RECLAMATION

Managing Water in the West

Groundwater Conditions at the Leavenworth National Fish Hatchery, Leavenworth, Washington

In cooperation with:

U.S. Department of the Interior
Bureau of Reclamation
Pacific Northwest Region
Boise, Idaho

U.S. Department of the Interior
U.S. Fish and Wildlife Service
Leavenworth Fish Hatchery
Leavenworth Washington

February 2010

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.

Groundwater Conditions at the Leavenworth National Fish Hatchery, Leavenworth, Washington

prepared by

River and Reservoir Operations
Kayti Didricksen, Hydrogeologist
Jennifer Johnson, Hydraulic Engineer

In cooperation with the U.S. Fish and Wildlife Service

Cover Photo: Leavenworth Hatchery Channel by K. Didricksen.

U.S. Department of the Interior
Bureau of Reclamation
Pacific Northwest Region
Boise, Idaho

U.S. Department of the Interior
U.S. Fish and Wildlife Service
Leavenworth Fish Hatchery
Leavenworth Washington

February 2010

Acknowledgments

The authors would like to acknowledge the help of Fred Wurster and the employees at the Leavenworth National Fish Hatchery (Hatchery), and U.S. Fish and Wildlife Service for their help in taking field measurements during the seepage monitoring that was conducted at the Hatchery during October, 2009. The data was essential for upgrading and recalibrating the groundwater flow model that is the essence of this report.

Contents

Page

Acknowledgments iv
Executive Summary 1
1 Introduction 3
1.1 Purpose and Scope 3
1.2 Background 3
1.3 Use of Groundwater at the Hatchery 4
1.4 Water Rights 6
2 Hydrogeologic Setting 7
2.1 Aquifer Properties 7
2.2 Groundwater Temperature 8
3 Seepage Monitoring 9
3.1 October 2009 Monitoring Results 10
4 Groundwater Modeling 11
4.1 Previous Modeling Work 11
4.2 Current Model Updates 12
4.3 Scenarios 13
4.3.1 Scenario 1 results 15
4.3.2 Scenario 2 results 15
4.3.3 Scenario 3 results 16
4.3.4 Scenario 4 results 17
4.3.5 Scenario 5 results 18
4.3.6 Scenario 6 results 18
4.3.7 Scenario 7 results 19
4.3.8 Scenario 8 results 20
5 Conclusions and Recommendations 23

References 25

Appendix A: Version 2 Model and Scenario Development
A.1 Model Parameters
A.2 Model Calibration
A.2.1 Calibration Uniqueness
A.3 Scenarios
Appendix A References

Appendix B: Well logs and construction schematics for wells at Leavenworth National Fish Hatchery

Appendix C: Seepage Monitoring Data

List of Tables

Table 1-1: Water rights for the Hatchery. 6
Table 3-1: Well data for new observation wells at the Hatchery 9
Table 4-1: Recommended schedule for production well pumping (modified from GeoEngineers, 1995) 13
Table 4-2: Conditions for Model Scenarios 14
Table 4-3: Pump intake elevations used in model scenarios 14
Table 4-4: Summary of Scenario Results 21

List of Figures

Figure 1-1: Location of Hatchery features. 5
Figure 4-1: Plot of water level elevation in pumping wells under scenario 1 conditions. 15
Figure 4-2: Plot of water level elevation in pumping wells under scenario 2 conditions. 16
Figure 4-3: Plot of water level elevation in pumping wells under scenario 3 conditions. 17
Figure 4-4: Plot of water level elevation in pumping wells under scenario 4 conditions. 17
Figure 4-5: Plot of water level elevation in pumping wells under scenario 5 conditions. 18
Figure 4-6: Plot of water level elevation in pumping wells under scenario 6 conditions. 19
Figure 4-7: Plot of water level elevation in pumping wells under scenario 7 conditions. 19
Figure 4-8: Plot of water level elevation in pumping wells under scenario 8 conditions. 20

Executive Summary

The Leavenworth National Fish Hatchery (Hatchery) depends on groundwater from 7 production wells that supplement the surface water supply from Icicle Creek. Groundwater is also used to adjust the temperature of surface flows to meet fish production targets. Extended production from the shallow wells is dependent on aquifer recharge that is sustained by diverting Icicle Creek flows into the man-made Hatchery channel.

From 1940 to 2005, Hatchery operations directed most creek flows into the Hatchery channel, which helped recharge the aquifer but limited flow into the historic channel of Icicle Creek. Since 2006, operations were changed to improve fish passage and habitat in the historic channel. The gates at the control structure are currently open most of the year and the Hatchery channel usually remains dry. For two weeks at a time the gates are partially closed and water is diverted into the Hatchery channel. Although these recharge periods help well production temporarily, a two week period has not been sufficient to significantly improve well capacity.

A groundwater flow model was developed in the mid-1990's by GeoEngineers using MODFLOW96 software. The model simulates groundwater flow conditions in the shallow sand and gravel aquifer beneath the site. At the time of model development, water was diverted to the Hatchery channel on a regular basis so the GeoEngineers model simulated this source of recharge to the aquifer. In order to update the model for current Hatchery operations, features within the model were changed to represent current conditions and the absence of continuous recharge from the Hatchery channel.

In October 2009, Hatchery management adjusted the control structure gate and diverted water into the Hatchery channel to promote aquifer recharge. During that two week period, water levels were measured in Hatchery wells to monitor the aquifer response to the induced recharge. The test results were incorporated into the updated groundwater model and the model was recalibrated. During calibration, the parameters of riverbed conductance, hydraulic conductivity and storativity of the aquifer were adjusted to match simulated observations to measured observations over time. Following calibration, predictive simulations (scenarios) were run with the updated model to represent pumping conditions and the effect of induced aquifer recharge by diverting water into the Hatchery channel for various time durations. The purpose of these simulations was to determine the aquifer response to various combinations and duration of recharge to help manage groundwater use at the Hatchery.

A total of 8 predictive scenarios were run with the updated model. The pumping schedule for the production wells remained the same for all of the scenarios while the seasonal water level conditions and the presence or absence of water in the Hatchery channel were varied.

Results from the scenario model runs show that the presence of water in the Hatchery channel is of primary importance to extended pumping from the Hatchery production wells. Recharge from the canal raises aquifer water levels and maintains higher levels, even during well pumping. Without that source of induced recharge, water levels quickly fall and some wells are forced to stop pumping as the water levels drop to the pump intake elevations. A cycled diversion to the Hatchery channel, consisting of 15 days with water in the Hatchery channel followed by 15 days without water, allows full extended pumping from all of the production wells. If water is diverted to the channel for only 15-days (then the channel is dry for the remaining 45 days of the 60-day simulation) the wells with relatively shallow pump settings are forced to shut-off after about 42 to 58 days of pumping, depending on the seasonal water level conditions.

1 Introduction

1.1 Purpose and Scope

The purpose of this report is to:

1) Update the available groundwater information for the Hatchery with current data.
2) Describe the changes made to a numerical groundwater flow model of the site.
3) Document the modeling results in order to evaluate the groundwater supply capacity under various recharge conditions.

1.2 Background

The Hatchery has used groundwater as a supplemental source of water since about 1940. Groundwater is used periodically to enhance water quantities and adjust the temperature of surface flows to meet fish production targets (USFWS, 2009a). A flow control structure, known as "Structure No. 2", is located at RM 3.8 on Icicle Creek, and was designed to divert flow into a man-made channel, called the "Hatchery channel" (Figure 1-1). The Hatchery channel was built in the late 1930's so a portion of Icicle Creek could be used to accommodate Hatchery fish production. Diverting flow into the Hatchery channel protected those in-creek Hatchery operations, particularly during high flow events. The Hatchery channel is about 5 feet higher than the historic channel of Icicle Creek and parallels the historic channel for 1 mile, before rejoining the creek at RM 2.8. Production wells for the Hatchery are located just west of the Hatchery channel and benefit from increased recharge provided by diverting water into the channel.

From 1940 to 2005, Hatchery operations directed most creek flows into the Hatchery channel (the gates at Structure No. 2 were regularly closed), which limited flow into the historic channel of Icicle Creek. Since 2006, operations were changed to improve fish passage and habitat in Icicle Creek. The gates at Structure No. 2 are fully open most of the year and the Hatchery channel remains dry. Since operation changes, the restriction of flow in the Hatchery channel reduces recharge to the shallow alluvial aquifer and reduces pumping capacity of the Hatchery's production wells.

1.3 Use of Groundwater at the Hatchery

The Hatchery needs between 1,060 gallons per minute (gpm) and 6,590 gpm of groundwater during its fish production cycle (Sverdrup 2000). The largest demand is in June (6,590 gpm)[1] to supply cool water to the holding adults and again in December (6,110 gpm), when young salmon fry begin to feed. Groundwater use continues throughout the winter months in order to temper cold surface water used on yearling salmon in outdoor ponds (USFWS, 2009a). The groundwater is also used to cool surface water in the summer months as surface water temperatures begin to rise.

Since 2006, the gates at Structure 2 are not closed for more than two weeks at a time in order to maintain higher flows in the historic channel of Icicle Creek. However, the two week period of diversion into the Hatchery channel has not been sufficient to significantly improve well capacity. Without aquifer recharge from the Hatchery channel, well production is substantially reduced (USFWS, 2009a).

The timing and quantity of surface water needed to maintain recharge to the aquifer in order to support the production wells needs to be known to optimally manage the water supply at the Hatchery.

[1] Quantities listed are from hatchery records from 10/1998 – 09/1999. In 2008, pumping rates were less than 4,600 gpm all year (personal communication, F. Wurster)

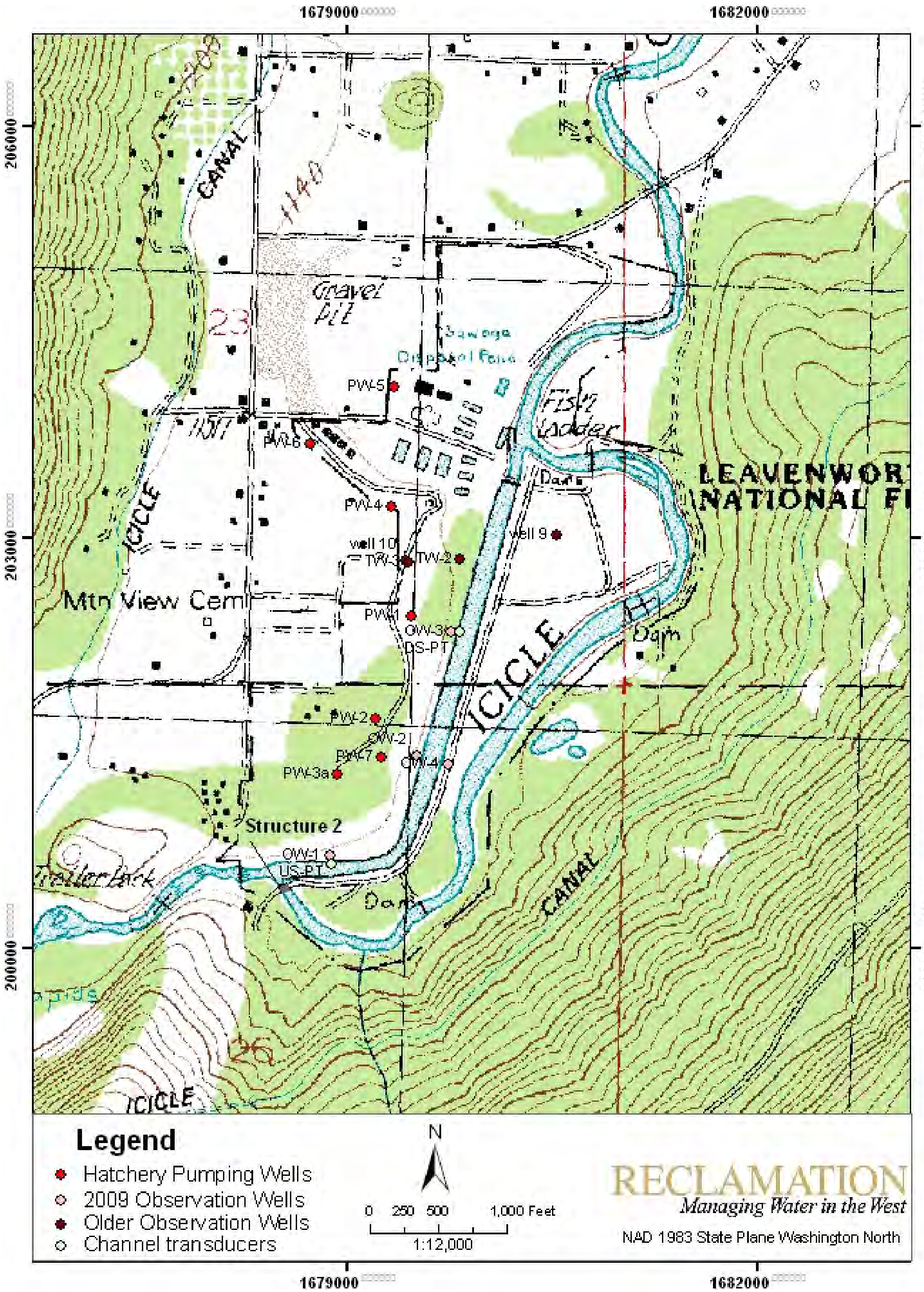


Figure 1-1: Location of Hatchery features.

1.4 Water Rights

Table 1-1 lists the water rights that have been issued by the State of Washington for the Hatchery.

Table 1-1: Water rights for the Hatchery.

Certificate Number	Source	Purpose of Use	Priority Date	Amount
1824	Icicle Creek	Fish Propagation	3/26/42	42 cfs
1825	Snow and Nada Lakes	Fish Propagation	3/26/42	16,000 AF
3103-A (well 1)	Groundwater	Fish Culture	10/16/57	1200 gpm/ 1120 AF
Claim # 016379 (well 2)	Groundwater	Fish Culture	6/1940	900 gpm/ 730 AF
Claim # 016378 (well 3)	Groundwater	Fish Culture	8/1939	700 gpm/ 570 AF
G4-27115C (well 4: 800 gpm, well 5: 1500 gpm, well 6: 1200 gpm, well 7: 400 gpm)	Groundwater	Fish Propagation	10/20/80	3900 gpm/ 5257 AF

A water right to divert water from the Wenatchee River to supplement Icicle Creek flow was abandoned in the 1980's (personal communication, F. Wurster).

2 Hydrogeologic Setting

Unconsolidated sediments of glaciofluvial and river origin underlie the Hatchery site and consist of interbedded gravel, sand, silt and clay. Granite bedrock underlies the sediments and forms a north-northeast trending trough beneath the site. Bedrock is encountered at depths ranging from about 190 feet in the south to 320 feet in the central part of the Hatchery. The unconsolidated sediments are stratified (layered) and comprise two aquifers; a shallow unconfined aquifer of sand and gravel that extends over most of the valley and a deeper confined aquifer of more limited extent.

The shallow aquifer has a maximum thickness of about 200 feet near well 4, in the central part of the site, but is typically 80 to 100 feet thick in other areas. The deep aquifer is about 30 to 50 feet thick and is limited to the north-central part of the site, near wells 5 and 6. The deep, sand and gravel aquifer is confined by overlying layers of silt and clay. Since the clay layers are not continuous, the aquifer is likely semi-confined or leaky and is probably influenced by stresses (pumping) and recharge in the overlying unconfined aquifer.

Drill logs for the Hatchery wells indicate that the shallow aquifer is stratified with layers and stringers of silt and clay interspersed with sand and gravel. Several test wells have been drilled onsite that have not encountered productive aquifer materials or have limited exposures of the aquifer. Hydraulic conductivity probably varies significantly in the horizontal and vertical directions due to the stratification of the aquifer.

2.1 Aquifer Properties

During 1994, constant rate pumping tests were conducted in each of the 7 production wells and a 24-hour constant rate test was conducted with all 7 wells pumping simultaneously (GeoEngineers, 1995). Transmissivity and hydraulic conductivity values for the shallow and deep aquifers were calculated using data obtained during the individual aquifer tests (GeoEngineers, 1995). The transmissivity of the shallow aquifer ranged between 25,000 ft^2/d (square feet per day) and 85,000 ft^2/d. The calculated transmissivity of the deeper aquifer was about 6,000 ft^2/d. Based on aquifer thicknesses of the shallow aquifer ranging from 80 to 200 feet and assuming homogeneous conditions in the aquifer, the hydraulic conductivity ranges from 283.5 ft/d (feet per day) to 425.2 ft/d. The hydraulic conductivity of the deep aquifer is about 142 ft/d.

The calculated storativity values determined from the aquifer test data ranged between 0.005 and 0.02 for the shallow aquifer and between 1×10^{-5} and 5×10^{-4}

for the deep aquifer (GeoEngineers, 1995). The storativity values for the shallow unconfined aquifer are lower than typical for sand and gravel aquifers, and may be related to the stratification of the glaciofluvial and alluvial aquifer materials.

Well interference drawdown of as much as 3.5 feet (additional water level drawdown) was observed during the individual pumping tests in the shallow aquifer (GeoEngineers, 1995). During the tests, water flowing in the Hatchery channel was actively recharging the shallow aquifer, which prevented excessive drawdown in the wells. Current conditions of no water flowing in the Hatchery channel results in greater drawdown and more interference between the wells.

2.2 Groundwater Temperature

The Hatchery staff monitored well water temperature in selected wells during water year 2009 (USFWS, 2009b). Water in the shallow aquifer averages about 48° F to 49° F (degrees Fahrenheit) in wells 4a and 7, with a range from 43.2° F to 53.4° F. Water temperature in well 5, in the deep aquifer, averages 52.8° F. Well 6, completed in both aquifers, has a composite temperature averaging 50.1° F.

The lowest water temperature recorded for well 7 (43.2° F) occurred in May, 2009 and the highest water temperature (53.4° F) was recorded in November, 2008. Surface water temperatures are generally lowest in mid-winter and highest in the summer. The lag time of several months between high and low temperatures in the surface water of Icicle Creek and the groundwater temperature in well 7 is probably a result of the travel time of groundwater flow through the aquifer.

3 Seepage Monitoring

During September 2009, the Bureau of Reclamation (Reclamation) Pacific Northwest Regional drill crew was at the Hatchery to drill investigative boreholes to provide design level geologic information for repairs to various structures at the site. During that time, water resource specialists from Reclamation and the U.S. Fish and Wildlife Service (USFWS) were discussing data needs to better monitor the hydrologic conditions and groundwater use at the Hatchery. The Hatchery was planning to divert water into the Hatchery channel for a span of two weeks in early October to recharge the aquifer (and increase capacity of their production wells). It was decided to have four shallow observation wells drilled by the Reclamation drill crew and use the wells to monitor water seepage from the Hatchery channel into the shallow aquifer. Well data from the new observation wells are tabulated in Table 3-1. All of the available well logs and well construction schematics from the Hatchery site are included in Appendix B. The location of the wells and other features of the Hatchery site are shown on Figure 1-1.

The purpose of the seepage monitoring was to determine the temporal and spatial response within the shallow aquifer to the addition of water in the Hatchery channel. This information was then used to update and adjust calibration parameters within an existing MODFLOW groundwater flow model, developed in 1994 by GeoEngineers (1995). It has long been understood that water-flow in the Hatchery channel provides recharge to the shallow aquifer and Hatchery production wells, but operations at the Hatchery have changed since the flow model was developed and the model needed to be updated to reflect current Hatchery operations prior to using the model to run new predictive scenarios.

Table 3-1: Well data for new observation wells at the Hatchery

Well Number	Northing	Easting	Elevation of MP (top PVC)	Depth of Completed Well (feet)
OW-09-1	1678875.015	200668.731	1149.981	37.0
OW-09-2	1679510.438	201404.146	1149.709	42.0
OW-09-3	1679758.376	202309.673	1152.622	48.0
OW-09-4	1679741.378	201341.592	1149.076	42.0

Survey datum NAD83, projection State Plane Washington North, vertical datum NAVD88.

Each of the new observation wells was completed with 2-inch diameter, Schedule 40 PVC piezometer pipe that had a 5-foot length of slotted pipe (0.020-inch slot) at the bottom. From September 29 to October 23, the wells were equipped with Instrumentation Northwest PT2X pressure transducers with dedicated data loggers for hourly monitoring of water levels.

In addition, two In-Situ Level Troll 500 transducers were placed in the Hatchery channel to monitor water levels. Locations of the channel transducers are shown on Figure 1-1. Hatchery personnel measured water levels daily in 5 of the production wells (wells 1, 2, 3a, 4a, and 7) and in wells 9, 10 and TW2. Only production well 5 was pumped during the 2-week time period. The hydrographs of the field data from each of the monitored wells are included in Appendix C.

The flow control gate at Structure No. 2 was partially closed beginning September 30 to divert a portion of the flow from Icicle Creek into the Hatchery channel. The gate was again adjusted to the full open position beginning on October 13. Observed flows and gate measurements are included in Appendix C.

3.1 October 2009 Monitoring Results

As shown in the graphs of the well response data (included in Appendix C), water levels in the shallow aquifer responded almost immediately to recharge from the Hatchery channel. Aquifer water levels in the Hatchery area were raised about 6 feet during the 2 week recharge period. Accordingly, as the diversion of surface water to the channel ended, groundwater levels quickly declined (in OW-3 the water level declined about 4 feet in the first 4 days). This response indicates high conductivity in the shallow aquifer. It also indicates that temporarily recharging the aquifer by diverting water to the Hatchery channel has only short-term benefits to increasing well capacity.

4 Groundwater Modeling

Groundwater modeling was used in this study to incorporate the new data acquired during the seepage monitoring and to evaluate possible Hatchery water management plans.

4.1 Previous Modeling Work

In the mid-1990's, GeoEngineers developed a 3-dimensional, numerical groundwater flow model, utilizing the USGS MODFLOW96 software, to simulate groundwater conditions in the shallow aquifer beneath the site (GeoEngineers, 1995). The shallow aquifer was simulated as a single, isotropic, unconfined layer. The model did not include the deeper, confined aquifer. The model consists of a 45 by 45 cell grid (2,025 cells total) that are 100 feet on each side.

Hydrologic features, such as production wells and streams (represented by MODFLOW river features) were included in the model. Production wells 1, 2, 3A, 4, 6, and 7 each occupy a separate cell; well 5 was not simulated because it is completed in the deeper confined aquifer. The Hatchery channel, Icicle Creek, and two ditches (Wenatchee Channel[2], a.k.a. onsite ditch, and the Icicle Irrigation District canal) were included, as well as areas that receive surface irrigation within the model domain.

Model input parameters, such as hydraulic conductivity and storativity, were determined from the pump testing program that GeoEngineers conducted during 1994. The measured parameters were used as starting points and then were manually adjusted during calibration of the model to match observed water level conditions. Following calibration of the steady state simulations, transient conditions were simulated to calibrate to the pumping test data and to run predictive scenarios for various pumping operations. In each case, and under high and low water conditions, the model simulated water flowing in the Hatchery channel. The results of the scenarios and a full description of the model development are included in Appendix E of the GeoEngineers (1995) report.

[2] During the 1990's, water in the Wenatchee channel was excess spill from a mixing chamber in the Hatchery pipeline.

4.2 Current Model Updates

Adjustments were made to the GeoEngineers model (Version 1) to incorporate new data from the seepage monitoring and to represent current water operations and management practices. When the original model was developed, surface water was regularly diverted to the Hatchery channel and the onsite ditch (Wenatchee Channel), so these features were incorporated as sources of recharge. Since operations of Structure No. 2 were modified, both channels are dry except during periods of high flows and during 2-week periods when water from Icicle Creek is temporarily diverted to the Hatchery channel. The more recent activity was incorporated into a new version (Version 2) of the GeoEngineers model. The Version 2 model also used an updated version of the modeling software, MODFLOW2000.

High resolution LiDAR data (2006) were incorporated to improve the accuracy of ground surface and channel bottom elevations. The results of HEC-RAS modeling (Knutson, 2009) were used to provide river stage and bottom elevations at various locations along Icicle Creek using the flow rates observed during the October 2009 seepage monitoring. Water depths for the Hatchery channel were stage values recorded by pressure transducers. Since the seepage monitoring occurred during the non-irrigation season, areal recharge due to irrigation was not included during the recalibration. In addition, no precipitation occurred during the monitoring period, so areal recharge due to precipitation was not included.

Hydraulic conductivity, storativity, river conductance, and general head boundary conductance values were adjusted during the recalibration of the model. The calibration model was a time-dependent simulation with a 12-hour stress period, meaning that the water levels in the Hatchery channel and Icicle Creek were adjusted every 12 hours. Water level observations were recorded in wells 1, 2, 3a, 4a[3], and 7 during the seepage monitoring and were used during the calibration process. The parameters were adjusted to also calibrate the model to the observed water level response in the 4 new observation wells (OW-1 through OW-4) monitored during the seepage monitoring. The model matched the observed water levels to within 10 percent of the total change in head, 13.5 feet, which is generally considered well calibrated. Figure A-6 in Appendix A shows the modeled versus observed head values. A perfect match between modeled and observed would graph along a straight line, with an R-squared value of 1. The modeled versus observed values in this model plot along a line with an R-squared value of 0.78, which is considered good. A detailed description of the model development and calibration is included in Appendix A.

[3] A new pump well, well 4a, was drilled near original pump well 4 in January 2009 but well 4a has a lower well yield (about 500 vs 850 gpm) and the pump intake is at a higher elevation, which limits the available drawdown. The model uses well 4a in the pumping scenarios.

4.3 Scenarios

Predictive simulations were run with the Version 2 model to represent pumping conditions and the effect of induced aquifer recharge by diverting water into the Hatchery channel for various time durations. The purpose of these simulations was to determine the aquifer response to various combinations and duration of recharge to help manage groundwater use at the Hatchery.

Previous studies at the Hatchery (GeoEngineers, 1995) recommended a pumping schedule based on the well characteristics such as specific capacity, available drawdown and well interference effects observed during the pumping tests. Their schedule was developed under the condition of full Hatchery channel flow, so it reflected a different recharge condition than what exists currently. The recommended schedule was modified slightly to compensate for the changed condition and is shown in Table 4-1.

Table 4-1: Recommended schedule for production well pumping (modified from GeoEngineers, 1995)

Discharge (gpm)	Constant Pump Wells	Cycled Pump Wells [1]
Up to 3,000	Wells 1, 4a and 6	Wells 2, 3A, and 7
4,000 [2]	Wells 1, 4a, 5, and 6	Wells 2, 3A and 7

1. Pumping cycle of 15 days on, 15 days off is intended to allow water levels to recover after extended periods of pumping.
2. Maximum sustainable flow rate from the existing production wells in late summer and fall was estimated in 1995 to be about 6,000 gpm. Without artificial recharge from the Hatchery channel, those rates are significantly decreased. This combination of wells (including well 5) was not modeled because well 5 is completed in the deeper aquifer.

Each of the scenarios was run under simulated high water level conditions (to represent late spring and early summer) and low water level conditions (to represent late summer through winter). The high water level condition was represented by increasing the general head boundary (GHB) elevation to 1147.0 feet (from 1140.0 feet) and by simulating a high flow rate in Icicle Creek (2100 cfs). The low water level condition matched the calibrated, non-irrigation season condition.

The simulated pumping rates for wells 1, 2, 3A, 4A, 6, and 7 are 800, 600, 400, 500, 400[4], and 300 gpm, respectively. These rates were common discharge rates for the wells during 2008 and 2009. Well 5, which is capable of producing up to 1100 gpm, but is normally pumped at about 900 gpm, was not included in the model simulations since it is completed in the deeper, confined aquifer. During periods of high demand, the combination of well 5 with the other production wells would produce more than 4,000 gpm.

[4] Well 6 pumps about 700 to 800 gpm but draws from both the shallow and deep aquifer. A reduced amount of discharge was simulated in the model scenarios to represent only that portion that is from the shallow aquifer.

Distributed recharge (from precipitation and applied on-farm irrigation) was not included in the model. The water level conditions (high or low) and Hatchery channel conditions for the model scenarios are listed in Table 4-2.

Table 4-2: Conditions for Model Scenarios

Scenario	High or Low Water Conditions	Full or Dry Hatchery Channel	Wells Pumping for full 60-day duration	Wells Pumping for 15-day alternate cycles[1]
1	High	Dry	1, 4A, 6	2, 3A, 7
2	Low	Dry	1, 4A, 6	2, 3A, 7
3	High	Full	1, 4A, 6	2, 3A, 7
4	Low	Full	1, 4A, 6	2, 3A, 7
5	High	Cycle: Full – 15 days, Dry – 15 days	1, 4A, 6	2, 3A, 7
6	Low	Cycle: Full – 15 days, Dry – 15 days	1, 4A, 6	2, 3A, 7
7	High	Cycle: Full - 15 days, Dry - 45 days	1, 4A, 6	2, 3A, 7
8	Low	Cycle: Full - 15 days, Dry - 45 days	1, 4A, 6	2, 3A, 7

1 – well 2 pumps for 15 days while wells 3 and 7 are allowed to recover, then wells 3 and 7 pump for 15 days while well 2 recovers.

During the 60 day model simulation, it was possible for the water levels to drop below the pump intake elevation because MODFLOW does not account for the intake depth. When this occurred, a second version of the scenario was run with the well turned off when the water level in the well reached 5 feet above the intake depth. Only the second version of the scenario is shown in the results below; however, the times (in days) at which the water level elevations dropped below the water level cut-off elevation (WLCO) are noted. Table 4-3 lists the pump intake elevations used to control the pumping of wells in the model scenarios.

Table 4-3: Pump intake elevations used in model scenarios

Well Number	Intake Depth	Pump Intake Elevation	Water Level Cut-off Elevation (pump intake + 5 ft)
1	70	1078	1083
2	70	1078	1083
3a	55	1096.3	1101.3

4a	60	1091.3	1096.3
6	103	1048.3	1053.3
7	75	1073.7	1078.7

4.3.1 Scenario 1 results

Figure 4-1 shows a plot of the water level elevation in the pumping wells under the conditions described for scenario 1 (high water levels, dry channel). Arrows on the data line for well 3a explain the water level fluctuations seen on the scenario graphs; they are due to the 15-day cycling on/off of wells 2, 3a, and 7. In scenario 1, the water level in well 3a dropped below the WLCO elevation after 36 days.

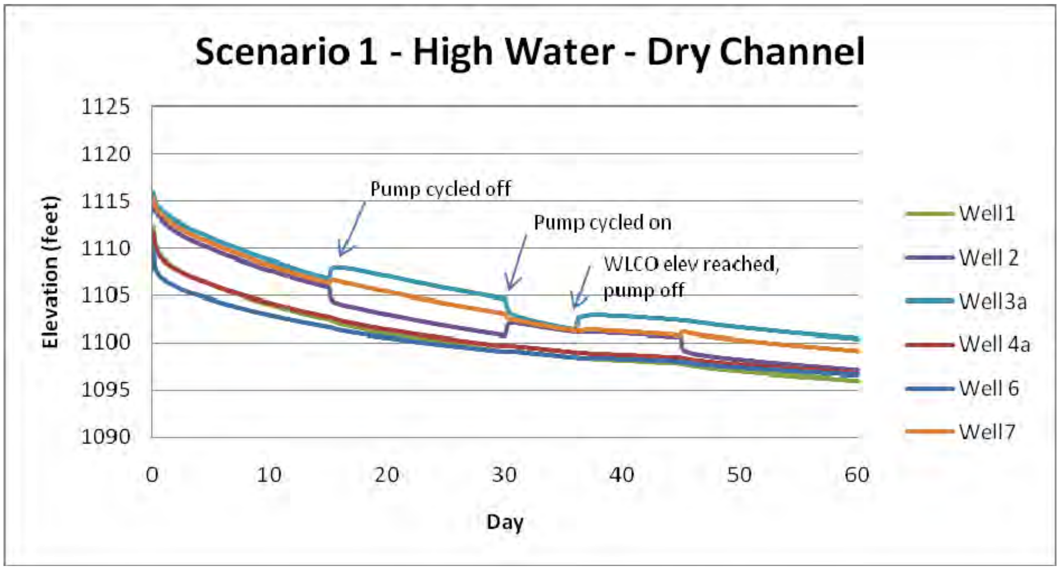


Figure 4-1: Plot of water level elevation in pumping wells under scenario 1 conditions.

With the channel dry, the overall water surface elevation declines under pumping conditions.

4.3.2 Scenario 2 results

Figure 4-2 shows a plot of the water level elevation in the pumping wells under the conditions described for scenario 2 (low water levels, dry channel). In scenario 2, the water level in well 3a reached the WLCO elevation after 30 days and in well 4a after 37 days. Extended pumping from these wells is limited by water supply and by the shallow placement depth of the pump in well 4a. The available drawdown in original well 4 is significantly greater, since the pump intake is about 30 feet lower in well 4 than in well 4a.

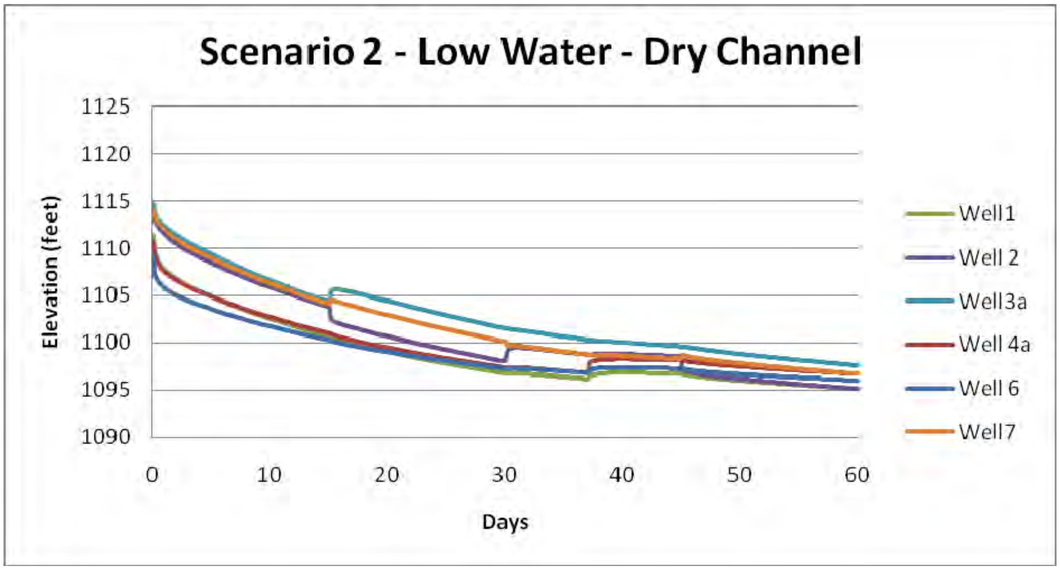


Figure 4-2: Plot of water level elevation in pumping wells under scenario 2 conditions.

The water surface elevation declines overall as a result of the pumping conditions and it has not yet reached an equilibrium condition at day 60. The water surface declines faster in the low water condition than in the high water condition (scenario 2 vs. scenario 1). The pumps have a similar localized effect on the water surface elevation near the pumping wells. Without the addition of recharge from the Hatchery channel to maintain a higher water level in the aquifer, the pumping wells with shallow pump settings are not sustainable for extended pumping periods.

4.3.3 Scenario 3 results

Figure 4-3 shows a plot of the water level elevation in the pumping wells under the conditions described for scenario 3 (high water levels, full channel). In scenario 3, the water level elevations remained above the WLCO elevations for all wells.

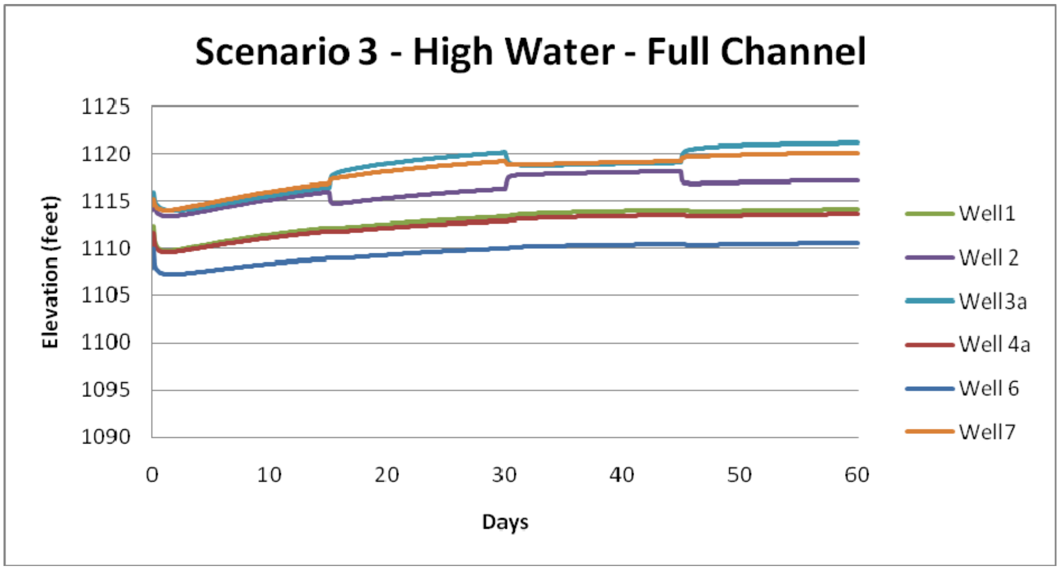


Figure 4-3: Plot of water level elevation in pumping wells under scenario 3 conditions.

With a full channel, the overall water level in the shallow aquifer increases. After about 50 days, the water surface elevation in the pumped wells nearly reaches equilibrium, indicating that pumping can continue for extended periods.

4.3.4 Scenario 4 results

Figure 4-4 shows a plot of the water level elevation in the pumping wells under the conditions described for scenario 4 (low water levels, full channel). In scenario 4, the water level elevations remained above the pump intake elevations for all wells.

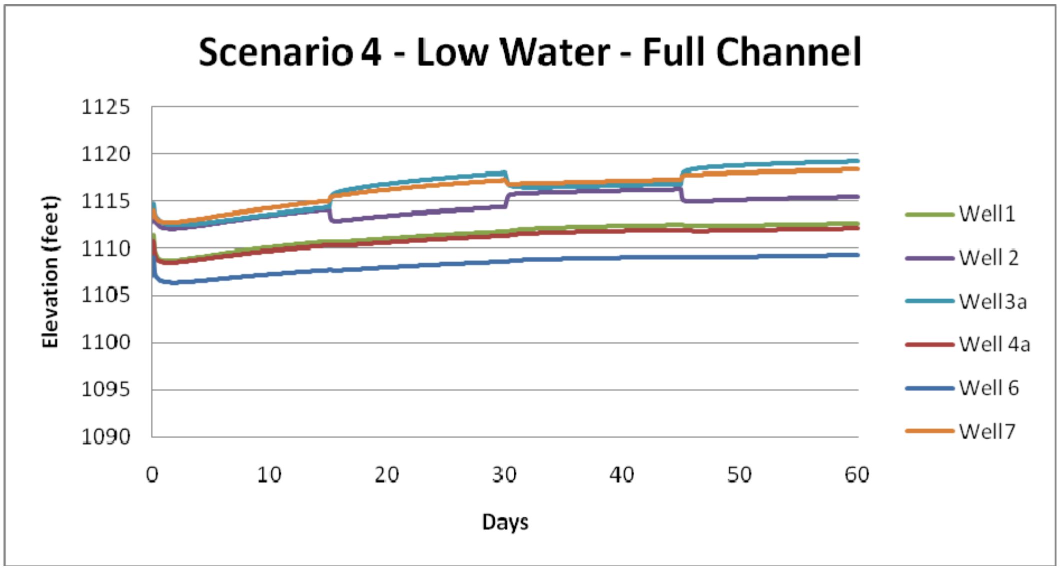


Figure 4-4: Plot of water level elevation in pumping wells under scenario 4 conditions.

As in scenario 3, the full channel provides recharge to the shallow aquifer and the overall water level increases. After about 50 days, the water surface elevation in the pumped wells nearly reaches equilibrium. The addition of recharge from the Hatchery channel is much more important than seasonal water level conditions in determining the ability to pump from the shallow aquifer.

4.3.5 Scenario 5 results

Figure 4-5 shows a plot of the water level elevation in the pumping wells under the conditions described for scenario 5 (high water levels, cycling water into the Hatchery channel every 15 days). In scenario 5, the water level elevations remained above the WLCO elevations for all wells.

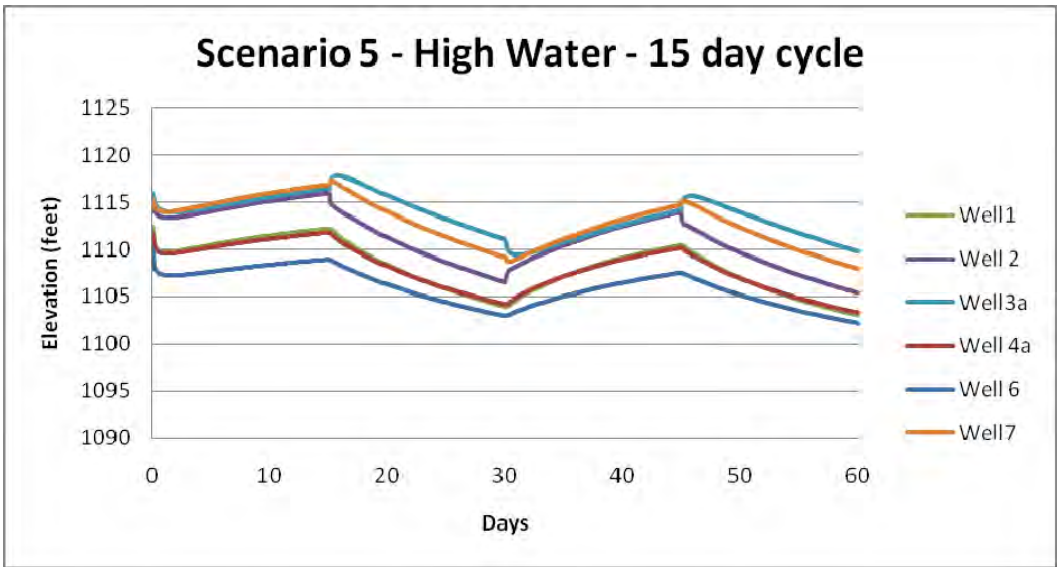


Figure 4-5: Plot of water level elevation in pumping wells under scenario 5 conditions.

When water is diverted to the channel, the overall water surface elevation increases, even during well pumping, but the water level declines sharply when the channel is empty. The amount of water in the channel has a larger impact on the aquifer water level than the drawdown effects from pumping the wells.

4.3.6 Scenario 6 results

Figure 4-6 shows a plot of the water level elevation in the pumping wells under the conditions described for scenario 6 (low water levels, cycling water into Hatchery channel every 15 days). In scenario 6, the water level elevations remained above the WLCO elevations for all wells.

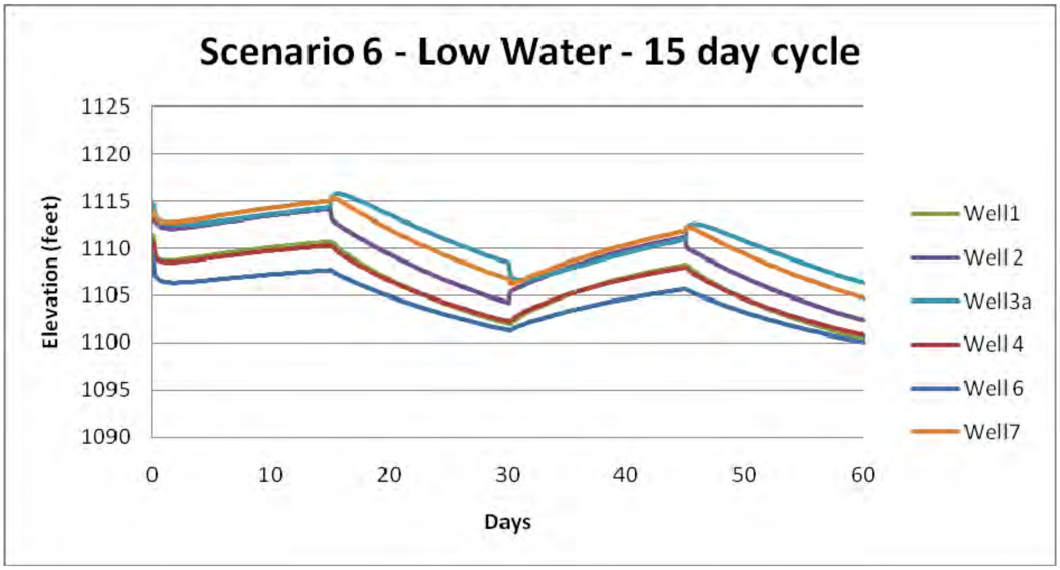


Figure 4-6: Plot of water level elevation in pumping wells under scenario 6 conditions.

When the channel is full, the overall water surface elevation increases and it declines sharply when the channel is empty. The amount of water in the channel has a larger impact on the aquifer water level than the pumping effects from the wells. These periodic recharge events allow pumping from the wells during the entire simulation period.

4.3.7 Scenario 7 results

Figure 4-7 shows a plot of the water level elevation in the pumping wells under the conditions described for scenario 7 (high water levels, water in Hatchery channel for only 15 days). In scenario 7, the water level in well 3a reached the WLCO elevation after 51 days and in well 4a after 58 days.

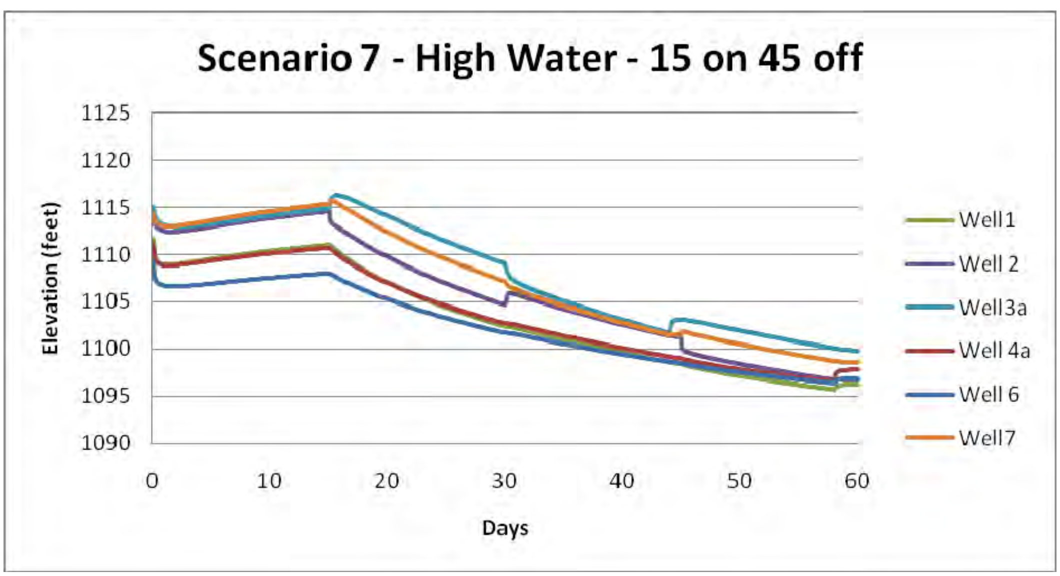


Figure 4-7: Plot of water level elevation in pumping wells under scenario 7 conditions.

Water diverted to the Hatchery channel for the first 15 days of this scenario supports a raised water level in the aquifer. When water is no longer diverted to the channel, the water level drops steeply and the final water levels (at 60 days) are similar to those in scenario 1 that diverts no water to the channel.

4.3.8 Scenario 8 results

Figure 4-8 shows a plot of the water level elevation in the pumping wells under the conditions described for scenario 8 (low water levels, water in Hatchery channel for only 15 days). In scenario 8, the water level in well 3a reached the WLCO elevation after 42 days and in well 4a after 55 days. The low seasonal water conditions reduced the time available to pump wells 3a and 4a, as compared to scenario 7 with high water level conditions. As in the other scenarios in which water is not diverted to the Hatchery channel, the aquifer cannot support extended pumping of the production wells without the addition of recharge from the Hatchery channel.

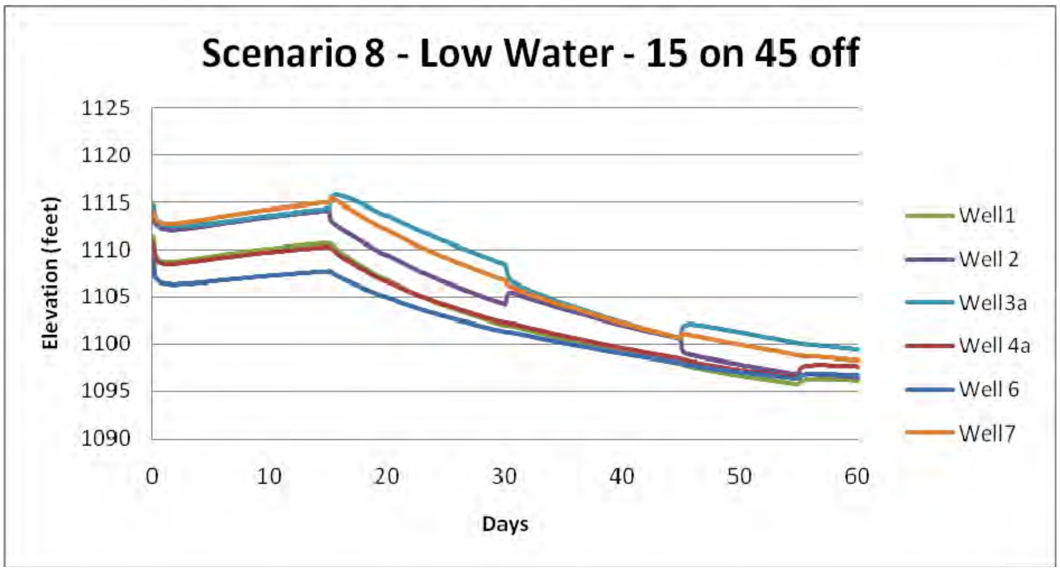


Figure 4-8: Plot of water level elevation in pumping wells under scenario 8 conditions.

Table 4-4: Summary of Scenario Results

Scenario	High or Low Water Conditions	Full or Dry Hatchery Channel	Number of days wells can pump during 60-day model simulation[1] Well 3a	Well 4a	Wells 1, 2, 6, 7
1	High	Dry	36	C	C
2	Low	Dry	30	37	C
3	High	Full	C	C	C
4	Low	Full	C	C	C
5	High	Cycle: Full – 15 days, Dry – 15 days	C	C	C
6	Low	Cycle: Full – 15 days, Dry – 15 days	C	C	C
7	High	Cycle: Full - 15 days, Dry - 45 days	51	58	C
8	Low	Cycle: Full - 15 days, Dry - 45 days	42	55	C

1 – At the day listed, the modeled water level elevation drops to 5 feet above the pump intake elevation (see table 4-3) and the pump is turned off for the remainder of the simulation period.
C = continuous pumping (wells 2 and 7 cycle on/off every 15 days during simulation period)

This page intentionally left blank.

5 Conclusions and Recommendations

The Hatchery depends on groundwater from 7 production wells that supplement the surface water supply from Icicle Creek. Groundwater is also used to adjust the temperature of surface flows to meet fish production targets.

Unconsolidated sediments of glaciofluvial and river origin underlie the Hatchery site and consist of interbedded gravel, sand, silt and clay. The unconsolidated sediments are stratified (layered) and comprise two aquifers; a shallow unconfined aquifer that extends over most of the valley and a deeper confined aquifer of more limited extent. All but one of the Hatchery's production wells pump from the shallow unconfined aquifer. Well 5 is completed in the deeper aquifer and well 6 is screened in both aquifers.

From 1940 to 2005, Hatchery operations directed most creek flows into the Hatchery channel, a man-made channel built in the late 1930's so that a portion of Icicle Creek could be used to accommodate Hatchery fish production. It has long been understood that water flow in the Hatchery channel provides recharge to the shallow aquifer. Since 2006, operations were changed to improve fish passage in Icicle Creek. The gates at the diversion control structure are kept open most of the year and the Hatchery channel is usually kept dry. Under current operations, the gates are partially closed at the control structure for two weeks at a time, allowing water into the Hatchery channel. Although these recharge periods help well production temporarily, a two week period has not been sufficient to significantly improve well capacity.

Groundwater monitoring during October 2009 helped quantify the aquifer response to induced recharge by diverting water into the Hatchery channel. The purpose of the monitoring was to determine the temporal and spatial response within the shallow aquifer to the addition of water in the Hatchery channel. The test results were used to update and adjust calibration parameters within an existing MODFLOW groundwater flow model that was developed by GeoEngineers (1995). Other updates to the model were also completed to better represent current Hatchery conditions.

Following calibration, predictive simulations were run with the updated model to represent pumping conditions and the effect of induced aquifer recharge by diverting water into the Hatchery channel for various time durations. The purpose of these simulations was to determine the aquifer response to various combinations and duration of recharge to help manage groundwater use at the Hatchery. Each simulation was run for 60-days.

A total of eight predictive scenarios were run with the updated (Version 2) model. The pumping schedule for the production wells remained the same for all of the scenarios while the seasonal water level conditions and the presence or absence of water in the Hatchery channel was varied.

Results from the scenario runs show that the presence of water in the Hatchery channel is of primary importance to extended pumping from the Hatchery production wells. Recharge from the channel raises aquifer water levels and maintains higher levels, even during well pumping. Without recharge from the channel, water levels quickly fall and some wells are forced to stop pumping as the water levels drop to the pump intake elevations. A cycled diversion of 15 days of water in the channel followed by 15 days without water, allows pumping from all of the production wells for the 60 day simulation. If water is diverted to the channel for only 15 days, and the channel is dry the remaining 45 days, the wells with relatively shallow pump settings are forced to shut off after 42 to 58 days of pumping, depending on the seasonal water level conditions.

References

GeoEngineers, Inc., 1995, Report of Phase 1 and Phase 2 Hydrogeologic Services, Leavenworth NFH, Leavenworth, WA

GeoEngineers, Inc., 2009, Report Hydrogeologic Services, Water Supply Well 4A, Leavenworth National Fish Hatchery Leavenworth, Washington

Sverdrup Civil, Inc, 2000, Icicle Creek Fish Passage Restoration and Intake Alternatives Study at the Leavenworth National Fish Hatchery

U.S. Fish and Wildlife Service (USFWS), 2009a, Leavenworth National Fish Hatchery Proposed Flow Management Operations for 2009 -2014

U.S. Fish and Wildlife Service (USFWS), 2009b, Guidance for Compromised Water Quantity and Quality Situations at the Leavenworth National Fish Hatchery

This page intentionally left blank.

Appendix A: Version 2 Model and Scenario Development

The Version 2 groundwater model of the Hatchery used the GeoEngineers model (Version 1 model) as a starting point to develop an upgraded model of the system. The cell size, number of cells, and location of the boundary conditions remained the same. Recharge and stream conditions were changed to represent the current conditions at the Hatchery. The model was recalibrated to develop refined hydraulic conductivity and storativity distributions, which was recommended by GeoEngineers (1995).

A.1 Model Parameters

LiDAR elevation data (Watershed Sciences, 2007) with an accuracy of +/- 0.04 meters (1.6 inches) was incorporated into Version 2 because it provides a more accurate representation of the top elevation of the model. Figure A-1 shows the new elevations that are used in the model.

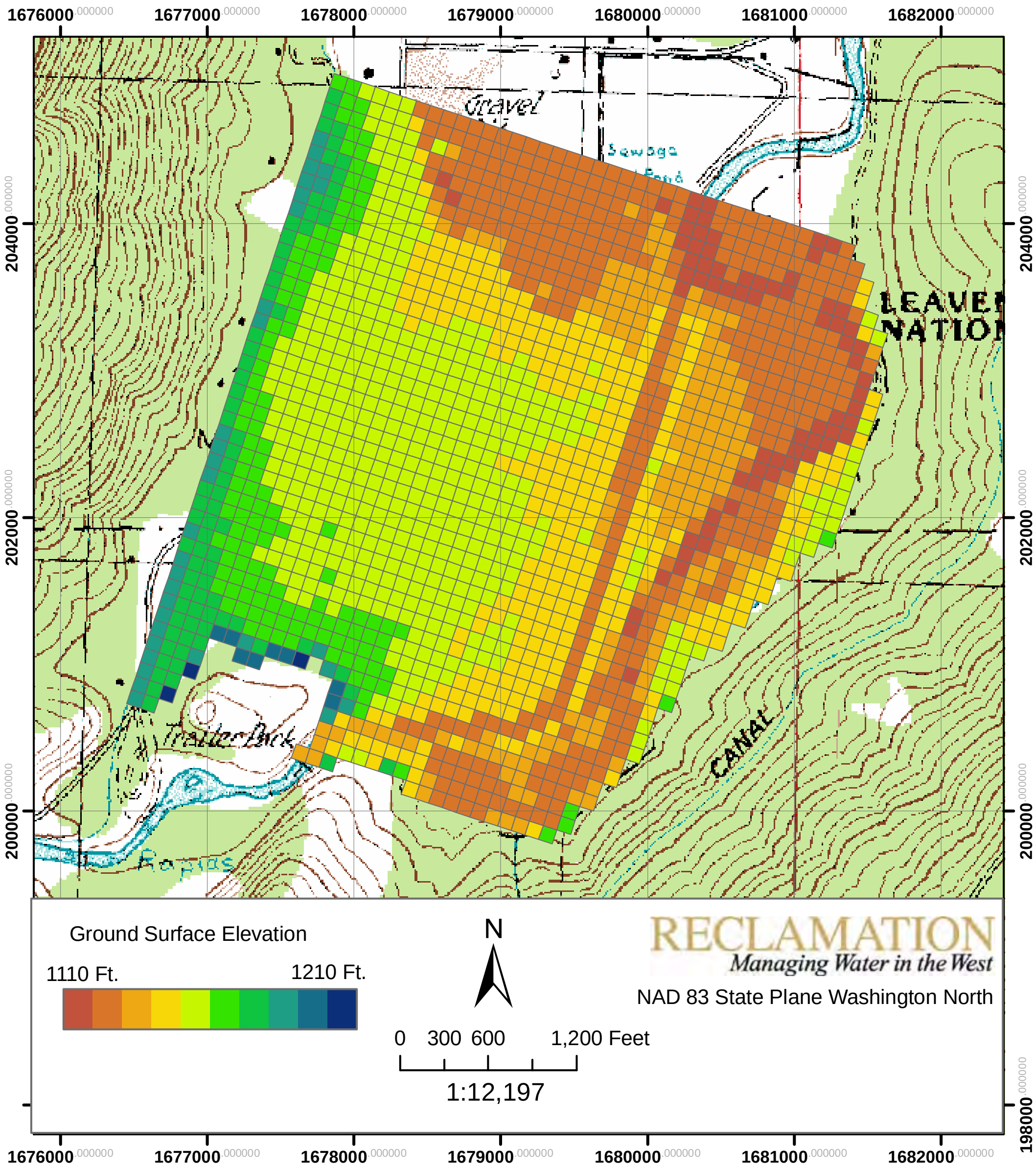


Figure A-1: Map of ground surface elevations used in model extracted from LiDAR.

Version 2 was calibrated using a time-dependent model that simulated the seepage monitoring performed in October 2009. Since the monitoring was performed during the non-irrigation season, the off-site irrigation ditch (Icicle Canal) was removed from the model and no recharge from the application of irrigation water or precipitation was simulated. The GeoEngineers model simulated the on-site ditch (Wenatchee Channel) but that feature was removed from the version 2 model since water was not flowing in the ditch during the calibration time period. The effect of calibrating the model to a period without recharge from precipitation or irrigation represents a “worst-case” groundwater condition; when there is additional recharge from precipitation or irrigation, the results from pumping would be less severe and there would be less water level drawdown. The general head boundary locations were left the same as those in the GeoEngineers model. Figure A-2 shows the location of the surface features that were used in the calibration process.

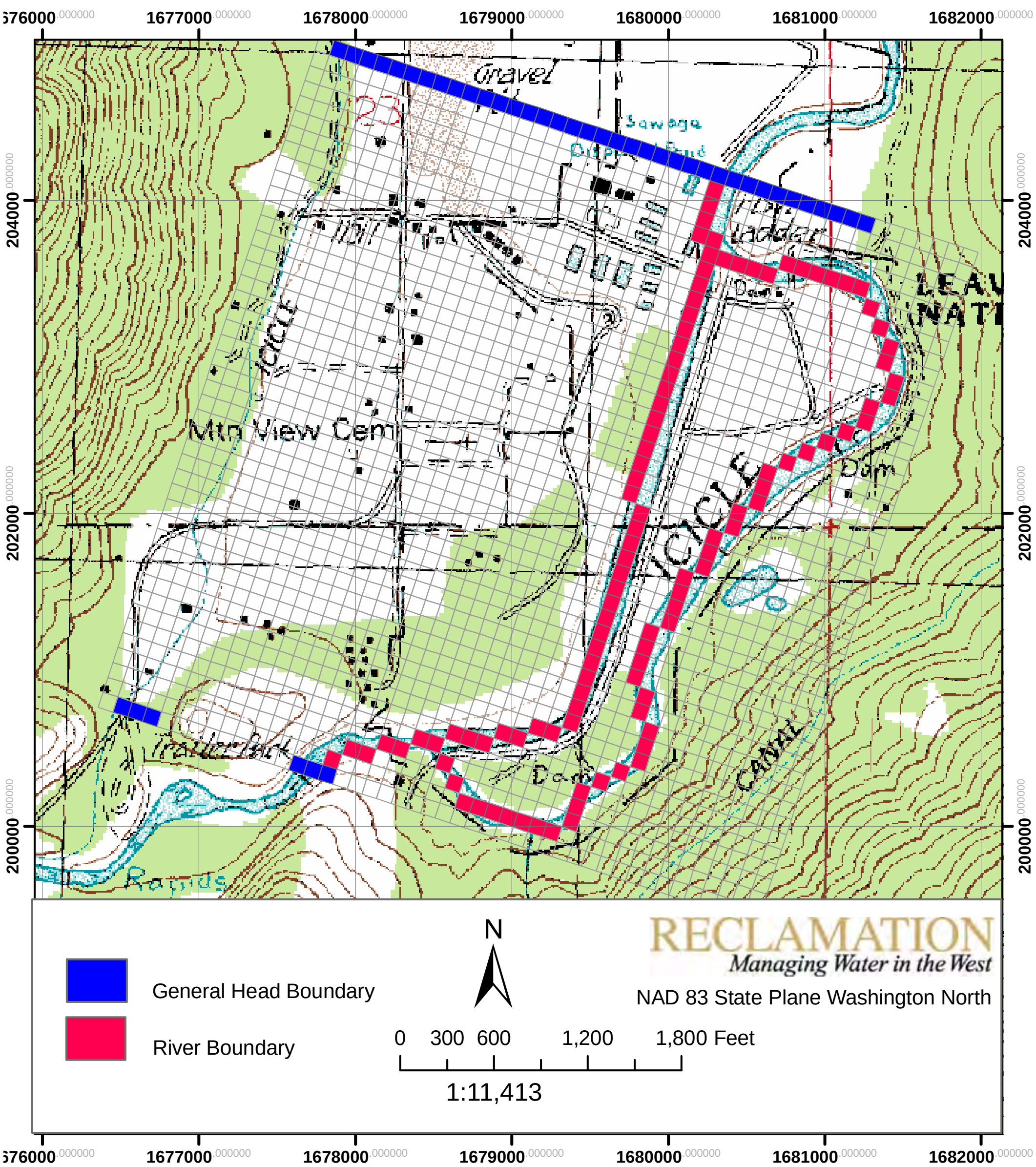


Figure A-2: Map of general head and river MODFLOW boundary conditions.

A.2 Model Calibration

The model was calibrated to match observations that were recorded during the 2009 seepage monitoring using PEST (Doherty, 2008), an automated parameter estimation software. GeoEngineers (1995) suggested, in the recommendations section of their report, that an automated calibration procedure be attempted to better refine the hydraulic conductivity distribution in the model.

Pilot points and Tikhonov regularization (Tikhonov 1963a, 1963b) were applied to the PEST calibration scheme. Pilot points are a way to characterize the spatial distribution of parameters (such as hydraulic conductivity) within the grid that eliminates the need for lumping the parameter into piecewise homogeneous zones. Parameters are estimated at the pilot points and are then interpolated to the remaining cells (in this case, the pilot points are interpolated using kriging). Since the pilot points are at discreet locations, PEST has the ability to make large changes at each point to best match an observation, which can lead to large variations in a parameter over short distances. Tikhonov regularization constrains the PEST calibration process so that PEST does not calculate unrealistic parameters simply to meet the observations. It has been argued that using pilot points with Tikhonov regularization calculates the most unique parameter distribution possible and reduces uncertainty in the model results (Fienen and others, 2009).

The locations of the pilot points were selected based on the criteria that at least one pilot point should be between any two observations. The remaining pilot points were placed to minimize the number, but to evenly cover the remaining area. Pilot points were used for both horizontal hydraulic conductivity and storativity. In addition to pilot points, hydraulic conductivity targets were used to assist the PEST calibration. The targets were measured values in wells 1, 2, 3A, 4A, and 6.

Figure A-3 shows the hydraulic conductivity distribution calculated during the calibration process.

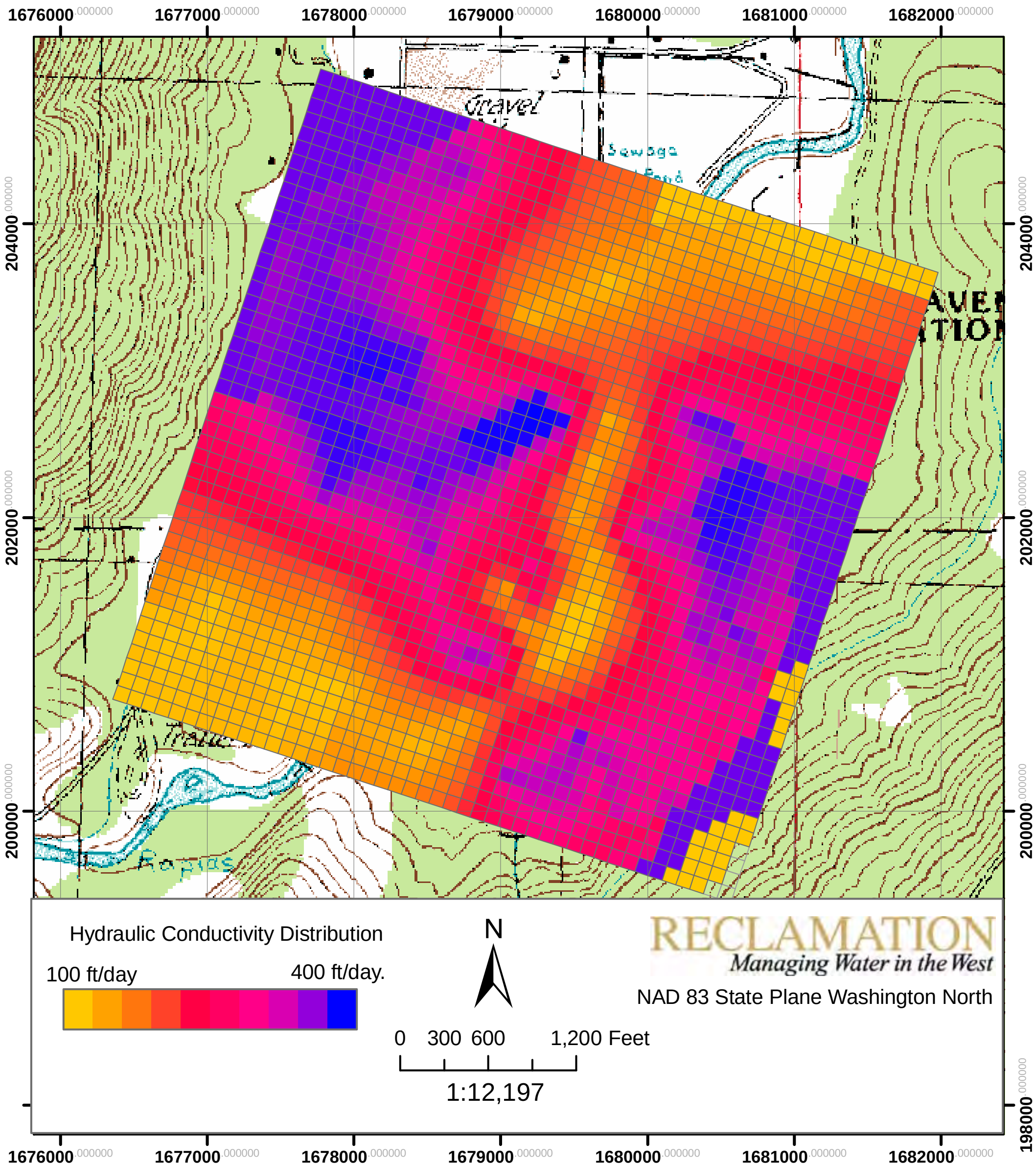


Figure A-3: Hydraulic conductivity distribution calculated during calibration process.

Figure A-4 shows the storativity distribution calculated during the calibration process.

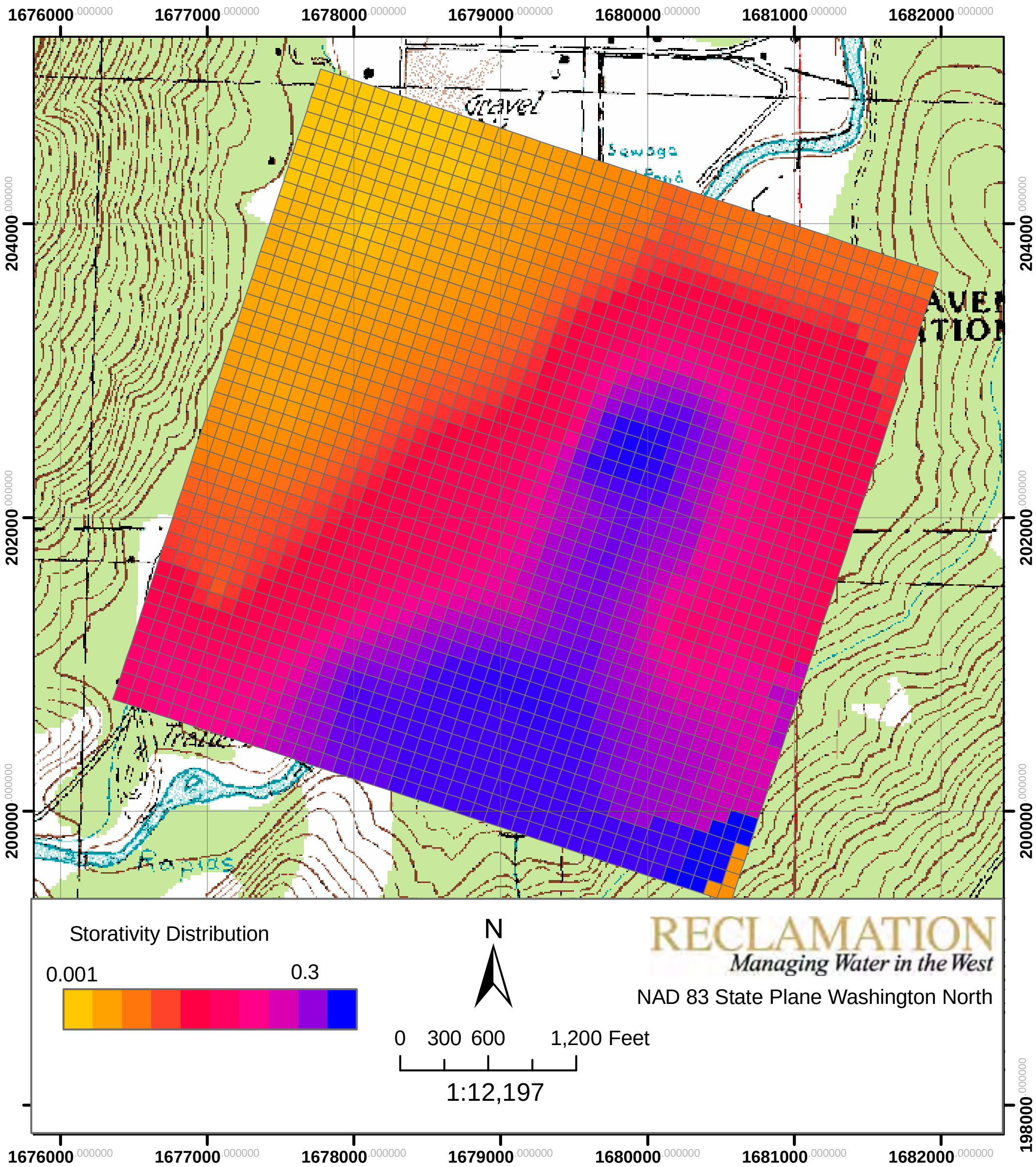


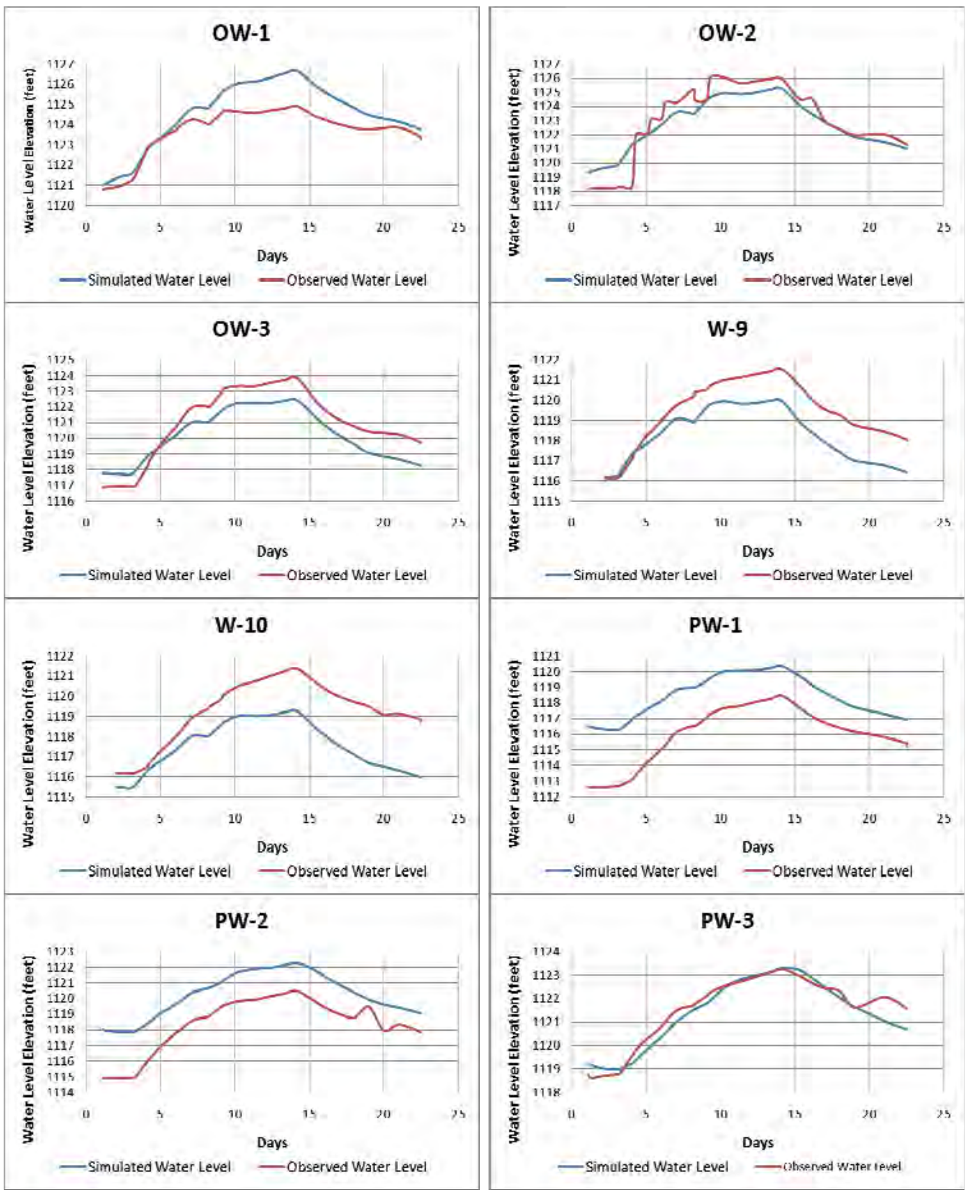
Figure A-4: Storativity calculated during the calibration process.

The model calibrated conductances for four separate river reaches: Icicle Creek upstream of Structure No. 2, Icicle Creek between Structure No. 2 and the confluence of Icicle Creek and Hatchery Channel, Icicle creek downstream of the confluence, and the Hatchery Channel. The conductance values are shown in Table A-1.

Table A-1: Table of calibrated conductances for river reaches in model.

River Reach	Conductance (ft^2/d)
Icicle Creek u/s of Structure No. 2	500
Icicle Creek between Structure No. 2 and Channel confluence	500
Icicle Creek d/s of confluence	1290
Hatchery Channel	8203

Figure A-5 shows the hydrographs of the observed versus the simulated water levels.



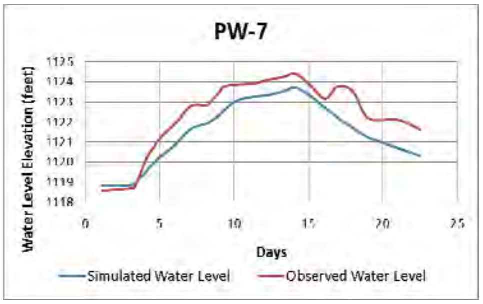


Figure A-5: Plots of observed versus simulated water levels.

The model was calibrated to within 10% of the total change in observed water levels within the model domain. A model is considered well calibrated if it is within 10%. Figure A-6 shows a plot of the simulated versus observed values with an R-squared value of 0.78.

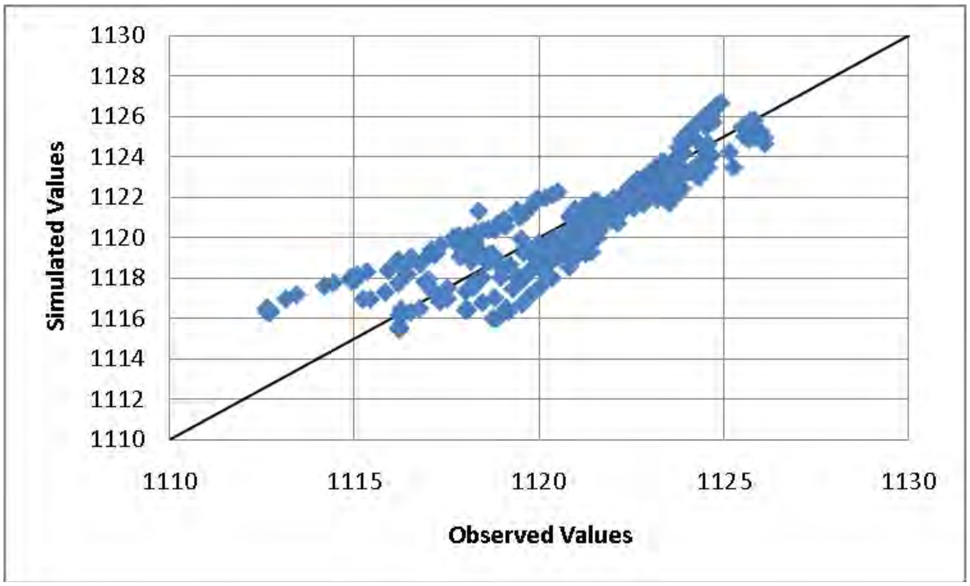


Figure A-6: Observed versus simulated values.

A.2.1 Calibration Uniqueness

Models are simplified representations of complex natural systems that can never match reality perfectly. In any modeling endeavor, it is important to examine the uncertainty related to the model and its calibration so as to understand the applicability and limitations of the model.

In the case of the Version 2 LNFH groundwater model, utilizing pilot points and Tichonov regularization provides a unique solution with reduced uncertainty.

A.3 Scenarios

Six scenarios were run to show the consequences of proposed operations at LNFH. The scenarios are described in the main text of this report. All of the scenarios used the same pumping schedule (Section 4, Table 4-1). The seasonal water conditions (high or low) and Hatchery channel operations were varied. Each scenario was run for 75 days: 15 days to allow the water levels to adjust to the water condition type and 60 days applying the well pumping schedule.

Scenario 1 – High water conditions with dry channel
This scenario represented high water conditions (such as during spring and early summer) with no water flowing in the Hatchery channel through the entire 75 day simulation. To simulate high water conditions, the calibrated model simulated a general head boundary elevation at 1147 feet. In addition, Icicle Creek was simulated with high flow of 2100 cfs. The HEC-RAS model was used to develop water surface elevations at the 2100 cfs flow rate, which were then fed into the MODFLOW model. The wells begin pumping at day 15 of the simulation to allow the system to equilibrate with respect to the high water conditions before applying the pumping stress. Scenario results are shown in Section 4-3.

Scenario 2 – Low water conditions with dry channel
This scenario represented low water conditions (such as late summer through winter) with no water flowing in the Hatchery channel through the entire 75 day simulation. The general head boundary elevation was set at 1140 feet to simulate low water conditions. Icicle Creek had a minimum flow of 50cfs.

Scenario 3 – High water conditions with full channel
This scenario is similar to Scenario 1, except that the Hatchery channel is simulated to have three feet of water in it, simulating full conditions.

Scenario 4 – Low water conditions with full channel
This scenario is similar to Scenario 2, except that the Hatchery channel is simulated to have three feet of water in it.

Scenario 5 – High water conditions with 15 day cycle of water in Hatchery channel
The scenario is similar to Scenarios 1 and 3 except the water in the Hatchery channel is cycled full for 15 days, then empty 15 days. The cycle repeats twice in the 75 day simulation period.

Scenario 6 – High water conditions with 15 day cycle of water in Hatchery channel
The scenario is similar to Scenarios 2 and 4 except the water in the Hatchery channel is cycled full for 15 days, then empty 15 days. The cycle repeats twice in the 75 day simulation period.

Scenario 7 – High water conditions with 15 day full channel
The scenario is similar to Scenarios 1 and 3 except the water in the Hatchery channel is cycled full for 15 days, then empty 45 days.

Scenario 8 – High water conditions with 15 day full channel
The scenario is similar to Scenarios 2 and 4 except the water in the Hatchery channel is cycled full for 15 days, then empty 45 days.

Appendix A References

Doherty J., 2008, PEST, Model Independent Parameter Estimation. User manual, 5th ed., Brisbane, Australia, Watermark Numerical Computing. http://www.pesthomepage.org/files/pestman.pdf (accessed February 1, 2009)

Fienen, M., Muffels, C., and Hunt, R., 2009, On Constraining Pilot Point Calibration with Regularization in PEST, *Groundwater* 47.6: 835-844.

GeoEngineers, Inc., 1995, Report of Phase 1 and Phase 2 Hydrogeologic Services, Leavenworth NFH, Leavenworth, WA

Tikhonov, A.N., 1963a, Solution of incorrectly formulated problems and the regularization method, *Soviet Mathematics Doklady* 4, 1035-1038.

Tikhonov, A.N., 1963b, Regularization of incorrectly posed problems, *Soviet Mathematics Doklady* 4, 1624-1637.

Watershed Sciences, 2007, LiDAR Remote Sensing Data Collection: Upper & Lower Okanogan River, Methow River, Lake Roosevelt, Wenatchee River and John Data River Study Areas

Appendix B: Well logs and construction schematics for wells at Leavenworth National Fish Hatchery

Table B-1: Summary of Well Information for Hatchery Wells

Well Number	Well Construction Details						Source Aquifer	Status of well	Static Water Level	
	Date Drilled	Drilled Depth (ft)	Completion Depth (ft)	Diameter (inches)	Perforated Casing or Screened Depth (ft)	Pump Inlet Depth (ft)			Date	Depth (ft)
1	(04/58)?	80	80	12	40-80	70	Shallow	Active	28.5	5/5/09
2	1940	94	94	12.5	20-90	77	Shallow	Replaced by 2A	--	--
2A	07/91	206	203	20	70-90	--	Shallow	Active	24.0	5/5/09
3	--	103	103	12	20-92[5]	75	Shallow	Replaced by 3A	25.8	5/5/09
3A	06/91	120	98	16	63-98	55[6]	Shallow	Active	30.8	9/30/09
4	10/76	324	237	16	60-69 95-225[7]	92	Shallow	Active	38.75	8/25/09
4A	10/08	333	105	16	64-94	60	Shallow	Active	29.04	7/8/09
5	07/79	290	279	14	249-279	120	Deep	Active	17.0	5/5/09
5A	02/78	300	300	14	250-300		Deep	Collapsed during pumping test	--	--
5B	10/76	286	280	16			Deep	Pumped excessive sand during pumping test	--	--

[5] Screen is filled with sand to a depth of 92 ft.
[6] Pump inlet depth is estimated
[7] Screen is filled with sand to a depth of 101 ft.

6	12/76	195	170	14	102-112 150-170	103	Shallow and Deep	Active	35.44	7/8/09
7	11/76	192	110	14	72-82 92-110	75	Shallow	Active	24.5	5/5/09
8	10/76	278	278[8]	1.5	--	--		Obser. Well	--	--
9	11/76	213	205	16	80-105 115-136 180-200	--	Shallow	Collapsed during pumping test, used as obser. well	17.7	9/30/09
10	2/95	110	104	12	75-100	--	Shallow	Not Pumped	38.15	9/30/09
11	2/95	278	278	16	--	--	Shallow	Decommissioned	--	--
TW-1	9/94	276	--	--	--	--	--	Abandoned	--	--
TW-2	11/94	150	--	--	--	--	Shallow	Used as obser. well	34.75	9/30/09
TW-3	1/95	145	--	--	--	--	Shallow	Cased well near well 10	--	--

[8] Collapsed or filled with sand to a depth of 56 ft.

GEOLOGIC LOG OF DRILL HOLE NO. OW-09-1

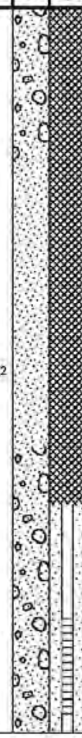
SHEET 1 OF 2

FEATURE: Leavenworth National Fish Hatchery - Repairs
LOCATION: North Side - Diversion Canal
BEGUN: 9/25/09 FINISHED: 9/26/09
DEPTH AND ELEV OF WATER
LEVEL AND DATE MEASURED: 26.3' 9/29/2009

PROJECT: Columbia Basin Project
COORDINATES: N 200,668.7 E 1,678,875.0
TOTAL DEPTH: 38.0
DEPTH TO BEDROCK: Not Encountered

STATE: Washington
GROUND ELEVATION: *1149.9
ANGLE FROM HORIZONTAL: -90 AZIMUTH
HOLE LOGGED BY: Stelma/Dirdriksen
REVIEWED BY: D. Bennett

NOTES	DEPTH	% RECOVERY	SPT	MC	FIELD / CLASSIFICATION	USCS LAB	GEOLOGIC UNIT	GRAPHIC	HOLE COMPLETION	CLASSIFICATION AND PHYSICAL CONDITION
	0–8				SPgc		Ogd2			
	8–23				SP					
	23–38				SPg					



BOTTOM OF HOLE

NOTES

All elevations measured from ground surface and are same as driller reported.

PURPOSE OF HOLE:
Drilled hole to install piezometer for monitoring seepage from the diversion canal.

DRILL SETUP:
Set up on the access road on the north side of the diversion canal.

DRILLER:
Chris Peterson

DRILLING EQUIPMENT:
Ingersoll Rand T2W truck mounted rotary drill rig with ODEX casing advancer system.

DRILLING METHODS:
0.0 to 38.0': Advanced 6-inch O.D. threaded steel casing with the ODEX casing advancer system (down-hole hammer), used compressed air to activate hammer and remove cuttings.

DRILLING CONDITIONS:
0.0 to 38.0': Moderately hard to soft and fast with DHH.

CASING RECORD:

2009 Date	Cs Sz	Depth Hole	Depth Cs
09/25	6"	38.0'	38.0'

FLUID COLOR:
0.0 to 8.0': Gray to brown cuttings (air).

8.0 to 38.0': Brown cuttings (air).

FLUID RETURN:
0.0 to 38.0': Drilled with air.

WATER LEVEL DURING DRILLING:

Date	Fluid Level
09/26	26.0'

WATER LEVEL AFTER DRILLING:

Date	Fluid Level
09/29/09	26.3'

CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 38.0 QUATERNARY GLACIAL DRIFT - OUTWASH SUBUNIT (Qgd2) Pleistocene deposits associated with alpine glaciation. The unit consists of outwash deposits composed of medium to coarse sand and gravel with cobbles and scattered boulders.

0.0 - 8.0': SAND AND GRAVEL WITH COBBLES. Description based on drilling conditions and cuttings returned.

8.0 - 23.0': SAND. Description based on drilling conditions and cuttings returned.

23.0 - 38.0': SAND AND GRAVEL. Description based on drilling conditions and cuttings returned.

BOTTOM OF HOLE: 38.0 FEET

COMMENTS: Samples were logged in the field using Designation USBR 5005-86, "Procedures for Determining Unified Soil Classification (Visual Method)."

Center column descriptors are defined in the Reclamation Engineering Geology Field Manual, Volume 1, Second Edition, distributed February 1999.

Cs = Casing Sz = Size of Casing I.D. = Inside Diameter O.D. = Outside diameter DHH = ODEX down-hole hammer casing advancer system.

* = Elevation at top of protective steel casing

GEOLOGIC LOG OF DRILL HOLE NO. OW-09-1

SHEET 2 OF 2

FEATURE: Leavenworth National Fish Hatchery - Repairs	PROJECT: Columbia Basin Project	STATE: Washington
LOCATION: North Side - Diversion Canal	COORDINATES: N 200,668.7 E 1,678,875.0	GROUND ELEVATION: *1149.9
BEGUN: 9/25/09 FINISHED: 9/26/09	TOTAL DEPTH: 38.0	ANGLE FROM HORIZONTAL: -90 AZIMUTH:
DEPTH AND ELEV OF WATER	DEPTH TO BEDROCK: Not Encountered	HOLE LOGGED BY: Stelma/Didriksen
LEVEL AND DATE MEASURED: 36.3' 9/29/2009		REVIEWED BY: D. Bennett

NOTES	DEPTH	% RECOVERY	SPT	MC	FIELD / CLASSIFICATION	USCS LAB	GEOLOGIC UNIT	GRAPHIC	HOLE COMPLETION	CLASSIFICATION AND PHYSICAL CONDITION
* From ground surface. DRILLING TIME: Drilling 15 hrs. Moving: 5 hrs. (Travel time not included) HOLE COMPLETION: Placed #8 silica sand from 37.0-38.0'. Installed 2-inch, schedule 40 PVC riser and slotted-pipe piezometer from 0.0-37.0', with slotted (0.02") section from 32.0-37.0'. Filter sand (#8 silica sand) sand was placed from 37.0 to 26.0 feet (6.0' above slotted section). Bentonite chips (surface seal) were placed from 0.0 to 26.0'. A protective steel standpipe with a locking cover was cemented in at the surface, stick up is approximately 24-inches. Developed well by flushing with clear water upon completion.										

COMMENTS:

USBR_PN_3 LEAVENWORTHOH.GPJ USBR_PN.GDT 10/26/09 3:46:27 PM

GEOLOGIC LOG OF DRILL HOLE NO. OW-09-2

SHEET 1 OF 2

FEATURE: Leavenworth National Fish Hatchery - Repairs
LOCATION: North Side - Diversion Canal
BEGUN: 9/26/09 FINISHED: 9/27/09
DEPTH AND ELEV OF WATER
LEVEL AND DATE MEASURED: 28.7' 9/29/2009

PROJECT: Columbia Basin Project
COORDINATES: N 201,404.1 E 1,679,509.6
TOTAL DEPTH: 43.0
DEPTH TO BEDROCK: Not Encountered

STATE: Washington
GROUND ELEVATION: ¹1149.7
ANGLE FROM HORIZONTAL: -90 AZIMUTH
HOLE LOGGED BY: Stoima/Didrickson
REVIEWED BY: D. Bennett

NOTES	DEPTH	% RECOVERY	SPT	MC	FIELD / CLASSIFICATION	USCS LAB	GEOLOGIC UNIT	GRAPHIC	HOLE COMPLETION	CLASSIFICATION AND PHYSICAL CONDITION
All elevations measured from ground surface and are same as driller reported.	0–28.0				SP		Qgd2			**0.0 to 43.0 QUATERNARY GLACIAL DRIFT - OUTWASH SUBUNIT (Qgd2)** Pleistocene deposits associated with alpine glaciation. The unit consists of outwash deposits composed of medium to coarse sand and gravel with cobbles and scattered boulders.
	28.0–43.0				SPg		Qgd2			0.0 - 28.0': SAND. Description based on drilling conditions and cuttings returned.
										28.0 - 43.0': SAND AND GRAVEL. Description based on drilling conditions and cuttings returned.
										BOTTOM OF HOLE: 43.0 FEET

BOTTOM OF HOLE

NOTES:

PURPOSE OF HOLE:
Drilled hole to install piezometer for monitoring seepage from the diversion canal.

DRILL SETUP:
Set up on the access road on the north side of the diversion canal.

DRILLER:
Chris Peterson

DRILLING EQUIPMENT:
Ingersoll Rand T2W truck mounted rotary drill rig with ODEX casing advancer system.

DRILLING METHODS:
0.0 to 43.0': Advanced 6-inch O.D. threaded steel casing with the ODEX casing advancer system (down-hole hammer), used compressed air to activate hammer and remove cuttings.

DRILLING CONDITIONS:
0.0 to 43.0': Moderately hard to soft and fast with DHH.

CASING RECORD:

2009 Date	Cs Sz	Depth Hole	Depth Cs
09/26	6"	43.0'	43.0'

FLUID COLOR:
0.0 to 43.0': Gray to brown cuttings (air).

FLUID RETURN:
0.0 to 43.0': Drilled with air.

WATER LEVEL DURING DRILLING:

Date	Fluid Level
09/26	28.7'

WATER LEVEL AFTER DRILLING:

Date	¹Fluid Level
09/29/09	28.7'

¹ From ground surface.

COMMENTS: Samples were logged in the field using Designation USBR 5005-86 "Procedures for Determining Unified Soil Classification (Visual Method)."

Center column descriptors are defined in the Reclamation Engineering Geology Field Manual, Volume 1, Second Edition, distributed February 1998.

Cs = Casing Sz = Size of Casing I.D. = Inside Diameter O.D. = Outside diameter DHH = ODEX down hole hammer casing advancer system

¹ = Elevation at top of protective steel casing

USBR_PN_3 LEAVENWORTHDH.GPJ USBR_PN.GDT 10/26/09 3:46:21 PM

GEOLOGIC LOG OF DRILL HOLE NO. OW-09-2

FEATURE: Leavenworth National Fish Hatchery - Repairs	PROJECT: Columbia Basin Project	STATE: Washington
LOCATION: North Side - Diversion Canal	COORDINATES: N 201,404.1 E 1,879,509.6	GROUND ELEVATION: *1149.7
BEGUN: 9/26/09 FINISHED: 9/27/09	TOTAL DEPTH: 43.0	ANGLE FROM HORIZONTAL: -90 AZIMUTH:
DEPTH AND ELEV OF WATER	DEPTH TO BEDROCK: Not Encountered	HOLE LOGGED BY: Stolma/Didrickson
LEVEL AND DATE MEASURED: 26.7' 9/23/2009		REVIEWED BY: D. Bennett

NOTES	DEPTH	% RECOVERY	SPT	MC	FIELD / CLASSIFICATION	USCS LAB	GEOLOGIC UNIT	GRAPHIC	HOLE COMPLETION	CLASSIFICATION AND PHYSICAL CONDITION
DRILLING TIME: Drilling: 15 hrs. Moving: 5 hrs. (Travel time not included) **HOLE COMPLETION:** Placed #8 silica sand from 42.0-43.0'. Installed 2-inch, schedule 40 PVC riser and slotted-pipe piezometer from 0.0-42.0', with slotted (0.02") section from 37.0-42.0'. Filter sand (#8 silica sand) sand was placed from 42.0 to 32.0 feet (5.0' above slotted section). Bentonite chips (surface seal) were placed from 0.0 to 32.0'. A protective steel standpipe with a locking cover was cemented in at the surface, stick up is approximately 24-inches. Developed well by flushing with clear water upon completion.										

COMMENTS:

USBR_PN_3 LEAVENWORTHDH.GPJ USBR_PN.GDT 10/28/09 3:48:32 PM

GEOLOGIC LOG OF DRILL HOLE NO. OW-09-3

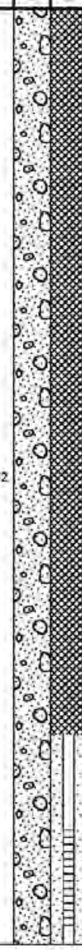
SHEET 1 OF 2

FEATURE: Lanvatnwonn National Fish Hatchery - Repairs
LOCATION: North Side - Diversion Canal
BEGUN: 9/27/09 FINISHED: 9/28/09
DEPTH AND ELEV OF WATER
LEVEL AND DATE MEASURED: 32.7' 9/29/2009

PROJECT: Columbia Basin Project
COORDINATES: N 202,309.7 E 1,879,756.4
TOTAL DEPTH: 49.0
DEPTH TO BEDROCK: Not Encountered

STATE: Washington
GROUND ELEVATION: †1152.6
ANGLE FROM HORIZONTAL: -90 AZIMUTH
HOLE LOGGED BY: Stolma/Didrickson
REVIEWED BY: D. Bennett

NOTES	DEPTH	% RECOVERY	SPT	MC	FIELD / CLASSIFICATION	USCS LAB	GEOLOGIC UNIT	GRAPHIC	HOLE COMPLETION	CLASSIFICATION AND PHYSICAL CONDITION
All elevations measured from ground surface and are same as driller reported.	0–49.0				SPg		Qgd2	(pattern)	(pattern)	**0.0 to 49.0 QUATERNARY GLACIAL DRIFT - OUTWASH SUBUNIT (Qgd2)** Pleistocene deposits associated with alpine glaciation. The unit consists of outwash deposits composed of medium to coarse sand and gravel with cobbles and scattered boulders.



Notes:

All elevations measured from ground surface and are same as driller reported.

PURPOSE OF HOLE:
Drilled hole to install piezometer for monitoring seepage from the diversion canal.

DRILL SETUP:
Set up on the access road on the north side of the diversion canal.

DRILLER:
Chris Peterson

DRILLING EQUIPMENT:
Ingersoll Rand T2W truck mounted rotary drill rig with ODEX casing advancer system.

DRILLING METHODS:
0.0 to 49.0': Advanced 6-inch O.D. threaded steel casing with the ODEX casing advancer system (down-hole hammer), used compressed air to activate hammer and remove cuttings.

DRILLING CONDITIONS:
0.0 to 49.0': Moderately hard to soft and fast with DHH.

CASING RECORD:

2009 Date	Cs Sz	Depth Hole	Depth Cs
09/27	6"	49.0'	49.0'

FLUID COLOR:
0.0 to 49.0': Gray to brown cuttings (air).

FLUID RETURN:
0.0 to 49.0': Drilled with air.

WATER LEVEL DURING DRILLING:

Date	Fluid Level
09/28	32.6'

WATER LEVEL AFTER DRILLING:

Date	*Fluid Level
09/29/09	32.7'

* From ground surface.

Classification and Physical Condition:

0.0 to 49.0 QUATERNARY GLACIAL DRIFT - OUTWASH SUBUNIT (Qgd2) Pleistocene deposits associated with alpine glaciation. The unit consists of outwash deposits composed of medium to coarse sand and gravel with cobbles and scattered boulders.

0.0 - 49.0': SAND AND GRAVEL. Description based on drilling conditions and cuttings returned.

BOTTOM OF HOLE: 49.0 FEET

BOTTOM OF HOLE

COMMENTS: Samples were logged in the field using Designation USBR 5005-86 "Procedures for Determining Unified Soil Classification (Visual Method)."

Center column descriptors are defined in the Reclamation Engineering Geology Field Manual, Volume 1, Second Edition, distributed February 1998.

Cs = Casing Sz = Size of Casing I.D. = Inside Diameter O.D. = Outside diameter DHH = ODEX down hole hammer casing advancer system

† = Elevation at top of enterizwe steel casing

GEOLOGIC LOG OF DRILL HOLE NO. OW-09-3

SHEET 2 OF 2

FEATURE: Leavenworth National Fish Hatchery - Repairs
LOCATION: North Side - Diversion Canal
BEGUN: 9/27/09 FINISHED: 9/28/09
DEPTH AND ELEV OF WATER
LEVEL AND DATE MEASURED: 32.7' 9/29/2009

PROJECT: Columbia Basin Project
COORDINATES: N 202,309.7 E 1,879,758.4
TOTAL DEPTH: 49.0
DEPTH TO BEDROCK: Not Encountered

STATE: Washington
GROUND ELEVATION: *1152.6
ANGLE FROM HORIZONTAL: -90 AZIMUTH
HOLE LOGGED BY: Stolma/Didrickson
REVIEWED BY: D. Bennett

NOTES	DEPTH	% RECOVERY	SPT	MC	FIELD CLASSIFICATION	USCS LAB	GEOLOGIC UNIT	GRAPHIC	HOLE COMPLETION	CLASSIFICATION AND PHYSICAL CONDITION
DRILLING TIME: **Drilling: 10 hrs.** **Moving: 5 hrs.** **(Travel time not included)** **HOLE COMPLETION:** **Placed #8 silica sand from 48.0-49.0'. Installed 2-inch, schedule 40 PVC riser and slotted-pipe piezometer from 0.0-48.0', with slotted (0.02") section from 43.0-48.0'. Filter sand (#8 silica sand) sand was placed from 48.0 to 38.0 feet (5.0' above slotted section). Bentonite chips (surface seal) were placed from 0.0 to 38.0'. A protective steel standpipe with a locking cover was cemented in at the surface, stick up is approximately 24-inches. Developed well by flushing with clear water upon completion.**										

COMMENTS:

USBR_FN_3 LEAVENWORTHDH.GPJ USBR_FN.GDT 10/26/09 3:48:26 PM

GEOLOGIC LOG OF DRILL HOLE NO. OW-09-4

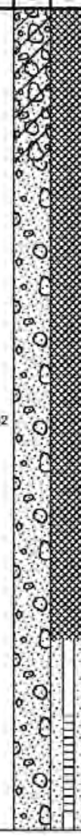
SHEET 1 OF 2

FEATURE: Leavenworth National Fish Hatchery - Repairs
LOCATION: South Side - Diversion Canal
BEGUN: 9/30/09 FINISHED: 9/30/09
DEPTH AND ELEV OF WATER
LEVEL AND DATE MEASURED: 30' 10/01/2009

PROJECT: Columbia Basin Project
COORDINATES: N 201,341.6 E 1,679,741.4
TOTAL DEPTH: 43.0
DEPTH TO BEDROCK: Not Encountered

STATE: Washington
GROUND ELEVATION: *1149.1
ANGLE FROM HORIZONTAL: -90 AZIMUTH
HOLE LOGGED BY: Stolma/Didrickson
REVIEWED BY: D. Bennett

NOTES	DEPTH	% RECOVERY	SPT	MC	FIELD / CLASSIFICATION	USCS LAB	GEOLOGIC UNIT	GRAPHIC	HOLE COMPLETION	CLASSIFICATION AND PHYSICAL CONDITION
All elevations measured from ground surface and are same as driller reported.	0.0 – 8.0				SPg		Qgd2			**0.0 to 43.0 QUATERNARY GLACIAL DRIFT - OUTWASH SUBUNIT (Qgd2)** Pleistocene deposits associated with alpine glaciation. The unit consists of outwash deposits composed of medium to coarse sand and gravel with cobbles and scattered boulders. 0.0 - 8.0': SAND AND GRAVEL. Description based on drilling conditions and cuttings returned.
	8.0 – 43.0				SPgc		Qgd2			8.0 - 43.0': SAND, GRAVEL AND COBBLES. Description based on drilling conditions and cuttings returned. **BOTTOM OF HOLE: 43.0 FEET**



BOTTOM OF HOLE

NOTES

All elevations measured from ground surface and are same as driller reported.

PURPOSE OF HOLE:
Drilled hole to install piezometer for monitoring seepage from the diversion canal.

DRILL SETUP:
Set up on the access road on the south side of the diversion canal.

DRILLER:
Chris Peterson

DRILLING EQUIPMENT:
Ingersoll Rand T2W truck mounted rotary drill rig with ODEX casing advancer system.

DRILLING METHODS:
0.0 to 43.0': Advanced 6-inch O.D. threaded steel casing with the ODEX casing advancer system (down-hole hammer), used compressed air to activate hammer and remove cuttings.

DRILLING CONDITIONS:
0.0 to 43.0': Moderately hard to soft and fast with DHH.

CASING RECORD:

2009 Date	Cs Sz	Depth Hole	Depth Cs
10/01	6"	43.0'	43.0'

FLUID COLOR:
0.0 to 43.0': Gray to brown cuttings (air).

FLUID RETURN:
0.0 to 43.0': Drilled with air.

WATER LEVEL DURING DRILLING:

Date	Fluid Level
10/01	30'

WATER LEVEL AFTER DRILLING:
Date *Fluid Level
Not measured.

* From ground surface.

COMMENTS: Samples were logged in the field using Designation USBR 5005-86 "Procedures for Determining Unified Soil Classification (Visual Method)."

Center column descriptors are defined in the Reclamation Engineering Geology Field Manual, volume 1, Second Edition, distributed February 1998.

Cs = Casing Sz = Size of Casing I.D. = Inside Diameter O.D. = Outside diameter DHH = ODEX down hole hammer casing advancer system

* = Elevation at top of protective steel casing

GEOLOGIC LOG OF DRILL HOLE NO. OW-09-4

FEATURE: Leavenworth National Fish Hatchery - Repairs
LOCATION: South Side - Diversion Canal
BEGUN: 9/30/09 FINISHED: 9/30/09
DEPTH AND ELEV OF WATER
LEVEL AND DATE MEASURED: 30' 10/01/2009

PROJECT: Columbia Basin Project
COORDINATES: N 201,341.6 E 1,679,741.4
TOTAL DEPTH: 43.0
DEPTH TO BEDROCK: Not Encountered

STATE: Washington
GROUND ELEVATION: *1149.1
ANGLE FROM HORIZONTAL: -90 AZIMUTH:
HOLE LOGGED BY: Stolma/Didrickson
REVIEWED BY: D. Bennett

NOTES	DEPTH	% RECOVERY	SPT	MC	FIELD / CLASSIFICATION	USCS LAB	GEOLOGIC UNIT	GRAPHIC	HOLE COMPLETION	CLASSIFICATION AND PHYSICAL CONDITION
DRILLING TIME: Drilling 8 hrs. Moving: 2 hrs. (Travel time not included) HOLE COMPLETION: Placed #8 silica sand from 42.0-43.0'. Installed 2-inch, schedule 40 PVC riser and slotted-pipe piezometer from 0.0-42.0', with slotted (0.02") section from 37.0-42.0'. Filter sand (#8 silica sand) sand was placed from 42.0 to 33.0 feet (5.0' above slotted section). Bentonite chips (surface seal) were placed from 0.0 to 33.0'. A protective steel standpipe with a locking cover was cemented in at the surface, stick up is approximately 24-inches. Developed well by flushing with clear water upon completion.										

COMMENTS:

USBR_FN_3 LEAVENWORTHDH.GPJ USBR_PN.GDT 10/28/09 3:46:40 PM

1200/14 = 85.7

473[illegible]120400001

Well #1

24/17-23Q01

Date ... APPENDIX A

Record by well driller

Source driller's record

Location: State of WASHINGTON

County Chelan

xxx Lot 4, Blk.8 of

xxx Cascade Orchard

xxxxxxxxx sec. 23 T.24 N. R. 17 E.

Diagram of Section

Drilling Co. Western Drill. & Equipment Co.

Address Tacoma, Wash.

Method of Drilling ... Date Apr. 1958

Owner U.S. Fish & Wildlife

Address Portland, Oregon

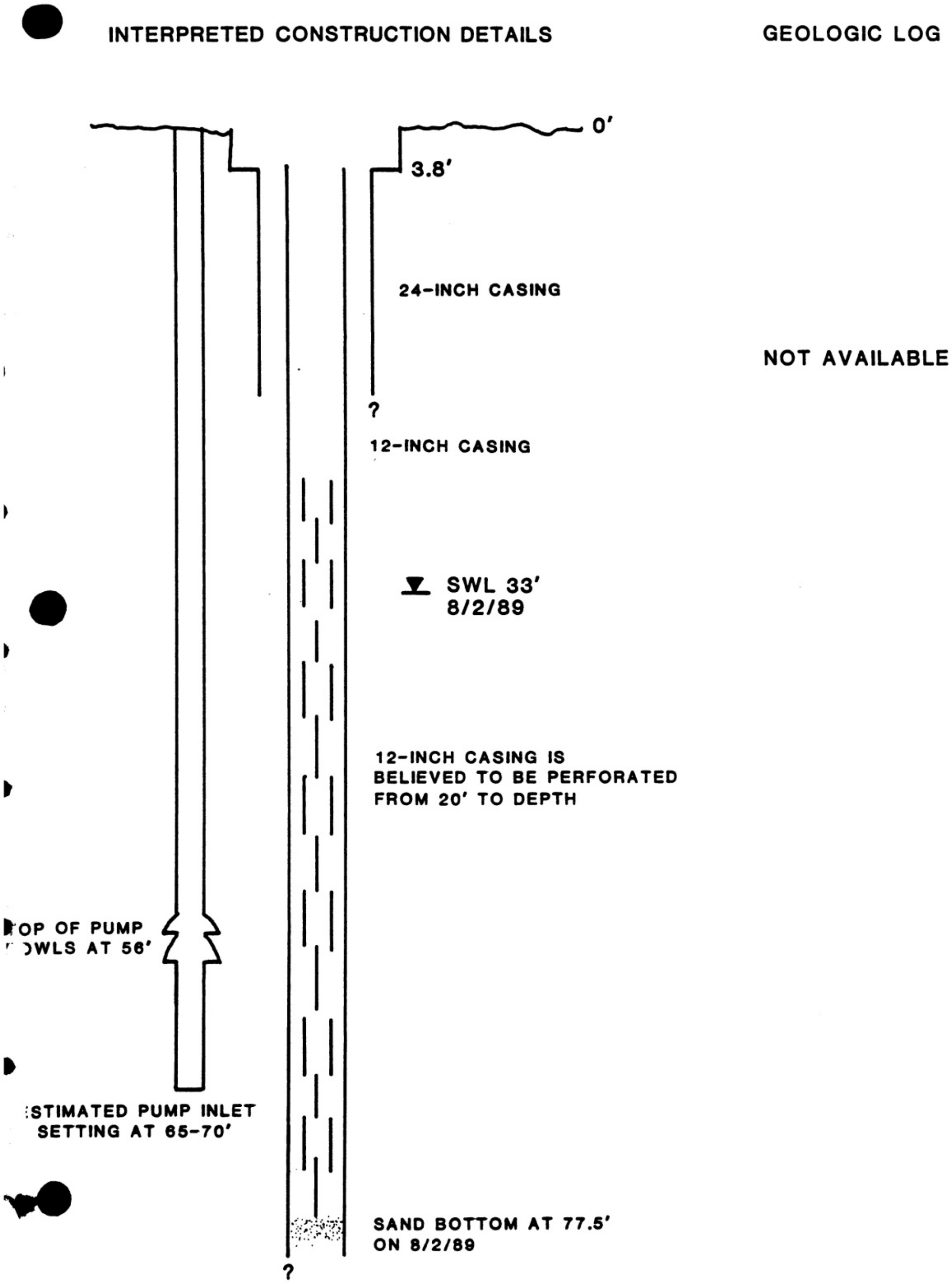
Land surface, datum ... ft. above / below

Corre-lation	Material 24/17-23Q01	Thickness (feet)	Depth (feet)
	(Transcribe driller's terminology literally but paraphrase as necessary, in parentheses. If material water-bearing, so state and record static level if reported. Give depths in feet below land-surface datum unless otherwise indicated. Correlate with stratigraphic column, if feasible. Following log of materials, list all casings, perforations, screens, etc.)		
	Sand & gravel	14	14
	Boulders	5	19
	Med. sand & gravel with decomposed granite boulders	1	20
	Med. sand & gravel with decomposed granite	10	30
	Med. sand & Gravel "	5	35
	Med. sand & fine gravel with decomposed granite	5	40
	Med. sand & fine gravel	5	45
	" " " "	5	50
	" " " "	5	55
	" " " "	5	60
	" " " "	5	65
	" " " "	5	70
	" " " "	5	75
	" " " "	5	80
	PUMP TEST:		
	Dim. 80'x14"		
	SWL: 28 ft.		
	DD: 14 ft.		
	Yield: 1200 gp.m.		
	Type & size of pump: deep well turbine pump - 12" bowls		
	Type & size of motor: 40 h.p. hollow shaft 3 phase		
	CASING: 14" diam. from 0 to 80 ft.		
	PERFORATIONS: 1/8" x1½" 40 per ft. from 40 to 80 ft.		
	24/17-23		

Appendix B

LEAVENWORTH NATIONAL FISH HATCHERY WELL 1

FIGURE 3



NOTE: INTERPRETED CONSTRUCTION DETAILS BASED ON SURFACE MEASUREMENTS, SOUNDINGS & NFH RECORDS

File Original and First Copy with Department of Ecology
Second Copy—Owner's Copy
Third Copy—Driller's Copy

WATER WELL REPORT

STATE OF WASHINGTON

Start Card No. 028743

Water Right Permit No. ______

(1) OWNER: Name DEPT OF FISH & WILDLIFE Address ICICLE RD

(2) LOCATION OF WELL: County CHELAN NW ¼ NW ¼ Sec 26 T 24 N., R 17 W.M.

(2a) STREET ADDDRESS OF WELL (or nearest address) ICICLE RD

(3) PROPOSED USE: ☐ Domestic ☐ Irrigation ☐ DeWater Industrial ☐ Test Well ☐ Municipal ☐ Other ☒ HATCHERY

(4) TYPE OF WORK: Owner's number of well (if more than one) 2A
Abandoned ☐ New well ☒ Deepened ☐ Reconditioned ☐
Method: Dug ☐ Cable ☒ Rotary ☐ Bored ☐ Driven ☐ Jetted ☐

(5) DIMENSIONS: Diameter of well ______ inches.
Drilled ______ feet. Depth of completed well ______ ft.

(6) CONSTRUCTION DETAILS:
Casing installed: 24" Diam. from 0 ft. to 20 ft.
Welded ☒ 20" Diam. from 0 ft. to 203 ft.
Liner installed ☐
Threaded ☐ ______" Diam. from ______ ft. to ______ ft.

Perforations: Yes ☐ No ☒
Type of perforator used ______
SIZE of perforations ______ in. by ______ in.
______ perforations from ______ ft. to ______ ft.
______ perforations from ______ ft. to ______ ft.
______ perforations from ______ ft. to ______ ft.

Screens: Yes ☐ No ☒
Manufacturer's Name ______
Type ______ Model No. ______
Diam. ______ Slot size ______ from ______ ft. to ______ ft.
Diam. ______ Slot size ______ from ______ ft. to ______ ft.

Gravel packed: Yes ☐ No ☐ Size of gravel ______
Gravel placed from ______ ft. to ______ ft.

Surface seal: Yes ☒ No ☐ To what depth? 20 ft.
Material used in seal #8 BENTONITE
Did any strata contain unusable water? Yes ☐ No ☒
Type of water? ______ Depth of strata ______
Method of sealing strata off ______

(7) PUMP: Manufacturer's Name ______
Type: ______ H.P. ______

(8) WATER LEVELS: Land-surface elevation above mean sea level ______ ft.
Static level ______ ft. below top of well Date ______
Artesian pressure ______ lbs. per square inch Date ______
Artesian water is controlled by ______ (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☐ No ☐ If yes, by whom? ______
Yield: ______ gal./min. with ______ ft. drawdown after ______ hrs.

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test ______
Bailer test ______ gal./min. with ______ ft. drawdown after ______ hrs.
Airtest ______ gal./min. with stem set at ______ ft. for ______ hrs.
Artesian flow ______ g.p.m. Date ______
Temperature of water ______ Was a chemical analysis made? Yes ☐ No ☐

(10) WELL LOG or ABANDONMENT PROCEDURE DESCRIPTION

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of information.

MATERIAL	FROM	TO
SAND	0	3
SAND & BOULDERS	3	25
LARGE GRAVEL-SAND & WATER	25	50
COARSE SAND-LG. GRAVEL	50	65
COARSE SAND-LG COBBLES	65	85
COARSE SAND-MED GRAVEL	85	111
SILT-SAND, BLACK	111	123
SILT-BOULDERS, BLACK	123	126
BLACK SILT	126	140
BLACK SILT w/ SILTSTONE LAY.	140	180
BLACK SILT, COBBLES	180	195
GRANITE BOULDERS, BLACK SILT	195	200
GRANITE, HARD	200	206

Work started 6/3/91, 19. Completed 7/22, 19 91

WELL CONSTRUCTOR CERTIFICATION:

I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

NAME BACH DRILLING CO (PERSON, FIRM, OR CORPORATION) (TYPE OR PRINT)

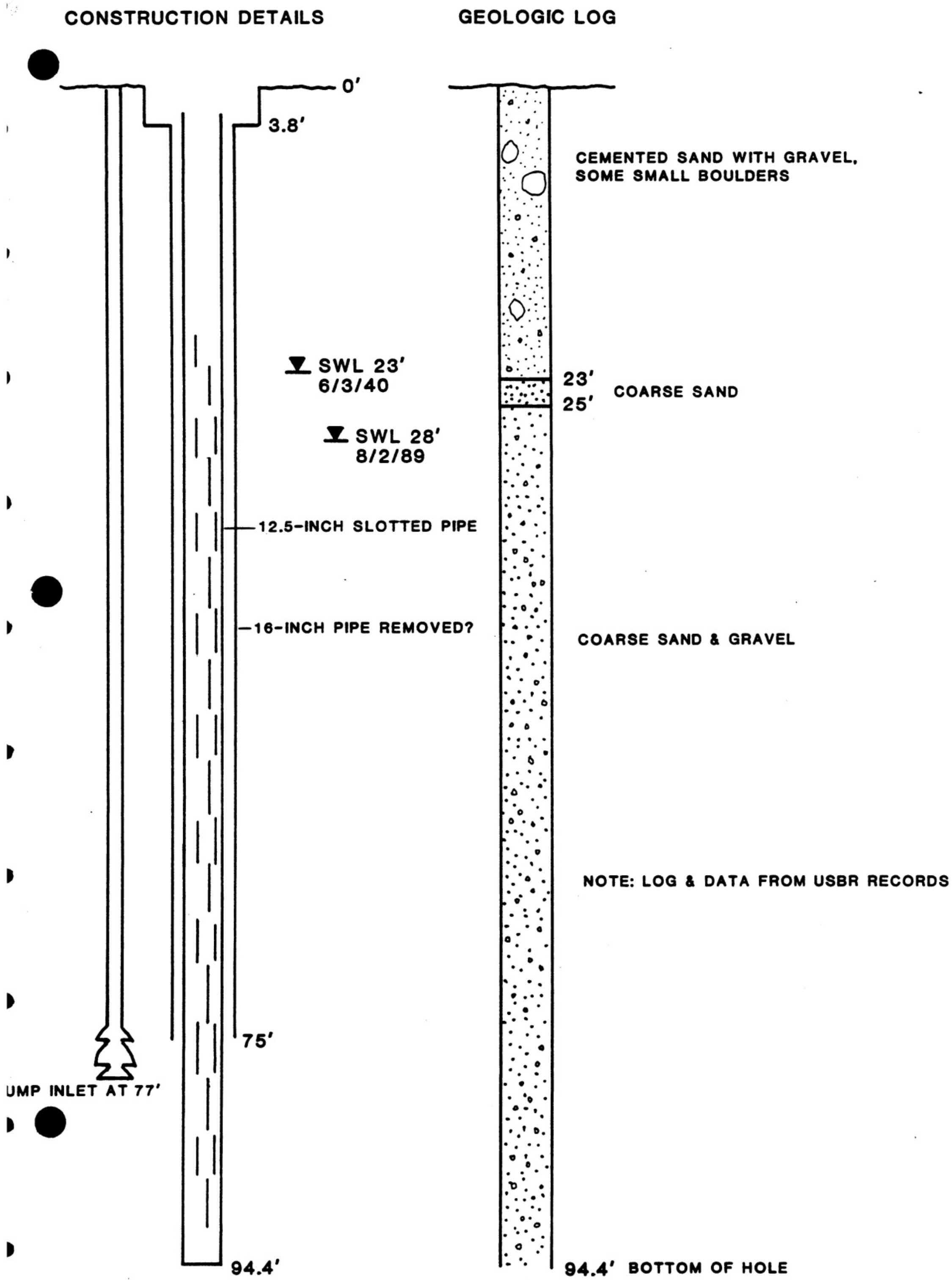
Address RT 5 BOX 1010 ELLENSBURG

(Signed) [signature] (WELL DRILLER) License No. 1778

Contractor's Registration No. MIKE BDC133N4 Date ______, 19 91

(USE ADDITIONAL SHEETS IF NECESSARY)

WELL 2


CONSTRUCTION DETAILS
GEOLOGIC LOG
0'
3.8'
SWL 23'
6/3/40
SWL 28'
8/2/89
12.5-INCH SLOTTED PIPE
16-INCH PIPE REMOVED?
75'
UMP INLET AT 77'
94.4'
CEMENTED SAND WITH GRAVEL, SOME SMALL BOULDERS
23'
COARSE SAND
25'
COARSE SAND & GRAVEL
NOTE: LOG & DATA FROM USBR RECORDS
94.4' BOTTOM OF HOLE

Original and First Copy with Department of Ecology
Second Copy—Owner's Copy
Third Copy—Driller's Copy

WATER WELL REPORT

STATE OF WASHINGTON

Start Card No. ______

Water Right Permit No. ______

(1) OWNER: Name U.S. FISH & WILDLIFE Address 911 N.E. 11TH AV PORTLAND OR

(2) LOCATION OF WELL: County CHELAN NW ¼ NE ¼ Sec 26 T 24 N., R 17 W.M.

(2a) STREET ADDDRESS OF WELL (or nearest address) LEAVENWORTH NATIONAL FISH HATCHERY

(3) PROPOSED USE: ☐ Domestic ☐ Irrigation ☐ DeWater Industrial ☐ Test Well ☐ Municipal ☐ Other ☒

(4) TYPE OF WORK: Owner's number of well (if more than one) 3A

Abandoned ☐ New well ☒ Deepened ☐ Reconditioned ☐ Method: Dug ☐ Cable ☒ Rotary ☐ Bored ☐ Driven ☐ Jetted ☐

(5) DIMENSIONS: Diameter of well 16 inches.
Drilled 120 feet. Depth of completed well 98 ft.

(6) CONSTRUCTION DETAILS:
Casing installed: 16" Diam. from +2 ft. to 65 ft.
Welded ☒ ______" Diam. from ______ ft. to ______ ft.
Liner installed ☐
Threaded ☐ ______" Diam. from ______ ft. to ______ ft.

Perforations: Yes ☐ No ☒
Type of perforator used ______
SIZE of perforations ______ in. by ______ in.
______ perforations from ______ ft. to ______ ft.
______ perforations from ______ ft. to ______ ft.
______ perforations from ______ ft. to ______ ft.

Screens: Yes ☒ No ☐
Manufacturer's Name JOHNSON
Type 304 stainless steel Model No. ______
Diam. 16 TS Slot size 60 from 63 ft. to 93 ft.
Diam. 16 TS Slot size 40 from 93 ft. to 98 ft.

Gravel packed: Yes ☐ No ☒ Size of gravel ______
Gravel placed from ______ ft. to ______ ft.

Surface seal: Yes ☒ No ☐ To what depth? 20 ft.
Material used in seal cement grout
Did any strata contain unusable water? Yes ☐ No ☒
Type of water? ______ Depth of strata ______
Method of sealing strata off ______

(7) PUMP: Manufacturer's Name ______
Type: ______ H.P. ______

(8) WATER LEVELS: Land-surface elevation above mean sea level ______ ft.
Static level # 37 ft. below top of well Date 3/27/91
Artesian pressure ______ lbs. per square inch Date ______
Artesian water is controlled by ______ (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☒ No ☐ If yes, by whom? WELLS WADE
Yield: 650 gal./min. with 26 ft. drawdown after ______ hrs.

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level
RAPID RECOVERY					

Date of test ______ APR 18 1992

Bailer test ______ gal./min. with ______ ft. drawdown after ______ hrs.
Airtest ______ gal./min. with stem set at ______ ft. for ______ hrs.
Artesian flow ______ g.p.m. Date ______
Temperature of water ______ Was a chemical analysis made? Yes ☐ No ☐

(10) WELL LOG or ABANDONMENT PROCEDURE DESCRIPTION

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of information.

MATERIAL	FROM	TO
sand & gravel cobbles & boulders	0	10
sand &gravel large cobbles	10	20
sand, silt w/gravel	20	25
sand w/ large gravel	25	30
sand w/large gravel	30	35
med coarse sand	35	40
sand	40	45
sand w/some gravel	45	50
med coarse sand & gravel	50	60
coarse sand small gravel	60	75
med coarse sand small gravel	75	80
coares sand small gravel	80	85
fine sand trace small gravel	85	90
fine sand small gravel	90	95
fine sand some large gravel	95	100
fine sand	100	120

Work started 10/15/90, 19__. Completed 6/1/91, 19__

WELL CONSTRUCTOR CERTIFICATION:

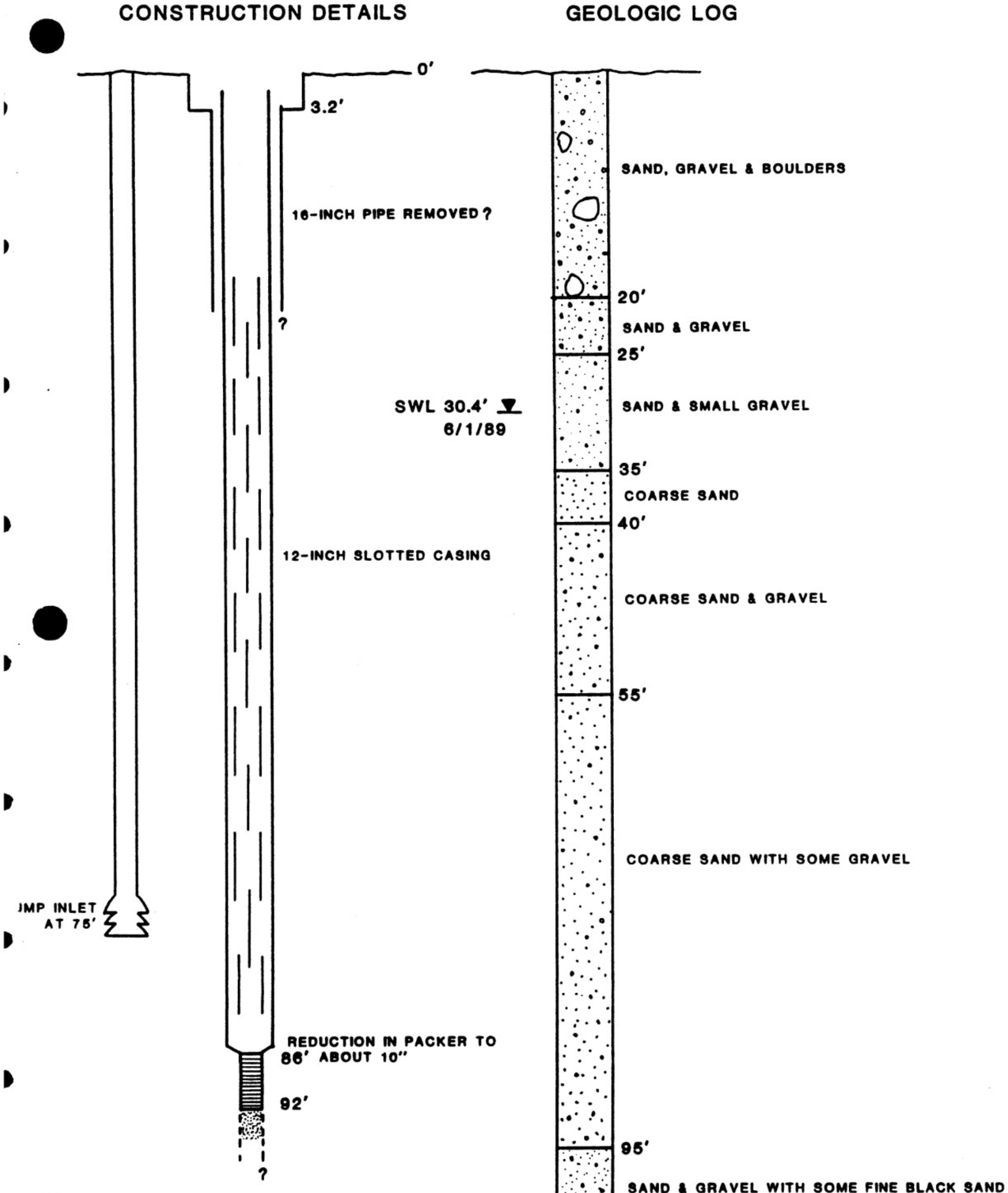
I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

NAME DIETRICH DRILLING (PERSON, FIRM, OR CORPORATION) (TYPE OR PRINT)
Address P.O. BOX 3340 WENATCHEE
(Signed) [signature] (WELL DRILLER) License No. 1152
Contractor's Registration No. DIETRD*101LH Date 3/13/92, 19__

(USE ADDITIONAL SHEETS IF NECESSARY)

050-1-20 (10/87) -1329-

LEAVENWORTH NATIONAL FISH HATCHERY
WELL 3



WELL SCREEN IS FILLED WITH SAND TO 92'

SCREEN SLOT SIZE, DIAMETER, & DEPTH IS UNKNOWN

NOTE: LOG & DATA FROM USBR RECORDS.
VERIFIED BY VIDEO INSPECTION ON 6/15/89

File Original and First Copy with Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

WATER WELL REPORT

STATE OF WASHINGTON

Application No. ....

Permit No. ....

(1) OWNER: Name U.S. Department of Interior Leavenworth Fish Hatchery Address 500 NE Multnomah Street; Portland, OR

(2) LOCATION OF WELL: County Chelan — SW ¼ SE ¼ Sec. 23 T. 24 N., R. 17E W.M. NW

Bearing and distance from section or subdivision corner

(3) PROPOSED USE: Domestic ☐ Industrial XX Municipal ☐ Irrigation ☐ Test Well ☐ Other ☐

(4) TYPE OF WORK: Owner's number of well (if more than one) 4 ✓
New well ☐ Deepened ☐ Reconditioned ☐
Method: Dug ☐ Bored ☐ Cable ☐ Driven ☐ Rotary XX Jetted ☐

(5) DIMENSIONS: Diameter of well 28" x 16" inches. Drilled 324 ft. Depth of completed well 250 ft.

(6) CONSTRUCTION DETAILS:

Casing installed: 28" Diam. from 0 ft. to 20 ft.
Threaded ☐ 16" Diam. from 0 ft. to 237.5 ft.
Welded ☐ " Diam. from ...... ft. to ...... ft.

Perforations: Yes XX No ☐
Type of perforator used Slotted Pipe
SIZE of perforations ...... in. by ...... in.
perforations from 95 ft. to 115 ft.
perforations from 165 ft. to 175 ft.
perforations from ...... ft. to ...... ft.

Screens: Yes XX No ☐
Manufacturer's Name UOP Johnson
Type Wirewrap Model No. ......
Diam. 60-80 115-165 175-225
Diam. ...... Slot size ...... from ...... ft. to ...... ft.

Gravel packed: Yes XX No ☐ Size of gravel 1/4-3/8"
Gravel placed from 0 ft. to 250 ft.

Surface seal: Yes XX No ☐ To what depth? 20 ft.
Material used in seal Neat Cement
Did any strata contain unusable water? Yes ☐ No XX
Type of water? ...... Depth of strata ......
Method of sealing strata off ......

(7) PUMP: Manufacturer's Name ......
Type: ...... H.P. ......

(8) WATER LEVELS: Land-surface elevation above mean sea level.... 48 ft.
Static level 24' 11" ft. below top of well Date 10-21-76
Artesian pressure ...... lbs. per square inch Date ......
Artesian water is controlled by ...... (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes X No ☐ If yes, by whom? EELCO LAYNE-WESTERN
Yield: 2000 gal./min. with 85 ft. drawdown after 3 hrs.

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test ......
Bailer test ...... gal./min. with ...... ft. drawdown after ...... hrs.
Artesian flow ...... g.p.m. Date ......
Temperature of water ...... Was a chemical analysis made? Yes ☐ No ☐

(10) WELL LOG:

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of formation.

MATERIAL	FROM	TO
Large rocks 3"-5"	3	5
Gravels & sands	5	10
Unconsolidated gravel	10	20
Gravel & rocks	20	31
Gravel & Large rocks	31	47
Gravel & rocks	47	50
Gravel & rocks	50	75
Pea gravel & sands	75	112
Gravel Coarse	112	181
Gravels & sands	181	245
Clays & gravels	245	312
Quartzite in rock	312	318
Quartz, white & gray granite	318	324

per letter received 1-18-80

Work started 10-1, 1976 Completed 10-21, 1976

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME LAYNE-WESTERN COMPANY, INC. (Person, firm, or corporation) (Type or print)

Address P.O. BOX 336 Moses Lake, WA 98837

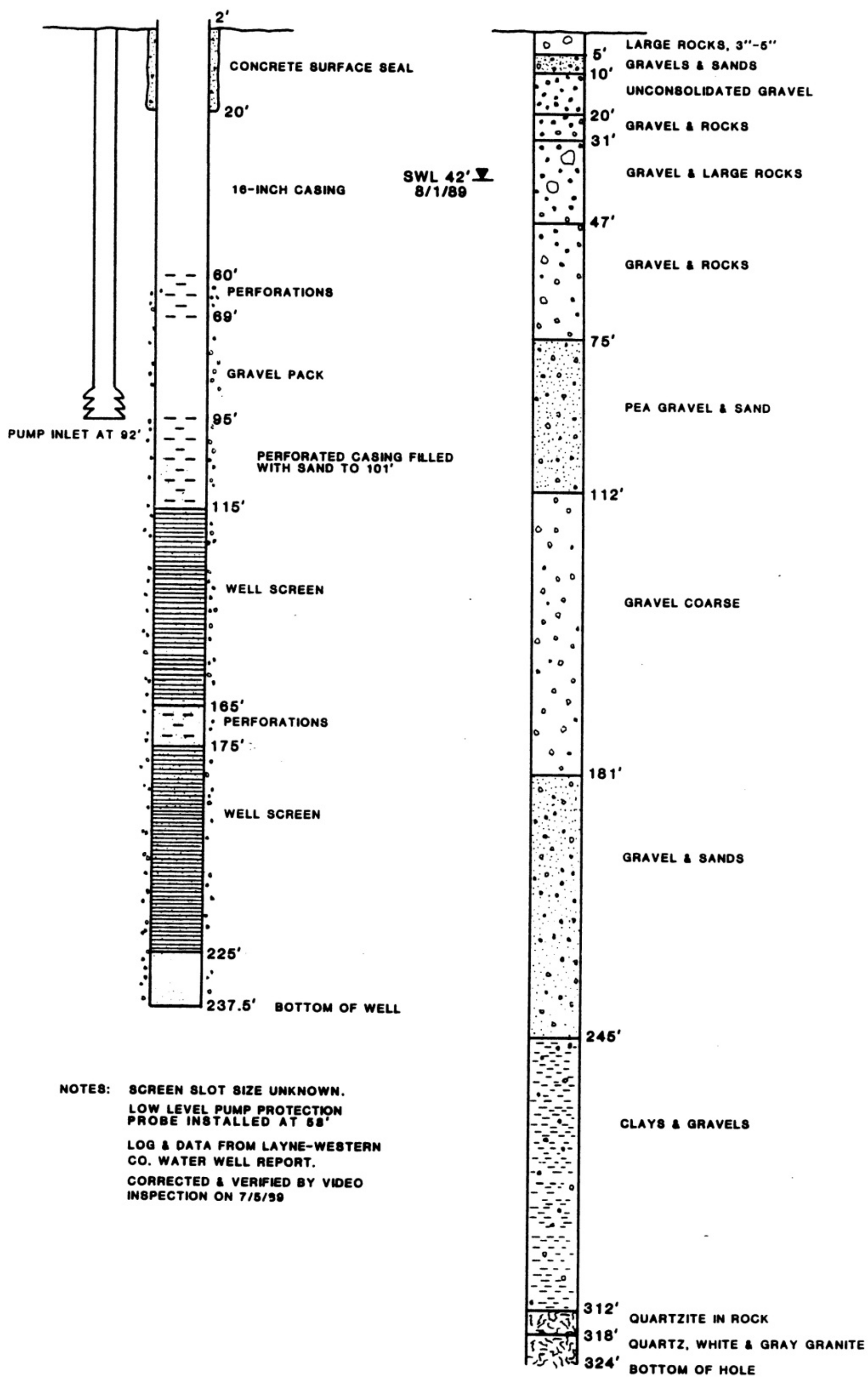
[Signed] [signature] (Well Driller)

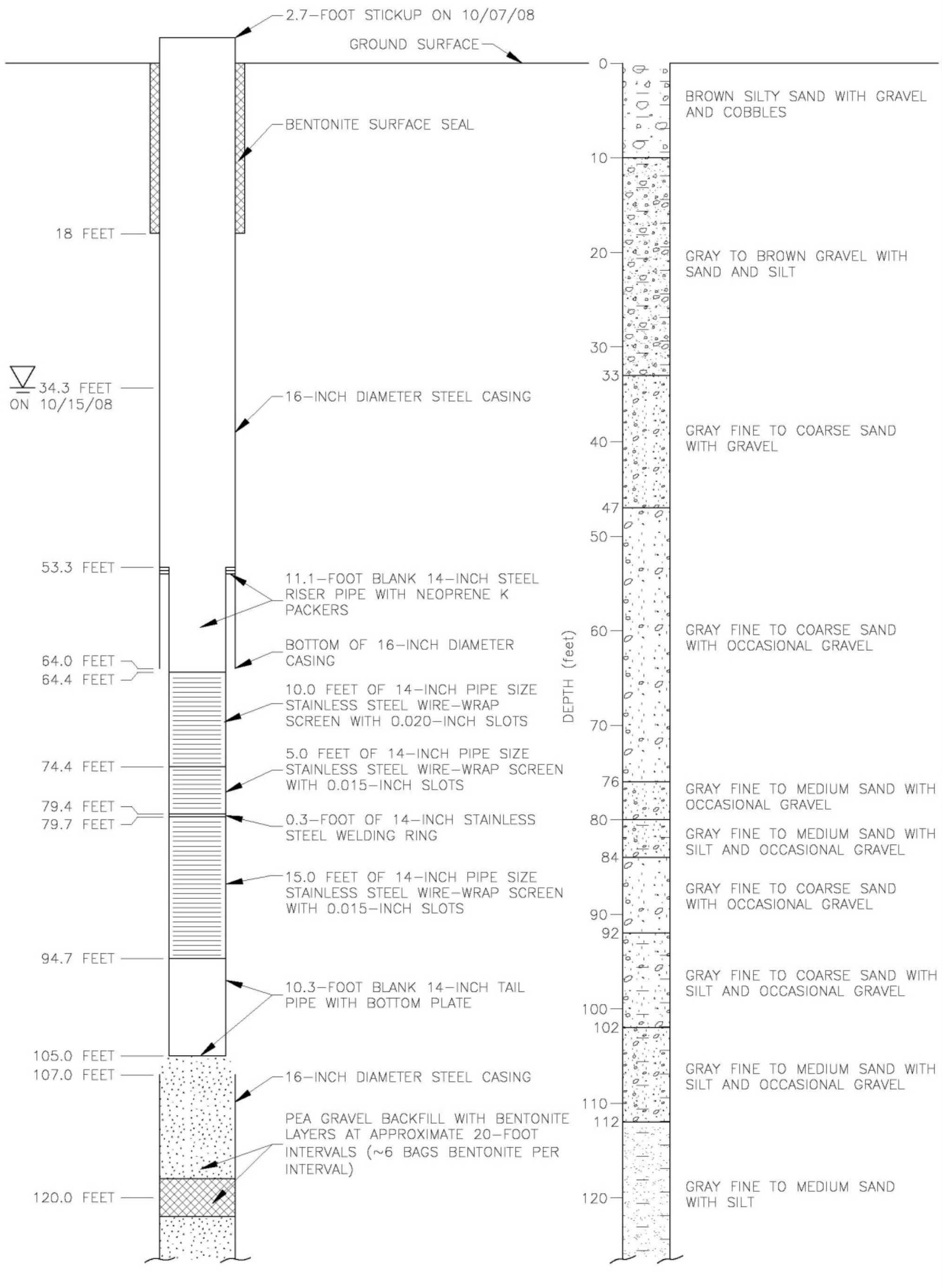
License No. 0733 Date Dec. 12, 1979

(USE ADDITIONAL SHEETS IF NECESSARY)

Appendix B

LEAVENWORTH NATIONAL FISH HATCHERY FIGURE 6
WELL 4





Well 4A Log and Construction Details
Page 1 of 2

Leavenworth National Fish Hatchery, Well 4A
Leavenworth, Washington

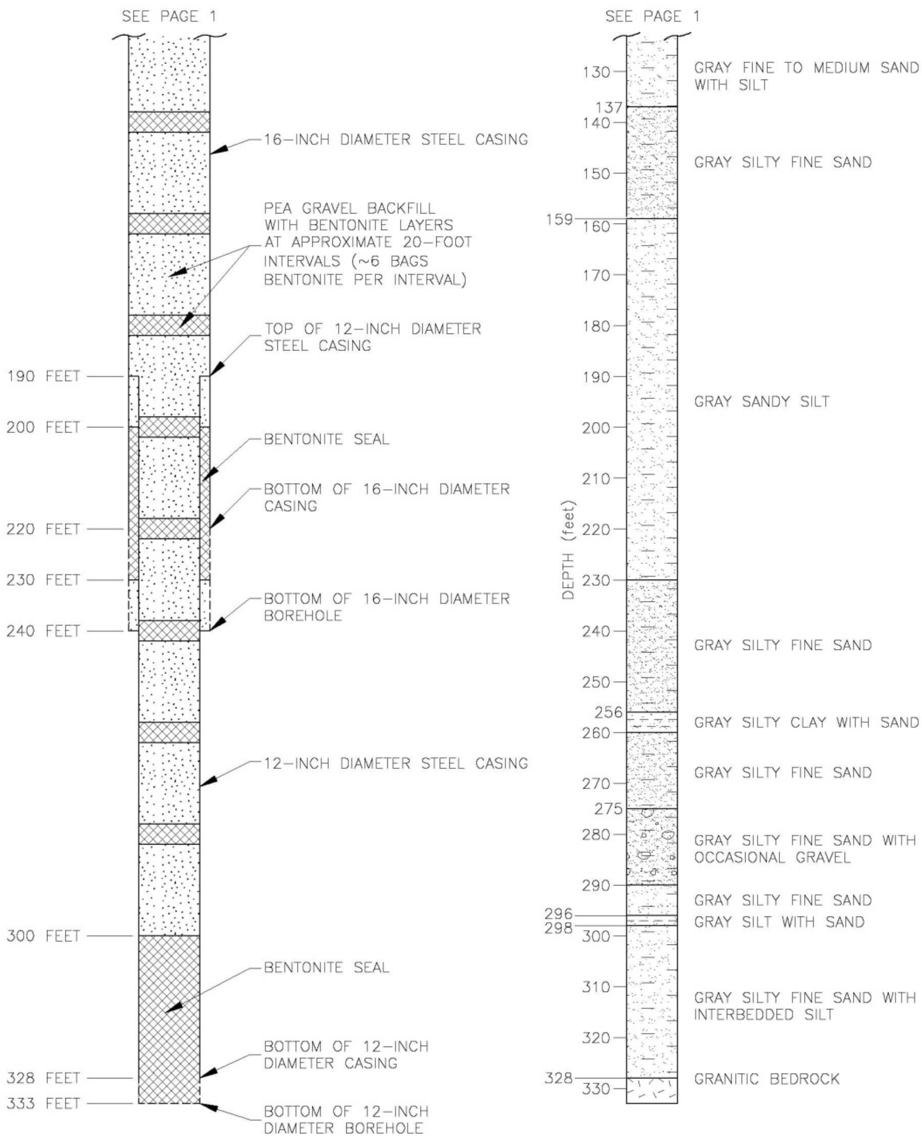
GEOENGINEERS

Figure 3

Notes

1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Appendix B



MAXIMUM WATER TRANSMITTING CAPACITY OF THE WELL SCREEN IS 670 GALLONS PER MINUTE (GPM) PER THE WELL SCREEN VENDOR.

Notes

1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Well 4A Log and Construction Details Page 2 of 2	
Leavenworth National Fish Hatchery, Well 4A Leavenworth, Washington	
GEOENGINEERS	**Figure 3**

P:\0\0758022\03\CAD\075802203F3B.dwg\TAB:F3 modified by TMICHAUD on Nov 25, 2008 - 12:00

File Original and First Copy with Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

WATER WELL REPORT

STATE OF WASHINGTON

Application No.
Permit No.

(1) OWNER: Name US Department of Interior Leavenworth - Fish Hatchery Address 500 NE Multnomah Street; Portland, OR

(2) LOCATION OF WELL: County Chelan SW ¼ SW ¼ Sec. 23 T. 24 N., R. 17E W.M.
Bearing and distance from section or subdivision corner

(3) PROPOSED USE: Domestic ☐ Industrial ☒ Municipal ☐ Irrigation ☐ Test Well ☐ Other ☐

(4) TYPE OF WORK: Owner's number of well (if more than one) #5
New well ☒ Method: Dug ☐ Bored ☐
Deepened ☐ Cable ☐ Driven ☐
Reconditioned ☐ Rotary ☒ Jetted ☐

(5) DIMENSIONS: Diameter of well 28 inches.
Drilled 290 ft. Depth of completed well 290 ft.

(6) CONSTRUCTION DETAILS:

Casing installed: 20" Diam. from 0 ft. to 250 ft.
Threaded ☐ 14" Diam. from 210 ft. to 249 ft.
Welded ☒ " Diam. from ft. to ft.

Perforations: Yes ☐ No ☒
Type of perforator used
SIZE of perforations in. by in.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.

Screens: Yes ☒ No ☐
Manufacturer's Name UPO Johnson
Type stainless steel Model No.
Diam. 10 Slot size .065 from 249 ft. to 279 ft.
Diam. Slot size from ft. to ft.

Gravel packed: Yes ☒ No ☐ Size of gravel: 8-12
Gravel placed from 209 ft. to 279 ft.

Surface seal: Yes ☒ No ☐ To what depth? 247 ft.
Material used in seal Neat cement
Did any strata contain unusable water? Yes ☐ No ☒
Type of water? Depth of strata
Method of sealing strata off

(7) PUMP: Manufacturer's Name Layne & Bowler
Type: 12 THC H.P. 250

(8) WATER LEVELS: Land-surface elevation above mean sea level ft.
Static level 14 ft. below top of well Date 7-23-79
Artesian pressure lbs. per square inch Date
Artesian water is controlled by (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☒ No ☐ If yes, by whom? Layne

Yield (gal./min.)	with ft. drawdown	after hrs.
1500	70	4
1050	53	2.5
750	40	2

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level
3	28	6	26	10	25
4	27	7	26	20	25
5	27	8	26	60	20

Date of test 7-23-79
Bailer test gal./min. with ft. drawdown after hrs.
Artesian flow g.p.m. Date
Temperature of water Was a chemical analysis made? Yes ☐ No ☐

(10) WELL LOG:

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of formation.

MATERIAL	FROM	TO
Sand & gravel	0	5
Sand & silt	5	13
Fine & course sand & gravel, some cobbles & stones	13	20
Course sand fine to medium gravel	20	55
Gray silt & very fine grain sand	55	119
Gray silt & seams of clay	119	223
Fine & course sand & fine to medium gray gravel	223	224
Gray silt & fine gray sand	224	240
Gray fine to course sand & gravel stones & cobbles (263-264½ sand stone boulder)	240	270
Gray fine to course sand & fine gravel	270	275
Medium to course sand & fine to course gravel & boulders & layer of rock 4" to 1' thick	275	286
Basalt	286	290

Work started , 19 . Completed , 19 .

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME LAYNE WESTERN COMPANY (Person, firm, or corporation) (Type or print)

Address P.O. Box 326

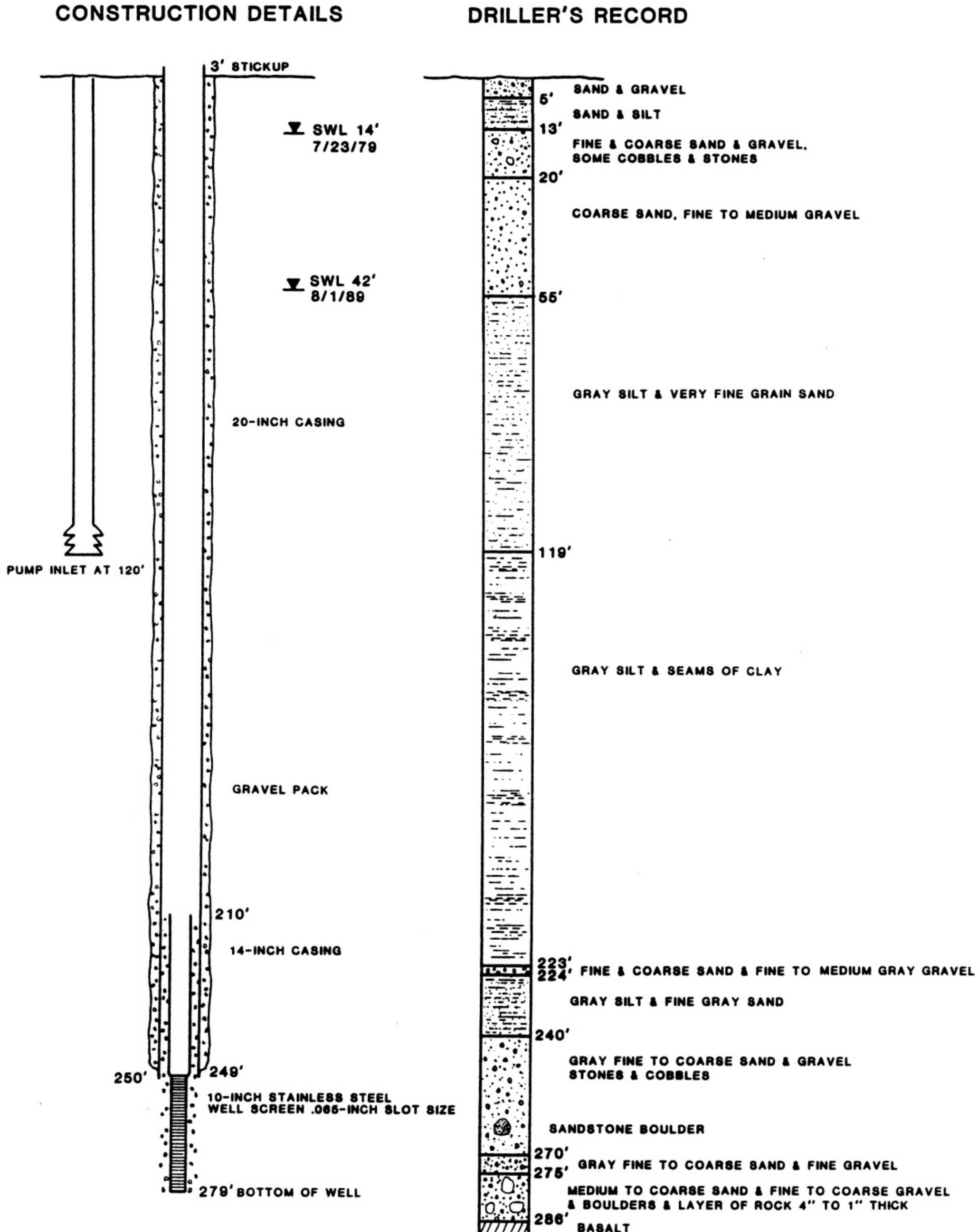
[Signed] Walter C. Gustafson (Well Driller)

License No. 0733 Date Dec. 14, 1979

(USE ADDITIONAL SHEETS IF NECESSARY)

LEAVENWORTH NATIONAL FISH HATCHERY
WELL 5

FIGURE 7



NOTE: LOG & DATA FROM LAYNE-WESTERN CO. WATER WELL REPORT

File Original and First Copy with Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

WATER WELL REPORT

STATE OF WASHINGTON

Application No. ....
Permit No. ....

(1) OWNER: Name U.S. Department of Interior Leavenworth - Fish Hatchery Address 500 NE Multnomah Street; Portland, OR

(2) LOCATION OF WELL: County Chelan — NW ¼ SE ¼ Sec. 23 T. 24 N., R. 17 EW.M.

Bearing and distance from section or subdivision corner

(3) PROPOSED USE: Domestic ☐ Industrial XX Municipal ☐ Irrigation ☐ Test Well ☐ Other ☐

(4) TYPE OF WORK: Owner's number of well (if more than one) 5A
New well XX Method: Dug ☐ Bored ☐
Deepened ☐ Cable ☐ Driven ☐
Reconditioned ☐ Rotary ☐ Jetted ☐

(5) DIMENSIONS: Diameter of well 14 inches.
Drilled 300 ft. Depth of completed well 170 ft.

(6) CONSTRUCTION DETAILS:

Casing installed: 24" Diam. from 0 ft. to 20 ft.
Threaded ☐ 14" Diam. from 0 ft. to 300 ft.
Welded ☐ " Diam. from ft. to ft.

Perforations: Yes ☐ No XX
Type of perforator used
SIZE of perforations in. by in.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.

Screens: Yes XX No ☐
Manufacturer's Name UOP Jonhson
Type 14" Model No.
Diam. 14" Slot size 50 from 250 ft. to 300 ft.
Diam. Slot size from ft. to ft.

Gravel packed: Yes XX No ☐ Size of gravel 1/4"-3/8"
Gravel placed from 0 ft. to 300 ft.

Surface seal: Yes ☐ No ☐ To what depth? 20 ft.
Material used in seal Neat Cement
Did any strata contain unusable water? Yes ☐ No XX
Type of water? Depth of strata
Method of sealing strata off

(7) PUMP: Manufacturer's Name
Type: H.P.

(8) WATER LEVELS: Land-surface elevation above mean sea level 25 ft.
Static level 10 ft. below top of well Date 1-31-78
Artesian pressure lbs. per square inch Date
Artesian water is controlled by (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes XX No ☐ If yes, by whom? E. E. Luhdorf Co.
Yield: 1500 gal./min. with ft. drawdown after hrs.

- Well Collapsed in Short Time

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test
Bailer test gal./min. with ft. drawdown after hrs.
Artesian flow g.p.m. Date
Temperature of water Was a chemical analysis made? Yes ☐ No ☐

(10) WELL LOG:

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of formation.

MATERIAL	FROM	TO
Medim brown sand	0	10
Boulder, sand gravel	10	18
Sand & gravel	18	89
Sand & fine silt & clay	89	159
Silty, clay, sand	159	246
Large gravel, boulders	246	300

per letter rec'd 1-18-80

Work started 12-22, 19 77 Completed 2-1, 19 78

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME LAYNE-WESTERN COMPANY, INC. (Person, firm, or corporation) (Type or print)

Address P.O. Box 336; Moses Lake, WA 98837

[Signed] [signature] (Well Driller)

License No. 0733 Date Dec. 14, 1979

(USE ADDITIONAL SHEETS IF NECESSARY)

Appendix B

File Original and First Copy with Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

WATER WELL REPORT

STATE OF WASHINGTON

Application No. ....

Permit No. ....

(1) OWNER: Name U.S. Department Of Interior Leavenworth Fish Hatery Address 500 NE Multnomah Street; Portland, OR

(2) LOCATION OF WELL: County Chelan — NW ¼ SE ¼ Sec. 23 T. 24 N., R. 17E W.M.

Bearing and distance from section or subdivision corner

(3) PROPOSED USE: Domestic ☐ Industrial XX Municipal ☐ Irrigation ☐ Test Well ☐ Other ☐

(4) TYPE OF WORK: Owner's number of well (if more than one).... 5.587

New well ☐ Method: Dug ☐ Bored ☐
Deepened ☐ Cable ☐ Driven ☐
Reconditioned ☐ Rotary XX Jetted ☐

(5) DIMENSIONS: Diameter of well 30x16" inches.
Drilled 286 ft. Depth of completed well 276.11 ft.

(6) CONSTRUCTION DETAILS:

Casing installed: 30 " Diam. from 0 ft. to 20.5 ft.
Threaded ☐ 16 " Diam. from 0 ft. to 276.11 ft.
Welded ☐ ...... " Diam. from ...... ft. to ...... ft.

Perforations: Yes ☐ No XX
Type of perforator used ......
SIZE of perforations ...... in. by ...... in.
...... perforations from ...... ft. to ...... ft.
...... perforations from ...... ft. to ...... ft.
...... perforations from ...... ft. to ...... ft.

Screens: Yes XX No ☐
Manufacturer's Name UOP Johnson
Type Wirewrap Model No. ......
Diam. ...... Slot size ...... from ...... ft. to ...... ft.
Diam. ...... Slot size ...... from ...... ft. to ...... ft.

Gravel packed: Yes XX No ☐ Size of gravel: 1/4" - 53/8"
Gravel placed from 0 ft. to 280 ft.

Surface seal: Yes XX No ☐ To what depth? 20.5 ft.
Material used in seal Neat Cement
Did any strata contain unusable water? Yes ☐ No XX
Type of water? ...... Depth of strata ......
Method of sealing strata off ......

(7) PUMP: Manufacturer's Name ......
Type: ...... H.P. ......

(8) WATER LEVELS: Land-surface elevation above mean sea level.... 25 ft.
Static level 10 ft. below top of well Date 10/12/76
Artesian pressure ...... lbs. per square inch Date ......
Artesian water is controlled by ...... (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes XX No ☐ If yes, by whom? E.E. Luhdorff Co.
Yield: 1500 gal./min. with ...... ft. drawdown after 8.3 hrs.
" " " "
" PUMPED EXCESSIVE SAND " "

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test 10-12-76
Bailer test ...... gal./min. with ...... ft. drawdown after ...... hrs.
Artesian flow ...... g.p.m. Date ......
Temperature of water ...... Was a chemical analysis made? Yes ☐ No ☐

(10) WELL LOG:

Formation: *Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of formation.*

MATERIAL	FROM	TO
Top soil sandy	0	10
Unconsolidated gravel	10	20
Gravels & sands	20	50
Gravels & Sands	50	166
Gravels & sands	166	176
Gravel & sand	176	210
Gravel, large, some clay	210	245
Hard rock, gravel	245	253
Hard rock	253	257
Gravel	257	278
Granite	278	279
Granite	279	280
	280	286

per letter rec'd 1-18-80

Work started 9-21, 1976. Completed 10-12, 1976

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME LAYNE-WESTERN COMPANY, INC. (Person, firm, or corporation) (Type or print)

Address P.O. Box 336; Moses Lake, WA 98837

[Signed] [signature] (Well Driller)

License No. 0733 Date Dec. 14, 1979

(USE ADDITIONAL SHEETS IF NECESSARY)

Well #6

File Original and First Copy with Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

WATER WELL REPORT

STATE OF WASHINGTON

Application No. ______

Permit No. ______

(1) OWNER: Name U.S. Dept. of Interior Leavenworth Fish Hatchery Address 500 NE Multnomah St., Portland, OR

(2) LOCATION OF WELL: County Chelan SW ¼ SW ¼ Sec. 23 T. 24 N., R 17E W.M.

Bearing and distance from section or subdivision corner

(3) PROPOSED USE: Domestic ☐ Industrial ☒ Municipal ☐ Irrigation ☐ Test Well ☐ Other ☐

(4) TYPE OF WORK: Owner's number of well (if more than one) #6
New well ☒ Method: Dug ☐ Bored ☐
Deepened ☐ Cable ☐ Driven ☐
Reconditioned ☐ Rotary ☒ Jetted ☐

(5) DIMENSIONS: Diameter of well 26 inches.
Drilled 195 ft. Depth of completed well 170 ft.

(6) CONSTRUCTION DETAILS:

Casing installed: 14" Diam. from 0 ft. to 170 ft.
Threaded ☐ 30" Diam. from 0 ft. to 25 ft.
Welded ☐ ___" Diam. from ___ ft. to ___ ft.

Perforations: Yes ☒ No ☐
Type of perforator used ______
SIZE of perforations ___ in. by ___ in.
___ perforations from ___ ft. to ___ ft.
___ perforations from ___ ft. to ___ ft.
___ perforations from ___ ft. to ___ ft.

Screens: Yes ☒ No ☐
Manufacturer's Name ______
Type Slotted pipe Model No. ______
Diam. 14 Slot size ___ from 102 ft. to 112 ft.
Diam. 14 Slot size ___ from 150 ft. to 170 ft.

Gravel packed: Yes ☒ No ☐ Size of gravel: 1/4 - 3/8"
Gravel placed from 0 ft. to 170 ft.

Surface seal: Yes ☒ No ☐ To what depth? 25 ft.
Material used in seal 30" steel pipe - cemented
Did any strata contain unusable water? Yes ☐ No ☒
Type of water? ______ Depth of strata ______
Method of sealing strata off cement

(7) PUMP: Manufacturer's Name ______
Type: ______ H.P. ______

(8) WATER LEVELS: Land-surface elevation above mean sea level.... ______ ft.
Static level 90 ft. below top of well Date 12-20-76
Artesian pressure ______ lbs. per square inch Date ______
Artesian water is controlled by ______ (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☒ No ☐ If yes, by whom? E.E. Luhdorff Co.
Yield: 1600 gal./min. with 1 ft. drawdown after 4 hrs.

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test ______
Bailer test ___ gal./min. with ___ ft. drawdown after ___ hrs.
Artesian flow ___ g.p.m. Date ______
Temperature of water ___ Was a chemical analysis made? Yes ☐ No ☐

(10) WELL LOG:

Formation: *Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of formation.*

MATERIAL	FROM	TO
Sand & Gravel	0	22
Coarse Sand	22	39
Gravel 3/8	39	52
Gravel	52	70
Coarse Sand Gravel	70	115
Clay	115	139
Sand & Gravel	139	149
Coarse Sand Small Gravel	149	172
Boulders	172	177
Granite	177	195

Work started ______, 19__. Completed ______, 19__.

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME LAYNE-WESTERN COMPANY, INC. (Person, firm, or corporation) (Type or print)

Address P.O. Box 336; Moses Lake, WA 98837

[Signed] [signature] (Well Driller)

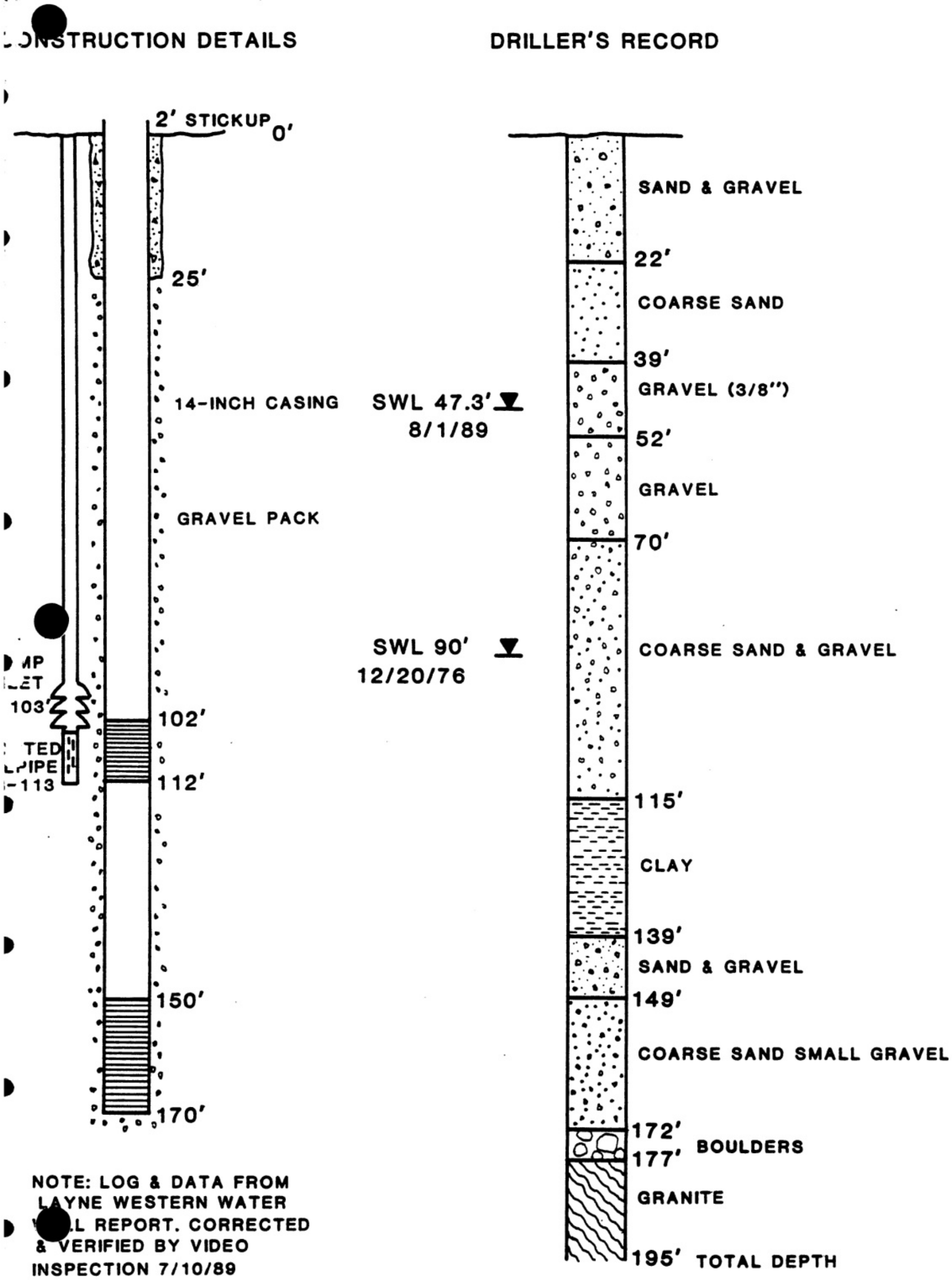
License No. 0733 Date Dec. 14, 1979

(USE ADDITIONAL SHEETS IF NECESSARY)

Appendix B

LEAVENWORTH NATIONAL FISH HATCHERY WELL 6

FIGURE 8



NOTE: LOG & DATA FROM LAYNE WESTERN WATER WELL REPORT. CORRECTED & VERIFIED BY VIDEO INSPECTION 7/10/89

LOW LEVEL PUMP PROTECTION PROBE INSTALLED AT 96'

File Original and First Copy with Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

WATER WELL REPORT

STATE OF WASHINGTON

Application No. ....
Permit No. ....

(1) OWNER: Name U.S. Department of Interior ~~Leavenworth - Fish Hatchery~~ Address 500 NE Multnomah Street; Portland, OR

(2) LOCATION OF WELL: County Chelan — ~~SW ¼ SW ¼~~ Sec. 23 T. 24 N., R. 17 E W.M. NW NE 26

Bearing and distance from section or subdivision corner

(3) PROPOSED USE: Domestic ☐ Industrial ☒ Municipal ☐ Irrigation ☐ Test Well ☐ Other ☐

(4) TYPE OF WORK: Owner's number of well (if more than one) #7 #8
New well ☒ Method: Dug ☐ Bored ☐
Deepened ☐ Cable ☐ Driven ☐
Reconditioned ☐ Rotary ☒ Jetted ☐

(5) DIMENSIONS: Diameter of well 23 inches.
Drilled 192 ft. Depth of completed well 115 ft.

(6) CONSTRUCTION DETAILS:

Casing installed: 14" Diam. from 0 ft. to 115 ft.
Threaded ☐ 24" Diam. from 0 ft. to 30 ft.
Welded ☐ ...." Diam. from ...... ft. to ...... ft.

Perforations: Yes ☒ No ☐
Type of perforator used ....
SIZE of perforations ...... in. by ...... in.
...... perforations from ...... ft. to ...... ft.
...... perforations from ...... ft. to ...... ft.
...... perforations from ...... ft. to ...... ft.

Screens: Yes ☒ No ☐
Manufacturer's Name UPO Johnson
Type wire wrap Model No. ......
Diam. 14 Slot size 50 from 72 ft. to 82 ft.
Diam. 14 Slot size 50 from 92 ft. to 110 ft.

Gravel packed: Yes ☒ No ☐ Size of gravel: ......
Gravel placed from ...... ft. to ...... ft.

Surface seal: Yes ☒ No ☐ To what depth? 30 ft.
Material used in seal 24" steel pipe - cemented
Did any strata contain unusable water? Yes ☐ No ☒
Type of water? ...... Depth of strata ......
Method of sealing strata off cement

(7) PUMP: Manufacturer's Name ......
Type: ...... H.P. ......

(8) WATER LEVELS: Land-surface elevation above mean sea level.... ...... ft.
Static level 12 ft. below top of well Date 11-1-76
Artesian pressure ...... lbs. per square inch Date ......
Artesian water is controlled by ...... (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☐ No ☐ If yes, by whom? E.E. Luhdorff Co.
Yield: 400 gal./min. with 33 ft. drawdown after 2 hrs.
" 1025 " " 4 "
" " " "

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test ......
Bailer test ...... gal./min. with ...... ft. drawdown after ...... hrs.
Artesian flow ...... g.p.m. Date ......
Temperature of water ...... Was a chemical analysis made? Yes ☐ No ☐

(10) WELL LOG:

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of formation.

MATERIAL	FROM	TO
Large Boulders	0	13
Large rock, gravel	13	29
Gravel	29	30
Large rock & gravels	30	78
Gravel	78	136
Clay Streaks & gravel	136	145
Gravel	145	161
Gravel (clay traces)	161	184
Gravel	184	186
Hard rock (granite quartz)	186	192

Work started ......, 19..... Completed ......, 19.....

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

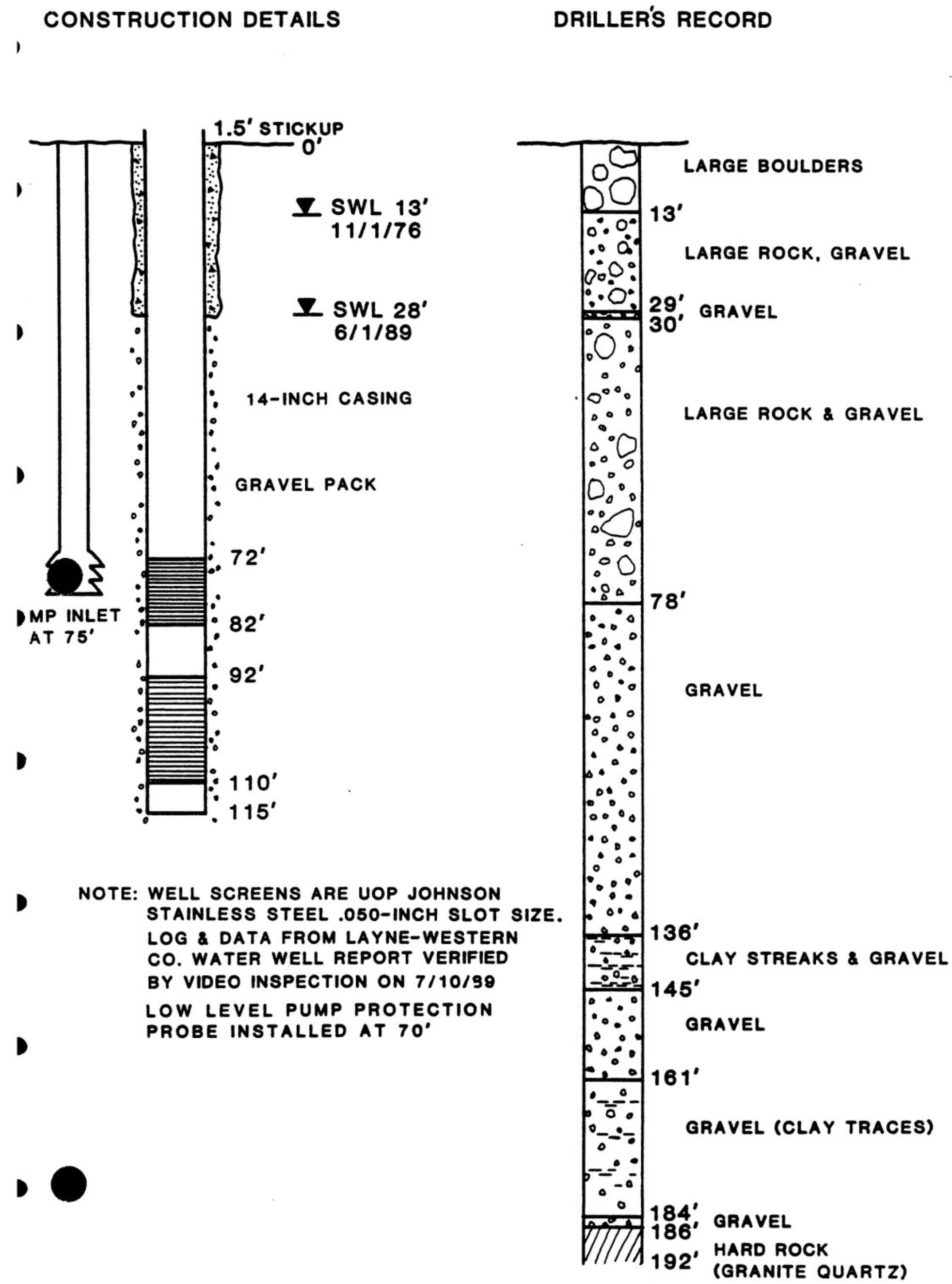
NAME LAYNE-WESTERN COMPANY (Person, firm, or corporation) (Type or print)

Address P.O. Box 336; 24th & Dover

[Signed] [signature] (Well Driller)

License No. 0733 Date Dec. 14, 1979

LEAVENWORTH NATIONAL FISH HATCHERY FIGURE 9
WELL 7



NOTE: WELL SCREENS ARE UOP JOHNSON STAINLESS STEEL .050-INCH SLOT SIZE.
LOG & DATA FROM LAYNE-WESTERN CO. WATER WELL REPORT VERIFIED BY VIDEO INSPECTION ON 7/10/99
LOW LEVEL PUMP PROTECTION PROBE INSTALLED AT 70'

File Original and First Copy with Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

WATER WELL REPORT

STATE OF WASHINGTON

Application No. ....

Permit No. ....

(1) OWNER: Name U.S. Department of Interior Leavenworth - Fish Hatchery   Address 500 NE Multnomah Street; Portland, OR

(2) LOCATION OF WELL: County Chelan   SW ¼ SW ¼ Sec. 23 T. 24 N., R. 17E W.M. N

Bearing and distance from section or subdivision corner

(3) PROPOSED USE: Domestic ☐ Industrial ☐ Municipal ☐ Irrigation ☐ Test Well ☐ Other XX OBSERVATION

(4) TYPE OF WORK: Owner's number of well (if more than one) #8 1
New well XX Method: Dug ☐ Bored ☐
Deepened ☐ Cable ☐ Driven ☐
Reconditioned ☐ Rotary XX Jetted ☐

(5) DIMENSIONS: Diameter of well 9 7/8 inches.
Drilled 278 ft. Depth of completed well 278 ft.

(6) CONSTRUCTION DETAILS:

Casing installed: 1½ PVC " Diam. from 0 ft. to 278 ft.
Threaded ☐ " Diam. from 0 ft. to 20 ft.
Welded ☐ " Diam. from ft. to ft.

Perforations: Yes XX No ☐
Type of perforator used Slots
SIZE of perforations in. by in.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.

Screens: Yes ☐ No XX
Manufacturer's Name
Type Model No.
Diam. Slot size from ft. to ft.
Diam. Slot size from ft. to ft.

Gravel packed: Yes XXX No ☐ Size of gravel: Pea
Gravel placed from 28 ft. to 208 ft.

Surface seal: Yes XX No ☐ To what depth? 28 ft.
Material used in seal Neat Cement
Did any strata contain unusable water? Yes ☐ No XX
Type of water? Depth of strata
Method of sealing strata off

(7) PUMP: Manufacturer's Name
Type: H.P.

(8) WATER LEVELS: Land-surface elevation above mean sea level.... 25 ft.
Static level 26' 10" ft. below top of well Date 10-20-76
Artesian pressure lbs. per square inch Date
Artesian water is controlled by (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☐ No XX If yes, by whom?
Yield: gal./min. with ft. drawdown after hrs.

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test
Bailer test gal./min. with ft. drawdown after hrs.
Artesian flow g.p.m. Date
Temperature of water Was a chemical analysis made? Yes ☐ No ☐

(10) WELL LOG:

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of formation.

MATERIAL	FROM	TO
Sand	0	13
Sand	13	60
Clay	60	70
Sand & clay	70	80
Sands	80	171
Clay & sands	171	250
Sand & gravel	250	274
Quartz & sand	274	278

Looks like this could be well #8 on WFW Map/site plan

Observation well

per letter rec'd 1-18-80

Work started 10-13, 1976. Completed 10-20, 1976

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME LAYNE-WESTERN COMPANY, INC.
(Person, firm, or corporation) (Type or print)

Address P.O. Box 336; Moses Lake, WA 98837

[Signed] [signature]
(Well Driller)

License No. 0733 Date Dec. 14, 1979

(USE ADDITIONAL SHEETS IF NECESSARY)

File Original and First Copy with Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

WATER WELL REPORT

STATE OF WASHINGTON

Application No. ....
Permit No. ....

(1) OWNER: Name U.S. Department of Interior ~~Leavenworth Fish Hatchery~~ Address 500 NE Multnomah Street; Portland, OR

(2) LOCATION OF WELL: County Chelan — SW ¼ SW ¼ Sec. 23 T. 24 N., R. 17E W.M.
Bearing and distance from section or subdivision corner

(3) PROPOSED USE: Domestic ☐ Industrial ☒ Municipal ☐ Irrigation ☐ Test Well ☐ Other ☐

(4) TYPE OF WORK: Owner's number of well (if more than one).... #6 ?
New well ☒ Method: Dug ☐ Bored ☐
Deepened ☐ Cable ☐ Driven ☐
Reconditioned ☐ Rotary ☒ Jetted ☐

(5) DIMENSIONS: Diameter of well 30"x16" inches.
Drilled 213 ft. Depth of completed well 213 ft.

(6) CONSTRUCTION DETAILS:

Casing installed: 30" Diam. from 0 ft. to 20 ft.
Threaded ☐ 16" Diam. from 0 ft. to 205 ft.
Welded ☐ " Diam. from ..... ft. to ..... ft.

Perforations: Yes ☐ No ☒X
Type of perforator used ....
SIZE of perforations ..... in. by ..... in.
..... perforations from ..... ft. to ..... ft.
..... perforations from ..... ft. to ..... ft.
..... perforations from ..... ft. to ..... ft.

Screens: Yes XX No ☐
Manufacturer's Name UOP Jonhson
Type Wirewrap Model No. .....
Diam. 16" 80-90 95-105 115-120
Diam. 122-127 131-136 180-200

Gravel packed: Yes X☒ No ☐ Size of gravel: 1/4"-3/8"
Gravel placed from 0 ft. to 205 ft.

Surface seal: Yes XX No ☐ To what depth? 20 ft.
Material used in seal Neat Cement
Did any strata contain unusable water? Yes ☐ No X☒X
Type of water? ..... Depth of strata .....
Method of sealing strata off .....

(7) PUMP: Manufacturer's Name .....
Type: ..... H.P. .....

(8) WATER LEVELS: Land-surface elevation above mean sea level.... ..... ft.
Static level 12 ft. below top of well Date 11-2-76
Artesian pressure ..... lbs. per square inch Date .....
Artesian water is controlled by ..... (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes XX No ☐ If yes, by whom? E.E. Luhdorff Co.
Yield: 400 gal./min. with 50 ft. drawdown after 7 hrs.
" " " "
" Well Callapsed " "

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test .....
Bailer test ..... gal./min. with ..... ft. drawdown after ..... hrs.
Artesian flow ..... g.p.m. Date .....
Temperature of water ..... Was a chemical analysis made? Yes ☐ No ☐

(10) WELL LOG:

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of formation.

MATERIAL	FROM	TO
Top soil sand	0	20
Sand & gravel	20	52
Caving, sand & gravel	52	63
Sand & gravel	63	160
Sand & gravel	160	205
Boulders	205	207
Granite hard Quartzite	207	213

Based on depth to bedrock, this could be well #9 on original W.F.W. Figure.

Ob. well

Work started ....., 19..... Completed ....., 19.....

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME LAYNE-WESTERN COMPANY, INC.
(Person, firm, or corporation) (Type or print)

Address P.O. Box 336; Moses Lake, WA 98837

[Signed] [signature] (Well Driller)

License No. 0733 Date Dec 14, 1979

(USE ADDITIONAL SHEETS IF NECESSARY)

June, 80

File Original and First Copy with Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

WATER WELL REPORT

STATE OF WASHINGTON

Start Card No. W 18689
UNIQUE WELL I.D. # ABV 293
Water Right Permit No. ______

(1) OWNER: Name US Fish + Wildlife Address 911 N.E. 11th Ave Portland OR 9723?

(2) LOCATION OF WELL: County Chelan NW 1/4 SE 1/4 Sec 23 T. 25 N., R 17 W.M.

(2a) STREET ADDRESS OF WELL (or nearest address) Leavenworth Fish Hatchery

(3) PROPOSED USE: ☐ Domestic ☐ Irrigation ☐ DeWater Industrial ☐ Test Well ☐ Municipal ☐ Other ☐

(4) TYPE OF WORK: Owner's number of well (if more than one) #10
Abandoned ☐ New well ☒ Deepened ☐ Reconditioned ☐
Method: Dug ☐ Cable ☒ Rotary ☐ Bored ☐ Driven ☐ Jetted ☐

(5) DIMENSIONS: Diameter of well 12" inches.
Drilled 110 feet. Depth of completed well 104 ft.

(6) CONSTRUCTION DETAILS:
Casing installed: 12" Diam. from +2 ft. to 75 ft.
Welded ☒ ______" Diam. from ______ ft. to ______ ft.
Liner installed ☐ ______" Diam. from ______ ft. to ______ ft.
Threaded ☐

Perforations: Yes ☐ No ☒
Type of perforator used ______
SIZE of perforations ______ in. by ______ in.
______ perforations from ______ ft. to ______ ft.
______ perforations from ______ ft. to ______ ft.
______ perforations from ______ ft. to ______ ft.

Screens: Yes ☒ No ☐
Manufacturer's Name Johnson
Type SS Model No. ______
Diam. 10 Slot size 10 from 100 ft. to 95 ft.
Diam. 10 Slot size 15 / 10 from 95 / 80 ft. to 80 / 75 ft.

Gravel packed: Yes ☐ No ☐ Size of gravel ______
Gravel placed from ______ ft. to ______ ft.

Surface seal: Yes ☒ No ☐ To what depth? ______ ft.
Material used in seal Benonite
Did any strata contain unusable water? Yes ☐ No ☒
Type of water? ______ Depth of strata ______
Method of sealing strata off ______

(7) PUMP: Manufacturer's Name ______
Type: ______ H.P. ______

(8) WATER LEVELS: Land-surface elevation above mean sea level ______ ft.
Static level 35' ft. below top of well Date 2/23/95
Artesian pressure ______ lbs. per square inch Date ______
Artesian water is controlled by ______ (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☐ No ☒ If yes, by whom? ______
Yield: ______ gal./min. with ______ ft. drawdown after ______ hrs.
" " " "
" " " "

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test ______
Bailer test ______ gal./min. with ______ ft. drawdown after ______ hrs.
Airtest ______ gal./min. with stem set at ______ ft. for ______ hrs.
Artesian flow ______ g.p.m. Date ______
Temperature of water ______ Was a chemical analysis made? Yes ☐ No ☐

(10) WELL LOG or ABANDONMENT PROCEDURE DESCRIPTION

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of information.

MATERIAL	FROM	TO
Silty Sand + Cobles	0	5
Sand, Gravels + Cobles	5	30
Corse Sand	30	44
Sand + Gravel	44	50
Sand	50	70
med Sand	70	110

Work Started 1-23-95, 19. Completed 2-24-95, 1995

WELL CONSTRUCTOR CERTIFICATION:

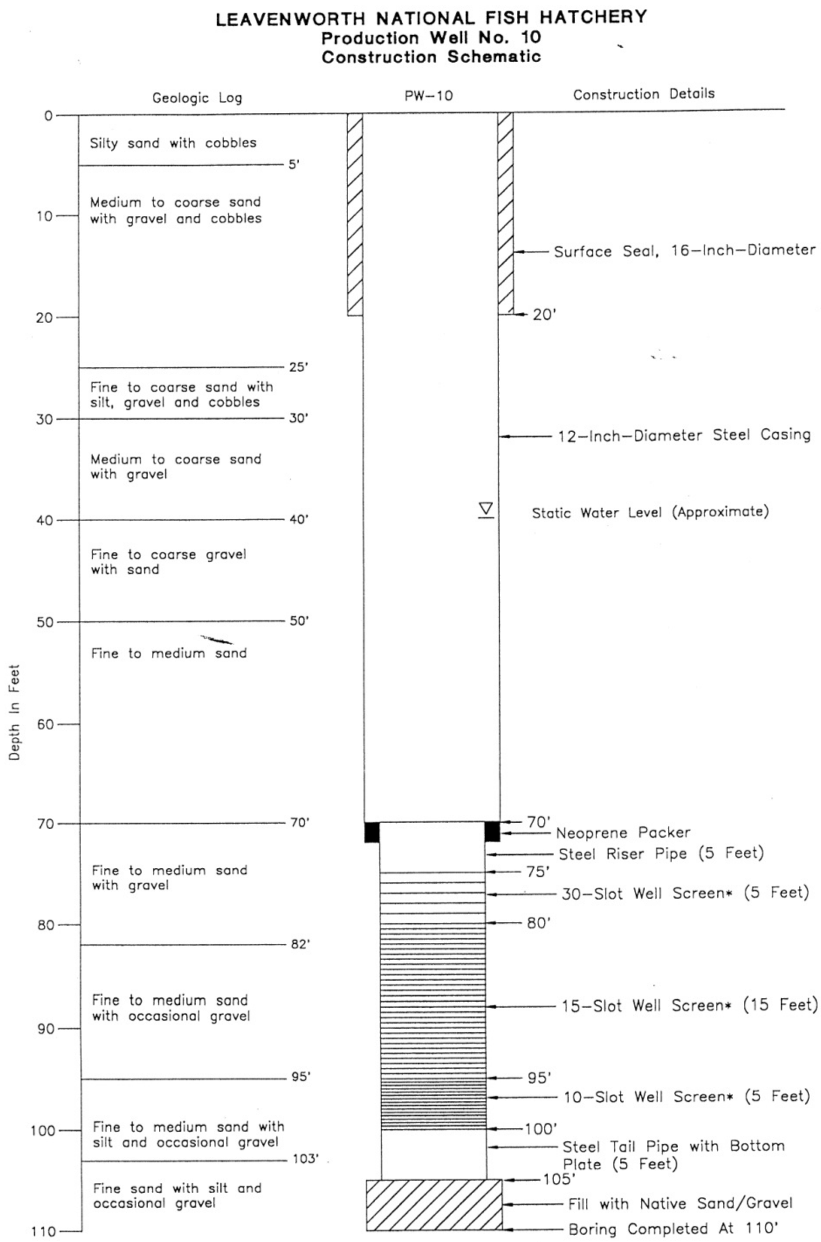
I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

NAME Holt Drilling Inc (PERSON, FIRM, OR CORPORATION) (TYPE OR PRINT)
Address 10621 Todd Rd E Puyallup WA 9837?
(Signed) [signature] (WELL DRILLER) License No. 597
Contractor's Registration No. HOLTTDI080J Date 3-14, 1995

(USE ADDITIONAL SHEETS IF NECESSARY)

Appendix B

D:\0758\022\0758022A.DWG JGR:DDW 02/11/95 BASE



*Johnson Type 304 Stainless Steel Continuous–Slot, 12–Inch–Diameter, Telescope Size. Design Capacity of the screen is 510 gpm.

Note: Geology based on driller's log and GeoEngineers' review of samples collected by driller.

GeoEngineers

WELL PW-10 SCHEMATIC

FIGURE 1

File Original and First Copy with Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

WATER WELL REPORT

STATE OF WASHINGTON

Start Card No. W 16349
UNIQUE WELL I.D. # ABV 292
Water Right Permit No. ____

(1) OWNER: Name US Fish & Wildlife Address 911 NE 11th Ave Portland OR 97232-4181

(2) LOCATION OF WELL: County Chelan — NW 1/4 SE 1/4 Sec 23 T. 25 N., R. 17 W.M.

(2a) STREET ADDRESS OF WELL (or nearest address) Leavenworth Fish Hatchery

(3) PROPOSED USE: ☐ Domestic ☐ Irrigation ☐ DeWater ☐ Industrial ☐ Test Well ☐ Municipal ☒ Other

(4) TYPE OF WORK: Owner's number of well (If more than one) 11
☒ Abandoned ☒ New well ☐ Deepened ☐ Reconditioned
Method: ☐ Dug ☐ Cable ☐ Rotary ☐ Bored ☐ Driven ☐ Jetted

(5) DIMENSIONS: Diameter of well 16 inches.
Drilled 278 feet. Depth of completed well 0 ft.

(6) CONSTRUCTION DETAILS:

Casing installed: ____" Diam. from ____ ft. to ____ ft.
☐ Welded ____" Diam. from ____ ft. to ____ ft.
☐ Liner installed ____" Diam. from ____ ft. to ____ ft.
☐ Threaded

Perforations: Yes ☐ No ☐
Type of perforator used ____
SIZE of perforations ____ in. by ____ in.
____ perforations from ____ ft. to ____ ft.
____ perforations from ____ ft. to ____ ft.
____ perforations from ____ ft. to ____ ft.

Screens: Yes ☐ No ☒
Manufacturer's Name ____
Type ____ Model No. ____
Diam. ____ Slot size ____ from ____ ft. to ____ ft.
Diam. ____ Slot size ____ from ____ ft. to ____ ft.

Gravel packed: Yes ☐ No ☐ Size of gravel ____
Gravel placed from ____ ft. to ____ ft.

Surface seal: Yes ☒ No ☐ To what depth? 20 ft.
Material used in seal Bentonite
Did any strata contain unusable water? Yes ☐ No ☐
Type of water? ____ Depth of strata ____
Method of sealing strata off ____

(7) PUMP: Manufacturer's Name ____
Type: ____ H.P. ____

(8) WATER LEVELS: Land-surface elevation above mean sea level ____ ft.
Static level ____ ft. below top of well Date ____
Artesian pressure ____ lbs. per square inch Date ____
Artesian water is controlled by ____ (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☐ No ☐ If yes, by whom? ____
Yield: ____ gal./min. with ____ ft. drawdown after ____ hrs.
" " " "
" " " "

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test ____
Bailer test ____ gal./min. with ____ ft. drawdown after ____ hrs.
Airtest ____ gal./min. with stem set at ____ ft. for ____ hrs.
Artesian flow ____ g.p.m. Date ____
Temperature of water ____ Was a chemical analysis made? Yes ☐ No ☐

(10) WELL LOG or ABANDONMENT PROCEDURE DESCRIPTION

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of information.

MATERIAL	FROM	TO
Brown Sand	0	12
Sand & Gravels Cobs	12	18
Brown Sand	18	55
Gray Silt (wet)	55	261
Gray Silt w/ Cobs	261	274
Granite Bed Rock	274	278
Abandoned with Bentonite & Pea Gravel From 228-20'		

Work Started ____, 19__. Completed ____, 19__

WELL CONSTRUCTOR CERTIFICATION:

I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

NAME Holt Drilling Inc (PERSON, FIRM, OR CORPORATION) (TYPE OR PRINT)
Address 10621 Todd Rd E
(Signed) Wade Turner (WELL DRILLER) License No. 597
Contractor's Registration No. HOLTTDI08705 Date 3-14, 1995

(USE ADDITIONAL SHEETS IF NECESSARY)

This page intentionally left blank.

Appendix C: Seepage Monitoring Data

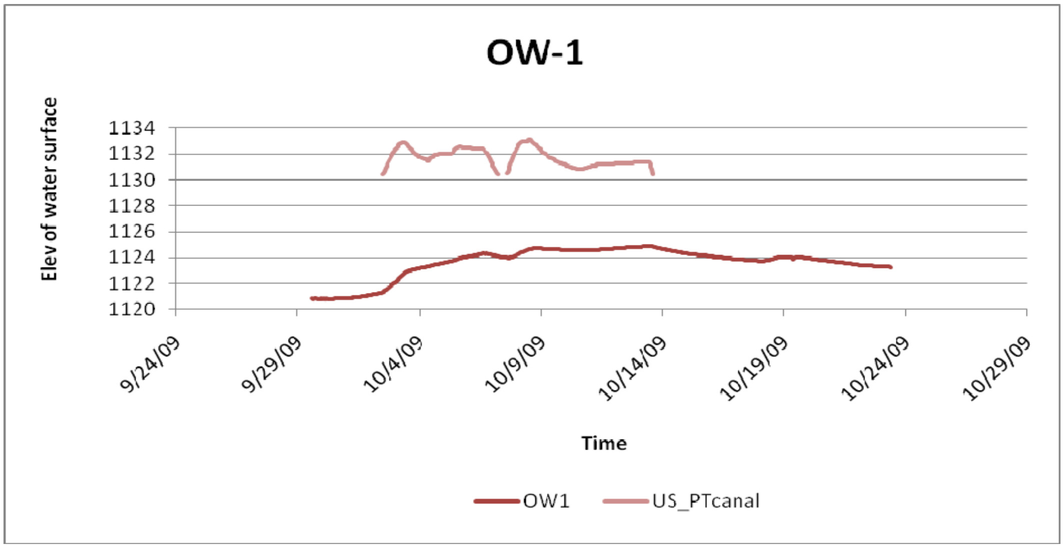


Figure C-1: Hydrograph of water level response in OW-1 and upstream transducer in hatchery channel

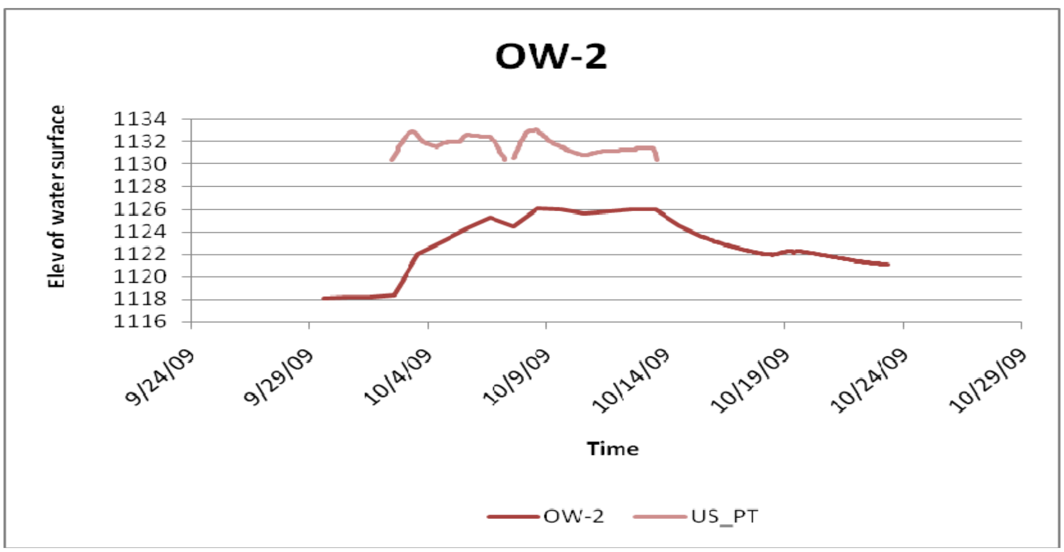


Figure C-2: Hydrograph of water level response in OW-2 and upstream transducer in Hatchery channel

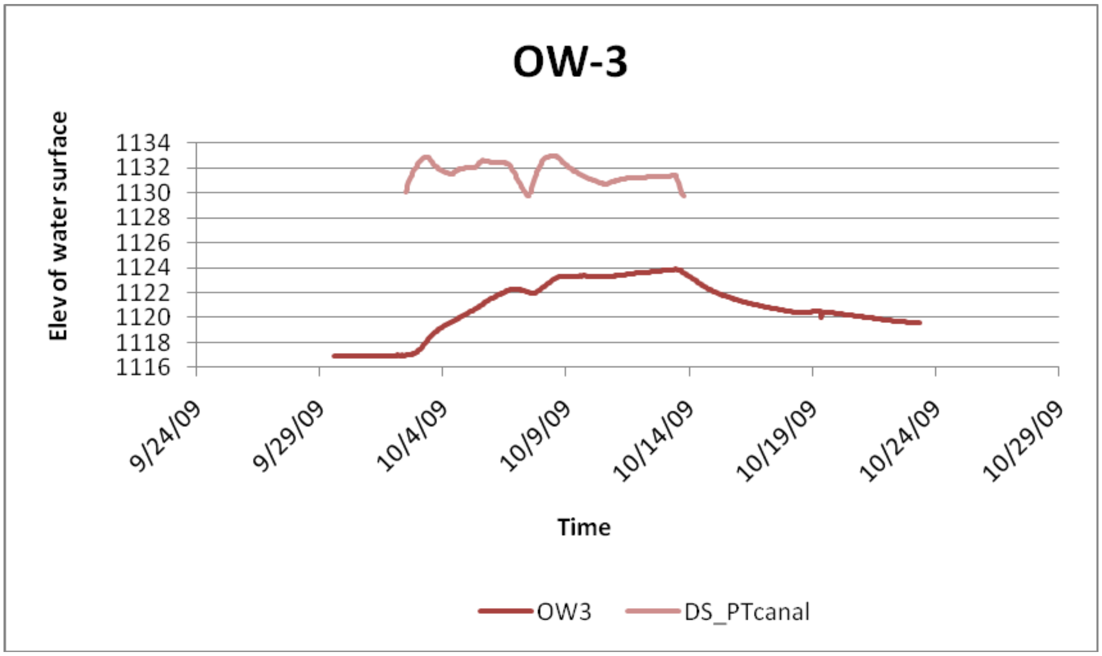


Figure C-3: Hydrograph of water level response in OW-3 and downstream transducer in hatchery channel

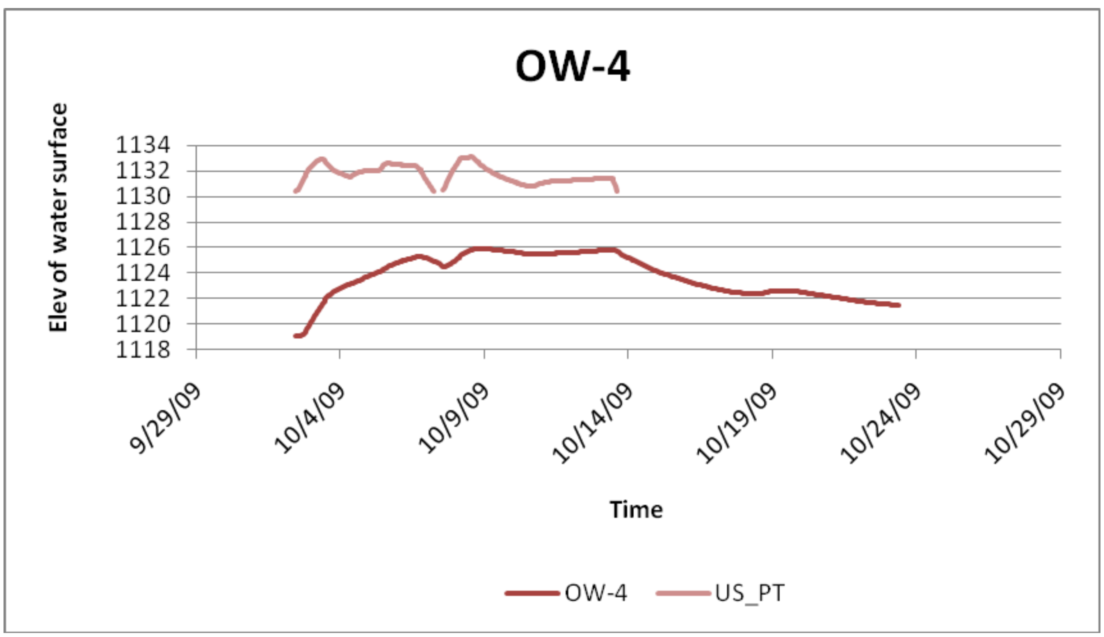


Figure C-4: Hydrograph of water level response in OW-4 and upstream transducer in Hatchery channel

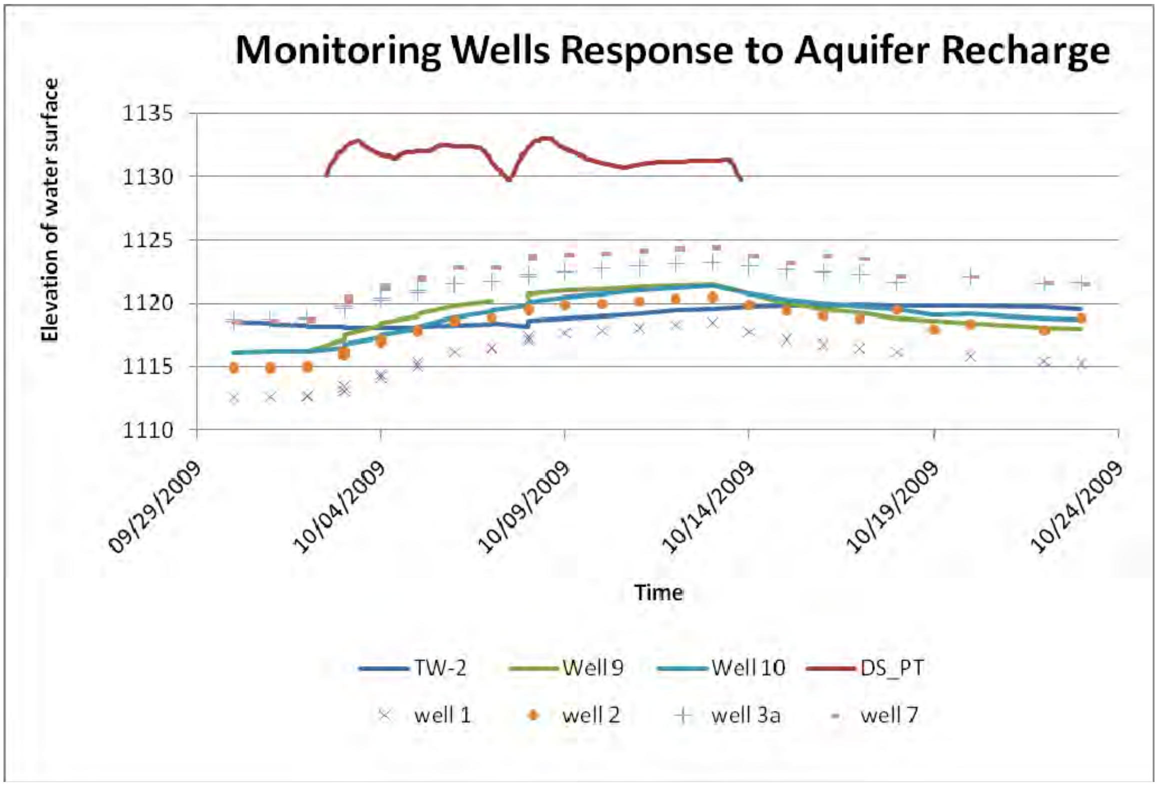


Figure C-5: Hydrograph of water level response in monitoring wells and downstream transducer in Hatchery channel

Table C-1: Gate and flow measurements at Structure No. 2 during Oct. 2009 seepage monitoring (personal communication, F. Wurster)

Date/Time	Structure No. 2 Gate Opening (ft)	Flow in Icicle Crk. Historic Channel (cfs)	Water Elev. u/s of Structure No. 2
9/29/09 17:00	5	47	1128.6
9/30/09 8:45	5	52	1128.6
9/30/09 9:45	5	52	1128.6
9/30/09 10:37	0.3	46	1129.3
9/30/09 15:03	0.3	53	1129.8
10/1/09 7:20	0.3	54	1129.9
10/1/09 10:37	0.3	54	1129.9
10/1/09 12:40	0.3	55	1129.9
10/1/09 14:40	0.3	55	1129.9
10/2/09 8:40	0.3	54	1129.9
10/2/09 11:50	0.3	64	1130.7
10/2/09 15:10	0.3	69	1131.1
10/3/09 9:10	0.3	87	1133.0
10/3/09 16:00	0.4	108	1132.4
10/4/09 9:30	0.4	99	1131.6
10/4/09 15:20	0.3	78	1132.0
10/5/09 7:50	0.3	79	1132.1
10/5/09 11:50	0.23	64	1132.6
10/5/09 14:00	0.23	64	1132.6
10/6/09 9:30	0.26	90	1132.5
10/6/09 13:00	0.26	90	1132.5
10/7/09 10:20	0.26	60	1130.0
10/7/09 10:45	0.26	59	1129.9
10/7/09 12:10	0.26	58	1129.8
10/7/09 13:20	0.26	56	1129.7
10/7/09 16:20	0.06	14	1131.0
10/8/09 8:10	0.06	18	1133.1
10/8/09 12:30	0.06	18	1133.1
10/8/09 13:00	0.06	18	1133.1
10/8/09 15:45	0.16	47	1133.0
10/9/09 12:10	0.16	40	1131.7
10/9/09 13:20	0.16	40	1131.7
10/9/09 14:30	0.16	40	1131.7
10/10/09 15:20	0.16	35	1130.8
10/11/09 16:25	0.16	38	1131.3
10/12/09 16:00	0.16	39	1131.4
10/13/09 11:00	0.16	39	1131.5
10/13/09 13:35	0.31	70	1131.0
10/13/09 14:00	0.31	68	1130.8
10/13/09 14:40	0.46	95	1130.5
10/14/09 11:20	0.46	50	1128.6
10/14/09 12:20	0.46	51	1128.7
10/14/09 14:30	0.46	49	1128.6
10/15/09 9:40	3	98	1129.0
10/16/09 8:00	3	75	1128.8
10/17/09 7:20	3	92	1128.9
10/18/09 7:25	3	75	1128.8

10/19/09 9:00	3	197	1129.6
10/20/09 9:08	3	139	1129.2
10/22/09 8:50	3	116	1129.1
10/22/09 15:30	3	124	1129.1

Note: Values in red are estimated