STONY CREEK GROUNDWATER RECHARGE INVESTIGATION, 2003 GLENN COUNTY, CALIFORNIA

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Prepared by the California Department of Water Resources
Northern District Groundwater Section
in Cooperation with
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This summary report was prepared by the Department of Water Resources, Northern District, Groundwater Section, on behalf of the Glenn County Department of Agriculture. It was prepared under the direct supervision of Toccoy Dudley, Chief of the Northern District Groundwater Section, Registered Geologist No. 3732, and was written by Kelly Staton, Registered Geologist No. 7501, in accordance with the provisions of the Geologist and Geophysicists Act of the State of California.

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Table of Contents

Introduction 5
Background 5
Scope of Work 6
Methods 7
Data collection. 7
Groundwater Level Measurements. 9
Surface Water Measurements/Staff Gauge Readings. 9
Staff Gauge Readings. 9
Return Flow Measurements 9
Temperature Data. 9
Results 10
Groundwater Level Response. 10
Study Area. 10
Reaches. 10
Individual wells. 11
Groundwater in Storage. 16
Inflow. 16
Outflow. 16
Change in Storage. 16
Water Balance Equation. 17
Discussion. 18
Groundwater Flow Velocity. 19
Temperature Data 22
Flow Rate for Optimal Groundwater Recharge. 22
Description of the Hydrogeologic System 24
Regional Geology. 24
Tehama Formation. 24
Tuscan Formation. 24
Riverbank Formation. 25
Modesto Formation. 25
Alluvium. 25
Local Geology and Hydrogeology. 25
Stony Creek Fan Alluvium. 26

List of Figures

Figure 1. Location Map of Project Area 6
Figure 2. Black Butte Reservoir Release Schedule. 7
Figure 3. Location of Monitoring Wells, Cross-Section and Return Flow Sites. 8
Figure 4. Groundwater Level Hydrograph of 22N03W05F02M. 13
Figure 5. Groundwater Level Hydrograph of 22N03W01R03M. 13
Figure 6. Groundwater Level Hydrograph of 22N02W15C05M. 14
Figure 7. Groundwater Level Hydrograph of 22N02W36D01M. 14

DRAFT

Figure 8. Groundwater Level Hydrograph of 21N02W01F04M. 15
Figure 9. Groundwater Level Hydrograph of 21N01W04N01M. 15
Figure 10. Groundwater Levels and Flow Data for 22N02W36D01M. 20
Figure 11. Groundwater Levels and Flow Data for 21N02W01F04M. 21
Figure 12. Groundwater Levels and Flow Data for 22N02W15C05M. 21
Figure 13. Groundwater Levels and Flow Data for 21N03W01R03M. 22
Figure 14. Temperature data for well 22N03W01R03M and Stony Creek at TCC. 23
Figure 15. Regional Geologic Map with Stony Creek Fan Boundary. 27

List of Tables

Table 1. Cross-Section Site Names and Acronyms. 9
Table 2. Groundwater Surface Elevation and Flow, by Reach and by Date. 12
Table 3. Potential Groundwater in Storage. 17
Table 4. Water Balance. 17
Table 5. Estimates of Groundwater Velocity in Shallow Wells 19

Appendices

Appendix A: Cross-sectional Area vs. Flow 28
Appendix B: Groundwater Level Hydrographs 51
Appendix C: Surface Water Flow Data 55

DRAFT

Introduction

A pilot recharge project was performed during summer and fall of 2003 to study the hydraulic relationship between surface water flow in Stony Creek and recharge to groundwater in the surrounding Stony Creek Fan alluvium. During the study, groundwater and surface water parameters were measured in a cooperative effort by local, state and federal agencies. Following completion of the project, data were analyzed to determine the flow rate in Stony Creek that would optimize recharge into the alluvial aquifer system.

Background

Stony Creek flows through the northern part of Glenn County from the foothills in the western part of the county, across the valley floor to the east where it discharges into the Sacramento River. Black Butte Reservoir, which is located on Stony Creek at the base of the western foothills, is operated by the United States Bureau of Reclamation (USBR) for water supply in the spring through fall months and by the United States Army Corp of Engineers for flood control in the winter months. The project area is shown in Figure 1.

Black Butte Reservoir has a total capacity of 136,000 acre-feet. By November of every year, the volume must be reduced to a minimum of 20,000 acre-feet for flood reservation space. Because of the flood reservation requirement, it is common for water to be released by the USBR over and above the minimum instream flow requirements of 30 cubic feet per second (cfs). These releases are typically made in the late fall to maximize summer recreation opportunities in the reservoir.

In June 2003, the USBR determined that approximately 37,000 acre-feet of water in Black Butte Reservoir should be released to achieve the required November flood reservation space. During a Glenn County Technical Advisory Committee meeting, the Bureau reported that this water could be made available to test aquifer recharge strategies. A pilot recharge project was undertaken from July to November, 2003 to study the relationship between the controlled release of surface water in Stony Creek and groundwater recharge.

The following entities were involved in this project:

- United States Bureau of Reclamation (USBR)
- Glenn County Technical Advisory Committee (TAC)
- Glenn County Department of Agriculture (GC)
- Department of Water Resources (DWR),
- Department of Fish and Game (DFG)
- Orland Unit Water User's Association (OUWUA)
- Orland-Artois Water District (OAWD)

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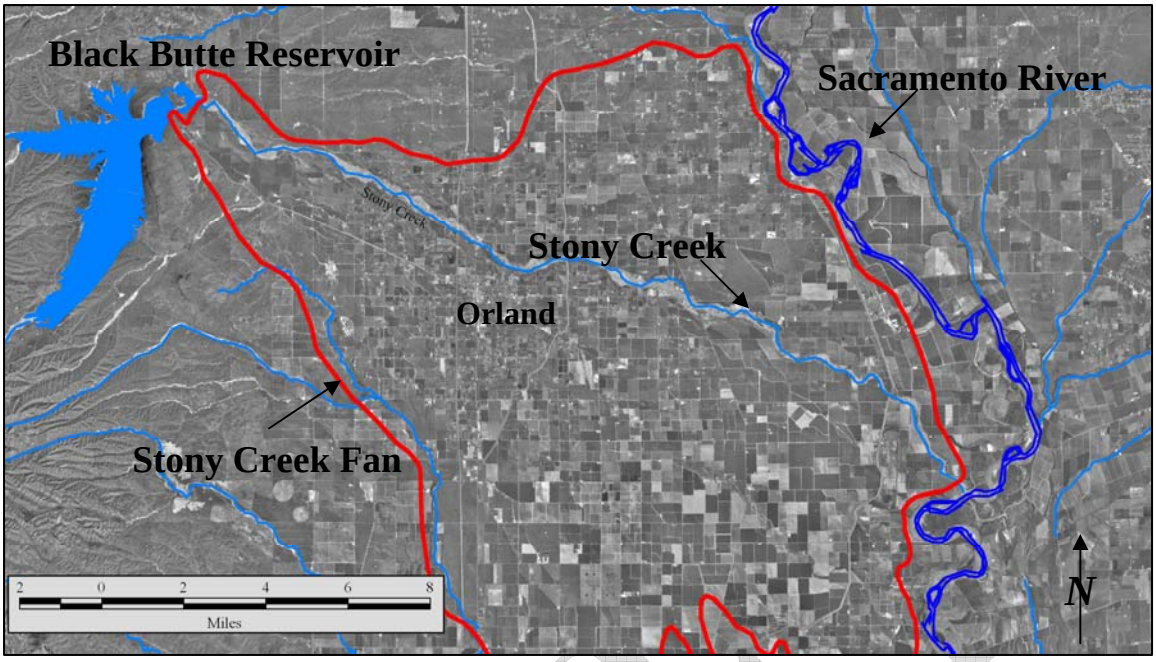

Figure 1. Location Map of Project Area

Scope of Work

The scope of work focused on data collection and how to best regulate the release of water from Black Butte Dam in order to achieve maximum streambed infiltration. Data collection consisted of measuring groundwater levels in wells surrounding Stony Creek and taking surface water flow measurements and staff gauge readings at sites along the creek on a weekly basis. Releases from Black Butte Reservoir were modified by the USBR every Monday throughout the duration of the study. Originally, releases were to be implemented in a steadily increasing and decreasing weekly flow pattern, but due to circumstances beyond the project's control, a slight variation to this pattern was the case. Figure 2 shows the proposed release schedule versus the actual release schedule.

At the end of the study, data were compiled and analyzed with results in the following areas: response of groundwater levels in wells relating to surface water flow, change in groundwater in storage, groundwater velocity, and the optimal flow rate at which to operate releases from Black Butte Dam to enhance groundwater recharge.

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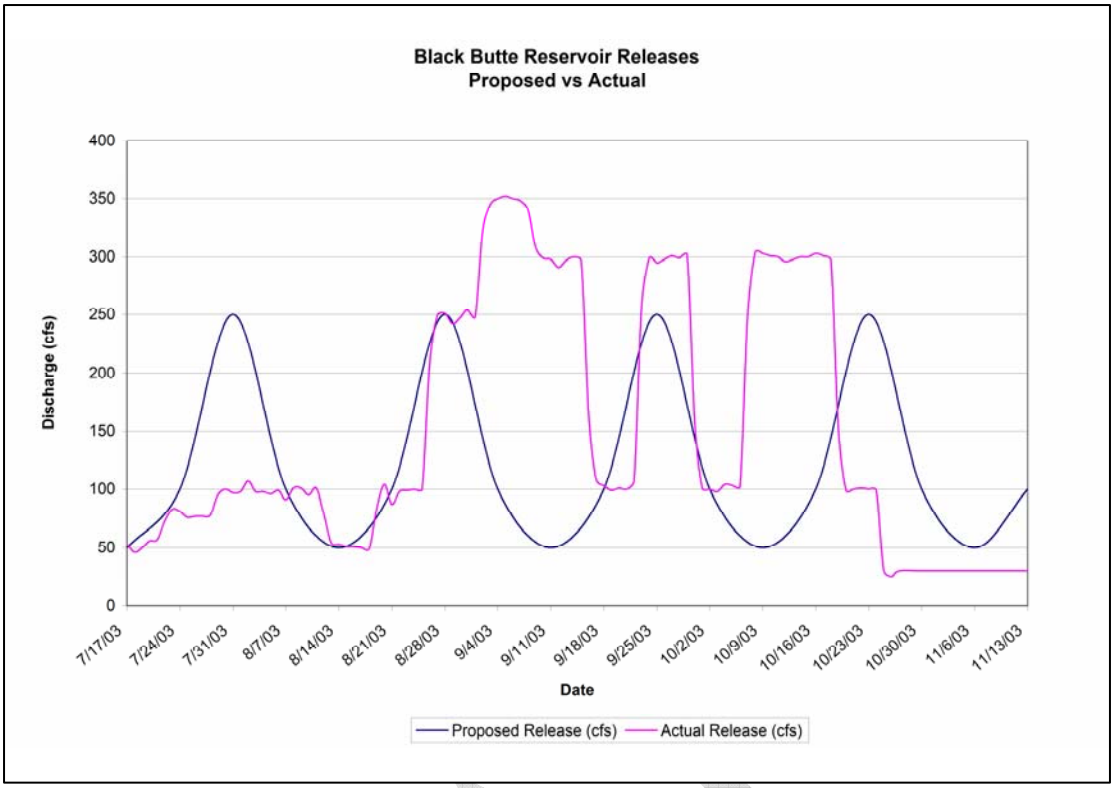

Figure 2. Black Butte Reservoir Release Schedule.

Methods

The project area was divided into five reaches extending from Black Butte Dam to the confluence of Stony Creek and the Sacramento River. Each reach encompassed groundwater wells within about a one mile radius from Stony Creek; the division between reaches were the cross-section sites at which surface water flow measurements were taken, as shown in Figure 3.

Data collection.

Collection of groundwater level and surface water flow data were fundamental to this recharge investigation. To determine the relationship between surface water flows and groundwater levels, data were collected on a regular basis throughout the study period. This effort was conducted through multi-agency cooperation, with duties assigned to the following entities:

- Groundwater Level Measurements: DWR/GC, OAWD
- Surface Water: DWR/USBR/DFG
  - Staff Gauge Measurements: DWR/USBR/DFG/GC
  - Return Flow Measurements: OUWUA/USBR
- Temperature Data: DWR/USBR

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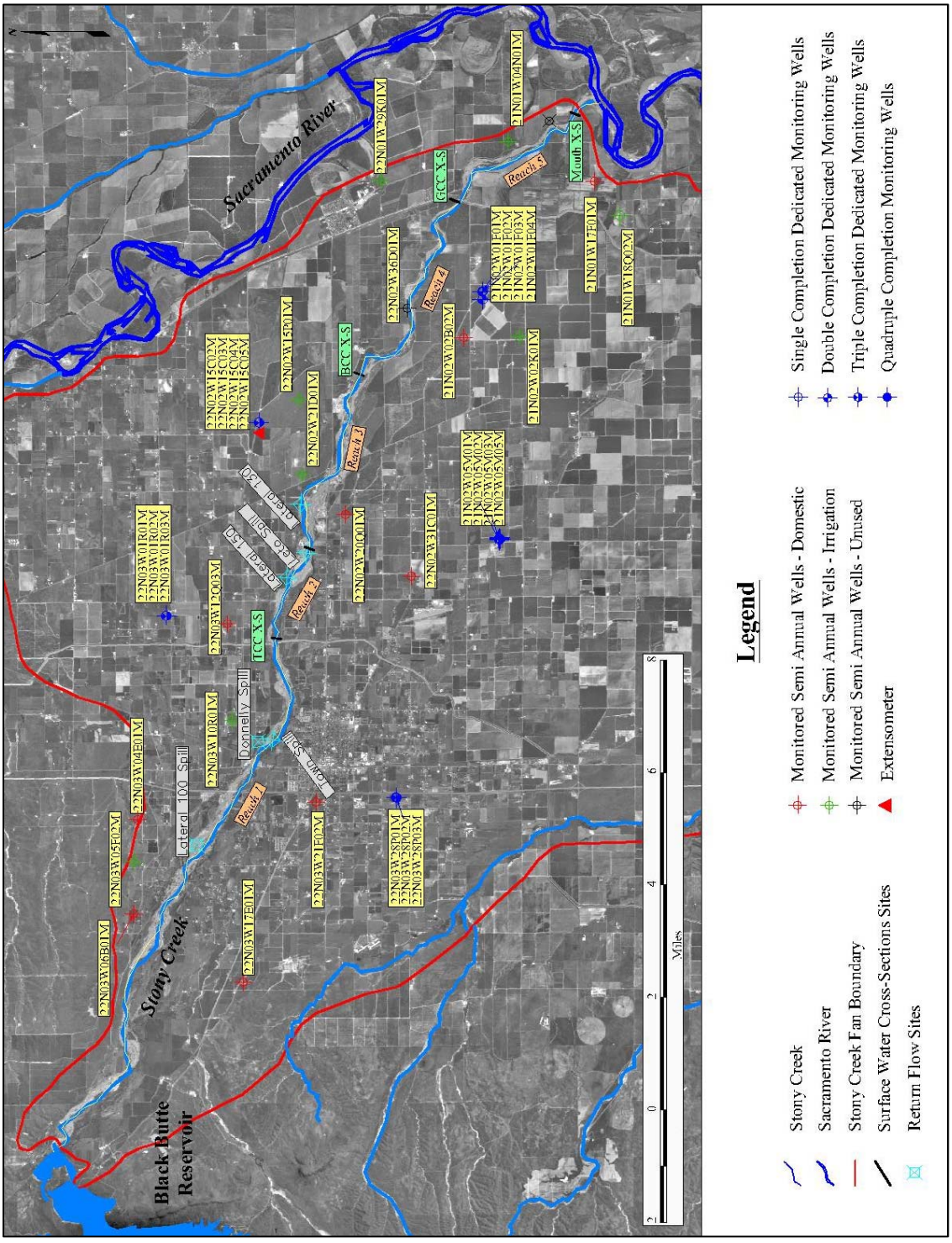

Figure 3. Location of Monitoring Wells, Cross-Section and Return Flow Sites.

Figure 3 also shows the location of the groundwater wells, surface water flow measurement and staff gauge sites, and return flow sites that were monitored during the study. Continuous data logging devices (data loggers) recorded surface water and groundwater temperature data. Methods of data collection are outlined below.

Groundwater Level Measurements. Groundwater level elevations were measured weekly in 36 wells using an electronic sounder, data loggers or a steel tape. Eighteen of the wells were dedicated observation wells and measured on a continuous basis using installed data logger/pressure transducers. Of the remaining wells, 9 were domestic wells, 8 were irrigation wells and one was an unused well. These wells were manually measured using a steel tape.

Surface Water Measurements/Staff Gauge Readings. Weekly surface water flow measurements were taken at five cross-section sites using a current-meter. These sites were selected where flow on Stony Creek was laminar or had limited turbulence 10 feet up- or downstream from the cross-section site. These five sites were also selected for their available access and right of entry. Names and acronyms of the flow measurement sites are shown in Table 1.

Staff Gauge Readings. In the event that daily flow data would be necessary in the final data analysis, staff gauges were installed and surveyed in at each flow measurement site. Staff gauge readings were recorded daily.

Return Flow Measurements. Irrigation return flow measurements were taken at six weirs that were within the Orland Unit Water User's Association boundary. These were areas where excess surface irrigation water was returned into Stony Creek. Return flow measurements were taken three times a week throughout the duration of the study.

Temperature Data. Data loggers were installed in Stony Creek at the top of Reach 2 near the TCC cross-section site and at the bottom of Reach 5, near the confluence of Stony Creek and the Sacramento River. Data loggers recorded groundwater temperature in the 18 observation wells.

Cross-Section Site Name	Acronym
Black Butte Dam	BBD
Tehama-Colusa Canal	TCC
Leto Spill	Leto
Baldwin Construction Company	BCC
Glenn-Colusa Canal Siphon	GCC
Mouth of Stony Creek & Sacramento River	Mouth

Table 1. Surface Water Measurement Site Name and Acronym.

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Results

After compiling and analyzing the data collected throughout the study period, findings in the following areas emerged:

- Groundwater level response to the increasing/decreasing flows in Stony Creek
- Groundwater in storage
- Groundwater velocity
- Water temperature, and
- Flow rate in Stony Creek for optimal groundwater recharge.

Data indicate that groundwater levels in shallow wells near Stony Creek had a greater response to changing flows while no response was evident in wells farther from the creek. The data also suggest that Stony Creek has a higher capacity for groundwater storage in areas where it is a losing stream, and a lower storage capacity in areas where it is a gaining stream. The velocity, or travel time, of water moving from Stony Creek into the aquifer tends to be faster in alluvium near the creek and decreases in velocity as it moves farther from the creek.

Temperature data indicated that a correlation between surface water temperature and groundwater temperature was inconclusive. In addition, data show that the optimal flow rate at which to achieve the highest amount of groundwater recharge is around 100 cubic feet per second (cfs). During the study period, higher flow rates of around 350 cfs did not increase groundwater recharge, while lower flow rates of less than about 60 cfs do not have the capacity to adequately recharge the aquifer. Data supporting these findings are presented below.

Groundwater Level Response.

Groundwater level data were analyzed by examining groundwater level hydrographs and groundwater elevation contour maps. Wells identified as "shallow wells" are screened in the Stony Creek Fan alluvium from about 20 feet to about 120 feet below ground surface. Wells identified as "deep wells" indicate wells that are screened below 120 feet and most likely reflect conditions in the Tehama Formation. Groundwater level data were evaluated by study area, by reach and by individual well.

Study Area. Across the larger study area, groundwater levels in shallow wells rose about one and a half feet over the study period in response to increased flow in Stony Creek. Groundwater levels in deep wells did not show a definitive response to flow in Stony Creek.

Reaches. Utilizing the reaches to evaluate groundwater level contour data on a more localized level, groundwater levels in Reach 1 and Reach 5 tended to fluctuate less than levels in Reach 2, Reach 3, or Reach 4, indicating that groundwater levels in the aquifer were higher in those areas. Besides recharge from Stony Creek, additional sources of recharge in Reach 1 may have come from surface water irrigation by OUWUA and/or proximity to Black Butte Reservoir. Reach 1 is a gaining area of Stony Creek,

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meaning the groundwater level in the aquifer is higher than the surface water level in the creek and that water is flowing from the aquifer into Stony Creek.

Recharge in Reach 5 most likely was from the Sacramento River. Reach 5 is also classified as a gaining area, although because it is near the Sacramento River, subsurface underflow from the river may be moving into Stony Creek, and not necessarily groundwater from the Stony Creek Fan alluvium.

Groundwater level fluctuations increased in Reach 2, Reach 3 and Reach 4, where groundwater extraction is the primary source of water for irrigation. Other than Stony Creek, there are no other sources of recharge for these areas. Reaches 2, 3 and 4 are losing areas of the creek, meaning that water is flowing from Stony Creek into the groundwater aquifer. Greater fluctuations in groundwater level indicate that these areas have a higher available capacity for storage of groundwater. Table 2 shows the minimum, maximum, average and change, or fluctuation, in groundwater elevations by reach, and measurement date. Black Butte Dam releases for the measurement dates are also shown in the table.

Individual wells. Groundwater level hydrographs for individual wells showed varying responses to flow in Stony Creek. Hydrographs for deep wells tended to show influence from nearby pumping or pumping in the well itself. No direct correlations between increasing or decreasing flows in the creek could be made with groundwater levels in the deep wells. The majority of hydrographs for shallow wells show an overall increase in groundwater levels responding to the higher flows in the creek. Only a few wells showed a discernible response to the increasing and decreasing flow pattern. These wells were in areas where groundwater extraction predominates and are discussed below. Hydrographs of groundwater levels for all wells in the study are found in Appendix A.

Hydrographs for wells in Reach 1 showed very little response to changing flows in Stony Creek, which was most likely the result of higher groundwater levels in the aquifer. The average groundwater fluctuation in wells was around three feet over the study period. A hydrograph of well 22N03W05F02M, illustrating this is shown in Figure 4. In Reach 2, groundwater levels in wells increased about 12 feet during the test, indicating a greater available capacity for storage in the aquifer. Figure 5 shows the upward trend for one of these wells, well 22N03W01R03M.

In Reach 3, groundwater levels dropped almost three feet from the beginning of the test until the higher flows were released. From that point groundwater levels were trending upward, gaining about five and a half feet by the end of the test, as shown for well 22N02W15C05M, on Figure 6.

In Reach 4, well 22N02W36D01M, which is about 500 feet from Stony Creek, showed a more pronounced groundwater level response to the change in flows than other wells. Figure 7 illustrates that groundwater levels rose and fell up to four feet in response to the release pattern. However, in observation well 21N02W01F04M, that was farther

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from the creek, the change in groundwater level responding to changing flow in the creek was only in the tenths of a foot range, as seen in Figure 8.

In Reach 5, groundwater levels fluctuated around two feet in well 21N01W04N01M, which is about 1,000 feet from Stony Creek. This well showed a response to the changing flows in the creek even though it was used periodically throughout the study period. A hydrograph of this well can be seen in Figure 9. Other wells in this reach did not respond to flow in the creek and may be responding to the nearly constant flow in the Sacramento River.

	BBD Release	Reach 1		Reach 2	Reach 3	Reach 4	Reach 5
		High Contour near BDD	BBD to TCC	TCC to Leto	Leto to BCC	BCC to GCC	GCC to MOUTH
Date	**Flow (cfs)**	**GROUNDWATER SURFACE ELEVATION (ft-msl)***					
7/11/2003	30	270	230	186	146	*no data*	*no data*
7/17/2003	53	270	240	199	174	143	*no data*
7/24/2003	81	270	234	191	171	141	120
7/31/2003	97	269	234	190	168	139	120
8/7/2003	91	270	240	202	177	143	119
8/14/2003	53	270	240	202	169	134	120
8/21/2003	87	270	235	193	166	135	*no data*
8/28/2003	251	270	236	192	162	132	120
9/4/2003	350	270	236	193	161	131	120
9/11/2003	298	270	236	193	163	131	116
9/18/2003	103	270	236	193	168	137	118
9/25/2003	295	270	236	194	166	135	120
10/2/2003	100	270	237	194	162	132	119
10/9/2003	303	270	236	192	166	137	120
10/16/2003	301	270	236	193	170	141	121
10/23/2003	100	270	235	193	167	135	*no data*
10/30/2003	30	270	236	193	171	140	*no data*
11/6/2003	30	270	237	195	167	137	121
11/13/2004	31	271	238	195	167	137	121
MIN		269	230	186	146	131	116
MAX		271	240	202	177	143	121
AVG		270	236	194	166	137	119
CHANGE		2	10	16	31	12	5

*Average of low and high contour for each reach.

Table 2. Groundwater Surface Elevation and Flow, by Reach and by Date.

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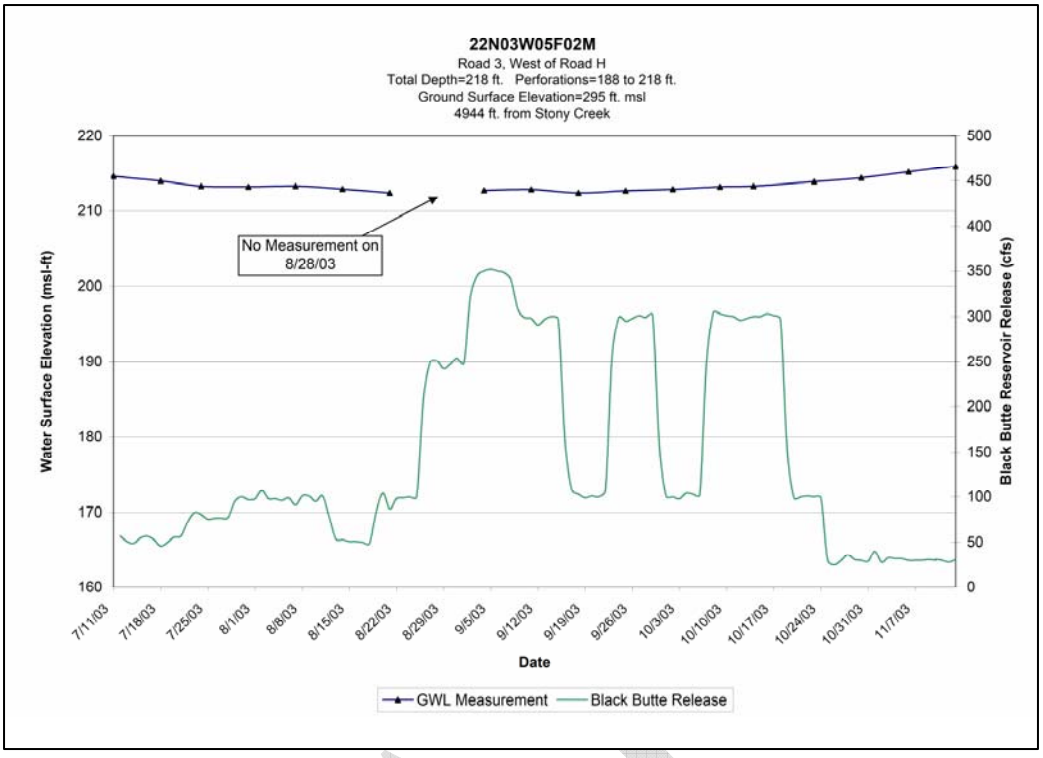

Figure 4. Groundwater Level Hydrograph of 22N03W05F02M.

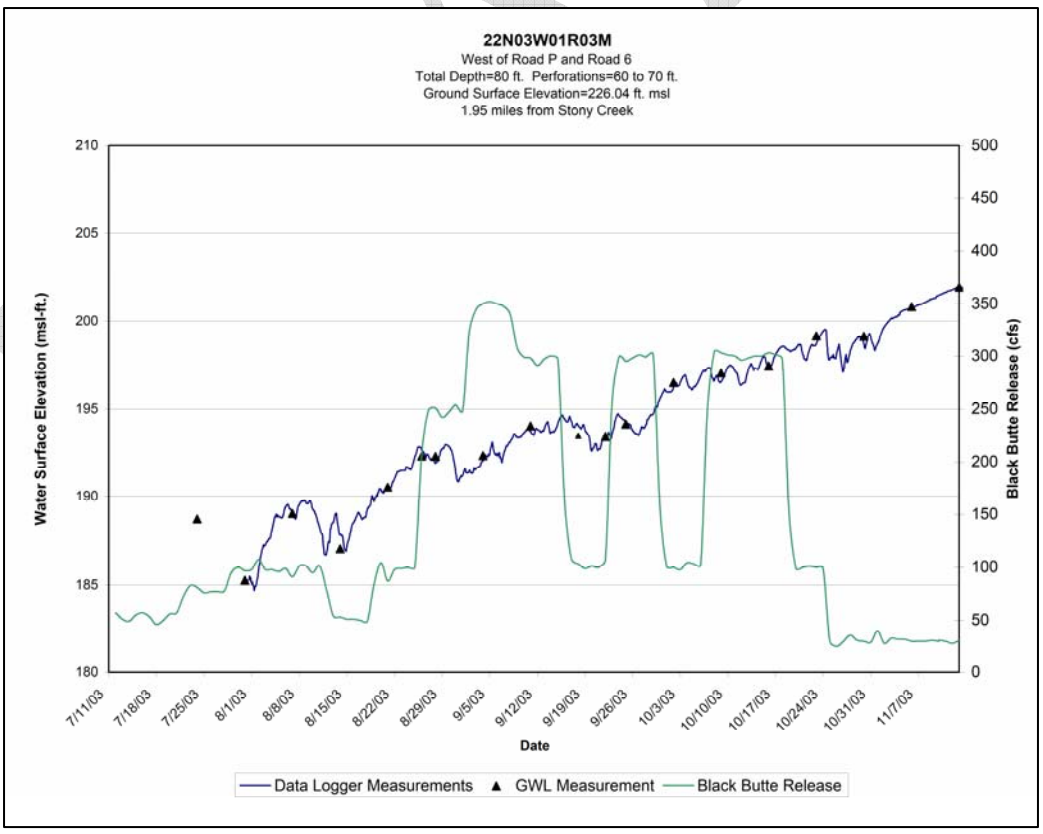

Figure 5. Groundwater Level Hydrograph of 22N03W01R03M.

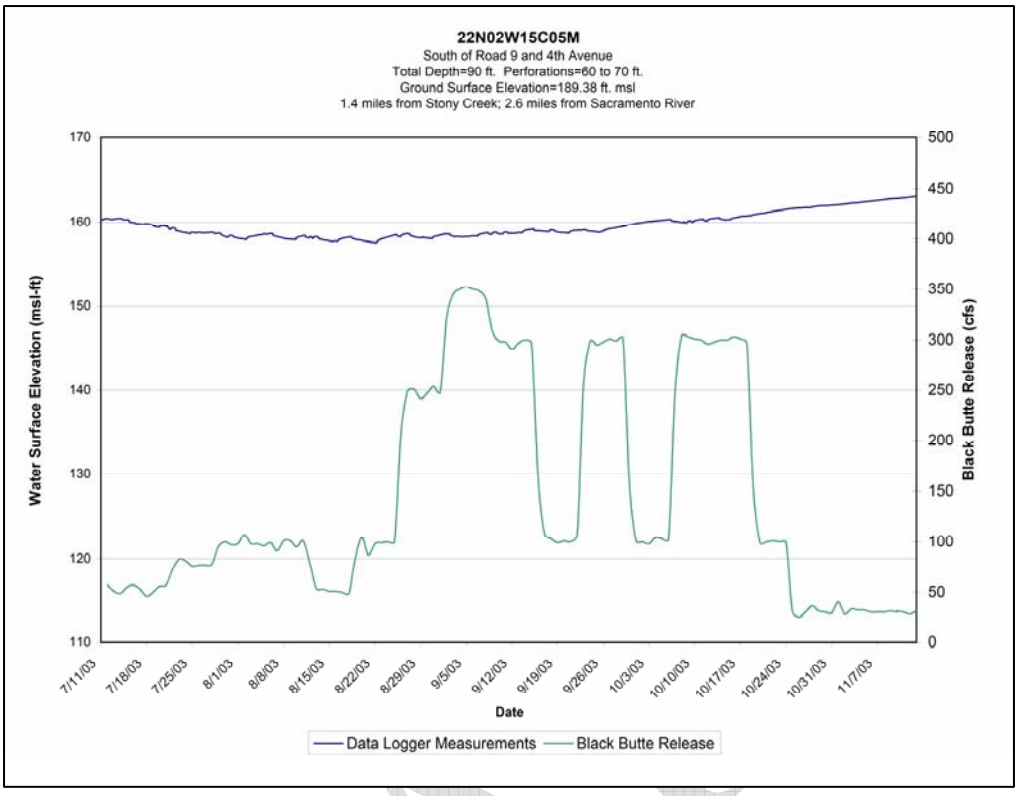

Figure 6. Groundwater Level Hydrograph of 22N02W15C05M.

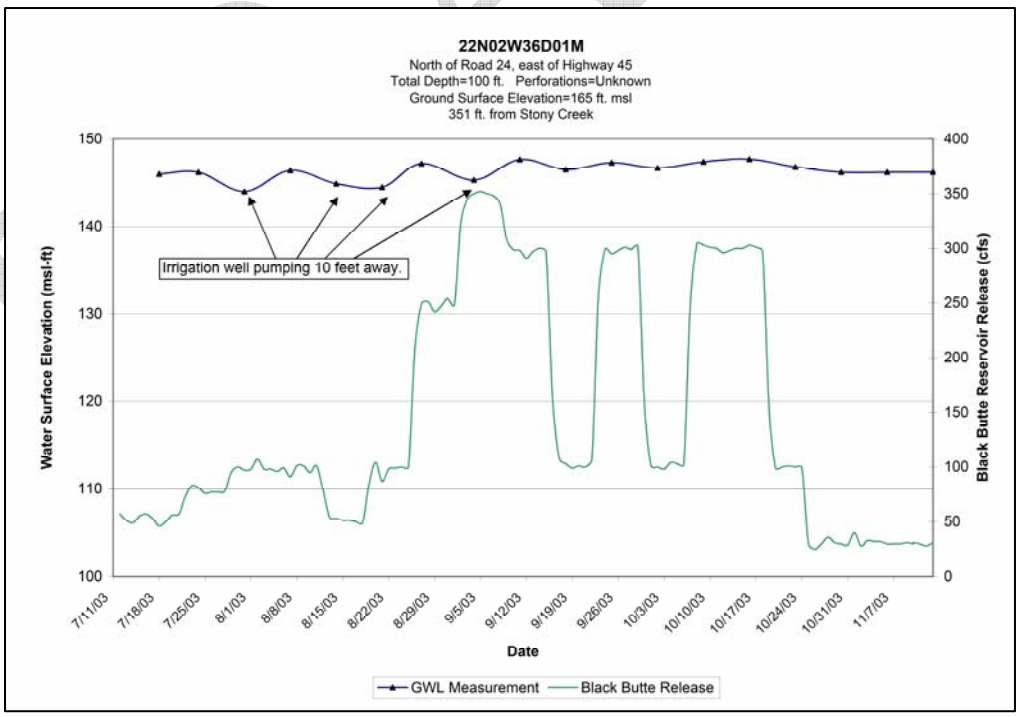

Figure 7. Groundwater Level Hydrograph of 22N02W36D01M.

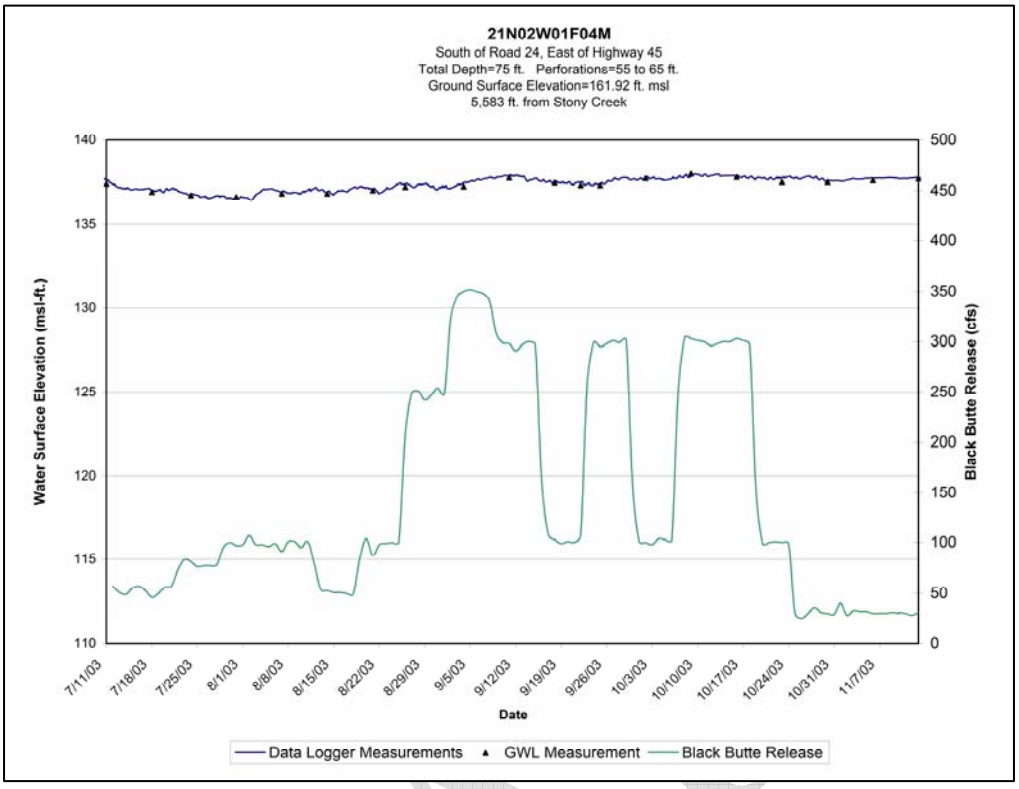

Figure 8. Groundwater Level Hydrograph of 21N02W01F04M.

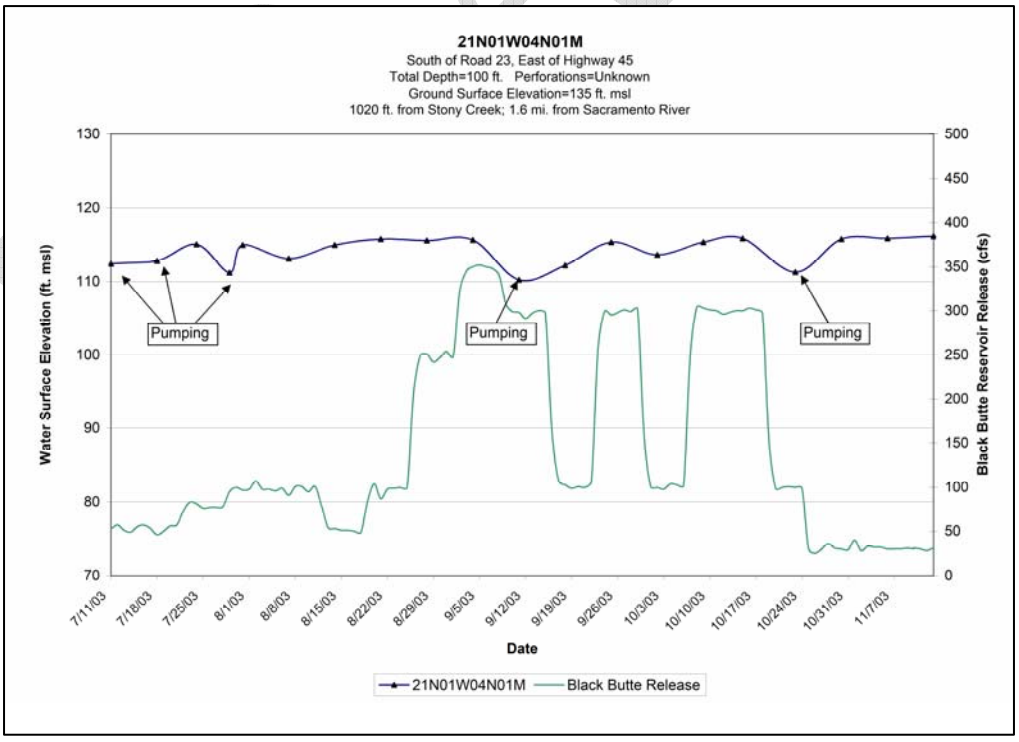

Figure 9. Groundwater Level Hydrograph of 21N01W04N01M.

Groundwater in Storage.

This part of the study looked at the water balance equation in an effort to better understand the variables that affect the aquifer system. The data and discussion in the succeeding paragraphs are presented to provide a greater working knowledge of the surface water and groundwater system surrounding Stony Creek.

Groundwater in storage is estimated by using the water balance equation that states that the change in groundwater in storage is equal to inflow into the system minus the outflow from the system:

$$\Delta S = I - O$$

Where:

ΔS = Change in Storage
I = Input, or gain to the system
O = Output, or loss from the system

The main sources of input into a system include precipitation, surface water inflow, return flow, recharge from irrigation and groundwater inflow into the aquifer. Sources of output include surface water outflow, evapotranspiration (ET), discharge from wells (groundwater extraction) and groundwater outflow from the aquifer.

For this analysis, known input sources were surface water inflow and return flow. Recharge from irrigation was an unknown variable and there was no measurable precipitation over the study period. The only known system output was surface water outflow. Evapotranspiration values change dramatically depending on crop type, soil type, air temperature, wind speed and cloud cover, among others, and was an unknown variable. Groundwater extraction was not metered or quantified by any other method, and was also an unknown variable. Groundwater flow into and out of the aquifer is very difficult to quantify and was not used in the calculations.

Inflow. Over the study period, the total volume of water released into Stony Creek, below the north and south irrigation diversions, was about 36,000 acre-feet. Total return flow to the creek was approximately 1,170 acre-feet. Return flow is the excess surface irrigation water (runoff) that was not utilized by crops and did not infiltrate into the soil. It was "returned" to Stony Creek though the OUWUA canal system. Adding the volume released with the return flow equals a total of 37,520 ac-ft. This is the known amount of inflow that went into the system over the study period.

Outflow. The known volume of outflow, water that flowed through the mouth of Stony Creek into the Sacramento River, was around 25,900 acre-feet.

Change in Storage. The change in groundwater storage was estimated for each reach by using groundwater elevation contours that were developed throughout the study period. Change in groundwater elevation (head) was calculated by subtracting the high groundwater elevation minus the low groundwater elevation for a net change (see Table

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2). Area was calculated by taking the acreage around the five reaches that encompassed the wells used in calculating groundwater elevation change and creating the groundwater elevation contours. A specific yield of 15%, which is typical of the highly permeable Stony Creek Fan alluvium, was used.

Multiplying the change in head by the area and the specific yield gave an estimated volume of groundwater that went into storage. The total estimated amount of groundwater that potentially went into storage was about 52,488 acre-feet, as seen in Table 3.

	Change in Groundwater Surface Elevation (ft.)	Acreage per Reach	Specific Yield	Potential Δ in Groundwater in Storage per Reach (ac-ft)
Reach 1	10	7487	0.15	11,230
Reach 2	16	2050	0.15	4,920
Reach 3	31	4723	0.15	21,962
Reach 4	12	7177	0.15	12,919
Reach 5	5	1942	0.15	1,457
Total Potential Change in Groundwater in Storage				52,488

Table 3. Total Potential Change in Groundwater in Storage.

Water Balance Equation. Table 4 summarizes the inflow, outflow and the estimated change in storage variables used in the estimation.

Inputs (Gain):	**Acre-Feet (over Study Period)**
Inflow	36,350
Return Flow	1,170
Recharge from Irrigation	x
Total:	**36,350 + 1,170 + x**
Outputs (Loss):	
Outflow	25,900
Evapotranspiration	y
Groundwater Extraction	z
Total:	**25,900 + y + z**
Change in Storage:	**52,488**

Table 4. Water Balance.

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Using the water balance equation, which states that inflow minus outflow equals the change in storage, and solving for the variables, yields the following:

$$\Delta S = I - O$$

$$52{,}488 = (37{,}520 + x) - (25{,}900 + y + z)$$

$$52{,}488 = 11{,}620 + x - y - z$$

$$+40{,}868 = +x-y-z$$

This suggests that there was at least 40,868 acre feet that went into the groundwater system by means other than from surface water from Stony Creek. Additional input into the system was most likely through recharge from irrigation (x). Knowing that ET (y) is a significant loss to the system, and that that groundwater extraction is the major source of water for irrigation (z) in the lower reaches, the amount of recharge from surface water irrigation is probably higher than reported here.

Discussion. One of the factors that may contribute to recharge of the Stony Creek Fan alluvium may be through the application of water using the flood irrigation method utilized by OUWUA. Although losses from this method of irrigation are high (according to the United States Geological Survey, as much as 50% of the water applied by the flood irrigation method is lost to infiltration, evaporation, or runoff, and not used by the crops), the Stony Creek Fan alluvium benefits significantly through aquifer recharge. Crop acreage is flood irrigated on a rotational basis, meaning that water is applied to the crops every 10 days or so, allowing infiltration, or recharge, to occur.

Another factor may be that in areas of groundwater extraction, irrigation wells screened in the deeper Tehama Formation may contribute to recharge of the upper aquifer. This water is pumped from the deeper aquifer and applied to the crops, with no net loss to the upper aquifer (Stony Creek Fan alluvium). Any excess water not used by the crop, or lost to other factors such as evapotransipiration, may actually contribute to recharge of the upper system.

An example of a loss from the system due to vegetation usage other than by crops may come from native riparian vegetation, such as the bamboo-like Arrundo that grows profusely along the banks of Stony Creek. It has been documented that Arrundo can use up to 48 gallons per square foot of water and can grow up to 2 inches per day. Using the data from the DWR 1998 land use survey, approximately 2,900 acres were delineated as native riparian vegetation or native vegetation. If it is *presumed* that only half of that acreage is occupied by Arrundo, around 8,000 acre-feet of water over a season would be used by the Arrundo alone.

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Groundwater Flow Velocity.

Groundwater flow velocity was estimated in four wells to explain why response to the differing flows in Stony Creek was seen in some wells and not others. Groundwater flow velocity (also referred to as the seepage velocity) was calculated for two shallow wells whose hydrographs showed a correlation between flow in the creek and groundwater levels in the wells. Groundwater flow velocity was also estimated for two shallow wells that showed a slightly discernible response to changing flows.

Groundwater velocity was calculated using the seepage velocity equation. This equation uses hydraulic gradient, hydraulic conductivity, and the effective porosity to calculate groundwater movement. The hydraulic gradient is a calculated value and shown in Table 5 for each of the four wells. A hydraulic conductivity of 200,000 gpd/ft^2 and a standard

State Well Number	Gradient (ft./ft.)	Distance to Stony Creek (ft.)	Seepage Velocity (ft./day)	Time from Stony Creek to Well (days)
22N02W36D01M	0.07	351	12,011	0.03
21N02W01F04M	0.003	5,853	537	11
22N02W15C05M	0.003	7,913	576	14
22N03W01R03M	0.003	9,625	568	17
Gradient and Seepage velocity were averaged over course of study period.				
K=200,000 gpd/ft^2; n_e=15%				

Table 5. Estimates of Groundwater Velocity in Shallow Wells

porosity of 15%, (which are typical values for the sand and gravel characteristics of the Stony Creek Fan alluvium) were used in the calculations.

Hydrographs for wells 22N02W36D01M and 21N02W01F04M, seen in Figure 10 and 11, showed an apparent response to the changing flows in Stony Creek. The seepage velocity was fastest in the well closest to the creek (22N02W36D01M). The calculated time for groundwater to travel a distance of about 350 feet from the creek to the well was only about one hour. The hydrograph for this well shows that the high groundwater levels occurred almost simultaneously with high flows in Stony Creek. The hydrograph for well 21N02W01F04M, which is about a mile from the creek, shows an apparent lag time of between 8 and 16 days (an average of about 12 days) for groundwater levels to respond to high flows in the creek. The calculated velocity for groundwater flow to this well is around 11 days.

Groundwater velocity was also estimated for two shallow wells that showed a slightly discernible correlation between flow in the creek and groundwater levels. The estimated groundwater velocity to one of these wells, 22N02W15C05M, was about 14 days. The distance from the creek to this well is about one and a half miles. Well 22N03W01R03M is farthest from the creek (about 2 miles) and has an estimated groundwater velocity of around 17 days. These two wells show an increase of groundwater levels, but not

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necessarily a direct response between the increasing and decreasing flow in Stony Creek. Hydrographs for these wells are shown in Figure 12 and 13.

The data suggest that groundwater velocity in the groundwater aquifer is highest closer to the creek where the hydraulic gradient is greater. As the distance from Stony Creek to the well increases and the hydraulic gradient decreases, the seepage velocity tends to decrease.

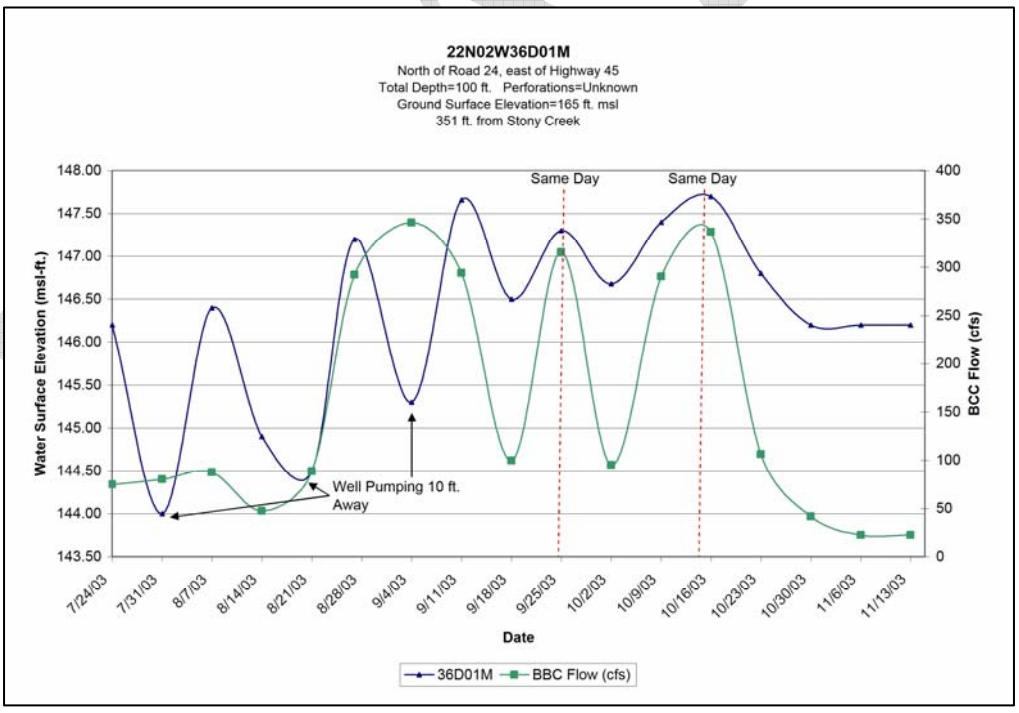

Figure 10. Groundwater Levels and Flow Data for 22N02W36D01M.

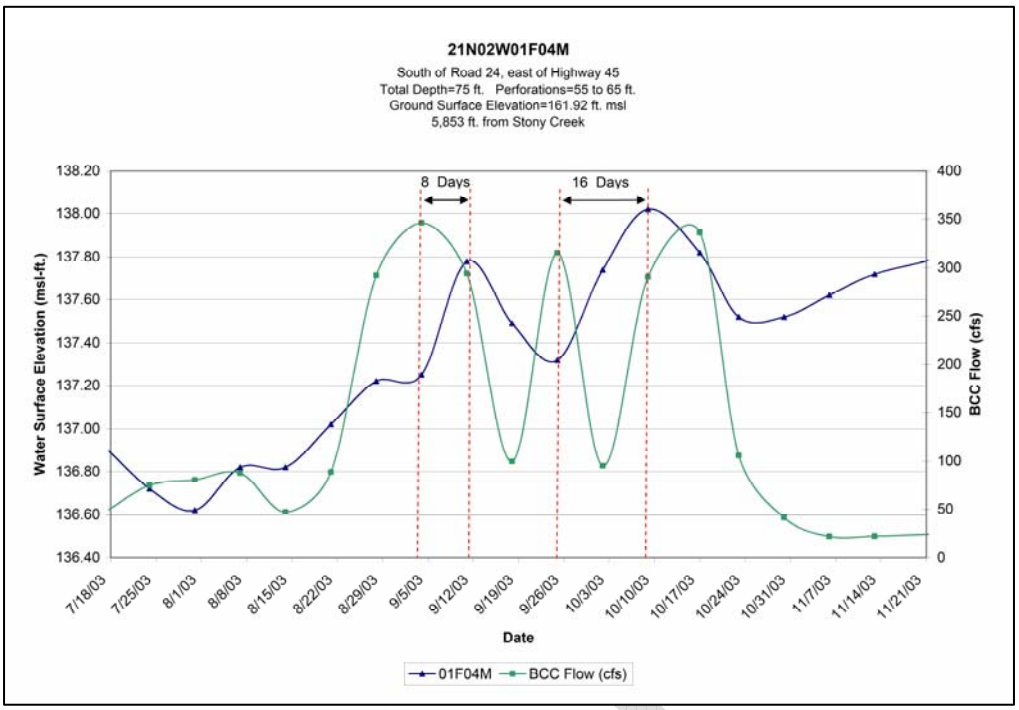

Figure 11. Groundwater Levels and Flow Data for 21N02W01F04M.

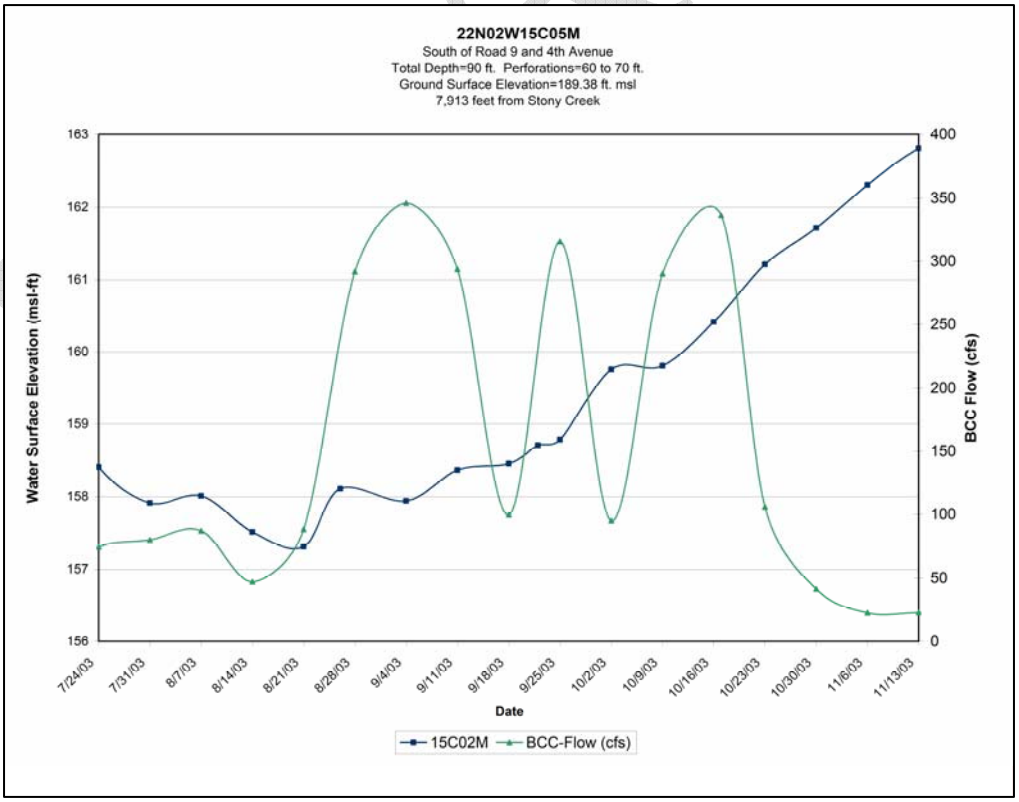

Figure 12. Groundwater Levels and Flow Data for 22N02W15C05M.

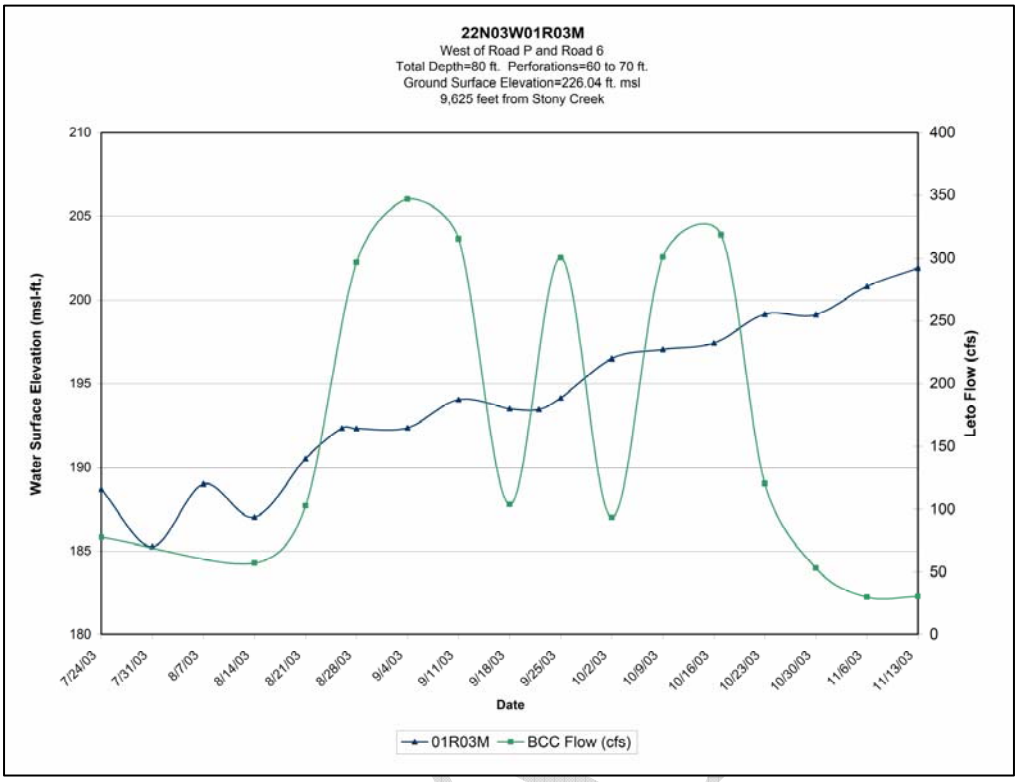

Figure 13. Groundwater Levels and Flow Data for 21N03W01R03M.

Temperature Data.

Temperature data was collected with data loggers at two cross-section sites in Stony Creek, one at the top of Reach 2 and the other at the top of Reach 5. Groundwater temperature was recorded by data loggers installed in the observation wells. After graphing and reviewing the data, no obvious correlations could be made between surface water and groundwater temperatures. A representative graph of groundwater temperature in the closest shallow observation well to Stony Creek (about 2 miles north of Reach 2) and the temperature of the surface water at Reach 2 where a surface water temperature probe was installed is shown in Figure 14.

Flow Rate for Optimal Groundwater Recharge.

Recharge rates are related to the gradient between the surface water and groundwater system, the permeability of the aquifer, the available storage space in the aquifer and the wetted perimeter of the stream. The hydraulic gradient between surface water levels in Stony Creek and groundwater levels measured in each of the wells differed depending on groundwater level and distance to each well. Although the Stony Creek Fan sediments are generally very permeable, there are localized areas of low permeability within the aquifer. The available storage space is also variable depending on permeability of the

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aquifer and recharge sources. Because of these disparities, data analysis concentrated on the relationship between the wetted perimeter of the creek and surface water flows.

With all other factors being equal, the larger the ground surface area exposed to surface water, the greater the aquifer recharge potential. Data from this study suggest that stream flow over about 100 cfs and up to about 350 cfs did not significantly increase the wetted perimeter and therefore showed little increased effect on recharge to the groundwater aquifer. Higher flows stayed within the surface water system, discharging into the Sacramento River. Flows of less than about 80 cfs did not have the volume or capacity to effectively increase the wetted perimeter of the stream and thus had less of an influence on groundwater recharge. These data suggest that a flow rate of around 100 cfs would optimize recharge to the groundwater aquifer system.

Graphs showing the cross-sectional area (wetted perimeter) in square feet (ft^2), versus surface water flow in cubic feet per second for each of the cross-section sites are shown in Appendix B and cross-sectional flow data is shown in Appendix C.

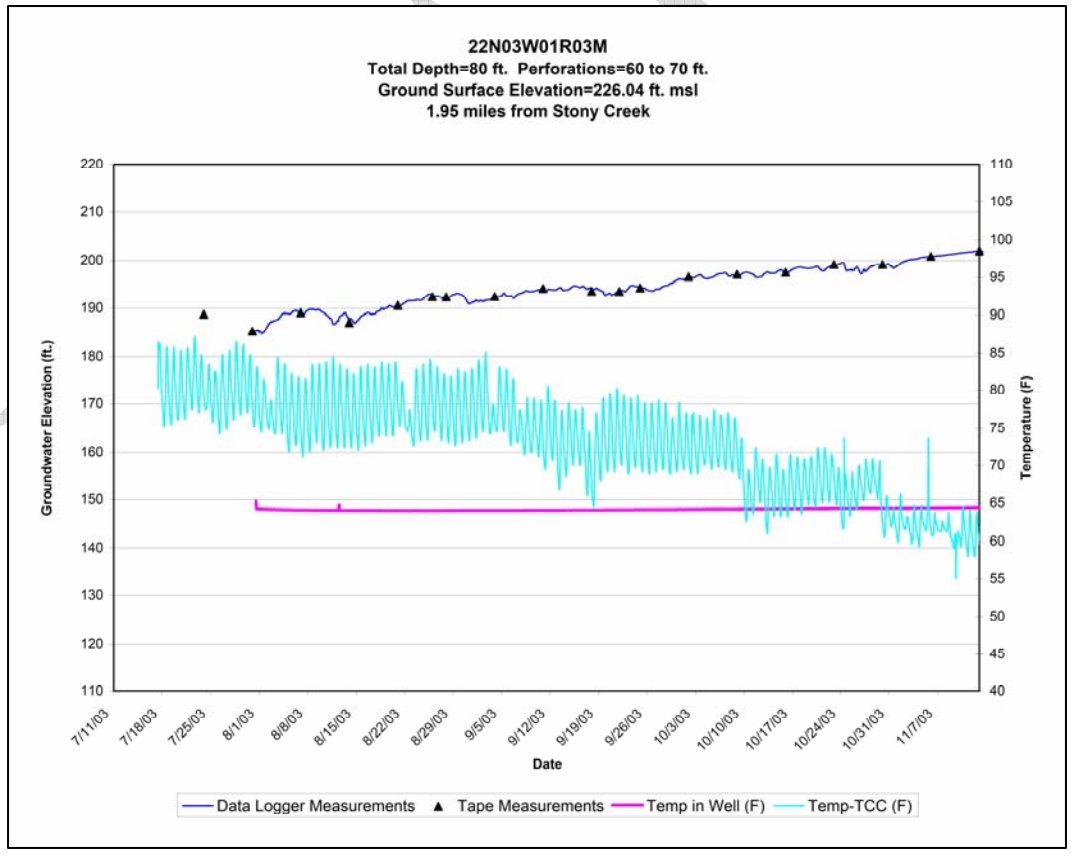

Figure 14. Temperature data for Well 22N03W01R03M and Stony Creek at TCC.

Description of the Hydrogeologic System

Regional Geology.

Prior to 5 million years ago, the shape of the Sacramento Valley was different than it is today; the land surface was a broad plain sloping from the eastern eroded, ancient Sierra Nevada Mountains to the western Pacific shoreline. During that time, the Coast Range had not yet been formed on the west side of the Sacramento Valley, therefore the Pacific shoreline was found farther east than the present-day shoreline. The Sacramento Valley began taking its present shape and structure about 5 million years ago due to Basin and Range extension in the east aiding in the uplift of the granitic Sierra Nevada Range, volcanism to the east and north creating the Cascade Mountain Range, and the transform and subduction action of the tectonic plates to the west forming the metamorphic Coast Ranges. These orogenic, or mountain building events, have been occurring over the past 5 million years, and still continue today.

As the mountains were being uplifted, sediments eroded from the mountains and were deposited along stream and river beds, and into the valley. In the Sacramento Valley, the oldest freshwater deposits are the sediments of the Tehama and Tuscan Formations, which are about 5 million to 1.8 million years old. Intermediary in age are the Riverbank and Modesto Formations, from 1.8 million years to 11,000 years old, and youngest is the younger alluvium, from 11,000 years old to present. The Stony Creek Fan alluvium is comprised of alluvial sediments of the Riverbank and Modesto Formations and younger alluvium. A geologic map with the Stony Creek Fan boundary outline is shown in Figure 15.

Tehama Formation. The Tehama Formation is composed of metamorphic and sedimentary sediments derived from the Coast Ranges. These sediments consist of tan to greenish-blue clay and silt with interstratified beds and lenses of predominately grey, black, white and brown gravel and sand. They are heterogeneous in nature due to the fluvatile depositional environment of the Tehama Formation. The clay and silt were deposited during periods of longer term, lower flows in the streams and rivers, while sands and gravels were deposited over shorter term, higher flow events. These depositional events created the interlayering and discontinuous beds of clay, silt, sand and gravel.

Thickness of the formation ranges from up to around 1,500 feet towards the center of the valley to surface exposure of sediments at the western basin margins. The discontinuous gravel and sand interlayers compose the water-bearing aquifers of the Tehama Formation. Permeability of this formation is low to moderate, with areas of locally high permeability in the water-producing sand and gravel zones.

Tuscan Formation. The Tuscan Formation consists of four distinct units: Unit A & Unit B comprise the lower Tuscan Formation and Unit C & Unit D comprise the upper Tuscan Formation. The Tuscan Formation is composed of volcanic sediments derived

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from the Cascade Range which consist of buff, tan and reddish-brown volcanic mudflows, tuff breccia, tuffaceous sandstone, volcanic ash layers and black sands. Most of the sediments were deposited as volcanic lahars (mudflows) with interbedded volcanic conglomerate and sandstone. Many of the lahars followed channels and streambeds that had been down-cut into the sediments. The reworked gravel and sand in these ancient channels and streambeds in the lower Tuscan Formation provide the main source of water to wells on the east side of the valley.

Thickness of the Tuscan Formation is up to about 1,700 feet near the center of the valley and is exposed at the surface at its eastward extent. The water-bearing sediments of the lower Tuscan Formation are moderate to highly permeable, while the fine-grained, consolidated lahars of the upper Tuscan Formation form thick, low permeability confining layers for the lower Tuscan Formation.

Riverbank Formation. Older alluvial sediments of the Stony Creek Fan alluvium are often referred to as the Riverbank Formation. This formation has an age-date of between 450,000 and 130,000 years old. The Riverbank Formation consists of gravel, sand and silt, and is found throughout the Sacramento Valley forming wide alluvial fans and terrace deposits. The Riverbank Formation is moderately to highly permeable and yields moderate quantities of water to domestic and shallow irrigation wells. It also provides water to deeper irrigation wells that have multiple zones of perforation. Well yields are higher in areas where concentrations of gravel and sand are present.

Modesto Formation. Younger alluvial fan deposits are frequently referred to as the Modesto Formation with an age date of between 42,000 and 14,000 years old. The Modesto Formation consists of tan and light grey gravelly sand, silt and clay, and forms coalescing alluvial fans and stream bank terraces. These deposits provide water to domestic and shallow irrigation wells as well as to deeper wells with multiple zones of perforations. In locations where gravel and sand predominate, groundwater yields are moderate. Lesser yields are found in areas with high silt and clay content.

Alluvium. The undifferentiated alluvium and stream channel deposits are referred to as alluvium, which has been deposited over the last 11,000 years. These sediments are composed of unweathered gravel, sand and silt deposited by present day streams. Permeability ranges from low to high due to the variability of deposits from place to place.

Local Geology and Hydrogeology.

The Stony Creek Fan is a broad alluvial fan in Glenn County which covers about 212 square miles, or 135,189 acres, and extends about 26 miles north to south and about 14 miles east to west. Stony Creek flows through Glenn County, from its headwaters in the foothills of the Coast Ranges to the confluence of the Sacramento River in roughly a northwest to southeast direction. The reach of Stony Creek between Black Butte Dam and the Sacramento River is about 25 miles in length with a gradient of about 11 feet per mile.

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Stony Creek Fan Alluvium. The Stony Creek Fan alluvium is comprised of sediments deposited by Stony Creek, which consist mainly of rounded to sub-angular gravel and sand of metamorphic and sedimentary origin, with interbedded clay and silt layers. Thickness of the alluvium ranges up to 120 feet, averaging around 50 to 80 feet. Although the Stony Creek Fan alluvium is specific to the area surrounding Stony Creek, these sediments have been mapped regionally as Riverbank Formation, Modesto Formation or alluvium.

The deposits of the Stony Creek Fan alluvium include lenses of highly permeable gravel and sand. Previous aquifer performance tests on the Stony Creek Fan alluvium indicate that the transmissivity of the sediments is around 400,000 gallons per day per foot and the average hydraulic conductivity is about 3,625 gallons per day per foot^2. Draw-down data in a test production well indicated a specific capacity of about 50 gallons per minute per foot of drawdown.

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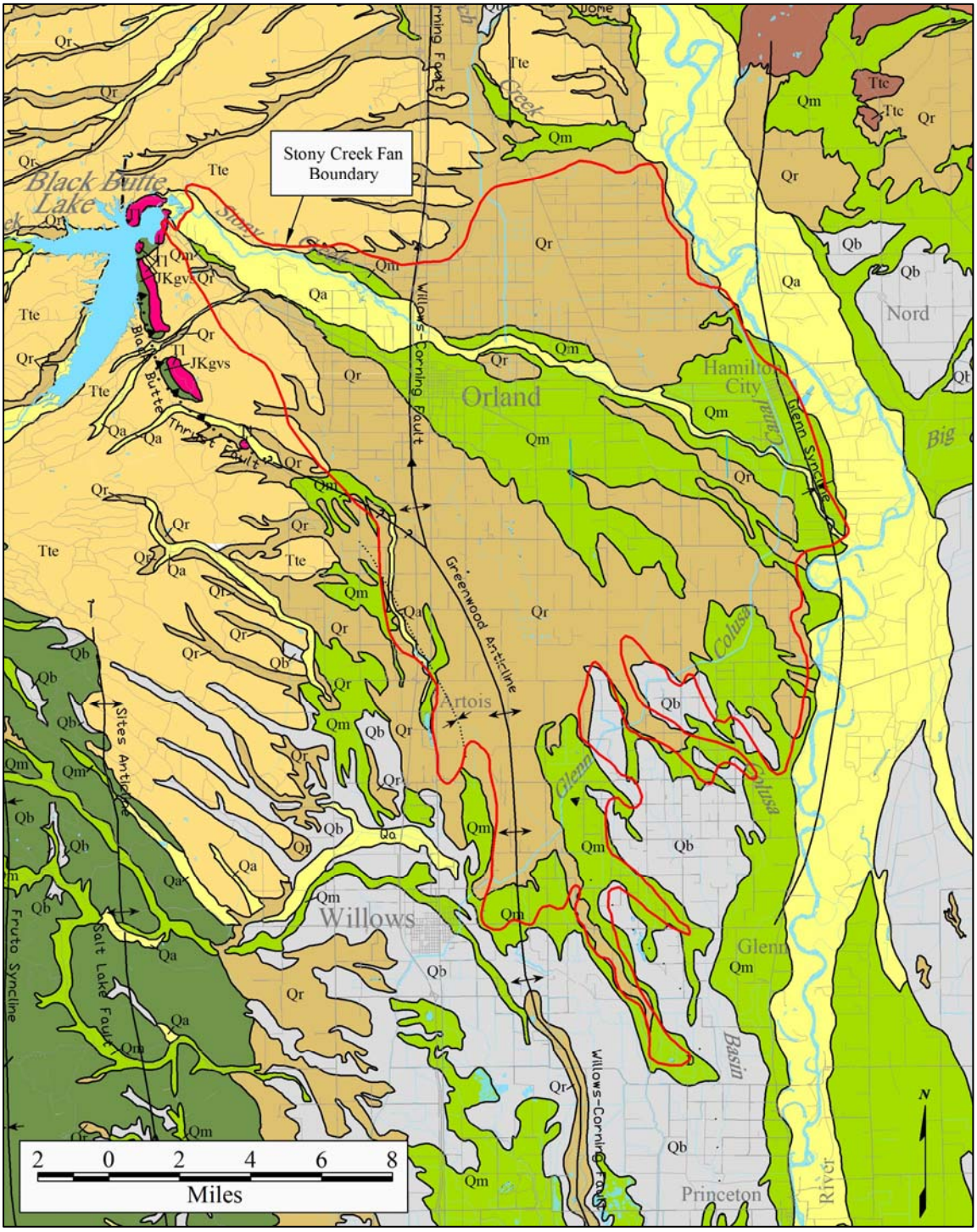

Figure 15. Regional Geologic Map with Stony Creek Fan Boundary.

Appendices

Appendix A: Groundwater Level Hydrographs

Appendix B: Cross-sectional Area vs. Flow

Appendix C: Surface Water Flow Data

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Appendix A.

Groundwater Level Hydrographs

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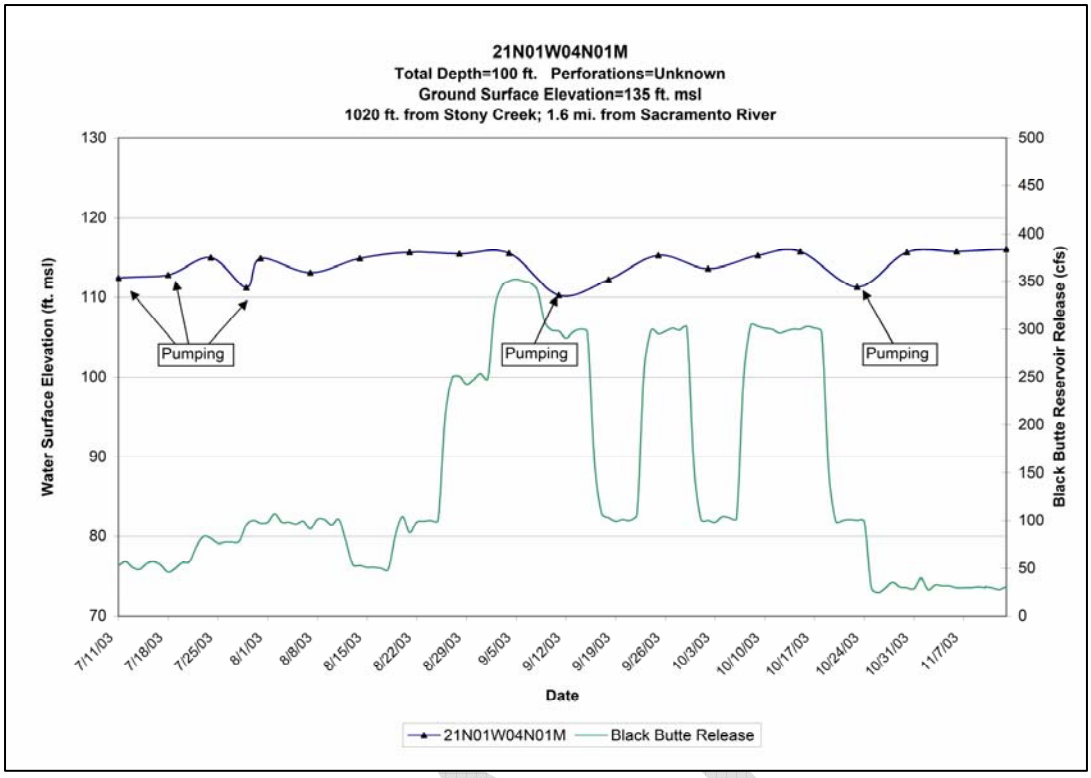
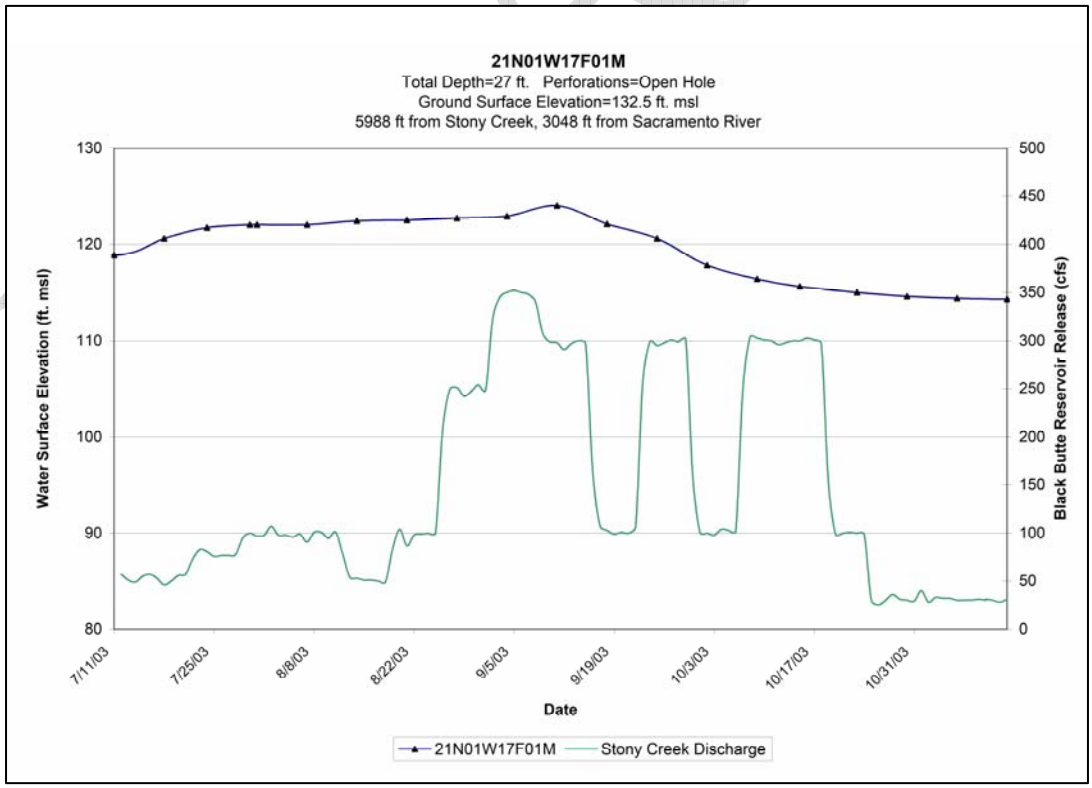
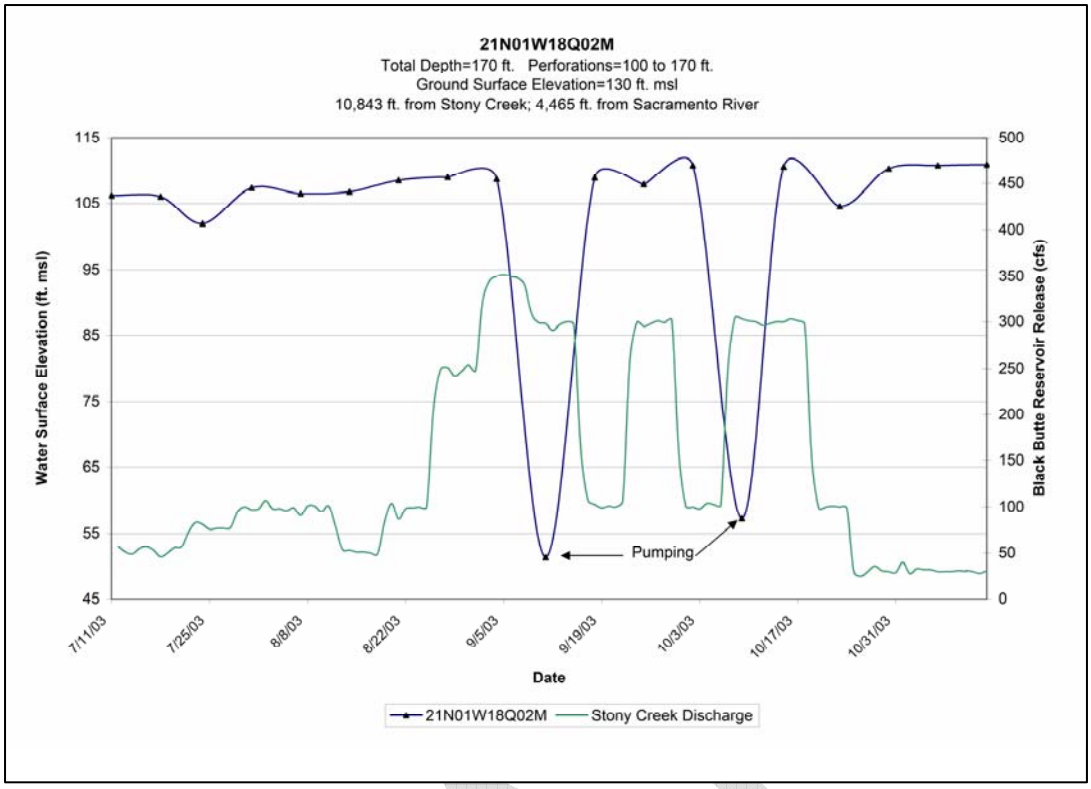
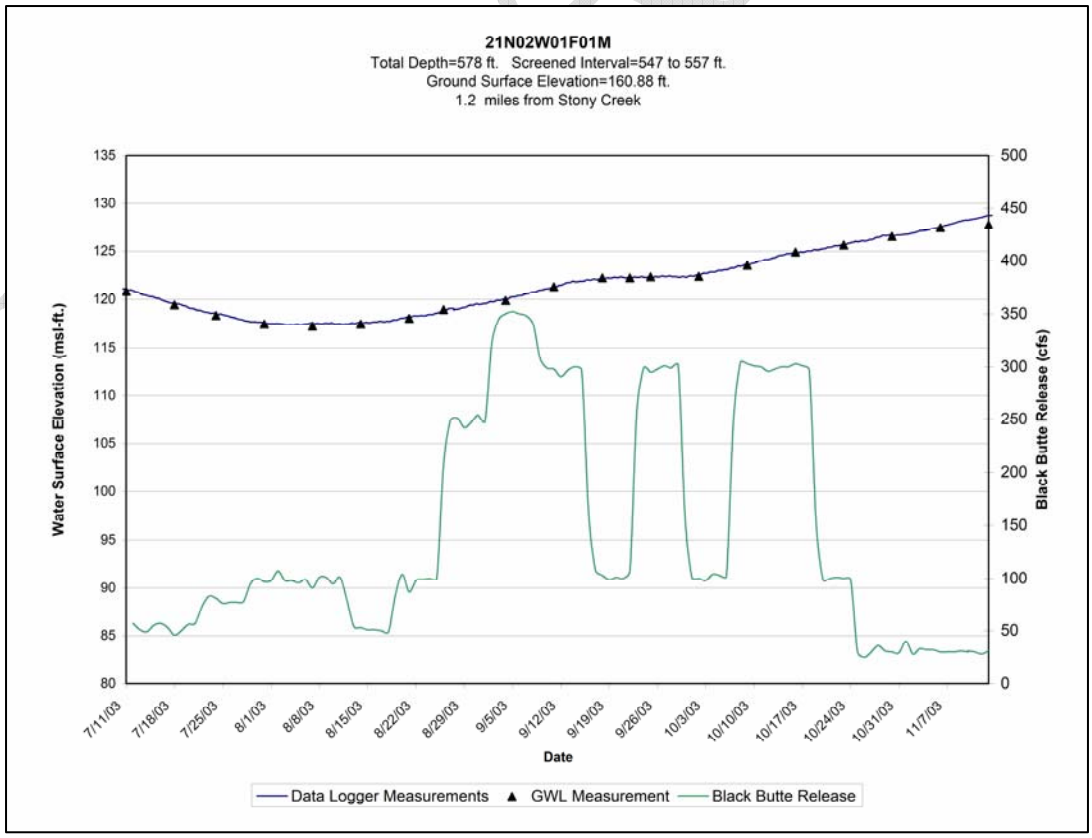
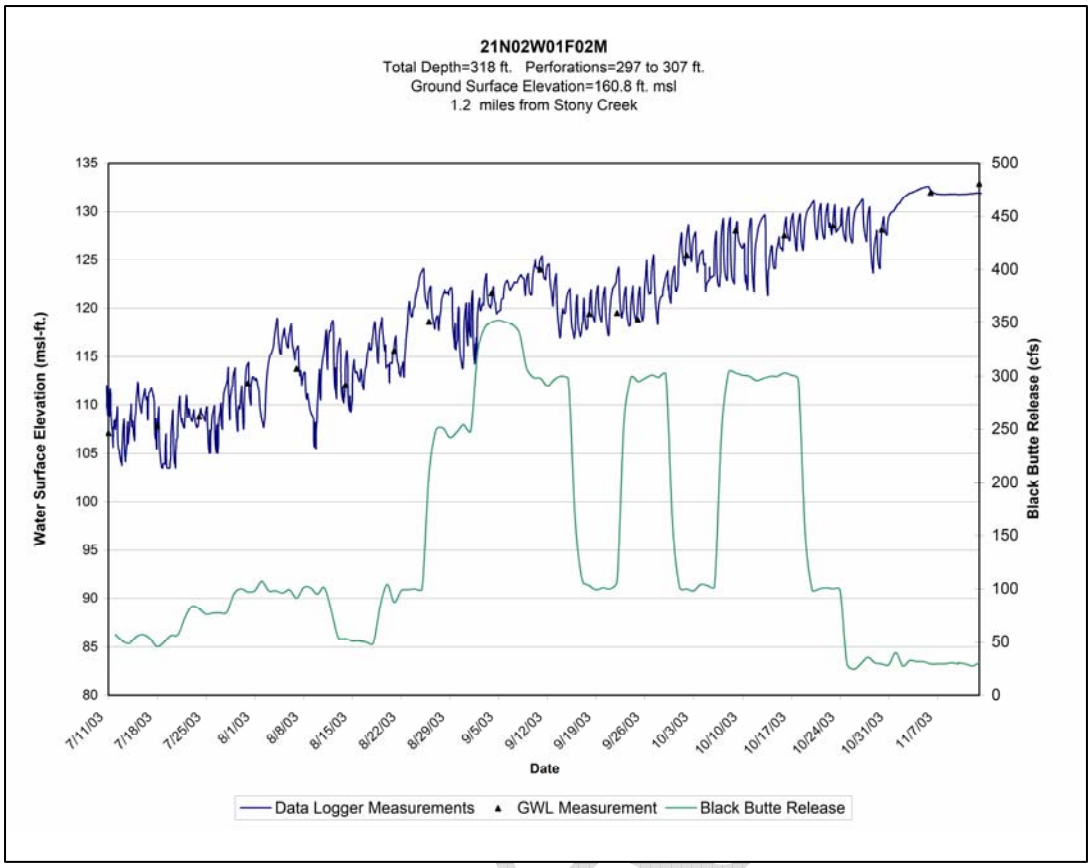
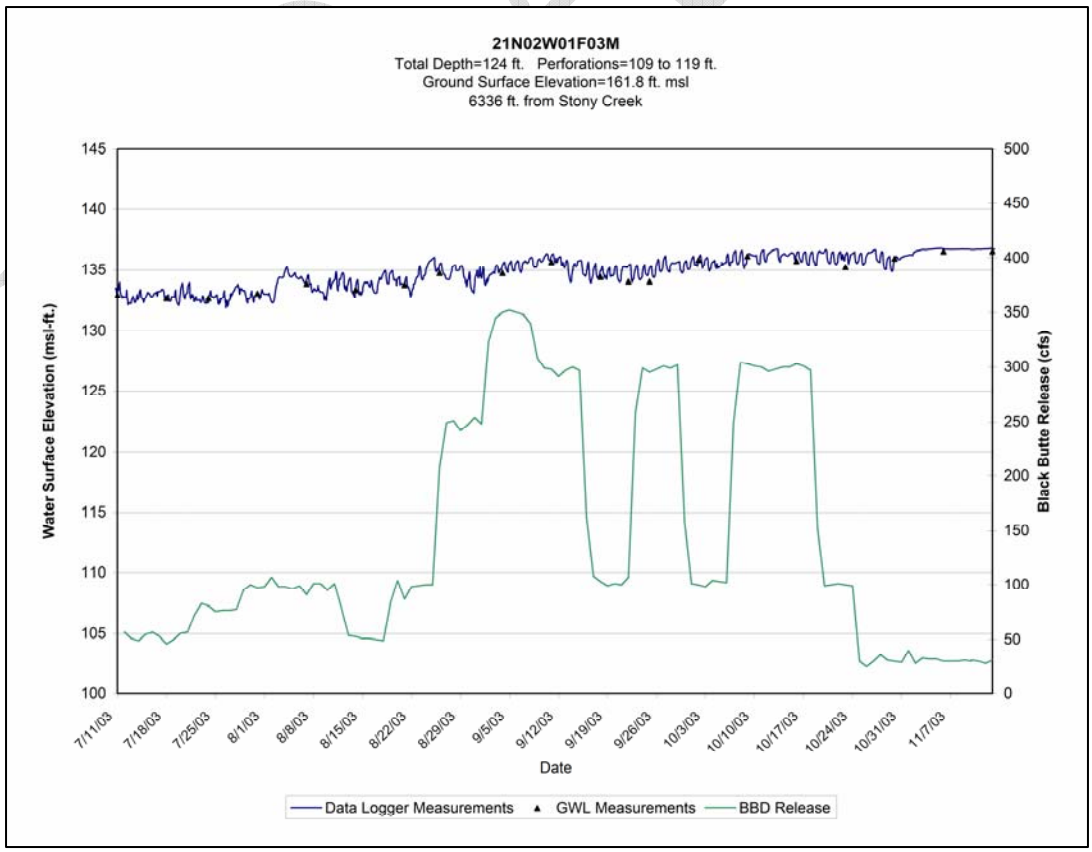

21N01W04N01M
Total Depth=100 ft. Perforations=Unknown
Ground Surface Elevation=135 ft. msl
1020 ft. from Stony Creek; 1.6 mi. from Sacramento River
Water Surface Elevation (ft. msl)
Black Butte Reservoir Release (cfs)
Pumping
Pumping
Pumping
Date
21N01W04N01M
Black Butte Release

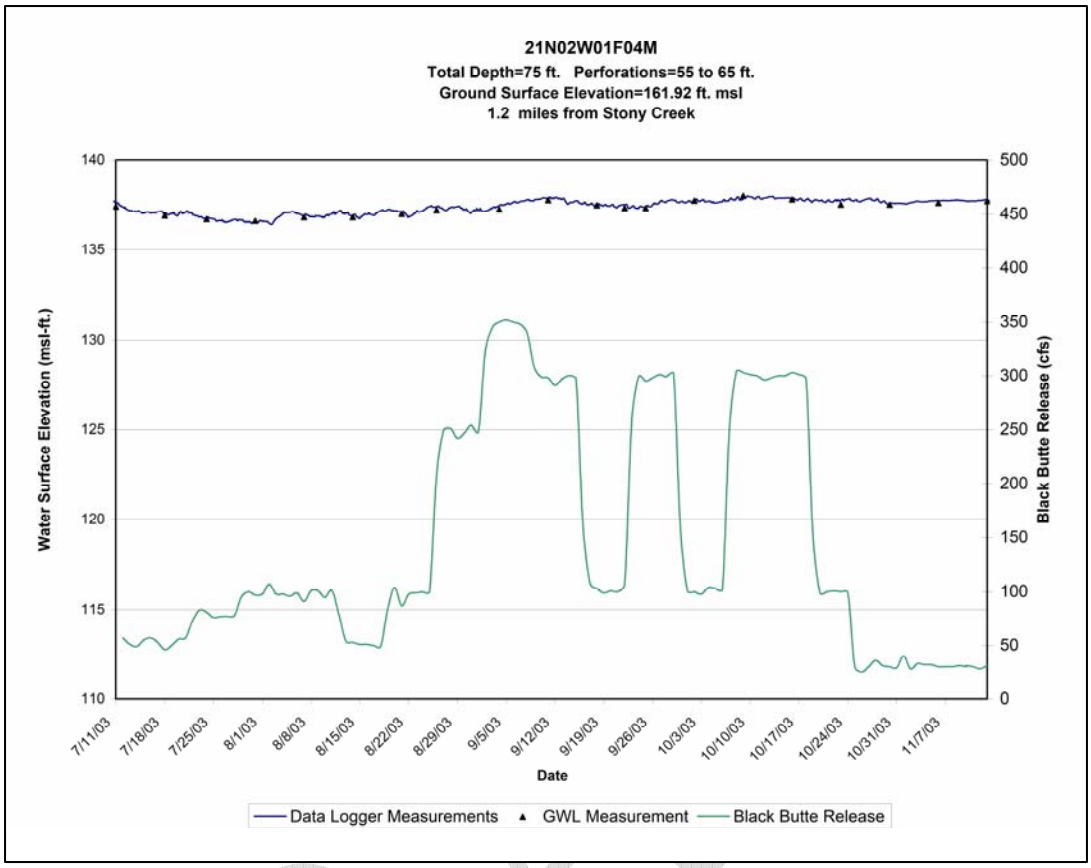

21N01W17F01M
Total Depth=27 ft. Perforations=Open Hole
Ground Surface Elevation=132.5 ft. msl
5988 ft from Stony Creek, 3048 ft from Sacramento River
Water Surface Elevation (ft. msl)
Black Butte Reservoir Release (cfs)
Date
21N01W17F01M
Stony Creek Discharge

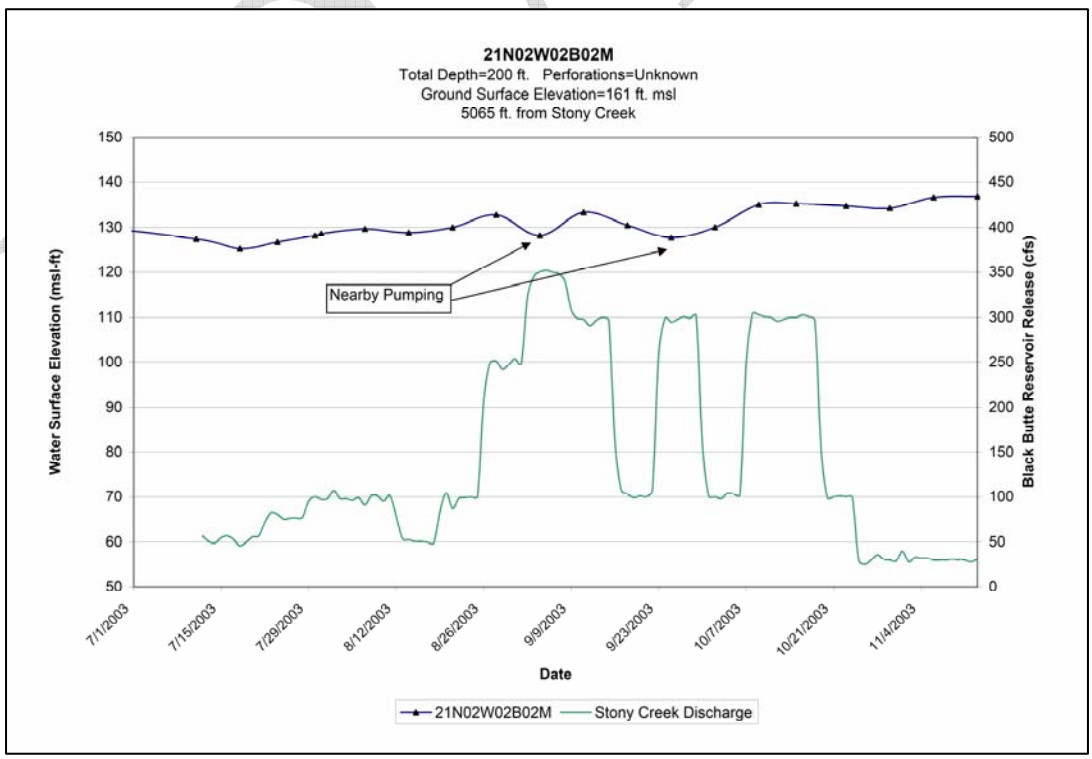

21N01W18Q02M
Total Depth=170 ft. Perforations=100 to 170 ft.
Ground Surface Elevation=130 ft. msl
10,843 ft. from Stony Creek; 4,465 ft. from Sacramento River
Water Surface Elevation (ft. msl)
Black Butte Reservoir Release (cfs)
Pumping
Date
21N01W18Q02M
Stony Creek Discharge

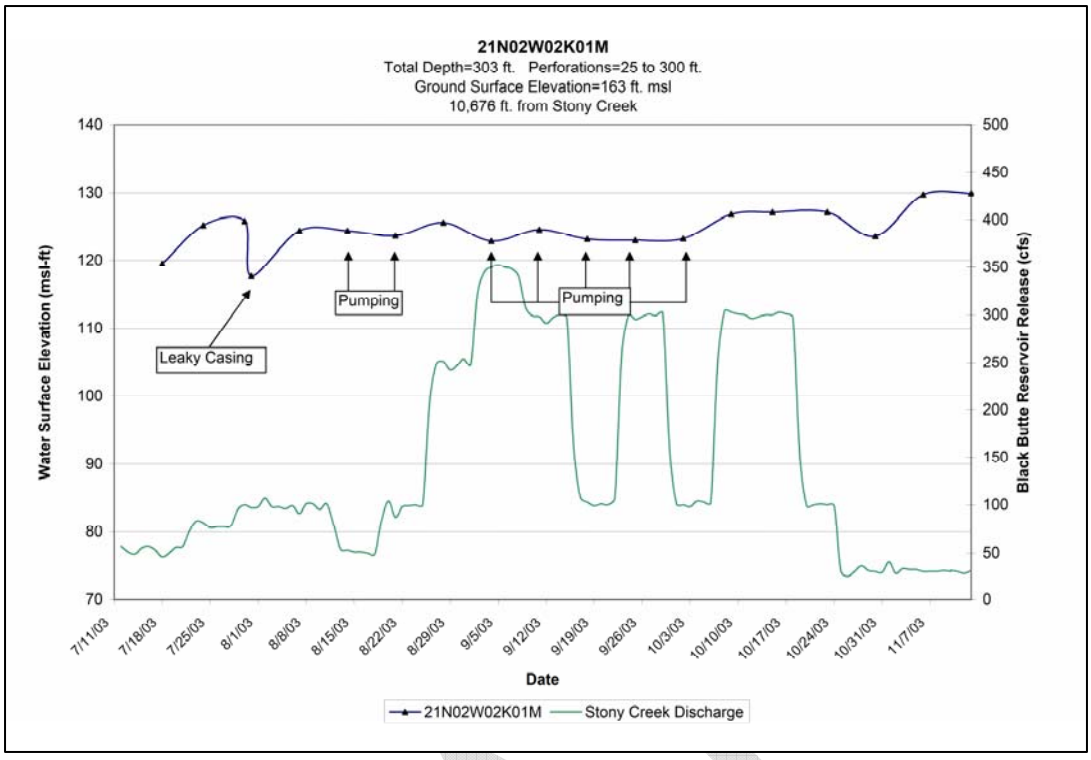

21N02W01F01M
Total Depth=578 ft. Screened Interval=547 to 557 ft.
Ground Surface Elevation=160.88 ft.
1.2 miles from Stony Creek
Water Surface Elevation (msl-ft.)
Black Butte Release (cfs)
Date
Data Logger Measurements
GWL Measurement
Black Butte Release

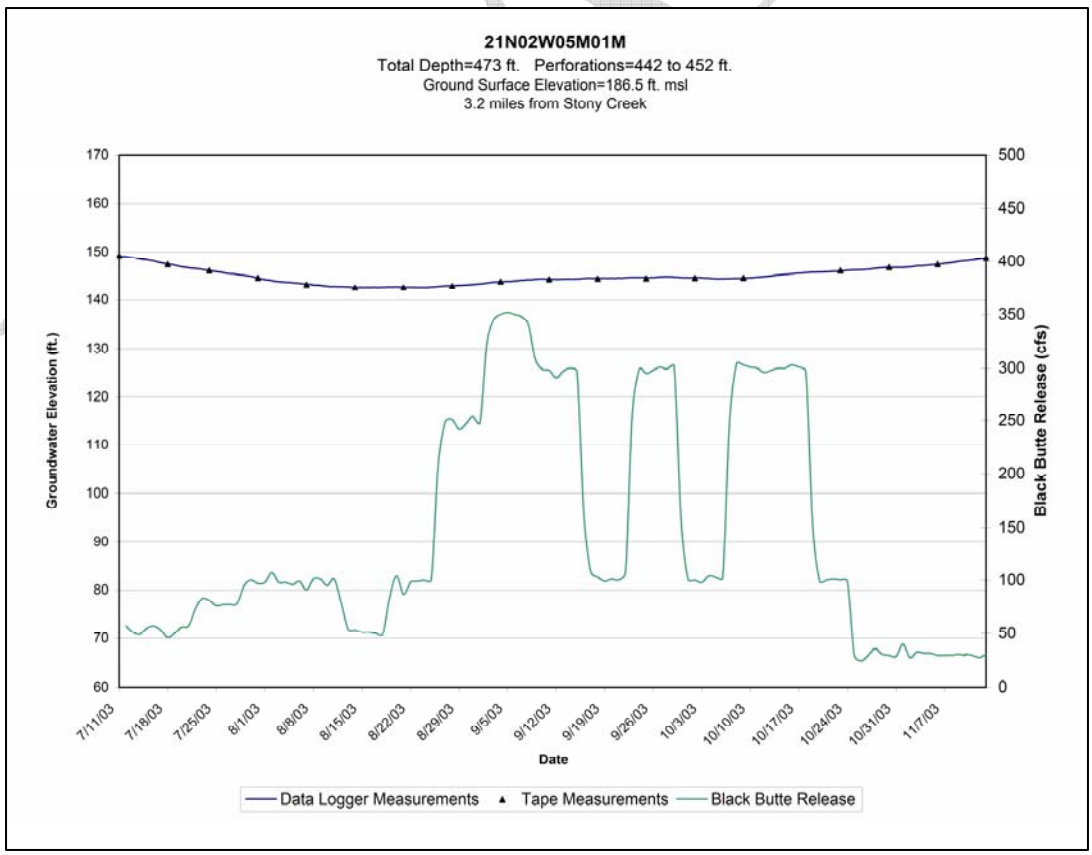

21N02W01F02M
Total Depth=318 ft. Perforations=297 to 307 ft.
Ground Surface Elevation=160.8 ft. msl
1.2 miles from Stony Creek
Water Surface Elevation (msl-ft.)
Black Butte Release (cfs)
Date
Data Logger Measurements
GWL Measurement
Black Butte Release

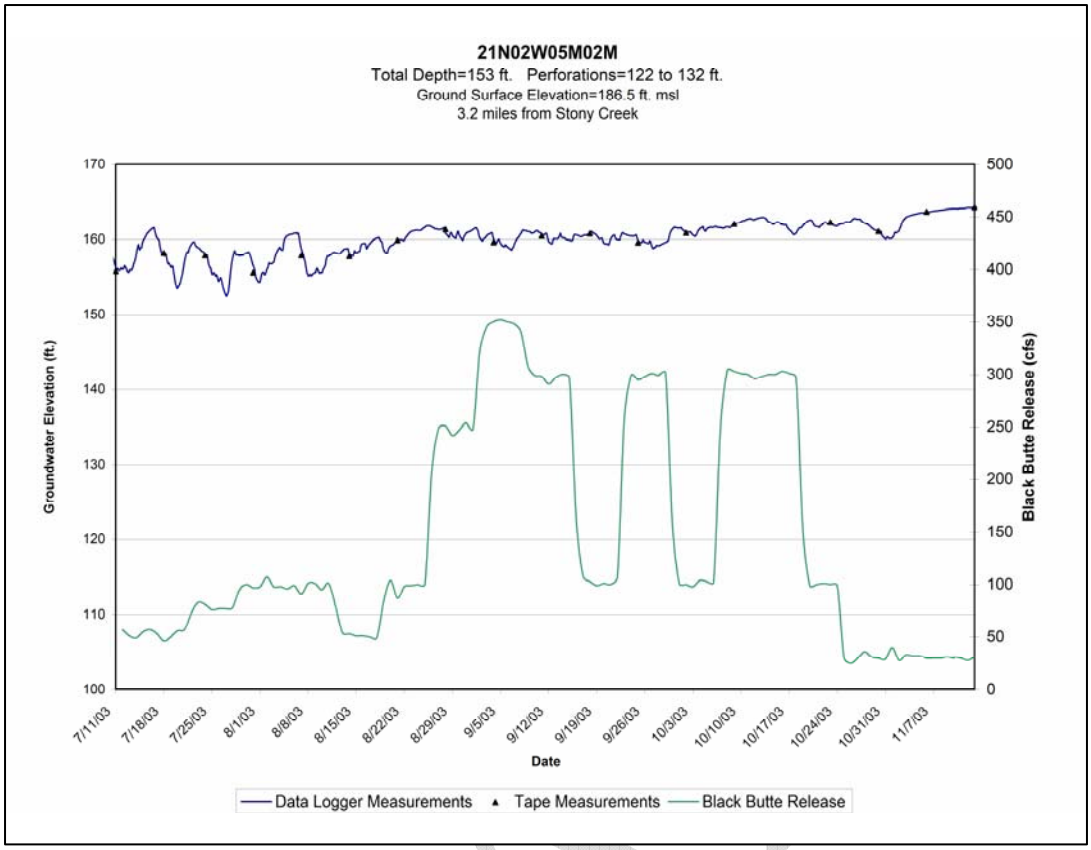

21N02W01F03M
Total Depth=124 ft. Perforations=109 to 119 ft.
Ground Surface Elevation=161.8 ft. msl
6336 ft. from Stony Creek
Water Surface Elevation (msl-ft.)
Black Butte Release (cfs)
Date
Data Logger Measurements
GWL Measurements
BBD Release

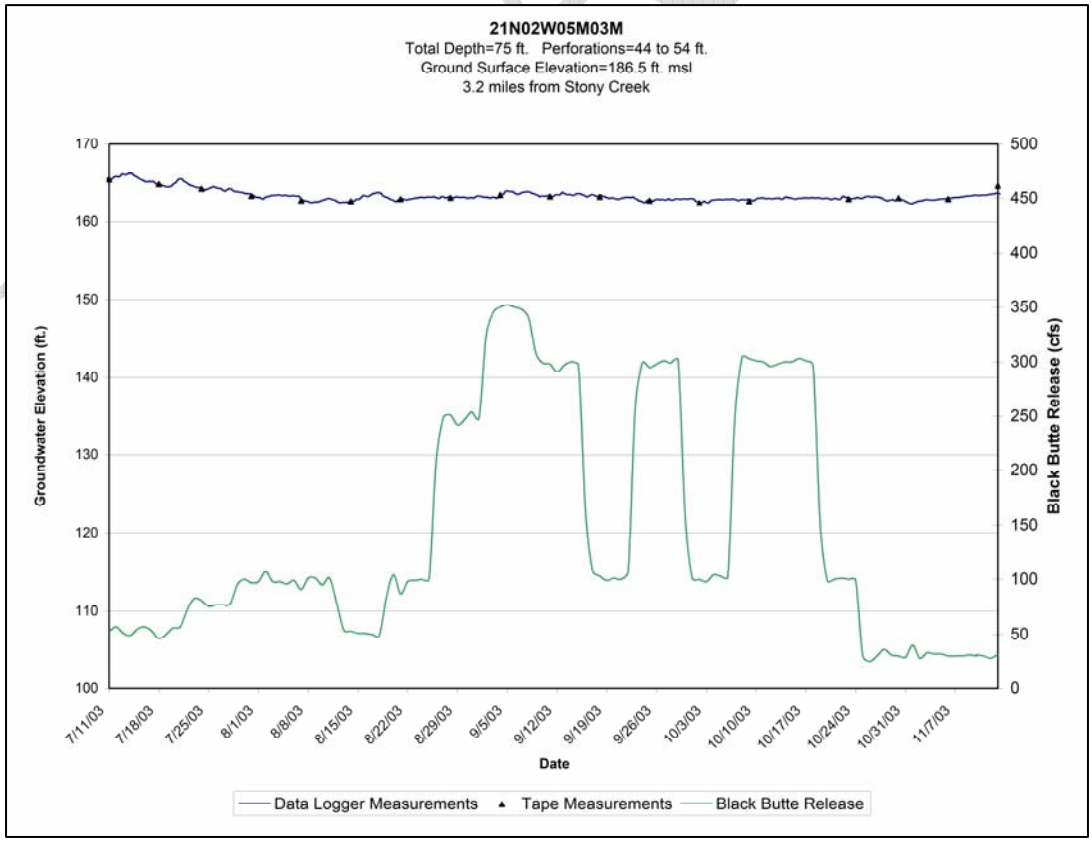

21N02W01F04M
Total Depth=75 ft. Perforations=55 to 65 ft.
Ground Surface Elevation=161.92 ft. msl
1.2 miles from Stony Creek
Water Surface Elevation (msl-ft.)
Black Butte Release (cfs)
Date
Data Logger Measurements
GWL Measurement
Black Butte Release

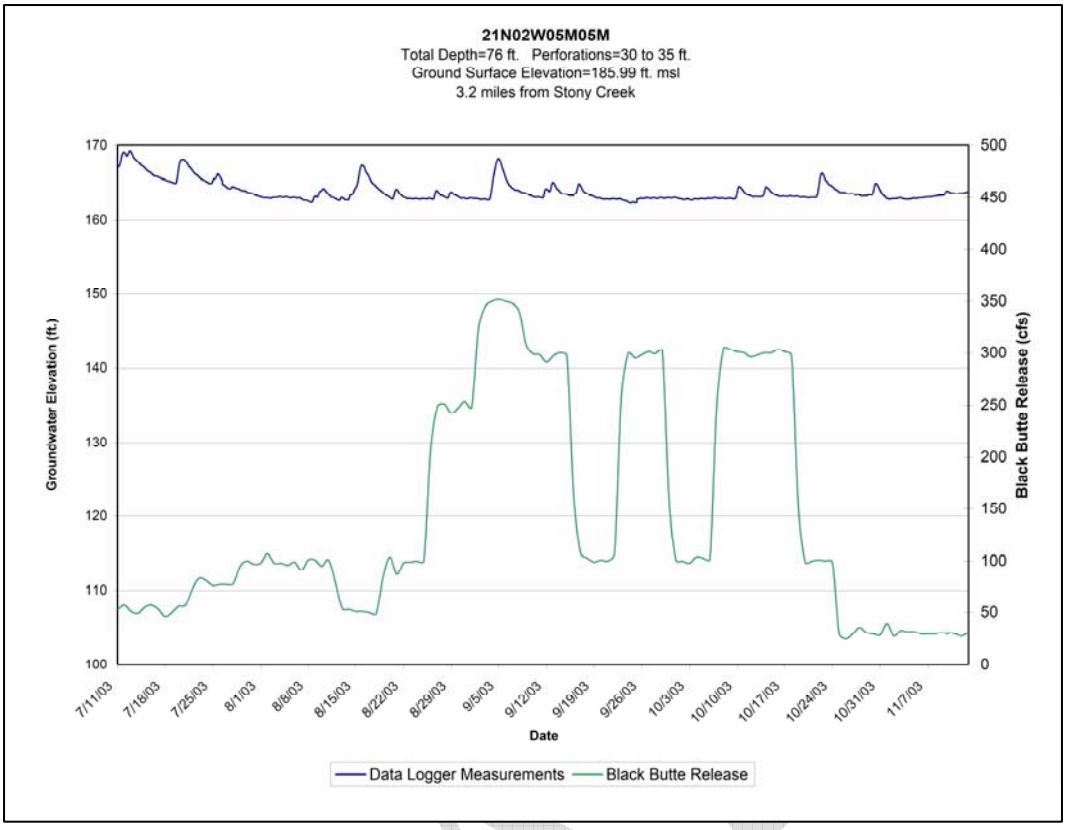

21N02W02B02M
Total Depth=200 ft. Perforations=Unknown
Ground Surface Elevation=161 ft. msl
5065 ft. from Stony Creek
Water Surface Elevation (msl-ft)
Black Butte Reservoir Release (cfs)
Nearby Pumping
Date
21N02W02B02M
Stony Creek Discharge

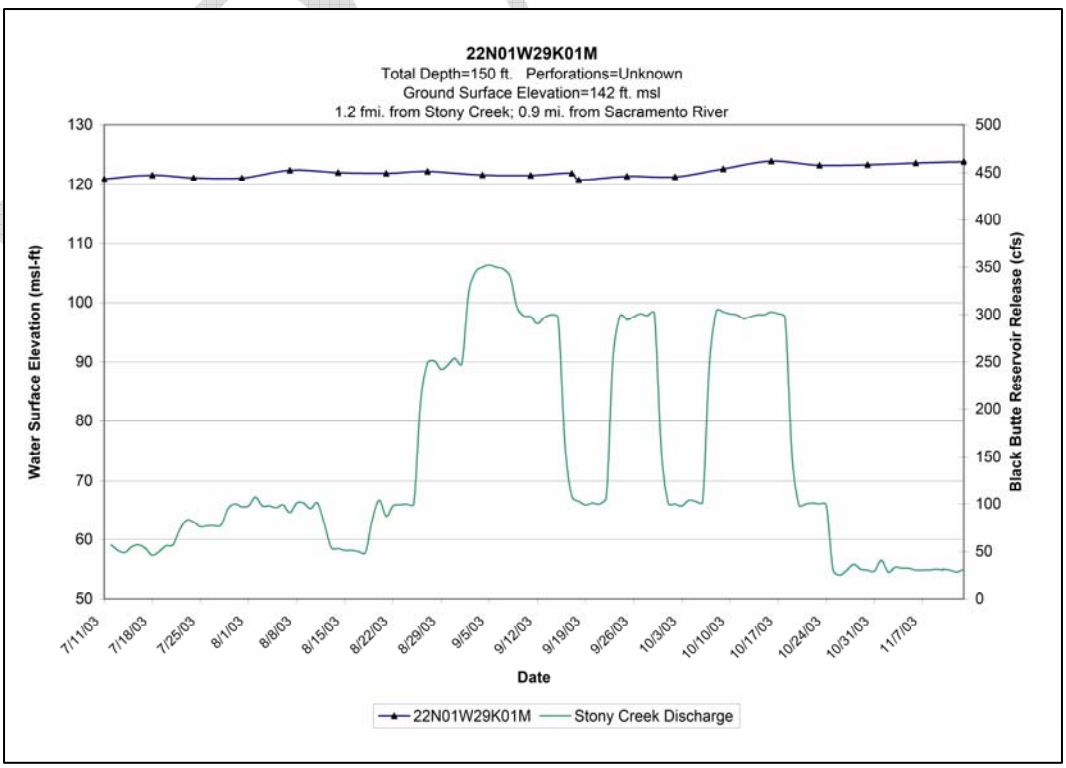

21N02W02K01M
Total Depth=303 ft. Perforations=25 to 300 ft.
Ground Surface Elevation=163 ft. msl
10,676 ft. from Stony Creek
Water Surface Elevation (msl-ft)
Black Butte Reservoir Release (cfs)
Pumping
Pumping
Leaky Casing
Date
21N02W02K01M
Stony Creek Discharge

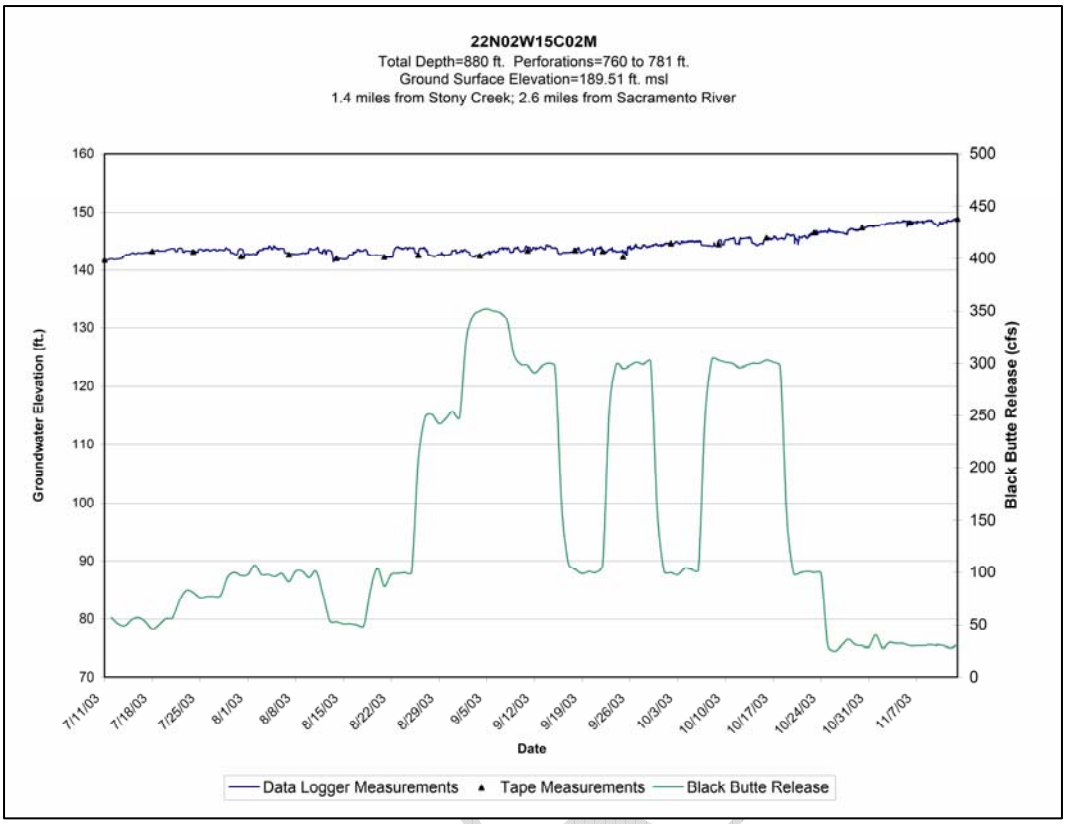

21N02W05M01M
Total Depth=473 ft. Perforations=442 to 452 ft.
Ground Surface Elevation=186.5 ft. msl
3.2 miles from Stony Creek
Groundwater Elevation (ft.)
Black Butte Release (cfs)
Date
Data Logger Measurements
Tape Measurements
Black Butte Release

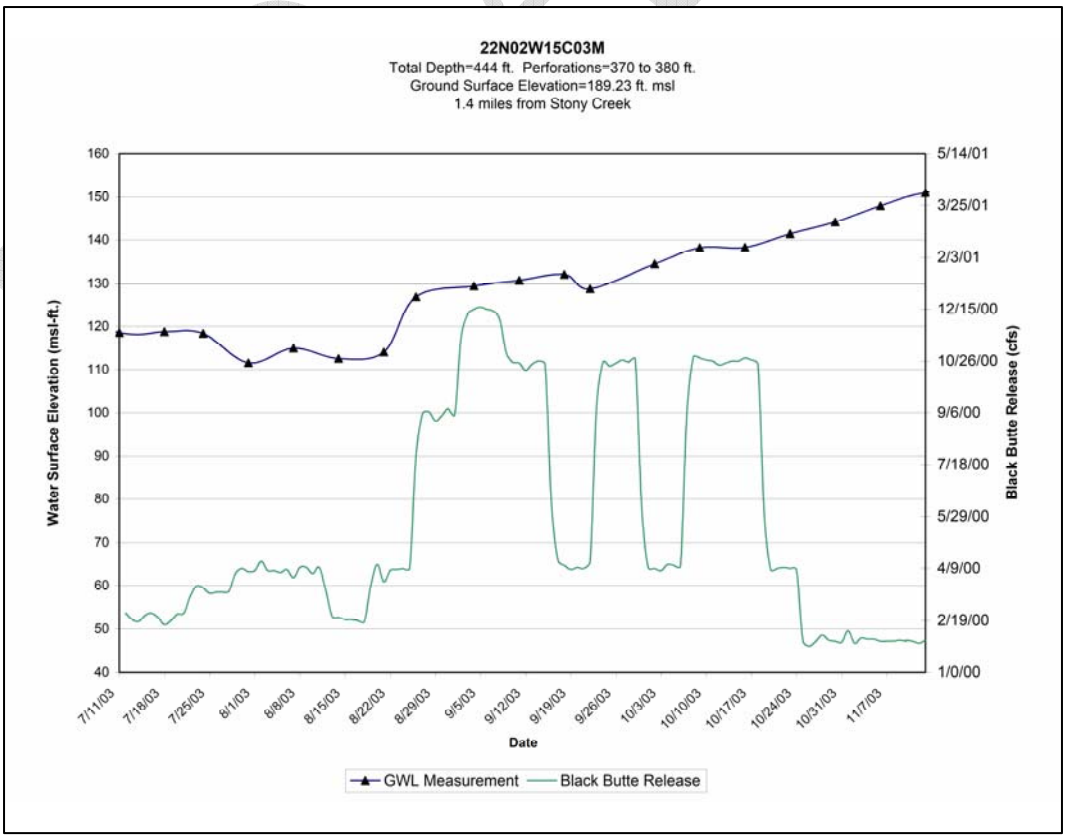

21N02W05M02M
Total Depth=153 ft. Perforations=122 to 132 ft.
Ground Surface Elevation=186.5 ft. msl
3.2 miles from Stony Creek
Groundwater Elevation (ft.)
Black Butte Release (cfs)
Date
Data Logger Measurements
Tape Measurements
Black Butte Release

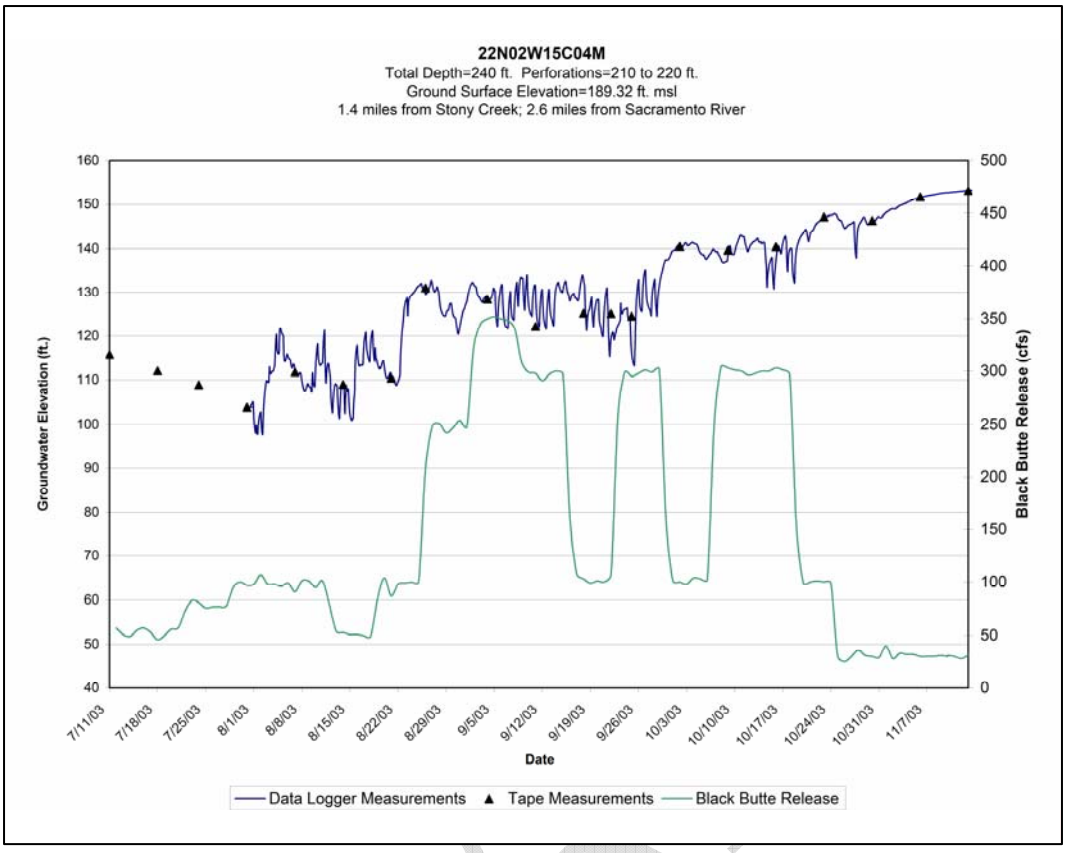

21N02W05M03M
Total Depth=75 ft. Perforations=44 to 54 ft.
Ground Surface Elevation=186.5 ft. msl
3.2 miles from Stony Creek
Groundwater Elevation (ft.)
Black Butte Release (cfs)
Date
Data Logger Measurements
Tape Measurements
Black Butte Release

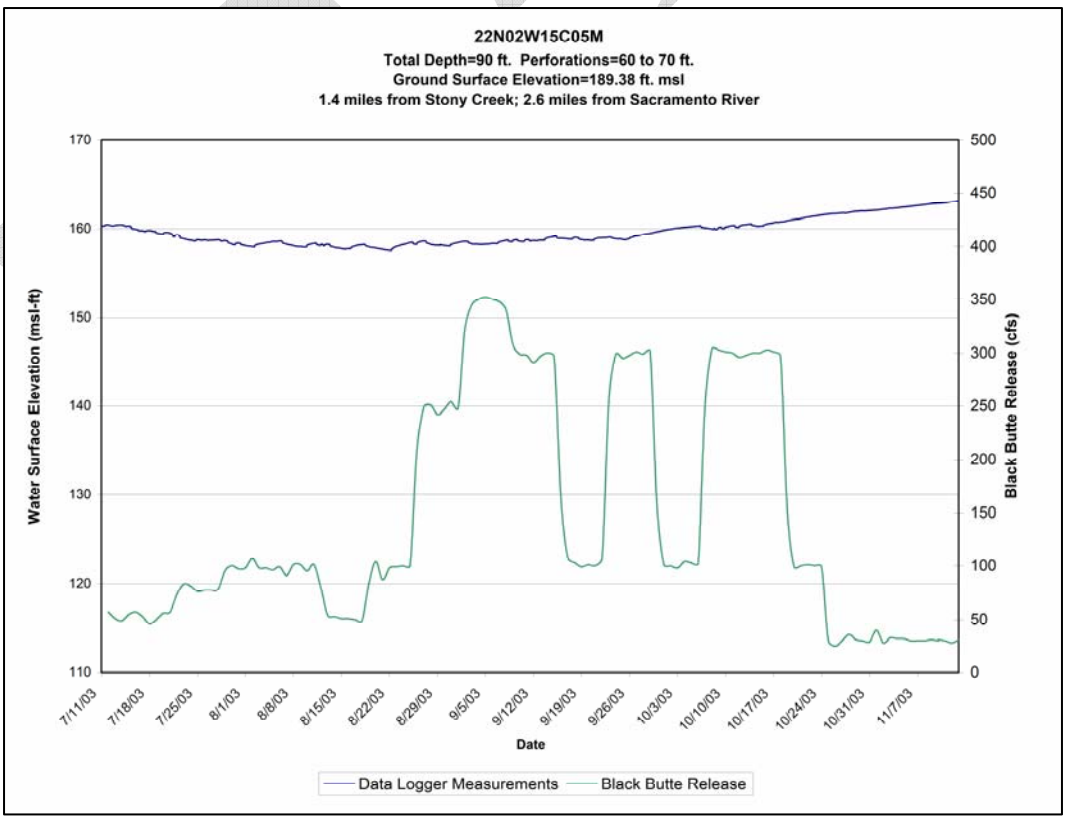

21N02W05M05M
Total Depth=76 ft. Perforations=30 to 35 ft.
Ground Surface Elevation=185.99 ft. msl
3.2 miles from Stony Creek
Groundwater Elevation (ft.)
Black Butte Release (cfs)
Date
Data Logger Measurements
Black Butte Release

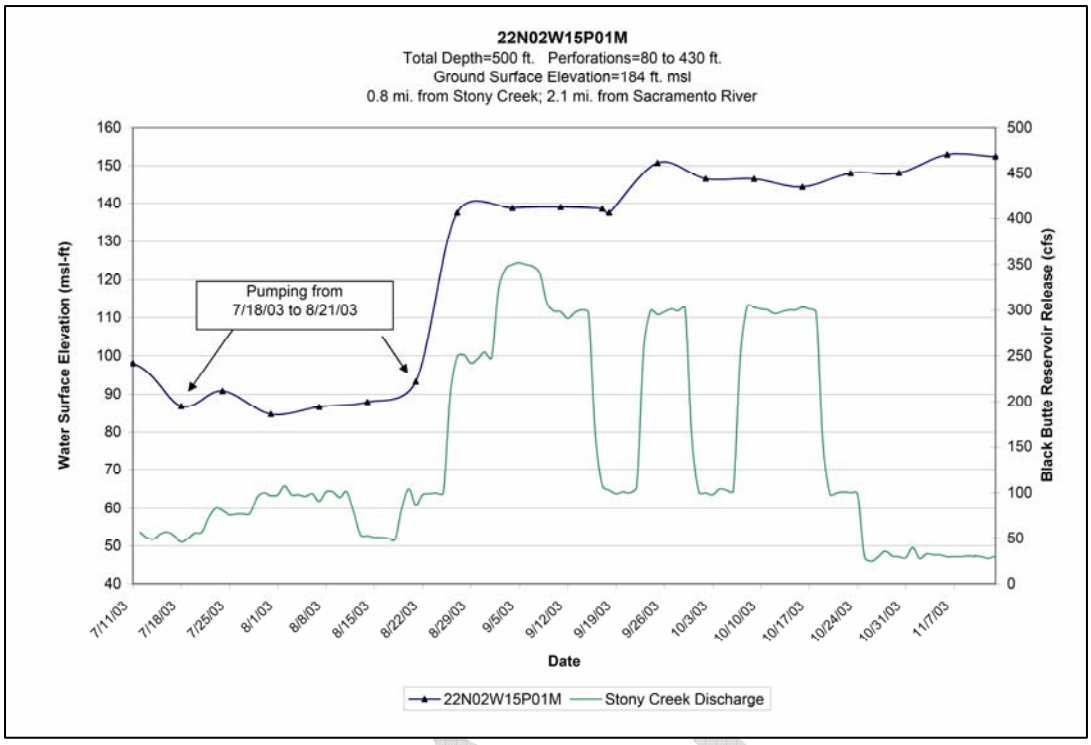

22N01W29K01M
Total Depth=150 ft. Perforations=Unknown
Ground Surface Elevation=142 ft. msl
1.2 fmi. from Stony Creek; 0.9 mi. from Sacramento River
Water Surface Elevation (msl-ft)
Black Butte Reservoir Release (cfs)
Date
22N01W29K01M
Stony Creek Discharge

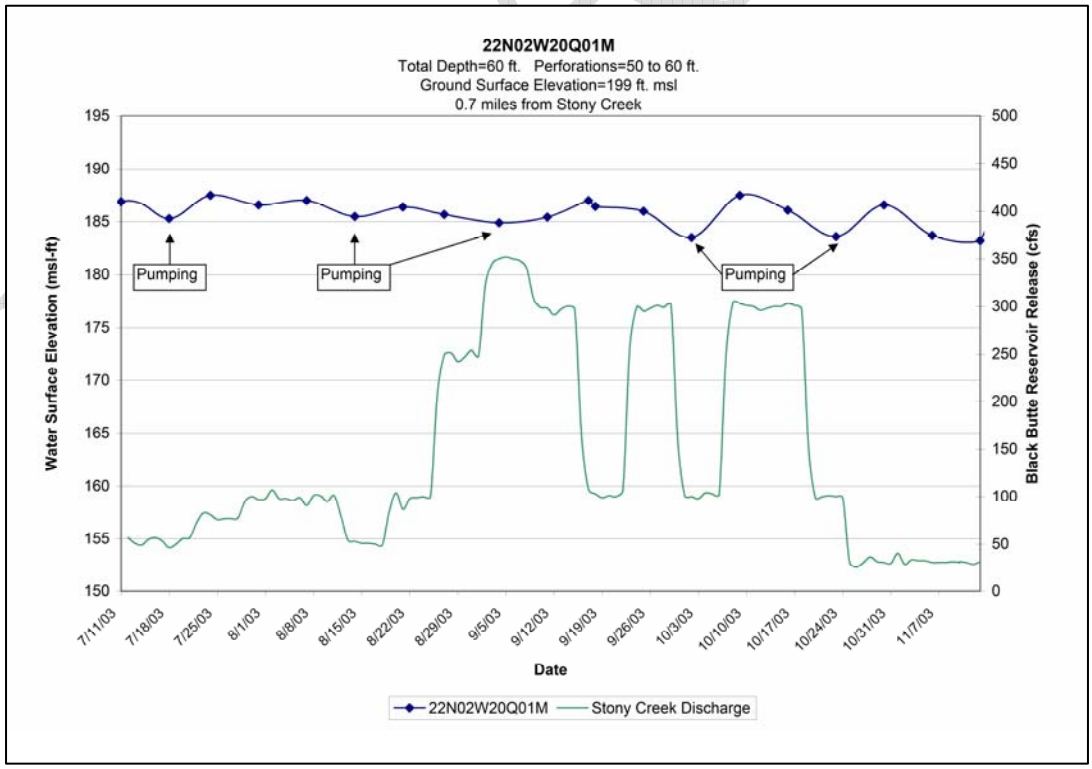

22N02W15C02M
Total Depth=880 ft. Perforations=760 to 781 ft.
Ground Surface Elevation=189.51 ft. msl
1.4 miles from Stony Creek; 2.6 miles from Sacramento River
Groundwater Elevation (ft.)
Black Butte Release (cfs)
Date
Data Logger Measurements
Tape Measurements
Black Butte Release

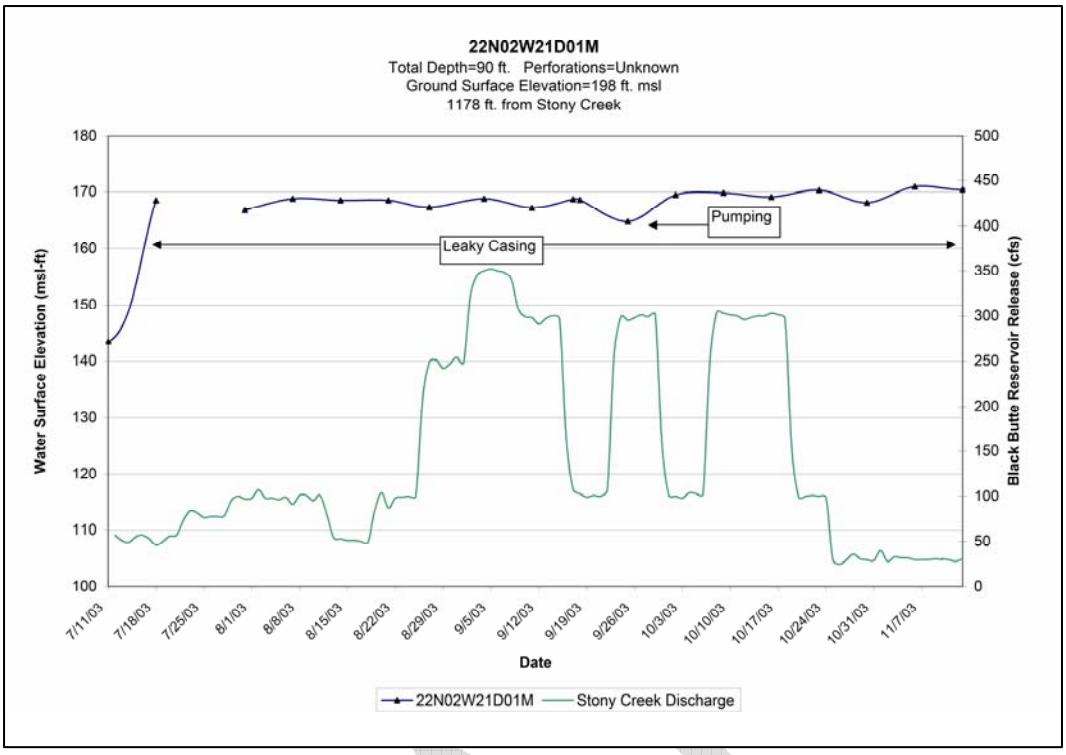

22N02W15C03M
Total Depth=444 ft. Perforations=370 to 380 ft.
Ground Surface Elevation=189.23 ft. msl
1.4 miles from Stony Creek
Water Surface Elevation (msl-ft.)
Black Butte Release (cfs)
Date
GWL Measurement
Black Butte Release

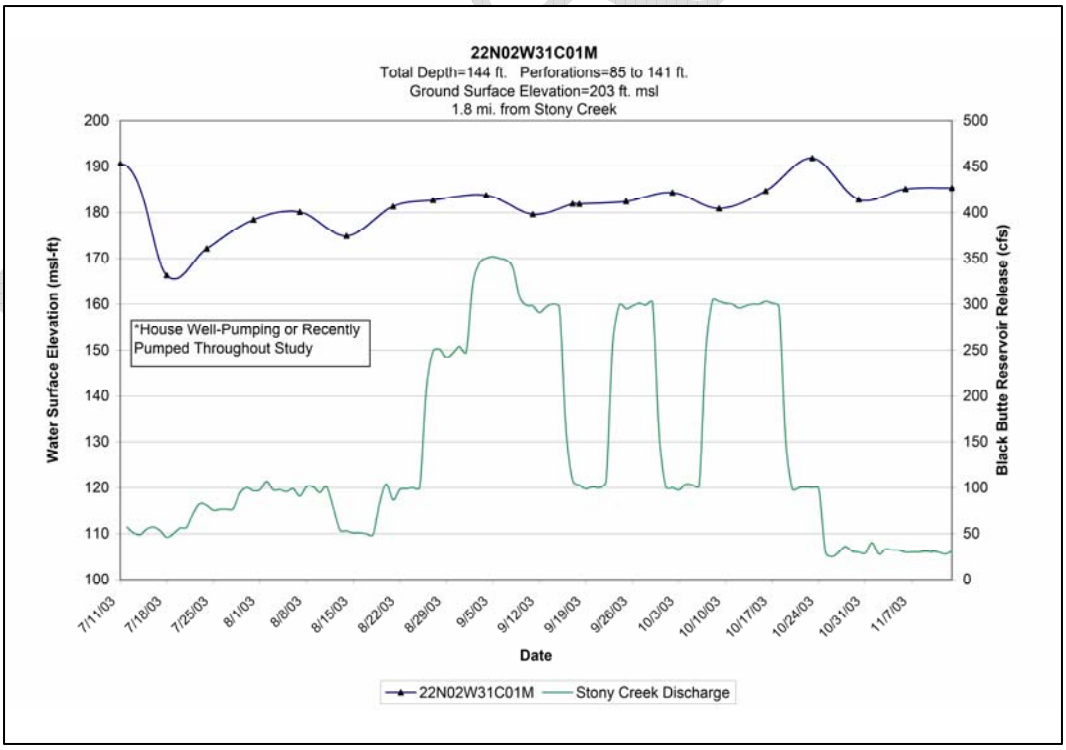

22N02W15C04M
Total Depth=240 ft. Perforations=210 to 220 ft.
Ground Surface Elevation=189.32 ft. msl
1.4 miles from Stony Creek; 2.6 miles from Sacramento River
Groundwater Elevation (ft.)
Black Butte Release (cfs)
Date
Data Logger Measurements
Tape Measurements
Black Butte Release

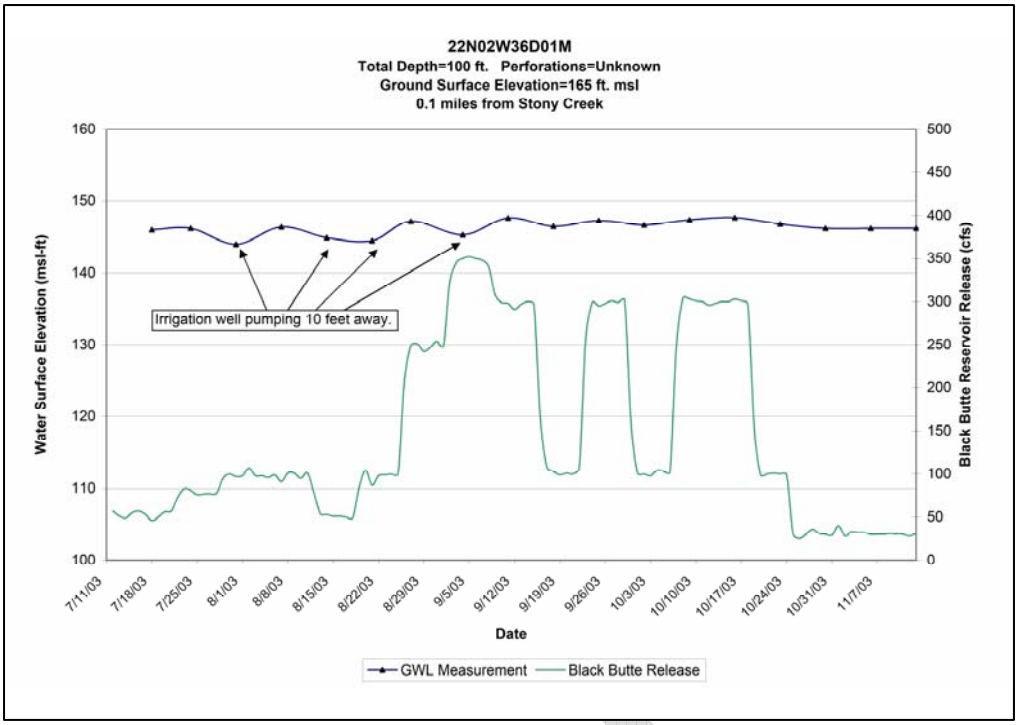

22N02W15C05M
Total Depth=90 ft. Perforations=60 to 70 ft.
Ground Surface Elevation=189.38 ft. msl
1.4 miles from Stony Creek; 2.6 miles from Sacramento River
Water Surface Elevation (msl-ft)
Black Butte Release (cfs)
Date
Data Logger Measurements
Black Butte Release

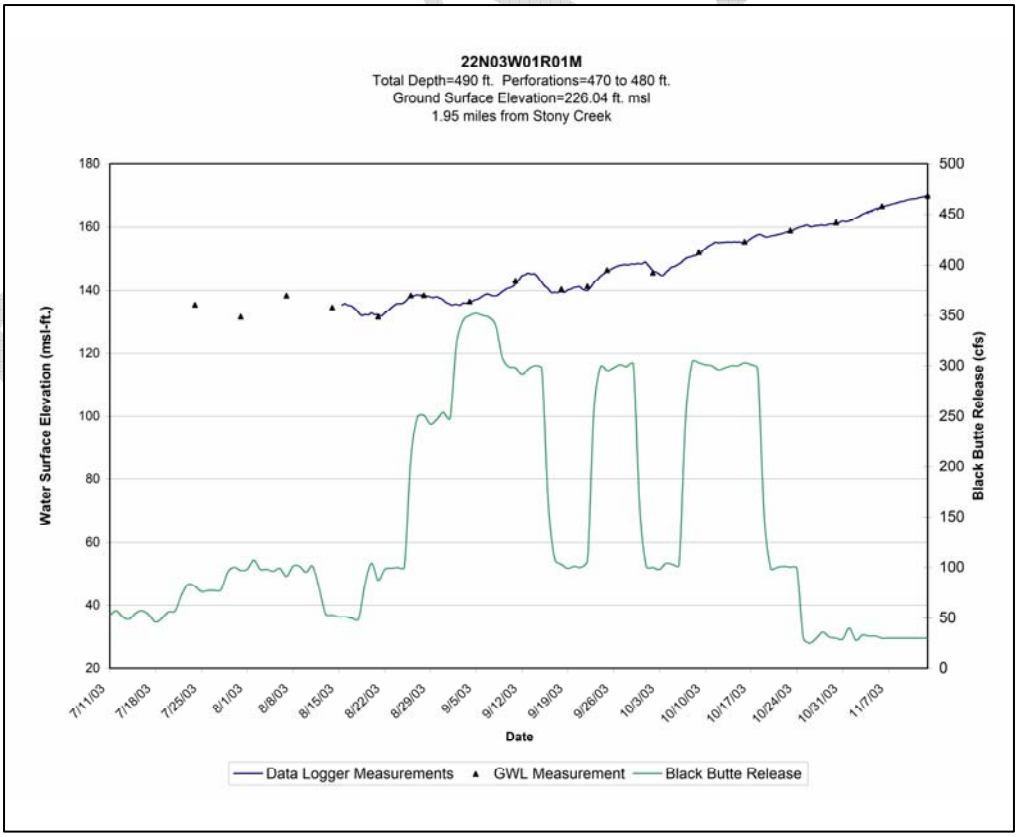

22N02W15P01M
Total Depth=500 ft. Perforations=80 to 430 ft.
Ground Surface Elevation=184 ft. msl
0.8 mi. from Stony Creek; 2.1 mi. from Sacramento River
Water Surface Elevation (msl-ft)
Black Butte Reservoir Release (cfs)
Pumping from
7/18/03 to 8/21/03
Date
22N02W15P01M
Stony Creek Discharge

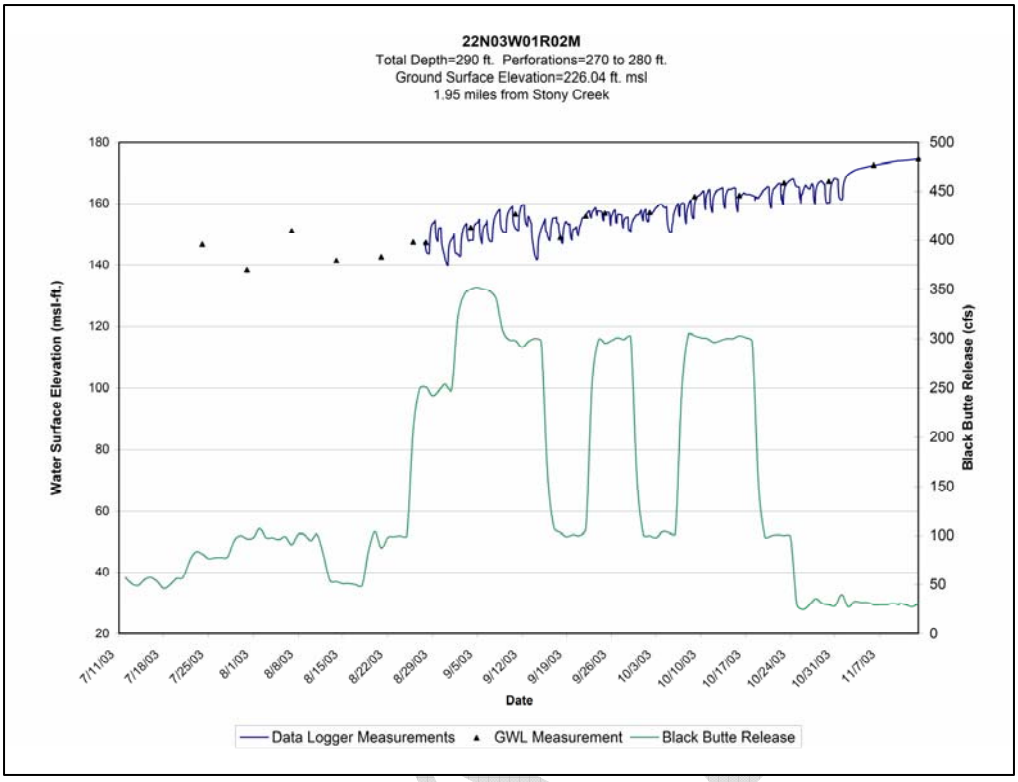

22N02W20Q01M
Total Depth=60 ft. Perforations=50 to 60 ft.
Ground Surface Elevation=199 ft. msl
0.7 miles from Stony Creek
Water Surface Elevation (msl-ft)
Black Butte Reservoir Release (cfs)
Pumping
Pumping
Pumping
Date
22N02W20Q01M
Stony Creek Discharge

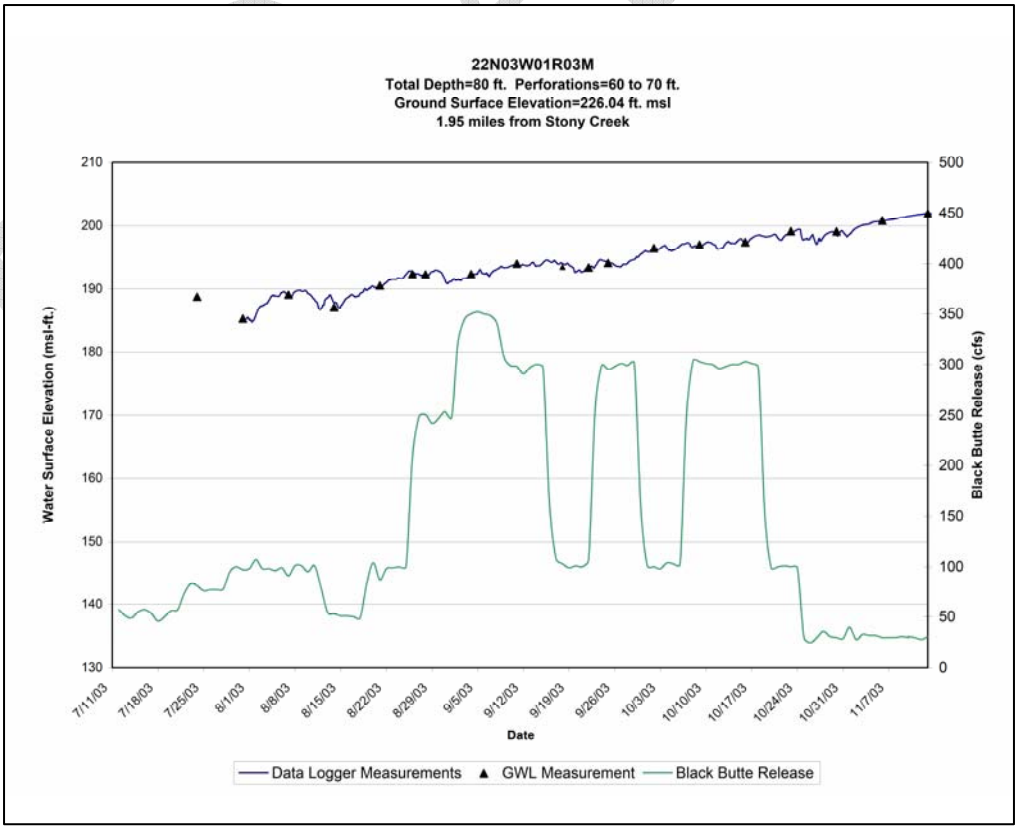

22N02W21D01M
Total Depth=90 ft. Perforations=Unknown
Ground Surface Elevation=198 ft. msl
1178 ft. from Stony Creek
Water Surface Elevation (msl-ft)
Black Butte Reservoir Release (cfs)
Pumping
Leaky Casing
Date
22N02W21D01M
Stony Creek Discharge

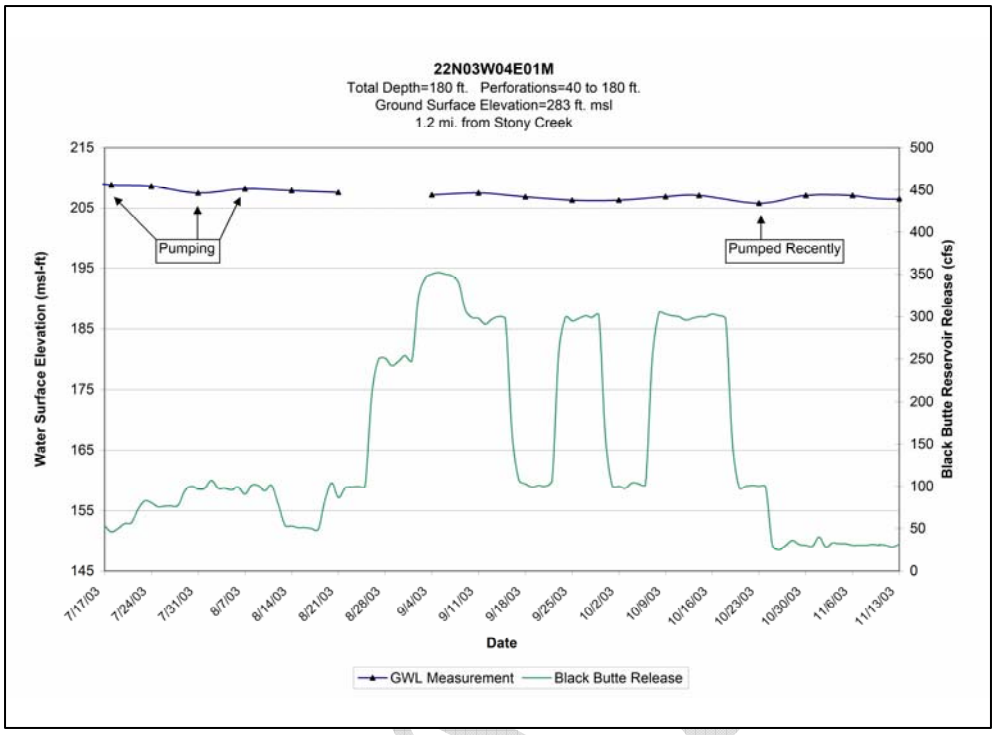

22N02W31C01M
Total Depth=144 ft. Perforations=85 to 141 ft.
Ground Surface Elevation=203 ft. msl
1.8 mi. from Stony Creek
Water Surface Elevation (msl-ft)
Black Butte Reservoir Release (cfs)
*House Well-Pumping or Recently Pumped Throughout Study
Date
22N02W31C01M
Stony Creek Discharge

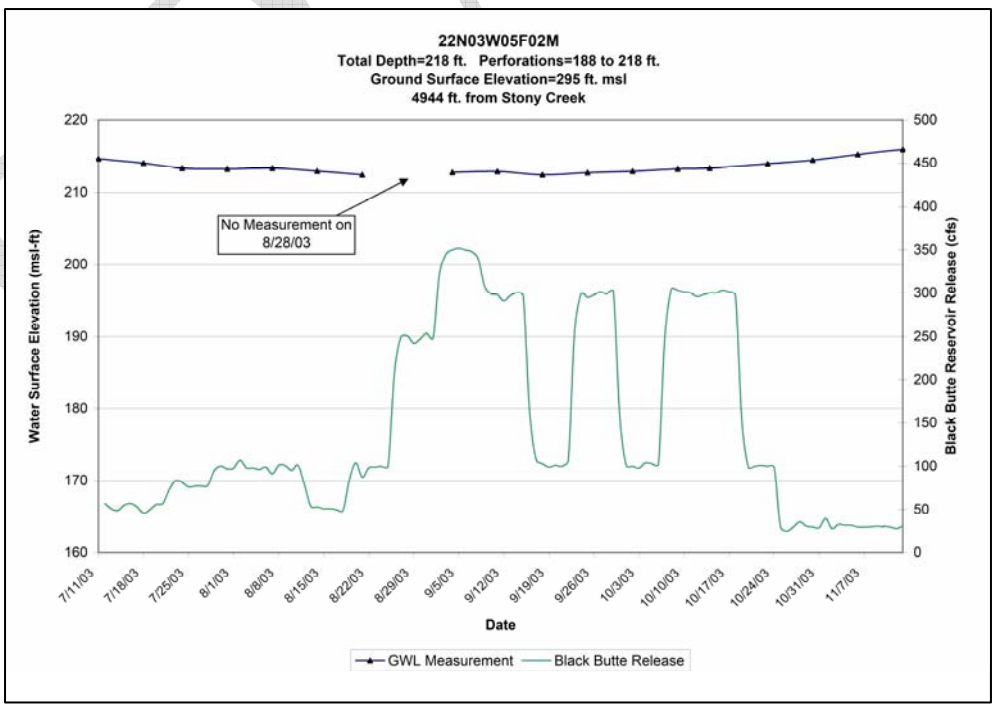

22N02W36D01M
Total Depth=100 ft. Perforations=Unknown
Ground Surface Elevation=165 ft. msl
0.1 miles from Stony Creek
Water Surface Elevation (msl-ft)
Black Butte Reservoir Release (cfs)
Irrigation well pumping 10 feet away.
Date
GWL Measurement
Black Butte Release

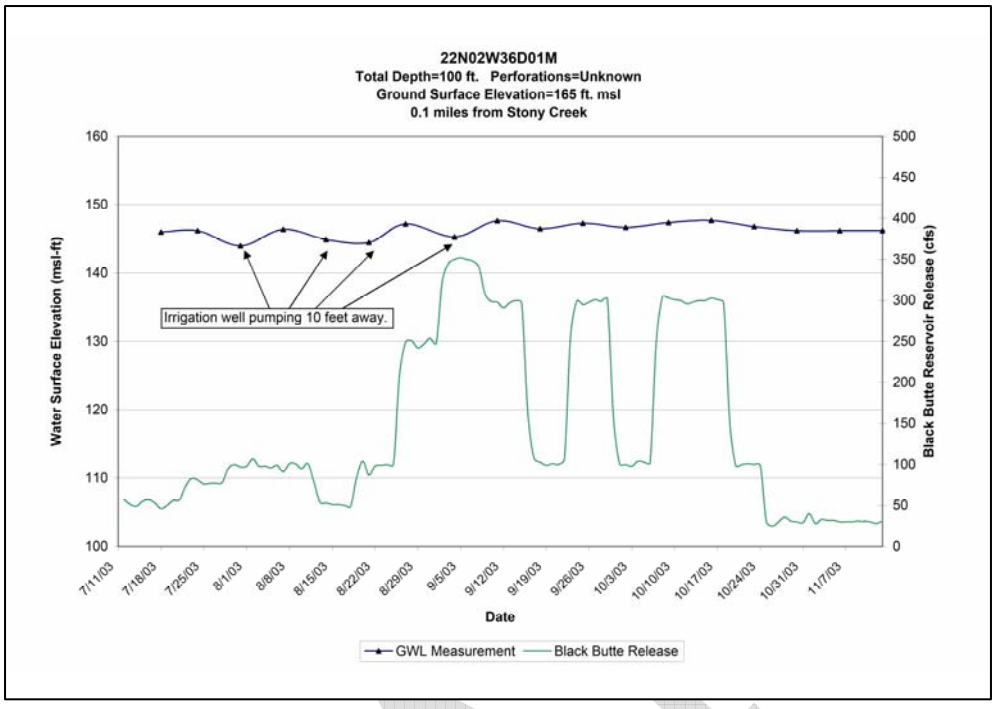

22N03W01R01M
Total Depth=490 ft. Perforations=470 to 480 ft.
Ground Surface Elevation=226.04 ft. msl
1.95 miles from Stony Creek
Water Surface Elevation (msl-ft.)
Black Butte Release (cfs)
Date
Data Logger Measurements
GWL Measurement
Black Butte Release

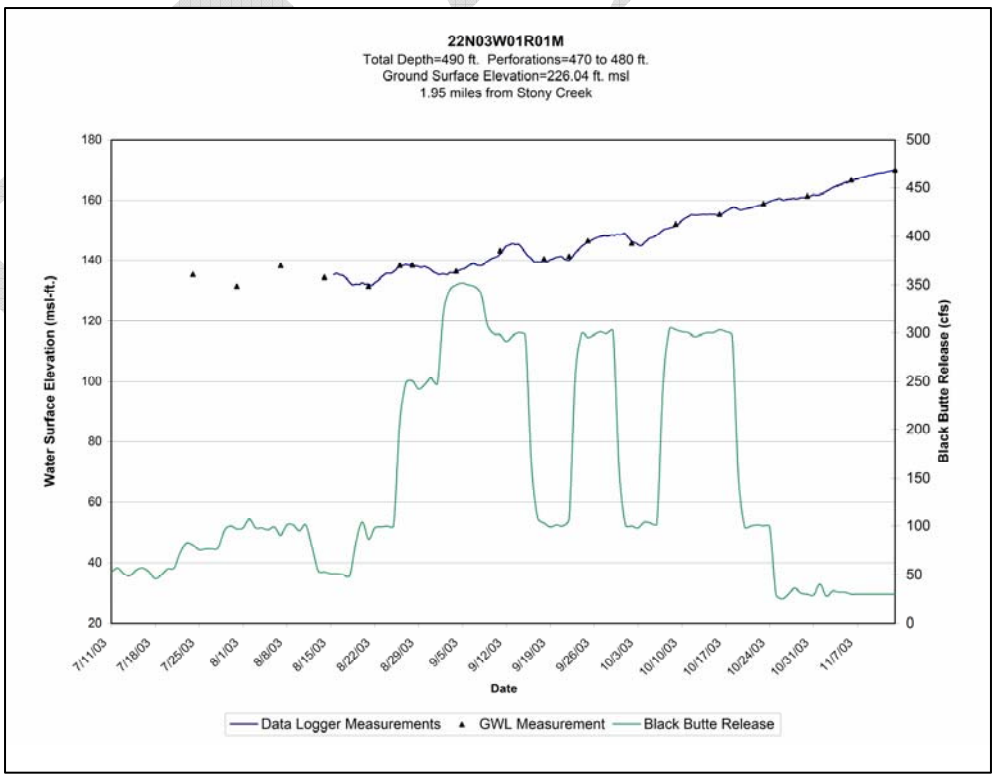

22N03W01R02M
Total Depth=290 ft. Perforations=270 to 280 ft.
Ground Surface Elevation=226.04 ft. msl
1.95 miles from Stony Creek
Water Surface Elevation (msl-ft.)
Black Butte Release (cfs)
Date
Data Logger Measurements
GWL Measurement
Black Butte Release

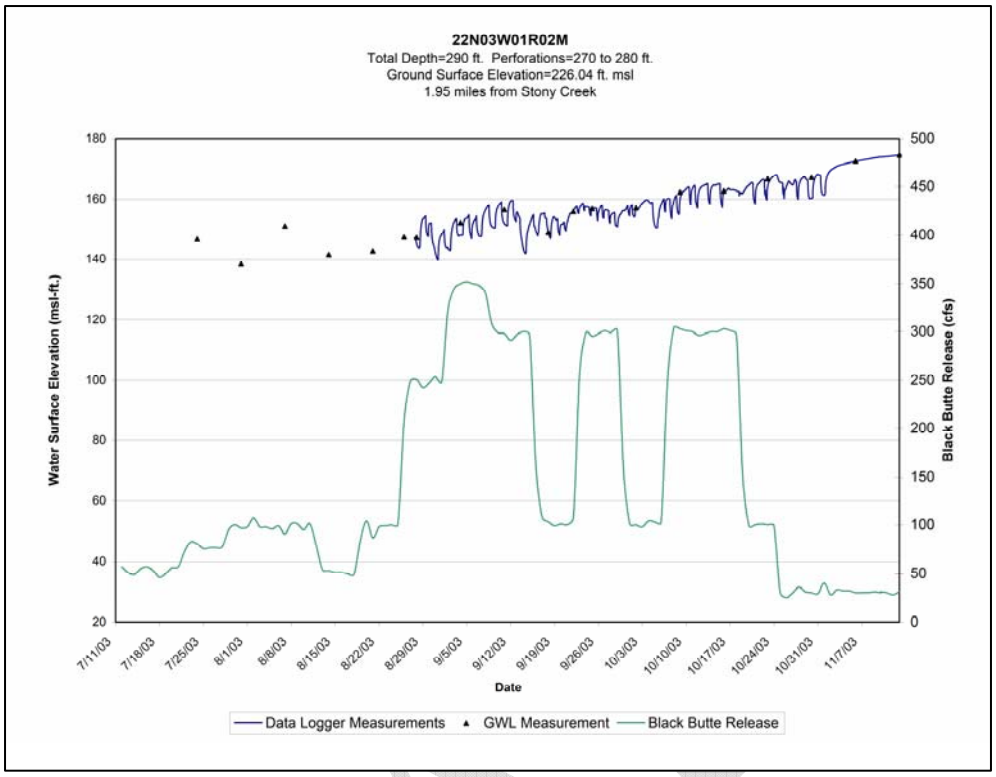

22N03W01R03M
Total Depth=80 ft. Perforations=60 to 70 ft.
Ground Surface Elevation=226.04 ft. msl
1.95 miles from Stony Creek
Water Surface Elevation (msl-ft.)
Black Butte Release (cfs)
Date
Data Logger Measurements
GWL Measurement
Black Butte Release

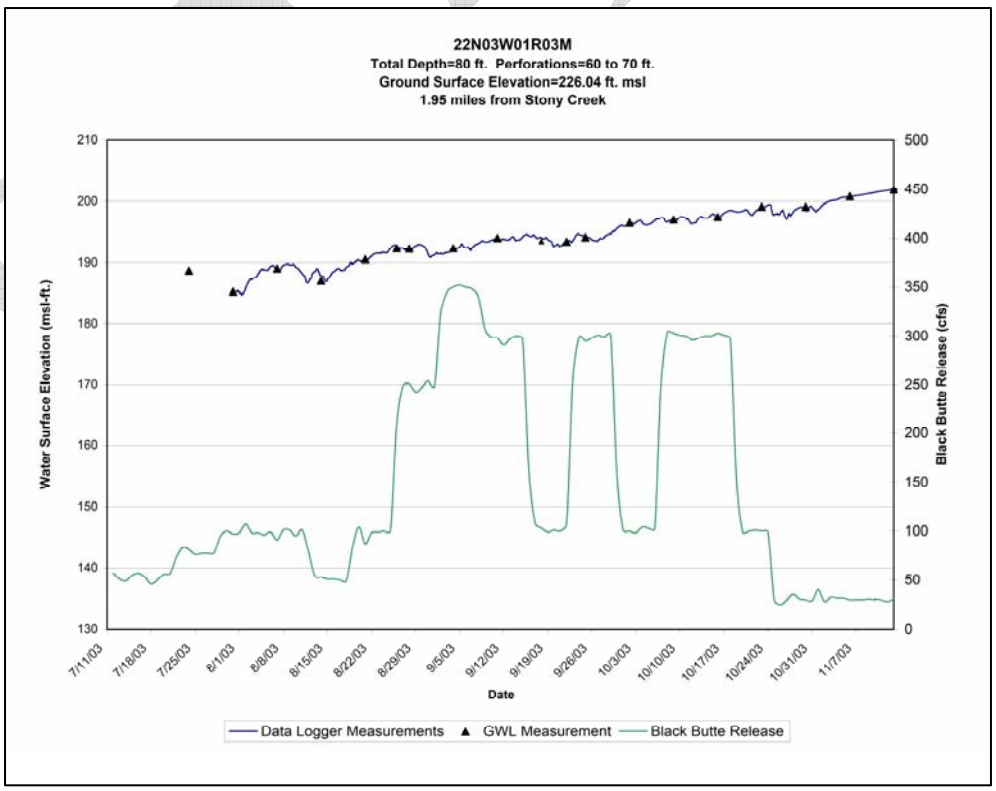

22N03W04E01M
Total Depth=180 ft. Perforations=40 to 180 ft.
Ground Surface Elevation=283 ft. msl
1.2 mi. from Stony Creek
Water Surface Elevation (msl-ft)
Black Butte Reservoir Release (cfs)
Pumping
Pumped Recently
Date
GWL Measurement
Black Butte Release

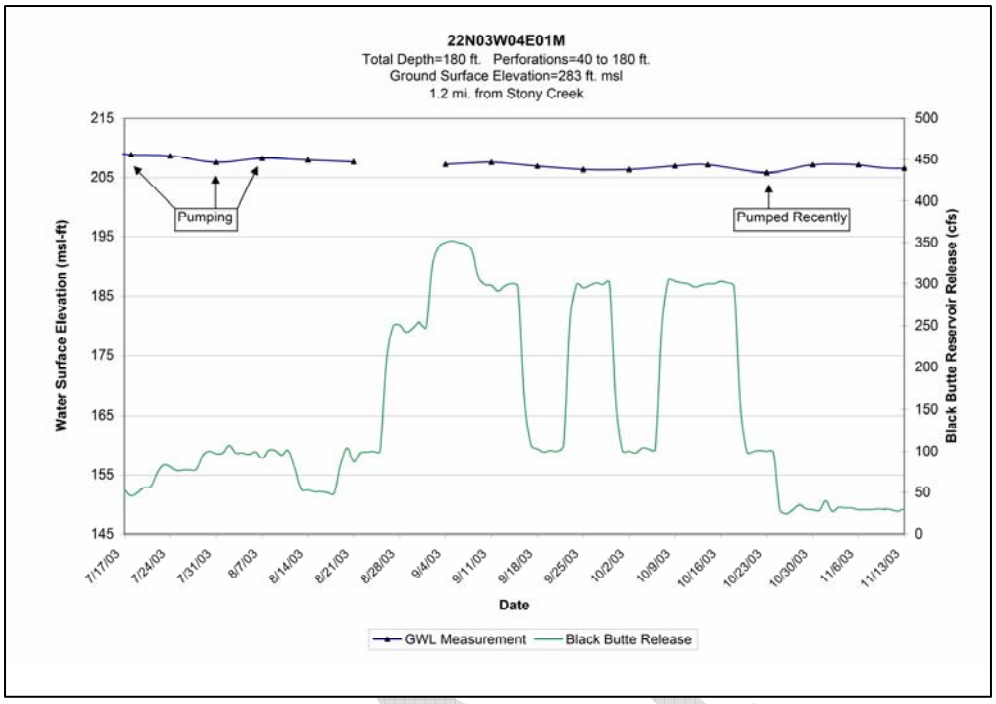

22N03W05F02M
Total Depth=218 ft. Perforations=188 to 218 ft.
Ground Surface Elevation=295 ft. msl
4944 ft. from Stony Creek
Water Surface Elevation (msl-ft)
Black Butte Reservoir Release (cfs)
No Measurement on 8/28/03
Date
GWL Measurement
Black Butte Release

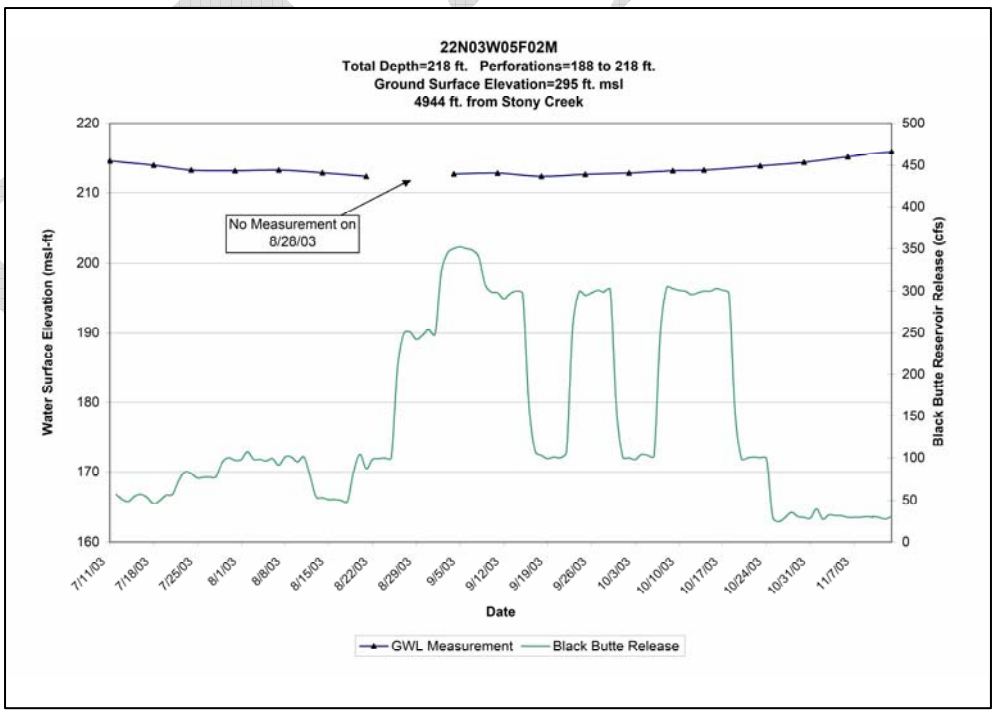

22N02W36D01M
Total Depth=100 ft. Perforations=Unknown
Ground Surface Elevation=165 ft. msl
0.1 miles from Stony Creek
Water Surface Elevation (msl-ft)
Black Butte Reservoir Release (cfs)
Irrigation well pumping 10 feet away.
Date
GWL Measurement
Black Butte Release

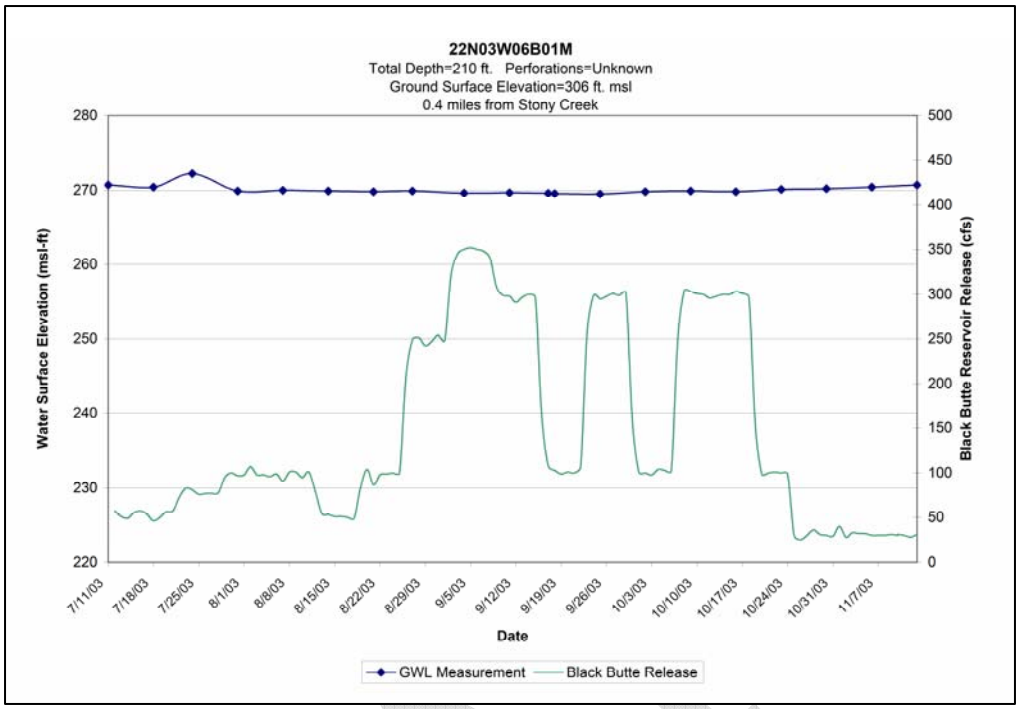

22N03W01R01M
Total Depth=490 ft. Perforations=470 to 480 ft.
Ground Surface Elevation=226.04 ft. msl
1.95 miles from Stony Creek
Water Surface Elevation (msl-ft.)
Black Butte Release (cfs)
Date
Data Logger Measurements
GWL Measurement
Black Butte Release

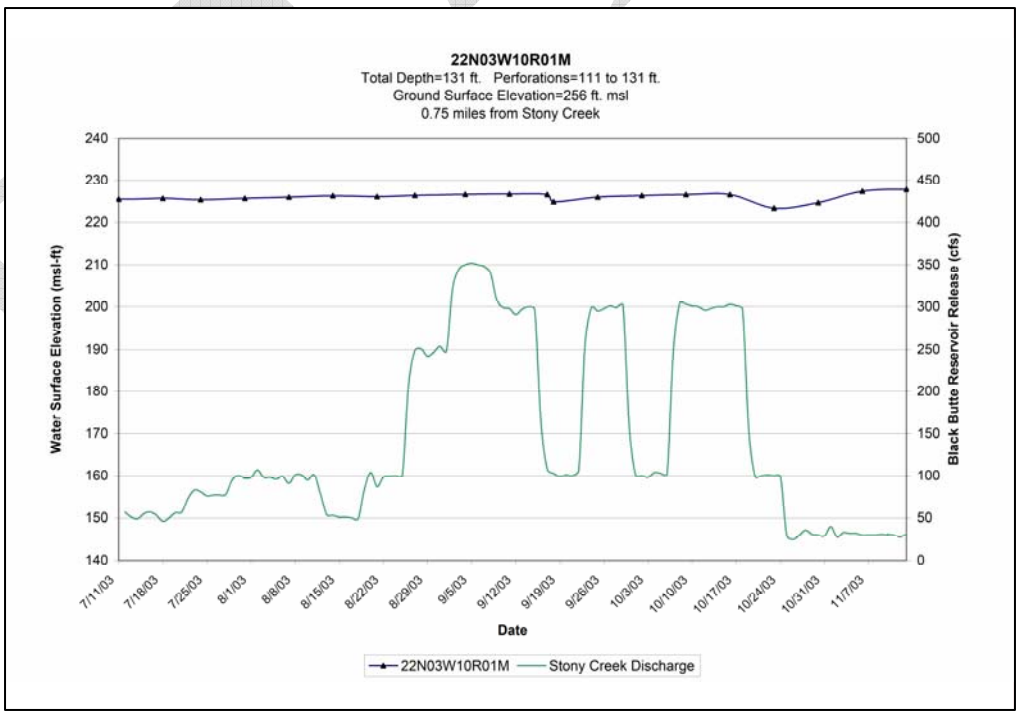

22N03W01R02M
Total Depth=290 ft. Perforations=270 to 280 ft.
Ground Surface Elevation=226.04 ft. msl
1.95 miles from Stony Creek
Water Surface Elevation (msl-ft.)
Black Butte Release (cfs)
Date
Data Logger Measurements
GWL Measurement
Black Butte Release

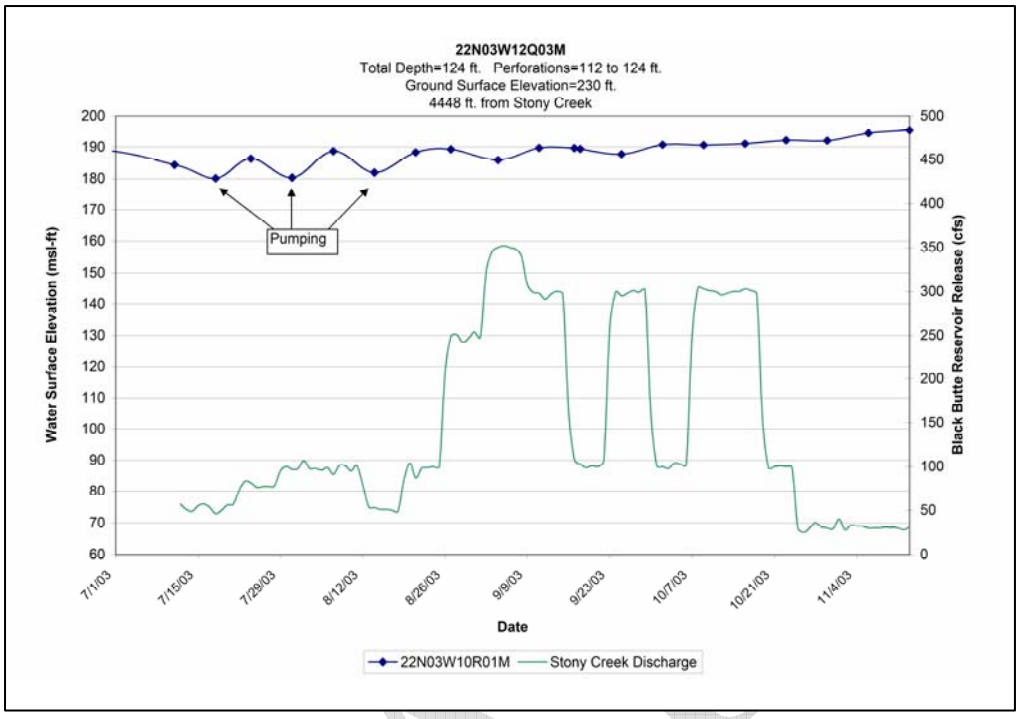

22N03W01R03M
Total Depth=80 ft. Perforations=60 to 70 ft.
Ground Surface Elevation=226.04 ft. msl
1.95 miles from Stony Creek
Water Surface Elevation (msl-ft.)
Black Butte Release (cfs)
Date
Data Logger Measurements
GWL Measurement
Black Butte Release

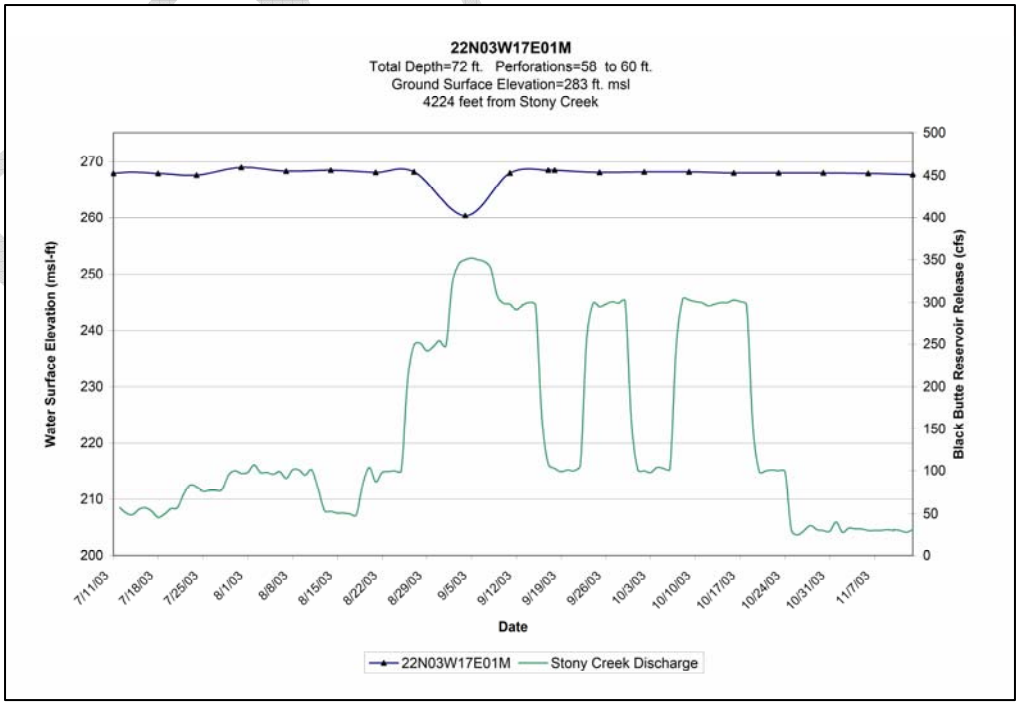

22N03W04E01M
Total Depth=180 ft. Perforations=40 to 180 ft.
Ground Surface Elevation=283 ft. msl
1.2 mi. from Stony Creek
Water Surface Elevation (msl-ft)
Black Butte Reservoir Release (cfs)
Pumping
Pumped Recently
Date
GWL Measurement
Black Butte Release

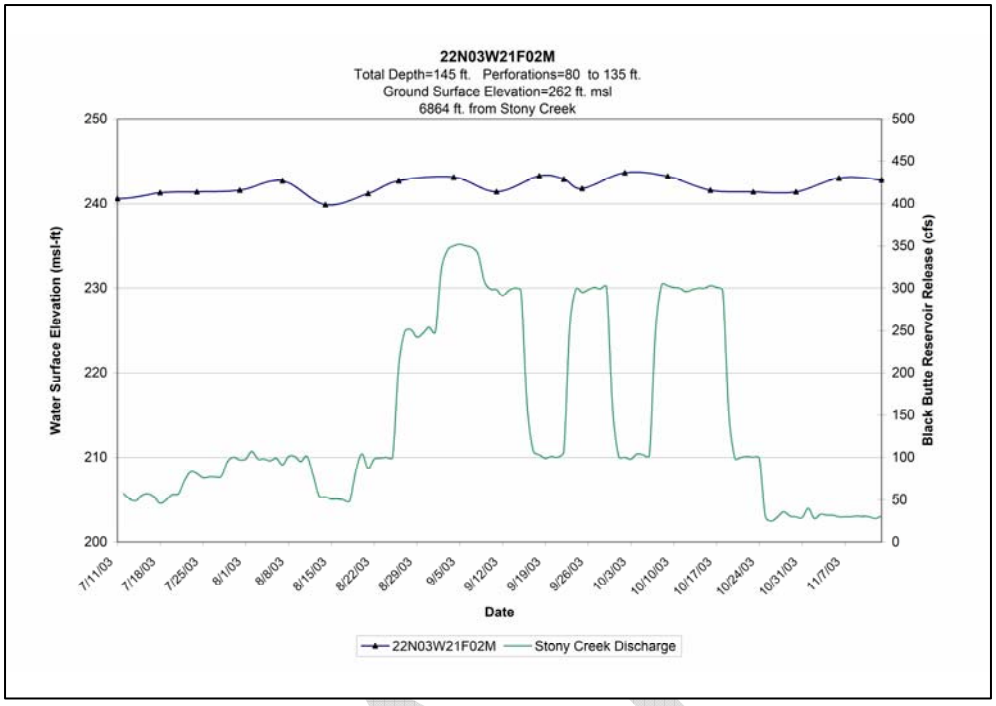

22N03W05F02M
Total Depth=218 ft. Perforations=188 to 218 ft.
Ground Surface Elevation=295 ft. msl
4944 ft. from Stony Creek
Water Surface Elevation (msl-ft)
Black Butte Reservoir Release (cfs)
No Measurement on 8/28/03
Date
GWL Measurement
Black Butte Release

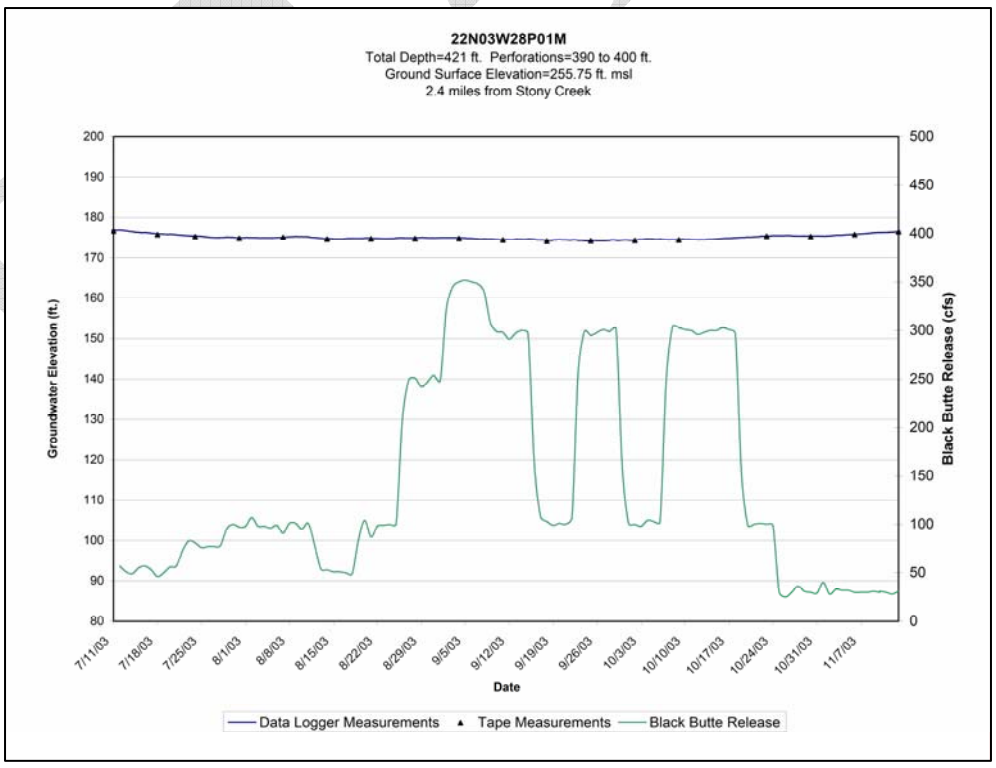

22N03W06B01M
Total Depth=210 ft. Perforations=Unknown
Ground Surface Elevation=306 ft. msl
0.4 miles from Stony Creek
Water Surface Elevation (msl-ft)
Black Butte Reservoir Release (cfs)
Date
GWL Measurement
Black Butte Release

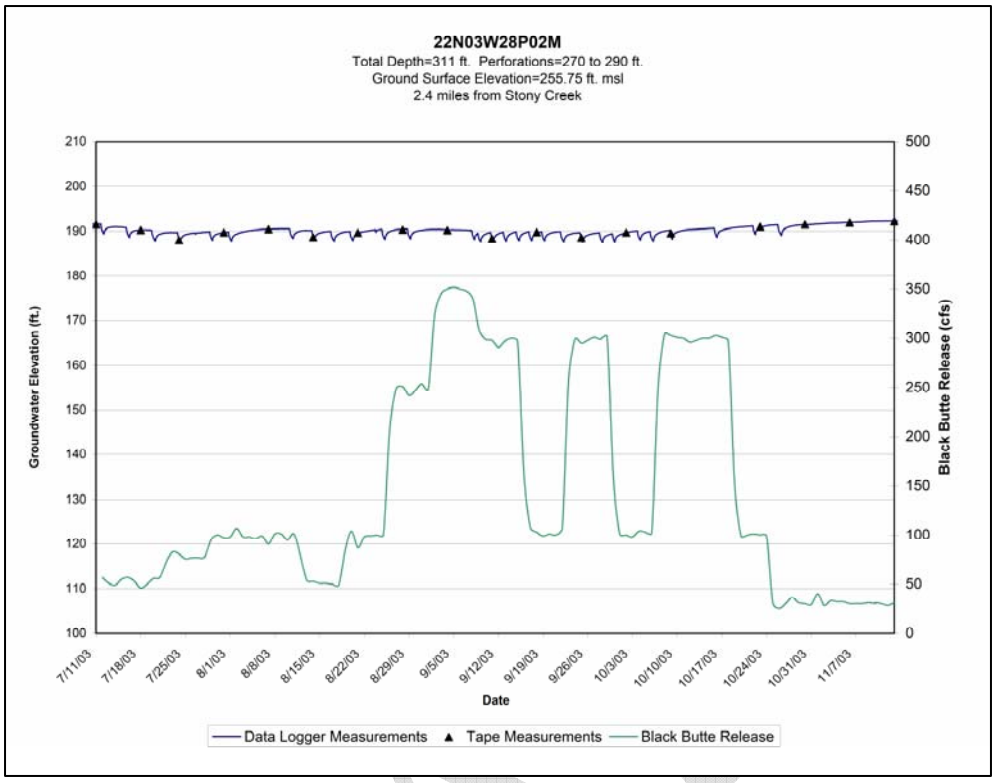

22N03W10R01M
Total Depth=131 ft. Perforations=111 to 131 ft.
Ground Surface Elevation=256 ft. msl
0.75 miles from Stony Creek
Water Surface Elevation (msl-ft)
Black Butte Reservoir Release (cfs)
Date
22N03W10R01M
Stony Creek Discharge

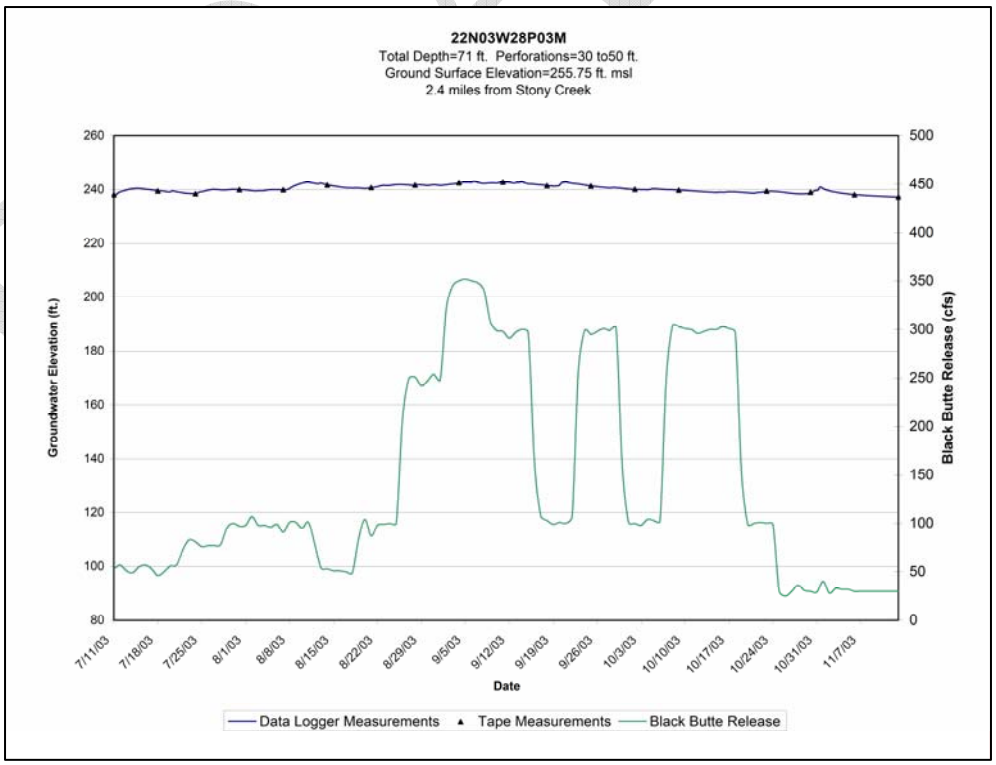

22N03W12Q03M
Total Depth=124 ft. Perforations=112 to 124 ft.
Ground Surface Elevation=230 ft.
4448 ft. from Stony Creek
Water Surface Elevation (msl-ft)
Black Butte Reservoir Release (cfs)
Pumping
Date
22N03W10R01M
Stony Creek Discharge


22N03W17E01M
Total Depth=72 ft. Perforations=58 to 60 ft.
Ground Surface Elevation=283 ft. msl
4224 feet from Stony Creek
Water Surface Elevation (msl-ft)
Black Butte Reservoir Release (cfs)
Date
22N03W17E01M
Stony Creek Discharge


22N03W21F02M
Total Depth=145 ft. Perforations=80 to 135 ft.
Ground Surface Elevation=262 ft. msl
6864 ft. from Stony Creek
Water Surface Elevation (msl-ft)
Black Butte Reservoir Release (cfs)
Date
22N03W21F02M
Stony Creek Discharge


22N03W28P01M
Total Depth=421 ft. Perforations=390 to 400 ft.
Ground Surface Elevation=255.75 ft. msl
2.4 miles from Stony Creek
Groundwater Elevation (ft.)
Black Butte Release (cfs)
Date
Data Logger Measurements
Tape Measurements
Black Butte Release


22N03W28P02M
Total Depth=311 ft. Perforations=270 to 290 ft.
Ground Surface Elevation=255.75 ft. msl
2.4 miles from Stony Creek
Groundwater Elevation (ft.)
Black Butte Release (cfs)
Date
Data Logger Measurements
Tape Measurements
Black Butte Release


22N03W28P03M
Total Depth=71 ft. Perforations=30 to50 ft.
Ground Surface Elevation=255.75 ft. msl
2.4 miles from Stony Creek
Groundwater Elevation (ft.)
Black Butte Release (cfs)
Date
Data Logger Measurements
Tape Measurements
Black Butte Release

Appendix B.

Cross-sectional Area vs. Flow
at each
Surface Water Flow Measurement Site

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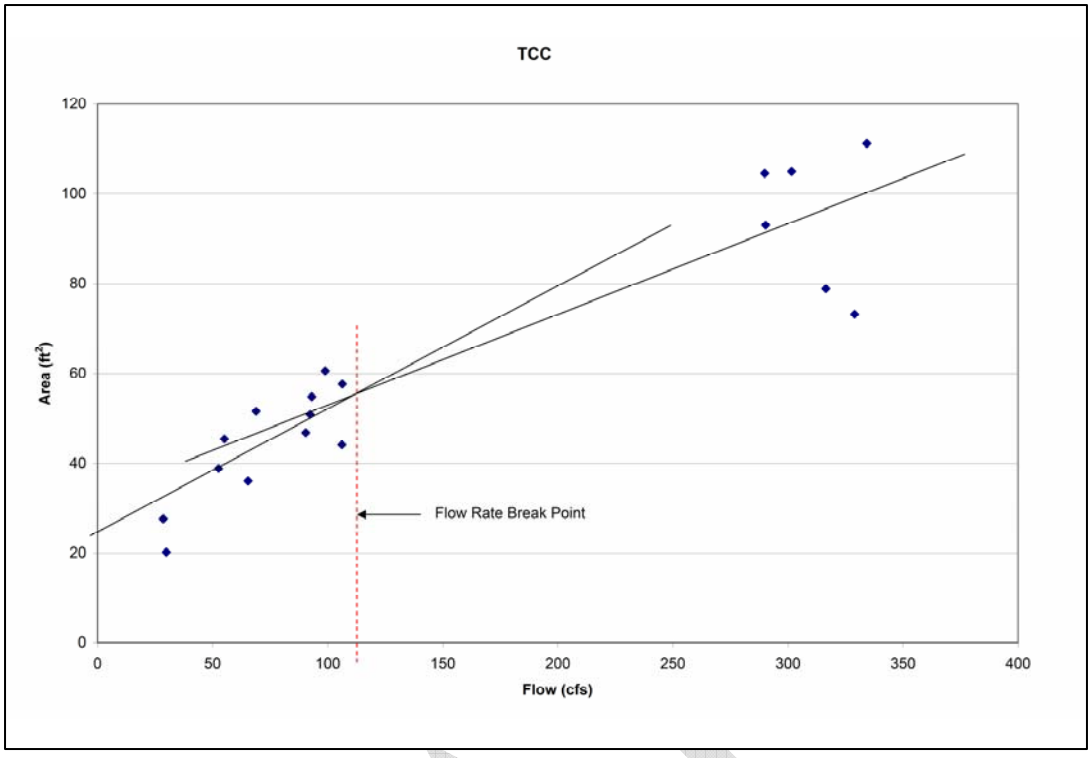
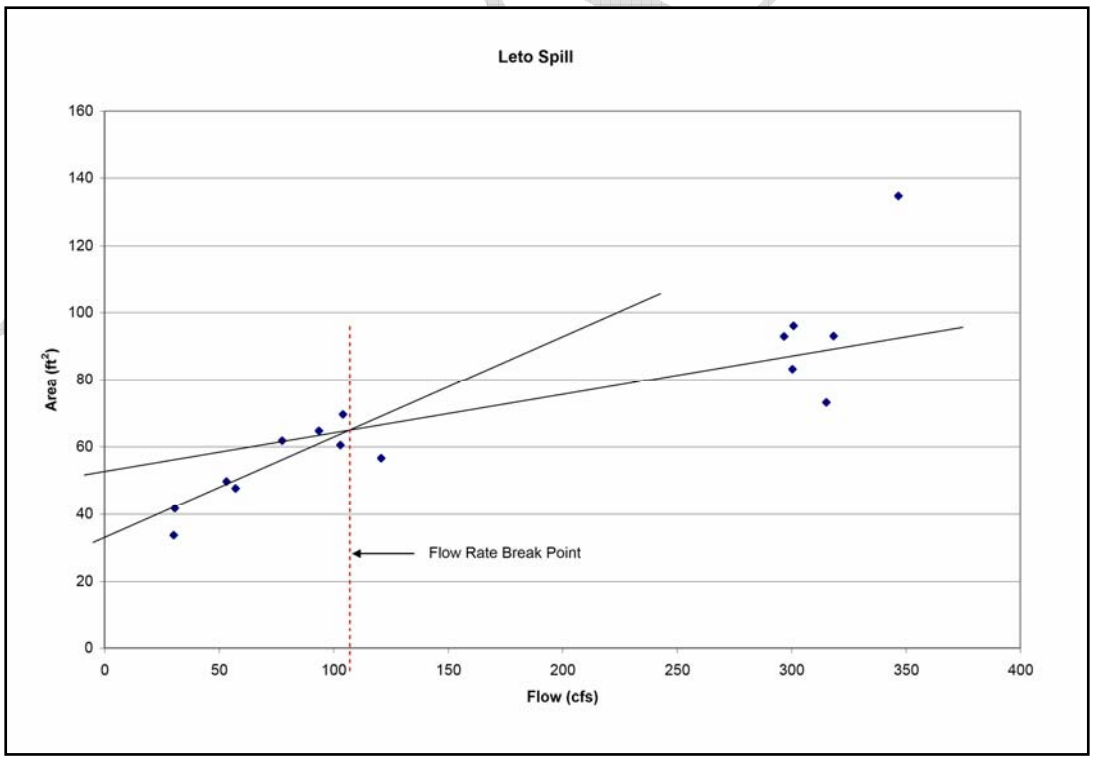
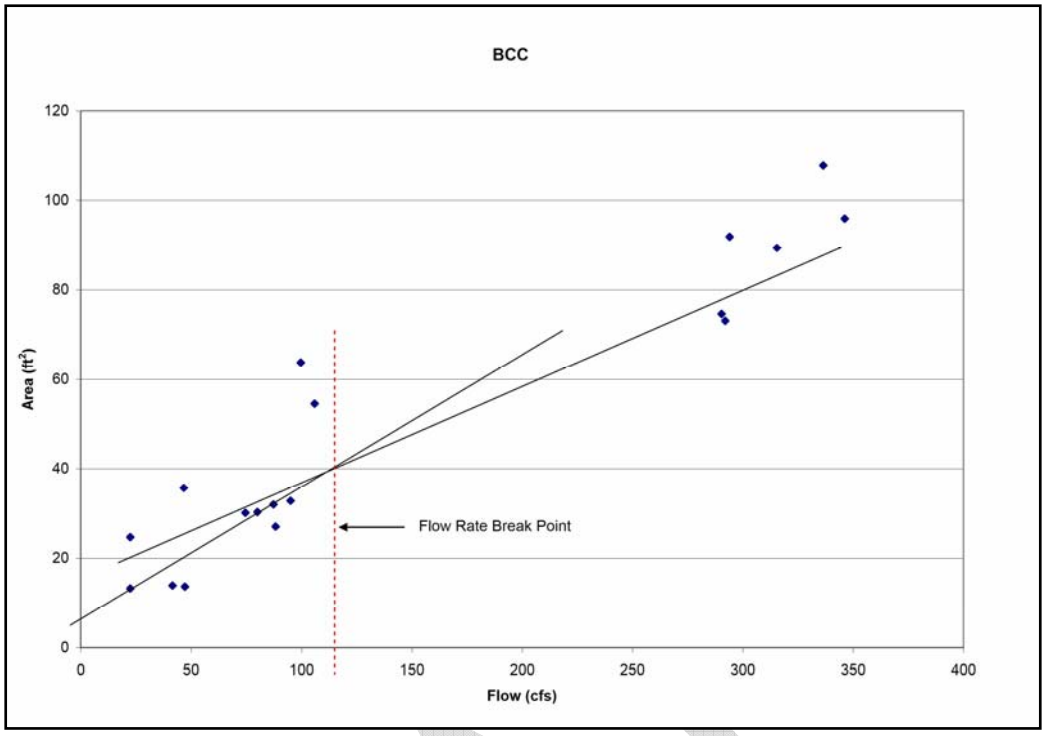
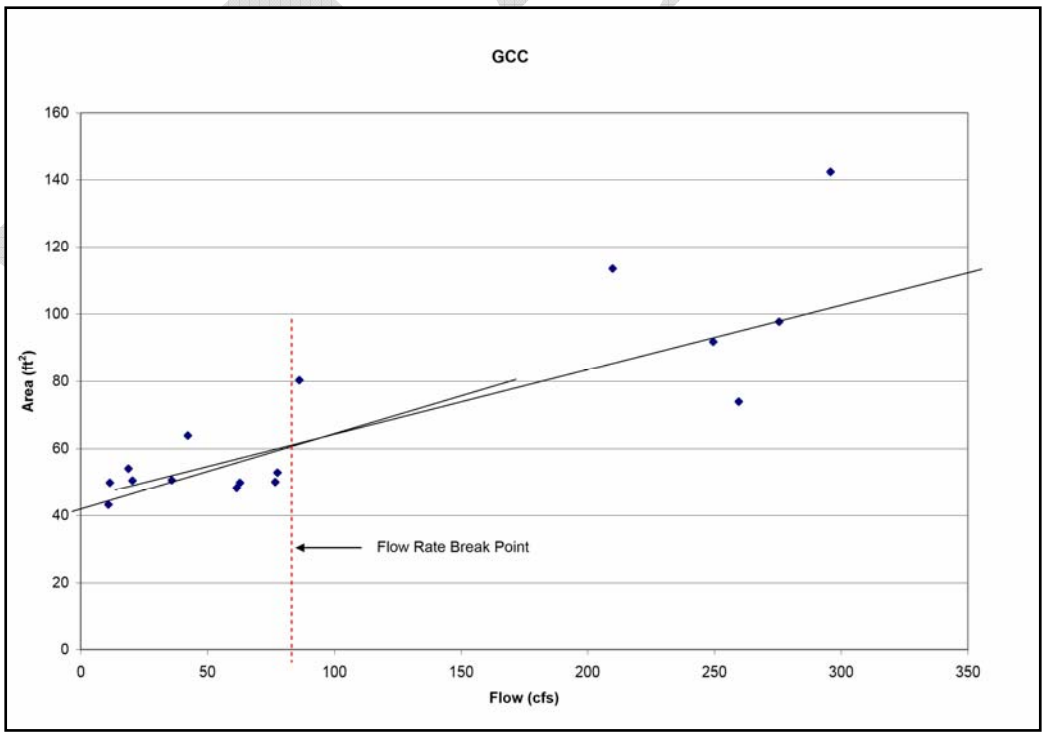
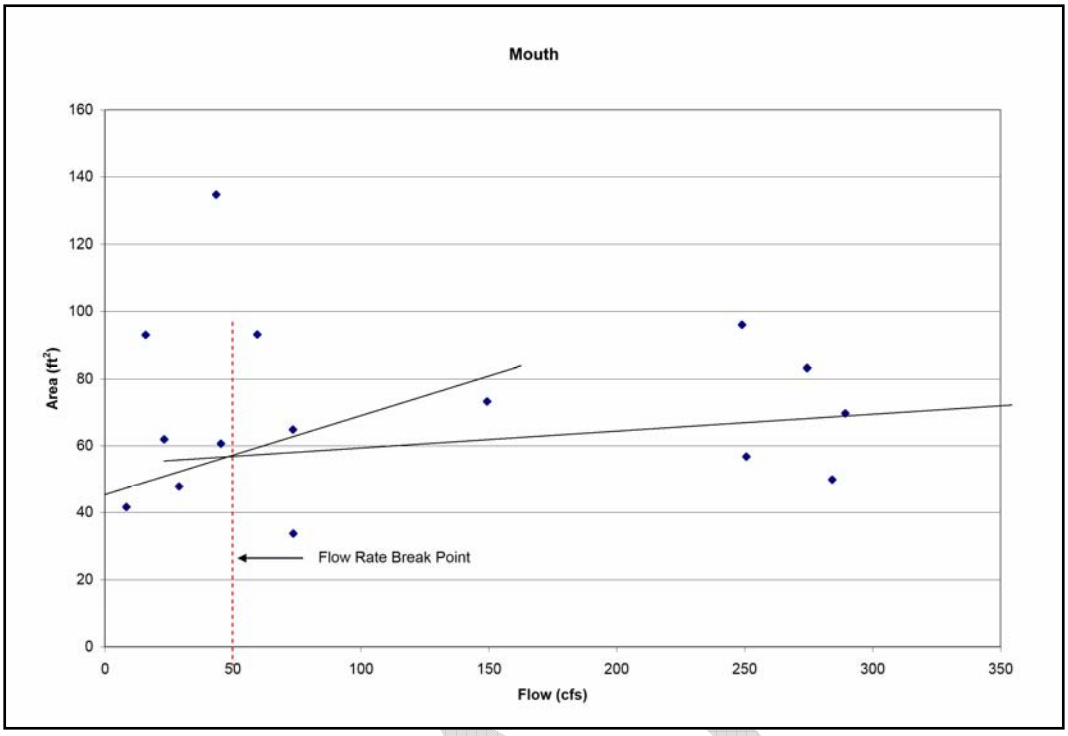

TCC
Area (ft²)
Flow (cfs)
Flow Rate Break Point
0
20
40
60
80
100
120
0
50
100
150
200
250
300
350
400


Leto Spill
Area (ft²)
Flow (cfs)
Flow Rate Break Point
0
20
40
60
80
100
120
140
160
0
50
100
150
200
250
300
350
400


BCC
120
100
80
60
40
20
0
Area (ft²)
0
50
100
150
200
250
300
350
400
Flow (cfs)
Flow Rate Break Point


GCC
160
140
120
100
80
60
40
20
0
Area (ft²)
0
50
100
150
200
250
300
350
Flow (cfs)
Flow Rate Break Point


Mouth
160
140
120
100
80
60
40
20
0
Area (ft²)
0
50
100
150
200
250
300
350
Flow (cfs)
Flow Rate Break Point

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Appendix C.

Surface Water Flow Data

Black Butte Dam and Cross-Sectional Flow Measurements

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Cross-Section ID	Date	Surface Water Flow (cfs)	Measuring Agency
BBD	7/17/2003	53	USBR
TCC	7/17/2003	65	DWR
BCC	7/17/2003	47	DWR
GCC	7/17/2003	19	DWR
BBD	7/24/2003	81	USBR
TCC	7/24/2003	90	DFG
Leto Spill	7/24/2003	78	DWR
BCC	7/24/2003	75	DFG
GCC	7/24/2003	36	DFG
SC/SR Mouth	7/24/2003	23	DFG
BBD	7/31/2003	97	USBR
TCC	7/31/2003	93	DFG
BCC	7/31/2003	80	DFG
GCC	7/31/2003	42	DFG
SC/SR Mouth	7/31/2003	29	DFG
BBD	8/7/2003	91	USBR
TCC	8/7/2003	69	DWR
BCC	8/7/2003	87	USBR
GCC	8/7/2003	62	USBR
SC/SR Mouth	8/7/2003	45	USBR
BBD	8/14/2003	53	USBR
TCC	8/14/2003	55	DFG
Leto Spill	8/14/2003	57	DFG
BCC	8/14/2003	47	DFG
GCC	8/14/2003	26	DFG
SC/SR Mouth	8/14/2003	16	DFG
BBD	8/21/2003	87	USBR
TCC	8/21/2003	99	DFG
Leto Spill	8/21/2003	103	DFG
BCC	8/21/2003	88	DFG
GCC	8/21/2003	63	DFG
SC/SR Mouth	8/21/2003	43	DFG
BBD	8/28/2003	251	USBR
TCC	8/28/2003	290	USBR
Leto Spill	8/28/2003	297	USBR
BCC	8/28/2003	292	USBR
GCC	8/28/2003	210	USBR
SC/SR Mouth	8/28/2003	149	USBR
BBD	9/4/2003	350	USBR
TCC	9/4/2003	334	DWR
Leto Spill	9/4/2003	347	DWR
BCC	9/4/2003	346	USBR

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Cross-Section ID	Date	Cross-Sectional Flow (cfs)	Measuring Agency
GCC	9/4/2003	311	USBR
SC/SR Mouth	9/4/2003	289	DFG
BBD	9/11/2003	298	USBR
TCC	9/11/2003	329	DFG
Leto Spill	9/11/2003	315	DWR
BCC	9/11/2003	294	DWR
GCC	9/11/2003	276	DFG
SC/SR Mouth	9/11/2003	274	DFG
BBD	9/18/2003	103	USBR
TCC	9/18/2003	106	DFG
Leto Spill	9/18/2003	104	DWR
BCC	9/18/2003	100	DWR
GCC	9/18/2003	78	DFG
SC/SR Mouth	9/18/2003	74	USBR
BBD	9/25/2003	295	USBR
TCC	9/25/2003	316	DFG
Leto Spill	9/25/2003	300	DFG
BCC	9/25/2003	315	DFG
GCC	9/25/2003	250	DFG
SC/SR Mouth	9/25/2003	249	DFG
BBD	10/2/2003	100	USBR
TCC	10/2/2003	92	DWR
Leto Spill	10/2/2003	94	DWR
BCC	10/2/2003	95	USBR
GCC	10/2/2003	77	USBR
SC/SR Mouth	10/2/2003	60	USBR
BBD	10/9/2003	303	USBR
TCC	10/9/2003	290	DWR
Leto Spill	10/9/2003	301	DWR
BCC	10/9/2003	290	DFG
GCC	10/9/2003	260	DFG
SC/SR Mouth	10/9/2003	251	DFG
BBD	10/17/2003	301	USBR
TCC	10/17/2003	302	DWR
Leto Spill	10/17/2003	318	DWR
BCC	10/17/2003	336	USBR/DWR
GCC	10/17/2003	296	DWR
SC/SR Mouth	10/17/2003	284	USBR/DWR
BBD	10/23/2003	100	USBR
TCC	10/23/2003	106	DWR
Leto Spill	10/23/2003	121	DWR
BCC	10/23/2003	106	DWR
GCC	10/23/2003	86	DWR

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Cross-Section ID	Date	Cross-Sectional Flow (cfs)	Measuring Agency
SC/SR Mouth	10/23/2003	74	DWR
BBD	10/30/2003	30	USBR
TCC	10/30/2003	53	DWR
Leto Spill	10/30/2003	53	DWR
BCC	10/30/2003	42	USBR/DFG
GCC	10/30/2003	20	DWR
SC/SR Mouth	10/30/2003	8	USBR/DFG
BBD	11/6/2003	30	USBR
TCC	11/6/2003	30	USBR/DFG
Leto Spill	11/6/2003	30	USBR/DFG
BCC	11/6/2003	22	USBR/DFG
GCC	11/6/2003	11	USBR/DFG
SC/SR Mouth	11/6/2003	2	USBR/DFG
BBD	11/13/2003	31	USBR
TCC	11/13/2003	29	DWR
Leto Spill	11/13/2003	31	DWR
BCC	11/13/2003	22	DWR
GCC	11/13/2003	12	DWR
SC/SR Mouth	11/13/2003	2	DWR

Key:	
BBD	Black Butte Dam
TCC	Tehama-Colusa Canal
BCC	Baldwin Construction Company
GCC	Glenn-Colusa Canal
SC/SR Mouth	Mouth of Stony Creek
DWR	Department of Water Resources
USBR	United States Bureau of Reclamation
DFG	Department of Fish and Game

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