating Estimate from MDU

Chin, Ginette

From: Tom Tomlinson <tom.tomlinson@cummins.com>
Sent: Wednesday, February 24, 2016 3:30 PM
To: Chin, Ginette
Subject: RE: Generator planning study pricing

Budget numbers

5 pump stations:

Station 1: (3) 170 Hp motors, (1) 30kW fish pump – recommended generator: ~~750DQFAE~~
500 kW, 48 hour tank, WPE no sound attenuation $120,000 Adder for 75 dBA $10,000

Station 2: (3) 426 Hp motors, (1) 30kW fish pump – recommended generator~~: 1750DQKAK~~
1250 kW, same $450,000 Adder for 75 dBA $50,000

Station 3: (3) 535 Hp motors, (1) 30kW fish pump – recommended generator: ~~1750DQKAK~~
1750 kW, 48 hour tank, WPE no sound attenuation $625,000 Adder for 75 dBA $65,000

Station 4: (3) 630 Hp motors, (1) 30kW fish pump – recommended generator~~: 1750DQKAK~~
1750 kW, 48 hour tank, WPE no sound attenuation $625,000 Adder for 75 dBA $65,000

Station 5: (3) 683 Hp motors, (1) 30kW fish pump – recommended generator: ~~1750DQKAK~~
2000 kW, 48 hour tank, WPE no sound attenuation $675,000 Adder for 75 dBA $65,000

I have attached the Recommended Generator Reports for your information.

Can you please let me know when you think you could have planning pricing for the units?

Let me know if you have any questions, or have generator recommendations that differ from the selected units.

Thank you~

Ginette D. Chin, PE | **Senior Electrical Engineer**
WA, IN, GA, KY, CA
Direct: 425.732.5702 | Main: 425.635.1000 | Fax: 425.635.1150
ginette.chin@tetratech.com

Tetra Tech
400 112th Ave NE, Suite 400 | Bellevue, WA 98004 | www.tetratech.com

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Attachment 8
Irrigation Canal Modifications

TETRA TECH

Job No.: 100-SET-T35234

Project: Lower Yellowstone River
Subject: Multiple Pump Station Alternative
Design Topic: Small Pumping Facility Friction Losses
Made By: JPP **Date:** 18-Mar-16 **Chk'd By:** **Date:**

1.0 ISSUE BEING ADDRESSED

Calculate the pipe friction losses for the small pumping facilities required between the main irrigation canal and laterals AA, BB, CC, DD, and FF.

2.0 APPROACH

Discharge piping from each pump station is assumed to include 300' of pipe, with typical valves, checks and bends.

3.0 REFERENCES

References used in this calculation are as follows:

1) AWWA, M-11 Manual, "Steel Water Pipe-A Guide for Design and Installation"

4.0 ASSUMPTIONS

1) A typical discharge pipe system including 300' of pipe, one check valve, one gate valve, and two bends is required at each site.

5.0 CALCULATIONS

1) Calculate the friction losses at each facility using the Darcy-Weisbach formula

Lateral	Flow Rate (cfs)	Pipe Len. (feet)	Pipe Dia.[a] (feet)	Pipe Vel. (ft/sec)	Minor HL 'k' value	Major HL[b] (feet)	Minor HL[b] (feet)	Total HL (feet)
AA	6.0	300	1.0	7.6	7.7	3.9	7.0	10.9
BB	6.0	300	1.0	7.6	7.7	3.9	7.0	10.9
CC	9.0	300	1.3	7.3	7.7	2.8	6.4	9.3
DD	12.5	300	1.5	7.1	7.7	2.2	6.0	8.2
FF	8.0	300	1.3	6.5	7.7	2.2	5.1	7.3

a) Discharge Pipe Diameters chosen to produce flow velocities in the discharge pipes less than 10 FPS and to avoid excessive head losses.
b) Head losses calculated using the Darcy-Weisbach formula.

Typical fittings for 'k' value shown:

Feature	Qty	Unit k-value[Ref 3]	k-value
Entrance Losses	1	1	1
90° Bend	2	1.2	2.4
Wye	2	1.3	2.6
Check Valve	1	1.5	1.5
Gate Valve	1	0.2	0.2
Total K:			**7.7**

Lower Yellowstone Intake Diversion Dam Fish Passage Project, Montana

ENGINEERING APPENDIX A-3

Lower Yellowstone Intake Fish Passage EIS

Ranney Wells with Conservation Measures Alternative

MAY 2016

Contents

LIST OF TABLES

LIST OF FIGURES

ATTACHMENTS

1.0 Alternative Description

The Multiple Pumping Stations with Conservation Measures Alternative includes four primary components: removal of dam, implementation of water conservation measures, gravity diversions through the existing headworks, and pumping from Ranney Wells. The alternative assumes that use of wind energy to offset pumping costs.

This alternative includes removal of the existing Intake Diversion Dam along the Yellowstone River while accommodating a changed diversion condition for the main irrigation diversion canal (main canal) and providing a continued water source to the Lower Yellowstone Project (LYP). The diversion dam, made of timber frame filled with riprap, is located at river mile (RM) 72 on the Yellowstone River between Sidney and Glendive, Montana, and is currently used to keep the river stage high enough to divert the river flow into the main canal through the headworks. The main canal supplies the diverted flow to the complex irrigation lateral system within the irrigation district as it flows downstream for more than 70 miles. The target diversion flow rate to the main canal after the diversion dam removal is approximately 608 cubic feet per second (cfs). Installing water conservation measures throughout the system is proposed to reduce the amount of water needed by the project; both by reducing inefficiency losses in the delivery system and for on farm. The conservation measures propose a savings of approximately 766 cfs, reducing the diversion from the current water right of 1,374 cfs to a diversion of 608 cfs.

Table 1.1 below includes the proposed list of conservation measures and the estimated cubic foot per second of water that could be conserved. These were proposed by Defenders of Wildlife (Defenders) and Natural Resources Defense Council (NRDC) by letter dated February 17, 2016 (Defenders and NRDC, 2016). Although the values proposed are based upon a conservation plan (LYP, 2009), and a value planning study (Reclamation, 2005, Reclamation 2013) the estimates included in those documents were not field verified. The value planning study noted that “Cost and demand reduction estimates are currently at a low level of confidence and need to be field evaluated and refined.”

Table 1.1 - Conservation Measures and Estimated Savings (cfs)

Component	Description	Estimated conservation (cfs)
Check Structures[1]	Installation of check structures in the canal for water control	61.5
Flow measuring devices[2]	Measuring devices installed on the canals	18.5
Laterals to pipe	Convert laterals to pipe	255.8
Sprinklers	Install center pivot sprinklers	160
Lining main canal/laterals	Line main canal and laterals with concrete	200
Control over checking	Operational change to water levels in the canals	20.6
Groundwater pumping[3]	Install groundwater pumps	49.5
	Total Savings	**765.9 cfs**

1- Check structures are intended to assist in management of water diversion to laterals and therefore reduce necessary diversions.

2- Flow measuring devices themselves do not conserve water. They would provide a tool for water management to reduce over diversions.

3. Groundwater pumping is not a conservation measure, it is change of the water source and could reduce diversions but would not conserve water.

Conceptual designs of the proposed components of this alternative are presented below. The amount of conservation that can be achieved with these measures has not been verified or field measured and is conceptual as presented.

2.0 Design Guidelines

2.1. Alternative-Specific Criteria

The primary design criteria for this alternative is to construct a continuous river geometry through the existing intake diversion dam location in order to provide fish passage for native fishes. This would require removal of any flow obstruction at the dam site to the adjacent river bottom elevation (±1982 feet).

The water conservation measures have been developed based primarily on the measures identified in District's 2009 *Water Conservation Plan* (District 2009) with the exception of the main canal lining measure. The measures need to be designed so that the main canal and irrigation laterals would maintain the same ability to meet the current water delivery requirements for all water in the district under the reduced diversion rate (608 cfs) condition at the headworks.

2.2. Assumptions

This alternative does not include modification or improvement to the existing headworks but assumes that the structure would be able to divert all 608 cfs to the main canal when the water stage in the Yellowstone River is high enough.

Design details and quantities provided for the water conservation measures identified in District's 2009 *Water Conservation Plan* (District 2009) were assumed to best represent the project conditions and used as a basis to develop cost estimates for the alternative. This assumption needs to be field verified and verified using detail modeling during the construction-level design in future.

2.3. Existing Conditions Data

Existing conditions topographic mapping was developed based on multiple survey sources, and the accuracy of the survey data was not field verified for the conceptual-level design analysis. For the dam removal design, the 2012 survey information including LiDAR (flown October, 2012) and Acoustic Doppler Current Profiler (ADCP) bathymetric survey (survey of river geometry below water surface, collected April, 2012), provided by the U.S. Corps of Engineers (Corps) Omaha District was used. The horizontal control datum for the survey is the North American Datum of 1983 (NAD 83), State Plane, Montana, in feet, while the vertical control datum is North American Vertical Datum of 1988 (NAVD 88). A 3-dimensional surface and 1-foot interval contour mapping shapefile were generated based on the survey data using the

ArcMap 10.1 software. The contour mapping was then converted to a Microstation format file to be used in the design.

For the design analysis along the main canal and Ranney well pumping sites, the county-wide LiDAR flown in 2004 (Dawson County) and 2007 (Richland and McKenzie Counties) available on the Yellowstone River Corridor Resource Clearinghouse on the State of Montana government website were used. The horizontal and vertical control datums for the surveys are the NAD 1983, State Plane, Montana, in feet, and NAVD 88, respectively.

The dimensions, elevations, and details of the existing intake diversion dam at RM 72 were determined based on the as-built plans by Reclamation (Reclamation 1910). The elevations shown on the as-built plans were based on the old local datum which was used in the area prior to establishment of the National Geodetic Vertical Datum of 1927 (NGVD 1927). The elevations on the as-built plans were converted to the NAVD 88, based on the conversion information shown on the Corps' 2006 Preliminary Design Report (Corps 2006b). Determination of the existing conditions of other features, including the main canal, is described in later sections of this report, as appropriate.

The horizontal control datum for the project is the NAD 83, State Plane, Montana, in feet, while the vertical control datum is NAVD 88. All the elevations presented in this appendix report are measured in NAVD 88, unless otherwise stated.

3.0 Engineering Considerations

3.1. Hydrology and Hydraulics

Hydrologic and hydraulic analyses were performed to assess the existing hydraulic conditions of the Yellowstone River and main canal and potential hydraulic impacts to the river and canal if the existing dam were to be removed.

The Multiple Pumping Stations with Conservation Measures Alternative was evaluated based on the existing dam structure and downstream rock would be removed down to the approximate natural bed elevations through the project reach. After the removal, diversion from the Yellowstone River to the main canal would be affected due to lower head (water surface elevation) at the headworks, especially during periods of low flow in the river. The required diversion discharges to the main canal would be supplemented through pumping water from Ranney wells when required.

3.1.1 Modeling

Hydraulic modeling for this alternative involved simulating conditions in the Yellowstone River with the diversion dam removed in order to determine the potential for gravity diversions over a range of operational discharges and modeling the irrigation canal to evaluate potential limitations in supplying water to the laterals at lower water surface elevations in the Yellowstone River.

Intake Dam Removal Model

The hydraulic modeling of the removal of Intake Diversion Dam focused on evaluating the potential for gravity diversion with the diversion dam (weir portion only) and downstream rock to the prevailing natural bed elevations removed. The existing conditions HEC-RAS model that included the diversion dam with the natural high flow channel connecting as a junction was the starting point for the modeling. The analysis was conducted in a two-step process with the first version of the Ranney Well alternative, or “no-dam” model, consisting of simply removing the cross sections including the dam crest, downstream existing rock, and the scour hole at the downstream end of the rock. The model was run for the 2-year discharge to assess whether upstream deposition has occurred over the life of the dam. Figure 3.1 shows the channel bed and 2-year water surface profiles of the “with-dam” and first version of the “no-dam” models. Removal of the dam would drop the water surface immediately upstream of the dam by approximately 6 feet for the 2-year flow, but there is also a convexity in the 2-year water surface that likely indicates the presence of a wedge of sediment that has collected during the life of the dam.

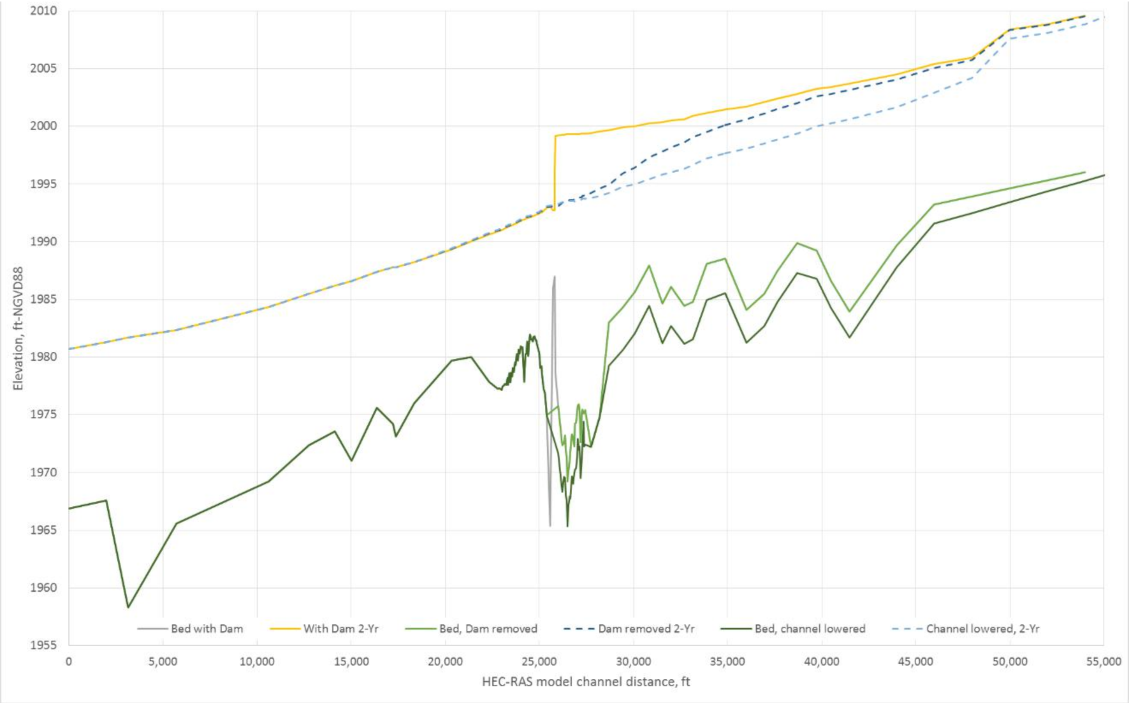


Figure 3.1 – Yellowstone River Profiles for Existing and Dam Removal Conditions

The second version of the "no-dam" model represents an estimate of the future channel condition after the Yellowstone River has adjusted to the removal of the structure and rock. The sediment wedge is considered to be approximately 4 feet thick at the dam and tapers to zero feet at the upstream end of the model. The downstream channel was left unchanged assuming that over several years the sediment released from the wedge would distribute downstream and would have an indiscernible impact. The second version of the model showed no convexity in the water surface profile (Figure 3.1), so no further adjustments were made. This final model included a lateral structure representing the fish screens and gates. The lateral structure incorporated a stage-discharge rating curve for the canal that was offset assuming 1 foot head loss across the screens and gates to estimate the required stage on the Yellowstone River to determine the potential gravity diversion flow.

When this model was run for a range of flows, the potential gravity diversion for the non-weir Ranney Well alternative was computed. Table 3.1 shows the potential gravity diversion-flow duration curves based on the Yellowstone River flow-duration curves for Sydney Gage (USGS gage Number 06329500) (Corps 2006a). In the table, the diversion potentials for the non-weir condition during the irrigation season (May through September) are compared to the diversion potentials for the existing condition with the weir in place. According to the table, under the non-weir condition, a 608 cfs flow (target diversion flow rate) could be diverted by gravity approximately 60 percent of the irrigation season, while a 1,374 cfs (current diversion flow rate) could be diverted by gravity only approximately 15 percent of time. The diversion potential for the existing condition is 1,374 cfs during the entire irrigation season when the flow in the river is constantly higher than 3,000 cfs (minimum flow requirement for diversion of 1,374 cfs).

Table 3.1 – Potential Gravity Diversion at Headworks for Different Design Conditions

Percent Time Exceeded (%)	**Diversion Potential based on Yellowstone River Flow Duration (cfs)**						
	Non-weir Condition						**Existing Condition**
	May	June	July	August	Sept	5 months	5 months
0.01	1,374	1,374	1,374	1,374	1,374	1,374	1,374
0.05	1,374	1,374	1,374	1,374	1,374	1,374	1,374
0.1	1,374	1,374	1,374	1,374	1,374	1,374	1,374
0.2	1,374	1,374	1,374	1,374	1,331	1,374	1,374
0.5	1,374	1,374	1,374	1,302	1,095	1,374	1,374
1	1,374	1,374	1,374	1,214	946	1,374	1,374
2	1,374	1,374	1,374	1,116	847	1,374	1,374
5	1,374	1,374	1,374	904	748	1,374	1,374
10	1,374	1,374	1,374	790	692	1,374	1,374
15	1,269	1,374	1,374	731	647	1,374	1,374
20	1,141	1,374	1,374	692	612	1,282	1,374
30	1,002	1,374	1,245	620	569	1,035	1,374
40	908	1,374	1,088	544	525	853	1,374
50	828	1,374	916	491	472	724	1,374
60	765	1,262	801	442	427	620	1,374
70	692	1,120	674	379	387	527	1,374
80	614	977	523	334	352	443	1,374
85	554	908	474	308	331	400	1,374
90	513	832	428	267	314	356	1,374
95	452	731	385	215	286	307	1,374
98	403	625	331	192	247	245	1,374
99	364	559	314	187	231	210	1,374
99.5	277	521	289	182	203	194	1,374
99.8	250	492	254	177	192	186	1,374
99.9	231	466	249	174	188	182	1,374
99.95	229	464	246	172	186	177	1,374
99.99	227	464	240	167	181	169	1,374

Irrigation Canal Model

Figure 3.2 shows the results of the upper 20 miles of the HEC-RAS model developed for the main canal. Main canal profiles for diversion discharges of 1,374 (current diversion flow rate), 1,200, and 608 cfs (target flow rate for the alternative) entering at the headworks are shown in the figure. Based on Table 3.1, a 608 cfs flow could be diverted by gravity approximately 60 percent of the irrigation season. The remaining time pumping may be required to bring the main canal discharge to the target operational level.

It should be noted that Figure 3.2 shows that the water surface in the main canal under the target flow rate (608 cfs) condition would likely be too low for gravity diversion into the laterals. This could potentially be compensated though operation of existing and addition of new canal check structures, or by pumping from the main canal into the laterals. However, if canal check structure operation produces a higher tailwater at headworks, gravity diversion would be limited or even eliminated. The construction level design should include an analysis of how a higher tailwater at headworks created by proposed check structures would impact the ability of the headworks to divert the target diversion flow rate.

Further analysis and design would be required to determine the necessary modifications to the canal and laterals. It was assumed that the canal would need to be modified to allow gravity diversion into the laterals throughout the system. The cost estimate incorporates that assumption, and assumes that the canal would need to be reduced in size by half.

3.1.2 Channel Migration of Yellowstone River

At Diversion Dam Removal Site

The Yellowstone River Cumulative Effects Assessment (YRCEA) (Corps and YRCDC 2015) describes geomorphic trends primarily occurring after 1950 with a focus on analysis of GIS data to describe the spatial distribution and temporal shifts of overall channel planform and associated complexity. The analysis included degree of braiding, extent and blockage of side channels, bankfull channel area, floodplain turnover and channel migration, and bank armoring. The YRCEA indicated the reach that included the intake diversion dam has an average migration rate of around 5 feet per year, which is less than historical rates of around 7 to 8 feet per year. The bend at the head of the high flow channel shows migration of approximately 400 feet in approximately 60 years. If this rate of migration continues in the upstream bend, there is low risk for adverse impact on the gravity flow diversion potential.

Channel migration at the intake diversion location is a low risk concern because the channel location has persisted throughout the life of the diversion project. The left (north) bank of the Yellowstone River is against a bedrock outcrop consisting of shale and siltstone. This is also the location of a railroad alignment where riprap bank protection is present.

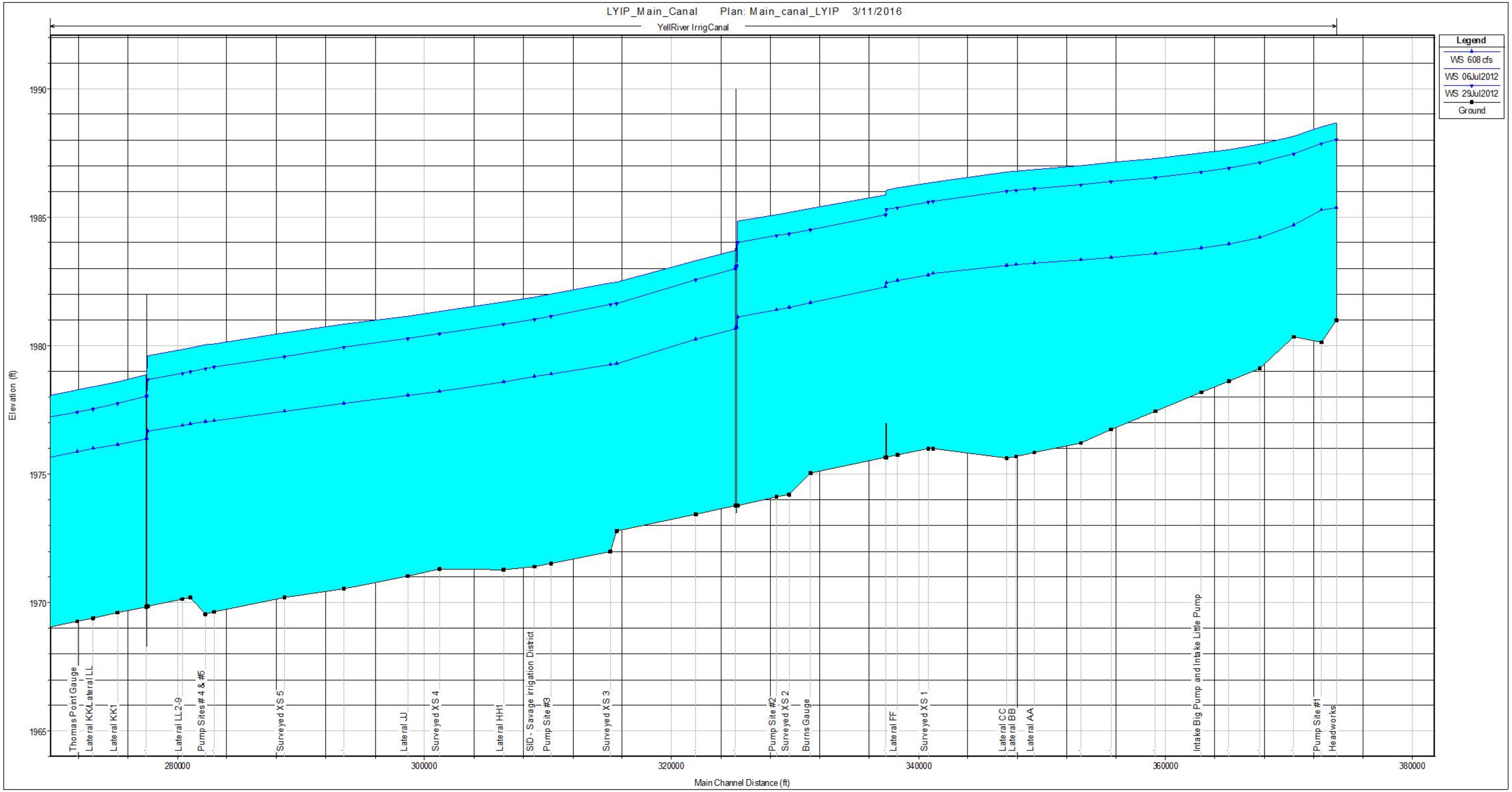


Figure 3.2 – Main Canal Water Surface Profiles for Various Discharges

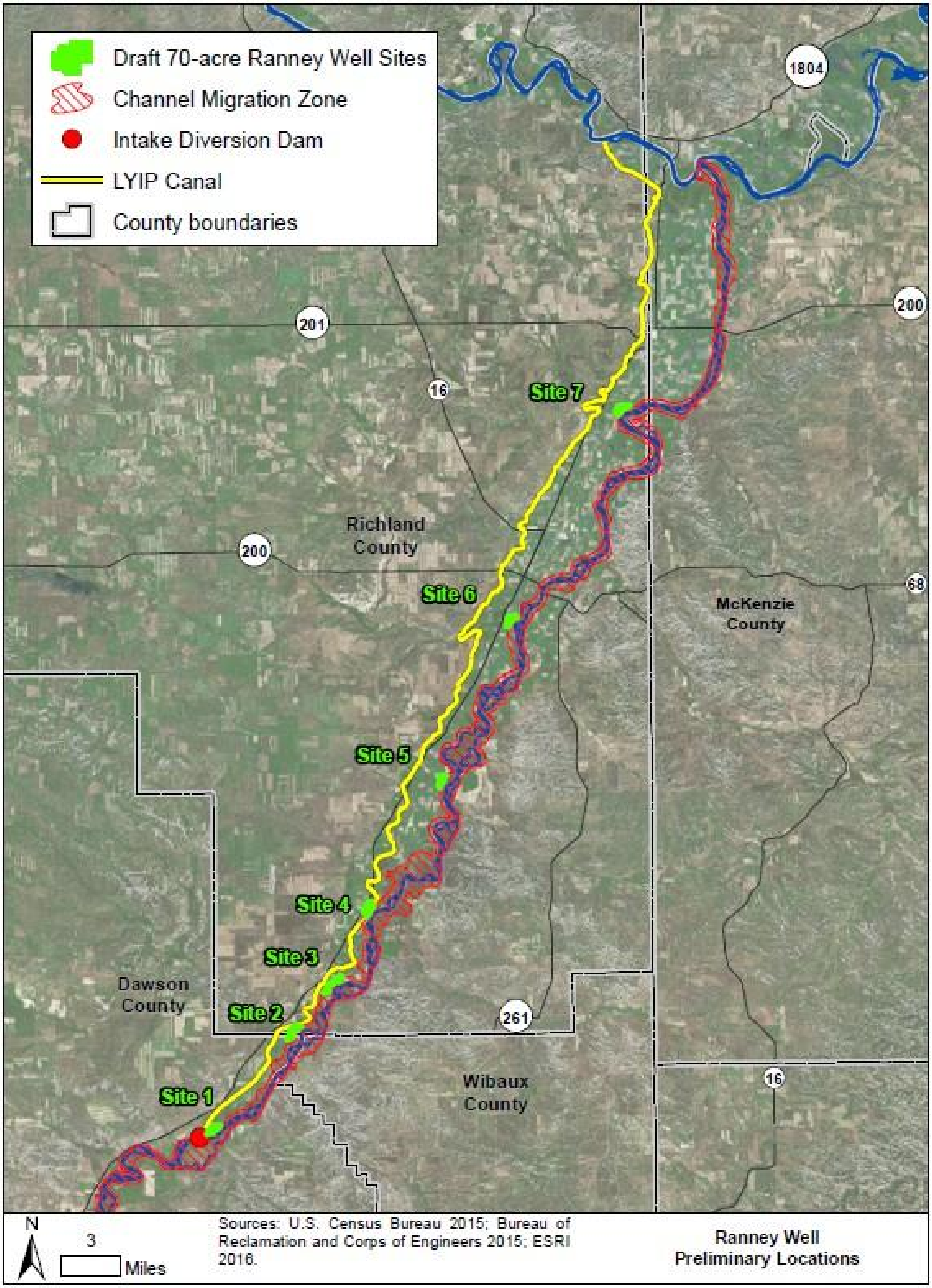
Ranney Well Sites along Yellowstone River

As part of the pump station construction (see Section 4.5), Ranney wells would be constructed along the Yellowstone River as shown in Figure 3.3. Areas where channel migration, based on typical rates, is expected to occur over the next 100 years were delineated as the channel migration zone (CMZ) in this reach of the Yellowstone River (DTM and AGI 2009). The CMZ typically extends approximately 1,000 feet from the banks of the Yellowstone River. The assumed migration rate of 1000 feet per 100 years may vary; in some locations the migration rate may be much higher, especially at the outside of bends. All of the Ranney well locations would be outside of the CMZ boundaries. Placing Ranney wells outside the CMZ may reduce the amount of water that could be produced, but that could only be determined by pumping tests.

3.1.3 Sediment Transport

Sediment transport analyses were not conducted for this alternative. As discussed above, sediment transport on the Yellowstone River is assumed to be only locally affected in approximately the first 5 miles upstream of the diversion dam site, and the effects of removal of the dam were evaluated based on removing the sediment wedge from the upstream channel in this reach of the hydraulic model.

Operation of the Ranney wells would likely not be affected by sediment transport along the Yellowstone River because when pumping at the wells is at the highest rate, the river is likely experiencing the low flow condition and, therefore, low sediment transport conditions in the river. The amount of flow diverted by the Ranney wells would have a negligible effect on sediment transport rates of the Yellowstone River.



Sources: U.S. Census Bureau 2015; Bureau of Reclamation and Corps of Engineers 2015; ESRI 2016.

Figure 3.3 – Preliminary Ranney Well Locations

4.0 Design

This section presents details of each of the design components, including development process, assumptions, limitations, and requirements. Also, quantity development for each design element is described.

The alternative design includes removal of the existing intake diversion dam and implementing water conservation measures along the main canal to accommodate the loss in diversion flow into the main canal due to the removal of the diversion dam. The water conservation measures would minimize loss in the diverted flow (canal lining, installing flow measuring devices, canal check structures, and piping irrigational laterals). Additional irrigation water would be provided by pumping from Ranney wells into the main canal.

The design for the Ranney Well alternative was developed based on the available data and engineering judgment. No additional survey or geotechnical or structural analyses were conducted for the design.

4.1. Design Features

4.1.1 Existing Dam Removal

Description

The existing intake diversion dam near RM 72 was constructed by Reclamation in 1910 to control the water surface elevation of the Yellowstone River at the original headworks, located just upstream of the dam on the left bank. The existing dam structure consisted of timber frame filled with riprap, timber piles, and riprap apron downstream. However, during its operation since construction, some of the riprap and boulders from the dam structure were broken and separated from the structure due to the winter’s freeze and thaw process and carried downstream by flows, creating a boulder field. The boulder field appears to be as wide as 370 feet near the left bank as shown in Figure 4.1 and as thick as 6 feet, based on the bathymetric survey (Corps 2012). Currently, as part of its maintenance, new riprap is being placed annually over the length of the dam crest using the overhead trolley system across the river in order to keep the dam crest elevation at 1988 feet.

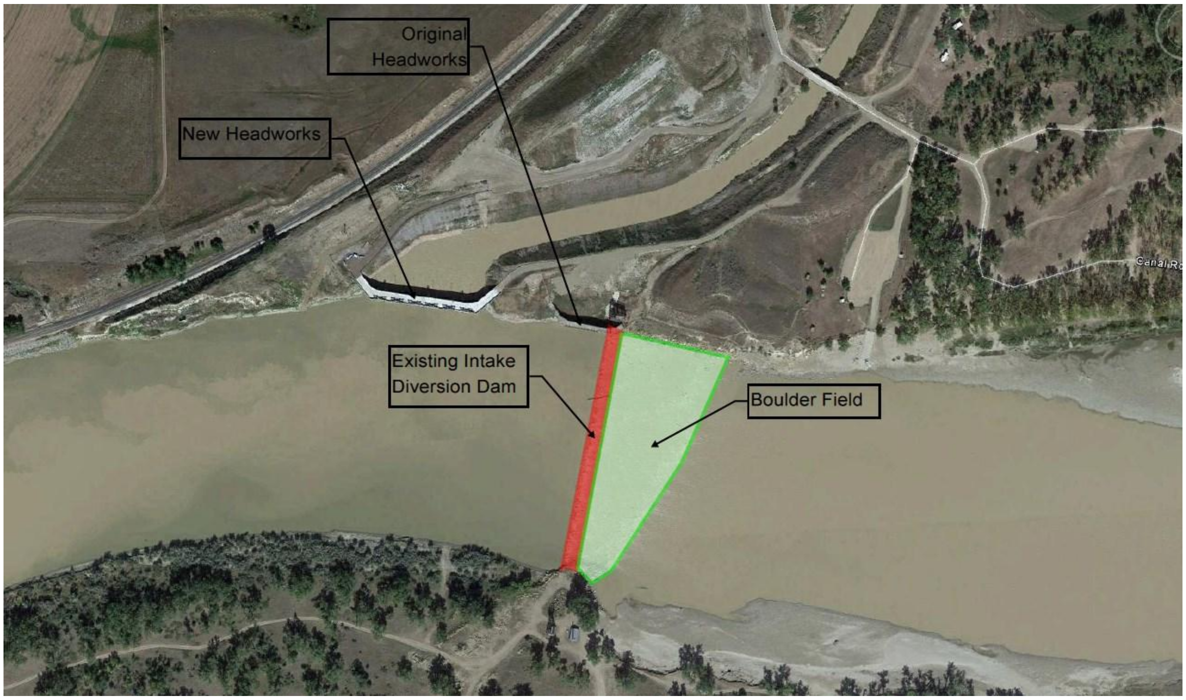


Figure 4.1 – Existing Intake Diversion Dam Removal Layout

The removal of the existing intake dam and boulder field would improve fish passage for the endangered pallid sturgeon and other native fishes by providing a continuous river geometry through the dam location. For the removal, only the portion of the dam that is above the adjacent river invert elevation (approximately at 1982 feet ±) would be demolished and removed, while the foundation with timber piles and downstream below-ground apron would remain in place as shown in Figure 4.2. Leaving the timber piles and downstream below-ground apron will provide a minimal amount of grade control to assure that the desired gravity diversion is achieved without adversely affecting fish passage. Further evaluation of the removal elevation is warranted if this alternative is selected. The riprap and boulders in the boulder field which is as wide as 370 feet would also need to be removed.

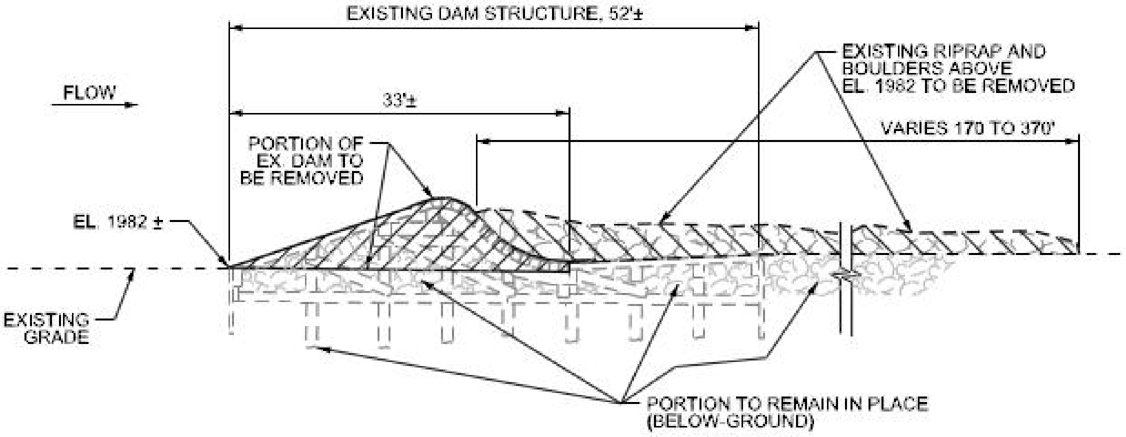


Figure 4.2 – Typical Dam Removal Section

Phasing and Cofferdam

The dam removal would take place in two phases to allow continuous conveyance of the Yellowstone River during construction. In the first phase, only the left (north) half of the existing dam and boulder field would be removed, while the river would be able to flow downstream over the right (south) half of the existing dam structure. The right half of the existing dam and boulder field would be removed in the next phase, while the river would flow downstream over the left half of the river cross section where the existing dam would be removed in the first phase. In each phase, the portion of the dam and boulder field to be removed would be surrounded by temporary cofferdams to prevent the river flow from entering the work area. The cofferdams would be removed at the end of each phase.

Temporary cofferdams are assumed to be a combination of sheet pile and earthen dam with riprap revetment. For a sheet pile cofferdam, a total height of each sheet pile would be the sum of exposed height (10 feet = elevation 1992-1982) and embedded depth (30 feet = 3 times the exposed height), which is 40 feet. The embedded depth was determined based on an engineering judgment. The embedded depth should be verified during the construction-level design, based on the geotechnical and structural stability analyses.

Exact layout and specific configuration of cofferdam would be determined during the construction-level design in future. For the quantity development purposes in subsection 4.3.1.3, *Quantities*, it was assumed that sheet pile would be used for the entire cofferdam length with the exception of an earthen segment extending from west to east along the flow direction in Phase 1 due to difficulty in driving sheet pile through the existing riprap on the river bottom.

Typical sections of sheet pile cofferdam and earthen cofferdam with riprap on the riverside are shown in Figure 4.3 and Figure 4.4, respectively.

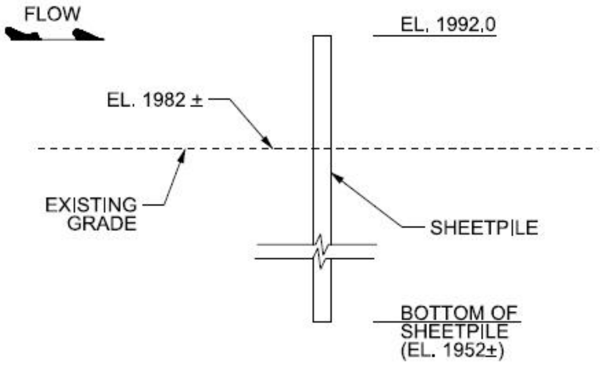


Figure 4.3 – Typical Sheet Pile Cofferdam

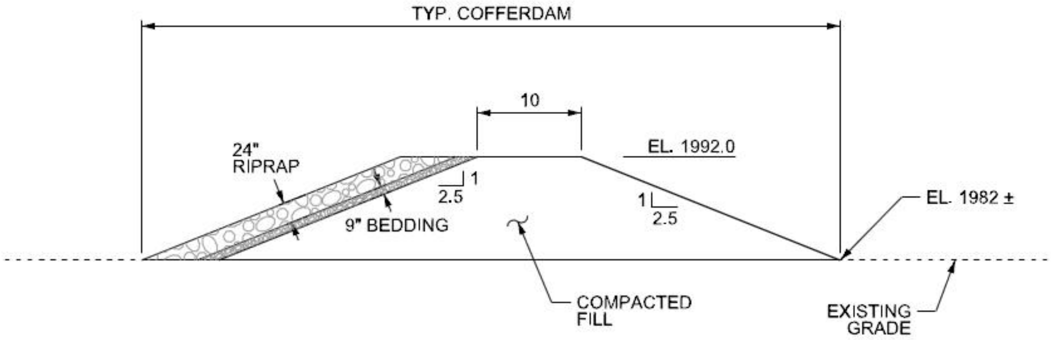


Figure 4.4 – Typical Earthen Cofferdam with Riprap Revetment

Quantities

The quantities to remove the existing intake diversion dam and construct cofferdams are summarized in Table 4.1 and Table 4.2, respectively.

Table 4.1 – Summary of Quantities for Existing Dam Removal

Item	Length (ft)	Surface Area [1] (SF)	Average Thickness [1] (ft)	Section Area [2] (SF/ft)	Volume (CY)
Existing Dam (Riprap)	700			112	**2,904**
Boulder Field (Riprap and Boulder)		190,190	6		**42,264**

Note

1. Surface area and average thickness of boulder field were determined based on aerial survey and bathymetric survey, respectively.
2. Section area of the existing dam above the adjacent ground elevation (1982 feet±) was estimated based on the as-built plans.

Table 4.2 – Summary of Quantities for Cofferdam (Combination of Earthen Dam and Sheet pile)

			Earthen Dam Volume (CY)		
Item	**Sheet Pile Span (ft)**	**Section Area [1] (CF/ft)**	**Compacted Fill**	**9” Bedding**	**24” Riprap**
Phase 1 – Removing Left (North) Half of Dam					
Sheet pile (40’ Length)	**895**				
Compacted Fill (Earthen Dam)	410	380	**5,770**		
9” Bedding (Earthen Dam)	410	21.2		**322**	
24” Riprap (Earthen Dam)	410	56.5			**859**
Phase 2 – Removing Right (South) Half of Dam					
Sheet pile (40’ Length)	**1,420**				
Total (Phase 1 + Phase 2):	**2,315**		**5,770**	**322**	**859**

Note
1. Section area of the earthen dam is based on Figures 4.3 and 4.4.

Drawings

The detailed plan view of the existing dam removal is shown on Sheet C-101, titled, “Plan (01) Existing Dam Removal”, of Attachment 1.

4.2. Water Conservation Measures

With the reduced diversion into the main canal after the existing Intake Diversion Dam removal, more efficient ways to convey the diverted flow throughout the irrigation system to meet the water demands of each water users would be necessary to compensate for the reduced diversion flow. Also important is to reduce any potential loss of the diverted flow due to seepage, evaporation, or inefficient operation of irrigational facilities. Water conservation measures were developed to comply with these requirements in the main canal, as a result of removal of the dam and subsequent new flow conditions in the river. The following subsections describe the design components and pertinent analyses of each water conservation measure as it was proposed.

The ability to conserve the amounts proposed and reduce diversions is uncertain. Attachment 3 provides a summary of information pertaining to the conservation measures that were proposed and shows that the quantities shown in Table 1.1 may not be possible. In addition to this comparison of NRCS Irrigation Water Requirement Data shows that the current crops have significantly higher water demand than could be provided by 608 cfs. During times of peak evapotranspiration 1,100 cfs would be required to support the mix of crops currently grown. This is discussed further in the main body of the EIS.

4.2.1 Main Canal Lining

Typical Cross Sections

The approximately 70-mile long main canal is an unlined, earthen trapezoidal channel that flows generally in the northeasterly direction. For the conceptual-level of this study, a total of 11 cross sections were chosen along the main canal, based on Reclamation's 1992 document (Reclamation 1992) to represent typical dimensions of the entire canal and to perform quantity development. The summary of the 11 cross sections are shown in Table 4.3. During future design a reduction in the canal sizing may be identified, which may result in modified canal geometries and associated canal lining.

Table 4.3 – Summary of Main Canal Geometry

Cross Section Location	RM	Bottom (ft)	Side Slope (H:V)	Bank Height (ft)	Invert Slope (ft/ft)
Upstream End of Main Canal (RM 0)					
near Headworks (1)	0.05	28.5	1.5:1	40	0.0001
near Headworks (2)	0.2	23.5	1.5:1	26	0.0001
below Lateral HH	11	20.5	1.5:1	12	0.0001
below Pumping Plant	19.3	21.5	1.5:1	11	0.0001
at Sears Bridge	24.7	20.5	1.5:1	18	0.0001
below Fox Creek Siphon	36	23	1.5:1	10	0.0001
below Lone Tree Creek Siphon	42.5	23.5	1.5:1	9	0.0001
below Lateral G	47	15.5	1.5:1	8	0.0002
below Lateral J	51	16.5	1.5:1	7	0.0003
below Lateral M	57	14.5	1.5:1	6	0.0001
below Lateral P	60.5	9	1.5:1	5	0.0001
Downstream End of Main Canal (RM 70.3)					

According to Table 4.3, a typical canal cross section has the bottom width varying from **9** to **29** feet, bank height from **5** to **40** feet, and invert slope of 0.0001 to 0.0003 foot/foot. The side slope of the banks are **1.5** (horizontal): **1** (vertical). The 1992 Reclamation document also states that for these 11 cross sections listed in the table, the maximum flow velocity is estimated to be **2.4** feet per second (fps) at the cross section below Lateral J. For the quantity calculations, each of the 11 cross sections was applied uniformly over the reach lengths between the cross section locations.

Preferred Canal-lining Method

Lining of the canal surface would significantly reduce loss of canal flow due to seepage. In order to select the preferred canal lining method, Reclamation's canal-lining program documents available on the agency's website were reviewed and analyzed. Reclamation's 10-year long canal-lining demonstration project, completed in 2002, concluded that a type of lining which included geomembrane with concrete cover would result in the best durability (40-60 years), benefit-cost ratio (3.5-3.7), and effectiveness in seepage reduction (95%) (Reclamation 2002).

For this project, it was assumed that a typical canal lining section would include placing of geomembrane over re-graded canal geometry and shotcrete cover with the minimum 3-inch thickness as shown in Figure 4.5. It was also assumed that no reinforcing was used to strengthen the shotcrete cover due to a slow flow velocity (maximum of 2.4 fps, see section 2.3.1.1) and that any significant cracks would be repaired during a regular canal-lining maintenance. Geomembrane is likely to reduce seepage through minor cracks on the shotcrete surface. Minor re-grading of the existing canal geometry is expected to even out any steep banks or surface irregularities prior to placing the lining material.

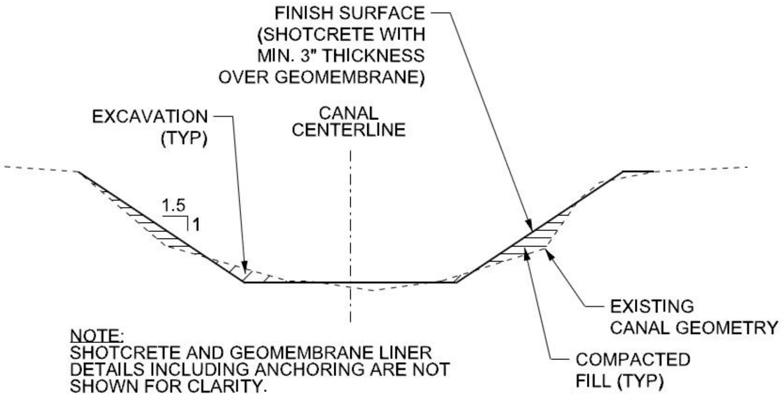


Figure 4.5 – Typical Canal-lining Section

Quantities

The quantities for the main canal lining using a 3-inch thick shotcrete cover over geomembrane are summarized in Table 4.4. The quantities were developed based on the 11 cross sections shown in Table 4.3 with the assumption that each cross section is applied uniformly over the reach length between the cross section locations.

Table 4.4 – Summary of Quantities for Main Canal Lining

				Shotcrete		Geomembrane
Cross Section Location	**RM**	**Canal Segment Distance (ft)**	**Surface Area at Each Section (SF) [1]**	**Shotcrete Thickness (in)**	**Volume (CY)**	**Surface Area at Each Section (SF) [1]**
Upstream End of Main Canal (RM 0)						
near Headworks (1)	0.05	660	113,850	3	1,054	113,850
near Headworks (2)	0.2	28,908	3,385,127	3	31,344	3,385,127
below Lateral HH	11	50,424	3,212,009	3	29,741	3,212,009
below Pumping	19.3	36,168	2,209,865	3	20,462	2,209,865

				Shotcrete		**Geomembrane**
Cross Section Location	**RM**	**Canal Segment Distance (ft)**	**Surface Area at Each Section (SF) [1]**	**Shotcrete Thickness (in)**	**Volume (CY)**	**Surface Area at Each Section (SF) [1]**
Plant						
at Sears Bridge	24.7	44,088	3,760,706	3	34,821	3,760,706
below Fox Creek Siphon	36	46,992	2,772,528	3	25,672	2,772,528
below Lone Tree Creek Siphon	42.5	29,040	1,623,336	3	15,031	1,623,336
below Lateral G	47	2,2440	994,092	3	9,205	994,092
below Lateral J	51	26,400	1,100,880	3	10,193	1,100,880
below Lateral M	57	25,080	905,388	3	8,383	905,388
below Lateral P	60.5	60,984	1,646,568	3	15,246	1,646,568
Downstream End of Main Canal (RM 70.3)						
Total:					**201,151**	**21,724,349**

Note

1. Surface Area at Each Section was calculated by adding 2 side slope lengths to bottom width shown in Table 4.3.

Drawings

The plan view of the main canal lining is shown on Sheet C-102, titled, “Plan (02) Main Canal Lining Plan”, of Attachment 1.

4.2.2 Installing Measuring Devices

Description

Diverted flow from the Yellowstone River into the main canal is distributed among the water users in the irrigation districts via a complex network of the laterals and sub-laterals. The distribution is determined daily based on the water needs of the water users and water availability. Currently, diversions into the laterals and sub-laterals are being estimated daily without measuring devices, and there are no measuring devices at lateral end spill sites (District 2009). Lack of measuring devices may lead to misappropriation of water or diversion of excess water at times.

District’s 2009 *Water Conservation Plan* identified the locations for future measuring device installation and recommended types of measuring devices, as summarized in Table 4.5. Based on the table, the project would require installation of 3 different types of flow measuring devices (Cipolletti weir, Parshall flume, and Overshot gate) at 120 individual locations.

Table 4.5 – Summary of New Measuring Devices

Locations	Number of Devices Needed	Type of Device
Lateral Turnout Structures	19	50% Cipolletti Weir / 50% Parshall Flumes
Sub-lateral Turnout Structures	31	50% Cipolletti Weir / 50% Parshall Flumes
Lateral End Spill Sites	68	Cipolletti Weir
Four Mile and Ferry Coulee Spillway Sites	2	Overshot Gates

A Cipolletti weir type flow measuring device is shown in Figure 4.6 and Figure 4.7. As shown in Figure 4.6, flow is forced to discharge downstream through a trapezoidal, sharp-crested (Cipolletti) weir. By measuring the flow head (or depth) relative to the bottom of the weir at a specified distance upstream and comparing it to the discharge table, prepared using a weir equation, the flow can be estimated. The Cipolletti weir can also be combined with a simple irrigation turnout structure (Figure 4.7) to standardize a pool behind the weir and flow approach conditions (Reclamation 1997).

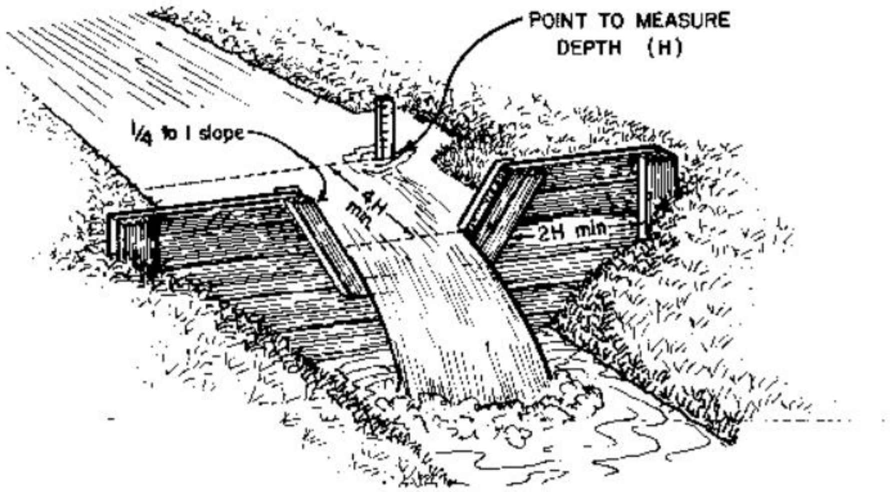


Figure 4.6 – Typical Cipolletti Weir Type Measuring Device along Channel

Figure 4.7 – Typical Cipolletti Weir Type Measuring Device with Turnout Structure

A Parshall flume is a flow measuring device that consists of an open channel flow section that forces flow to accelerate by converging the sidewalls and raising the bottom, creating a “throat”, and a diverging flow section downstream (Figure 4.8). When the downstream flow depth is shallow and enough convergence exists at the throat between upstream and downstream channels, the flow passes through critical depth (Reclamation 1997). By measuring flow head at the flume, the discharge through the channel can be estimated. It should be noted that for a channel that is very flat in slope (as in this project) may create submerged flow condition in a Parshall flume which would require extensive calibration process which could lead to inaccuracy in flow measurement (Reclamation 1997).

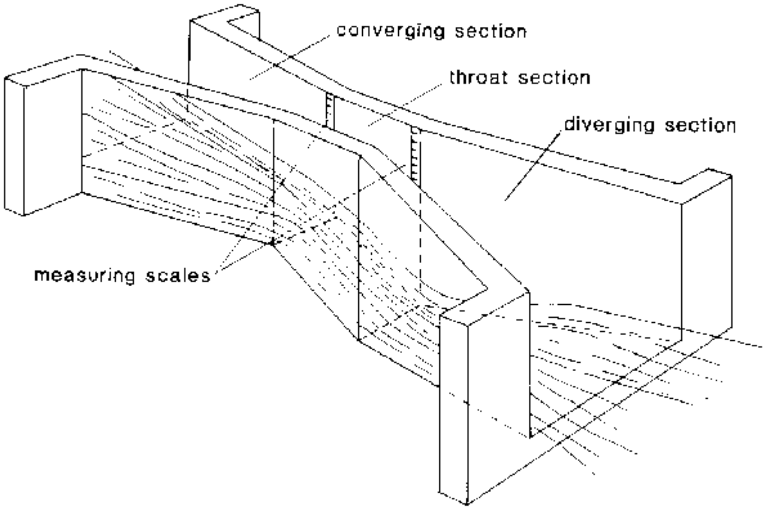


Figure 4.8 – Typical Parshall Flume Type Measuring Device

An overshot gate type flow measuring device is recommended at Four Mile and Ferry Coulee spillway sites. As shown in Figure 4.9, an overshot gate usually includes a rectangular panel (gate) that is hinged at the bottom and lifting cables that is used to lift and lower the panel to the desired height. The purpose of the gate is to maintain a constant water depth along the main canal upstream of the spillway into a main drainage so that a near constant flow would be delivered into the main drainage downstream. Based on the depth of flow in the main canal, the gate would be lifted or lowered to divert the required flow rate (Reclamation 1997). Currently, this type of flow measuring device is installed at 3 other main drainages along the main canal.

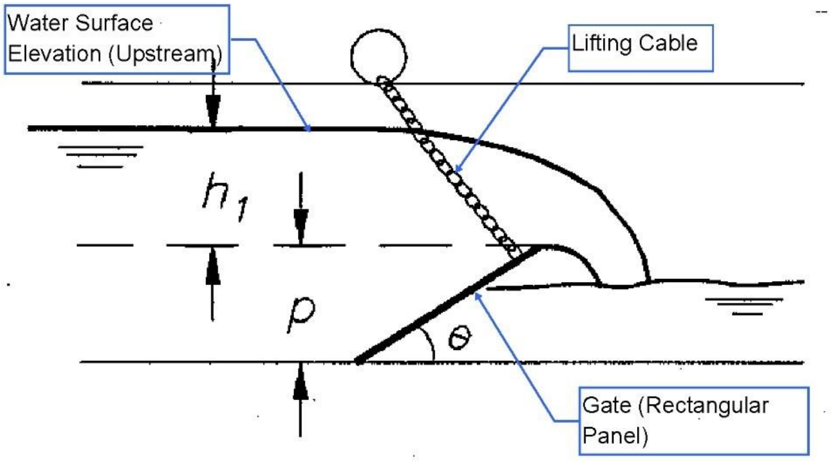


Figure 4.9 – Typical Overshot Gate Measuring Device at Spillway (Profile)

A recommended flow measuring device was selected among the 3 types of devices, described above, at each required site based on District’s 2009 *Water Conservation Plan* recommendations. However, at the construction-level design, adequacy of each selection of the recommended devices should be field verified against the site specific conditions, including structural and hydraulic conditions, prior to finalizing the design selection.

Quantities

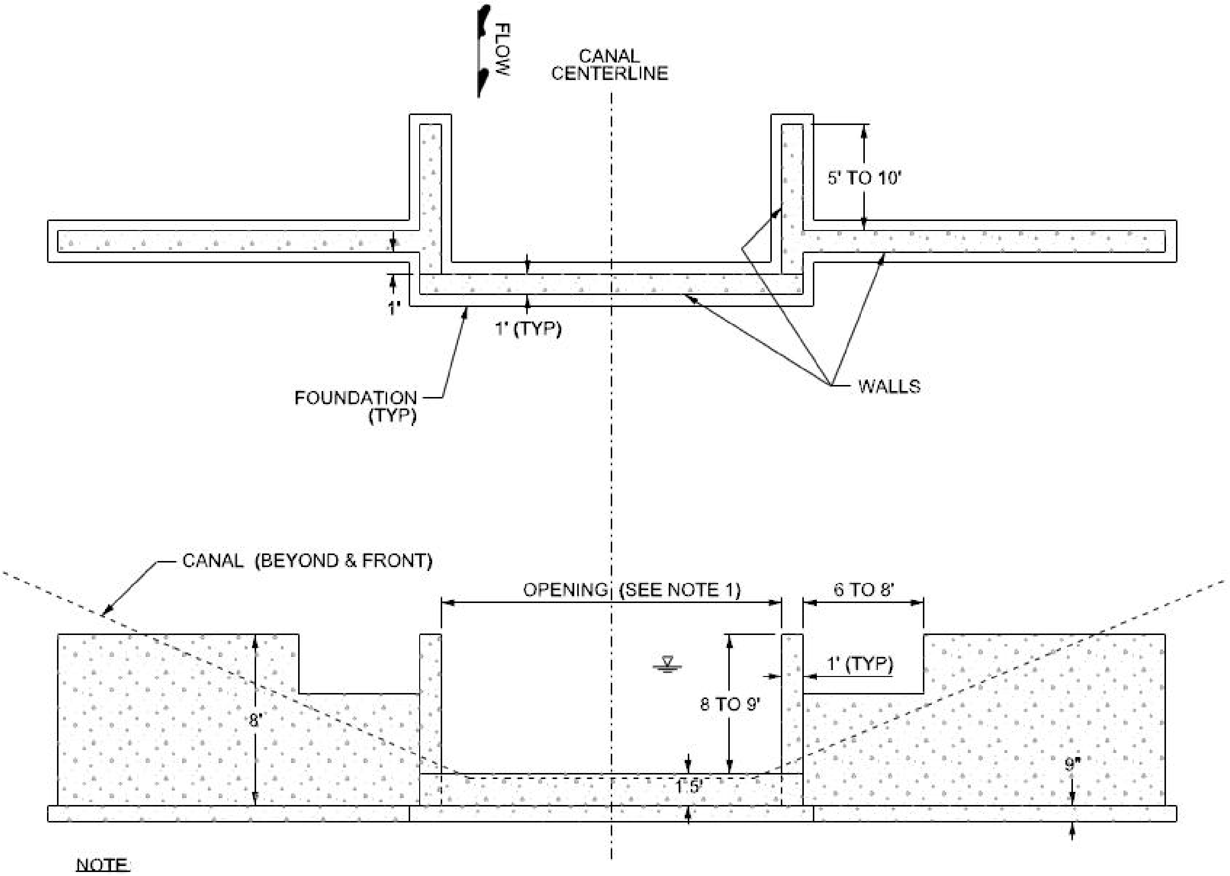
The number of each flow measuring devices (Cipolletti weir, Parshall flume, and Overshot gate types) that would be installed are summarized in Table 4.5.

4.2.3 Canal Check Structures

Description

Water level control structures, or canal check structures, are necessary to maintain the canal water level at the lateral diversion locations during a low flow season by obstructing canal flow and creating a pool behind the structure. Low water level at the diversion locations may lead to low delivery efficiency to the laterals due to the inability to draw water from the main canal. According to District’s 2009 *Water Conservation Plan*, a previous study in 2007 found 9 canal check structures were needed to accommodate critical areas (District 2009). Four check structures have since been installed, leaving a total of **5** canal check structures still needing to be installed along the main canal.

The irrigation district has a standardized canal check structure which would be used for this project. A typical check structure would be a reinforced concrete check structure with automated gate features as shown in Figure 4.10. The opening of the structure would be either a single bay with a 20-foot opening or double bay with two 16-foot openings based on recommendations in District’s 2009 *Water Conservation Plan.*



NOTE:

1. THE OPENING IS EITHER A SINGLE BAY (20-FT OPENING) OR DOUBLE BAY (TWO, 16-FT OPENINGS).
2. MECHANICAL AND ELECTRICAL COMPONENTS OF CHECK STRUCTURE ARE NOT SHOWN.
3. STRUCTURAL DETAILS ARE DEVELOPED BASED ON DISTRICT'S 2009 WATER CONSERVATION REPORT.

Figure 4.10 – Typical Canal Check Structure

Quantities

It was assumed that 5 canal check structures to be constructed along the main canal. Selection of either a single bay or double bay check structure at each critical site would be made during the construction level design. In cost estimate, a conservative average volume of the two check structures types was used.

4.2.4 Piped Laterals

Current Lateral System

Once the flow from the Yellowstone River is diverted to the main canal, it is then distributed to many laterals that are located along the entire length of the main canal. Distribution to the laterals is facilitated at the canal banks by either pump facilities or diversion weirs with the check structures in the main canal (see section 4.4.3 for description of a check structure). In many cases, a lateral includes a main distribution channel and multiple smaller laterals that stem from the main distribution channel, creating a complex network of water distribution systems. The current laterals are mostly open earthen trapezoidal channels with very minimal and localized linings.

With limited survey and field measurements of the laterals available, the dimensions of the laterals were determined based on Reclamation's *Canal System and Operating Map* (Reclamation 1923). Based on the map, the information on typical laterals are summarized in Table 4.6. It is possible that the data shown on the map may not correctly represent the current field conditions in some areas due to any field modification by the irrigation districts or even adjacent property owners over the years. The recent field measurements of the laterals conducted by LYP in March, 2016, were used to confirm or adjust the dimensions from the 1923 Operating Map as necessary.

Table 4.6 – Summary of Typical Lateral Geometry

Lateral [1]	Total Pipe Length [2] (ft)	Bottom Width (ft)	Flow Depth [3] (ft)	Invert Slope (ft/ft)
H	44,629	4 to 6	1 to 2.5	0.0003 to 0.001
K	93,927	5 to 8	2 to 2.5	0.0002 to 0.00125
L	27,561	2.5 to 5	1 to 1.5	0.00035 to 0.00075
M	39,331	4 to 5	1 to 2.5	0.0002 to 0.0007
N	66,028	2 to 5	0.5 to 3	0.0002 to 0.0007
O	15,398	3 to 6	0.75 to 2	0.0002 to 0.003
P	74,633	4 to 7	1 to 2	0.0004 to 0.002
Q	30,977	5 to 6	1.5 to 2	0.0003
S	11,527	6	1 to 1.5	0.001 to 0.006
T	6,684	N.A.[4]		
U	3,232	N.A.[4]		
V	8,622	N.A.[4]		

1. These laterals have been selected for replacement with pipes (See section 2.3.4.2).
2. Total pipe length includes combined lengths of a main lateral channel and sub-laterals stemming from the main lateral.
3. Flow depth is based on the operational flow rate listed in Reclamation's 1923 operating map.
4. N.A. – Not Available; Laterals T, U, and V are not covered in Reclamation's 1923 operating map.

Piping of Existing Laterals

The current laterals are subjected to potential loss of the diverted flow due to seepage, evaporation, and spillage at the downstream end of the laterals. As part of the water conservation measures, some of the existing earthen laterals would be replaced with pipes. The pipes can be either reinforced concrete or high-density polyethylene (HDPE) materials. After the coordination with Reclamation, a total of 12 lateral networks with combine length of approximately 80 miles were selected for consideration to be piped. A section view of typical replacement pipe is shown in Figure 4.11.

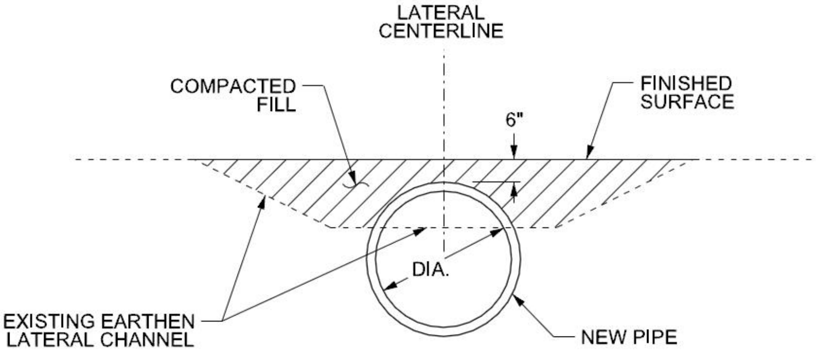


Figure 4.11 – Typical Pipe Replacement Section

In pipe sizing, lateral pipes were sized to provide the same flow capacity as the existing lateral channels. The pipe capacity requirement was determined based on two sources: 2015 Lateral Design Flow Calculation by District (District 2015) and Reclamation's 1923 operating map. The District's 2015 lateral flow calculation estimated the design flow that was diverted from the main canal to each lateral, but did not include any data on how the lateral flow was being used and distributed among the water users along its length. Therefore, it was decided that the upstream 15 percent of the lateral system in length would be sized with the 2015 lateral design flow, while the rest of the lateral system (85% in length) would be designed with the 1923 document.

A pipe diameter was determined using the FlowMaster software that would convey the same flow rate as the existing channels at the same invert slope. The pipe material was assumed to be concrete (Manning's n value of 0.015). The total lengths of new lateral pipes are summarized by pipe diameters in Table 4.7. If a certain segment of the existing lateral channel required a replacement pipe size of bigger than a single 6-foot diameter pipe, it was decided that the segment would not be piped but instead more cost effective to line it.

Table 4.7 – Breakdown of New Lateral Pipe Lengths Required by Lateral Locations

	Pipe Diameter (feet)						
Lateral	**1.5**	**2**	**3**	**4**	**5**	**6**	**No Piping**
		Pipe Length (feet)					
H	-	1,653	14,994	16,181	11,800	-	-
K	-	1,760	27,742	26,425	23,911	-	14,089
L	-	2,973	14,688	5,766	-	4,134	-
M	-	511	32,620	-	300	-	5,900
N	3026	8,027	35,775	5,200	4,096	-	9,904
O	-	10,548	2,150	-	-	2,700	-
P	-	17,075	25,522	23,635	-	-	8,400
Q	-	-	14,377	5,600	11,000	-	-
S	652	-	5,275	5,600	-	-	-
T	-	-	-	6,684	-	-	-
U	-	-	3,232	-	-	-	-
V	-	-	-	8,622	-	-	-
Total:	**3,678**	**42,547**	**176,375**	**103,713**	**51,107**	**6,834**	**38,293**

In Table 4.7, the large size pipes were results of flat invert slopes of the laterals. According to Table 4.6, most of the laterals have a profile slope that is flatter than 0.0005 foot/foot (0.05 %). Even with flow rates less than 30 cfs in most pipe reaches, the required pipe sizes were mostly 3 to 4 feet in diameters (almost 73% of all pipe required by length) due to a flat invert slope. Also, approximately, 38,293 feet of the existing laterals (9%) would not be piped but remain in the existing open channel condition due to excessive pipe sizes that piping would require.

It is likely that the piping of the existing laterals would include sprinkler irrigation. Currently, only about 9% of the project site is involved in sprinkler irrigation. Sprinkler irrigation would provide a more effective and efficient way to deliver water onto farming lands.

The pipe sizing determination provided in Table 4.7 is based on the lateral geometries and operational flow rates shown on Reclamation’s 1923 operating map. For the construction-level design, the geometries should be field verified, and the flow rates should be confirmed based on the future operating requirements. It is possible that piping and subsequent reduction in seepage, evaporation, and end spillage loss may lead to reduction in required flow diversion to the laterals and reduction in pipe size requirements.

Quantities

The quantities of lateral piping are summarized in Table 4.8. A breakdown of the quantities by lateral locations are shown in Table 4.7.

Table 4.8 – Summary of New Lateral Pipe Lengths

Pipe Diameter (ft)	Total Pipe Length (miles)
1.5	0.70
2	8.06
3	33.40
4	19.64
5	9.68
6	1.29
No piping [1]	7.25

Note:

1. This portion lateral will not be piped because it would require a replacement pipe size of bigger than a single 6-foot diameter pipe and simple lining of the existing earthen lateral to avoid seepage loss is more cost effective.

Drawings

The layout of all of the laterals which totals up to more than 225 linear miles is shown on Sheet C-102, titled, "Plan (02) Main Canal Lining", of Attachment 1.

4.3. Pumping Station

Ranney Wells were identified as a potential water source in this alternative. It is proposed that wind turbines would be a power source for this measure.

4.3.1 Ranney Well

Description

Under this alternative, the diversion requirement would be reduced by 766 cfs [The difference between the current diversion rate (1,374 cfs) and target diversion rate (608 cfs)] by implementing the water conservation measures described above. This would result in the new required water diversion of 608 cfs into the main canal, instead of the current operation discharge of 1,374 cfs. This pump station measure assumes that the 608 cfs could be accomplished through pumping from the alluvial aquifer during periods of low Yellowstone River flows, instead of diversion through the existing headworks at the upstream end of the main canal. The pumping stations would be installed at seven locations along the Yellowstone River (Sites 1 through 7, as shown in Figure 3.3) and pump water from the alluvial aquifer to the canal.

One technology assumed to be feasible is the use of Ranney Wells which typically include a reinforced concrete caisson, 10 feet to 20 feet inside diameter, sunk from grade to a confining layer or bedrock. Horizontal well screen laterals are projected into the alluvial aquifer a distance of 100 to 250 feet. The caisson becomes the foundation of a pumping station. Plan and section views of a typical Ranney well structure are shown in Figure 4.12 and Figure 4.13, respectively.

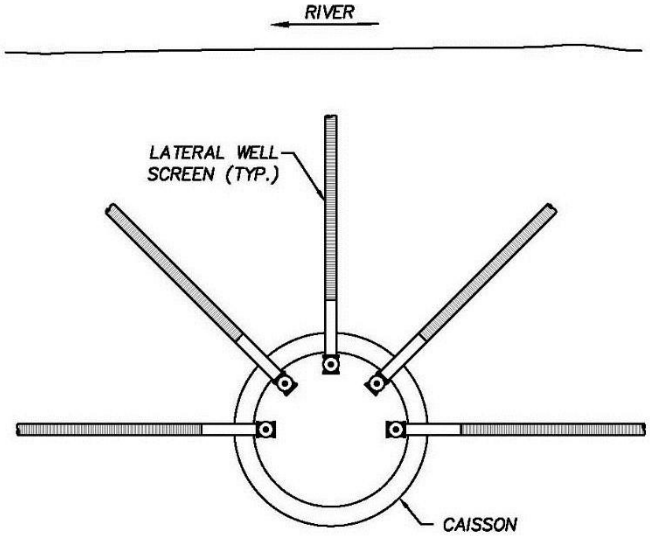


Figure 4.12 – Typical Ranney Well (Plan View)

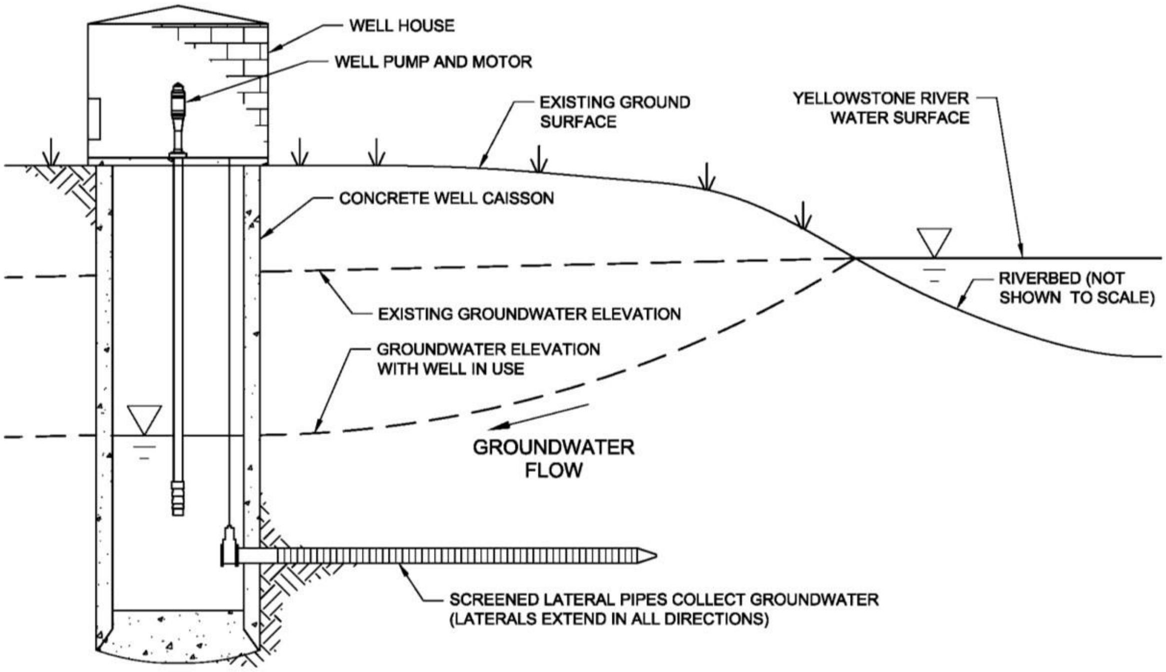


Figure 4.13 – Typical Ranney Well (Section View)

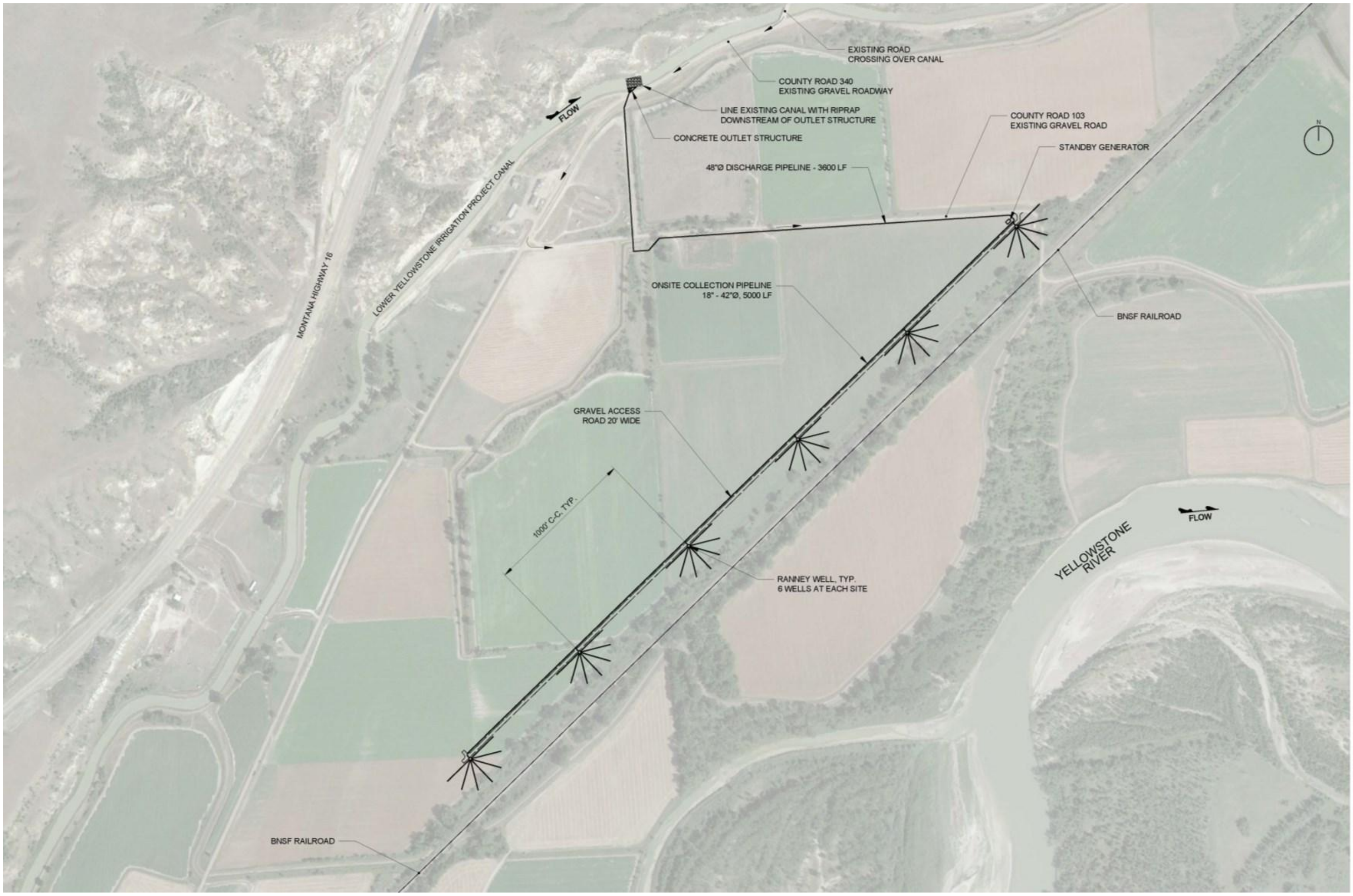
Design Layout

The previous Ranney (Reclamation 2013) well alternative study was updated for this analysis with additional information from the study area. While Ranney wells could be placed anywhere in the study areas there is available information to indicate that sites closer to Sidney may be more suitable for this project. Both well logs and literature suggest that although there is an alluvial aquifer with up to 80 feet of available drawdown the conditions appear more prevalent near Sidney (Tetra Tech 2016).

In a memo proving information on Ranney Wells and their feasibility for use on the Lower Yellowstone, Layne Heavy Civil, Inc. suggested that wells are usually located on the river bank within 100 feet of the water's edge. It was also suggested that individual wells on a site be located a minimum of 100 feet from each other to reduce interference while pumping. They suggested that upon completion of a hydrogeological study from 6 to 10 locations could be chosen (Layne Heavy Civil 2016). Therefore, the Ranney well design was modified to account for a broader range of possible sites, and uncertainty in suitable locations.

While Ranney wells are typically placed on the river bank within 100 feet of the water's edge, such placement is not recommended on the Yellowstone River. Because of the high rates of channel migration, it is recommended that the wells be placed outside the Channel Migration Zone (CMZ) which is up to 1,000 feet wide in some locations (DTM and AGI 2009). The down side of this is well production may be reduced due to the increased distance from the main recharge source, the Yellowstone River. Possible locations have been identified that are outside or as far away from the CMZ as possible, have road access, and do not require additional grading or clearing of the river floodplain.

An example layout of Ranney wells was prepared for one of the 7 sites shown on Figure 3.3. The example Ranney well layout for Site 3 is shown in Figure 4.14. Attachment 4 includes maps of all of the potential sites.



Note: Ranney Well locations shown are CONCEPTUAL ONLY.

Figure 4.14 – Example Ranney Well Layout (Site 3)

Quantities

The Layne's 2016 memo provided a cost estimate with the assumption that 14 collector wells (7000 gallons per minutes (gpm) each) would provide approximately 95,000 gpm. To provide the new required diversion rate of 608 cfs, a total of 42 Ranney wells would be required along the river. It is assumed that 6 Ranney wells would be placed at each of the 7 sites previously identified between Intake Dam and Sydney (Figure 3.3).

Table 4.9 – Summary of Ranney Well Quantities

Item	Quantity (Each)
Ranney Wells at Each Pump Station	6
Number of Pump Station	7
Total Ranney Wells for Project	**42** (= 6 x 7)

Power Consumption for Ranney Wells

The Ranney Wells proposed by this design alternative would consume approximately 4.0 Gigawatt hours of power in a typical year. This estimate assumes an average diversion rate of 608 cfs continuously from May 1 to September 30.

The existing headworks would be used to divert water by gravity when the Yellowstone River water level is high enough to permit gravity diversions to take place, and the Ranney Wells would be used when they are not. Due to backwater effects between the pumped inflows and gravity diversions, the Ranney Wells are assumed to be used in downstream to upstream order starting with Site 7. When the Ranney Wells at Sites 1 and 2 are required, the headworks would be closed and all irrigation water would be diverted by pumping.

A summary of the operation and power demand in each operating mode is shown in Table 4.10, below. The average annual energy consumption calculation is included in Attachment 2.

Table 4.10 – Typical Operation and Power Demand for the Ranney Wells

Ranney Well Sites in Use	Power Demand[a] (kW)	Gravity Diversion[b] (cfs)	Time Operating in this Mode[b]	Days Operating in this Mode[b]	Energy Consumption (GWH)
None	0	> 608	61%	93	0.0
Site 7	1100	608 - 521	9%	14	0.4
Sites 6 & 7	2400	521 - 434	10%	16	0.9
Sites 5-7	3500	434 - 347	10%	15	1.2
Sites 4-7	4000	347 - 261	6%	10	0.9
Sites 3-7	4600	261 - 174	3%	4	0.5
All Sites	5100	< 174	< 1%	< 1	< 0.1
Total	-		100%	-	**4.0**

Notes:

a) Power demand shown is for the Ranney Well pumps only.

b) Estimated time in each operating mode is based on the analysis of the existing headworks, as described in section 3.1.1, assuming a total diversion rate of 608 cfs.

c) Values shown are rounded.

4.3.2 Wind Turbine

Description

Energy consumption calculation for the Ranney Wells is included in Attachment 2. In order to supply electricity to pump stations, construction and operation of wind turbine are considered. Since the upper Great Plains is a region known for its wind energy resources, it is proposed under this alternative that Federal funds be used to pay for the capital cost of a windmill that would supply enough energy, on average, to meet the pump loads. Because the hours in which wind generation would occur would be spread across all twelve months of the year, while irrigation pump loads would be limited to May-September, banking arrangements would be needed with a utility (quite possibly Western Area Power Administration (WAPA), which operates power generation and transmission facilities across the western U.S.) to deliver unneeded generation to them in exchange for receiving generation back from them when pump loads exceeded the wind generation. This would also require generating 10 percent in excess of pump loads to account for transmission and distribution losses between the generator and the load, and a further 20 percent in excess of that to account for banking costs.

This component would require either partnering with a planned wind farm or construction of wind turbines as part of the project. If power is marketed (i.e., power is generated in excess of that directly needed to operate the project and sold), it is likely Congressional authorization would be necessary to add power as an authorized purpose on the Lower Yellowstone Project. Discussion with Western staff resulted in the conclusion that Western does not have authority to serve as a power credit banking facility (Shalund, 2016). Western has had past agreements with utilities such as PGE but those were displacement arrangements where Western served PGE loads and vice versa where each had existing facilities.

An inquiry was made to Montana Dakota Utilities, which serves the project area, about building a wind turbine or buying into one of their facilities. That is not a likely scenario with a regulated utility. Alternatively, there could be a net metering agreement developed if the LYP were to install wind turbines in the project area. This would also require regulatory approval (Helm 2016). Typically, a wind farm requires several years of study for siting and permitting. That analysis is beyond the scope of this EIS, and would be carried out separately.

Reclamation believes it has sufficient authority to carry out actions necessary to accomplish fish passage at the Lower Yellowstone Project, including construction, operation and maintenance of wind power to operate necessary facilities. If power is marketed (i.e., power is generated in excess of that directly needed to operate Lower Yellowstone Project facilities and then sold), it is likely Congressional action would be necessary to authorize power as a project purpose for the Lower Yellowstone Project.

4.4. Further Design Considerations/Next Steps

Currently, no updated survey of the existing structures such as the main canal, laterals, and other canal structures is available. Future construction-level design shall include updated survey of the project area including existing structures as well as geotechnical and structural analyses.

For the dam removal, it was assumed that the foundation portion of the existing dam (portion below elevation 1982 feet) would be left in place. However, there was no detailed information available on the gradation and quality of the foundation riprap. Considering the weir portion of the dam has been experiencing damages due to years of freeze and thaw process, the adequacy of the foundation riprap and its structural stability after the removal of the weir should be further assessed in future design to confirm the design assumption.

Implementation of the water conservation measures will change the operational flow rates in the main canal and irrigational laterals by minimizing flow losses and providing more efficient operation of the facilities. For the construction-level design, design flow rates in these facilities should be adjusted and confirmed through coordination between all affected water users and stakeholders prior to beginning of future design.

A hydrogeological study including drilling and pumping tests will be required to locate Ranney wells within the study area, and determine volume of water that could be produced by those wells.

5.0 Construction Considerations

5.1. Construction Risk

The alternative design presented in this engineering appendix is conceptual and based on limited information and a number of assumptions. Future geotechnical or structural analysis as well as updated field survey to be performed for the construction-level design may affect the design details shown in this report as well as the project costs. Therefore, there is a risk that construction costs could be higher than estimated.

For the existing dam removal, dewatering and control of water at the project site would be critical during construction, as there is a risk of flooding the project site which is located in the active flow area of the river. It is anticipated that surface water flow and groundwater seepage into the construction site would be controlled by the contractor’s dewatering system that includes temporary cofferdams and subsurface pumping wells. Constant subsurface seepage monitoring would be required at the job site especially since some level of flow is expected in the river for the entire construction period. Additionally, potential risk with cofferdam design is that river flow could exceed the cofferdam design flow rate, overtopping the dam and flooding of the construction site or possibly damaging the cofferdam.

For the Ranney well design, there is very little data available on the existing underground aquifer properties near the proposed well locations, and design assumptions have been made, based on engineering judgments, to develop the design. Therefore, there is a risk that Ranney wells may not perform as designed at these sites.

5.2. Disturbance during Construction and Operation

Because the project site including a potential staging area, stockpile location, and access road would be located within farm lands, construction disturbance to public land would be minimal. However, since construction includes working in the Yellowstone River, the contractor would have to comply with any construction requirements of federal, state, and/or local laws and regulations, associated with working in the streambed. Also, biological surveys may be necessary in order to determine whether any endangered species in the area would be affected by the construction activities.

Implementation of some of the water conservation measures, such as main canal lining, piping of laterals, and installation of check structure, are likely to temporarily interrupt services of these facilities and impact many water users during construction. The construction would have to include diversion of canal or lateral flow around the construction area and/or performing the construction in multiple phases in order to minimize disruption of services to water users.

6.0 References

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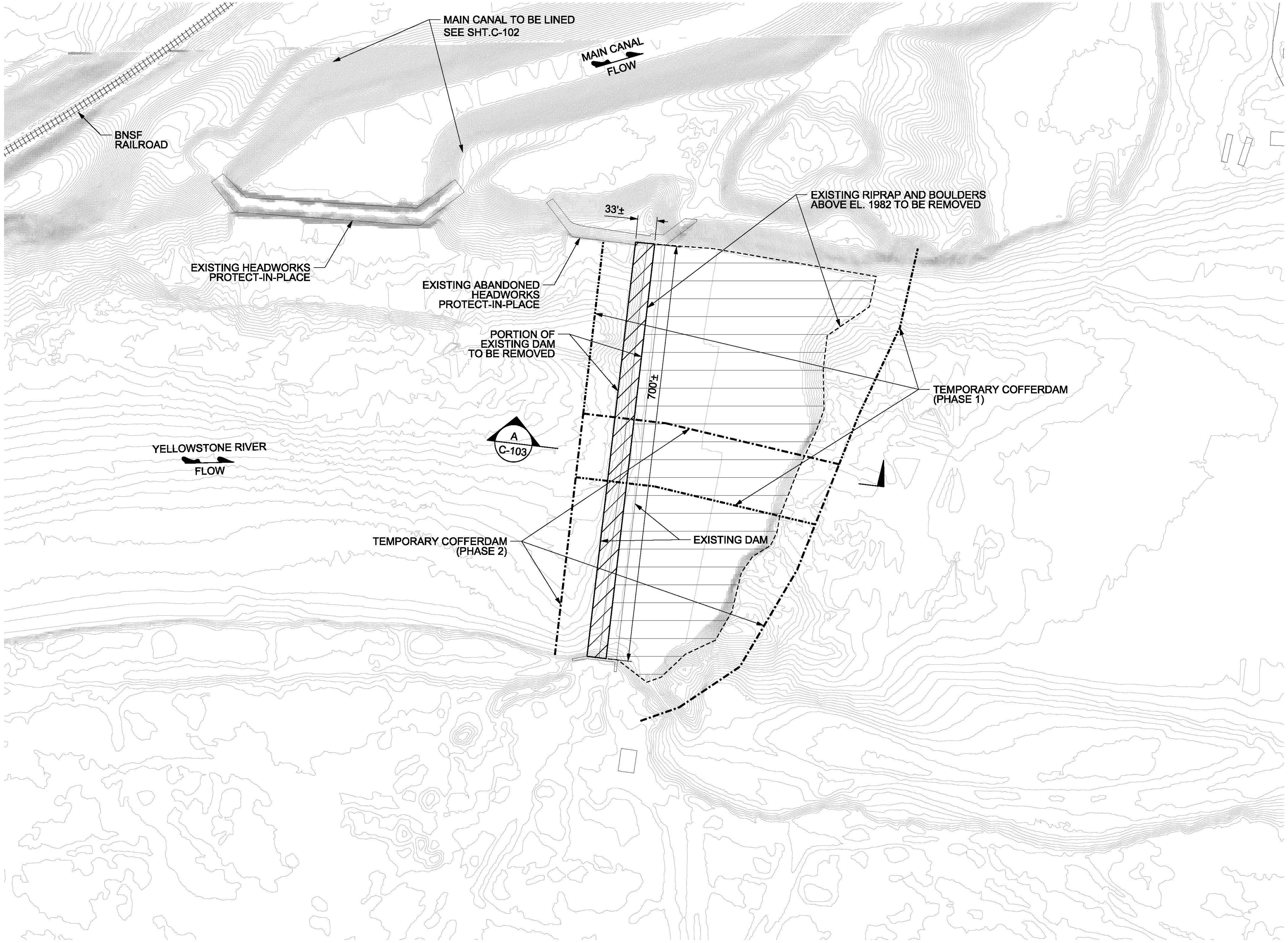
Attachment 1
Ranney Wells with Conservation Measures Design Plans



EXISTING DAM REMOVAL PLAN

1" = 100'

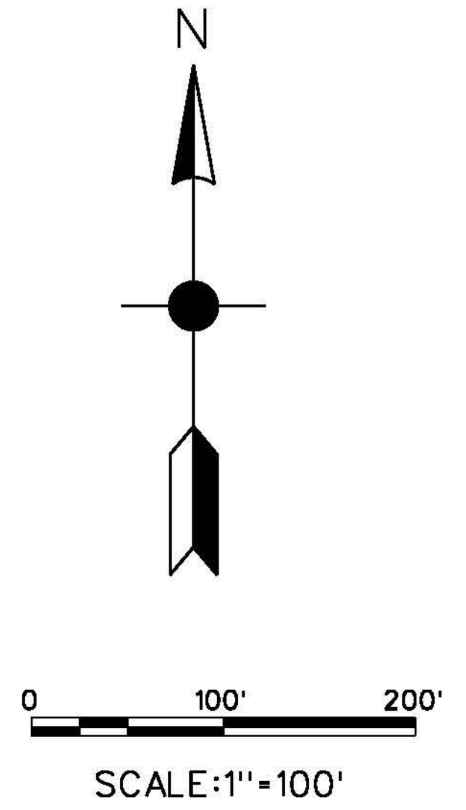
LEGEND

-··-··-··- TEMPORARY COFFERDAM (PHASE 1)

-·-·-·-·- TEMPORARY COFFERDAM (PHASE 2)

▨ PORTION OF EXISTING DAM TO BE REMOVED

┄┄┄ EXISTING RIPRAP AND BOULDERS ABOVE EL. 1982 TO BE REMOVED



US Army Corps
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Omaha District

MARK	DESCRIPTION	DATE	APPR.

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U.S. ARMY CORPS OF ENGINEERS
OMAHA DISTRICT
OMAHA, NE

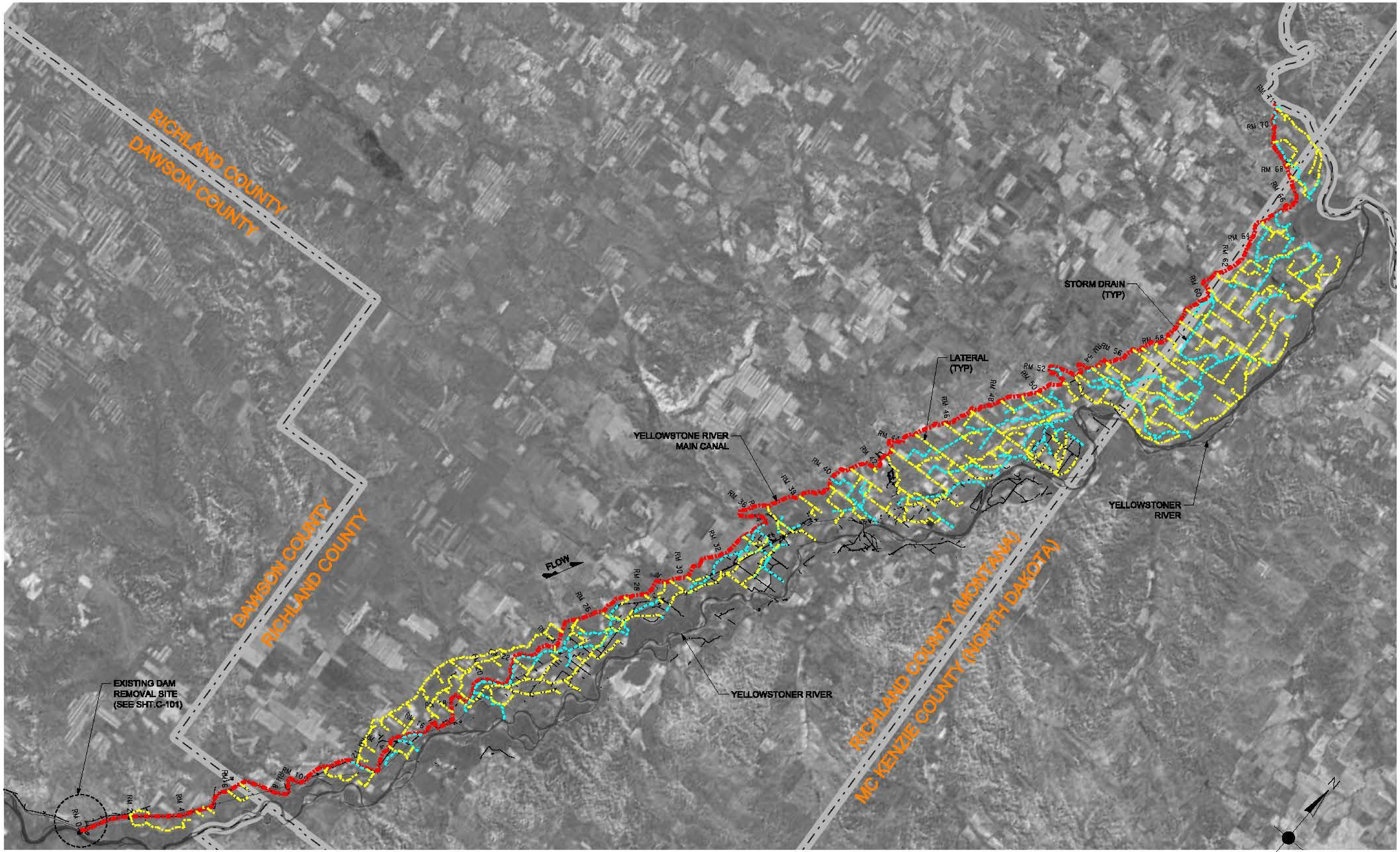
TETRA TECH
400 112TH AVE NE, SUITE 400
BELLEVUE, WA 98004

DESIGNED BY: J. SUH
DWN BY: J. SUH
CKD BY: XXXX
SUBMITTED BY: XXXX
PLOT SCALE: AS SHOWN
PLOT DATE: $$Date$$
SIZE: ANSI D
FILE NAME: T35234CF101RMV.DGN
DATE: $$Date$$
SOLICITATION NO.:
CONTRACT NO.:
FILE NUMBER:

LOWER YELLOWSTONE RIVER, MONTANA
INTAKE DIVERSION DAM FISH PASSAGE PROJECT
MULTIPLE PUMPS WITH CONSERVATION
MEASURES ALTERNATIVE

PLAN (01)
EXISTING DAM REMOVAL

SHEET
IDENTIFICATION
C-101
SHEET X OF Y



YELLOWSTONE RIVER MAIN CANAL LINING PLAN

1" = 10,000'

LEGEND

🟥	MAIN CANAL CENTER LINE (TO BE IMPROVED WITH CANAL LINING)
🟨	EXISTING LATERAL CENTER LINE
🟦	EXISTING STORM DRAIN CENTER LINE
—	EXISTING ROADWAY
RM 4	RIVER MILE ALONG MAIN CANAL

0 10,000' 20,000'
SCALE:1"=10,000'

US Army Corps
of Engineers®
Omaha District

MARK	DESCRIPTION	DATE	APPR.

MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
OMAHA DISTRICT
OMAHA, NE

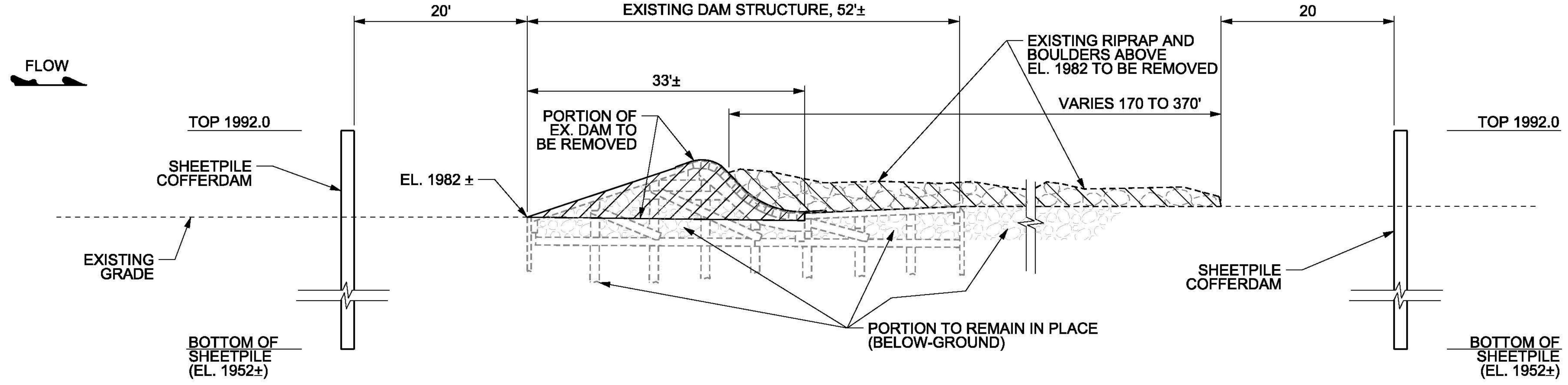
TETRA TECH
400 112TH AVE NE, SUITE 400
BELLEVUE, WA 98004

DESIGNED BY: J. SUH		DATE: [illegible]
DWN BY: J. SUH	CKD BY: XXXX	SOLICITATION NO.:
SUBMITTED BY: XXXX		CONTRACT NO.:
PLOT SCALE: AS SHOWN	PLOT DATE: [illegible]	FILE NUMBER:
SIZE: ANSI D	FILE NAME: T35234CF101RMV.DGN	

LOWER YELLOWSTONE RIVER, MONTANA
INTAKE DIVERSION DAM FISH PASSAGE PROJECT
MULTIPLE PUMPS WITH CONSERVATION
MEASURES ALTERNATIVE

PLAN (02)
MAIN CANAL LINING PLAN

SHEET
IDENTIFICATION
C-102
SHEET X OF Y

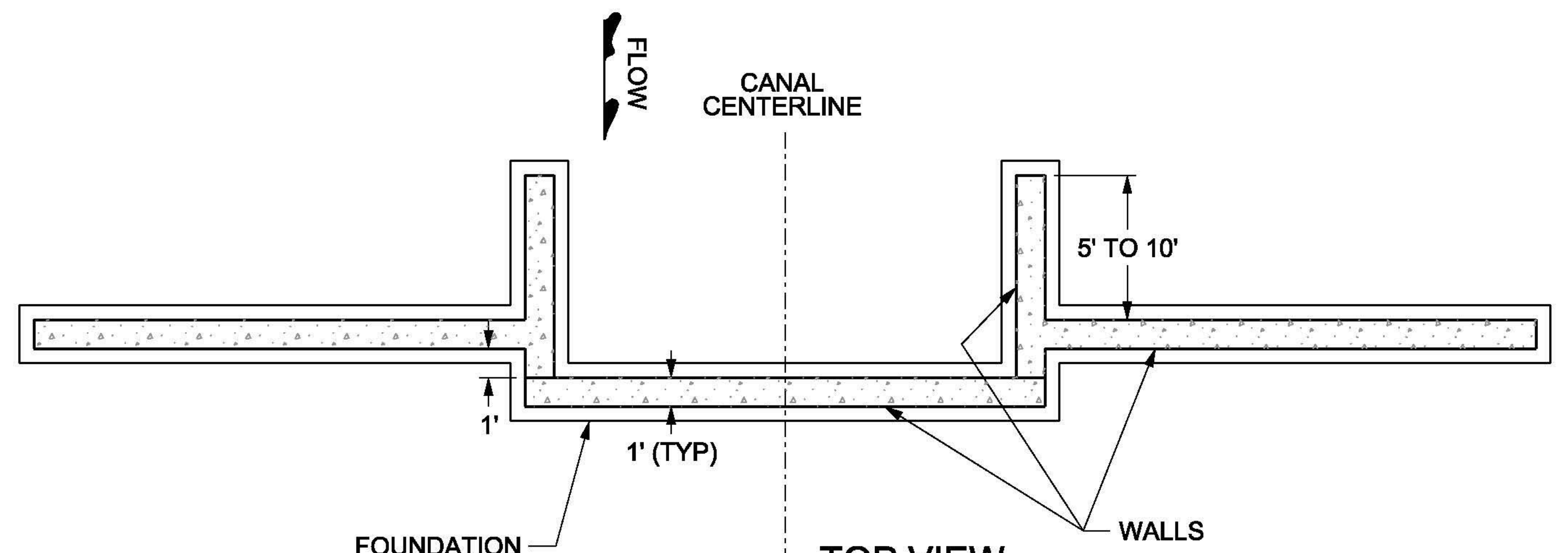


NOTE:
1. COFFERDAM SHOWN HEREON IS SHEETPILE. HOWEVER, THE CONSTRUCTION-LEVEL DESIGN IS LIKELY TO INCLUDE COFFERDAM SYSTEM THAT COMBINES BOTH SHEETPILE AND EARTHEN DAM. TYPICAL EARTHEN COFFERDAM IS ALSO SHONW ON THIS SHEET.

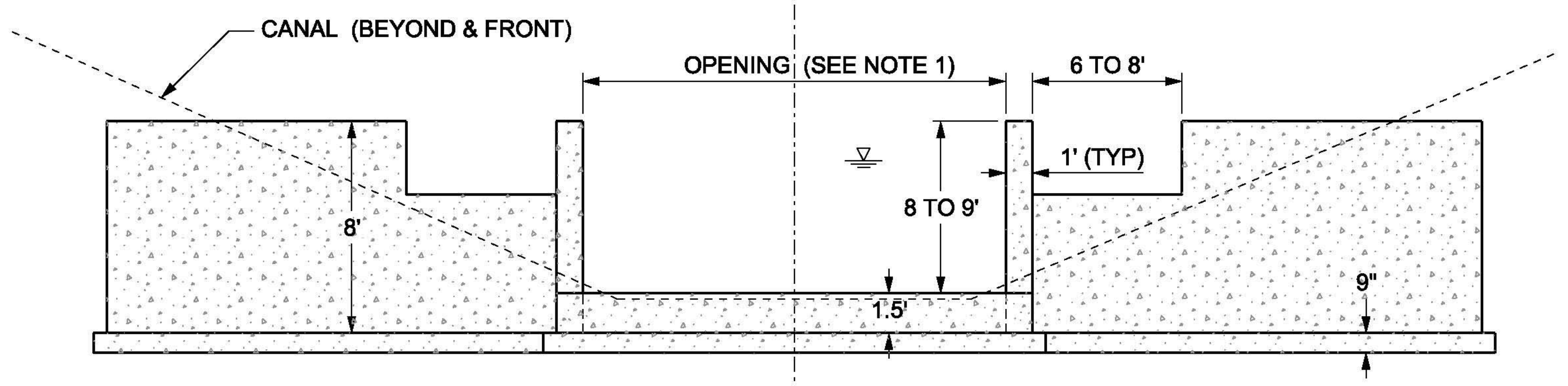
SECTION - EXISTING DAM REMOVAL

A C-101

N.T.S



TOP VIEW

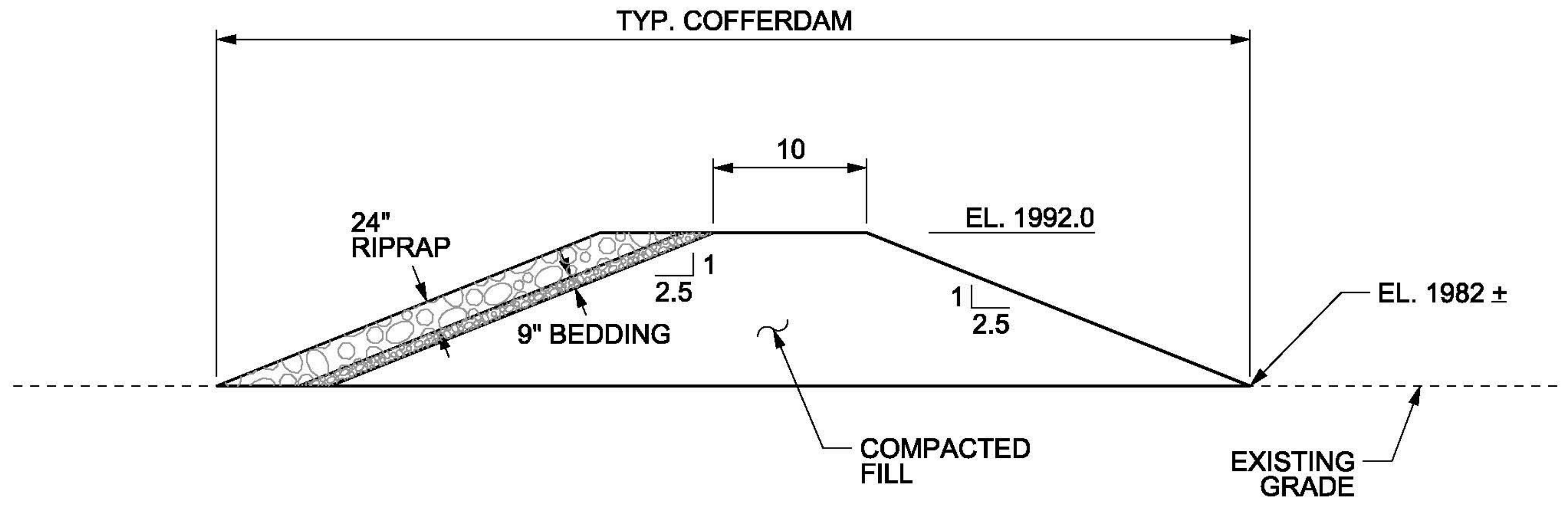


NOTE:
1. THE OPENING IS EITHER A SINGLE BAY (20-FT OPENING) OR DOUBLE BAY (TWO, 16-FT OPENINGS).
2. MECHANICAL AND ELECTRICAL COMPONENTS OF CHECK STRUCTURE ARE NOT SHOWN.

FRONT VIEW

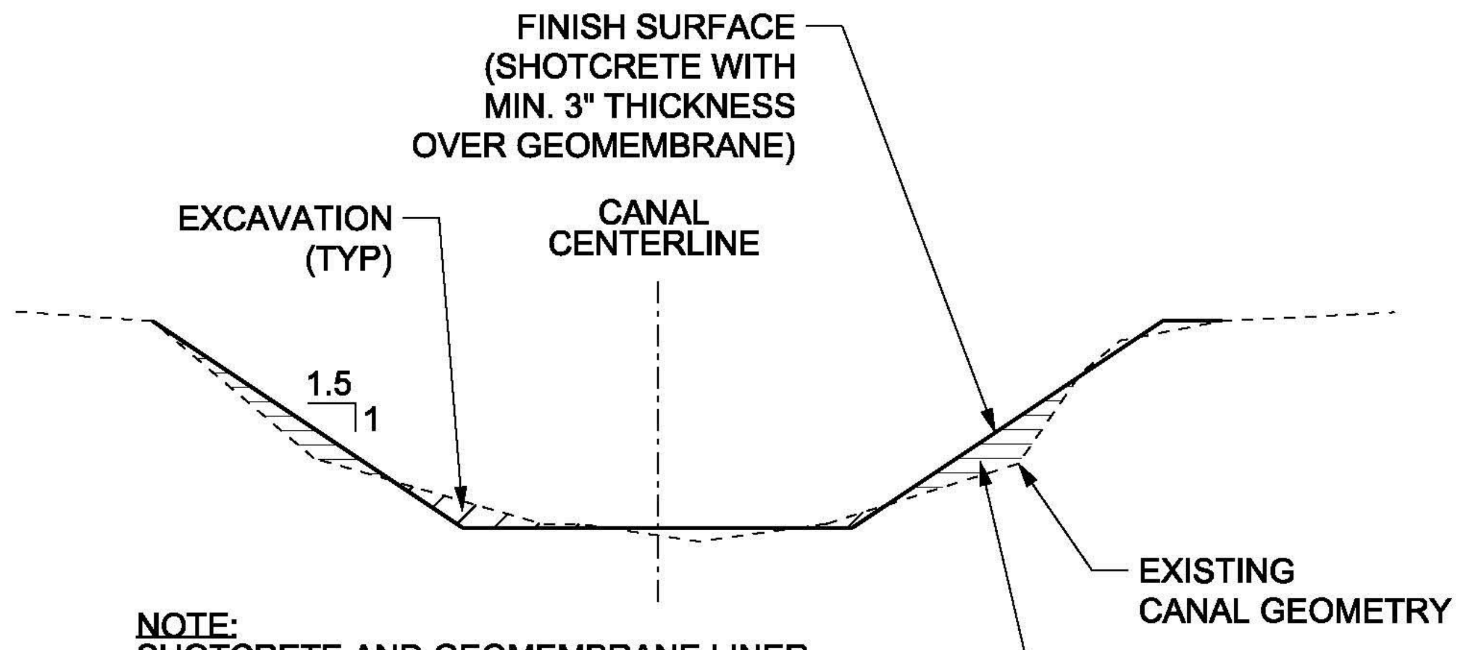
TYPICAL CHECK STRUCTURE

N.T.S



TYPICAL EARTHEN COFFERDAM

N.T.S



NOTE:
SHOTCRETE AND GEOMEMBRANE LINER DETAILS INCLUDING ANCHORING ARE NOT SHOWN FOR CLARITY.

TYPICAL CANAL LINING SECTION

N.T.S

US Army Corps of Engineers®
Omaha District

MARK	DESCRIPTION	DATE	APPR.

MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY: J. SUH
DWN BY: J. SUH
CKD BY: XXXX
SUBMITTED BY: XXXX
PLOT SCALE: AS SHOWN
PLOT DATE: $$Date$$
SIZE: ANSI D
FILE NAME: T35234CF101RMV.DGN
DATE: $$Date$$
SOLICITATION NO.:
CONTRACT NO.:
FILE NUMBER:

U.S. ARMY CORPS OF ENGINEERS
OMAHA DISTRICT
OMAHA, NE

TETRA TECH
400 112TH AVE NE, SUITE 400
BELLEVUE, WA 98004

LOWER YELLOWSTONE RIVER, MONTANA
INTAKE DIVERSION DAM FISH PASSAGE PROJECT
MULTIPLE PUMPS WITH CONSERVATION MEASURES ALTERNATIVE

TYPICAL SECTIONS AND DETAILS

SHEET IDENTIFICATION
C-103
SHEET X OF Y

T35234CF103TYP.dgn 5/5/2016 11:41:55 AM

Attachment 2

Ranney Well Energy Consumption Estimate

TETRA TECH

Job No.:	100-SET-T35234
Project:	Lower Yellowstone River
Subject:	Ranney well Alternative
Design Topic:	Average Annual Energy Consumption by the Ranney Wells

Made By: JPP **Date:** 21-Mar-16 **Chk'd By:** FMB **Date:** 4-Mar-16

1.0 ISSUE BEING ADDRESSED

Calculate the average annual energy consumption for the 42 Ranney wells proposed by the non-weir alternative.

2.0 APPROACH

Calculate the average number of days per year when gravity diversions permit the use of Ranney Wells at sites 3-7, based on results of the gravity flow potential model. Then calculate the power demand in each mode based on the number of days the pumping stations are in that mode and the power demand in that mode.

3.0 REFERENCES

References used in this calculation are as follows:

1) Gravity flow potential technical memo, TetraTech, 2016
2) Ranney Well Power calculations, TetraTech, 2016.

4.0 ASSUMPTIONS

1) A total diversion of 615 cfs is required at all times during the irrigation season.
2) Pumped inflows from Ranney wells at sites 1 and 2 cannot be used simultaneously with gravity inflow from the existing headworks due to backwater effects. Ranney wells at sites 3-7 can be used simultaneously, but must be started in downstream-to-upstream order.
3) Variation in the pump flow rates due to changes in the river WSEL will be small and can be ignored.

TETRA TECH

Job No.: 100-SET-T35234

Project: Lower Yellowstone River
Subject: Ranney well Alternative
Design Topic: Average Annual Energy Consumption by the Ranney Wells
Made By: JPP **Date:** 21-Mar-16 **Chk'd By:** FMB **Date:** 4-Mar-16

5.0 CALCULATIONS

Number of days in irrigation period (May - September)	152	
Pumping capacity at each Ranney Well site	87.9	cfs

Power demand at each pumping station [Ref 2]:

Site 1	187	kW
Site 2	391	kW
Site 3	550	kW
Site 4	584	kW
Site 5	1041	kW
Site 6	1295	kW
Site 7	1162	kW
Lateral Diversion Pumping Stations (total)	50	kW

Ranney Well Sites in Use:	**None**	**Site 7**	**Sites 6 & 7**	**Sites 5-7**	**Sites 4-7**	**Sites 3-7**	**All Sites**
Pumped Diversion Flow Rate (cfs)	0	88	176	264	351	439	615
Gravity Diversion Flow Rate, Qg (cfs)	615	527	439	351	264	176	0
Days when gravity could supply Qg[Ref 1]	61%	70%	80%	90%	97%	99.96%	100%
Days operated in only this mode	61%	9%	10%	10%	7%	3%	0.04%
Number of days in this mode per year	92	14	16	15	10	4	0
Power Demand (kW)	0	1212	2507	3548	4132	4682	5259
Energy consumed (GigaWatt hours)	0.0	0.4	1.0	1.3	1.0	0.5	0

Average Annual Energy Consumption: **4.2 GigaWatt hours per year**

Attachment 3
Water Conservation Measure Information

Lower Yellowstone Intake Diversion Dam Fish Passage Project, Environmental Impact Statement

April 2016

Conservation Measure Information

Submitted by:
Tetra Tech, Inc.

INTRODUCTION

One of the primary components of the Ranney Wells with Conservation Measures Alternative is the implementation of water conservation measures to reduce the amount of water required for diversion by the project to accommodate agricultural production. These were proposed by Defenders of Wildlife (Defenders) and Natural Resources Defense Council (NRDC) by letter dated February 17, 2016 (Defenders and NRDC, 2016), and summarized in an Excel Spreadsheet.

The conservation measures as proposed were based primarily on review of a 2009 Conservation Plan prepared by the Lower Yellowstone Irrigation District (LYIP, 2009), and results of value planning studies (Reclamation 2005, Reclamation 2013). Table 1 summarizes the conservation measures as proposed.

The value planning study noted that "Cost and demand reduction estimates are currently at a low level of confidence and need to be field evaluated and refined" (Reclamation, 2013). Therefore efforts have been made to identify additional information pertaining to the proposed conservation measures that may inform the analysis of this alternative. However, this has not include field verification or site specific design.

Table 1 Proposed Conservation Measures and Estimated Savings (cfs)

Component	Description	Estimated conservation (cfs)
Check Structures	Installation of check structures in the canal for water control	61.5
Flow measuring devices	Measuring devices installed on the canals	18.5
Laterals to pipe	Convert laterals to pipe	255.8
Sprinklers	Install center pivot sprinklers	160
Lining main canal/laterals	Line main canal and laterals with concrete	200
Control over checking	Operational change to water levels in the canals	20.6
Groundwater pumping	Install groundwater pumps	49.5
	Total Savings	**765.9 cfs**

CONSERVATION MEASURE INFORMATION

Check Structures – Installation of additional check structures is currently proposed to reduce diversion requirements by 61.5 cfs, or 10% of current diversions. Check structures provide water control along the canal as a means of raising water levels high enough to divert into laterals. Existing check structures are used to raise water levels at times of low flows, and it was stated in the 2009 Conservation Plan that even with the current structures, inefficiencies persist due to inability to provide deliveries from an uncontrolled main canal water surface under low flow conditions. Therefore it seems that this measure has potential to provide some savings during low flow conditions, but perhaps not provide savings during higher flows in the main canal.

The 2009 Conservation Plan assumed a savings of 10% of current diversions by installation of check structures but did not provide backup for that assumed savings. A recent WWC Engineering evaluation of check structure productivity for the study indicated that there is no basis behind check structures providing conservation; and their installation poses added risks including increased water levels in the canals, increased seepage due to additional head in the canals, reduced flow velocity within the canals, and increased risk of damage to the canal banks due to higher water levels (Higley, 2016).

If an alternative including this measure is carried forward, more detailed investigations should be conducted to confirm productivity.

Flow Measuring Devices – Devices to provide flow measurements on the laterals are proposed to provide a savings of 18.5 cfs, or 3% of current diversions. Flow measurement would provide additional information beyond that already gathered by ditch riders and in theory that information would allow for improved water management. The 2009 Conservation Plan proposed that these could provide savings equivalent to 3% of current diversions and that is the same basis as currently proposed, although there is no data to suggest what savings could actually be provided by implementation of flow measuring devices. If an alternative including this measure is carried forward, more detailed investigations should be conducted to confirm productivity.

Laterals to Pipe – This proposed measure includes the conversion of open laterals to pipe. As proposed this measure would place 72 miles of laterals into pipe and reduce diversions by 255.8 cfs. There are 225 miles of unlined laterals within the LYIP, so it is assumed that 72 miles of laterals could be placed in pipe.

The Sidney Water Users Irrigation District conducted flow measurements and estimated seepage losses in their irrigation district in 2009 (Sidney Water Users, 2009). That data was compared to estimate unlined lateral canal flow losses from the region. Table 2 summarizes that data, and original data is included in Attachment 1.

Table 2 Sidney Water Users Lateral Water Loss Analysis, 2009

Begin (cfs)	End (cfs)	Adjustment (cfs)	cfs loss rate	% loss	Length (ft)	Length (mi)	Loss cfs/mi
12.57	10.5	+3.94	6.06	0.48	7350	1.39	4.35
11.25	10.7		0.58	0.05	7350	1.39	0.42
2.04	1.42		0.62	0.30	2475	0.47	1.32
5.23	1.83	-2.04	1.36	0.26	8650	1.64	0.83
10.45	2.17	-6.59	1.69	0.16	5425	1.03	1.64
6.59	4.91		1.68	0.25	3954	0.75	2.24
4.69	4.63		0.06	0.01	2600	0.49	0.12

7.52	6.42		1.10	0.15	12100	2.29	0.48
17.71	3.36	-14.26	0.09	0.01	9200	1.74	0.05
4.01	2.97		1.04	0.26	4900	0.93	1.12
4.66	3.9		0.76	0.16	2000	0.38	2.01
Average =1.33 cfs/mile							

WWC Engineering (Higley, 2016) provided 2015 records showing losses for 4 laterals. Data for those laterals show losses ranging from an average loss of 7% in Lateral H, 1% in Lateral L, 24% in Lateral M, and 15% in Lateral N. They caution against using average losses since the system needs to be designed to handle peak consumptive use. For example "Lateral M, which has the highest average seepage loss of the sampled laterals, only lost 3.9% on June 29th during peak demand and high flows". (See Attachment 2)

Table 3 Losses Recorded from LYIP Laterals, 2015

Lateral	Length (mi)	Average cfs Loss	Seepage Loses (cfs/mi)
H	5.28	1.59	0.30
L	3.41	0.10	0.03
M	4.86	5.33	1.10
N	5.72	6.36	1.10
Average = 0.69 cfs/mile			

The Sidney Water Users data is based upon a detailed field study and LYID data a sample of 2015 records from 4 laterals. In both cases seepage losses were converted to loss per mile to simplify comparison with the number of laterals in the LYIP. Table 4 shows the range with the two different seepage values from 50 to 96 cfs that could be conserved by this measure.

Table 4 Range of Savings from Converting Laterals to Pipe

Range of Losses	.69 cfs/mile	1.33 cfs/mile
72 Miles Converted to Pipe	49.68 cfs	95.76 cfs

The Sidney Water Users Irrigation District data and the WWC Engineering data from the LYIP both would result in lower estimates of savings if applied to the pipe lining lengths proposed. If an alternative including this measure is carried forward, more detailed investigations should be conducted to confirm seepage rates, and productivity of this conservation measure.

Sprinklers – This measure is proposed to convert from existing flood irrigation practices to sprinklers. Sprinkler irrigation is generally more efficient than flood irrigation, and is therefore recommended as a measure to reduce water consumption and the associated need for diversion. As of 2009 approximately 9% of LYIP acres were involved in sprinkler irrigation (LYID, 2009), and this alternative proposes doubling that to conserve 160 cfs. As of 2016 approximately 7,988 acres (14%) of LYID has been converted to sprinkler irrigation (Hier. 2016).

While on farm irrigation requirements and conditions are site specific we assumed that flood irrigation has an on farm efficiency between 40-50% and sprinkler 70-80% based on the NRCS National Engineering Handbook. Potential savings from the sprinkler conservation measure were based upon the following assumptions:

1. 5,000 acres will be converted to sprinklers,
2. Peak Daily ET for Alfalfa is 0.33 (in/day) (NRCS IWR Data),
3. Field flood irrigation efficiency is assumed as 45%,
4. Sprinkler irrigation efficiency was assumed as 75%

As shown in Table 5 this measure is estimated to result in savings of 62 cfs. If an alternative inkling this measure is carried forward more detailed investigations should be conducted to confirm productivity.

Table 5 Estimate of Conservation by Converting 5,000 acres to Sprinkler

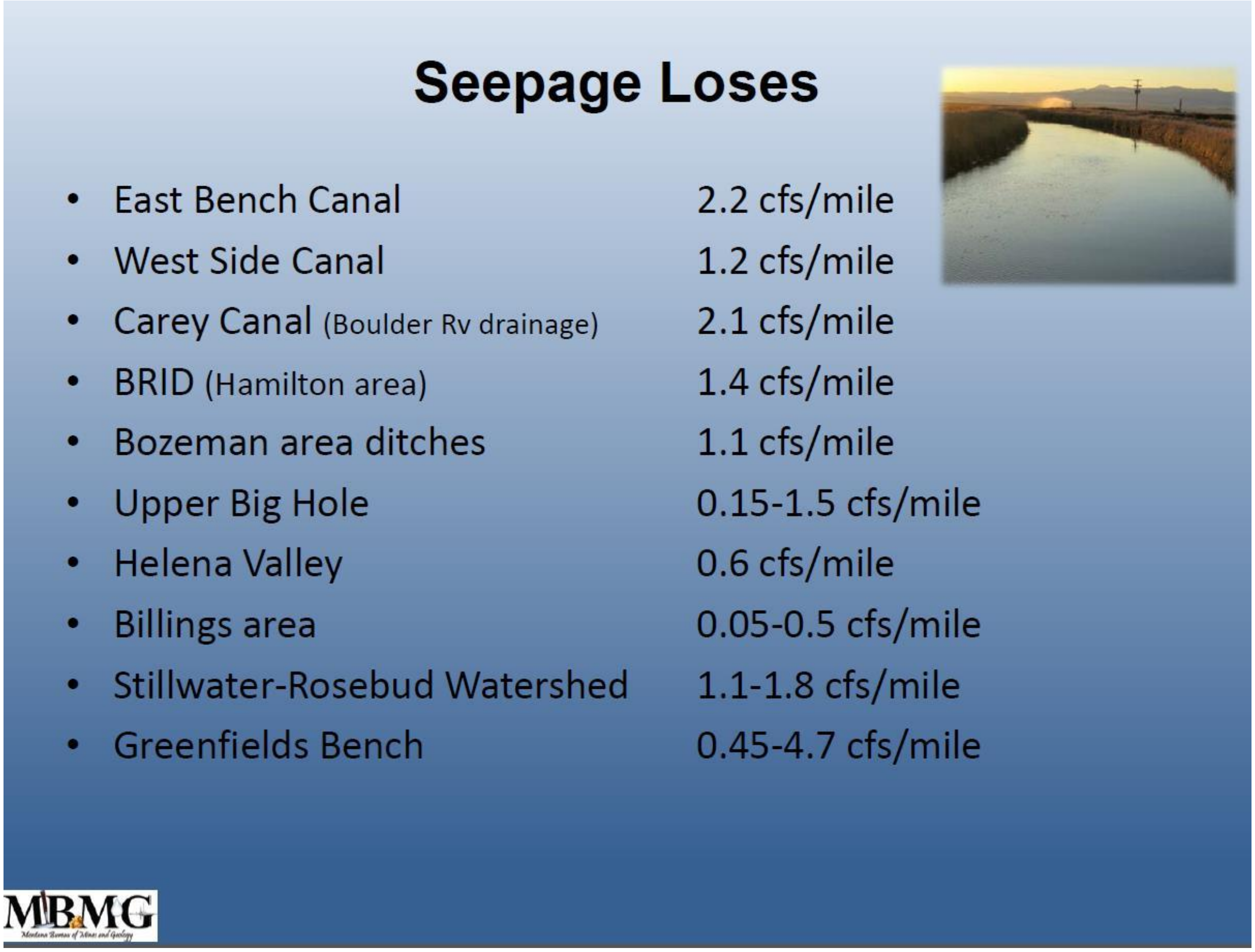
Irrigation Type	Water Required (cfs)
Field Flooding	154
Pivot Sprinkler	92
Savings	62

Lining Main Canal/Laterals – Currently the canal and most of the laterals are unlined, it is proposed that they be lined to reduce seepage losses. As shown in Table 1 it is assumed that lining the 72 miles of main canal and 153 miles of laterals that weren't enclosed in pipes would conserve 200 cfs.

Laterals – Using the same information from Table 4 between 0.69 cfs and 1.33 cfs/mile could be conserved by lining the laterals. That is between 106 and 203 cfs conserved by lining 153 miles of laterals.

Main Canal – Water loss data for two years (2000 and 2012) was evaluated by Higley, 2016. Their analysis of the flow records found *"minimal loss during periods of high demand and significant use (nearly 1,100 cfs delivered with a 1,300 cfs diversion) during peak periods. Additionally, the records show losses in the main canal system are as low as 6% during the peak demand periods. For example, the 2000 flow records show that there are 5 days when the loss within the main canal is less than 10%, 19 days when the loss within the main canal is less than 15%, and 54 days when the loss within the main canal is less than 20%. In addition, the 2012 flow records show that there are 30 days when the loss within the main canal is less than 10%, 73 days when the loss within the main canal is less than 15%, and 121 days when the loss within the main canal is less than 20%. This data clearly shows that the 2009 loss data is not correct for the LYIP, and that there is not 200 cfs of available loss to save within the LYIP main canal."*

In addition to evaluating the LYIP flow record data, measurements from several irrigation canal systems throughout Montana. Were reviewed as presented in (Lafave and Abdo, 2015). The average seepage losses per mile as identified in this report are presented in Figure 1 below and average 1.62 cfs/mile. Using that average the potential seepage losses on the main canal would be 116 cfs. Note that this is not site specific information and no actual seepage measurements have been calculated for the Lower Yellowstone Project canal.



Seepage Loses

East Bench Canal	2.2 cfs/mile
West Side Canal	1.2 cfs/mile
Carey Canal (Boulder Rv drainage)	2.1 cfs/mile
BRID (Hamilton area)	1.4 cfs/mile
Bozeman area ditches	1.1 cfs/mile
Upper Big Hole	0.15-1.5 cfs/mile
Helena Valley	0.6 cfs/mile
Billings area	0.05-0.5 cfs/mile
Stillwater-Rosebud Watershed	1.1-1.8 cfs/mile
Greenfields Bench	0.45-4.7 cfs/mile

Figure 1 Seepage Losses Presented in Lafave and Abdo, 2015

Therefore the information pertaining to the seepage losses from canal lining shows that there is a range of values that could be assumed. The only way to be certain of the amount of seepage losses is to conduct field investigations.

Control Over-Checking - Over-checking is the use of canal check structures to maintain water elevations high enough to divert water into laterals. Maintaining water levels at higher elevations can exacerbate the seepage losses on unlined canals. The proposal assumes that 20.6 cfs of reduced diversion could be accomplished by controlling over checking. This is an operational item and would presumably require operational changes to be carried out by ditch riders

The 2009 Conservation Plan noted that over checking exacerbates seepage on about 56 miles of lateral systems. If those laterals are either placed into pipe or lined this measure may not actually provide the savings proposed.

Groundwater Pumping – Pumping groundwater was proposed as a means to reduce the diversion during times of peak demand. This is not a "conservation" measure per say but an alternative water source. This proposes the installation of pumps and reduce diversions by 49.5 cfs, through pumping of groundwater as opposed to surface water.

The largest LYIP water right is surface water with a 1905 Priority date (Reclamation March 21, 2016). Should the LYIP decide to install wells to provide 49.5 cfs instead of using that surface water right it would first require filing of an Application for Beneficial Water Use Permit, and associated documentation, to the Montana DNRC. This is outlined in Form No. 600 from DNRC (MDNRC 2016c), where requirements include at the minimum an aquifer testing report.

The impacts relinquishing a senior water right for a new source with unknown capacity carries risks and unknown impacts. It is uncertain whether this is a feasible component based on that risk and uncertainty.

IRRIGATION WATER REQUIREMENTS DATA COMPARISON

The LYP currently supplies irrigation to approximately 55,000 acres of crops. The amount of water that those crops require needs to be considered when evaluating conservation measures, and therefore additional analysis was conducted and is explained below.

Reclamation, 2016 and Higley, 2016 both provided information on crop water requirements. Both are based on the NRCS Irrigation Water Requirements (IWR) Program which can be used to calculate water requirements of crops (NRCS, 1993). When comparing peak evapotranspiration rates in the IWR program, and assuming a very aggressive 70% efficiency the 55,000 acres of the LYIP would require 1,150 cfs (Reclamation, 2016).

In addition to this calculation Tetra Tech used the IWR data to estimate crop water needs over the irrigation season. That estimate uses average daily evapotranspiration since it is estimating demand over each month. The analysis was conducted u for the mix of crops in in that 2013 crop census. The analysis applied the average evapotranspiration (ET) rates in order to estimate crop water needs over the season. The following subsections summarize data sources, analysis, and results.

Irrigation Water Requirements (IWR) Model Outputs

The IWR model is the standard tool for estimating crop irrigation requirements including evapotranspiration. In March 2016, Reclamation provided a letter detailing an estimate of water requirements using Peak ET (Reclamation 2016). The letter provided the following summary of the IWR model:

> *"IWR is a crop consumptive use program developed specifically for NRCS use in development of Consumptive Use Table for the new NRCS Irrigation Guide. IWR is based on USDA Natural Resources Conservation Service Handbook: NEH Chapter 2, Irrigation Water Requirements, dated September 1993 and Original SCS Technical Release No. 21, dated April 1967. IWR uses the Blaney-Criddle Computation Method from the local Sidney, MT weather station. The Blaney-Criddle equation is a relatively simplistic method for calculating evapotranspiration."*

The IWR model uses known factors for ET to allow estimation of water demand by crops. It presents both Peak Daily ET and Average Daily ET. The purpose of this analysis was to evaluate irrigation needs using Average Daily ET in order to assess needs under conservative conditions and bracket results from Reclamation's Peak Daily ET analysis. A PDF with IWR output summaries by crop was provided by WWC Engineering on behalf of the LYIP via email on March 7, (Higley 2016). For each crop, the Average Daily ET (daily irrigation requirement in inches per acre), by month between April and September, was imported to Excel. Table 6 summarizes the Average Daily ET by month and crop which was used in the analysis.

Table 6 Average Daily ET by Crop and Month

	Average Daily ET (inches)					
CROP	Apr	May	Jun	Jul	Aug	Sep
Alfalfa Hay	0.09	0.14	0.22	0.26	0.21	0.11
Spring Wheat	0.03	0.08	0.21	0.30	0.18	0.03
Sugar Beet	0.04	0.07	0.17	0.27	0.25	0.13
Grass Hay	0.08	0.12	0.18	0.21	0.18	0.10
Corn, Grain	0.04	0.07	0.16	0.25	0.21	0.11
Dry Beans	0.04	0.08	0.19	0.26	0.19	0.08
Barley	0.03	0.08	0.21	0.30	0.18	0.03
Total	0.35	0.64	1.34	1.85	1.40	0.59

2013 Crop Census

Crop acreages were obtained from the 2013 LYIP Crop Census (Lower Yellowstone Irrigation Project 2013). Per the March Reclamation letter, "This is the number of acres that will be utilized for assessing the peak crop requirement for irrigation needs since it is the most representative of the market and current cropping patterns."

Table 7 summarizes acreages for LYIP crops.

Table 7 LYIP Crop Acreages, 2013 Census

Crops	Acres	%
Sugar Beets	20,160	36.5%
Spring Wheat	13,017	23.6%
Barley	6,994	12.7%
Corn, Grain	4,690	8.5%
Alfalfa Hay	7,113	12.9%
Grass (for hay)	2,493	4.5%
Soy Bean	691	1.3%
TOTAL	55,158	100%

Sources: LYIP 2013 Crop Census (Lower Yellowstone Irrigation Project 2013)

Calculations and assumptions

The key assumption in application of Average Daily ET to estimate annual acre-feet (AF) and average daily cubic-feet-per-second (CFS) is the assumed irrigation system delivery efficiency (the proportion of diverted water that is delivered to farms). Based on the March Reclamation letter, non-flood irrigation system can range from 50-75% efficient. In order to capture uncertainty, this analysis presents results assuming both 60% and 70% irrigation delivery efficiency.

Conversion of Average Daily ET to annual AF and CFS was a multi-step process of unit conversion and scaling based on the acreages of each crop in the LYIP. All calculations were completed by month by crop, in order to present detailed results.

For each crop and month, Average Daily ET values were converted to daily acre-inches by multiplying Average Daily ET by the total acres of that crop. Next, the delivery efficiency factor was applied to estimate need including delivery losses. This acre-inch value was then converted to AF per day by dividing by 12. AF per month was then estimated by multiplying the AF per day by the number of days in the month. CFS was calculated by dividing the AF per day by 43,560, the square feet in an acre, and then again by 86,400, the seconds in a day. Tables 8 and 9 present these calculations at 60% and 70% efficiency, respectively.

Table 8 Water Requirement Calculations, 60% Efficiency

Month	Avg daily ET (in)	Crops Acres	Daily ac-in	Eff. %	Daily ac-in with eff.	AF per day	AF per month	Cubic feet per day	CFS, avg daily
Alfalfa Hay									
Apr	0.09	7,113	640	60%	1,067	89	2,667	3,872,893	44.8
May	0.14		996		1,660	138	4,287	6,024,500	69.7
Jun	0.22		1,565		2,608	217	6,520	9,467,072	109.6
Jul	0.26		1,849		3,082	257	7,962	11,188,357	129.5
Aug	0.21		1,494		2,489	207	6,431	9,036,750	104.6
Sep	0.11		782		1,304	109	3,260	4,733,536	54.8
Spring Wheat									
Apr	0.03	13,017	391	60%	651	54	1,627	2,362,529	27.3
May	0.08		1,041		1,736	145	4,484	6,300,077	72.9
Jun	0.21		2,734		4,556	380	11,390	16,537,703	191.4
Jul	0.30		3,905		6,508	542	16,813	23,625,291	273.4
Aug	0.18		2,343		3,905	325	10,088	14,175,174	164.1
Sep	0.03		391		651	54	1,627	2,362,529	27.3
Sugar Beet									
Apr	0.04	20,160	806	60%	1,344	112	3,360	4,878,659	56.5
May	0.07		1,411		2,352	196	6,076	8,537,654	98.8
Jun	0.17		3,427		5,712	476	14,280	20,734,302	240.0
Jul	0.27		5,443		9,072	756	23,436	32,930,950	381.1
Aug	0.25		5,040		8,400	700	21,700	30,491,620	352.9
Sep	0.13		2,621		4,368	364	10,920	15,855,643	183.5
Grass Hay									
Apr	0.08	2,493	199	60%	332	28	831	1,206,704	14.0
May	0.12		299		499	42	1,288	1,810,057	20.9
Jun	0.18		449		748	62	1,870	2,715,085	31.4
Jul	0.21		524		873	73	2,254	3,167,599	36.7
Aug	0.18		449		748	62	1,932	2,715,085	31.4
Sep	0.10		249		416	35	1,039	1,508,381	17.5

Continued below…

Month	Avg daily ET (in)	Crops Acres	Daily ac-in	Eff. %	Daily ac-in with eff.	AF per day	AF per month	Cubic feet per day	CFS, avg daily
Corn, Grain									
Apr	0.04	4,690	188	60%	313	26	782	1,135,056	13.1
May	0.07		328		547	46	1,414	1,986,349	23.0
Jun	0.16		750		1,251	104	3,127	4,540,226	52.5
Jul	0.25		1,173		1,954	163	5,049	7,094,103	82.1
Aug	0.21		985		1,642	137	4,241	5,959,046	69.0
Sep	0.11		516		860	72	2,150	3,121,405	36.1
Dry Beans (Soybeans)									
Apr	0.04	691	28	60%	46	4	115	167,221	1.9
May	0.08		55		92	8	238	334,442	3.9
Jun	0.19		131		219	18	547	794,300	9.2
Jul	0.26		180		299	25	774	1,086,937	12.6
Aug	0.19		131		219	18	565	794,300	9.2
Sep	0.08		55		92	8	230	334,442	3.9
Barley									
Apr	0.03	6,994	210	60%	350	29	874	1,269,445	14.7
May	0.08		560		933	78	2,409	3,385,186	39.2
Jun	0.21		1,469		2,448	204	6,120	8,886,112	102.8
Jul	0.3		2,098		3,497	291	9,034	12,694,446	146.9
Aug	0.18		1,259		2,098	175	5,420	7,616,667	88.2
Sep	0.03		210		350	29	874	1,269,445	14.7

Table 9 Water Requirement Calculations, 70% Efficiency

Month	Avg daily ET (in)	Crops Acres	Daily ac-in	Eff. %	Daily ac-in with eff.	AF per day	AF per month	Cubic feet per day	CFS, avg daily
Alfalfa Hay									
Apr	0.09	7,113	640	70%	914	76	2,286	3,319,623	38.4
May	0.14		996		1,423	119	3,675	5,163,857	59.8
Jun	0.22		1,565		2,235	186	5,589	8,114,633	93.9
Jul	0.26		1,849		2,642	220	6,825	9,590,021	111.0
Aug	0.21		1,494		2,134	178	5,512	7,745,786	89.7
Sep	0.11		782		1,118	93	2,794	4,057,316	47.0
Spring Wheat									
Apr	0.03	13,017	391	70%	558	46	1,395	2,025,025	23.4
May	0.08		1,041		1,488	124	3,843	5,400,066	62.5
Jun	0.21		2,734		3,905	325	9,763	14,175,174	164.1
Jul	0.3		3,905		5,579	465	14,411	20,250,249	234.4
Aug	0.18		2,343		3,347	279	8,647	12,150,149	140.6
Sep	0.03		391		558	46	1,395	2,025,025	23.4
Sugar Beet									
Apr	0.04	20,160	806	70%	1,152	96	2,880	4,181,708	48.4
May	0.07		1,411		2,016	168	5,208	7,317,989	84.7
Jun	0.17		3,427		4,896	408	12,240	17,772,259	205.7
Jul	0.27		5,443		7,776	648	20,088	28,226,529	326.7
Aug	0.25		5,040		7,200	600	18,600	26,135,675	302.5
Sep	0.13		2,621		3,744	312	9,360	13,590,551	157.3
Grass Hay									
Apr	0.08	2,493	199	70%	285	24	712	1,034,318	12.0
May	0.12		299		427	36	1,104	1,551,477	18.0
Jun	0.18		449		641	53	1,603	2,327,216	26.9
Jul	0.21		524		748	62	1,932	2,715,085	31.4
Aug	0.18		449		641	53	1,656	2,327,216	26.9
Sep	0.1		249		356	30	890	1,292,898	15.0

Continued below…

Month	Avg daily ET (in)	Crops Acres	Daily ac-in	Eff. %	Daily ac-in with eff.	AF per day	AF per month	Cubic feet per day	CFS, avg daily
Corn, Grain									
Apr	0.04	4,690	188	70%	268	22	670	972,906	11.3
May	0.07		328		469	39	1,212	1,702,585	19.7
Jun	0.16		750		1,072	89	2,680	3,891,622	45.0
Jul	0.25		1,173		1,675	140	4,327	6,080,660	70.4
Aug	0.21		985		1,407	117	3,635	5,107,754	59.1
Sep	0.11		516		737	61	1,843	2,675,490	31.0
Dry Beans (Soybeans)									
Apr	0.04	691	28	70%	39	3	99	143,332	1.7
May	0.08		55		79	7	204	286,665	3.3
Jun	0.19		131		188	16	469	680,828	7.9
Jul	0.26		180		257	21	663	931,660	10.8
Aug	0.19		131		188	16	485	680,828	7.9
Sep	0.08		55		79	7	197	286,665	3.3
Barley									
Apr	0.03	6,994	210	70%	300	25	749	1,088,095	12.6
May	0.08		560		799	67	2,065	2,901,588	33.6
Jun	0.21		1,469		2,098	175	5,246	7,616,667	88.2
Jul	0.3		2,098		2,998	250	7,744	10,880,954	125.9
Aug	0.18		1,259		1,799	150	4,646	6,528,572	75.6
Sep	0.03		210		300	25	749	1,088,095	12.6

Results Summary

Tables 10 and 11 summarize this analysis. Table 10 presents the monthly AF of diversion and the total annual diversion that is required for irrigation based on Average Daily ET, at both 60% and 70% efficiency. Table 11 presents the average daily CFS that would need to be diverted during each month of the season. As shown in the tables, the AF required per month, and the average daily CFS by month, have substantially variability over the course of the season. Based on this analysis using Average Daily ET, in the month of July (highest demand period) the CFS being diverted would need to average between 900 and 1100 CFS depending on irrigation system efficiency.

Table 10 Monthly and Annual Diversion (AF) Based on Average ET For May-Aug, 60% & 70% Efficiency

Efficiency	Apr	May	Jun	Jul	Aug	Sep	Total
60%	10,257	20,196	43,853	65,322	50,378	20,100	210,105
70%	8,791	17,311	37,588	55,990	43,181	17,229	180,090

Table 11 Average Daily Diversion (CFS) by Month Based on Avg ET, 60% & 70% Efficiency

Efficiency	Apr	May	Jun	Jul	Aug	Sep
60%	172	328	737	1,062	819	338
70%	148	282	632	911	702	290

REFERENCES

Hier, William. 2016. Personal communication to James Brower. “Pivot Counts.”

Higley, 2016. Responses to High Priority Questions/Information (Conservation Measures). March 7, 2016 from Shawn Higley, WWC Engineering to Scott Estergard, Tetra Tech, with attachments.

John Lafave and Ginette Abdo, 2015. Irrigation and “Incidental Recharge” in Montana. Montana Bureau of Mines and Geology, Presented to: Shallow Recharge Technical Meeting Helena, MT Oct. 21, 2015. Available online at http://dnrc.mt.gov/divisions/water/management/docs/training-and-education/sar-4_lafave.pdf

NRCS, 1993. Part 623 National Engineering Handbook. Chapter 2 Irrigation Water Requirements. 210-vi-NEH, September 1993. Available online at http://ftp.wcc.nrcs.usda.gov/ftpref/wntsc/waterMgt/irrigation/NEH15/ch2.pdf

Reclamation, 2016. Lower Yellowstone Irrigation Project Water Requirements. March 4, 2016 Memo to David Trimpe and Gerald Benock from Jim Forseth, with attachments.

Sidney Water Users, 2009. Lateral Water Loss Analysis Data. Provided by email from David Trimpe to Scott Estergard.

ATTACHMENTS

1- Sidney Water Users Water Loss Measurements

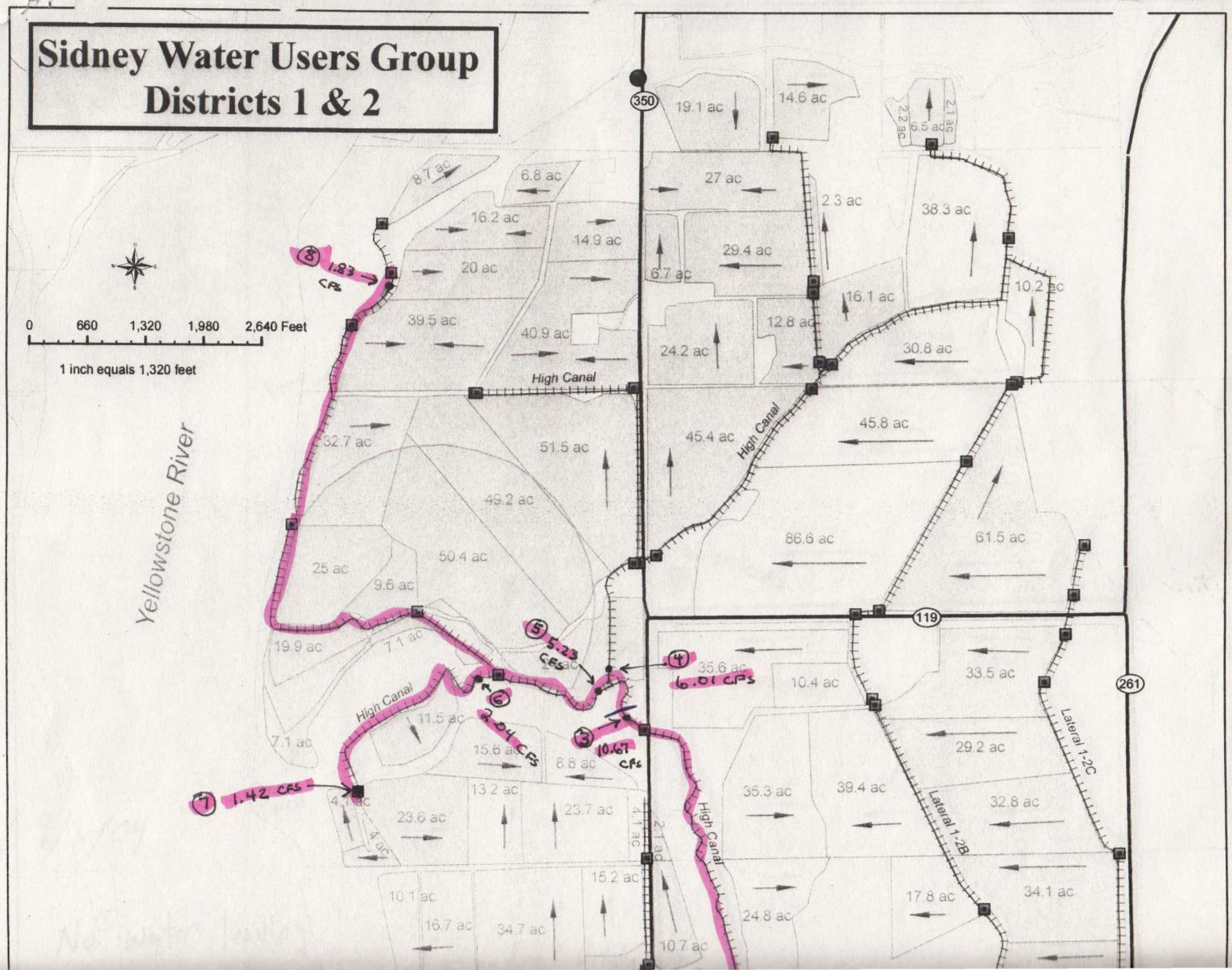
2- Higley, 2016 Letter and Data

3- Presentation “Irrigation and “Incidental Recharge” in Montana

4- Reclamation 2016, Lower Yellowstone Irrigation Project Crops Requirements

ATTACHMENT 1

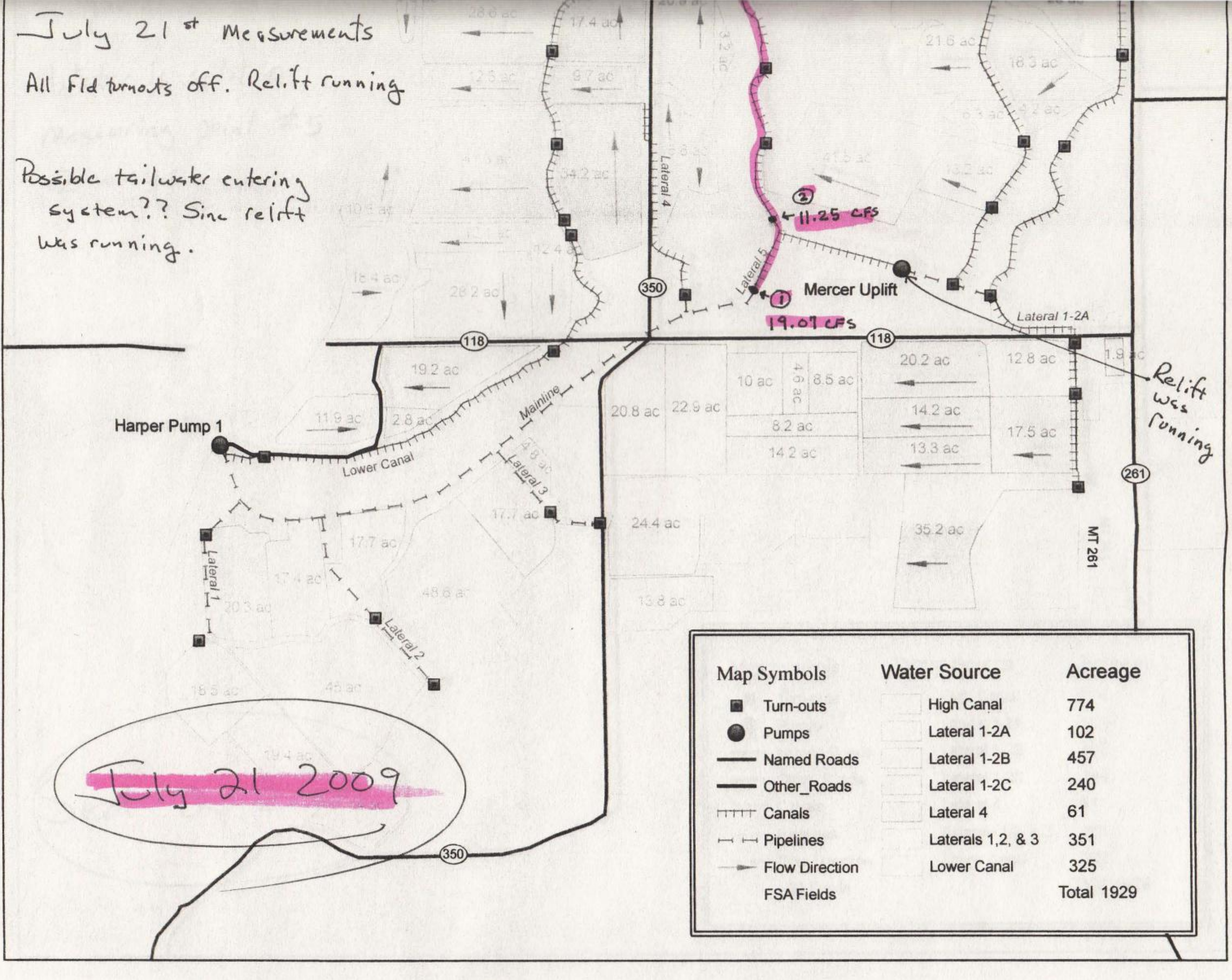
Sidney Water Users Group
Districts 1 & 2



July 21st Measurements

All Fld turnouts off. Relift running

Possible tailwater entering system?? Since relift was running.



② 11.25 CFS

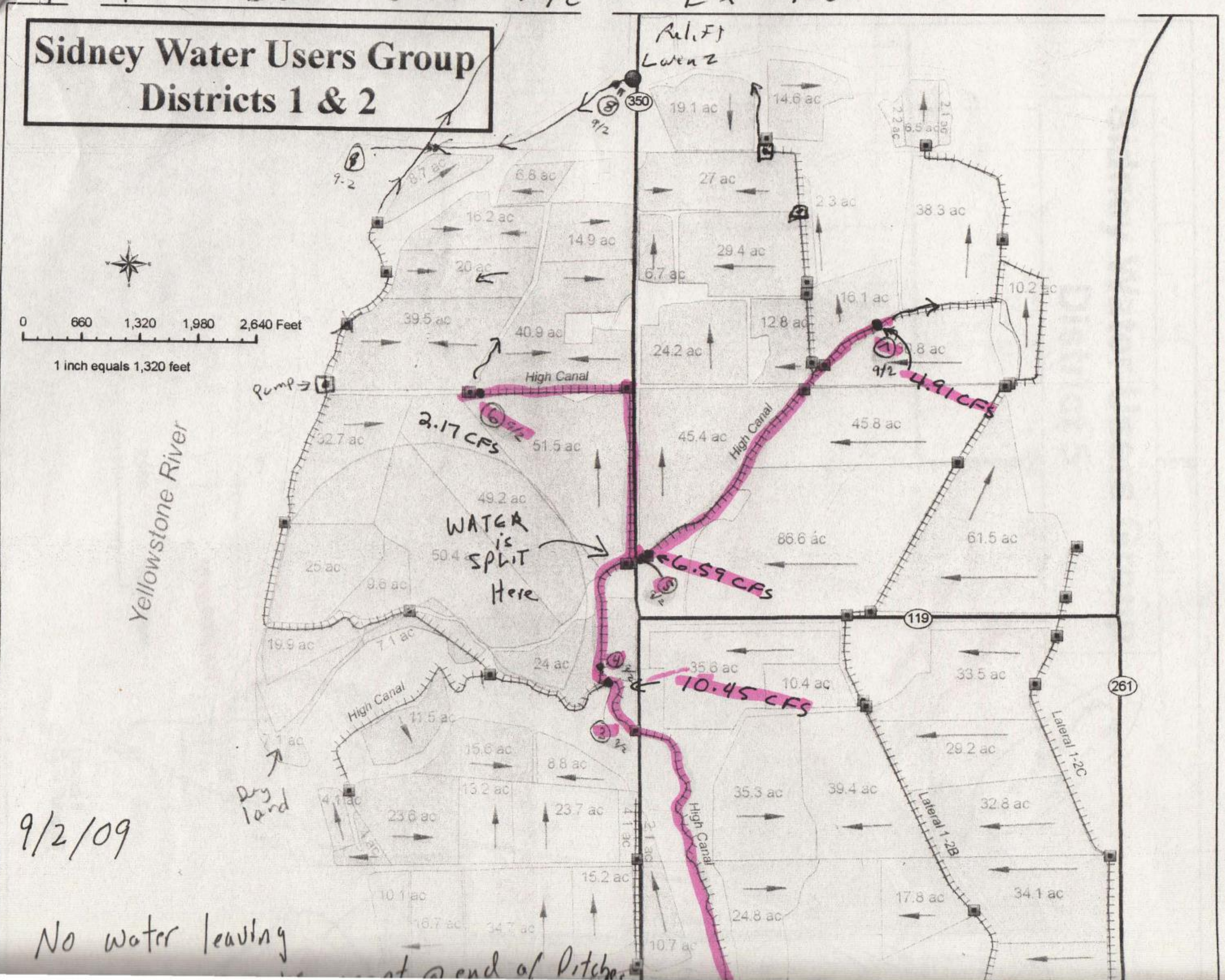
① 19.07 CFS

Relift was running

July 21 2009

Maps Bob 232-7965 Ex 102

Sidney Water Users Group
Districts 1 & 2

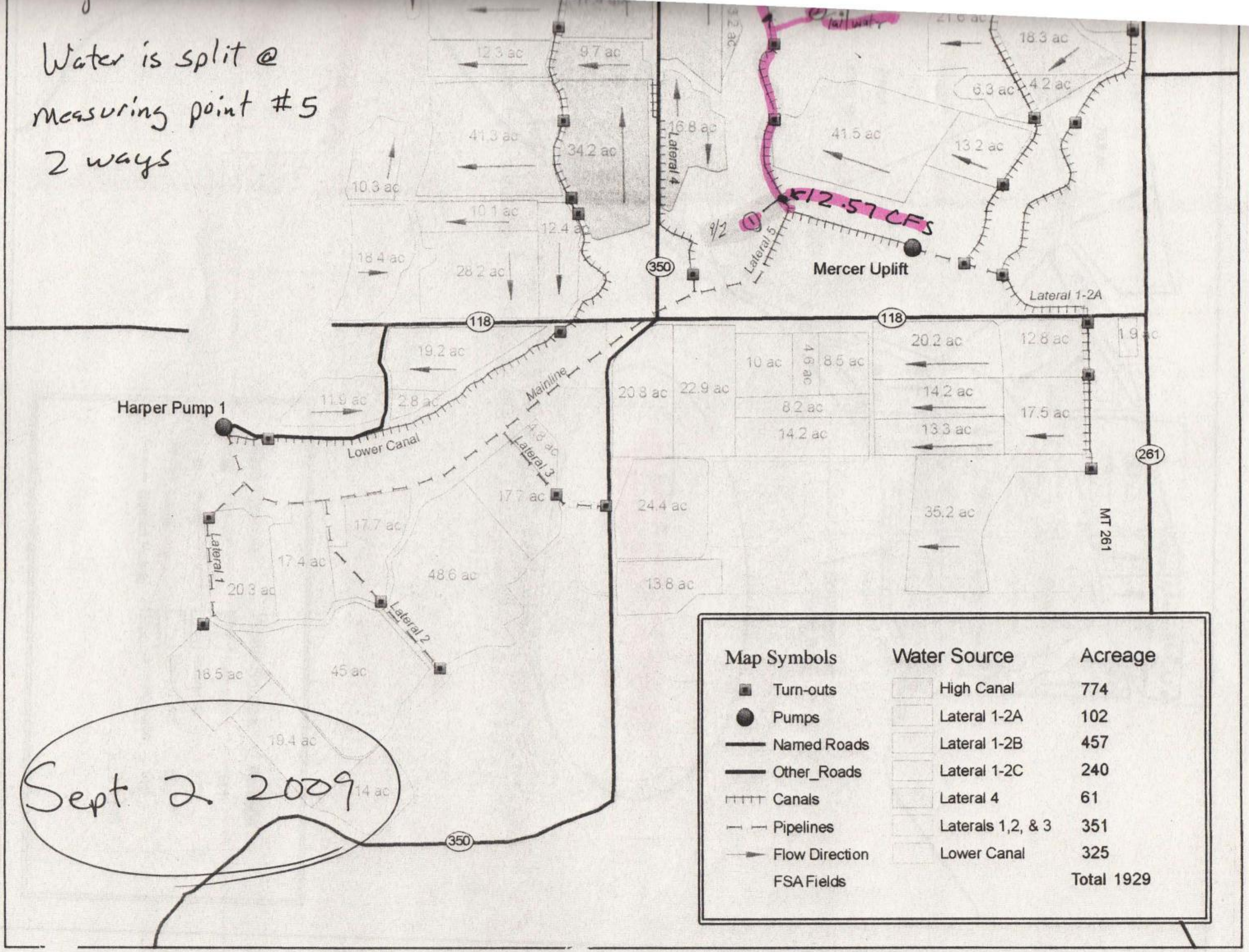


9/2/09

No water leaving

at @ end of Ditches

Water is split @
measuring point #5
2 ways



Map Symbols	Water Source	Acreage
■ Turn-outs	High Canal	774
● Pumps	Lateral 1-2A	102
Named Roads	Lateral 1-2B	457
Other_Roads	Lateral 1-2C	240
Canals	Lateral 4	61
Pipelines	Laterals 1,2, & 3	351
Flow Direction	Lower Canal	325
FSA Fields		Total 1929

Sept 2 2009

1 CFS = 448 GPM

SWU JULY WATER MEASUREMENTS

DATE	DISTRICT	LATERAL	MAP REF #	LOCATION DESCRIPTION	FLOW
21-Jul	1	HIGH CANAL	1	Lateral 5 @ concrete outlet	19.07
21-Jul	1	HIGH CANAL	2	80' downstream of Mercer Y	11.25
21-Jul	1	HIGH CANAL	3	75' downstream of CR 350	10.67
21-Jul	1	HIGH CANAL	4	75' North of Degn Y	6.01
21-Jul	1	HIGH CANAL	5	60' West of Degn Y	5.23
21-Jul	1	HIGH CANAL	6	2nd Degn Y turnout West before pivot	2.04
21-Jul	1	HIGH CANAL	7	End of 2nd Y West turnout	1.42
21-Jul	1	HIGH CANAL	8	Northwest end @ Scheetz	1.83
30-Jul	5	LATERAL 1	1	Main Turnout (begin lateral)	17.71
30-Jul	5	LATERAL 1	2	Turnout 2 (Dahl)	3.13
30-Jul	5	LATERAL 1	3	Turnout 3 (Dahl)	3.4
30-Jul	5	LATERAL 1	4	Turnout 4 (Dahl)	5.33
30-Jul	5	LATERAL 1	5	Turnout 5 (Walla)	2.4
30-Jul	5	LATERAL 1	6	Turnout 6 (Walla) End of water	3.36
30-Jul	5	LATERAL 2	7	Main turnout, begin lateral	4.66
30-Jul	5	LATERAL 2	8	West end (Dahl)	3.8

5%

SWU SEPTEMBER WATER MEASUREMENTS

DATE	DISTRICT	LATERAL	MAP REF #	LOCATION DESCRIPTION	FLOW
9/2/2009	1 & 2	HIGH CANAL	1	50' Below mercer Y	12.57
9/2/2009	1 & 2	HIGH CANAL	2	Mercer tailwater entering system	3.94
9/2/2009	1 & 2	HIGH CANAL	3	Degn place approx 50' upstream of Degn Y	10.45
9/2/2009	1 & 2	HIGH CANAL	4	Degn place approx 50' downstream of Degn Y	10.45
9/2/2009	1 & 2	HIGH CANAL	5	Petersen place 20' downstream of CR 350	6.59
9/2/2009	1 & 2	HIGH CANAL	7	East end of lateral at sunny's	4.91
9/2/2009	1 & 2	HIGH CANAL	6	West end at Marker/Scheetz	2.17
9/4/2009	3	RELIFT	8	At relift 1A-1 on CR 350. Begin lateral	4.69
9/6/2009	3	RELIFT	9	End lateral on relift 1A-1	4.63
9/3/2009	5	ONE	1	Lateral 1 Start	7.52
9/3/2009	5	ONE	2	Lateral 1 end	6.42
9/3/2009	5	TWO	3	Lateral 2 start	4.01
9/3/2009	5	TWO	4	Lateral 2 end	2.97

48 %

SWU LATERAL WATER LOSS ANALYSIS

Date	DISTRICT	LATERAL	Segment	BEGIN CFS	Adjustmer Add water	Adjustmt Subtract	END CFS	CFS Loss	LOSS Percent	distance	CFS loss/foot	GPM LOSS/FT	Comment		
Sept	1 & 2	HIGH CANAL	High canal Beginning to CR 350 (Degn Y)	12.57	3.94	0	10.5	6.06	48%	7350	0.00082449	0.375143			
July	1 & 2	HIGH CANAL	High canal Beginning to CR 350 (Degn Y)	11.25	0	0	10.7	0.58	5%	7350	7.89116E-05	0.035905	Possible Tailwater missed		
July	1 & 2	HIGH CANAL	Degn Y turnout to SW end (Degn)	2.04	0	0	1.42	0.62	30%	2475	0.000250505	0.11398			
July	1 & 2	HIGH CANAL	Degn Y to NW end (Scheetz)	5.23	0	2.04	1.83	1.36	26%	8650	0.000157225	0.071538			
Sept	1 & 2	HIGH CANAL	Degn Y to North end (Sheetz/Marker)	10.45	0	6.59	2.17	1.69	16%	5425	0.000311521	0.141742			
Sept	1 & 2	HIGH CANAL	CR 350 to East end (Lorenz)	6.59	0	0	4.91	1.68	25%	3954	0.000424886	0.193323			
Sept	3	LATERAL 1	Relift pump east to end @ old ditch (Lorenz)	4.69	0	0	4.63	0.06	1%	2600	2.30769E-05	0.0105			
Sept	5	LATERAL 1	Begin to end at Dahl's	7.52	0	0	6.42	1.1	15%	12100	9.09091E-05	0.041364			
July	5	LATERAL 1	Begin to last open turnout (Walla)	17.71	0	14.26	3.36	0.09	1%	9200	9.78261E-06	0.004451	many measurements -		
Sept	5	LATERAL 2	Begin to end at Bell's	4.01	0	0	2.97	1.04	26%	4900	0.000212245	0.096571			
July	5	LATERAL 2	Begin to west end (Dahl)	4.66	0	0	3.9	0.76	16%	2000	0.00038	0.1729			

ATTACHMENT 2

Letter-Tetra Tech Information 3-7-16.pdf

WWC ENGINEERING
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March 7, 2016

Mr. Scott K. Estergard
Senior Project Manager/Water Resource Planner
Tetra Tech
3030 N. 3rd Street, Suite 200
Phoenix, AZ 85012

RE: Responses to High Priority Questions/Information (Conservation Measures)

Dear Mr. Estergard:

At the request of the Lower Yellowstone Irrigation Project, WWC Engineering has prepared a response to your question on the accuracy of the conservation assumptions from the BOR's 2013 Planning Study and LYIP's 2009 Conservation Plan. For clarification, we have provided your original question followed by our response.

It was stated that the conservation assumptions in the previous reports were highly uncertain. Is there any data available to change or verify the assumed conservation as proposed? Barring any better data we are going to have to use the estimates that were previously documented and discuss uncertainties.

One of the largest issues with the Non-Weir Alternative is the reduction of the LYIP's diversion rate from 1,374 cfs to 608 cfs. The alternative suggests that the LYIP can save 765.9 cfs through conservation measures. As shown below, this is not practical nor can it be achieved without significant harm to the farmers within the LYIP. As a further point, if the LYIP were to reduce its diversion rate from 1,374 cfs to 608 cfs (well over a reduction of half of its legal diversion rate), the entire LYIP delivery system would have to be re-designed and retrofitted to accommodate the new reduced diversion rate. For example, the LYIP system was originally designed for the delivery of 1,374 cfs to 55,000 +/- acres. However, if that diversion rate were changed to 608 cfs, the canals and laterals would be significantly oversized. Water levels throughout the LYIP system would be substantially lower with the reduced diversion rate, resulting in a lack of head to provide irrigation water to the users of the LYIP system. In order to provide the appropriate head to facilitate delivery of water to the system irrigators, the canals and laterals would need to be reshaped and filled in to accommodate the lower flows. In fact there is no guarantee that the existing system would even be able to be successfully changed to accommodate the lower diversion rate. The entire system would likely have to be completely reconstructed in order to provide water to the irrigation users. However, this is a moot point. The following sections show that the peak crop demand for the LYIP is 1,342 cfs assuming that the delivery system is 100% efficient (not possible) with an on-farm efficiency of 60%, which represents a reasonable efficiency assuming a mix of center pivot, sideroll, flood irrigation, and other practices that are or could be implemented within the district. Based on this crop demand, the Non-Weir

Alternative suggests removing ***<u>OVER</u>*** half of the water required to satisfy the crop requirements for this project. This proposed water reduction would likely put many of the farmers within the LYIP out of business.

The Non-Weir Alternative appears to be using the table identified within the Bureau of Reclamation's 2013 Lower Yellowstone Fish Passage Alternatives Planning Study to estimate losses within the LYIP system. For example, Item 4 of the table suggests that lining 7 miles of the LYIP main canal or select laterals will save 200 cfs. To our knowledge there has not been 7 miles of canal or laterals identified that exhibit severe seepage. Although seepage throughout the LYIP system appears to be somewhat inconsistent, losses of this magnitude have not been identified. Putting this into perspective, if the LYIP were to line all 72 miles of the main canal, this analysis would conclude that this conservation measure would save over 4,900 cfs. Since the LYIP diverts only up to their maximum water right of 1,374 cfs and the flow records of the LYIP show that water is delivered throughout the LYIP system and to the end of the main canal, these estimates are obviously overstated. We believe that there are better and more accurate estimates of loss that should be utilized including use of the LYIP flow records, which provide the best available information that is specific to the LYIP. WWC has prepared the following information to use in lieu of the data contained within the 2013 Planning Study:

<u>Installation of water control/check structures</u>

The installation of additional water control/check structures within the LYIP system will not conserve water. Check structures sole purpose is to raise water levels within the canal to be able to supply enough head to facilitate adequate flows into irrigation turnouts. The addition of check structures within the LYIP system will increase water levels in the canals, increase seepage due to additional head in the canals, reduce flow velocity within the canals and increase the risk of damage to the canal banks due to higher water levels. There is no basis behind water conservation through the installation of check structures. Water control structures can save water at certain times of the year, by reducing spills from the system. However, during periods of peak demand, spills are reduced to a minimum in order to provide all available water to crops. <u>It is important to realize that an irrigation system must be designed to accommodate flows that will support the maximum demand, not an average use.</u> Crop consumptive use changes throughout the year based on precipitation, soil water content, stage of the crop being grown, and many other factors such as sustained windy periods coupled with high temperatures. The consumptive use of alfalfa, for example, is much higher when the plant is developing flowers and is subjected to higher temperatures. Thus, the amount of water required to fulfill the plant's transpiration requirements is much higher in the late summer months.

<u>Installation of flow measuring devices</u>

One of the items that are proposed to invoke further water savings are the implementation of flow measuring devices. Flow measuring devices can only be used to implement water savings if there are excessive diversions. As the LYIP main canal and lateral flow records show, there are not excessive diversions throughout the year. Although some water savings can be achieved within any given year with these devices, it is important to NOT use an average when looking at the amount of water that a system is designed for. An irrigation system must be designed to be able to supply the maximum amount of water that is required during any given year, not an average. As the following calculations will show, the LYIP requires a diversion rate that far exceeds that proposed in the Non-Weir Alternative. Flow measuring devices may be able to save water during certain times of the year, but they will not be able to save water during timeframes that require the peak crop consumptive use, which typically occur during the late summer months. The LYIP 2000 & 2012 flow records along with a sampling of 2015 lateral flow records show that at certain times of the year the losses within the LYIP system are minimal, when the maximum amount of water is being delivered to the crops.

Conversion of open laterals to pipe

A sampling of several of the larger LYIP laterals from 2015 records (attached) shows that there are fairly minor losses within the laterals, ranging from an average loss of 7% in Lateral H (27,898 feet in length), 1% in Lateral L (17,983 feet in length), 24% in Lateral M (25,653 feet in length), and 15% in Lateral N (30,209 feet in length). This data clearly shows that severe losses in the sampling of LYIP laterals does not exist. Again, it is important to NOT use averages in this analysis, but to utilize the losses that exist during times of peak demand, which show how efficient the system is during times of peak consumptive use. A review of each of these laterals shows that the losses during times of peak consumptive use are very low. For example, Lateral M, which has the highest average seepage loss of the sampled laterals, only lost 3.9% on June 29th during peak demand and high flows. This shows that the overall ability to reduce the amount of water flow being diverted by piping or canal lining is minimal.

Lining selected sections of canals and laterals

LYIP 2000 & 2012 flow records show minimal loss during periods of high demand and significant use (nearly 1,100 cfs delivered with a 1,300 cfs diversion) during peak periods. Additionally, the records show losses in the main canal system are as low as 6% during the peak demand periods. For example, the 2000 flow records show that there are 5 days when the loss within the main canal is less than 10%, 19 days when the loss within the main canal is less than 15%, and 54 days when the loss within the main canal is less than 20%. In addition, the 2012 flow records show that there are 30 days when the loss within the main canal is less than 10%, 73 days when the loss within the main canal is less than 15%, and 121 days when the loss within the main canal is less than 20%. This data clearly shows that the 2009 loss data is not correct for the LYIP, and that there is not 200 cfs of available loss to save within the LYIP main canal.

Conversion of selected fields from flood to sprinkler

On-farm efficiency varies based on land slope, soils, crop, cover, temperature, precipitation and many other factors. Therefore, the use of average or typical values for irrigation application efficiency are not valid for the design of an irrigation system.

Typical on-farm efficiencies are somewhat ambiguous and vary widely from site to site. Typical values from the NRCS National Engineering Handbook vary from 40-50% for flood irrigation to 70-80% for center pivots. The NRCS guidance is very careful to point out that on-farm efficiency is site-specific, and can vary considerably based on site-specific conditions. The NRCS guidance also points out that the on-farm efficiency of any given application is also heavily influenced by the type of equipment, maintenance of the equipment and operation of the equipment.

The main point

The main issue with the use of the 2009 loss numbers is that they are not based on ***ANY*** measured data within the LYIP system. These loss numbers assume that the district and the operators can implement water conservation measures within the LYIP system and save hundreds of cfs. However, the water conservation plan numbers are based on an AVERAGE water loss throughout the irrigation season, and do not reflect time specific water conservation. It is important to note that water conservation plans are an excellent way to strategize on ways to save water, and can be very effective over the course of an irrigation season. However, the conservation of water rarely leads to the ability to reduce the maximum amount of water diverted into an irrigation system, as the peak consumptive use governs the total amount that needs to be diverted at any given time. For example, if a large farm is given a maximum diversion rate of 10 cfs, and 10 cfs is diverted to the farm during the spring, the farm will not need the entire 10 cfs and spill a considerable amount of that water back to the river. However, if the farm is given that same 10 cfs during the period between late July and early September, they may use ALL of the 10 cfs without any spills and in all reality not have enough depending on the particular scenario. Thus, conservation measures may help to save water during the times that the farm doesn’t need all of their appropriated amount, but will not save water when they need the entire appropriated amount.

The Non-Weir Alternative suggests that the LYIP could get by with less than the legal rate of diversion of 1,374 cfs. However, when the lands irrigated by the LYIP are evaluated based on their peak daily consumptive use requirements as calculated using the NRCS methodology with local data and the 2013 LYIP Crop Census information (attached), the amount of water required to satisfy the peak crop water requirement is very close to the legal rate of diversion of 1,374 cfs, conservatively assuming a 100% efficient delivery system to each field (not realistic), and a reasonably efficient on-farm irrigation efficiency of 60% to account for a mix of center pivot, wheel-line, flood irrigation and other methods being utilized or that could be utilized in the future. Therefore, a reduction in the rate of diversion and delivery to the LYIP system would cause significant harm to existing producers.

The peak daily ET of each crop was derived from the Irrigation Water Requirements (IWR) program. IWR is a crop consumptive use program developed specifically for NRCS use in development of Consumptive Use Table for the new NRCS Irrigation Guide. IWR is based on USDA Natural Resources Conservation Service Handbook: NEH Chapter 2, Irrigation Water Requirements, dated September 1993 and Original

SCS Technical Release No. 21, dated April 1967. IWR uses the Blaney-Criddle Computation Method from the local Sidney, MT weather station. The Blaney-Criddle equation is a relatively simplistic method for calculating evapotranspiration. The peak consumptive use was developed using LYIP's 2013 crop census data. Using the known factor of ET for each crop and the amount of acres of each crop we were able to calculate the amount of water required to meet peak demand. Calculations are based solely on unit conversions to go from in/day to cfs.

Additional Information

Water rationing occurs during the peak demand period within the LYIP on an annual basis. Water savings realized from conservation efforts would first go to provide the allotted water to all users to fulfill their appropriations. In fact, the LYIP utilizes 4 pump stations to provide an additional 62 cfs at the lower end of the system to alleviate water rationing, which still does not resolve this problem. The peak consumptive use requirements identified above clearly show that there is marginally enough water available for diversion through the LYIP's water right to satisfy the demand. Therefore, any water savings realized from water conservation efforts during periods of peak irrigation demand would go to satisfy the peak consumptive use requirement of crops under the LYIP.

Thank you for the opportunity to provide additional information. Should you have any questions regarding this information, do not hesitate to contact us.

Sincerely,

Shawn Higley, P.E.
Principal

SH/mh

Enc.: Lateral Flows, Main Canal Flows, Crop ET

cc: LYIP, File

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LYIP ET All Crops.pdf

Irrigation Water Requirements
Crop Data Summary

Job:	**LYIP**	Crop:	**Alfalfa Hay**
Location:	**Richland County**	County:	**Richland, MT**
By:	**WWC**	Date:	**02/12/16**
Weather Station:	**SIDNEY**	Sta No:	**MT7560**
Latitude: **4744**	Longitude: **10409**	Elevation: **1920**	feet above sea level

Computation Method: **Blaney Criddle (TR21)**

Crop Curve: **Blaney Criddle Perennial Crop**

Begin Growth: **4/22** End Growth: **9/27**

Net irrigation application: **1** inches
Estimated carryover moisture used at season:
Begin: **0.5** inches End: **0.5** inches

Month	Total Monthly ET (3) inches	Dry Year 80% Chance (1)		Normal Year 50% Chance (1)		Average Daily ETc inches	Peak Daily ETPk inches
		Effective Precipitation inches	Net Irrigation Reqirements inches (2)	Effective Precipitation inches	Net Irrigation Reqirements inches (2)		
January	0.00	0.00	0.00	0.00	0.00	0.00	
February	0.00	0.00	0.00	0.00	0.00	0.00	
March	0.00	0.00	0.00	0.00	0.00	0.00	
April	0.81	0.12	0.19	0.16	0.15	0.09	
May	4.43	0.82	3.60	1.09	3.33	0.14	0.17
June	6.71	1.17	5.54	1.55	5.16	0.22	0.27
July	7.99	0.89	7.10	1.19	6.81	0.26	0.33
August	6.56	0.65	5.91	0.86	5.70	0.21	0.26
September	3.09	0.47	2.12	0.63	1.96	0.11	
October	0.00	0.00	0.00	0.00	0.00	0.00	
November	0.00	0.00	0.00	0.00	0.00	0.00	
December	0.00	0.00	0.00	0.00	0.00	0.00	
TOTAL	**29.59**	**4.12**	**24.46**	**5.48**	**23.11**		

(1) For 80 percent occurrence, growing season effective precipitation will be equaled or exceeded 8 out of 10 years. For 50 percent chance occurrence, effective precipitation will be equaled or exceeded 1 out of 2 years.

(2) Net irrigation requirements is adjusted for carryover moisture used at the beginning of the season and carryover moiature used at the end of the growing season.

(3) ET Evapotranspiration) is adjusted upwards 10% per 1000 meters above sea level.

Date: 2/12/2016

Irrigation Water Requirements
Crop Data Summary

Job:	**LYIP**	Crop:	**Spring wheat**
Location:	**Richland County**	County:	**Richland, MT**
By:	**WWC**	Date:	**02/12/16**
Weather Station:	**SIDNEY**	Sta No:	**MT7560**

Latitude: **4744** Longitude: **10409**

Elevation: **1920** feet above sea level

Computation Method: **Blaney Criddle (TR21)**

Crop Curve: **Blaney Criddle Annual Crop**

Begin Growth: **4/22** End Growth: **9/27**

Net irrigation application: **1** inches
Estimated carryover moisture used at season:
Begin: **0.5** inches End: **0.5** inches

Month	Total Monthly ET (3) inches	Dry Year 80% Chance (1) Effective Precipitation inches	Dry Year 80% Chance (1) Net Irrigation Reqirements inches (2)	Normal Year 50% Chance (1) Effective Precipitation inches	Normal Year 50% Chance (1) Net Irrigation Reqirements inches (2)	Average Daily ETc inches	Peak Daily ETPk inches
January	0.00	0.00	0.00	0.00	0.00	0.00	
February	0.00	0.00	0.00	0.00	0.00	0.00	
March	0.00	0.00	0.00	0.00	0.00	0.00	
April	0.25	0.11	0.00	0.14	0.00	0.03	
May	2.46	0.74	1.36	0.98	1.09	0.08	0.09
June	6.25	1.14	5.11	1.51	4.74	0.21	0.25
July	9.24	0.96	8.28	1.27	7.97	0.30	0.38
August	5.54	0.61	4.76	0.81	4.43	0.18	0.22
September	0.74	0.41	0.00	0.54	0.00	0.03	
October	0.00	0.00	0.00	0.00	0.00	0.00	
November	0.00	0.00	0.00	0.00	0.00	0.00	
December	0.00	0.00	0.00	0.00	0.00	0.00	
TOTAL	**24.47**	**3.96**	**19.51**	**5.26**	**18.22**		

(1) For 80 percent occurrence, growing season effective precipitation will be equaled or exceeded 8 out of 10 years. For 50 percent chance occurrence, effective precipitation will be equaled or exceeded 1 out of 2 years.

(2) Net irrigation requirements is adjusted for carryover moisture used at the beginning of the season and carryover moiature used at the end of the growing season.

(3) ET Evapotranspiration) is adjusted upwards 10% per 1000 meters above sea level.

Date: 2/12/2016

Irrigation Water Requirements
Crop Data Summary

Job: **LYIP**
Location: **Richland County**
By: **WWC**
Weather Station: **SIDNEY**
Latitude: **4744** Longitude: **10409**
Computation Method: **Blaney Criddle (TR21)**
Crop Curve: **Blaney Criddle Annual Crop**
Begin Growth: **4/22** End Growth: **9/27**

Crop: **Sugar beet**
County: **Richland, MT**
Date: **02/12/16**
Sta No: **MT7560**
Elevation: **1920** feet above sea level

Net irrigation application: **1** inches
Estimated carryover moisture used at season:
Begin: **0.5** inches End: **0.5** inches

Month	Total Monthly ET (3) inches	Dry Year 80% Chance (1)		Normal Year 50% Chance (1)		Average Daily ETc inches	Peak Daily ETPk inches
		Effective Precipitation inches	Net Irrigation Reqirements inches (2)	Effective Precipitation inches	Net Irrigation Reqirements inches (2)		
January	0.00	0.00	0.00	0.00	0.00	0.00	
February	0.00	0.00	0.00	0.00	0.00	0.00	
March	0.00	0.00	0.00	0.00	0.00	0.00	
April	0.36	0.11	0.00	0.15	0.00	0.04	
May	2.29	0.73	1.31	0.97	1.04	0.07	0.08
June	5.20	1.08	4.13	1.43	3.77	0.17	0.21
July	8.25	0.91	7.34	1.20	7.05	0.27	0.34
August	7.62	0.69	6.94	0.91	6.71	0.25	0.31
September	3.47	0.48	2.48	0.64	2.32	0.13	
October	0.00	0.00	0.00	0.00	0.00	0.00	
November	0.00	0.00	0.00	0.00	0.00	0.00	
December	0.00	0.00	0.00	0.00	0.00	0.00	
TOTAL	**27.19**	**3.99**	**22.20**	**5.30**	**20.89**		

(1) For 80 percent occurrence, growing season effective precipitation will be equaled or exceeded 8 out of 10 years. For 50 percent chance occurrence, effective precipitation will be equaled or exceeded 1 out of 2 years.

(2) Net irrigation requirements is adjusted for carryover moisture used at the beginning of the season and carryover moiature used at the end of the growing season.

(3) ET Evapotranspiration) is adjusted upwards 10% per 1000 meters above sea level.

Irrigation Water Requirements
Crop Data Summary

Job: **LYIP**
Location: **Richland County**
By: **WWC**
Weather Station: **SIDNEY**
Latitude: **4744** Longitude: **10409**
Computation Method: **Blaney Criddle (TR21)**
Crop Curve: **Blaney Criddle Perennial Crop**
Begin Growth: **4/22** End Growth: **9/27**

Crop: **Grass Hay**
County: **Richland, MT**
Date: **02/12/16**
Sta No: **MT7560**
Elevation: **1920** feet above sea level

Net irrigation application: **1** inches
Estimated carryover moisture used at season:
Begin: **0.5** inches End: **0.5** inches

Month	Total Monthly ET (3) inches	Dry Year 80% Chance (1) Effective Precipitation inches	Dry Year 80% Chance (1) Net Irrigation Reqirements inches (2)	Normal Year 50% Chance (1) Effective Precipitation inches	Normal Year 50% Chance (1) Net Irrigation Reqirements inches (2)	Average Daily ETc inches	Peak Daily ETPk inches
January	0.00	0.00	0.00	0.00	0.00	0.00	
February	0.00	0.00	0.00	0.00	0.00	0.00	
March	0.00	0.00	0.00	0.00	0.00	0.00	
April	0.69	0.12	0.07	0.15	0.03	0.08	
May	3.68	0.79	2.89	1.05	2.63	0.12	0.14
June	5.49	1.09	4.40	1.45	4.04	0.18	0.22
July	6.64	0.83	5.81	1.10	5.54	0.21	0.27
August	5.60	0.61	4.99	0.81	4.79	0.18	0.22
September	2.71	0.46	1.75	0.61	1.59	0.10	
October	0.00	0.00	0.00	0.00	0.00	0.00	
November	0.00	0.00	0.00	0.00	0.00	0.00	
December	0.00	0.00	0.00	0.00	0.00	0.00	
TOTAL	**24.80**	**3.90**	**19.90**	**5.18**	**18.62**		

(1) For 80 percent occurrence, growing season effective precipitation will be equaled or exceeded 8 out of 10 years. For 50 percent chance occurrence, effective precipitation will be equaled or exceeded 1 out of 2 years.

(2) Net irrigation requirements is adjusted for carryover moisture used at the beginning of the season and carryover moiature used at the end of the growing season.

(3) ET Evapotranspiration) is adjusted upwards 10% per 1000 meters above sea level.

Date: 2/12/2016

Irrigation Water Requirements
Crop Data Summary

Job: **LYIP**

Location: **Richland County**

By: **WWC**

Weather Station: **SIDNEY**

Latitude: **4744** Longitude: **10409**

Computation Method: **Blaney Criddle (TR21)**

Crop Curve: **Blaney Criddle Annual Crop**

Begin Growth: **4/22** End Growth: **9/27**

Crop: **Corn, Grain**

County: **Richland, MT**

Date: **02/12/16**

Sta No: **MT7560**

Elevation: **1920** feet above sea level

Net irrigation application: **1** inches

Estimated carryover moisture used at season:

Begin: **0.5** inches End: **0.5** inches

Month	Total Monthly ET (3) inches	Dry Year 80% Chance (1)		Normal Year 50% Chance (1)		Average Daily ETc inches	Peak Daily ETPk inches
		Effective Precipitation inches	Net Irrigation Reqirements inches (2)	Effective Precipitation inches	Net Irrigation Reqirements inches (2)		
January	0.00	0.00	0.00	0.00	0.00	0.00	
February	0.00	0.00	0.00	0.00	0.00	0.00	
March	0.00	0.00	0.00	0.00	0.00	0.00	
April	0.36	0.11	0.00	0.15	0.00	0.04	
May	2.22	0.73	1.24	0.97	0.97	0.07	0.08
June	4.90	1.06	3.85	1.40	3.50	0.16	0.19
July	7.63	0.88	6.76	1.16	6.47	0.25	0.31
August	6.38	0.64	5.74	0.85	5.53	0.21	0.26
September	2.84	0.47	1.87	0.62	1.72	0.11	
October	0.00	0.00	0.00	0.00	0.00	0.00	
November	0.00	0.00	0.00	0.00	0.00	0.00	
December	0.00	0.00	0.00	0.00	0.00	0.00	
TOTAL	**24.33**	**3.88**	**19.46**	**5.15**	**18.19**		

(1) For 80 percent occurrence, growing season effective precipitation will be equaled or exceeded 8 out of 10 years. For 50 percent chance occurrence, effective precipitation will be equaled or exceeded 1 out of 2 years.

(2) Net irrigation requirements is adjusted for carryover moisture used at the beginning of the season and carryover moiature used at the end of the growing season.

(3) ET Evapotranspiration) is adjusted upwards 10% per 1000 meters above sea level.

Date: 2/12/2016

Irrigation Water Requirements

Crop Data Summary

Job: **LYIP**

Location: **Richland County**

By: **WWC**

Weather Station: **SIDNEY**

Latitude: **4744** Longitude: **10409**

Computation Method: **Blaney Criddle (TR21)**

Crop Curve: **Blaney Criddle Annual Crop**

Begin Growth: **4/22** End Growth: **9/27**

Crop: **Dry beans**

County: **Richland, MT**

Date: **02/12/16**

Sta No: **MT7560**

Elevation: **1920** feet above sea level

Net irrigation application: **1** inches

Estimated carryover moisture used at season:

Begin: **0.5** inches End: **0.5** inches

Month	Total Monthly ET (3) inches	Dry Year 80% Chance (1)		Normal Year 50% Chance (1)		Average Daily ETc inches	Peak Daily ETPk inches
		Effective Precipitation inches	Net Irrigation Reqirements inches (2)	Effective Precipitation inches	Net Irrigation Reqirements inches (2)		
January	0.00	0.00	0.00	0.00	0.00	0.00	
February	0.00	0.00	0.00	0.00	0.00	0.00	
March	0.00	0.00	0.00	0.00	0.00	0.00	
April	0.35	0.11	0.00	0.15	0.00	0.04	
May	2.48	0.74	1.48	0.98	1.20	0.08	0.09
June	5.58	1.10	4.48	1.46	4.12	0.19	0.22
July	7.93	0.89	7.04	1.18	6.75	0.26	0.33
August	5.83	0.62	5.21	0.82	5.01	0.19	0.23
September	2.18	0.45	1.24	0.59	1.09	0.08	
October	0.00	0.00	0.00	0.00	0.00	0.00	
November	0.00	0.00	0.00	0.00	0.00	0.00	
December	0.00	0.00	0.00	0.00	0.00	0.00	
TOTAL	**24.36**	**3.90**	**19.46**	**5.18**	**18.18**		

(1) For 80 percent occurrence, growing season effective precipitation will be equaled or exceeded 8 out of 10 years. For 50 percent chance occurrence, effective precipitation will be equaled or exceeded 1 out of 2 years.

(2) Net irrigation requirements is adjusted for carryover moisture used at the beginning of the season and carryover moiature used at the end of the growing season.

(3) ET Evapotranspiration) is adjusted upwards 10% per 1000 meters above sea level.

Date: 2/12/2016

Irrigation Water Requirements
Crop Data Summary

Job:	**LYIP**	Crop:	**Barley**
Location:	**Richland County**	County:	**Richland, MT**
By:	**WWC**	Date:	**02/12/16**
Weather Station:	**SIDNEY**	Sta No:	**MT7560**
Latitude: **4744**	Longitude: **10409**	Elevation: **1920**	feet above sea level
Computation Method:	**Blaney Criddle (TR21)**		
Crop Curve:	**Blaney Criddle Annual Crop**		
Begin Growth: **4/22**	End Growth: **9/27**		

Net irrigation application: **1** inches
Estimated carryover moisture used at season:
Begin: **0.5** inches End: **0.5** inches

Month	Total Monthly ET (3) inches	Dry Year 80% Chance (1)		Normal Year 50% Chance (1)		Average Daily ETc inches	Peak Daily ETPk inches
		Effective Precipitation inches	Net Irrigation Reqirements inches (2)	Effective Precipitation inches	Net Irrigation Reqirements inches (2)		
January	0.00	0.00	0.00	0.00	0.00	0.00	
February	0.00	0.00	0.00	0.00	0.00	0.00	
March	0.00	0.00	0.00	0.00	0.00	0.00	
April	0.25	0.11	0.00	0.14	0.00	0.03	
May	2.46	0.74	1.36	0.98	1.09	0.08	0.09
June	6.25	1.14	5.11	1.51	4.74	0.21	0.25
July	9.24	0.96	8.28	1.27	7.97	0.30	0.38
August	5.54	0.61	4.76	0.81	4.43	0.18	0.22
September	0.74	0.41	0.00	0.54	0.00	0.03	
October	0.00	0.00	0.00	0.00	0.00	0.00	
November	0.00	0.00	0.00	0.00	0.00	0.00	
December	0.00	0.00	0.00	0.00	0.00	0.00	
TOTAL	**24.47**	**3.96**	**19.51**	**5.26**	**18.22**		

(1) For 80 percent occurrence, growing season effective precipitation will be equaled or exceeded 8 out of 10 years. For 50 percent chance occurrence, effective precipitation will be equaled or exceeded 1 out of 2 years.

(2) Net irrigation requirements is adjusted for carryover moisture used at the beginning of the season and carryover moiature used at the end of the growing season.

(3) ET Evapotranspiration) is adjusted upwards 10% per 1000 meters above sea level.

Date: 2/12/2016

LYIP Peak Water Requirements.xlsx

Peak Water Requirements at 40% On-farm Efficiency

Crop Type	Irrigated Acres	Peak Daily ET (in/day)
Sugar Beets	20,160	0.34
Wheat	13,017	0.38
Barley	6,994	0.38
Corn	4,690	0.31
Alfalfa Hay	7,113	0.33
Grass Hay	2,493	0.27
Soy Beans	691	0.33

<u>Peak Water Requirements</u>

Sugar Beets	17,136	ac-in/day	On-farm efficiency (%) =	40%
	1,428	ac-ft/day		
	62,203,680	ft^3/day		
	720	**cfs**		
Wheat	12,366	ac-in/day	On-farm efficiency (%) =	40%
	1,031	ac-ft/day		
	44,889,125	ft^3/day		
	520	**cfs**		
Barley	6,644	ac-in/day	On-farm efficiency (%) =	40%
	554	ac-ft/day		
	24,118,809	ft^3/day		
	279	**cfs**		
Corn	3,635	ac-in/day	On-farm efficiency (%) =	40%
	303	ac-ft/day		
	13,194,143	ft^3/day		
	153	**cfs**		
Alfalfa Hay	5,868	ac-in/day	On-farm efficiency (%) =	40%
	489	ac-ft/day		
	21,301,657	ft^3/day		
	247	**cfs**		
Grass Hay	1,683	ac-in/day	On-farm efficiency (%) =	40%
	140	ac-ft/day		
	6,108,473	ft^3/day		
	71	**cfs**		
Soy Beans	570	ac-in/day	On-farm efficiency (%) =	40%
	48	ac-ft/day		
	2,069,372	ft^3/day		
	24	**cfs**		

Total Water Requirement = 2,013 cfs

Note: This analysis assumes a delivery system to each farm field that is 100% efficient, and assumes NO delivery system losses to each farm field. The analysis shows the amount of water required to satisfy the peak consumptive use for the crops within the LYIP at the on-farm efficiency stated.

Peak Water Requirements at 50% On-farm Efficiency

Crop Type	Irrigated Acres	Peak Daily ET (in/day)
Sugar Beets	20,160	0.34
Wheat	13,017	0.38
Barley	6,994	0.38
Corn	4,690	0.31
Alfalfa Hay	7,113	0.33
Grass Hay	2,493	0.27
Soy Beans	691	0.33

Peak Water Requirements

Sugar Beets	13,709	ac-in/day	On-farm efficiency (%) =	50%
	1,142	ac-ft/day		
	49,762,944	ft^3/day		
	576	**cfs**		
Wheat	9,893	ac-in/day	On-farm efficiency (%) =	50%
	824	ac-ft/day		
	35,911,300	ft^3/day		
	416	**cfs**		
Barley	5,315	ac-in/day	On-farm efficiency (%) =	50%
	443	ac-ft/day		
	19,295,047	ft^3/day		
	223	**cfs**		
Corn	2,908	ac-in/day	On-farm efficiency (%) =	50%
	242	ac-ft/day		
	10,555,314	ft^3/day		
	122	**cfs**		
Alfalfa Hay	4,695	ac-in/day	On-farm efficiency (%) =	50%
	391	ac-ft/day		
	17,041,325	ft^3/day		
	197	**cfs**		
Grass Hay	1,346	ac-in/day	On-farm efficiency (%) =	50%
	112	ac-ft/day		
	4,886,779	ft^3/day		
	57	**cfs**		
Soy Beans	456	ac-in/day	On-farm efficiency (%) =	50%
	38	ac-ft/day		
	1,655,498	ft^3/day		
	19	**cfs**		

Total Water Requirement = 1,610 cfs

Note: This analysis assumes a delivery system to each farm field that is 100% efficient, and assumes NO delivery system losses to each farm field. The analysis shows the amount of water required to satisfy the peak consumptive use for the crops within the LYIP at the on-farm efficiency stated.

Peak Water Requirements at 60% On-farm Efficiency

Crop Type	Irrigated Acres	Peak Daily ET (in/day)
Sugar Beets	20,160	0.34
Wheat	13,017	0.38
Barley	6,994	0.38
Corn	4,690	0.31
Alfalfa Hay	7,113	0.33
Grass Hay	2,493	0.27
Soy Beans	691	0.33

Peak Water Requirements

Sugar Beets	11,424	ac-in/day	On-farm efficiency (%) =	60%
	952	ac-ft/day		
	41,469,120	ft^3/day		
	480	**cfs**		
Wheat	8,244	ac-in/day	On-farm efficiency (%) =	60%
	687	ac-ft/day		
	29,926,083	ft^3/day		
	346	**cfs**		
Barley	4,430	ac-in/day	On-farm efficiency (%) =	60%
	369	ac-ft/day		
	16,079,206	ft^3/day		
	186	**cfs**		
Corn	2,423	ac-in/day	On-farm efficiency (%) =	60%
	202	ac-ft/day		
	8,796,095	ft^3/day		
	102	**cfs**		
Alfalfa Hay	3,912	ac-in/day	On-farm efficiency (%) =	60%
	326	ac-ft/day		
	14,201,105	ft^3/day		
	164	**cfs**		
Grass Hay	1,122	ac-in/day	On-farm efficiency (%) =	60%
	93	ac-ft/day		
	4,072,316	ft^3/day		
	47	**cfs**		
Soy Beans	380	ac-in/day	On-farm efficiency (%) =	60%
	32	ac-ft/day		
	1,379,582	ft^3/day		
	16	**cfs**		
	Total Water Requirement =		***1,342***	***cfs***

Note: This analysis assumes a delivery system to each farm field that is 100% efficient, and assumes NO delivery system losses to each farm field. The analysis shows the amount of water required to satisfy the peak consumptive use for the crops within the LYIP at the on-farm efficiency stated.

Peak Water Requirements at 70% On-farm Efficiency

Crop Type	Irrigated Acres	Peak Daily ET (in/day)
Sugar Beets	20,160	0.34
Wheat	13,017	0.38
Barley	6,994	0.38
Corn	4,690	0.31
Alfalfa Hay	7,113	0.33
Grass Hay	2,493	0.27
Soy Beans	691	0.33

Peak Water Requirements

Sugar Beets	9,792	ac-in/day	On-farm efficiency (%) =	70%
	816	ac-ft/day		
	35,544,960	ft^3/day		
	411	**cfs**		
Wheat	7,066	ac-in/day	On-farm efficiency (%) =	70%
	589	ac-ft/day		
	25,650,928	ft^3/day		
	297	**cfs**		
Barley	3,797	ac-in/day	On-farm efficiency (%) =	70%
	316	ac-ft/day		
	13,782,177	ft^3/day		
	160	**cfs**		
Corn	2,077	ac-in/day	On-farm efficiency (%) =	70%
	173	ac-ft/day		
	7,539,510	ft^3/day		
	87	**cfs**		
Alfalfa Hay	3,353	ac-in/day	On-farm efficiency (%) =	70%
	279	ac-ft/day		
	12,172,375	ft^3/day		
	141	**cfs**		
Grass Hay	962	ac-in/day	On-farm efficiency (%) =	70%
	80	ac-ft/day		
	3,490,556	ft^3/day		
	40	**cfs**		
Soy Beans	326	ac-in/day	On-farm efficiency (%) =	70%
	27	ac-ft/day		
	1,182,498	ft^3/day		
	14	**cfs**		

Total Water Requirement = ***1,150 cfs***

Note: This analysis assumes a delivery system to each farm field that is 100% efficient, and assumes NO delivery system losses to each farm field. The analysis shows the amount of water required to satisfy the peak consumptive use for the crops within the LYIP at the on-farm efficiency stated.

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LYIP Lateral L Analysis 1.xlsx

No	Date	Flow
1160	04-May-15	3.00
		3.00
1160	05-May-15	3.00
1180	05-May-15	3.00
1181	05-May-15	3.00
		9.00
1160	06-May-15	3.00
1180	06-May-15	3.00
1181	06-May-15	3.00
		9.00
1160	08-May-15	3.40
		3.40
1160	09-May-15	3.40
		3.40
1160	10-May-15	3.40
		3.40
1160	11-May-15	3.40
		3.40
1171	28-May-15	3.00
1188	28-May-15	3.20
		6.20
1171	29-May-15	3.00
1172	29-May-15	4.00
1188	29-May-15	3.20
		10.20
1161	30-May-15	4.00
1166	30-May-15	2.00
1171	30-May-15	3.00
1172	30-May-15	4.00
1188	30-May-15	3.20
		16.20
1161	31-May-15	4.00
1166	31-May-15	2.00
1170	31-May-15	3.50
1171	31-May-15	3.00
1172	31-May-15	4.00
1188	31-May-15	3.20
1191	31-May-15	2.20
		21.90
1160	01-Jun-15	2.90
1161	01-Jun-15	4.00
1166	01-Jun-15	2.00
1170	01-Jun-15	3.50
1171	01-Jun-15	3.00
1172	01-Jun-15	4.00
1188	01-Jun-15	3.20

No	Date	Flow
1191	01-Jun-15	2.20
		22.60
1160	02-Jun-15	2.90
1161	02-Jun-15	4.00
1166	02-Jun-15	2.00
1170	02-Jun-15	3.50
1171	02-Jun-15	3.00
1172	02-Jun-15	4.00
1188	02-Jun-15	3.20
1191	02-Jun-15	2.20
		24.80
1166	03-Jun-15	2.00
1171	03-Jun-15	3.00
1172	03-Jun-15	4.00
1188	03-Jun-15	3.20
1191	03-Jun-15	2.40
		14.60
1171	04-Jun-15	3.00
1188	04-Jun-15	3.20
1191	04-Jun-15	2.40
		8.60
1171	05-Jun-15	3.00
1191	05-Jun-15	2.40
		5.40
1164	09-Jun-15	3.00
		3.00
1164	10-Jun-15	3.00
1177	10-Jun-15	2.50
1178	10-Jun-15	2.20
		7.70
1164	11-Jun-15	3.50
1177	11-Jun-15	2.50
1178	11-Jun-15	2.20
		8.20
1164	12-Jun-15	3.50
1177	12-Jun-15	2.50
1178	12-Jun-15	2.20
		8.20
1164	13-Jun-15	3.50
1174	13-Jun-15	3.60
1177	13-Jun-15	2.50
		9.60
1164	14-Jun-15	3.50
1174	14-Jun-15	3.60
1177	14-Jun-15	2.50
		9.60

No	Date	Flow
1161	15-Jun-15	3.50
1164	15-Jun-15	3.80
1174	15-Jun-15	3.60
1177	15-Jun-15	2.50
		13.40
1161	16-Jun-15	3.50
1164	16-Jun-15	3.80
1174	16-Jun-15	3.60
1177	16-Jun-15	2.50
		13.40
1161	17-Jun-15	3.50
1164	17-Jun-15	3.80
1174	17-Jun-15	3.60
1177	17-Jun-15	2.50
		13.40
1161	18-Jun-15	3.50
1174	18-Jun-15	3.60
		7.10
1160	19-Jun-15	2.00
1161	19-Jun-15	3.50
1174	19-Jun-15	3.60
1187	19-Jun-15	3.40
		12.50
1160	20-Jun-15	2.00
1161	20-Jun-15	3.50
1187	20-Jun-15	3.40
		8.90
1160	21-Jun-15	2.00
		2.00
1160	22-Jun-15	2.50
		2.50
1160	23-Jun-15	2.50
1201	23-Jun-15	4.60
		7.10
1196	24-Jun-15	2.00
1201	24-Jun-15	4.60
		6.60
1196	25-Jun-15	2.00
1200	25-Jun-15	1.60
1201	25-Jun-15	3.00
		6.60
1159	26-Jun-15	3.10
1196	26-Jun-15	2.00
1203	26-Jun-15	4.60
		9.70
1159	27-Jun-15	3.10

No	Date	Flow
1193	27-Jun-15	3.30
1196	27-Jun-15	2.00
1203	27-Jun-15	4.60
		0.00
1159	28-Jun-15	3.10
1193	28-Jun-15	3.30
1196	28-Jun-15	2.00
1203	28-Jun-15	4.60
		13.00
1160	29-Jun-15	3.10
1179	29-Jun-15	1.20
1181	29-Jun-15	3.20
1186	29-Jun-15	3.40
1193	29-Jun-15	3.30
1196	29-Jun-15	2.00
1203.01	29-Jun-15	4.60
		20.80
1160	30-Jun-15	3.10
1179	30-Jun-15	1.20
1180	30-Jun-15	2.50
1181	30-Jun-15	3.20
1186	30-Jun-15	3.40
1193	30-Jun-15	3.30
1203.01	30-Jun-15	4.60
		21.30
1172	01-Jul-15	2.50
1179	01-Jul-15	1.20
1180	01-Jul-15	2.50
1181	01-Jul-15	3.20
1186	01-Jul-15	3.40
1192	01-Jul-15	1.50
1196	01-Jul-15	3.00
		17.30
1172	02-Jul-15	2.80
1179	02-Jul-15	1.20
1180	02-Jul-15	2.50
1181	02-Jul-15	3.20
1186	02-Jul-15	3.40
1195	02-Jul-15	2.20
1196	02-Jul-15	3.00
		18.30
1172	03-Jul-15	2.80
1180	03-Jul-15	2.50
1181	03-Jul-15	3.20
1186	03-Jul-15	3.40
		11.90

No	Date	Flow
1172	04-Jul-15	2.80
1180	04-Jul-15	2.50
1181	04-Jul-15	3.20
1186	04-Jul-15	3.40
		11.90
1172	05-Jul-15	2.80
1180	05-Jul-15	2.50
1181	05-Jul-15	3.20
		8.50
1172	06-Jul-15	2.80
1181	06-Jul-15	3.20
		6.00
1172	07-Jul-15	2.80
1181	07-Jul-15	3.20
		6.00
1172	08-Jul-15	2.80
1196	08-Jul-15	2.00
		4.80
1196	09-Jul-15	2.00
		2.00
1159	10-Jul-15	3.70
1196	10-Jul-15	2.00
1201	10-Jul-15	4.60
		10.30
1159	11-Jul-15	3.70
1196	11-Jul-15	2.00
1201	11-Jul-15	4.60
		10.30
1159	12-Jul-15	3.70
1193	12-Jul-15	2.80
1196	12-Jul-15	2.00
1201	12-Jul-15	4.60
		13.10
1159	13-Jul-15	3.70
1193	13-Jul-15	2.80
1196	13-Jul-15	2.00
1200	13-Jul-15	4.60
		13.10
1159	14-Jul-15	3.70
1193	14-Jul-15	2.80
1196	14-Jul-15	2.00
1203.01	14-Jul-15	4.60
		13.10
1192	15-Jul-15	1.50
1196	15-Jul-15	2.00
1203.01	15-Jul-15	4.60

No	Date	Flow
		8.10
1189	20-Jul-15	1.30
		1.30
1172	21-Jul-15	2.80
1189	21-Jul-15	1.30
		4.10
1172	22-Jul-15	2.80
1195	22-Jul-15	3.00
		5.80
1172	23-Jul-15	2.80
1179	23-Jul-15	1.60
1180	23-Jul-15	1.60
1181	23-Jul-15	2.70
1196	23-Jul-15	2.00
		10.70
1172	24-Jul-15	2.80
1179	24-Jul-15	1.60
1180	24-Jul-15	1.60
1181	24-Jul-15	2.70
1196	24-Jul-15	2.00
		10.70
1172	25-Jul-15	2.80
1180	25-Jul-15	1.60
1181	25-Jul-15	2.70
1196	25-Jul-15	2.00
		9.10
1172	26-Jul-15	2.80
1180	26-Jul-15	1.60
1181	26-Jul-15	2.70
1196	26-Jul-15	2.00
		9.10
1172	27-Jul-15	2.80
1180	27-Jul-15	1.60
1181	27-Jul-15	2.70
1196	27-Jul-15	2.00
		9.10
1180	28-Jul-15	1.60
1181	28-Jul-15	2.70
1186	28-Jul-15	2.90
1196	28-Jul-15	2.00
		9.20
1159	29-Jul-15	3.00
1180	29-Jul-15	1.60
1181	29-Jul-15	2.70
1186	29-Jul-15	2.90
1196	29-Jul-15	2.00

No	Date	Flow
1201	29-Jul-15	4.60
		0.00
1159	30-Jul-15	3.00
1180	30-Jul-15	1.60
1181	30-Jul-15	2.70
1186	30-Jul-15	2.90
1196	30-Jul-15	2.00
1201	30-Jul-15	4.60
		16.80
1159	31-Jul-15	3.00
1180	31-Jul-15	1.60
1181	31-Jul-15	2.70
1186	31-Jul-15	2.90
1193	31-Jul-15	3.00
1196	31-Jul-15	2.00
1201	31-Jul-15	4.60
		19.80
1159	01-Aug-15	3.00
1186	01-Aug-15	2.90
1193	01-Aug-15	3.00
1201	01-Aug-15	4.60
		13.50
1159	02-Aug-15	3.00
1193	02-Aug-15	3.00
1200	02-Aug-15	4.00
		10.00
1159	03-Aug-15	3.00
1179	03-Aug-15	1.60
1193	03-Aug-15	3.00
1203.01	03-Aug-15	4.60
		12.20
1179	04-Aug-15	1.60
1203.01	04-Aug-15	4.60
		6.20
1179	05-Aug-15	1.60
1196	05-Aug-15	2.00
		3.60
1196	06-Aug-15	2.00
		2.00
1196	07-Aug-15	2.00
		2.00
1172	09-Aug-15	2.80
		2.80
1172	10-Aug-15	2.80
1180	10-Aug-15	2.20
1181	10-Aug-15	3.00

No	Date	Flow
		8.00
1172	11-Aug-15	2.80
1180	11-Aug-15	2.20
1181	11-Aug-15	3.00
		8.00
1172	12-Aug-15	2.80
1180	12-Aug-15	2.20
1181	12-Aug-15	3.00
		8.00
1172	13-Aug-15	2.80
1180	13-Aug-15	2.20
1181	13-Aug-15	3.00
1192	13-Aug-15	1.50
		9.50
1172	14-Aug-15	2.80
1180	14-Aug-15	2.20
1181	14-Aug-15	3.00
1193	14-Aug-15	3.20
1196	14-Aug-15	2.00
		13.20
1172	15-Aug-15	2.80
1180	15-Aug-15	2.20
1193	15-Aug-15	3.20
1195	15-Aug-15	3.00
1196	15-Aug-15	2.00
		13.20
1159	16-Aug-15	3.40
1180	16-Aug-15	2.20
1193	16-Aug-15	3.20
1195	16-Aug-15	3.00
1196	16-Aug-15	2.00
		13.80
1159	17-Aug-15	3.40
1180	17-Aug-15	2.40
1181	17-Aug-15	3.20
1186	17-Aug-15	3.50
1193	17-Aug-15	3.20
1196	17-Aug-15	2.00
1201	17-Aug-15	5.60
		23.30
1159	18-Aug-15	3.40
1181	18-Aug-15	3.20
1186	18-Aug-15	3.50
1193	18-Aug-15	3.20
1196	18-Aug-15	2.00
1200	18-Aug-15	5.60

No	Date	Flow
		20.90
1159	19-Aug-15	3.40
1179	19-Aug-15	2.20
1186	19-Aug-15	3.50
1196	19-Aug-15	2.00
1203.01	19-Aug-15	5.60
		16.70
1159	20-Aug-15	3.40
1179	20-Aug-15	2.20
1186	20-Aug-15	3.50
1196	20-Aug-15	2.00
1203.01	20-Aug-15	5.60
		16.70
1179	21-Aug-15	2.20
1186	21-Aug-15	2.50
		4.70
1172	25-Aug-15	3.00
		3.00
1172	26-Aug-15	3.00
		3.00
1172	27-Aug-15	3.00
1189	27-Aug-15	1.00
		4.00
1172	28-Aug-15	3.00
1192	28-Aug-15	1.50
1201	28-Aug-15	5.60
		10.10
1158	29-Aug-15	3.50
1172	29-Aug-15	3.00
1201	29-Aug-15	5.60
		12.10
1158	30-Aug-15	3.50
1172	30-Aug-15	3.00
1193	30-Aug-15	3.00
1200	30-Aug-15	5.60
		15.10
1159	31-Aug-15	3.50
1172	31-Aug-15	3.00
1193	31-Aug-15	3.00
1196	31-Aug-15	2.00
1203.01	31-Aug-15	5.60
		17.10
1159	01-Sep-15	3.50
1193	01-Sep-15	3.00
1196	01-Sep-15	2.00
1203.01	01-Sep-15	5.60

No	Date	Flow
		14.10
1159	02-Sep-15	3.50
1193	02-Sep-15	3.00
1196	02-Sep-15	2.00
1203.01	02-Sep-15	5.60
		14.10
1196	03-Sep-15	2.00
		2.00

2015	L Flow	L Spill	Delivery	Loss
4/30/15	0	0	0	0
5/1/15	0	0	0	0
5/2/15	15	15	0	0
5/3/15	15	15	0	0
5/4/15	16	13	3.00	0
5/5/15	19	8	9.00	2
5/6/15	19	11	9.00	-1
5/7/15	19	18	0.00	1
5/8/15	19	15	3.40	0.6
5/9/15	21	16	3.40	1.6
5/10/15	19	12	3.40	3.6
5/11/15	19	19	3.40	-3.4
5/12/15	14	14	0.00	0
5/13/15	16	16	0.00	0
5/14/15	16	16	0.00	0
5/15/15	16	16	0.00	0
5/16/15	16	16	0.00	0
5/17/15	16	16	0.00	0
5/18/15	12	12	0.00	0
5/19/15	12	12	0.00	0
5/20/15	12	11	0.00	1
5/21/15	11	10	0.00	1
5/22/15	11	9	0.00	2
5/23/15	10	8	0.00	2
5/24/15	10	7	0.00	3
5/25/15	10	10	0.00	0
5/26/15	12	7	0.00	5
5/27/15	12	12	0.00	0
5/28/15	12	6	6.20	-0.2
5/29/15	17	6	10.20	0.8
5/30/15	25	7	16.20	1.8
5/31/15	25	6	21.90	-2.9
6/1/15	25	5	24.80	-4.8
6/2/15	26	7	24.80	-5.8
6/3/15	20	8	14.60	-2.6
6/4/15	20	11	8.60	0.4
6/5/15	20	15	5.40	-0.4
6/6/15	19	17	0.00	2
6/7/15	19	18	0.00	1
6/8/15	14	14	0.00	0
6/9/15	14	11	3.00	0
6/10/15	14	8	7.70	-1.7
6/11/15	14	6	8.20	-0.2
6/12/15	16	7	8.20	0.8
6/13/15	16	5	9.60	1.4
6/14/15	20	5	9.60	5.4
6/15/15	20	8	13.40	-1.4
6/16/15	20	9	13.40	-2.4
6/17/15	19	8	13.40	-2.4
6/18/15	19	14	7.10	-2.1
6/19/15	19	9	12.50	-2.5
6/20/15	19	8	8.90	2.1
6/21/15	19	8	2.00	9
6/22/15	17	8	2.50	6.5
6/23/15	22	14	7.10	0.9
6/24/15	17	10	6.60	0.4
6/25/15	17	9	6.60	1.4
6/26/15	22	10	9.70	2.3
6/27/15	22	11	13.00	-2
6/28/15	22	9	13.00	0
6/29/15	22	5	20.80	-3.8
6/30/15	22	7	21.30	-6.3
7/1/15	22	9	17.30	-4.3
7/2/15	22	7	18.30	-3.3
7/3/15	22	10	11.90	0.1
7/4/15	22	10	11.90	0.1
7/5/15	22	14	8.50	-0.5
7/6/15	19	15	6.00	-2
7/7/15	19	16	6.00	-3
7/8/15	19	13	4.80	1.2
7/9/15	19	15	2.00	2
7/10/15	23	14	10.30	-1.3
7/11/15	20	10	10.30	-0.3
7/12/15	20	8	13.10	-1.1
7/13/15	21	10	13.10	-2.1
7/14/15	21	9	13.10	-1.1
7/15/15	21	12	8.10	0.9
7/16/15	16	15	0.00	1
7/17/15	16	15	0.00	1
7/18/15	16	14	0.00	2
7/19/15	15	13	0.00	2
7/20/15	15	12	1.30	1.7
7/21/15	15	10	4.10	0.9
7/22/15	15	9	5.80	0.2
7/23/15	15	7	10.70	-2.7
7/24/15	15	6	10.70	-1.7
7/25/15	15	7	9.10	-1.1
7/26/15	15	7	9.10	-1.1
7/27/15	15	7	9.10	-1.1
7/28/15	16	9	9.20	-2.2
7/29/15	21	6	16.80	-1.8
7/30/15	20	7	16.80	-3.8
7/31/15	20	8	19.80	-7.8
8/1/15	20	10	13.50	-3.5
8/2/15	20	10	10.00	0
8/3/15	20	12	12.20	-4.2
8/4/15	20	12	6.20	1.8
8/5/15	20	12	3.60	4.4
8/6/15	15	11	2.00	2
8/7/15	15	12	2.00	1
8/8/15	15	12	0.00	3
8/9/15	15	12	2.80	0.2
8/10/15	15	10	8.00	-3
8/11/15	15	8	8.00	-1
8/12/15	15	8	8.00	-1
8/13/15	15	9	9.50	-3.5
8/14/15	15	8	13.20	-6.2
8/15/15	20	8	13.20	-1.2

2015	L Flow	L Spill	**Delivery**	Loss
8/16/15	26	7	13.80	5.2
8/17/15	26	7	23.30	-4.3
8/18/15	26	10	20.90	-4.9
8/19/15	26	9	16.70	0.3
8/20/15	26	9	16.70	0.3
8/21/15	26	10	4.70	11.3
8/22/15	20	15	0.00	5
8/23/15	20	15	0.00	5
8/24/15	15	14	0.00	1
8/25/15	15	12	3.00	0
8/26/15	15	10	3.00	2
8/27/15	15	10	4.00	1
8/28/15	15	10	10.10	-5.1
8/29/15	21	10	12.10	-1.1
8/30/15	21	8	15.10	-2.1
8/31/15	21	7	17.10	-3.1
9/1/15	21	10	14.10	-3.1
9/2/15	21	10	14.10	-3.1
9/3/15	20	12	2.00	6
9/4/15	20	7	0.00	13
9/5/15	20	8	0.00	12
9/6/15	19	12	0.00	7
9/7/15	12	11	0.00	1
9/8/15	12	12	0.00	0
9/9/15	12	12	0.00	0
9/10/15	12	12	0.00	0
9/11/15	12	12	0.00	0
9/12/15	12	12	0.00	0
9/13/15	12	12	0.00	0
9/14/15	12	12	0.00	0
9/15/15	12	12	0.00	0
9/16/15	12	12	0.00	0
9/17/15	12	12	0.00	0
9/18/15	12	12	0.00	0
9/19/15	12	12	0.00	0
9/20/15	12	12	0.00	0
9/21/15	12	12	0.00	0
9/22/15	12	12	0.00	0
9/23/15	12	12	0.00	0
9/24/15	12	12	0.00	0
9/25/15	12	12	0.00	0
Avg	**17.1**	**10.5**	**6.5**	**0.1**
Lat L	L Flow	L Spill	Div	Loss
	Lat L	**Avg**	%Loss	0.627%

Note: The overall average considers the differences in flows (positive and negative) that can be caused by a timing issue on the readings (i.e. water fed into the lateral in the morning; or the afternoon) that causes water level changes when a farm is turned on or off during the day. The reading for water spilled out of the lateral is taken only once daily, whenever the Ditchriders drive by it sometime during the day. However, farm deliveries can be turned on or off throughout the day, which changes water levels in the lateral. If the timing is wrong, it would cause the loss to not take into account farm delivery changes until the next day.

Operational spills are flows diverted into the LYIP system that are not delivered to the farm. It is necessary to divert excess water to the main canal or lateral to act as a buffer necessary to allow for normal water deliveries and the elevations needed for water deliveries to elevated fields. Operational spills are either returned to the LYIP Main Canal to be utilized for irrigation or to the LYIP drainages where they support wildlife habitat and then discharge back to the Yellowstone River. Operational spills are utilized in most gravity irrigation systems to manage downstream irrigation demand. This contingency water is needed to provide a buffer for water level fluctuations caused by significantly varying losses due to high day-time temperatures, winds, and water quality variances and to cover future deliveries, delivery adjustments, unauthorized deliveries, and to cover shrinkage due to large loss variances. If enough water is not kept in the LYIP system to cover downstream demands and varying water losses, water shortages are certain to occur. Constant buffered water flow and minimum water elevations must be maintained to each individual farm or the siphons and/or pump irrigation systems will stop drawing water from the laterals or private farm ditches. When these systems stop drawing water, suddenly there is not enough room in the progressively smaller laterals, pipe lines or private farm ditches to carry the sudden gain in water (because it is no longer taken out at the farms or siphon tubes) and this blows out the tops of the canals and causes dangerous large scale public flooding. Without operational spills, a constant water flow and minimum water elevations are NOT possible to achieve. In addition, The LYIP consists of over 72 miles of main canal and 220 miles of laterals. A call on water to the downstream end of the system would take over a week to get water from the diversion to the downstream portion of the system if operational spills were not in place. This timing could result in serious and irrepairable damage to crops that would have a devastating financial impact to the farmers.

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LYIP Lateral H Analysis 7.xlsx

No	Date	Flow
977	04-May-15	2.00
		2.00
977	05-May-15	1.50
1023	05-May-15	1.00
1024	05-May-15	4.00
		6.50
977	06-May-15	1.50
1023	06-May-15	1.00
1024	06-May-15	4.00
		6.50
977	07-May-15	2.00
1023	07-May-15	1.00
1024	07-May-15	4.00
		7.00
977	08-May-15	2.00
1023	08-May-15	1.00
1024	08-May-15	4.00
		7.00
977	09-May-15	2.00
1023	09-May-15	1.00
1024	09-May-15	4.00
		7.00
977	10-May-15	2.00
1014	10-May-15	3.00
		5.00
977	11-May-15	2.00
1015	11-May-15	3.00
		5.00
977	12-May-15	1.50
1014	12-May-15	3.00
		4.50
977	13-May-15	1.50
1014	13-May-15	3.00
		4.50
1015	25-May-15	2.00
1020	25-May-15	5.00
		7.00
1015	26-May-15	2.00
1020	26-May-15	5.00
		7.00
1015	27-May-15	2.50
		2.50
997	28-May-15	1.70
999.01	28-May-15	4.00
1000	28-May-15	2.00
1006	28-May-15	4.80
1015	28-May-15	2.00
		14.50
988	29-May-15	4.50
994	29-May-15	4.50
997	29-May-15	2.00
999.01	29-May-15	4.00
1000	29-May-15	2.00
1006	29-May-15	4.80
1015	29-May-15	2.00

No	Date	Flow
1027.01	29-May-15	4.40
		23.80
989	30-May-15	4.50
994	30-May-15	4.50
997	30-May-15	2.50
999.01	30-May-15	4.00
1000	30-May-15	2.00
1006	30-May-15	4.80
1015	30-May-15	2.00
1027.01	30-May-15	4.40
		28.70
989	31-May-15	4.50
994	31-May-15	4.50
997	31-May-15	2.50
999.01	31-May-15	4.00
1000	31-May-15	2.00
1006	31-May-15	4.80
1027.01	31-May-15	4.60
		26.90
970	01-Jun-15	4.80
991	01-Jun-15	3.20
997.01	01-Jun-15	3.00
999.01	01-Jun-15	4.00
1000	01-Jun-15	2.00
1003	01-Jun-15	4.80
1027.01	01-Jun-15	4.60
		26.40
970	02-Jun-15	4.80
991	02-Jun-15	3.20
997.01	02-Jun-15	3.00
999.01	02-Jun-15	4.00
1000	02-Jun-15	2.00
		17.00
970	03-Jun-15	4.80
991	03-Jun-15	3.20
997.01	03-Jun-15	3.00
998	03-Jun-15	3.00
999.01	03-Jun-15	4.00
		18.00
998	04-Jun-15	3.00
999.01	04-Jun-15	4.00
		7.00
998	05-Jun-15	3.00
999.01	05-Jun-15	4.00
		7.00
966	08-Jun-15	4.70
968	08-Jun-15	2.20
971	08-Jun-15	3.40
		10.30
968	09-Jun-15	2.20
971	09-Jun-15	3.40
		5.60
968	10-Jun-15	2.20
971	10-Jun-15	3.40
		5.60

No	Date	Flow
968	11-Jun-15	2.20
971	11-Jun-15	3.40
		5.60
968	12-Jun-15	2.20
971	12-Jun-15	3.40
		5.60
968	13-Jun-15	2.20
		2.20
985	16-Jun-15	4.00
986	16-Jun-15	5.00
987	16-Jun-15	3.50
		12.50
978	17-Jun-15	3.50
986	17-Jun-15	5.00
996	17-Jun-15	3.00
1015	17-Jun-15	2.00
		13.50
977	18-Jun-15	2.00
978	18-Jun-15	3.50
986	18-Jun-15	5.00
996	18-Jun-15	3.00
1015	18-Jun-15	2.00
		15.50
977	19-Jun-15	2.00
978	19-Jun-15	3.50
986	19-Jun-15	5.00
996	19-Jun-15	3.00
		13.50
980	20-Jun-15	3.20
986	20-Jun-15	5.00
996	20-Jun-15	3.00
		11.20
980	21-Jun-15	3.20
986	21-Jun-15	5.00
		8.20
980	22-Jun-15	3.20
		3.20
966	23-Jun-15	4.70
980	23-Jun-15	3.20
1012	23-Jun-15	1.00
		8.90
966	24-Jun-15	4.70
974	24-Jun-15	3.40
1012	24-Jun-15	1.00
		9.10
964	25-Jun-15	1.20
966	25-Jun-15	4.70
974	25-Jun-15	3.40
990	25-Jun-15	3.20
1012	25-Jun-15	1.00
1021	25-Jun-15	2.50
		16.00
964	26-Jun-15	1.20
966	26-Jun-15	4.70
969	26-Jun-15	4.20

No	Date	Flow
974	26-Jun-15	3.40
990	26-Jun-15	3.20
1012	26-Jun-15	1.00
1021	26-Jun-15	2.50
		0.00
964	27-Jun-15	1.20
966	27-Jun-15	4.70
969	27-Jun-15	4.20
972	27-Jun-15	2.70
990	27-Jun-15	3.20
992	27-Jun-15	3.00
995	27-Jun-15	2.00
1012	27-Jun-15	1.00
1021	27-Jun-15	2.50
		24.50
968	28-Jun-15	2.50
969	28-Jun-15	4.20
972	28-Jun-15	2.70
978	28-Jun-15	2.50
990	28-Jun-15	3.20
992	28-Jun-15	3.00
1021	28-Jun-15	2.50
		20.60
969	29-Jun-15	2.50
970	29-Jun-15	4.20
973	29-Jun-15	2.70
977	29-Jun-15	2.00
979	29-Jun-15	2.50
990	29-Jun-15	3.20
992	29-Jun-15	3.00
1026	29-Jun-15	2.00
1027.01	29-Jun-15	1.00
		23.10
969	30-Jun-15	2.50
973	30-Jun-15	2.70
977	30-Jun-15	2.00
979	30-Jun-15	2.50
990	30-Jun-15	3.20
992	30-Jun-15	3.00
1026	30-Jun-15	2.00
1027.01	30-Jun-15	1.00
		18.90
969	01-Jul-15	2.50
973	01-Jul-15	2.70
977	01-Jul-15	2.20
979	01-Jul-15	2.50
992	01-Jul-15	3.00
1004	01-Jul-15	1.50
1026	01-Jul-15	2.00
1027.01	01-Jul-15	1.00
		17.40
969	02-Jul-15	2.50
973	02-Jul-15	2.70
977	02-Jul-15	2.00
979	02-Jul-15	2.50

No	Date	Flow
992	02-Jul-15	3.00
1023	02-Jul-15	3.00
		277.80
969	03-Jul-15	2.50
973	03-Jul-15	2.70
977	03-Jul-15	2.00
979	03-Jul-15	2.50
992	03-Jul-15	3.00
1023	03-Jul-15	3.00
1024	03-Jul-15	3.00
		18.70
992	04-Jul-15	3.00
1024	04-Jul-15	3.00
1025	04-Jul-15	3.00
		9.00
992	05-Jul-15	3.00
1025	05-Jul-15	4.00
		7.00
992	06-Jul-15	3.00
1004	06-Jul-15	1.50
1010	06-Jul-15	2.70
		7.20
964	07-Jul-15	1.50
965	07-Jul-15	5.40
974	07-Jul-15	3.20
1010	07-Jul-15	2.70
		12.80
964	08-Jul-15	1.50
965	08-Jul-15	5.40
974	08-Jul-15	3.20
978	08-Jul-15	3.20
983	08-Jul-15	2.40
1010	08-Jul-15	2.70
1012	08-Jul-15	2.00
		20.40
964	09-Jul-15	1.50
965	09-Jul-15	5.40
974	09-Jul-15	3.20
978	09-Jul-15	3.20
983	09-Jul-15	2.40
1010	09-Jul-15	2.70
1012	09-Jul-15	2.00
		20.40
965	10-Jul-15	5.40
970	10-Jul-15	3.60
974	10-Jul-15	3.20
978	10-Jul-15	3.20
983	10-Jul-15	2.40
990	10-Jul-15	3.60
1008	10-Jul-15	3.50
1010	10-Jul-15	2.70
1012	10-Jul-15	2.00
1022	10-Jul-15	3.60
		33.20
964	11-Jul-15	1.50

No	Date	Flow
965	11-Jul-15	5.40
970	11-Jul-15	3.60
974	11-Jul-15	3.20
977	11-Jul-15	2.00
978	11-Jul-15	3.20
983	11-Jul-15	2.40
990	11-Jul-15	3.60
1008	11-Jul-15	3.50
1010	11-Jul-15	2.70
1012	11-Jul-15	2.00
1022	11-Jul-15	3.60
		0.00
965	12-Jul-15	5.40
970	12-Jul-15	3.60
973	12-Jul-15	2.30
977	12-Jul-15	2.00
978	12-Jul-15	3.20
990	12-Jul-15	3.60
1008	12-Jul-15	3.50
1010	12-Jul-15	2.70
1012	12-Jul-15	2.00
		28.30
969	13-Jul-15	2.20
970	13-Jul-15	3.60
973	13-Jul-15	2.30
977	13-Jul-15	2.00
978	13-Jul-15	3.20
990	13-Jul-15	3.60
1007.1	13-Jul-15	3.60
1010	13-Jul-15	2.70
1026	13-Jul-15	3.00
1027	13-Jul-15	2.00
		28.20
969	14-Jul-15	2.20
973	14-Jul-15	2.30
979	14-Jul-15	3.20
990	14-Jul-15	3.60
1007.1	14-Jul-15	3.60
1011	14-Jul-15	2.70
1026	14-Jul-15	3.00
1027	14-Jul-15	2.00
		22.60
969	15-Jul-15	2.20
973	15-Jul-15	2.30
979	15-Jul-15	3.20
1007.1	15-Jul-15	3.60
1011	15-Jul-15	2.70
		14.00
973	16-Jul-15	2.30
979	16-Jul-15	3.20
1007.1	16-Jul-15	3.60
1011	16-Jul-15	2.70
		11.80
973	17-Jul-15	2.30
979	17-Jul-15	3.20

No	Date	Flow
1007.1	17-Jul-15	3.60
1011	17-Jul-15	2.70
		0.00
973	18-Jul-15	2.20
1004	18-Jul-15	3.20
1007.1	18-Jul-15	3.60
1011	18-Jul-15	2.70
		11.70
977	19-Jul-15	2.00
1004	19-Jul-15	3.20
1011	19-Jul-15	2.70
		7.90
977	20-Jul-15	2.00
992	20-Jul-15	3.40
995	20-Jul-15	3.00
1004	20-Jul-15	3.20
1011	20-Jul-15	2.70
		14.30
992	21-Jul-15	3.40
995	21-Jul-15	3.00
1011	21-Jul-15	2.70
		9.10
964	22-Jul-15	1.50
965	22-Jul-15	4.80
992	22-Jul-15	3.40
1008	22-Jul-15	3.50
1010	22-Jul-15	2.70
1012	22-Jul-15	2.00
		17.90
964	23-Jul-15	1.50
965	23-Jul-15	4.80
977	23-Jul-15	2.00
992	23-Jul-15	3.40
1008	23-Jul-15	3.50
1010	23-Jul-15	2.70
1012	23-Jul-15	2.00
		19.90
964	24-Jul-15	1.50
965	24-Jul-15	4.80
970	24-Jul-15	3.60
977	24-Jul-15	2.00
992	24-Jul-15	3.40
1010	24-Jul-15	2.70
1012	24-Jul-15	2.00
1022	24-Jul-15	4.20
		24.20
965	25-Jul-15	4.80
970	25-Jul-15	3.60
974	25-Jul-15	3.20
977	25-Jul-15	2.00
992	25-Jul-15	3.40
1010	25-Jul-15	2.70
1012	25-Jul-15	2.00
1022	25-Jul-15	4.20
		25.90

No	Date	Flow
965	26-Jul-15	4.80
970	26-Jul-15	3.60
974	26-Jul-15	3.20
992	26-Jul-15	3.40
1010	26-Jul-15	2.70
1012	26-Jul-15	2.00
1026	26-Jul-15	3.20
1027	26-Jul-15	2.60
		25.50
965	27-Jul-15	4.80
969	27-Jul-15	2.00
970	27-Jul-15	3.60
973	27-Jul-15	2.50
979	27-Jul-15	2.50
992	27-Jul-15	3.40
1010	27-Jul-15	2.70
1012	27-Jul-15	2.00
1026	27-Jul-15	3.20
1027	27-Jul-15	2.60
		29.30
969	28-Jul-15	2.20
973	28-Jul-15	2.70
979	28-Jul-15	2.70
992	28-Jul-15	3.40
1010	28-Jul-15	2.70
1011	28-Jul-15	2.00
1026	28-Jul-15	3.20
1027	28-Jul-15	2.60
		21.50
969	29-Jul-15	2.20
973	29-Jul-15	2.70
977	29-Jul-15	2.00
979	29-Jul-15	2.70
1010	29-Jul-15	2.70
1011	29-Jul-15	2.00
1026	29-Jul-15	3.20
1027	29-Jul-15	2.60
		20.10
969	30-Jul-15	2.20
973	30-Jul-15	2.60
977	30-Jul-15	2.00
979	30-Jul-15	2.70
995	30-Jul-15	3.00
1010	30-Jul-15	2.70
1011	30-Jul-15	2.00
		17.20
973	31-Jul-15	2.60
979	31-Jul-15	2.70
990	31-Jul-15	3.40
995	31-Jul-15	3.00
1010	31-Jul-15	2.70
1011	31-Jul-15	2.00
		16.40
973	01-Aug-15	2.60
990	01-Aug-15	3.40

No	Date	Flow
1004	01-Aug-15	2.70
1010	01-Aug-15	2.70
1011	01-Aug-15	2.00
		0.00
973	02-Aug-15	2.60
990	02-Aug-15	3.40
1004	02-Aug-15	2.70
1008	02-Aug-15	3.20
1010	02-Aug-15	2.70
1011	02-Aug-15	2.00
		16.60
964	03-Aug-15	1.60
965	03-Aug-15	5.40
973	03-Aug-15	2.60
990	03-Aug-15	3.40
1004	03-Aug-15	2.70
1008	03-Aug-15	3.20
1010	03-Aug-15	2.70
1012	03-Aug-15	2.00
		23.60
964	04-Aug-15	1.60
965	04-Aug-15	5.40
973	04-Aug-15	2.60
977	04-Aug-15	2.10
990	04-Aug-15	3.40
1004	04-Aug-15	2.70
1008	04-Aug-15	3.20
1010	04-Aug-15	2.70
1012	04-Aug-15	2.00
		25.70
964	05-Aug-15	1.60
965	05-Aug-15	5.40
974	05-Aug-15	3.20
977	05-Aug-15	2.10
1004	05-Aug-15	2.70
1008	05-Aug-15	3.20
1010	05-Aug-15	2.70
1012	05-Aug-15	2.00
		22.90
964	06-Aug-15	1.60
965	06-Aug-15	5.40
974	06-Aug-15	3.20
977	06-Aug-15	2.10
1004	06-Aug-15	2.70
1010	06-Aug-15	2.70
1012	06-Aug-15	2.00
		19.70
965	07-Aug-15	5.40
977	07-Aug-15	2.10
1004	07-Aug-15	2.70
1010	07-Aug-15	2.70
1012	07-Aug-15	2.00
1024	07-Aug-15	2.60
1025	07-Aug-15	4.00
		21.50

No	Date	Flow
977	08-Aug-15	2.10
979	08-Aug-15	3.20
1010	08-Aug-15	2.70
1024	08-Aug-15	2.60
1025	08-Aug-15	4.00
		14.60
977	09-Aug-15	2.10
979	09-Aug-15	3.20
1023	09-Aug-15	2.60
1025	09-Aug-15	4.00
		11.90
970	10-Aug-15	3.40
977	10-Aug-15	2.10
978	10-Aug-15	3.20
1022	10-Aug-15	2.60
1025	10-Aug-15	4.00
		15.30
970	11-Aug-15	3.40
977	11-Aug-15	1.50
980	11-Aug-15	3.20
1022	11-Aug-15	2.60
1025	11-Aug-15	4.00
		14.70
970	12-Aug-15	3.40
973	12-Aug-15	2.30
980	12-Aug-15	3.20
1026	12-Aug-15	3.20
1027	12-Aug-15	2.60
		14.70
969	13-Aug-15	2.50
973	13-Aug-15	2.30
980	13-Aug-15	3.20
1011	13-Aug-15	2.70
1026	13-Aug-15	3.20
1027	13-Aug-15	2.60
		16.50
969	14-Aug-15	2.50
973	14-Aug-15	2.30
980	14-Aug-15	3.20
1011	14-Aug-15	2.70
1026	14-Aug-15	3.20
1027	14-Aug-15	2.60
		16.50
969	15-Aug-15	2.50
973	15-Aug-15	2.30
980	15-Aug-15	3.20
992	15-Aug-15	3.20
1011	15-Aug-15	2.70
		13.90
965	16-Aug-15	5.40
969	16-Aug-15	2.50
973	16-Aug-15	2.30
980	16-Aug-15	3.20
992	16-Aug-15	3.20
1011	16-Aug-15	2.70

No	Date	Flow
		19.30
965	17-Aug-15	5.40
969	17-Aug-15	2.50
973	17-Aug-15	2.30
992	17-Aug-15	3.20
1011	17-Aug-15	2.70
1012	17-Aug-15	2.00
		18.10
964	18-Aug-15	1.80
965	18-Aug-15	5.40
969	18-Aug-15	2.50
977	18-Aug-15	2.00
992	18-Aug-15	3.20
1011	18-Aug-15	2.70
1012	18-Aug-15	2.00
		19.60
964	19-Aug-15	1.80
965	19-Aug-15	5.40
977	19-Aug-15	2.00
992	19-Aug-15	3.20
1004	19-Aug-15	3.20
1011	19-Aug-15	2.70
1012	19-Aug-15	2.00
		20.30
965	20-Aug-15	5.40
990	20-Aug-15	4.20
992	20-Aug-15	3.20
1004	20-Aug-15	3.20
1008	20-Aug-15	3.50
1010	20-Aug-15	2.70
1012	20-Aug-15	2.00
		24.20
990	21-Aug-15	4.20
992	21-Aug-15	3.20
1004	21-Aug-15	3.20
1008	21-Aug-15	3.50
1010	21-Aug-15	2.70
1012	21-Aug-15	2.00
		18.80
990	22-Aug-15	4.20
992	22-Aug-15	3.20
1004	22-Aug-15	3.20
1008	22-Aug-15	3.50
1010	22-Aug-15	2.70
1012	22-Aug-15	2.00
		18.80
990	23-Aug-15	4.20
992	23-Aug-15	3.20
1004	23-Aug-15	3.20
1010	23-Aug-15	2.70
		13.30
990	24-Aug-15	4.20
992	24-Aug-15	3.20
1010	24-Aug-15	2.70
		10.10

No	Date	Flow
979	25-Aug-15	3.20
990	25-Aug-15	4.20
992	25-Aug-15	3.20
		10.60
979	26-Aug-15	3.20
990	26-Aug-15	4.20
995	26-Aug-15	3.00
		10.40
979	27-Aug-15	3.20
995	27-Aug-15	3.00
		6.20
964	28-Aug-15	1.80
965	28-Aug-15	5.40
977	28-Aug-15	2.00
979	28-Aug-15	3.20
		12.40
964	29-Aug-15	1.80
965	29-Aug-15	5.40
969	29-Aug-15	2.50
977	29-Aug-15	2.00
1026	29-Aug-15	3.60
1027	29-Aug-15	2.40
		17.70
964	30-Aug-15	1.80
965	30-Aug-15	5.40
969	30-Aug-15	2.50
977	30-Aug-15	2.00
1026	30-Aug-15	3.60
1027	30-Aug-15	2.40
		17.70
964	31-Aug-15	1.80
965	31-Aug-15	5.40
969	31-Aug-15	2.50
1026	31-Aug-15	3.60
1027	31-Aug-15	2.40
		15.70
964	01-Sep-15	1.80
965	01-Sep-15	5.40
969	01-Sep-15	2.50
		9.70
964	02-Sep-15	1.80
965	02-Sep-15	5.40
970	02-Sep-15	3.50
		10.70
964	03-Sep-15	1.80
965	03-Sep-15	5.40
970	03-Sep-15	3.50
		10.70
970	04-Sep-15	3.50
		3.50
970	05-Sep-15	3.50
		3.50
970	06-Sep-15	3.50
		3.50

2015	Lat H Flow	Lat H Spill	Delivery	Loss
4/30/15	16	16	0	0
5/1/15	16	16	0	0
5/2/15	17	17	0	0
5/3/15	17	17	0	0
5/4/15	15	13	2.00	0
5/5/15	19	8	6.50	4.5
5/6/15	20	8	6.50	5.5
5/7/15	20	9	7.00	4
5/8/15	20	7	7.00	6
5/9/15	17	7	7.00	3
5/10/15	15	7	5.00	3
5/11/15	15	9	5.00	1
5/12/15	17	11	4.50	1.5
5/13/15	17	12	4.50	0.5
5/14/15	14	12	0.00	2
5/15/15	12	11	0.00	1
5/16/15	12	11	0.00	1
5/17/15	12	11	0.00	1
5/18/15	8	8	0.00	0
5/19/15	8	7	0.00	1
5/20/15	7	6	0.00	1
5/21/15	6	5	0.00	1
5/22/15	6	5	0.00	1
5/23/15	6	5	0.00	1
5/24/15	5	4	0.00	1
5/25/15	12	4	7.00	1
5/26/15	11	3	7.00	1
5/27/15	6	4	2.50	-0.5
5/28/15	25	9	14.50	1.5
5/29/15	32	6	28.20	-2.2
5/30/15	37	8	28.70	0.3
5/31/15	35	6	26.90	2.1
6/1/15	35	11	26.40	-2.4
6/2/15	30	12	17.00	1
6/3/15	26	9	18.00	-1
6/4/15	24	16	7.00	1
6/5/15	24	16	7.00	1
6/6/15	17	16	0.00	1
6/7/15	17	15	0.00	2
6/8/15	11	6	10.30	-5.3
6/9/15	11	6	5.60	-0.6
6/10/15	11	6	5.60	-0.6
6/11/15	11	5	5.60	0.4
6/12/15	11	5	5.60	0.4
6/13/15	11	8	2.20	0.8
6/14/15	11	10	0.00	1
6/15/15	12	11	0.00	1
6/16/15	17	8	12.50	-3.5
6/17/15	20	7	13.50	-0.5
6/18/15	20	7	15.50	-2.5
6/19/15	18	5	13.50	-0.5
6/20/15	19	5	11.20	2.8
6/21/15	17	11	8.20	-2.2
6/22/15	15	11	3.20	0.8

2015	Lat H Flow	Lat H Spill	Delivery	Loss
6/24/15	16	8	9.10	-1.1
6/25/15	27	9	16.00	2
6/26/15	32	6	20.20	5.8
6/27/15	35	4	24.50	6.5
6/28/15	34	5	20.60	8.4
6/29/15	31	8	23.10	-0.1
6/30/15	31	9	18.90	3.1
7/1/15	28	9	17.40	1.6
7/2/15	26	8	15.70	2.3
7/3/15	32	9	18.70	4.3
7/4/15	32	12	9.00	11
7/5/15	30	13	7.00	10
7/6/15	26	15	7.20	3.8
7/7/15	26	15	12.80	-1.8
7/8/15	28	10	20.40	-2.4
7/9/15	28	9	20.40	-1.4
7/10/15	36	5	33.20	-2.2
7/11/15	36	5	36.70	-5.7
7/12/15	37	5	28.30	3.7
7/13/15	35	10	28.20	-3.2
7/14/15	35	9	22.60	3.4
7/15/15	30	13	14.00	3
7/16/15	30	13	11.80	5.2
7/17/15	30	16	11.80	2.2
7/18/15	30	16	11.70	2.3
7/19/15	30	18	7.90	4.1
7/20/15	30	11	14.30	4.7
7/21/15	30	12	9.10	8.9
7/22/15	32	9	17.90	5.1
7/23/15	32	10	19.90	2.1
7/24/15	36	9	24.20	2.8
7/25/15	36	8	25.90	2.1
7/26/15	37	9	25.50	2.5
7/27/15	37	9	29.30	-1.3
7/28/15	37	12	21.50	3.5
7/29/15	31	12	20.10	-1.1
7/30/15	30	10	17.20	2.8
7/31/15	26	10	16.40	-0.4
8/1/15	26	11	13.40	1.6
8/2/15	26	10	16.60	-0.6
8/3/15	31	6	23.60	1.4
8/4/15	36	2	25.70	8.3
8/5/15	36	9	22.90	4.1
8/6/15	31	9	19.70	2.3
8/7/15	36	12	21.50	2.5
8/8/15	36	15	14.60	6.4
8/9/15	33	16	11.90	5.1
8/10/15	30	11	15.30	3.7
8/11/15	25	11	14.70	-0.7
8/12/15	24	10	14.70	-0.7
8/13/15	27	9	16.50	1.5
8/14/15	27	6	16.50	4.5
8/15/15	26	9	13.90	3.1
8/16/15	26	7	19.30	-0.3

6/23/15	16	7	8.90	0.1
8/17/15	28	8	18.10	1.9

2015	Lat H Flow	Lat H Spill	Delivery	Loss
8/18/15	28	8	19.60	0.4
8/19/15	28	6	20.30	1.7
8/20/15	28	5	24.20	-1.2
8/21/15	28	7	18.80	2.2
8/22/15	28	10	18.80	-0.8
8/23/15	26	9	13.30	3.7
8/24/15	26	9	10.10	6.9
8/25/15	23	9	10.60	3.4
8/26/15	23	12	10.40	0.6
8/27/15	23	12	6.20	4.8
8/28/15	23	13	12.40	-2.4
8/29/15	29	10	17.70	1.3
8/30/15	29	11	17.70	0.3
8/31/15	29	12	15.70	1.3
9/1/15	21	12	9.70	-0.7
9/2/15	21	10	10.70	0.3
9/3/15	24	9	10.70	4.3
9/4/15	23	12	3.50	7.5
9/5/15	23	13	3.50	6.5
9/6/15	23	11	3.50	8.5
9/7/15	14	12	0.00	2
9/8/15	14	13	0.00	1
9/9/15	12	11	0.00	1
9/10/15	12	11	0.00	1
9/11/15	12	11	0.00	1
9/12/15	10	9	0.00	1
9/13/15	10	9	0.00	1
9/14/15	10	9	0.00	1
9/15/15	10	10	0.00	0
9/16/15	10	10	0.00	0
9/17/15	10	10	0.00	0
9/18/15	10	10	0.00	0
9/19/15	10	10	0.00	0
9/20/15	10	10	0.00	0
9/21/15	8	8	0.00	0
9/22/15	7	7	0.00	0
9/23/15	7	7	0.00	0
9/24/15	7	6	0.00	1
9/25/15	5	5	0.00	0
Average	**22.03**	**9.49**	**10.95**	**1.59**
Lateral H	**Avg Flow**	**Avg Spill**	**vg Deliver**	**Avg Loss**

Lateral H Avg % Los	**7%**

Note: The overall average considers the differences in flows (positive and negative) that can be caused by a timing issue on the readings (i.e. water fed into the lateral in the morning; or the afternoon) that causes water level changes when a farm is turned on or off during the day. The reading for water spilled out of the lateral is taken only once daily, whenever the Ditchriders drive by it sometime during the day. However, farm deliveries can be turned on or off throughout the day, which changes water levels in the lateral. If the timing is wrong, it would cause the loss to not take into account farm delivery changes until the next day.

Operational spills are flows diverted into the LYIP system that are not delivered to the farm. It is necessary to divert excess water to the main canal or lateral to act as a buffer necessary to allow for normal water deliveries and the elevations needed for water deliveries to elevated fields. Operational spills are either returned to the LYIP Main Canal to be utilized for irrigation or to the LYIP drainages where they support wildlife habitat and then discharge back to the Yellowstone River. Operational spills are utilized in most gravity irrigation systems to manage downstream irrigation demand. This contingency water is needed to provide a buffer for water level fluctuations caused by significantly varying losses due to high day-time temperatures, winds, and water quality variances and to cover future deliveries, delivery adjustments, unauthorized deliveries, and to cover shrinkage due to large loss variances. If enough water is not kept in the LYIP system to cover downstream demands and varying water losses, water shortages are certain to occur. Constant buffered water flow and minimum water elevations must be maintained to each individual farm or the siphons and/or pump irrigation systems will stop drawing water from the laterals or private farm ditches. When these systems stop drawing water, suddenly there is not enough room in the progressively smaller laterals, pipe lines or private farm ditches to carry the sudden gain in water (because it is no longer taken out at the farms or siphon tubes) and this blows out the tops of the canals and causes dangerous large scale public flooding. Without operational spills, a constant water flow and minimum water elevations are NOT possible to achieve. In addition, The LYIP consists of over 72 miles of main canal and 220 miles of laterals. A call on water to thedownstream end of the system would take over a week to get water from the diversion to the downstream portion of the system if operational spills were not in place. This timing could result in serious and irrepairable damage to crops that would have a devastating financial impact to the farmers.

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LYIP Lateral M Analysis 24.xlsx

No	Date	Flow
1209	04-May-15	1.80
1219.6	04-May-15	1.90
1221.01	04-May-15	2.10
1225.1	04-May-15	2.10
		7.90
1209	05-May-15	1.80
1219.6	05-May-15	1.90
1221.01	05-May-15	2.10
1225.1	05-May-15	2.10
		7.90
1209	06-May-15	1.80
1219.6	06-May-15	1.90
1221.01	06-May-15	2.10
1224	06-May-15	3.60
1225.1	06-May-15	2.10
		11.50
1209	07-May-15	1.80
1219.6	07-May-15	1.90
1221.01	07-May-15	2.10
1224	07-May-15	3.60
		9.40
1209	08-May-15	1.80
1224	08-May-15	3.60
		5.40
1224	09-May-15	3.60
		3.60
1224	10-May-15	3.60
		3.60
1224	11-May-15	3.60
		3.60
1224	12-May-15	3.60
		3.60
1224	13-May-15	3.60
1225.1	13-May-15	2.10
		5.70
1225.1	14-May-15	2.10
1234	14-May-15	4.00
		6.10
1220.1	15-May-15	2.00
		2.00
1220.1	16-May-15	2.00
		2.00
1230	25-May-15	3.00
		3.00
1230	26-May-15	3.00
1231	26-May-15	3.40
		6.40
1230	27-May-15	3.00
1231	27-May-15	3.40
		6.40
1228	28-May-15	1.50
1230	28-May-15	3.00
1231	28-May-15	3.40
		7.90

No	Date	Flow
1223	29-May-15	3.00
1228	29-May-15	1.50
1230	29-May-15	3.00
1231	29-May-15	3.40
1233.1	29-May-15	1.80
		12.70
1219.6	30-May-15	2.10
1223	30-May-15	3.00
1228	30-May-15	1.70
1230	30-May-15	3.00
1231	30-May-15	3.40
1233	30-May-15	3.00
1233.1	30-May-15	1.80
		18.00
1219.6	31-May-15	2.10
1223	31-May-15	3.00
1228	31-May-15	1.70
1230	31-May-15	3.00
1231	31-May-15	3.40
1233	31-May-15	3.00
		16.20
1219.6	01-Jun-15	2.10
1223	01-Jun-15	3.00
1228	01-Jun-15	1.70
1230	01-Jun-15	3.00
1231	01-Jun-15	3.40
1233	01-Jun-15	3.00
1234	01-Jun-15	4.40
		20.60
1223	02-Jun-15	3.00
1228	02-Jun-15	1.70
1231	02-Jun-15	3.40
		8.10
1223	03-Jun-15	3.20
		3.20
1221.01	13-Jun-15	2.10
1233.1	13-Jun-15	2.60
		4.70
1221.01	14-Jun-15	2.10
1233.1	14-Jun-15	2.60
		4.70
1221.01	15-Jun-15	2.10
1230	15-Jun-15	2.60
1231	15-Jun-15	2.40
1233	15-Jun-15	1.50
1242	15-Jun-15	4.10
		12.70
1230	16-Jun-15	2.60
1231	16-Jun-15	2.60
1233	16-Jun-15	2.20
1240	16-Jun-15	4.10
		11.50

No	Date	Flow
1230	17-Jun-15	2.60
1231	17-Jun-15	2.60
1233	17-Jun-15	2.20
1240	17-Jun-15	4.10
		11.50
1220.1	18-Jun-15	2.10
1230	18-Jun-15	2.60
1231	18-Jun-15	2.60
1233	18-Jun-15	2.20
1240	18-Jun-15	4.10
		13.60
1220.1	19-Jun-15	2.10
1230	19-Jun-15	2.60
1231	19-Jun-15	2.60
1233	19-Jun-15	2.20
1240	19-Jun-15	4.10
		13.60
1220.1	20-Jun-15	2.10
1224	20-Jun-15	4.00
1240	20-Jun-15	4.10
		10.20
1220.1	21-Jun-15	2.10
1224	21-Jun-15	4.00
		6.10
1220.1	22-Jun-15	2.10
1224	22-Jun-15	4.00
		6.10
1207	23-Jun-15	2.00
1211	23-Jun-15	4.40
1221.01	23-Jun-15	2.10
1229	23-Jun-15	2.00
		10.50
1207	24-Jun-15	2.00
1211	24-Jun-15	4.40
1221.01	24-Jun-15	2.10
1229	24-Jun-15	2.00
		10.50
1207	25-Jun-15	2.10
1209	25-Jun-15	2.50
1217	25-Jun-15	3.20
1221.01	25-Jun-15	2.10
1229	25-Jun-15	2.00
1237	25-Jun-15	4.10
		16.00
1207	26-Jun-15	2.10
1209	26-Jun-15	2.50
1217	26-Jun-15	3.20
1219.6	26-Jun-15	2.10
1229	26-Jun-15	2.00
1237	26-Jun-15	4.10
		16.00

No	Date	Flow
1209	27-Jun-15	2.50
1219.6	27-Jun-15	2.10
1229	27-Jun-15	2.00
1237	27-Jun-15	4.10
		10.70
1209	28-Jun-15	2.50
1219.6	28-Jun-15	2.10
1227	28-Jun-15	2.90
1229	28-Jun-15	2.00
1231	28-Jun-15	3.30
1237	28-Jun-15	4.10
1239	28-Jun-15	3.80
		20.70
1206	29-Jun-15	3.50
1209	29-Jun-15	2.50
1219.6	29-Jun-15	2.10
1227	29-Jun-15	2.90
1229	29-Jun-15	2.00
1232	29-Jun-15	3.30
1234	29-Jun-15	3.20
1237	29-Jun-15	4.10
1239	29-Jun-15	3.80
1244	29-Jun-15	2.70
		30.10
1206	30-Jun-15	3.50
1214	30-Jun-15	3.00
1219.6	30-Jun-15	2.10
1225.1	30-Jun-15	2.10
1227	30-Jun-15	2.90
1229	30-Jun-15	2.00
1232	30-Jun-15	3.30
1234	30-Jun-15	3.20
1239	30-Jun-15	3.80
1244	30-Jun-15	2.70
		28.60
1206	01-Jul-15	3.50
1214	01-Jul-15	3.00
1219.6	01-Jul-15	2.10
1225.1	01-Jul-15	2.10
1227	01-Jul-15	2.90
1229	01-Jul-15	2.00
1232	01-Jul-15	3.30
1234	01-Jul-15	3.20
1239	01-Jul-15	3.80
		25.90
1206	02-Jul-15	3.50
1214	02-Jul-15	3.00
1225.1	02-Jul-15	2.10
1227	02-Jul-15	2.90
1229	02-Jul-15	2.00
1232	02-Jul-15	3.30
1234	02-Jul-15	3.20
1239	02-Jul-15	3.80
		23.80

No	Date	Flow
1206	03-Jul-15	3.50
1214	03-Jul-15	3.00
1221.01	03-Jul-15	2.10
1225.1	03-Jul-15	2.10
1227	03-Jul-15	2.90
1229	03-Jul-15	2.00
1239	03-Jul-15	3.80
		19.40
1206	04-Jul-15	3.50
1214	04-Jul-15	3.00
1221.01	04-Jul-15	2.10
1225	04-Jul-15	5.60
1225.1	04-Jul-15	2.10
1227	04-Jul-15	2.90
1229	04-Jul-15	2.00
		21.20
1214	05-Jul-15	3.00
1221.01	05-Jul-15	2.10
1225	05-Jul-15	5.60
1225.1	05-Jul-15	2.10
		12.80
1208	06-Jul-15	3.00
1218	06-Jul-15	4.00
1219.6	06-Jul-15	2.00
1221.01	06-Jul-15	2.10
1222	06-Jul-15	3.00
1225	06-Jul-15	5.60
1225.1	06-Jul-15	2.10
		21.80
1208	07-Jul-15	3.00
1218	07-Jul-15	4.00
1219.6	07-Jul-15	2.00
1222	07-Jul-15	3.00
1225	07-Jul-15	5.60
1225.1	07-Jul-15	2.10
1236	07-Jul-15	3.60
		23.30
1219.6	08-Jul-15	2.00
1225.1	08-Jul-15	2.10
1236	08-Jul-15	3.60
		7.70
1219.6	09-Jul-15	2.00
		2.00
1219.6	10-Jul-15	2.00
1234	10-Jul-15	4.50
		6.50
1219.6	11-Jul-15	2.00
1224	11-Jul-15	4.40
1234	11-Jul-15	4.50
		10.90
1219.6	12-Jul-15	2.00
1224	12-Jul-15	4.40
1232	12-Jul-15	3.20
		9.60

No	Date	Flow
1219.6	13-Jul-15	2.00
1224	13-Jul-15	4.40
1232	13-Jul-15	3.20
1235	13-Jul-15	3.80
		13.40
1219.6	14-Jul-15	2.00
1224	14-Jul-15	4.40
1232	14-Jul-15	3.20
1235	14-Jul-15	3.80
1244	14-Jul-15	2.80
		16.20
1219.6	15-Jul-15	2.00
1224	15-Jul-15	4.40
1232	15-Jul-15	3.20
1244	15-Jul-15	2.80
		12.40
1219.6	16-Jul-15	2.00
		2.00
1209	17-Jul-15	2.90
1214	17-Jul-15	4.00
1219.6	17-Jul-15	2.00
1221.01	17-Jul-15	2.10
1229	17-Jul-15	1.70
		12.70
1209	18-Jul-15	2.90
1214	18-Jul-15	4.00
1219.6	18-Jul-15	2.00
1221.01	18-Jul-15	2.10
1229	18-Jul-15	1.70
		12.70
1209	19-Jul-15	2.90
1214	19-Jul-15	4.00
1218	19-Jul-15	3.20
1219.6	19-Jul-15	2.00
1221.01	19-Jul-15	2.10
1229	19-Jul-15	1.70
		15.90
1209	20-Jul-15	2.90
1214	20-Jul-15	4.00
1217	20-Jul-15	3.20
1225.1	20-Jul-15	2.10
1229	20-Jul-15	1.70
1237	20-Jul-15	4.00
1239	20-Jul-15	4.00
		21.90
1209	21-Jul-15	2.90
1214	21-Jul-15	4.00
1219.6	21-Jul-15	2.00
1221	21-Jul-15	3.00
1225.1	21-Jul-15	2.10
1227	21-Jul-15	2.60
1237	21-Jul-15	4.00
1239	21-Jul-15	4.00
		24.60

No	Date	Flow
1219.6	22-Jul-15	2.00
1221	22-Jul-15	3.00
1225.1	22-Jul-15	2.10
1227	22-Jul-15	2.60
1237	22-Jul-15	4.00
1239	22-Jul-15	4.00
		17.70
1219.6	23-Jul-15	2.00
1225	23-Jul-15	6.10
1225.1	23-Jul-15	2.10
1227	23-Jul-15	2.60
1237	23-Jul-15	4.00
1239	23-Jul-15	4.00
		20.80
1219.6	24-Jul-15	2.00
1222	24-Jul-15	2.60
1225	24-Jul-15	6.10
1225.1	24-Jul-15	2.10
1227	24-Jul-15	2.60
1237	24-Jul-15	4.00
1239	24-Jul-15	4.00
		23.40
1222	25-Jul-15	2.60
1225	25-Jul-15	6.10
1225.1	25-Jul-15	2.10
1227	25-Jul-15	2.60
1237	25-Jul-15	4.00
		17.40
1225	26-Jul-15	6.10
1225.1	26-Jul-15	2.10
1227	26-Jul-15	2.60
1237	26-Jul-15	4.00
		14.80
1225.1	27-Jul-15	2.20
1234	27-Jul-15	3.80
		6.00
1234	28-Jul-15	3.80
		3.80
1206	29-Jul-15	3.80
1219.6	29-Jul-15	2.00
1234	29-Jul-15	3.80
		9.60
1206	30-Jul-15	3.80
1219.6	30-Jul-15	2.00
1221.01	30-Jul-15	2.00
1234	30-Jul-15	2.50
		10.30
1206	31-Jul-15	3.80
1219.6	31-Jul-15	2.00
1221.01	31-Jul-15	2.00
1225.1	31-Jul-15	2.00
1244	31-Jul-15	2.70
		12.50

No	Date	Flow
1206	01-Aug-15	3.80
1219.6	01-Aug-15	2.00
1221.01	01-Aug-15	2.00
1225.1	01-Aug-15	2.00
1244	01-Aug-15	2.70
		12.50
1206	02-Aug-15	3.80
1219.6	02-Aug-15	2.00
1225.1	02-Aug-15	2.10
		7.90
1206	03-Aug-15	3.80
1219.6	03-Aug-15	2.00
1225.1	03-Aug-15	2.10
1229	03-Aug-15	2.30
		10.20
1208	04-Aug-15	3.00
1219.6	04-Aug-15	2.00
1225.1	04-Aug-15	2.10
1229	04-Aug-15	2.30
		9.40
1208	05-Aug-15	3.00
1219.6	05-Aug-15	2.00
1225.1	05-Aug-15	2.10
1229	05-Aug-15	2.30
		9.40
1208	06-Aug-15	3.00
1217	06-Aug-15	3.50
1219.6	06-Aug-15	2.00
1221.01	06-Aug-15	2.00
1225.1	06-Aug-15	2.10
1229	06-Aug-15	2.30
		14.90
1209	07-Aug-15	3.00
1217	07-Aug-15	3.50
1221.01	07-Aug-15	2.00
1229	07-Aug-15	2.30
		10.80
1209	08-Aug-15	3.00
1221.01	08-Aug-15	2.00
1229	08-Aug-15	2.30
1237	08-Aug-15	4.00
		11.30
1209	09-Aug-15	3.00
1229	09-Aug-15	2.30
1237	09-Aug-15	4.00
		9.30
1209	10-Aug-15	3.00
1229	10-Aug-15	2.30
1237	10-Aug-15	4.00
1239	10-Aug-15	3.80
		13.10

No	Date	Flow
1209	11-Aug-15	3.00
1219.6	11-Aug-15	2.00
1225	11-Aug-15	6.10
1225.1	11-Aug-15	2.00
1230	11-Aug-15	3.00
1237	11-Aug-15	4.00
1239	11-Aug-15	3.80
		23.90
1209	12-Aug-15	3.00
1219.6	12-Aug-15	2.00
1225	12-Aug-15	6.10
1225.1	12-Aug-15	2.00
1230	12-Aug-15	3.00
1234	12-Aug-15	4.00
1237	12-Aug-15	4.00
1239	12-Aug-15	3.80
		27.90
1214	13-Aug-15	4.30
1218	13-Aug-15	3.50
1219.6	13-Aug-15	2.00
1225.1	13-Aug-15	2.00
1230	13-Aug-15	3.00
1234	13-Aug-15	4.00
1239	13-Aug-15	3.80
		22.60
1214	14-Aug-15	4.30
1218	14-Aug-15	3.50
1219.6	14-Aug-15	2.00
1225.1	14-Aug-15	2.00
1230	14-Aug-15	3.00
1234	14-Aug-15	4.00
1239	14-Aug-15	3.80
		22.60
1214	15-Aug-15	4.30
1218	15-Aug-15	3.50
1219.6	15-Aug-15	2.00
1224	15-Aug-15	4.40
1225.1	15-Aug-15	2.10
1230	15-Aug-15	3.00
1234	15-Aug-15	4.00
		23.30
1214	16-Aug-15	4.30
1219.6	16-Aug-15	2.00
1221	16-Aug-15	3.00
1221.01	16-Aug-15	2.10
1224	16-Aug-15	4.40
1225.1	16-Aug-15	2.10
1230	16-Aug-15	3.00
1235	16-Aug-15	4.00
		24.90

No	Date	Flow
1214	17-Aug-15	4.30
1219.6	17-Aug-15	2.00
1221.01	17-Aug-15	2.10
1222	17-Aug-15	2.50
1224	17-Aug-15	4.40
1225.1	17-Aug-15	2.10
1230	17-Aug-15	3.00
1245	17-Aug-15	3.00
		23.40
1219.6	18-Aug-15	2.00
1221.01	18-Aug-15	2.10
1222	18-Aug-15	2.50
1224	18-Aug-15	4.40
1225.1	18-Aug-15	2.10
1230	18-Aug-15	3.00
1245	18-Aug-15	3.00
		19.10
1219.6	19-Aug-15	2.00
1222	19-Aug-15	2.50
1224	19-Aug-15	4.40
1225.1	19-Aug-15	2.10
1230	19-Aug-15	3.00
1245	19-Aug-15	3.00
		17.00
1219.6	20-Aug-15	2.00
1225.1	20-Aug-15	2.10
1236	20-Aug-15	2.00
		6.10
1219.6	21-Aug-15	2.00
1225.1	21-Aug-15	2.10
1236	21-Aug-15	2.00
		6.10
1219.6	22-Aug-15	2.00
1225.1	22-Aug-15	2.10
		4.10
1219.6	23-Aug-15	2.00
1225.1	23-Aug-15	2.10
		4.10
1206	24-Aug-15	3.80
1209	24-Aug-15	2.40
1225	24-Aug-15	6.10
1227	24-Aug-15	2.80
1229	24-Aug-15	2.30
		17.40
1206	25-Aug-15	3.80
1209	25-Aug-15	2.40
1217	25-Aug-15	3.50
1225	25-Aug-15	6.10
1227	25-Aug-15	2.80
1229	25-Aug-15	2.30
1239	25-Aug-15	3.90
		24.80

No	Date	Flow
1206	26-Aug-15	3.80
1209	26-Aug-15	2.40
1217	26-Aug-15	3.50
1225	26-Aug-15	6.10
1227	26-Aug-15	2.80
1229	26-Aug-15	2.30
1239	26-Aug-15	3.90
		24.80
1206	27-Aug-15	3.80
1209	27-Aug-15	2.40
1227	27-Aug-15	2.80
1229	27-Aug-15	2.30
1237	27-Aug-15	4.00
1239	27-Aug-15	3.90
		19.20
1206	28-Aug-15	3.80
1209	28-Aug-15	2.40
1227	28-Aug-15	2.80
1237	28-Aug-15	4.00
1239	28-Aug-15	3.90
		16.90
1206	29-Aug-15	3.80
1237	29-Aug-15	4.00
1239	29-Aug-15	3.90
		11.70
1206	30-Aug-15	3.80
1221.01	30-Aug-15	2.00
1232	30-Aug-15	3.40
1237	30-Aug-15	4.00
		13.20
1221.01	31-Aug-15	2.00
1232	31-Aug-15	3.40
		5.40
1221.01	01-Sep-15	2.00
1232	01-Sep-15	3.40
		5.40
1232	02-Sep-15	3.40
		3.40
1232	03-Sep-15	3.40
		3.40

No	Date	Flow

2015	M Flow	M Spill	Delivered	Loss
5/2/15	19	19	0	0
5/3/15	19	19	0	0
5/4/15	20	7	7.90	5.1
5/5/15	19	8	7.90	3.1
5/6/15	21	10	11.50	-0.5
5/7/15	21	12	9.40	-0.4
5/8/15	21	12	5.40	3.6
5/9/15	19	15	3.60	0.4
5/10/15	19	6	3.60	9.4
5/11/15	19	7	3.60	8.4
5/12/15	19	8	3.60	7.4
5/13/15	19	8	5.70	5.3
5/14/15	19	10	6.10	2.9
5/15/15	20	10	2.00	8
5/16/15	20	10	2.00	8
5/17/15	20	10	0.00	10
5/18/15	20	11	0.00	9
5/19/15	20	12	0.00	8
5/20/15	15	8	0.00	7
5/21/15	15	8	0.00	7
5/22/15	15	7	0.00	8
5/23/15	15	7	0.00	8
5/24/15	15	7	0.00	8
5/25/15	15	7	3.00	5
5/26/15	15	3	6.40	5.6
5/27/15	15	3	6.40	5.6
5/28/15	15	5	7.90	2.1
5/29/15	20	5	12.70	2.3
5/30/15	28	5	18.00	5
5/31/15	28	6	16.20	5.8
6/1/15	28	5	20.60	2.4
6/2/15	29	10	8.10	10.9
6/3/15	26	8	3.20	14.8
6/4/15	21	9	0.00	12
6/5/15	21	9	0.00	12
6/6/15	17	7	0.00	10
6/7/15	17	6	0.00	11
6/8/15	16	5	0.00	11
6/9/15	16	5	0.00	11
6/10/15	16	7	0.00	9
6/11/15	16	6	0.00	10
6/12/15	16	8	0.00	8
6/13/15	16	8	4.70	3.3
6/14/15	16	6	4.70	5.3
6/15/15	23	10	12.70	0.3
6/16/15	23	9	11.50	2.5
6/17/15	22	8	11.50	2.5
6/18/15	22	7	13.60	1.4
6/19/15	22	4	13.60	4.4
6/20/15	22	8	10.20	3.8
6/21/15	22	9	6.10	6.9
6/22/15	25	15	6.10	3.9
6/23/15	25	9	10.50	5.5
6/24/15	25	9	10.50	5.5
6/25/15	25	8	16.00	1
6/26/15	25	8	16.00	1
6/27/15	28	7	10.70	10.3
6/28/15	28	3	20.70	4.3
6/29/15	36	2	30.10	3.9
6/30/15	38	2	28.60	7.4
7/1/15	33	5	25.90	2.1
7/2/15	33	7	23.80	2.2
7/3/15	33	0	19.40	13.6
7/4/15	33	4	21.20	7.8
7/5/15	33	4	12.80	16.2
7/6/15	33	2	21.80	9.2
7/7/15	33	6	23.30	3.7
7/8/15	28	13	7.70	7.3
7/9/15	28	13	2.00	13
7/10/15	23	12	6.50	4.5
7/11/15	22	8	10.90	3.1
7/12/15	22	8	9.60	4.4
7/13/15	22	9	13.40	-0.4
7/14/15	25	8	16.20	0.8
7/15/15	25	8	12.40	4.6
7/16/15	22	11	2.00	9
7/17/15	23	7	12.70	3.3
7/18/15	29	11	12.70	5.3
7/19/15	29	7	15.90	6.1
7/20/15	29	5	21.90	2.1
7/21/15	29	0	24.60	4.4
7/22/15	28	10	17.70	0.3
7/23/15	28	5	20.80	2.2
7/24/15	28	2	23.40	2.6
7/25/15	31	6	17.40	7.6
7/26/15	31	9	14.80	7.2
7/27/15	31	12	6.00	13
7/28/15	31	15	3.80	12.2
7/29/15	31	12	9.60	9.4
7/30/15	31	10	10.30	10.7
7/31/15	30	6	12.50	11.5
8/1/15	30	7	12.50	10.5
8/2/15	27	10	7.90	9.1
8/3/15	27	8	10.20	8.8
8/4/15	26	10	9.40	6.6
8/5/15	26	8	9.40	8.6
8/6/15	26	8	14.90	3.1
8/7/15	26	10	10.80	5.2
8/8/15	25	9	11.30	4.7
8/9/15	25	8	9.30	7.7
8/10/15	25	0	13.10	11.9
8/11/15	31	0	23.90	7.1
8/12/15	31	0	27.90	3.1
8/13/15	31	4	22.60	4.4
8/14/15	31	4	22.60	4.4
8/15/15	31	4	23.30	3.7
8/16/15	31	0	24.90	6.1
8/17/15	34	5	23.40	5.6
8/18/15	34	6	19.10	8.9
8/19/15	31	9	17.00	5

2015	M Flow	M Spill	Delivered	Loss
8/20/15	28	10	6.10	11.9
8/21/15	28	9	6.10	12.9
8/22/15	28	11	4.10	12.9
8/23/15	28	12	4.10	11.9
8/24/15	31	8	17.40	5.6
8/25/15	32	4	24.80	3.2
8/26/15	32	4	24.80	3.2
8/27/15	31	10	19.20	1.8
8/28/15	31	12	16.90	2.1
8/29/15	31	12	11.70	7.3
8/30/15	28	9	13.20	5.8
8/31/15	28	15	5.40	7.6
9/1/15	25	12	5.40	7.6
9/2/15	15	12	3.40	-0.4
9/3/15	17	13	3.40	0.6
9/4/15	17	12	0.00	5
9/5/15	14	12	0.00	2
9/6/15	13	12	0.00	1
9/7/15	13	13	0.00	0
9/8/15	13	12	0.00	1
9/9/15	12	11	0.00	1
9/10/15	9	9	0.00	0
9/11/15	9	9	0.00	0
9/12/15	8	8	0.00	0
9/13/15	8	7	0.00	1
9/14/15	8	8	0.00	0
9/15/15	8	8	0.00	0
9/16/15	8	8	0.00	0
9/17/15	8	8	0.00	0
9/18/15	8	8	0.00	0
9/19/15	8	8	0.00	0
9/20/15	8	8	0.00	0
9/21/15	7	7	0.00	0
9/22/15	7	6	0.00	1
9/23/15	7	6	0.00	1
9/24/15	5	4	0.00	1
9/25/15	3	3	0.00	0
Average	22.42	7.94	9.15	5.33
Lateral M	**Avg Flow**		**Avg Delivere**	**Avg Loss**
Lateral M		**Average**	% Loss	24%

Note: The overall average considers the differences in flows (positive and negative) that can be caused by a timing issue on the readings (i.e. water fed into the lateral in the morning; or the afternoon) that causes water level changes when a farm is turned on or off during the day. The reading for water spilled out of the lateral is taken only once daily, whenever the Ditchriders drive by it sometime during the day. However, farm deliveries can be turned on or off throughout the day, which changes water levels in the lateral. If the timing is wrong, it would cause the loss to not take into account farm delivery changes until the next day.

Operational spills are flows diverted into the LYIP system that are not delivered to the farm. It is necessary to divert excess water to the main canal or lateral to act as a buffer necessary to allow for normal water deliveries and the elevations needed for water deliveries to elevated fields. Operational spills are either returned to the LYIP Main Canal to be utilized for irrigation or to the LYIP drainages where they support wildlife habitat and then discharge back to the Yellowstone River. Operational spills are utilized in most gravity irrigation systems to manage downstream irrigation demand. This contingency water is needed to provide a buffer for water level fluctuations caused by significantly varying losses due to high day-time temperatures, winds, and water quality variances and to cover future deliveries, delivery adjustments, unauthorized deliveries, and to cover shrinkage due to large loss variances. If enough water is not kept in the LYIP system to cover downstream demands and varying water losses, water shortages are certain to occur. Constant buffered water flow and minimum water elevations must be maintained to each individual farm or the siphons and/or pump irrigation systems will stop drawing water from the laterals or private farm ditches. When these systems stop drawing water, suddenly there is not enough room in the progressively smaller laterals, pipe lines or private farm ditches to carry the sudden gain in water (because it is no longer taken out at the farms or siphon tubes) and this blows out the tops of the canals and causes dangerous large scale public flooding. Without operational spills, a constant water flow and minimum water elevations are NOT possible to achieve. In addition, The LYIP consists of over 72 miles of main canal and 220 miles of laterals. A call on water to the downstream end of the system would take over a week to get water from the diversion to the downstream portion of the system if operational spills were not in place. This timing could result in serious and irrepairable damage to crops that would have a devastating financial impact to the farmers.

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No	Date	Flow
1258.01	5/4/15	2.00
1266	5/4/15	3.00
1267	5/4/15	3.60
1290.1	5/4/15	2.00
1302	5/4/15	3.40
1306.2	5/4/15	2.00
		16.00
1249	5/5/15	4.00
1258.01	5/5/15	2.00
1266	5/5/15	3.00
1267	5/5/15	3.60
1290	5/5/15	2.00
1290.1	5/5/15	2.00
1302	5/5/15	3.60
1306.2	5/5/15	2.00
		22.20
1249	5/6/15	4.00
1258.01	5/6/15	2.00
1266	5/6/15	3.00
1267	5/6/15	3.60
1286	5/6/15	3.20
1290	5/6/15	2.00
1290.1	5/6/15	2.00
1302	5/6/15	3.60
		23.40
1249	5/7/15	4.00
1266	5/7/15	3.00
1267	5/7/15	3.60
1286	5/7/15	3.20
1290	5/7/15	2.00
1290.1	5/7/15	2.00
1302	5/7/15	3.60
		21.40
1249	5/8/15	4.00
1266	5/8/15	3.00
1267	5/8/15	3.60
1286	5/8/15	3.20
1302	5/8/15	3.60
		17.40
1249	5/9/15	4.00
1267	5/9/15	3.60
1286	5/9/15	3.20
1302	5/9/15	3.60
		14.40
1249	5/10/15	4.00
1257.1	5/10/15	2.00
1267	5/10/15	3.60
1302	5/10/15	3.60
		13.20
1249	5/11/15	4.00
1257.1	5/11/15	2.00
1267	5/11/15	3.60
1302	5/11/15	3.60
		13.20

No	Date	Flow
1249	5/12/15	4.00
1258.01	5/12/15	2.10
1302	5/12/15	3.60
		9.70
1249	5/13/15	4.00
1258.01	5/13/15	2.10
1302	5/13/15	3.60
		9.70
1249	5/14/15	4.00
1257.1	5/14/15	2.00
1302	5/14/15	3.60
		9.60
1302	5/15/15	3.60
		3.60
1261	5/25/15	1.60
1299	5/25/15	4.00
		5.60
1259.1	5/26/15	2.00
1261	5/26/15	4.00
1263	5/26/15	3.00
1299	5/26/15	4.00
		13.00
1259.1	5/27/15	2.00
1261	5/27/15	4.00
1262	5/27/15	3.00
1263	5/27/15	3.00
1299	5/27/15	4.00
		16.00
1247.1	5/28/15	2.00
1259.1	5/28/15	2.00
1263	5/28/15	3.00
1264	5/28/15	2.60
1300	5/28/15	3.40
		13.00
1247.1	5/29/15	2.00
1259.1	5/29/15	2.00
1263	5/29/15	3.40
1306.2	5/29/15	2.00
		9.40
1247.1	5/30/15	2.00
1259.1	5/30/15	2.00
1263	5/30/15	3.40
1306.2	5/30/15	2.00
		9.40
1263	5/31/15	3.40
1306.2	5/31/15	2.00
		5.40

No	Date	Flow
1257.1	6/1/15	2.00
1263	6/1/15	3.40
1273	6/1/15	3.20
1290.1	6/1/15	2.00
1303	6/1/15	3.00
1304	6/1/15	3.20
1306	6/1/15	2.50
1306.2	6/1/15	2.00
		21.30
1257.1	6/2/15	2.00
1263	6/2/15	3.40
		5.40
1263	6/3/15	3.40
		3.40
1252.1	6/11/15	2.00
1253.1	6/11/15	2.10
1306.2	6/11/15	2.00
		6.10
1252.1	6/12/15	2.00
1253.1	6/12/15	2.10
1257.1	6/12/15	2.00
1273	6/12/15	4.00
1278	6/12/15	4.20
1306.2	6/12/15	2.00
		16.30
1247.1	6/13/15	2.10
1252.1	6/13/15	2.00
1253.1	6/13/15	2.10
1257.1	6/13/15	2.00
1273	6/13/15	4.00
1278	6/13/15	4.20
1306.2	6/13/15	2.00
		18.40
1247.1	6/14/15	2.10
1252.1	6/14/15	2.00
1253.1	6/14/15	2.10
1257.1	6/14/15	2.00
1273	6/14/15	4.00
1278	6/14/15	4.20
1306.2	6/14/15	2.00
		18.40
1247.1	6/15/15	2.10
1249	6/15/15	4.60
1251	6/15/15	5.20
1252.1	6/15/15	2.00
1253.1	6/15/15	2.10
1257.1	6/15/15	2.00
1258.1	6/15/15	2.00
1274	6/15/15	4.00
1278	6/15/15	4.20
1303	6/15/15	2.50
1304	6/15/15	3.60
1306	6/15/15	1.80
1306.2	6/15/15	2.00
		38.10

No	Date	Flow
1247.1	6/16/15	2.10
1249	6/16/15	4.60
1251	6/16/15	5.20
1252.1	6/16/15	2.00
1253.1	6/16/15	2.10
1258.1	6/16/15	2.00
1274	6/16/15	4.00
1278	6/16/15	4.20
1303	6/16/15	2.50
1304	6/16/15	3.60
1306	6/16/15	1.80
1306.2	6/16/15	2.00
		36.10
1247.1	6/17/15	2.10
1249	6/17/15	4.60
1251	6/17/15	5.20
1274	6/17/15	4.00
1278	6/17/15	4.20
1304	6/17/15	3.60
1306	6/17/15	2.00
		25.70
1247.1	6/18/15	2.10
1251	6/18/15	5.20
1274	6/18/15	4.00
1278	6/18/15	4.20
1306	6/18/15	2.50
		18.00
1251	6/19/15	5.20
1274	6/19/15	4.00
1278	6/19/15	4.20
		13.40
1258.1	6/23/15	2.00
		2.00
1258.1	6/24/15	2.00
		2.00
1258.01	6/25/15	2.00
1258.1	6/25/15	2.00
1306.2	6/25/15	2.00
		6.00
1258.01	6/26/15	2.00
1258.1	6/26/15	2.00
1290	6/26/15	2.00
1305	6/26/15	3.80
1306.2	6/26/15	2.00
		11.80
1258.01	6/27/15	2.00
1258.1	6/27/15	2.00
1290	6/27/15	2.00
1290.1	6/27/15	2.00
1305	6/27/15	3.80
1306.2	6/27/15	2.00
		13.80

No	Date	Flow
1258.01	6/28/15	2.00
1282	6/28/15	5.70
1286	6/28/15	3.00
1290	6/28/15	2.00
1290.1	6/28/15	2.00
1305	6/28/15	3.80
1306.2	6/28/15	2.00
		20.50
1258.01	6/29/15	2.00
1282	6/29/15	5.70
1286	6/29/15	3.00
1290	6/29/15	2.00
1290.1	6/29/15	2.00
1305	6/29/15	3.80
1306.2	6/29/15	2.00
		20.50
1258.01	6/30/15	2.00
1281	6/30/15	4.10
1282	6/30/15	5.70
1286	6/30/15	3.00
1290	6/30/15	2.00
1290.1	6/30/15	2.00
1305	6/30/15	3.80
1306.2	6/30/15	2.00
		24.60
1258.01	7/1/15	2.00
1266	7/1/15	3.00
1269	7/1/15	2.10
1281	7/1/15	4.10
1282	7/1/15	5.70
1284	7/1/15	2.50
1290.1	7/1/15	2.00
1302	7/1/15	3.40
1305	7/1/15	3.80
		28.60
1258.01	7/2/15	2.00
1258.1	7/2/15	2.00
1266	7/2/15	3.00
1269	7/2/15	2.10
1278	7/2/15	5.50
1281	7/2/15	4.10
1282	7/2/15	5.70
1284	7/2/15	2.50
1302	7/2/15	3.40
1305	7/2/15	3.80
		34.10

No	Date	Flow
1250	7/3/15	3.80
1258.01	7/3/15	2.00
1258.1	7/3/15	2.00
1260	7/3/15	2.50
1266	7/3/15	3.00
1269	7/3/15	2.10
1278	7/3/15	5.50
1281	7/3/15	4.10
1282	7/3/15	3.60
1284	7/3/15	2.50
1293	7/3/15	2.90
1302	7/3/15	3.40
		37.40
1250	7/4/15	3.80
1258.01	7/4/15	2.00
1258.1	7/4/15	2.00
1260	7/4/15	2.50
1266	7/4/15	3.00
1269	7/4/15	2.10
1278	7/4/15	5.50
1281	7/4/15	4.10
1282	7/4/15	3.60
1284	7/4/15	2.50
1293	7/4/15	2.90
1302	7/4/15	3.40
		37.40
1250	7/5/15	3.80
1258.01	7/5/15	2.00
1258.1	7/5/15	2.00
1265.01	7/5/15	4.00
1266	7/5/15	3.00
1278	7/5/15	5.50
1281	7/5/15	4.10
1284	7/5/15	2.50
1293	7/5/15	2.90
1302	7/5/15	3.40
		33.20
1250	7/6/15	3.80
1258.01	7/6/15	2.00
1258.1	7/6/15	2.00
1265.01	7/6/15	4.00
1266	7/6/15	3.00
1278	7/6/15	5.30
1281	7/6/15	4.10
1284	7/6/15	2.50
1293.1	7/6/15	3.50
1295	7/6/15	3.50
1302	7/6/15	3.40
		37.10

No	Date	Flow
1250	7/7/15	3.80
1258.01	7/7/15	2.00
1258.1	7/7/15	2.00
1265.01	7/7/15	4.00
1266	7/7/15	3.00
1278	7/7/15	5.30
1281	7/7/15	4.10
1284	7/7/15	2.50
1293.1	7/7/15	3.50
1295	7/7/15	3.50
1302	7/7/15	3.40
		37.10
1250	7/8/15	3.80
1265.01	7/8/15	4.00
1266	7/8/15	3.00
1270	7/8/15	3.00
1278	7/8/15	5.30
1281	7/8/15	4.10
1284	7/8/15	2.50
1293.1	7/8/15	3.50
1295	7/8/15	3.50
1302	7/8/15	3.40
		36.10
1249	7/9/15	4.60
1265.01	7/9/15	4.00
1266	7/9/15	3.00
1270	7/9/15	3.00
1277	7/9/15	4.70
1281	7/9/15	4.10
1284	7/9/15	2.50
1293.1	7/9/15	3.50
1295	7/9/15	3.50
1302	7/9/15	3.40
		36.30
1249	7/10/15	4.60
1265.01	7/10/15	4.00
1267	7/10/15	3.30
1270	7/10/15	3.00
1277	7/10/15	4.70
1290	7/10/15	2.00
1290.1	7/10/15	2.00
1293.1	7/10/15	3.50
1295	7/10/15	3.50
1302	7/10/15	3.40
		34.00
1249	7/11/15	4.60
1258.01	7/11/15	2.00
1265.01	7/11/15	4.00
1267	7/11/15	3.30
1270	7/11/15	3.00
1277	7/11/15	4.70
1290	7/11/15	2.00
1290.1	7/11/15	2.00
		25.60

No	Date	Flow
1249	7/12/15	4.60
1258.01	7/12/15	2.00
1265.01	7/12/15	4.00
1267	7/12/15	3.30
1270	7/12/15	3.00
1290.1	7/12/15	2.00
		18.90
1249	7/13/15	4.60
1258.01	7/13/15	2.00
1258.1	7/13/15	2.00
1267	7/13/15	3.30
1282	7/13/15	5.40
1290	7/13/15	2.00
1305	7/13/15	4.10
		23.40
1249	7/14/15	4.60
1258.01	7/14/15	2.00
1258.1	7/14/15	2.00
1267	7/14/15	3.30
1282	7/14/15	5.40
1290	7/14/15	2.00
1290.1	7/14/15	2.00
1305	7/14/15	4.10
		25.40
1249	7/15/15	4.60
1258.01	7/15/15	2.00
1258.1	7/15/15	2.00
1282	7/15/15	5.40
1290.1	7/15/15	2.00
1305	7/15/15	4.10
		20.10
1258.1	7/16/15	2.00
1282	7/16/15	5.40
1305	7/16/15	4.10
		11.50
1282	7/17/15	5.40
		5.40
1282	7/18/15	5.40
		5.40
1282	7/19/15	5.40
1286	7/19/15	2.70
		8.10
1258.01	7/20/15	2.00
1258.1	7/20/15	2.00
1282	7/20/15	5.40
1286	7/20/15	2.70
1305	7/20/15	4.00
		16.10
1258.01	7/21/15	2.00
1258.1	7/21/15	2.00
1282	7/21/15	5.40
1284	7/21/15	3.00
1286	7/21/15	2.70
1305	7/21/15	4.00
		19.10

No	Date	Flow
1258.01	7/22/15	2.00
1258.1	7/22/15	2.00
1266	7/22/15	2.60
1278	7/22/15	6.40
1284	7/22/15	3.00
1290	7/22/15	2.00
1290.1	7/22/15	2.00
1305	7/22/15	4.00
		24.00
1258.01	7/23/15	2.00
1258.1	7/23/15	2.00
1266	7/23/15	2.60
1278	7/23/15	6.40
1284	7/23/15	3.00
1290	7/23/15	2.00
1290.1	7/23/15	2.00
1305	7/23/15	4.00
		24.00
1258.01	7/24/15	2.00
1258.1	7/24/15	2.00
1266	7/24/15	2.60
1278	7/24/15	6.40
1281	7/24/15	4.10
1284	7/24/15	3.00
1305	7/24/15	4.00
		24.10
1258.01	7/25/15	2.00
1258.1	7/25/15	2.00
1265.01	7/25/15	3.60
1266	7/25/15	2.60
1269	7/25/15	3.20
1278	7/25/15	6.40
1281	7/25/15	4.10
1284	7/25/15	3.00
1290	7/25/15	2.00
		28.90
1258.01	7/26/15	2.00
1258.1	7/26/15	2.00
1265.01	7/26/15	3.60
1266	7/26/15	2.60
1269	7/26/15	3.20
1278	7/26/15	6.40
1281	7/26/15	4.10
1284	7/26/15	3.00
		26.90

No	Date	Flow
1258.01	7/27/15	2.00
1258.01	7/27/15	2.00
1258.1	7/27/15	2.00
1258.1	7/27/15	2.00
1265.01	7/27/15	3.60
1265.01	7/27/15	3.60
1266	7/27/15	2.60
1269	7/27/15	3.20
1278	7/27/15	4.90
1281	7/27/15	4.10
1284	7/27/15	3.00
1290.1	7/27/15	2.00
1293	7/27/15	3.60
		38.60
1258.1	7/28/15	2.00
1258.1	7/28/15	2.00
1265.01	7/28/15	3.60
1265.01	7/28/15	3.60
1266	7/28/15	2.60
1269	7/28/15	3.20
1281	7/28/15	4.10
1290.1	7/28/15	2.00
		23.10
1265.01	7/29/15	3.60
1265.01	7/29/15	3.60
1266	7/29/15	2.60
1269	7/29/15	3.20
1281	7/29/15	4.10
1293	7/29/15	3.60
		20.70
1250	7/30/15	4.00
1250	7/30/15	4.00
1258.01	7/30/15	2.00
1258.01	7/30/15	2.00
1265.01	7/30/15	3.60
1265.01	7/30/15	3.60
1266	7/30/15	2.60
1281	7/30/15	4.10
1290	7/30/15	2.00
1293.1	7/30/15	4.50
		32.40
1250	7/31/15	4.00
1250	7/31/15	4.00
1258.01	7/31/15	2.00
1258.01	7/31/15	2.00
1259.1	7/31/15	2.00
1259.1	7/31/15	2.00
1265.01	7/31/15	3.60
1265.01	7/31/15	3.60
1266	7/31/15	2.60
1270	7/31/15	2.70
1277	7/31/15	5.50
1281	7/31/15	4.10
1290	7/31/15	2.00
1293.1	7/31/15	4.50
		44.60

No	Date	Flow
1250	8/1/15	4.00
1250	8/1/15	4.00
1258.01	8/1/15	2.00
1258.01	8/1/15	2.00
1258.1	8/1/15	2.00
1258.1	8/1/15	2.00
1259.1	8/1/15	2.00
1259.1	8/1/15	2.00
1265.01	8/1/15	3.60
1265.01	8/1/15	3.60
1267	8/1/15	3.30
1270	8/1/15	2.70
1277	8/1/15	5.50
1281	8/1/15	4.10
1293.1	8/1/15	4.50
		47.30
1250	8/2/15	4.00
1250	8/2/15	4.00
1258.01	8/2/15	2.00
1258.01	8/2/15	2.00
1258.1	8/2/15	2.00
1258.1	8/2/15	2.00
1259.1	8/2/15	2.00
1259.1	8/2/15	2.00
1267	8/2/15	3.30
1270	8/2/15	2.70
1281	8/2/15	4.10
		30.10
1250	8/3/15	3.40
1258.01	8/3/15	2.00
1258.1	8/3/15	2.00
1267	8/3/15	3.30
1270	8/3/15	2.70
1290	8/3/15	2.00
1290.1	8/3/15	2.00
		17.40
1249	8/4/15	5.40
1258.1	8/4/15	2.00
1267	8/4/15	3.30
1270	8/4/15	2.70
1290.1	8/4/15	2.00
		15.40
1249	8/5/15	5.40
1258.1	8/5/15	2.00
1267	8/5/15	3.30
1270	8/5/15	2.70
1290.1	8/5/15	2.00
		15.40
1249	8/6/15	5.40
1286	8/6/15	3.50
1290.1	8/6/15	2.00
1305	8/6/15	4.00
		14.90

No	Date	Flow
1249	8/7/15	5.40
1258.01	8/7/15	2.00
1282	8/7/15	5.40
1286	8/7/15	3.50
1290.1	8/7/15	2.00
1305	8/7/15	4.00
		22.30
1249	8/8/15	5.40
1258.01	8/8/15	2.00
1282	8/8/15	5.40
1286	8/8/15	3.50
1305	8/8/15	4.50
		20.80
1249	8/9/15	5.40
1258.01	8/9/15	2.00
1282	8/9/15	5.40
1286	8/9/15	3.50
1290	8/9/15	2.00
1305	8/9/15	4.50
		22.80
1249	8/10/15	5.40
1258.01	8/10/15	2.00
1258.1	8/10/15	2.00
1282	8/10/15	5.40
1284	8/10/15	3.10
1290	8/10/15	2.00
1305	8/10/15	4.50
		24.40
1249	8/11/15	5.40
1258.01	8/11/15	2.00
1258.1	8/11/15	2.00
1282	8/11/15	5.40
1284	8/11/15	3.10
1290	8/11/15	2.00
1305	8/11/15	4.50
		24.40
1258.01	8/12/15	2.00
1258.1	8/12/15	2.00
1282	8/12/15	5.40
1284	8/12/15	3.10
1302	8/12/15	3.30
1305	8/12/15	4.50
		20.30
1258.01	8/13/15	2.00
1258.1	8/13/15	2.00
1260	8/13/15	2.50
1284	8/13/15	3.10
1290	8/13/15	2.00
1290.1	8/13/15	2.00
1302	8/13/15	3.30
1305	8/13/15	4.50
		21.40

No	Date	Flow
1258.01	8/14/15	2.00
1258.1	8/14/15	2.00
1260	8/14/15	2.50
1266	8/14/15	3.00
1284	8/14/15	3.10
1290	8/14/15	2.00
1290.1	8/14/15	2.00
1302	8/14/15	3.30
		19.90
1258.01	8/15/15	2.00
1258.1	8/15/15	2.00
1266	8/15/15	3.00
1277	8/15/15	4.60
1295	8/15/15	6.60
1302	8/15/15	3.30
		21.50
1258.01	8/16/15	2.00
1258.1	8/16/15	2.00
1266	8/16/15	3.00
1269	8/16/15	2.30
1277	8/16/15	4.60
1295	8/16/15	6.60
1302	8/16/15	3.30
		23.80
1266	8/17/15	3.00
1269	8/17/15	2.40
1277	8/17/15	4.60
1281	8/17/15	3.80
1295	8/17/15	6.60
1302	8/17/15	3.40
		23.80
1266	8/18/15	3.00
1269	8/18/15	2.40
1278	8/18/15	6.10
1281	8/18/15	3.80
1295	8/18/15	6.60
1302	8/18/15	3.40
		25.30
1266	8/19/15	3.00
1269	8/19/15	2.40
1278	8/19/15	6.10
1281	8/19/15	3.80
1295	8/19/15	6.60
1302	8/19/15	3.40
		25.30
1266	8/20/15	3.00
1269	8/20/15	2.40
1278	8/20/15	6.10
1281	8/20/15	3.80
1302	8/20/15	3.40
		18.70
1266	8/21/15	3.10
1278	8/21/15	6.10
1281	8/21/15	3.80
		13.00

No	Date	Flow
1258.01	8/22/15	2.00
1258.1	8/22/15	2.00
1266	8/22/15	3.10
1281	8/22/15	3.80
		10.90
1258.01	8/23/15	2.00
1258.1	8/23/15	2.00
1266	8/23/15	3.10
1281	8/23/15	3.80
		10.90
1258.01	8/24/15	2.00
1258.1	8/24/15	2.00
1265.01	8/24/15	4.00
1267	8/24/15	3.20
1270	8/24/15	2.70
1284	8/24/15	3.50
1290	8/24/15	2.00
		19.40
1258.01	8/25/15	2.00
1258.1	8/25/15	2.00
1265.01	8/25/15	4.00
1267	8/25/15	3.20
1270	8/25/15	2.70
1284	8/25/15	3.50
1286	8/25/15	2.50
1290	8/25/15	2.00
		21.90
1258.01	8/26/15	2.00
1265.01	8/26/15	4.00
1267	8/26/15	3.20
1270	8/26/15	2.70
1284	8/26/15	3.50
1286	8/26/15	2.50
		17.90
1258.01	8/27/15	2.00
1265.01	8/27/15	4.00
1267	8/27/15	3.20
1270	8/27/15	2.70
1284	8/27/15	3.50
1286	8/27/15	2.50
1293	8/27/15	5.60
		23.50
1258.01	8/28/15	2.00
1265.01	8/28/15	4.00
1267	8/28/15	3.20
1282	8/28/15	6.50
1293.1	8/28/15	6.40
		22.10
1258.01	8/29/15	2.00
1265.01	8/29/15	4.00
1267	8/29/15	3.20
1282	8/29/15	6.50
1293.1	8/29/15	6.40
		22.10

No	Date	Flow
1250	8/30/15	4.50
1258.01	8/30/15	2.00
1265.01	8/30/15	4.00
1267	8/30/15	3.20
1282	8/30/15	6.50
1293.1	8/30/15	6.40
		26.60
1250	8/31/15	4.50
1258.1	8/31/15	2.00
1265.01	8/31/15	4.00
1277	8/31/15	4.80
1282	8/31/15	6.50
1293.1	8/31/15	6.40
		28.20
1250	9/1/15	4.50
1258.1	9/1/15	2.00
1265.01	9/1/15	4.00
1277	9/1/15	4.80
1282	9/1/15	6.50
1293.1	9/1/15	6.40
		28.20
1250	9/2/15	4.50
1258.01	9/2/15	2.00
1258.1	9/2/15	2.00
1277	9/2/15	4.80
1282	9/2/15	6.50
		19.80
1250	9/3/15	4.50
1258.01	9/3/15	2.00
1258.1	9/3/15	2.00
1282	9/3/15	6.50
		15.00
1258.01	9/4/15	2.00
1282	9/4/15	6.50
		8.50
1258.01	9/5/15	2.00
		2.00
1258.01	9/6/15	2.00
		2.00
1258.01	9/7/15	2.00
		2.00
1258.01	9/8/15	2.00
		2.00
1258.01	9/9/15	2.00
		2.00
1258.01	9/10/15	2.00
		2.00
1259.1	9/18/15	2.00
		2.00
1259.1	9/19/15	2.00
		2.00
1259.1	9/20/15	2.00
		2.00

2015	Lat N Div	Lat N Spill	Pump Flow	Delivery	Total Flow	Loss
4/30/15	0	0		0	0	0
5/1/15	0	0		0	0	0
5/2/15	0	0		0	0	0
5/3/15	32	32		0	32	0
5/4/15	42	17		16.00	42	9
5/5/15	45	18		22.20	45	4.8
5/6/15	49	17		23.40	49	8.6
5/7/15	49	25		21.40	49	2.6
5/8/15	49	24		17.40	49	7.6
5/9/15	45	27		14.40	45	3.6
5/10/15	45	27		13.20	45	4.8
5/11/15	45	27		13.20	45	4.8
5/12/15	45	29		9.70	45	6.3
5/13/15	45	28		9.70	45	7.3
5/14/15	45	23		9.60	45	12.4
5/15/15	45	26		3.60	45	15.4
5/16/15	44	27		0.00	44	17
5/17/15	44	27		0.00	44	17
5/18/15	42	28		0.00	42	14
5/19/15	50	37		0.00	50	13
5/20/15	50	35		0.00	50	15
5/21/15	50	33		0.00	50	17
5/22/15	50	33		0.00	50	17
5/23/15	50	33		0.00	50	17
5/24/15	50	33		0.00	50	17
5/25/15	50	33		5.60	50	11.4
5/26/15	50	28		13.00	50	9
5/27/15	50	26		16.00	50	8
5/28/15	50	27		13.00	50	10
5/29/15	42	30		9.40	42	2.6
5/30/15	35	23		9.40	35	2.6
5/31/15	35	26		5.40	35	3.6
6/1/15	35	7		21.30	35	6.7
6/2/15	35	27		5.40	35	2.6
6/3/15	34	25		3.40	34	5.6
6/4/15	34	29		0.00	34	5
6/5/15	34	27		0.00	34	7
6/6/15	35	32		0.00	35	3
6/7/15	35	30		0.00	35	5
6/8/15	34	31		0.00	34	3
6/9/15	34	31		0.00	34	3
6/10/15	34	30		0.00	34	4
6/11/15	34	29		6.10	34	-1.1
6/12/15	34	21		16.30	34	-3.3
6/13/15	34	12		18.40	34	3.6
6/14/15	45	13		18.40	45	13.6
6/15/15	45	5		38.10	45	1.9
6/16/15	49	9		36.10	49	3.9
6/17/15	49	17		25.70	49	6.3
6/18/15	47	25		18.00	47	4
6/19/15	47	31		13.40	47	2.6
6/20/15	47	35		0.00	47	12
6/21/15	39	38		0.00	39	1

2015	Lat N Div	Lat N Spill	Pump Flow	Delivery	Total Flow	Loss
6/22/15	35	32		0.00	35	3
6/23/15	35	31		2.00	35	2
6/24/15	31	26		2.00	31	3
6/25/15	31	19		6.00	31	6
6/26/15	31	17		11.80	31	2.2
6/27/15	31	13		13.80	31	4.2
6/28/15	31	1		20.50	31	9.5
6/29/15	31	6	16	20.50	47	20.5
6/30/15	37	15	16	24.60	53	13.4
7/1/15	37	13	16	28.60	53	11.4
7/2/15	41	8	16	34.10	57	14.9
7/3/15	41	14	16	37.40	57	5.6
7/4/15	44	11	16	37.40	60	11.6
7/5/15	44	23	16	33.20	60	3.8
7/6/15	47	12	16	37.10	63	13.9
7/7/15	47	13	16	37.10	63	12.9
7/8/15	47	16	16	36.10	63	10.9
7/9/15	47	17	16	36.30	63	9.7
7/10/15	46	19	16	34.00	62	9
7/11/15	46	27	16	25.60	62	9.4
7/12/15	47	31	16	18.90	63	13.1
7/13/15	47	16		23.40	47	7.6
7/14/15	47	21		25.40	47	0.6
7/15/15	47	24		20.10	47	2.9
7/16/15	47	28		11.50	47	7.5
7/17/15	47	30		5.40	47	11.6
7/18/15	47	33		5.40	47	8.6
7/19/15	47	31		8.10	47	7.9
7/20/15	47	27		16.10	47	3.9
7/21/15	47	24		19.10	47	3.9
7/22/15	46	14		24.00	46	8
7/23/15	46	18		24.00	46	4
7/24/15	46	12		24.10	46	9.9
7/25/15	46	18		28.90	46	-0.9
7/26/15	46	20	16	26.90	62	15.1
7/27/15	46	10	16	38.60	62	13.4
7/28/15	46	20	16	23.10	62	18.9
7/29/15	39	14	11	20.70	50	15.3
7/30/15	42	17	15	32.40	57	7.6
7/31/15	42	11	15	44.60	57	1.4
8/1/15	47	10	15	47.30	62	4.7
8/2/15	47	26	15	30.10	62	5.9
8/3/15	47	22		17.40	47	7.6
8/4/15	47	13		15.40	47	18.6
8/5/15	47	18		15.40	47	13.6
8/6/15	47	19		14.90	47	13.1
8/7/15	47	25		22.30	47	-0.3
8/8/15	46	26		20.80	46	-0.8
8/9/15	46	19		22.80	46	4.2
8/10/15	46	15		24.40	46	6.6
8/11/15	46	16		24.40	46	5.6
8/12/15	46	19		20.30	46	6.7
8/13/15	44	18		21.40	44	4.6

2015	Lat N Div	Lat N Spill	Pump Flow	Delivery	Total Flow	Loss
8/14/15	44	21		19.90	44	3.1
8/15/15	44	18		21.50	44	4.5
8/16/15	44	12		23.80	44	8.2
8/17/15	44	23	15	23.80	59	12.2
8/18/15	44	22	15	25.30	59	11.7
8/19/15	44	23	15	25.30	59	10.7
8/20/15	47	19		18.70	47	9.3
8/21/15	47	21		13.00	47	13
8/22/15	47	23		10.90	47	13.1
8/23/15	47	25		10.90	47	11.1
8/24/15	46	22		19.40	46	4.6
8/25/15	47	20		21.90	47	5.1
8/26/15	47	22		17.90	47	7.1
8/27/15	47	19		23.50	47	4.5
8/28/15	47	20		22.10	47	4.9
8/29/15	46	23		22.10	46	0.9
8/30/15	49	14		26.60	49	8.4
8/31/15	49	22		28.20	49	-1.2
9/1/15	49	22		28.20	49	-1.2
9/2/15	49	23		19.80	49	6.2
9/3/15	49	34		15.00	49	0
9/4/15	49	32		8.50	49	8.5
9/5/15	39	36		2.00	39	1
9/6/15	39	36		2.00	39	1
9/7/15	39	37		2.00	39	0
9/8/15	37	35		2.00	37	0
9/9/15	36	34		2.00	36	0
9/10/15	36	36		2.00	36	-2
9/11/15	33	33		0.00	33	0
9/12/15	29	27		0.00	29	2
9/13/15	29	27		0.00	29	2
9/14/15	29	28		0.00	29	1
9/15/15	21	21		0.00	21	0
9/16/15	21	21		0.00	21	0
9/17/15	20	20		0.00	20	0
9/18/15	19	17		2.00	19	0
9/19/15	19	17		2.00	19	0
9/20/15	19	19		2.00	19	-2
9/21/15	18	17		0.00	18	1
9/22/15	16	15		0.00	16	1
9/23/15	16	15		0.00	16	1
9/24/15	13	12		0.00	13	1
9/25/15	9	8		0.00	9	1
AVG.		22.09	Supplement	14.40	42.86	6.36
Lateral N			**Pump**	**Avg Delivered**	**Avg Flow**	**Avg Loss**

Lateral N	**Avg % Loss**	=	**15%**

Note: The overall average considers the differences in flows (positive and negative) that can be caused by a timing issue on the readings (i.e. water fed into the lateral in the morning; or the afternoon) that causes water level changes when a farm is turned on or off during the day. The reading for water spilled out of the lateral is taken only once daily, whenever the Ditchriders drive by it sometime during the day. However, farm deliveries can be turned on or off throughout the day, which changes water levels in the lateral. If the timing is wrong, it would cause the loss to not take into account farm delivery changes until the next day. Operational spills are flows diverted into the LYIP system that are not delivered to the farm. It is necessary to divert excess water to the main canal or lateral to act as a buffer necessary to allow for normal water deliveries and the elevations needed for water deliveries to elevated fields. Operational spills are either returned to the LYIP Main Canal to be utilized for irrigation or to the LYIP drainages where they support wildlife habitat and then discharge back to the Yellowstone River. Operational spills are utilized in most gravity irrigation systems to manage downstream irrigation demand. This contingency water is needed to provide a buffer for water level fluctuations caused by significantly varying losses due to high day-time temperatures, winds, and water quality variances and to cover future deliveries, delivery adjustments, unauthorized deliveries, and to cover shrinkage due to large loss variances. If enough water is not kept in the LYIP system to cover downstream demands and varying water losses, water shortages are certain to occur. Constant buffered water flow and minimum water elevations must be maintained to each individual farm or the siphons and/or pump irrigation systems will stop drawing water from the laterals or private farm ditches. When these systems stop drawing water, suddenly there is not enough room in the progressively smaller laterals, pipe lines or private farm ditches to carry the sudden gain in water (because it is no longer taken out at the farms or siphon tubes) and this blows out the tops of the canals and causes dangerous large scale public flooding. Without operational spills, a constant water flow and minimum water elevations are NOT possible to achieve. In addition, The LYIP consists of over 72 miles of main canal and 220 miles of laterals. A call on water to thedownstream end of the system would take over a week to get water from the diversion to the downstream portion of the system if operational spills were not in place. This timing could result in serious and irrepairable damage to crops that would have a devastating financial impact to the farmers.

LYIP 2000 MC Water Loss Data Calculations.xlsx

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	Div 1	MC Spill	Div Total	Div 2	MC Spill	Div Total	Div 3	MC Spill	Div Total	Div 4	MC Spill	Div Total	Div 5	MC Spill	Div Total	Div 6	MC Spill	Div Total	MC Spill Sum	Willot Flow	Seep Evap	Div 6	Div 5	Div 4	Div3	Div 2	Div 1	O Check	Hay Creek	Lone Tree	Struckman Gauge	SID Pumps	Headgates
																						CFS Intentional diverted or spilled						CFS Passing Main Canal Structures					
4/11/2000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
4/12/2000	0	300	300	0	300	300	0	100	100	0	0	0	0	0	0	0	0	0	700	755	7.9%	0	0	0	100	400	700	0.0	0.0	0.0	107.9	431.4	755.0
4/13/2000	0	302	302	0	227	227	0	100	100	0	110	110	10	0	10	0	0	0	739	945	26.2%	0	10	120	220	447	749	0.0	12.6	151.4	277.6	564.0	945.0
4/14/2000	0	301	301	0	269	269	0	100	100	0	0	0	10	0	10	0	0	0	670	945	39.0%	0	10	10	110	379	680	0.0	13.9	13.9	152.9	526.7	945.0
4/15/2000	0	260	260	0	240	240	0	80	80	0	0	0	10	0	10	0	0	0	580	770	30.5%	0	10	10	90	330	590	0.0	13.1	13.1	117.5	430.7	770.0
4/16/2000	0	260	260	0	220	220	0	80	80	0	150	150	10	0	10	0	0	0	710	784	8.9%	0	10	160	240	460	720	0.0	10.9	174.2	261.3	500.9	784.0
4/17/2000	0	260	260	0	220	220	0	80	80	0	120	120	38	0	38	6	0	6	680	784	8.3%	6	44	164	244	464	724	6.5	47.6	177.6	264.2	502.5	784.0
4/18/2000	0	260	260	0	60	60	8	80	88	0	100	100	38	0	38	8	0	8	500	835	50.7%	8	46	146	234	294	554	12.1	69.3	220.1	352.7	443.1	835.0
4/19/2000	0	270	270	0	152	152	15	100	115	0	0	0	58	0	58	25	0	25	522	945	52.4%	25	83	83	198	350	620	38.1	126.5	126.5	301.8	533.5	945.0
4/20/2000	0	275	275	0	152	152	24	100	124	0	0	0	87	25	112	72	10	82	562	945	26.8%	82	194	194	318	470	745	104.0	246.1	246.1	403.4	596.2	945.0
4/21/2000	0	273	273	0	152	152	29	0	29	50	32	82	97	30	127	81	0	81	487	945	27.0%	81	208	290	319	471	744	102.9	264.2	368.3	405.2	598.2	945.0
4/22/2000	0	275	275	0	100	100	33	0	33	80	49.5	129.5	96	20	116	79	7	86	451.5	945	27.8%	86	202	331.5	364.5	464.5	739.5	109.9	258.1	423.6	465.8	593.6	945.0
4/23/2000	0	144	144	0	102	102	35	0	35	80	118	198	130	25	155	84	12	96	401	963	31.9%	96	251	449	484	586	730	126.6	331.1	592.3	638.5	773.0	963.0
4/24/2000	15	57	72	20	115	135	48	0	48	89	136	225	155	25	180	87	12	99	345	980	29.1%	99	279	504	552	687	759	127.8	360.2	650.8	712.7	887.0	980.0
4/25/2000	8	70	78	40	112	152	64	25	89	99	102.7	201.7	165	28	193	81	0	81	337.7	980	23.3%	81	274	475.7	564.7	716.7	794.7	99.9	337.9	586.6	696.4	883.8	980.0
4/26/2000	15	77	92	40	159	199	64	24	88	101	75.9	176.9	165	22	187	97	2	99	359.9	980	16.4%	99	286	462.9	550.9	749.9	841.9	115.2	332.9	538.8	641.3	872.9	980.0
4/27/2000	15	133	148	40	128	168	83	24	107	108	51.7	159.7	165	11	176	97	0	97	347.7	1000	16.9%	97	273	432.7	539.7	707.7	855.7	113.4	319.0	505.7	630.7	827.0	1000.0
4/28/2000	15	162	177	0	60	60	80	0	80	127	22.7	149.7	167	0	167	97	0	97	244.7	980	34.1%	97	264	413.7	493.7	553.7	730.7	130.1	354.1	554.8	662.1	742.6	980.0
4/29/2000	15	152	167	40	44	84	81	0	81	130	14.8	144.8	170	0	170	109	0	109	210.8	963	27.4%	109	279	423.8	504.8	588.8	755.8	138.9	355.5	540.0	643.2	750.2	963.0
4/30/2000	18	141	159	40	56	96	81	0	81	130	19	149	170	0	170	115	0	115	216	963	25.1%	115	285	434	515	611	770	143.8	356.4	542.8	644.1	764.1	963.0
5/1/2000	22	136	158	40	56	96	89	0	89	131	15.4	146.4	170	0	170	120	2	122	209.4	963	23.2%	122	292	438.4	527.4	623.4	781.4	150.4	359.9	540.3	650.0	768.3	963.0
5/2/2000	31	121	152	34	55	89	85	0	85	137	0	137	181	0	181	119	0	119	176	963	26.2%	119	300	437	522	611	763	150.2	378.6	551.5	658.8	771.2	963.0
5/3/2000	38	56	94	74	0	74	110	0	110	167	0.7	167.7	193	0	193	120	0	120	56.7	1000	31.8%	120	313	480.7	590.7	664.7	758.7	158.2	412.5	633.6	778.6	876.1	1000.0
5/4/2000	30	69	99	80	36	116	108	0	108	163	5.5	168.5	187	0	187	126	0	126	110.5	1042	29.5%	126	313	481.5	589.5	705.5	804.5	163.2	405.4	623.6	763.5	913.8	1042.0
5/5/2000	30	19	49	80	61	141	113	0	113	201	8.4	209.4	182	0	182	114	0	114	88.4	1042	28.9%	114	296	505.4	618.4	759.4	808.4	146.9	381.5	651.4	797.1	978.8	1042.0
5/6/2000	36	68	104	80	46	126	126	0	126	203	0	203	187	0	187	116	0	116	114	1065	23.5%	116	303	506	632	758	862	143.3	374.4	625.2	780.8	936.5	1065.0
5/7/2000	36	57	93	80	40	120	132	0	132	206	1.1	207.1	186	0	186	116	8	124	106.1	1085	25.9%	124	310	517.1	649.1	769.1	862.1	156.1	390.2	650.8	816.9	968.0	1085.0
5/8/2000	38	74	112	114	40	154	140	0	140	207	2.5	209.5	169	0	169	115	0	115	116.5	1133	26.0%	115	284	493.5	633.5	787.5	899.5	144.9	357.7	621.6	797.9	991.9	1133.0
5/9/2000	45	42	87	114	24	138	146	0	146	207	2.9	209.9	169	0	169	113	0	113	68.9	1133	31.3%	113	282	491.9	637.9	775.9	862.9	148.4	370.3	645.9	837.6	1018.8	1133.0
5/10/2000	39	28	67	114	59	173	160	1	161	196	13.5	209.5	169	0	169	113	0	113	101.5	1160	30.0%	113	282	491.5	652.5	825.5	892.5	146.9	366.5	638.8	848.1	1072.9	1160.0
5/11/2000	21	22	43	100	85	185	140	0	140	195	15.4	210.4	169	0	169	112	0	112	122.4	1160	35.0%	112	281	491.4	631.4	816.4	859.4	151.2	379.3	663.3	852.3	1102.0	1160.0
5/12/2000	30	76	106	100	106	206	128	0	128	163	48	211	163	0	163	102	0	102	230	1108	21.0%	102	265	476	604	810	916	123.4	320.5	575.8	730.6	979.8	1108.0
5/13/2000	24	93	117	103	79	182	125	0	125	163	5.8	168.8	163	0	163	102	0	102	177.8	1108	29.2%	102	265	433.8	558.8	740.8	857.8	131.8	342.3	560.3	721.8	956.9	1108.0
5/14/2000	24	79	103	97	81	178	115	0	115	155	8	163	157	3	160	100	12	112	183	1085	30.6%	112	272	435	550	728	831	146.2	355.1	568.0	718.1	950.5	1085.0
5/15/2000	21	92	113	91	108	199	141	20	161	153	1.4	154.4	157	3	160	113	12	125	236.4	1085	18.9%	125	285	439.4	600.4	799.4	912.4	148.6	338.9	522.5	714.0	950.6	1085.0
5/16/2000	18	132	150	80	70	150	148	12	160	153	2.5	155.5	157	3	160	109	10	119	229.5	1108	23.9%	119	279	434.5	594.5	744.5	894.5	147.4	345.6	538.2	736.4	922.2	1108.0
5/17/2000	24	96	120	114	33	147	153	0	153	151	6	157	157	1	158	114	8	122	144	1085	26.6%	122	280	437	590	737	857	154.5	354.5	553.3	747.0	933.1	1085.0
5/18/2000	27	28	55	134	39	173	157	0	157	171	27.8	198.8	157	0	157	143	8	151	102.8	1133	27.0%	151	308	506.8	663.8	836.8	891.8	191.8	391.3	643.9	843.3	1063.1	1133.0
5/19/2000	39	0	39	134	46	180	191	0	191	181	26.7	207.7	158	0	158	145	2	147	74.7	1133	22.8%	147	305	512.7	703.7	883.7	922.7	180.5	374.5	629.6	864.1	1085.1	1133.0
5/20/2000	42	24	66	144	26	170	200	0	200	188	19	207	162	0	162	150	0	150	69	1216	27.3%	150	312	519	719	889	955	191.0	397.3	660.8	915.5	1132.0	1216.0
5/21/2000	68	69	137	161	48	209	191	10	201	194	6	200	170	0	170	142	0	142	133	1310	23.7%	142	312	512	713	922	1059	175.7	385.9	633.4	882.0	1140.5	1310.0
5/22/2000	83	20	103	166	27	193	197	10	207	186	6.9	192.9	170	0	170	170	0	170	63.9	1280	23.6%	170	340	532.9	739.9	932.9	1035.9	210.1	420.1	658.5	914.3	1152.7	1280.0
5/23/2000	94	10	104	172	17	189	220	0	220	206	8	214	182	0	182	161	0	161	35	1280	19.6%	161	343	557	777	966	1070	192.6	410.3	666.3	929.5	1155.6	1280.0
5/24/2000	94	41	135	172	9	181	241	0	241	201	5	206	182	0	182	167	0	167	55	1310	17.8%	167	349	555	796	977	1112	196.7	411.1	653.8	937.7	1151.0	1310.0
5/25/2000	9	82	91	172	26	198	244	0	244	219	13	232	160	0	160	171	0	171	121	1350	23.2%	171	331	563	807	1005	1096	210.6	407.7	693.5	994.0	1237.9	1350.0
5/26/2000	87	92	179	172	11	183	230	0	230	223	6	229	148	0	148	171	0	171	109	1390	21.9%	171	319	548	778	961	1140	208.5	389.0	668.2	948.6	1171.7	1390.0
5/27/2000	87	18	105	172	45	217	178	0	178	212	0	212	130	0	130	167	0	167	63	1280	26.9%	167	297	509	687	904	1009	211.9	376.8	645.7	871.5	1146.8	1280.0
5/28/2000	87	69	156	169	77	246	181	15	196	204	23	227	142	3	145	174	3	177	190	1310	14.2%	177	322	549	745	991	1147	202.2	367.8	627.0	850.9	1131.8	1310.0
5/29/2000	82	100	182	169	88	257	172	15	187	172	27	199	127	3	130	174	7	181	240	1350	18.8%	181	311	510	697	954	1136	215.1	369.6	606.1	828.3	1133.7	1350.0
5/30/2000	69	40	109	166	121	287	176	27	203	177	26	203	128	0	128	168	0	168	214	1280	16.6%	168	296	499	702	989	1098	195.8	345.1	581.7	818.4	1152.9	1280.0
5/31/2000	66	92	158	156	126	282	169	27	196	175	22	197	126	0	126	145	0	145	267	1250	13.2%	145	271	468	664	946	1104	164.2	306.8	529.9	751.8	1071.1	1250.0
6/1/2000	59	89	148	134	154	288	136	52	188	153	40	193	122	0	122	122	0	122	335	1310	23.5%	122	244	437	625	913	1061	150.6	301.3	539.6	771.7	1127.3	1310.0
6/2/2000	52	42	94	134	121	255	123	52	175	126	32	158	110	6	116	96	3	99	256	1133	26.3%	99	215	373	548	803	897	125.0	271.6	471.1	692.2	1014.3	1133.0
6/3/2000	42	27	69	117	107	224	125	32	157	126	20	146	96	22	118	99	5	104	213	1042	27.4%	104	222	368	525	749	818	132.5	282.8	468.8	668.8	954.1	1042.0
6/4/2000	36	45	81	117	121	238	105	32	137	111	37	148	96	22	118	84	20	104	277	1022	23.7%	104	222	370	507	745	826	128.7	274.7	457.8	627.3	921.8	1022.0
6/5/2000	30	67	97	117	99	216	109	24	133	108	38	146	96	0	96	87	0	87	228	1022	31.9%	87	183	329	462	678	775	114.7	241.3	433.9	609.2	894.1	1022.0
6/6/2000	27	59	86	105	84	189	118	14	132	108	43	151	96	25	121	81	20	101	245	1000	28.2%	101	222	373	505	694	780	129.5	284.6	478.2	647.4	889.7	1000.0
6/7/2000	24	82	106	105	87	192	115	14	129	104	67	171	97	30	127	81	18	99	298	1022	24.0%	99	226	397	526	718	824	122.8	280.3	492.4	652.4	890.5	1022.0
6/8/2000	27	77	104	108	83	191	110	14	124	107	56	163	97	30	127	81	18	99	278	1042	29.0%	99	226	389	513	704	808	127.7	291.5	501.7	661.6	907.9	1042.0
6/9/2000	27	108	135	102	147	249	114	14	128	96	67	163	97	35	132	81	18	99	389	1085	19.8%	99	231	394	522	771	906	118.6	276.6	471.8	625.1	923.3	1085.0
6/10/2000	0	128	128	102	188	290	112	14	126	96	67	163	97	35	132	81	18	99	450	1085	15.7%	99	231	394	520	810	938	114.5	267.2	455.7	601.5	936.9	1085.0
6/11/2000	27	107	134	108	144	252	106	14	120	101	57	158	100	35	135	81	18	99	375	1085	20.8%	99	234	392	512	764	898	119.6	282.7	473.6	618.6	923.1	1085.0
6/12/2000	40	97	137	142	97	239	111	14	125	163	45	208	100	35	135	77	18	95	306	1085	15.5%	95	230	438	563	802	939	109.8	265.8	506.1	650.5	926.7	1085.0
6/13/2000	18	74	92	142	58	200	135	8	143	171	27	198	100	35	135	70	18	88	220	1065	24.4%	88	223	421	564	764	856	109.5	277.4	523.8	701.7	950.5	1065.0
6/14/2000	3	70	73	156	28	184	139	8	147	184	5	189	100	40	140	70	18	88	169	1042	26.9%	88	228	417	564	748	821	111.7	289.4	529.2	715.8	949.3	1042.0
6/15/2000	0.3	44	44.3	151	49	200	125	8	133	171	30	201	82	40	122	66	18	84	189	1022	30.3%	84	206	407	540	740	784.3	109.5	268.4	530.4	703.7	964.3	1022.0
6/16/2000	3	43	46	134	55	189	117	8	125	145	43	188	82	45	127	64	18	82	212	1022	35.0%	82	209	397	522	711	757	110.7	282.2	536.0	704.7	959.9	1022.0
6/17/2000	3	82	85	128	81	209	109	8	117	134	40	174	82	50	132	64	18	82	279	1000	25.2%	82	214	388	505	714	799	102.6	267.8	485.6	632.0	893.6	1000.0
6/18/2000	3	72	75	128	41	169	105	8	113	114	0	114	82	50	132	64	18	82	189	963	40.6%	82	214	328	441	610	685	115.3	300.8	461.1	620.0	857.6	963.0
6/19/2000	0	55	55	128	45	173	109	8	117	105	56	161	69	42	111	55	18	73	224	945	37.0%	73	184	345	462	635	690	100.0	252.0	472.5	632.7	869.7	945.0
6/20/2000	0	41	41	111	59	170	108	8	116	99	82	181	69	50	119	55	26	81	266	926	30.8%	81	200	381	497	667	708	105.9	261.6	498.3	650.0	872.4	926.0
6/21/2000	0	12	12	111	58	169	103	8	111	99	83	182	69	50	119	65	26	91	237	908	32.7%	91	210	392	503	672	684	120.8	278.8	520.4	667.7	892.1	908.0
6/22/2000	0	22	22	111	31	142	108	8	116	110	80	190	72	50	122	65	16	81	207	908	34.9%	81	203	393	509	651	673	109.3	273.9	530.2	686.7	878.3	908.0
6/23/2000	0	51	51	111	57	168	108	8	116	139	58	197	77	45	122	65	16	81	235	926	26.0%	81	203	400	516	684	735	102.0	255.8	503.9	650.1	861.7	926.0

6/24/2000	0	0	0	134	10	144	110	0	110	146	45	191	77	45	122	65	6	71	106	889	39.3%	71	193	384	494	638	638	98.9	268.9	535.1	688.3	889.0	889.0
6/25/2000	0	26	26	144	1	145	111	0	111	156	36	192	81	45	126	65	16	81	124	926	36.0%	81	207	399	510	655	681	110.1	281.5	542.5	693.5	890.6	926.0
6/26/2000	0	60	60	164	86	250	116	0	116	164	47	211	111	45	156	71	16	87	254	1042	18.4%	87	243	454	570	820	880	103.0	287.7	537.6	674.9	971.0	1042.0
6/27/2000	3	60	63	164	78	242	124	0	124	203	33	236	116	45	161	70	16	86	232	1042	14.3%	86	247	483	607	849	912	98.3	282.2	551.8	693.5	970.0	1042.0
6/28/2000	3	27	30	164	37	201	129	0	129	231	19	250	130	25	155	73	10	83	118	1065	25.6%	83	238	488	617	818	848	104.2	298.9	612.9	774.9	1027.3	1065.0
6/29/2000	39	22	61	172	91	263	148	0	148	257	13	270	142	25	167	96	16	112	167	1160	13.6%	112	279	549	697	960	1021	127.2	317.0	623.7	791.9	1090.7	1160.0
6/30/2000	59	24	83	186	57	243	153	0	153	256	10	266	155	0	155	119	0	119	91	1186	16.4%	119	274	540	693	936	1019	138.5	318.9	628.5	806.6	1089.4	1186.0
7/1/2000	68	22	90	186	42	228	161	0	161	256	5	261	157	0	157	127	0	127	69	1216	18.8%	127	284	545	706	934	1024	150.8	337.3	647.2	838.4	1109.1	1216.0
7/2/2000	75	30	105	186	41	227	167	0	167	262	0	262	158	0	158	132.5	0	132.5	71	1250	18.9%	132.5	290.5	552.5	719.5	946.5	1051.5	157.5	345.3	656.8	855.3	1125.2	1250.0
7/3/2000	74	44	118	189	0	189	190	0	190	262	2	264	159	0	159	100	0	100	46	1280	25.5%	100	259	523	713	902	1020	125.5	325.0	656.3	894.7	1131.9	1280.0
7/4/2000	102	30	132	189	78	267	172	0	172	221	9	230	129	35	164	74	20	94	172	1280	20.9%	94	258	488	660	927	1059	113.6	311.8	589.8	797.7	1120.5	1280.0
7/5/2000	65	54	119	186	62	248	155	0	155	191	44	235	117	35	152	61	25	86	220	1250	25.6%	86	238	473	628	876	995	108.0	299.0	594.2	788.9	1100.5	1250.0
7/6/2000	67	66	133	186	18	204	144	0	144	158	41	199	86	0	86	61	0	61	125	1133	37.0%	61	147	346	490	694	827	83.6	201.4	474.0	671.3	950.8	1133.0
7/7/2000	28	33	61	186	30	216	126	15	141	121	72	193	82	35	117	58	25	83	210	1108	36.6%	83	200	393	534	750	811	113.4	273.2	536.9	729.6	1024.7	1108.0
7/8/2000	55	37	92	189	88	277	119	15	134	112	69	181	82	35	117	58	30	88	274	1108	24.6%	88	205	386	520	797	889	109.7	255.5	481.1	648.1	993.3	1108.0
7/9/2000	42	39	81	172	92	264	117	15	132	112	54	166	82	35	117	58	25	83	260	1085	28.7%	83	200	366	498	762	843	106.8	257.4	471.1	641.0	980.7	1085.0
7/10/2000	36	29	65	135	135	270	125	33	158	112	59	171	85	35	120	58	25	83	316	1065	22.8%	83	203	374	532	802	867	102.0	249.4	459.4	653.5	985.2	1065.0
7/11/2000	21	170	191	152	138	290	121	15	136	112	26	138	85	35	120	58	25	83	409	1065	11.2%	83	203	341	477	767	958	92.3	225.7	379.1	530.3	852.7	1065.0
7/12/2000	21	42	63	152	100	252	129	15	144	101	34	135	85	35	120	58	25	83	251	1000	25.5%	83	203	338	482	734	797	104.1	254.7	424.1	604.8	921.0	1000.0
7/13/2000	22	17	39	149	72	221	132	15	147	118	33	151	85	35	120	58	25	83	197	980	28.8%	83	203	354	501	722	761	106.9	261.4	455.9	645.2	929.8	980.0
7/14/2000	18	42	60	149	35	184	139	0	139	165	13	178	88	35	123	58	25	83	150	1042	35.9%	83	206	384	523	707	767	112.8	279.9	521.7	710.5	960.5	1042.0
7/15/2000	38	24	62	171	93	264	199	0	199	178	16	194	88	35	123	58	25	83	193	1133	22.5%	83	206	400	599	863	925	101.7	252.3	489.9	733.7	1057.1	1133.0
7/16/2000	41	23	64	174	74	248	224	0	224	198	0	198	88	30	118	67	25	92	152	1186	25.6%	92	210	408	632	880	944	115.6	263.8	512.6	794.0	1105.6	1186.0
7/17/2000	83	29	112	194	32	226	230	0	230	214	0	214	160	18	178	106	5	111	84	1280	19.5%	111	289	503	733	959	1071	132.7	345.4	601.2	876.0	1146.1	1280.0
7/18/2000	105	22	127	197	26	223	225	0	225	205	7	212	170	18	188	120	5	125	78	1310	19.1%	125	313	525	750	973	1100	148.9	372.8	625.2	893.2	1158.8	1310.0
7/19/2000	106	20	126	197	10	207	210	0	210	209	3	212	192	0	192	125	0	125	33	1310	22.2%	125	317	529	739	946	1072	152.8	387.4	646.4	903.1	1156.0	1310.0
7/20/2000	114	14	128	197	14	211	196	18	214	200	10	210	200	0	200	125	0	125	56	1280	17.6%	125	325	535	749	960	1088	147.1	382.4	629.4	881.2	1129.4	1280.0
7/21/2000	121	6	127	191	72	263	172	18	190	185	21	206	201	0	201	135	0	135	117	1310	16.8%	135	336	542	732	995	1122	157.6	392.3	632.8	854.7	1161.7	1310.0
7/22/2000	118	72	190	191	83	274	176	18	194	167	24	191	200	0	200	142	0	142	197	1310	10.0%	142	342	533	727	1001	1191	156.2	376.2	586.3	799.6	1101.0	1310.0
7/23/2000	104	76	180	174	111	285	150	18	168	156	25	181	200	0	200	149	0	149	230	1310	12.6%	149	349	530	698	983	1163	167.8	393.1	597.0	786.2	1107.2	1310.0
7/24/2000	86	98	184	174	60	234	161	18	179	176	29	205	220	0	220	149	0	149	205	1310	11.9%	149	369	574	753	987	1171	166.7	412.8	642.1	842.4	1104.2	1310.0
7/25/2000	92	66	158	194	46	240	195	0	195	192	29	221	209	0	209	154	0	154	141	1280	8.8%	154	363	584	779	1019	1177	167.5	394.8	635.1	847.2	1108.2	1280.0
7/26/2000	97	25	122	194	20	214	195	0	195	211	18.7	229.7	196	0	196	154	0	154	63.7	1280	15.2%	154	350	579.7	774.7	988.7	1110.7	177.5	403.3	668.1	892.8	1139.4	1280.0
7/27/2000	82	20	102	197	27	224	190	0	190	224	16	240	183	0	183	143	0	143	63	1250	15.5%	143	326	566	756	980	1082	165.2	376.6	653.9	873.4	1132.2	1250.0
7/28/2000	73	19	92	197	24	221	190	0	190	245	17	262	164	0	164	132	0	132	60	1280	20.6%	132	296	558	748	969	1061	159.2	357.1	673.2	902.4	1169.0	1280.0
7/29/2000	78	0	78	194	22	216	193	0	193	244	0	244	155	0	155	134	4	138	26	1280	25.0%	138	293	537	730	946	1024	172.5	366.3	671.3	912.5	1182.5	1280.0
7/30/2000	75	28	103	191	27	218	189	0	189	244	0	244	157	0	157	134	3	137	58	1280	22.1%	137	294	538	727	945	1048	167.3	359.1	657.1	887.9	1154.2	1280.0
7/31/2000	95	19	114	188.75	19	207.75	190	0	190	245	0	245	159	0	159	139.5	0	139.5	38	1280	21.3%	139.5	298.5	543.5	733.5	941.25	1055.3	169.2	362.1	659.3	889.7	1141.7	1280.0
8/1/2000	92	17	109	193.75	5	198.75	192	0	192	229	0	229	169	0	169	123	0	123	22	1280	25.4%	123	292	521	713	911.75	1020.8	154.2	366.2	653.3	894.1	1143.3	1280.0
8/2/2000	86	7	93	194	0	194	216	0.05	216.05	209	15	224	175	0	175	144.5	0	144.5	22.05	1310	25.2%	144.5	319.5	543.5	759.55	953.55	1046.6	180.9	399.9	680.3	950.8	1193.6	1310.0
8/3/2000	89	7	96	188	0	188	217	0.05	217.05	198	22	220	175	0	175	132	0	132	29.05	1280	24.5%	132	307	527	744.05	932.05	1028.1	164.3	382.2	656.2	926.4	1160.5	1280.0
8/4/2000	92	0	92	188	0	188	225	0	225	192	34	226	175	3	178	126.5	0	126.5	37	1280	23.6%	126.5	304.5	530.5	755.5	943.5	1035.5	156.4	376.4	655.8	933.9	1166.3	1280.0
8/5/2000	88	0	88	178	0	178	212	0	212	192	32	224	170	0	170	126	0	126	32	1280	28.3%	126	296	520	732	910	998	161.6	379.6	666.9	938.8	1167.1	1280.0
8/6/2000	78	34	112	178	14	192	198	10	208	189	44	233	160	0	160	138	0	138	102	1310	25.6%	138	298	531	739	931	1043	173.3	374.3	666.9	928.2	1169.3	1310.0
8/7/2000	80	32	112	184	35	219	200	24	224	190	62	252	163	0	163	152.5	0	152.5	153	1280	14.0%	152.5	315.5	567.5	791.5	1010.5	1122.5	173.9	359.8	647.1	902.6	1152.3	1280.0
8/8/2000	83	0	83	191	38	229	187	18	205	197	40	237	163	0	163	128.5	0	128.5	96	1280	22.4%	128.5	291.5	528.5	733.5	962.5	1045.5	157.3	356.9	647.0	898.0	1178.4	1280.0
8/9/2000	70	12	82	195	60	255	196	18	214	179	30	209	164	0	164	126	0	126	120	1280	21.9%	126	290	499	713	968	1050	153.6	353.5	608.3	869.2	1180.0	1280.0
8/10/2000	95	59	154	210	57	267	204	0	204	190	26	216	162	0	162	112	0	112	142	1250	12.1%	112	274	490	694	961	1115	125.6	307.2	549.3	778.0	1077.4	1250.0
8/11/2000	84	45	129	207	49	256	192	0	192	196	6	202	163	0	163	111	0	111	100	1280	21.6%	111	274	476	668	924	1053	134.9	333.1	578.6	812.0	1123.2	1280.0
8/12/2000	81	73	154	196	62	258	198	0	198	217	4	221	163	3	166	110	6	116	148	1310	17.7%	116	282	503	701	959	1113	136.5	331.9	592.0	825.1	1128.7	1310.0
8/13/2000	57	82	139	196	23	219	193	0	193	222	0	222	163	6.5	169.5	105	9	114	120.5	1250	18.3%	114	283.5	505.5	698.5	917.5	1056.5	134.9	335.4	598.1	826.4	1085.5	1250.0
8/14/2000	54	52	106	204	24	228	202	0	202	243	6	249	175	11	186	134	0	134	93	1250	13.1%	134	320	569	771	999	1105	151.6	362.0	643.7	872.2	1130.1	1250.0
8/15/2000	66	54	120	204	9	213	191	0	191	245	4	249	175	9	184	133.5	1	134.5	77	1250	14.5%	134.5	318.5	567.5	758.5	971.5	1091.5	154.0	364.8	649.9	868.6	1112.6	1250.0
8/16/2000	77	8	85	207	16	223	205	0	205	247	0	247	175	6	181	134	0	134	30	1280	19.1%	134	315	562	767	990	1075	159.6	375.1	669.2	913.3	1178.8	1280.0
8/17/2000	95	0	95	207	21	228	202	0	202	243	4	247	169	6	175	127.5	0	127.5	31	1310	21.9%	127.5	302.5	549.5	751.5	979.5	1074.5	155.4	368.8	669.9	916.2	1194.2	1310.0
8/18/2000	100	6	106	204	9	213	203	0	203	221	15	236	173	6	179	128.5	0	128.5	36	1280	20.1%	128.5	307.5	543.5	746.5	959.5	1065.5	154.4	369.4	652.9	896.8	1152.7	1280.0
8/19/2000	103	5	108	201	24	225	185	0	185	183	21	204	171	8	179	131	4	135	62	1280	23.6%	135	314	518	703	928	1036	166.8	388.0	640.0	868.6	1146.6	1280.0
8/20/2000	89	42	131	198	27	225	176	6	182	182	38	220	168	9	177	110	5	115	127	1280	21.9%	115	292	512	694	919	1050	140.2	356.0	624.2	846.0	1120.3	1280.0
8/21/2000	84	71	155	198	0	198	174	6	180	177	38	215	162	0	162	128	5	133	120	1216	16.6%	133	295	510	690	888	1043	155.1	343.9	594.6	804.4	1035.3	1216.0
8/22/2000	93	54	147	196	14	210	188	0	188	169	33	202	171	0	171	126	1.5	127.5	102.5	1216	16.3%	127.5	298.5	500.5	688.5	898.5	1045.5	148.3	347.2	582.1	800.8	1045.0	1216.0
8/23/2000	100	48	148	201	16	217	186	0	186	167	34	201	168	0	168	127	0	127	98	1216	16.1%	127	295	496	682	899	1047	147.5	342.6	576.1	792.1	1044.1	1216.0
8/24/2000	88	74	162	201	19	220	180	0	180	168	19	187	181	0	181	135	0	135	112	1216	14.2%	135	316	503	683	903	1065	154.1	360.8	574.3	779.8	1031.0	1216.0
8/25/2000	82	56	138	198	25	223	177	0	177	156	36	192	158	0	158	136.5	0	136.5	117	1186	15.8%	136.5	294.5	486.5	663.5	886.5	1024.5	158.0	340.9	563.2	768.1	1026.2	1186.0
8/26/2000	73	59	132	198	45	243	173	0	173	173	36	209	158	0	158	127.5	0	127.5	140	1216	16.6%	127.5	285.5	494.5	667.5	910.5	1042.5	148.7	333.0	576.8	778.6	1062.0	1216.0
8/27/2000	69	65	134	198	45	243	168	0	168	178	16	194	157	0	157	133.5	0	133.5	126	1216	18.1%	133.5	290.5	484.5	652.5	895.5	1029.5	157.7	343.1	572.3	770.7	1057.7	1216.0
8/28/2000	66	72	138	193	46	239	175	0	175	199	22	221	154	0	154	137.5	0	137.5	140	1186	11.4%	137.5	291.5	512.5	687.5	926.5	1064.5	153.2	324.8	571.0	766.0	1032.2	1186.0
8/29/2000	66	62	128	193	49	242	163	0	163	199	9	208	153	0	153	128	0	128	120	1216	19.0%	128	281	489	652	894	1022	152.3	334.3	581.8	775.8	1063.7	1216.0
8/30/2000	72	54	126	188	53	241	167	0	167	194	10	204	159	9	168	118	0	118	126	1186	15.8%	118	286	490	657	898	1024	136.7	331.2	567.5	760.9	1040.1	1186.0
8/31/2000	72	89	161	191	40	231	172	0	172	170	4	174	119	13	132	83.5	3	86.5	149	1133	18.5%	86.5	218.5	392.5	564.5	795.5	956.5	102.5	258.8	464.9	668.7	942.3	1133.0
9/1/2000	66	80	146	191	44	235	168	0	168	159	35	194	110	35	145	83.5	15	98.5	209	1160	17.6%	98.5	243.5	437.5	605.5	840.5	986.5	115.8	286.3	514.4	712.0	988.3	1160.0
9/2/2000	63	85	148	178	55	233	149	12	161	150	45	195	110	35	145	62	15	77	247	1160	21.0%	77	222	417	578	811	959	93.1	268.5	504.4	699.1	981.0	1160.0
9/3/2000	63	68	131	178	56	234	145	18	163	138	49	187	110	40	150	62	15	77	246	1160	23.1%	77	227	414	577	811	942	94.8	279.5	509.8	710.5	998.7	1160.0
9/4/2000	63	60	123	171	51	222	140	16	156	126	64	190	110	40	150	56	15	71	246	1133	24.2%	71	221	411	567	789	912	88.2	274.6	510.6	704.4	980.2	1133.0
9/5/2000	63	70	133	191	67	258	118	18	136	117	57	174	110	40	150	85	15	100	267	1133	19.1%	100	250	424	560	818	951	119.1	297.8	505.1	667.2	974.5	1133.0
9/6/2000	60	66	126	181	52	233	123	18	141	141	67	208	110	30	140	85	8	93	241	1133	20.4%	93	233	441	582	815	941	112.0	280.5	531.0	700.8	981.3	1133.0
9/7/2000	48	46	94	181	76	257	121	18	139	149	45	194	117	30	147	80.5	8	88.5	223	1108	20.5%	88.5	235.5	429.5	568.5	825.5	919.5	106.6	283.8	517.5	685.0	994.7	1108.0
9/8/2000	38	26	64	181	65	246	133	18	151	145	0	145	108	35	143	70.5	8	78.5	152	1000	20.8%	78.5	221.5	366.5	517.5	763.5	827.5	94.9	267.7	442.9	625.4	922.7	1000.0
9/9/2000	23	27	50	164	69	233	122	18	140	128	0	128	108	35	143	69.5	12	81.5	161	1000	28.9%	81.5	224.5	352.5	492.5	725.5	775.5	105.1	289.5	454.5	635.1	935.5	1000.0
9/10/2000	20	30	50	164	55	219	108	18	126	104	0	104	108	35	143	77.5	12	89.5	150	963	31.6%	89.5	232.5	336.5	462.5	681.5	731.5	117.8	306.1	443.0	608.9	897.2	963.0

9/11/2000	26	35	61	167	77	244	85	18	103	121	52	173	76	35	111	64	12	76	229	**963**	**25.4%**	76	187	360	463	707	768	**95.3**	**234.5**	**451.4**	**580.6**	**886.5**	**963.0**
9/12/2000	26	64	90	167	60	227	86	18	104	128	127	255	73	25	98	67.5	22	89.5	316	**986**	**14.2%**	89.5	187.5	442.5	546.5	773.5	863.5	**102.2**	**214.1**	**505.3**	**624.0**	**883.2**	**986.0**
9/13/2000	21	54	75	130	46	176	83	18	101	126	119	245	73	25	98	58	22	80	284	**926**	**19.5%**	80	178	423	524	700	775	**95.6**	**212.7**	**505.4**	**626.1**	**836.4**	**926.0**
9/14/2000	24	55	79	115	53	168	80	20	100	116	123	239	70	30	100	51	22	73	303	**926**	**22.0%**	73	173	412	512	680	759	**89.1**	**211.1**	**502.7**	**624.7**	**829.6**	**926.0**
9/15/2000	12	44	56	115	97	212	82	18	100	104	123	227	70	4	74	55.5	22	77.5	308	**926**	**24.0%**	77.5	151.5	378.5	478.5	690.5	746.5	**96.1**	**187.9**	**469.5**	**593.6**	**856.5**	**926.0**
9/16/2000	12	55	67	112	69	181	83	18	101	80	124	204	70	40	110	40.5	26	66.5	332	**889**	**21.9%**	66.5	176.5	380.5	481.5	662.5	729.5	**81.0**	**215.1**	**463.7**	**586.8**	**807.4**	**889.0**
9/17/2000	9	53	62	85	80	165	84	18	102	74	113	187	70	35	105	40.5	22	62.5	321	**855**	**25.1%**	62.5	167.5	354.5	456.5	621.5	683.5	**78.2**	**209.5**	**443.4**	**571.0**	**777.4**	**855.0**
9/18/2000	6	17	23	63	70	133	84	18	102	75	122	197	70	35	105	40.5	22	62.5	284	**818**	**31.4%**	62.5	167.5	364.5	466.5	599.5	622.5	**82.1**	**220.1**	**479.0**	**613.0**	**787.8**	**818.0**
9/19/2000	0	40	40	33	60	93	78	18	96	58	113	171	68	35	103	34.5	22	56.5	288	**818**	**46.2%**	56.5	159.5	330.5	426.5	519.5	559.5	**82.6**	**233.2**	**483.2**	**623.6**	**759.5**	**818.0**
9/20/2000	0	41	41	3	60	63	71	18	89	43	123	166	68	35	103	34	22	56	299	**784**	**51.4%**	56	159	325	414	477	518	**84.8**	**240.6**	**491.9**	**626.6**	**721.9**	**784.0**
9/21/2000	0	60	60	3	60	63	62	18	80	40	128	168	68	35	103	53	22	75	323	**755**	**37.5%**	75	178	346	426	489	549	**103.1**	**244.8**	**475.8**	**585.8**	**672.5**	**755.0**
9/22/2000	0	5	5	0	30	30	58	18	76	40	126	166	68	35	103	53	8	61	222	**707**	**60.3%**	61	164	330	406	436	441	**97.8**	**262.9**	**529.0**	**650.9**	**699.0**	**707.0**
9/23/2000	0	5	5	0	30	30	56	18	74	30	133	163	68	35	103	53	10	63	231	**707**	**61.4%**	63	166	329	403	433	438	**101.7**	**267.9**	**531.1**	**650.5**	**698.9**	**707.0**
9/24/2000	0	5	5	0	30	30	55	18	73	30	132	162	68	35	103	53	10	63	230	**722**	**65.6%**	63	166	328	401	431	436	**104.3**	**274.9**	**543.2**	**664.0**	**713.7**	**722.0**
9/25/2000	0	10	10	0	30	30	57	12	69	30	139	169	68	35	103	53	10	63	236	**707**	**59.2%**	63	166	335	404	434	444	**100.3**	**264.3**	**533.4**	**643.3**	**691.1**	**707.0**
9/26/2000	0	10	10	0	30	30	44	0	44	30	100	130	60	35	95	44	10	54	185	**645**	**77.7%**	54	149	279	323	353	363	**96.0**	**264.8**	**495.7**	**573.9**	**627.2**	**645.0**
9/27/2000	0	20	20	0	30	30	39	10	49	30	62	92	40	35	75	44	10	54	167	**570**	**78.1%**	54	129	221	270	300	320	**96.2**	**229.8**	**393.7**	**480.9**	**534.4**	**570.0**
9/28/2000	0	20	20	0	30	30	21	0	21	10	48	58	4	35	39	43	10	53	143	**495**	**100.0%**	53	92	150	171	201	221	**106.0**	**184.0**	**300.0**	**342.0**	**402.0**	**442.0**
9/29/2000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0.0%**	0	0	0	0	0	0	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

Average Seepage & Evaporation Loss: 23.3%

Avg Seepage Evaporation Loss:

23.3% **n Loss*:**

* Excluding system loading (not shown) and system shutdown (9/18 to 9/29)

5.00	days when loss is less than 10%
19.00	days when loss is less than 15%
54.00	days when loss is less than 20%

5.00	days when loss is less than 10%
19.00	days when loss is less than 15%
54.00	days when loss is less than 20%

Notes: It is important to realize that canal conservation measures can only reduce maximum flow diverted by the smallest amount lost during the highest water demands. An irrigation system must be designed to accommodate flows that will support the maximum crop demand, not just the average use. It is important to NOT use averages in this analysis, but to utilize the losses that exist during times of peak demand, which show how efficient the system is during times of peak consumptive use

A review of each of these years of Main Canal flows show that the losses during times of peak consumptive use are very low. For example in 2000 the year the Main Canal has it highest 25.6% average seepage loss of both years analyzed; But, only lost 8.8% on July 25th of 2000 during a week of peak demand high flows and low seepage and evaporation losses On July 25th perfect conservation measures would only save 8.8% of the diverted water while the crops would still need practically the full water right.

Operational spills are flows diverted into the LYIP system that are not delivered to the farm. It is necessary to divert excess water to the main canal or lateral to act as a buffer necessary to allow for normal water deliveries and the elevations needed for water deliveries to elevated fields. Operational spills are either returned to the LYIP Main Canal to be utilized for irrigation or to the LYIP drainages where they support wildlife habitat and then discharge back to the Yellowstone River. Operational spills are utilized in most gravity irrigation systems to manage downstream irrigation demand. This contingency water is needed to provide a buffer for water level fluctuations caused by significantly varying losses due to high day-time temperatures, winds, and water quality variances and to cover future deliveries, delivery adjustments, unauthorized deliveries, and to cover shrinkage due to large loss variances. If enough water is not kept in the LYIP system to cover downstream demands and varying water losses, water shortages are certain to occur. Constant buffered water flow and minimum water elevations must be maintained to each individual farm or the siphons and/or pump irrigation systems will stop drawing water from the laterals or private farm ditches. When these systems stop drawing water, suddenly there is not enough room in the progressively smaller canals, laterals, pipe lines or private farm ditches to carry the sudden gain in water (because it is no longer taken out at the farms or siphon tubes) and this blows out the tops of the canals and causes dangerous large scale public flooding. Without operational spills, a constant water flow and minimum water elevations are NOT possible to achieve. In addition, The LYIP consists of over 72 miles of main canal and 220 miles of laterals. A call on water to the downstream end of the system would take over a week to get water from the diversion to the downstream portion of the system if operational spills were not in place. This timing could result in serious and irrepairable damage to crops that would have a devastating financial impact to the farmers.

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LYIP 2012 MC Water Loss Data Calculations.xlsx

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	Div 1	MC Spill	Div 1 total	Div 2	MC Spill	Div 2 total	Div 3	MC Spill	Div 3 Total	D4	MC Spill	Div 4 Total	D5	MC Spill	Div 5 Total	D6	MC Spill	Div 6 Total	MC Spill Sum	Lat Div & MC spill Total	Willet Bridge Reading	Willot CFS	Seep Evap
																			Operation Spill Total				
4/20/2012	0	80	80	0	260	260	0	0	0	0	0	0	0	0	0	0	0	0	340	340	8.56	815	139.7%
4/21/2012	0	80	80	0	260	260	0	0	0	0	0	0	0	0	0	0	0	0	340	340	8.56	815	139.7%
4/22/2012	0	80	80	77	180	257	0	0	0	0	169	169	103	0	103	0	0	0	429	609	8.54	812	33.3%
4/23/2012	0	80	80	77	125	202	0	0	0	0	152	152	72	46	118	94	0	94	403	646	8.54	812	25.7%
4/24/2012	13	114	127	99	70	169	0	0	0	0	127	127	103	9	112	119	4	123	324	658	8.64	825	25.4%
4/25/2012	13	40	53	77	207	284	0	0	0	57	58	115	153	9	162	149	0	149	314	763	9.34	950	24.5%
4/26/2012	20	42	62	77	150	227	72.3	0	72.3	1.25	0	1.25	183	0	183	153	0	153	192	698.55	9.34	950	36.0%
4/27/2012	38	43	81	0	100	100	59	0	59	34	53	87	205	6	211	158	9	167	211	705	9.62	1002	42.1%
4/28/2012	35	92	127	77	124	201	31.5	0	31.5	64	0	64	208	20	228	158	8	166	244	817.5	9.84	1050	28.4%
4/29/2012	26	149	175	77	142	219	0	0	0	64	109	173	196	12	208	132	11	143	423	918	10	1085	18.2%
4/30/2012	26	102	128	0	152	152	22.16	0	22.16	79.5	92	171.5	196	24	220	132	16	148	386	841.66	9.82	1042	23.8%
5/1/2012	26	136	162	0	105	105	63	0	63	102	90	192	196	27	223	132	16	148	374	893	9.94	1075	20.4%
5/2/2012	12	163	175	0	55	55	58	0	58	104	90	194	211	23	234	146	2	148	333	864	9.76	1035	19.8%
5/3/2012	12	86	98	0	85	85	102	0	102	79.6	82	161.6	237	18	255	143	7	150	278	851.6	9.74	1030	20.9%
5/4/2012	12	67	79	0	87	87	101	24	125	92.9	70.4	163.3	235	17	252	147	12	159	277.4	865.3	9.66	1011	16.8%
5/5/2012	12	43	55	0	79	79	101	24	125	109	56	165	235	17	252	139	13	152	232	828	9.62	1005	21.4%
5/6/2012	9	34	43	77	81	158	101	24	125	109	53	162	230	12	242	139	13	152	217	882	9.6	1000	13.4%
5/7/2012	9	22	31	78.9	89	167.9	101	48	149	95	50	145	225	9	234	138	11	149	229	875.9	9.54	990	13.0%
5/8/2012	0	12	12	86.9	86	172.9	84.3	30	114.3	109.8	57	166.8	221	16	237	120	12	132	213	835	9.54	990	18.6%
5/9/2012	4	66	70	86.9	83	169.9	94	42	136	120	62	182	218	14	232	95	16	111	283	900.9	9.68	1022	13.4%
5/10/2012	7	62	69	86.5	97	183.5	77.5	42	119.5	118.4	35	153.4	208	20	228	113	14	127	270	880.4	9.68	1022	16.1%
5/11/2012	7	40	47	86.9	95	181.9	79	42	121	115	69	184	194	11	205	109	19	128	276	866.9	9.64	1011	16.6%
5/12/2012	3	22	25	96.9	88	184.9	79	42	121	117	63	180	187	12	199	109	15	124	242	833.9	9.54	990	18.7%
5/13/2012	0	14	14	96	88	184	79	42	121	127	59	186	174	15	189	109	11	120	229	814	9.52	985	21.0%
5/14/2012	0	43	43	129.9	89	218.9	77.6	42	119.6	123	92	215	163	29	192	116	16	132	311	920.5	9.66	1011	9.8%
5/15/2012	0	56	56	119.9	90	209.9	84.7	42	126.7	130	84	214	163	18	181	117	14	131	304	918.6	9.8	1042	13.4%
5/16/2012	6	29	35	119.5	88	207.5	125	42	167	137	57	194	164	14	178	119	12	131	242	912.5	9.7	1022	12.0%
5/17/2012	23	27	50	119	69	188	131.6	20	151.6	146	26	172	168	16	184	112	14	126	172	871.6	9.66	1011	16.0%
5/18/2012	28	45	73	119.9	64	183.9	160.3	20	180.3	157	41	198	178	15	193	106	14	120	199	948.2	9.94	1075	13.4%
5/19/2012	29	84	113	119.2	61	180.2	168.6	0	168.6	155	48.4	203.4	180	18	198	106	16	122	227.4	985.2	10.18	1133	15.0%
5/20/2012	29	163	192	119.9	74	193.9	168.5	20	188.5	164	42.9	206.9	183	9	192	121	11	132	319.9	1105.3	10.3	1160	4.9%
5/21/2012	29	10	39	130.5	25	155.5	168.1	0	168.1	200	20.5	220.5	200	14	214	108	12	120	81.5	917.1	9.88	1060	15.6%
5/22/2012	23	143	166	145	8	153	174	0	174	122	43.6	165.6	220	14	234	137	14	151	222.6	1043.6	10.36	1170	12.1%
5/23/2012	21	48	69	145	51	196	207	0	207	152	16.5	168.5	239	8	247	138	10	148	133.5	1035.5	10.28	1160	12.0%
5/24/2012	13	21	34	145	50	195	196.3	0	196.3	195	1.8	196.8	248	4	252	148	8	156	84.8	1030.1	10.24	1140	10.7%
5/25/2012	32	57	89	145.04	43	188.04	207.9	0	207.9	191	1	192	236	4	240	139	6	145	111	1061.94	10.36	1170	10.2%
5/26/2012	32	76	108	148	49	197	198.5	0	198.5	173	31	204	233	6	239	136	8	144	170	1090.5	10.52	1220	11.9%
5/27/2012	32	85	117	145	86	231	166.9	42	208.9	139	34	173	220	8	228	104	16	120	271	1077.9	10.38	1180	9.5%
5/28/2012	25	81	106	145	171	316	153	42	195	129	29	158	196	17	213	94	10	104	350	1092	10.42	1190	9.0%
5/29/2012	25	62	87	125	184	309	140.8	39	179.8	119	42.2	161.2	195	28	223	81	12	93	367.2	1053	10.36	1170	11.1%
5/30/2012	25	130	155	108	169	277	129.5	39	168.5	94	37	131	182	44	226	87	12	99	431	1056.5	10.34	1168	10.6%
5/31/2012	24	123	147	102	202	304	129	30	159	83	55	138	174	57	231	88	14	102	481	1081	10.18	1130	4.5%
6/1/2012	24	15	39	102	215	317	116	30	146	85	64.9	149.9	176	59	235	88	13	101	396.9	987.9	10.02	1085	9.8%
6/2/2012	24	52.4	76.4	102	120	222	116	30	146	89	60.5	149.5	176	51	227	95	18	113	331.9	933.9	9.9	1065	14.0%
6/3/2012	24	58.1	82.1	102	121.8	223.8	116	30	146	89	78.1	167.1	185	33	218	102	14	116	335	953	9.96	1085	13.9%
6/4/2012	27	58	85	102	190	292	120.7	30	150.7	80	78.5	158.5	185	36	221	138	6	144	398.5	1051.2	10	1085	3.2%
6/5/2012	31	97	128	102	150	252	104.9	30	134.9	110	66	176	189	13	202	153	5	158	361	1050.9	10	1085	3.2%
6/6/2012	39	82	121	102	129	231	108.3	0	108.3	150	2.42	152.42	192	5	197	178	2	180	220.42	989.72	9.96	1085	9.6%
6/7/2012	39	49	88	102	85	187	135	0	135	178	37	215	189	4	193	183	2	185	177	1003	9.84	1050	4.7%
6/8/2012	43	133	176	112	38	150	150.2	0	150.2	189	28.6	217.6	191	3	194	187	4	191	206.6	1078.8	10.44	1190	10.3%
6/9/2012	41	83	124	114.2	20	134.2	150.2	0	150.2	218	30	248	191	6	197	185	11	196	150	1049.4	10.06	1100	4.8%
6/10/2012	41	6	47	132	59	191	150.3	0	150.3	233	41	274	189	7	196	168	14	182	127	1040.3	10	1085	4.3%
6/11/2012	42.4	92	134.4	152	67	219	154.3	0	154.3	220	32.6	252.6	189	8	197	161	4	165	203.6	1122.3	10.32	1162	3.5%
6/12/2012	42	93	135	152	27	179	165.2	18	183.2	223	49.1	272.1	192	10	202	144	4	148	201.1	1119.3	10.36	1175	5.0%
6/13/2012	44	81	125	152	30	182	177.5	4	181.5	228	20.5	248.5	194	9	203	137	6	143	150.5	1083	10.32	1165	7.6%
6/14/2012	44	45	89	185	26	211	177.4	4	181.4	231	4	235	194	12	206	134	14	148	105	1070.4	10.2	1133	5.8%
6/15/2012	64	0	64	192	21	213	181.4	0	181.4	217	11.7	228.7	182	12	194	119	21	140	65.7	1021.1	10.42	1190	16.5%
6/16/2012	56	44	100	186	36	222	176.6	0	176.6	210	17.6	227.6	184	12	196	98	20	118	129.6	1040.2	10.56	1225	17.8%
6/17/2012	56	68	124	186	41	227	167.8	0	167.8	220	22.7	242.7	180	17	197	87	20	107	168.7	1065.5	10.6	1250	17.3%
6/18/2012	60	66	126	186	41	227	170.8	18	188.8	180	30.8	210.8	193	17	210	98	25	123	197.8	1085.6	10.6	1250	15.1%
6/19/2012	45	51	96	186	45	231	170.8	18	188.8	167	44.4	211.4	193	18	211	80	21	101	197.4	1039.2	10.58	1245	19.8%
6/20/2012	47	54	101	186	54	240	178.5	36	214.5	167	49.9	216.9	177	20	197	90	18	108	231.9	1077.4	10.62	1255	16.5%
6/21/2012	48	62	110	189	77	266	175.6	36	211.6	155	59.8	214.8	176	24	200	90	19	109	277.8	1111.4	10.62	1255	12.9%
6/22/2012	48	48	96	189	98	287	186.7	36	222.7	158	45.8	203.8	176	24	200	91	46	137	297.8	1146.5	10.58	1245	8.6%
6/23/2012	26	45	71	180	97	277	201.3	36	237.3	178	37.8	215.8	176	29	205	91	36	127	280.8	1133.1	10.56	1225	8.1%
6/24/2012	22	56	78	186	113	299	201.3	36	237.3	177	15.7	192.7	176	26	202	89	22	111	268.7	1120	10.62	1255	12.1%
6/25/2012	22	53	75	186	89	275	202	36	238	171	48.4	219.4	167	39	206	80	17	97	282.4	1110.4	10.62	1255	13.0%
6/26/2012	52	70	122	169	89	258	206.4	36	242.4	179	53.2	232.2	169	49	218	69	25	94	322.2	1166.6	10.6	1250	7.1%
6/27/2012	58	45	103	169	80	249	233.8	18	251.8	182	58.3	240.3	169	43	212	50	39	89	283.3	1145.1	10.6	1250	9.2%
6/28/2012	0	0	0	0	0	0	0	56.5	56.5	0	0	0	182	0	182	0	0	0	56.5	238.5	0	ø	
6/29/2012	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.72	675	
6/30/2012	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8.8	855	
7/1/2012	0	75.3	75.3	0	17.5	17.5	0	0	0	0	37.8	37.8	0	0	0	0	0	0	130.6	130.6	8.88	868	

	Div 6	Div 5	Div 4	Div 3	Div 2	Div 1	O Check	Hay Creek	Lone Tree	Struckman Gauge	SID Pumps	Headgates
	CFS Intentional diverted or spilled						CFS Passing Main Canal Structures					
4/20/2012	0	0	0	0	260	340	0	0	0	0	623	815
4/21/2012	0	0	0	0	260	340	0	0	0	0	623	815
4/22/2012	0	103	272	272	529	609	0	137	363	363	705	812
4/23/2012	94	212	364	364	566	646	118	266	458	458	711	812
4/24/2012	123	235	362	362	531	658	154	295	454	454	666	825
4/25/2012	149	311	426	426	710	763	186	387	530	530	884	950
4/26/2012	153	336	337.25	409.55	636.55	698.55	208	457	459	557	866	950
4/27/2012	167	378	465	524	624	705	237	537	661	745	887	1002
4/28/2012	166	394	458	489.5	690.5	817.5	213	506	588	629	887	1050
4/29/2012	143	351	524	524	743	918	169	415	619	619	878	1085
4/30/2012	148	368	539.5	561.66	713.66	841.66	183	456	668	695	884	1042
5/1/2012	148	371	563	626	731	893	178	447	678	754	880	1075
5/2/2012	148	382	576	634	689	864	177	458	690	759	825	1035
5/3/2012	150	405	566.6	668.6	753.6	851.6	181	490	685	809	911	1030
5/4/2012	159	411	574.3	699.3	786.3	865.3	186	480	671	817	919	1011
5/5/2012	152	404	569	694	773	828	184	490	691	842	938	1005
5/6/2012	152	394	556	681	839	882	172	447	630	772	951	1000
5/7/2012	149	383	528	677	844.9	875.9	168	433	597	765	955	990
5/8/2012	132	369	535.8	650.1	823	835	157	437	635	771	976	990
5/9/2012	111	343	525	661	830.9	900.9	126	389	596	750	943	1022
5/10/2012	127	355	508.4	627.9	811.4	880.4	147	412	590	729	942	1022
5/11/2012	128	333	517	638	819.9	866.9	149	388	603	744	956	1011
5/12/2012	124	323	503	624	808.9	833.9	147	383	597	741	960	990
5/13/2012	120	309	495	616	800	814	145	374	599	745	968	985
5/14/2012	132	324	539	658.6	877.5	920.5	145	356	592	723	964	1011
5/15/2012	131	312	526	652.7	862.6	918.6	149	354	597	740	978	1042
5/16/2012	131	309	503	670	877.5	912.5	147	346	563	750	983	1022
5/17/2012	126	310	482	633.6	821.6	871.6	146	360	559	735	953	1011
5/18/2012	120	313	511	691.3	875.2	948.2	136	355	579	784	992	1075
5/19/2012	122	320	523.4	692	872.2	985.2	140	368	602	796	1003	1133
5/20/2012	132	324	530.9	719.4	913.3	1105.3	139	340	557	755	958	1160
5/21/2012	120	334	554.5	722.6	878.1	917.1	139	386	641	835	1015	1060
5/22/2012	151	385	550.6	724.6	877.6	1043.6	169	432	617	812	984	1170
5/23/2012	148	395	563.5	770.5	966.5	1035.5	166	442	631	863	1083	1160
5/24/2012	156	408	604.8	801.1	996.1	1030.1	173	452	669	887	1102	1140
5/25/2012	145	385	577	784.9	972.94	1061.9	160	424	636	865	1072	1170
5/26/2012	144	383	587	785.5	982.5	1090.5	161	428	657	879	1099	1220
5/27/2012	120	348	521	729.9	960.9	1077.9	131	381	570	799	1052	1180
5/28/2012	104	317	475	670	986	1092	113	345	518	730	1074	1190
5/29/2012	93	316	477.2	657	966	1053	103	351	530	730	1073	1170
5/30/2012	99	325	456	624.5	901.5	1056.5	109	359	504	690	997	1168
5/31/2012	102	333	471	630	934	1081	107	348	492	659	976	1130
6/1/2012	101	336	485.9	631.9	948.9	987.9	111	369	534	694	1042	1085
6/2/2012	113	340	489.5	635.5	857.5	933.9	129	388	558	725	978	1065
6/3/2012	116	334	501.1	647.1	870.9	953	132	380	571	737	992	1085
6/4/2012	144	365	523.5	674.2	966.2	1051.2	149	377	540	696	997	1085
6/5/2012	158	360	536	670.9	922.9	1050.9	163	372	553	693	953	1085
6/6/2012	180	377	529.42	637.72	868.72	989.72	197	413	580	699	952	1085
6/7/2012	185	378	593	728	915	1003	194	396	621	762	958	1050
6/8/2012	191	385	602.6	752.8	902.8	1078.8	211	425	665	830	996	1190
6/9/2012	196	393	641	791.2	925.4	1049.4	205	412	672	829	970	1100
6/10/2012	182	378	652	802.3	993.3	1040.3	190	394	680	837	1036	1085
6/11/2012	165	362	614.6	768.9	987.9	1122.3	171	375	636	796	1023	1162
6/12/2012	148	350	622.1	805.3	984.3	1119.3	155	367	653	845	1033	1175
6/13/2012	143	346	594.5	776	958	1083	154	372	640	835	1031	1165
6/14/2012	148	354	589	770.4	981.4	1070.4	157	375	623	815	1039	1133
6/15/2012	140	334	562.7	744.1	957.1	1021.1	163	389	656	867	1115	1190
6/16/2012	118	314	541.6	718.2	940.2	1040.2	139	370	638	846	1107	1225
6/17/2012	107	304	546.7	714.5	941.5	1065.5	126	357	641	838	1105	1250
6/18/2012	123	333	543.8	732.6	959.6	1085.6	142	383	626	844	1105	1250
6/19/2012	101	312	523.4	712.2	943.2	1039.2	121	374	627	853	1130	1245
6/20/2012	108	305	521.9	736.4	976.4	1077.4	126	355	608	858	1137	1255
6/21/2012	109	309	523.8	735.4	1001.4	1111.4	123	349	591	830	1131	1255
6/22/2012	137	337	540.8	763.5	1050.5	1146.5	149	366	587	829	1141	1245
6/23/2012	127	332	547.8	785.1	1062.1	1133.1	137	359	592	849	1148	1225
6/24/2012	111	313	505.7	743	1042	1120	124	351	567	833	1168	1255
6/25/2012	97	303	522.4	760.4	1035.4	1110.4	110	342	590	859	1170	1255
6/26/2012	94	312	544.2	786.6	1044.6	1166.6	101	334	583	843	1119	1250
6/27/2012	89	301	541.3	793.1	1042.1	1145.1	97	329	591	866	1138	1250
6/28/2012	0	182	182	238.5	238.5	238.5	0	182	182	239	239	239
6/29/2012	0	0	0	0	0	0	0	0	0	0	0	0
6/30/2012	0	0	0	0	0	0	0	0	0	0	0	0
7/1/2012	0	0	37.8	37.8	55.3	130.6	0	0	38	38	55	131

7/2/2012	34.5	116.3	150.8	182	66.7	248.7	110	0	110	203	1.2	204.2	0	0	0	0	0	0	184.2	713.7	9.85	1050	47.1%	0	0	204.2	314.2	562.9	713.7	0	0	300	462	828	1050
7/3/2012	70	0	70	202	0	202	169.2	0	169.2	249	60.5	309.5	148	0	148	106	0	106	60.5	1004.7	10.24	1140	13.5%	106	254	563.5	732.7	934.7	1004.7	120	288	639	831	1061	1140
7/4/2012	96	0	96	218	0	218	169.2	0	169.2	293	8.1	301.1	190	0	190	119	4	123	12.1	1097.3	10.6	1250	13.9%	123	313	614.1	783.3	1001.3	1097.3	140	357	700	892	1141	1250
7/5/2012	100	4	104	226	45	271	183.4	0	183.4	222	9.9	231.9	216	0	216	124	4	128	62.9	1134.3	10.92	1355	19.5%	128	344	575.9	759.3	1030.3	1134.3	153	411	688	907	1231	1355
7/6/2012	97	0	97	226.3	0	226.3	183.4	0	183.4	200	17.9	217.9	242	0	242	127	2	129	19.9	1095.6	10.92	1355	23.7%	129	371	588.9	772.3	998.6	1095.6	160	459	728	955	1235	1355
7/7/2012	77	4	81	220.2	45	265.2	183.5	0	183.5	184	29.3	213.3	255	0	255	132	0	132	78.3	1130	10.86	1340	18.6%	132	387	600.3	783.8	1049	1130	157	459	712	929	1244	1340
7/8/2012	77	20	97	180.8	44	224.8	180.4	0	180.4	167	47.7	214.7	252	0	252	131	3	134	114.7	1102.9	10.86	1340	21.5%	134	386	600.7	781.1	1005.9	1102.9	163	469	730	949	1222	1340
7/9/2012	58	34	92	189	51	240	174.5	0	174.5	167	56.1	223.1	280	0	280	141	1	142	142.1	1151.6	10.86	1340	16.4%	142	422	645.1	819.6	1059.6	1151.6	165	491	751	954	1233	1340
7/10/2012	76	35	111	192.5	45	237.5	173.9	0	173.9	169	55.7	224.7	273	0	273	155	4	159	139.7	1179.1	10.88	1345	14.1%	159	432	656.7	830.6	1068.1	1179.1	181	493	749	947	1218	1345
7/11/2012	60	35	95	186.4	127	313.4	162	0	162	129	64	193	260	0	260	137	1	138	73	1161.4	10.92	1356	16.8%	138	398	591	753	1066.4	1161.4	161	465	690	879	1245	1356
7/12/2012	63	58	121	192.5	73	265.5	186.9	30	216.9	177	57.8	234.8	247	9	256	157	11	168	238.8	1262.2	10.88	1345	6.6%	168	424	658.8	875.7	1141.2	1262.2	179	452	702	933	1216	1345
7/13/2012	49	59	108	192.5	51	243.5	198	30	228	151	47.7	198.7	232	12	244	143	10	153	209.7	1175.2	10.88	1345	14.4%	153	397	595.7	823.7	1067.2	1175.2	175	454	682	943	1221	1345
7/14/2012	49	59	108	189.9	49	238.9	198	30	228	163	48.4	211.4	216	13	229	137	14	151	213.4	1166.3	10.88	1345	15.3%	151	380	591.4	819.4	1058.3	1166.3	174	438	682	945	1220	1345
7/15/2012	53	59	112	189	56	245	194.1	30	224.1	163	52	215	216	14	230	127	30	157	241	1183.1	10.9	1350	14.1%	157	387	602	826.1	1071.1	1183.1	179	442	687	943	1222	1350
7/16/2012	60	57	117	206.4	50	256.4	186	48	234	165	56.5	221.5	195	26	221	126	19	145	256.5	1194.9	10.9	1350	13.0%	145	366	587.5	821.5	1077.9	1194.9	164	414	664	928	1218	1350
7/17/2012	58	51	109	200.9	67	267.9	186	15	201	154	49.9	203.9	197	20	217	104	18	122	220.9	1120.8	10.84	1338	19.4%	122	339	542.9	743.9	1011.8	1120.8	146	405	648	888	1208	1338
7/18/2012	66	56	122	203.9	77	280.9	186	18	204	143	53	196	195	28	223	95	48	143	280	1168.9	10.9	1350	15.5%	143	366	562	766	1046.9	1168.9	165	423	649	885	1209	1350
7/19/2012	73	55	128	203.9	92	295.9	180	30	210	139	53.2	192.2	188	36	224	87	32	119	298.2	1169.1	10.92	1355	15.9%	119	343	535.2	745.2	1041.1	1169.1	138	398	620	864	1207	1355
7/20/2012	67	77	144	203.9	151	354.9	170	30	200	128	45.8	173.8	188	49	237	89	35	124	387.8	1233.7	10.92	1355	9.8%	124	361	534.8	734.8	1089.7	1233.7	136	396	587	807	1197	1355
7/21/2012	62	96	158	170.9	83	253.9	164	30	194	131	51.7	182.7	188	55	243	69	19	88	334.7	1119.6	10.76	1300	16.1%	88	331	513.7	707.7	961.6	1119.6	102	384	596	822	1117	1300
7/22/2012	65	91	156	170.9	93	263.9	164	30	194	133	59.8	192.8	188	55	243	63	43	106	371.8	1155.7	10.74	1295	12.1%	106	349	541.8	735.8	999.7	1155.7	119	391	607	824	1120	1295
7/23/2012	80	89	169	159.18	71	230.18	133	30	163	162	45.1	207.1	188	0	188	71	30	101	265.1	1058.28	10.52	1220	15.3%	101	289	496.1	659.1	889.28	1058.3	116	333	572	760	1025	1220
7/24/2012	73	71	144	159	83	242	139.9	6	145.9	160	42.2	202.2	204	0	204	75	76	151	278.2	1089.1	10.6	1250	14.8%	151	355	557.2	703.1	945.1	1089.1	173	407	640	807	1085	1250
7/25/2012	72	59	131	159	78	237	139	12	151	161	46.6	207.6	196	0	196	74	79	153	274.6	1075.6	10.5	1216	13.1%	153	349	556.6	707.6	944.6	1075.6	173	395	629	800	1068	1216
7/26/2012	69	61	130	159.1	81	240.1	130.6	6	136.6	162	52.4	214.4	196	0	196	73	70	143	270.4	1060.1	10.52	1220	15.1%	143	339	553.4	690	930.1	1060.1	165	390	637	794	1070	1220
7/27/2012	70	67	137	159.8	81	240.8	136.4	6	142.4	177	46.6	223.6	207	0	207	68	88	156	288.6	1106.8	10.5	1216	9.9%	156	363	586.6	729	969.8	1106.8	171	399	644	801	1065	1216
7/28/2012	58	72	130	163.2	79	242.2	136.3	12	148.3	151	23.4	174.4	211	0	211	67	78	145	264.4	1050.9	10.52	1220	16.1%	145	356	530.4	678.7	920.9	1050.9	168	413	616	788	1069	1220
7/29/2012	42	68	110	183.8	34	217.8	141.3	18	159.3	145	35.5	180.5	215	46	261	63	35	98	236.5	1026.6	10.46	1200	16.9%	98	359	539.5	698.8	916.6	1026.6	115	420	631	817	1071	1200
7/30/2012	62	15	77	206.2	62	268.2	164.1	18	182.1	148	53.9	201.9	215	28	243	94	21	115	197.9	1087.2	10.5	1216	11.8%	115	358	559.9	742	1010.2	1087.2	129	400	626	830	1130	1216
7/31/2012	68	14	82	206.1	37	243.1	171.7	0	171.7	159	27.5	186.5	224	21	245	104	22	126	121.5	1054.3	10.66	1270	20.5%	126	371	557.5	729.2	972.3	1054.3	152	447	672	878	1171	1270
8/1/2012	69	23	92	206.1	34	240.1	169	0	169	151	59.8	210.8	217	17	234	102	19	121	152.8	1066.9	10.7	1280	20.0%	121	355	565.8	734.8	974.9	1066.9	145	426	679	882	1170	1280
8/2/2012	66	66	132	206.2	44	250.2	173	0	173	146	53.2	199.2	217	19	236	102	19	121	201.2	1111.4	10.84	1325	19.2%	121	357	556.2	729.2	979.4	1111.4	144	426	663	869	1168	1325
8/3/2012	61	58	119	206	58	264	173	12	185	147	55	202	219	19	238	91	20	111	222	1119	10.84	1325	18.4%	111	349	551	736	1000	1119	131	413	652	871	1184	1325
8/4/2012	60	55	115	206.2	89	295.2	174	6	180	132	53.2	185.2	203	26	229	91	22	113	251.2	1117.4	10.82	1320	18.1%	113	342	527.2	707.2	1002.4	1117.4	133	404	623	835	1184	1320
8/5/2012	55	86	141	188	117	305	174	6	180	123	72	195	201	33	234	105	19	124	333	1179	10.72	1290	9.4%	124	358	553	733	1038	1179	136	392	605	802	1136	1290
8/6/2012	70.5	91	161.5	189.18	117	306.18	171.6	6	177.6	129	63.1	192.1	201	30	231	105	27	132	334.1	1200.38	10.73	1293	7.7%	132	363	555.1	732.7	1038.9	1200.4	142	391	598	789	1119	1293
8/7/2012	59	74	133	189.2	147	336.2	113.2	6	119.2	138	66	204	196	36	232	105	27	132	356	1156.4	10.63	1258	8.8%	132	364	568	687.2	1023.4	1156.4	144	396	618	748	1113	1258
8/8/2012	73	109	182	183.1	89	272.1	113.2	0	113.2	139	44.4	183.4	195	23	218	106	27	133	292.4	1101.7	10.49	1210	9.8%	133	351	534.4	647.6	919.7	1101.7	146	386	587	711	1010	1210
8/9/2012	67	107	174	163.1	70	233.1	147	0	147	151	45.8	196.8	193	31	224	99	26	125	279.8	1099.9	10.4	1186	7.8%	125	349	545.8	692.8	925.9	1099.9	135	376	589	747	998	1186
8/10/2012	49	77	126	163.1	64	227.1	143	0	143	134	21.6	155.6	191	30	221	93	27	120	219.6	992.7	10.36	1170	17.9%	120	341	496.6	639.6	866.7	992.7	141	402	585	754	1021	1170
8/11/2012	45	83	128	162	75	237	137	0	137	156	27.8	183.8	192	32	224	86	30	116	247.8	1025.8	10.35	1165	13.6%	116	340	523.8	660.8	897.8	1025.8	132	386	595	750	1020	1165
8/12/2012	36	90	126	162	89	251	137	0	137	160	41.3	201.3	189	32	221	90	34	124	286.3	1060.3	10.34	1162	9.6%	124	345	546.3	683.3	934.3	1060.3	136	378	599	749	1024	1162
8/13/2012	37.5	85	122.5	162	53	215	156.76	0	156.76	191	37	228	190	23	213	129	28	157	226	1092.26	10.31	1162	6.4%	157	370	598	754.76	969.76	1092.3	167	394	636	803	1032	1162
8/14/2012	49	109	158	175	59	234	151.26	0	151.26	146	12.1	158.1	190	8	198	148	7	155	195.1	1054.36	10.59	1245	18.1%	155	353	511.1	662.36	896.36	1054.4	183	417	604	782	1058	1245
8/15/2012	30	72	102	175	56	231	142.97	0	142.97	155	20.9	175.9	199	11	210	143	6	149	165.9	1010.87	10.5	1216	20.3%	149	359	534.9	677.87	908.87	1010.9	179	432	643	815	1093	1216
8/16/2012	29	83	112	175	58	233	130.9	0	130.9	188	24.5	212.5	196	13	209	175	6	181	184.5	1078.4	10.54	1225	13.6%	181	390	602.5	733.4	966.4	1078.4	206	443	684	833	1098	1225
8/17/2012	22	41	63	175	57	232	127	0	127	182	45.11	227.11	196	16	212	165	8	173	167.11	1034.11	10.4	1186	14.7%	173	385	612.11	739.11	971.11	1034.1	198	442	702	848	1114	1186
8/18/2012	26	41	67	163	67	230	129	12	141	173	49.9	222.9	198	21	219	163	14	177	204.9	1056.9	10.42	1190	12.6%	177	396	618.9	759.9	989.9	1056.9	199	446	697	856	1115	1190
8/19/2012	26	48	74	165	117	282	120.7	20	140.7	143	36.3	179.3	194	22	216	145	18	163	261.3	1055	10.49	1210	14.7%	163	379	558.3	699	981	1055	187	435	640	802	1125	1210
8/20/2012	36	43	79	180.5	125	305.5	121.3	22	143.3	134	46	180	197	21	218	145	2	147	259	1072.8	10.43	1190	10.9%	147	365	545	688.3	993.8	1072.8	163	405	605	763	1102	1190
8/21/2012	59	49	108	178.3	69	247.3	145	0	145	135	59	194	197	19	216	131	2	133	198	1043.3	10.41	1188	13.9%	133	349	543	688	935.3	1043.3	151	397	618	783	1065	1188
8/22/2012	61	54	115	179	66	245	148	0	148	133	47.7	180.7	195	31	226	122	7	129	205.7	1043.7	10.45	1200	15.0%	129	355	535.7	683.7	928.7	1043.7	148	408	616	786	1068	1200
8/23/2012	66	48	114	186	68	254	152	0	152	136	36	172	192	21	213	115	6	121	179	1026	10.45	1200	17.0%	121	334	506	658	912	1026	142	391	592	770	1067	1200
8/24/2012	45	56	101	184	67	251	152	0	152	152	49	201	192	19	211	110	13	123	204	1039	10.45	1200	15.5%	123	334	535	687	938	1039	142	386	618	793	1083	1200
8/25/2012	47	50	97	169	48	217	153	0	153	140	29.3	169.3	186	13	199	104	12	116	152.3	951.3	10.45	1200	26.1%	116	315	484.3	637.3	854.3	951.3	146	397	611	804	1078	1200
8/26/2012	18	68	86	169	64	233	153	0	153	142	60.5	202.5	189	19	208	107	27	134	238.5	1016.5	10.47	1195	17.6%	134	342	544.5	697.5	930.5	1016.5	158	402	640	820	1094	1195
8/27/2012	57	75	132	168	68	236	153	10	163	132	52	184	193	15	208	104	30	134	250	1057	10.48	1200	13.5%	134	342	526	689	925	1057	152	388	597	782	1050	1200
8/28/2012	56	79	135	168	63	231	161	10	171	140	51	191	200	16	216	94	32	126	251	1070	10.51	1220	14.0%	126	342	533	704	935	1070	144	390	608	803	1066	1220
8/29/2012	60	80	140	169	46	215	159	10	169	155	38	193	199	13	212	113	18	131	205	1060	10.5	1216	14.7%	131	343	536	705	920	1060	150	393	615	809	1055	1216
8/30/2012	72	28	100	165.5	55	220.5	165	10	175	142	44	186	191	9	200	113	19	132	165	1013.5	10.51	1220	20.4%	132	332	518	693	913.5	1013.5	159	400	624	834	1100	1220
8/31/2012	72	27	99	167	59	226	173	10	183	142	51	193	184	13	197	122	24	146	184	1044	10.5	1216	16.5%	146	343	536	719	945	1044	170	400	624	837	1101	1216
9/1/2012	67	32	99	160	73	233	173	10	183	133	45	178	178	21	199	106	25	131	206	1023	10.5	1216	18.9%	131	330	508	691	924	1023	156	392	604	821	1098	1216
9/2/2012	60	32	92	161	73	234	173	10	183	141	59.8	200.8	178.5	31	209.5	90	29	119	234.8	1038.3	10.5	1216	17.1%	119	328.5	529.3	712.3	946.3	1038.3	139	385	620	834	1108	1216
9/3/2012	60	42	102	161	78	239	173	10	183	135	60	195	177	36	213	79	28	107	254	1039	10.52	1225	17.9%	107	320	515	698	937	1039	126	377	607	823	1105	1225
9/4/2012	54	40	94	161	102	263	162	24	186	138	28	166	178	33	211	90	33	123	260	1043	10.51	1220	17.0%	123	334	500	686	949	1043	144	391	585	802	1110	1220
9/5/2012	16	37	53	184	93	277	167	10	177	145	41	186	178	36	214	90	31	121	248	1028	10.51	1220	18.7%	121	335	521	698	975	1028	144	398	618	828	1157	1220
9/6/2012	46	31	77	188	86	274	162	10	172	142	36	178	177	45	222	76	40	116	248	1039	10.5	1216	17.0%	116	338	516	688	962	1039	136	396	604	805	1126	1216
9/7/2012	41	34	75	188	97	285	136	20	156	146	39	185	168	44	212	61	38	99	272	1012	10.52	1220	20.6%	99	311	496	652	937	1012	119	375	598	786	1130	1220
9/8/2012	40	44	84	188	97	285	118	20	138	135	79	214	156	50	206	40	71	111	361	1038	10.55	1235	19.0%	111	317	531	669	954	1038	132	377	632	796	1135	1235
9/9/2012	40	55	95	186	122	308	116	24	140	129	99	228	156	53	209	32	52	84	405	1064	10.5	1216	14.3%	84	293	521	661	969	1064	96	335	595	755	1107	1216
9/10/2012	31.2	27	58.2	152	103	255	102	20	122	101	119.6	220.6	139	53	192	32	63	95	385.6	942.8	10.25	1145	21.4%	95	287	507.6	629.6	884.6	942.8	115	349	616	765	1074	1145
9/11/2012	35	31	66	145	127	272	81	30	111	82	124	206	137	73	210	32	35	67	420	932	9.96	1075	15.3%	67	277	483	594	866	932	77	320	557	685	999	1075
9/12/2012	41	46	87	143.5	87	230.5	64	61.15	125.15	85	122	207	124	69	193	29	34	63	419.15	905.65	9.76	1035	14.3%	63	256	463	588.15	818.65	905.65	72	293	529	672	936	1035
9/13/2012	37.5	57	94.5	110.8	64	174.8	67	80	147	75	110	185	123	65	188	29	36	65	412	854.3	9.54	995	16.5%	65	253	438	585	759.8	854.3	76	295	510	681	885	995
9/14/2012	11	76	87	109	92	201	67	70	137	76	106	182	114	65	179	39	32	71	441	857	9.52	985	14.9%	71	250	432	569	770	857	82	287	497	654	885	985
9/15/2012	3	27	30	110	55	165	67	70	137	68	111	179	111	68	179	26	34	60	365	750	9.15	915	22.0%	60	239	418	555	720	750	73	292	510	677	878	915
9/16/2012	3	31	34	110	61	171	61	70	131	64	124	188	110	67	177	26	30	56	383	757	9.15	915	20.9%	56	233	421	552	723	757	68	282	509	667	874	915
9/17/2012	4.5	35	39.5	80	63	143	46	70	116	69	125	194	109	73	182	27	30	57	396	731.5	9.2	926	26.6%	57	239	433	549	692	731.5	72	303	548	695	876	926

9/18/2012	4.5	42	46.5	78	89	167	46	70	116	53	142	195	109	74	183	26	21	47	438	754.5	9.19	920	21.9%	47	230	425	541	708	754.5	57	280	518	660	863	920
9/19/2012	4.5	40	44.5	72	89	161	46	70	116	45	154	199	108	80	188	28	22	50	455	758.5	9.18	918	21.0%	50	238	437	553	714	758.5	61	288	529	669	864	918
9/20/2012	4.5	45	49.5	62	28	90	33	70	103	45	172	217	107	74	181	28	30	58	419	698.5	8.97	880	26.0%	58	239	456	559	649	698.5	73	301	574	704	818	880
9/21/2012	4.5	0	4.5	45	5.7	50.7	33	70	103	43	172	215	99	66	165	30	22	52	335.7	590.2	8.7	835	41.5%	52	217	432	535	585.7	590.2	74	307	611	757	829	835
9/22/2012	4.5	0	4.5	45	40	85	33	70	103	37	155	192	99	51	150	30	14	44	330	578.5	8.49	790	36.6%	44	194	386	489	574	578.5	60	265	527	668	784	790
9/23/2012	3	0	3	45	40	85	33	70	103	37	157	194	97	53	150	30	20	50	340	585	8.47	788	34.7%	50	200	394	497	582	585	67	269	531	669	784	788
9/24/2012	3	0	3	43	42	85	31	70	101	37	158	195	97	57	154	27	18	45	345	583	8.5	800	37.2%	45	199	394	495	580	583	62	273	541	679	796	800
9/25/2012	0	0	0	43	0	43	31	70	101	31	157	188	75	64	139	27	20	47	311	518	8.41	787	51.9%	47	186	374	475	518	518	71	283	568	722	787	787
9/26/2012	0	0	0	0	22	22	13	70	83	26	155	181	67	67	134	27	22	49	336	469	8.03	724	54.4%	49	183	364	447	469	469	76	282	562	690	724	724
9/27/2012	3	4	7	0	0	0	0	0	0	24	148	172	67	63	130	27	20	47	235	356	7.6	657	84.6%	47	177	349	349	349	356	87	327	644	644	644	657
9/28/2012	0	0	0	0	0	0	0	70	70	0	1.38	1.38	0	55	55	0	22	22	148.38	148.38	7.4	Ø		22	77	78.38	148.38	148.38	148.38	22	77	78	148	148	148
9/29/2012	0	0	0	0	0	0	0	70	70	0	128	128	0	46	46	25	14	39	258	283	7.4	Ø		39	85	213	283	283	283	39	85	213	283	283	283
9/30/2012	0	0	0	0	0	0	0	70	70	0	120	120	0	46	46	0	14	14	250	250	0	Ø		14	60	180	250	250	250	14	60	180	250	250	250

Avg Evaporation and Seepage Loss* 15.5% For the Year

* Excluding system loading (4/20 to 4/21) and system shutdown (9/21 to 9/30)

30.00 **days when loss is less than 10%**

73.00 **days when loss is less than 15%**

121.00 **days when loss is less than 20%**

Avg Evaporation and Seepage Loss 15.5%

30.00 days when loss is less than 10%

73.00 days when loss is less than 15%

121.00 days when loss is less than 20%

Notes: It is important to realize that canal conservation measures can only reduce maximum flow diverted by the smallest amount lost during the highest water demands. An irrigation system must be designed to accommodate flows that will support the maximum crop demand, not just the average use. It is important to NOT use averages in this analysis, but to utilize the losses that exist during times of peak demand, which show how efficient the system is during times of peak consumptive use

A review of each of these years of Main Canal flows show that the losses during times of peak consumptive use are very low. For example in 2012 the Main Canal has 18.5% average seepage loss of the entire season But, only lost 3.5% on June 12th and 6.6% July 12th of 2012 during a week of peak demand high flows On June 12th perfect conservation measures would only save 3.5% of the diverted water while the crops would still need practically the full water right

Operational spills are flows diverted into the LYIP system that are not delivered to the farm. It is necessary to divert excess water to the main canal or lateral to act as a buffer necessary to allow for normal water deliveries and the elevations needed for water deliveries to elevated fields. Operational spills are either returned to the LYIP Main Canal to be utilized for irrigation or to the LYIP drainages where they support wildlife habitat and then discharge back to the Yellowstone River. Operational spills are utilized in most gravity irrigation systems to manage downstream irrigation demand. This contingency water is needed to provide a buffer for water level fluctuations caused by significantly varying losses due to high day-time temperatures, winds, and water quality variances and to cover future deliveries, delivery adjustments, unauthorized deliveries, and to cover shrinkage due to large loss variances. If enough water is not kept in the LYIP system to cover downstream demands and varying water losses, water shortages are certain to occur. Constant buffered water flow and minimum water elevations must be maintained to each individual farm or the siphons and/or pump irrigation systems will stop drawing water from the laterals or private farm ditches. When these systems stop drawing water, suddenly there is not enough room in the progressively smaller canals, laterals, pipe lines or private farm ditches to carry the sudden gain in water (because it is no longer taken out at the farms or siphon tubes) and this blows out the tops of the canals and causes dangerous large scale public flooding. Without operational spills, a constant water flow and minimum water elevations are NOT possible to achieve. In addition, The LYIP consists of over 72 miles of main canal and 220 miles of laterals. A call on water to the downstream end of the system would take over a week to get water from the diversion to the downstream portion of the system if operational spills were not in place. This timing could result in serious and irrepairable damage to crops that would have a devastating financial impact to the farmers.

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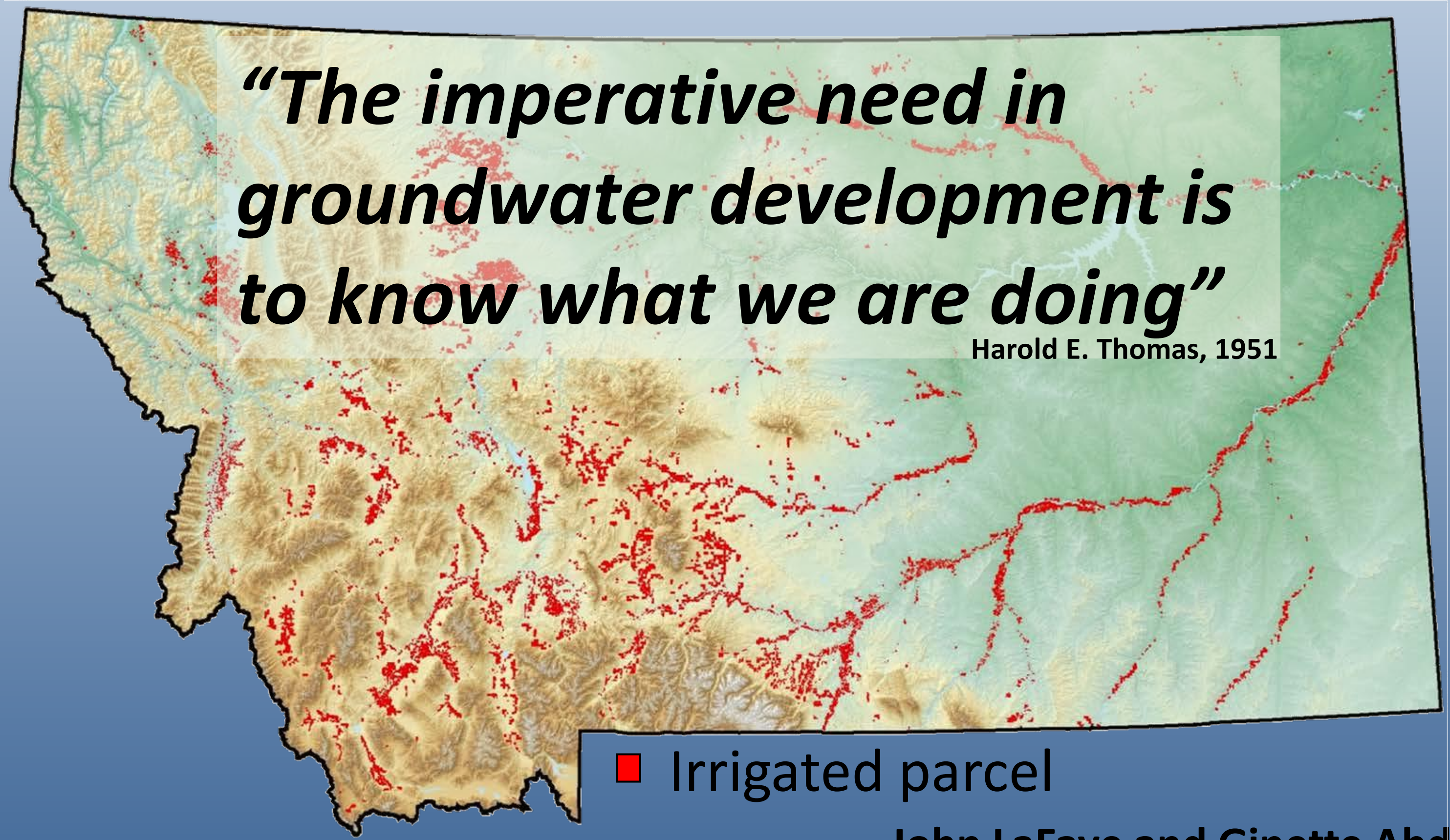
ATTACHMENT 3

Irrigation and "Incidental Recharge" in Montana



> *"The imperative need in groundwater development is to know what we are doing"*
>
> **Harold E. Thomas, 1951**

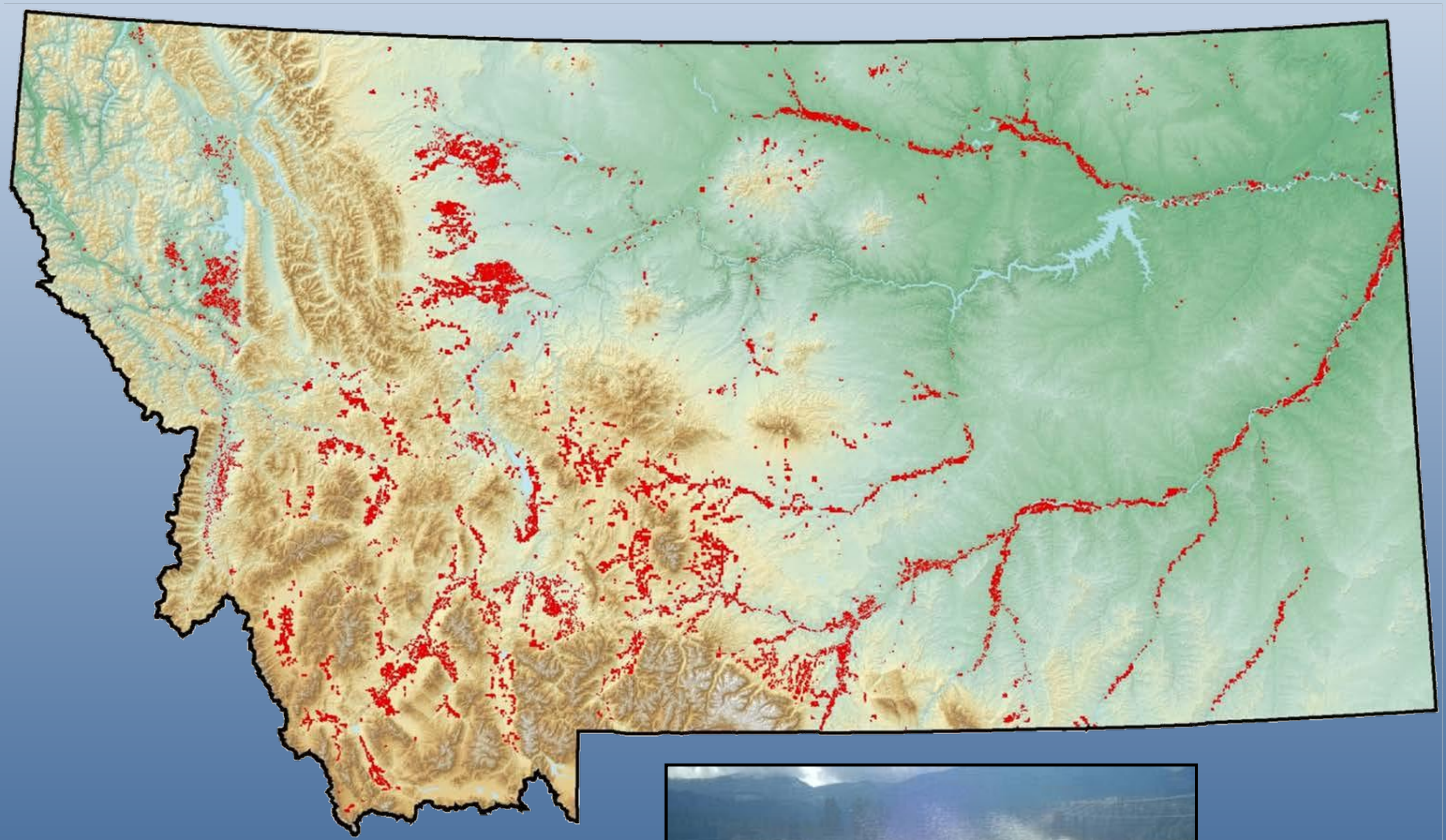
🟥 Irrigated parcel

John LaFave and Ginette Abdo
Montana Bureau of Mines and Geology
Presented to:
Shallow Recharge Technical Meeting
Helena, MT Oct. 21, 2015

Incidental Recharge

- Recharge that occurs related to irrigation use
- Unintended consequence of the use
- Unmanaged
- Prevalent in MT alluvial valleys
  - Irrigated areas
- Volumetrically Significant
  - Measurable impacts

In Montana we irrigate about 2 million acres…



🟥 Irrigated parcel

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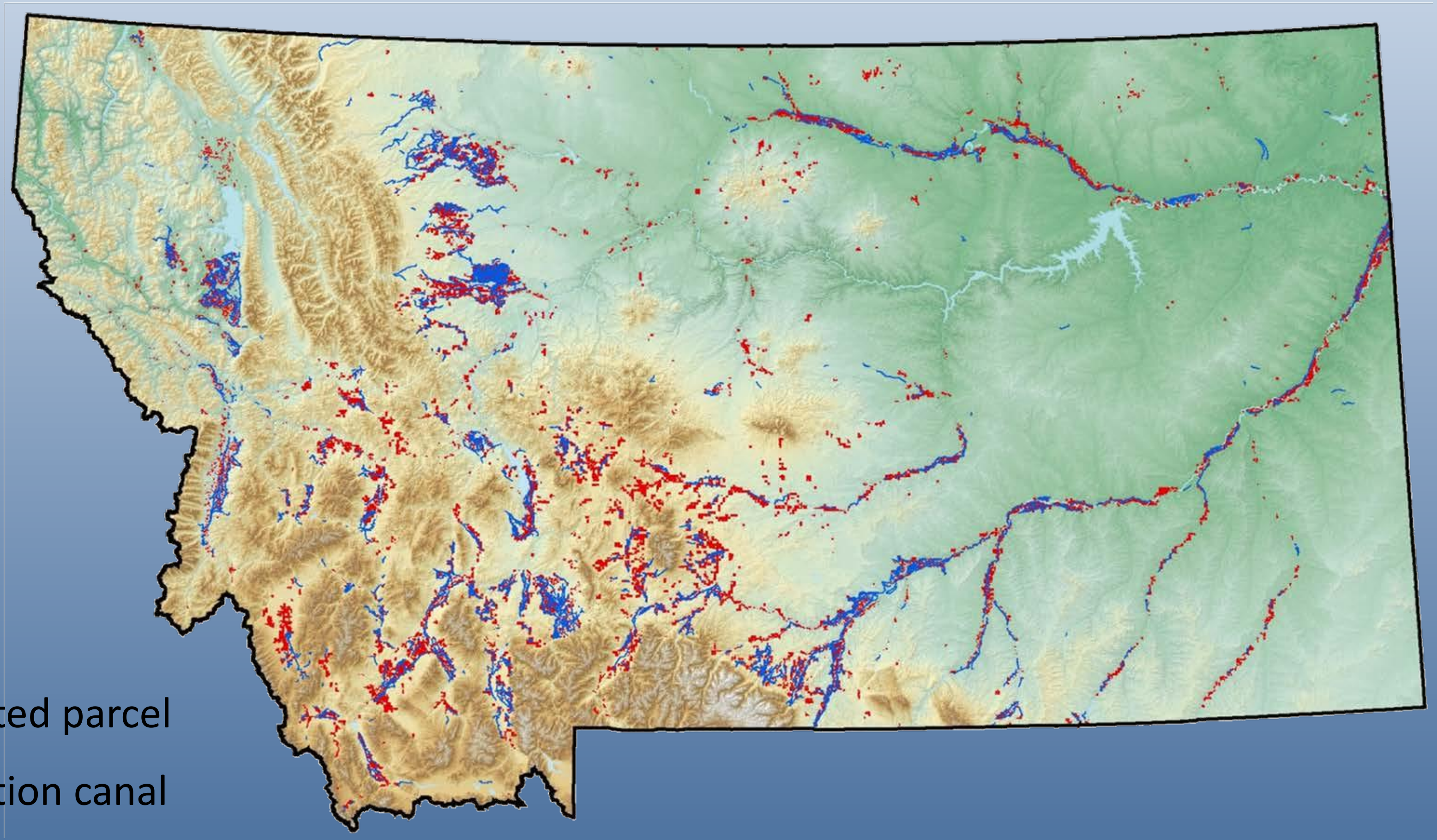
We divert about 11.6 million acre-ft per yr through more than 7,000 miles of canals

MBMG
Montana Bureau of Mines and Geology

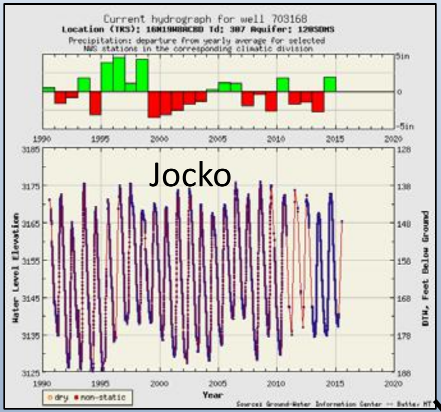
That’s 5.5 ft of water per acre…

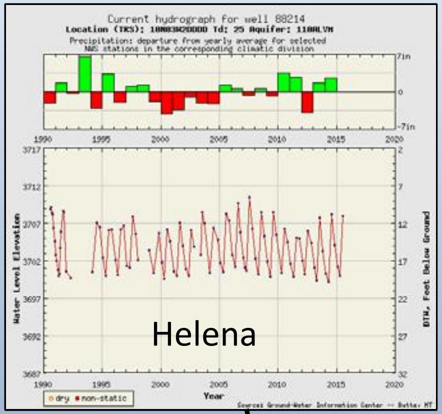


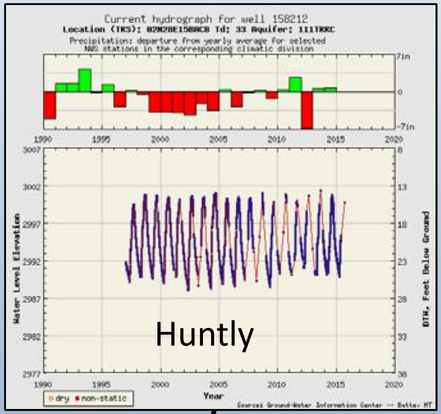
🟥 Irrigated parcel

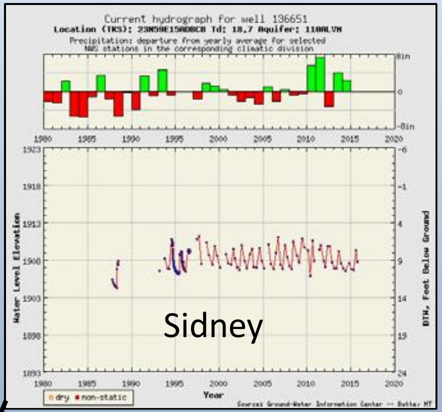
— Irrigation canal

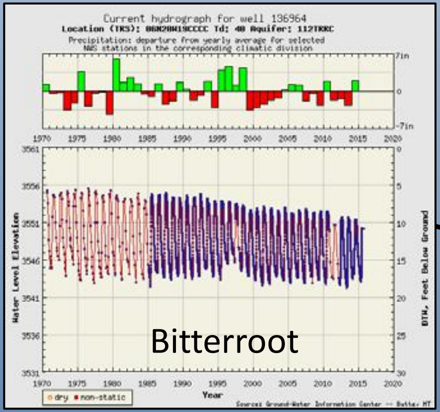
If it takes 2 ft of water to grow a crop, where does the rest of the water go?

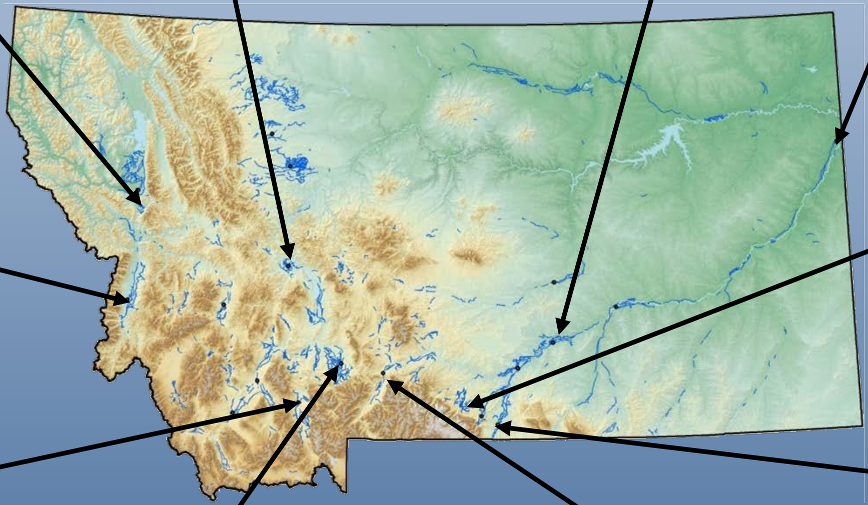


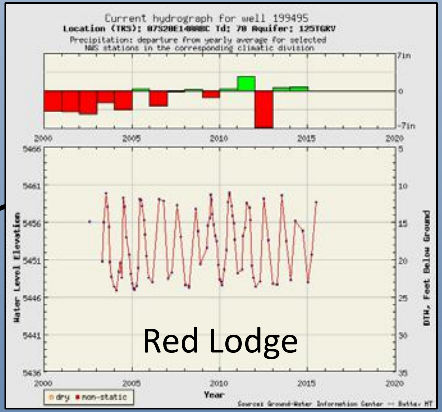


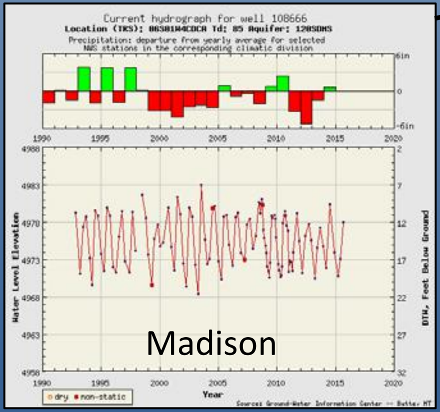


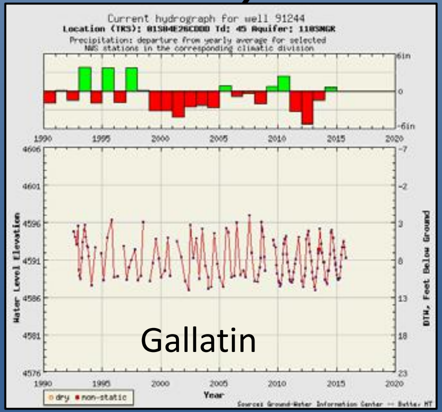


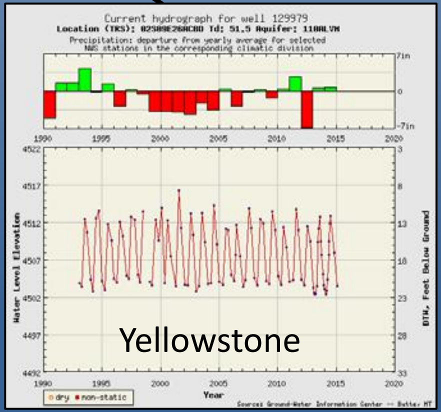


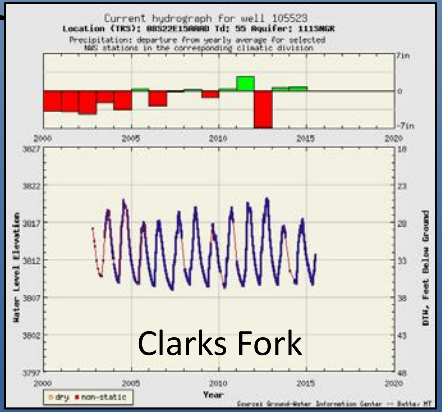












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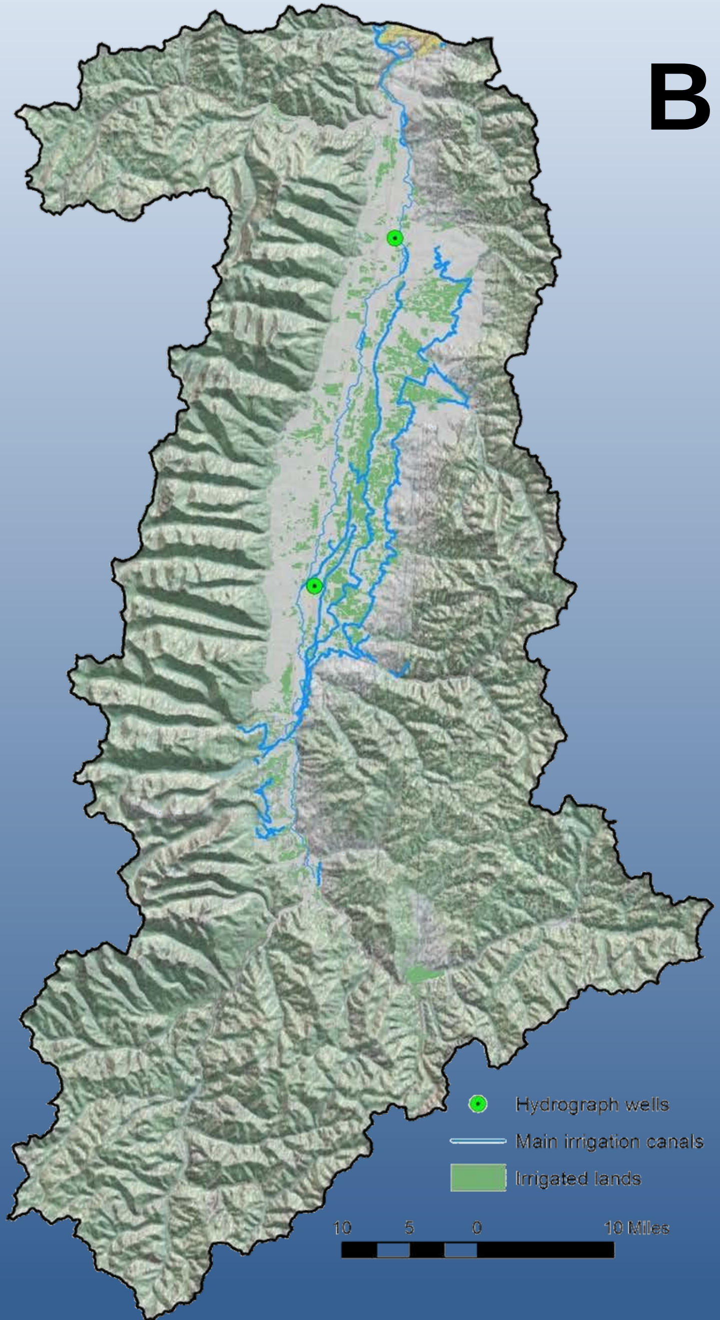
Montana Bureau of Mines and Geology

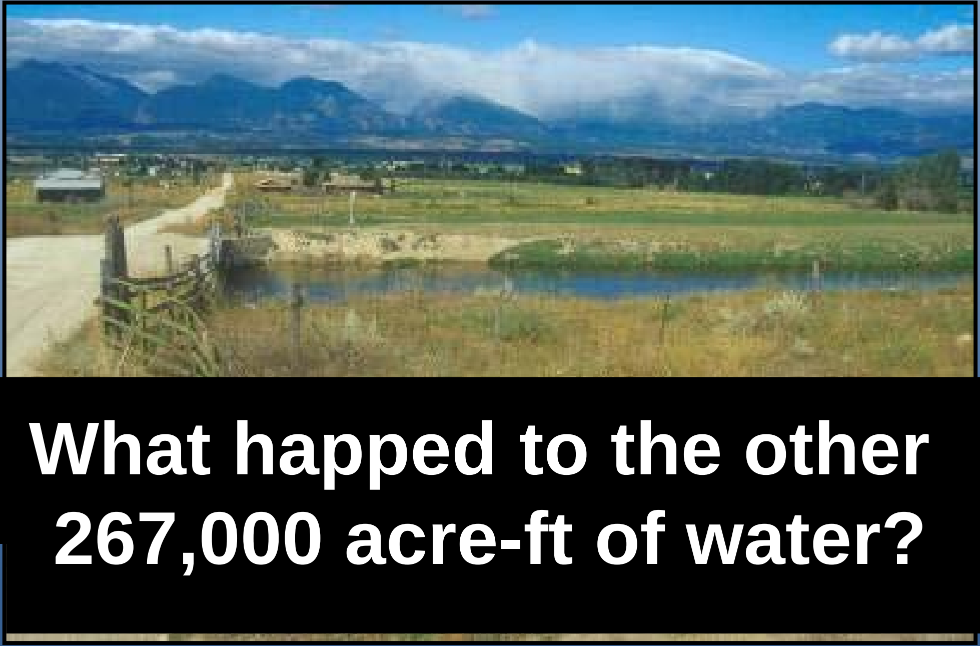


Bitterroot Valley Example

85,000 acres of irrigated land

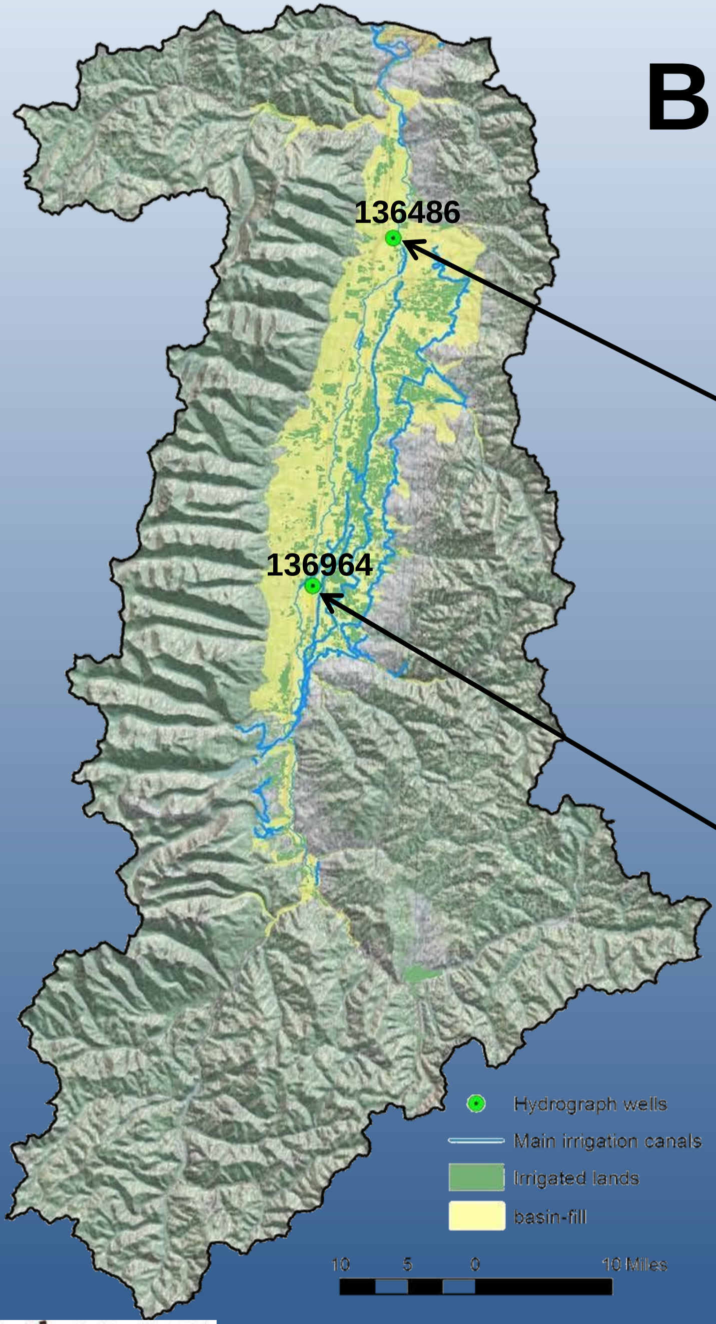
374,000 acre-ft of water diverted
(~4.5 ft of water per acre)

107,000 acre-ft consumed
(~1.3 ft of water per irrigated acre)

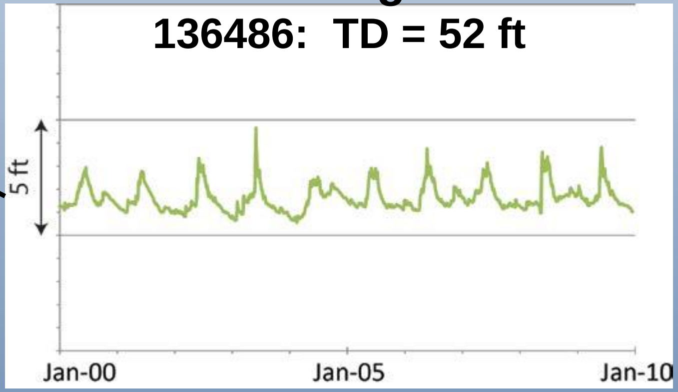


What happed to the other 267,000 acre-ft of water?

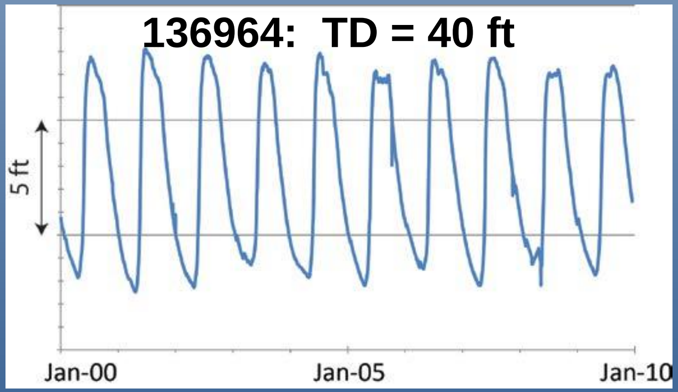
Bitterroot Valley Example



Outside of irrigated area

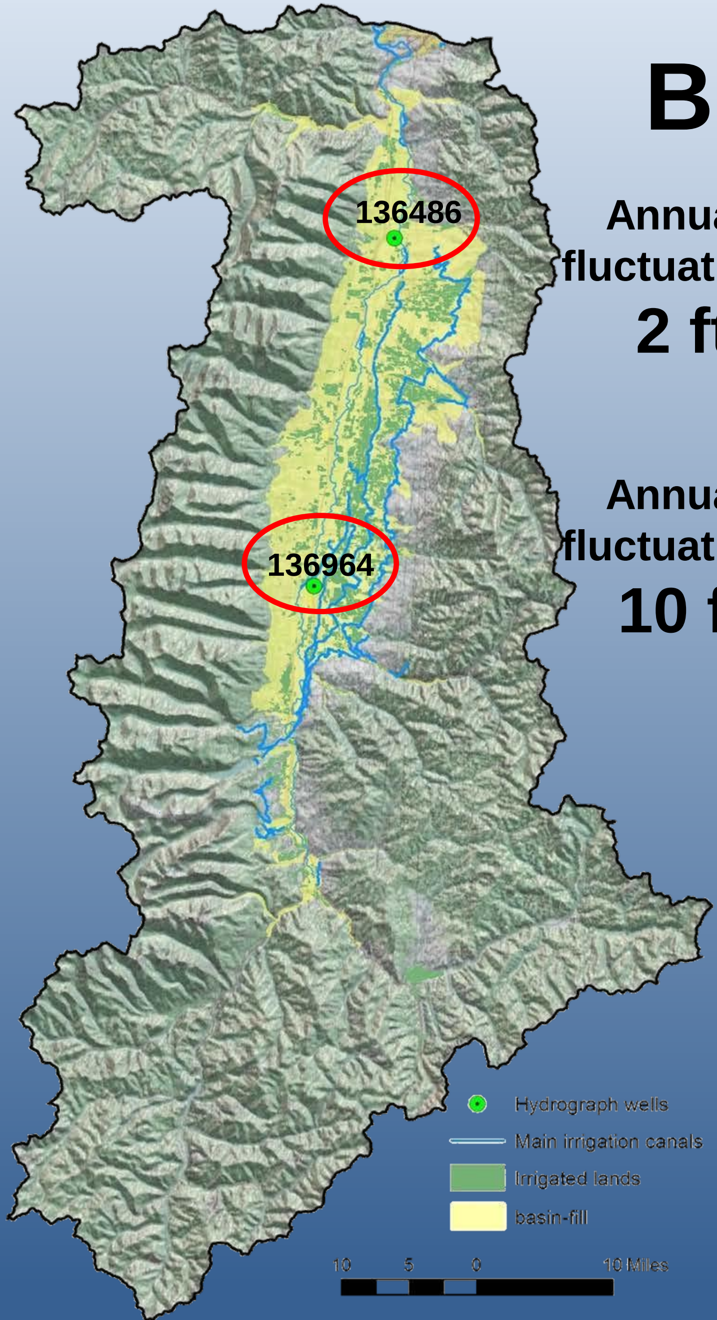

136486: TD = 52 ft

In irrigated area


136964: TD = 40 ft

Same Aquifer

Bitterroot Valley Example



Annual fluctuation:

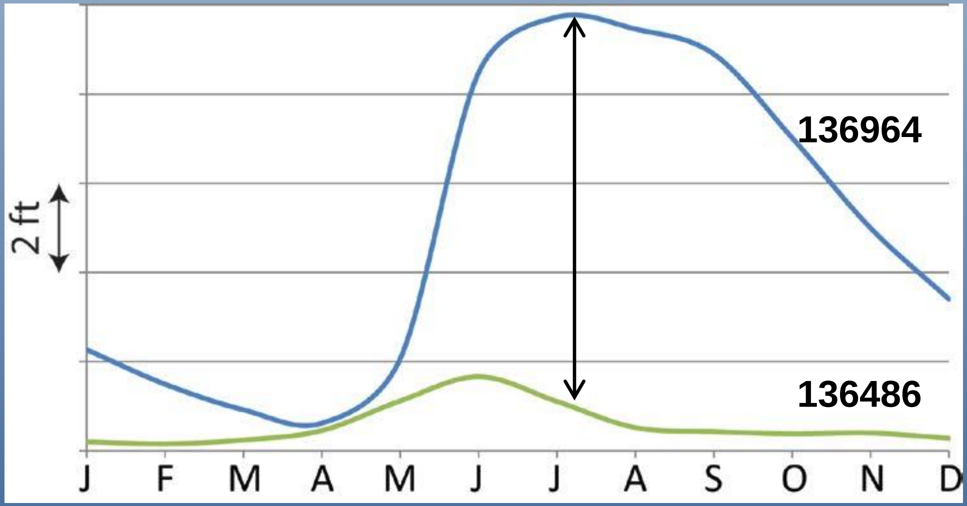
2 ft

Annual fluctuation:

10 ft

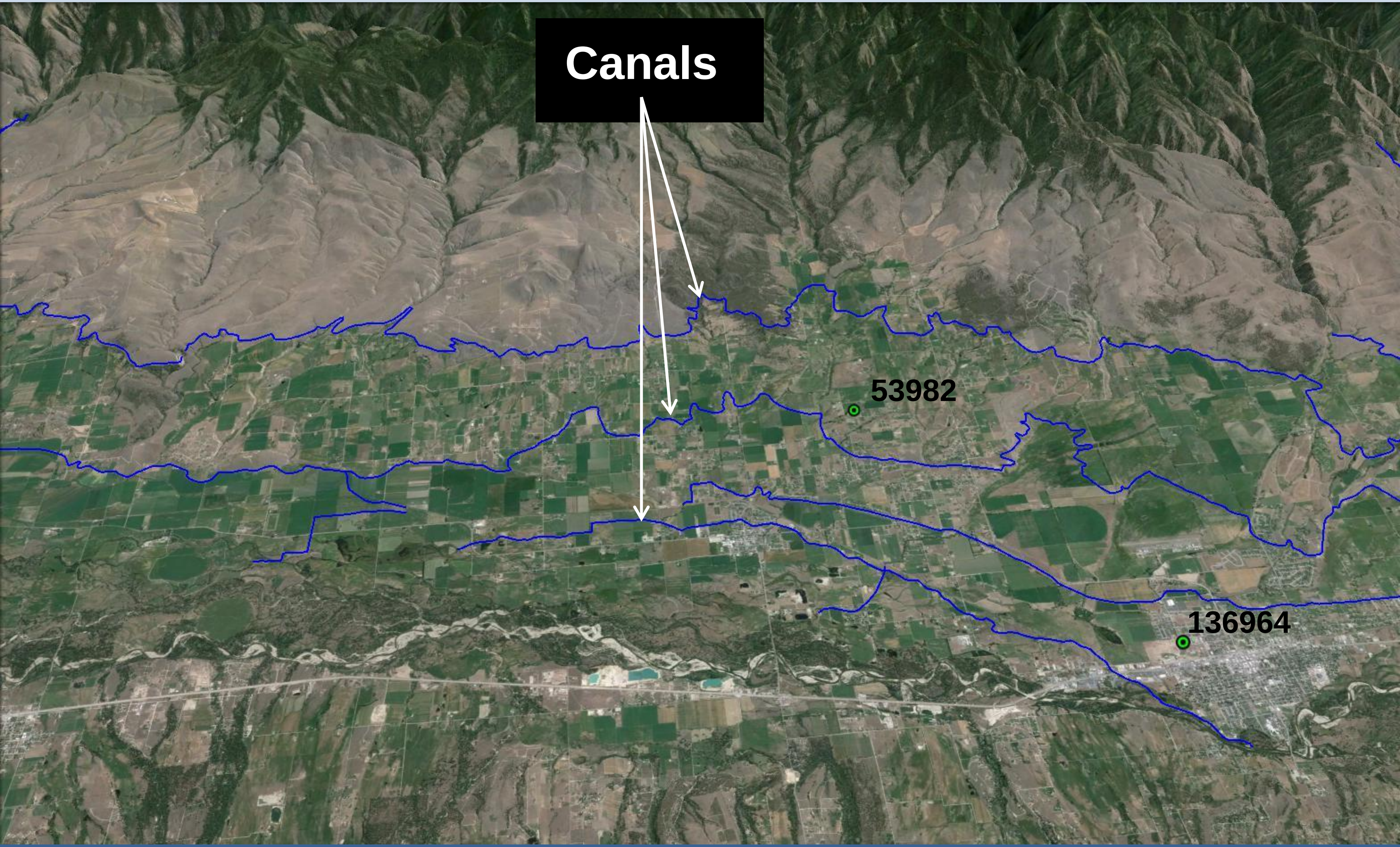
Irrigation returns provide significant groundwater recharge

Average monthly water levels

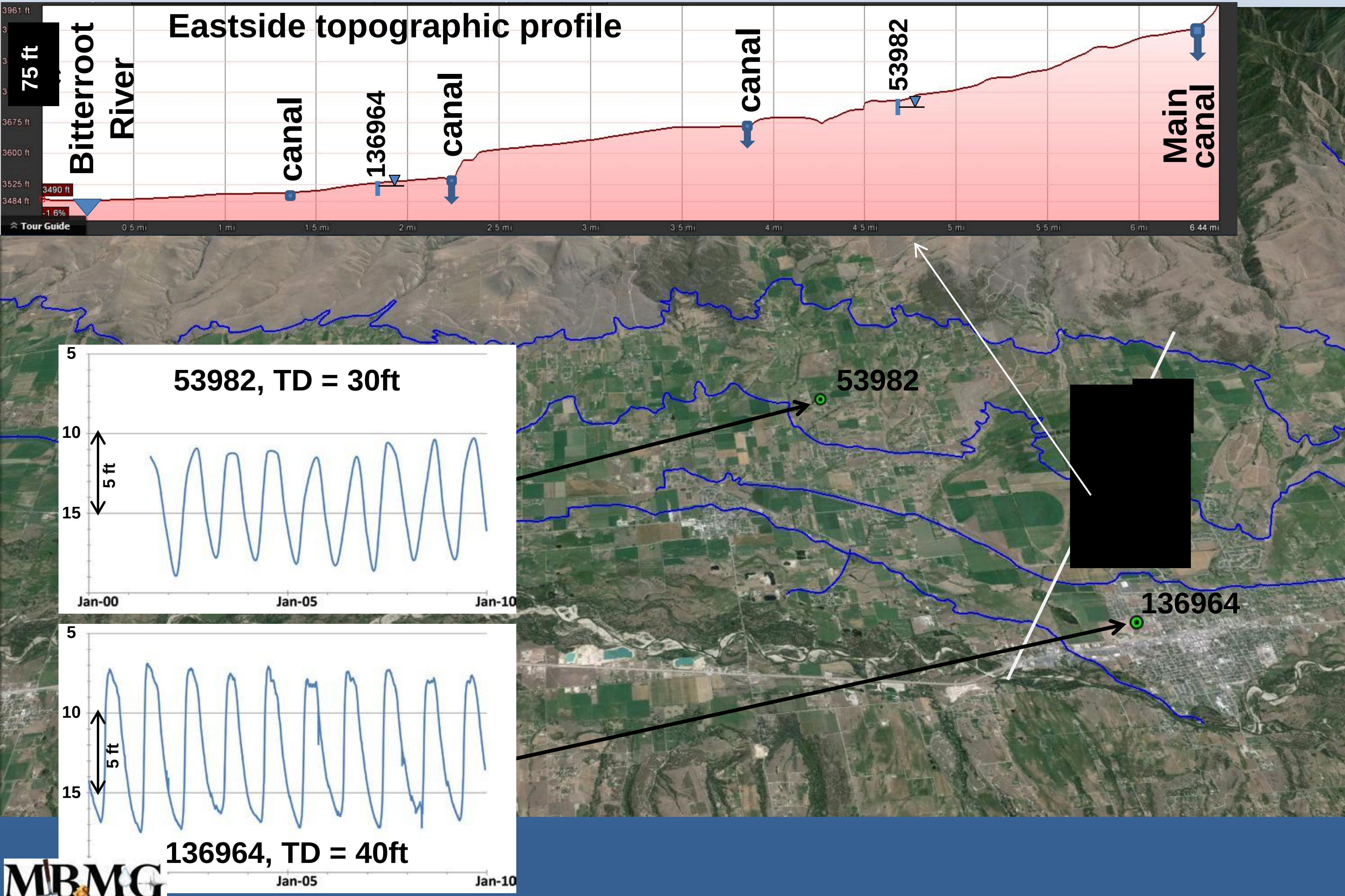


Same Aquifer

Irrigation leakage: Dependent systems



Irrigation leakage: Dependent systems


Eastside topographic profile

53982, TD = 30ft

136964, TD = 40ft

[redacted]

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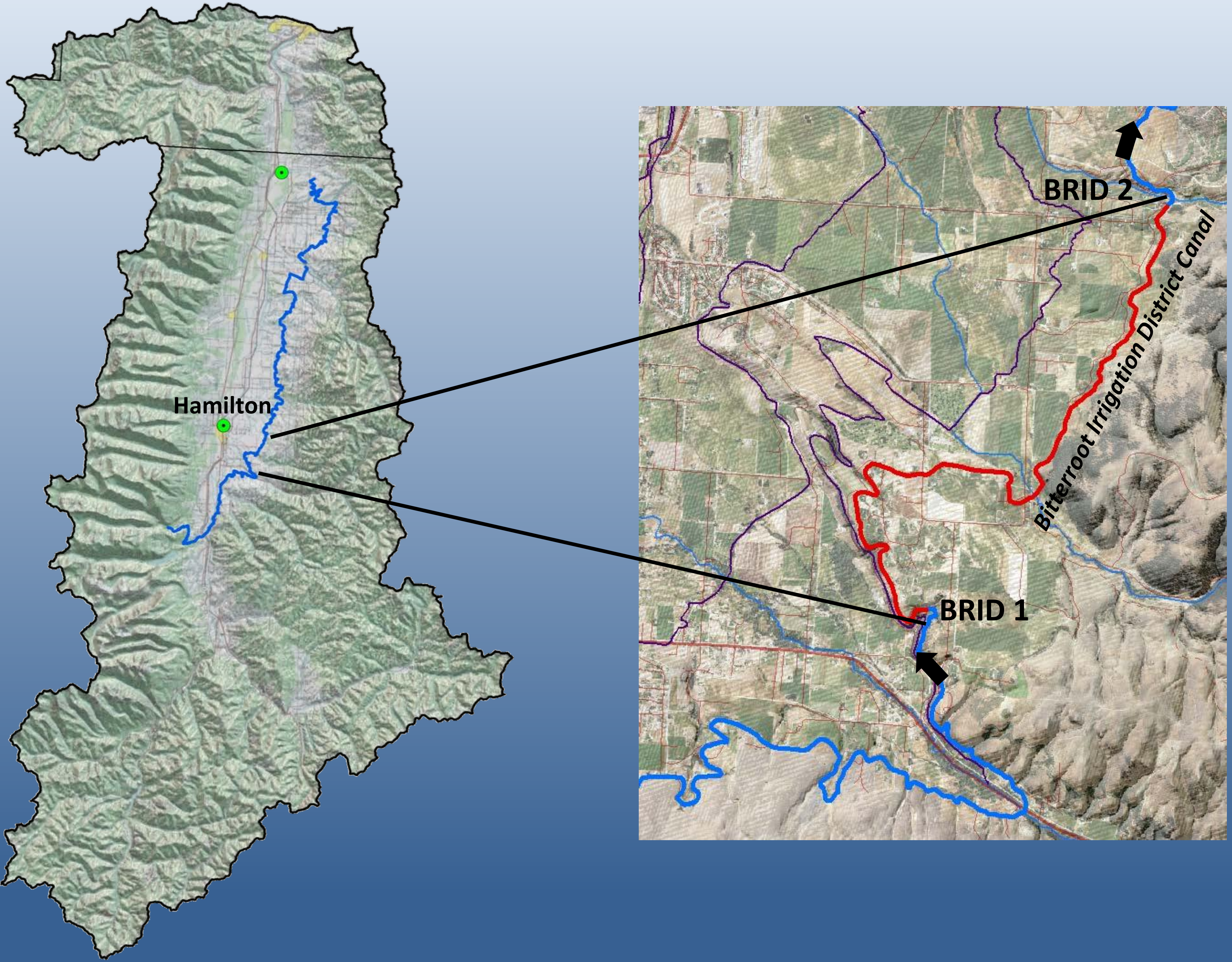
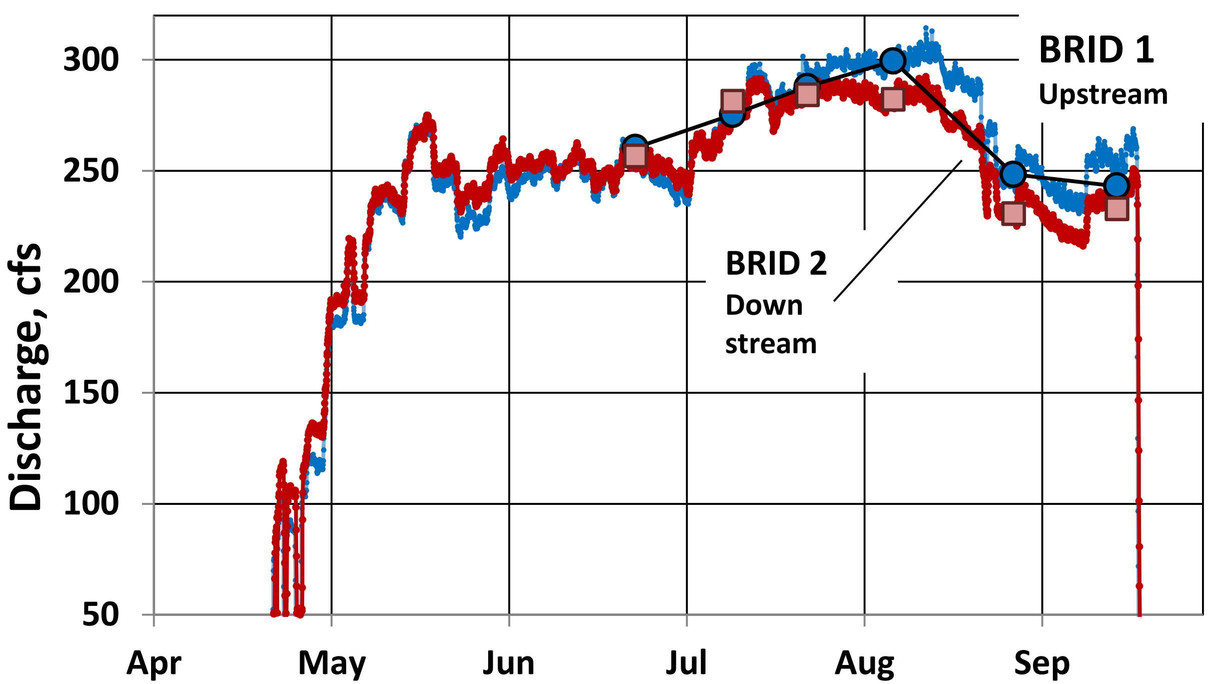
Montana Bureau of Mines and Geology

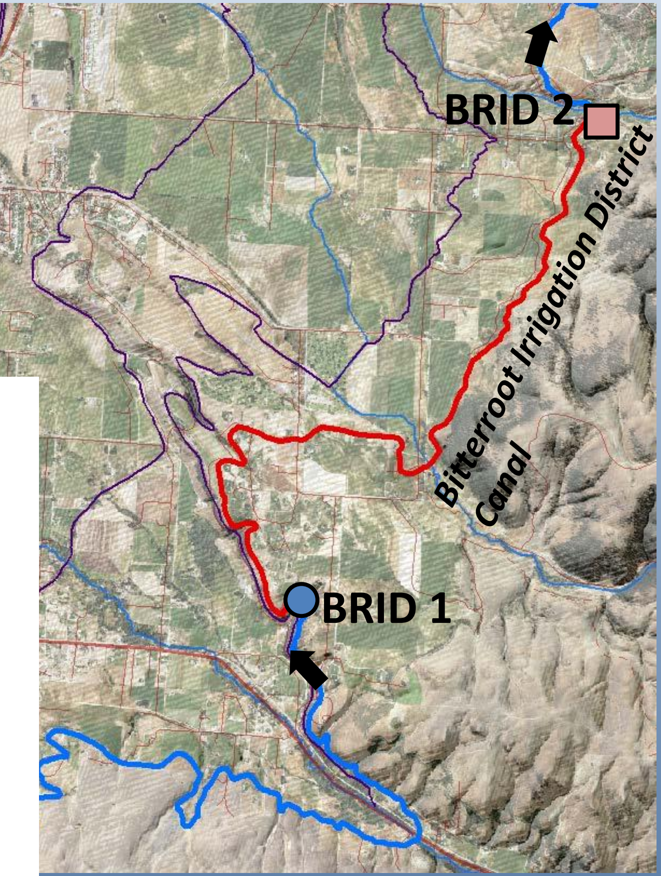

Hamilton
BRID 2
BRID 1
Bitterroot Irrigation District Canal

Bitterroot Irrigation District Canal

5.8 miles

2014

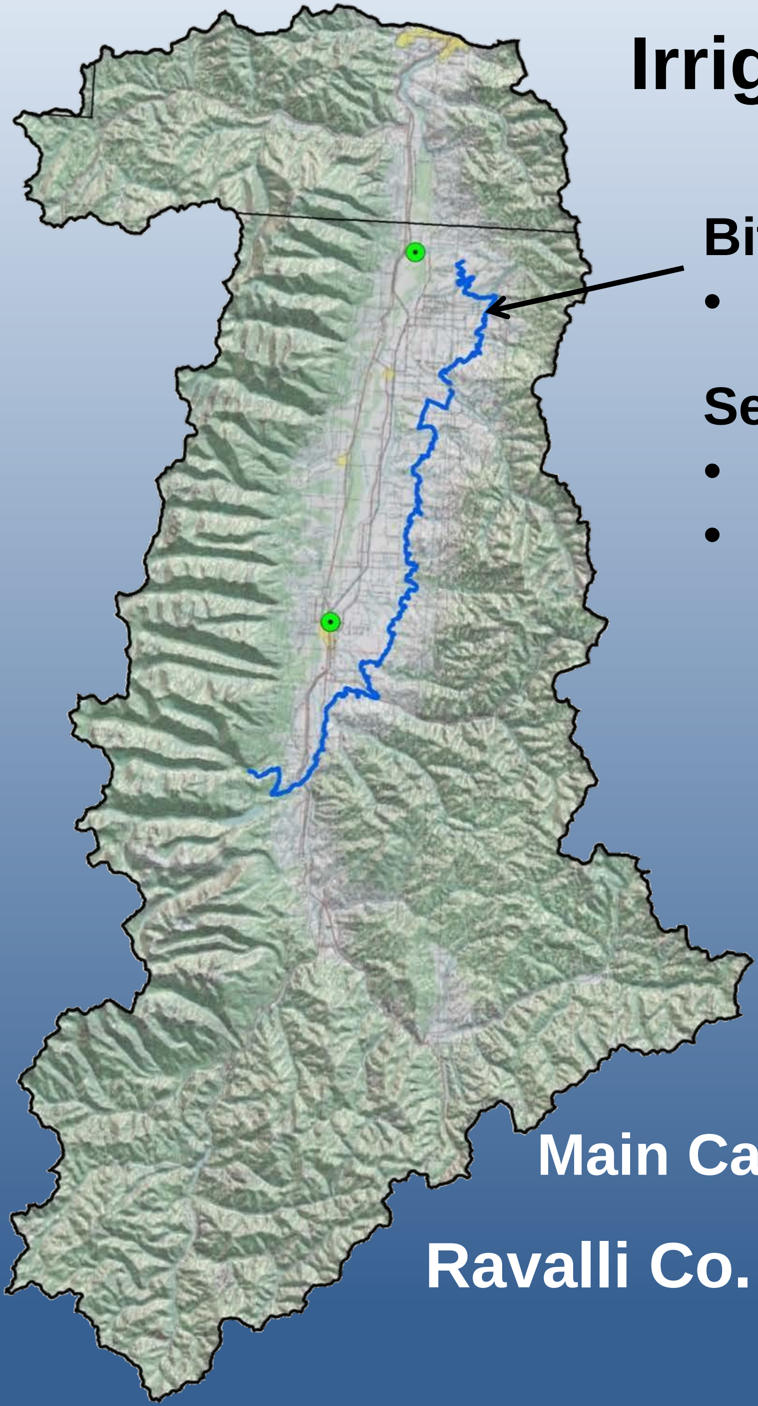




3.1 cfs/mile loss

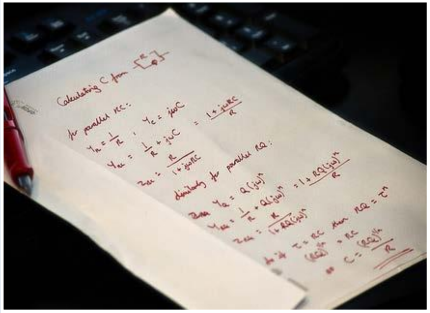
Provisional data

Irrigation leakage: How much?



Bitterroot Main Canal
- 77 miles mostly unlined

Seepage loss
- ~ 3 cfs/mile (GWIP)
- (1 cfs/mile)



Back of the envelope

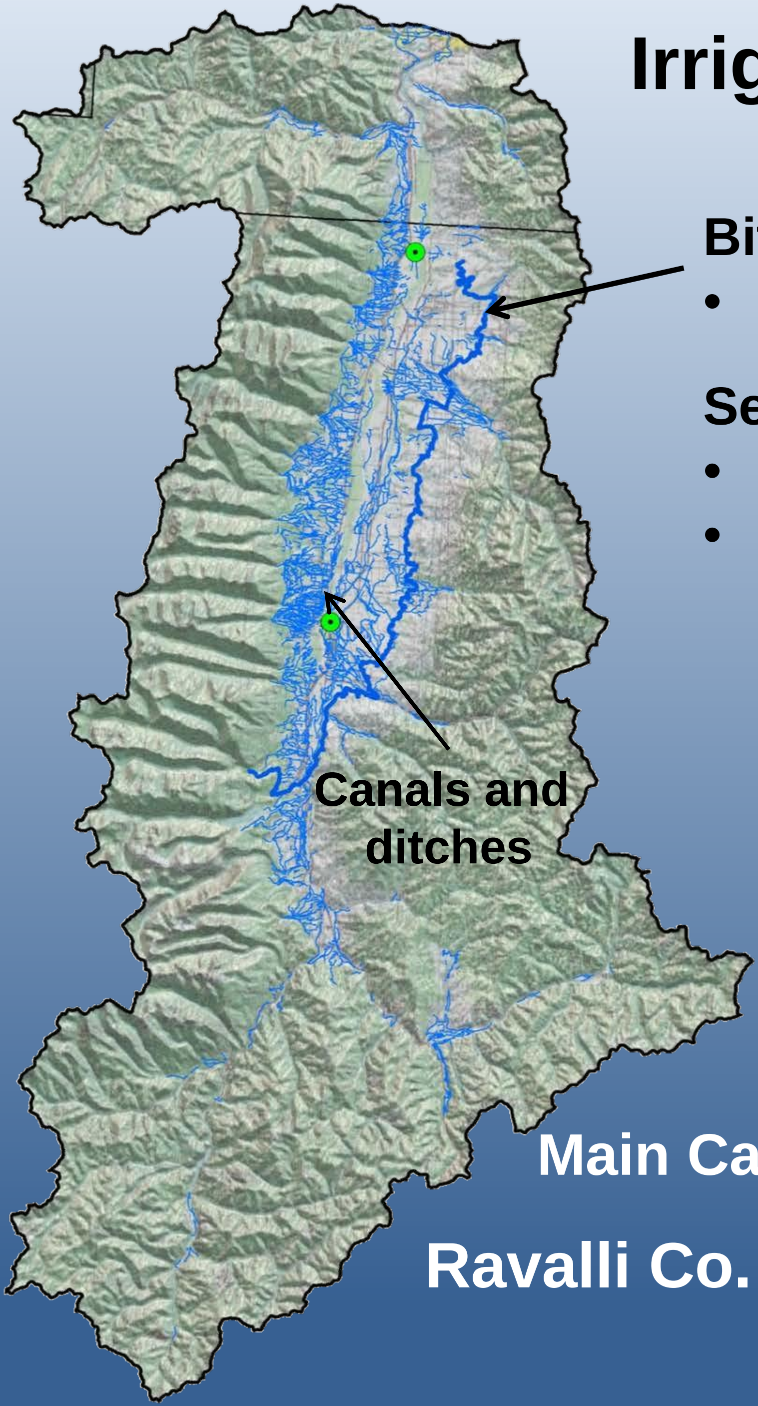
77 cfs = ~150 ac-ft/day = 50 MGD

Irrigation season
- April 15 – Sept 15 (150 days)

Main Canal seepage loss = 7.5 Billion gal/season

Ravalli Co. GW withdrawals = 3.4 Billion gal/year

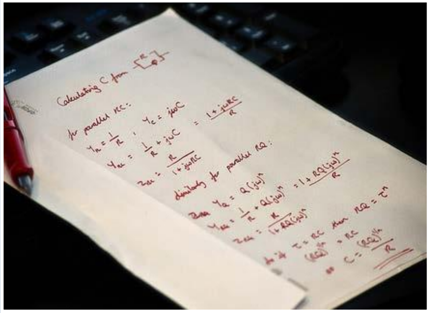
Irrigation leakage: How much?


Canals and ditches

Bitterroot Main Canal
- 77 miles mostly unlined

Seepage loss
- ~ 3 cfs/mile (GWIP)
- (1 cfs/mile)

Back of the envelope



77 cfs = ~150 ac-ft/day = 50 MGD

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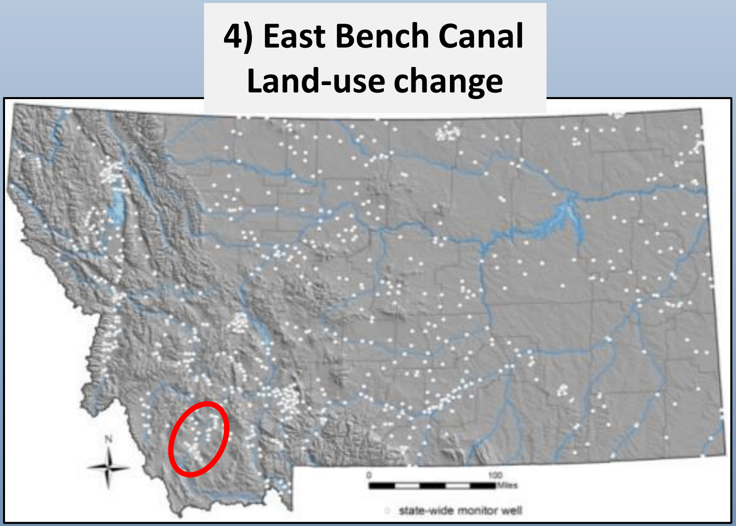
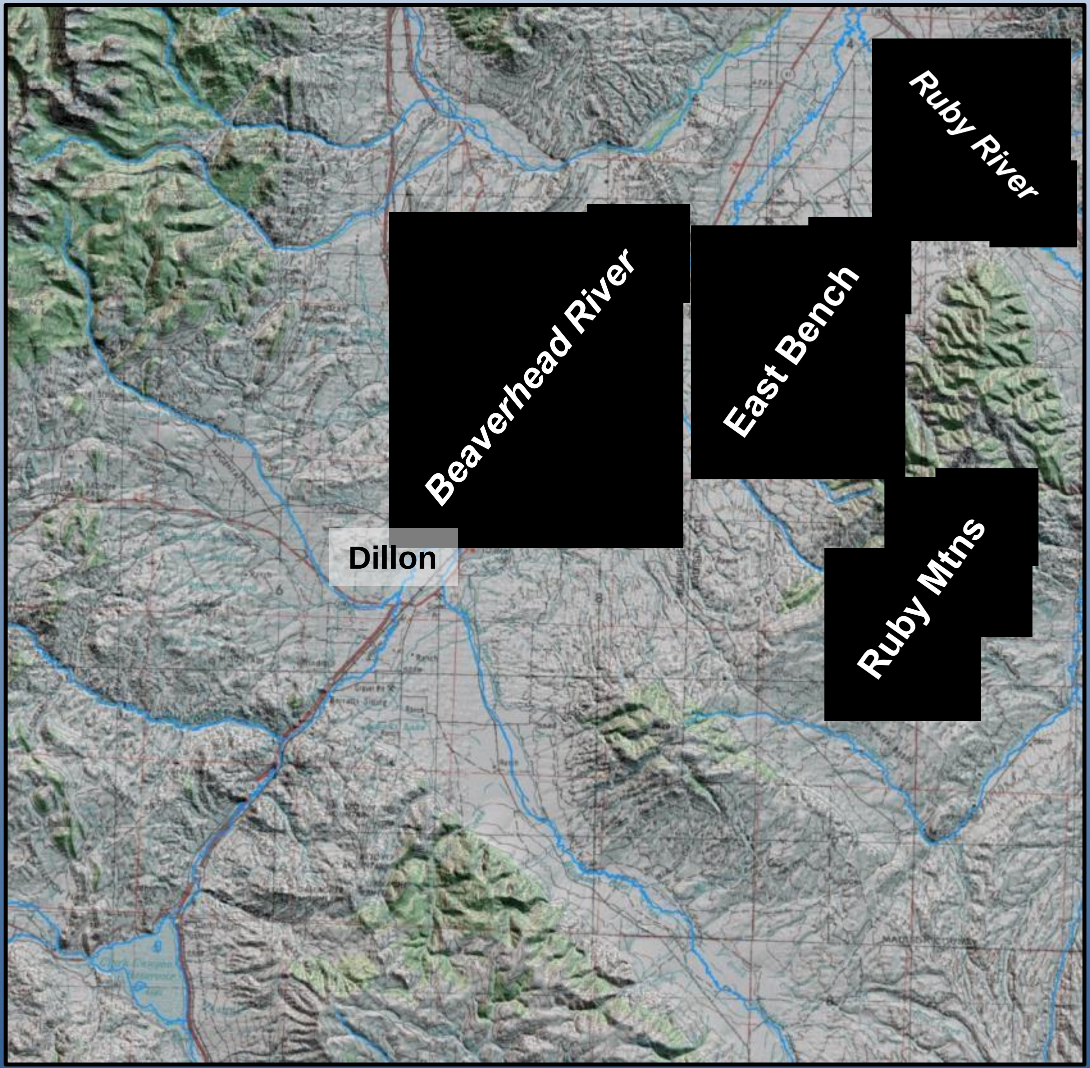
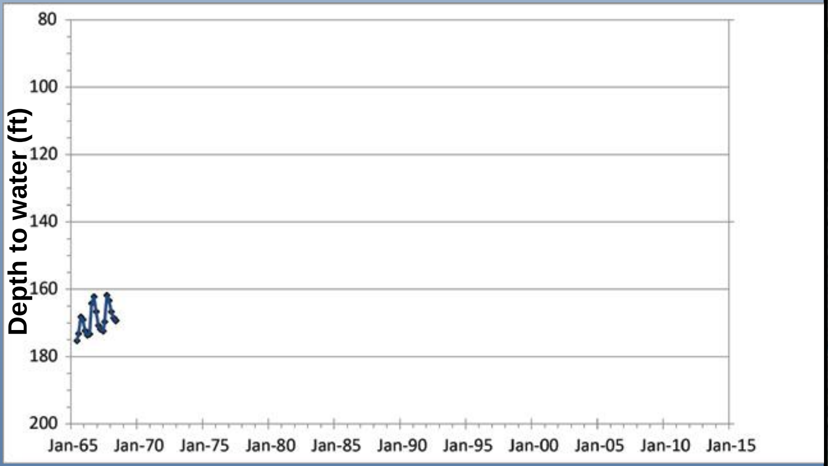
East Bench Canal Example

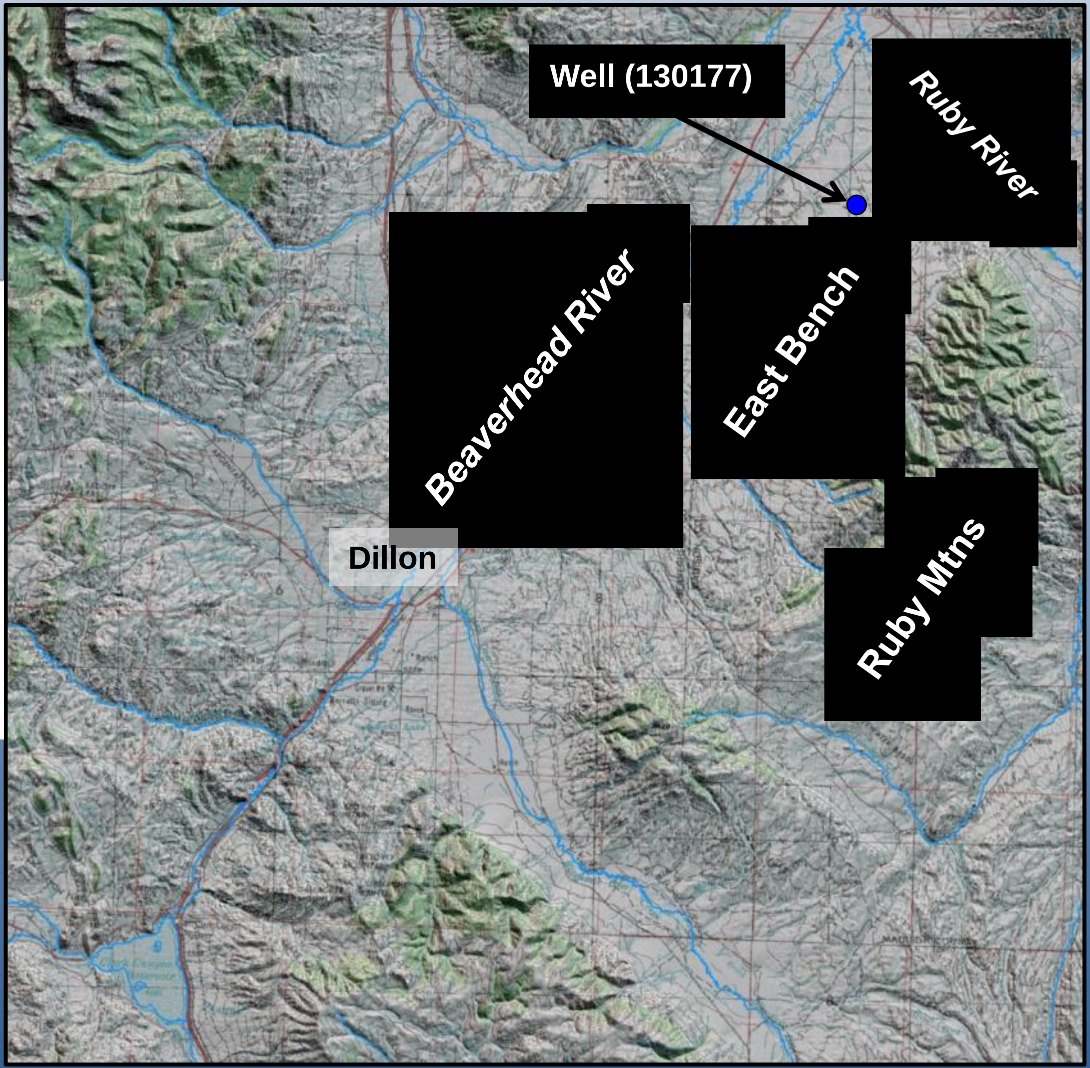

4) East Bench Canal Land-use change



East Bench Canal Example

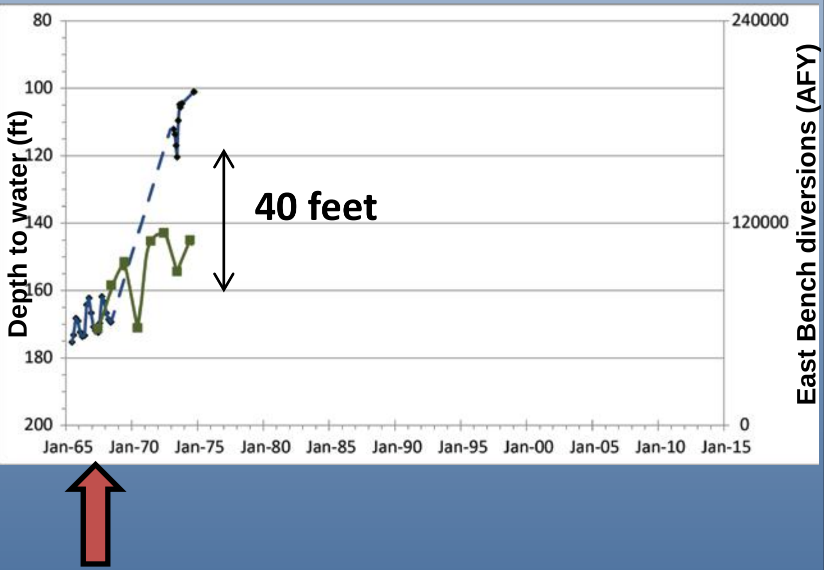
Hydrograph 130177, TD = 200 ft



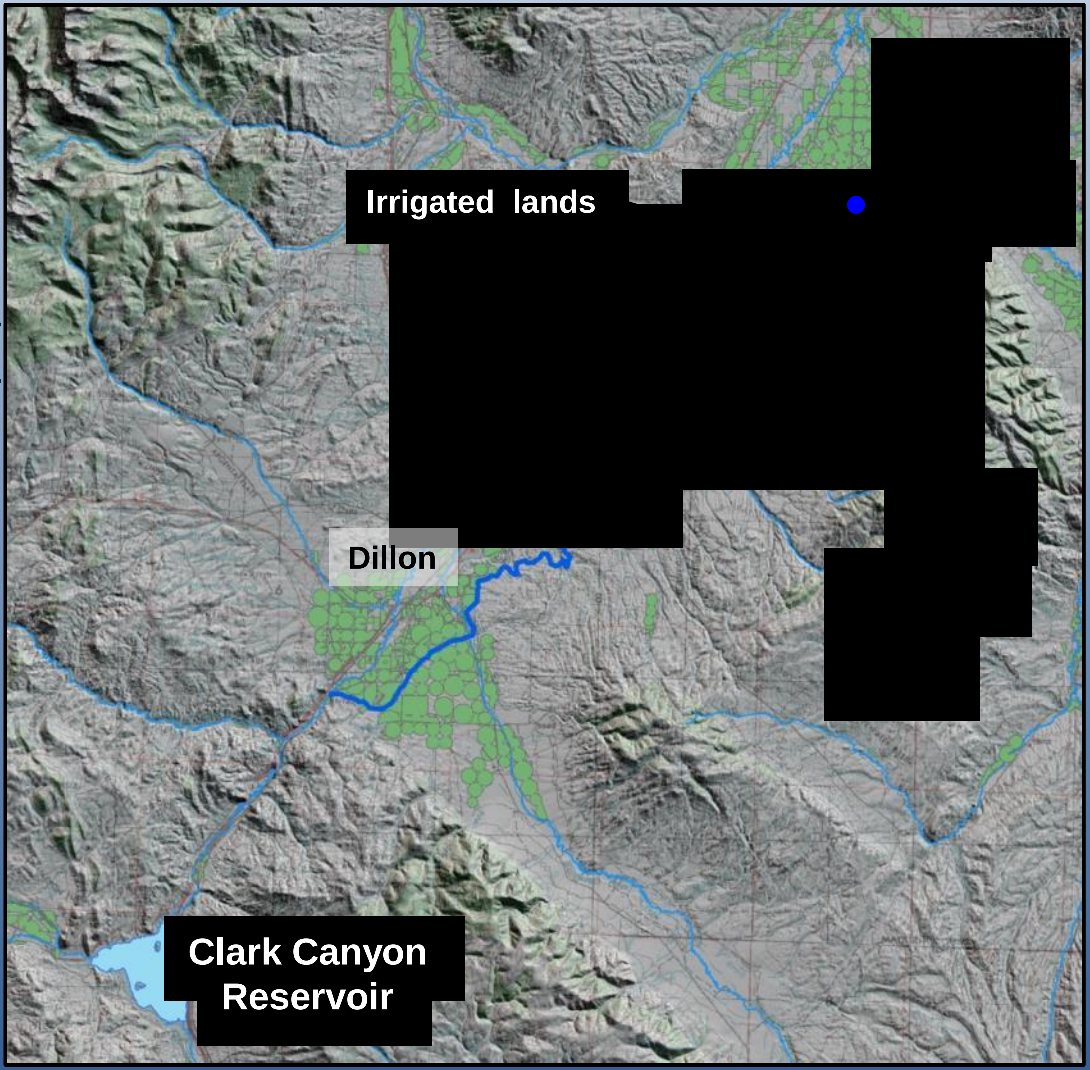


East Bench Canal Example

Hydrograph 130177, TD = 200 ft



Canal installed

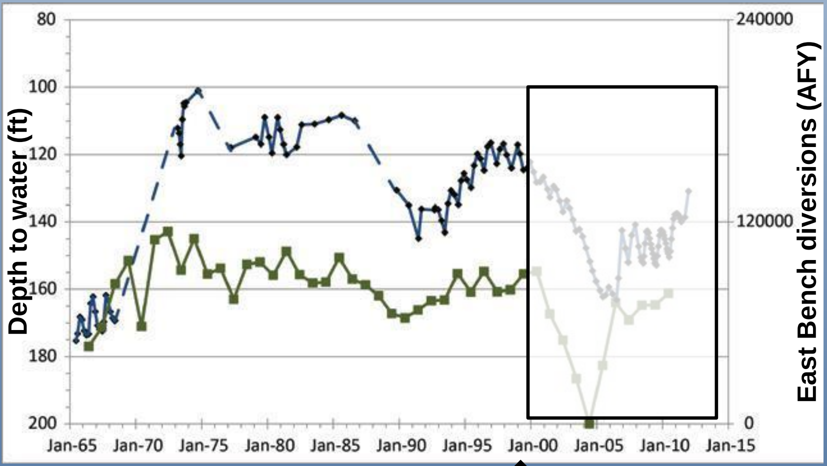


[redacted]

[redacted]

East Bench Canal Example

Hydrograph 130177, TD = 200 ft



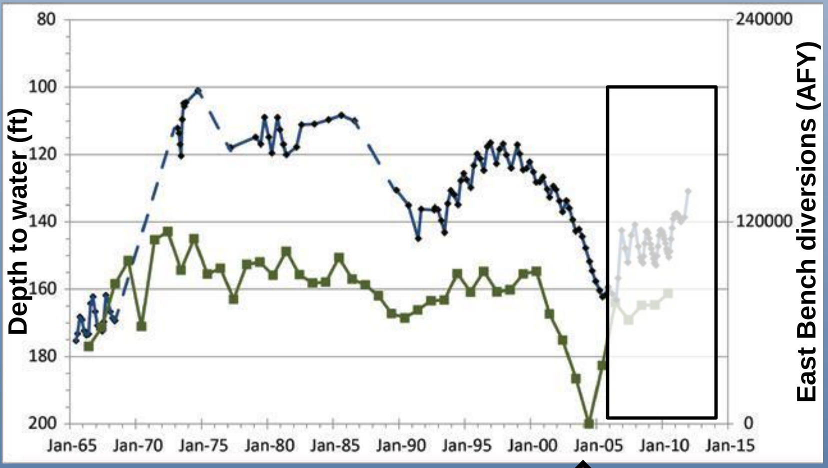
2000

[redacted]

Montana Bureau of Mines and Geology

East Bench Canal Example

Hydrograph 130177, TD = 200 ft




2004

[redacted]

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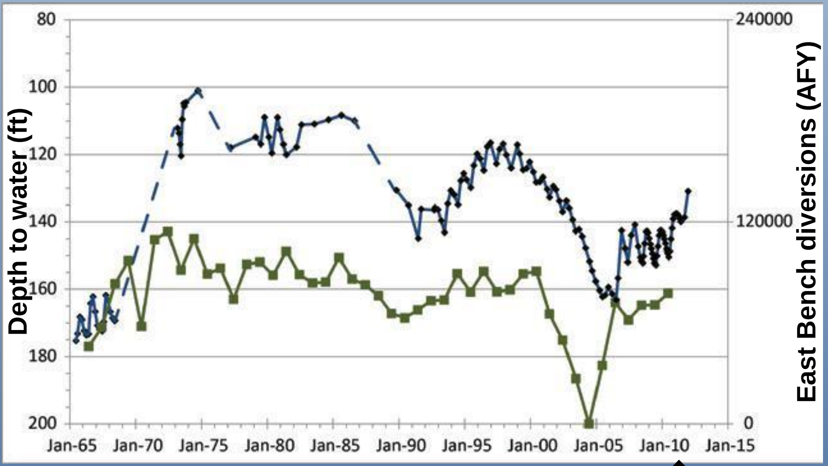
East Bench Canal Example

2011

Hydrograph 130177, TD = 200 ft



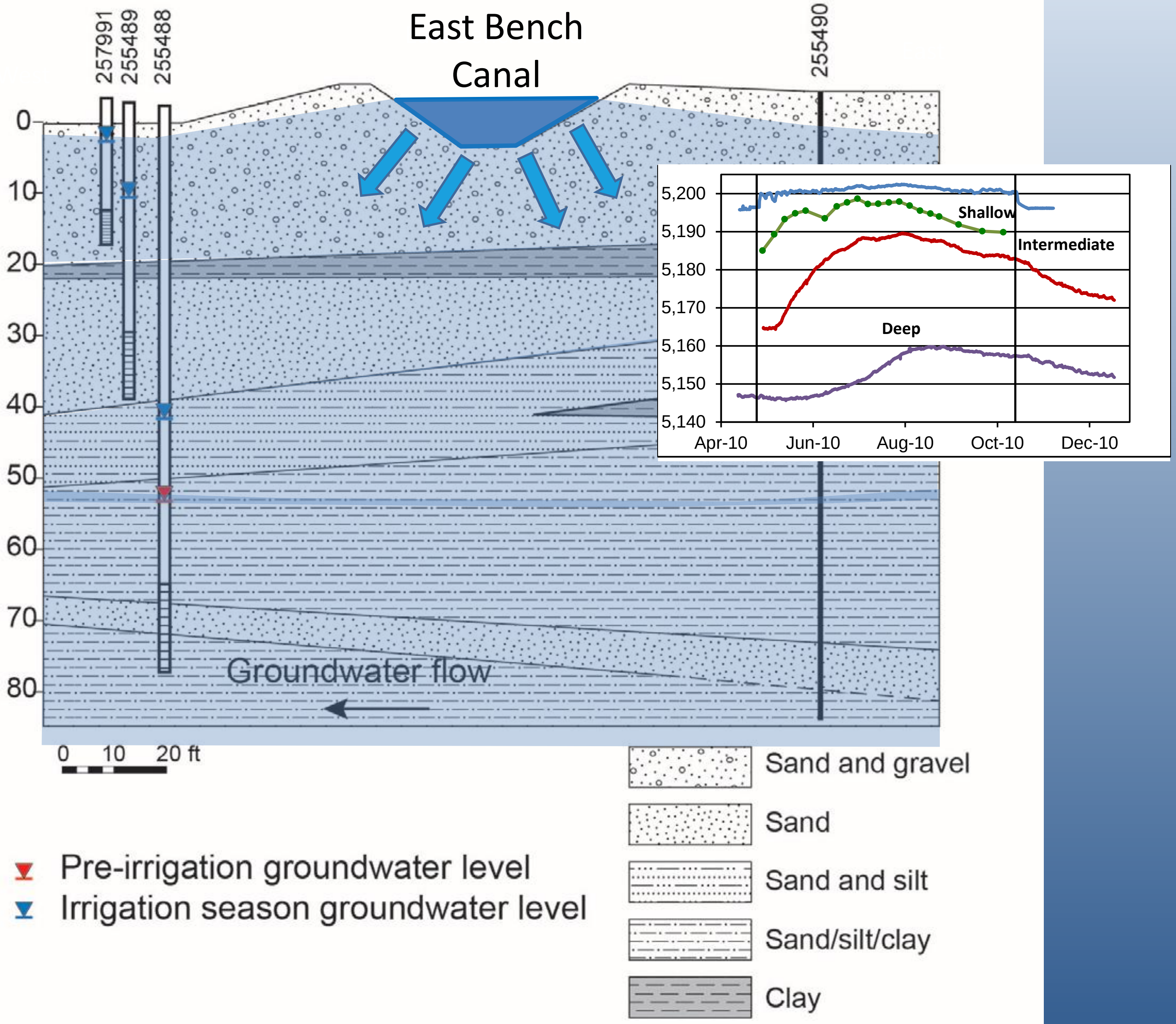
[redacted]

East Bench Canal

Seepage Rate….

2.2 cfs/mile

[redacted]

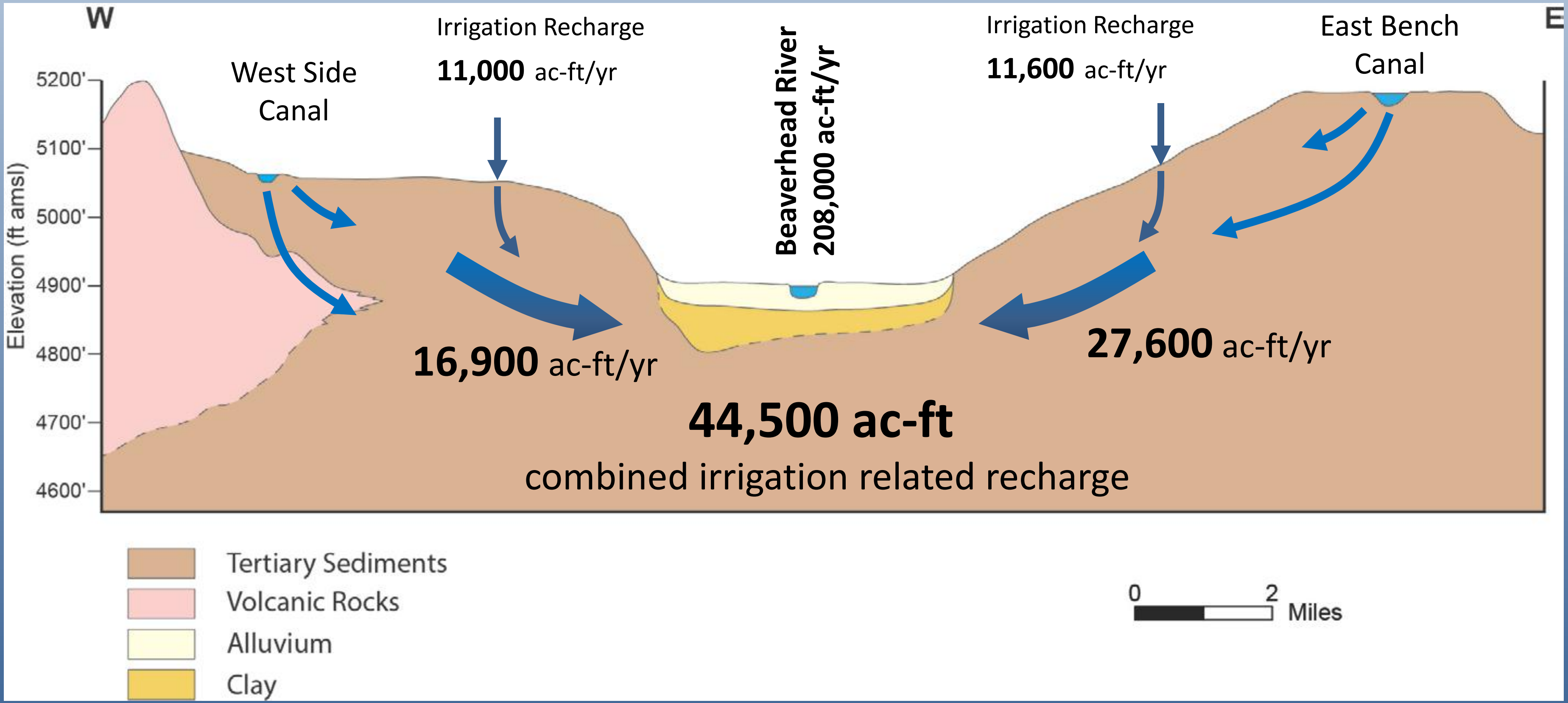

East Bench Canal
257991
255489
255488
255490
0
10
20
30
40
50
60
70
80
Groundwater flow
0 10 20 ft
5,200
5,190
5,180
5,170
5,160
5,150
5,140
Apr-10
Jun-10
Aug-10
Oct-10
Dec-10
Shallow
Intermediate
Deep
Pre-irrigation groundwater level
Irrigation season groundwater level
Sand and gravel
Sand
Sand and silt
Sand/silt/clay
Clay

Groundwater Recharge from Irrigation and Canal Seepage

2010

Seepage Loss
5,900 ac-ft/yr

Seepage Loss
17,000 ac-ft/yr



West Side Canal

Irrigation Recharge
11,000 ac-ft/yr

Beaverhead River
208,000 ac-ft/yr

Irrigation Recharge
11,600 ac-ft/yr

East Bench Canal

16,900 ac-ft/yr

27,600 ac-ft/yr

44,500 ac-ft
combined irrigation related recharge

MBMG
Montana Bureau of Mines and Geology

Seepage Loses

East Bench Canal	2.2 cfs/mile
West Side Canal	1.2 cfs/mile
Carey Canal (Boulder Rv drainage)	2.1 cfs/mile
BRID (Hamilton area)	1.4 – 3.1 cfs/mile
Bozeman area ditches	1.1 cfs/mile
Upper Big Hole	0.15-1.5 cfs/mile
Helena Valley	0.6 cfs/mile
Billings area	0.05-0.5 cfs/mile
Stillwater-Rosebud Watershed	1.1-1.8 cfs/mile
Greenfields Bench	0.45-4.7 cfs/mile

1 cfs = 724 acre-feet/year

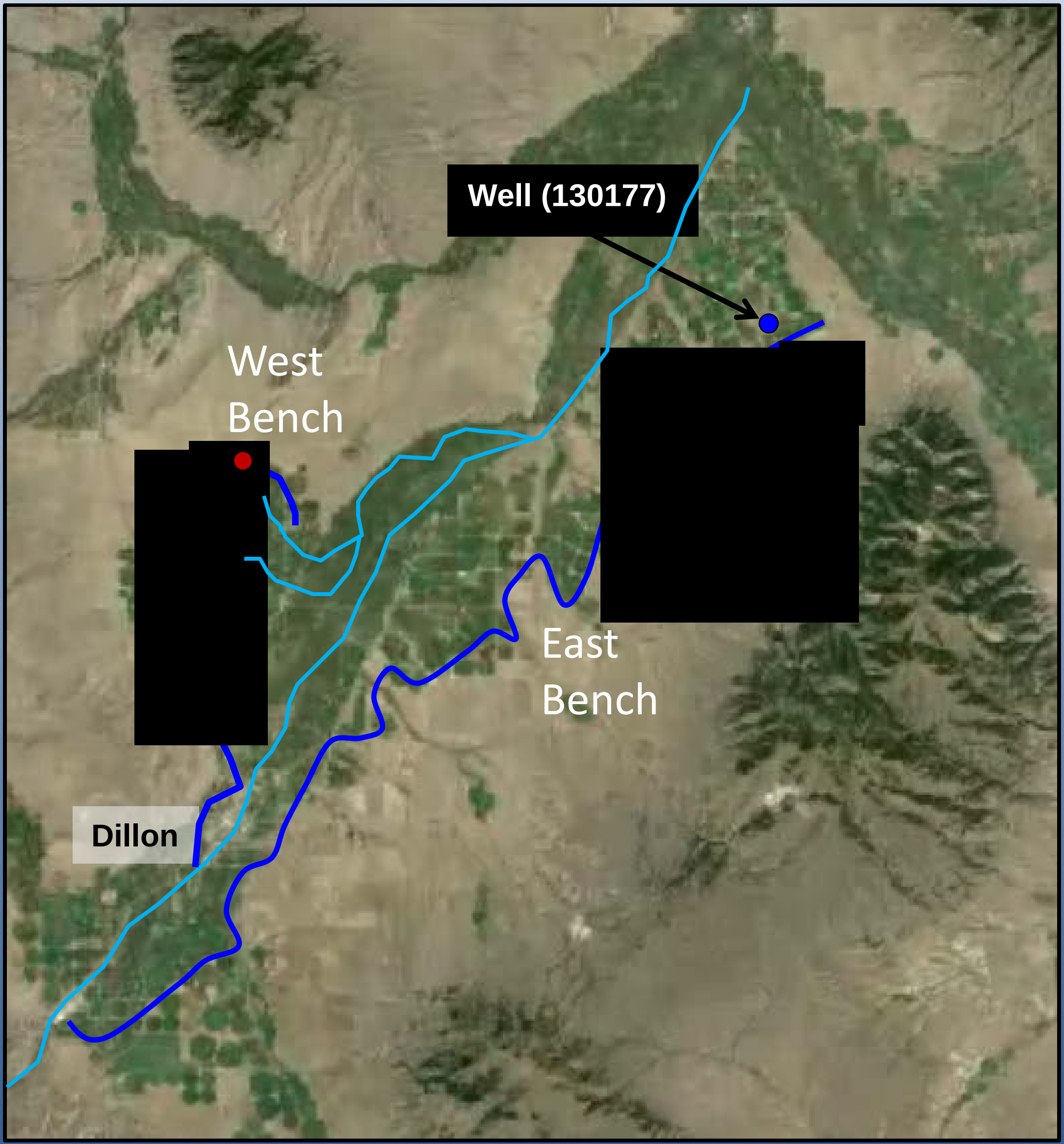
West Side Canal And Black Slough

Seepage Rate….

1.1 cfs/mile

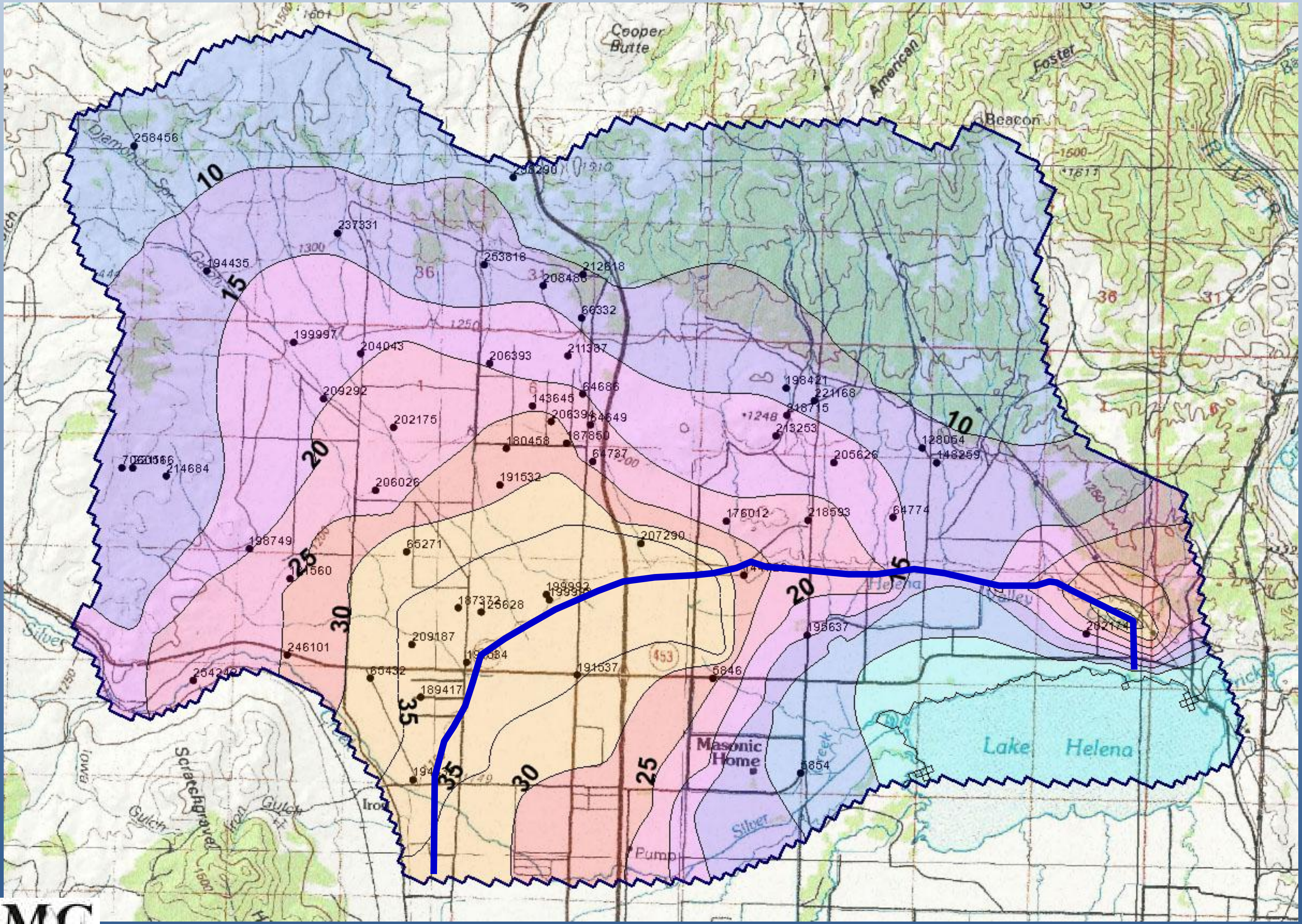
Modeling Scenario

Additional groundwater recharge by increasing period of canal flow offset stream depletion



North Hills

Removing the influence of the HVID Canal and associated irrigated areas.



Seepage Loses

East Bench Canal	2.2 cfs/mile
West Side Canal	1.2 cfs/mile
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Stillwater-Rosebud Watershed	1.1-1.8 cfs/mile
Greenfields Bench	0.45-4.7 cfs/mile

ATTACHMENT 4

RECLAMATION
Managing Water in the West

Date: March 4, 2016

To: David Trimpe (BOR), Gerald Benock (BOR)

From: Jim Forseth (BOR)

Subject: Lower Yellowstone Irrigation Project Crop Requirements

INTRODUCTION

The Lower Yellowstone Irrigation Project (LYIP) irrigated 55,158 acres according to the 2013 crop census. This is the number of acres that will be utilized for assessing the peak crop requirement for irrigation needs since it is the most representative of the market and current cropping patterns. The attached spreadsheets show the calculated crop demands and the acreages for the corresponding crops that were planted. The efficiency cited for each of the two demand calculations are for on-farm efficiency only and does not take into consideration the level of efficiency of the delivery/ transmission infrastructure. The efficiency of the transmission infrastructure will be addressed as well in this summary.

EVALUATION OF CROP REQUIREMENTS

In order to present a realistic representation of the demands of the district there are two efficiency levels included in this analysis in order to bracket the efficiency that would be realized with a mix of hand lines, gated pipe and pivot irrigation methods. The industry standard “Rule of Thumb” for irrigation efficiencies is flood irrigation is 30-40% efficient, gated pipe and siphon tubes are 50-60% efficient, hand lines and wheel lines are about 60% efficient and pivots are 65-75% efficient. There are some areas that would not be conducive to pivot sprinkler and some operators that would opt to not employ any method other than flood irrigation or only a combination of some of the above. Assuming that the entire district will be operated at maximum efficiency or will implement all of the recommended improvements is not realistic. The cumulative efficiency that is used for this assessment will be 70% which is the higher level of the bracket. This results in a crop requirement of 1,150 cfs when you take into account acres planted, peak daily crop ET and efficiency as calculated using standard NRCS guidelines for this area**. This level of efficiency is overly optimistic considering all of the variables that will impact on-farm efficiency throughout the 55,158 acres that were irrigated in this analysis. Some of the variables that effect efficiency are field size, field shape, soil type, topography of the field (has it been leveled for even distribution), flow rate available to the field, and diligence of the operator/irrigator in monitoring water sets. According to a Natural Resource Conservation Service (NRCS) study done by local staff in the area in 2004 (per phone conversation with Jaime Selting, NRCS staff, 2/26/2016), they found that flood irrigation has a 30-40% maximum efficiency application rate. This lower efficiency quickly reduces the overall efficiency of an irrigated area. An example is if a lateral supplies a 200 acre area that is planted in sugar beets. If all 200 acres are in pivot at 70% efficiency the water demand is 4 cfs. If all 200 acres are flood irrigated the demand is 7 cfs. If it is split in half with 100 each in flood and pivot the demand is 6 cfs.

Standard design practice utilizes a 6-8 gallon per minute (gpm) per acre for pipeline delivery to the field turnout for sprinklers and gated pipe and a 9-12 gpm per acre flow rate for flood. Given the layout of LYIP, it would be erroneous to assume that all laterals could be converted to pipe. Each lateral would have to be evaluated most importantly for proper grade and then flow rate required for the irrigated area. Included in this analysis is the assessment of the on-farm distribution methods. An area with a majority of flood irrigation will require a higher flow rate than a sprinkler. The biggest consideration with the conversion to pipeline is the siltation of the pipe. The water in the lower Yellowstone River is very turbulent for a majority of the year. This sediment load settling out of the water in the pipe would be a significant maintenance issue for piped laterals and would require regular flushing to remove it from the pipe and prevent blockage.

Surrounding districts such as Buffalo Rapids #2 and Sidney Water Users that pump their irrigation water directly from the Yellowstone River have to rebuild or replace their pumps every 3 to 5 years due to the sand and silt in the water. Buffalo Rapids #2 has three on river pumps in three separate locations that include the Terry (3,252.92 acres), Shirley (5,051.66 acres) and Fallon (3,225.33 acres) stations. They rotate their pumps at each station to be redone every 3 years due to the sediment load that is the water. According to the district if they go longer than 3 years the cost to rebuild the pump is too great as well as they go over their power consumption allotment which results in having to pay a fine. During the season they have issues with moss in the river which plugs their trash screens and causes cavitation which can render a pump inoperable in a very short time if not addressed right away. The motors on the pumps are rebuilt every 5 years. Sidney Water Users monitors their pump output and will replace their pumps somewhere between 3 and 5 years.

SUMMARY

In summary, the 1,150 cfs computed here for the peak crop demand is insufficient and will not fulfill the requirements of the LYIP crops because the reality of achieving an overall 70% on-farm efficiency is highly unlikely. The mixture shown here is common for the area but will fluctuate with market price and demands and what is represented here is an actual scenario for analysis. This flow would impact the irrigation district as a whole because it would cause shortages at critical demand times and in times of hot and dry weather that regularly occurs and will happen when the crop is at a critical period in the growth cycle for yield. If a crop is allowed to enter into the wilt stage the yield is adversely affected which causes undue hardship to the operators and the district. A sampling of a 44 day (July 17 – August 29, 2000) period when the demand was a minimum of 1,200 cfs showed the efficiency is approximately 81.6% at peak demand periods as shown by LYIP 2000 MC Water Data Calculation spreadsheet accounting. With this being the case another 15% *minimum* should be added to this flow rate. This assumes that all areas of the district have been evaluated and had all beneficial water conservation measures implemented both on farm and in the delivery system.

REFERENCES

**The peak daily ET of each crop was derived from the Irrigation Water Requirements (IWR) program. IWR is a crop consumptive use program developed specifically for NRCS use in development of Consumptive Use Table for the new NRCS Irrigation Guide. IWR is based on USDA Natural Resources Conservation Service Handbook: NEH Chapter 2, Irrigation Water Requirements, dated September 1993 and Original SCS Technical Release No. 21, dated April 1967. IWR uses the Blaney-Criddle Computation Method from the local Sidney, MT weather station. The Blaney-Criddle equation is a relatively simplistic method for calculating evapotranspiration. The peak consumptive use was developed using LYIP’s 2013 crop census data. Using the known factor of ET for each crop and the amount of acres of each crop we were able to calculate the amount of water required to meet peak demand. Calculations are based solely on unit conversions to go from in/day to cfs.

Crop Type	Irrigated Acres	Peak Daily ET (in/day)
Sugar Beets	20,160	0.34
Wheat	13,017	0.38
Barley	6,994	0.38
Corn	4,690	0.31
Alfalfa Hay	7,113	0.33
Grass Hay	2,493	0.27
Soy Beans	691	0.33

Peak Water Requirements

Sugar Beets	17,136	ac-in/day **	On-farm efficiency (%) =	**40%**
	1,428	ac-ft/day		
	62,203,680	ft^3/day		
	720	**cfs**		
Wheat	12,366	ac-in/day **	On-farm efficiency (%) =	**40%**
	1,031	ac-ft/day		
	44,889,125	ft^3/day		
	520	**cfs**		
Barley	6,644	ac-in/day **	On-farm efficiency (%) =	**40%**
	554	ac-ft/day		
	24,118,809	ft^3/day		
	279	**cfs**		
Corn	3,635	ac-in/day **	On-farm efficiency (%) =	**40%**
	303	ac-ft/day		
	13,194,143	ft^3/day		
	153	**cfs**		
Alfalfa Hay	5,868	ac-in/day **	On-farm efficiency (%) =	**40%**
	489	ac-ft/day		
	21,301,657	ft^3/day		
	247	**cfs**		
Grass Hay	1,683	ac-in/day **	On-farm efficiency (%) =	**40%**
	140	ac-ft/day		
	6,108,473	ft^3/day		
	71	**cfs**		
Soy Beans	570	ac-in/day **	On-farm efficiency (%) =	**40%**
	48	ac-ft/day		
	2,069,372	ft^3/day		
	24	**cfs**		

Total Water Requirement = 2,013 cfs

** (Irrigated Area (acres) x Peak Daily ET (in/day)) / Efficiency (%)= ac-in/day

Crop Type	Irrigated Acres	Peak Daily ET (in/day)
Sugar Beets	20,160	0.34
Wheat	13,017	0.38
Barley	6,994	0.38
Corn	4,690	0.31
Alfalfa Hay	7,113	0.33
Grass Hay	2,493	0.27
Soy Beans	691	0.33

Peak Water Requirements

Sugar Beets	11,424	ac-in/day **	On-farm efficiency (%) =	**60%**
	952	ac-ft/day		
	41,469,120	ft^3/day		
	480	**cfs**		
Wheat	8,244	ac-in/day **	On-farm efficiency (%) =	**60%**
	687	ac-ft/day		
	29,926,083	ft^3/day		
	346	**cfs**		
Barley	4,430	ac-in/day **	On-farm efficiency (%) =	**60%**
	369	ac-ft/day		
	16,079,206	ft^3/day		
	186	**cfs**		
Corn	2,423	ac-in/day **	On-farm efficiency (%) =	**60%**
	202	ac-ft/day		
	8,796,095	ft^3/day		
	102	**cfs**		
Alfalfa Hay	3,912	ac-in/day **	On-farm efficiency (%) =	**60%**
	326	ac-ft/day		
	14,201,105	ft^3/day		
	164	**cfs**		
Grass Hay	1,122	ac-in/day **	On-farm efficiency (%) =	**60%**
	93	ac-ft/day		
	4,072,316	ft^3/day		
	47	**cfs**		
Soy Beans	380	ac-in/day **	On-farm efficiency (%) =	**60%**
	32	ac-ft/day		
	1,379,582	ft^3/day		
	16	**cfs**		
		Total Water Requirement =	***1,342***	***cfs***

** (Irrigated Area (acres) x Peak Daily ET (in/day)) / Efficiency (%)= ac-in/day

Crop Type	Irrigated Acres	Peak Daily ET (in/day)
Sugar Beets	20,160	0.34
Wheat	13,017	0.38
Barley	6,994	0.38
Corn	4,690	0.31
Alfalfa Hay	7,113	0.33
Grass Hay	2,493	0.27
Soy Beans	691	0.33

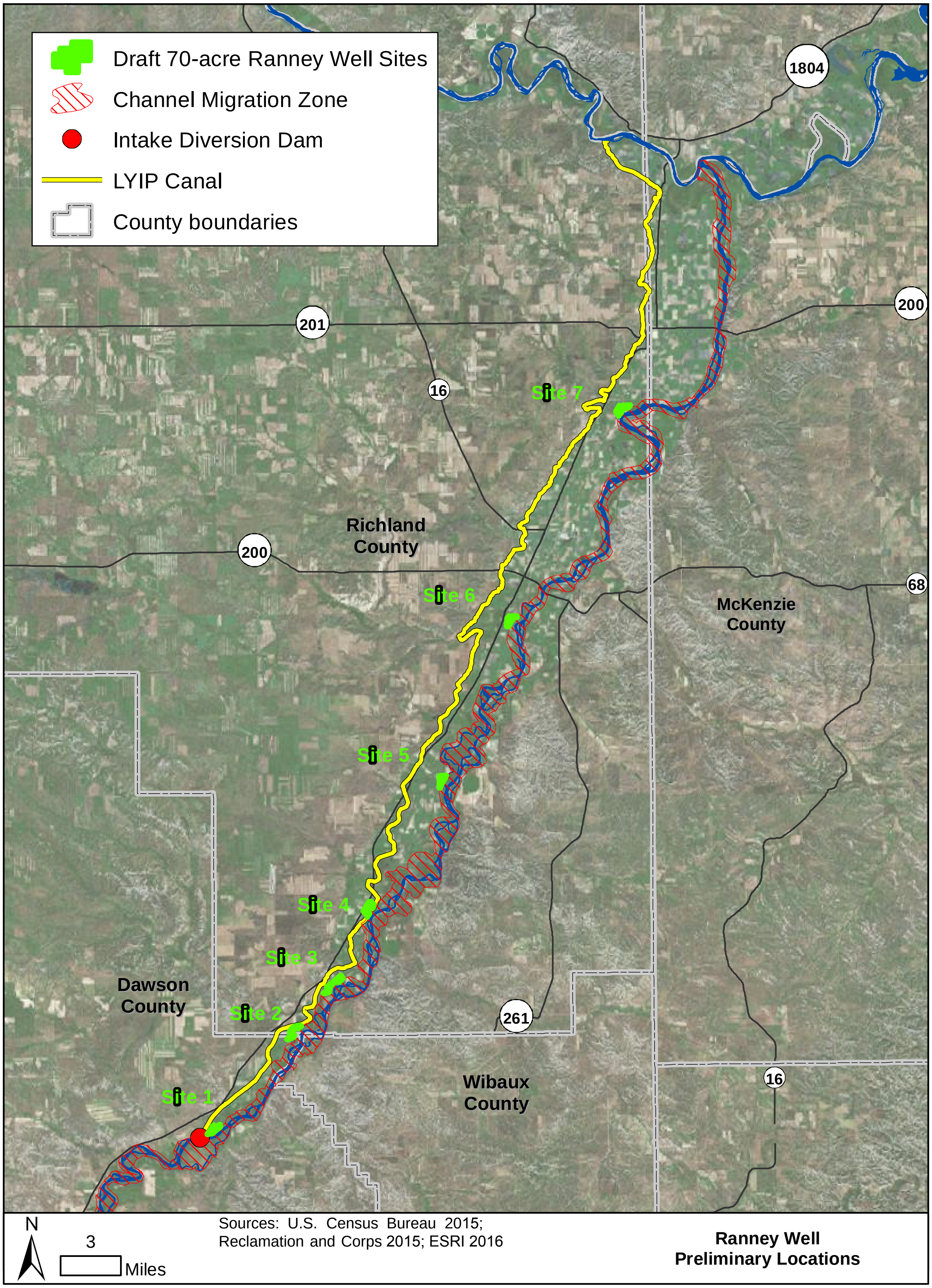
Peak Water Requirements

Sugar Beets	9,792	ac-in/day **	On-farm efficiency (%) =	**70%**
	816	ac-ft/day		
	35,544,960	ft^3/day		
	411	**cfs**		
Wheat	7,066	ac-in/day **	On-farm efficiency (%) =	**70%**
	589	ac-ft/day		
	25,650,928	ft^3/day		
	297	**cfs**		
Barley	3,797	ac-in/day **	On-farm efficiency (%) =	**70%**
	316	ac-ft/day		
	13,782,177	ft^3/day		
	160	**cfs**		
Corn	2,077	ac-in/day **	On-farm efficiency (%) =	**70%**
	173	ac-ft/day		
	7,539,510	ft^3/day		
	87	**cfs**		
Alfalfa Hay	3,353	ac-in/day **	On-farm efficiency (%) =	**70%**
	279	ac-ft/day		
	12,172,375	ft^3/day		
	141	**cfs**		
Grass Hay	962	ac-in/day **	On-farm efficiency (%) =	**70%**
	80	ac-ft/day		
	3,490,556	ft^3/day		
	40	**cfs**		
Soy Beans	326	ac-in/day **	On-farm efficiency (%) =	**70%**
	27	ac-ft/day		
	1,182,498	ft^3/day		
	14	**cfs**		

Total Water Requirement = 1,150 cfs

** (Irrigated Area (acres) x Peak Daily ET (in/day)) / Efficiency (%)= ac-in/day

Attachment 4
Potential Well Locations

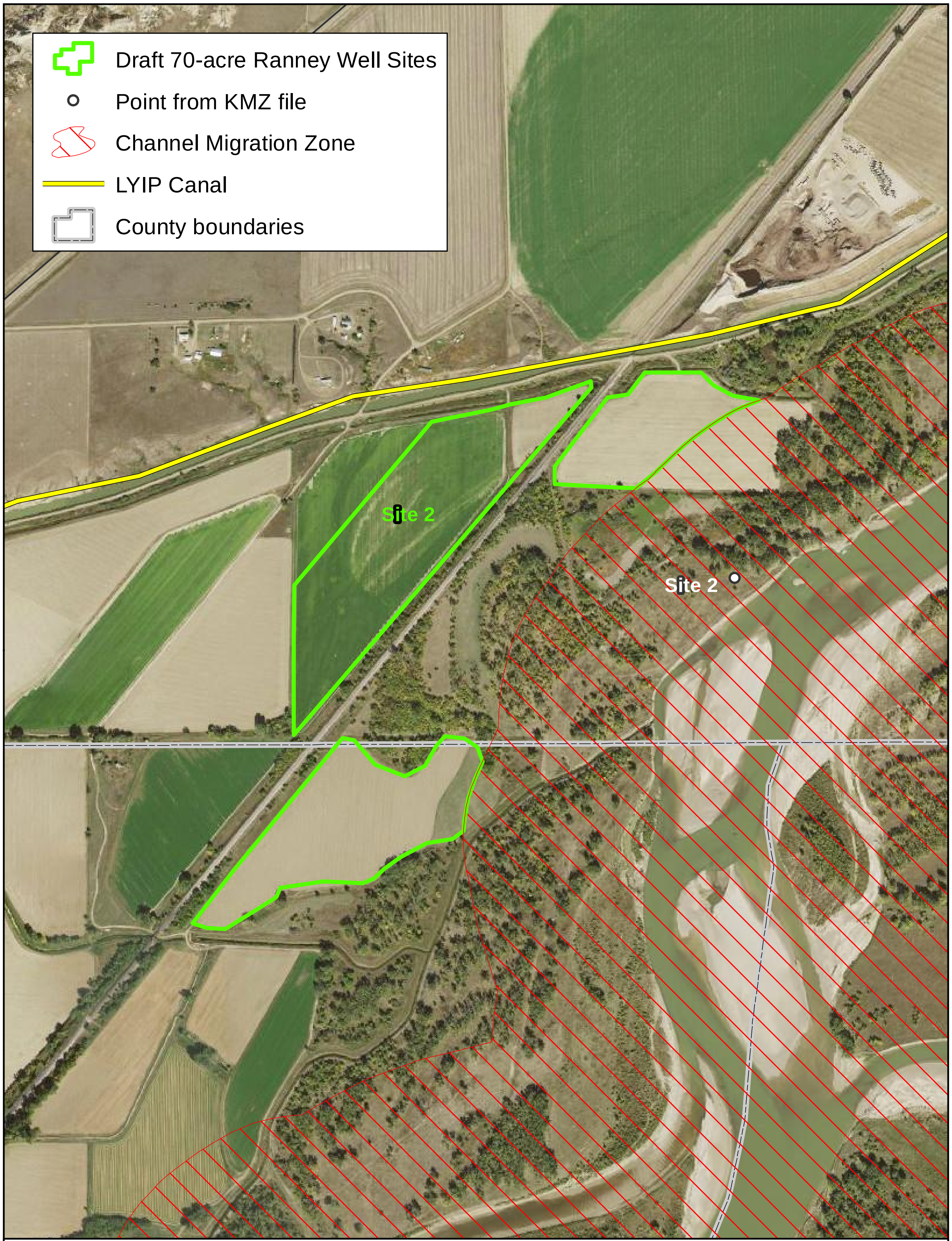


Sources: U.S. Census Bureau 2015;
Reclamation and Corps 2015; ESRI 2016

Ranney Well
Preliminary Locations

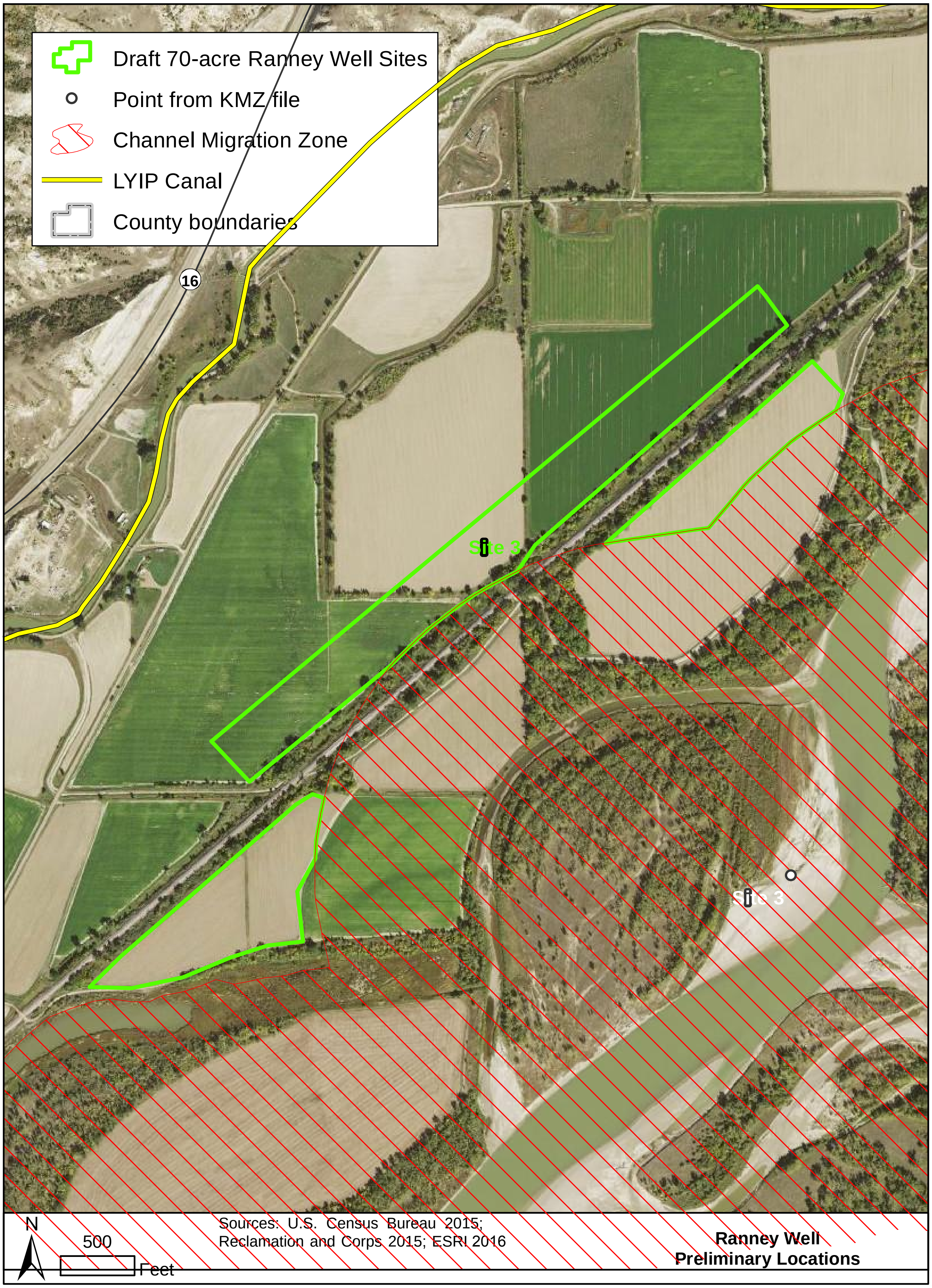
Sources: U.S. Census Bureau 2015;
Reclamation and Corps 2015; ESRI 2016

Ranney Well
Preliminary Locations



Sources: U.S. Census Bureau 2015;
Reclamation and Corps 2015; ESRI 2016

Ranney Well
Preliminary Locations

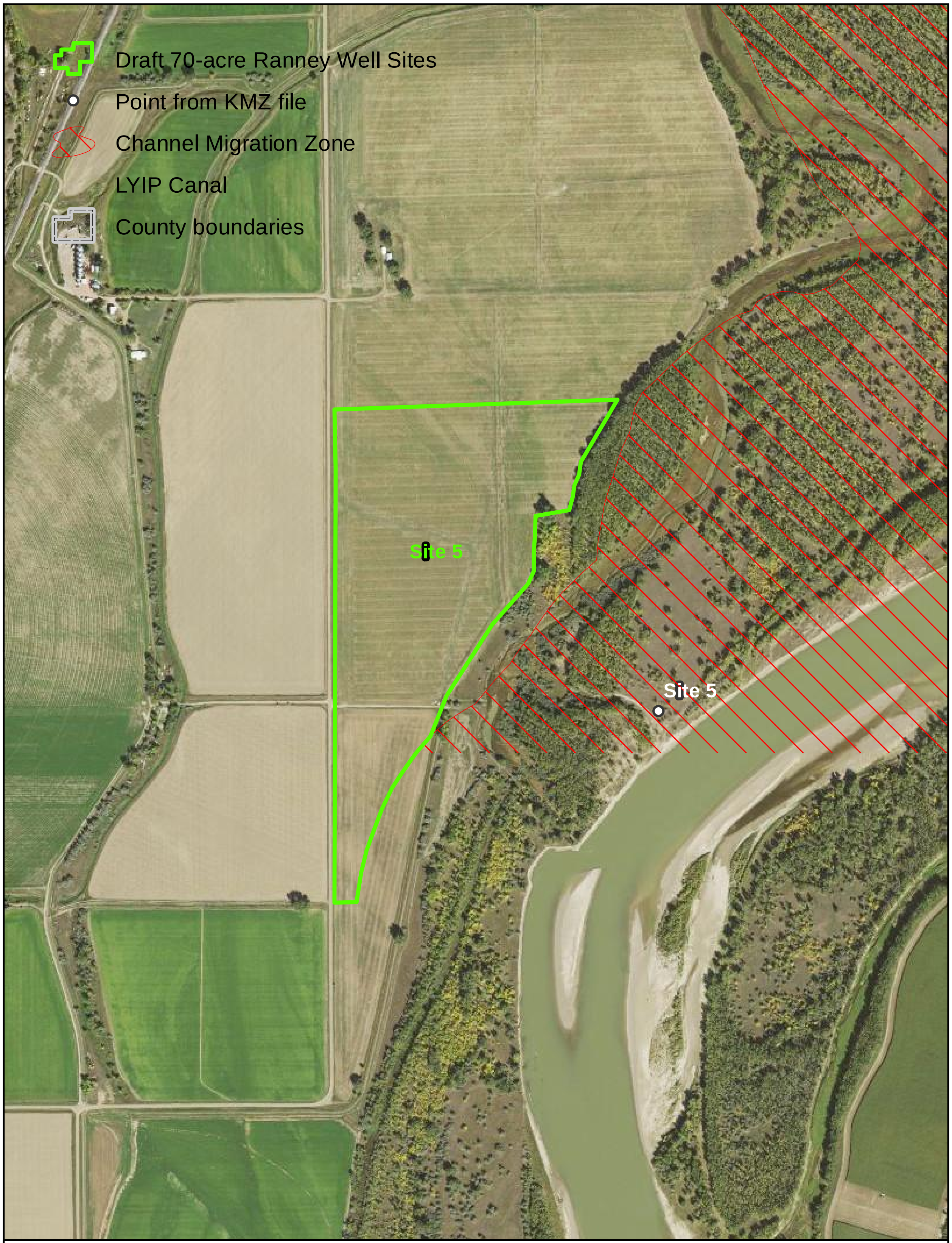


Sources: U.S. Census Bureau 2015; Reclamation and Corps 2015; ESRI 2016

Ranney Well Preliminary Locations

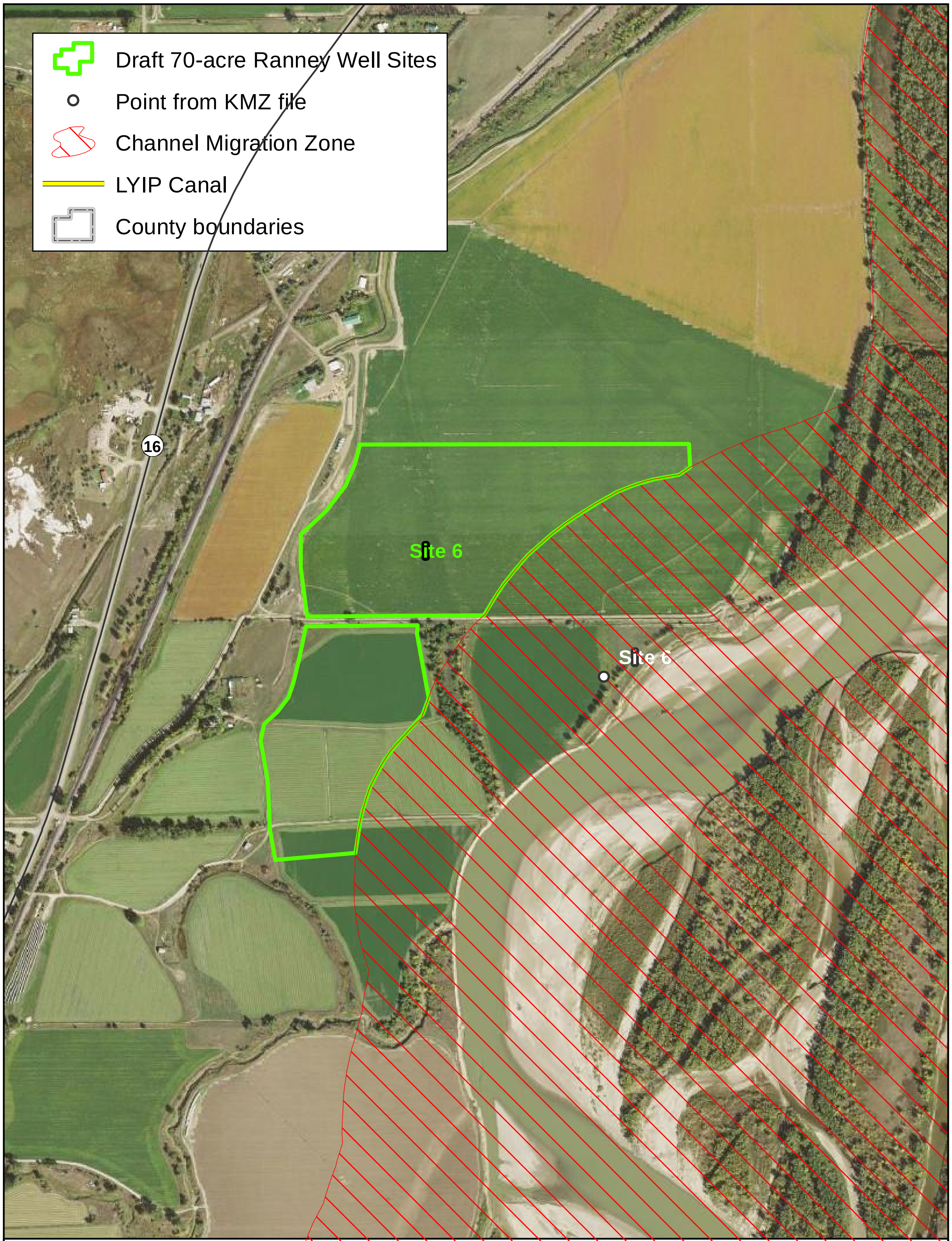
Sources: U.S. Census Bureau 2015; Reclamation and Corps 2015, ESRI 2016

Ranney Well Preliminary Locations



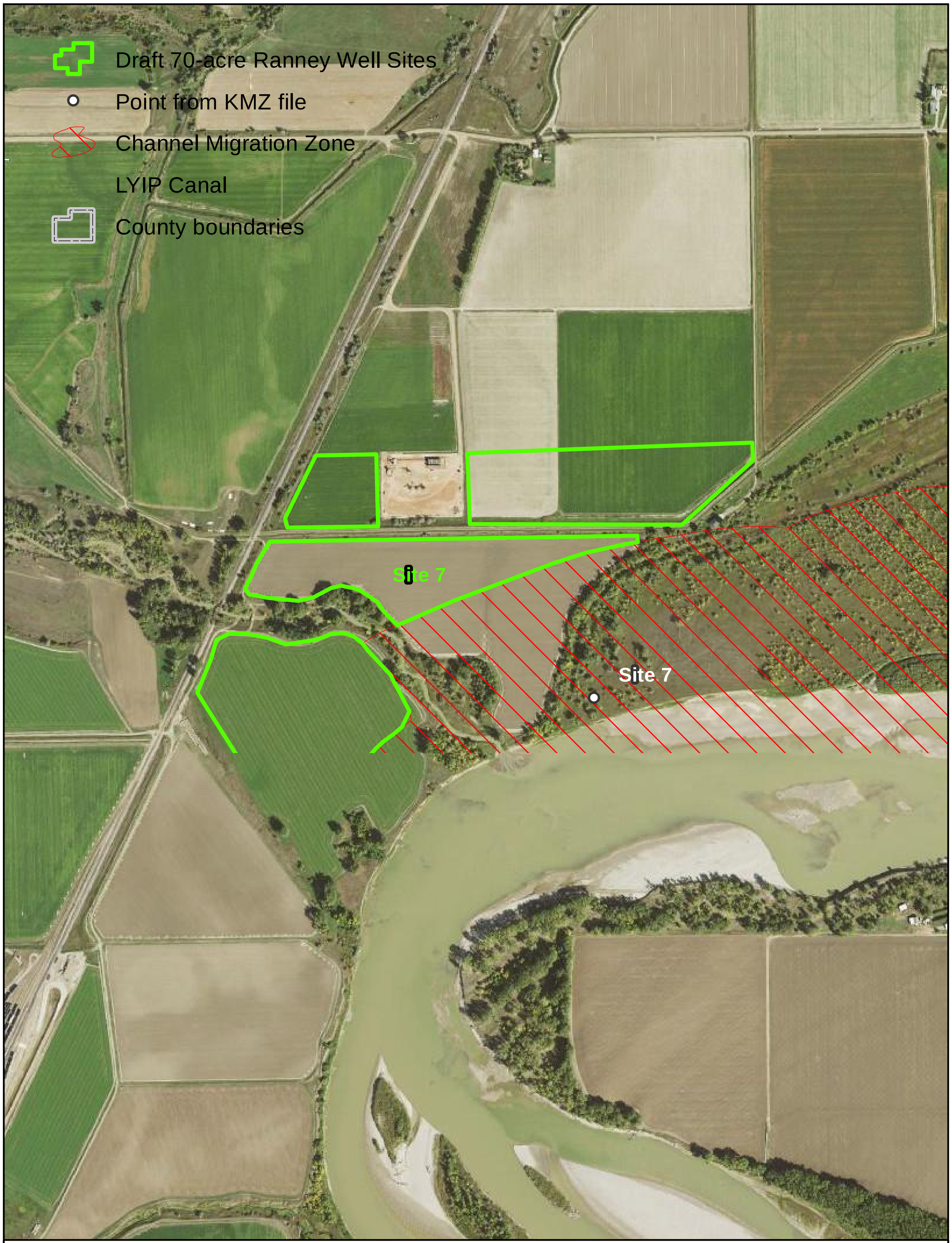
Sources: U.S. Census Bureau 2015;
Reclamation and Corps 2015; ESRI 2016

Ranney Well
Preliminary Locations



Sources: U.S. Census Bureau 2015; Reclamation and Corps 2015; ESRI 2016

**Ranney Well
Preliminary Locations**



Sources: U.S. Census Bureau 2015; Reclamation and Corps 2015; ESRI 2016

Ranney Well
Preliminary Locations