RECLAMATION
Managing Water in the West

Draft Water Supply Evaluation: Feasibility Study for Water Supply System, Santee Sioux Nation, Santee, Nebraska and Village of Niobrara, Nebraska

Santee Nation Water Supply Evaluation, Nebraska
Great Plains Region

U.S. Department of the Interior
Bureau of Reclamation

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Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

BUREAU OF RECLAMATION
Technical Service Center, Denver, Colorado
Water Resources Planning and Operations
Support Group, 86-68210

Draft Water Supply Evaluation: Feasibility Study for Water Supply System, Santee Sioux Nation, Santee, Nebraska and Village of Niobrara, Nebraska

Santee Nation Water Supply Evaluation, Nebraska
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Abbreviations

cfs	Cubic Feet per Second
DH	Drill Hole
ES	Executive Summary
gpd	Gallons per Day
gpm	Gallons per Minute
MGD	Million Gallons per Day
MSY	Maximum Sustained Yield
OSY	Optimum Sustained Yield
PMDD	Peak Month Daily Demand
RO	Reverse Osmosis
SPT	Standard Penetration Test
TDS	Total Dissolved Solids
TOC	Total Organic Carbon
USBR	Bureau of Reclamation

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EXECUTIVE SUMMARY

Public Law 108-204, Sec. 125, authorized Reclamation to conduct a feasibility study for a water supply and distribution system to serve the Santee Sioux Nation and adjacent communities. An interim product of that study entitled "Draft, Feasibility Study for Water Supply System, Economics and Water Demand Analyses Components, FY2006" projected that the water demand in the year 2050 for the Santee Sioux Reservation and adjacent Village of Niobrara would be 337,725 gallons per day of treated water. The peak month daily demand is projected to be 675,451 gallons per day. This Report documents the geohydrologic evaluation of potential water supply sites within the vicinity of the Village of Santee and provides design data suitable for feasibility level designs and cost estimates.

The geohydrologic evaluation was conducted in two phases. The first phase reviewed existing data and identified five sites within the vicinity of the Village of Santee that appeared to hold potential for a water supply system. An exploratory drill hole was installed at each of the identified sites, samples of the downhole materials were obtained for laboratory testing, and depth to water was measured (or estimated). The second phase consisted of prioritizing the identified sites, selecting one site for further testing, conducting an aquifer test at the selected site, and completing the analysis of the test data.

Two exploratory drill holes, designated DH-1 and DH-2, were previously completed in 1993 near the Village of Santee along the banks of the Missouri River about 2000 feet upstream of the Village. Phase 1 of this evaluation identified five additional sites for exploratory drilling, designated DH-3 through DH-7. DH-3 and DH-4 were completed in October of 2006, and DH-5, DH-6, and DH-7 were completed in April of 2007.

All sites were drilled to top of bedrock, the material sequence was logged, and several Standard Penetration Test (SPT) drive core samples of the materials were collected for laboratory analysis. The depth to bedrock in the seven exploratory drill holes ranged from 38.5 to 99.4 feet below ground surface. The materials encountered in the drill holes consisted primarily of alluvial deposits of sands, silts, lean clays, and some gravels. Bedrock in DH-1 was identified as Carlile Shale, bedrock in all the other drill holes was identified as chalk or shaly chalk of the Niobrara Formation.

Due to the proximity of six of the sites to the Missouri River, the sites were evaluated as to their potential suitability for four different types of water supply systems: bed-mounted infiltration galleries, on-land infiltration galleries, radial infiltration galleries, and traditional vertical wells. DH-7 site was only evaluated as a potential site for traditional vertical wells due to its distance from the Missouri River.

Estimated hydraulic conductivities for each site were obtained from the gradation analyses of the material samples collected. Conductivities were estimated using the Bureau of Reclamation (USBR) Method developed by Creager, Justin, and Hinds (1945). For Phase 1, it was assumed that the water would require Reverse Osmosis (RO) treatment and it would be between 75% to 85% efficient – that is, 75% to 85% of the feed water to the treatment plant would end up as treated product water, and 25% to 15% would be discharged as brine water. Based on this assumption, and using a conservative estimate of RO efficiency of 75%, the daily demand and peak month daily demand for feed water would be 450,300 (or about 312 gallons per minute - gpm) and 900,600 (or about 625 gpm) gallons per day respectively.

Based on the raw water volumes needed for treatment, six of the seven exploratory sites were evaluated for their potential as suitable sites for the four types of water supply systems, and the seventh site for its suitability for traditional vertical wells. Bed-mounted infiltration galleries would be technically viable at all the sites with the exception of DH-7 due to its distance from the Missouri River. On-land infiltration galleries would only be technically viable at DH-6 due to the excessive lengths of infiltration pipe required. Radial infiltration galleries would be technically viable at all seven sites, but because of the small peak demand of less than 1 million gallons per day a radial infiltration gallery would probably not be economical. Traditional vertical production wells are technically viable at all seven sites. Table ES-1 summarizes the maximum drawdown, theoretical maximum yield per well at each site at the indicated drawdown, and the theoretical optimal yield per well at each site.

Table ES-1. Theoretical well yields at sites DH-1 through DH-7.

Parameter	DH-1	DH-2	DH-3	DH-4	DH-5	DH-6	DH-7
Maximum Drawdown (ft)	45	30.5	16.5	30.5	19	24	10.5
Maximum Yield (gpm)	537	111	25	335	89	705	451
Optimal Yield (gpm)	360	74	17	225	60	472	302

Maximum drawdown is set at 50% of the saturated thickness at the well site; maximum yield assumes a 100% efficient well; optimal yield assumes a generally recognized lower limit within the water well industry for well efficiency as being 67%.

A ranking system was used to prioritize the seven sites for further testing. The ranking system included such criteria as estimated aquifer characteristics, type of supply system, relative potential yields, access, existing infrastructure, an RO treatment system, and tribal preferences. Based on these criteria, DH-7 site was selected as the preferred site for further evaluation.

Phase 2 consisted of an aquifer test conducted at the DH-7 site between October 9 and 12, 2007. The test layout consisted of one pumping well and four observation wells. Testing consisted of one 2-hour variable rate test to determine the maximum discharge possible from the test well, and one 24-hour constant rate test at 425 gpm. Water levels in all five wells were recorded using an automated data logger and pressure transducers during the pumping and recovery portions of the test. Additionally, manual water level readings were obtained on all five wells during the test, and the pump discharge was measured hourly during the pumping portion of the test.

The calculated transmissivities from the observation well test data varied between 2.59×10^4 and 4.18×10^4 ft^2/day. The average transmissivity based on just the observation well recovery data, and the average transmissivity based on the recovery data from all five wells are 3.26×10^4 and 3.71×10^4 ft^2/day respectively. Extrapolating the 3.26×10^4 ft^2/day transmissivity to a projected future well field at the DH-7 site indicates that the aquifer at the site could sustain a well with an estimated peak yield of approximately 625 gpm over a sustained period of time without well drawdown exceeding 50% of the saturated thickness. The estimated daily demand of approximately 312 gpm is well within the capability of the aquifer to support the demand over a long sustained period without the drawdown exceeding 25% of saturated thickness.

Results of water quality analyses for two water samples collected during the 24-hour test indicated that the water quality did not exceed any EPA Primary Drinking Water Standards. However, EPA secondary standards were significantly exceeded for Total Dissolved Solids (TDS) and sulfate. High levels of TDS and sulfate will produce taste and odor problems. The water was also extremely hard which could lead to scaling. Scale adversely affects plumbing fixtures in homes, especially water heaters and washing machines. Other constituents detected that may be of potential but not immediate concern were manganese, total organic carbon (TOC) and radionuclides (alpha particles).

Based on the existing data, and the results of this evaluation, the DH-7 site should provide a reliable water supply to meet the Village of Santee water needs out to the year 2050, although the high TDS will require more rigorous treatment. Sufficient data were gathered to develop feasibility cost estimates for a water supply source and treatment facility.

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1.0 Background

This report documents the evaluation of the suitability of several sites for a source water supply system along or in close proximity to the Missouri River within or near the Santee Indian Reservation, Knox County, Northeast Nebraska. The evaluation examined the potential for installing several different types of supply systems, including different infiltration gallery designs as well as more traditional vertical wells along the Missouri River in close proximity to the Village of Santee on the Santee Indian Reservation that would be capable of yielding a raw water peak month daily supply demand of 900,600 gallons per day (gpd)(or approximately 625 gpm, or roughly 1.4 cubic feet per second - cfs).

The evaluation examined the features and parameters of a number of different types of collector intake systems and traditional vertical wells. It also examined the existing lithologic information and hydrologic information related to the Missouri River alluvial sediments in the vicinity of the Village of Santee. Information sources are listed in the Reference section at the end of this document. For the evaluation of the Ranney-Type Collector system, this review looked at a report from International Water Consultants, Inc. for the City of Bismarck titled “Horizontal Collector Well Feasibility Study; Report of Findings” dated February 17, 2004. The International Water Consultants, Inc report presents the practical aspects for calculating the yields and other parameters for a Ranney-Type Collector system. Hantusch and Papadopulos (1962) derived a series of equations for radial collector wells for both confined and unconfined aquifers. The report by the International Water Consultants, Inc uses the Hantush and Papadapulos equation for collector wells near a stream in a water-table aquifer (Hantush and Papadopulos, 1962, Eq. 25).

The evaluation was conducted in two phases, both of which involved field activities. Phase 1 of the evaluation was to review existing literature and previous drilling reports for wells in the area. The Phase 1 field program installed and evaluated 5 drill holes in the vicinity of the Village of Santee. Thiele Geotech Inc. of Omaha, NE was contracted to drill and sample three exploration holes in or near the alluvial deposits of the Missouri River near Santee, NE. Two of the three holes (designated DH-3 and DH-4) were successfully completed in October 2006. Materials were encountered in the third hole (DH-5) which prevented completion of that hole with the specified wash-boring drilling method employed. Thiele Geotech Inc. subsequently finished DH-5 and two additional holes (DH-6 and DH-7) in April 2007 using a hollow-stem auger. Two previous drill holes (DH-1 and DH-2) were completed in August 1993 and are documented in ‘Water Supply Investigation for the Village of Santee’ by L. Cast, dated June 1994. Logs of these drill holes are included in Appendix A. All exploratory drill holes were backfilled and abandoned in accordance with local and state requirements.

The Phase 2 field program installed and pumped a test well, and installed 4 observation wells at the preferred site as determined from the evaluation of the previous drill holes and the Phase 1 field activity drill holes. The new pumping well and observation wells were used to conduct an aquifer test to determine aquifer hydraulic properties. These properties were used to assess feasibility and develop/prepare feasibility-level design costs for a water supply system using an appropriate technology – either a type of collector system or traditional vertical wells.

2.0 Purpose and Need

A recent planning document (US Bureau of Reclamation, 2006) projected that the Village of Santee treated water demand in 2050 will be 337,725 gallons per day (gpd) (0.337 Million Gallons per Day - MGD), with a peak month daily demand of 675,451 gpd (0.675 MGD). These demands are for treated product water from a planned RO treatment plant. A planning estimate for the Santee's RO recovery is between 75% and 85% of the raw feed water would be treated product water (see Water Quality Discussion in Section 4.5). Actual recovery may be higher than this, but it depends on the concentrations of contaminants and the selected properties of the RO membrane. For the purposes of this feasibility evaluation, a conservative recovery value of 75% will be used for estimating raw feed water amounts. Accordingly, the estimated raw feed water amounts using the conservative estimate of 75% recovery from the RO plant would be 450,300 gpd (0.45 MGD, or 312.7 gpm, hereafter rounded to 312 gpm) with a peak month daily demand of 900,600 gpd (0.900 MGD, or 625.5 gpm, hereafter rounded to 625 gpm). The remainder of this report will simply use the 312 and 625 gpm values in calculations and tables, unless noted otherwise.

The current water supply system (water source supply and treatment capacity) does not have the capacity to meet the anticipated demands. Accordingly, a new reliable source of raw water is needed in order for the Village of Santee to meet anticipated 2050 demands (US Bureau of Reclamation, December 8, 2005, "The Santee Sioux Reservation Water Supply Study Feasibility Study Alternatives Formulation/Screening Process Support Document"). The Purpose of this report is the evaluation of potential water supply sites within the vicinity of the Village of Santee and to provide design data suitable for feasibility level designs and cost estimates.

3.0 Phase 1 Evaluation

3.1 General Discussion

Figure 1 shows the locations of DH-1 through DH-7 in the vicinity of the Village of Santee. Table 3-1 summarizes the physical features of drill holes DH-1 through DH-7. These data are obtained from the driller's logs.

Horizontal collector intake systems, which are essentially just horizontal wells, are of two general types – bed-mounted and on-land (on-shore) systems. There are several parameters, as in more traditional vertical wells, that concern flow velocities within the pipes and screens that are also important to horizontal collector systems. These parameters are inflow velocity through the screen slots and the flow (axial) velocity along the casing/screen strings.

The inflow velocity through the screen slots, regardless of the orientation of the screen (horizontal, vertical, or inclined) should be limited to 0.1 ft/sec or less. Inflow velocities greater than 0.1 ft/sec can damage the screen and shorten the life of the well. Inflow velocities can be directly controlled by the proper selection and combination of 1) screen slot sizes, 2) screen diameter, and 3) screen length; and indirectly by 4) percent of open area per foot of screen (design of the slots), 5) percent of saturated aquifer screened (screen length), and 6) filter pack material (larger filter pack gradations will allow for the use of a larger slot size and greater yields).

The axial velocity inside the casing/screen string should be 3 ft/sec or less so that the head loss is 1 ft or less. Axial velocity is a function of pipe diameter and yield related by the following equation:

$$V = \frac{2.228 \times 10^{-3}\, Q}{\pi r^2} \qquad \begin{array}{l} Q \text{ in gpm} \\ V \text{ in ft/sec} \\ r \text{ in ft} \end{array}$$

The yield, Q, can be controlled by proper selection of screen characteristics (slot size, diameter, and length), and the burial depth below static water level (the term *H* for bed-mounted galleries, *d* for on-land galleries, and Zi for radial galleries) of the system.

There are a number of factors to be considered when deciding between a bed-mounted or on-land infiltration galleries (Driscoll, 1986, "Groundwater and Wells", pg 762). They are:

1. Yield requirements: galleries placed under a water body initially produce twice the yield of galleries placed adjacent to the water body. As the disturbed lake or river bed assumes its normal sedimentation regime, the transmissivity values will fall as finer grained particles infiltrate the filter pack material surrounding the screens. *This reduction in transmissivity values can be somewhat offset (mitigated for) by use of backwash systems (discussed below).*

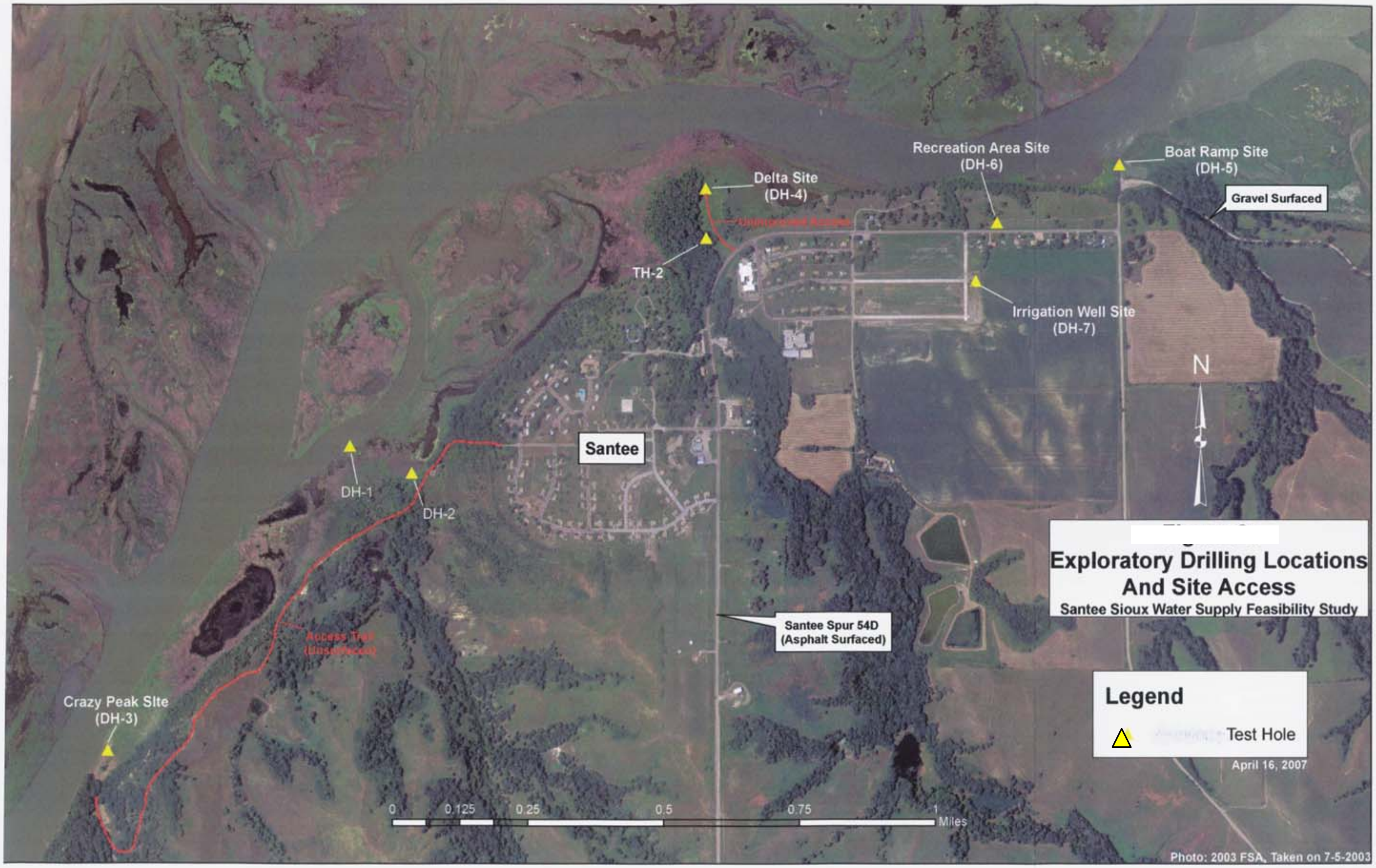

Figure 1. Location Map: showing the Village of Santee, exploratory drilling locations DH-1 through DH-7, and site access.

Table 3-1. Summary of Drill Hole Attributes. Logs presented in Appendix A

Attribute	DH-1	DH-2	DH-3	DH-4	DH-5	DH-6	DH-7
Location	Floodplain Site 1	Floodplain Site 2	Crazy Peak Site	Delta Site	Boat Ramp Site	Recreation Area Site	Irrigation Well Site
Driller	Terracon, Consultants	Terracon Consultants	Thield Geotech, Omaha, NB	Thield Geotech, Omaha, NB	Thield Geotech, Omaha, NB	Thield Geotech, Omaha, NB	Thield Geotech, Omaha, NB
Date	August 3, 1993	August 3, 1993	October 30, 2006	October 30, 2006	April 3, 2007	April 3-4, 2007	April 4, 2007
Depth to Water (ft)	2.7	1.3	Not obtained	Not obtained	Not obtained	27	29
PLSS	SE1/4 Sec 14 T33N R5W	SE1/4 Sec 14 T33N R5W	NW1/4 NW1/4 Sec 23 T33N R5W	NE1/4 NW1/4 NW1/4 Sec 13 T33N R5W	NE1/4 NE1/4 NE1/4 Sec 13 T33N R5W	1050' S & 1150' W of NE Corner Sec 13 T33N R5W	1600' S and 1650' W of NE Corner Sec 13 T33N R5W
Coordinates	N/A	N/A	N 551,825 E 2,570,026	N 557,381 E 2,575,894	N/A	N/A	N/A
Drill Method	3" roller bit	3" roller bit	3" Wash Bore	3" Wash Bore	3" Wash Bore/ Hollow Stem Auger	3.5" Hollow Stem Auger/3" roller bit	3.5" Hollow Stem Auger/3" roller bit
Depth	99.4 ft	40.1 ft	38.5 ft	66.0 ft	47.0 ft	82.5 ft	57.0 ft
GS Elev.	1,210 ft	1,210 ft	1,220 ft	1,218 ft	1,218 ft	1,238 ft	1,239 ft
Sample Method	SPT drive sampler	SPT drive sampler	SPT sampler	SPT sampler	SPT sampler	2" drive samples	2" drive samples
Number of Samples	9	4	4	5	4	8	6
Sediment Sequence	0-11 CL 11-25 SP-SM 25-67 SP 67-75 SP 75-92 SP-SM 92-99.4 Shale (bedrock)	0-11 CL-CH 11-25 SM 25-39 SP 39-40.1 Chalk (bedrock)	0-18 ML 18-37 SM 37-38.5 Shaly Chalk (bedrock)	0-20 ML 20-40 SP-SM 40-50 SP 50-64.7 SP 64.7-66 Chalk (bedrock)	0-2 compacted embankment 2-10 CL 10-21 CL 21-45.5 SM-SP 41.5-46 SM-CM 46-47 Chalk (bedrock	0-10 ML 10-27 CL 27-55 SM, ML, SP 55-70 GM 70-82.5 GM 82.5 Bit Refusal	0-2 CL 2-17 CL 17-25 CL 25-33 GM 33-37 SP 37-54 GM 54-57 SM 57 Bit Refusal
Bedrock	Carlile Shale	Niobrara FM	Niobrara FM	Niobrara FM	Niobrara FM	Niobrara FM	Niobrara FM

2. Water quality requirements: galleries located adjacent to a water body usually receive water that has lower turbidity and fewer bacteria than bed-mounted galleries because the water has been filtered more extensively.
3. Construction difficulties: it is generally more difficult to install a gallery beneath a stream or lake bed than along the shoreline adjacent to a water body. Bed-mounted systems generally cause more direct impacts on the water body, and have higher associated environmental impacts.
4. Maintenance considerations: maintenance and repairs are easier to perform on galleries installed adjacent to a water body. In general, more maintenance is required for bed-mounted galleries because fine material is continually added to the top of the filter pack by stream current.
5. Stability of the river course or lake level: rivers may meander great distances over relatively short periods, and either carry away a gallery placed on the river bank or cover completely a bed-mounted gallery with less permeable material. Changes in the elevation of a water body can also affect where the gallery is placed.

Traditional vertical wells and Ranney-Type Collector systems have some of the same considerations as bed-mounted and on-land infiltration galleries. However, because vertical wells and radial collector systems are not limited by open trench excavation depths, the placement of the intake screens has the flexibility to take advantage of water bearing zones, zones of high conductivity, zones of better quality waters, etc.

3.2 Bed-Mounted Infiltration Galleries

Bed-mounted infiltration galleries are systems where the screened intervals of the horizontal wells are beneath a water body such as a lake or river. The following figure (Driscoll, 1986, "Groundwater and Wells", pg 761) shows a typical cross-section of a bed-mounted infiltration gallery.

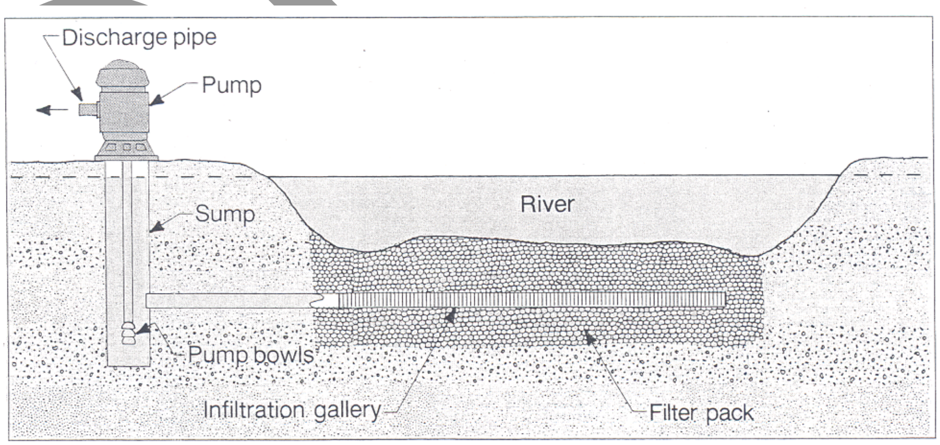

Figure 22.23. Cross section of pump placed in sump of infiltration gallery.

The following figure (Driscoll, 1986, “Groundwater and Wells”, pg 763) shows a plan view of some different configurations of screen arrangements for bed-mounted infiltration galleries.

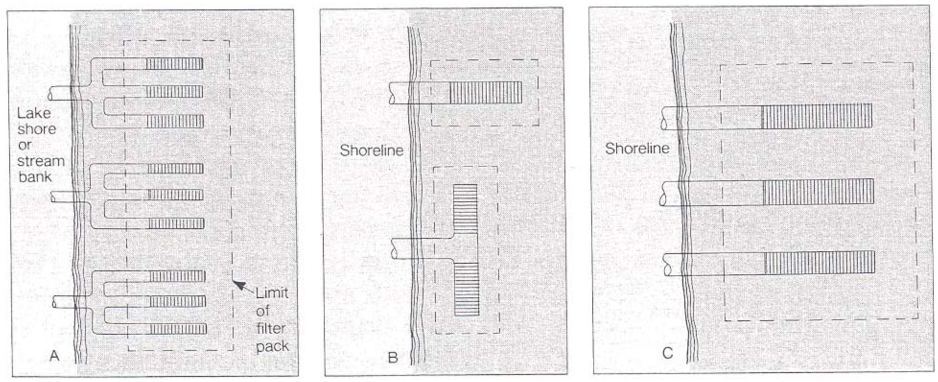

Figure 22.24. Screen arrangements for bed-mounted infiltration galleries.

The governing equation for bed-mounted systems is:

$$L = \frac{528\ Q \log(1.1\ d/r)}{0.25\ K\ H} \qquad \text{(Driscoll, 1986, equation 22.9, pg 763)}$$

where: L = length of infiltration screen, in ft
d = burial depth of screen below bottom of the water body, in ft
r = radius of the screen, in ft
K = hydraulic conductivity of filter pack, in gpd/ft^2
H = submergence depth (distance between the surface of the water body and the center of the screen.

From the equation it can be seen that K and H have the biggest impact on L, while d and r have much smaller impacts. Generally, decreasing K or H by half will double L; doubling K or H will decrease L by half. Decreasing by 50%, or doubling d or r will generally result in about a 10% change in L.

3.3 On-Land Infiltration Galleries

On-land infiltration galleries (also referred to as ‘on-shore’ galleries) are usually placed adjacent to a stream or river, less often adjacent to a lake. A single screen is run parallel to the bank or shore. Burial depths should be at least 4 feet, and because of limits on depths of trench excavations, they are generally not more than 25 feet deep. The following figures (Driscoll, 1986, “Groundwater and Wells”, pg 765) show a typical cross-section and plan view of an on-land infiltration gallery.

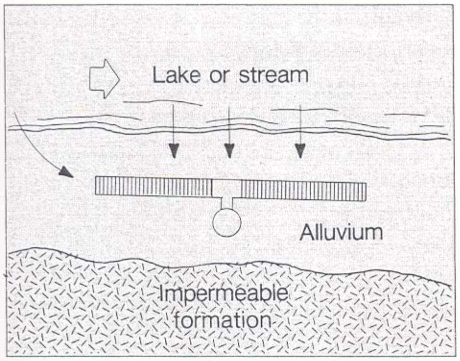

Figure 22.26. On-land infiltration gallery installed adjacent to lake or stream.

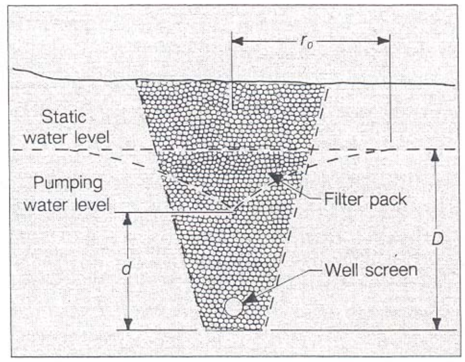

Figure 22.27. Terms used in the equation for determining the flow rate into the screen and the length of the screen.

The controlling equation for on-land galleries is:

$$L = \frac{2880\, r_o\, Q}{K\,(D^2 - d^2)}$$ (Driscoll, 1986, equation 22.11, pg 765)

where: L = length of infiltration screen, in ft
d = depth of saturated trench material above bottom of trench while operating, in ft
r_o = distance to point of no drawdown (zone of influence), in ft
K = hydraulic conductivity of the sediments, in gpd/ft^2
D = depth of the trench below static water level

From the equation, it can be seen that K, D, d, and r_o all have direct impacts on L. However, d and r_o are both dependent on Q, D, and K, thus only K and D have independent impacts on L. Generally, doubling K or D will decrease L; likewise decreasing K or D by 50% will increase L.

3.4 Collector Wells

A collector well is a special adaptation of infiltration galleries. Commonly called a ‘Ranney-type collector system’ after the Ranney Corporation which first developed this type of system, or a ‘radial collector system’, it consists of a series of screens (called laterals) extending radially outward from a large central vertical caisson constructed adjacent to a stream, river, or lake. This system combines the features of bed-mounted and on-land infiltration galleries because some of the laterals may extend beneath the water body while other laterals may be parallel to the bank or shoreline. The following figure (Driscoll, 1986, “Groundwater and Wells”, pg 768) shows a typical cross-section of a Ranney-type collector well.

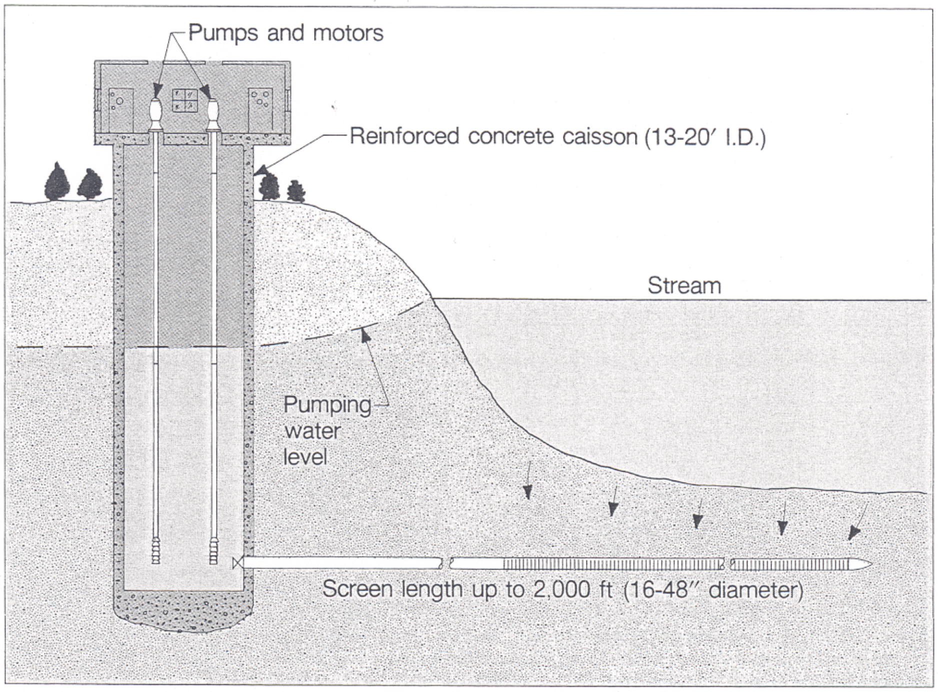

Figure 22.31. Collector well with screen jacked out from a large caisson. *(Hydro Group, Ranney Division)*

The governing equation for estimating the yield from a collector well near a stream in a water-table aquifer (Hantush and Papadopulos, 1962) under steady-state conditions is:

$$s_{cs} \geq (Q/2\,\pi K b) \quad \mathrm{Ln} \left[\frac{\Gamma^{\Gamma}}{\varepsilon^{\varepsilon}} \left[\frac{[b/\pi\, r_w]^2}{2(l - \cos \pi/b(2_{Zi} + r_w)} \right]^{b/4l} \right]$$

where: s_{cs} = drawdown in collector well, in ft
Q = yield of collector, in ft^3/day
K = hydraulic conductivity of materials, in ft/day
b = saturated thickness of aquifer, in ft
Γ = $(2\,(a - r_c))/l$
a = effective distance to a line of recharge, in ft
l = average length of laterals, in ft
r_c = radius of collector caisson, in ft
ε = $(2a - 2r_c - l)/l$
r_w = effective radius of each lateral, in ft
Zi = depth of lateral below static water level, in ft

Generally, the closer the caisson is to the recharge source the higher the yield; the deeper, longer, and larger the diameter the laterals, and the more of them, the higher the yield. The saturated thickness above the laterals has a greater impact than does the distance from the recharge source; basically if the saturated thickness is doubled then the yield will be doubled. However, if the distance to the recharge source is decreased by 50%, then the yield only increases by around 30%. Doubling the length of the laterals or doubling the radius of the laterals only has between a 15% and 20% increase in yields.

3.5 Backwash System

A backwash system can be installed with any infiltration gallery, although it is more difficult to install in a Ranney-Type Collector well than in systems installed by excavation or trenching. The system consists of perforated pipes permanently installed in the filter pack material or native materials above the screens. Compressed air (or pressurized water) can be forced through the perforated pipe to inject air into the filter pack. This has the effect of agitating the finer grained materials that tend to infiltrate into the filter pack over time. The agitation has the effect of loosening the finer grained materials and mobilizing them so that they move out of the filter pack and into the water body where they are dispersed or removed by the natural water currents. Chemicals can also be injected into the backwash pipes, or the screens, for treatment of iron bacteria, and organic and/or inorganic incrustations. The following figure (Driscoll, 1986, “Groundwater and Wells”, pg 768) shows a typical configuration for a backwash system. In the figure, the backwash pipes are perpendicular to the collector pipes, but the backwash pipes can also be installed so that they are parallel to, or aligned with, the collector pipes.

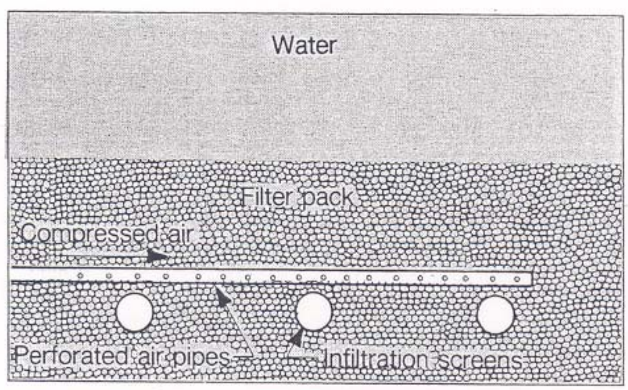

Figure 22.30. Placement of perforated pipes used to backwash infiltration gallery.

Backwash systems are a way to mitigate for the normal build-up of fine grained sediments in the bed-mounted filter pack material and can also be used in on-land infiltration galleries and radial collector systems. Backwash systems are obviously not suitable for vertical wells.

3.6 Computations

Driscoll, Chapter 22, pages 761 to 769, provides a discussion of infiltration galleries including equations (22.9 and 22.11 presented above) for computing the production rates, Q, of various designs and the length of screen necessary to obtain a desired Q. Hantush and Papadolpulos (1962) developed an equation (presented above) for calculating the drawdown in the caisson for a Ranney-type collector well. By rearranging their equation, it can be used to calculate the production rate of a single lateral or the entire collector well.

These equations, both from Driscoll and from Hantush and Papadopulos (1962) were used to calculate the theoretical yields and required length of screens for bed-mounted infiltration galleries, on-land infiltration galleries, and Ranney-type collector wells at the sites of the seven drill holes, DH-1 through DH-7. The results of these calculations are discussed below. A copy of the Excel spreadsheet used to perform the calculations, from which the following tables are derived, is available upon request from the BOR.

In the following discussions, and for the remainder of the report, the following symbol and unit conventions will be used, unless otherwise noted:

Q - yield in gallons per minute (gpm),
T - transmissivity in square feet per day (ft^2/day),
K - hydraulic conductivity in feet per day (ft/day),
312 gpm - represents the 2050 estimated raw water feed (see Section 2.0),
625 gpm - represents the 2050 estimated peak month daily demand (PMDD) for the raw water feed (see Section 2.0).

In the computations, several assumptions were made about conditions and properties. These assumptions are that:

1. The hydraulic conductivity of the alluvium is unknown; for each site it was estimated from gradation samples collected from the exploratory drill holes using the USBR method (Creager, Justin, and Hinds, 1945). A table of computed values of *K* based on the USBR method is presented in Appendix J, on page J-9. A discussion of the USBR method is also in Appendix J, beginning on page J-10. The gradations curves from each drill hole are in Appendix A following the log for each drill hole. This method provides only rough estimates of *K* obtained from samples that do not retain any semblance of stratification, and as such should not be taken as true or final estimates of field conditions. However, in the absence of any aquifer testing data from the exploratory drill holes, this method is useful as a relative comparison between the seven drill sites.
2. The river is about 15 feet deep on average,
3. There is sufficient lateral extent of the alluvial materials present to accommodate the lengths of laterals and screen required.
4. The estimated demand in 2050 will be 312 gpm, with an estimated PMDD of 625 gpm. These demands are for raw feed water to a treatment plant, but will change if either part of assumption 5 changes.
5. The assumed treatment alternative is RO with a conservative estimated operational efficiency of 75%. This means that 25% of the water supplied to the treatment plant is lost through brine removal. Accordingly, to account for the treatment loss and to meet the PMDD of 675,451 gpd, the source water supply system must be capable of supplying 900,600 gpd (625 gpm) to the treatment plant. Alternate treatment processes, while not considered for this report, may be chosen based on the water quality of the raw water supply.

6. The recharge source is assumed to be the Missouri River. Site specific testing will be required to determine the actual recharge source, or sources, and the amounts of potential recharge from each source which could influence the determination as to the most suitable system at each site.
7. The site conditions are uniform throughout each site. Actual field conditions may significantly change the results of the calculations.

Table B-1 (in Appendix B - Computation Tables) is a table of parameter values for all 7 drill sites used in the calculations for on-shore, bed-mounted, Ranney-Type Collector systems, and traditional vertical wells.

3.6.1 Bed-Mounted Infiltration Gallery

Table B-2 (in Appendix B - Computation Tables) is a table of parameter values for the bed-mounted equation (equation 22.9 above) with the calculated lengths of buried intake screen required for a variety of conditions. From the previous discussion of a bed-mounted infiltration gallery, it can be seen that the local material's hydraulic conductivity does not factor into the equation. This is due to three attributes of the bed-mounted gallery: 1) the backfill material in the trench into which the screens are installed has a direct hydraulic connection with the bed of the water body; 2) the backfill material typically has a much higher conductivity than the local materials; and 3) the trench is wide enough to minimize any hydraulic interaction with the local materials.

Accordingly, Table B-2 would apply to any bed-mounted infiltration gallery regardless of where it is located. So Table B-2 is applicable for sites DH-1 through DH-6. Since site DH-7 is over ¼ mile from the shoreline, the application of a bed-mounted infiltration gallery at DH-7 is not applicable.

Some assumptions unique to the bed-mounted infiltration gallery computations are that:

1 - The intake screen is buried 10 feet below the bottom of the river or lake, and
2 - The flow velocity through the screen does not exceed 0.1 ft/sec.

In the case of the second assumption, the lengths of screen shown in Table B-2 are the minimum lengths required without considering the intake velocity. If the calculated flow velocity through the screen exceeds 0.1 ft/sec then sufficient additional screen will have to be added to bring the flow velocity down to 0.1 ft/sec or lower. The calculation of flow velocities through the screen can only be made after a proper combination of screen slot size and filter pack gradations has been determined based on gradations of the river or lake sediments.

3.6.2 On-Land Infiltration Gallery

Tables B-3a through B-3f (in Appendix B - Computation Tables) are the computation tables for the on-land infiltration galleries at each of the six sites, DH-1 through DH-6. No computations were done for site DH-7 as it is over ¼ mile from the shoreline and an on-land infiltration gallery at DH-7 would be meaningless.

As was the case for the bed-mounted infiltration gallery, several assumptions had to be made in the calculations for the on-land infiltration gallery. Those assumptions were:

1 - The deepest that the trench for the pipe could be excavated was 30 ft,
2 - Depths to water were not recorded for DH-3 through DH-5, so the depth to water was estimated as the difference between the ground surface elevation of the drill hole and the elevation of the nearest recharge source. When the nearest recharge source was Lewis and Clark Lake, the water elevation was taken from the USGS Santee Quadrangle topographic map, (this is reported as being at elevation 1,208 ft while it is noted that the COE reports that the average daily lake elevation for the period 1967 to 2005 varies between 1,205.2 ft and 1,207.9 ft). When the nearest recharge source was the Missouri River, the water elevation was taken as the contour elevation for the river at that point as shown on the USGS Santee Quadrangle topo map.
3 - The maximum allowable drawdown was 50% of the calculated saturated thickness at each site,
4 - The hydraulic conductivity of the local materials was taken from the gradation analysis of the sample collected nearest to 30 feet below ground surface, and
5 - The flow velocity through the screen does not exceed 0.1 ft/sec.

In the case of the fifth assumption, the lengths of screen shown in Tables B-3a through B-3f are the minimum lengths required without considering intake velocity. If the calculated flow velocity through the screen exceeds 0.1 ft/sec then sufficient additional screen will have to be added to bring the flow velocity down to 0.1 ft/sec or lower. The calculation of flow velocities through the screen can only be made after a proper combination of screen slot size and filter pack gradations has been determined based on gradations of the sediments along the trench alignment.

Tables B-3a through B-3f have exceedingly large amounts of pipe required for the on-shore infiltration galleries. This is due in large part to the low estimated conductivities of the surficial materials.

3.6.3 Ranney-Type Collector Well

Yields for a radial collector system at each DH site were calculated for three different lengths of laterals and for two different diameters of the laterals. The values input for *K* and the inflow velocity are held constant and the burial depth of the laterals were set to the estimated bottom depth of the highest conductivity zone.

Figures B-2 through B-8 show the number of laterals versus the yields for six different conditions at each drillhole site. The six conditions represent three different lengths (100', 150', and 200', except for site DH-3) of two sizes of laterals (1' diameter and 2' diameter). The concept behind longer lengths of laterals is to spread the zone of influence out over a larger area and thus reduce the amount of drawdown at any given point within the zone of influence. From the governing equation for radial collector systems (Section 3.4) the number and length of the laterals has a greater influence on the capacity of the overall system than does the radius of the laterals. The 1' and 2' diameters are common sizes for laterals in medium sized collector systems, although larger diameters are also commonly used. Diameters down to 4" to 6" are more common in smaller sized systems, generally less than 1.5 MGD. Systems below 1 to 1.5 MGD are not considered by industry practice to be cost effective. The caisson diameter is held constant at 20' in the calculations, but smaller diameters down to 13' are possible which would help the cost effectiveness of smaller systems.

At each site, the depth of the laterals was set to the depth of the zone with the highest estimated conductivity. The hydraulic conductivity for the system as a whole was set at the average of the highest conductivity zone plus all the saturated zones above the level of the laterals. The distance to a line of recharge was the estimated distance from the drill hole to the nearest shoreline.

Although the Irrigation Well site (DH-7) is over ¼ mile from the line of recharge, it is still within common operational distances for a Ranney-Type Collector system provided the alluvial sediments are hydraulically connected to the recharge source.

3.6.4 Traditional Vertical Production Wells

Table 3.2 is a comparison of traditional production well capacities at each site based on the hydraulic conductivities (see Appendix B – Table B-1) determined from the sample gradations from each site, and the depth to water and depth to bedrock. The values shown are for the theoretical maximum and optimum 2-week sustained yields. As used in this report, the maximum sustained yield (MSY) is the maximum yield that a well could maintain over a specified period of time within the limitations of Transmisivity, Storativity, pumping well radius, and an allowable drawdown and assuming a 100% efficient well. The optimum sustained yield (OSY) is the yield that would be reasonably expected for a specified period of time when well efficiency is taken into account. For the purposes of this report, the OSY is assumed to be 67% of the maximum sustained yield; in other words, it assumes a well that is 67% efficient. Such low efficiencies are considered in the industry as a minimum acceptable efficiency. Conversely, 100% efficient wells are seldom attained in the field. Actual production capacities will be limited by the design of the screen slot size and filter pack gradation, the allowable drawdown in the production well, recharge boundaries, and other site specific conditions and will fall somewhere between 67% and 100% efficient. In the computations for the theoretical MSY and OSY, the drawdown in each well was limited to 50% of the saturated thickness. The transmissivity of the local materials was based on the saturated thickness and the average estimated hydraulic conductivity of the materials (Table B-1 of Appendix B, and Appendix J) in the saturated zone based on gradation analyses only, which varied from well to well. Pumping duration was set at 2 weeks, a reasonable upper limit for estimates as to how long a well or well field would be expected to operate at the PMDD levels. Table 3.2 shows the relative differences between the seven sites for purposes of evaluating the seven sites, and is based solely on theoretical yields. Yields are calculated using the Theis Solution, and are only as accurate as the Theis Solution for the given site conditions. No attempts were made to adjust the solution for stratification of materials at the sites, distance to a recharge boundary, or other site specific conditions as the actual locations of a well or wells at each site are unknown. Actual yields at each site will be highly dependent upon field conditions at each site in addition to well construction characteristics.

Table 3-2 is for comparison purposes only. It uses the theoretical OSY value for each well as a limiting factor. In practice, a properly designed and constructed production well will undoubtedly have an efficiency closer to 90% or 95% as opposed to the OSY at 67%.

Table 3-2. Theoretical well yields at sites DH-1 through DH-7.

Parameter	DH-1	DH-2	DH-3	DH-4	DH-5	DH-6	DH-7
Maximum Drawdown (ft)	45	30.5	16.5	30.5	19	24	10.5
MSY (gpm)	537.9	110.7	25.4	335.2	89.2	704.9	451.3
OSY (gpm)	360.4	74.2	17.0	224.6	59.7	472.3	302.4
Radius of Influence*** at OSY (ft)	66.6	30.1	14.8	52.9	27.7	77.9	63.9
Alternative Yield 1* (gpm) – AY1	312	74.2	17.0	224.6	59.7	312	302.4
Radius of Influence*** at Alt. Yield 1 (ft)	61.6	30.1	14.8	52.9	27.7	64.1	63.9
Estimated number of wells required to meet PMDD (625 gpm) – AY1	2	9	37	3	11	2	3
Estimated number of wells required to meet daily demand (312 gpm) – AY1	1	5	19	2	6	1	2
Alternative Yield 2** (gpm) – AY2	484.1	99.6	23.1	301.7	80.3	634.4	406.2
Radius of Influence*** at Alt. Yield 2 (ft)	75.8	34.2	16.3	59.9	30.5	64.5	67.7
Estimated number of wells required to meet PMDD (625 gpm) – AY2	2	7	27	3	8	1	2
Estimated number of wells required to meet daily demand (312 gpm) – AY2	1	4	14	2	4	1	1

* Alternative Yield 1: either the daily demand of 312 gpm or the OSY, whichever is lower.
** Alternative Yield 2: estimated yield for a production well at a conservative efficiency of 90%.
*** Radius of Influence is calculated as the distance from the pumping well where drawdown is 0.1 ft.

The OSY is a function of transmissivity, maximum allowable drawdown, storativity, well radius, and pumping duration. The only variable parameter at any particular site is the pumping duration. As the pumping duration increases, the OSY decreases. However, the rate of decrease in the OSY also decreases as the pumping durations increase. This relationship is illustrated in Table 3-3 that shows the theoretical OSY for conditions at DH-6 at increasing pumping durations up to 30 years. Table 3-3 also shows the incremental drop in OSY from one pumping duration to the next, as well as the cumulative drop in OSY.

As can be seen from Table 3-3, the maximum incremental drop in OSY occurs within the first 14 days of continuous pumping, and the incremental change in the OSY values rapidly drops off afterwards.

Table 3-3. Theoretical OSYs at DH-6.

Duration of Pumping	OSY (gpm)	Incremental. Difference (%)	Cumulative Difference (%)
1 day	568		
14 days	472	16.4	16.4
30 days	450	4.7	21.1
60 days	432	4.0	25.1
90 days	422	2.3	27.4
120 days	415	1.7	29.1
150 days	410	1.2	30.3
180 days	406	1.0	31.3
1 year	391	3.7	35.0
2 years	377	3.5	38.5
3 years	370	1.9	40.4
4 years	364	1.6	42.0
5 years	360	1.1	43.1
10 years	348	3.3	46.4
20 years	338	2.9	49.3
30 years	331	2.1	51.4

Table 3-4 compares the operational times for single wells operating at the shown yields. The operational times are the number of hours that a well would have to pump each day, seven days a week, to meet the anticipated 2050 PMDD with a 75% efficient RO plant.

Table 3-4. Comparison of operational times for single wells.

	DH-1	DH-2	DH-3	DH-4	DH-5	DH-6	DH-7
@ OSY	41.7 hrs	202+ hrs	882+ hrs	66.8 hrs	250+ hrs	31.7 hrs	49.6 hrs
@ 625 gpm	N/A*	N/A	N/A	N/A	N/A	21.3 hrs	N/A
@ 312 gpm	13.9 hrs	N/A	N/A	32.3 hrs	N/A	10.6 hrs	16.6 hrs
@ MSY**	27.9 hrs	135+ hrs	590+ hrs	44.8 hrs	168+ hrs	21.3 hrs	33.2 hrs

* - N/A indicates that the indicated yields are probably not attainable at the indicated site.

** - The estimated operational times are for a single well operating at the estimated MSY for the site.

Given the assumptions used to compute the MSY and OSY values, a single well operating at the OSY rate would theoretically be unable to meet the anticipated 2050 PMDD at all the sites. At only one site, DH-6, is the production rate needed to meet the PMDD even attainable. The operational times shown for the MSY rate at each site, with the exception of DH-6, indicate that more than one well would be needed at these sites to meet the PMDD. This was also shown in Table 3-2 for wells assumed to be operating at

90% efficiency (Alternative Yield 2). Site DH-3 would require an unreasonable number of wells, and sites DH-3 and DH-5 would require a significant number of wells.

Sites DH-1, DH-4, DH-6, and DH-7 are theoretically the only sites where a reasonably small well field would be required to meet the anticipated 2050 PMDDs. Assuming that each site would have one back-up well to maintain the desired yields when one of the other wells is off line for maintenance, repair, or replacement, the as indicated in Table 3-2, site DH-6 would require 2 wells, sites DH-1 and DH-7 would require 3 wells, and site DH-4 would require 4 wells. Table 3-2 shows the radius of influence for a single well pumping at the indicated capacity for each site. Multiple wells at any site would have to be separated from the adjacent wells by a minimum of 2X the individual radii of influence.

3.7 Discussion of Results

Based on Table B-2 for a bed-mounted infiltration gallery, the axial flow velocity for the 0.25 ft radius pipe (3" radius or 6" diameter) exceeds the maximum flow velocity of 3 ft/sec, and thus would not be an appropriate size to use. The remaining sizes of pipe all would be appropriate sizes based on axial flow velocities. Based on the calculations, the length of pipe required ranges between 6 and 12 feet. However, the flow velocity through the screen slots is also a limiting factor ($\leq$ 0.1 ft/sec). The length of pipe is also dependent upon the screen slot size selected, which in turn depends upon the gradation of the sediments in the river or lake where the bed-mounted infiltration gallery will be sited. If this method is the preferred method, then additional data collection will be necessary to design and size an appropriate bed-mounted infiltration gallery.

However, the results from Table B-2 suggests that a fairly high capacity bed-mounted infiltration gallery could be constructed using a reasonable amount of screen and materials at any of the sites with the exception of DH-7 which is over ¼ mile away from the nearest shoreline.

Tables B-3a through B-3f all indicate, that with the possible exception of the 0.25 ft radius pipe at DH-1, axial flow velocities in the on-land infiltration galleries at all sites are not a limiting factor. The limiting factors are the burial depths and the conductivity of the local materials at those depths. For a 0.90 MGD system (or 1.0 MGD in the tables), the required lengths of intake screen would appear to be prohibitively long, ranging from around 3,600 to 3,700 feet at DH-6 to over 130,000 feet at DH-3. Whether there is sufficient room at the DH-6 site to install 3,600 feet of trench and pipe would be the primary limiting factor. Tables B-3a through B-3f all assume the maximum practical burial depths of 30 feet. If local conditions or installer's capabilities limit the burial depths to less than 30 feet, then the required lengths of screen would increase accordingly.

The graphs for the Ranney-Type Collector well design (Figures B-2 through B-8) suggest that this type of collector system would be technically and hydrologically viable at all sites. For a 0.90 MGD system, the number of laterals would vary between 1 (at the DH-6

Site) and as many as 11 (at the Crazy Peak Site) depending upon the diameter of the laterals and the average length of the laterals. Depending upon the design of the caisson, a typical caisson design could have as few as one to as many as 18 laterals, with nine laterals being an average number. However, a typical Ranney-Type Collector system with a 20' diameter caisson may be considered 'over-kill' and may be too expensive (in capital costs) for the benefits received. A smaller caisson design (less than 20 feet) might be more cost effective. The industry 'rule of thumb' is that a 1.5 MGD system is about the lower limit of when a Ranney-Type Collector system is cost effective.

Inherent in all the designs is the necessity for the proper amount of Missouri River alluvium to be used as the aquifer. This means that there needs to be material of appropriate hydrologic properties in sufficient thickness and lateral extent to accommodate the different design requirements for each type of system.

Based on the amount of existing data that is specifically applicable to the design of a horizontal collector system, there are a number of concerns and data gaps. These are:

1. The material hydrologic properties are critical to the evaluation of any type of horizontal collector system; there is only limited data related to the hydraulic conductivity (based on gradation analyses), and no data of storativity, porosity, or specific yields of the Missouri River alluvial sediments.
2. The necessary amounts of aquifer materials must be present (both thickness and lateral extent) for a successful infiltration gallery: in the case of the Ranney-Type Collector system, only sites DH-1 and DH-6 have a fairly thick section of alluvial sediments (92' and 82' respectively); the remaining sites have alluvial sections that range from 37' to 64' thick which will limit the effectiveness of the Ranney-Type Collector system.
3. The shoreline must be relatively stable in the case of the bed-mounted and on-shore infiltration galleries: the migration of the Missouri River channel and/or the advance of the Missouri River delta into Lewis and Clark Lake could be problems for these types of infiltration galleries. The rate of advance of the Missouri River delta into Lewis and Clark Lake and the migration pattern of the Missouri River channel, have not been fully quantified at this point.
4. A set of test wells 1,000 to 2,000 feet upstream of the Village of Santee found high TDS water at depth near the bottom of the Missouri River alluvial materials, but it was postulated that wells producing from nearer the top of the alluvium may not encounter the high TDS water: in the case of the Ranney-Type Collector system, it is designed to draw water from depths that are typically 75 – 100 feet below the static water levels – this might cause a Ranney-Type Collector system to produce poor quality water if such waters are present in the Village of Santee area. The quality of the water at depth in the vicinity of the Village of Santee is unknown.

3.8 Other Considerations

Besides just the technical viability of infiltration galleries, there are a number of other considerations that should be taken into the evaluation of the viability of an infiltration gallery system. They are:

1. Feasibility Design: the existing data is adequate for feasibility design and cost estimates of a water supply system, whether it is an infiltration gallery of some type, or traditional vertical wells. Additional data needs exist that would be required in order to complete a final design. These data needs are described in Appendix I.
2. Construction: It is apparent that in terms of ease of construction, the on-land would be the easiest, and the Ranney-Type Collector system would be the most difficult. The bed-mounted systems would need to be constructed during a period when the water body elevation is low, or would require the use of cofferdams, or both.
3. Cost: The Ranney-Type Collector system is the most expensive to construct; the other two are about equal (the one with the most materials is also the easiest to construct). Most Ranney systems are not cost effective below about 1.5 MGD due to capital costs associated with the infrastructure of the caisson and associated components.
4. Operation and Maintenance: The Ranney-Type Collector system is the design that would be least influenced by fluctuations of water levels in the river and/or reservoir, or by shifts in the position of the delta being created by the Missouri River in Lewis and Clark Lake: the bed-mounted system is the most sensitive to shifts in the shoreline away from the site: both the bed-mounted and on-land systems are highly sensitive to changes in water levels: the bed-mounted system is more susceptible to being covered with large amounts of sediment (i.e. from a flood event or migration of the delta) than the on-land system: the Ranney-Type Collector system is more likely to be impacted by poor quality water at depth than either the bed-mounted or on-land systems.
5. Land Disturbance: The on-land infiltration gallery requires the greatest amount of land disturbance, the Ranney-Type Collector system would require the least amount of land disturbance: the bed-mounted system is the only system that would require any actions that might impact river flows or cause turbidity problems in the river.

3.9 Conclusions: Phase 1

1 - A bed-mounted infiltration gallery system would be technically viable at any of the sites with the exception of DH-7, which is over ¼ mile from the nearest shoreline.

2 - An on-land infiltration system would not be technically viable at any of the sites with the exception of DH-6. At sites DH-1 through DH-5 the required lengths of

intake screen is prohibitively large (in excess of 4.6 miles); site DH-7 is too far away from the nearest shoreline to make an on-land infiltration gallery viable.

3 - A Ranney-Type Collector system is technically viable at all seven sites, but because of the small anticipated 2050 peak demand (0.90 MGD) the Ranney-Type Collector system may not be economically viable.

4 - Traditional vertical production wells are technically viable at all seven sites. Based on the theoretical optimal well yields shown in Table 2, sites DH-2, DH-3 and DH-5 would require a well field consisting of a minimum of 2, 6, and 2 wells respectively. The remaining sites would be able to meet anticipated 2050 PMDDs with a single, properly design and installed well (although a back-up well would be advisable at all the sites).

3.10 Recommendations: Phase 1

1 - The seven sites should be prioritized based on the information presented herein and with non-technical considerations incorporated as appropriate (such as level of risk that is acceptable to the Tribe, level of reliability, political considerations, future needs, land ownership, right of ways, access, OM&R considerations, and costs). The following technical recommendations are presented as part of the prioritization criteria:

   a. On-land infiltration galleries should be eliminated from consideration due to the prohibitive amounts of required screen and the environmental impact of constructing trenches.
   b. Bed-mounted infiltration galleries should be ranked last, but not eliminated from consideration, due to the environmental impacts of constructing them in the river or lake, due to the potential impacts on the galleries from flooding events, and/or the migration of the river channel, and/or the elimination of the lake shore as the Missouri River delta advances into Lewis and Clark Lake.
   c. Ranney-Type Collector systems should only be considered at sites DH-1 and DH-6 where adequate thicknesses of alluvial sediments are present. Also, since the effectiveness of the system depends in part on the distance from the line of recharge, the systems should be designed for twice or triple the anticipated yields to compensate for migration of the river channel away from the system or filling in of the lake by the MR delta. Consideration should be given to the possibility of smaller diameter caissons to reduce the capital costs.
   d. Traditional production wells should be considered for all sites with the exception of DH-2, DH-3 and DH-5 due to the low material conductivities and the limited amount of space in which to install a well field at DH-3 and DH-5.
   e. Consideration should be given to a production well or small well field at site DH-7: this site has the second highest estimated optimal yield value, and is at a site that has a proven history of production (i.e. the nearby irrigation well).

f. Consideration should be given to a production well at sites DH-1 and DH-6 as these sites are near the river, have the thickest amount of alluvial sediments, and would essentially be pumping river water. Additionally, DH-6 has the highest estimated optimal yield of any of the 7 sites.
g. Consideration should be given to a multiple site configuration; as an example – a production well at DH-7 and DH-1 or DH-4.
h. Ranking the 7 sites with regard to potential yields and site suitability, the top three sites in order would be DH-6, DH-7 and either DH-1 or DH-4.

2 - An exploratory testing program designed to investigate the top three sites, which should include, but not be limited to a full scale aquifer test of the sites to determine aquifer properties and recharge source. The testing program should be done in a phased, step-wise approach whereby the highest prioritized site is tested first and if it proves adequate to meet all the future needs, then the testing program can be terminated. If highest prioritized site only meets some of the anticipated future demands, then second-highest prioritized site can be tested – if it meets all future demands by itself, or in combination with the highest prioritized site, then testing can be terminated. Testing of the third-highest prioritized site would follow the same rationale.

3 - During the exploratory testing, sufficient data should be collected to properly design the preferred system – or the most appropriate system for that site. The data needs will vary depending upon the sites selected and the type of system that would be best suited to the sites. The details of the data collection can be laid out during the design of the exploratory testing program.

3.11 Action Taken: Phase 1

The study team evaluated the pros and cons of each testhole location. Based on several selection criteria (including logistics, aquifer properties, access, and tribal preferences among others), the team arrived at the conclusion that DH-7 was the most promising site in meeting the required raw water demands and utilizing a conventional vertical well field which would be most economical to construct. Accordingly, the DH-7 site was recommended to be used in Phase 2 of this study.

4.0 Phase 2 Testing

4.1 General Discussion

Phase 2 of the testing program was conducted between October and December of 2007. The field work portion of Phase 2 consisted of the installation of a pumping well and four observation wells at the preferred exploratory site, and the completion of a 24 hour aquifer test at that site. The field work was conducted between October 9 and October 19, 2007.

The analytical portion of Phase 2 was completed in December of 2007, and included the analysis of the test data obtained during the field work and the generation of this report.

4.2 Field Activities

Phase 2 field activities consisted of the drilling and installation of a pumping well and four observation wells in the vicinity of DH-7, and the completion of two testing programs – a 2 hour variable discharge rate test to determine range of potential yields, and a 24 hour constant discharge rate test to determine aquifer properties.

The testing configuration consisted of a pumping well with four observation wells (Page G-1 of Appendix G). Two observation wells were located to the east (E-1 and E-2) of the pumping well at a distance of 51 feet and 102 feet respectively. The other two observation wells were located to the north (N-1 and N2-30) of the pumping well at a distance of 45 feet and 26.5 feet respectively (see page G-1 in Appendix G).

Water levels and flow rates were monitored in the pumping well and observation wells E-1 and E-2 during the 2 hour variable discharge rate test, and in the pumping well and observation wells E-1, E-2, N-1, and N2-30 during the 24 hour constant rate test. Flow rates during both tests were recorded manually using an in-line flow meter on the pump's discharge line. The discharge point is shown on the well layout diagram (page G-1). Water levels were recorded both manually and electronically during both tests using a manual water level indicator (M-Scope) and an automated Hermit Data Logger with pressure transducers installed in each well. The 24-hour constant rate test had a recorded discharge rate of 425 gpm.

The drilling activity, test well construction, and aquifer testing (also called a 'pump test') are summarized in a field activity report by Larry Cast (geological consultant), and Robert Schieffer and Clinton Powell of Reclamation's Nebraska-Kansas Area Office (see Appendix C, pages C-1 through C-4). The field notes taken during the development of the test well (Well 1) are also included in Appendix C, pages C-5 and C-6. The well log for Test Well 1 is included on page C-7.

Two water quality samples were collected during the 24-hour constant rate test. The sampling procedures, analysis results, and evaluation document are included in Appendix D.

The raw water level data, as recorded by the Hermit Data Logger, are attached as Appendix E. The manual readings of water levels and flow rates are attached as Appendix F. A schematic well construction diagram for the pumping well is attached as Figure G-2 in Appendix G.

4.3 24 Hour Aquifer Test Analysis

The water level data collected during the pumping phase and recovery phase of the Phase 2 twenty-four hour aquifer test was analyzed using two software packages. The primary software package is called 'Aquifer Test Pro v4.2' (AQTSTPv4.2), created and distributed by Waterloo Hydogeologic, Inc., a Schlumberger Company, located in Waterloo, Ontario, Canada. The second software package is called 'Infinite Extent' (InfinExt) and was created and distributed by StarPoint Software. Printouts of the analyses are included in Appendix H.

The first printout in Appendix H (page H-1) is a summary of the physical configurations of the five wells monitored during the 24 hour aquifer test. Page H-2 is a summary of the well characteristics used in the data analysis by AQTSTPv4.2. Although not shown on page H-2, the software does account for the annular radius (the difference between the borehole radius and the screen radius – the dimension 'B' in the figure) and the conductivity of the filter pack material. The remaining printouts are the analyses for individual wells for both the pumping and the recovery phases of the aquifer test, and are discussed in the following sections.

4.3.1 Pumping Well – Well 1

The data from the pumping phase for the test well, Well 1, was analyzed using the Theis method with a Jacob correction (page H-3). This method is essentially a classic Theis analysis but with a correction applied to account for the aquifer being unconfined. The classic Theis analysis was developed for aquifers under confined conditions, but the method can be applied to unconfined aquifers with an appropriate correction applied (i.e. the Jacob Correction).

The cluster of data points beyond time 1487 minutes represents the recovery data, and is not included in the drawdown analysis. The horizontal line of data points from time zero to just about 2 minutes represents a programmed delay between starting the data recording and starting the pump. The purpose of this delay is to obtain a couple of minutes of pre-pumping static readings that will form the reference reading for the data analysis.

The drawdown data indicates that the drawdown in the well was almost instantaneous following pump start-up – dropping just about 8 feet within the first minute of pumping and then dropping another 3 feet or so over the rest of the 24 hour test. There was an apparent increase in drawdown just before the pumping test was terminated. It may indicate that the radius of influence of the pumping (the 'cone of depression') encountered a no-flow boundary – maybe the edge of the aquifer on one side of the cone. Alternatively, this could have been a mechanical or operator induced drop. Additional pump testing for a longer period of time may be needed to conclude that the cause of the decline is related to encountering some change in conditions in the aquifer or just an anomaly in the data.

Transmissivity (and the corresponding Hydraulic Conductivity) of the aquifer in the vicinity of the test well is obtained from the analysis of the drawdown data. Transmissivity and Hydraulic Conductivity are related by the equation: $T = K \times B$ where T is the transmissivity (ft^2/day), K is the Hydraulic Conductivity (ft/day), and B (ft) is the aquifer or saturated thickness.

Page H-4 is the analysis of the recovery data for Well 1. This recovery analysis uses the Cooper and Jacob Method I analysis. The data points between 0.1 minutes and about 5:30 minutes represent the early recovery data, and again represents a time delay between starting the data logger and stopping the pump. The five or so minutes of recordings prior to stopping the pump provide a base line for the recovery analysis. During the short 5 minute interval, no change in drawdown was recorded, even though an increase in drawdown of just over 1 foot (about 11% of the total drawdown) was recorded in the preceding 2 hours.

The sudden rise in water level on H-5 (this is represented on the plot as a negative y-axis direction) indicates that there was a very rapid recovery to the well after the pump was turned off. The left axis suggests that the water level in the well continued to decline after the pump was turned off. In reality, the water level in the well recovered – the way it is represented on the graph is an artifact produced by having the reference point for the data logger's pressure readings reset at the start of the recovery phase. The curved tail at the end of the recovery phase shows that the water levels recovered to above pre-testing static levels, and then dropped back down to near static. This sort of rebound affect is often seen in wells that recover very rapidly. However, in Well 1 this rise and fall near the end of the recovery phase can not be attributed to a rebound affect. Nothing in the data suggests that there was a transducer malfunction – so the data is not an artifact of the transducer or data logger operation. The cause of this anomaly at the end of the recovery can not be determined based on the existing data. Regardless, the rebound does not affect the analysis of the recovery data.

Excluding the data at the end of the test, and only analyzing the main part of the recovery data, results in a calculated transmissivity that is very close to the values calculated from the drawdown data (namely 5.49×10^4 for the recovery data versus 5.01×10^4 and 5.15×10^4 for the drawdown data).

4.3.2 Observation Well – E-1

The data from the pumping phase for observation well E-1 was analyzed using the Cooper and Jacob Method I (page H-5). Because the drawdown in E-1 was so small, the Theis analysis with the Jacob correction did not provide a definitive solution through curve matching the Theis curve against the drawdown data curve (the drawdown data curve was essentially a straight line when plotted against the Theis type curve).

In the figure on page H-5, the cluster of data points beyond time 1487 minutes represents the recovery data, and is not included in the drawdown analysis. The horizontal line of data points from time zero to just about 2 minutes represents a programmed delay between starting the data recording and starting the pump. The purpose of this delay is to get a couple of minutes of pre-pumping static readings that will form the reference reading for the data analysis. This is the same condition that was described above for the test well, and also applies to all the data for all four observation wells.

The drawdown data indicates that the drawdown in well E-1 was not as instantaneous as it was in the test well, but the cone of depression from the test well reached well E-1 in a very short period of time. The drawdown plots for all of the observation wells demonstrate some level of an s-shaped pattern …that is, for the pumping period roughly between 4 to 20 minutes, the drawdown flattens out a bit and then increases after that. This is typical pattern of drawdown in unconfined aquifers. Note that there is an increased drawdown near the end of the pumping phase represented by the breakpoint in the drawdown curve around 1400 minutes.

The analysis of the drawdown data produced essentially the same calculated results for the transmissivity (and the corresponding Hydraulic Conductivity - $4.73x10^4$ and $1.82x10^3$ respectively) of the aquifer in the vicinity of well E-1 as were calculated for the test well

Page H-6 is the residual drawdown analysis of the recovery data for well E-1. This recovery analysis uses the Theis Recovery method. The time axis is the ratio of *t/t'* where *t* is the time since the test started (i.e. when the pump was turned on) and *t'* is the time since the pump was turned off. Using the ratio of *t/t'* for the time axis results in the early time recovery data plotting on the right side of the graph and the late time recovery data plotting on the left side (i.e. time since the pump was stopped increases to the left). The cluster of constant readings on the right side of the graph are the five or so minutes of recordings prior to stopping the pump that again provide a base line for the recovery analysis – and show that the drawdown in the well was fairly stable just prior to stopping the pump.

Transmissivities calculated from observation wells are generally considered more accurate than values calculated from pumping wells. This is because the only 'stress' on the observation well is from the aquifer itself. The drawdown in a pumping well is influenced by a number of factors related to the well that do not indicate conditions in the aquifer, such as wellbore storage and well efficiency. If a pumping well were 100% efficient, then the drawdown in the aquifer immediately adjacent to the well would be identical to the drawdown in the well. However, pumping wells are rarely 100% efficient, and the inefficiency is reflected in the drawdown in the well being more than in the aquifer immediately adjacent to the well. The more inefficient the well, the more difference there is between the drawdown in the well and the in the aquifer immediately adjacent to the well. Within the industry, an acceptable efficiency for a new well is generally in the range of 90% to 95%. Well efficiencies will decline over time and usage.

The graph on page H-7 is a distance drawdown plot of the observation wells at the end of the pumping phase. The straight line on the graph is the line of 'best fit' between the drawdowns in the observation wells and the drawdown in the pumping well (10.399 ft). If a line of 'best fit' extending only through the observation wells were drawn on H-7, it would intersect the drawdown axis at zero distance from the pumping well (i.e.

immediately adjacent to the pumping well) at around 3+/- feet. Well efficiency is calculated as the ratio of the theoretical drawdown (dd_t) to the actual drawdown (dd_a), or dd_t/dd_a. In the case of the test well, this ratio would be 3/10.399 = 0.2884, or 28.8% efficient. This low efficiency mostly likely indicates that the test well may not have fully penetrated the aquifer and/or the entire saturated thickness was not screened, or it was not completely developed. A filter pack that is too fine for the formation being screened can also reduce a well's efficiency. The efficiency calculated from the line of 'best fit' that includes the drawdown (shown on Figure H-7) in the test well is 57.69%. Based on the estimated *K* for site DH-7 and a pumping duration of 24 hours (the length of the pumping duration in Phase 2), the theoretical MSY and OSY for a well at the DH-7 site would be 540 and 362 gpm, respectively. During the testing of pumping well at DH-7, the test well attained a constant 425 gpm. That would suggest that the well efficiency was on the order of 78% as opposed to the calculated efficiency of 57%. This difference might suggest that the well was more efficient than the drawdowns would indicate, or the estimated *K* based on sample gradations (and hence the theoretical MSY and OSY) is significantly lower than actual site conditions. Based on a well efficiency of around 57%, and a yield of 425 gpm, the calculated MSY would need to be around 746 gpm. Back calculating from the MSY, the value of *T* would have to be around 15,000 ft^2/d as opposed to the estimated 10,584 ft^2/d based on the gradation analysis.

Page H-8 is a Theis recovery graph for well E-1 using the InfinExt software package. This package allows individual data points to be graphically selected and excluded from the analysis (the 'ghosted out' data points on the right side of the graph). The 'ghosted out' data points represent the first 5 minutes of data just before the pump was turned off. The calculated transmissivity is very close to the value calculated using the AQTSTPv4.2 software package – namely $3.2x10^4$ and $3.0x10^4$ respectively.

4.3.3 Observation Well – E-2

The graphs on pages H-9 through H-11 represent the same type of analyses as were done for well E-1 and represented in the graphs on pages H-5, -6, & -8. The response in E-2 was very similar to the response in E-1, just slightly less. The calculated transmissivities from the AQTSTPv4.2 drawdown and recovery calculations (H-9 and -10 respectively), and the calculated transmissivity from the InfinExt recovery (H-11) are $5.41x10^4$, $4.18x10^4$, and $3.70x10^4$ respectively.

4.3.4 Observation Well – N-1

The graphs on pages H-12 through H-14 represent the same type of analyses as were done for wells E-1 and E-2. The response in well N-1 was very similar to the response in the two 'E' wells. The major difference was that the end of the pumping phase did not have a significant increase in drawdown like the two 'E' wells did. The calculated transmissivities from the AQTSTPv4.2 drawdown and recovery calculations (H-12 and -13 respectively), and the calculated transmissivity from the InfinExt recovery (F-15) are $4.06x10^4$, $3.22x10^4$, and $3.34x10^4$ respectively.

4.3.5 Observation Well – N2-30

The graphs on pages H-15 through H-17 represent the same type of analyses as were done for the previous wells. The response in N2-30 was very similar to the response in

N-1, just slightly more since it was closer to the test well than N-1. The calculated transmissivities from the AQTSTPv4.2 drawdown and recovery calculations (H-9 and -10 respectively), and the calculated transmissivity from the InfinExt recovery (H-11) are 3.86×10^4, 2.59×10^4, and 3.12×10^4 respectively.

4.4 Discussion

The fact that both N-1 and N2-30 did not have a noticeable increase in drawdown just prior to the pump being turned off, as was seen in the test well and wells E-1 and E-2, could have several explanations.

Construction of the test well was such that the designed filter pack only packed off a portion of the well screen. The top portion of the well screen did not have a designed filter pack, rather it was left to develop a 'natural' filter pack from the formation materials as they collapsed around the well casing/screen. Given the variability of the formation material gradations, it is likely that the 'natural' filter pack was not fully developed during the well development process.

The noticeable increase in the drawdown near the end of the testing could suggest that the cone of depression encountered an aquifer boundary of some type around 23 hours after the start of the pump test. The noticeable increase in drawdowns in E-1 and E-2 would suggest that such a boundary would be somewhere to the southeast of the test site. Based solely on the results of the pumping test, the direction of the boundary could be anywhere between east-southeast and south-southeast of the site. The boundary could be a no-flow boundary, such as would be caused by the aquifer pinching out, or it could indicate that the aquifer is getting thinner or the transmissivity is decreasing to the southeast.

It should be noted that the data recorded during the pumping and recovery phases of the testing program do not conclusively identify any one explanation for the patterns seen in the data analysis. If the increased drawdown is a result of a boundary condition of some type, then the drawdowns should increase and remain so, but in the case of well E-2, the drawdown first increased and then recovered somewhat. An un-noticed fluctuation in the pumping rate could also account for the patterns seen in the recorded data. A longer term pumping test, either on this well, or on a production well, may have provided information necessary to determine the cause of the fluctuations in the drawdown curves prior to the end of the tests.

The final page in Appendix H, page H-18, is a summary table of the AQTSTPv4.2 analyses for the five wells. The extremely small storage coefficients, *S*, shown for the test well are artifacts of the conditions in the test well. Due to conditions such as well efficiency, borehole storage, and variations in pumping rates, Storativity (storage coefficient) calculated from a pumping well is not a reliable estimate of aquifer Storativity.

Generally, transmissivity values calculated from recovery data are considered more reliable than values calculated from drawdown data, and values calculated from observation wells are more reliable than values calculated from pumping wells. The transmissivities for the observation wells' recovery data vary between $2.59 x 10^4$ and $4.18 x 10^4$, and are different for each well site which is to be expected given the type of materials encountered at the well sites. The transmissivity from the test well recovery data is $5.49 x 10^4$, and although it is higher than any of the observation well values, it is in the same general range as the transmissivities of the observation wells.

The average transmissivity based on just the observation well recovery data, and the average transmissivity based on the recovery data from all five wells are $3.26 x 10^4$ and $3.71 x 10^4$ respectively.

The InfinExt software has calculators for estimating Specific Capacity, Radius of Influence, and Well Yield using different values for T or K, storativity, allowable drawdowns, pumping rates, distances from the pumping well, and desired time frames. Table 4.1 is a comparison of estimated MSY, OSY[1], steady state drawdown at 24 hrs of pumping, radius of influence, and specific capacity based on existing parameters of Well 1 (the 'test' well) as it was installed, and based on a projected production well using aquifer properties based on the average recovery values of the four observation wells.

In Table 4-1, the Well 1 transmissivity value is taken from the recovery data for Well 1. The recovery data is less dependent upon well construction issues/problems than the pumping data as the only stress on the aquifer is the drawdown at the well at the end of the pumping cycle.

In Table 4-1 the allowable drawdown is shown as either 6.5 feet or 13 feet. The allowable drawdown in well has a significant effect on the estimated sustained yields (maximum or optimum) from that well, which in turn affects the radius of influence and other estimated values. 6.5 feet and 13 feet were chosen as the two allowable drawdowns for comparison purposes based on the following criteria:

1) allowable drawdown in a well equal to 25% of the saturated thickness of the aquifer is considered by the industry to be a conservative allowable drawdown that protects the aquifer; and
2) industry standards/common practice is that the drawdown in a well should not exceed 50% of the saturated thickness of the aquifer.

The actual allowable drawdown in the pumping well(s) is of course a choice the owner should make, based on how much risk is acceptable to the owner in terms of aquifer protection, operational costs, aquifer 'mining', etc.

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[1] Maximum Sustained Yield assumes the well efficiency is 100%. OSY accounts for well efficiency less than 100% - 67% efficiency is generally considered the minimum acceptable well efficiency. By default, OSY is calculated assuming a well efficiency of 67%.

Table 4-1. Comparison table of estimated values for MSY, OSY, steady state drawdown at 1 day and 7 days of pumping, radius of influence, and specific capacity for Well 1 (the test well) and a hypothetical pumping well. Values shown with gray shading are the estimated values; all other values are known, assumed, or calculated from the aquifer test data.

Parameter\Well	Well 1 (test well)				Projected Production Well			
Transmissivity (ft^2/day)	5.49 E+4 (recovery value)				3.26E+4			
Storativity	2.01 E-1				2.01 E-1			
Allowable drawdown (ft)	6.5	13	6.5	13	6.5	13	6.5	13
% of saturated thickness*	25	50	25	50	25	50	25	50
Time (days)	1		7		1		7	
Well Radius (ft)**	.416				.416			
MSY (gpm)	1042	2084	958.7	1917	633.6	1267	581.7	1163
OSY (gpm)	698.3	1396	642.3	1288	424.5	849	389.8	779.5
Steady State Pumping drawdown	4.299	8.707	4.006	8.034	4.355	8.71	3.999	7.997
Open Interval (in^2/ft)****	48				48			
Drawdown at end of test (ft)	10.4				N/A			
Radius of Influence (ft)***	784		2076		604		1600	
Specific Capacity (gpm/ft)	40				N/A			
Partial Penetration Factor	1.85				N/A			
Estimated Transmissivity (ft^2/day)	1224.5				N/A			
Estimated Conductivity (ft/day)	470.99				N/A			

* - Saturated thickness assumed to be 26 feet based on the 5 well logs
** - Existing well is 10" ID, hypothetical well is assumed to be same ID
*** - Steady State drawdown @ 24 hrs and Radius of Influence are estimated based on the OSY values
**** - Open interval is for 0.020" slotted stainless steel screen

Note: there is no post development aquifer test for the projected production well, so the values shown as N/A can not be estimated.

Also, in Table 4-1, two pumping periods are used – namely 1 day and 7 days. In the case of the former, it is assumed that the aquifer is allowed to recover to static (or near static) levels following a 24 hour continuous pumping event. Likewise, in the case of a 7 day pumping period, it is assumed that the aquifer is allowed to recover following a period of continuous pumping lasting 7 days. The 7 day time period was selected as the upper time period because after about 7 days the rate of change in estimated values of OSYs, Radius of Influence, and Steady State pumping drawdown at 24 hours drop off drastically. In other words, the majority of the change in these parameters occurs in the first 7 days of pumping, and very little change occurs after about 7 days.

As shown in Table 4-1, longer pumping periods necessitate a lower pumping rate in order for the drawdowns to remain within acceptable limits. Lower pumping rates also result in lower Steady State pumping drawdowns after 24 hrs of pumping and smaller Radius of Influence values.

Based on the OSY values in Table 4.1 for the Projected Production Well with a transmissivity around 3.26E+4 ft^2/day, the aquifer could support the peak amount of withdrawals over a sustained period of time without exceeding 50% of the saturated thickness. The estimated Radius of Influence at 625 gpm would be around 736 ft and the Steady State pumping drawdown at 24 hrs would be 4.5 feet. The daily demand of 312 gpm is well within the capability of the aquifer to support over a long sustained period with drawdowns well below the 25% of saturated thickness threshold.

At 312 gpm, a well could pump indefinitely without exceeding 6.5 feet of drawdown. At 312 gpm, the Radius of Influence would be around 440 feet and the Steady State pumping drawdown at 24 hrs would be around 2.15 feet.

4.5 Water Quality

The water quality results and discussion are included in Appendix D. Field measurements of conductivity, temperature, and pH are included as page D-1. Laboratory analyses and discussion of the water quality samples begins on page D-2.

Overall, none of the water quality parameters in the samples collected during the testing in Phase 2 exceeded any EPA Primary Drinking Water Standards. The EPA secondary standards significantly exceeded are TDS and sulfate. The high levels of TDS and sulfate will produce taste and odor problems.

The water sampled is extremely hard as a result of high concentrations of calcium and magnesium combining with bicarbonate. Very hard water is defined as having a total hardness (mg/L in $CaCO_3$) greater than 180. The Santee Sioux well water is about 900 mg/L. In addition to scale caused by calcium carbonate and magnesium carbonate, calcium can form with elevated levels of sulfate to form calcium sulfate. Scale adversely affects plumbing fixtures in homes, especially water heaters and washing machines.

Some constituents that may be of potential but not immediate concern are manganese, total organic carbon (TOC) and radionuclides (alpha particles). The manganese concentration from 10/18/07 slightly exceeded the EPA secondary standard of 0.05 mg/L. Soluble manganese will cause a black precipitation when exposed to oxygen.

Total organic carbon will trigger the disinfection byproduct rule if the influent concentration exceeds 2 mg/L. Santee Sioux well water was reported at 1.5 and 1.6 mg/L. Disinfectants such as free chlorine, ozone and chlorine dioxide react with natural organic and inorganic matter in source water and distribution systems to form disinfection byproducts (DBPs). Results from toxicology studies have shown several DBPs (e.g., bromodichloromethane, bromoform, chloroform, chloroacetic acid, and bromate) may be carcinogenic.

The water sample from 10/19/07 produced a gross alpha particle concentration of 13 pCi/L, which is approaching the EPA MCL of 15 pCi/L. The EPA specifies that the potential health impact from alpha particles is an increased risk of cancer.

Based on the analysis of the water samples collected during Phase 2 Testing, it is anticipated that an RO treatment system would be able to address the water quality issues/concerns. A planning estimate for Santee's RO recovery is between 75% and 85% of the raw water feed would be treated product water. Actual recovery may be higher than this but it depends on the concentrations of contaminants and the selected properties of the membrane (personal communications, 2008)

5.0 Conclusions

5.1 Phase 1

The Conclusions from Phase 1 Testing were discussed previously (Section 3.9 above).

5.2 Phase 2

Based on the 24 hour aquifer test conducted at Test Well 1 (DH-7 site), with observation wells E-1, E-2, N-1, and N2-30, the Transmissivities range between 2.59E+4 and 4.18E+4 ft^2/day for the observation wells and 5.49E+4 ft^2/day for the pumping well (based on recovery data). Since transmissivities calculated from pumping wells are often unreliable because of conditions inherent in the well itself, the observation wells provide a better estimate of 'site wide' transmissivities. An average of the transmissivity values from the observation well recovery data is 3.26E+4 ft^2/day.

Estimates based on the average transmissivity value for pumping periods of 1 day and 7 days, and for allowable drawdowns of 6.5 feet and 13 feet result in OSYs between around 390 and 850 gpm. An allowable drawdown of 6.5 feet is 25% of the aquifer saturated thickness (assuming a saturated thickness of 26 feet), an allowable drawdown of 13 feet is 50% of the aquifer saturated thickness.

The estimated Radius of Influence for OSYs between 390 and 850 gpm range from 653 feet to 1113 feet.

The estimated daily demand in 2050 for the Village of Santee is around 312.7 gpm with a PMDD of 625 gpm (double the daily demand). Based on the results of this evaluation, the aquifer at the test site appears that it could sustain a pumping rate of 312 gpm indefinitely without exceeding 6.5 feet of drawdown, and sustain a pumping rate of 625 gpm for a week without exceeding 8 feet of drawdown (assuming that the pumping well is around 70 to 90% efficient – as opposed to the 30 to 60% efficiency of Test Well 1).

The results of the water quality analysis indicate that the quality of the water does not exceed any EPA Primary Drinking Water Standards. There are, however, several species of concern as they relate to secondary standards, taste, odor, and precipitates. These species of concern can be mitigated for using an appropriate treatment option such as RO.

Accordingly, the test site near DH-07 appears to be suitable to meet the quantity and quality demands for a water supply system that would meet the projected 2050 needs of the Village of Santee.

Although not evaluated in Phase 2, DH-6 has a similarly high *T* and *K*, has a greater saturated thickness (Table B-1), has a thicker zone of gravel materials (soil class GM) (Table 3-1), and is closer to a known recharge source with potentially better quality water. Accordingly, site DH-6 in all likelihood would also be suitable to meet the quantity and quality demands for a water supply system to meet the projected 2050 needs of the Village of Santee, either by itself, or in combination with a supply system at DH-7.

6.0 Feasibility/Final Design Considerations

Based on the Phase 2 testing results and analysis, the following items are forwarded for consideration for feasibility level design and cost estimates.

6.1 Considerations

Based on the existing data, and the results of the Phase 2 aquifer test, the DH-7 site appears to be a feasible site for the installation of a water supply system for the Village of Santee to meet the projected 2050 demands. In order to prepare final construction level designs for a water supply system, refined evaluation of any site that is chosen as the primary water supply source is recommended.

Such evaluation should consist of a long term aquifer test, in the range of up to 7 days of continuous pumping. Additional observation wells should be installed prior to the long term testing. A couple of these wells should be from the southeast to the southwest of the test site to evaluate the potential for an aquifer boundary in that direction.

In order to identify the recharge source(s) of the aquifer at the DH-7 site, additional observation wells, 2 or 3, should be installed to the north and west of the site prior to the long-term testing to evaluate the potential for aquifer recharge coming from the Missouri River – either directly or indirectly. Identification of the aquifer recharge source(s) will assist in the design of the system by identifying potential water quality issues and either designing the treatment facility to account for such issues, or designing mitigation factors into the system to prevent potential water quality problems from arising.

The layout of the test well and the observation wells for the long-term testing program should be designed to utilize as many of the existing wells in the vicinity of DH-7 as possible. Additionally, the test well should be designed so that it can be converted from a test well to a production well following the long-term test.

The aquifer test should be conducted at the maximum sustainable yield possible to place as much stress on the aquifer system as possible, but drawdowns should not exceed 70 to 75% of the saturated thickness to reduce potential damage to the aquifer from localized dewatering.

Based on the results of the previous aquifer test, and the current understanding of the aquifer, a feasibility level design would probably include the following elements:

1) The well field would consist of at least three, but no more than, four production wells.

2) Each new well should be designed to have a long term capacity of 312 gpm, recognizing that well efficiencies and pump capacities drop off with age and usage.

3) The spacing between the wells should be at about 2.5 times the estimated Radius of Influence; based on the current understanding of the aquifer properties, this would be about 1,840 feet (2.5 times 736 feet) between pumping wells. Actual well spacing would be determined based on the results of the long-term testing program.

4) Operational plans for the wells would be to rotate the pumping of each well so that wear and tear is reduced. During peak demand times, a second well would be brought

on-line to meet the estimated PMDD of 625 gpm. Additionally, having a minimum of three wells capable of 312 gpm each would provide a safety factor such that any one well could be off-line for repair or maintenance without impacting the system's ability to meet the 625 gpm peak demand.

5) Additional observation wells should be strategically placed such that the recharge source(s) can be monitored for both quantity and quality. Other observation wells should be strategically placed to monitor known, suspected, or potential contamination sources. A Contamination Response Plan should be developed to identify response strategies in the event contamination, either natural or human generated, is detected so that remediation can begin before the water supply is compromised.

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APPENDIX A

WELL LOGS

Attachment No. 2

7-1557 (5-74)
Water and Power

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 1

FEATURE Santee Water Supply PROJECT STATE NE

HOLE NO. DH-1 LOCATION SE1/4, Sec. 14, T33N, R4W. GROUND ELEV. 1210 DIP (ANGLE FROM HORIZ.) 90°

COORDS. N. E.

BEGUN 8-3-93 FINISHED 8-3-93 DEPTH OF OVERBURDEN 92' TOTAL DEPTH 99.4' BEARING ---

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 2.7' 8-3-93 LOGGED BY Cast LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	PERCOLATION TESTS: DEPTH (FEET) FROM (P, Cs, or Cm)	TO	LOSS (G.P.M.)	PRESSURE (P.S.I.)	LENGTH OF TEST (MIN.)	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
Purpose: Investigate potential water supply source for Village of Santee.	4"											0-11+' LEAN CLAY, about 90% fines with medium plasticity and 10% fine sand; wet to saturated; dark gray to black; streaks of organic material. (CL)
Driller: Ron Falk, Terracon Consultants, Omaha NE	W A S H		Blow Counts/1.0'						11			11-25+' POORLY GRADED SAND with SILT, about 90% fine sand, trace of medium, and 10% nonplastic fines; maximum size medium sand; saturated; gray, sand contains visible amount of biotite; moderate reaction with HCl. (SP-SM)
		SPT							20			
Drill Rig: CME 850	B O R E								25			25-67+' POORLY GRADED SAND, about 95% fine sand, scattered zones which contain fine to coarse sand and 5+% fine gravel, with 5% nonplastic fines; coarser zones occur within 46-56' interval; gray; sand contains visible amount of biotite; maximum size 3/8"; saturated; slight to moderate reaction with HCl. (SP)
Drill Method: Set 10' of 3¼" I.D. hollow stem augers as surface casing; SPT drive samples taken at 10' intervals beginning at 19+'; 140 lb. CME auto-hammer used to advance sampler; hole advanced between samples with 3" roller bit using bentonite drilling fluid.		SPT	13						30		X	
		SPT	21						40			
		SPT	11						50		X	
Off-Set Hole: A hole for water quality sampling was completed using 4-inch I.D. hollow stem augers with the bottom 5' containing areas of 0.010 slot well screen.		SPT	20						60		X	
									67			67-75+' POORLY GRADED SAND, about 90% fine to coarse sand, pred. fine to medium, 5% fine gravel, and 5% nonplastic fines; maximum size 3/8"; saturated; gray-brown; no reaction with HCl. (SP)
		SPT	10						70		X	
Completion: Holes were backfilled with drill cuttings.									75			75-92+' POORLY GRADED SAND with SILT, about 90% very fine to fine sand and 10% nonplastic fines; coarser zone 90-92; maximum size coarse sand; saturated; gray; sand contains visible amount of biotite; moderate reaction with HCl. (SP-SM)
		SPT	37						80			
Water Samples: Collected on 8-2-93 from depth of 67-72'. Offset hole located 10' north of DH-1.		SPT							90		X	
									92			CARLILE SHALE 92-99.4' SHALE, unweathered; highly plastic; cuts easily with knife; black; no reaction with HCl.
		SPT	49						99.4			

Drawdown Data

Pumping Rate	Drawdown
10.7 gpm	1.3 ft.
37.5 gpm	8.3 ft.

EXPLANATION

CORE LOSS

CORE RECOVERY

Type of hole . . . D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

Hole Location:
33-14-14 DBBD

7-1887 (6-74)
Water and Power

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 1

FEATURE: Santee Water Supply   PROJECT: STATE: NE
HOLE NO.: DH-2   LOCATION: SE1/4, Sec. 14, T33N, R4W   COORDS. N.   E.   GROUND ELEV.: 1210   DIP (ANGLE FROM HORIZ.): 90°
BEGUN: 8-3-93   FINISHED: 8-3-93   DEPTH OF OVERBURDEN: 39±'   TOTAL DEPTH: 40.1'   BEARING: ---
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 1.3'   8-4-93   LOGGED BY: Cast   LOG REVIEWED BY:

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Purpose:
Investigate potential water supply source for Village of Santee.

Driller:
Ron Falk, Terracon. Consultants, Omaha NE

Drill Rig:
CME 850

Drill Method:
Set 10' of 3½" I.D. hollow stem augers as surface casing; SPT drive samples taken at 10' intervals beginning at 19±'; 140 lb. CME auto-hammer used to advance sampler; hole advanced between samples with 3" roller bit using bentonite drilling fluid.

Off-Set Hole:
A hole for water quality sampling was completed using 4-inch I.D. hollow stem augers with the bottom 5' containing areas of 0.010 slot well screen.

Completion:
Holes were backfilled with drill cuttings.

Water Samples:
Collected on 8-4-93 from depth of 34-39'. Offset hole located 10' south of DH-2.

TYPE AND SIZE OF HOLE: 4" WASH BORE

PERCOLATION TESTS / SAMPLES

Sample	Blow Counts/1.0'	Samples for testing
SPT	3	X
SPT (20')	2	
SPT (30')	15	X
SPT (40')	50/0.6'	

DEPTH (FEET): 11; 25; 39; 40.1

CLASSIFICATION AND PHYSICAL CONDITION

0-11±' LEAN TO FAT CLAY, about 95% fines with high plasticity and 5% fine sand; maximum size fine sand; scattered organic streaks; saturated; black. (CL-CH)

11-25±' SILTY SAND, about 85% very fine to fine sand and 15% nonplastic fines; maximum size fine sand; saturated; dark gray; sand contains visible amount of biotite. (SM)

25-39±' POORLY GRADED SAND, about 95% very fine to fine sand and 5% non-plastic fines; maximum size fine sand; saturated; gray; sand contains visible amount of biotite. (SP)

NIOBRARA FORMATION
39-40.1' FORT HAYS CHALK, lightly to nonweathered; firm, can be cut with knife; light gray; strong reaction with HCl.

Drawdown Data

Pumping Rate	Drawdown
3.0 gpm	7.4 ft.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole .... D = Diamond, H = Hoyxtaillie, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series).. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

Hole Location:
33-14-14 DBDB

SUMMARY OF PHYSICAL PROPERTIES TEST RESULTS (Proctor Compaction)

PROJECT ____ FEATURE Santee Water Supply Investigations

TABLE ____
SHEET 1 OF 1

Sample Number	Hole Number	Depth - feet (m)	Classification Symbol	Silt & Clay	Fine Sand #200	Fine Sand #100	Fine Sand #50	Medium Sand #30	Medium Sand #16	Coarse Sand #8	Gravel #4	Gravel 3/8"	Gravel 3/4"	Gravel 1½"	Gravel 3"		Liquid Limit	Plasticity Index	In-Place Moisture	
	DH-1	29.0-30.0	SP	1.3	5.0	40.2	52.6	0.5	0.2	0.2	0.0	0.0	0.0							
		49.0-50.0	SP	4.1	3.2	16.3	35.0	16.4	10.1	8.5	5.2	1.2	0.0							
		59.0-60.0	SP	3.7	3.8	36.4	34.1	9.2	4.0	2.5	2.8	3.5	0.0							
		69.0-70.0	SP	3.3	2.2	6.2	23.3	25.5	21.4	11.0	2.9	4.2	0.0							
		89.0-90.0	SP-SM	8.5	9.5	67.5	10.0	2.5	1.1	0.4	0.5	0.0	0.0							
	DH-2	5.0- 6.5	CH	98.7	1.3												55.9	30.3	45.6	
		29.0-30.5	SP-SM	5.8	14.6	73.6	5.8	0.1	0.1	0.0	0.0	0.0	0.0							

NOTE: Numbers in parentheses are metric equivalents of numbers directly above.

Attachment No. 4

(1-55)
BUREAU OF RECLAMATION

GEOLOGIC LOG OF DRILL HOLE

FEATURE: Santee Water Supply — PROJECT: Spec. No. 065Q600125 — STATE: Nebraska

HOLE NO.: DH-3 — LOCATION: NW¼, NW¼, NW¼, T33N R5W — COORDINATES: N 551,825 E 2,570,023 — GROUND ELEVATION: ~~122.0~~ 1220 — ANGLE FROM VERTICAL: 90°

BEGUN: 10-29-06 — FINISHED: 10-30-06 — DEPTH OF OVERBURDEN: 37.0' — TOTAL DEPTH: 38.5' — BEARING OF ANGLE HOLE:

DEPTH OR ELEV. OF WATER TABLE: Not Obtained — HOLE LOGGED BY: Cast — FOREMAN:

NOTES On water table levels, water return, character of drilling etc.	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	PERCOLATION TESTS: DEPTH (FT.) FROM (P, Cs or Cm)	TO	LOSS IN (G.P.M.)	PRESSURE (P.S.I.)	LENGTH OF TEST (min)	ELEVATION	DEPTH	LOG / SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
Crazy Peak Site Purpose: Evaluate potential water supply source for Village of Santee Driller: Dave Mather of Thield Geotech of Omaha NE Drill Rig: CME-55 Drill Method: Set 22.5' of 3¼" ID Hollow stem augers as surface casing. Drive samples taken at 10' intervals beginning at 9.1' using SPT sampler. 140 lb. CME auto-hammer used to advance sampler. Hole advanced 22.5-37.0' between drive samples with 3" roller bit. Drill Fluid: 150 gallons of water with 1 pint of EZ-mud (anionic polymer). Completion: Hole backfilled with cuttings, top section contains mixture of bentonite. Coordinates by GPS; elev. from USGS Quad Sheet.	3" Washbore	S (at ~10, 20, 30, 38)	S = Sample						18 37 38.5		0-18±' SANDY SILT, about 80% nonplastic fines and 20% very fine sand; grades sandier with depth; saturated below 4'; paper-thin bedding with organic streaks; grayish-brown. (ML) 18-37±' SILTY SAND, about 60% very fine sand and 40% nonplastic fines grading to 80% very fine to fine sand and 20% nonplastic fines at bottom of interval; saturated; paperthin bedding with organic streaks; grayish brown. (SM) NIOBRARA FORMATION 37-38.5 SHALEY CHALK, thinly bedded; lightly weathered; medium gray; can be cut with knife and crushed with high finger pressure.

EXPLANATION

CORE LOSS — CORE RECOVERY

Type of hole........ D = Diamond, H = Haystellite, S = Shot, C = Churn

Hole sealed........ P = Packer, Cm = Cemented, Cs = Bottom of casing

Approximate size of hole (X-series)........ Ex = 1 1/2", Ax = 1 7/8", Bx = 2 3/8", Nx = 3"

Approximate size of core (X-series)........ Ex = 7/8", Ax = 1 1/8", Bx = 1 5/8", Nx = 2 1/8"

Outside diameter of casing (X-series)........ Ex = 1 13/16", Ax = 2 1/4", Bx = 2 7/8", Nx = 3 1/2"

Inside diameter of casing (X-series)........ Ex = 1 1/2", Ax = 1 29/32", Bx = 2 3/8", Nx = 3"

ANGLE HOLE ☐ VERTICAL HOLE ☐

GPO 844140

HOLE NO. DH-3

Grand Island Testin aboratories

Division of Benjamin & Associates, Inc.

SOIL - BITUMINOUS - CONCRETE TESTING SOIL INVESTIGATIONS ENVIRONMENTAL AUDITS
TELEPHONE (308) 382-8465 3550 WEST OLD HIGHWAY 30 P.O. BOX 339
FAX (308) 382-8467 GRAND ISLAND, NEBRASKA 68802

DATE: November 8, 2006 NAME OF PROJECT: Water Supply for the Village of Santee DH-3 LOCATION: ....

TYPE OF TESTS: WASH GRADATIONS FOR: Bureau of Reclamation-Nebraska/Kansas AO, 203 W. Second Street, Grand Island, NE 68801

MECHANICAL ANALYSIS OF MATERIAL

*WASH = W, DRY = D

SAMPLE DATE	SAMPLE NO.	*	1"	3/4"	1/2"	3/8"	4	8	10	12	16	20	30	40	50	80	100	200
			PERCENT RETAINED:															
	S-2 28.5-30.0	W	0	0	0	0	0	0	0	0.1	0.1	0.1	0.2	0.3	1.0	51.1	74.1	95.7
	S-1 37.5-38.5	W	0	0	0	0	0.9	4.9	5.9	7.0	9.4	11.4	13.3	16.3	17.6	21.9	24.4	34.1

GEOLOGIC LOG OF DRILL HOLE

FEATURE Santee Water Supply PROJECT Spec No. 065Q600125 STATE Nebraska

HOLE NO. DH-4 LOCATION NE¼NW¼NW¼ T33N R5W

COORDINATES N 557,381 E 2,575,894 GROUND ELEVATION ~~121.8~~ 1218 ANGLE FROM VERTICAL 90°

BEGUN 10-30-06 FINISHED 10-30-06 DEPTH OF OVERBURDEN 64.7 TOTAL DEPTH 66.0 BEARING OF ANGLE HOLE

DEPTH OR ELEV. OF WATER TABLE Not Obtained HOLE LOGGED BY Cast FOREMAN

NOTES On water table levels, water return, character of drilling etc.	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	PERCOLATION TESTS DEPTH (FT.) FROM (P, Cs or Cm)	TO	LOSS IN (G.P.M.)	PRESSURE (P.S.I.)	LENGTH OF TEST (min)	ELEVATION	DEPTH	LOG / SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
Delta Site Purpose: Evaluate potential water supply source for Village of Santee Driller: Dave Mather of Thiele Geotech of Omaha NE Drill Rig: CME955 Drill Method: Set 22.5' of 3¼" ID Hollowstem augers as surface casing. Drive samples taken at 10" intervals beginning at 9.1' using SPT sampler. 140 lb. auto-hammer used to advance sampler. Hole advanced 22.5-65.0' with 3" roller bit between drive samples. Drill Fluid: 200 gallons of water, 100 lbs of bentonite, and 1 quart of EZ-mud (anionic polymer). Completion: Backfilled hole with drill cuttings, Coordinates by GPS; elev. taken from USGS Quad Sheet.	10 20 30 40 50 60 70 80 90	S S S S S S	S=Sample						10 20 30 40 50 60 64.7 66.0 70 80 90		0-20±' SANDY SILT, about 65% no to low plasticity fines and 35% fine sand, becomes sandier with depth; saturated below 4'; scattered 0.1 to 0.2' interbeds of silty sand and lean clay; random 1/4" pieces of chalk; some rust staining; grayish brown. (ML) 20-40±' POORLY GRADED SAND with SILT, about 90% fine sand and 10% non-plastic fines; scattered medium to coarse sand grains; maximum size coarse sand; saturated; gray. (SP-SM) 40-50±' POORLY GRADED SAND, about 95% fine to medium sand; maximum size coarse sand; scattered layers of silt and wood at 42±'; saturated; medium gray. (SP) 50-64.7' POORLY GRADED SAND, about 95% fine sand and 5% nonplastic fines; scattered 0.1' seams of medium sand, trace of coarse, and silt; maximum size coarse sand, grayish brown; saturated. (SP) NIOBRARA FORMATION 64.7-66.0' CHALK, lightly weathered; gray; separates into thin plates; can be cut with knife; requires high finger pressure to break fragments.

EXPLANATION

☐ CORE LOSS

■ CORE RECOVERY

Type of hole........................D = Diamond, H = Haystellite, S = Shot, C = Churn

Hole sealed........................P = Packer, Cm = Cemented, Cs = Bottom of casing

Approximate size of hole (X-series)........Ex = $1\frac{1}{2}$", Ax = $1\frac{7}{8}$", Bx = $2\frac{3}{8}$", Nx = 3"

Approximate size of core (X-series)........Ex = $\frac{7}{8}$", Ax = $1\frac{1}{8}$", Bx = $1\frac{5}{8}$", Nx = $2\frac{1}{8}$"

Outside diameter of casing (X-series)........Ex = $1\frac{13}{16}$", Ax = $2\frac{1}{4}$", Bx = $2\frac{7}{8}$", Nx = $3\frac{1}{2}$"

Inside diameter of casing (X-series)........Ex = $1\frac{1}{2}$", Ax = $1\frac{29}{32}$", Bx = $2\frac{3}{8}$", Nx = 3"

ANGLE HOLE ☐

VERTICAL HOLE ☐

GPO 844140

HOLE NO. DH-4

Grand Island Testin_ _aboratories

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SOIL - BITUMINOUS - CONCRETE TESTING SOIL INVESTIGATIONS ENVIRONMENTAL AUDITS
TELEPHONE (308) 382-8465 3550 WEST OLD HIGHWAY 30 P. O. BOX 339
FAX (308) 382-8467 GRAND ISLAND, NEBRASKA 68802

DATE: November 8, 2006 NAME OF PROJECT: Water Supply for the Village of Santee DH-4 LOCATION: ....

TYPE OF TESTS: WASH GRADATIONS FOR: Bureau of Reclamation-Nebraska/Kansas AO, 203 W. Second Street, Grand Island, NE 68801

MECHANICAL ANALYSIS OF MATERIAL

*WASH = W DRY = D			PERCENT RETAINED:																
SAMPLE DATE	SAMPLE NO.	*	1"	3/4"	1/2"	3/8"	4	8	10	12	16	20	30	40	50	80	100	200
	S-3 23.0-24.5	W	0	0	0	0	0.3	0.8	0.9	1.0	1.2	1.4	1.5	5.7	10.1	35.2	52.6	83.6
	S-4 35.0-36.5	W	0	0	0	0	0	0	0	0	0	0.1	0.1	1.0	4.2	75.3	85.9	97.1
	S-5 45.0-46.0	W	0	0	0	0	1.0	4.5	5.6	7.6	12.6	18.8	33.7	66.1	75.8	87.4	91.9	98.4
	S-6 55.0-56.5	W	0	0	0	0	0	0.6	0.7	1.0	1.7	2.3	2.8	6.2	9.0	69.7	83.0	96.7

GEOLOGIC LOG OF DRILL HOLE

FEATURE Santee Water Supply PROJECT Spec. No. 06SQ600125 STATE Nebraska

HOLE NO. DH-5 LOCATION NE¼NE¼NE¼ Sec 13-T33N-R5W GROUND ELEVATION 1218 ANGLE FROM VERTICAL 90°

COORDINATES

BEGUN 10-31-06 FINISHED 4-03-07 DEPTH OF OVERBURDEN 46± TOTAL DEPTH 47.0 BEARING OF ANGLE HOLE

DEPTH OR ELEV. OF WATER TABLE Not Obtained HOLE LOGGED BY Cast FOREMAN

NOTES On water table levels, water return, character of drilling etc.	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	PERCOLATION TESTS: DEPTH (FT.) FROM (P, Cs or Cm)	TO	LOSS IN (G.P.M.)	PRESSURE (P.S.I.)	LENGTH OF TEST (min)	ELEVATION	DEPTH	LOG (SAMPLES FOR TESTING)	CLASSIFICATION AND PHYSICAL CONDITION
Boat Ramp Site Purpose: Evaluate potential water supply source for Village of Santee Driller: Dave Mather of Thiele Geotech of Omaha NE Drill Rig: CME-55 Drill Method: Set 22.5±' of 3¼" ID hollow stem augers as surface casing. Drive samples taken at 10' intervals beginning at 23.5' using SPT sampler. 140 lb. auto-hammer used to advance sampler. Hole advanced 22.5-46' with 3" roller bit between drive samples. Drill Fluid: Water, bentonite, and EZ-mud (anionic polymer) Completion: Backfilled with drill cuttings. Coordinates by GPS; elev. taken from USGS Quad Sheet.		SM S S S S							10 21 41.5 46 47		0-2±' COMPACTED EMBANKMENT, mixture of sand, gravel, and clay, max. size 1" 2-10±' COMPACTED EMBANKMENT, LEAN CLAY, about 90% fines with low to medium plasticity and 10% fine sand; moist; quite firm; gray-black. (CL) 10-21±' LEAN CLAY, about 90% fines with low plasticity and 10% fine sand; saturated; organic odor; soft; black (CL) 21-41.5±' SILTY SAND grading to POORLY GRADED SAND, about 85-95% very fine to fine sand; saturated; scattered fragments of wood; loose; gray brown (SM to SP) 41.5-46±' SILTY SAND and GRAVEL, about 50% fine gravel, 25% fine to coarse sand, and 25% no to low plasticity fines; max. size recovered 1½"; dense; rusty gray; obtained sample appeared impervious to very low permeability; (SM-CM) NIOBRARA FORMATION 46±-47.0' CHALK, weathered to clay-like indistinct layering, bands of gray and yellow; moldable with fingers. Off-Set Hole Off-set 10 feet west on 4-03-07; advanced hole to 43' with 3¼" ID hollow-stem augers, sampled at 43' and advanced augers to 45', advanced roller bit to 46', drive sample 46-47'. Hole backfilled with auger cuttings.

EXPLANATION

CORE LOSS

CORE RECOVERY

Type of hole........................D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed........................P = Packer, Cm = Cemented, Cs = Bottom of casing
Approximate size of hole (X-series)........Ex = 1 1/2", Ax = 1 7/8", Bx = 2 3/8", Nx = 3"
Approximate size of core (X-series).......Ex = 7/8", Ax = 1 1/8", Bx = 1 5/8", Nx = 2 1/8"
Outside diameter of casing (X-series)......Ex = 1 13/16", Ax = 2 1/4", Bx = 2 7/8", Nx = 3 1/2"
Inside diameter of casing (X-series)......Ex = 1 1/2", Ax = 1 29/32", Bx = 2 3/8", Nx = 3"

ANGLE HOLE ☐

VERTICAL HOLE ☐

GPO 844140

HOLE NO. DH-5

Grand Island Testin aboratories

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SOIL - BITUMINOUS - CONCRETE TESTING SOIL INVESTIGATIONS ENVIRONMENTAL AUDITS
TELEPHONE (308) 382-8465 3550 WEST OLD HIGHWAY 30 P. O. BOX 339
FAX (308) 382-8467 GRAND ISLAND, NEBRASKA 68802

DATE: November 8, 2006 NAME OF PROJECT: Water Supply for the Village of Santee DH-5 LOCATION: ....

TYPE OF TESTS: WASH GRADATIONS FOR: Bureau of Reclamation-Nebraska/Kansas AO, 203 W. Second Street, Grand Island, NE 68801

MECHANICAL ANALYSIS OF MATERIAL

*WASH = W DRY = D			PERCENT RETAINED:															
SAMPLE DATE	SAMPLE NO.	*	1"	3/4"	1/2"	3/8"	4	8	10	12	16	20	30	40	50	80	100	200
	S-7 23.5-25.0	W	0	0	0	0	0.5	0.9	0.9	1.0	1.2	1.3	1.4	4.6	9.5	30.2	39.1	82.5
	S-9 33.5-35.0	W	0	0	0	0	0.1	0.2	0.2	0.2	0.3	0.3	0.4	1.9	4.6	83.7	89.1	96.5
	S-8 43.5-45.0	W	0	15.1	21.7	30.4	41.5	49.7	50.8	51.9	54.1	55.6	57.2	60.7	63.1	78.7	83.4	91.7

GEOLOGIC LOG OF DRILL HOLE

FEATURE Santee Water Supply .... PROJECT Spec. No. 06SQ600125 .... STATE Nebraska

HOLE NO. DH-6 LOCATION See Notes ...... GROUND ELEVATION 1238 ...... ANGLE FROM VERTICAL 90°

COORDINATES ....

BEGUN 4-03-07 FINISHED 4-04-07 DEPTH OF OVERBURDEN 82.5' TOTAL DEPTH 82.5' BEARING OF ANGLE HOLE ....

DEPTH OR ELEV. OF WATER TABLE Est 27' 4-03-07 HOLE LOGGED BY Cast .... FOREMAN ....

NOTES On water table levels, water return, character of drilling etc.	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	PERCOLATION TESTS DEPTH (FT) FROM (P, Cs or Cm)	TO	LOSS IN (G.P.M.)	PRESSURE (P.S.I.)	LENGTH OF TEST (min)	ELEVATION	DEPTH	LOG (SAMPLES FOR TESTING)	CLASSIFICATION AND PHYSICAL CONDITION
Recreation Area Site Purpose: Evaluate potential water supply source for Village of Santee Driller: Dave Mather of Thiele Geotech of Omaha NE Drill Rig: CME-55 Drill Method: Advanced 3½" ID hollow stem augers 74.5'; 2" drive samples attempted at 29.5', 34.5', 35.5', 45', 48.5', 54.5', 59.5', 64.5' 69.5'*, 74.5', 79.5'* and 82.5'** * = 1 gravel recovered **= Refused Drill fluid-water with polymer; 3' roller bit used 74.5-82.5' Completion: Hole backfilled with cuttings. Elev. taken from USGS Quad Sheet. Location: 1050' S and 1150' W of NE Corner Sec. 13, T33N, R5W	10 20 30 40 50 60 70 80 90	S S S S S S S * S * **							10 20 30 40 50 55 60 70 80 82.5 90		0-10+' SILT, about 90% no to low plasticity fines and 10% fine sand; moist; light brown; topsoil 0-1.5' (ML) 10-27+' LEAN CLAY, about 90% fines with medium plasticity and 10% fine sand; scattered lime nodules and chalk fragments to ¼"; moist; brown with variations to brown-black; contains old soil horizons; minor rust streaking and lime spots. (CL) 27-55+' Alternating layers of SANDY SILT, SILTY SAND, and POORLY GRADED SAND, silts and silty sands predominate; layers are 0.3-0.8' thick; Sandy Silts are about 60% fines and 40% fine to coarse sand; silty sands are about 75% fine sand and 25% fines; poorly graded sands are about 95% fine to medium sand with trace of coarse sand and fine gravel; scattered fragments of chalk up to 3"; shades of brown; saturated. (SM, ML, and SP) 55-70+' SILTY GRAVEL, about 60% fine to coarse sand and gravel with 40% nonplastic fines; max. size recovered 2", shades of brown, dark gray, and yellow; saturated. (GM) 70-82.5' SILTY GRAVEL, about 85% fine to coarse sand and fine to coarse gravel and 15% fines; max. size recovered 2"; dark gray; saturated. 82.5' Bit refusal, a few chert shards recovered. Drilling action and shards interrupted as bedrock surface - Niobrara Fm.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole .... D = Diamond, H = Haystellite, S = Shot, C = Churn

Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing

Approximate size of hole (X-series) .... Ex = 1 $\frac{1}{2}$", Ax = 1 $\frac{7}{8}$", Bx = 2 $\frac{3}{8}$", Nx = 3"

Approximate size of core (X-series) .... Ex = $\frac{7}{8}$", Ax = 1 $\frac{1}{8}$", Bx = 1 $\frac{5}{8}$", Nx = 2 $\frac{1}{8}$"

Outside diameter of casing (X-series) ...... Ex = 1 $\frac{13}{16}$", Ax = 2 $\frac{1}{4}$", Bx = 2 $\frac{7}{8}$", Nx = 3 $\frac{1}{2}$"

Inside diameter of casing (X-series) ...... Ex = 1 $\frac{1}{2}$", Ax = 1 $\frac{29}{32}$", Bx = 2 $\frac{3}{8}$", Nx = 3"

ANGLE HOLE ☐ VERTICAL HOLE ☐

GPO 844140

HOLE NO. DH-6

Grand Island Testir ̃aboratories

Division of Benjamin & Associates, Inc.

SOIL - BITUMINOUS - CONCRETE TESTING SOIL INVESTIGATIONS ENVIRONM
TELEPHONE (308) 382-8465 3550 WEST OLD HIGHWAY 30 P.
FAX (308) 382-8467 GRAND ISLAND, NEBI

Post-it® Fax Note 7671	Date 04-12-07 # of pages ▶ 2
To Margo	From Lee Wagner
Co./Dept.	Co. GI Testing
Phone #	Phone # 382-8465
Fax # 389-4780	Fax # 382-8467

DATE: April 11, 2007 NAME OF PROJECT: Water Supply for the Village of Santee DH-6 LOCATION: ....

TYPE OF TESTS: WASH GRADATIONS FOR: Bureau of Reclamation-Nebraska/Kansas AO, 203 W. Second Street, Grand Island, NE 6880!

MECHANICAL ANALYSIS OF MATERIAL

*WASH = W DRY = D			25.4	19	13.2	9.5	4.25	2.36	2.0	1.7	1.18	.85	.6	.425	.3	.18	.15	.075
			PERCENT RETAINED:															
SAMPLE DATE	SAMPLE NO.	*	1"	3/4"	1/2"	3/8"	4	8	10	12	16	20	30	40	50	80	100	200
	S-7 29.5-31.0	W	5.2	12.5	19.6	25.4	37.8	50.7	53.2	56.6	62.2	66.3	68.4	71.0	71.9	73.9	74.9	77.8
	S-8 34.5-35.0	W	0	2.2	4.9	5.6	8.7	11.5	12.0	12.8	15.7	23.5	60.5	92.9	94.5	96.2	96.6	97.4
	S-9 35.5-36.0	W	0	0	0	0.5	1.3	2.4	2.5	2.6	2.8	3.0	3.9	6.1	7.3	14.7	21.1	42.9
	S-10 45.0-46.0	W	13.8	13.8	22.0	28.4	42.3	58.3	60.2	62.3	65.5	67.6	69.2	72.9	75.5	80.8	82.5	86.5
	S-11 48.5-50.0	W	10.5	10.5	16.8	23.7	43.3	57.6	59.6	62.0	65.7	68.6	71.3	76.5	78.4	81.6	82.7	85.6
	S-12 54.5-56.0	W	12.0	13.1	19.4	24.8	38.0	55.1	56.8	60.4	64.8	69.9	77.0	84.9	86.7	89.0	89.6	91.3
	S-13 59.5-61.0	W	4.6	17.5	27.5	33.3	41.5	50.4	51.6	53.1	55.3	57.8	62.4	69.5	72.6	78.5	80.4	84.8
	S-14 64.5-66.0	W	35.3	39.8	46.5	51.8	62.1	71.3	72.9	74.7	77.2	79.8	83.0	86.0	87.2	89.2	90.0	92.3
	S-15 74.5-76.0	W	13.5	16.5	27.0	38.8	56.0	67.7	68.9	70.3	72.7	74.6	76.5	79.0	80.7	87.1	89.4	92.9

GEOLOGIC LOG OF DRILL HOLE

FEATURE Santee Water Supply .... PROJECT .... STATE Nebraska

HOLE NO. DH-7 LOCATION See Notes .... GROUND ELEVATION 1238 1239 ... ANGLE FROM VERTICAL ....

COORDINATES .... TOTAL DEPTH 57.0'

BEGUN 4-04-07 FINISHED 4-04-07 DEPTH OF OVERBURDEN 57.0' ..... BEARING OF ANGLE HOLE ....

DEPTH OR ELEV. OF WATER TABLE 29' Est. HOLE LOGGED BY Cast .... FOREMAN ....

NOTES On water table levels, water return, character of drilling etc.	CLASSIFICATION AND PHYSICAL CONDITION
Irrigation Well Site Purpose: Evaluate potential water supply source for Village of Santee Driller: Dave Mather of Thiele Geotech of Omaha NE Drill Rig: CME-55 Drill Method: Advanced 3½" ID hollow stem augers advanced to 57'; attempted roller bit at 57' with no advancement. 2" x 1.5' drive samples taken at 29.5', 34.5', 39.5', 44.5', 49.5', and 54.5'. Completion: Hole backfilled with cuttings. Elev. taken from USGS Quad Sheet. Location: 1600' S and 1650' W of NE Corner, Sec. 13, T33N, R5W	0-2+' LEAN CLAY, Topsoil, about 95% fines with low plasticity; max. size noted medium sand; moist; black; some organic material. (CL) 2-17+' LEAN CLAY, about 90% fines with low plasticity and 10% fine sand; scattered lime nodules to 1/8"; tan; dry-moist. (CL) 17-25+' LEAN CLAY with layers of gravel considerable drill chatter and short intervals of slow advancement; maximum size recovered 1½". 25-33+' POORLY GRADED GRAVEL with SILT; about 60% fine gravel with some coarse grains; 30% fine to coarse sand, and 10% nonplastic fines; max. size recovered 1.5"; grains are subrounded to rounded; saturated at 29'; dark brown; (GM) 33-37+' POORLY GRADED SAND, about 95% fine to medium sand with some coarse sand and fine gravel and 5% nonplastic fines; max. size recovered 3/4"; saturated; tan with black specks. (SP) 37-54+' POORLY GRADED GRAVEL with SILT; about 60% fine to coarse gravel, 30% fine to coarse sand, and 10% nonplastic fines; max. size recovered 1"; particles are subrounded to rounded; saturated; dark grayish brown. 54-57.0' SILTY SAND, about 85% fine to medium sand, predominately fine; trace of coarse sand and fine gravel, and 15% fines with no to low plasticity max. size recovered 1/2"; dark brown; saturated. (SM) 57.0 Bit Refusal; drilling action interpreted as bedrock surface - Niobrara Formation.

Columns (no entries): TYPE AND SIZE OF HOLE; CORE RECOVERY (%); PERCOLATION TESTS — DEPTH (FT.) FROM (P, Cs or Cm) TO; LOSS IN (G.P.M.); PRESSURE (P.S.I.); LENGTH OF TEST (min); ELEVATION; DEPTH (10–90); LOG — SAMPLES FOR TESTING.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole .... D = Diamond, H = Haystellite, S = Shot, C = Churn

Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing

Approximate size of hole (X-series) .... Ex = 1 1/2", Ax = 1 7/8", Bx = 2 3/8", Nx = 3"

Approximate size of core (X-series) .... Ex = 7/8", Ax = 1 1/8", Bx = 1 5/8", Nx = 2 1/8"

Outside diameter of casing (X-series) ..... Ex = 1 13/16", Ax = 2 1/4", Bx = 2 7/8", Nx = 3 1/2"

Inside diameter of casing (X-series) ...... Ex = 1 1/2", Ax = 1 29/32", Bx = 2 3/8", Nx = 3"

ANGLE HOLE ☐ VERTICAL HOLE ☐

GPO 844160

HOLE NO. DH-7

Grand Island Testin… aboratories

Division of Benjamin & Associates, Inc.

SOIL - BITUMINOUS - CONCRETE TESTING SOIL INVESTIGATIONS ENVIRONMENTAL AUDITS

TELEPHONE (308) 382-8465 3550 WEST OLD HIGHWAY 30 P. O. BOX 339

FAX (308) 382-8467 GRAND ISLAND, NEBRASKA 68802

DATE: April 10, 2007 NAME OF PROJECT: Water Supply for the Village of Santee DH-7 LOCATION: ....

TYPE OF TESTS: WASH GRADATIONS FOR: Bureau of Reclamation-Nebraska/Kansas AO, 203 W. Second Street, Grand Island, NE 68801

MECHANICAL ANALYSIS OF MATERIAL

*WASH = W DRY = D			PERCENT RETAINED:																
SAMPLE DATE	SAMPLE NO.	*	1"	3/4"	1/2"	3/8"	4	8	10	12	16	20	30	40	50	80	100	200
	S-1 29.5-31.0	W	13.1	15.5	25.7	35.2	53.0	66.9	69.0	71.2	74.7	78.0	82.5	87.1	89.1	92.4	93.2	94.9
	S-2 34.5-36.0	W	0	4.4	6.0	6.9	10.3	16.6	18.4	21.1	27.5	37.6	56.7	83.7	90.5	96.2	97.2	98.6
	S-3 39.5-41.0	W	0	1.8	7.4	16.4	45.2	70.7	74.1	77.2	81.1	83.9	86.8	89.8	91.3	94.8	95.4	96.9
	S-4 44.5-46.0	W	15.4	16.9	28.0	33.9	54.0	72.1	74.4	77.0	80.2	82.7	83.9	87.6	88.7	90.8	91.4	92.9
	S-5 49.5-51.0	W	16.3	18.0	22.3	26.2	36.0	46.7	49.2	53.7	59.6	66.7	73.5	82.6	85.2	88.6	89.4	91.4
	S-6 54.5-56.0	W	0	3.0	5.0	6.1	8.5	11.8	12.5	13.5	15.6	17.9	21.2	40.3	49.9	83.6	87.8	92.8

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APPENDIX B

COMPUTATION TABLES

Table B-1. Table of parameters used for DH-1 through DH-7 in the equations for bed-mounted, on-land, Ranney-type radial collector, and traditional vertical well calculations.

Parameter		DH-1	DH-2	DH-3	DH-4	DH-5	DH-6	DH-7
Caisson radius (ft) – RC only		20	20	20	20	20	20	20
Depth below bottom of river/lake bed (ft) – BM only		10	10	10	10	10	10	10
Depth below SWL (ft)	BM	25	25	25	25	25	25	NA
	OL	27.3	28.7	20	12	12	3	NA
	RC	60	35	30	48	34	45	22
	VW	85	36	31	58	35	52	25
Discharge (gpm)		Varies	Varies	Varies	Varies	Varies	Varies	Varies
Distance to recharge (ft)		500	600	50	500	500	200	1320
K of filter pack (gpd/ft^2)		7000	7000	7000	7000	7000	7000	7000
K of formation (gpd/ft^2)	BM	NA	NA	NA	NA	NA	NA	NA
	OL	40*	15*	9*	49*	20*	1645*	NA
	RC**	2310	91.55	66.78	227.26	193.86	1,711.59	7,906.53
	VW**	236.95	91.55	66.78	301.75	193.86	1,098.58	3,769.63
T of aquifer (ft^2/d)	RC	33,407.98	973.21	267.85	914.40	439.56	6,478.00	2,325.60
	VW	2,692.82	746.65	294.64	2,460.98	984.93	7,050.25	10,584.00
Length of laterals (ft)		Varies	Varies	Varies	Varies	Varies	Varies	Varies
Maximum drawdown (ft)	BM	NA	NA	NA	NA	NA	NA	NA
	OL	13.65	14.35	10	6	6	1.5	NA
	RC	30	20	15	25	15	18	8
	VW	45	30.5	16.5	30.5	19	24	10.5
Pumping duration (minutes)		Varies	Varies	Varies	Varies	Varies	Varies	Varies
River depth (assumed ave.)(ft)		15	15	15	15	15	15	15
Saturated thickness while pumping (ft)	BM	NA	NA	NA	NA	NA	NA	NA
	OL	13.65	14.35	10	6	6	1.5	NA
	RC	45	35	15	30	19	25	8
	VW	45	30.5	16.5	30.5	19	24	10.56

Screen radius (ft = .416 for VW)		Varies	Varies	Varies	Varies	Varies	Varies	Varies
Static saturated thickness (ft)	BM	25	25	25	25	25	25	NA
	OL	27.3	28.7	20	12	12	3	NA
	RC	89	37.7	33	61	38	55	28
	VW	89	37.7	33	61	38	55	28
Storativity (dimensionless)		0.2	0.2	0.2	0.2	0.2	0.2	0.2

BM = Bed-Mounted infiltration gallery   OL = On-Land infiltration gallery   RC = Ranney-type (or radial) Collector system   VW = Traditional Vertical Wells.   NA indicates that no samples were obtained or the listed parameter is not applicable at the site. See Tables B-2 and B-3a through B-3f for parameters marked as 'varies'

* = indicates that no samples were obtained from the zone in which on-land gallery intake screens would most likely be placed. Burial depths of the intake screens would be limited to 30 feet or less due to limitations on excavation depths. These *K* values are estimated based on physical descriptions of the materials encountered as described in the driller's logs.

** = It is assumed that the laterals for the Ranney-style Collector system would be placed in the most conductive zone and the conductivity would be the average of that zone plus all the zones above it; while the conductivity for the Vertical Wells is the average of the entire saturated thickness. *K* values are taken from the Table of Conductivity Values in Appendix J.

Table B-2. Table of bed-mounted infiltration gallery computations, DH-1 through DH-6.

Pipe radius (ft)	Desired Q (gpm) or Max. flow – whichever is less	Desired Q (MGD)	Burial Depth (below stream bottom)	water depth (ft bgs)	K (gpd/ft2)	Flow Velocity in Pipe (<= 3 ft/sec)	Minimum Length of pipe (ft)	Calculated length of pipe @ .5MGD	Calculated length of pipe @ .75MGD	Calculated length of pipe @ 1.0MGD	Calculated length of pipe @ 1.25MGD	Calculated length of pipe @ 1.5MGD
0.25	265*	0.38*	10.00	15.0	7000.00	3.01	5.26	N/A	N/A	N/A	N/A	N/A
0.50	625.5	0.90	10.00	15.0	7000.00	1.77	10.13	5.63	8.44	11.25	14.06	16.88
0.75	625.5	0.90	10.00	15.0	7000.00	0.79	8.80	4.89	7.33	9.77	12.22	14.66
1.00	625.5	0.90	10.00	15.0	7000.00	0.44	7.86	4.36	6.55	8.73	10.91	13.09
1.25	625.5	0.90	10.00	15.0	7000.00	0.28	7.13	3.96	5.94	7.92	9.89	11.87
1.50	625.5	0.90	10.00	15.0	7000.00	0.20	6.53	3.63	5.44	7.25	9.07	10.88
1.75	625.5	0.90	10.00	15.0	7000.00	0.14	6.03	3.35	5.02	6.69	8.36	10.04
2.00	625.5	0.90	10.00	15.0	7000.00	0.11	5.59	3.10	4.65	6.20	7.76	9.31

* this is the maximum Q that a pipe of 0.25 feet can have and not exceed 3 ft/sec of axial flow.

Notes:

1 – Because DH-7 is located over ¼ mile from the shoreline, a bed-mounted infiltration gallery at that location is non-applicable.

2 – Because the hydraulic conductivity of the local materials does not factor into the calculations for a bed-mounted system, one set of calculations will apply to all bed-mounted system regardless of where they are located.

3 – A *K* of 7000 gpd/ft^2 is a fairly common value for clean, well graded sandy gravel, however just about any value of *K* can be obtained simply by varying the make up and gradations of the filter pack around the screen intakes. The critical factor in designing the filter pack gradation will be the gradation of the river/lake sediments that would be available to sift into the filter pack and reduce its *K* value.

4 – N/A (in Table B-2 and all the B-3 tables) indicates that the velocity in the pipe exceeds 3 ft/sec at these flows for the indicated pipe radius.

Table B-3a. Table of on-land infiltration gallery computations, DH-1 (all distances are in feet).

Pipe radius (ft)	Maximum Q (gpm)	Maximum Q (MGD)	Static Water Level	Saturated thickness	K (gpd/ft2)	Flow Velocity in Pipe (<= 3 ft/sec)	Length of pipe	Radius of Influence	Drawdown	Calculated length of pipe @ .5MGD	Calculated length of pipe @ .75MGD	Calculated length of pipe @ 1.0MGD	Calculated length of pipe @ 1.25MGD	Calculated length of pipe @ 1.5MGD
0.25	265.00	0.38	2.70	27.30	40.00	3.01	13278.27	389.00	13.65	N/A	N/A	N/A	N/A	N/A
0.50	530.00	0.76	2.70	27.30	40.00	1.50	35021.86	513.00	13.65	22944.09	34416.13	45888.18	57360.22	68832.27
0.75	535.00	0.77	2.70	27.30	40.00	0.67	37350.72	542.00	13.65	24241.12	36361.68	48482.25	60602.81	72723.37
1.00	560.00	0.81	2.70	27.30	40.00	0.40	40033.81	555.00	13.65	24822.55	37233.83	49645.10	62056.38	74467.66
1.25	575.00	0.83	2.70	27.30	40.00	0.26	41698.67	563.00	13.65	25180.35	37770.53	50360.71	62950.89	75541.06
1.50	590.00	0.85	2.70	27.30	40.00	0.19	43394.44	571.00	13.65	25538.16	38307.24	51076.31	63845.39	76614.47
1.75	605.00	0.87	2.70	27.30	40.00	0.14	45043.19	578.00	13.65	25851.23	38776.85	51702.47	64628.09	77553.70
2.00	620.00	0.89	2.70	27.30	40.00	0.11	46798.86	586.00	13.65	26209.04	39313.56	52418.07	65522.59	78627.11

Table B-3b. Table of on-land infiltration gallery computations, DH-2 (all distances are in feet).

Pipe radius (ft)	Maximum Q (gpm)	Maximum Q (MGD)	Static Water Level	Saturated thickness	K (gpd/ft2)	Flow Velocity in Pipe (<= 3 ft/sec)	Length of pipe	Radius of Influence	Drawdown	Calculated length of pipe @ .5MGD	Calculated length of pipe @ .75MGD	Calculated length of pipe @ 1.0MGD	Calculated length of pipe @ 1.25MGD	Calculated length of pipe @ 1.5MGD
0.25	225.00	0.32	1.30	28.70	15.00	2.55	14335.49	205.00	14.35	N/A	N/A	N/A	N/A	N/A
0.50	210.00	0.30	1.30	28.70	15.00	0.60	22125.61	339.00	14.35	36583.34	54875.01	73166.68	91458.36	109750.03
0.75	225.00	0.32	1.30	28.70	15.00	0.28	24545.16	351.00	14.35	37878.33	56817.49	75756.66	94695.82	113634.98
1.00	235.00	0.34	1.30	28.70	15.00	0.17	26293.39	360.00	14.35	38849.57	58274.35	77699.13	97123.92	116548.70
1.25	245.00	0.35	1.30	28.70	15.00	0.11	27945.27	367.00	14.35	39604.98	59407.46	79209.95	99012.44	118814.93
1.50	250.00	0.36	1.30	28.70	15.00	0.08	28981.78	373.00	14.35	40252.47	60378.70	80504.94	100631.17	120757.40
1.75	260.00	0.37	1.30	28.70	15.00	0.06	30706.70	380.00	14.35	41007.88	61511.81	82015.75	102519.69	123023.63
2.00	265.00	0.38	1.30	28.70	15.00	0.05	31626.66	384.00	14.35	41439.54	62159.31	82879.08	103598.85	124318.62

Table B-3c. Table of on-land infiltration gallery computations, DH-3 (all distances are in feet).

Pipe radius (ft)	Maximum Q (gpm)	Maximum Q (MGD)	Static Water Level	Saturated thickness	K (gpd/ft2)	Flow Velocity in Pipe (<= 3 ft/sec)	Length of pipe	Radius of Influence	Drawdown	Calculated length of pipe @ .5MGD	Calculated length of pipe @ .75MGD	Calculated length of pipe @ 1.0MGD	Calculated length of pipe @ 1.25MGD	Calculated length of pipe @ 1.5MGD
0.25	65.00	0.09	10.00	20.00	9.00	0.74	12826.67	185.00	10.00	N/A	N/A	N/A	N/A	N/A
0.50	75.00	0.11	10.00	20.00	9.00	0.21	14080.00	176.00	10.00	65185.19	97777.78	130370.37	162962.96	195555.56
0.75	80.00	0.12	10.00	20.00	9.00	0.10	15616.00	183.00	10.00	67777.78	101666.67	135555.56	169444.44	203333.33
1.00	85.00	0.12	10.00	20.00	9.00	0.06	16048.00	177.00	10.00	65555.56	98333.33	131111.11	163888.89	196666.67
1.25	90.00	0.13	10.00	20.00	9.00	0.04	15840.00	165.00	10.00	61111.11	91666.67	122222.22	152777.78	183333.33
1.50	90.00	0.13	10.00	20.00	9.00	0.03	19104.00	199.00	10.00	73703.70	110555.56	147407.41	184259.26	221111.11
1.75	95.00	0.14	10.00	20.00	9.00	0.02	18138.67	179.00	10.00	66296.30	99444.44	132592.59	165740.74	198888.89
2.00	95.00	0.14	10.00	20.00	9.00	0.02	20773.33	205.00	10.00	75925.93	113888.89	151851.85	189814.81	227777.78

Table B-3d. Table of on-land infiltration gallery computations, DH-4 (all distances are in feet).

Pipe radius (ft)	Maximum Q (gpm)	Maximum Q (MGD)	Static Water Level	Saturated thickness	K (gpd/ft2)	Flow Velocity in Pipe (<= 3 ft/sec)	Length of pipe	Radius of Influence	Drawdown	Calculated length of pipe @ .5MGD	Calculated length of pipe @ .75MGD	Calculated length of pipe @ 1.0MGD	Calculated length of pipe @ 1.25MGD	Calculated length of pipe @ 1.5MGD
0.25	125.00	0.18	18.00	12.00	49.00	1.42	15578.23	229.00	6.00	N/A	N/A	N/A	N/A	N/A
0.50	140.00	0.20	18.00	12.00	49.00	0.40	16761.90	220.00	6.00	41572.18	62358.28	83144.37	103930.46	124716.55
0.75	150.00	0.22	18.00	12.00	49.00	0.19	17959.18	220.00	6.00	41572.18	62358.28	83144.37	103930.46	124716.55
1.00	155.00	0.22	18.00	12.00	49.00	0.11	20582.31	244.00	6.00	46107.33	69161.00	92214.66	115268.33	138322.00
1.25	160.00	0.23	18.00	12.00	49.00	0.07	22378.23	257.00	6.00	48563.87	72845.80	97127.74	121409.67	145691.61
1.50	165.00	0.24	18.00	12.00	49.00	0.05	23616.33	263.00	6.00	49697.66	74546.49	99395.31	124244.14	149092.97
1.75	170.00	0.24	18.00	12.00	49.00	0.04	24331.97	263.00	6.00	49697.66	74546.49	99395.31	124244.14	149092.97
2.00	175.00	0.25	18.00	12.00	49.00	0.03	24857.14	261.00	6.00	49319.73	73979.59	98639.46	123299.32	147959.18

Table B-3e. Table of on-land infiltration gallery computations, DH-5 (all distances are in feet).

Pipe radius (ft)	Maximum Q (gpm)	Maximum Q (MGD)	Static Water Level	Saturated thickness	K (gpd/ft2)	Flow Velocity in Pipe (<= 3 ft/sec)	Length of pipe	Radius of Influence	Drawdown	Calculated length of pipe @ .5MGD	Calculated length of pipe @ .75MGD	Calculated length of pipe @ 1.0MGD	Calculated length of pipe @ 1.25MGD	Calculated length of pipe @ 1.5MGD	
0.25	65.00	0.09	18.00	12.00	20.00	0.74	5200.00	60.00	6.00	N/A	N/A	N/A	N/A	N/A	
0.50	70.00	0.10	18.00	12.00	20.00	0.20	5693.33	61.00	6.00	28240.74	42361.11	56481.48	70601.85	84722.22	
0.75	78.00	0.11	18.00	12.00	20.00	0.10	6656.00	64.00	6.00	29629.63	44444.44	59259.26	74074.07	88888.89	
1.00	83.00	0.12	18.00	12.00	20.00	0.06	7304.00	66.00	6.00	30555.56	45833.33	61111.11	76388.89	91666.67	
1.25	87.00	0.13	18.00	12.00	20.00	0.04	7888.00	68.00	6.00	31481.48	47222.22	62962.96	78703.70	94444.44	
1.50	90.00	0.13	18.00	12.00	20.00	0.03	8280.00	69.00	6.00	31944.44	47916.67	63888.89	79861.11	95833.33	
1.75	95.00	0.14	18.00	12.00	20.00	0.02	8866.67	70.00	6.00	32407.41	48611.11	64814.81	81018.52	97222.22	
2.00	97.00	0.14	18.00	12.00	20.00	0.02	9312.00	72.00	6.00	33333.33	50000.00	66666.67	83333.33	100000.00	

Table B-3f. Table of on-land infiltration gallery computations, DH-6 (all distances are in feet).

Pipe radius (ft)	Maximum Q (gpm)	Maximum Q (MGD)	Static Water Level	Saturated thickness	K (gpd/ft2)	Flow Velocity in Pipe (<= 3 ft/sec)	Length of pipe	Radius of Influence	Drawdown	Calculated length of pipe @ .5MGD	Calculated length of pipe @ .75MGD	Calculated length of pipe @ 1.0MGD	Calculated length of pipe @ 1.25MGD	Calculated length of pipe @ 1.5MGD
0.25	7.00	0.01	27.00	3.00	1645.00	0.08	27.23	15.00	1.50	N/A	N/A	N/A	N/A	N/A
0.50	8.00	0.01	27.00	3.00	1645.00	0.02	35.27	17.00	1.50	1531.01	2296.52	3062.03	3827.54	4593.04
0.75	9.00	0.01	27.00	3.00	1645.00	0.01	42.02	18.00	1.50	1621.07	2431.61	3242.15	4052.68	4863.22
1.00	10.00	0.01	27.00	3.00	1645.00	0.01	51.87	20.00	1.50	1801.19	2701.79	3602.39	4502.98	5403.58
1.25	11.00	0.02	27.00	3.00	1645.00	0.00	59.91	21.00	1.50	1891.25	2836.88	3782.51	4728.13	5673.76
1.50	11.00	0.02	27.00	3.00	1645.00	0.00	59.91	21.00	1.50	1891.25	2836.88	3782.51	4728.13	5673.76
1.75	12.00	0.02	27.00	3.00	1645.00	0.00	65.36	21.00	1.50	1891.25	2836.88	3782.51	4728.13	5673.76
2.00	12.50	0.02	27.00	3.00	1645.00	0.00	74.57	23.00	1.50	2071.37	3107.06	4142.74	5178.43	6214.12

Notes:

1 – In Tables 4a through 4f, the columns with the vertical labeling are the calculations for a 'unit' length of screen with the parameters listed. The columns labeled as 'Maximum Q (gpm)' and 'Maximum Q (MGD' are the maximum yields possible from the calculated 'unit' lengths in the column labeled 'Length of

Pipe'. To obtain the yields necessary to meet desired peak daily demands, the unit length is simply multiplied by an appropriate factor to result in the desired maximum Q. For example, if a unit length of 5' has a maximum Q of 10 gpm, and one needs a yield of 100 gpm, one would simply multiply both the maximum Q and unit length by the same factor – in this example that would be 10 – to obtain 50' of screen yielding 100 gpm.

2 – All calculations are rounded of to two decimal places.

3 – Because DH-7 is located over ¼ mile from the shoreline, an on-shore infiltration gallery at that location is non-applicable.

4 – N/A indicates that the velocity in the pipe exceeds 3 ft/sec at these flows for the indicated pipe radius.

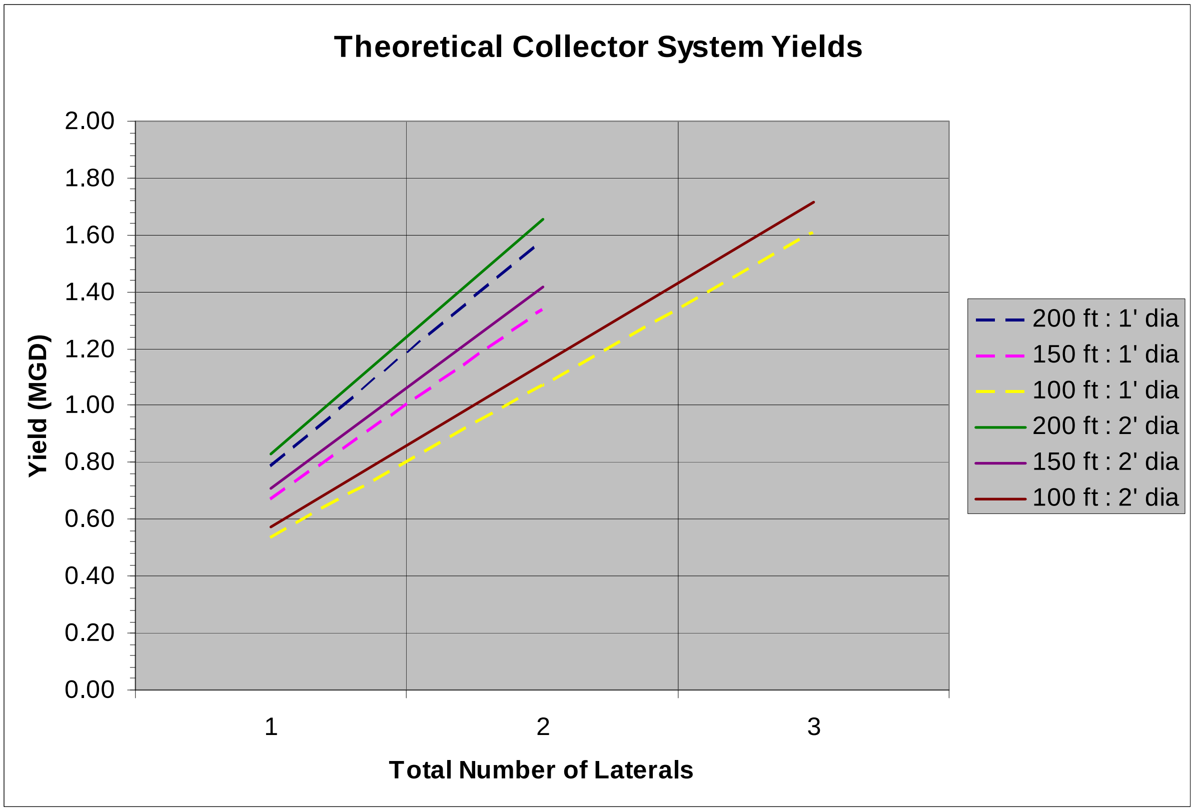

Figure B-2. Graph of yields versus number of laterals for site DH-1

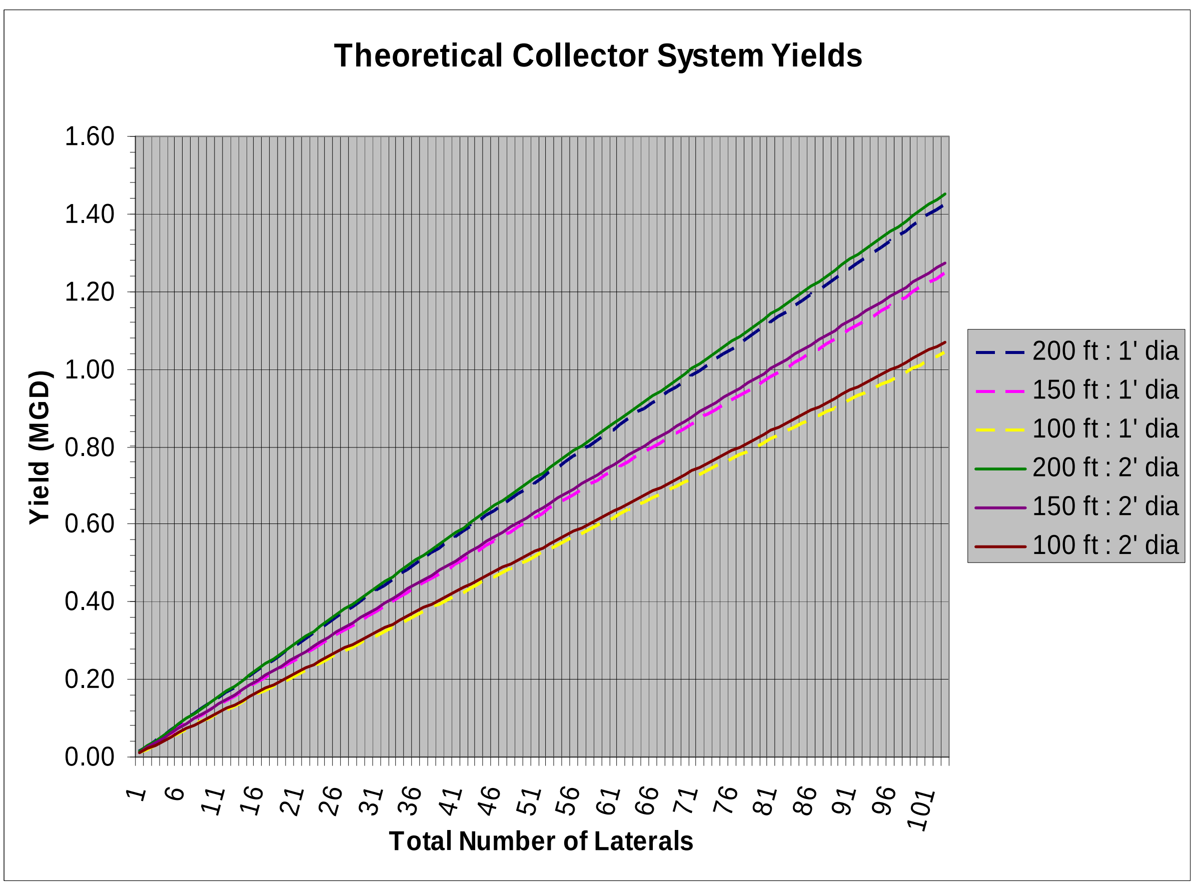

Figure B-3. Graph of yields versus number of laterals for site DH-2

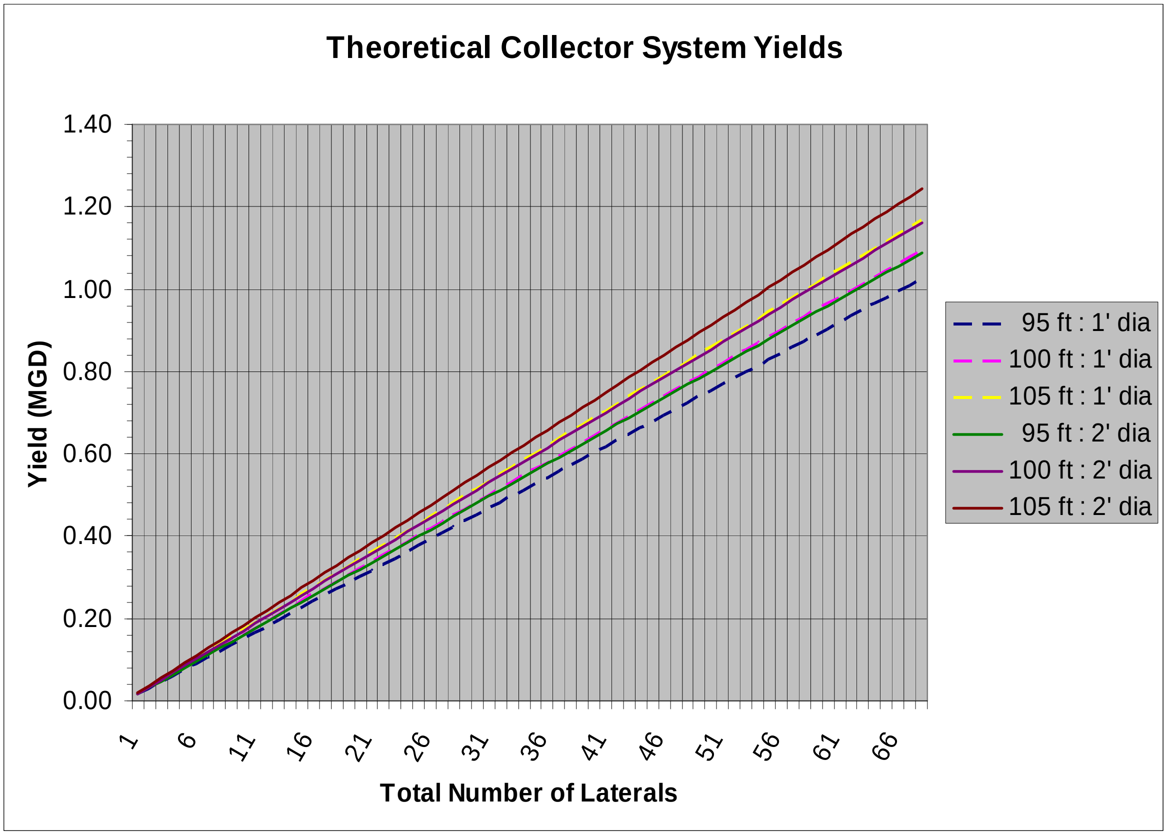

Figure B-4. Graph of yields versus number of laterals for site DH-3

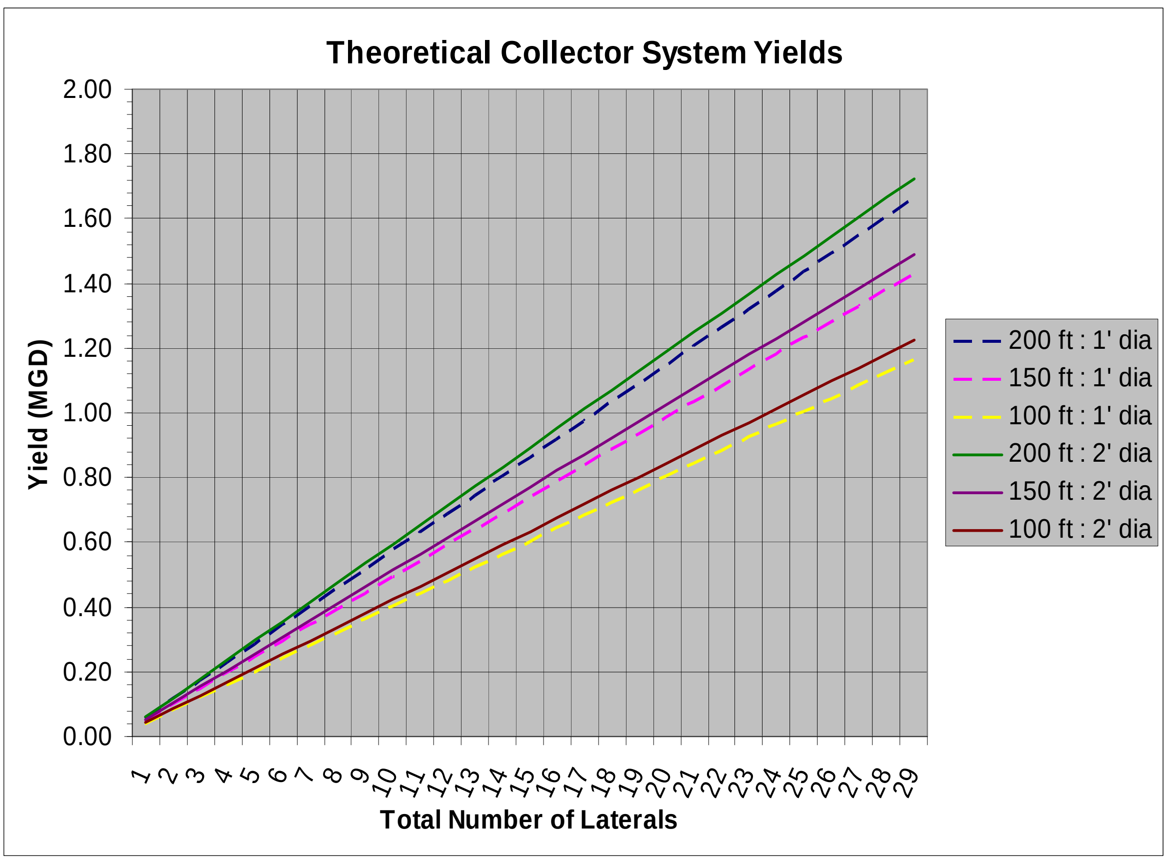

Figure B-5. Graph of yields versus number of laterals for site DH-4

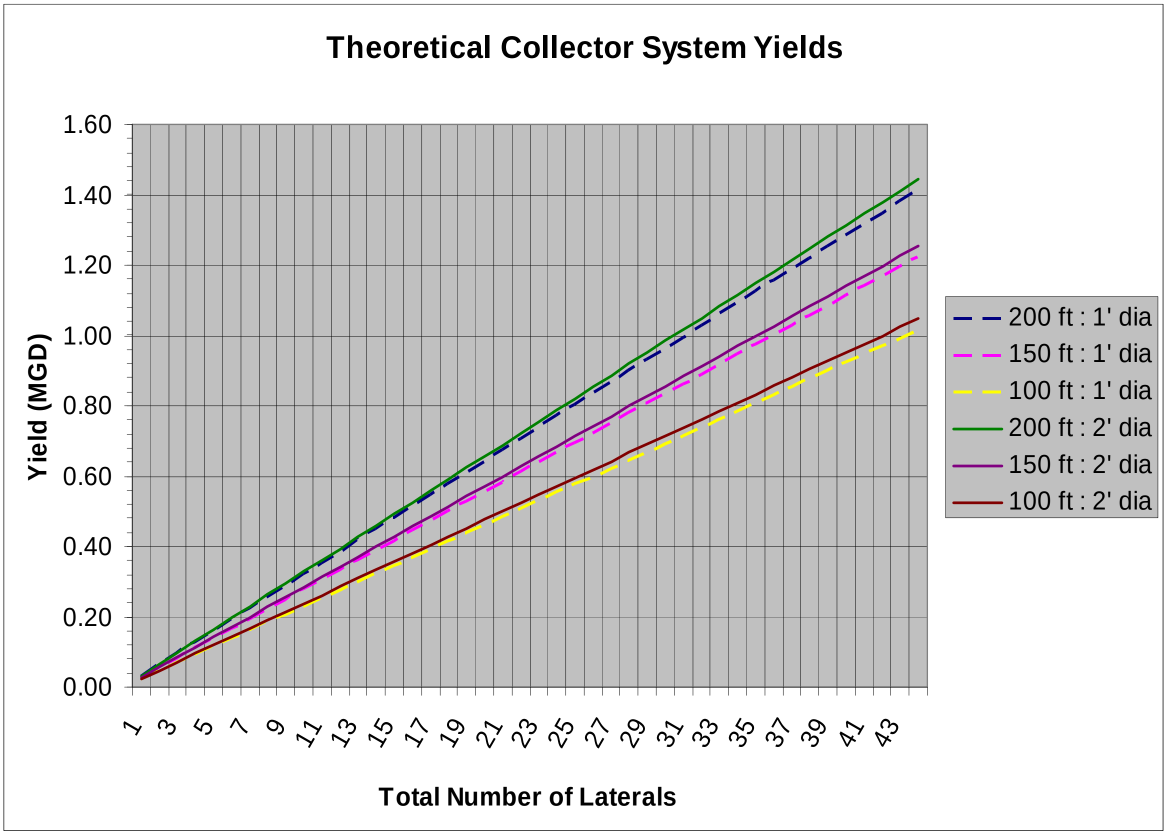

Figure B-6. Graph of yields versus number of laterals for site DH-5

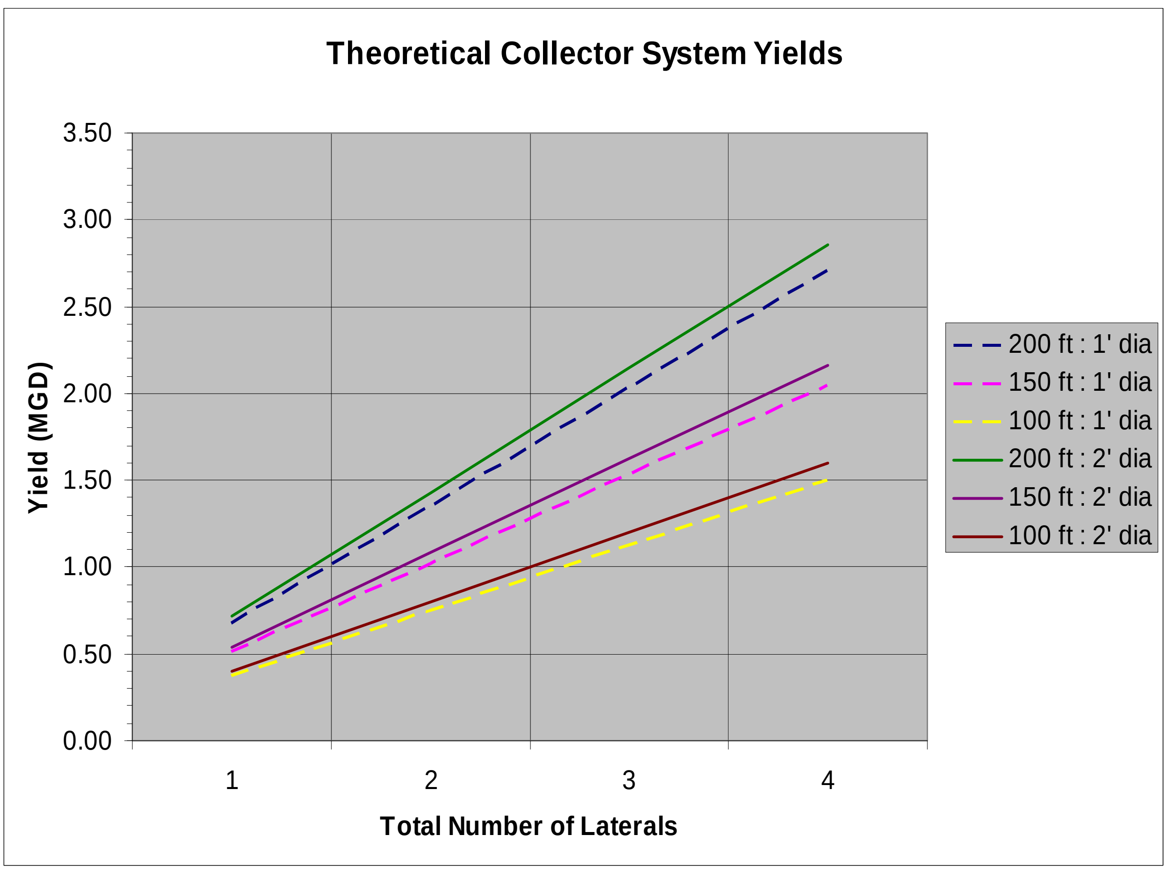

Figure B-7. Graph of yields versus number of laterals for site DH-6

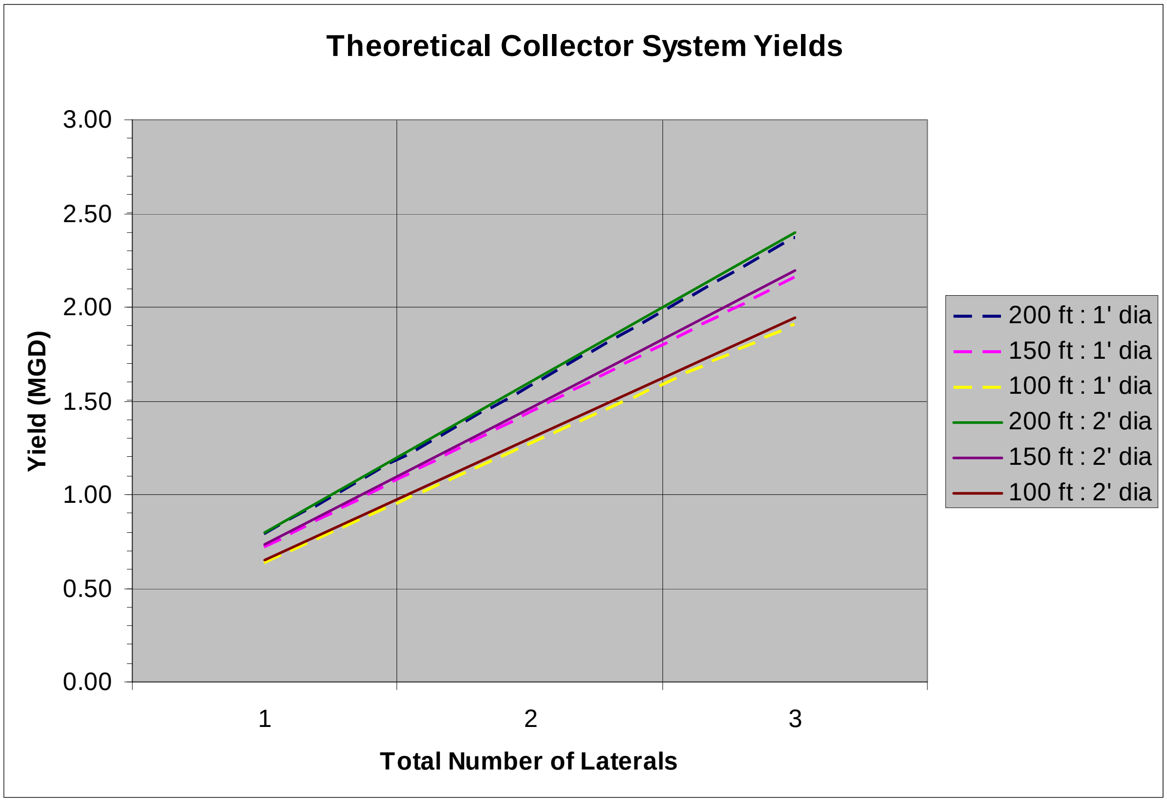

Figure B-8. Graph of yields versus number of laterals for site DH-7

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APPENDIX C

FIELD ACTIVITY REPORT,

FIELD NOTES,

and

TEST WELL LOG

TO: Files, Nebraska-Kansas Area Office, Bureau of Reclamation,

FROM: NK-320: Larry Cast, Robert Schieffer, Clinton Powell

DATE: November 19, 2007

SUBJECT: Drilling Activity Summary, Test Well Construction and Pump Test, Santee Sioux Water Supply Feasibility Study (October 9th thru 12th, 2007)

Tuesday October 9, 2007 -
Tracy McConnell (Grosch Well Drilling Project Manager), Bob Schieffer (Bureau of Reclamation, Grand Island), and Larry Cast (Bureau of Reclamation, Grand Island) arrived at the jobsite around noon on October 9, 2007. The work, specifications, and safety requirements were discussed prior to commencement of the work. The contractor set up a rotary drill CME on Obs. well E-2 and completed other preparation work for drilling. The contractor left the site at 4:30 p.m.

Wednesday October 10, 2007 –

Drilling began in the morning on observation well E-2. Very "rough" drilling was encountered below 20'. The hole was advanced to 50' at which time gravel and cobbles had accumulatively collected at the bottom of the hole and could not be washed out or pushed aside. The hole was considered complete and a 2" flush coupled PVC pipe and 10' screen was installed to a depth of 45' (hole had caved some). No gravel pack was placed as the hole collapsed around the screen. During the drilling of E-2, several 3,000 gallon truck loads of water were required to maintain circulation. Water losses began around 20 feet and continued the entire depth of the hole.

Observation well E-2 was developed by lowering 1" PVC pipe to near the bottom of screen and using an air compressor to air lift water from the 2" pipe. The water discharge rate was 1+/- gpm and the process was continued until the discharge water cleared (typically 2-4 hours). To check hydraulic connection with the aquifer, 5 gallons of clean water was poured in the pipe. A water level measurement was immediately taken to verify that the added water had quickly flowed through the screen.

The drilling of observation well E-1 began in the afternoon. Permission to use bentonite as a drilling additive (for observation wells only) was given to the contractor in an effort to reduce fluid losses, maintain hole integrity, and help remove larger fragments from the hole. Despite the use of bentonite, the hole could not be advanced past 50' and kept collapsing back to 25'. The decision was made to shut down and get additional drill rods of different lengths to give more options when adding rods.

Thursday October 11, 2007 –
A contractor representative arrived in the morning with drill rods and additional bentonite. E-1 had collapsed to 27'. The contractor back filled the hole with cuttings and bentonite before re-drilling in an effort to reduce fluid loss and increase hole stability. Drilling commenced and the contractor advanced the hole to 50'. The rods were pulled and the hole collapsed to 45'. The hole was then cleaned out and advanced to 58'. The contractor pulled the rods and removed the bit, then jetted the rods back down to 58'. A 2" PVC pipe and screen were installed (screen 42`-52`). The rods were

then pulled from hole and hole collapsed to near top of screen. Gravel pack was added to 35'. The well was then air developed in the same manner as observation E-2.

It was decided that it would be advantageous to place observation wells N-1 and N-2 inside the fenced area of adjacent storage facility. The owner of the storage facility, Mr. Jim James, was contacted and verbal permission to drill inside the fenced area was granted.

Observation well N-1 was initiated in the afternoon and completed to a depth of 50' at which point the hole kept collapsing to a depth that did not allow the adding of rods. A short 3.7' rod was added and the hole was drilled that additional amount. The bit was then removed and the rods jetted down and 50' of PVC pipe and screen was installed (screen 37`-47`). The hole collapsed around the screen and a small amount of gravel pack was used.

<u>Friday October 12, 2007</u>-
The drilling of observation well N-2 was started at a point 100' north of the test well. The hole was advanced to 50' at which time the Kelly hose blew and drilling was halted until Monday (take note that the hole location was changed on Monday).

The test well mud pit was excavated, the reverse rotary drill was set-up, and drilling commenced. From 0-14', the contractor used a bit which made a 3' diameter hole. Below 14', the contractor used a bit which made an 18" hole (theoretically). At 19 feet, material containing gravel and cobbles was encountered and a "rock trap" was installed to aid in removing this material. Rock up to 8"-diameter was retrieved by the "rock trap". It is estimated that approximately 1 cubic yard of this oversize material was removed during drilling. At 55', the bit could not be advanced, either due to a hard layer or accumulated cobbles that could not be removed or displaced. The hole depth was considered adequate and 15' well screen (stainless steel) and 10" PVC casing was installed (screened from 38`-53'.) Centering guides were installed at 20' and 40'. Gravel packing by tremie pipe and pumps began at 6:30 p.m. and ended at 10:30 p.m. when the gravel pack material was exhausted. It is estimated that 54 cubic feet of gravel pack was installed, which is approximately twice the volume of gravel pack required for an 18" with a 10" screen. Only 7`-8` of the 15'screened interval received gravel pack. No options were available other than letting the hole collapse around the upper portion of the screen for a natural gravel pack.

Drillings conditions encountered were more difficult than anticipated. Previous exploratory geologic drilling had the capability of only obtaining or removing 1 ½" diameter material. The medium size cobbles recovered from the current drilling was 8"+/-. There was a considerable amount of this oversize material and if instantaneous removal did not occur then these cobbles were "wallowed" around by the drill bit causing a much larger diameter hole than anticipated.

Some rough calculations indicated that 54 cubic feet of gravel pack around 7'-8' of the screen equates to an approximate hole diameter of 36".

<u>Monday, October 15, 2007</u>-
Over the weekend, the test well had collapsed to a depth of 30 ft +/- around the screen and casing. The contractor arrived in the afternoon and delivered pea gravel to the site. The rest of the test well hole was filled with pea gravel in effort to stabilize the PVC casing.

Due to the collapse of material around the test well screen, it was decided to move observation well N-2 from 100' north of the test well, to a distance of 25' north of the test well. This change was in effort to provide more sensitive drawdown data, due to the potentially reduced yield from the collapse of the well around the screen and casing. The contractor agreed to abandon the partially drilled N-2 hole and setup at a new location 25' north of the test well. The N-2 hole was renamed as N2-30.

Tuesday, October 16, 2007-
The contractor spent the morning setting up the development equipment for the test well. The mechanical surge block had a plastic bristle washer which needed to be trimmed from a 12" diameter to a 10" diameter.

Development of the test well began at 1:00 pm with the pump discharging 40 gpm+/-, and continued until 6:20 pm. At 1:30, the contractor started drilling the N2-30 drill hole, at which time it was noticed that the test well development process was drawing drill fluid from the N2-30 hole. Therefore, the test well development was stopped from 2:15 pm to 3:50 pm so the N2-30 drilling could be continued.

The crew drilled N2-30 to 35' +/- encountering the same issues as the other observation wells. The contractor decided to stop drilling at 4:00 pm and went back to North Bend for the evening.

Wednesday, October 17, 2007-
The contractor resumed drilling of observation well N2-30, with resistance being met at 42'. The PVC screen and pipe were then installed. Observation wells N2-30 and N-1 were then developed using air-lift methods.

The contractor installed the test pump, stem, and flow meter on the test well. The preliminary pump test was initiated at 1:54 pm and was completed at 6:50 pm. Drawdown data was recorded automatically with an electronic data logger. Measurements were taken simultaneously by hand as often as possible for the first hour, then every hour thereafter. The well stabilized at 425 gallons per minute.

Recovery data was recorded immediately after the pump was shut down. Data was recorded automatically with an electronic data logger, and the logger was allowed to read throughout the night. Measurements were taken simultaneously by hand as often as possible for the first hour, then every hour thereafter.

Ph and conductivity readings were taken periodically by tribal staff. Later the next day, it was discovered that the pH meter was faulty.

Thursday, October 18, 2007-
Reclamation representatives setup the 24-hr pump test. The pump was started at 10:19 am. A Tribal representative took water quality samples at 10:30 am.

At 11:45 am we realized that the pH meter was reading inaccurately. A pH meter was borrowed from the city of Niobrara and the first pH reading was taken at 2:30 pm.

Drawdown data was recorded automatically with an electronic data logger, and the logger was allowed to read through the night. Measurements were taken simultaneously by hand as often as possible for the first hour, then every hour thereafter.

Friday, October 19, 2007-

The pump test continued through 11:00 am. Recovery data was recorded automatically with an electronic data logger, and the logger was allowed to read through the night. Measurements were taken simultaneously by hand as often as possible for the first hour, then every hour until 7:00 pm.

Saturday, October 20, 2007-
One last set of manual readings was taken at 9:15 am, and the recovery test was ended shortly thereafter.

7-1654 (11-94)
Bureau of Reclamation

COMPUTATION SHEET

BY C. Powell	DATE 10-17-07	PROJECT Santee Test Well	SHEET 1 OF 2
CHKD BY	DATE	FEATURE Test Well	
DETAILS Development Field Notes			

Test well development began at 13:00.

the estimated well output was 40 gpm

development began at a depth of 53'4" across a span of about 2'

at 13:20 the water on the upstroke of the development plug had lost a majority of its turbidity and began to appear opaque

at 13:25 development of the test well was raised 23" to a depth of 51'5"

well output remained near 40gpm

at 13:25 water had a weak brown color similar to weak chocolate milk. However, no grit could be felt in a discharge sample.

by 13:35 water on the upstroke of the development plug began to appear opaque. The downstroke also became more opaque but retained a murky appearance.

at 13:41 development of the test well was raised to a depth of 49'

water became tinted lightly brown

no grit was felt in a hand sample and the water smelled fresh and nearly odorless

at 13:55 development was raised to a depth of 47'
water again became milky, but progressed to opaque

samples continued to be free of grit

at 14:12 development was raised to 45'
at 14:15 pumping from the test well stopped for drilling to proceed at "N2-30'".

~~[illegible]~~ development resumed at 15:52

7-1654 (11-94)
Bureau of Reclamation

COMPUTATION SHEET

BY	DATE	PROJECT	SHEET 2 OF 2
C. Powell	10-17-07	Santee Test Well	
CHKD BY	DATE	FEATURE	
		Test Well	
DETAILS			
Development Field Notes			

at 16:21 development was raised to a depth of 43'

at 16:44 development was dropped to a depth of 52'

at 18:20 development stopped

7-1337
(1-55)
BUREAU OF RECLAMATION

GEOLOGIC LOG OF DRILL HOLE

FEATURE Santee Water Supply PROJECT Spec. No. 07SQ600144 STATE Nebraska

HOLE NO. Pump LOCATION See Notes COORDINATES GROUND ELEVATION 1240 ANGLE FROM VERTICAL 90°

BEGUN 10-12-07 FINISHED 10-12-07 DEPTH OF OVERBURDEN Unknown TOTAL DEPTH 55.0' BEARING OF ANGLE HOLE

DEPTH OR ELEV. OF WATER TABLE 30' Est HOLE LOGGED BY Cast FOREMAN

NOTES On water table levels, water return, character of drilling etc.	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	PERCOLATION TESTS DEPTH (FT.) FROM (P, Cs or Cm)	TO	LOSS IN (G.P.M.)	PRESSURE (P.S.I.)	LENGTH OF TEST (min)	ELEVATION	DEPTH	LOG / SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
Irrigation Well Site Purpose: Pumped well of aquifer performance test Driller: Tim Haase of Grosch Irrigation, North Bend NE Drill Rig: Reverse Rotary Drill Method: Clear water, 0-14' used 31" diam. bit, 14-55' used 18" diam. bit. Installed rock trap in pipe column after 20'. Completion: Installed 10" stainless steel screen (Johnson) 0.030" slot 30-53'; 10" PVC casing 0-30'. Gravel packed 46-54', ran out of pack and hole was allowed to collapse around upper interval of screen. Est. hole diam. was 36+". On 10-15-07 annular area was open to 30' contractor backfilled hole to surface with pea gravel. At completion of test attempted to pull casing and screen from hole. Casing separated at the 19' coupler. Hole then abandoned and backfilled per State of NE regulations. Location: Approx. 20' NE of DH-7; 1600' S. and 1650' W. of NE Corner Sec. 13, T33N, R5W.											0-19' LEAN CLAY, tan 19-24' LEAN CLAY with layers of GRAVEL and COBBLES, max. size recovered 4". 24-55' SILTY GRAVEL with COBBLES, max. size recovered 8"; est. 1 cubic yard of cobbles recovered from 24-55' using rock trap. Hole could not be advanced below 55' due to accumulation of very large cobbles or extremely hard layer.

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole........ D=Diamond, H=Haystellite, S=Shot, C=Churn
Hole sealed........ P=Packer, Cm=Cemented, Cs=Bottom of casing
Approximate size of hole (X-series)....... Ex = $1\frac{1}{2}$", Ax = $1\frac{7}{8}$", Bx = $2\frac{3}{8}$", Nx = 3"
Approximate size of core (X-series)...... Ex = $\frac{7}{8}$", Ax = $1\frac{1}{8}$", Bx = $1\frac{5}{8}$", Nx = $2\frac{1}{8}$"
Outside diameter of casing (X-series)...... Ex = $1\frac{13}{16}$", Ax = $2\frac{1}{4}$", Bx = $2\frac{7}{8}$", Nx = $3\frac{1}{2}$"
Inside diameter of casing (X-series)...... Ex = $1\frac{1}{2}$", Ax = $1\frac{29}{32}$", Bx = $2\frac{3}{8}$", Nx = 3"

ANGLE HOLE ☐
VERTICAL HOLE ☐

GPO 844140 HOLE NO.

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APPENDIX D

WATER QUALITY DATA

(including Missouri River Water Quality data
and field measurements during test)

Aquifer (pumping) Test Field Data Sheet

Project: Santee Test Well			Feature: 24-hr Pump Test		
Pump Well ID: Test	Location:				
Obs Well ID: Test	Radius (inches)			Dir. & Dist.	
Static W.L.	Elev of M.P.*			G.S. Elev.*	
Observer Powell/Schieffer		Type of Test			

Date & Time (24 hr clock)	~~Elapsed Time (m/n)~~	~~Depth to Water (decimal ft)~~	~~Drawdown (ft)~~	~~Discharge (gpm or ft³/s)~~	Remarks
		Conductivity	Temp	PH	425 GPM
11:45		17.01	13.4	6.9? MAYBE?	
12:30		17.85	12.7		
13:30		17.9	12.6		
14:40		17.94	12.7	7.3	— DUE TO A FAULTY PH
15:44		17.96	12.7	7.21	METER, THE FIRST
16:42		17.98	12.6	7.32	PH READING WAS
17:40		18.09	12.4	7.28	TAKEN AT 14:40.
18:53		18.03	12.3	7.27	THE CITY OF NIOBRARA
19:44		18.15	12.3	7.37	PROVIDED THE PH
20:40		18.18	12.2	7.33	METER.
21:40		18.16	12.2	7.35	
22:42		18.24	12.2	7.37	
23:38		18.00	12.2	7.31	
00:45		17.04	12.2	7.20	
01:40		17.31	12.1	7.34	
02:41		18.05	12.0	7.22	
3:50		18.41	11.6	7.20	
4:51		18.42	11.7	7.25	
5:50		18.48	11.6	7.27	
7:00		18.72	11.6	7.25	
8:05		17.89	11.9	7.28	
9:39		18.29	12.4	7.36	

* = if elevations are not known, then record the distance between the measuring point and ground surface (i.e. stick-up)

M.P. = measuring point W.L. = water level Dir. = Direction Dist. = Distance

Test dates: 10/18/2007 to 10/19/2007

Subject: Santee Sioux Water Quality Review and Treatment Recommendations

SCOPE OF WORK

Reclamation's Plant Structures Group was tasked to review the water quality of Santee Sioux well water and provide recommendations for treatment.

WATER QUALITY ANALYSIS

Water quality sampling on the Santee Sioux well water was conducted on October 18 and October 19, 2007. The analysis of the samples was conducted by Midwest Laboratories, Inc. of Omaha, Nebraska. A summary of the sampling sessions is provided in Table 1.

Sampling Dates	October 18, 2007	October 19, 2007
Lab Reference #	212031	212041
Lab Report #	07-298-2093	07-319-2239

The water quality reports are provided as Attachments 1 and 2 of this memo.

WATER QUALITY OBJECTIVES

The water quality objectives are dictated by the U.S. Environmental Protection Agency's (EPA) National Primary Drinking Water Regulations (NPDWR) or primary standard. The EPA has established primary and secondary standards to protect public health and to improve the aesthetics of the nation's drinking water supplies respectively. NPDWRs are legally enforceable standards that apply to public water systems. Primary standards protect drinking water quality by limiting the levels of specific contaminants that can adversely affect public health and that are known or anticipated to occur in water. The standards take the form of maximum contaminant levels (MCL) or Treatment Techniques.

A National Secondary Drinking Water Regulation (NSDWR or secondary standard) is a nonenforceable guideline regarding contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. EPA recommends secondary standards to water systems but does not require systems to comply. However, States may choose to adopt them as enforceable standards.

A summary of EPA National Primary Drinking Water Standards can be found at http://www.epa.gov/safewater/contaminants/index.html and is provided in Attachment 3.

ANALYSIS OF WATER QUALITY DATA

Table 2 is a partial summary of the analyte concentrations sampled on 10/18/07 and 10/19/07. As further defined below, analytes of obvious concern are in red while analytes of potential concern are in yellow.

Review of Table 2 shows that the concentrations from the sampled well water do not exceed any EPA Primary Drinking Water Standards. The EPA secondary standards significantly exceeded are TDS and sulfate. The high levels of TDS and sulfate will produce taste and odor problems.

Also, this water is extremely hard as a result of high concentrations of calcium and magnesium combining with bicarbonate. Very hard water is defined as having a total hardness (mg/l in $CaCO_3$) greater than 180. The Santee Sioux well water is about 900 mg/l. In addition to scale caused by calcium carbonate and magnesium carbonate, calcium can form with elevated levels of sulfate to form calcium sulfate. Scale adversely affects plumbing fixtures in homes, especially water heaters and washing machines.

Some constituents that may be of potential but not immediate concern are manganese, total organic carbon (TOC) and radionuclides (alpha particles). The manganese concentration from 10/18/07 slightly exceeded the EPA secondary standard of 0.05 mg/l. Soluble manganese will cause a black precipitation when exposed to oxygen.

Total organic carbon will trigger the disinfection byproduct rule if the influent concentration exceeds 2 mg/l. Santee Sioux well water was reported at 1.5 and 1.6 mg/l. Disinfectants such as free chlorine, ozone and chlorine dioxide react with natural organic and inorganic matter in source water and distribution systems to form disinfection byproducts (DBPs). Results from toxicology studies have shown several DBPs (e.g., bromodichloromethane, bromoform, chloroform, chloroacetic acid, and bromate) may be carcinogenic.

The water sample from 10/19/07 produced a gross alpha particle concentration of 13 pCi/L, which is approaching the EPA MCL of 15 pCi/L. The EPA specifies that the potential health impact from alpha particles is an increased risk of cancer.

Table 2 — Partial Summary of Sampling Data (includes Primary and Secondary Contaminants): analytes of obvious concern are in red, analytes of potential concern are in yellow.

	EPA Primary or Secondary Standard	Date Sampled	
		10/18/07	10/19/07
pH [2]	$6.8 \leq pH \leq 8.5$	7.34	
Turbidity (ntu)	TT[3]	-	0.15
Conductance (µS/cm)	-	1,593	1,600
TSS (mg/l)	-	8	ND
TDS (mg/l) [2]	500	1,290	1,276
Giardia (oocysts/10 L)		ND	ND
Cryptosporidium (oocysts/10 L)			ND
Na (mg/l)	-	39.7	-
Ca (mg/l)	-	231	243
Mg (mg/l)	-	65.2	70.7
Total Hardness (mg/l as $CaCO_3$)	-	845	898
K (mg/l)	-	-	9.3
Cl (mg/l) [2]	250	-	22
F (mg/l) [2]	2	-	0.7
Silica (SiO_2)(mg/l)	-	-	30.2
Dissolved Silicon (mg/l)	-	12	-
Total Silicon (mg/l)		12	14.1
SO_4 (mg/l) [2]	250	-	587
Alk (mg/l as $CaCO_3$)	-	362	320
HCO_3 (mg/l as $CaCO_3$)	-	320	358
CO_3 (mg/l as $CaCO_3$)	-	0.52	4.43
NO_2+ NO_3(mg/l as N) [1]	11	1.0	1.3
NO_2 (mg/l as N) [1]	1		ND
NO_3 (mg/l as N) [1]	10	-	1.3
Total Phosphorus (mg/l)	-	-	ND
Dissolved organic carbon (mg/l)	-	1.9	1.6
Total organic carbon (mg/l)	-	1.5	1.6
Gross Alpha (pCi/L) [1]	15	-	13
Gross Beta (pCi/L) [1]		-	15
Arsenic (µg/L) [1]	10	ND	ND
Total Barium (mg/l)	2	-	0.01
Cadmium (µg/L) [1]	5	-	ND
Chromium (µg/L) [1]	100	-	ND
Iron (mg/l) [2]	0.3	-	0.03

	EPA Primary or Secondary Standard	Date Sampled	
		10/18/07	10/19/07
Cyanide (mg/l)	0.2	-	ND
Manganese (mg/l) [2]	0.05	0.06	0.02
Mercury (µg/L) [1]	2	-	ND
Nickel (mg/l)	-	-	ND
Selenium (mg/l) [1]	0.050	0.013	0.014
Uranium (mg/l) [1]	0.03	-	0.0188
Zinc (µg/L) [1]	5,000	-	ND
Lead (µg/L) [1]	TT[7] 0.015	-	ND
Copper (mg/l)[1]	TT[7] 1.3	-	ND

Notes:

—	= No Primary MCL applicable or sample not taken
NA	= Data not available; µg/L = microseism per centimeter' mg/l = milligrams per liter
cfs	= cubic feet per second.
1	= Primary MCL
2	= Secondary MCL
TT[3]	= Treatment Technique. See footnote 3 in EPA National Primary Drinking Water Standards (Attachment 3)
TT[7]	= Treatment Technique. See footnote 7 in EPA National Primary Drinking Water Standards (Attachment 3)

RECOMMENDED TREATMENT ALTERNATIVES

A matrix (Table 3) is provided which shows which treatment technologies are effective for the removal of TDS, sulfate, hardness, manganese, TOC and radionuclides (alpha particles). The presence of TDS, SO4 and Hardness warrant advanced water treatment processes. Advanced processes are processes other than coagulation, flocculation, sedimentation, and filtration. **As shown, reverse osmosis (RO) membranes alone can remove all the constituents of concern and is therefore recommended.** For RO, the high levels of calcium, magnesium and sulfates require the use of an anti-scalent to prevent scaling on the membrane surface. In addition, if manganese is exposed to oxygen prior to RO, suspended manganese particulates may clog the membranes. If RO is used for treatment, pretreatment to remove calcium, magnesium and manganese is warranted.

Reverse osmosis is recommended for the removal of TDS, lower concentrations of TOC (less than 2 mg/l) and radionuclides. A cartridge filter should be present before the RO system to remove suspended particles that remain after the pretreatment processes. The waste stream from the RO will be a brine stream which should be discharged to a wastewater treatment plant or evaporation ponds.

The final treatment step should be disinfection with chlorine or chloramines using contact time from a clearwell. The chorine or chloramine dosage will be dependent on the required disinfectant residual in the potable water distribution system.

PRETREATMENT DISCUSSION

Removal of calcium and magnesium can be performed with lime softening or ion exchange. Lime softening requires solid contact clarifier tanks where lime is added. This step produces a chemical sludge which may require dewatering and specific handling and disposal. For smaller treatment plant flows, ion exchange provides the advantage of compact pressure vessels filled with resin. Cations of calcium and magnesium are exchanged for cations of sodium which are attached to the resin. The resin requires routine regeneration (flushing with a chemical solution). The waste flow is a brine stream from the regeneration of the resin. Unlike lime softening, no sludge is produced by ion exchange. For the small flow expected at Santee Sioux, (<1mgd) ion exchange should be considered over lime softening for the removal of calcium and magnesium since it requires less space and is available from many vendors, some of which can provide the regeneration service.

If the combined iron and manganese concentrations are low (less than 1 mg/l), then it may be possible to remove the soluble manganese with ion exchange alone. If it is determined that iron and manganese exist in their dissolved, soluble form, (as manganous manganese or ferrous iron, which are not settleable) then oxidation with aeration, chlorine or manganese greensand filtration are alternatives to consider. These oxidizing agents convert the dissolved form to an insoluble, settleable form for removal by settling or filtration.

Oxidation with chlorine is not likely to form disinfection by-products at the TOC levels present (<2 mg/l).

Similar to ion exchange, manganese greensand filters have the advantage of compact pressure vessels and a waste stream that requires special attention for disposal. The pressure vessels are filled with greensand media which immediately oxidizes and retains the manganese particulates. The greensand media must be backwashed and recharged with a potassium permanganate solution.

Two potential RO treatment train alternatives are presented in Figures 1 and 2. They are provided to show options for pretreatment. Alternative 1 provides a system with ion exchange, a cartridge filter, RO and disinfection with chlorine or chloramines. This process can remove the hardness and may be used if the iron and manganese are low or are in settleable form (manganic manganese and ferric iron). The second alternative adds greensand filtration after ion exchange for the removal of higher concentrations of manganese (and iron if the iron level exceeds the standard).

OTHER RECOMMENDATIONS

Additional water quality tests (monthly) should be made to characterize the seasonal variation of the contaminants of concern.

A pilot program to optimize the pre-treatment possibilities for RO is recommended for Feasibility or Final design of the water treatment process.

Investigate the possibility of locating another raw water source, of better water quality, to either avoid the water treatment described for this well, or to blend in with the water from this well to improve its quality and reduce the treatment needed.

Table 3 – Summary of Treatment Alternatives

Treatment Technique						
	TDS	SO_4	Hardness	Mn	TOC	Radionuclides
Coagulation/Flocculation/Sedimentation					X	
GAC					X	
Greensand Filtration				X		
Ion Exchange			X			
Lime Softening			X			
Reverse Osmosis	X	X	X	X	X	X
Oxidation (chlorination/sedimentation)				X		

Note: The presence of TDS, SO4 and Hardness warrant advanced water treatment processes.

Figure 1 – Potential RO Treatment Train No. 1

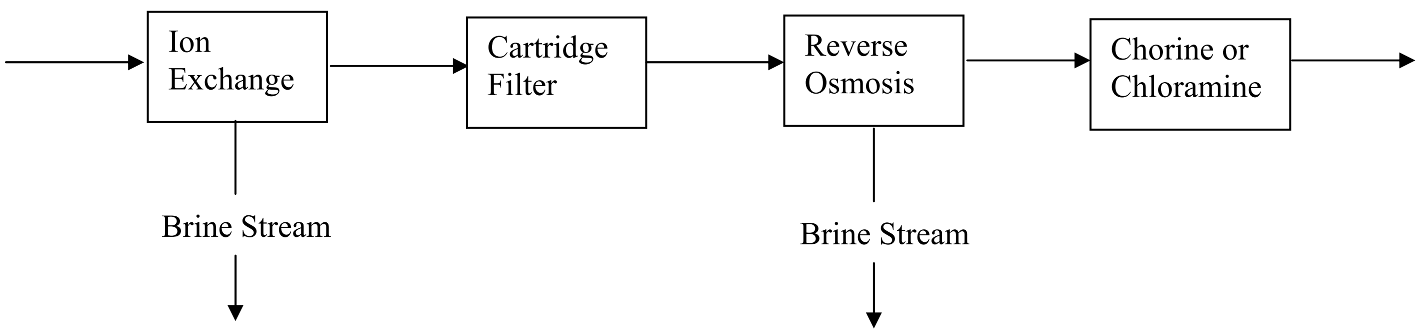
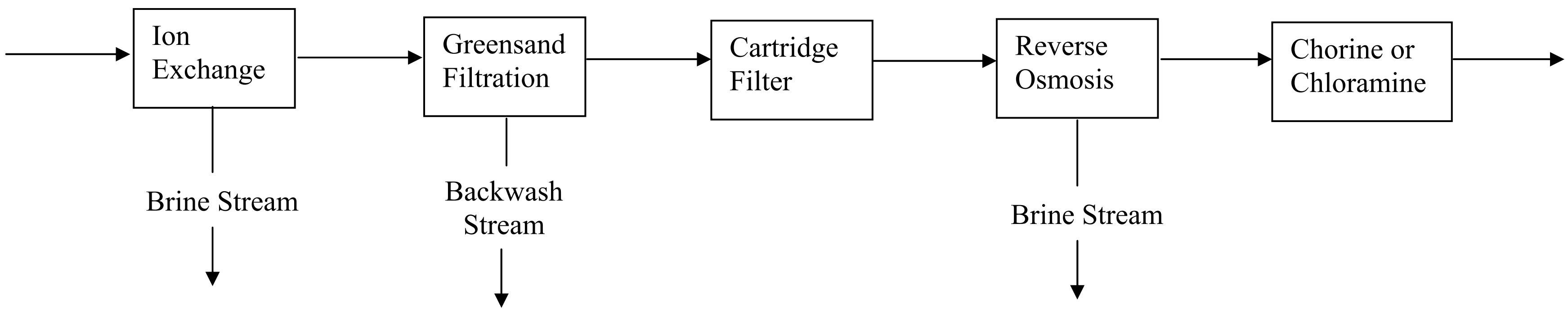


Figure 2 – Potential RO Treatment Train No. 2



PREVIOUS WATER QUALITY RESULTS
Excerpted from:

Cast, Larry D., 1994, Water Supply Investigations for the Village of Santee, Nebraska, Bureau of Reclamation, Nebraska-Kansas Area Office, Grand Island, Nebraska.

Groundwater from Bazille Creek alluvium, approximately 7.5 miles from the Village of Santee:

Inorganic Chemicals	*MCL (mg/l) Secondary Standards	Water Supply 1977 (mg/l)	Water Supply 1986 (mg/l)
Total Dissolved Solids	500	1070	776
** Sodium	20	41	44
Sulfate	250	520	620
Manganese	0.05	0.5	0.1

* Maximum Contaminant Level
** EPA Guidance Level, No secondary standard

Missouri River Water Quality:

Species	Niobrara River[1] near Verdel, NE	Missouri River[2] at Springfield, SD	Missouri River[3] at Yankton, SD
Nitrate	<0.1 mg/l	<0.1 mg/l	0.2 mg/l
Fluoride	---	0.55 mg/l	0.5 mg/l
Chloride	---	17.4 mg/l	9.0 mg/l
Iron	---	2.48 mg/l	0.0 mg/l
Manganese	0.8 mg/l	0.23 mg/l	---
Sulfate	15 mg/l	234 mg/l	191 mg/l
TDS	302 mg/l	496 mg/l	447 mg/l
pH	8.3	8.0	7.8
Alkalinity ($CaCO_3$)	97 mg/l	176 mg/l	---
Bicarbonate	119 mg/l	215 mg/l	176 mg/l
EC	242 micromhos	778 micromhos	676 micromhos
Calcium	---	67 mg/l	57 mg/l
Magnesium	---	24.3 mg/l	18 mg/l
Hardness ($CaCO_3$)	---	267 mg/l	217 mg/l
Sodium	11 mg/l	69 mg/l	60 mg/l
Potassium	---	4.7 mg/l	5.0 mg/l

[1] USGS (1990)
[2] Village of Springfield, South Dakota (1992)
[3] USGS (1957)

Water Supply Investigation, 1994, Boreholes DH-1 and DH-2:
Laboratory analysis performed by the State of Nebraska, Department of Health

Inorganic Chemicals	Hole No. DH-1 67–72 ft (mg/l)*	Hole No. DH-2 34–39 ft (mg/l)*	Irrigation Well (mg/l)*	Spring (mg/l)*
Coliform	1/100 ML	2.2/100 ML	0/100 ML	Confluent Growth
Calcium	532	564	316	99
Chloride	38	52	24	4
Fluoride	0.38	0.68	0.53	0.31
Iron	2.9	18.0	>0.1	>0.1
Total Alkalinity ($CaCO_3$)	424	492	376	240
Total Hardness ($CaCO_3$)	1,600	1,824	1,208	340
Total Dissolved Solids	2,420	2,604	1,768	494
pH	7.4	7.4	7.3	7.8
Nitrate-N	<0.1	<0.1	2.0	2.2
Sodium	72	95	49	15
Sulfate	1,150	1,330	870	139
Manganese	7.6	3.8	0.08	>0.05
Volatile Organics (EPA Method 524.2)	Not Detected	Not Detected		
Pesticide/Herbicide (EPA Scan)	Not Detected	Not Detected		
Pesticide/Herbicide (Nebraska Scan)	< MDL	<MDL		
Radon	376 pCi/l	117 pCi/l		
Gross Alpha	12.0 pCi/l	10 pCi/l		
Gross Alpha Radium (226)	0.3 pCi/l	0.2 pCi/l		
Arsenic	0.005	0.011		
Barium	<0.1	<0.1		
Cadmium	<0.001	<0.001		
Chromium	0.002	0.011		
Lead	0.001	0.005		
Mercury	<0.001	<0.001		
Selenium	<0.005	<0.005		
Silver	<0.001	<0.001		

* - all concentrations are in mg/l unless otherwise noted., with the exception of pH.
MDL – Method Detection Limit
pCi/l – picoCurie/liter
ML – Milliliter
Mg/l – milligram per liter

Attachment 1

Ref. Lab #: 212031
Report Number
07-298-2093

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REPORT OF ANALYSIS

For: (21825) US BUREAU OF RECLAMATION
(308)389-5319

Mail to: **US BUREAU OF RECLAMATION**
BOB SCHIEFFER
203 W 2ND ST
GRAND ISLAND NE 68801

Date Reported: 12/27/07
Date Received: 10/19/07
Date Sampled: 10/18/07

SANTEE SIOUX WELL WATER

Lab number: 1353814

Analysis	Level Found	Units	Detection Limit	Method	Analyst-Date	Verified-Date
Sample ID: WELL						
Arsenic (total)	n.d.	mg/L	0.0005	EPA 200.8	jmb-10/23	bab-10/23
Calcium (total)	231	mg/L	0.01	EPA 200.7	emr-10/23	bab-10/23
Magnesium (total)	65.2	mg/L	0.01	EPA 200.7	emr-10/23	bab-10/23
Hardness (total)	845	mg Eq CaCO3/L	1	SM2340B	bab-10/19	llm-10/19
Alkalinity (Total)	320	mg CaCO3/L	10	SM 2320 B	jdb-10/22	cmw-10/25
Bicarbonate as CaCO3	320	mg/L	10	SM 2320 B	jdb-10/22	cmw-10/25
Carbonate as CaCO3	0.52	mg/L	0.01	EPA 310.1	jdb-10/22	cmw-10/25
Conductance	1,600	uS/cm	2	SM 2510 B	jdb-10/19	cmw-10/25
Dissolved organic carbon	1.9	mg/L	1.0	EPA 415.1	kkr-10/23	cmw-10/25
Kjeldahl nitrogen	n.d.	mg/L	0.50	EPA 351.3	dmg-10/24	cmw-10/25
Manganese (total)	0.06	mg/L	0.01	EPA 200.7	emr-10/23	bab-10/23
Nitrate/Nitrite Nitrogen	1.0	mg/L	0.2	EPA 353.2	dmg-10/22	jjd-10/23
Selenium (total)	0.013	mg/L	0.001	EPA 200.8	jmb-10/23	bab-10/23
Silicon (total)	12.0	mg/L	0.05	EPA 200.7	emr-10/23	bab-10/23
Total Nitrogen (TKN + NO3)	1.00	mg/L	0.05	CALCULATION	cmw-10/19	llm-10/19
Total dissolved solids	1,290	mg/L	10	SM 2540C	gjj-10/22	cmw-10/25
Total organic carbon	1.5	mg/L	1.0	SM 5310 B	kkr-10/23	cmw-10/25
Total suspended solids	8	mg/L	4	USGS I-3765-85/SM2540D	gjj-10/22	cmw-10/25
True Color	n.d.	APHA	5	ASTM D1209-05	lkr-10/22	cmw-10/25
pH	7.34	S.U.		EPA 150.1	jdb-10/19	cmw-10/25

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REPORT OF ANALYSIS

Account: 21825 US BUREAU OF RECLAMATION

Report Number: 07-298-2093

Analysis	Level Found	Units	Detection Limit	Method	Analyst-Date	Verified-Date
Sample ID: WELL						
Silicon (dissolved)	12	mg/L	0.10	EPA 200.7	emr-10/23	bab-10/23

Notes:
n.d. - Not Detected.
The solid analyses have been weighed to a constant weight by leaving the samples in the oven overnight. This protocol is an approved variation from the stated method.

Respectfully Submitted

Heather Ramig/Sue Ann Seitz/Rob Ferris
Prem Arora/Client Services

ORDER NUMBER:
212031

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PAGE NUMBER: 1

CHAIN OF CUSTODY

ACCOUNT NO: 8678
SANTEE SIOUX NATION
WATER RESOURCES/FELIX KITTO
52948 HWY 12
NIOBRARA, NE 68760-7047

SAMPLE DESCRIPTION
WELL ANALYSIS

COPY TO:

PO NUMBER:

Automatic Order Submittal Form

PLACED BY: ferris on Oct 05, 2007

	SAMPLE	DATE/TIME SAMPLED	MX	TESTS REQUESTED	# CONT	COMMENTS
1	WELL 1353814 WELL ANALYSIS	10/18/07 10:35	WA	NO3,TDS,TKN,TOC,TSS,TOTAL NITROGEN,ALKALINITY,BICARB ,CARBONATE,DISS CARBON,CONDUCTANCE,As Drink Water ,Ca Mg Hardness,MN,SE-MS,SI	5	Add on Color
2	WELL 1353815 WELL ANALYSIS	10/18/07 10:35	WA	DIS SI	1	
3						
4				Report Silica (SiO_2)		
5	RECEIVED					
6						
7	OCT 19 2007					
8	MIDWEST LABORATORIES, INC.					
9	INT.					
10						

Sampled by: (Signature)	Temp on Arrival 18°	Cooler arrived Intact?	Relinquished by: (Signature)	Date/Time	Received by: (Signature)
Relinquished by: (Signature)	Date/Time 10/19/07 3:5	Received by: (Signature) Heather Ramirez	Relinquished by: (Signature)	Date/Time	Received in Lab by: (Signature)

CHAIN OF CUSTODY

Attachment 2

Ref. Lab #: 212041
Report Number
07-319-2239

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REPORT OF ANALYSIS

For: (21825) US BUREAU OF RECLAMATION
(308)389-5319

Mail to: US BUREAU OF RECLAMATION
BOB SCHIEFFER
203 W 2ND ST
GRAND ISLAND NE 68801

Date Reported: 12/27/07
Date Received: 10/19/07
Date Sampled: 10/19/07

SANTEE SIOUX WELL WATER

Lab number: 1353822

Analysis	Level Found	Units	Detection Limit	Method	Analyst-Date	Verified-Date
Sample ID: WELL						
Arsenic (total)	n.d.	mg/L	0.0005	EPA 200.8	jmb-10/24	bab-10/25
Calcium (total)	243	mg/L	0.01	EPA 200.7	emr-10/26	kkh-10/26
Magnesium (total)	70.7	mg/L	0.01	EPA 200.7	emr-10/24	bab-10/25
Hardness (total)	898	mg Eq CaCO3/L	1	SM2340B	bab-10/19	llm-10/19
Lead (total)	n.d.	mg/L	0.0005	EPA 200.8	jmb-10/24	bab-10/25
Copper (total)	n.d.	mg/L	0.01	EPA 200.7	emr-10/24	bab-10/25
Cryptosporidium	n.d.	oocysts/10 L	10	SM	arj-10/24	arj-10/24
Giardia	n.d.	oocysts/10 L	10	9711B	arj-10/24	arj-10/24
APC-Total plate count	1,100	cfu/100 mL	1	SM 9215 D	arj-10/21	arj-10/24
Alkalinity (Total)	362	mg CaCO3/L	20	SM 2320 B	jdb-10/22	cmw-10/26
Aluminum (total)	n.d.	mg/L	0.05	EPA 200.7	emr-10/24	bab-10/25
Antimony (total)	n.d.	mg/L	0.0005	EPA 200.8	jmb-10/24	bab-10/25
Asbestos	n.d.	MFL	0.20	EPA 600/4-83-043 (100.1)	out-11/15	jjk-11/15
Barium (total)	0.01	mg/L	0.005	EPA 200.7	emr-10/24	bab-10/25
Beryllium (total)	n.d.	mg/L	0.0005	EPA 200.7	emr-10/24	bab-10/25
Bicarbonate as CaCO3	358	mg/L	20	SM 2320 B	jdb-10/22	cmw-10/26
Boron (total)	0.18	mg/L	0.05	EPA 200.7	emr-10/24	bab-10/25
Bromide	n.d.	µg/L	50	EPA 300.0	jdb-10/22	cmw-10/26
Cadmium (total)	n.d.	mg/L	0.0005	EPA 200.8	jmb-10/24	bab-10/25
Carbonate as CaCO3	4.43	mg/L	0.02	EPA 310.1	jdb-10/22	cmw-10/26
Chloride	22	mg/L	1	EPA 300.0	jdb-10/19	cmw-10/26
Chromium (total)	n.d.	mg/L	0.01	EPA 200.7	emr-10/24	bab-10/25
Conductance	1,593	uS/cm	2	SM 2510 B	jdb-10/19	cmw-10/26

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REPORT OF ANALYSIS

Account: 21825 US BUREAU OF RECLAMATION
Report Number: 07-319-2239

Analysis	Level Found	Units	Detection Limit	Method	Analyst-Date	Verified-Date
Cyanide	n.d.	mg/L	0.02	SM 4500 CN-E	jlc-10/26	cmw-10/26
Dissolved organic carbon	1.6	mg/L	1.0	EPA 415.1	kkr-10/23	cmw-10/26
Fluoride	0.7	mg/L	0.1	EPA 300.0	jdb-10/19	cmw-10/26
Gross Alpha	13	pCi/L	1.0	EPA 900.0	out-11/15	jjk-11/15
Gross Beta	15	pCi/L	2.0	EPA 900.0	out-11/15	jjk-11/15
Hexavalent chromium	n.d.	mg/L	0.02	SM 3500CR D	jad-10/23	cmw-10/26
Iron (total)	0.03	mg/L	0.01	EPA 200.7	emr-10/24	bab-10/25
Kjeldahl nitrogen	n.d.	mg/L	0.50	EPA 351.3	dmg-10/24	cmw-10/26
Manganese (total)	0.02	mg/L	0.01	EPA 200.7	emr-10/24	bab-10/25
Mercury (total)	n.d.	mg/L	0.0004	EPA 245.1	mlm-10/24	bab-10/25
Nickel (total)	n.d.	mg/L	0.01	EPA 200.7	emr-10/24	bab-10/25
Nitrate nitrogen	1.3	mg/L	0.2	EPA 300.0	jdb-10/19	cmw-10/26
Nitrate/Nitrite Nitrogen	1.3	mg/L	0.2	EPA 353.2	dmg-10/22	jjd-10/23
Nitrite nitrogen	n.d.	mg/L	0.02	SM 4500 NO2- B	jjd-10/19	cmw-10/26
Orthophosphate phosphorus	n.d.	mg/L	0.05	SM 4500 P	lkr-10/19	cmw-10/26
Phosphorus (total)	n.d.	mg/L	0.1	EPA 200.7	emr-10/24	bab-10/25
Potassium (total)	9.3	mg/L	0.5	EPA 200.7	emr-10/24	bab-10/25
Selenium (total)	0.014	mg/L	0.001	EPA 200.8	jmb-10/24	bab-10/25
Silica (SiO2)	30.2	mg/L	0.05	CALC	bab-10/19	llm-10/19
Silicon (total)	14.1	mg/L	0.05	EPA 200.7	emr-10/24	bab-10/25
Silver (total)	n.d.	mg/L	0.01	EPA 200.7	emr-10/24	bab-10/25
Sodium (total)	39.7	mg/L	0.01	EPA 200.7	emr-10/24	bab-10/25
Strontium (total)	1.165	mg/L	0.005	EPA 200.7	emr-10/24	bab-10/25
Sulfate	587	mg/L	5	EPA 300.0	jdb-10/19	cmw-10/26
Thallium (total)	n.d.	mg/L	0.0005	EPA 200.8	jmb-10/24	bab-10/25
Total Coliform (PWS)	n.d.	cfu/100 mL	1	SM 9222 B	arj-10/24	arj-10/24
Total Nitrogen (TKN + NO3)	1.30	mg/L	0.05	CALCULATION	cmw-10/19	llm-10/19
Total dissolved solids	1,276	mg/L	10	SM 2540C	gjj-10/22	cmw-10/26
Total organic carbon	1.6	mg/L	1.0	SM 5310 B	kkr-10/23	cmw-10/26
Total phosphorus	n.d.	mg/L	0.05	SM 4500 P-F	lkr-10/23	cmw-10/26
Total suspended solids	n.d.	mg/L	4	USGS I-3765-85/SM2540D	gjj-10/22	cmw-10/26

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REPORT OF ANALYSIS

Account: 21825 US BUREAU OF RECLAMATION

Report Number: 07-319-2239

Analysis	Level Found	Units	Detection Limit	Method	Analyst-Date	Verified-Date
True Color	n.d.	APHA	5	ASTM D1209-05	lkr-10/22	cmw-10/26
Turbidity	0.15	NTU	0.01	EPA 180.1	lkr-10/22	cmw-10/26
Uranium (total)	0.0188	mg/L	0.0001	EPA 200.8	jmb-10/24	bab-10/25
Sample ID:						
Antimony (dissolved)	n.d.	mg/L	0.0005	EPA 200.8	jmb-10/24	bab-10/25
Arsenic (dissolved)	n.d.	mg/L	0.001	EPA 200.8	jmb-10/24	bab-10/25
Barium (dissolved)	0.177	mg/L	0.005	EPA 200.7	emr-10/24	bab-10/25
Beryllium (dissolved)	n.d.	mg/L	0.002	EPA 200.7	emr-10/24	bab-10/25
Cadmium (dissolved)	n.d.	mg/L	0.0005	EPA 200.8	jmb-10/24	bab-10/25
Chromium (dissolved)	n.d.	mg/L	0.01	EPA 200.7	emr-10/24	bab-10/25
Copper (dissolved)	n.d.	mg/L	0.01	EPA 200.7	emr-10/24	bab-10/25
Lead (dissolved)	n.d.	mg/L	0.0005	EPA 200.8	jmb-10/24	bab-10/25
Mercury (total)	n.d.	mg/L	0.0004	EPA 245.1	mlm-10/24	bab-10/25
Selenium (dissolved)	0.015	mg/L	0.001	EPA 200.8	jmb-10/24	bab-10/25
Thallium (dissolved)	n.d.	mg/L	0.001	EPA 200.8	jmb-10/24	bab-10/25

Notes:

n.d. - Not Detected.
The following tests were performed by a subcontracted laboratory: Asbestos, Gross alpha, and Gross beta.

Shipping charges are for overnight UPS delivery related to sample method preservation conditions.
The solid analyses have been weighed to a constant weight by leaving the samples in the oven overnight. This protocol is an approved variation from the stated method.

Respectfully Submitted

Heather Ramig/Sue Ann Seitz/Rob Ferris
Prem Arora/Client Services

ORDER NUMBER: **212041**

Midwest Laboratories, Inc.®

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PAGE NUMBER: **1**

CHAIN OF CUSTODY

ACCOUNT NO: 8678
SANTEE SIOUX NATION
WATER RESOURCES/FELIX KITTO
52948 HWY 12
NIOBRARA, NE 68760-7047

SAMPLE DESCRIPTION
WELL ANALYSIS

COPY TO:

PO NUMBER:

Automatic Order Submittal Form

PLACED BY: shipping2 on Oct 05, 2007

	SAMPLE ID	DATE/TIME SAMPLED	MX	TESTS REQUESTED	# CONT	COMMENTS
1	WELL 1353822 12 WELL ANALYSIS	10/19/07 / 10:15am	WA	NO2,NO3,NO3,E-PHOS,PO4,CYANIDE,SULFATE,TDS,TKN,TOC,TSS ,TOTAL NITROGEN,TURBIDITY,ALKALINITY,BICARB,BROMIDE ,CARBONATE,CL,DISS CARBON,CONDUCTANCE,FLUORIDE,HEXA CHROM,APC/CFU/100ML,PWS COLIFORM,AL,Sb-MS,As D	12	Add Color + (SiO_2) + Gross Beta
2	WELL 1353823 WELL ANALYSIS	10/19/10:15am	WA	HG,DIS PB,DIS Sb,DIS AS,DIS BA,DIS BE,DIS CD,DIS CR,DIS CU ,DIS SE,DISS TL,	2	
3				Add Cryptosporidium &		
4				* Run Dissolved Cr^{+6} + Dissolved Cyanide		Giardia
5	RECEIVED			if totals show Reportable level		
6						
7	OCT 19 2007					
8	MIDWEST LABORATORIES, INC.					
9	INT.					
10						

Sampled by: (Signature)	Temp on Arrival 9	Cooler arrived Intact?	Relinquished by: (Signature)	Date/Time	Received by: (Signature)
Relinquished by: (Signature)	Date/Time 10/19/07 315	Received by: (Signature)	Relinquished by: (Signature)	Date/Time	Received in Lab by: (Signature)

CHAIN OF CUSTODY

Attachment 3

EPA National Primary Drinking Water Standards

	Contaminant	MCL or TT[1] (mg/L)[2]	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal
OC	Acrylamide	TT[8]	Nervous system or blood problems;	Added to water during sewage/wastewater increased risk of cancer treatment	zero
OC	Alachlor	0.002	Eye, liver, kidney or spleen problems; anemia; increased risk of cancer	Runoff from herbicide used on row crops	zero
R	Alpha particles	15 picocuries per Liter (pCi/L)	Increased risk of cancer	Erosion of natural deposits of certain minerals that are radioactive and may emit a form of radiation known as alpha radiation	zero
IOC	Antimony	0.006	Increase in blood cholesterol; decrease in blood sugar	Discharge from petroleum refineries; fire retardants; ceramics; electronics; solder	0.006
IOC	Arsenic	0.010 as of 1/23/06	Skin damage or problems with circulatory systems, and may have increased risk of getting cancer	Erosion of natural deposits; runoff from orchards, runoff from glass & electronics production wastes	0
IOC	Asbestos (fibers >10 micrometers)	7 million fibers per Liter (MFL)	Increased risk of developing benign intestinal polyps	Decay of asbestos cement in water mains; erosion of natural deposits	7 MFL
OC	Atrazine	0.003	Cardiovascular system or reproductive problems	Runoff from herbicide used on row crops	0.003
IOC	Barium	2	Increase in blood pressure	Discharge of drilling wastes; discharge from metal refineries; erosion of natural deposits	2
OC	Benzene	0.005	Anemia; decrease in blood platelets; increased risk of cancer	Discharge from factories; leaching from gas storage tanks and landfills	zero
OC	Benzo(a)pyrene (PAHs)	0.0002	Reproductive difficulties; increased risk of cancer	Leaching from linings of water storage tanks and distribution lines	zero
IOC	Beryllium	0.004	Intestinal lesions	Discharge from metal refineries and coal-burning factories; discharge from electrical, aerospace, and defense industries	0.004
R	Beta particles and photon emitters	4 millirems per year	Increased risk of cancer	Decay of natural and man-made deposits of certain minerals that are radioactive and may emit forms of radiation known as photons and beta radiation	zero
DBP	Bromate	0.010	Increased risk of cancer	Byproduct of drinking water disinfection	zero
IOC	Cadmium	0.005	Kidney damage	Corrosion of galvanized pipes; erosion of natural deposits; discharge from metal refineries; runoff from waste batteries and paints	0.005
OC	Carbofuran	0.04	Problems with blood, nervous system, or reproductive system	Leaching of soil fumigant used on rice and alfalfa	0.04
OC	Carbon tetrachloride	0.005	Liver problems; increased risk of cancer	Discharge from chemical plants and other industrial activities	zero
D	Chloramines (as Cl_2)	MRDL=4.0[1]	Eye/nose irritation; stomach discomfort, anemia	Water additive used to control microbes	MRDLG=4[1]

LEGEND

D	Dinsinfectant	IOC	Inorganic Chemical	OC	Organic Chemical
DBP	Disinfection Byproduct	M	Microorganism	R	Radionuclides

1

	Contaminant	MCL or TT[1] (mg/L)[2]	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal
OC	Chlordane	0.002	Liver or nervous system problems; increased risk of cancer	Residue of banned termiticide	zero
D	Chlorine (as Cl_2)	MRDL=4.0[1]	Eye/nose irritation; stomach discomfort	Water additive used to control microbes	MRDLG=4[1]
D	Chlorine dioxide (as ClO_2)	MRDL=0.8[1]	Anemia; infants & young children: nervous system effects	Water additive used to control microbes	MRDLG=0.8[1]
DBP	Chlorite	1.0	Anemia; infants & young children: nervous system effects	Byproduct of drinking water disinfection	0.8
OC	Chlorobenzene	0.1	Liver or kidney problems	Discharge from chemical and agricultural chemical factories	0.1
IOC	Chromium (total)	0.1	Allergic dermatitis	Discharge from steel and pulp mills; erosion of natural deposits	0.1
IOC	Copper	TT[7]; Action Level = 1.3	Short term exposure: Gastrointestinal distress. Long term exposure: Liver or kidney damage. People with Wilson's Disease should consult their personal doctor if the amount of copper in their water exceeds the action level	Corrosion of household plumbing systems; erosion of natural deposits	1.3
M	*Cryptosporidium*	TT[3]	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste	zero
IOC	Cyanide (as free cyanide)	0.2	Nerve damage or thyroid problems	Discharge from steel/metal factories; discharge from plastic and fertilizer factories	0.2
OC	2,4-D	0.07	Kidney, liver, or adrenal gland problems	Runoff from herbicide used on row crops	0.07
OC	Dalapon	0.2	Minor kidney changes	Runoff from herbicide used on rights of way	0.2
OC	1,2-Dibromo-3-chloropropane (DBCP)	0.0002	Reproductive difficulties; increased risk of cancer	Runoff/leaching from soil fumigant used on soybeans, cotton, pineapples, and orchards	zero
OC	o-Dichlorobenzene	0.6	Liver, kidney, or circulatory system problems	Discharge from industrial chemical factories	0.6
OC	p-Dichlorobenzene	0.075	Anemia; liver, kidney or spleen damage; changes in blood	Discharge from industrial chemical factories	0.075
OC	1,2-Dichloroethane	0.005	Increased risk of cancer	Discharge from industrial chemical factories	zero
OC	1,1-Dichloroethylene	0.007	Liver problems	Discharge from industrial chemical factories	0.007
OC	cis-1,2-Dichloroethylene	0.07	Liver problems	Discharge from industrial chemical factories	0.07
OC	trans-1,2-Dichloroethylene	0.1	Liver problems	Discharge from industrial chemical factories	0.1
OC	Dichloromethane	0.005	Liver problems; increased risk of cancer	Discharge from drug and chemical factories	zero
OC	1,2-Dichloropropane	0.005	Increased risk of cancer	Discharge from industrial chemical factories	zero
OC	Di(2-ethylhexyl) adipate	0.4	Weight loss, live problems, or possible reproductive difficulties	Discharge from chemical factories	0.4
OC	Di(2-ethylhexyl) phthalate	0.006	Reproductive difficulties; liver problems; increased risk of cancer	Discharge from rubber and chemical factories	zero
OC	Dinoseb	0.007	Reproductive difficulties	Runoff from herbicide used on soybeans and vegetables	0.007
OC	Dioxin (2,3,7,8-TCDD)	0.00000003	Reproductive difficulties; increased risk of cancer	Emissions from waste incineration and other combustion; discharge from chemical factories	zero
OC	Diquat	0.02	Cataracts	Runoff from herbicide use	0.02
OC	Endothall	0.1	Stomach and intestinal problems	Runoff from herbicide use	0.1

LEGEND

D	Dinsinfectant	IOC	Inorganic Chemical	OC	Organic Chemical
DBP	Disinfection Byproduct	M	Microorganism	R	Radionuclides

	Contaminant	MCL or TT[1] (mg/L)[2]	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal
OC	Endrin	0.002	Liver problems	Residue of banned insecticide	0.002
OC	Epichlorohydrin	TT[8]	Increased cancer risk, and over a long period of time, stomach problems	Discharge from industrial chemical factories; an impurity of some water treatment chemicals	zero
OC	Ethylbenzene	0.7	Liver or kidneys problems	Discharge from petroleum refineries	0.7
OC	Ethylene dibromide	0.00005	Problems with liver, stomach, reproductive system, or kidneys; increased risk of cancer	Discharge from petroleum refineries	zero
IOC	Fluoride	4.0	Bone disease (pain and tenderness of the bones); Children may get mottled teeth	Water additive which promotes strong teeth; erosion of natural deposits; discharge from fertilizer and aluminum factories	4.0
M	*Giardia lamblia*	TT[3]	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste	zero
OC	Glyphosate	0.7	Kidney problems; reproductive difficulties	Runoff from herbicide use	0.7
DBP	Haloacetic acids (HAA5)	0.060	Increased risk of cancer	Byproduct of drinking water disinfection	n/a[6]
OC	Heptachlor	0.0004	Liver damage; increased risk of cancer	Residue of banned termiticide	zero
OC	Heptachlor epoxide	0.0002	Liver damage; increased risk of cancer	Breakdown of heptachlor	zero
M	Heterotrophic plate count (HPC)	TT[3]	HPC has no health effects; it is an analytic method used to measure the variety of bacteria that are common in water. The lower the concentration of bacteria in drinking water, the better maintained the water system is.	HPC measures a range of bacteria that are naturally present in the environment	n/a
OC	Hexachlorobenzene	0.001	Liver or kidney problems; reproductive difficulties; increased risk of cancer	Discharge from metal refineries and agricultural chemical factories	zero
OC	Hexachlorocyclopentadien e	0.05	Kidney or stomach problems	Discharge from chemical factories	0.05
IOC	Lead	TT[7]; Action Level = 0.015	Infants and children: Delays in physical or mental development; children could show slight deficits in attention span and learning abilities; Adults: Kidney problems; high blood pressure	Corrosion of household plumbing systems; erosion of natural deposits	zero
M	*Legionella*	TT[3]	Legionnaire's Disease, a type of pneumonia	Found naturally in water; multiplies in heating systems	zero
OC	Lindane	0.0002	Liver or kidney problems	Runoff/leaching from insecticide used on cattle, lumber, gardens	0.0002
IOC	Mercury (inorganic)	0.002	Kidney damage	Erosion of natural deposits; discharge from refineries and factories; runoff from landfills and croplands	0.002
OC	Methoxychlor	0.04	Reproductive difficulties	Runoff/leaching from insecticide used on fruits, vegetables, alfalfa, livestock	0.04
IOC	Nitrate (measured as Nitrogen)	10	Infants below the age of six months who drink water containing nitrate in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits	10
IOC	Nitrite (measured as Nitrogen)	1	Infants below the age of six months who drink water containing nitrite in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits	1

LEGEND

D	Dinsinfectant	IOC	Inorganic Chemical	OC	Organic Chemical
DBP	Disinfection Byproduct	M	Microorganism	R	Radionuclides

	Contaminant	MCL or TT[1] (mg/L)[2]	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal
OC	Oxamyl (Vydate)	0.2	Slight nervous system effects	Runoff/leaching from insecticide used on apples, potatoes, and tomatoes	0.2
OC	Pentachlorophenol	0.001	Liver or kidney problems; increased cancer risk	Discharge from wood preserving factories	zero
OC	Picloram	0.5	Liver problems	Herbicide runoff	0.5
OC	Polychlorinated biphenyls (PCBs)	0.0005	Skin changes; thymus gland problems; immune deficiencies; reproductive or nervous system difficulties; increased risk of cancer	Runoff from landfills; discharge of waste chemicals	zero
R	Radium 226 and Radium 228 (combined)	5 pCi/L	Increased risk of cancer	Erosion of natural deposits	zero
IOC	Selenium	0.05	Hair or fingernail loss; numbness in fingers or toes; circulatory problems	Discharge from petroleum refineries; erosion of natural deposits; discharge from mines	0.05
OC	Simazine	0.004	Problems with blood	Herbicide runoff	0.004
OC	Styrene	0.1	Liver, kidney, or circulatory system problems	Discharge from rubber and plastic factories; leaching from landfills	0.1
OC	Tetrachloroethylene	0.005	Liver problems; increased risk of cancer	Discharge from factories and dry cleaners	zero
IOC	Thallium	0.002	Hair loss; changes in blood; kidney, intestine, or liver problems	Leaching from ore-processing sites; discharge from electronics, glass, and drug factories	0.0005
OC	Toluene	1	Nervous system, kidney, or liver problems	Discharge from petroleum factories	1
M	Total Coliforms (including fecal coliform and *E. coli*)	5.0%[4]	Not a health threat in itself; it is used to indicate whether other potentially harmful bacteria may be present[5]	Coliforms are naturally present in the environment as well as feces; fecal coliforms and *E. coli* only come from human and animal fecal waste.	zero
DBP	Total Trihalomethanes (TTHMs)	0.10 0.080 after 12/31/03	Liver, kidney or central nervous system problems; increased risk of cancer	Byproduct of drinking water disinfection	n/a[6]
OC	Toxaphene	0.003	Kidney, liver, or thyroid problems; increased risk of cancer	Runoff/leaching from insecticide used on cotton and cattle	zero
OC	2,4,5-TP (Silvex)	0.05	Liver problems	Residue of banned herbicide	0.05
OC	1,2,4-Trichlorobenzene	0.07	Changes in adrenal glands	Discharge from textile finishing factories	0.07
OC	1,1,1-Trichloroethane	0.2	Liver, nervous system, or circulatory problems	Discharge from metal degreasing sites and other factories	0.20
OC	1,1,2-Trichloroethane	0.005	Liver, kidney, or immune system problems	Discharge from industrial chemical factories	0.003
OC	Trichloroethylene	0.005	Liver problems; increased risk of cancer	Discharge from metal degreasing sites and other factories	zero
M	Turbidity	TT[3]	Turbidity is a measure of the cloudiness of water. It is used to indicate water quality and filtration effectiveness (e.g., whether disease-causing organisms are present). Higher turbidity levels are often associated with higher levels of disease-causing micro-organisms such as viruses, parasites and some bacteria. These organisms can cause symptoms such as nausea, cramps, diarrhea, and associated headaches.	Soil runoff	n/a
R	Uranium	30 ug/L as of 12/08/03	Increased risk of cancer, kidney toxicity	Erosion of natural deposits	zero

LEGEND

D	Disinfectant	IOC	Inorganic Chemical	OC	Organic Chemical
DBP	Disinfection Byproduct	M	Microorganism	R	Radionuclides

	Contaminant	MCL or TT[1] (mg/L)[2]	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal
OC	Vinyl chloride	0.002	Increased risk of cancer	Leaching from PVC pipes; discharge from plastic factories	zero
M	Viruses (enteric)	TT[3]	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste	zero
OC	Xylenes (total)	10	Nervous system damage	Discharge from petroleum factories; discharge from chemical factories	10

NOTES

1 Definitions

- Maximum Contaminant Level Goal (MCLG)—The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals.
- Maximum Contaminant Level (MCL)—The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards.
- Maximum Residual Disinfectant Level Goal (MRDLG)—The level of a drinking water disinfectant below which there is no known or expected risk to health. MRDLGs do not reflect the benefits of the use of disinfectants to control microbial contaminants.
- Maximum Residual Disinfectant Level (MRDL)—The highest level of a disinfectant allowed in drinking water. There is convincing evidence that addition of a disinfectant is necessary for control of microbial contaminants.
- Treatment Technique (TT)—A required process intended to reduce the level of a contaminant in drinking water.

2 Units are in milligrams per liter (mg/L) unless otherwise noted. Milligrams per liter are equivalent to parts per million (ppm).

3 EPA's surface water treatment rules require systems using surface water or ground water under the direct influence of surface water to (1) disinfect their water, and (2) filter their water or meet criteria for avoiding filtration so that the following contaminants are controlled at the following levels:

- *Cryptosporidium* (as of 1/1/02 for systems serving >10,000 and 1/14/05 for systems serving <10,000) 99% removal.
- *Giardia lamblia*: 99.9% removal/inactivation
- Viruses: 99.99% removal/inactivation
- *Legionella*: No limit, but EPA believes that if *Giardia* and viruses are removed/inactivated, *Legionella* will also be controlled.
- Turbidity: At no time can turbidity (cloudiness of water) go above 5 nephelolometric turbidity units (NTU); systems that filter must ensure that the turbidity go no higher than 1 NTU (0.5 NTU for conventional or direct filtration) in at least 95% of the daily samples in any month. As of January 1, 2002, for systems servicing >10,000, and January 14, 2005, for systems servicing <10,000, turbidity may never exceed 1 NTU, and must not exceed 0.3 NTU in 95% of daily samples in any month.
- HPC: No more than 500 bacterial colonies per milliliter.
- Long Term 1 Enhanced Surface Water Treatment (Effective Date: January 14, 2005); Surface water systems or (GWUDI) systems serving fewer than 10,000 people must comply with the applicable Long Term 1 Enhanced Surface Water Treatment Rule provisions (e.g. turbidity standards, individual filter monitoring, *Cryptosporidium* removal requirements, updated watershed control requirements for unfiltered systems).
- Filter Backwash Recycling: The Filter Backwash Recycling Rule requires systems that recycle to return specific recycle flows through all processes of the system's existing conventional or direct filtration system or at an alternate location approved by the state.

4 No more than 5.0% samples total coliform-positive in a month. (For water systems that collect fewer than 40 routine samples per month, no more than one sample can be total coliform-positive per month.) Every sample that has total coliform must be analyzed for either fecal coliforms or *E. coli* if two consecutive TC-positive samples, and one is also positive for *E. coli* fecal coliforms, system has an acute MCL violation.

5 Fecal coliform and *E. coli* are bacteria whose presence indicates that the water may be contaminated with human or animal wastes. Disease-causing microbes (pathogens) in these wastes can cause diarrhea, cramps, nausea, headaches, or other symptoms. These pathogens may pose a special health risk for infants, young children, and people with severely compromised immune systems.

6 Although there is no collective MCLG for this contaminant group, there are individual MCLGs for some of the individual contaminants:

- Haloacetic acids: dichloroacetic acid (zero); trichloroacetic acid (0.3 mg/L)
- Trihalomethanes: bromodichloromethane (zero); bromoform (zero); dibromochloromethane (0.06 mg/L)

7 Lead and copper are regulated by a Treatment Technique that requires systems to control the corrosiveness of their water. If more than 10% of tap water samples exceed the action level, water systems must take additional steps. For copper, the action level is 1.3 mg/L, and for lead is 0.015 mg/L.

8 Each water system must certify, in writing, to the state (using third-party or manufacturers certification) that when it uses acrylamide and/or epichlorohydrin to treat water, the combination (or product) of dose and monomer level does not exceed the levels specified, as follows: Acrylamide = 0.05% dosed at 1 mg/L (or equivalent); Epichlorohydrin = 0.01% dosed at 20 mg/L (or equivalent).

LEGEND

D	Disinfectant	IOC	Inorganic Chemical	OC	Organic Chemical
DBP	Disinfection Byproduct	M	Microorganism	R	Radionuclides

National Secondary Drinking Water Standards

National Secondary Drinking Water Standards are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. EPA recommends secondary standards to water systems but does not require systems to comply. However, states may choose to adopt them as enforceable standards.

Contaminant	Secondary Standard
Aluminum	0.05 to 0.2 mg/L
Chloride	250 mg/L
Color	15 (color units)
Copper	1.0 mg/L
Corrosivity	noncorrosive
Fluoride	2.0 mg/L
Foaming Agents	0.5 mg/L
Iron	0.3 mg/L
Manganese	0.05 mg/L
Odor	3 threshold odor number
pH	6.5-8.5
Silver	0.10 mg/L
Sulfate	250 mg/L
Total Dissolved Solids	500 mg/L
Zinc	5 mg/L

Office of Water (4606M)
EPA 816-F-03-016
www.epa.gov/safewater
June 2003

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APPENDIX E

HERMIT DATA RECORDINGS

```
In-Situ Inc.      Hermit 3000

Report generated: 11/04/07    00:36:01
Report from file: C:\Documents and Settings\W. Robert Talbot\Desktop\Data\SN45888 2007-10-17 124652 2hr Pump
.bin
DataMgr Version   3.71

Serial number:    00045888
Firmware Version  7.10
Unit name:  HERMIT 3000

Test name:        2hr Pump

Test defined on:  10/17/07    11:10:38
Test started on:  10/17/07    12:46:53
Test stopped on:  10/17/07    17:41:12
Test extracted on:      01/01/01    00:00:42

Data gathered using Logarithmic testing
   Maximum time between data points:      10.0000     Minutes.
   Number of data samples:    139


TOTAL DATA SAMPLES      139

Channel number [1]
  Measurement type:     Pressure
  Channel name:   ETwo
  Linearity:       0.0015000
  Scale:          10.3030000
  Offset:         -0.0134000
  Warmup:         50
  Specific gravity:        1.000
  Mode:     TOC
  User-defined reference:       31.640    Feet H2O
  Referenced on:  test start
  Pressure head at reference:   12.821    Feet H2O

Channel number [2]
  Measurement type:     Pressure
  Channel name:   EOne
  Linearity:       0.1253000
```

Scale: 19.6723000
Offset: -0.1940000
Warmup: 50
Specific gravity: 1.000
Mode: TOC
User-defined reference: 32.270 Feet H2O
Referenced on: test start
Pressure head at reference: 19.660 Feet H2O

Channel number [3]
Measurement type: Pressure
Channel name: Test
Linearity: 0.0696000
Scale: 19.9209000
Offset: -0.0091000
Warmup: 50
Specific gravity: 1.000
Mode: TOC
User-defined reference: 31.660 Feet H2O
Referenced on: test start
Pressure head at reference: 15.428 Feet H2O

Channel number [0]
Measurement type: Barometric Pressure
Channel name: Barometric
Linearity: 0.0000000
Scale: 0.0000000
Offset: 0.0000000
Warmup: 50

Date	Time	ET (min)	Chan[1] Feet H2O	Chan[2] Feet H2O	Chan[3] Feet H2O	Chan[0] Inches Hg
10/17/07	12:46:53	0.0000	31.640	32.270	31.660	28.192
10/17/07	12:46:54	0.0218	31.639	32.273	31.660	28.192
10/17/07	12:46:55	0.0437	31.639	32.273	31.663	28.192
10/17/07	12:46:56	0.0655	31.640	32.273	31.660	28.190
10/17/07	12:46:58	0.0873	31.639	32.270	31.657	28.190
10/17/07	12:46:59	0.1092	31.640	32.273	31.660	28.188
10/17/07	12:47:00	0.1310	31.640	32.273	31.660	28.190
10/17/07	12:47:02	0.1528	31.640	32.273	31.660	28.188

10/17/07	12:47:03	0.1747	31.639	32.273	31.660	28.188
10/17/07	12:47:04	0.1965	31.640	32.273	31.657	28.188
10/17/07	12:47:06	0.2183	31.640	32.273	31.660	28.188
10/17/07	12:47:07	0.2402	31.640	32.273	31.660	28.188
10/17/07	12:47:08	0.2620	31.640	32.273	31.657	28.188
10/17/07	12:47:10	0.2838	31.640	32.273	31.660	28.186
10/17/07	12:47:11	0.3057	31.640	32.276	31.660	28.188
10/17/07	12:47:12	0.3275	31.641	32.273	31.660	28.184
10/17/07	12:47:13	0.3493	31.640	32.273	31.660	28.184
10/17/07	12:47:15	0.3712	31.641	32.273	31.660	28.184
10/17/07	12:47:16	0.3930	31.640	32.273	31.657	28.184
10/17/07	12:47:17	0.4148	31.640	32.273	31.660	28.182
10/17/07	12:47:19	0.4367	31.640	32.276	31.657	28.182
10/17/07	12:47:20	0.4588	31.640	32.273	31.660	28.182
10/17/07	12:47:21	0.4823	31.640	32.276	31.657	28.180
10/17/07	12:47:23	0.5072	31.640	32.273	31.657	28.180
10/17/07	12:47:25	0.5335	31.640	32.273	31.660	28.180
10/17/07	12:47:26	0.5615	31.640	32.276	31.657	28.180
10/17/07	12:47:28	0.5912	31.640	32.273	31.657	28.180
10/17/07	12:47:30	0.6225	31.640	32.273	31.657	28.180
10/17/07	12:47:32	0.6557	31.641	32.276	31.657	28.178
10/17/07	12:47:34	0.6908	31.641	32.276	31.657	28.176
10/17/07	12:47:36	0.7282	31.641	32.273	31.657	28.174
10/17/07	12:47:39	0.7677	31.641	32.276	31.657	28.176
10/17/07	12:47:41	0.8095	31.643	32.276	31.657	28.178
10/17/07	12:47:44	0.8538	31.641	32.276	31.654	28.176
10/17/07	12:47:47	0.9008	31.641	32.276	31.654	28.174
10/17/07	12:47:50	0.9507	31.641	32.276	31.657	28.172
10/17/07	12:47:53	1.0033	31.641	32.273	31.657	28.172
10/17/07	12:47:56	1.0592	31.641	32.276	31.657	28.170
10/17/07	12:48:00	1.1183	31.641	32.273	31.654	28.170
10/17/07	12:48:03	1.1810	31.641	32.273	31.657	28.168
10/17/07	12:48:07	1.2473	31.640	32.273	31.660	28.168
10/17/07	12:48:12	1.3177	31.641	32.276	31.654	28.168
10/17/07	12:48:16	1.3922	31.641	32.276	31.651	28.166
10/17/07	12:48:21	1.4712	31.641	32.273	31.657	28.166
10/17/07	12:48:26	1.5548	31.640	32.273	31.651	28.164
10/17/07	12:48:31	1.6433	31.640	32.273	31.654	28.164
10/17/07	12:48:37	1.7372	31.640	32.273	31.654	28.162
10/17/07	12:48:43	1.8365	31.640	32.276	31.651	28.162
10/17/07	12:48:49	1.9418	31.640	32.276	31.651	28.162
10/17/07	12:48:56	2.0533	31.641	32.279	31.651	28.160

10/17/07	12:49:03	2.1715	31.641	32.276	31.651	28.156
10/17/07	12:49:10	2.2967	31.640	32.276	31.651	28.156
10/17/07	12:49:18	2.4292	31.640	32.276	31.651	28.154
10/17/07	12:49:27	2.5697	31.640	32.273	31.654	28.154
10/17/07	12:49:36	2.7185	31.640	32.270	31.651	28.154
10/17/07	12:49:45	2.8760	31.640	32.270	31.654	28.150
10/17/07	12:49:55	3.0428	31.640	32.273	31.654	28.150
10/17/07	12:50:06	3.2197	31.639	32.273	31.651	28.148
10/17/07	12:50:17	3.4070	31.636	32.267	31.651	28.131
10/17/07	12:50:29	3.6053	31.637	32.267	31.651	28.138
10/17/07	12:50:41	3.8155	31.637	32.270	31.651	28.144
10/17/07	12:50:55	4.0382	31.670	32.492	40.512	28.148
10/17/07	12:51:09	4.2740	31.693	32.481	36.834	28.150
10/17/07	12:51:24	4.5238	31.702	32.492	37.098	28.150
10/17/07	12:51:40	4.7885	31.710	32.504	37.202	28.152
10/17/07	12:51:57	5.0688	31.716	32.510	37.142	28.154
10/17/07	12:52:14	5.3657	31.720	32.515	37.142	28.154
10/17/07	12:52:33	5.6802	31.726	32.524	37.090	28.154
10/17/07	12:52:53	6.0133	31.729	32.527	37.113	28.154
10/17/07	12:53:14	6.3662	31.731	32.532	37.096	28.156
10/17/07	12:53:37	6.7400	31.735	32.538	37.234	28.154
10/17/07	12:54:01	7.1360	31.737	32.541	37.159	28.156
10/17/07	12:54:26	7.5553	31.741	32.549	37.228	28.154
10/17/07	12:54:52	7.9997	31.747	32.555	37.248	28.154
10/17/07	12:55:21	8.4703	31.748	32.558	37.182	28.152
10/17/07	12:55:51	8.9688	31.753	32.564	37.124	28.152
10/17/07	12:56:22	9.4968	31.754	32.567	37.205	28.154
10/17/07	12:56:56	10.0562	31.760	32.575	37.119	28.152
10/17/07	12:57:31	10.6487	31.765	32.578	37.188	28.152
10/17/07	12:58:09	11.2762	31.768	32.584	37.225	28.154
10/17/07	12:58:49	11.9410	31.772	32.592	37.285	28.152
10/17/07	12:59:31	12.6452	31.777	32.598	37.167	28.154
10/17/07	13:00:16	13.3910	31.781	32.598	37.222	28.152
10/17/07	13:01:03	14.1810	31.786	32.604	37.254	28.150
10/17/07	13:01:54	15.0178	31.789	32.612	37.300	28.148
10/17/07	13:02:47	15.9043	31.805	32.658	38.608	28.150
10/17/07	13:03:43	16.8433	31.812	32.669	38.663	28.148
10/17/07	13:04:43	17.8380	31.818	32.675	38.695	28.146
10/17/07	13:05:46	18.8917	31.821	32.684	38.574	28.146
10/17/07	13:06:53	20.0077	31.841	32.729	40.060	28.144
10/17/07	13:08:04	21.1898	31.851	32.746	40.190	28.142
10/17/07	13:09:19	22.4420	31.860	32.758	40.385	28.144

10/17/07	13:10:39	23.7685	31.854	32.732	40.362	28.144
10/17/07	13:12:03	25.1735	31.864	32.746	40.454	28.142
10/17/07	13:13:32	26.6618	31.872	32.755	40.420	28.144
10/17/07	13:15:07	28.2383	31.891	32.812	42.590	28.144
10/17/07	13:16:47	29.9082	31.904	32.835	42.958	28.144
10/17/07	13:18:33	31.6770	31.915	32.852	43.147	28.144
10/17/07	13:20:26	33.5507	31.919	32.863	43.337	28.138
10/17/07	13:22:25	35.5353	31.927	32.875	43.495	28.133
10/17/07	13:24:31	37.6377	31.950	32.937	43.716	28.131
10/17/07	13:26:44	39.8645	31.964	32.934	43.828	28.131
10/17/07	13:29:06	42.2233	31.970	32.943	43.831	28.127
10/17/07	13:31:36	44.7220	31.983	32.957	43.926	28.127
10/17/07	13:34:15	47.3687	31.998	32.972	43.975	28.127
10/17/07	13:37:03	50.1722	32.007	32.980	44.047	28.125
10/17/07	13:40:01	53.1418	32.020	32.994	44.090	28.129
10/17/07	13:43:10	56.2875	32.035	33.017	44.099	28.129
10/17/07	13:46:30	59.6195	32.046	33.026	44.254	28.127
10/17/07	13:50:01	63.1490	32.053	33.037	44.208	28.123
10/17/07	13:53:46	66.8875	32.060	33.043	44.326	28.119
10/17/07	13:57:43	70.8477	32.077	33.063	44.337	28.119
10/17/07	14:01:55	75.0425	32.089	33.071	44.371	28.113
10/17/07	14:06:22	79.4858	32.101	33.088	44.440	28.111
10/17/07	14:11:04	84.1925	32.114	33.106	44.475	28.113
10/17/07	14:16:03	89.1780	32.126	33.114	44.512	28.111
10/17/07	14:21:20	94.4588	32.142	33.131	44.541	28.115
10/17/07	14:26:56	100.0527	32.153	33.145	44.604	28.111
10/17/07	14:32:51	105.9780	32.164	33.160	44.518	28.109
10/17/07	14:39:08	112.2543	32.178	33.171	44.530	28.107
10/17/07	14:45:47	118.9027	32.193	33.185	44.524	28.097
10/17/07	14:52:49	125.9448	32.210	33.203	44.573	28.101
10/17/07	15:00:17	133.4043	32.218	33.208	44.504	28.101
10/17/07	15:08:11	141.3058	32.227	33.222	44.550	28.099
10/17/07	15:16:33	149.6755	32.230	33.191	41.733	28.089
10/17/07	15:25:25	158.5412	32.233	33.185	41.733	28.085
10/17/07	15:34:48	167.9322	32.242	33.191	41.782	28.097
10/17/07	15:44:45	177.8797	32.246	33.197	41.788	28.064
10/17/07	15:54:45	187.8797	32.259	33.208	41.800	28.119
10/17/07	16:04:45	197.8797	32.270	33.214	41.834	28.070
10/17/07	16:14:45	207.8797	32.273	33.220	41.604	28.056
10/17/07	16:24:45	217.8797	32.262	33.180	40.310	28.058
10/17/07	16:34:45	227.8797	32.264	33.180	40.287	28.054
10/17/07	16:44:45	237.8797	32.268	33.183	40.267	28.070

10/17/07	16:54:45	247.8797	32.274	33.188	40.290	28.066
10/17/07	17:04:45	257.8797	32.280	33.208	40.906	28.044
10/17/07	17:14:45	267.8797	32.301	33.208	41.038	28.034
10/17/07	17:24:45	277.8797	32.304	33.203	40.943	28.034
10/17/07	17:34:45	287.8797	32.313	33.214	41.018	28.019

```
In-Situ Inc.      Hermit 3000

Report generated: 11/04/07    00:36:50
Report from file: C:\Documents and Settings\W. Robert Talbot\Desktop\Data\SN45888 2007-10-17 174138 2hr recovery
.bin
DataMgr Version   3.71

Serial number:    00045888
Firmware Version  7.10
Unit name:  HERMIT 3000

Test name:        2hr recovery

Test defined on:  10/17/07    11:11:23
Test started on:  10/17/07    17:41:38
Test stopped on:  10/18/07    07:24:13
Test extracted on:      01/01/01    00:01:31

Data gathered using Logarithmic testing
   Maximum time between data points:      10.0000     Minutes.
   Number of data samples:    192


TOTAL DATA SAMPLES      192

Channel number [1]
  Measurement type:     Pressure
  Channel name:   ETwo
  Linearity:       0.0015000
  Scale:          10.3030000
  Offset:         -0.0134000
  Warmup:         50
  Specific gravity:        1.000
  Mode:     TOC
  User-defined reference:       31.640    Feet H2O
  Referenced on:  test start
  Pressure head at reference:   12.135    Feet H2O

Channel number [2]
  Measurement type:     Pressure
  Channel name:   EOne
  Linearity:       0.1253000
```

Scale: 19.6723000
Offset: -0.1940000
Warmup: 50
Specific gravity: 1.000
Mode: TOC
User-defined reference: 32.270 Feet H2O
Referenced on: test start
Pressure head at reference: 18.711 Feet H2O

Channel number [3]
Measurement type: Pressure
Channel name: Test
Linearity: 0.0696000
Scale: 19.9209000
Offset: -0.0091000
Warmup: 50
Specific gravity: 1.000
Mode: TOC
User-defined reference: 31.660 Feet H2O
Referenced on: test start
Pressure head at reference: 6.093 Feet H2O

Channel number [0]
Measurement type: Barometric Pressure
Channel name: Barometric
Linearity: 0.0000000
Scale: 0.0000000
Offset: 0.0000000
Warmup: 50

Date	Time	ET (min)	Chan[1] Feet H2O	Chan[2] Feet H2O	Chan[3] Feet H2O	Chan[0] Inches Hg
10/17/07	17:41:38	0.0000	31.640	32.270	31.660	28.062
10/17/07	17:41:39	0.0218	31.639	32.273	31.605	28.060
10/17/07	17:41:40	0.0437	31.639	32.273	31.692	28.060
10/17/07	17:41:41	0.0655	31.639	32.273	31.706	28.060
10/17/07	17:41:43	0.0873	31.639	32.273	31.706	28.060
10/17/07	17:41:44	0.1092	31.639	32.273	31.637	28.058
10/17/07	17:41:45	0.1310	31.639	32.273	31.608	28.060
10/17/07	17:41:47	0.1528	31.639	32.273	31.726	28.060

10/17/07	17:41:48	0.1747	31.639	32.270	31.703	28.060
10/17/07	17:41:49	0.1965	31.639	32.273	31.643	28.058
10/17/07	17:41:51	0.2183	31.639	32.273	31.631	28.058
10/17/07	17:41:52	0.2402	31.639	32.273	31.703	28.058
10/17/07	17:41:53	0.2620	31.639	32.273	31.720	28.058
10/17/07	17:41:55	0.2838	31.639	32.270	31.666	28.058
10/17/07	17:41:56	0.3057	31.639	32.273	31.623	28.058
10/17/07	17:41:57	0.3275	31.639	32.273	31.700	28.058
10/17/07	17:41:58	0.3493	31.640	32.273	31.700	28.056
10/17/07	17:42:00	0.3712	31.640	32.273	31.637	28.058
10/17/07	17:42:01	0.3930	31.639	32.273	31.634	28.058
10/17/07	17:42:02	0.4148	31.639	32.273	31.674	28.060
10/17/07	17:42:04	0.4367	31.640	32.273	31.683	28.058
10/17/07	17:42:05	0.4588	31.639	32.273	31.637	28.058
10/17/07	17:42:06	0.4823	31.640	32.273	31.700	28.056
10/17/07	17:42:08	0.5072	31.639	32.273	31.634	28.056
10/17/07	17:42:10	0.5335	31.639	32.273	31.628	28.056
10/17/07	17:42:11	0.5615	31.639	32.273	31.646	28.054
10/17/07	17:42:13	0.5912	31.640	32.273	31.674	28.056
10/17/07	17:42:15	0.6225	31.639	32.273	31.669	28.058
10/17/07	17:42:17	0.6557	31.640	32.273	31.686	28.058
10/17/07	17:42:19	0.6908	31.640	32.273	31.683	28.056
10/17/07	17:42:21	0.7282	31.640	32.276	31.680	28.056
10/17/07	17:42:24	0.7677	31.640	32.273	31.732	28.054
10/17/07	17:42:26	0.8095	31.640	32.276	31.651	28.058
10/17/07	17:42:29	0.8538	31.640	32.276	31.643	28.056
10/17/07	17:42:32	0.9008	31.640	32.276	31.671	28.056
10/17/07	17:42:35	0.9507	31.640	32.276	31.626	28.058
10/17/07	17:42:38	1.0033	31.640	32.279	31.649	28.056
10/17/07	17:42:41	1.0592	31.640	32.276	31.715	28.056
10/17/07	17:42:45	1.1183	31.640	32.276	31.657	28.054
10/17/07	17:42:48	1.1810	31.640	32.276	31.669	28.056
10/17/07	17:42:52	1.2473	31.640	32.276	31.723	28.054
10/17/07	17:42:57	1.3177	31.640	32.276	31.643	28.054
10/17/07	17:43:01	1.3922	31.641	32.276	31.709	28.054
10/17/07	17:43:06	1.4712	31.640	32.276	31.686	28.054
10/17/07	17:43:11	1.5548	31.640	32.276	31.666	28.052
10/17/07	17:43:16	1.6433	31.640	32.276	31.709	28.052
10/17/07	17:43:22	1.7372	31.640	32.276	31.674	28.052
10/17/07	17:43:28	1.8365	31.640	32.276	31.706	28.050
10/17/07	17:43:34	1.9418	31.640	32.276	31.674	28.052
10/17/07	17:43:41	2.0533	31.641	32.276	31.697	28.052

10/17/07	17:43:48	2.1715	31.640	32.276	31.637	28.052
10/17/07	17:43:55	2.2967	31.640	32.273	31.706	28.050
10/17/07	17:44:03	2.4292	31.640	32.273	31.689	28.050
10/17/07	17:44:12	2.5697	31.640	32.273	31.669	28.050
10/17/07	17:44:21	2.7185	31.641	32.273	31.643	28.052
10/17/07	17:44:30	2.8760	31.641	32.276	31.660	28.048
10/17/07	17:44:40	3.0428	31.641	32.273	31.651	28.048
10/17/07	17:44:51	3.2197	31.640	32.273	31.643	28.050
10/17/07	17:45:02	3.4070	31.636	32.270	31.657	27.999
10/17/07	17:45:14	3.6053	31.636	32.270	31.640	28.005
10/17/07	17:45:26	3.8155	31.636	32.270	31.717	28.007
10/17/07	17:45:40	4.0382	31.636	32.267	31.683	28.009
10/17/07	17:45:54	4.2740	31.636	32.270	31.732	28.013
10/17/07	17:46:09	4.5238	31.636	32.270	31.807	28.013
10/17/07	17:46:25	4.7885	31.637	32.267	31.680	28.013
10/17/07	17:46:42	5.0688	31.634	32.267	31.643	28.013
10/17/07	17:46:59	5.3657	31.636	32.267	31.666	28.017
10/17/07	17:47:18	5.6802	31.618	32.099	20.915	28.015
10/17/07	17:47:38	6.0133	31.563	32.013	22.625	28.017
10/17/07	17:47:59	6.3662	31.557	32.011	22.645	28.019
10/17/07	17:48:22	6.7400	31.549	31.996	22.630	28.017
10/17/07	17:48:46	7.1360	31.543	31.985	22.616	28.019
10/17/07	17:49:11	7.5553	31.537	31.979	22.605	28.019
10/17/07	17:49:37	7.9997	31.532	31.968	22.593	28.021
10/17/07	17:50:06	8.4703	31.526	31.962	22.579	28.021
10/17/07	17:50:36	8.9688	31.521	31.953	22.570	28.021
10/17/07	17:51:07	9.4968	31.515	31.945	22.558	28.024
10/17/07	17:51:41	10.0562	31.509	31.936	22.547	28.028
10/17/07	17:52:16	10.6487	31.505	31.931	22.538	28.026
10/17/07	17:52:54	11.2762	31.499	31.922	22.527	28.026
10/17/07	17:53:34	11.9410	31.494	31.916	22.515	28.028
10/17/07	17:54:16	12.6452	31.488	31.908	22.504	28.030
10/17/07	17:55:01	13.3910	31.483	31.899	22.492	28.032
10/17/07	17:55:48	14.1810	31.477	31.894	22.481	28.032
10/17/07	17:56:39	15.0178	31.471	31.885	22.469	28.032
10/17/07	17:57:32	15.9043	31.463	31.879	22.455	28.032
10/17/07	17:58:28	16.8433	31.456	31.868	22.443	28.032
10/17/07	17:59:28	17.8380	31.450	31.857	22.432	28.034
10/17/07	18:00:31	18.8917	31.444	31.848	22.420	28.036
10/17/07	18:01:38	20.0077	31.439	31.842	22.409	28.034
10/17/07	18:02:49	21.1898	31.432	31.834	22.403	28.032
10/17/07	18:04:04	22.4420	31.426	31.825	22.386	28.034

10/17/07	18:05:24	23.7685	31.420	31.817	22.374	28.038
10/17/07	18:06:48	25.1735	31.413	31.811	22.366	28.036
10/17/07	18:08:17	26.6618	31.407	31.800	22.354	28.038
10/17/07	18:09:52	28.2383	31.399	31.794	22.343	28.038
10/17/07	18:11:32	29.9082	31.393	31.785	22.328	28.036
10/17/07	18:13:18	31.6770	31.387	31.780	22.320	28.036
10/17/07	18:15:11	33.5507	31.382	31.771	22.311	28.036
10/17/07	18:17:10	35.5353	31.376	31.762	22.297	28.036
10/17/07	18:19:16	37.6377	31.368	31.754	22.288	28.036
10/17/07	18:21:29	39.8645	31.361	31.745	22.279	28.036
10/17/07	18:23:51	42.2233	31.355	31.737	22.268	28.038
10/17/07	18:26:21	44.7220	31.346	31.725	22.256	28.040
10/17/07	18:29:00	47.3687	31.335	31.714	22.242	28.042
10/17/07	18:31:48	50.1722	31.325	31.705	22.225	28.042
10/17/07	18:34:46	53.1418	31.318	31.697	22.213	28.042
10/17/07	18:37:55	56.2875	31.310	31.688	22.204	28.044
10/17/07	18:41:15	59.6195	31.303	31.680	22.193	28.042
10/17/07	18:44:46	63.1490	31.294	31.671	22.181	28.042
10/17/07	18:48:31	66.8875	31.285	31.665	22.176	28.042
10/17/07	18:52:28	70.8477	31.279	31.660	22.167	28.042
10/17/07	18:56:40	75.0425	31.273	31.651	22.158	28.040
10/17/07	19:01:07	79.4858	31.266	31.643	22.147	28.034
10/17/07	19:05:49	84.1925	31.260	31.634	22.138	28.034
10/17/07	19:10:48	89.1780	31.254	31.628	22.130	28.030
10/17/07	19:16:05	94.4588	31.246	31.620	22.124	28.030
10/17/07	19:21:41	100.0527	31.234	31.606	22.107	28.028
10/17/07	19:27:36	105.9780	31.223	31.594	22.086	28.028
10/17/07	19:33:53	112.2543	31.214	31.588	22.075	28.019
10/17/07	19:40:32	118.9027	31.202	31.577	22.058	28.017
10/17/07	19:47:34	125.9448	31.178	31.560	22.023	28.013
10/17/07	19:55:02	133.4043	31.169	31.549	21.997	28.015
10/17/07	20:02:56	141.3058	31.208	31.537	21.965	28.013
10/17/07	20:11:18	149.6755	31.199	31.537	21.951	28.005
10/17/07	20:20:10	158.5412	31.191	31.537	21.928	27.999
10/17/07	20:29:33	167.9322	31.182	31.537	21.937	27.993
10/17/07	20:39:30	177.8797	31.177	31.531	21.937	27.987
10/17/07	20:49:30	187.8797	31.171	31.534	21.948	27.987
10/17/07	20:59:30	197.8797	31.166	31.540	21.968	27.983
10/17/07	21:09:30	207.8797	31.159	31.529	21.965	27.981
10/17/07	21:19:30	217.8797	31.151	31.531	21.974	27.977
10/17/07	21:29:30	227.8797	31.145	31.529	21.986	27.971
10/17/07	21:39:30	237.8797	31.142	31.523	21.988	27.969

10/17/07	21:49:30	247.8797	31.139	31.511	21.977	27.966
10/17/07	21:59:30	257.8797	31.133	31.511	21.977	27.964
10/17/07	22:09:30	267.8797	31.127	31.509	21.977	27.958
10/17/07	22:19:30	277.8797	31.126	31.503	21.971	27.960
10/17/07	22:29:30	287.8797	31.120	31.509	21.986	27.956
10/17/07	22:39:30	297.8797	31.116	31.503	21.988	27.954
10/17/07	22:49:30	307.8797	31.114	31.494	21.988	27.952
10/17/07	22:59:30	317.8797	31.111	31.494	21.986	27.952
10/17/07	23:09:30	327.8797	31.107	31.489	21.988	27.952
10/17/07	23:19:30	337.8797	31.104	31.486	21.986	27.950
10/17/07	23:29:30	347.8797	31.099	31.483	21.988	27.946
10/17/07	23:39:30	357.8797	31.098	31.480	21.988	27.944
10/17/07	23:49:30	367.8797	31.096	31.477	21.988	27.940
10/17/07	23:59:30	377.8797	31.092	31.474	21.986	27.938
10/18/07	00:09:30	387.8797	31.090	31.472	21.988	27.938
10/18/07	00:19:30	397.8797	31.087	31.472	21.986	27.932
10/18/07	00:29:30	407.8797	31.084	31.469	21.986	27.926
10/18/07	00:39:30	417.8797	31.081	31.463	21.980	27.926
10/18/07	00:49:30	427.8797	31.081	31.460	21.977	27.924
10/18/07	00:59:30	437.8797	31.075	31.460	21.977	27.920
10/18/07	01:09:30	447.8797	31.075	31.457	21.977	27.916
10/18/07	01:19:30	457.8797	31.073	31.457	21.977	27.912
10/18/07	01:29:30	467.8797	31.071	31.452	21.971	27.909
10/18/07	01:39:30	477.8797	31.068	31.449	21.971	27.907
10/18/07	01:49:30	487.8797	31.064	31.449	21.974	27.899
10/18/07	01:59:30	497.8797	31.064	31.452	21.980	27.895
10/18/07	02:09:30	507.8797	31.062	31.446	21.980	27.891
10/18/07	02:19:30	517.8797	31.061	31.446	21.980	27.887
10/18/07	02:29:30	527.8797	31.059	31.443	21.977	27.885
10/18/07	02:39:30	537.8797	31.058	31.440	21.974	27.885
10/18/07	02:49:30	547.8797	31.056	31.437	21.974	27.881
10/18/07	02:59:30	557.8797	31.053	31.437	21.977	27.879
10/18/07	03:09:30	567.8797	31.053	31.434	21.974	27.875
10/18/07	03:19:30	577.8797	31.052	31.429	21.971	27.875
10/18/07	03:29:30	587.8797	31.050	31.432	21.971	27.871
10/18/07	03:39:30	597.8797	31.049	31.429	21.971	27.871
10/18/07	03:49:30	607.8797	31.049	31.426	21.971	27.869
10/18/07	03:59:30	617.8797	31.047	31.426	21.971	27.869
10/18/07	04:09:30	627.8797	31.046	31.423	21.971	27.867
10/18/07	04:19:30	637.8797	31.046	31.420	21.971	27.867
10/18/07	04:29:30	647.8797	31.043	31.420	21.968	27.867
10/18/07	04:39:30	657.8797	31.041	31.420	21.968	27.865

10/18/07	04:49:30	667.8797	31.041	31.417	21.965	27.865
10/18/07	04:59:30	677.8797	31.041	31.415	21.963	27.865
10/18/07	05:09:30	687.8797	31.038	31.412	21.957	27.863
10/18/07	05:19:30	697.8797	31.038	31.412	21.954	27.863
10/18/07	05:29:30	707.8797	31.038	31.409	21.951	27.863
10/18/07	05:39:30	717.8797	31.035	31.406	21.948	27.863
10/18/07	05:49:30	727.8797	31.037	31.403	21.945	27.863
10/18/07	05:59:30	737.8797	31.037	31.403	21.942	27.863
10/18/07	06:09:30	747.8797	31.035	31.403	21.940	27.865
10/18/07	06:19:30	757.8797	31.035	31.397	21.934	27.865
10/18/07	06:29:30	767.8797	31.032	31.397	21.931	27.867
10/18/07	06:39:30	777.8797	31.031	31.397	21.928	27.867
10/18/07	06:49:30	787.8797	31.031	31.397	21.925	27.867
10/18/07	06:59:30	797.8797	31.031	31.395	21.922	27.867
10/18/07	07:09:30	807.8797	31.031	31.395	21.917	27.867
10/18/07	07:19:30	817.8797	31.029	31.392	21.917	27.869

```
In-Situ Inc.      Hermit 3000

Report generated: 11/04/07    00:37:21
Report from file: C:\Documents and Settings\W. Robert Talbot\Desktop\Data\SN45888 2007-10-18 091346 24hr
.bin
DataMgr Version   3.71

Serial number:    00045888
Firmware Version  7.10
Unit name:  HERMIT 3000

Test name:        24hr

Test defined on:  10/18/07    08:12:59
Test started on:  10/18/07    09:13:47
Test stopped on:  10/19/07    10:02:25
Test extracted on:      01/01/01    00:02:03

Data gathered using Logarithmic testing
   Maximum time between data points:      10.0000     Minutes.
   Number of data samples:    252


TOTAL DATA SAMPLES      252

Channel number [1]
  Measurement type:     Pressure
  Channel name:   ETwo
  Linearity:       0.0015000
  Scale:          10.3030000
  Offset:         -0.0134000
  Warmup:         50
  Specific gravity:        1.000
  Mode:     TOC
  User-defined reference:       31.640    Feet H2O
  Referenced on:  test start
  Pressure head at reference:   12.746    Feet H2O

Channel number [2]
  Measurement type:     Pressure
  Channel name:   EOne
  Linearity:       0.1253000
```

```
  Scale:          19.6723000
  Offset:         -0.1940000
  Warmup:         50
  Specific gravity:        1.000
  Mode:     TOC
  User-defined reference:       32.270    Feet H2O
  Referenced on:  test start
  Pressure head at reference:   19.540    Feet H2O

Channel number [3]
  Measurement type:     Pressure
  Channel name:   Test
  Linearity:       0.0696000
  Scale:          19.9209000
  Offset:         -0.0091000
  Warmup:         50
  Specific gravity:        1.000
  Mode:     TOC
  User-defined reference:       31.660    Feet H2O
  Referenced on:  test start
  Pressure head at reference:   15.969    Feet H2O

Channel number [4]
  Measurement type:     Pressure
  Channel name:   N2 30
  Linearity:       0.0135000
  Scale:          19.9752000
  Offset:         -0.0205000
  Warmup:         50
  Specific gravity:        1.000
  Mode:     TOC
  User-defined reference:       30.600    Feet H2O
  Referenced on:  test start
  Pressure head at reference:    9.155    Feet H2O

Channel number [5]
  Measurement type:     Pressure
  Channel name:   N1
  Linearity:      -0.0107000
  Scale:          10.0122000
  Offset:         -0.1073000
  Warmup:         50
```

Specific gravity: 1.000
Mode: TOC
User-defined reference: 32.200 Feet H2O
Referenced on: test start
Pressure head at reference: 19.711 Feet H2O

Channel number [0]
Measurement type: Barometric Pressure
Channel name: Barometric
Linearity: 0.0000000
Scale: 0.0000000
Offset: 0.0000000
Warmup: 50

Date	Time	ET (min)	Chan[1] Feet H2O	Chan[2] Feet H2O	Chan[3] Feet H2O	Chan[4] Feet H2O	Chan[5] Feet H2O	Chan[0] Inches Hg
10/18/07	09:13:47	0.0000	31.640	32.270	31.660	30.600	32.200	27.930
10/18/07	09:13:48	0.0323	31.640	32.273	31.660	30.600	32.197	27.926
10/18/07	09:13:50	0.0647	31.639	32.273	31.660	30.600	32.199	27.928
10/18/07	09:13:52	0.0970	31.640	32.273	31.660	30.597	32.197	27.926
10/18/07	09:13:54	0.1293	31.640	32.273	31.660	30.597	32.199	27.924
10/18/07	09:13:56	0.1617	31.640	32.273	31.660	30.597	32.197	27.924
10/18/07	09:13:58	0.1940	31.639	32.273	31.660	30.597	32.199	27.924
10/18/07	09:14:00	0.2263	31.639	32.273	31.663	30.597	32.197	27.922
10/18/07	09:14:02	0.2587	31.639	32.273	31.660	30.597	32.197	27.922
10/18/07	09:14:04	0.2910	31.639	32.273	31.660	30.600	32.196	27.922
10/18/07	09:14:06	0.3233	31.637	32.273	31.660	30.597	32.197	27.924
10/18/07	09:14:08	0.3557	31.637	32.273	31.660	30.600	32.197	27.924
10/18/07	09:14:10	0.3880	31.639	32.273	31.660	30.600	32.197	27.926
10/18/07	09:14:12	0.4203	31.637	32.273	31.663	30.600	32.199	27.922
10/18/07	09:14:14	0.4527	31.639	32.273	31.663	30.600	32.197	27.920
10/18/07	09:14:16	0.4850	31.639	32.273	31.663	30.597	32.197	27.922
10/18/07	09:14:18	0.5173	31.637	32.273	31.660	30.600	32.197	27.920
10/18/07	09:14:19	0.5497	31.639	32.273	31.660	30.597	32.197	27.920
10/18/07	09:14:21	0.5820	31.640	32.273	31.663	30.597	32.196	27.920
10/18/07	09:14:23	0.6143	31.639	32.273	31.660	30.597	32.196	27.918
10/18/07	09:14:25	0.6467	31.639	32.273	31.660	30.597	32.196	27.918
10/18/07	09:14:27	0.6798	31.639	32.273	31.660	30.600	32.196	27.920
10/18/07	09:14:29	0.7150	31.639	32.270	31.660	30.600	32.197	27.918
10/18/07	09:14:32	0.7523	31.640	32.273	31.660	30.600	32.197	27.916

10/18/07	09:14:34	0.7918	31.639	32.273	31.660	30.597	32.196	27.916
10/18/07	09:14:37	0.8337	31.637	32.273	31.660	30.600	32.196	27.916
10/18/07	09:14:39	0.8780	31.636	32.273	31.660	30.600	32.196	27.914
10/18/07	09:14:42	0.9250	31.637	32.270	31.660	30.600	32.193	27.916
10/18/07	09:14:45	0.9748	31.639	32.276	31.663	30.600	32.196	27.918
10/18/07	09:14:48	1.0275	31.639	32.273	31.660	30.600	32.197	27.914
10/18/07	09:14:52	1.0833	31.637	32.276	31.663	30.600	32.197	27.914
10/18/07	09:14:55	1.1425	31.637	32.276	31.663	30.600	32.197	27.914
10/18/07	09:14:59	1.2052	31.639	32.273	31.660	30.600	32.197	27.916
10/18/07	09:15:03	1.2715	31.637	32.273	31.660	30.600	32.197	27.916
10/18/07	09:15:07	1.3418	31.639	32.276	31.660	30.603	32.197	27.914
10/18/07	09:15:11	1.4163	31.639	32.276	31.660	30.600	32.199	27.912
10/18/07	09:15:16	1.4953	31.640	32.276	31.660	30.600	32.200	27.912
10/18/07	09:15:21	1.5790	31.639	32.276	31.663	30.603	32.197	27.914
10/18/07	09:15:27	1.6675	31.639	32.276	31.660	30.600	32.196	27.912
10/18/07	09:15:32	1.7613	31.640	32.276	31.660	30.603	32.196	27.912
10/18/07	09:15:38	1.8607	31.656	32.430	39.771	30.992	32.380	27.909
10/18/07	09:15:44	1.9660	31.691	32.515	39.768	31.078	32.410	27.909
10/18/07	09:15:51	2.0775	31.701	32.515	39.466	31.070	32.420	27.909
10/18/07	09:15:58	2.1957	31.710	32.532	39.532	31.087	32.436	27.907
10/18/07	09:16:06	2.3208	31.717	32.544	39.702	31.107	32.446	27.907
10/18/07	09:16:14	2.4533	31.725	32.552	39.687	31.118	32.455	27.907
10/18/07	09:16:22	2.5938	31.729	32.561	39.868	31.127	32.468	27.907
10/18/07	09:16:31	2.7427	31.732	32.569	39.820	31.136	32.474	27.905
10/18/07	09:16:41	2.9002	31.735	32.572	39.883	31.144	32.478	27.905
10/18/07	09:16:51	3.0670	31.738	32.578	39.883	31.150	32.484	27.905
10/18/07	09:17:01	3.2438	31.743	32.584	39.966	31.156	32.488	27.903
10/18/07	09:17:12	3.4312	31.744	32.587	39.937	31.165	32.492	27.881
10/18/07	09:17:24	3.6295	31.745	32.589	39.880	31.167	32.497	27.893
10/18/07	09:17:37	3.8397	31.747	32.592	39.943	31.173	32.501	27.895
10/18/07	09:17:50	4.0623	31.748	32.595	39.949	31.179	32.507	27.901
10/18/07	09:18:04	4.2982	31.751	32.598	39.894	31.182	32.510	27.903
10/18/07	09:18:19	4.5480	31.754	32.604	39.986	31.191	32.516	27.903
10/18/07	09:18:35	4.8127	31.757	32.607	39.914	31.193	32.521	27.903
10/18/07	09:18:52	5.0930	31.760	32.609	39.952	31.202	32.526	27.903
10/18/07	09:19:10	5.3898	31.763	32.615	40.018	31.205	32.531	27.905
10/18/07	09:19:29	5.7043	31.766	32.618	39.906	31.211	32.533	27.905
10/18/07	09:19:49	6.0375	31.769	32.624	40.001	31.216	32.540	27.905
10/18/07	09:20:10	6.3903	31.772	32.629	39.975	31.222	32.544	27.907
10/18/07	09:20:32	6.7642	31.775	32.632	39.998	31.228	32.547	27.905
10/18/07	09:20:56	7.1602	31.778	32.635	39.932	31.234	32.553	27.907
10/18/07	09:21:21	7.5795	31.778	32.641	39.940	31.239	32.559	27.905

10/18/07	09:21:48	8.0238	31.783	32.644	40.038	31.245	32.562	27.907
10/18/07	09:22:16	8.4945	31.789	32.649	40.001	31.251	32.567	27.907
10/18/07	09:22:46	8.9930	31.789	32.652	39.969	31.257	32.573	27.907
10/18/07	09:23:18	9.5210	31.793	32.658	40.098	31.263	32.579	27.909
10/18/07	09:23:51	10.0803	31.799	32.664	40.078	31.271	32.585	27.909
10/18/07	09:24:27	10.6728	31.802	32.666	40.018	31.280	32.590	27.909
10/18/07	09:25:05	11.3003	31.806	32.669	40.004	31.286	32.596	27.909
10/18/07	09:25:44	11.9652	31.811	32.675	40.087	31.294	32.603	27.909
10/18/07	09:26:27	12.6693	31.814	32.684	40.084	31.300	32.608	27.909
10/18/07	09:27:11	13.4152	31.818	32.689	40.116	31.306	32.614	27.912
10/18/07	09:27:59	14.2052	31.821	32.692	40.044	31.311	32.618	27.912
10/18/07	09:28:49	15.0420	31.824	32.698	40.162	31.320	32.624	27.912
10/18/07	09:29:42	15.9285	31.830	32.701	40.098	31.329	32.631	27.912
10/18/07	09:30:39	16.8675	31.835	32.703	40.133	31.337	32.638	27.914
10/18/07	09:31:38	17.8622	31.839	32.709	40.124	31.346	32.645	27.912
10/18/07	09:32:41	18.9158	31.841	32.715	40.136	31.355	32.651	27.912
10/18/07	09:33:48	20.0318	31.846	32.721	40.121	31.360	32.660	27.916
10/18/07	09:34:59	21.2140	31.849	32.726	40.142	31.369	32.664	27.914
10/18/07	09:36:14	22.4662	31.854	32.729	40.121	31.375	32.675	27.916
10/18/07	09:37:34	23.7927	31.858	32.738	40.150	31.383	32.683	27.916
10/18/07	09:38:58	25.1977	31.872	32.749	40.179	31.395	32.691	27.926
10/18/07	09:40:28	26.6860	31.872	32.752	40.196	31.401	32.699	27.912
10/18/07	09:42:02	28.2625	31.875	32.758	40.245	31.409	32.703	27.914
10/18/07	09:43:42	29.9323	31.882	32.766	40.219	31.418	32.713	27.916
10/18/07	09:45:29	31.7012	31.890	32.775	40.282	31.430	32.723	27.916
10/18/07	09:47:21	33.5748	31.894	32.783	40.314	31.441	32.732	27.916
10/18/07	09:49:20	35.5595	31.901	32.789	40.251	31.450	32.739	27.916
10/18/07	09:51:26	37.6618	31.909	32.798	40.259	31.461	32.748	27.918
10/18/07	09:53:40	39.8887	31.919	32.803	40.271	31.467	32.755	27.918
10/18/07	09:56:01	42.2475	31.927	32.812	40.372	31.476	32.766	27.918
10/18/07	09:58:31	44.7462	31.933	32.823	40.351	31.487	32.775	27.920
10/18/07	10:01:10	47.3928	31.937	32.826	40.386	31.499	32.784	27.920
10/18/07	10:03:58	50.1963	31.943	32.835	40.340	31.510	32.791	27.920
10/18/07	10:06:56	53.1660	31.950	32.840	40.369	31.519	32.804	27.920
10/18/07	10:10:05	56.3117	31.956	32.849	40.369	31.533	32.814	27.922
10/18/07	10:13:25	59.6437	31.959	32.852	40.441	31.542	32.824	27.922
10/18/07	10:16:57	63.1732	31.967	32.860	40.363	31.551	32.833	27.924
10/18/07	10:20:41	66.9117	31.977	32.866	40.395	31.562	32.844	27.924
10/18/07	10:24:39	70.8718	31.991	32.880	40.395	31.574	32.856	27.938
10/18/07	10:28:51	75.0667	31.994	32.883	40.469	31.588	32.867	27.924
10/18/07	10:33:17	79.5100	31.998	32.889	40.443	31.597	32.876	27.926
10/18/07	10:38:00	84.2167	32.011	32.900	40.515	31.605	32.883	27.926

10/18/07	10:42:59	89.2022	32.016	32.909	40.556	31.620	32.894	27.928
10/18/07	10:48:15	94.4830	32.019	32.914	40.507	31.631	32.906	27.936
10/18/07	10:53:51	100.0768	32.020	32.917	40.512	31.646	32.919	27.936
10/18/07	10:59:47	106.0022	32.025	32.923	40.561	31.654	32.930	27.938
10/18/07	11:06:03	112.2785	32.184	32.923	40.558	31.669	32.942	27.940
10/18/07	11:12:42	118.9268	32.193	32.932	40.475	31.683	32.954	27.944
10/18/07	11:19:45	125.9690	32.200	32.940	40.533	31.692	32.964	27.948
10/18/07	11:27:12	133.4285	32.212	32.949	40.561	31.703	32.977	27.948
10/18/07	11:35:06	141.3300	32.210	32.957	40.602	31.715	32.990	27.954
10/18/07	11:43:28	149.6997	32.196	32.963	40.550	31.726	33.003	27.956
10/18/07	11:52:20	158.5653	32.205	32.977	40.521	31.738	33.013	27.960
10/18/07	12:01:44	167.9563	32.218	32.991	40.541	31.752	33.024	27.960
10/18/07	12:11:41	177.9038	32.215	33.000	40.610	31.764	33.036	27.969
10/18/07	12:21:41	187.9038	32.219	33.051	40.570	31.775	33.047	27.969
10/18/07	12:31:41	197.9038	32.222	33.080	40.633	31.784	33.057	27.973
10/18/07	12:41:41	207.9038	32.219	33.077	40.682	31.795	33.069	27.977
10/18/07	12:51:41	217.9038	32.219	33.074	40.625	31.807	33.079	27.979
10/18/07	13:01:41	227.9038	32.225	33.083	40.676	31.816	33.090	27.983
10/18/07	13:11:41	237.9038	32.221	33.080	40.648	31.824	33.099	27.987
10/18/07	13:21:41	247.9038	32.216	33.083	40.711	31.833	33.105	27.989
10/18/07	13:31:41	257.9038	32.221	33.083	40.650	31.839	33.113	27.993
10/18/07	13:41:41	267.9038	32.359	33.083	40.714	31.847	33.121	27.999
10/18/07	13:51:41	277.9038	32.355	33.083	40.679	31.850	33.128	28.003
10/18/07	14:01:41	287.9038	32.355	33.083	40.639	31.862	33.137	28.007
10/18/07	14:11:41	297.9038	32.352	33.083	40.671	31.865	33.142	28.009
10/18/07	14:21:41	307.9038	32.350	33.086	40.599	31.870	33.148	28.013
10/18/07	14:31:41	317.9038	32.352	33.091	40.688	31.879	33.157	28.024
10/18/07	14:41:41	327.9038	32.350	33.094	40.650	31.888	33.161	28.026
10/18/07	14:51:41	337.9038	32.343	33.100	40.691	31.890	33.164	28.030
10/18/07	15:01:41	347.9038	32.332	33.125	40.650	31.896	33.170	28.036
10/18/07	15:11:41	357.9038	32.325	33.194	40.685	31.902	33.175	28.042
10/18/07	15:21:41	367.9038	32.323	33.185	40.719	31.908	33.181	28.050
10/18/07	15:31:41	377.9038	32.310	33.171	40.722	31.914	33.186	28.058
10/18/07	15:41:41	387.9038	32.303	33.160	40.627	31.916	33.190	28.064
10/18/07	15:51:41	397.9038	32.300	33.168	40.671	31.922	33.194	28.070
10/18/07	16:01:41	407.9038	32.297	33.177	40.705	31.928	33.203	28.074
10/18/07	16:11:41	417.9038	32.291	33.200	40.648	31.934	33.209	28.081
10/18/07	16:21:41	427.9038	32.280	33.202	40.665	31.937	33.210	28.087
10/18/07	16:31:41	437.9038	32.274	33.205	40.659	31.945	33.214	28.097
10/18/07	16:41:41	447.9038	32.267	33.202	40.711	31.945	33.216	28.103
10/18/07	16:51:41	457.9038	32.258	33.211	40.648	31.954	33.223	28.109
10/18/07	17:01:41	467.9038	32.251	33.222	40.671	31.954	33.229	28.117

10/18/07	17:11:41	477.9038	32.245	33.220	40.679	31.962	33.232	28.119
10/18/07	17:21:41	487.9038	32.236	33.222	40.639	31.965	33.236	28.127
10/18/07	17:31:41	497.9038	32.228	33.225	40.650	31.968	33.242	28.127
10/18/07	17:41:41	507.9038	32.228	33.225	40.665	31.974	33.243	28.138
10/18/07	17:51:41	517.9038	32.317	33.220	40.636	31.974	33.242	28.140
10/18/07	18:01:41	527.9038	32.314	33.214	40.622	31.977	33.249	28.142
10/18/07	18:11:41	537.9038	32.311	33.214	40.625	31.983	33.252	28.148
10/18/07	18:21:41	547.9038	32.309	33.211	40.662	31.986	33.256	28.152
10/18/07	18:31:41	557.9038	32.307	33.214	40.668	31.988	33.262	28.154
10/18/07	18:41:41	567.9038	32.310	33.211	40.610	31.994	33.265	28.162
10/18/07	18:51:41	577.9038	32.314	33.211	40.665	31.997	33.269	28.164
10/18/07	19:01:41	587.9038	32.314	33.225	40.610	32.000	33.271	28.172
10/18/07	19:11:41	597.9038	32.306	33.228	40.616	32.003	33.275	28.174
10/18/07	19:21:41	607.9038	32.304	33.242	40.650	32.006	33.279	28.176
10/18/07	19:31:41	617.9038	32.304	33.240	40.708	32.006	33.279	28.180
10/18/07	19:41:41	627.9038	32.304	33.237	40.668	32.011	33.288	28.184
10/18/07	19:51:41	637.9038	32.303	33.237	40.673	32.014	33.288	28.190
10/18/07	20:01:41	647.9038	32.300	33.262	40.668	32.017	33.291	28.176
10/18/07	20:11:41	657.9038	32.295	33.251	40.671	32.023	33.294	28.188
10/18/07	20:21:41	667.9038	32.291	33.248	40.616	32.023	33.296	28.197
10/18/07	20:31:41	677.9038	32.289	33.248	40.699	32.029	33.301	28.207
10/18/07	20:41:41	687.9038	32.289	33.242	40.728	32.034	33.305	28.211
10/18/07	20:51:41	697.9038	32.386	33.242	40.754	32.040	33.305	28.211
10/18/07	21:01:41	707.9038	32.384	33.240	40.783	32.040	33.308	28.215
10/18/07	21:11:41	717.9038	32.380	33.240	40.728	32.043	33.308	28.217
10/18/07	21:21:41	727.9038	32.378	33.302	40.783	32.046	33.311	28.221
10/18/07	21:31:41	737.9038	32.377	33.297	40.725	32.049	33.315	28.227
10/18/07	21:41:41	747.9038	32.378	33.294	40.754	32.046	33.314	28.225
10/18/07	21:51:41	757.9038	32.375	33.288	40.786	32.055	33.321	28.231
10/18/07	22:01:41	767.9038	32.375	33.291	40.734	32.055	33.321	28.229
10/18/07	22:11:41	777.9038	32.372	33.288	40.757	32.060	33.324	28.231
10/18/07	22:21:41	787.9038	32.371	33.285	40.737	32.060	33.325	28.235
10/18/07	22:31:41	797.9038	32.371	33.285	40.742	32.060	33.328	28.233
10/18/07	22:41:41	807.9038	32.402	33.288	40.771	32.066	33.328	28.235
10/18/07	22:51:41	817.9038	32.430	33.291	40.786	32.066	33.331	28.235
10/18/07	23:01:41	827.9038	32.432	33.291	40.760	32.066	33.335	28.237
10/18/07	23:11:41	837.9038	32.427	33.291	40.837	32.072	33.338	28.237
10/18/07	23:21:41	847.9038	32.427	33.297	40.849	32.072	33.340	28.235
10/18/07	23:31:41	857.9038	32.426	33.299	40.823	32.075	33.341	28.237
10/18/07	23:41:41	867.9038	32.427	33.302	40.898	32.078	33.345	28.233
10/18/07	23:51:41	877.9038	32.423	33.305	40.846	32.081	33.347	28.237
10/19/07	00:01:41	887.9038	32.430	33.311	40.892	32.086	33.353	28.233

10/19/07	00:11:41	897.9038	32.423	33.311	40.898	32.086	33.351	28.229
10/19/07	00:21:41	907.9038	32.417	33.308	40.926	32.089	33.353	28.235
10/19/07	00:31:41	917.9038	32.412	33.308	40.915	32.089	33.354	28.237
10/19/07	00:41:41	927.9038	32.408	33.308	40.932	32.092	33.357	28.243
10/19/07	00:51:41	937.9038	32.401	33.305	40.912	32.095	33.360	28.247
10/19/07	01:01:41	947.9038	32.396	33.308	40.886	32.095	33.361	28.250
10/19/07	01:11:41	957.9038	32.389	33.305	40.918	32.098	33.366	28.250
10/19/07	01:21:41	967.9038	32.380	33.302	40.886	32.098	33.367	28.252
10/19/07	01:31:41	977.9038	32.371	33.302	40.883	32.101	33.369	28.258
10/19/07	01:41:41	987.9038	32.359	33.356	40.961	32.101	33.371	28.258
10/19/07	01:51:41	997.9038	32.344	33.342	40.892	32.109	33.371	28.262
10/19/07	02:01:41	1007.9038	32.332	33.328	40.918	32.109	33.370	28.262
10/19/07	02:11:41	1017.9038	32.435	33.317	40.901	32.109	33.376	28.264
10/19/07	02:21:41	1027.9038	32.410	33.359	40.903	32.112	33.376	28.264
10/19/07	02:31:41	1037.9038	32.380	33.334	40.855	32.118	33.379	28.268
10/19/07	02:41:41	1047.9038	32.381	33.325	40.880	32.115	33.381	28.266
10/19/07	02:51:41	1057.9038	32.362	33.365	40.880	32.118	33.381	28.272
10/19/07	03:01:41	1067.9038	32.347	33.345	40.872	32.121	33.386	28.276
10/19/07	03:11:41	1077.9038	32.335	33.336	40.837	32.121	33.386	28.274
10/19/07	03:21:41	1087.9038	32.328	33.385	40.872	32.121	33.389	28.276
10/19/07	03:31:41	1097.9038	32.320	33.368	40.837	32.130	33.393	28.282
10/19/07	03:41:41	1107.9038	32.310	33.354	40.806	32.132	33.394	28.286
10/19/07	03:51:41	1117.9038	32.303	33.345	40.826	32.135	33.393	28.290
10/19/07	04:01:41	1127.9038	32.303	33.393	40.906	32.135	33.397	28.292
10/19/07	04:11:41	1137.9038	32.396	33.371	40.809	32.138	33.399	28.296
10/19/07	04:21:41	1147.9038	32.450	33.354	40.857	32.141	33.402	28.298
10/19/07	04:31:41	1157.9038	32.472	33.408	40.852	32.141	33.400	28.300
10/19/07	04:41:41	1167.9038	32.460	33.385	40.803	32.147	33.406	28.309
10/19/07	04:51:41	1177.9038	32.439	33.365	40.837	32.147	33.409	28.311
10/19/07	05:01:41	1187.9038	32.426	33.411	40.806	32.147	33.409	28.319
10/19/07	05:11:41	1197.9038	32.411	33.388	40.837	32.147	33.413	28.323
10/19/07	05:21:41	1207.9038	32.401	33.376	40.823	32.150	33.412	28.323
10/19/07	05:31:41	1217.9038	32.396	33.428	40.834	32.153	33.416	28.327
10/19/07	05:41:41	1227.9038	32.399	33.416	40.857	32.153	33.415	28.329
10/19/07	05:51:41	1237.9038	32.390	33.396	40.794	32.158	33.418	28.335
10/19/07	06:01:41	1247.9038	32.375	33.385	40.791	32.161	33.420	28.341
10/19/07	06:11:41	1257.9038	32.366	33.428	40.860	32.158	33.416	28.341
10/19/07	06:21:41	1267.9038	32.361	33.413	40.809	32.161	33.418	28.335
10/19/07	06:31:41	1277.9038	32.350	33.399	40.863	32.164	33.422	28.341
10/19/07	06:41:41	1287.9038	32.346	33.393	40.872	32.164	33.425	28.345
10/19/07	06:51:41	1297.9038	32.334	33.436	40.852	32.167	33.428	28.347
10/19/07	07:01:41	1307.9038	32.338	33.428	40.906	32.170	33.429	28.353

10/19/07	07:11:41	1317.9038	32.361	33.433	40.863	32.173	33.432	28.361
10/19/07	07:21:41	1327.9038	32.381	33.433	40.895	32.176	33.433	28.364
10/19/07	07:31:41	1337.9038	32.411	33.442	40.944	32.176	33.435	28.390
10/19/07	07:41:41	1347.9038	32.451	33.462	41.044	32.176	33.436	28.380
10/19/07	07:51:41	1357.9038	32.505	33.493	41.064	32.176	33.439	28.357
10/19/07	08:01:41	1367.9038	32.554	33.516	41.136	32.178	33.443	28.331
10/19/07	08:11:41	1377.9038	32.604	33.536	41.139	32.178	33.443	28.347
10/19/07	08:21:41	1387.9038	32.650	33.547	41.274	32.178	33.443	28.345
10/19/07	08:31:41	1397.9038	32.716	33.525	41.329	32.181	33.442	28.337
10/19/07	08:41:41	1407.9038	32.735	33.562	41.401	32.184	33.445	28.343
10/19/07	08:51:41	1417.9038	32.689	33.542	41.450	32.184	33.445	28.351
10/19/07	09:01:41	1427.9038	32.665	33.527	41.545	32.187	33.448	28.355
10/19/07	09:11:41	1437.9038	32.607	33.565	41.559	32.190	33.451	28.361
10/19/07	09:21:41	1447.9038	32.609	33.559	41.648	32.187	33.451	28.368
10/19/07	09:31:41	1457.9038	32.606	33.556	41.780	32.187	33.451	28.368
10/19/07	09:41:41	1467.9038	32.607	33.556	41.852	32.187	33.448	28.364
10/19/07	09:51:41	1477.9038	32.607	33.559	41.956	32.190	33.451	28.361
10/19/07	10:01:41	1487.9038	32.607	33.565	42.059	32.190	33.452	28.368

```
In-Situ Inc.      Hermit 3000

Report generated: 11/04/07    00:37:50
Report from file: C:\Documents and Settings\W. Robert Talbot\Desktop\Data\SN45888 2007-10-19 100348
24hrrecovery.bin
DataMgr Version   3.71

Serial number:    00045888
Firmware Version  7.10
Unit name:  HERMIT 3000

Test name:        24hr recovery

Test defined on:  10/18/07    08:15:06
Test started on:  10/19/07    10:03:49
Test stopped on:  10/20/07    08:31:13
Test extracted on:      01/01/01    00:02:39

Data gathered using Logarithmic testing
   Maximum time between data points:      10.0000     Minutes.
   Number of data samples:    237

TOTAL DATA SAMPLES      237

Channel number [1]
  Measurement type:     Pressure
  Channel name:   ETwo
  Linearity:       0.0015000
  Scale:          10.3030000
  Offset:         -0.0134000
  Warmup:         50
  Specific gravity:        1.000
  Mode:     TOC
  User-defined reference:       31.640    Feet H2O
  Referenced on:  test start
  Pressure head at reference:   11.771    Feet H2O

Channel number [2]
  Measurement type:     Pressure
  Channel name:   EOne
  Linearity:       0.1253000
  Scale:          19.6723000
```

```
  Offset:         -0.1940000
  Warmup:         50
  Specific gravity:        1.000
  Mode:     TOC
  User-defined reference:       32.270    Feet H2O
  Referenced on:  test start
  Pressure head at reference:   18.237    Feet H2O

Channel number [3]
  Measurement type:     Pressure
  Channel name:   Test
  Linearity:       0.0696000
  Scale:          19.9209000
  Offset:         -0.0091000
  Warmup:         50
  Specific gravity:        1.000
  Mode:     TOC
  User-defined reference:       31.660    Feet H2O
  Referenced on:  test start
  Pressure head at reference:    5.613    Feet H2O

Channel number [4]
  Measurement type:     Pressure
  Channel name:   N2 30
  Linearity:       0.0135000
  Scale:          19.9752000
  Offset:         -0.0205000
  Warmup:         50
  Specific gravity:        1.000
  Mode:     TOC
  User-defined reference:       30.600    Feet H2O
  Referenced on:  test start
  Pressure head at reference:    7.562    Feet H2O

Channel number [5]
  Measurement type:     Pressure
  Channel name:   N1
  Linearity:      -0.0107000
  Scale:          10.0122000
  Offset:         -0.1073000
  Warmup:         50
  Specific gravity:        1.000
```

Mode: TOC
User-defined reference: 32.200 Feet H2O
Referenced on: test start
Pressure head at reference: 18.459 Feet H2O

Channel number [0]
Measurement type: Barometric Pressure
Channel name: Barometric
Linearity: 0.0000000
Scale: 0.0000000
Offset: 0.0000000
Warmup: 50

Date	Time	ET (min)	Chan[1] Feet H2O	Chan[2] Feet H2O	Chan[3] Feet H2O	Chan[4] Feet H2O	Chan[5] Feet H2O	Chan[0] Inches Hg
10/19/07	10:03:49	0.0000	31.640	32.270	31.660	30.600	32.200	28.380
10/19/07	10:03:50	0.0322	31.639	32.270	31.671	30.600	32.197	28.380
10/19/07	10:03:52	0.0643	31.639	32.270	31.752	30.600	32.196	28.382
10/19/07	10:03:54	0.0965	31.639	32.270	31.631	30.600	32.196	28.380
10/19/07	10:03:56	0.1287	31.639	32.270	31.671	30.600	32.197	28.380
10/19/07	10:03:58	0.1608	31.639	32.270	31.720	30.600	32.197	28.382
10/19/07	10:04:00	0.1930	31.639	32.273	31.654	30.600	32.199	28.378
10/19/07	10:04:02	0.2252	31.639	32.270	31.663	30.600	32.199	28.378
10/19/07	10:04:04	0.2573	31.639	32.270	31.694	30.600	32.197	28.378
10/19/07	10:04:06	0.2895	31.639	32.273	31.689	30.600	32.197	28.380
10/19/07	10:04:08	0.3217	31.639	32.273	31.628	30.600	32.197	28.378
10/19/07	10:04:10	0.3538	31.639	32.273	31.700	30.600	32.197	28.376
10/19/07	10:04:12	0.3860	31.639	32.270	31.700	30.600	32.199	28.378
10/19/07	10:04:14	0.4182	31.639	32.273	31.692	30.600	32.197	28.374
10/19/07	10:04:16	0.4503	31.639	32.270	31.651	30.600	32.199	28.378
10/19/07	10:04:17	0.4825	31.637	32.270	31.683	30.600	32.197	28.378
10/19/07	10:04:19	0.5147	31.637	32.273	31.735	30.600	32.197	28.378
10/19/07	10:04:21	0.5468	31.637	32.270	31.683	30.603	32.197	28.378
10/19/07	10:04:23	0.5790	31.636	32.270	31.720	30.600	32.197	28.378
10/19/07	10:04:25	0.6112	31.636	32.270	31.660	30.600	32.196	28.378
10/19/07	10:04:27	0.6433	31.636	32.270	31.634	30.603	32.196	28.380
10/19/07	10:04:29	0.6765	31.636	32.270	31.663	30.603	32.196	28.378
10/19/07	10:04:31	0.7117	31.634	32.270	31.674	30.603	32.196	28.382
10/19/07	10:04:33	0.7490	31.634	32.270	31.720	30.600	32.197	28.378
10/19/07	10:04:36	0.7885	31.634	32.270	31.689	30.600	32.197	28.376
10/19/07	10:04:38	0.8303	31.634	32.270	31.683	30.603	32.197	28.376
10/19/07	10:04:41	0.8747	31.634	32.270	31.660	30.600	32.196	28.378

10/19/07	10:04:44	0.9217	31.634	32.270	31.689	30.603	32.196	28.376
10/19/07	10:04:47	0.9715	31.634	32.273	31.640	30.600	32.197	28.376
10/19/07	10:04:50	1.0242	31.636	32.270	31.634	30.600	32.196	28.378
10/19/07	10:04:53	1.0800	31.634	32.270	31.683	30.597	32.196	28.378
10/19/07	10:04:57	1.1392	31.636	32.270	31.657	30.600	32.196	28.378
10/19/07	10:05:01	1.2018	31.636	32.270	31.700	30.600	32.197	28.378
10/19/07	10:05:05	1.2682	31.637	32.270	31.726	30.600	32.199	28.376
10/19/07	10:05:09	1.3385	31.637	32.270	31.694	30.600	32.199	28.376
10/19/07	10:05:13	1.4130	31.637	32.270	31.692	30.600	32.197	28.378
10/19/07	10:05:18	1.4920	31.637	32.267	31.686	30.600	32.197	28.374
10/19/07	10:05:23	1.5757	31.637	32.273	31.697	30.603	32.199	28.376
10/19/07	10:05:28	1.6642	31.637	32.270	31.628	30.600	32.201	28.372
10/19/07	10:05:34	1.7580	31.639	32.270	31.649	30.600	32.200	28.374
10/19/07	10:05:40	1.8573	31.639	32.270	31.683	30.600	32.203	28.372
10/19/07	10:05:46	1.9627	31.636	32.273	31.697	30.600	32.203	28.372
10/19/07	10:05:53	2.0742	31.637	32.273	31.620	30.600	32.203	28.372
10/19/07	10:06:00	2.1923	31.641	32.276	31.694	30.600	32.203	28.372
10/19/07	10:06:08	2.3175	31.643	32.279	30.918	30.580	32.184	28.370
10/19/07	10:06:16	2.4500	31.592	31.993	20.685	30.041	31.938	28.370
10/19/07	10:06:24	2.5905	31.573	31.991	22.076	30.061	31.942	28.370
10/19/07	10:06:33	2.7393	31.572	32.028	22.953	30.133	31.971	28.368
10/19/07	10:06:42	2.8968	31.567	32.025	22.962	30.130	31.968	28.368
10/19/07	10:06:52	3.0637	31.561	32.019	22.948	30.122	31.959	28.366
10/19/07	10:07:03	3.2405	31.557	32.011	22.945	30.113	31.952	28.366
10/19/07	10:07:14	3.4278	31.555	32.008	22.936	30.107	31.949	28.366
10/19/07	10:07:26	3.6262	31.555	32.002	22.925	30.102	31.945	28.368
10/19/07	10:07:39	3.8363	31.549	31.985	22.919	30.093	31.936	28.366
10/19/07	10:07:52	4.0590	31.543	31.971	22.910	30.084	31.931	28.366
10/19/07	10:08:06	4.2948	31.540	31.951	22.905	30.079	31.926	28.364
10/19/07	10:08:21	4.5447	31.539	31.936	22.896	30.070	31.920	28.366
10/19/07	10:08:37	4.8093	31.536	31.931	22.893	30.061	31.916	28.364
10/19/07	10:08:54	5.0897	31.532	31.922	22.884	30.056	31.907	28.366
10/19/07	10:09:12	5.3865	31.527	31.919	22.879	30.050	31.903	28.364
10/19/07	10:09:31	5.7010	31.524	31.919	22.873	30.041	31.905	28.364
10/19/07	10:09:51	6.0342	31.521	31.914	22.864	30.035	31.892	28.351
10/19/07	10:10:12	6.3870	31.517	31.911	22.861	30.027	31.887	28.368
10/19/07	10:10:34	6.7608	31.509	31.905	22.856	30.018	31.880	28.372
10/19/07	10:10:58	7.1568	31.505	31.902	22.853	30.012	31.873	28.374
10/19/07	10:11:23	7.5762	31.502	31.899	22.844	30.004	31.866	28.378
10/19/07	10:11:50	8.0205	31.497	31.897	22.841	29.998	31.859	28.380
10/19/07	10:12:18	8.4912	31.493	31.891	22.833	29.984	31.847	28.382
10/19/07	10:12:48	8.9897	31.488	31.882	22.827	29.975	31.846	28.382

10/19/07	10:13:20	9.5177	31.481	31.879	22.818	29.972	31.834	28.384
10/19/07	10:13:53	10.0770	31.478	31.871	22.807	29.963	31.833	28.384
10/19/07	10:14:29	10.6695	31.477	31.868	22.798	29.955	31.828	28.384
10/19/07	10:15:06	11.2970	31.478	31.874	22.787	29.946	31.825	28.384
10/19/07	10:15:46	11.9618	31.475	31.874	22.781	29.938	31.818	28.386
10/19/07	10:16:28	12.6660	31.462	31.868	22.781	29.929	31.805	28.384
10/19/07	10:17:13	13.4118	31.459	31.862	22.784	29.920	31.798	28.386
10/19/07	10:18:01	14.2018	31.454	31.859	22.787	29.912	31.795	28.388
10/19/07	10:18:51	15.0387	31.448	31.842	22.789	29.906	31.788	28.390
10/19/07	10:19:44	15.9252	31.442	31.797	22.787	29.894	31.778	28.388
10/19/07	10:20:40	16.8642	31.436	31.791	22.775	29.886	31.766	28.388
10/19/07	10:21:40	17.8588	31.435	31.794	22.764	29.877	31.763	28.386
10/19/07	10:22:43	18.9125	31.429	31.788	22.755	29.865	31.755	28.390
10/19/07	10:23:50	20.0285	31.428	31.785	22.735	29.857	31.752	28.390
10/19/07	10:25:01	21.2107	31.420	31.785	22.723	29.845	31.739	28.388
10/19/07	10:26:16	22.4628	31.414	31.782	22.715	29.837	31.733	28.390
10/19/07	10:27:36	23.7893	31.401	31.780	22.709	29.825	31.725	28.390
10/19/07	10:29:00	25.1943	31.398	31.777	22.700	29.811	31.712	28.388
10/19/07	10:30:29	26.6827	31.396	31.785	22.700	29.802	31.706	28.386
10/19/07	10:32:04	28.2592	31.386	31.737	22.712	29.791	31.694	28.384
10/19/07	10:33:44	29.9290	31.380	31.737	22.720	29.776	31.686	28.384
10/19/07	10:35:30	31.6978	31.371	31.743	22.740	29.768	31.674	28.380
10/19/07	10:37:23	33.5715	31.371	31.728	22.761	29.759	31.673	28.380
10/19/07	10:39:22	35.5562	31.359	31.731	22.787	29.747	31.661	28.382
10/19/07	10:41:28	37.6585	31.350	31.671	22.781	29.739	31.648	28.386
10/19/07	10:43:42	39.8853	31.341	31.634	22.738	29.724	31.637	28.384
10/19/07	10:46:03	42.2442	31.343	31.634	22.723	29.710	31.632	28.386
10/19/07	10:48:33	44.7428	31.334	31.620	22.723	29.698	31.621	28.384
10/19/07	10:51:12	47.3895	31.327	31.611	22.740	29.690	31.614	28.388
10/19/07	10:54:00	50.1930	31.315	31.600	22.755	29.675	31.603	28.386
10/19/07	10:56:58	53.1627	31.310	31.591	22.769	29.670	31.592	28.384
10/19/07	11:00:07	56.3083	31.298	31.583	22.778	29.658	31.582	28.386
10/19/07	11:03:27	59.6403	31.292	31.574	22.792	29.647	31.573	28.386
10/19/07	11:06:59	63.1698	31.288	31.569	22.795	29.635	31.565	28.384
10/19/07	11:10:43	66.9083	31.272	31.551	22.798	29.626	31.550	28.382
10/19/07	11:14:41	70.8685	31.264	31.537	22.784	29.612	31.539	28.380
10/19/07	11:18:52	75.0633	31.263	31.537	22.795	29.600	31.534	28.378
10/19/07	11:23:19	79.5067	31.246	31.520	22.824	29.592	31.518	28.378
10/19/07	11:28:01	84.2133	31.236	31.512	22.818	29.580	31.510	28.380
10/19/07	11:33:00	89.1988	31.226	31.503	22.847	29.569	31.500	28.380
10/19/07	11:38:17	94.4797	31.223	31.494	22.858	29.554	31.490	28.376
10/19/07	11:43:53	100.0735	31.205	31.477	22.879	29.546	31.474	28.376

10/19/07	11:49:48	105.9988	31.200	31.472	22.850	29.534	31.467	28.372
10/19/07	11:56:05	112.2752	31.191	31.460	22.899	29.526	31.455	28.372
10/19/07	12:02:44	118.9235	31.181	31.449	22.913	29.514	31.444	28.370
10/19/07	12:09:46	125.9657	31.171	31.440	22.942	29.505	31.435	28.370
10/19/07	12:17:14	133.4252	31.160	31.432	22.896	29.494	31.423	28.366
10/19/07	12:25:08	141.3267	31.148	31.420	22.905	29.482	31.415	28.364
10/19/07	12:33:30	149.6963	31.136	31.403	22.928	29.471	31.396	28.361
10/19/07	12:42:22	158.5620	31.133	31.400	22.916	29.465	31.395	28.361
10/19/07	12:51:46	167.9530	31.122	31.389	22.968	29.448	31.380	28.359
10/19/07	13:01:43	177.9005	31.107	31.378	22.942	29.439	31.373	28.353
10/19/07	13:11:43	187.9005	31.101	31.369	22.991	29.428	31.360	28.353
10/19/07	13:21:43	197.9005	31.093	31.360	22.916	29.419	31.356	28.353
10/19/07	13:31:43	207.9005	31.089	31.355	22.953	29.410	31.344	28.349
10/19/07	13:41:43	217.9005	31.077	31.343	22.953	29.405	31.334	28.345
10/19/07	13:51:43	227.9005	31.073	31.335	22.922	29.390	31.325	28.339
10/19/07	14:01:43	237.9005	31.067	31.332	22.945	29.387	31.324	28.339
10/19/07	14:11:43	247.9005	31.055	31.318	22.953	29.376	31.311	28.331
10/19/07	14:21:43	257.9005	31.044	31.312	22.991	29.373	31.304	28.327
10/19/07	14:31:43	267.9005	31.053	31.315	22.942	29.370	31.305	28.302
10/19/07	14:41:43	277.9005	31.034	31.295	22.930	29.359	31.292	28.335
10/19/07	14:51:43	287.9005	31.028	31.286	22.953	29.356	31.286	28.331
10/19/07	15:01:43	297.9005	31.025	31.283	22.913	29.347	31.281	28.329
10/19/07	15:11:43	307.9005	31.021	31.278	22.861	29.341	31.276	28.317
10/19/07	15:21:43	317.9005	31.009	31.269	22.694	29.338	31.271	28.317
10/19/07	15:31:43	327.9005	31.007	31.266	22.781	29.333	31.268	28.319
10/19/07	15:41:43	337.9005	31.004	31.261	22.743	29.327	31.259	28.313
10/19/07	15:51:43	347.9005	30.995	31.255	22.781	29.321	31.255	28.304
10/19/07	16:01:43	357.9005	31.006	31.261	22.694	29.315	31.253	28.282
10/19/07	16:11:43	367.9005	30.991	31.252	22.669	29.310	31.245	28.329
10/19/07	16:21:43	377.9005	30.979	31.241	22.591	29.307	31.240	28.331
10/19/07	16:31:43	387.9005	30.979	31.241	22.597	29.301	31.236	28.335
10/19/07	16:41:43	397.9005	30.974	31.235	22.539	29.298	31.232	28.341
10/19/07	16:51:43	407.9005	30.973	31.229	22.467	29.292	31.226	28.341
10/19/07	17:01:43	417.9005	30.958	31.226	22.349	29.295	31.223	28.339
10/19/07	17:11:43	427.9005	30.963	31.224	22.228	29.289	31.222	28.302
10/19/07	17:21:43	437.9005	30.951	31.212	22.110	29.281	31.213	28.327
10/19/07	17:31:43	447.9005	30.948	31.209	21.955	29.281	31.210	28.335
10/19/07	17:41:43	457.9005	30.948	31.212	21.779	29.278	31.207	28.343
10/19/07	17:51:43	467.9005	30.946	31.204	21.658	29.272	31.203	28.343
10/19/07	18:01:43	477.9005	30.942	31.201	21.540	29.272	31.201	28.345
10/19/07	18:11:43	487.9005	30.939	31.198	21.448	29.269	31.199	28.341
10/19/07	18:21:43	497.9005	30.936	31.195	21.385	29.263	31.193	28.333

10/19/07	18:31:43	507.9005	30.936	31.195	21.298	29.266	31.194	28.335
10/19/07	18:41:43	517.9005	30.933	31.195	21.255	29.261	31.191	28.339
10/19/07	18:51:43	527.9005	30.930	31.186	21.270	29.255	31.184	28.337
10/19/07	19:01:43	537.9005	30.927	31.186	21.258	29.255	31.184	28.335
10/19/07	19:11:43	547.9005	30.924	31.186	21.215	29.252	31.181	28.333
10/19/07	19:21:43	557.9005	30.922	31.184	21.154	29.249	31.178	28.335
10/19/07	19:31:43	567.9005	30.919	31.178	21.059	29.246	31.177	28.337
10/19/07	19:41:43	577.9005	30.918	31.175	21.002	29.243	31.174	28.337
10/19/07	19:51:43	587.9005	30.899	31.178	20.956	29.243	31.173	28.337
10/19/07	20:01:43	597.9005	30.893	31.172	20.921	29.238	31.167	28.337
10/19/07	20:11:43	607.9005	30.888	31.167	20.941	29.235	31.165	28.335
10/19/07	20:21:43	617.9005	30.891	31.169	20.921	29.235	31.167	28.335
10/19/07	20:31:43	627.9005	30.890	31.172	20.913	29.232	31.163	28.337
10/19/07	20:41:43	637.9005	30.887	31.167	20.907	29.226	31.160	28.339
10/19/07	20:51:43	647.9005	30.887	31.167	20.907	29.229	31.160	28.343
10/19/07	21:01:43	657.9005	30.882	31.161	20.881	29.226	31.155	28.343
10/19/07	21:11:43	667.9005	30.882	31.161	20.864	29.220	31.152	28.343
10/19/07	21:21:43	677.9005	30.879	31.158	20.872	29.223	31.152	28.343
10/19/07	21:31:43	687.9005	30.878	31.158	20.852	29.220	31.151	28.345
10/19/07	21:41:43	697.9005	30.875	31.155	20.829	29.217	31.147	28.345
10/19/07	21:51:43	707.9005	30.872	31.152	20.803	29.214	31.142	28.343
10/19/07	22:01:43	717.9005	30.870	31.149	20.777	29.212	31.141	28.343
10/19/07	22:11:43	727.9005	30.869	31.149	20.780	29.209	31.141	28.341
10/19/07	22:21:43	737.9005	30.865	31.144	20.780	29.209	31.138	28.339
10/19/07	22:31:43	747.9005	30.866	31.147	20.757	29.206	31.137	28.333
10/19/07	22:41:43	757.9005	30.862	31.144	20.774	29.203	31.134	28.335
10/19/07	22:51:43	767.9005	30.862	31.144	20.751	29.203	31.132	28.337
10/19/07	23:01:43	777.9005	30.860	31.141	20.737	29.197	31.129	28.329
10/19/07	23:11:43	787.9005	30.859	31.138	20.720	29.197	31.129	28.329
10/19/07	23:21:43	797.9005	30.859	31.141	20.720	29.197	31.129	28.325
10/19/07	23:31:43	807.9005	30.853	31.132	20.717	29.194	31.124	28.321
10/19/07	23:41:43	817.9005	30.850	31.132	20.685	29.191	31.121	28.317
10/19/07	23:51:43	827.9005	30.853	31.132	20.676	29.189	31.121	28.315
10/20/07	00:01:43	837.9005	30.848	31.129	20.665	29.189	31.116	28.309
10/20/07	00:11:43	847.9005	30.847	31.129	20.651	29.186	31.116	28.302
10/20/07	00:21:43	857.9005	30.844	31.127	20.651	29.186	31.114	28.304
10/20/07	00:31:43	867.9005	30.842	31.124	20.653	29.183	31.114	28.302
10/20/07	00:41:43	877.9005	30.842	31.124	20.668	29.180	31.109	28.302
10/20/07	00:51:43	887.9005	30.842	31.121	20.651	29.180	31.108	28.309
10/20/07	01:01:43	897.9005	30.841	31.124	20.668	29.177	31.109	28.304
10/20/07	01:11:43	907.9005	30.836	31.118	20.737	29.177	31.102	28.288
10/20/07	01:21:43	917.9005	30.836	31.118	20.754	29.174	31.104	28.286

10/20/07	01:31:43	927.9005	30.836	31.121	20.841	29.174	31.102	28.286
10/20/07	01:41:43	937.9005	30.829	31.118	20.898	29.177	31.099	28.286
10/20/07	01:51:43	947.9005	30.827	31.115	20.878	29.171	31.096	28.292
10/20/07	02:01:43	957.9005	30.835	31.121	20.967	29.171	31.101	28.302
10/20/07	02:11:43	967.9005	30.827	31.115	20.999	29.168	31.095	28.304
10/20/07	02:21:43	977.9005	30.827	31.118	21.042	29.171	31.098	28.317
10/20/07	02:31:43	987.9005	30.826	31.112	21.071	29.168	31.095	28.317
10/20/07	02:41:43	997.9005	30.821	31.109	21.088	29.163	31.091	28.311
10/20/07	02:51:43	1007.9005	30.826	31.112	21.114	29.166	31.091	28.313
10/20/07	03:01:43	1017.9005	30.820	31.107	21.108	29.163	31.088	28.309
10/20/07	03:11:43	1027.9005	30.821	31.109	21.114	29.166	31.089	28.309
10/20/07	03:21:43	1037.9005	30.820	31.107	21.120	29.163	31.089	28.307
10/20/07	03:31:43	1047.9005	30.817	31.107	21.111	29.157	31.088	28.304
10/20/07	03:41:43	1057.9005	30.816	31.104	21.100	29.157	31.085	28.300
10/20/07	03:51:43	1067.9005	30.817	31.104	21.045	29.157	31.086	28.300
10/20/07	04:01:43	1077.9005	30.813	31.101	20.990	29.154	31.085	28.294
10/20/07	04:11:43	1087.9005	30.813	31.104	21.071	29.157	31.083	28.292
10/20/07	04:21:43	1097.9005	30.813	31.101	21.091	29.151	31.080	28.290
10/20/07	04:31:43	1107.9005	30.811	31.098	21.088	29.148	31.079	28.288
10/20/07	04:41:43	1117.9005	30.811	31.098	21.103	29.151	31.079	28.290
10/20/07	04:51:43	1127.9005	30.811	31.098	21.094	29.151	31.078	28.288
10/20/07	05:01:43	1137.9005	30.808	31.095	21.105	29.148	31.076	28.288
10/20/07	05:11:43	1147.9005	30.805	31.095	21.079	29.148	31.076	28.284
10/20/07	05:21:43	1157.9005	30.807	31.095	21.088	29.148	31.076	28.282
10/20/07	05:31:43	1167.9005	30.802	31.092	21.097	29.145	31.075	28.284
10/20/07	05:41:43	1177.9005	30.801	31.092	21.094	29.145	31.075	28.284
10/20/07	05:51:43	1187.9005	30.801	31.090	21.079	29.142	31.073	28.278
10/20/07	06:01:43	1197.9005	30.799	31.087	21.062	29.140	31.070	28.272
10/20/07	06:11:43	1207.9005	30.807	31.087	21.016	29.142	31.072	28.264
10/20/07	06:21:43	1217.9005	30.798	31.087	21.091	29.140	31.067	28.268
10/20/07	06:31:43	1227.9005	30.798	31.087	21.059	29.131	31.065	28.272
10/20/07	06:41:43	1237.9005	30.799	31.084	21.097	29.140	31.069	28.280
10/20/07	06:51:43	1247.9005	30.792	31.081	21.062	29.137	31.065	28.274
10/20/07	07:01:43	1257.9005	30.795	31.084	21.117	29.137	31.066	28.278
10/20/07	07:11:43	1267.9005	30.795	31.081	21.140	29.134	31.063	28.278
10/20/07	07:21:43	1277.9005	30.795	31.081	21.175	29.137	31.065	28.300
10/20/07	07:31:43	1287.9005	30.798	31.087	21.318	29.137	31.065	28.302
10/20/07	07:41:43	1297.9005	30.795	31.084	21.428	29.137	31.066	28.274
10/20/07	07:51:43	1307.9005	30.790	31.081	21.534	29.134	31.063	28.284
10/20/07	08:01:43	1317.9005	30.790	31.084	21.641	29.131	31.063	28.270
10/20/07	08:11:43	1327.9005	30.787	31.084	21.773	29.131	31.063	28.247
10/20/07	08:21:43	1337.9005	30.792	31.090	21.917	29.128	31.062	28.229

APPENDIX F

MANUAL DATA RECORDINGS

Aquifer (pumping) Test Field Data Sheet

Project: SANTEE TEST WELL	Feature: 2-HR PRE-TEST
Pump Well ID: TEST WELL	Location:
Obs Well ID: TEST WELL	~~Radius (inches)~~ 1.5" DIA. — Dir. & Dist. -N/A
Static W.L. 31.66'	Elev of M.P.* 2.1' STICK-UP — G.S. Elev.*
Observer SCHIEFFER/POWELL	Type of Test

Date & Time (24 hr clock)	Elapsed Time (min)	Depth to Water (decimal ft)	Drawdown (ft)	Discharge (gpm or ft³/s)	Remarks
1:54	START	31.6		360	CLOUDY WATER
1:57	3	37.0	5.4	360	
2:00	6	37.0	5.4	360	
2:05	11	37.1	5.5	360	
2:06	12				UP TO 425
2:07	13	38.4	6.8	425	
2:11	17				UP TO 500
2:12	18	40.0	8.4	500	
2:15	21	40.1	8.5	500	AS WE RAISE THE
2:17	23	40.2	8.6		GPM, THE FLOW GETS
2:18	24			UP TO 575	CLOUDIER THEN
2:19	25	42.3	10.7	575	CLEARS-UP
2:22	28	42.7	11.1	560	
2:26	32	43.1	11.5	560	~~[illegible]~~
2:31	37	43.5	11.9	560	
2:36	42	43.6	12.0	550	
2:41	47	43.7	12.1	550	
2:53	59	43.8	12.2	550	
3:03	69	44.0	12.4	550	
3:13	79	44.1	12.5	540	
3:23	89	44.15	12.55	540	
3:36	102	44.25	12.65	540	
4:14	140	44.5	12.9	525	
4:20	146	42.0	10.4	450	SWITCHED TO 450 GPM
4:25	151	42.0	10.4	450	WATER IS CLEAR
4:44	170	42.1	10.5	450	
4:49	175	42.1	10.5	450	
4:54	180	42.1	10.5	450	
5:19	205			400	CHANGED TO 400 GPM
5:25	211	40.6	9.0	400	
6:05	251			425	CHANGED TO 425 GPM
6:50	296			425	END TEST

* = if elevations are not known, then record the distance between the measuring point and ground surface (i.e. stick-up)

M.P. = measuring point W.L. = water level Dir. = Direction Dist. = Distance

Aquifer (pumping) Test Field Data Sheet

Project: Santee Test Well			Feature: 24-hr pump test		
Pump Well ID: Test		Location:			
Obs Well ID: N2-30		Radius (inches)		Dir. & Dist. 26.5' NORTH	
Static W.L. 30.60		Elev of M.P.* 1.0' STICKUP		G.S. Elev.*	
Observer Powell/Schieffer			Type of Test DRAWDOWN + RECOVERY		
Date & Time (24 hr clock)	Elapsed Time (min)	Depth to Water (decimal ft)	Drawdown (ft)	Discharge (gpm or ft³/s)	Remarks
10/19 10:41 (EST)		31.42	0.82	425 GPM	
10:55		31.48	0.88		
11:09		31.53	0.93		
11:26		31.65	1.05		
12:34		31.80	1.20		
13:39		31.85	1.25		
14:47		31.87	1.27		
15:54		31.98	1.38		
16:51		31.97	1.37		
17:51		31.98	1.38		
18:53		32.03	1.43		
19:44		32.06	1.46		
20:50		32.08	1.48		
21:52		32.09	1.49		
22:53		32.11	1.51		
23:52		32.13	1.53		
00:58		32.15	1.55		
01:57		32.16	1.56		
02:54		32.18	1.58		
4:02		32.18	1.58		
5:00		32.21	1.61		
6:01		32.25	1.65		
7:12		32.23	1.63		
8:13		32.24	1.64		
9:49		32.27	1.67		
RECOVERY				0 gpm	
		31.67	1.07		
11:33		31.46	0.86		
11:45		31.38	0.78		
14:06		31.09	0.49		
15:12		31.04	0.44		
16:50		30.99	0.39		
10/20 - 9:15		30.78	0.18		

* = if elevations are not known, then record the distance between the measuring point and ground surface (i.e. stick-up)

M.P. = measuring point W.L. = water level Dir. = Direction Dist. = Distance

Aquifer (pumping) Test Field Data Sheet

Project: Santee Test Well **Feature:** 24-hr+ Pump Test

Pump Well ID: Test **Location:**

Obs Well ID: N1 **Radius (inches)** **Dir. & Dist.** 45' NORTH

Static W.L. 32.20' **Elev of M.P.*** 2.8' STICK-UP **G.S. Elev.***

Observer Powell / Scheiffer **Type of Test** DRAWDOWN + RECOVERY

Date & Time (24 hr clock)	Elapsed Time (min)	Depth to Water (decimal ft)	Drawdown (ft)	Discharge (gpm or ft³/s)	Remarks
10/19 10:39 (CST)	Start	32.72	0.52	425 GPM	
10:54	15	32.80	0.60	↓	
11:07	28	32.85	0.65		
11:25	46	32.88	0.68		
12:33	114	33.0	0.80		
13:37	178	33.11	0.91		
14:45	246	33.19	0.99		
15:53	314	33.21	1.01		
16:50	381	33.24	1.04		
17:49	440	33.26	1.06		
18:52	503	33.28	1.08		
19:44	555	33.33	1.13		
20:42	620	33.33	1.13		
21:50	681	33.37	1.17		
22:50	741	33.37	1.17		
23:50	801	33.38	1.18		
00:55	866	33.39	1.19		
01:54	915	33.41	1.21		
02:52	973	33.46	1.26		
4:00	1041	33.48	1.28		
4:59	1100	33.48	1.28		
6:00	1161	33.47	1.27		
7:10	1231	33.49	1.29		
8:12	1293	33.51	1.31	↓	
9:47	1388	33.50	1.30		
RECOVERY				0 gpm	
		33.24	1.04	↓	
11:32		33.06	0.86		
11:45		32.98	0.78		
14:06		32.69	0.49		
15:10		32.63	0.43		
16:50		32.58	0.38		
10/20 - 9:15		32.38	0.18	↓	

* = if elevations are not known, then record the distance between the measuring point and ground surface (i.e. stick-up)

M.P. = measuring point W.L. = water level Dir. = Direction Dist. = Distance

Aquifer (pumping) Test Field Data Sheet

Project: Santee Test well | Feature: 24-hr pump test

Pump Well ID: Test | Location:

Obs Well ID: Test | Radius (inches) | Dir. & Dist. N/A

Static W.L. 31.66 | Elev of M.P.* 2.1' STICK-UP | G.S. Elev.*

Observer Powell / Schieffer | Type of Test DRAWDOWN + RECOVERY

Date & Time (24 hr clock)	Elapsed Time (min)	Depth to Water (decimal ft)	Drawdown (ft)	Discharge (gpm or ft³/s)	Remarks
10/19 10:23 (CST)		39.9		425 GPM	
10:28		40.0			
10:35		40.08			
10:46		40.08			
10:59		40.21			
11:14		40.37			
12:26		40.60			
13:29		40.69			
14:37		40.78			
15:44		40.78			
16:42		40.87			
17:40		40.94			
18:44		41.00			
19:35		41.02			
20:40		41.09			
21:40		41.10			
22:42		41.18			
23:38		41.21			
00:45		41.23			
01:40		41.27			
02:41		41.29			
3:50		41.34			
4:49		41.38			
5:50		41.40			
7:00		41.44			
8:04		41.48			
9:40		41.49		↓	
RECOVERY				0 gpm	
		32.53			
11:35		32.29			
12:18		32.18			
14:02		32.0			
15:10		31.91			
16:50		31.88			
10/20 - 9:15		31.71		↓	

* = if elevations are not known, then record the distance between the measuring point and ground surface (i.e. stick-up)

M.P. = measuring point W.L. = water level Dir. = Direction Dist. = Distance

Aquifer (pumping) Test Field Data Sheet

Project: Santee Test Well	Feature: 24-hr test
Pump Well ID: Test	Location:
Obs Well ID: E1	Radius (inches) / Dir. & Dist. 51' EAST
Static W.L. 32.27	Elev of M.P.* 1.7' STICK-UP / G.S. Elev.*
Observer Powell/Schieffer	Type of Test DRAWDOWN + RECOVERY

Date & Time (24 hr clock)	Elapsed Time (min)	Depth to Water (decimal ft)	Drawdown (ft)	Discharge (gpm or ft³/s)	Remarks
10/19 10:34 (CST)		32.58		425 GPM	
10:48		32.74			
11:00		32.77			
11:15		32.80			
12:28		33.0			
13:30		33.08			
14:40		33.11			
15:46		33.18			
16:44		33.17			
17:43		33.21			
18:45		33.24			
19:36		33.27			
20:41		33.34			
21:41		33.32			
22:44		33.33			
23:40		33.33			
00:47		33.34			
01:42		33.37			
02:43		33.41			
3:53		33.40			
4:50		33.42			
5:55		33.44			
7:02		33.43			
8:05		33.47			
9:40		33.49			
				0 gpm	
		33.06			
11:39		32.94			
12:15		32.82			
14:04		32.65			
15:26		32.55			
16:50		32.54			
10/20 - 9:15		32.35			

* = if elevations are not known, then record the distance between the measuring point and ground surface (i.e. stick-up)

M.P. = measuring point W.L. = water level Dir. = Direction Dist. = Distance

Aquifer (pumping) Test Field Data Sheet

Project: Santee Test Well	Feature: 24-hr Pump Test
Pump Well ID: Test	Location:
Obs Well ID: E2	Radius (inches) / Dir. & Dist. 105' EAST
Static W.L. 31.64	Elev of M.P.* 1.5' STICK-UP / G.S. Elev.*
Observer Powell / Schiefler	Type of Test DRAWDOWN & RECOVERY

Date & Time (24 hr clock)	Elapsed Time (min)	Depth to Water (decimal ft)	Drawdown (ft)	Discharge (gpm or ft³/s)	Remarks
10:26		31.71		425 GPM	[illegible]
10:50		31.82			
11:03		31.86			
11:17		31.88			
12:28		32.04			
13:32		32.12			
14:42		32.15			
15:48		32.18			
16:46		32.23			
17:44		32.28			
18:46		32.33			
19:38		32.30			
20:43		32.33			
21:43		32.34			
22:46		32.36			
23:42		32.36			
00:49		32.37			
01:44		32.40			
02:45		32.42			
3:55		32.42			
4:54		32.46			
5:55		32.48			
7:05		32.45			
8:07		32.48			
9:42		32.52			
		32.33		0 GPM	
11:40		32.25			
12:14		32.15			
14:05		32.03			
15:26		31.98			
16:50		31.90			
10/20 – 9:15		31.73			

* = if elevations are not known, then record the distance between the measuring point and ground surface (i.e. stick-up)

M.P. = measuring point W.L. = water level Dir. = Direction Dist. = Distance

7-1654 (11-94)
Bureau of Reclamation

COMPUTATION SHEET

BY	DATE	PROJECT	SHEET 1 OF 1
C. Powell	10-19-07	Santee Test Well	
CHKD BY	DATE	FEATURE	
		24-hr pump test data	

DETAILS
Data Collected by instrumentation for 5 hr period

	Ch 1	2	3	4	5
2:51	32.344	33.342	40.892	32.109	33.371
	32.332	33.328	40.918	32.109	33.370
	32.435	33.317	40.901	32.109	33.376
3:21	32.410	33.359	40.903	32.112	33.376
	32.380	33.334	40.855	32.118	33.379
	32.381	33.325	40.880	32.115	33.381
3:51	32.362	33.365	40.880	32.118	33.381
	32.347	33.345	40.872	32.121	33.386
	32.335	33.336	40.837	32.121	33.386
4:21	32.328	33.385	40.872	32.121	33.389
	32.320	33.368	40.837	32.130	33.393
	32.310	33.354	40.806	32.132	33.394
	32.303	33.345	40.826	32.135	33.393
	32.303	33.393	40.906	32.135	33.397
	32.396	33.371	40.809	32.138	33.399
5:21	32.450	33.354	40.857	32.141	33.402
	32.472	33.408	40.852	32.141	33.400
	32.460	33.385	40.803	32.147	33.406
	32.439	33.365	40.837	32.147	33.409
	32.426	33.411	40.806	32.147	33.409
	32.411	33.388	40.837	32.147	33.413
	32.401	33.376	40.823	32.150	33.412
	32.396	33.428	40.834	32.153	33.416
6:41	32.399	33.416	40.857	32.153	33.415
	32.390	33.396	40.794	32.158	33.418
	32.375	33.385	40.791	32.161	33.420
	32.366	33.428	40.860	32.158	33.416
	32.361	33.413	40.809	32.161	33.418
	32.350	33.399	40.863	32.164	33.422
7:41	32.346	33.393	40.872	32.164	33.425
	32.334	33.436	40.852	32.167	33.428
	32.338	33.428	40.906	32.170	33.429
8:11	32.361	33.433	40.863	32.173	33.432
Static	31.640	32.270	31.660	30.606	32.197
	E-2 STATIC	E-1 STATIC	WELL STATIC	N2-30 .01/HR	N-1 .01/HR
	.721	1.16	9.2	1.57	1.24
	31.68	32.33	32.123	30.68	32.25

7-1654 (11-94)
Bureau of Reclamation

COMPUTATION SHEET

BY R. SCHIEFFER	DATE 10/19/07 + 10/20/07	PROJECT SANTEE SIOUX FEAS. STUDY	SHEET 1 OF 1
CHKD BY	DATE	FEATURE TEST WELL + PUMP TEST	

DETAILS FIELD NOTES USED TO DETERMINE WHEN TO TERMINATE THE RECOVERY TEST - ALL READINGS TAKEN FROM HERMIT

	CH-1 E-2	CH-2 E-1	CH 3 TEST	CH-4 N-2-30	CH-5 N-1
STATIC	31.64	32.27	31.66	30.60	32.20
MAX DRAWDOWN (ELEV)	32.61	33.56	41.9	32.19	33.45
MAX DRAWDOWN (FT)	0.97	1.29	10.24	1.59	1.25

RECOVERY DATA - PUMP SHUT OFF AT 11:00 +/- (CST) ON 10/19

10/19 15:00 (CST)	31.07	31.33	22.95	29.39	31.32
ADJ*	(32.04)	(32.62)	(33.19)	(30.98)	(32.57)
RECOVERY	59%	73%	85%	76%	70%
10/19 16:00	31.03	31.28	22.91	29.35	31.28
ADJ*	(32.00)	(32.57)	(33.15)	(30.94)	(32.53)
RECOVERY	63%	77%	85%	78%	74%
Δ per hr	+.04	+.05	+.04	+.04	+.04
10/19 17:00	31.00	31.25	22.78	29.32	31.25
ADJ*	(31.97)	(32.54)	(33.02)	(30.91)	(32.50)
RECOVERY	66%	79%	87%	81%	76%
Δ per hr	+.03	+.03	+.13	+.03	+.03
10/19 18:00	30.97	31.23	22.40	29.29	31.22
ADJ*	(31.94)	(32.52)	(32.64)	(30.88)	(32.47)
RECOVERY	69%	81%	91%	82%	78%
Δ per hr	+.03	+.02	+.38 ?	+.03	+.03
10/20 9:15 (END OF TEST)	30.79	31.08	21.64	29.13	31.06
ADJ*	(31.76)	(32.37)	(31.88)	(30.72)	(32.31)
RECOVERY	88%	92%	98%	92%	91%

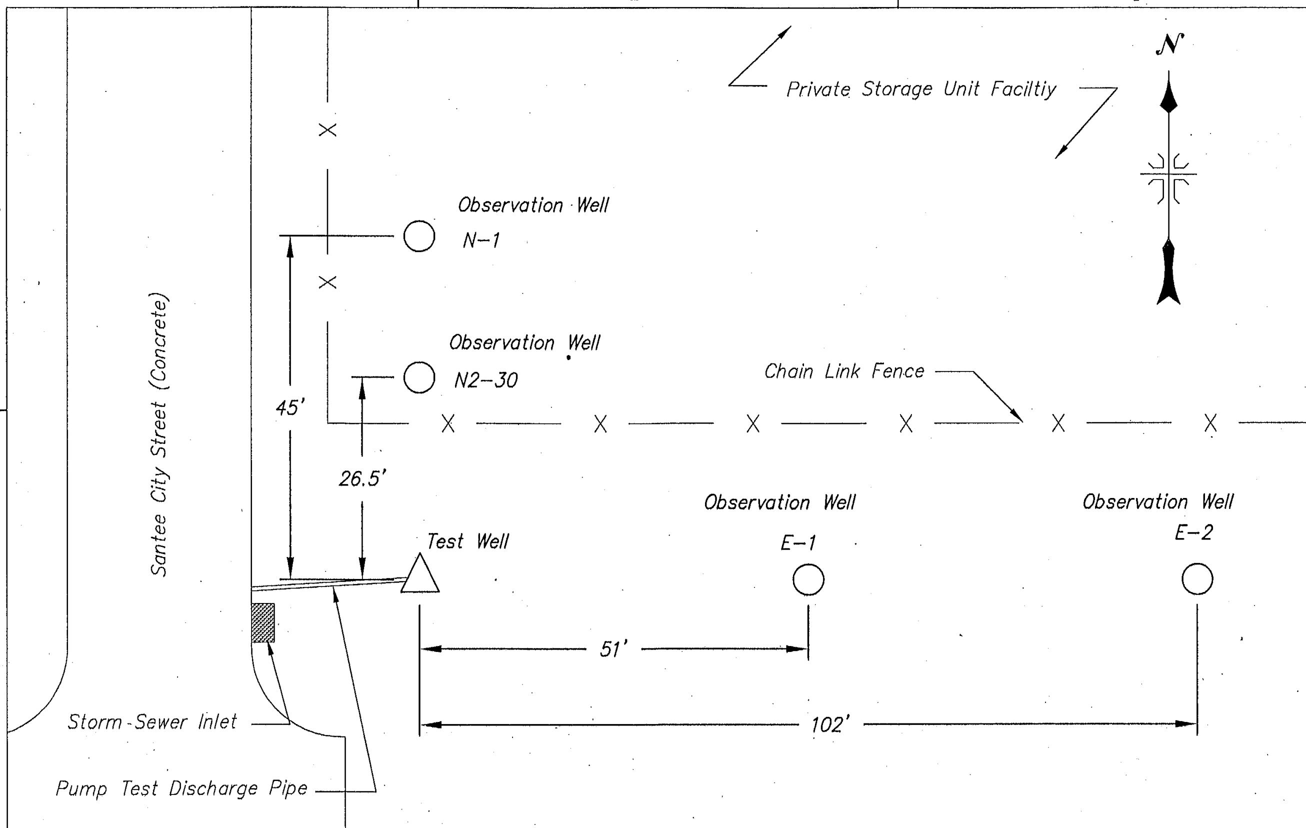
* ALL READINGS WERE ADJUSTED (BY ADDING THE MAX DRAWDOWN) SINCE THE PROBE REFERENCE LEVELS WERE LEFT AT THE TOC. MEASUREMENT.

APPENDIX G

WELL LAYOUT DIAGRAM

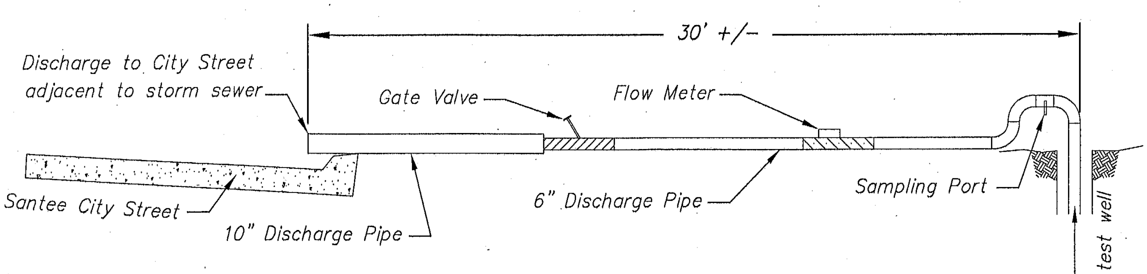
and

WELL 1 SCHEMATIC



SITE PLAN

NOT TO SCALE



DISCHARGE PIPE SCHEMATIC

NOT TO SCALE

NOTES

Water from the pump test discharged into the street and susequently into the storm sewer system. The discharge point of the storm sewer system is located 400' north of the test well site on the north side of Santee Spur 54d.

ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

SANTEE SIOUX WATER SUPPLY FEASIBILITY STUDY

TEST WELL AND PUMP TEST 10/09/2007

TEST WELL AND OBSERVATION WELL LAYOUT

CADD SYSTEM AUTOCAD 2006	CADD FILENAME PUMP TEST LAYOUT.DWG
GRAND ISLAND, NEBRASKA MARCH 14, 2008 SHEET 1 OF 1	

A	B	C	D	E	F	G	H	I	J	K	L
Well ID	Stick-up (TOC*) - ft	Total Depth (TOC) - ft	Depth BGS** - ft	Static Level (TOC) - ft	Dynamic Head Range - ft	Probe Range - psi	Probe Depth (TOC) - ft	Distance from Pumping Well - ft TO NEAREST ½ ft	Total Length of Cable - ft	Probe S/N	Data Logger Channel
---	----	----	[C – D]	----	[C – E]	[F / 2.3]	[E + G*2.3]***	----	[H + I]		
E-1	1.7′	54 ft		32.27			52′ to tip	51′		7008	2
E-2	1.5′	46 ft		31.64			44′ to tip	102′		2217397	1
TW	2.1′	53 ft		31.66			47.5′ to tip	—		21875565	3
N-1	2.8′	50 ft		32.20			48′ to tip	45′		7810	5
N2-30	1.0′	42 ft		30.60			40′ to tip	26.5′		218702250	4

* TOC = Top of Casing

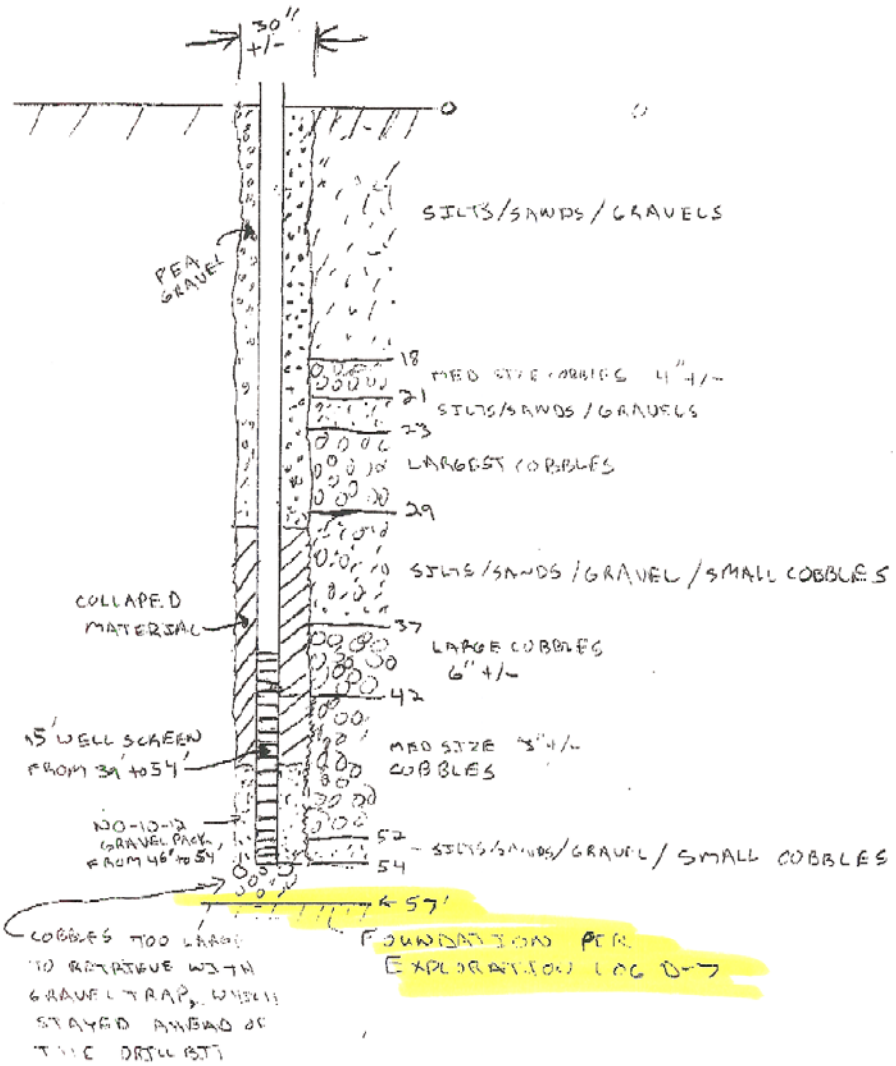
** BGS = Below Ground Surface

*** Probe should be set no deeper than 2.3 feet times the probe pressure range (psi range) below static water level, or 1 foot above the bottom of the well, whichever comes first. Example: if using a 10 psi probe, 2.3 feet times 10 = 23 feet, so this probe should be set no more than 23 feet below static water level. If the well is 65 feet deep and the static water level is 35 feet (i.e. 30 feet of water column) then the probe should be set at 53 feet (23 feet below static water level and 12 feet above the bottom of the well. Probes do not respond properly if they are set in mud, fine silts, or some types of debris in the bottom of the well. Mud is especially hard to work with – one may not know there is a mud layer at the bottom of the well simply from sounding the well – usually one finds out that there is a mud layer when the probe does not register any water level changes but the manual readings indicate a change in water levels, and when the probe is pulled the tip is coated with mud and the pressure ports in the tip are clogged.

7-1654 (11-94)
Bureau of Reclamation

COMPUTATION SHEET

BY R. SCHAEFFER	DATE 10-16-07	PROJECT SANTEE WATER SUP. FEAS. STUDY	SHEET ___ OF ___
CHKD BY	DATE	FEATURE TEST WELL CONSTRUCTION	
DETAILS ROUGH WELL LOG AS VERBALLY DESCRIBED BY INSPECTOR AND CONTRACTOR			



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APPENDIX H

ANALYSES PRINTOUTS

F-2

A	B	C	D	E	F	G	H	I	J	K	L
Well ID	Stick-up (TOC*) - ft	Total Depth (TOC) - ft	Depth BGS** - ft	Static Level (TOC) - ft	Dynamic Head Range - ft	Probe Range - psi	Probe Depth (TOC) - ft	Distance from Pumping Well - ft TO NEAREST ½ ft	Total Length of Cable - ft	Probe S/N	Data Logger Channel
---	----	----	[C–D]	----	[C–E]	[F/2.3]	[E+G*2.3]***	----	[H+I]		
E-1	1.7'	54. ft		32.27			52' to tip	51'		7008	2
E-2	1.5'	46 ft		31.64			44' to tip	102'		2217397	1
TW	2.1'	53 ft		31.66			47.5' to tip	—		21873565[illegible]	3
N-1	2.8'	50 ft		32.20			48' to tip	45'		7810	5
N2+3[illegible]	1.0'	42 ft		30.60			40' to tip	26.5'		2187020[illegible]	4

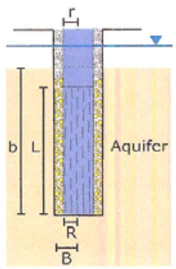
* TOC = Top of Casing

** BGS = Below Ground Surface

*** Probe should be set no deeper than 2.3 feet times the probe pressure range (psi range) below static water level, or 1 foot above the bottom of the well, whichever comes first. Example: if using a 10 psi probe, 2.3 feet times 10 = 23 feet, so this probe should be set no more than 23 feet below static water level. If the well is 65 feet deep and the static water level is 35 feet (i.e. 30 feet of water column) then the probe should be set at 53 feet (23 feet below static water level and 12 feet above the bottom of the well. Probes do not respond properly if they are set in mud, fine silts, or some types of debris in the bottom of the well. Mud is especially hard to work with – one may not know there is a mud layer at the bottom of the well simply from sounding the well – usually one finds out that there is a mud layer when the probe does not register any water level changes but the manual readings indicate a change in water levels, and when the probe is pulled the tip is coated with mud and the pressure ports in the tip are clogged.

Bureau of Reclamation Denver Technical Sevice Center Water Resources Planning and Operations Support Group 86-68210	**Wells**
	Project: Santee Water Supply Test
	Number: 6B763
	Client: Great Plains Office

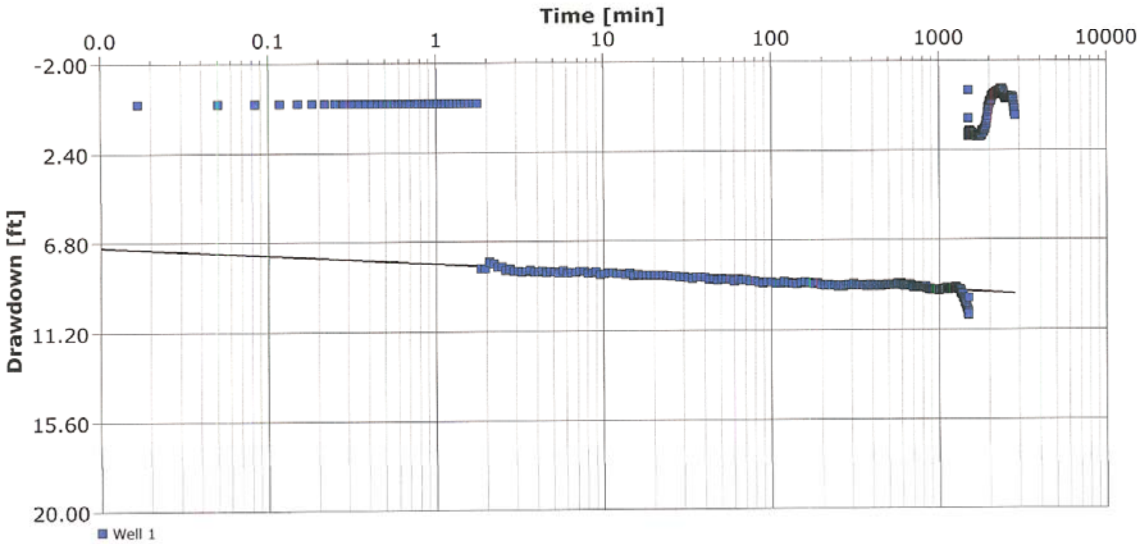
Location: Santee Reserevation, Nebraska



	Name	X [ft]	Y [ft]	Elevation (amsl) [ft]	Penetration	L [ft]	b [ft]
1	Well 1	500	500	1240	Fully	15	15.84
2	N-1	500	545	1240	Fully	10	15.8
3	N-2-30	500	526.5	1240	Fully	10	9.4
4	E-1	551	500	1240	Fully	10	19.73
5	E-2	602	500	1240	Fully	10	12.36

Bureau of Reclamation Denver Technical Sevice Center Water Resources Planning and Operations Support Group 86-68210	Pumping Test Analysis Report Project: Santee Water Supply Test Number: 6B763 Client: Great Plains Office

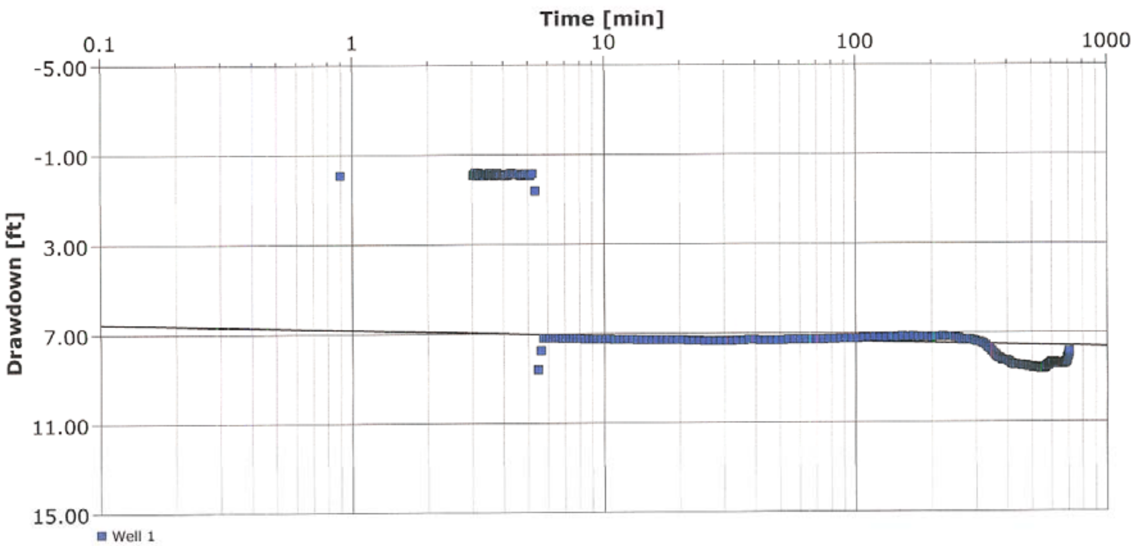
Location: Santee Reserevation, Nebraska	Pumping Test: 24 Hour Pump Test	Pumping Well: Well 1
Test Conducted by: Bob Schieffer		Test Date: 10/19/2007
Analysis Performed by: W Robert Talbot	W-1 - Theis w/Jacob Corr	Analysis Date: 12/17/2007
Aquifer Thickness: 26.00 ft	Discharge: variable, average rate 425 [U.S. gal/min]	



Calculation after Theis with Jacob Correction

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Storage coefficient	Radial Distance to PW [ft]	
Well 1	5.01×10^4	1.93×10^3	2.05×10^{-20}	0.42	

Bureau of Reclamation **Denver Technical Sevice Center** **Water Resources Planning and Operations Support Group** **86-68210**		**Pumping Test Analysis Report** Project: Santee Water Supply Test Number: 6B763 Client: Great Plains Office
Location: Santee Reserevation, Nebraska	Pumping Test: 24 Hour Pump Test	Pumping Well: Well 1
Test Conducted by: Bob Schieffer		Test Date: 10/19/2007
Analysis Performed by: W Robert Talbot	W-1 - Recovery	Analysis Date: 12/18/2007
Aquifer Thickness: 26.00 ft	Discharge: variable, average rate 425 [U.S. gal/min]	

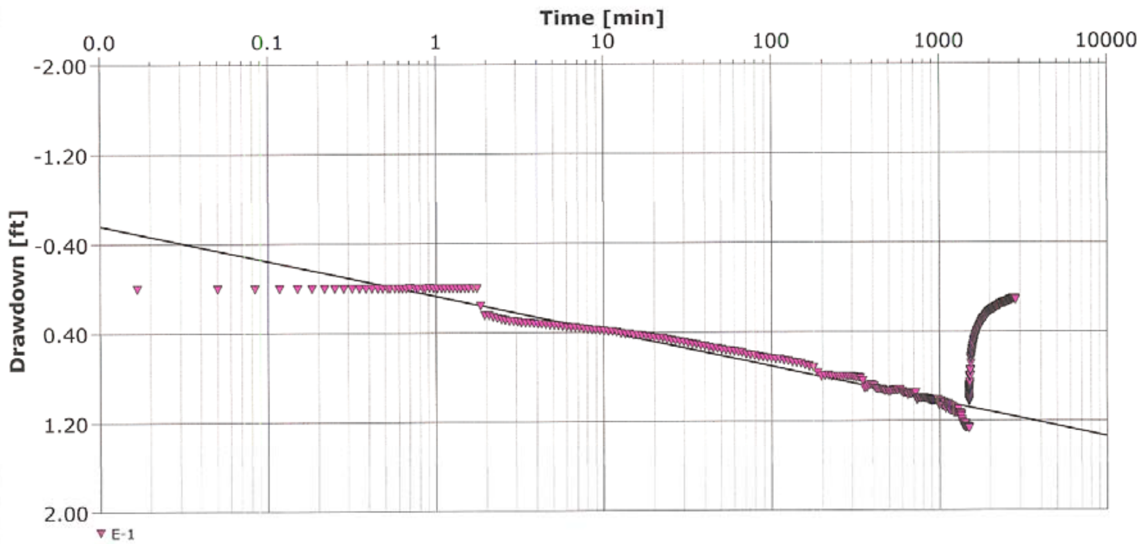


Calculation after Cooper & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Storage coefficient	Radial Distance to PW [ft]	
Well 1	5.49×10^{4}	2.11×10^{3}	4.84×10^{-23}	0.42	

Bureau of Reclamation Denver Technical Sevice Center Water Resources Planning and Operations Support Group 86-68210	Pumping Test Analysis Report Project: Santee Water Supply Test Number: 6B763 Client: Great Plains Office

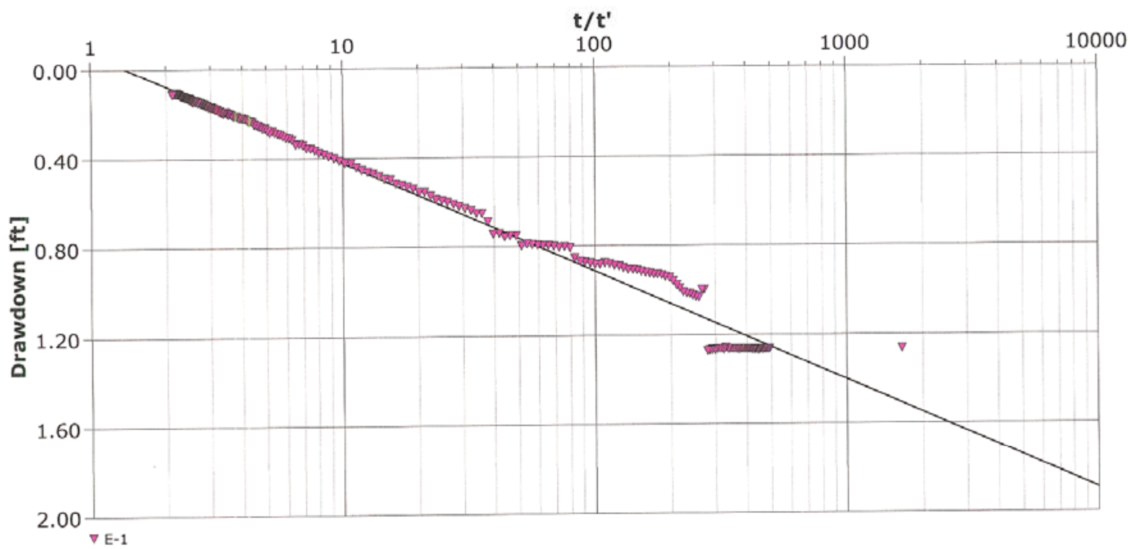
Location: Santee Reserevation, Nebraska	Pumping Test: 24 Hour Pump Test	Pumping Well: Well 1
Test Conducted by: Bob Schieffer		Test Date: 10/19/2007
Analysis Performed by: W Robert Talbot	E-1 Cooper/Jacob	Analysis Date: 12/17/2007
Aquifer Thickness: 26.00 ft	Discharge: variable, average rate 425 [U.S. gal/min]	



Calculation after Cooper & Jacob

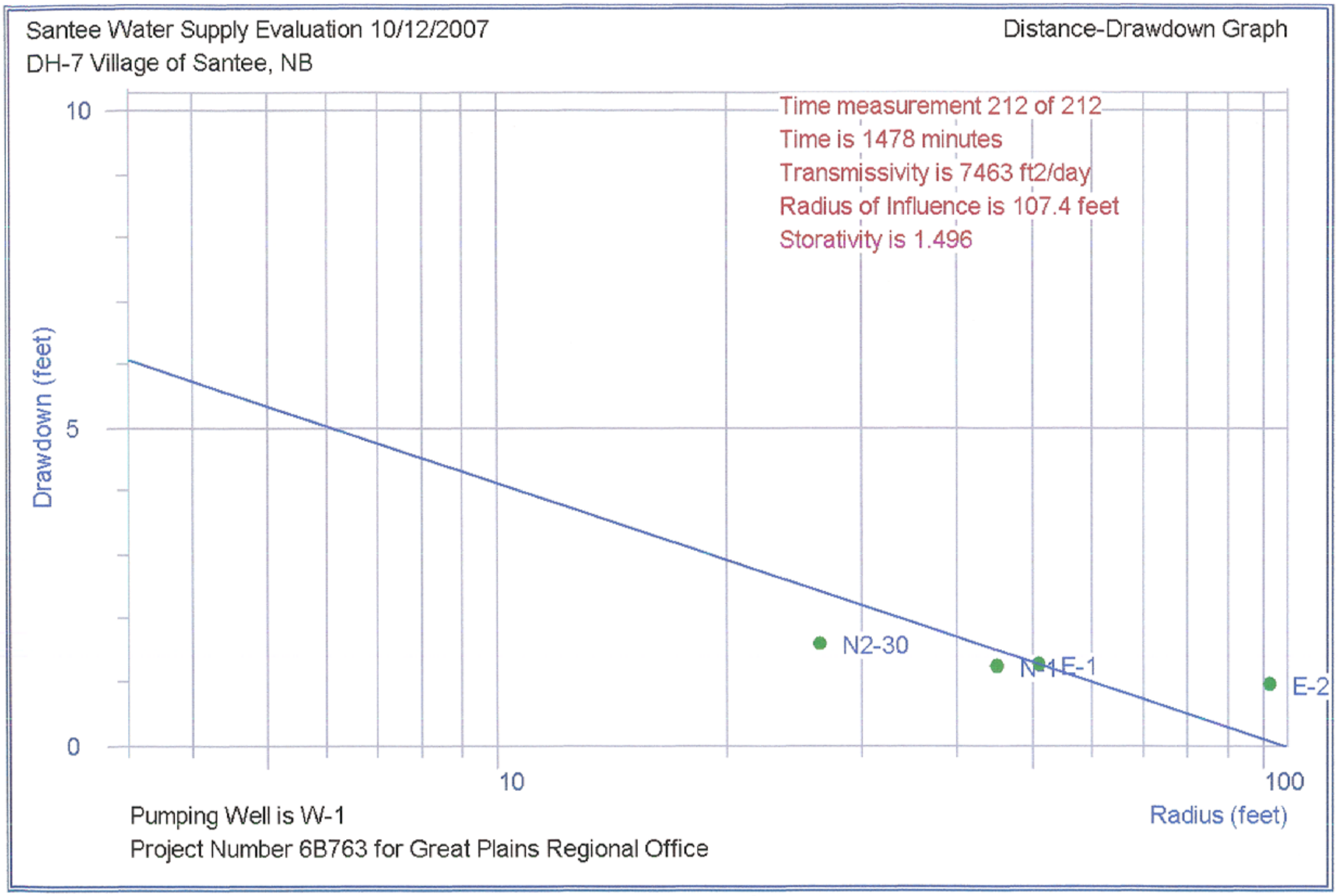
Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Storage coefficient	Radial Distance to PW [ft]	
E-1	4.73×10^{4}	1.82×10^{3}	1.67×10^{-2}	51.0	

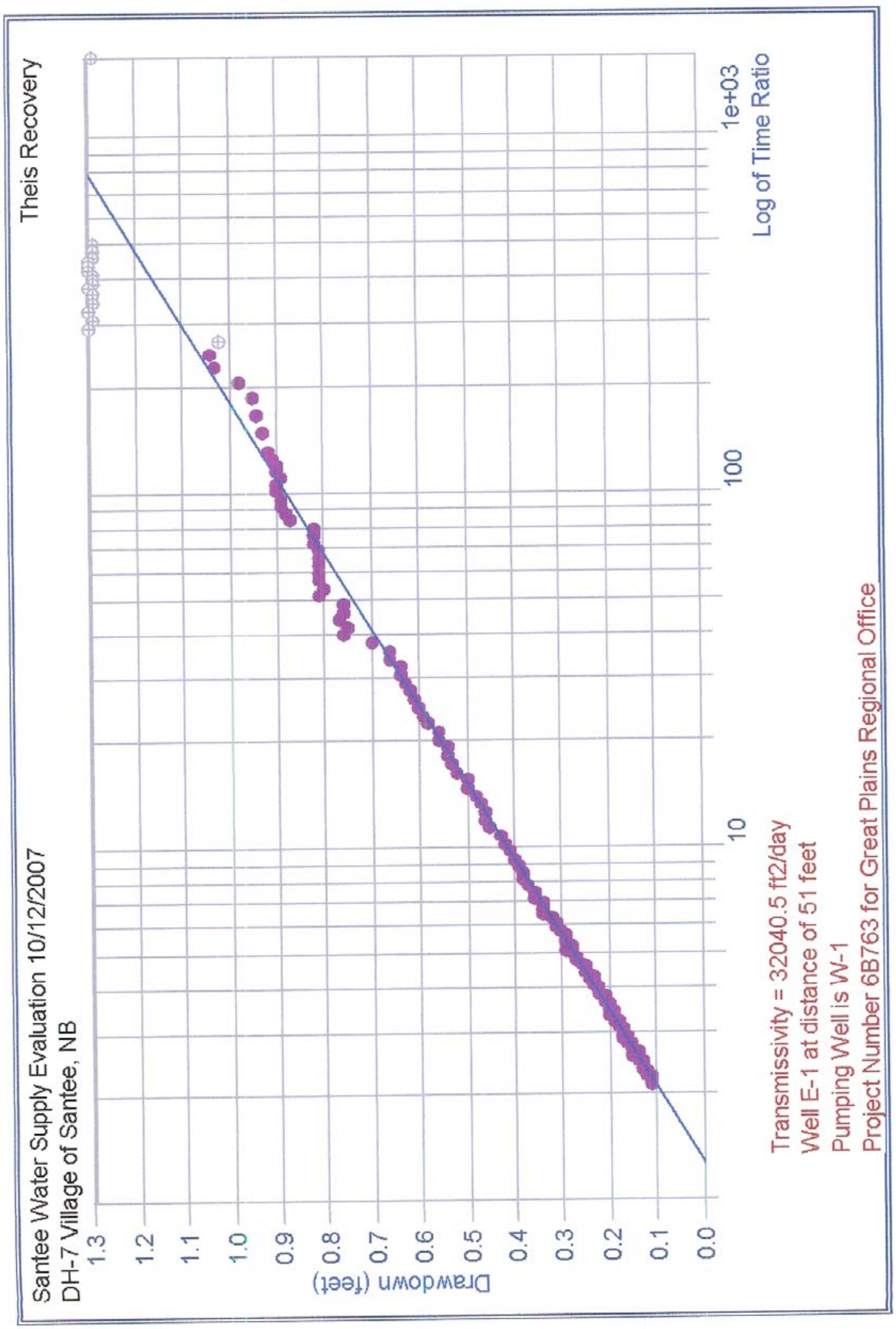
Bureau of Reclamation **Denver Technical Sevice Center** **Water Resources Planning and Operations Support Group** **86-68210**		**Pumping Test Analysis Report** Project: Santee Water Supply Test Number: 6B763 Client: Great Plains Office
Location: Santee Reserevation, Nebraska	Pumping Test: 24 Hour Pump Test	Pumping Well: Well 1
Test Conducted by: Bob Schieffer		Test Date: 10/19/2007
Analysis Performed by: W Robert Talbot	E-1 Recovery	Analysis Date: 12/17/2007
Aquifer Thickness: 26.00 ft	Discharge: variable, average rate 425 [U.S. gal/min]	



Calculation after Theis & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]
E-1	3.05×10^4	1.17×10^3	51.0

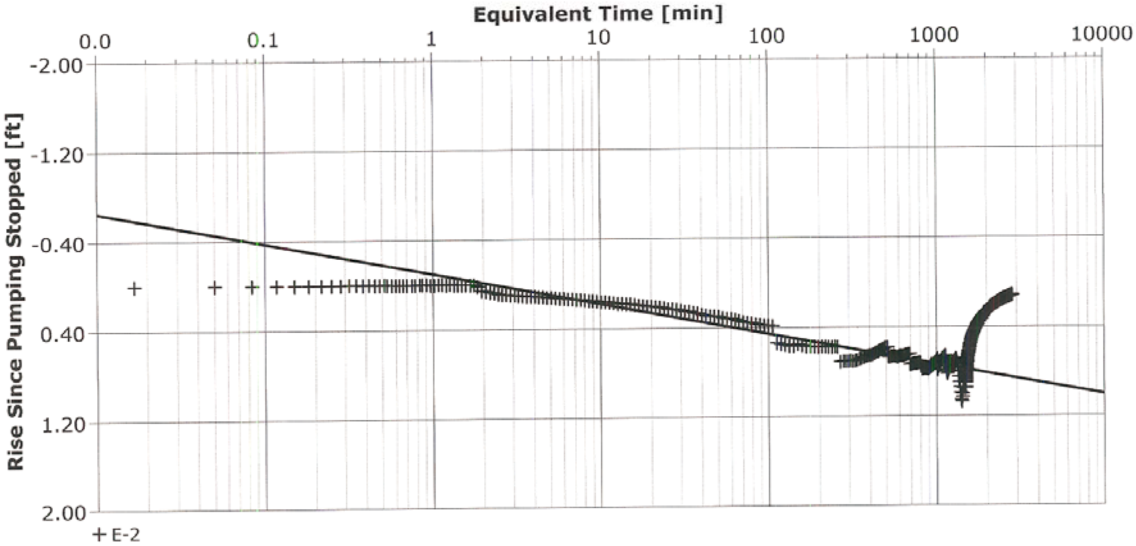

Santee Water Supply Evaluation 10/12/2007
DH-7 Village of Santee, NB
Distance-Drawdown Graph
Time measurement 212 of 212
Time is 1478 minutes
Transmissivity is 7463 ft2/day
Radius of Influence is 107.4 feet
Storativity is 1.496
Drawdown (feet)
10
5
0
N2-30
N1
E-1
E-2
10
100
Radius (feet)
Pumping Well is W-1
Project Number 6B763 for Great Plains Regional Office



Santee Water Supply Evaluation 10/12/2007
DH-7 Village of Santee, NB
Theis Recovery
Drawdown (feet)
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
10
100
1e+03
Log of Time Ratio
Transmissivity = 32040.5 ft2/day
Well E-1 at distance of 51 feet
Pumping Well is W-1
Project Number 6B763 for Great Plains Regional Office

Bureau of Reclamation Denver Technical Sevice Center Water Resources Planning and Operations Support Group 86-68210	Pumping Test Analysis Report Project: Santee Water Supply Test Number: 6B763 Client: Great Plains Office

Location: Santee Sereservation, Nebraska	Pumping Test: 24 Hour Pump Test	Pumping Well: Well 1
Test Conducted by: Bob Schieffer		Test Date: 10/19/2007
Analysis Performed by: W Robert Talbot	E-2 Cooper/Jacob	Analysis Date: 12/17/2007
Aquifer Thickness: 26.00 ft	Discharge: variable, average rate 425 [U.S. gal/min]	

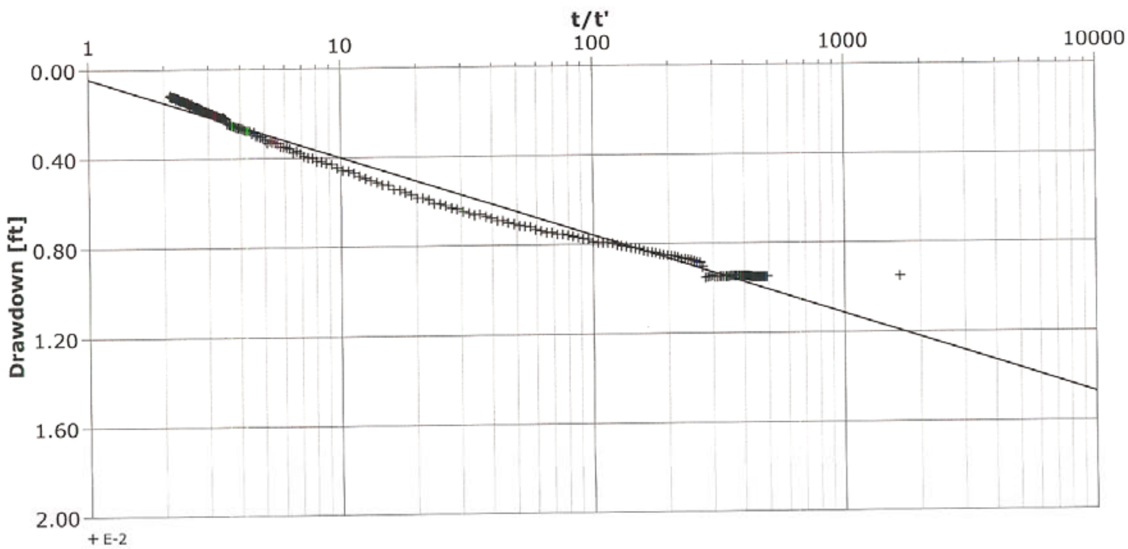


Calculation after Cooper & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Storage coefficient	Radial Distance to PW [ft]	
E-2	5.41×10^4	2.08×10^3	1.84×10^{-2}	102.0	

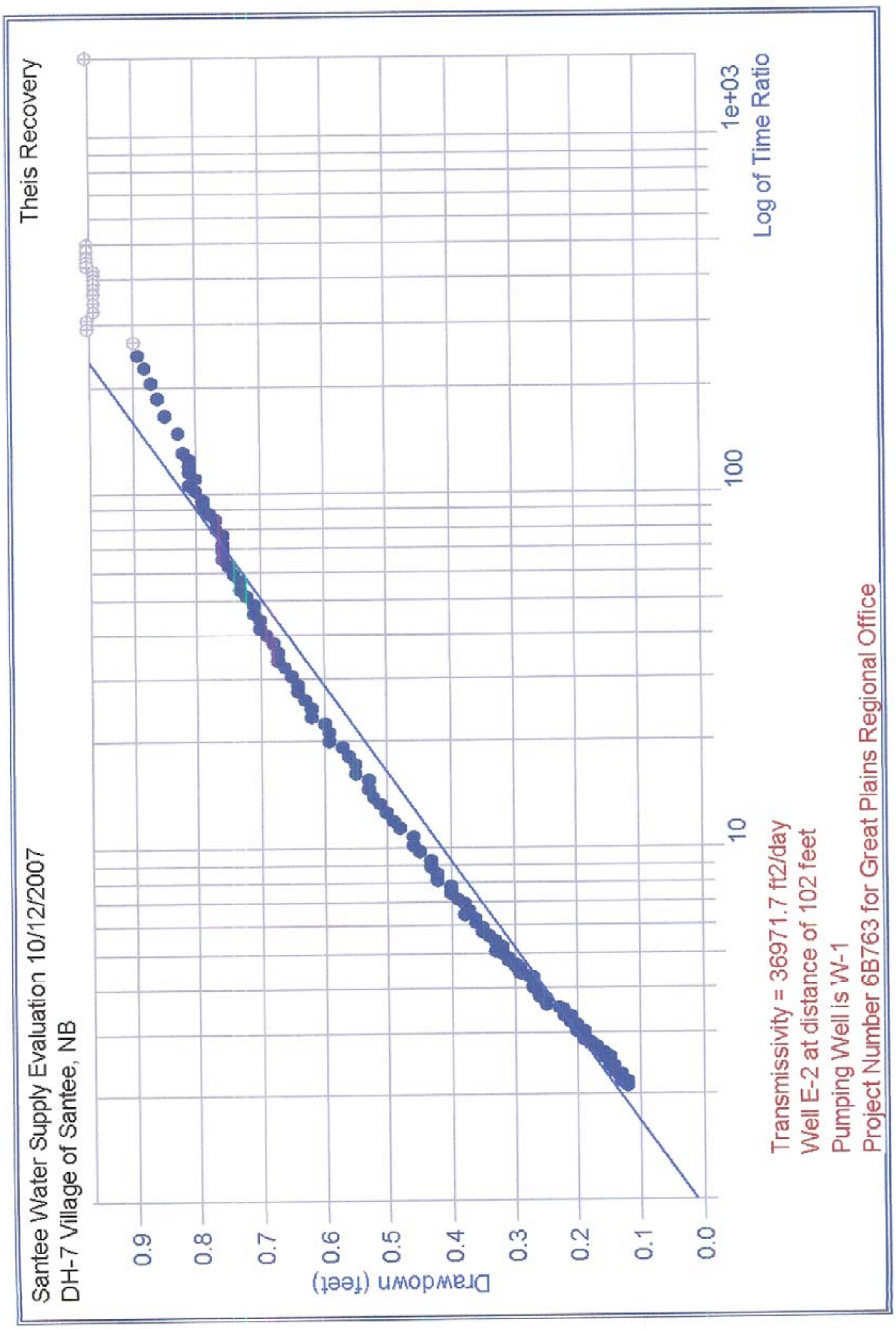
Bureau of Reclamation **Denver Technical Sevice Center** **Water Resources Planning and Operations Support Group** **86-68210**	**Pumping Test Analysis Report** Project: Santee Water Supply Test Number: 6B763 Client: Great Plains Office

Location: Santee Reserevation, Nebraska	Pumping Test: 24 Hour Pump Test	Pumping Well: Well 1
Test Conducted by: Bob Schieffer		Test Date: 10/19/2007
Analysis Performed by: W Robert Talbot	E-2 Recovery	Analysis Date: 12/17/2007
Aquifer Thickness: 26.00 ft	Discharge: variable, average rate 425 [U.S. gal/min]	



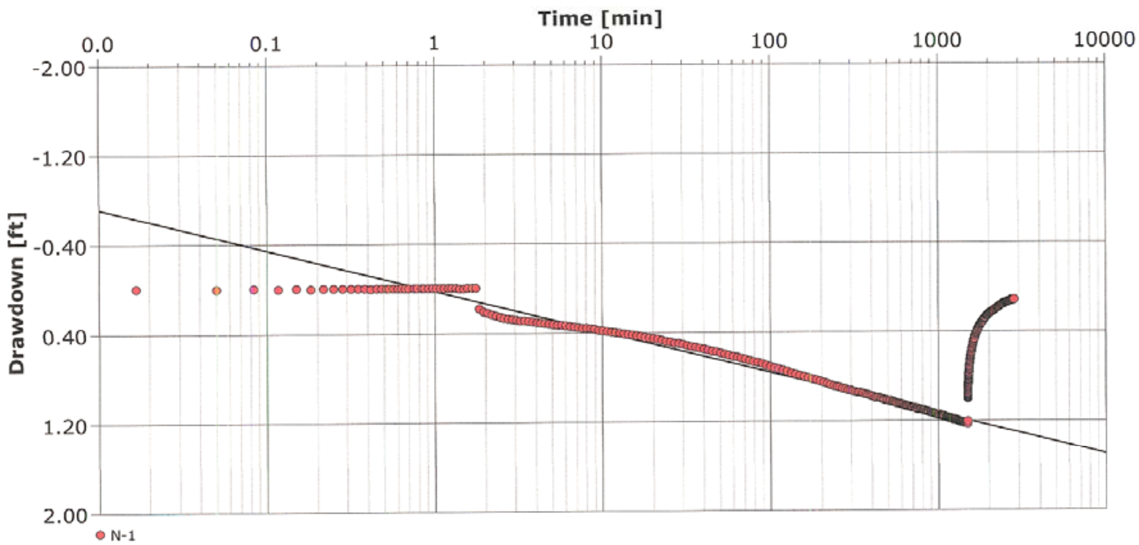
Calculation after Theis & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]	
E-2	4.18×10^4	1.61×10^3	102.0	


Santee Water Supply Evaluation 10/12/2007
DH-7 Village of Santee, NB
Theis Recovery
Drawdown (feet)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
10
100
1e+03
Log of Time Ratio
Transmissivity = 36971.7 ft2/day
Well E-2 at distance of 102 feet
Pumping Well is W-1
Project Number 6B763 for Great Plains Regional Office

Bureau of Reclamation Denver Technical Sevice Center Water Resources Planning and Operations Support Group 86-68210	Pumping Test Analysis Report Project: Santee Water Supply Test Number: 6B763 Client: Great Plains Office

Location: Santee Reserevation, Nebraska	Pumping Test: 24 Hour Pump Test	Pumping Well: Well 1
Test Conducted by: Bob Schieffer		Test Date: 10/19/2007
Analysis Performed by: W Robert Talbot	N-1 Cooper/Jacob	Analysis Date: 12/17/2007
Aquifer Thickness: 26.00 ft	Discharge: variable, average rate 425 [U.S. gal/min]	

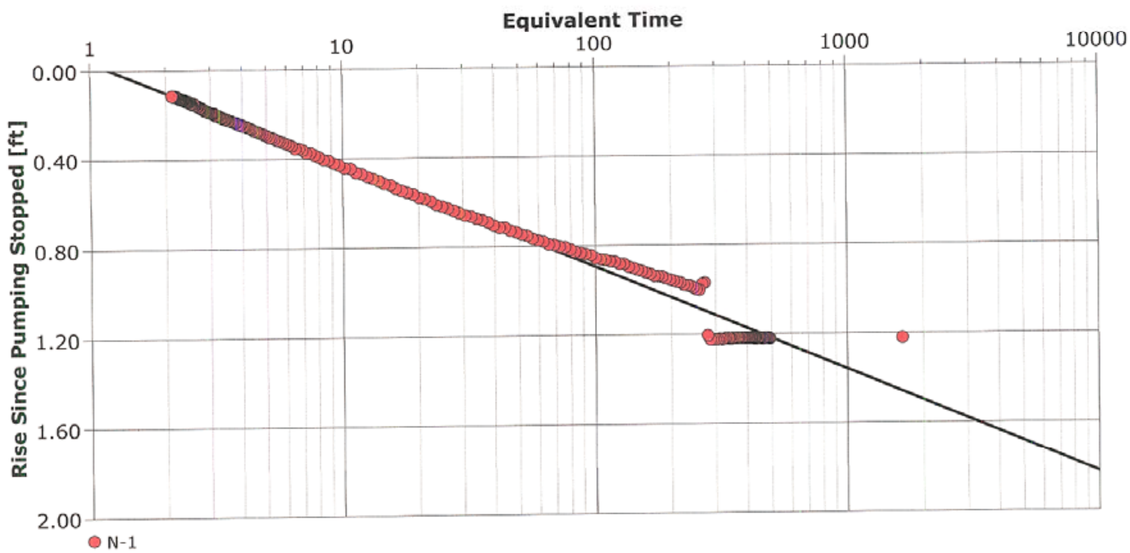


Calculation after Cooper & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Storage coefficient	Radial Distance to PW [ft]	
N-1	4.06×10^4	1.56×10^3	2.72×10^{-2}	45.0	

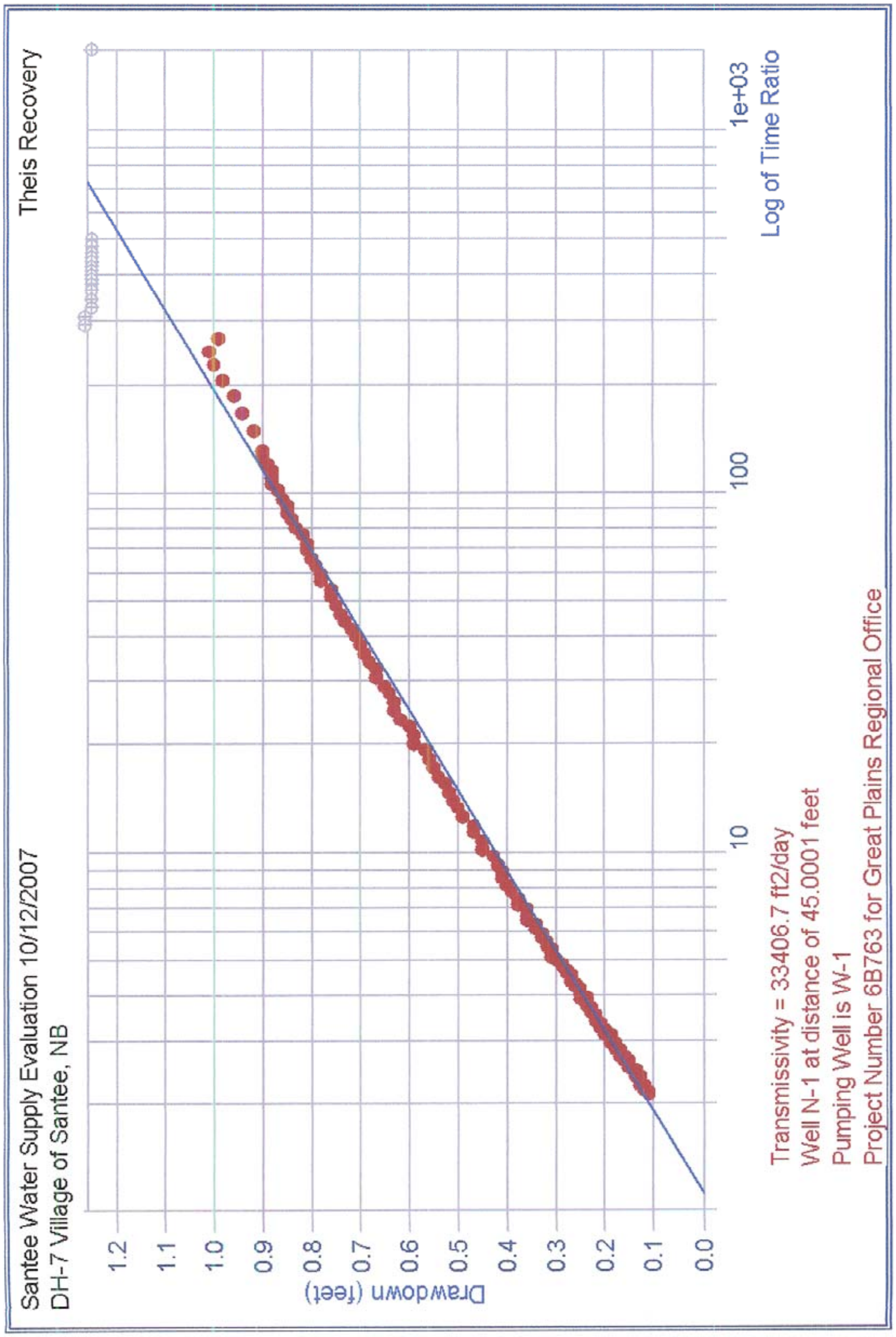
Bureau of Reclamation Denver Technical Sevice Center Water Resources Planning and Operations Support Group 86-68210	Pumping Test Analysis Report Project: Santee Water Supply Test Number: 6B763 Client: Great Plains Office

Location: Santee Reserevation, Nebraska	Pumping Test: 24 Hour Pump Test	Pumping Well: Well 1
Test Conducted by: Bob Schieffer		Test Date: 10/19/2007
Analysis Performed by: W Robert Talbot	N-1 Recovery	Analysis Date: 12/17/2007
Aquifer Thickness: 26.00 ft	Discharge: variable, average rate 425 [U.S. gal/min]	



Calculation after Theis & Jacob

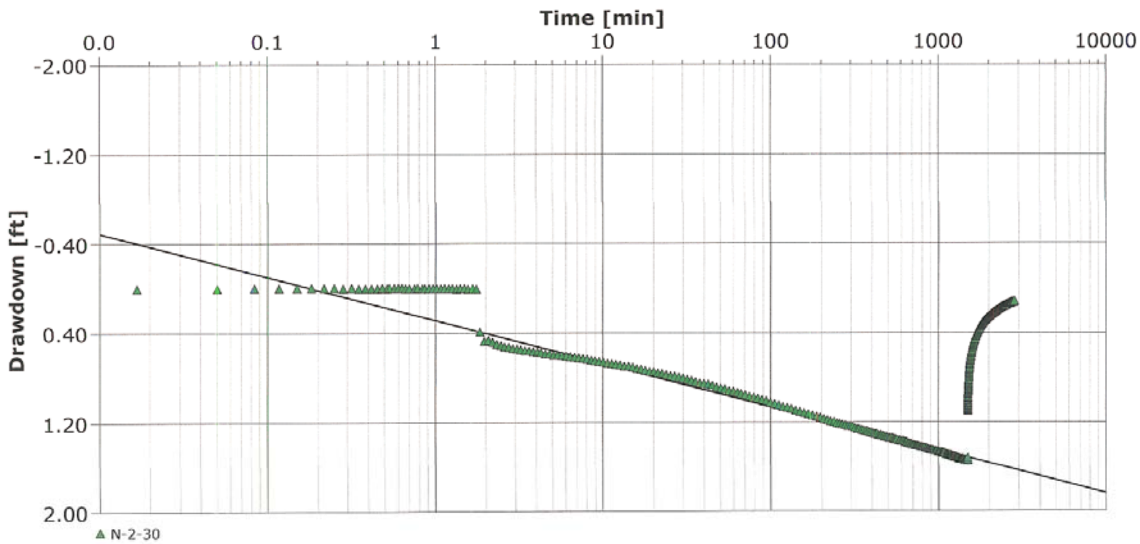
Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]
N-1	3.22×10^4	1.24×10^3	45.0



Santee Water Supply Evaluation 10/12/2007
DH-7 Village of Santee, NB
Theis Recovery
Drawdown (feet)
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
10
100
1e+03
Log of Time Ratio
Transmissivity = 33406.7 ft2/day
Well N-1 at distance of 45.0001 feet
Pumping Well is W-1
Project Number 6B763 for Great Plains Regional Office

Bureau of Reclamation **Denver Technical Sevice Center** **Water Resources Planning and Operations Support Group** **86-68210**	**Pumping Test Analysis Report** Project: Santee Water Supply Test Number: 6B763 Client: Great Plains Office

Location: Santee Reserevation, Nebraska	Pumping Test: 24 Hour Pump Test	Pumping Well: Well 1
Test Conducted by: Bob Schieffer		Test Date: 10/19/2007
Analysis Performed by: W Robert Talbot	N-2-30 Cooper/Jacob	Analysis Date: 12/17/2007
Aquifer Thickness: 26.00 ft	Discharge: variable, average rate 425 [U.S. gal/min]	

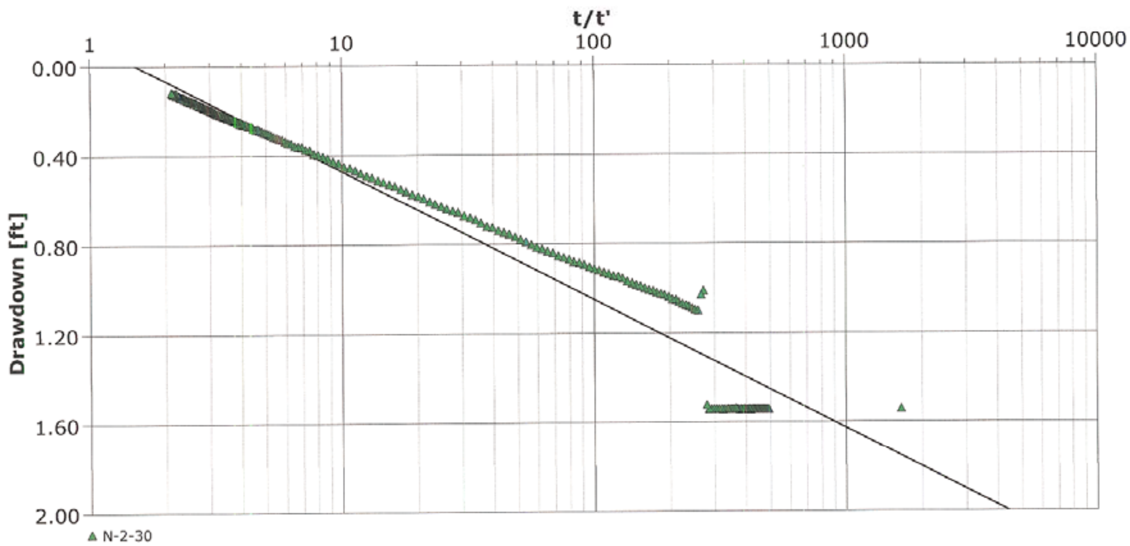


Calculation after Cooper & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Storage coefficient	Radial Distance to PW [ft]	
N-2-30	3.86×10^4	1.48×10^3	1.59×10^{-2}	26.5	

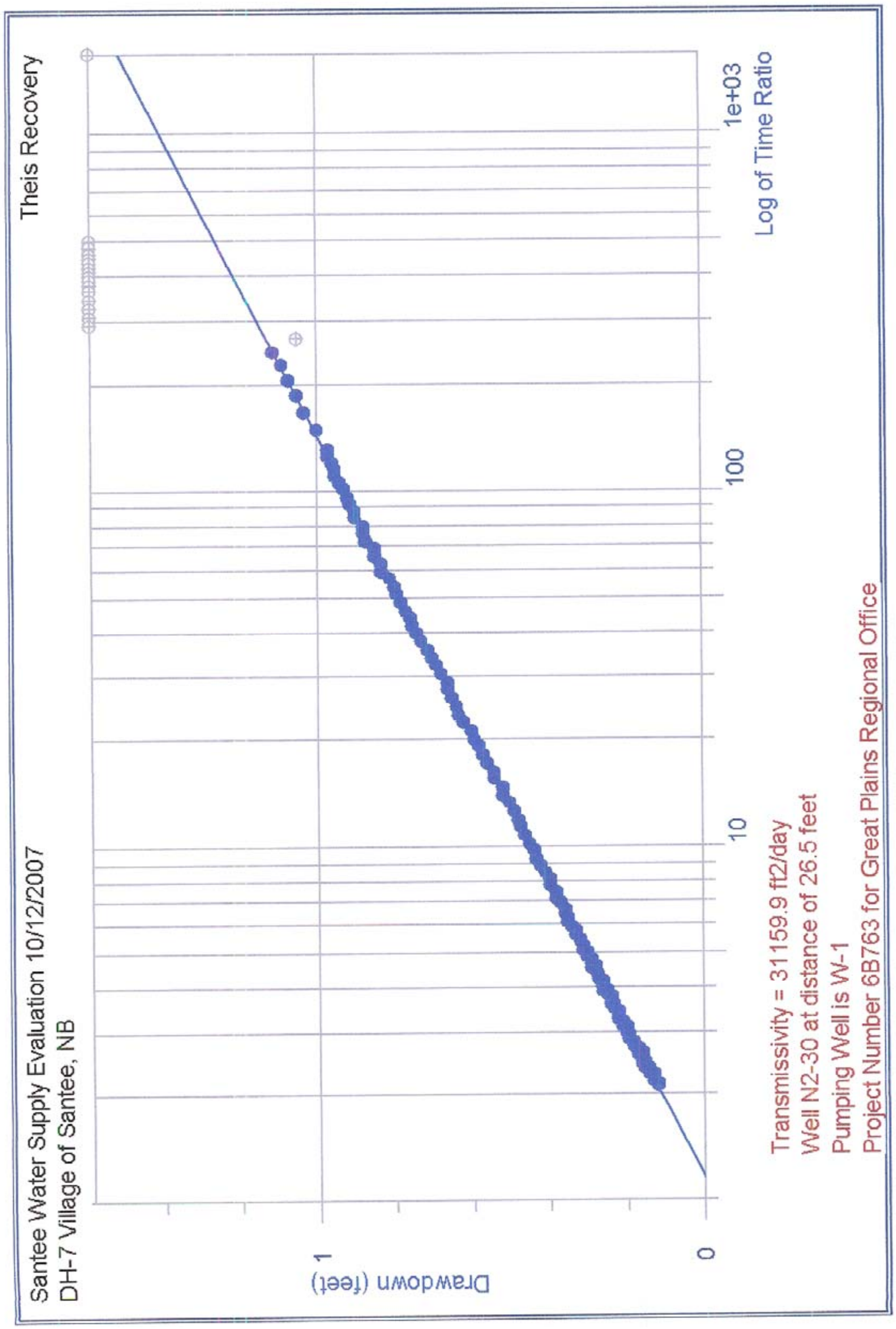
Bureau of Reclamation Denver Technical Sevice Center Water Resources Planning and Operations Support Group 86-68210	Pumping Test Analysis Report Project: Santee Water Supply Test Number: 6B763 Client: Great Plains Office

Location: Santee Reserevation, Nebraska	Pumping Test: 24 Hour Pump Test	Pumping Well: Well 1
Test Conducted by: Bob Schieffer		Test Date: 10/19/2007
Analysis Performed by: W Robert Talbot	N-2-30 Recovery	Analysis Date: 12/17/2007
Aquifer Thickness: 26.00 ft	Discharge: variable, average rate 425 [U.S. gal/min]	



Calculation after Theis & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]	
N-2-30	2.59×10^4	9.97×10^2	26.5	



Santee Water Supply Evaluation 10/12/2007
DH-7 Village of Santee, NB
Theis Recovery
Drawdown (feet)
0
1
10
100
1e+03
Log of Time Ratio
Transmissivity = 31159.9 ft2/day
Well N2-30 at distance of 26.5 feet
Pumping Well is W-1
Project Number 6B763 for Great Plains Regional Office

Bureau of Reclamation Denver Technical Sevice Center Water Resources Planning and Operations Support Group 86-68210	Pumping Test Analysis Report Project: Santee Water Supply Test Number: 6B763 Client: Great Plains Office

Location: Santee Reserevation, Nebraska	Pumping Test: 24 Hour Pump Test	Pumping Well: Well 1
Test Conducted by: Bob Schieffer		Test Date: 10/19/2007
Aquifer Thickness: 26.00 ft	Discharge: variable, average rate 425 [U.S. gal/min]	

	Analysis Name	Analysis Performed by	Analysis Date	Method name	Well	T [ft²/d]	K [ft/d]	S
1	W-1 - Cooper/Jacob I	W Robert Talbot	12/11/2007	Cooper & Jacob I	Well 1	5.15×10^{4}	1.98×10^{3}	1.00×10^{-20}
2	W-1 - Theis w/Jacob Cor	W Robert Talbot	12/17/2007	Theis with Jacob Correcti	Well 1	5.01×10^{4}	1.93×10^{3}	2.05×10^{-20}
3	N-2-30 Cooper/Jacob	W Robert Talbot	12/17/2007	Cooper & Jacob I	N-2-30	3.86×10^{4}	1.48×10^{3}	1.59×10^{-2}
4	N-1 Cooper/Jacob	W Robert Talbot	12/17/2007	Cooper & Jacob I	N-1	4.06×10^{4}	1.56×10^{3}	2.72×10^{-2}
5	E-1 Cooper/Jacob	W Robert Talbot	12/17/2007	Cooper & Jacob I	E-1	4.73×10^{4}	1.82×10^{3}	1.67×10^{-2}
6	E-2 Cooper/Jacob	W Robert Talbot	12/17/2007	Cooper & Jacob I	E-2	5.41×10^{4}	2.08×10^{3}	1.84×10^{-2}
7	N-1 Recovery	W Robert Talbot	12/17/2007	Theis Recovery	N-1	3.22×10^{4}	1.24×10^{3}	
8	N-2-30 Recovery	W Robert Talbot	12/17/2007	Theis Recovery	N-2-30	2.59×10^{4}	9.97×10^{2}	
9	E-1 Recovery	W Robert Talbot	12/17/2007	Theis Recovery	E-1	3.05×10^{4}	1.17×10^{3}	
10	E-2 Recovery	W Robert Talbot	12/17/2007	Theis Recovery	E-2	4.18×10^{4}	1.61×10^{3}	
11	W-1 - Recovery	W Robert Talbot	12/18/2007	Cooper & Jacob I	Well 1	5.49×10^{4}	2.11×10^{3}	4.84×10^{-23}
					Average	4.25×10^{4}	1.63×10^{3}	1.12×10^{-2}

APPENDIX I

FINAL DESIGN DATA NEEDS

Appendix I summarizes the existing data that relates to the evaluation of the infiltration gallery proposal that was found during a brief and limited review of existing data on the water resources and geologic setting of the Santee Indian Reservation. This Appendix also summarizes the data that would need to be collected in order to complete a final design of either an infiltration galley of some type or more traditional vertical production wells.

Data needed for final design of an infiltration gallery system or vertical production wells	**Existing data (see Reference section)**	**Data collection needs**
Hydraulic conductivity	Non-existent for the Missouri River (MR) alluvium near the Village of Santee – or within the Missouri River floodplain in the vicinity of Lewis and Clark Lake. Estimates based on gradation analysis of drill hole samples are available.	Need to conduct aquifer testing at a selected site to get a representative idea of the hydraulic conductivity of the MR alluvial sediments.
Storativity	Non-existent for the MR alluvium near the Village of Santee – or within the MR floodplain in the vicinity of Lewis and Clark Lake.	Need to conduct aquifer testing at a selected site to get a representative idea of the storativity of the MR alluvial sediments.
Porosity & Specific Yield	Non-existent for the MR alluvium near the Village of Santee – or within the MR floodplain in the vicinity of Lewis and Clark Lake.	Need to conduct aquifer testing at a selected site to get a representative idea of the hydraulic properties of the MR alluvial sediments.
Thickness of alluvial sediments	Previous studies indicate that the Missouri River Valley (MRV) in the vicinity of the Santee Indian Reservation is between 2 and 4 miles wide: a drilling program conducted 2000 - 3000 feet upstream of the Village of Santee found a thickness of 92 feet of sediment at a distance of 700 feet from the bluffs forming the valley wall, and 39 feet of sediment at a distance of 350 feet from the valley wall: one other report indicated that 8 – 10 miles upstream of the Village of Santee the MR alluvial sediments were 130+ feet thick and that this was ‘probably’ representative of the MRV in that reach of the MR.	A good indication that a sufficient thickness of materials may be present, but more detail is needed and a series of borings at several potential sites would need to be installed to determine the thickness over a wider area and to determine the material properties across the sites. **Exploratory drilling in the area of the Village of Santee indicate that MR alluvial sediments range in thickness from 37 feet to 92 feet.

Lateral extent of alluvial sediments	Previous studies indicate that the alluvial sediments go from ‘0’ thickness at the MRV edges to something near or greater than 130 feet in the center of the MRV, and that the valley is 2 to 4 miles wide.	This indicates that the lateral extent of the alluvial sediments is probably adequate for infiltration galleries.
General material properties	Studies indicate that the MR alluvial sediments are usually fine or fine to coarse sands with interbeds/layers of silts and clays; these are fairly consistent throughout the MRV.	These studies indicate that the nature of the sediments is relatively consistent; however, to evaluate and/or design an infiltration gallery, site details are needed (because of the nature of alluvial sediments and the processes by which they are deposited, while the regional nature of the sediments may be relatively consistent, the local nature may vary considerably). **Exploratory drilling in the area of the Village of Santee indicate that MR alluvial sediments consist of silty sand, sandy silt, poorly graded sand, and near the bottom of the section there are sandy gravels and poorly graded gravels. A lean clay is often capping the section.
Continuous soil core	Non-existent.	For the proper design of a Ranney-type radial system, a continuous core at the site of the well is required.

APPENDIX J

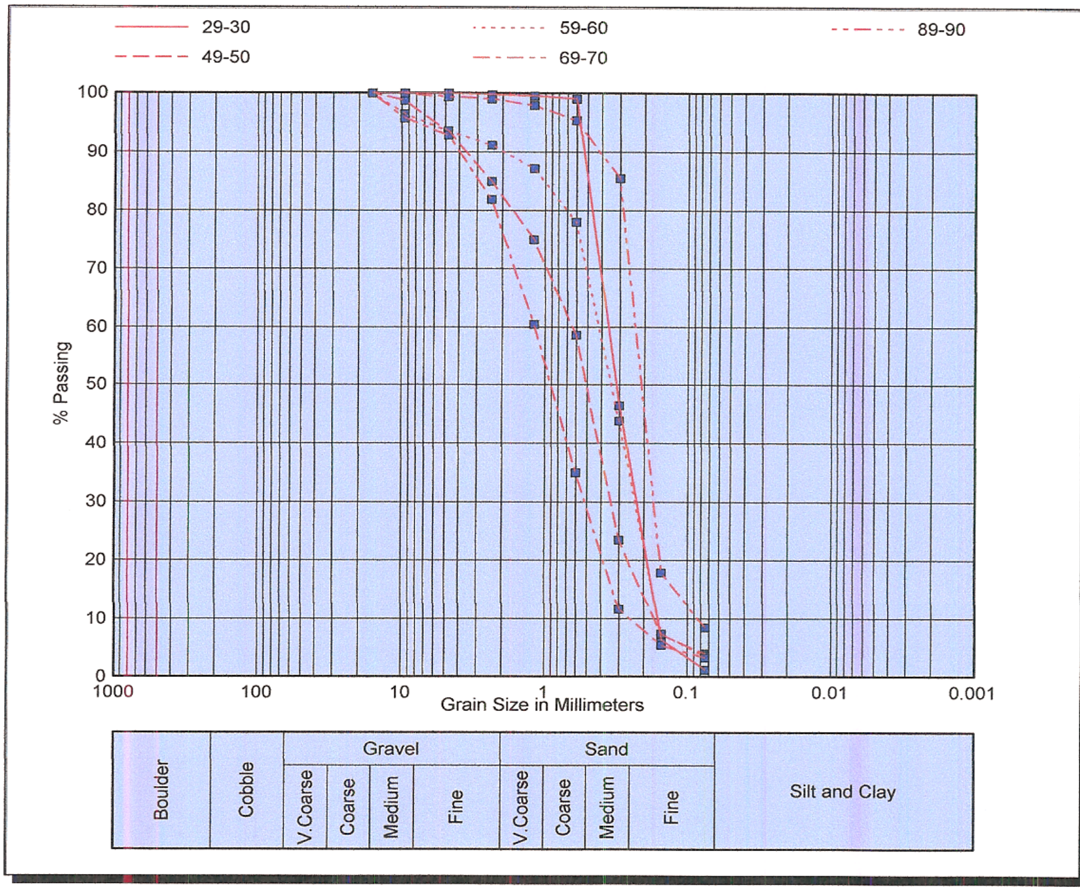
GRADATION CURVES

and

CONDUCTIVITY VALUES

Well Ident
DH-1

Name

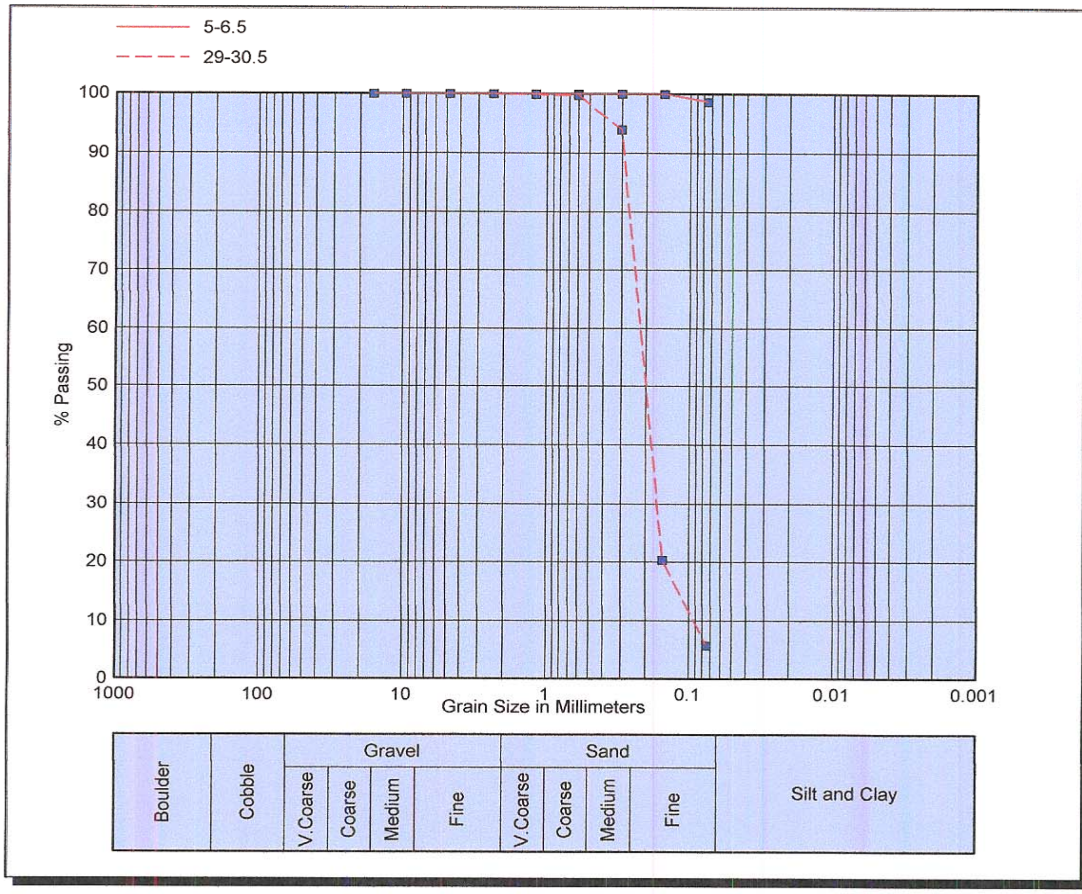


Sieve Sizes [mm]	29-30	49-50	59-60	69-70	89-90
0.075	1.30	4.10	3.70	3.30	8.50
0.150	6.30	7.30	7.50	5.50	18.00
0.300	46.50	23.60	43.90	11.70	85.50
0.600	99.10	58.60	78.00	35.00	95.50
1.180	99.60	75.00	87.20	60.50	98.00
2.360	99.80	85.10	91.20	81.90	99.10
4.750	100.00	93.60	93.70	92.90	99.50
9.500	100.00	98.80	96.50	95.80	100.00
16.000	100.00	100.00	100.00	100.00	100.00

Well Ident

DH-2

Name



Sieve Sizes [mm]	5-6.5	29-30.5
0.075	98.70	5.80
0.150	100.00	20.40
0.300	100.00	94.00
0.600	100.00	99.80
1.180	100.00	99.90
2.360	100.00	100.00
4.750	100.00	100.00
9.500	100.00	100.00
16.000	100.00	100.00

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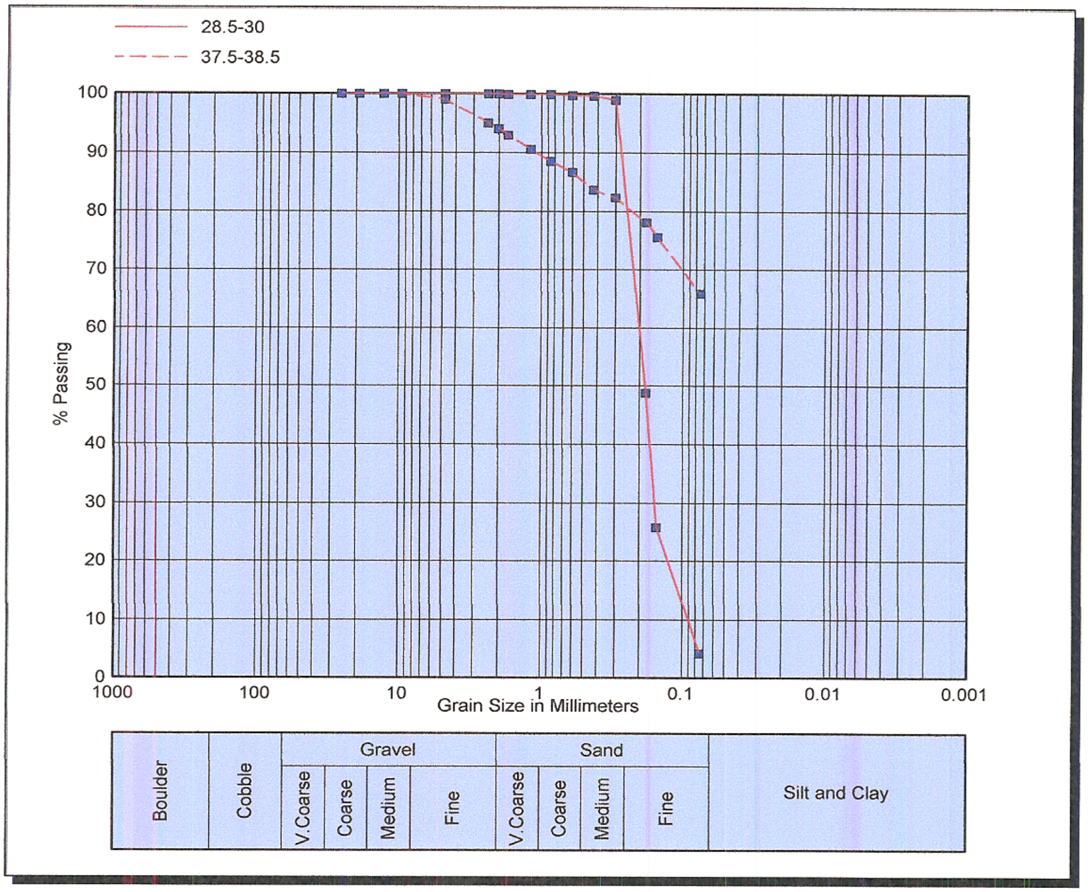
Well Ident

DH-3

Name



Sieve Sizes [mm]	28.5-30	37.5-38.5
0.075	4.30	65.90
0.150	25.90	75.60
0.180	48.90	78.10
0.300	99.00	82.40
0.425	99.70	83.70
0.600	99.80	86.70
0.850	99.90	88.60
1.180	99.90	90.60
1.700	99.90	93.00
2.000	100.00	94.10
2.360	100.00	95.10
4.750	100.00	99.10
9.500	100.00	100.00
12.700	100.00	100.00

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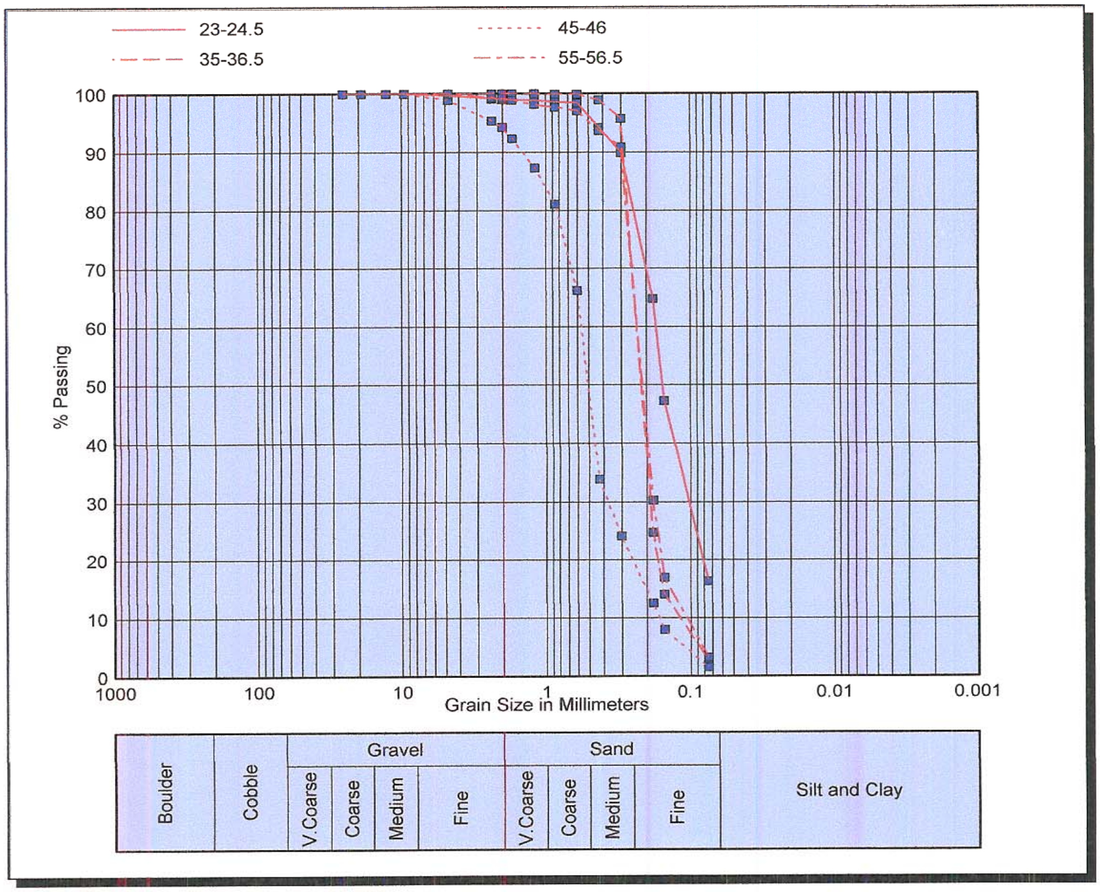
Well Ident

DH-4

Name



Sieve Sizes [mm]	23-24.5	35-36.5	45-46	55-56.5
0.075	16.40	2.90	1.60	3.30
0.150	47.40	14.10	8.10	17.00
0.180	64.80	24.70	12.60	30.30
0.300	89.90	95.80	24.20	91.00
0.425	94.30	99.00	33.90	93.80
0.600	98.50	99.90	66.30	97.20
0.850	98.60	99.90	81.20	97.70
1.180	98.80	100.00	87.40	98.30
1.700	99.00	100.00	92.40	99.00
2.000	99.10	100.00	94.40	99.30
2.360	99.20	100.00	95.50	99.40
4.750	99.70	100.00	99.00	100.00
9.500	100.00	100.00	100.00	100.00
12.700	100.00	100.00	100.00	100.00

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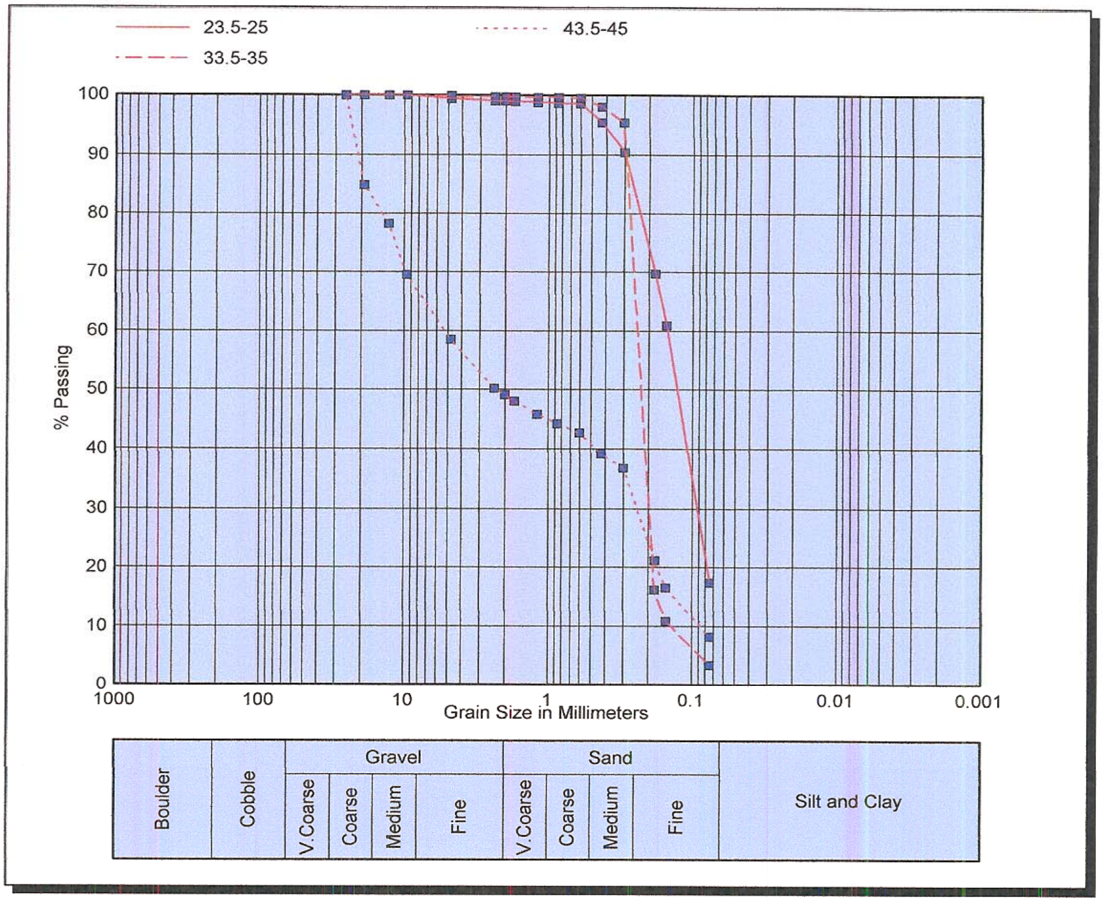
Well Ident

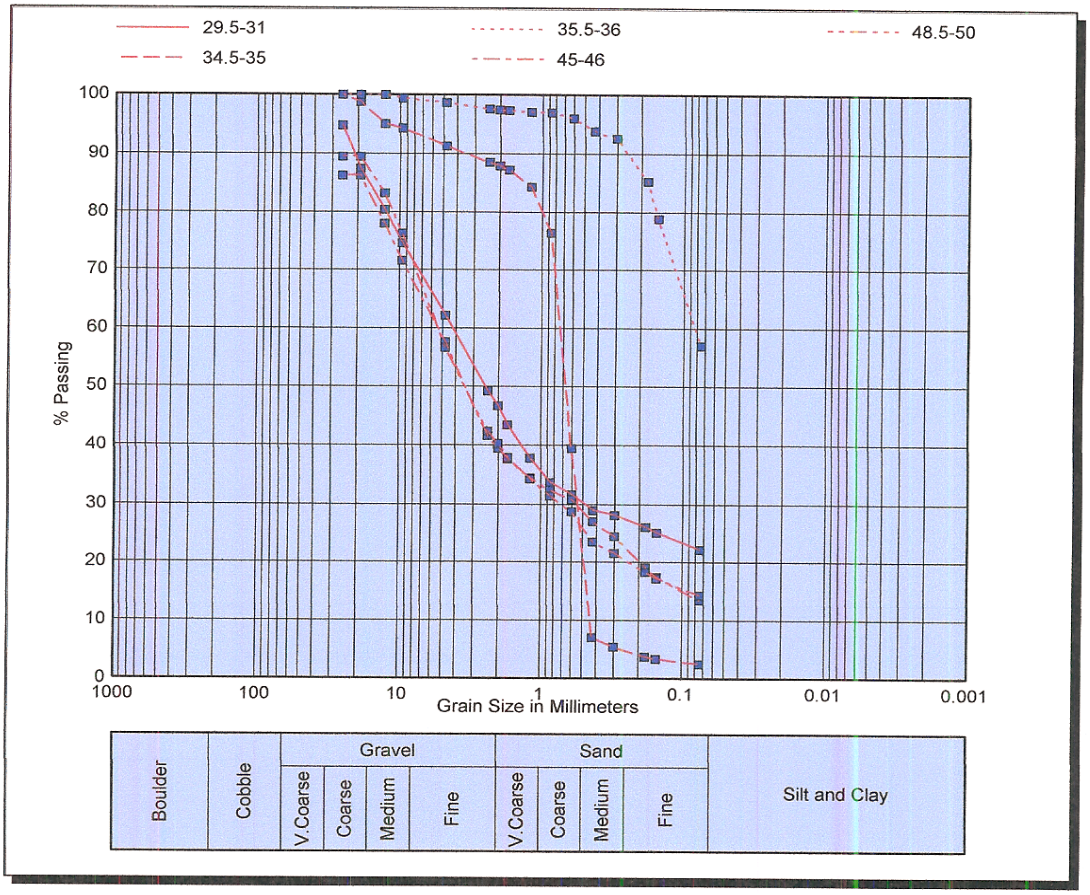
DH-5

Name



Sieve Sizes [mm]	23.5-25	33.5-35	43.5-45
0.075	17.50	3.50	8.30
0.150	60.90	10.90	16.60
0.180	69.80	16.30	21.30
0.300	90.50	95.40	36.90
0.425	95.40	98.10	39.30
0.600	98.60	99.60	42.80
0.850	98.70	99.70	44.40
1.180	98.80	99.70	45.90
1.700	99.00	99.80	48.10
2.000	99.10	99.80	49.20
2.360	99.10	99.80	50.30
4.750	99.50	99.90	58.50
9.500	100.00	100.00	69.60
12.700	100.00	100.00	78.30

Well Ident	Name
DH-6a	

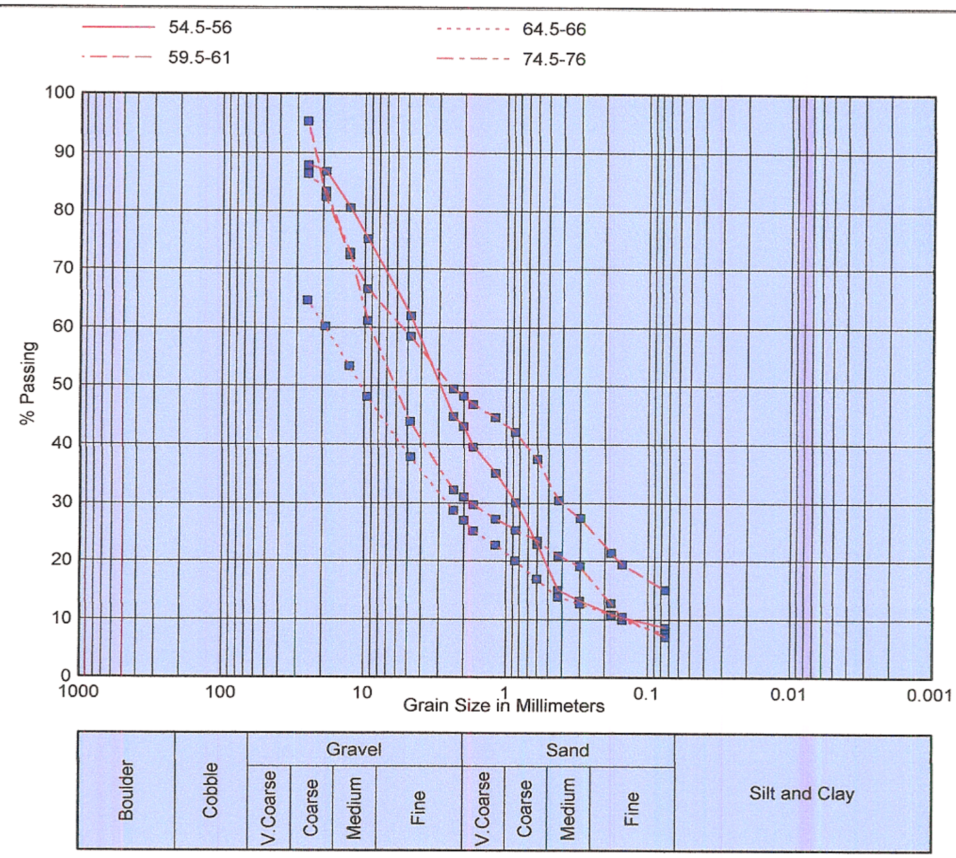


Sieve Sizes [mm]	29.5-31	34.5-35	35.5-36	45-46	48.5-50
0.075	22.20	2.60	57.10	13.50	14.40
0.150	25.10	3.40	78.90	17.50	17.30
0.180	26.10	3.80	85.30	19.20	18.40
0.300	28.10	5.50	92.70	24.50	21.60
0.425	29.00	7.10	93.90	27.10	23.50
0.600	31.60	39.50	96.10	30.80	28.70
0.850	33.70	76.50	97.00	32.40	31.40
1.180	37.80	84.30	97.20	34.50	34.30
1.700	43.50	87.20	97.40	37.70	38.00
2.000	46.80	88.00	97.50	39.50	40.40
2.360	49.30	88.50	97.60	41.70	42.40
4.750	62.20	91.30	98.70	57.70	56.70
9.500	74.60	94.40	99.50	71.60	76.30
12.700	80.40	95.10	100.00	78.00	83.20

Well Ident

DH-6

Name

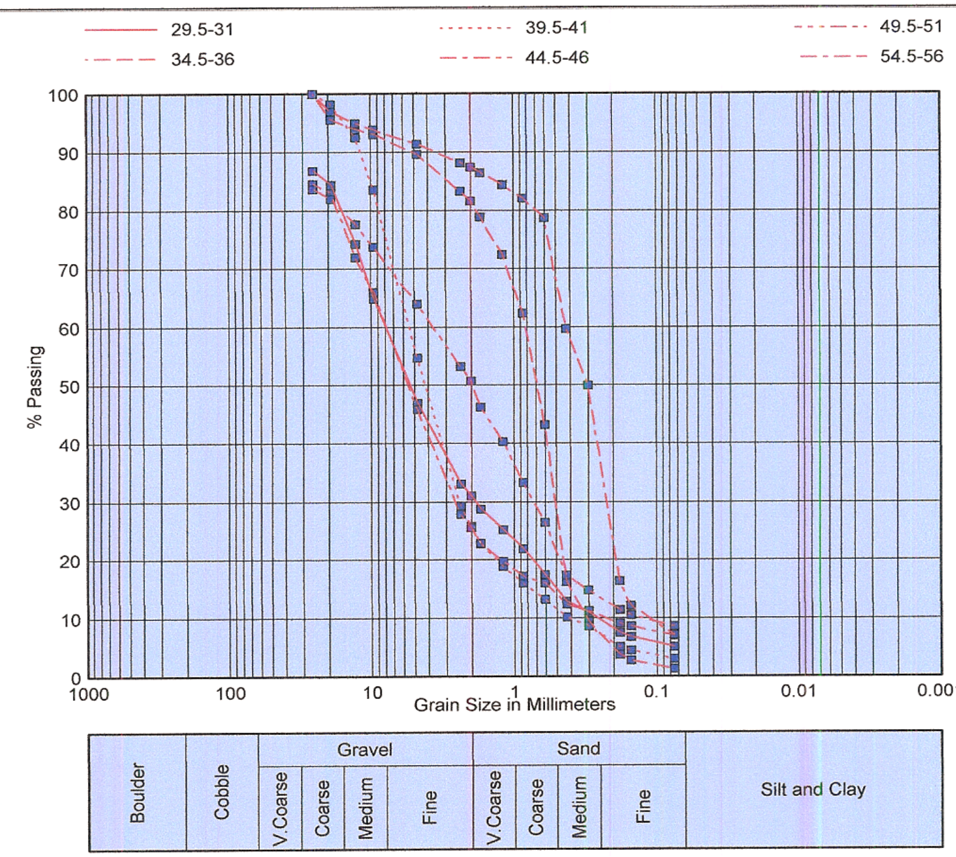


Sieve Sizes [mm]	54.5-56	59.5-61	64.5-66	74.5-76
0.075	8.70	15.20	7.70	7.10
0.150	10.40	19.60	10.00	10.60
0.180	11.00	21.50	10.80	12.90
0.300	13.30	27.40	12.80	19.20
0.425	15.10	30.50	14.00	21.00
0.600	23.00	37.60	17.00	23.50
0.850	30.10	42.20	20.20	25.40
1.180	35.20	44.70	22.80	27.30
1.700	39.60	46.90	25.30	29.70
2.000	43.20	48.40	27.10	31.10
2.360	44.90	49.60	28.70	32.30
4.750	62.00	58.50	37.90	44.00
9.500	75.20	66.70	48.20	61.20
12.700	80.60	72.50	53.50	73.00

Well Ident

DH-7

Name



Sieve Sizes [mm]	29.5-31	34.5-36	39.5-41	44.5-46	49.5-51	54.5-56
0.075	5.10	1.40	3.10	7.10	8.60	7.20
0.150	6.80	2.80	4.60	8.60	10.60	12.20
0.180	7.60	3.80	5.20	9.20	11.40	16.40
0.300	10.90	9.50	8.70	11.30	14.80	50.10
0.425	12.90	16.30	10.20	12.40	17.40	59.70
0.600	17.50	43.30	13.20	16.10	26.50	78.80
0.850	22.00	62.40	16.10	17.30	33.30	82.10
1.180	25.30	72.50	18.90	19.80	40.40	84.40
1.700	28.80	78.90	22.80	23.00	46.30	86.50
2.000	31.00	81.60	25.90	25.60	50.80	87.50
2.360	33.10	83.40	29.30	27.90	53.30	88.20
4.750	47.00	89.70	54.80	46.00	64.00	91.50
9.500	64.80	93.10	83.60	66.10	73.80	93.90
12.700	74.30	94.00	92.60	72.00	77.70	95.00

Table of Conductivity Values. All samples were obtained below the water table. N/A indicates that the gradation curve did not reach the D_{20} value. Since all gradations stopped at the #200 sieve, the D_{20} value for these samples would be in clays as opposed to being in fine sands or larger. (***K*** = hydraulic conductivity, values are rounded to nearest 100ths or 1000ths)

Drill Hole #	Interval (ft)	D20 (mm)	***K*** (gal/day/ft^2)	***K*** (ft/min)
DH-1	29.0-30.0	.19	193.86	0.018
	49.0-50.0	.23	236.95	0.022
	59.0-60.0	.19	193.86	0.018
	69.0-70.0	.38	8,616.30	0.800
	89.0-90.0	.16	107.70	0.010
DH-1 Average		**.23**	**236.95**	**0.022**
DH-2	5.0-6.5	N/A	----	----
	29.0-30.5	.15	86.16	0.008
DH-2 Average		**---**	**----**	**---**
DH-3	28.5-30.0	.13	64.62	0.006
	37.5-38.5	N/A	----	----
DH-3 Average		**---**	**---**	**---**
DH-4	23.0-24.5	.08	21.54	0.002
	35.0-36.5	.22	226.18	0.021
	45.0-46.0	.29	441.59	0.041
	55.0-56.5	.24	247.72	0.023
DH-4 Average	**(last 3 only)**	**.25**	**301.57**	**0.028**
DH-5	23.5-25.0	.08	21.54	0.002
	33.5-35.0	.19	193.86	0.018
	43.5-45.0	.18	161.56	0.015
DH-5 Average	**(last 2 only)**	**.19**	**193.86**	**0.018**
DH-6	29.5-31.0	N/A	----	----
	34.5-35.0	.53	1,723.26	0.160
	35.5-36.0	N/A	----	----
	45.0-46.0	.29	441.59	0.041
	48.5-50.0	.28	430.81	0.040
	54.5-56.0	.56	2,046.37	0.190
	59.5-61.0	.22	247.72	0.023
	64.5-66.0	.85	5,385.19	0.500
	74.5-76.0	.39	947.79	0.088
DH-6 Average		**.38**	**1,098.58**	**0.102**
DH-7	29.5-31.0	.72	3,446.52	0.320
	34.5-36.0	.35	656.99	0.061
	39.5-41.0	1.3	17,232.61	1.600
	44.5-46.0	1.2	16,155.57	1.500
	49.5-51.0	.56	2,046.37	0.190
	54.5-56.0	.23	236.95	0.022
DH-7 Average		**.47**	**3,769.63**	**0.350**

Conductivity values are based on the USBR Method of estimating conductivity from a gradation curve analysis relationship developed by Creager, Justin, and Hinds (1945) in which the conductivity of a material is related to the nominal particle size (in mm) that represents 20% of the sample smaller than that size – also termed the D_{20} value. On a gradation curve, the D_{20} value would be represented by the grain size for 20% of the sample passing a particular sieve size. The relationship is not as clear-cut for D_{20} values much above 2.0 mm, so D_{20} values much greater than 2.0+/- mm were not included in the averages.

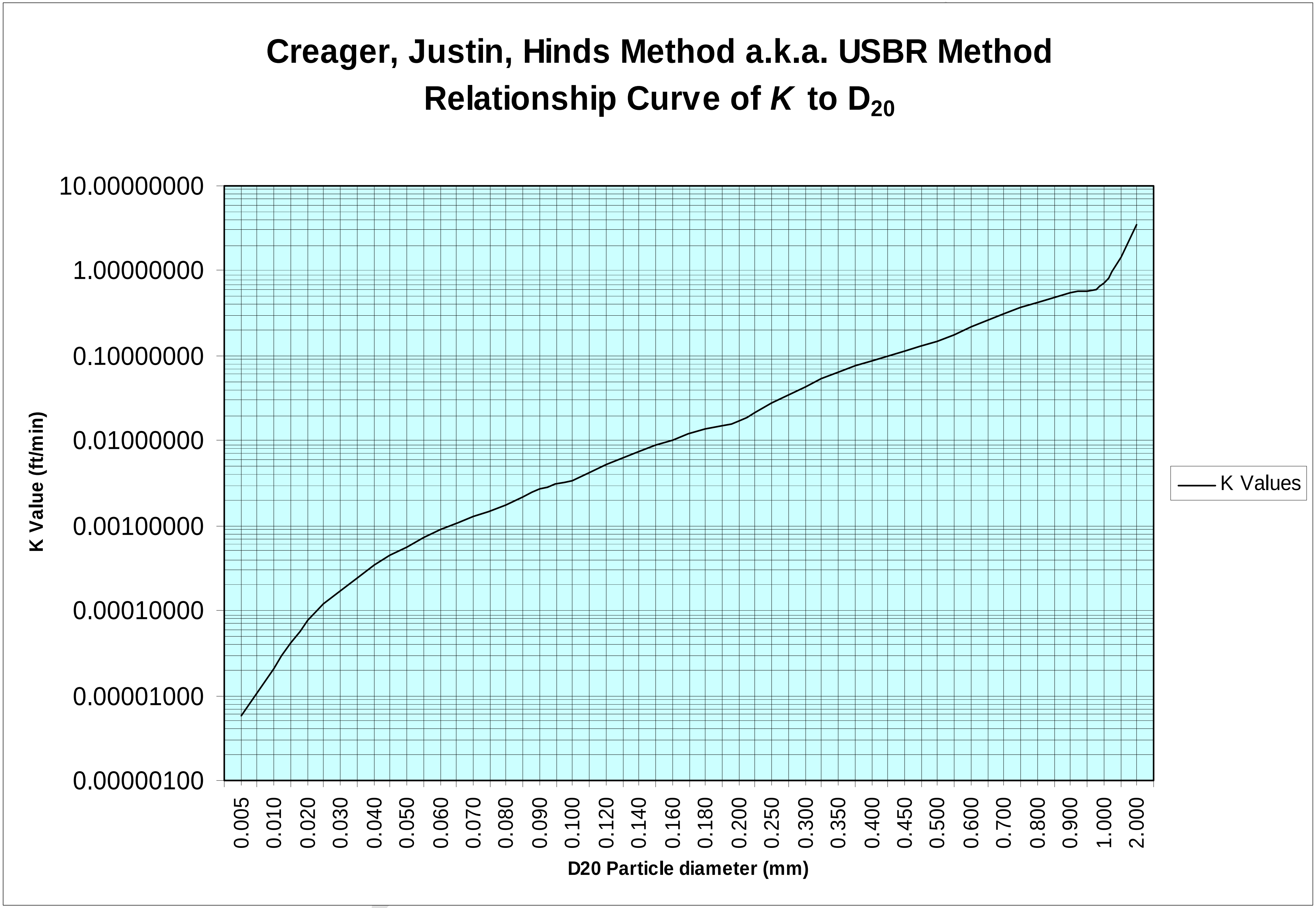
In most cases, the 20% passing grain size does not exactly match a standard sieve size, so the D_{20} value has to be interpolated from the gradation curve – where the grain size axis is on a log scale. This estimated D_{20} value is then used in the Creager, Justin, and Hinds curve (see following discussion and the curve on next page) to find the estimated value of *K* in ft/min. So the values of *K* in the above table are obtained by visually estimating the value on a log scale of where the relationship curve intersects the visually estimated value of D_{20} from a gradation curve.

Additionally, any stratification in the sample that might remain after being collected is lost in the process of being sieved, so any preferential flow paths that might influence the conductivity values are lost. Accordingly, the conductivity values obtained by this method are only an estimate to be used for comparative purposes or to determine an initial range of values for a material. Aquifer testing is required to obtain accurate values of conductivities for undisturbed, in situ aquifer materials.

Not to confuse matters, but the D_{20} notation only applies to gradation curves that plot the material that is sieved as 'percent passing'. Gradation curves are also plotted as 'percent retained'. On a 'percent retained' plot, the particle size of the D_{80} value would be used to obtain the estimated *K* value from the USBR Method.

Creager, William P., Justin, Joel D., and Hinds, Julian, 1945, "Engineering for Dams"

Creager, Justin, and Hinds discuss the various factors that influence the value of *K* (Creager, Justin, and Hinds, 1962, Vol. 2, pgs 647 – 650). These factors include a) the size and grading of particles, b) the density of the material as measured by porosity (or void ration), c) the temperature of the water, d) the presence of organic matter, and e) the presence of colloidal material. They state "The value of *K* is of greatest importance for gravels, sands, and silts. For the clays it is so small anyway that its exact value in not usually a matter of great importance." They further state "With many alluvial deposits the permeability coefficient in a horizontal direction may be several times that in a vertical direction . . ." They also present an empirical table of 'Coefficient of Permeability' versus the 20% grain size (mm) for four commonly used systems of units. When plotted on a semi-log scale, their table results in the graph on the following page. The authors state "The table represents the approximate average conditions met in the field for water-deposited materials and is based on several hundred percolation tests at Zanesville, fort Peck, Kingsley, and Quabbin Dams. As already indicated, no degree of accuracy can be expected unless the permeability coefficient is determined by carefully controlled experiments." Note that the units of *K* in the following graph are based on the authors' Coefficient of Permeability in ft/min data. Divide ft/min by 60 to get ft/sec; multiple it by 10,770.38 to get gpd/ft^2 (gallons per day per foot squared).


Creager, Justin, Hinds Method a.k.a. USBR Method
Relationship Curve of K to D20
K Value (ft/min)
10.00000000
1.00000000
0.10000000
0.01000000
0.00100000
0.00010000
0.00001000
0.00000100
0.005
0.010
0.020
0.030
0.040
0.050
0.060
0.070
0.080
0.090
0.100
0.120
0.140
0.160
0.180
0.200
0.250
0.300
0.350
0.400
0.450
0.500
0.600
0.700
0.800
0.900
1.000
2.000
D20 Particle diameter (mm)
K Values

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