HYDROGEOLOGIC INVESTIGATION REPORT

Wildhorse Spring Creek
Fish Habitat Enhancement Project

Prepared for: Colville Fish and Wildlife

Project No. 100073 • April 2, 2012

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1 Introduction

Colville Confederated Tribes (Tribe) Anadromous Fish Program (CCT AFP) is seeking to increase the low flow period stream flows in the lower ¾-mile of Wildhorse Spring Creek (Creek), near Ellisforde in Okanogan County to enhance spawning and rearing habitat for ESA-listed Okanogan River steelhead. In Fall 2010, CCT AFP engaged Aspect Consulting, LLC (Aspect) to evaluate alternatives for enhancing stream flows in the intermittent, lower portion of the Creek below Cordell Road. This work was performed as part of the Tribe's Okanogan Sub-Basin Habitat Improvement Project under Contract C11-051. The project location is presented on Figure 1, and the project vicinity is shown on Figure 2.

1.1 Purpose and Scope

A recent stream survey identified more than 50 steelhead spawning redds below natural passage barriers in the lower ¾-mile of the Creek; however, low flows following the spring freshet confine habitat suitable for rearing juvenile steelhead to a perennial reach located primarily east of Cordell Road. Numerous juvenile steelhead have been observed throughout the year in the perennial reach. The lower reach of the Creek is intermittent and does not flow all the way to the Okanogan River for most of the year.

Recognizing the potential for the Creek to serve an important role in salmonid recovery within the Okanogan River basin, CCT AFP seeks to improve habitat downstream of Cordell Road that could greatly increase juvenile steelhead survival and productivity. Based on scoping discussions with the Tribe, the focus of this investigation was development of design alternatives that augment stream flow through groundwater discharge. A preliminary analysis of other alternatives identified during the scoping phase is also evaluated, but focus primarily on whether they merit further study.

Fish habitat enhancement projects already initiated by Colville Confederated Tribes in lower Wildhorse Spring Creek include improving fish passage, restricting livestock access, and replacement of a domestic well with a well completed in a deeper bedrock zone with less direct continuity with the Creek.

1.2 Water Quality and Flow Objectives

The Tribe's primary objective is to increase stream productivity in the Creek by improving rearing habitat for juvenile steelhead in the lower ¾-mile of the Creek during low water months. Specific objectives include:

- Increase available rearing habitat by increasing the wetted length of the Creek below Cordell Road during low flow periods. Low flows in the lower reach occur after spring freshet tapers off in early summer and continue until snows melt again in the spring, beginning in about early April. The perennial reach located primarily upstream of Cordell Road experiences low flows typically on the order of 0.06 cubic feet per second (cfs) or 27 gallons per minute (gpm)[1]. Because these flows are observed to sustain numerous juvenile steelhead in the perennial reach, any appreciable increase in flow is likely to provide substantial benefit.

- Meet water quality parameters optimal for juvenile steelhead rearing, including water temperatures between 45 degrees F and 63 degrees F, dissolved oxygen between 5 milligrams per liter (mg/L) and 15 mg/L and pH between 6.7 and 8.3 (Bell, 1991). Copper and zinc are not expected to be present in concentrations affecting targeted species at Wildhorse Spring Creek.
- Minimize capital and long-term operations and maintenance costs. If feasible, the Tribe desires to develop an alternative that minimizes operational costs by sustaining juvenile populations in Wildhorse Spring Creek only through the summer months when temperatures in the Okanogan River are too warm to ensure survival. As main stem temperatures decline in the fall, the fish would be forced into the Okanogan River by incrementally reducing flows along the lower reach of the Creek.

1.3 Summary of Findings

Wildhorse Spring Creek is a snow melt dominated stream with perennial flows at Cordell Road varying from over 10 cfs (4,488 gpm) during the spring freshet to less than 0.02 cfs (10 gpm) during the late summer, fall and winter. The lower ¾-mile of the stream is accessible to anadromous fish from the Okanogan River to a natural fish barrier formed by steep bedrock cliffs. The lower portion of the Creek is intermittent and is generally dry from approximately July/August through April. The wetted length of the Creek varies in response to precipitation events, but some flow during the study period was consistently observed to about 900 feet downstream of Cordell Road.

Mini-piezometer data and seepage measurements along the lower, seasonally dry portion of the Creek indicate losses to the groundwater system at a rate of 0.00002 cfs/ft to 0.0001 cfs/ft (0.01 gpm/ft to 0.04 gpm/ft) of stream length. A flow of at least 0.25 cfs (110 gpm) at Cordell Road would be necessary to overcome these seepage losses, maintain flow to the Okanogan River confluence and provide habitat in the lowest reaches. The upper portion of the Creek above Cordell Road is predominantly gaining from groundwater, although some stream flow losses to the bank storage were noted during spring freshet high flows. The Creek was noted as being “detached” from the groundwater table (i.e., unsaturated conditions occurred between the Creek and the water table) during winter and fall near Cordell Road.

A 1-day pump test of a shallow, dug well (26C01) on August 31-September 1, 2011 indicated an aquifer transmissivity of about 1050 ft^2/day (7,900 gallons per day/foot [gpd/ft]) .The pump test was run at about 15 gpm and the increase in the wetted length of the Creek varied from about 350 feet to 590 feet. The variation in the wetted length of the Creek occurred in response to evapotranspiration-driven, diurnal variations in flow. Measured water quality parameters (dissolved oxygen, pH, and temperature) were within the criteria for steelhead habitat during the test.

[1] Stream flow units are typically expressed in cfs and gpm throughout this report because discharge volumes during low flow are very small and to maintain consistency with units used to express discharge from a well.

Four alternatives were evaluated for stream flow augmentation:

1. Groundwater pumping from a well.
2. Artificial recharge to groundwater.
3. Enhancing springs.
4. Surface water storage.

Stream flow augmentation from a new well sited near Cordell Road is the preferred alternative. This alternative simplifies land access issues by potentially having the well and piping on the same property. While well yields are potentially lower than a well location downstream of Cordell Road, the low cost of implementing this option off-sets the risk of a low yielding well. The well should be located at least 100 feet from the Creek to minimize hydraulic continuity. The distance between the pumping well and any existing wells should be maximized to minimize the risk of impairment. We recommend field locating all wells within about a ¼-mile of the Creek to facilitate well siting and water right permitting. If well yield is not adequate to provide the estimated 110 gpm required to extend habitat to the Okanogan River, we recommend installing a second well in the lower reach. Planning level cost for the single well alternative is estimated at $110,000 and for the two-well alternative is estimated at $175,000.

Hydrological and geological data examined in this study indicate water supplies could support surface water storage of about 1/5 of the 110 gpm target flow, but an additional feasibility study is required to quantify runoff and storage in the Summit Lake subbasin. Artificial recharge from an Okanogan-Tonasket Irrigation District (OTID) water source was considered a viable alternative, but would also require additional study. Enhancing springs was qualitatively assessed and determined to be infeasible due to limited groundwater resources in the watershed.

2 Hydrology

2.1 Basin Description

The Creek watershed occupies 4,000 acres of the western slope of Mount Hull, located west of Highway 97 between Tonasket and Oroville (Figure 1). The Creek flows in two branches that combine in the lower 1-mile of the Creek, near the base of high cliffs, separating the upper and lower portions of the watershed. The north branch originates at Summit Lake, the only lake in the watershed. Two named springs (Tamarack and Wildhorse) feed the south branch. Fish passage is restricted in both channels by waterfalls located just upstream of their confluence ¾-mile above the Okanogan River (Arterburn et al., 2007). CCT AFP has determined this small Creek has potential for steelhead in most years, provided water is available.

The upper portion of the watershed is characterized by shallow soils and exposed bedrock. Vegetation in the upper watershed is dominantly coniferous forest and land use is forestry. Land ownership is primarily United States Forest Service and Bureau of Land Management. The lower portion of the Creek flows across a terrace comprised of glacial sediments for approximately 1-mile before draining into the Okanogan River, west of Highway 97. Stream flow losses to groundwater occur along this reach. Native vegetation is grassland and shrub steppe that has been replaced in many places by dry and irrigated pasture. Land use in the lower reach of the Creek is agricultural with irrigation water supplied by Oroville-Tonasket Irrigation District and sourced in the Okanogan River.

Average annual precipitation ranges from 13 inches in the lower watershed to 20 inches in the upper watershed at Summit Lake (Figure 1). Most precipitation falls in winter months as snow. Precipitation is rare during summer months.

Surface water storage in the Wildhorse Spring Creek basin is primarily limited to Summit Lake in the upper watershed. A small earthen berm has been constructed at the lake outlet, raising the lake level several feet over the natural impoundment. Much of the water in Summit Lake drains out by mid-summer. Several small bedrock depressions (tarns) provide some natural surface water storage (Figure 1).

2.2 Stream Flow

2.2.1 Gauging

Data collected in the lower ¾-mile of the Creek from Fall 2010 through December 2011 were used to characterize stream flow patterns. No stream flow data are known to have been collected for the Creek prior to this study. Three staff gauges were installed in the section of the lower reach where anecdotal information and observations of low flow in Fall 2010 indicated a good probability of perennial flows (locations shown in Figure 2). Staff A is located near the downstream extent of perennial flow, Staff B is located just upstream of Cordell Road, and Staff C is located near the upstream extent of the fish passable reach, just downstream from the confluence of the two branches. A pressure/temperature transducer datalogger was installed for continuous recordings at

Staff B, beginning in March 2011. One manual measurement was taken at Staff B in November 2010 prior to starting the study and approximately 25 manual measurements were taken during the study at all three gauges from February through November 2011. Several stream flow measurements were also taken during a pumping test performed on August 31 and September 1, 2011.

Stage height and flow data were used to develop rating curves for each staff gauge (Appendix A). Flows were measured using flow velocity meter and volumetric methods during low flows. Results of stream flow monitoring are shown in Table 1. Figure 3 shows a hydrograph at Staff B for the period March through November 2011. Flows in the upper watershed (non-fish passable reach) were not evaluated.

2.2.2 Stream Flow Hydrograph

Seasonal stream flow patterns in the lower reach are indicative of a snowpack dominated watershed having limited groundwater storage to sustain baseflows throughout the year. The hydrograph at Staff B (Figure 3) shows peak flows occur during spring freshet and drop off after snow melt has peaked. Available groundwater storage sustains baseflows in the perennial reach (represented by a relatively flat hydrograph for the remainder of the year, except when substantial precipitation events occur). Some portion of low flows might be sustained by surface water stored in Summit Lake. The flashy nature of the watershed is attributed to vast areas of shallow soils or exposed bedrock in the upper watershed.

In 2011, peak flows representing the spring freshet began about April 1 and continued through the first week of July as snowpack melted off. Examination of stream flow hydrographs since 2003 for nearby Bonaparte and Tunk Creeks indicates the unusually cool spring and high snow pack of 2011 delayed the freshet by about 4 weeks with peak flows that were two to three times higher than normal in those basins. Peak flow from transducer data at Staff B (Figure 3) was 10.14 cfs (4,550 gpm) on May 26, which is likely 2 to 4 weeks later than the normal freshet peak. Average flow from the transducer data at Staff B during Spring 2011 freshet is estimated to be 4.80 cfs (2,154 gpm). Spot measurements at Staff C indicate peak flow was measured at 9.85 cfs (4,420 gpm) on May 27, 2011.

Average baseflow measured at Staff B is estimated to be about 0.06 cfs (27 gpm). Baseflow was indicated by the relatively constant stream flow volumes that began in the last week of August. Baseflow declined in response to falling groundwater levels and the lowest flow measured at Staff B was 0.02 cfs (10 gpm) on August 30. On several occasions during the summer, flows at Staff A and C were too low to measure. Stream flow began to increase beginning in November in response to fall precipitation. Average stream flow at Staff B, during times other than the freshet, is 0.14 cfs (62 gpm).

A diurnal flow pattern was observed during late summer and early fall when the Creek is controlled by baseflow. The diurnal pattern is characterized by flows that increase throughout the night, peaking in late morning and decrease throughout the day. This diurnal flow fluctuation is most apparent in the hydrograph at Staff B, during the low flow conditions of early August and continuing through mid-September (Figure 3). Flow measurements taken at all three gauges during the period of August 30 through September 1 indicate the diurnal fluctuation equals 0.02 cfs (10 gpm), or about 1/3 to 1/2 of baseflow. These fluctuations are attributed to daytime transpiration by phreatic riparian vegetation. Periods of significant snow melt and other surface runoff mask these diurnal fluctuations that are a function of groundwater discharge.

Flow in the lower reach of the Creek extends to the Okanogan River only when sufficiently high to overcome losses to groundwater, typically during the spring freshet (see Section 2.5). For the remainder of the year and barring substantial precipitation events, water in the lower reach is confined to a perennial section that extends down to about Staff A (Figure 2). During baseflow conditions, the terminus of flow was consistently observed to be located approximately 2,000 feet upstream of the confluence with the Okanogan River (900 feet downstream of Cordell Road). Backwater flooding from the Okanogan River occurs in the bottom 500-600 feet of the Creek during high river stages. Anecdotal accounts from local residents and spot observations indicated stream flow resumes in the lowest 500 feet of the Creek during baseflow conditions in some years.

Water Quality

Ambient water quality measured in the Creek was generally found to be suitable for juvenile steelhead rearing and generally met the project water quality objectives. These data are summarized below in Table 2. These data were collected during baseflow conditions on August 31, 2011, except temperature at Staff B which was continuously recorded from March through November 2011 and temperature near the mouth of the Creek that was measured in Summer 2007. Temperature was found to be below the project objective in early March (Table 2). Data collected by CCT AFP near the mouth of the Creek between the Highway 97 and railroad bridges indicate temperatures in the lowest section of the Creek remained at 57 degrees F throughout the summer months (Arterburn, et al., 2007). Specific conductance was at a maximum of 440 μS between Stations P-5 and P-6 consistent with inflow of higher conductivity groundwater along this reach. pH and dissolved oxygen were found to be within project objectives.

2.3 Geologic Conditions

The geologic setting of the Wildhorse Spring Creek vicinity is characterized by bedrock uplands overlain by unconsolidated sediments in the Okanogan River valley. The principal geologic units from a 1:100,000 scale map compilation from Washington Department of Natural Resources are presented in Figure 4. The relatively flat valley bottom has an elevation of approximately 900 feet and is comprised primarily of alluvium. Glacial deposits form gently sloping terraces on the valley margins to elevations of approximately 1,150 feet. The glacial terraces terminate abruptly on the eastern margin of the valley where they abut steep bedrock cliffs forming base of Mount Hull, to the east. Bedrock outcrops on Mount Hull exceed elevations of 4,600 feet.

Alluvium consisting of layered silt, clay, and sand and gravel was deposited across the Okanogan River floodplain in the period following retreat of the glacial ice sheet as the river incised underlying glacial deposits. These deposits are primarily limited to the lowermost reach of the Creek near its confluence with the Okanogan River.

Glacial deposits consisting primarily of fine sand, silt, and layers of clay and coarse sand and gravel were deposited by the Okanogan lobe of the Cordilleran continental glacial ice sheet, approximately 10,000 to 12,000 years ago. Following glacial ice retreat, the Okanogan River incised glacial sediments occupying the entire valley leaving behind remnant glacial terraces along the valley margins. The lower ¾-mile of the Creek comprising the area of interest for this project is located on a glacial terrace. The Creek has incised a straight, gently-rounded channel into the glacial terrace that narrows and deepens upstream to a depth of approximately 50 feet. Well log data indicate glacial drift thickens with distance from the valley margin. Glacial drift is underlain by bedrock at depths just below ground surface, east of Cordell Road to over 440 feet about ¼-mile north of the Creek along Highway 97.

Bedrock forming the glacially-overridden Mount Hull to the east is primarily mapped as crystalline metamorphic and intrusive rocks with banded gneiss mapped at the cliffs east of the project area. These rocks have little or no intrinsic permeability and yield water from secondary fractures. Bedrock is mantled in places by thin glacial deposits primarily concentrated in drainage bottoms and depressions on the bedrock surface. As stated above, depth to bedrock increases toward the valley bottom.

2.4 Hydrostratigraphic Units and Aquifers

A hydrostratigraphic unit is a geologic unit or collection of geologic units that exhibit similar hydraulic characteristics. Examination of well data obtained from Ecology's well database indicates two principal hydrostratigraphic units in the Creek vicinity:

- Glacial Drift Aquifer
- Bedrock Aquifer

Well logs for the Creek vicinity are contained in Appendix B. Well locations are presented on Figure 5 with the locational accuracy.

Glacial Drift Aquifer

The glacial drift aquifer represents the most important groundwater resource in the Creek vicinity. This aquifer generally consists of glacial outwash deposits comprised of sand and gravels. Locally, layers of silt and clay form aquitards at varying depths within the glacial drift aquifer. Generally, the glacial aquifer tends to be more productive in close proximity to the Okanogan River, where available well log data indicate the aquifer is predominantly a sand gravel mixture. The aquifer fines to the east, away from the Okanogan River and wells appear to be less productive with increasing distance from the river.

Three wells (26E01, 26E02, 26E03) located near O'Niel Road and close to the Okanogan River are completed in water-bearing sand and gravel units at depths from 30 to 90 feet. Yields are good ranging from 15 to 150 gpm with one well showing no drawdown at a pumping rate of 50 gpm. These wells likely have higher continuity with the river which could provide a long-term recharge source for the wells.

Most wells completed in the middle portion of the glacial terrace, about mid-way between the Okanogan River and the mountain front have well yields of about 15 gpm to 20 gpm and specific capacities of about 1.0. These wells are typically completed in fine sand and silty sand aquifer with most wells in the 80- to 90-foot depth range, but one well completed at a depth of 257 feet suggesting the aquifer is not uniformly present throughout the area (26F03). One well (26C03) reported a yield of 40 gpm with 4 feet of drawdown.

A replacement well recently installed by the Tribe near the Creek and close to the mountain front, encountered bedrock at a depth of 108 feet and was completed within bedrock from 160 to 206 feet (26B01). The overlying sediments were predominantly non-water bearing, clay, and clay gravel mixtures suggesting alluvial fan deposition near the mountain front.

Most wells in the project vicinity are completed in the glacial drift at depths 100 feet or less. Three dug wells are located in close proximity to the Creek that likely draw water from the glacial drift aquifer. Well 26C01 is completed at 26 feet below ground surface (bgs) and is located approximately 50 feet from the Creek. This well was pump-tested as part of this investigation as discussed in Section 2.6. Two unused shallow dug wells, 26B02 and 26C04,were identified within about 20 feet of the Creek and are likely in hydraulic continuity with the Creek.

Bedrock Aquifer

A bedrock aquifer is present beneath glacial deposits in the lower watershed at depths over 100 feet and deeper than 257 feet in places. Bedrock depth increases to the west. Wells completed in bedrock are located on the eastern margin of the glacial terrace where glacial deposits thin or bedrock lies just below the ground surface, for example Well 26B01. The bedrock aquifer presents a limited groundwater resource with one well (26B01) completed in bedrock which yields about 5 gpm.

In the upper watershed above the fish passable reach of the Creek, crystalline bedrock that outcrops or is mantled by thin glacial deposits in most places presents limited opportunity for groundwater recharge from precipitation and groundwater storage. Much of the groundwater in storage in the upper watershed resides in glacial deposits that are observed to be thin nearly everywhere except in some drainage bottoms and depressions in the bedrock surface. Groundwater stored in the upper watershed provides baseflow to the Creek through summer and early fall.

2.5 Groundwater Flow

2.5.1 Surface Water/Groundwater Interactions

Groundwater and surface water interactions were evaluated to quantify flow losses along the Creek and determine the quantity of project water required to reconnect the Creek to the Okanogan River. In addition, these interactions were also evaluated to determine if the stream flow could be affected by pumping from a flow augmentation well.

Groundwater and surface water are generally described as either losing, gaining or detached. If the surface water level is higher than groundwater level, the stream is in a losing condition. Conversely, if the groundwater level is higher than the surface water level, then the stream is gaining groundwater from the groundwater system. An unsaturated zone may exist between the groundwater and surface water indicating a stream that is disconnected from the groundwater system (Winter et al., 1998). A well completed in hydraulic continuity with the Creek would reduce stream flows, effectively recycling surface water that is drawn into the ground and toward the well. Under a detached condition, a stream loses to groundwater, however, seepage from the streambed is not controlled by depth to groundwater. Thus, pumping from a well adjacent to a detached stream would not increase seepage losses.

The interaction of surface water and groundwater was investigated through the use of seepage runs (measuring stream flow in the upstream and downstream reach of the Creek and computing the relative difference in flow), the installation of mini-piezometers, and temperature and specific conductance measurements collected prior to and during the pumping test at Well 26C01.

Losses from the Creek to groundwater result in the lower reach of the Creek going dry for most of the year. The losing characteristic of the lower Creek reach is similar to many tributaries to the Okanogan River. These creeks experience their greatest losses to groundwater in the lower most reaches where they traverse glacial and alluvial deposits that coarsen toward the river (Sumioka and Dinicola, 2009). Such stream flow losses have been observed at Antoine and Tonasket Creeks, where low or no flow conditions occur near their confluence with the Okanogan River. Wildhorse Spring Creek presents characteristics similar to these tributaries, including an upper watershed dominated by exposed bedrock and shallow soils having limited groundwater storage capacity and a lower reach that traverses coarse deposits where losses to groundwater are accelerated.

Water levels in shallow groundwater were monitored in seven mini-piezometers (P-1 through P-7) installed in February 2011 to evaluate the losing and gaining characteristics of the stream. The mini-piezometer locations are presented on Figure 2. The mini-piezometers (piezometers) are constructed of 1-inch steel pipe driven into the ground so that the middle of the screened interval lies 6 feet bgs.

Water levels in mini-piezometers were compared to water levels in the Creek to determine a vertical hydraulic gradient (Table 3). Conditions where surface water is losing to groundwater are indicated by a negative hydraulic gradient and vice versa. Detached conditions are assumed to exist when the shallow groundwater table is deeper than the screened interval of the mini-piezometers (i.e., piezometer is dry). However, detached conditions may also exist when the water table lies above the bottom of the piezometer but several feet below the stream bottom. Table 3 includes dates when detached conditions were judged to be present based on about 3 feet of vertical separation between the streambed and underlying water table.

Multiple lines of evidence are preferable when characterizing losing/gaining characteristics of a stream to reduce reliance on any single measurement. In addition to the hydraulic gradients at the mini-piezometers, gaining and losing reaches were identified by examining differences in stream flow between stations (seepage runs) and water quality data. Results of the surface water/groundwater characterization are summarized in Table 4.

2.5.1.1 Above Cordell Road

As a whole, the reach upstream of Cordell Road displays gaining characteristics except during the spring freshet as evidenced by seepage runs, a consistently positive hydraulic gradient at P-6, and specific conductance that increases downstream (between P-6 and

P-5). During baseflow conditions, measured stream flow at Staff C was less than downstream Staff B by an average of 0.04 cfs (18 gpm). Increased flow at Staff B is attributed to gains from groundwater (gaining reach). Mini-piezometer P-6 consistently indicated a positive hydraulic gradient (gaining from groundwater) after the spring freshet with the strongest upward gradient occurring in early October. Within this reach, contributions from groundwater are likely concentrated in a short segment of the stream near P-6 that likely play an important role in sustaining perennial flows above Cordell Road. During the spring freshet, the Staff C to Staff B reach was near neutral to losing to groundwater, in response to loss of high flows to bank storage.

2.5.1.2 Below Cordell Road

During baseflow conditions, the reach downstream of Cordell Road displays losing characteristics as evidenced by discharge measurements that are lower at Staff A than at upstream Staff B, strongly negative hydraulic gradients in P-1 through P-5 and a terminus of flow that is located approximately 2,000 feet above the confluence with Okanogan River (900 feet below Cordell Road). Discharge measured during baseflow conditions was lower at Staff A than upstream at Staff B by an average of 0.02 cfs (9 gpm). This difference is attributed to losses to groundwater between these stations (losing reach). The predominance of negative hydraulic gradients in the mini-piezometers along lower reach of the Creek is consistent with the observation that much of the lower Creek runs dry after spring freshet and is consistent with conditions in other Okanogan River tributaries.

A transition from a losing condition to a neutral to slightly gaining condition occurs between Staff A and Staff B during the spring freshet. Discharge measured on two of three occasions during the spring freshet was higher at Staff A than Staff B (0.95 cfs on 4/15/11 and 0.50 cfs on 5/27/11) indicating groundwater input. The mini-piezometer data at P-1 are consistent with this increase in flow. The downward vertical gradient at P-1 diminished from April through June indicating a transition from a losing condition to a neutral to slightly gaining condition in June and July (Table 3). The increase in flow along this reach is attributed to shallow interflow and loss of bank storage following spring freshet. Other piezometers (P-2, P-3, and P-4) in the lower reach showed a downward vertical gradient during the spring freshet, although the gradient was typically significantly less than during baseflow conditions. The downward vertical gradient during periods of groundwater gain to stream flow is not fully understood, but suggests interflow discharging to the creek is from the uppermost soils.

A detached condition was indicated at P-5 in February and March and again in November. Piezometer P-5 was dry or nearly dry at these times, although water was flowing in the overlying Creek, indicating unsaturated conditions are present between the stream and the water table. A detached condition was also indicated in March, August and November at piezometer P-2 and in March at P-4. Water levels in piezometers P-1, P-2, P-4, and P-5 trended downward following the spring freshet to near the bottom of the piezometers. The detached condition appears to predominate during baseflow conditions. Water levels at piezometer P-3 indicated the piezometer was dry following spring freshet, however, two measurements taken in November suggest a slight increase in the height of the groundwater table. Additional monitoring at P-3 is required to characterize groundwater trends at this location.

2.5.1.3 Seepage Rates

Seepage rates in the losing reach below Cordell Road were estimated using two methods. First, differences in discharge along the losing reach between Staff A and Staff B were compared. The distance between these stations along the stream channel is 890 feet. The average seepage rate calculated from measurements taken during baseflow conditions from late August through the beginning of November is 0.00002 cfs/ft (0.01 gpm/ft) of stream length. Second, discharge measured at Staff B during the pumping test when groundwater was used to augment stream flow was compared to the distance from Staff B to the terminus of flow resulting from flow augmentation. A seepage rate of 0.0001 cfs/ft (0.04 gpm/ft) of stream length was estimated. Results suggest seepage rates are higher below Staff A than between Staff A and Staff B. The average seepage rate from Staff B downstream to the confluence with the Okanogan River is therefore estimated to be 0.00006 cfs/ft (0.03 gpm/ft) of stream length.

2.5.2 Recharge and Discharge

Recharge to the glacial drift aquifer is primarily from the east where surface water running off the western slope of Mount Hull infiltrates glacial deposits at the foot of the large cliffs forming the base of the mountain. Other sources of recharge to the glacial drift aquifer include discharge from bedrock at the base of Mount Hull, infiltration of precipitation on the surface of the glacial terrace, infiltration from water applied to irrigated lands and losing reaches of the Creek. The general direction of groundwater flow is to the west, toward the Okanogan River. Hydraulic head in the glacial drift aquifer decreases toward the river (about 40 feet above the river at well 26C01) from near the eastern margin of the glacial terrace. The lower portion of the aquifer is likely in hydraulic continuity with the river and groundwater flow directions in the lower portion are likely subparallel to the south flowing river. The groundwater elevation data suggest the glacial drift aquifer discharges into the Okanogan River that likely comprises a natural regional discharge zone. Some water from the glacial drift aquifer discharges to the perennial reach of the Creek, as discussed above, but infiltrates below Cordell Road.

Bedrock in the lower watershed underlies glacial drift at various depths. Few wells in the project area are completed in bedrock and the relative head difference between the bedrock aquifer and the glacial drift aquifer is unknown. Recharge to the bedrock aquifer is likely dominated by spring snow melt and concentrated along fractures where bedrock outcrops. Lesser amounts of recharge occur from fall rain and snow melt. Groundwater in the bedrock likely upwells beneath the valley floor to discharge into the Okanogan River.

2.6 Well Test Results

Introduction

A hydraulic test or pumping test was conducted on August 31 through September 1, 2011 on an existing 48-inch diameter, 26 foot-deep dug well (26C01) to assess the feasibility of using groundwater pumped from a well to augment stream flow lower in the Creek. This field test had the following specific objectives:

- Measure aquifer performance and quantify aquifer hydraulic properties;
- Measure well performance and determine the feasibility of using existing Well 26C01 for flow augmentation;
- Assess the nature of the groundwater to surface water connection and determine if pumping will reduce baseflow in the stream;
- Determine whether groundwater pumped to the Creek meets the critical water quality criteria for the targeted species; and
- Assess the benefit of flow augmentation to the Creek; specifically observe the increase in wetted length resulting from additional flow provided by pumped groundwater.

The pumping test and associated groundwater and surface water monitoring were performed using methodology outlined in the pumping test work plan (Appendix C). General steps included the following:

- Monitoring of ambient surface water and groundwater conditions 1 day and a few hours prior to the test start;
- A step-rate pumping test to determine the optimal pumping rate for the constant-rate pumping test;
- A constant-rate pumping test; and
- Surface water and groundwater monitoring throughout the test including stream flow measurements, water levels in mini-piezometers, water levels in a pumping well using a pressure transducer datalogger and manual measurements, periodic manual water level measurements in two nearby wells, and water quality parameters in surface water and in the pumping well. Water levels in the pumping well were monitored until the well had nearly recovered.

Fogle Pump and Supply, Inc. was contracted to set up and monitor the pump and flow rates, electrical generator, and discharge piping. Groundwater pumped from the well was discharged into an energy dissipater constructed of perforated PVC pipe placed in the streambed 100 feet upstream of the well and P-5.

The step-rate pumping test proceeded at 30 gpm for 30 minutes before increasing discharge to 60 gpm. Within 15 minutes of increasing discharge, the test was terminated when the pump lost suction. Following recovery, the constant-rate pumping test was run at a rate of 15 gpm for a 23-hour period. The residents depended on the well for water supply, but minimized use during the test; however, there were some unavoidable pumping rate variations during the test as a result of the domestic use. At the initiation of the constant rate test, a rupture in the water supply line to the residence was noted, the test terminated, and the test restarted with the concurrence of the well owner.

Well Test Results

The pumping test yielded information regarding aquifer properties, well construction, groundwater continuity with the Creek, and potential benefits of using pumped groundwater to augment stream flow. Drawdown and recovery curves recorded during the test are presented in Appendix D.

Surface Water/ Groundwater Continuity

An assessment was made of the degree of continuity between the Creek and the pumping Well 26C01. The well is located about 50 feet from the Creek (Figure 2). A well in close continuity with a stream has the potential to “recycle” surface water offsetting the benefit of flow augmentation. There was no evidence that suggested an impact on stream flows during the duration of the pump test; however, drawdown in a mini-piezometer adjacent to the Creek suggests that long-term continuous pumping from this well may impact stream flows.

Other than changes in flow related to diurnal fluctuations, stream flow was consistent throughout the test indicating that water was not being recycled during the test. Groundwater temperatures in the well remained the same throughout the test at 56.4 degrees F, about 1 degree higher than ambient stream temperature, suggesting limited continuity between the well and stream during the pump test. Specific conductance measurements also indicate limited continuity between the well and the stream. Specific conductance measured throughout the test in the Creek, immediately upstream of the discharge location, ranged from 347 µS to 440 µS, while specific conductance in the well was a fairly constant at 390 µS.

Piezometer P-5 is located between the pumping well and the Creek. Prior to beginning the test, the depth of water measured to a common datum in P-5 was 4.45 feet compared to 4.75 feet in Well 26C01, indicating that groundwater under ambient conditions flows away from the Creek toward the well. Piezometer P-5 is seasonally detached from the water table, but at the time of the pump test was apparently continuously saturated. Water levels in P-5 decreased by 0.25 feet over the duration of the pumping test and had nearly recovered the day following the pumping test. During the test, water levels in other mini-piezometers remained about the same or showed no consistent trend. No diurnal pattern in shallow groundwater levels was observed and the observed decline in P-5 is attributed to pumping from Well 26C01.

The drawdown observed at P-5 during the test indicates that Well 26C01 potentially has some continuity with the stream, although the test was of insufficient duration to observe any effects on stream flow or groundwater quality parameters. With long-term pumping, well 26C01 may have an effect on stream flows.

Aquifer and Well Properties

Important properties of the aquifer and existing Well 26C01were derived from the pumping test. These include aquifer transmissivity, specific capacity of the well, available drawdown in the well, and predicted yield for the existing well and a new well.

Transmissivity (T) provides a means to estimate the yield of an aquifer that can be used to estimate well yield. It is defined as the volume of water flowing through a cross sectional area of the aquifer measuring 1-foot for a given time period, usually 1 day. Units of transmissivity reported here are in feet squared per day (ft^2/day). The drawdown of groundwater in the well measured in the pumping well during the constant-rate pumping test was plotted and used to estimate transmissivity by the Jacob Straight Line Method (Appendix D). The recovery of groundwater measured in the pumping well after the pump was shut off at the conclusion of the constant-rate pumping test was plotted and used to estimate apparent transmissivity by Jacob Method (Appendix D). Estimates for apparent transmissivity using these methods range from 440 ft^2/day to 1,050 ft^2/day. The apparent transmissivity of 1,050 ft^2/day is considered more reliable as the log cycle trend line captures almost a 12-hour period during the pumping test.

Specific capacity (Sc) provides a means to estimate well yield. It is defined as the well production per unit decline in head. Units for specific capacity are noted in gallons per minute per foot of drawdown (gpm/ft). Specific capacity for the pumping well (Well26C01) is estimated to be 3.9 gpm/ft.

Available drawdown in Well 26C01 estimated based on static water level of 9 feet and pump setting of 22 feet is about 10 feet allowing for 3 feet of pump submergence. Predicted long-term yield from Well 26C01 is limited by well construction to 15 gpm to 20 gpm.

Well Yield Estimates

Drilled wells in the area indicate a significantly thicker aquifer than indicated by the well depth at 26C01 and greater available drawdown. Based on review of nearby well logs, aquifer thickness is estimated to be at least 40 feet. However, Well 26F03 is completed at a depth of 257 feet, suggesting the shallow glacial drift aquifer was not present at the shallower depths and is, therefore, laterally discontinuous in places.

Available drawdown is expected to increase closer to the Okanogan River, as static water levels are higher. For an 80-foot deep well, available drawdown is estimated to range from 40 feet near Cordell Road, based on Wells 26C02 (23 feet available drawdown), 26F01 (50 feet available drawdown) and 26F02 (66 feet available drawdown), to about 80 feet in the lowermost reach near Highway 97, based on Well 26E03 (available drawdown of 79 feet).

Yields for a new well were estimated based on aquifer properties derived from pumping test results and available well log data for nearby wells. A well drilled to a depth of 80 feet in the lowermost reach is estimated to yield between 50 and 100 gpm, based on existing wells. High specific capacities in this area suggest yields greater than 100 gpm may be possible. Well yields near Cordell Road are lower, typically ranging from 20 to 40 gpm. Theoretical yield from a properly constructed, efficient well in the Cordell Road area is estimated at 80 gpm, assuming the apparent aquifer transmissivity measured during the pump test of 26C01 and estimated aquifer thickness prevail at the well site.

Any new wells drilled as part of the project should be located to maximize separation from any existing well to minimize impacts from well interference. Using the apparent transmissivity from the pump test of 1,050 ft^2/day, an assumed storage coefficient of 0.2, a 110 gpm pumping rate and a 9 month pumping period, a drawdown of about 5 feet is estimated at a distance of 400 feet. Boundary conditions and variations in aquifer hydraulic characteristics will affect this estimate. The potential for impairment is likely less in close proximity to the Okanogan River as it would likely act as a recharge boundary stabilizing drawdown levels. Near Cordell Road, there is less potential for a recharge boundary and, therefore, greater potential for impact on existing wells. A new well located near Cordell Road should be located several hundred feet from existing Well 26C01 to avoid impairment of the well in consideration of its shallow depth and limited available drawdown. Alternatives for siting new wells are discussed in Section 3.1 and Section 4.

Water Quality

Water quality parameters measured in Well 26C01 and the Creek throughout the pumping test meet criteria for the targeted species. The test cooled water in the Creek, about 1 degree F, and resulted in a slight depression of dissolved oxygen at Staff B (Table 5). Groundwater temperature averaged 56.4 degrees and remained steady throughout the pumping test. Stream water temperature at Staff B averaged 59.6 degrees in the 3 days prior to the test and decreased to 58.3 degrees during the test. Water temperature measured upstream of the discharge location varied diurnally by 1.5 degrees during the pumping test. Groundwater augmentation to the Creek lowered the surface water temperature by 1 degree at Staff B, about 200 feet downstream of the discharge location.

Dissolved oxygen measured in groundwater averaged 7.1 mg/L. Dissolved oxygen measured in the Creek at Staff B prior to the pumping test was 10.9 mg/L. During the pumping test, average dissolved oxygen measured at Staff B was 9.9 mg/L.

Observed pH in groundwater (7.4) was consistent with pH measured in the Creek prior to the test. Mixing of higher conductance groundwater with surface water resulted in a slight increase in specific conductance in the Creek. Specific conductance in groundwater from the well averaged 390 µS and remained steady throughout the pumping test. Specific conductance measured in the Creek at Staff B prior to the start of the pumping test was 368 µS. Average specific conductance measured at Staff B during the test was 392 µS. The highest specific conductance measured in the Creek occurred prior to the start of the test (440 µS at P-5).

Flow augmentation from groundwater resulted in little change to surface water quality and water chemistry with all parameters within project objectives. The energy dissipater worked well in controlling erosion of the streambed with no erosion during the test.

Wetted Length

The effect of flow augmentation on extending the wetted length of the Creek was observed throughout the pumping test. Prior to the test flow at Staff B ranged from 0.02 cfs to 0.04 cfs (9 gpm-18 gpm). During the pumping test, discharge at Staff B ranged from 0.07 cfs to 0.09 cfs (31 gpm-42 gpm). Following termination of pumping, stream flow was observed to decline back to 0.02 to 0.04 cfs. The observed increase in flow during the pumping test is predominantly attributed to the 15 gpm flow augmentation with the balance attributed to diurnal fluctuations estimated at 0.02 cfs (10 gpm; see *Section 2.2*, *Stream Flow*). Flow augmentation of 15 gpm was observed to extend the wetted length of the Creek beyond the ambient terminus of flow between 350 feet and 590 feet; the difference being attributed to changes in diurnal flows.

Potential increases to the wetted length of the Creek over baseflow conditions, assuming a seepage rate of 0.00006 cfs/foot (0.03 gpm/ft) of stream length and a discharge location at P-5, were examined for several flow augmentation discharge rates. A flow augmentation discharge rate of 0.03-0.05 cfs (15-20 gpm) is estimated to extend the wetted length by 500 feet to 700 feet. A flow augmentation discharge rate of at least 0.13 cfs (60 gpm) at P-5 is estimated to be required to extend flow to the Okanogan River, a distance of approximately 2,000 feet. The estimated minimum augmentation flow of 0.13 cfs (60 gpm) required to extend wetted length to the river is consistent with field observations at Piezometer P-1 that indicate the Creek went dry between 7/26/11 and 8/8/11, when measured flows at Staff B decreased from 0.15 cfs (67 gpm) to 0.11 cfs (49 gpm), respectively. However, a higher flow augmentation rate is required to enhance habitat in the lower reach as discussed in Section 3.

3 Conceptual Alternatives for Enhancing Flows

Alternatives evaluated for enhancing flows in the lower Creek are described below. These alternatives are as follows:

- Flow augmentation from a groundwater source;
- Artificial recharge to the aquifer to enhance groundwater discharge to creek;
- Enhancement of existing natural springs in the upper watershed; and,
- Surface water storage in the upper watershed.

Alternatives are shown schematically on Figure 6 and summarized in Table 6. The Tribe indicated a preference for using groundwater to augment stream flow in the lower Creek using an existing well and, therefore, alternatives for developing a pumped groundwater source were evaluated in greater detail than other alternatives.

Enhancing flows in the lower reach of the Creek could increase available habitat for rearing of juvenile steelhead under baseflow conditions (July through March) by extending the wetted length of the Creek downstream of the limit of perennial flow (Figure 2). Flow enhancement could also improve existing habitat within the perennial reach during baseflow conditions.

The estimated minimum flow augmentation volume required to provide substantial benefit to targeted species ranges from 0.05 cfs (20 gpm) to 0.13 cfs (60 gpm). The lower end of this range is based on observations of the existing condition which support steelhead smolts. Assuming flow augmentation discharge to the Creek would occur in the perennial reach near P-5, a discharge rate of 20 gpm would extend the wetted length of the Creek beyond the terminus of flow occurring under baseflow conditions by approximately 700 feet. Flow augmentation of 0.13 cfs (60 gpm) would extend wetted length by 2,000 feet and would reach the Okanogan River, assuming there is some water input to the lowest several hundred feet of the Creek as discussed in Section 2.2.2. At least an additional 20 gpm, above the 60 gpm, should be considered to generate habitat similar to that at Cordell Road, during low flow conditions in the most downstream reach.

An approximate 50% safety factor should be included in the target flow as seepage rates downstream of Staff A may be higher than estimated and water input may not be reliable from year-to-year in the lowermost several hundred feet. The target flow is, therefore, considered to be 0.25 cfs (110 gpm) (20+(60*1.5)). While identifying a water source capable of yielding 110 gpm is optimal, it is recognized that any appreciable flow augmentation will significantly increase wetted length for habitat and augmented flows as little as 0.13 cfs (60 gpm) may be sufficient to extend some flow to the river.

In the interest of minimizing operational costs, CCT AFP staff indicated it might be preferable to suspend flow augmentation in the fall. A pilot project with biologic monitoring would be necessary to evaluate the best method for suspending flow. One option is to slowly dry up the middle reach by progressively closing discharge points to force fish into the main stem or into the upper, perennial reach. Alternatively, if biologic monitoring indicates all fish migrate into the Okanogan as mainstem temperatures cool, then it may be possible to simply suspend flow at a discharge point near Cordell Road.

3.1 Flow Augmentation from Groundwater Sources

Using groundwater to augment stream flow involves pumping cool groundwater to the Creek from an existing or new well. Groundwater pumped from a well would ideally be discharged into the perennial reach of the Creek to improve existing habitat and create new habitat in the downstream, intermittent reach. Alternatives involving groundwater pumped from wells require a water right permit that is assumed to be attainable under the Hillis Rule. Under Hillis Rule, Washington Administrative Code (WAC) 173-152-050(3b), if the water right application is for a proposed water use that is nonconsumptive or with mitigation would be water budget neutral and, if approved would substantially enhance or protect the quality of the natural environment, then it qualifies for expedited processing.

3.1.1 Alternative A: Single Well Source

Three alternatives were evaluated for pumping from a single well source including an existing well, a new well near Cordell Road, and a new well closer to Highway 97. Predicted yields for these wells are discussed in Section 2.6.

A-1: Existing Wells

Several nearby existing wells were considered as groundwater sources. With the possible exception of Well 26D01, which was not tested, no wells nearest to the Creek are capable of supporting project flow objectives. In addition, most of these wells are likely in close hydraulic continuity with the Creek. Two abandoned shallow dug wells (26B02 and 26C04) were evaluated by inspection and water level monitoring. The dug Well 26C04 is dilapidated and too shallow with a total water column depth of approximately 3 feet. Water level monitoring in the abandoned dug Well 26B02 and adjacent mini-piezometer P-6 suggest this well is in close continuity with the Creek.

The new well drilled by CCT AFP in early 2011 (26B01) yields 5 gpm and is therefore not capable of meeting project water needs.

The pumping test performed on the existing dug Well 26C01indicates yield is likely limited by well construction to 15 gpm to 20 gpm; a yield insufficient to serve its two domestic users and stream flow augmentation. Using the existing Well 26C01 as a groundwater source would require drilling a new well for the domestic users; however, Well 26C01 alone, could not meet the full project flow objective. In light of the need to drill a replacement well for the domestic users, inability to yield flow augmentation that is sufficient to reach the river and the age and reliability of the existing well, using Well 26C01 as a single well source is not a viable alternative.

The existing well at 26D01 might produce sufficient volume for domestic and flow augmentation uses. This potential could be investigated by performing a pumping test similar to the one at Well 26C01. Water pumped from Well 26D01 in the lowermost reach, near Highway 97, would need to be pumped east (upstream) a distance of approximately 1,800 feet to discharge in the perennial reach near P-5.

A-2: New Well near Cordell Road

As discussed in Section 2.6, anticipated yield for a well completion near Cordell Road ranges from 20 to 80 gpm. Hydraulic continuity with the Creek is a concern, particularly for a well sited near the Creek. Pumping a single new well near Cordell Road would need to proceed from approximately July through March to sustain juvenile steelhead in the newly wetted reach. A short pipeline would be required to connect the well with a discharge location near P-5.

The distance from any existing wells should be maximized to minimize drawdown interference including Well 26C01, which has small limited available drawdown as a result of its construction. If a new project well showed impairment of Well 26C01, it could be pumped at a lower rate that would mitigate the impairment and option B-2 could be pursued (i.e., adding an additional well in the lower reach). Alternatively, a replacement well for 26C01 could be drilled to either increase available drawdown and/or be located outside the zone of influence of the project well. Prior to siting the project well, all existing wells within a ¼ mile north and south of the creek should be field located to optimize the location of the new well and to facilitate impairment analysis for water rights permitting purposes.

A-3: New Well in Lowermost Reach

Nearby well logs suggest a new well located in the lowermost reach of the Creek, several hundred feet east of Highway 97, could have yields on the order of 50 to 100 gpm for flow augmentation. Yields are expected to diminish with distance to the east of the Okanogan River.

A well located on the upper (eastern) portion of the property owned by Curdie is expected to be more productive then a well near Cordell Road. Again, well distance from existing wells should be maximized. Water pumped from a new well in the lowermost reach, near Highway 97, would need to be pumped east (upstream) a distance of approximately 1,800 feet to discharge in the perennial reach near P-5.

3.1.2 Alternative B: Multiple Well Sources

Two multi well scenarios were evaluated: two wells near Cordell Road and one well each near Cordell Road and in the lowermost reach.

B-1: Two New Wells near Cordell Road

A single well located in the vicinity of Cordell Road is predicted to yield between 20 and 80 gpm. Therefore, two new properly-spaced wells drilled near Cordell Road should be close to meeting flow objectives. Additional pumped groundwater could be used to further enhance rearing habitat in the formerly dry reach. If it were desired to suspend flow augmentation pumping in the fall, as described above, a pipeline extending downstream about 1,800 feet from wells near Cordell Road could be constructed so that groundwater could also be discharged in the lowermost reach of the Creek. A short pipeline would be also required to connect the well with a discharge location near P-5. This alternative has the disadvantage of increased well interference from two wells pumping in the same vicinity.

B-2: New Well near Cordell Road and New Well in Lowermost Reach

A new well near Cordell Road discharging to the perennial reach of the Creek and one on the Curdie property discharging to the lowermost reach of the Creek would enable suspending flow augmentation pumping in the fall as described above. Advantages of this alternative include reduced risk of exploration by targeting two areas of the aquifer; minimizing interference between the two wells, potentially less piping from two widely separated sources and ability to phase well drilling (i.e., drill the uppermost well first and if successful consider the cost and risk of drilling a second well). A short pipeline would be required to connect each well with a discharge location.

3.2 Alternative C: Artificial Recharge to Groundwater

Artificial recharge to groundwater could be used to augment stream flow in the lower ¾ miles of the Creek where surface water is gaining from groundwater. Artificial recharge involves infiltration of surface water into the ground, often using an infiltration pond or trench. Empty pore space in the aquifer media is used to temporarily store water that, in this case, would be intended to discharge to the surface at the Creek. This requires identifying a region of the aquifer that is sufficiently porous and thick to provide substantial water storage and where the infiltrated water will return to the surface without being lost to the aquifer. The only reach of the Creek identified as gaining from groundwater is located near P-6. Water could potentially be infiltrated on the glacial terrace above the Creek, near and slightly upstream of P-6 to be discharged into the Creek in the same reach (Figure 6). This alternative has the advantage of requiring no water right permit, if shares from OTID were used.

Substantial additional data would need to be collected to evaluate the feasibility of artificial recharge at this location. These data include the porosity of geologic media, presence of less porous layers (aquitards/aquicludes), depth to bedrock and groundwater levels and flow directions. Modeling would need to be performed including a mounding analysis to predict hydraulic gradients and storage capacity and a travel time analysis to predict the timing of infiltration versus beneficial discharge to the stream. Impacts to groundwater quality would need to be evaluated.

Artificial recharge requires a surface water source. Stream flow data collected during the course of this study suggest high flows in the Creek could be sufficient during the freshet to provide excess water for artificial recharge; however, adult migration and channel-forming flow would need to be evaluated to confirm this. In the absence of other sources of surface water, irrigation water from the OTID presents the most feasible source for artificial recharge. In the Creek vicinity, OTID pumps water from the Okanogan River and provides the majority water that is applied to irrigated lands. It is not known whether OTID would have shares of water available to allocate toward artificial recharge or the extent that irrigation conveyance would need to be improved to deliver water to an infiltration site.

3.3 Alternative D: Surface Water Storage

Expanding surface water storage in the upper watershed was preliminarily assessed as an alternative to augment stream flows in the lower reach. This alternative involves storing water during the spring to be released later in the year for the purpose of augmenting base flows. A preliminary assessment of potential storage locations and evaluation of available water supply reveal insufficient volume of water is available to divert to storage without negatively impacting stream flows in the fish passable reach.

Potential locations for surface water storage that were evaluated include Summit Lake and depressions in the bedrock surface in the upper watershed (tarns). Aspect accompanied CCT AFP staff in May 2010 to investigate Summit Lake and two tarns. Locations of other tarns were identified from examination of maps and air photos. The mapped area of Summit Lake, the largest surface water body in the watershed, is approximately 12 acres.

Assuming no stream flow losses occur between a storage site in the upper watershed and the lower reach where flow augmentation is needed, approximately 130 acre-feet of stored water would be required for the 9-month period from July through March to augment baseflow in the lower reach by 0.25 cfs (110 gpm). More storage is required if losses to groundwater exist in the upper watershed. As discussed below, this volume of water does not appear to be available.

The catchment surrounding Summit Lake is approximately 110 acres or about 2.8% of the 4,000-acre Wildhorse Spring Creek subbasin. A preliminary estimate of the volume of water available for storage during the spring freshet from the Summit Lake catchment was made based on gauging data from WHC at Staff B and the catchment area. For the approximate 3-month period of the spring freshet observed in 2011, flow from WHC basin averaged 4.8 cfs. Assuming that the flow originating from the Summit Lake subbasin was in direct proportion to its 2.8% of the total WHC catchment area, the estimated flow discharging from Summit Lake would be 0.13 cfs (60 gpm) or 23 acre-feet for the 3-month freshet period. Storing the estimated 23 acre-feet generated during the 2011 spring freshet within the 12-acre Summit Lake footprint would require raising the lake stage approximately 2 feet. Under this alternative, the stored water would be discharged during the 9-month low flow period which would equate to about 0.04 cfs (20 gpm) for 2011. WHC flows during the freshet would, therefore, be reduced from an average of 4.8 cfs to about 4.6 cfs.

Because Summit Lake is located in the wettest portion of the WHC subbasin (average precipitation 20 inches) and it is largely bounded by steeply sloping bedrock, the estimated 23 acre-feet of water generated during the spring freshet is likely an underestimate for 2011; however, 2011 likely had a significantly greater snowpack than normal which may offset the underestimate when considering the long term average.

Tarns in the upper watershed impound water for much of the year occupying areas of less than 1 acre to up to 3 acres. It is unlikely a single tarn could be improved to hold the volume of water required to effectively augment flows in the lower watershed.

While modifying Summit Lake and one or more tarns to store more water might produce an aggregate storage volume capable of benefiting flows in the lower watershed, the estimated volume is about on fifth of the project target flow of 110 gpm. Additional study is required to determine the actual available water supply available for a range of precipitation conditions and to estimate the storage volume. Assessing available water supply would require gauging precipitation and runoff within the Summit Lake watershed for a period of 1 year or more.

3.4 Spring Enhancement

Enhancing springs in the watershed was assessed as a potential flow augmentation alternative. Two components of the alternative were considered: 1) enhancing flow at the springs by development of the springs, and 2) by tightlining off channel spring discharge to the main Creek channel to prevent losses during overland flow.

At least two named springs exist on topographic maps (Wildhorse and Tamarack) in the upper watershed above fish passage barriers (Figure 1). Other springs are likely present throughout the upper watershed. No springs were observed in the lower reach of the Creek.

Flows from the springs could be potentially enhanced through the use of horizontal boreholes. The springs are located at relatively high elevations and any additional flow that would be captured by enhancing the spring would likely diminish flow elsewhere in the basin. Considering the high cost of an exploration program to identify the fracture flow system, this alternative was considered to be infeasible.

Enhancing an off-channel spring could benefit stream flow, if water emerging from the spring is lost to groundwater before it reaches the main Creek channel. However, examination of the geology of the upper watershed suggests shallow soils and the low porosity bedrock minimizes losses to groundwater therefore piping of discharge from off-channel springs to the main channel is not expected to provide significant benefit. In other words, nearly all groundwater emerging from springs in the upper watershed likely reaches the cliffs above the fish passable reach. Therefore, piping of spring discharge is not expected to provide significant flow enhancement.

3.5 Preliminary Cost Estimates

Planning level costs were estimated for the purpose of evaluating and comparing alternatives (Table 6).

3.5.1 Capital Costs

The lowest cost alternatives involve pumping groundwater from one or more new or existing wells. These alternatives range from less than $110,000 to nearly $195,000. Artificial recharge to groundwater is estimated to cost nearly $120,000. The highest cost alternative is developing surface water storage that is estimated to range from $600,000 to several million dollars. A comprehensive feasibility assessment would be necessary to refine the cost range for the surface storage alternative. Spring enhancement alternative is considered infeasible and was not costed.

Conceptual design elements considered in estimating capital costs for groundwater source alternatives include:

- Drilling a 6-inch diameter well to a depth of 80 feet ($10,000).
- Installing a 1-2 horsepower pump ($1,500-$2,000).
- Power improvements ($12,000).
- Well design, construction monitoring during drilling, and a well pumping test following well completion are highly recommended. A pumping test would be required for Well 26D01 to evaluate capacity and feasibility of this alternative. The cost to perform these tasks at any single well identified in Alternatives A and B is estimated at $20,000 for hydrogeological services and $7,000 for a pump contractor to perform the test.
- Groundwater pumping alternatives involve constructing a 4-inch pipeline for varying distances to a discharge location. Alternatives A-1, A-3, and B-1 require pipelines extending a distance of 1,800 feet between the perennial reach near P-5 and the lowermost reach. Alternatives A-2 and B-2 require shorter pipelines estimated at 400 feet to 600 feet to connect the wells with nearby discharge locations. Survey, engineering design and construction monitoring for a pipeline is estimated to cost from approximately $8,500 to $11,000, and construction is expected to cost from approximately $8,000 to $44,000 depending on pipeline length. Costs for flow meters and miscellaneous plumbing for all pipeline scenarios is estimated to be $2,000. Alternatively, a pipeline could be laid on top of the ground surface significantly lowering costs but limits its use to summer and early fall before freezing temperatures arrive. A surface-laid pipe would also be subject to heating during the summer months; potentially raising water temperature at the discharge point.
- Estimated costs for design and construction of groundwater discharge alternatives assume the systems will be manually operated (i.e. no SCADA).
- Permitting and agency coordination to obtain a water right under the Hillis Rule is estimated to cost approximately $20,000, and permitting for a pipeline crossing at Cordell Road (County Road) is estimated to cost about $2,000.
- Property access costs are not included in the cost estimates.

Important elements considered in estimating capital costs for artificial recharge to groundwater include:

- Resolving engineering uncertainties regarding hydrogeologic conditions ($60,000).
- Permitting and agency coordination ($20,000).
- Engineering design ($20,000).
- OTID conveyance improvements ($10,000).
- Infiltration pond construction ($8,000).

Important elements considered in estimating capital costs for developing surface water storage include:

- Monitoring/Feasibility study and pre-design ($80,000).
- Engineering design ($100,000).
- Permitting and agency coordination ($1100,000).
- Construction ($200,000).

A contingency of 20 percent was added to each estimated cost for alternatives in Table 6 to provide a contingency for cost elements that were not identified in the preliminary cost estimate.

3.5.2 Operating Costs

Operational costs for groundwater pumping alternatives are primarily power costs associated with pumping from a well. Continuous pumping under any of the groundwater pumping alternatives for the period July through March (270 days) is estimated to be $400. Leasing shares from OTID for artificial recharge that is estimated to cost $4,800 over the irrigation season (180 days). Labor for project monitoring and system operation would be in addition to these costs and are dependent on period of system operation and level of monitoring.

4 Evaluation of Alternatives

The most cost effective alternative with a reasonable potential to provide enough flow augmentation to extend the wetted length of the Creek to the Okanogan River is Alternative A-2, with estimated capital costs of $110,000, excluding any property access costs. Operational costs for this alternative are primarily power costs for the pump. A single well pumped for 270 days from July through March will cost approximately $400.

None of the alternatives are expected to create a bypass reach that would require mitigation for a new water right, but a demonstration would likely have to be made to Ecology, as part of the water right permitting process.

Moving forward, we recommend pursuing Alternative A-2 to enhance habitat for juvenile steelhead in the lower reach of the Creek. A single well drilled near Cordell Road has the potential to yield enough water to extend flow to the river, and is anticipated to have limited continuity with the Creek based on monitoring during testing of Well 26C01. We recommend the well be located at least 100 feet distance from Creek to minimize any connection between the Creek and the aquifer that may not have been recognized during the relatively short duration (1 day) of the test. Although a well located adjacent to Cordell Road has lower yield potential and greater potential to impact existing wells than a well closer to the Okanogan River, the lower cost of the Cordell Rd well alternative and simplified land access (confined to a single land owner) outweigh the risks associated with yield and impairment. Wells within a ¼-mile north and south of the Creek should be field located to minimize well interference when siting the project well and to assist in impairment analysis for water rights purposes.

If additional yield were required or if discharge needed to be reduced to avoid impairment of existing wells, we recommend drilling a second well on the Curdie property effectively implementing Alternative B-2. Drilling a second well on the Curdie property would increase total capital cost to $175,000. It would also offer flexibility in operating the Cordell Road well, should impairment be an issue at higher pumping rates.

This phased approach has the advantage of minimizing capital cost, while increasing options to develop groundwater sources sufficient to meet flow augmentation objectives without the need for a connecting pipeline between the lower reach and Cordell Road. The first phase of this alternative could be implemented in the spring of 2012 so that it is operational for the period following spring freshet, assuming expedited processing of a non-consumptive water right.

Biological monitoring of the targeted species following project implementation should be conducted to confirm use of the newly developed habitat and whether juvenile steelhead move out of the tributary in the fall. Water level monitoring program in nearby wells should also be performed to investigate potential impact on existing wells. Pumping period could be reduced or suspended, if monitoring indicates targeted species leave the tributary for the river in the fall or at any time prior to spring freshet.

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Limitations

Work for this project was performed and this report prepared in accordance with generally accepted professional practices for the nature and conditions of work completed in the same or similar localities, at the time the work was performed. It is intended for the exclusive use of Colville Fish and Wildlife for specific application to the referenced property. This report does not represent a legal opinion. No other warranty, expressed or implied, is made.

Table 1 - Stream Flow Measurements at Wildhorse Spring Creek

Wildhorse Spring Creek Fish Habitat Enhancement Project

Date	Staff A		Staff B		Staff C		Flow
	cfs	gpm	cfs	gpm	cfs	gpm	Characterization
11/18/10	-	-	0.08	36	-	-	baseflow
2/7/11	-	-	0.08	36	-	-	baseflow
3/8/11	0.06	28	0.09	42	0.09	42	baseflow
4/15/11	5.85	2625	4.90	2199	5.61	2519	freshet
4/27/11	7.83	3515	8.02	3600	7.88	3537	freshet
5/27/11	9.14	4100	8.64	3876	9.85	4421	freshet
6/30/11	0.48	215	0.44	197	0.52	233	declining limb
7/5/11	0.26	117	0.20	90	0.24	108	declining limb
7/12/11	0.15	67	0.22	99	0.10	45	declining limb
7/19/11	0.20	90	0.30	135	0.19	85	declining limb
7/26/11	0.14	63	0.15	67	0.14	63	declining limb
8/8/11	-	-	0.11	49	0.06	27	declining limb
8/23/11	0.03	13	0.04	18	0.02	9	baseflow
8/30/11	-	-	0.02	10	-	-	baseflow
8/31/11	0.01	4	0.04	18	0.02	7	baseflow
8/31/11	-		0.03	13	-	-	pumping test
9/1/11	0.04	18	0.09	40	0.03	13	pumping test
9/1/11	-	-	0.07	31	0.01	4	pumping test
9/1/11	-	-	0.03	13	-	-	pumping test
9/7/11	0.06	27	0.05	22	0.02	7	baseflow
10/4/11	0.06	27	0.10	45	0.03	13	baseflow
10/18/11	0.05	22	0.06	27	0.02	9	baseflow
10/23/11	0.01	4	0.05	22	0.01	4	baseflow
11/1/11	0.02	9	0.04	18	0.02	9	baseflow
11/9/11	0.16	72	0.30	135	0.01	4	baseflow
11/15/2011	0.13	58	0.50	224	0.08	36	baseflow
11/30/2011	0.15	67	0.20	90	0.13	58	baseflow

Flows on second half of 8/31/11 and 9/1/11 collected at Staff B and Staff C during pump test (groundwater discharge to stream).

Flow derived from observed stage height using rating curve.

Table 2 - Summary of Wildhorse Spring Creek Water Quality

Wildhorse Spring Creek Fish Habitat Enhancement Project

Location	Date[1]	Temperature (degrees F)	pH	Specific Conductance (µS)	Dissolved Oxygen (mg/L)	Comments
Objective	-	45-63	6.7-8.3	N/A	5-15	Bell, 1991
Staff C/P-7	8/31/2011	57.4	-	254	12.2	
P-6	8/31/2011	57.6	-	227	10.7	
P-5	8/31/2011	56.5	7.4	440	9.25	Higher spec. cond. & lower DO than P-7 suggests groundwater input
Staff B	Mar. 2011 through Nov. 2011	Low 37.5 (3/11/11) High 62.3 (8/25/11)	7.1	368	10.9	Temp. by continuous recording datalogger
P-4	8/31/2011	57.2	7.6	369	10	
Staff A/P-3	8/31/2011	57.9	8	395	10.1	
P-2	8/31/2011	-	-	-	-	Creek Dry
P-1	8/31/2011	-	-	-	-	Creek Dry
Near Mouth of Creek	Summer 2007	57 or less	-	-	-	Measured by CCT AFP. Consistent during summer months.

Notes:

1. Measurements taken on 8/31/11 prior to start of pumping test at Well 26C01.

Table 3 - Mini-Piezometer Data and Groundwater/Surface Water Gradients

Wildhorse Spring Creek Fish Habitat Enhancement Project

Station	Date	Stream Water Level (ft)	Groundwater Level (ft)	Hydraulic Gradient	Gaining/Losing
P-1	2/7/11	dry	dry	-	-
	3/8/11	dry	dry	-	-
	4/15/11	1.32	3.81	-0.66	losing
	5/27/11	1.10	2.02	-0.26	losing
	6/30/11	2.14	2.02	0.04	gaining
	7/5/11	2.25	2.12	0.04	gaining
	7/12/11	2.38	2.3	0.03	gaining
	7/19/11	2.37	2.42	-0.02	losing
	7/26/11	2.45	2.52	-0.02	losing
	8/8/11	dry	3.08	-	-
	8/16/11	dry	3.36	-	-
	8/23/11	dry	3.51	-	-
	8/30/11	dry	3.53	-	-
	8/31/11	dry	3.71	-	-
	9/7/11	dry	3.28	-	-
	10/4/11	dry	3.57	-	-
	10/18/11	dry	3.14	-	-
	10/25/11	dry	3.44	-	-
	11/1/11	dry	3.79	-	-
	11/9/11	dry	4.2	-	-
	11/15/11	dry	4.51	-	-
	11/30/11	dry	5.23	-	-
P-2	2/7/11	dry	dry	-	-
	3/8/11	1.28	dry	-	detached
	4/15/11	0.50	0.85	-0.08	losing
	5/27/11	0.52	0.61	-0.02	losing
	6/30/11	1.10	2.64	-0.41	losing
	7/5/11	1.06	2.97	-0.50	losing
	7/12/11	1.14	3.42	-0.59	losing
	7/19/11	1.10	3.71	-0.64	losing
	7/26/11	1.12	3.89	-0.68	losing
	8/8/11	1.42	4.3	-0.71	losing
	8/16/11	1.25	4.6	-0.85	detached
	8/23/11	1.20	4.77	-0.89	detached
	8/30/11	dry	5.01	-	-
	8/31/11	dry	5.02	-	-
	9/7/11	1.39	4.37	-0.75	losing
	10/4/11	1.37	4.57	-0.79	losing
	10/18/11	1.33	4.33	-0.76	losing
	10/25/11	1.40	4.54	-0.81	losing
	11/1/11	dry	4.92	-	-
	11/9/11	1.34	5.23	-0.99	detached
	11/15/11	1.33	5.45	-1.03	detached
	11/30/11	1.30	5.98	-1.18	detached

Table 3 - Mini-Piezometer Data and Groundwater/Surface Water Gradients

Wildhorse Spring Creek Fish Habitat Enhancement Project

Station	Date	Stream Water Level (ft)	Groundwater Level (ft)	Hydraulic Gradient	Gaining/Losing
P-3	2/7/11	1.70	4.05	-0.60	losing
	3/8/11	1.69	4.81	-0.75	losing
	4/15/11	1.06	3.23	-0.54	losing
	4/27/11	0.82	2.67	-0.43	losing
	5/27/11	0.79	2.74	-0.44	losing
	6/30/11	1.31	5.74	-1.12	detached
	7/5/11	1.42	dry	-	detached
	7/12/11	1.41	dry	-	detached
	7/19/11	1.53	dry	-	detached
	7/26/11	1.51	dry	-	detached
	8/8/11	1.61	dry	-	detached
	8/16/11	1.59	dry	-	detached
	8/23/11	1.57	dry	-	detached
	8/30/11	1.70	dry	-	detached
	8/31/11	1.61	dry	-	detached
	9/7/11	1.60	dry	-	detached
	10/4/11	1.78	dry	-	detached
	10/18/11	1.57	dry	-	detached
	10/25/11	1.58	dry	-	detached
	11/1/11	1.56	dry	-	detached
	11/9/11	1.57	5.73	-1.05	detached
	11/15/11	1.55	dry	-	detached
	11/30/11	1.46	5.72	-1.08	detached
P-4	2/7/11	1.80	4.93	-0.77	losing
	3/8/11	1.79	5.4	-0.90	detached
	4/15/11	1.06	2.57	-0.36	losing
	5/27/11	0.59	1.775	-0.29	losing
	6/30/11	1.52	3.61	-0.54	losing
	7/5/11	1.60	3.76	-0.57	losing
	7/12/11	1.74	3.88	-0.56	losing
	7/19/11	1.73	3.83	-0.56	losing
	7/26/11	1.84	3.71	-0.49	losing
	8/8/11	2.09	3.85	-0.46	losing
	8/16/11	2.05	3.74	-0.44	losing
	8/23/11	2.05	3.59	-0.40	losing
	8/30/11	2.14	3.6	-0.39	losing
	8/31/11	2.07	3.56	-0.39	losing
	9/7/11	2.07	2.98	-0.24	losing
	10/4/11	2.08	3.08	-0.26	losing
	10/18/11	2.08	2.94	-0.23	losing
	10/25/11	2.16	3.02	-0.23	losing
	11/1/11	2.08	3.15	-0.28	losing
	11/9/11	2.04	3.33	-0.34	losing
	11/15/11	1.75	3.45	-0.41	losing
	11/30/11	1.80	3.73	-0.48	losing

Table 3 - Mini-Piezometer Data and Groundwater/Surface Water Gradients

Wildhorse Spring Creek Fish Habitat Enhancement Project

Station	Date	Stream Water Level (ft)	Groundwater Level (ft)	Hydraulic Gradient	Gaining/Losing
P-5	2/7/11	1.96	dry	-	detached
	3/8/11	1.98	dry	-	detached
	4/15/11	1.50	4.3	-0.68	losing
	4/27/11	1.34	4.03	-0.65	losing
	5/27/11	1.19	2.39	-0.29	losing
	8/31/11	2.23	4.45	-0.62	losing
	9/2/11	2.23	4.54	-0.65	losing
	9/7/11	2.23	3.89	-0.48	losing
	10/4/11	2.23	3.65	-0.41	losing
	10/18/11	2.20	4.24	-0.58	losing
	10/25/11	2.20	4.57	-0.67	losing
	11/1/11	2.18	4.74	-0.72	losing
	11/15/11	2.15	5.11	-0.85	losing
	11/30/11	2.09	5.37	-0.92	detached
P-6	2/7/11	1.99	1.8	0.05	gaining
	3/8/11	1.98	1.8	0.05	gaining
	4/15/11	1.22	1.31	-0.02	losing
	4/27/11	0.94	1.15	-0.05	losing
	5/27/11	1.02	1.75	-0.18	losing
	6/30/11	1.74	1.52	0.06	gaining
	7/5/11	1.82	1.54	0.08	gaining
	7/12/11	1.84	1.54	0.08	gaining
	7/19/11	1.78	1.49	0.08	gaining
	7/26/11	1.89	1.49	0.11	gaining
	8/8/11	1.97	1.67	0.08	gaining
	8/16/11	1.96	1.59	0.10	gaining
	8/23/11	1.98	1.54	0.12	gaining
	8/30/11	2.01	1.66	0.10	gaining
	8/31/11	2.08	1.51	0.16	gaining
	9/7/11	1.98	1.19	0.22	gaining
	10/4/11	1.91	1.05	0.24	gaining
	10/18/11	1.88	1.27	0.16	gaining
	10/25/11	1.89	1.37	0.14	gaining
	11/1/11	1.84	1.44	0.11	gaining
	11/9/11	1.86	2.01	-0.04	losing
	11/15/11	1.86	1.56	0.08	gaining
	11/30/11	1.81	1.61	0.05	gaining

Table 3 - Mini-Piezometer Data and Groundwater/Surface Water Gradients

Wildhorse Spring Creek Fish Habitat Enhancement Project

Station	Date	Stream Water Level (ft)	Groundwater Level (ft)	Hydraulic Gradient	Gaining/Losing
P-7	2/7/11	1.64	1.84	-0.06	losing
	3/8/11	1.47	2.05	-0.17	losing
	4/15/11	1.10	1.3	-0.06	losing
	4/27/11	0.93	1.15	-0.06	losing
	5/27/11	0.94	1.11	-0.05	losing
	6/30/11	1.40	1.91	-0.16	losing
	7/5/11	1.40	1.97	-0.18	losing
	7/12/11	1.51	2	-0.16	losing
	7/19/11	1.50	1.97	-0.15	losing
	7/26/11	1.48	2.05	-0.18	losing
	8/8/11	1.71	2.19	-0.16	losing
	8/16/11	1.64	2.21	-0.18	losing
	8/23/11	1.68	2.21	-0.17	losing
	8/30/11	1.67	2.34	-0.22	losing
	8/31/11	1.69	2.19	-0.16	losing
	9/7/11	1.65	2.19	-0.18	losing
	10/4/11	1.63	2.15	-0.16	losing
	10/18/11	1.59	2.2	-0.19	losing
	10/25/11	1.62	2.16	-0.18	losing
	11/1/11	1.61	2.16	-0.17	losing
	11/9/11	1.55	2.15	-0.19	losing
	11/15/11	1.55	1.5	0.02	gaining
	11/30/11	1.49	2.13	-0.21	losing

Notes:

P-5 was not measured for several months due to field error.

Table 4 - Summary of Wildhorse Spring Creek Groundwater/Surface Water Interaction

Wildhorse Spring Creek Fish Habitat Enhancement Project

Flow Condition	Staff C to B	Staff B to A
	Upstream --→ Downstream	
	Characteristic	
Freshet	Losing	Gaining
Baseflow	Gaining	Losing

Table 5 - Summary of Water Quality during Pumping Test at Well 26C01 (8/31/11-9/1/11)

Wildhorse Spring Creek Fish Habitat Enhancement Project

Parameter	Groundwater (Well 26C01)	Surface Water prior to Test (Staff B)	Surface Water during Test (average at Staff B)
Temperature (F)	56.4	59.6 (average 3 days prior)	58.3
pH	7.4	7.1	7.4
Specific Conductance (µS)	390	368	392
Dissolved Oxygen (mg/L)	7.1	10.9	9.9

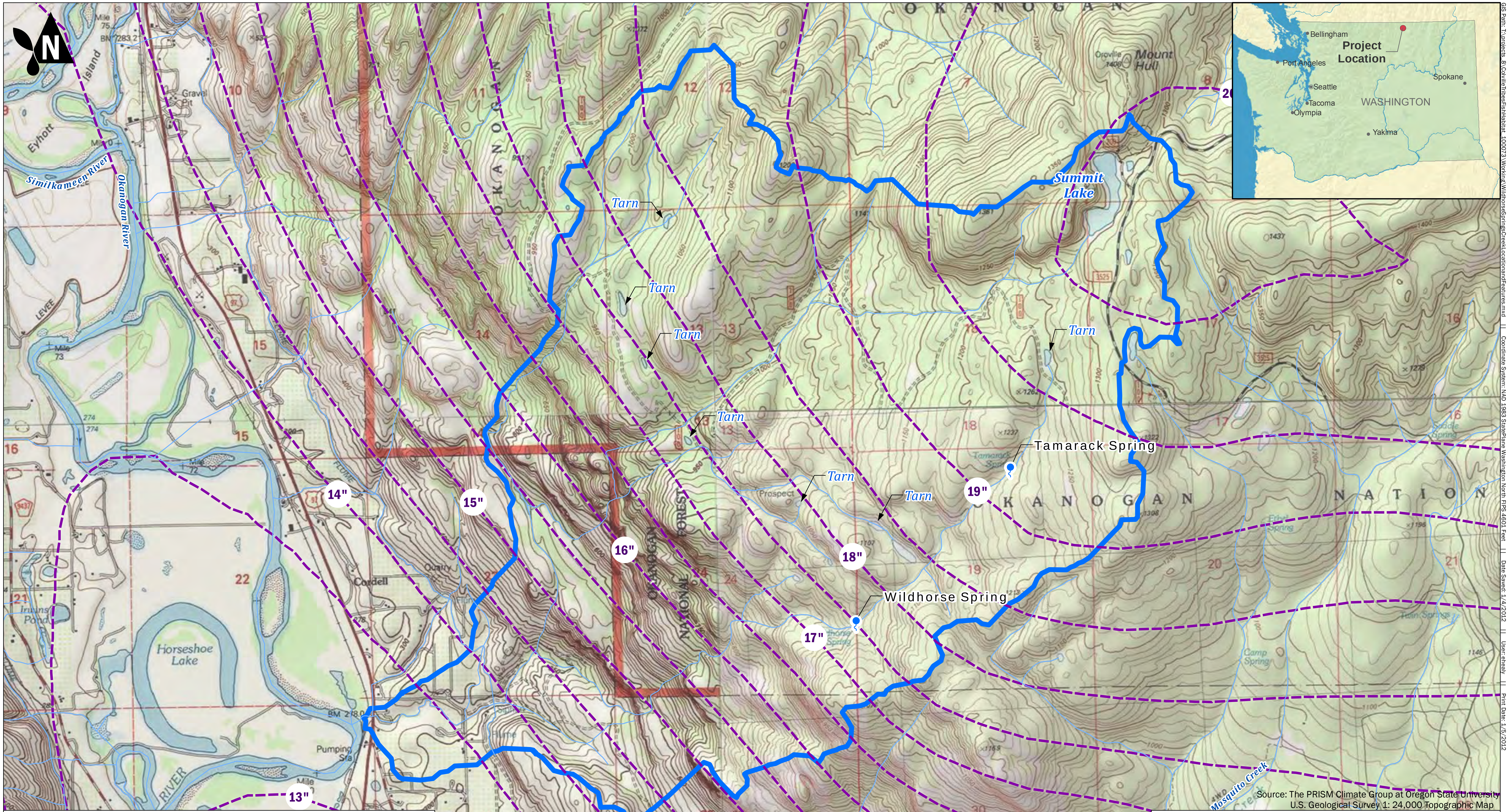
Table 6 - Flow Augmentation Alternatives

Wildhorse Spring Creek Fish Habitat Enhancement Project

Alternative	Description	Predicted Flow Augmentation (cfs/gpm)	Cost[1]	Advantage	Disadvantage
A	Single Well Source				
A-1	Existing Well (Well 26D01)	unknown	$115,000	cost	share w/domestic; well yield unknown; requires pipeline to Cordell Road
A-2	New Well near Cordell Road	0.18(80)	$110,000	lowest cost; near discharge location	lower well yield; continuity w/creek
A-3	New Well Lowermost Reach	0.22(100)	$150,000	higher well yield; continuity w/creek less likely	requires pipeline to Cordell Rd; multiple owner coordination
B	Multiple Well Sources				
B-1	Two New Wells near Cordell Road	0.36(160)	$195,000	minimizes owner coordination; likely sufficient yield; option to forego pipeline to lowermost reach will reduce cost	cost; well interference potential
B-2	New Well near Cordell Road and in Lowermost Reach	0.22(100)-lower 0.18(80)- upper	$175,000	no pipeline; increased potential to meet yield goals; can be phased	multiple owner coordination
C	Artificial Recharge	unknown	$120,000	potential low operational costs	additional study required; uncertainty of source water
D	Surface Water Storage	0.24(110)	>$600,000	gravity flow	cost, water temperature, extensive study and permitting required

Notes:

1. Costs are preliminary feasibility level developed for the purpose of screening alternatives.
2. Although target augmentation flows of 0.25 cfs (110 gpm) are optimal to extend flow and habitat from a discharge located near Piezometer P-5 to the river, flows greater than 0.13 cfs (60 gpm) are estimated to provide substantial benefit.



Spring

17" ½-inch Contours Showing 30-year Average Annual Precipitation (from PRISM)

DEM-derived Surface Water Drainages

Wildhorse Spring Creek Location and Features

Colville Tribes Fish Habitat Enhancement
Washington

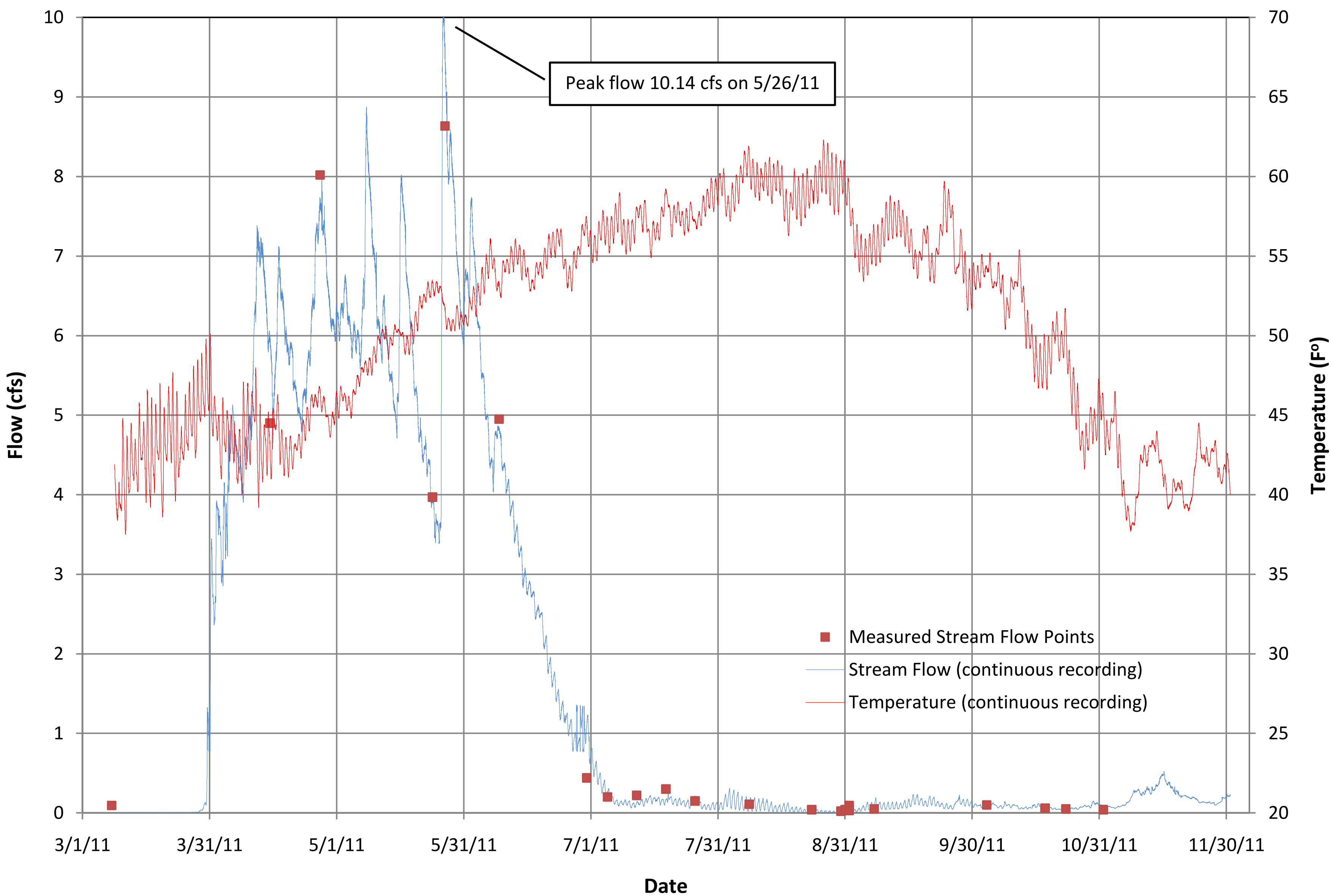
Aspect CONSULTING

JAN-2012	BY: WMS / EAH		FIGURE NO.
PROJECT NO. 100073	REV BY: - - -		1

Wildhorse Spring Creek
Site Layout
Colville Confederated Tribes
Okanogan County, Washington

Aspect CONSULTING

APR-2012	BY: WMS / EAH	FIGURE NO.	
PROJECT NO. 100073	REV BY: - - -	2	



Aspect Consulting

4/2/2012

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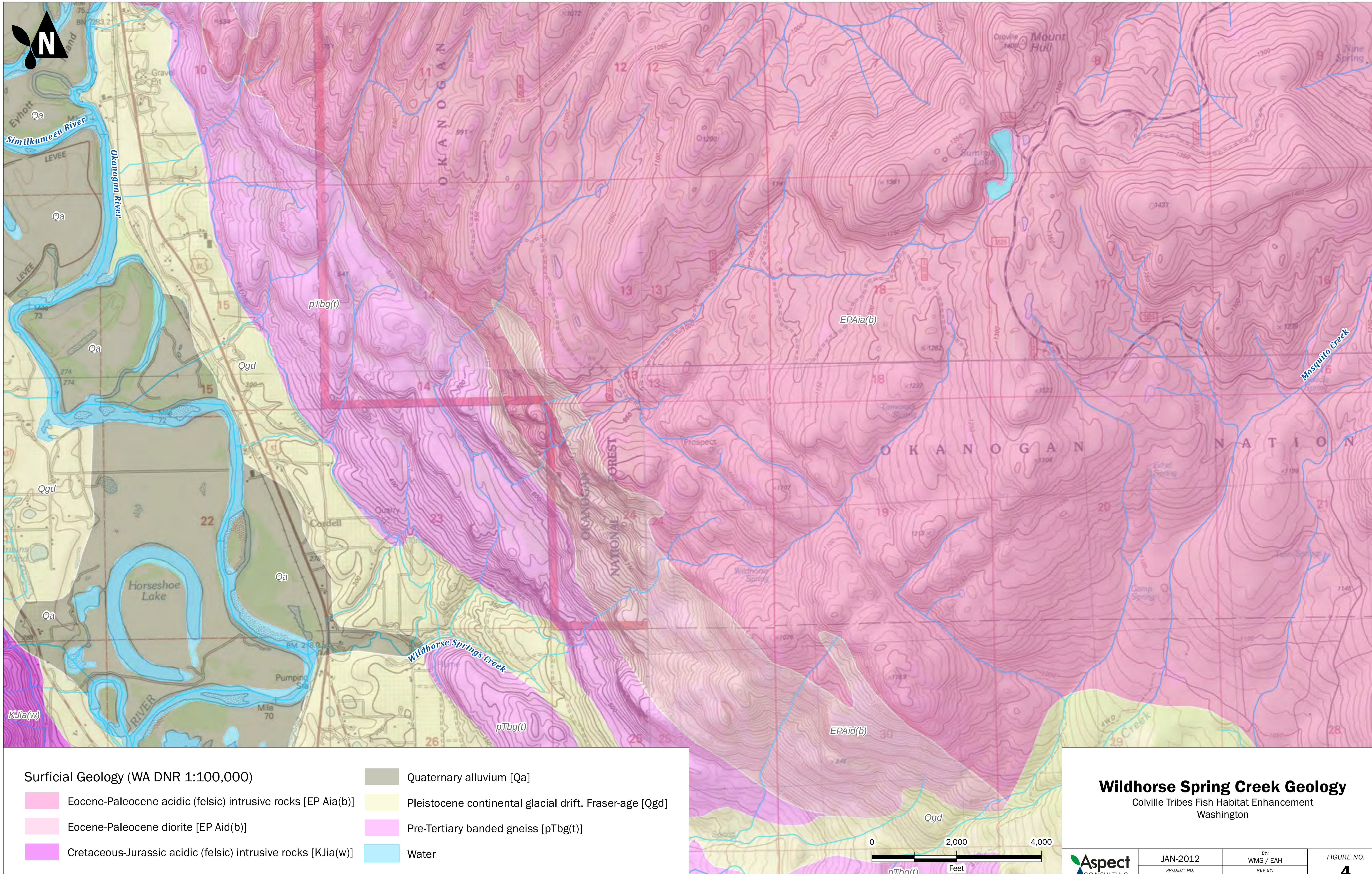
Figure 3 - Staff Gage B Hydrograph

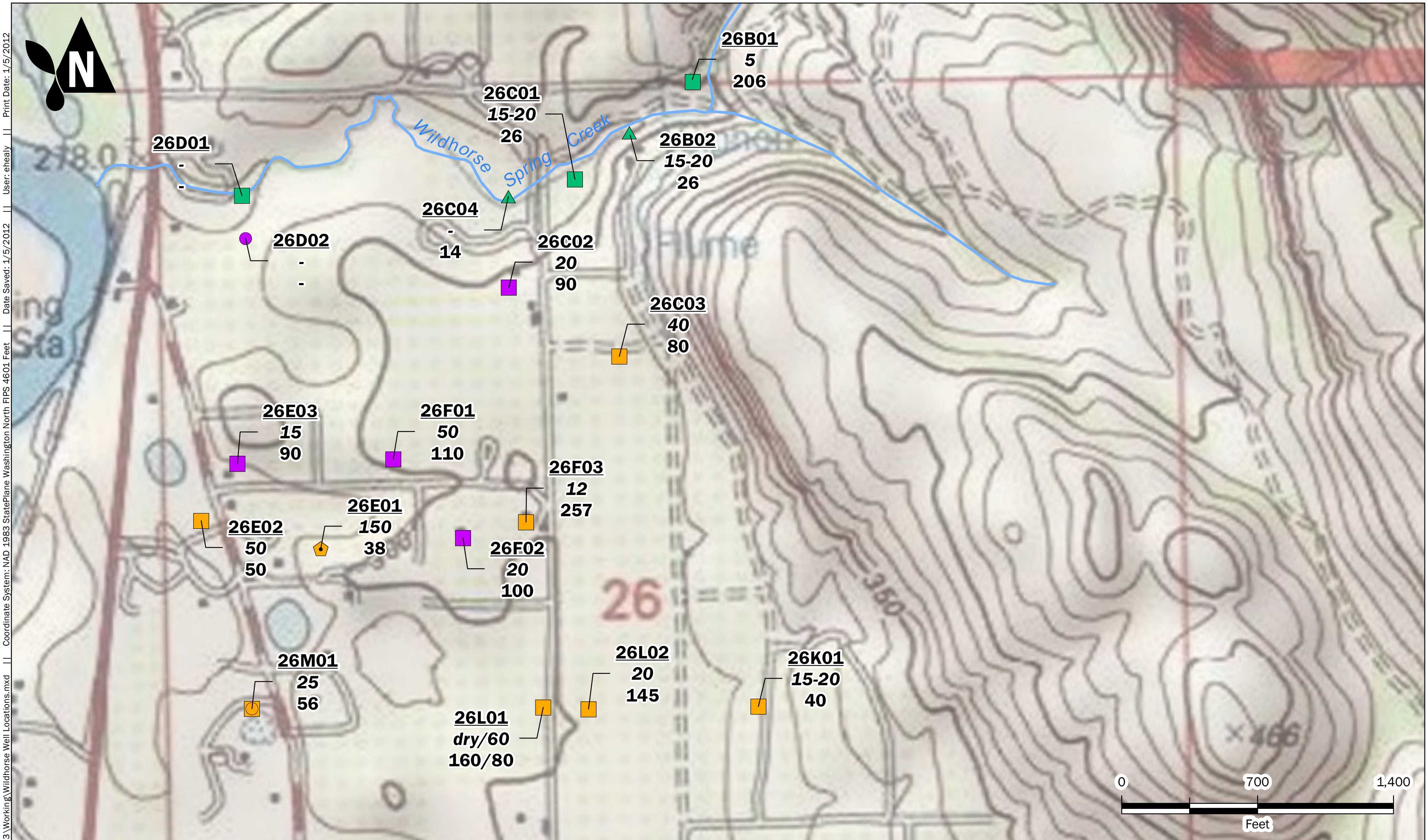
Wildhorse Spring Creek Habitat Enhancement Study

Okanogan County, WA



Wildhorse Spring Creek Geology
Colville Tribes Fish Habitat Enhancement
Washington

Aspect CONSULTING	JAN-2012	BY: WMS / EAH	FIGURE NO.
	PROJECT NO. 100073	REV BY: ---	4



Stream

Well Labels

26K01 ← Well Identifier
15-20 ← Reported Well Yield (gpm)
40 ← Well Depth (feet)

Well Type

△ Unused (confirmed)
□ Domestic
○ Irrigation
Unknown

Locational Accuracy

GPS
Parcel
Quarter-Quarter Section

Well use based on both the proposed use (WA State Department of Ecology well log) and field verification.

Wildhorse Spring Creek Well Locations

Colville Confederated Tribes
Okanogan County, Washington

Aspect CONSULTING

JAN-2012	BY: WMS / EAH	FIGURE NO. 5
PROJECT NO. 100073	REV BY: - - -	

GIS Path: T:\projects_8\ColvilleTribesFishHabitat_100073\Working\Wildhorse Well Locations.mxd || Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet || Date Saved: 1/5/2012 || User: ehealy || Print Date: 1/5/2012

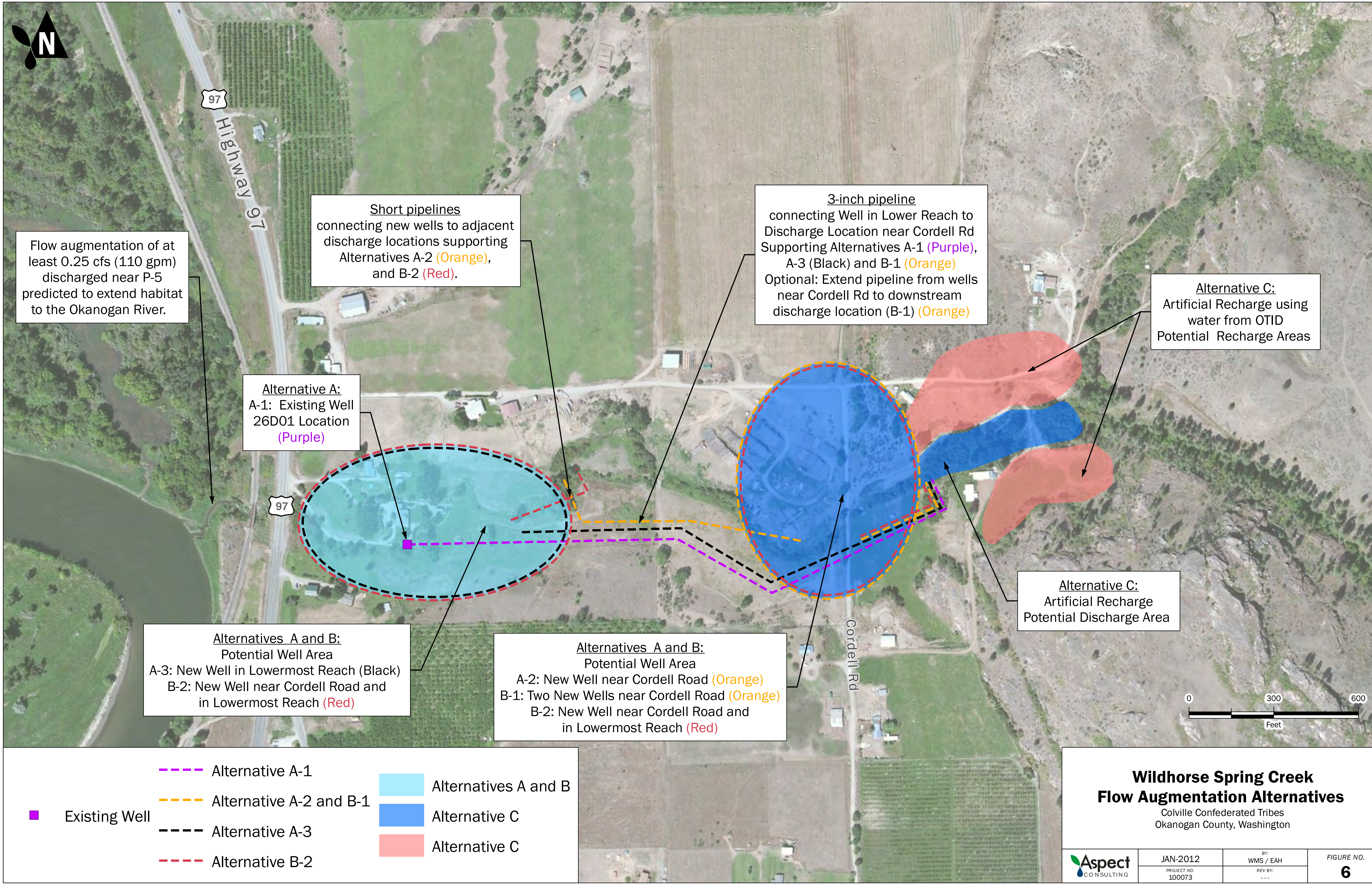

N
97
Highway 97
97
Flow augmentation of at least 0.25 cfs (110 gpm) discharged near P-5 predicted to extend habitat to the Okanogan River.
Short pipelines connecting new wells to adjacent discharge locations supporting Alternatives A-2 (Orange), and B-2 (Red).
3-inch pipeline connecting Well in Lower Reach to Discharge Location near Cordell Rd Supporting Alternatives A-1 (Purple), A-3 (Black) and B-1 (Orange) Optional: Extend pipeline from wells near Cordell Rd to downstream discharge location (B-1) (Orange)
Alternative C: Artificial Recharge using water from OTID Potential Recharge Areas
Alternative A: A-1: Existing Well 26D01 Location (Purple)
Alternative C: Artificial Recharge Potential Discharge Area
Cordell Rd
Alternatives A and B: Potential Well Area A-3: New Well in Lowermost Reach (Black) B-2: New Well near Cordell Road and in Lowermost Reach (Red)
Alternatives A and B: Potential Well Area A-2: New Well near Cordell Road (Orange) B-1: Two New Wells near Cordell Road (Orange) B-2: New Well near Cordell Road and in Lowermost Reach (Red)
0
300
600
Feet
Existing Well
Alternative A-1
Alternative A-2 and B-1
Alternative A-3
Alternative B-2
Alternatives A and B
Alternative C
Alternative C
Wildhorse Spring Creek
Flow Augmentation Alternatives
Colville Confederated Tribes
Okanogan County, Washington
Aspect CONSULTING
JAN-2012
PROJECT NO.
100073
BY:
WMS / EAH
REV BY:

FIGURE NO.
6

APPENDIX A

Rating Curves

Wildhorse Spring Creek Rating Curve Development

Rating curves are used to calculate discharge from measured stage data using empirically based mathematic formulae. Rating curves were developed for Staff Gages A, B, and C using stage and discharge measurements recorded from February through November 2011. For low flows under about 0.5 cfs stage-discharge data were best fit to a power-law equation (Maidment, 1993) of the form:

$Q = C(h + a)^N$, where

Q = discharge,

h = stage,

a = stage at which discharge is zero, and

C = constant related to cross-sectional shape or the stream channel.

N = exponent

Values for *a*, C and *N* were varied to fit curves to the stage-discharge data. Although staff gages were located to minimize shifts in hydraulic control, minor shifts may exist at all three gages resulting from sedimentation during spring freshet. Additional stream flow measurements should be taken with sufficient frequency to identify such changes and to verify the rating curves. Monitoring stream bed elevation to will help determine whether scour/sediment deposition has affected stage-discharge relationships. For a stable hydraulic control, the frequency of discharge measurements may be reduced after the rating curve is confirmed over several seasons.

For high flows during spring freshet, a linear equation was fit to measured data from about 0.5 cfs to over 9 cfs. The linear equation was extrapolated beyond the highest measured flow up to about 12 cubic feet per second (cfs). Overbank flows significantly changing the stage-discharge relationship are estimated to occur when discharge exceeds about 12 cfs.

For each staff gage rating curve, a table is included listing predicted stage-discharge values based on the formulae describe above. Estimated flow volumes are provided in these tables to the 100^{th} of a cfs for flows below about 0.1 cfs that were primarily measured using volumetric method (bucket and stop watch). Flows above about 0.1 cfs that were measured using a flow velocity meter are shown to the 10^{th} of a cfs.

Staff A Rating Curve Table

Stage (ft)	Flow (cfs)*
<0.30	<0.01
0.30	0.01
0.35	0.02
0.40	0.03
0.45	0.05
0.50	0.08
0.55	0.13
0.60	0.2
0.65	0.3
0.70	0.5
0.75	0.7
0.80	1.3
0.85	2.1
0.90	2.8
0.95	3.5
1.00	4.2
1.05	4.9
1.10	5.6
1.15	6.4
1.20	7.1
1.25	7.8
1.30	8.5
1.35	9.2
1.40	10.0
1.45	10.7
1.50	11.4
1.55	12.1

Staff B Rating Curve Table

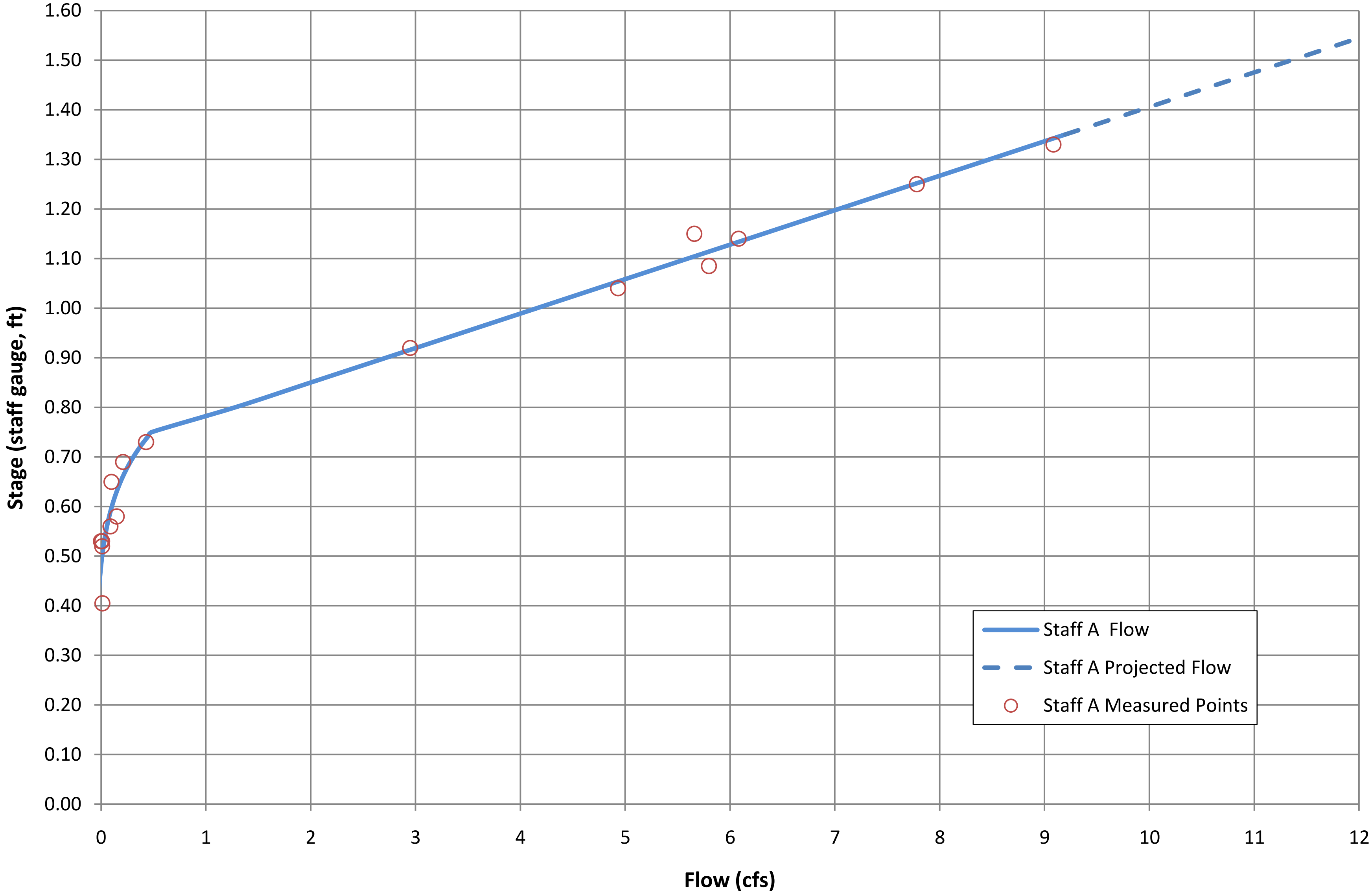
Stage (ft)	Flow (cfs)*
<0.80	<0.01
0.80	0.01
0.85	0.01
0.90	0.04
0.95	0.09
1.00	0.2
1.05	0.4
1.10	0.9
1.15	1.5
1.20	2.3
1.25	3.0
1.30	3.8
1.35	4.5
1.40	5.3
1.45	6.1
1.50	6.8
1.55	7.6
1.60	8.3
1.65	9.1
1.70	9.8
1.75	10.6
1.80	11.4
1.85	12.1
1.90	12.9

Staff C Rating Curve Table

Stage (ft)	Flow (cfs)*
<0.30	<0.01
0.35	0.03
0.40	0.10
0.45	0.3
0.50	0.5
0.55	0.9
0.60	1.5
0.65	2.2
0.70	3.1
0.75	3.8
0.80	4.6
0.85	5.4
0.90	6.2
0.95	6.9
1.00	7.7
1.05	8.5
1.10	9.3
1.15	10.0
1.20	10.8
1.25	11.6
1.30	12.4

*Flows less than about 0.1 cfs were primarily measured using volumetric method to precision of 1/100th cfs.

*Flows greater than about 0.1 cfs were measured using flow velovity meter to precision of 1/10th cfs



Aspect Consulting

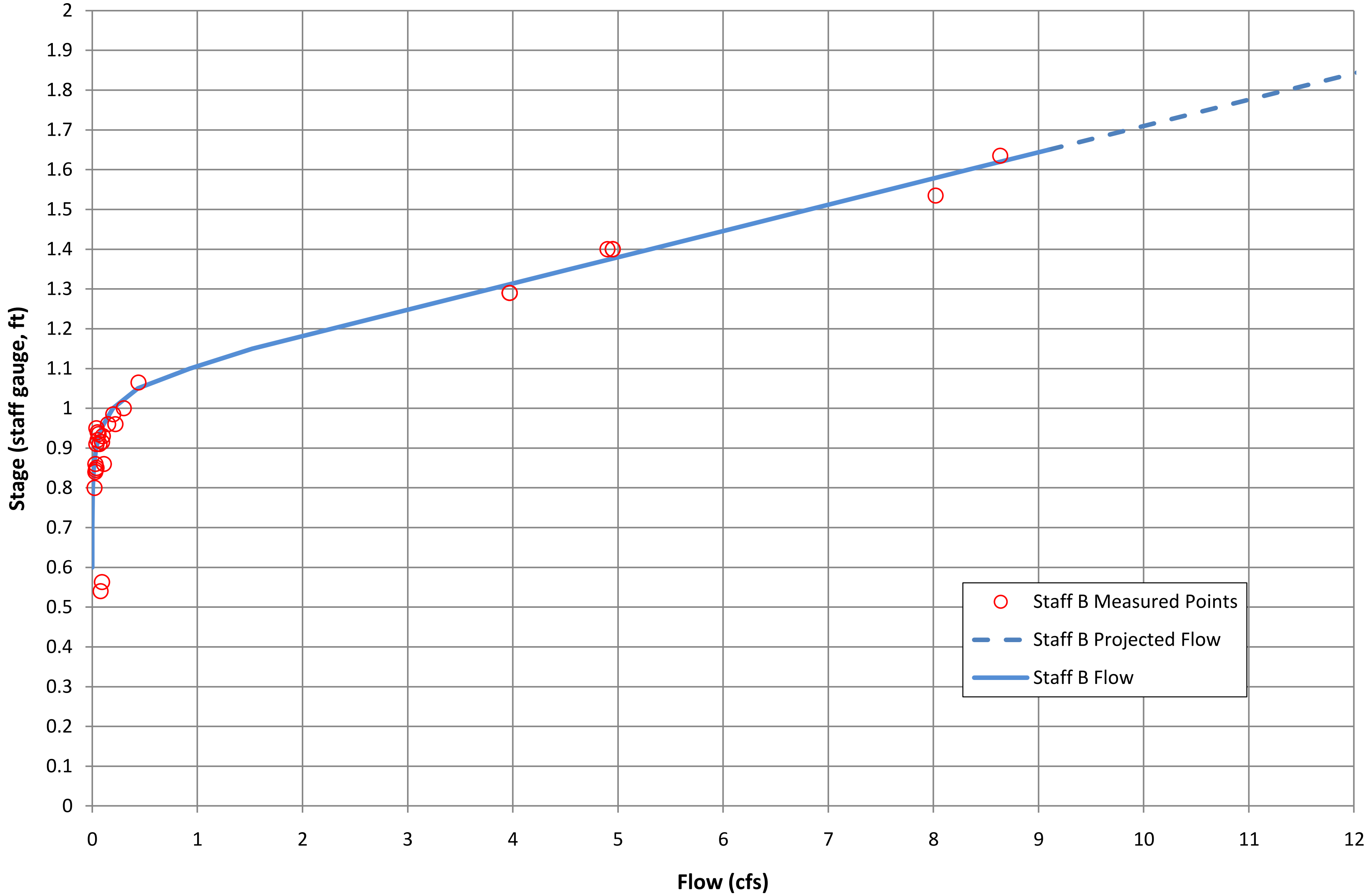
4/2/2012

K:\Projects\Colville Tribes- Wildhorse Spring Creek\Data\Analyses\WildhorseSpringCreek_DataPlots_121511.xlsx -Staff_A-rating

Staff A Rating Curve

Wildhorse Spring Creek Habitat Enhancement Study

Okanogan County, WA



Aspect Consulting

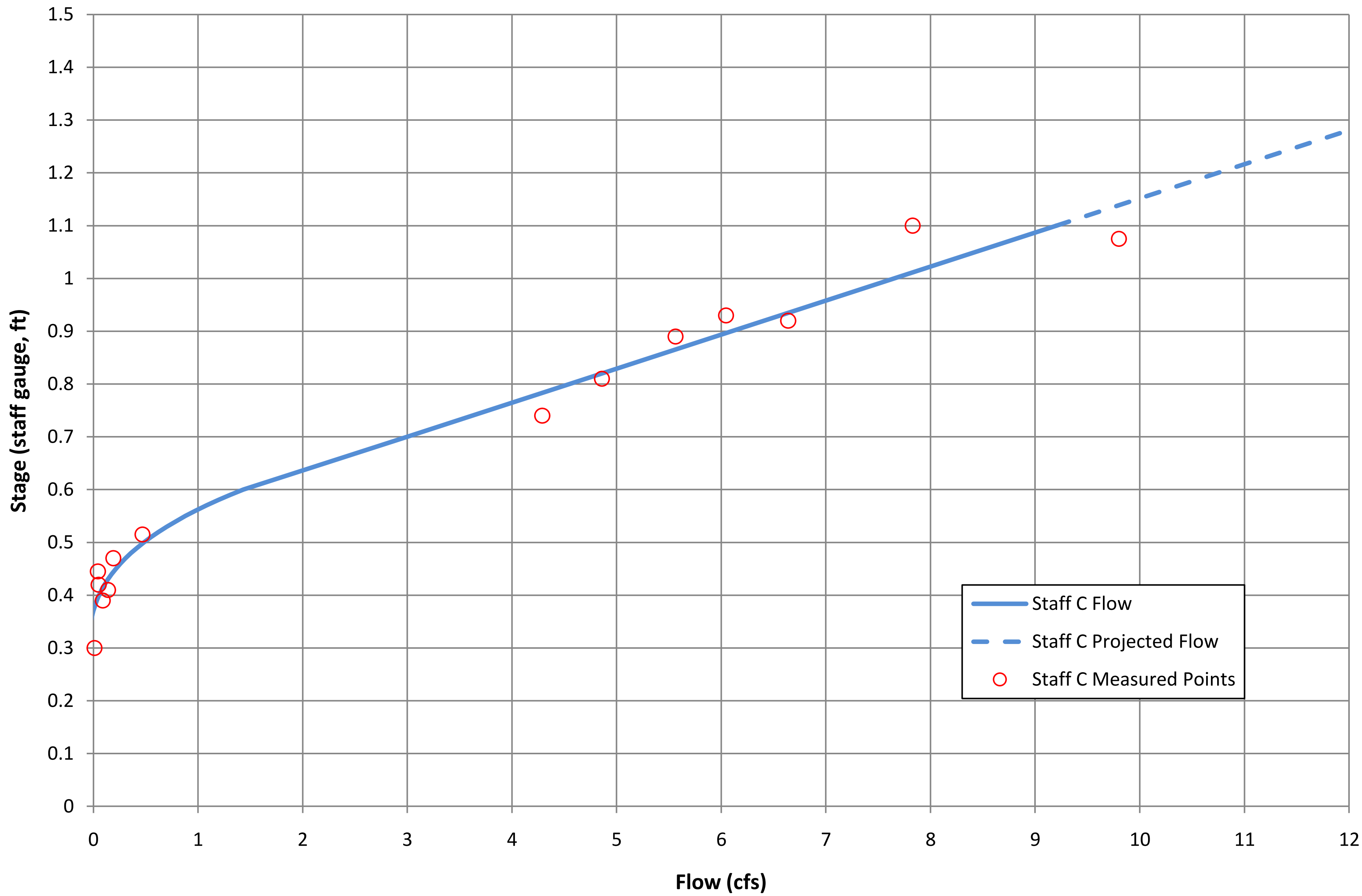
4/2/2012

K:\Projects\Colville Tribes- Wildhorse Spring Creek\Data\Analyses\WildhorseSpringCreek_DataPlots_121511.xlsx -Staff_B-rating

Staff B Rating Curve

Wildhorse Spring Creek Habitat Enhancement Study

Okanogan County, WA



Aspect Consulting

4/2/2012

K:\Projects\Colville Tribes- Wildhorse Spring Creek\Data\Analyses\WildhorseSpringCreek_DataPlots_121511.xlsx -Staff_C-rating

Staff C Rating Curve

Wildhorse Spring Creek Habitat Enhancement Study

Okanogan County, WA

APPENDIX B

Well Logs

Wells in Wildhorse Springs Creek Vicinity

Map ID	Name	Reported Yield (gpm)	Total Depth (ft)	
26E03	Brooks	15	90	
26F03	Brown/Lytle	12	257	
26D02	Cox	-	-	
26C03	Dicks	40	80	
26M01	Dixon	25	56	
26K01	Farmers Home Admin	15-20	40	
26F02	Fox	20	100	
26F01	Hailey	50	110	
26E02	Hines	50	50	
26E01	Lehrman	150	38	
26B01	McKinney	5	206	
26L02	Potter	20	145	
26L01	Scharf	dry/-	160/80	
26C02	Walker	20	90	
26C04	Acord (abandoned)	-	14	No well log
26D01	Curdie	-	-	No well log
26C01	Sydnes	15-20	26	No well log
26B02	Sydnes (abandoned)	-	10	No well log

The Department of Ecology does NOT Warranty the Data and/or the Information on this 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

Start Card No. W 36194
UNIQUE WELL I.D. # ABL 702
Water Right Permit No. ________

(1) OWNER: Name Mike Brooks Address RT 2 Box 561 Oroville Wash

(2) LOCATION OF WELL: County OKANOGAN - SW 1/4 NW 1/4 Sec 26 T. 39 N., R. 27 W.M.

(2a) STREET ADDRESS OF WELL (or nearest address) ________

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

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

(5) DIMENSIONS: Diameter of well 6 inches.
Drilled 90 feet. Depth of completed well 90 ft.

(6) CONSTRUCTION DETAILS:
Casing Installed: 6" Diam. from +2 ft. to 85 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 Stainless Model No. ____
Diam. 5" Slot size .010 from 85 ft. to 90 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? 18' 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 51' ft. below top of well Date 4-15-95
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? M&M
Yield: 15 gal./min. with 13 ft. drawdown after 1 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 & Gravel	0	40
light Gray clay	40	41
~~Fine Silt~~ Sand & Gravel Some water very littled	41	52
Sand Gravel ~~clay~~ Some water	52	62
Fine silty Sand & water	62	80
Fine Gray Sand water	80	85
~~Fine~~ Course Gravel	85	88
Fine Gray Sand	89	90

RECEIVED
APR 18 1995
DEPARTMENT OF ECOLOGY
CENTRAL REGION OFFICE

Work Started 3/31/95, 19__. Completed 4-15-95, 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 M&M Drilling (PERSON, FIRM, OR CORPORATION) (TYPE OR PRINT)
Address Rt 1 Box 201-A Oroville
(Signed) S.B. McElvain (WELL DRILLER) License No. 2018
Contractor's Registration No. MM WCLD 088DM Date 4-15-95, 19__

(USE ADDITIONAL SHEETS IF NECESSARY)

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ECY 050-1-20 (9/93)

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

Inv > 923408

WATER WELL REPORT

STATE OF WASHINGTON

7160

Start Card No. 55219

Water Right Permit No. H

The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.

(1) OWNER: Name Allan Brown/Frank Lytle Address RR 2 Box 570 Oroville, WA 98844

(2) LOCATION OF WELL: County Okanogan SE ¼ NE ¼ Sec. 26 T. 39 N., R. 27 W.M.

(2a) STREET ADDDRESS OF WELL (or nearest address) Cordell Road Ellisford, WA

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

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

(5) DIMENSIONS: Diameter of well 6 inches.
Drilled 257 feet. Depth of completed well 257 ft.

(6) CONSTRUCTION DETAILS:
Casing installed: 6 " Diam. from +1 ft. to 257 ft.
Welded ☒ " Diam. from ft. to ft.
Liner installed ☒
Threaded ☐ 4" " Diam. from -10 ft. to 247 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 PRE-PAC Model No.
Diam. 5" Slot size .010 from 247 ft. to 257 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? 18 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 39 ft. below top of well Date 7/21/92
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? BRETT DeJONG
Yield: 12 gal./min. with 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 12 gal./min. with 255 ft. drawdown after 4.0 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, silt-brown	0	35
Sand, gravel-brown	35	83
Sand, silt-gray	83	257

AUG 14 1992

Work started 7/25/92, 19. Completed 7/27/92, 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 Fogle Pump & Drilling West (PERSON, FIRM, OR CORPORATION) (TYPE OR PRINT)
Address P.O. Box 456 Republic WA 99166

(Signed) William B Davis (BY DRS) (WELL DRILLER) License No. 1356

Contractor's Registration No. #PS 095 L4 Date 7/27/92, 19

(USE ADDITIONAL SHEETS IF NECESSARY)

ECY 050-1-20 (10/87) -1328-

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

Water Right Permit No 64-30016 P

(1) OWNER Name Gene L Cox Address 151 Horse Spring Tonasket,

(2) LOCATION OF WELL County Okanogan NW ¼ NW ¼ Sec 26 T 39 N R 27 W M D

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

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

(4) TYPE OF WORK Owner s number of well (if more than one)

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

(5) DIMENSIONS Diameter of well 3' inches
Drilled ____ feet Depth of completed well 27' ft

(6) CONSTRUCTION DETAILS

Casing installed ____ Diam from ____ ft to ____ 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
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? ____ ft
Material used in seal
Did any strata contain unusable water? Yes ☐ No ☒
Type of water? ____ Depth of strata
Method of sealing strata off

(7) PUMP Manufacturer s Name Grundfos
Type Submersible HP

(8) WATER LEVELS Land surface elevation above mean sea level ____ ft
Static level 27 ft below top of well Date 8 15
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? Alpine
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
This is an existed well dug many years ago. Has cement well Tile To The lowest point. Well was Tested approx 20 yrs ago by Alpine Well Drilling. Well was in place when property was purchased in 1976.		

DEPT OF ECOLOGY
OCT 13 2009
CENTRAL REGION OFFICE

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 ____ (PERSON FIRM OR CORPORATION) (TYPE OR PRINT)

Address

(Signed) ____ (WELL DRILLER) License No

Contractor s Registration No ____ Date ____ 19 ____

(USE ADDITIONAL SHEETS IF NECESSARY)

ECY 050 1 20 (10/87) 1329 ® 18

The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.

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Second Copy — Owner's Copy
Third Copy — Driller's Copy

WATER WELL REPORT

STATE OF WASHINGTON

Start Card No. W-050484
UNIQUE WELL I.D. # ACL-352
Water Right Permit No.

The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.

(1) OWNER: Name Ross Dicks Address 325-B Hwy 7 South Tonasket

(2) LOCATION OF WELL: County Okanogan NW 1/4 NE 1/4 Sec 26 T. 39 N., R 27 W.M.

(2a) STREET ADDRESS OF WELL (or nearest address)

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

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

(5) DIMENSIONS: Diameter of well 6 inches.
Drilled 80 feet. Depth of completed well 80 ft.

(6) CONSTRUCTION DETAILS:
Casing Installed: 6" Diam. from +1 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 Houston
Type Stainless Model No.
Diam. 5 Slot size .020 from 70 ft. to 75 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? 18 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 42 ft. below top of well Date 8-9-97
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: 40 gal./min. with 4 ft. drawdown after 1 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
Black Top Soil	0	4
Brown Sand Soft	4	45
Brown Sand Small Gravel Soft	45	52
Brown Sand & Small Gravel Water Bearing	52	80

RECEIVED
AUG 26 [illegible]
DEPARTMENT OF ECOLOGY
CENTRAL REGION OFFICE

Work Started 8-7-97, 19. Completed 8-9-97, 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 M & M Well Drilling (PERSON, FIRM, OR CORPORATION) (TYPE OR PRINT)
Address 6 Airport Rd Oroville
(Signed) Tom Mc[illegible] (WELL DRILLER) License No. 2221
Contractor's Registration No. MM Well [illegible] Date 8-9-97, 19

(USE ADDITIONAL SHEETS IF NECESSARY)

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ECY 050-1-20 (9/93)

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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. 94-27135 P

(1) OWNER: Name DONALD N. DIXON Address RT 1 BOX 285

(2) LOCATION OF WELL: County OKANOGAN — ¼ NW ¼ Sec SW T 26 N., R 37 W.M. 27
Bearing and distance from section or subdivision corner

M

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

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

(5) DIMENSIONS: Diameter of well 48 inches.
Drilled .... ft. Depth of completed well 56 ft.

(6) CONSTRUCTION DETAILS:

Casing installed: 48 " Diam. from 0 ft. to 30 ft.
Threaded ☐ 56 " Diam. from 30 ft. to 56 ft.
Welded ☐ .... " Diam. from .... ft. to .... ft.

Perforations: Yes ☒ No ☐
Type of perforator used ....
SIZE of perforations 1 in. by 4 in.
.... perforations from 20 ft. to 56 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: 3/4 —
Gravel placed from 51 ft. to 56 ft.

Surface seal: Yes ☒ No ☐ To what depth? 20 ft.
Material used in seal concrete & mortar
Did any strata contain unusable water? Yes ☒ No ☐
Type of water? .... Depth of strata 26
Method of sealing strata off concrete

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

(8) WATER LEVELS: Land-surface elevation above mean sea level 1110 ft.
Static level 26 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? Contractor
Yield: 25 gal./min. with 4 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 25 gal./min. with 4 ft. drawdown after 4 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	0	4
Fine Sand	4	24
3/4 - gravel & sand	24	32
Coarse Sand - 1" gravel	32	56

RECEIVED
AUG 16 1982
DEPARTMENT OF ECOLOGY

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 O/K Water Wells
(Person, firm, or corporation) (Type or print)

Address RT 1 Box 250 Oroville, WN 98844

[Signed] [signature]
(Well Driller)

License No. 1154 Date ...., 19..........

EP 8/27/82

(USE ADDITIONAL SHEETS IF NECESSARY)

ECY 050-1-20

The Department of Ecology does NOT Warranty the Data and/or the Information on this 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

3026 Start Card No. 022244

Water Right Permit No. K

(1) OWNER: Name Farmers Home Administration Address Rt.1,1240 S.2nd Ave. Okanogan, WA

(2) LOCATION OF WELL: County Okanogan NW ¼ SE ¼ Sec 26 T. 39 N., R. 27 W.M.

(2a) STREET ADDDRESS OF WELL (or nearest address) O'Niel Road(North End) Ellisford, WA

(3) PROPOSED USE: [X] Domestic [ ] Irrigation [ ] DeWater Industrial [ ] Test Well [ ] Municipal [ ] Other [ ]

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

(5) DIMENSIONS: Diameter of well SIX(6) inches.
Drilled 40 feet. Depth of completed well 40 ft.

(6) CONSTRUCTION DETAILS:
Casing installed: 6 " Diam. from +2 ft. to 34 ft.
Welded [X] " Diam. from ft. to ft.
Liner installed [ ]
Threaded [ ] " 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 [X] No [ ]
Manufacturer's Name Johnson
Type Stainless Steel Model No.
Diam. 6" Slot size 14 from 34 ft. to 39 ft.
Diam. Slot size from ft. to ft.

Gravel packed: Yes [ ] No [X] Size of gravel
Gravel placed from ft. to ft.

Surface seal: Yes [X] No [ ] To what depth? 18 ft.
Material used in seal Bentonite
Did any strata contain unusable water? Yes [ ] No [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 25 ft. below top of well Date 4/11/90
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 [X] If yes, by whom?
Yield: 15-20 gal./min. with ft. drawdown after hrs.
" Est. Air Lift " "
" " " "

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 [X]

(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
Topsoil	0	2
Sand-brown	2	25
Sand-brown, Water-Bearing	25	30
Sand & gravel-brown	30	40

ENTERED

RECEIVED MAY 7 1990

RECEIVED MAY 11 1990 DEPARTMENT OF ECOLOGY CENTRAL REGION OFFICE

Work started 4/10, 19. Completed 4/11, 19 90

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 Fogle Pump & Well Drilling West (PERSON, FIRM, OR CORPORATION) (TYPE OR PRINT)

Address P.O. Box 147 Malo, WA 99150

(Signed) Richard Ray (By JES) (WELL DRILLER) License No. 1720

Contractor's Registration No. PS194MF Date 4/11, 19 90

(USE ADDITIONAL SHEETS IF NECESSARY)

The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.

WATER WELL REPORT

State of Washington   Date Printed: **02-Aug-2005**   Log No. **26905**

Construction / Decommission: Original Construction Notice

Construction 180330

CURRENT
Notice of Intent No.: W190456
Unique Ecology Well I.D. No **AKM269**
Water Right Permit Number:

OWNER: **FOX, DAN**
OWNER ADD **76 TORODA CR. RD**
WAUCONDA, WA 98859   K

Well Add **CORDELL RD**
City: **Oroville, WA 98844**   County: **Okanogan**
Location: **NW** 1/4 **SE** 1/4 Sec **26** T **39** R **27E** EW
Lat/Long: (s, t, r still REQUIRED) Lat Deg   Lat Min/Sec   Long Deg   Long Min/Se
Tax Parcel No.: **4700050003**

PROPOSED USE: **DOMESTIC**

TYPE OF WORK: Owners's Well Number: (If more than one well) **1**
NEW WELL   Method: **ROTARY**

DIMENSIONS Diameter of well: **6** inches
Drilled **100** ft.   Depth of completed well **97** ft.

CONSTRUCTION DETAILS:
Casing installed **WELDED**
6 " Dia from **+2** ft. to **89** ft.
" Dia from ft. to ft.
" Dia from ft. to ft.

Liner installed:
" Dia from ft. to ft.

Perforations: **No**   Used In:
Type of perforator used
SIZE of perforations in. b in.
Perforation from ft. to ft.
Perforation from ft. to ft.
Perforation from ft. to ft.

Screens: **Yes** K-Pac Location 84'
Manufacture's Name JOHNSON
Type: **SLOTTED**   Model No **STAINLESS**
Diam. **5**   slot size **14**   from **89** ft. to **94** ft.
Diam.   slot size   from   ft. to   ft.

Gravel/Filter packed: **No**   Size of Gravel
Material placed fro   ft. to   ft.

Surface seal: **Yes**   To what depth **18** ft.
Seal method: Material used in seal **BENTONITE**
Did any strata contain unusable water **No**
Type of water   Depth of strata
Method of sealing strata off

PUMP: Manufacture's name
Type: H.P. **0**

WATER LEVELS Land-surface elevation above mean sea level: **0** ft.
Static level **23** ft. below top of well Date **07/18/2005**
Artesian Pressure   lbs per square inch Date
Artesian water controlled by

WELL TESTS: Drawdown is amount water level is lowered below static level.
Was a pump test made **No**   If yes, by whom
Yield   gal/min with   ft drawdown after
Yield   gal/min with   ft drawdown after
Yield   gal/min with   ft drawdown after

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   ft drawdown after   hrs.
Air test **20** gal/min w/ stem set at **95** ft. for **1** hours
Artesian flow   gpm   Date
Temperature of water   Was a chemical analysis made **No**

CONSTRUCTION OR DECOMMISSION PROCEDURE

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

Material	From	To
TOP SOIL	0	3
SAND SILTY FINE	3	58
SAND FINE	58	70
SAND MED W /WATER	70	90
SAND GRAVEL W /WATER	90	95
CEMENTED GRAVEL CLAY GRAY	95	100

DEPT OF ECOLOGY Received SEP 07 2005 CENTRAL REGION OFFICE

Notes:

Work starte **07/15/2005**   Complete **07/18/2005**

WELL CONSTRUCTION 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 are true to my best knowledge and belief.

☑ Driller ☐ Engineer ☐ Trainee

Name: **MARTY RUGO**   License No.: **2038**
Signature: Marty Rugo

If trainee, Licensed driller is: License No.:
Licensed Driller Signature

Drilling Company:
NAME: **FOGLE PUMP & SUPPLY, INC.**   Shop: **REPUBLIC**
ADDRESS: **PO Box 456**
Republic, WA 99166
Phone: Toll Free: **8008453500**
E-Mail: **foglewest@rcabletv.com**
FAX: **5097750498**   WEB Site: **www.foglepump.com**

Contractor's Registration No.: **FOGLEPS095L4**   Date Log Created: 07/27/200

The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.

WATER WELL REPORT

Original & 1st copy - Ecology, 2nd copy - owner, 3rd copy - driller

Construction/Decommission *("x" in circle)* 205923

- [x] Construction
- [ ] Decommission *ORIGINAL CONSTRUCTION Notice of Intent Number* ______

CURRENT Notice of Intent No. W 207860

Unique Ecology Well ID Tag No. AGE 258

Water Right Permit No. ______

Property Owner Name ZAC D. HAILEY

Well Street Address 23 Nigg Rd.

City Oroville County: Okanogan

Location NW 1/4- 1/4 NW 1/4 Sec 26 Twn 39 R 27 EWM (circle one) or WWM

Lat/Long: (s,t,r still REQUIRED) Lat Deg ______ Lat Min/Sec ______ Long Deg ______ Long Min/Sec ______

Tax Parcel No. ______

PROPOSED USE: [x] Domestic [ ] Industrial [ ] Municipal [ ] DeWater [ ] Irrigation [ ] Test Well [ ] Other ______

TYPE OF WORK: Owner's number of well (if more than one) 1

[x] New Well [ ] Reconditioned *Method:* [ ] Dug [ ] Bored [ ] Driven [ ] Deepened [x] Cable [ ] Rotary [ ] Jetted

DIMENSIONS: Diameter of well 6 inches, drilled 108 ft. Depth of completed well 110 ft.

CONSTRUCTION DETAILS

Casing Installed: [x] Welded 6" Diam. from +2 ft. to 100 ft.
[ ] Liner installed ______" Diam. from ______ ft. to ______ ft.
[ ] Threaded ______" Diam. from ______ ft. to ______ ft.

Perforations: [ ] Yes [x] No

Type of perforator used ______

SIZE of perfs ______ in. by ______ in. and no. of perfs ______ from ______ ft. to ______ ft.

Screens: [x] Yes [ ] No [x] K-Pac Location 2 FT K-pac

Manufacturer's Name Johnson

Type ______ Model No. ______

Diam. 5 Slot Size 66 from 110 ft. to 100 ft.

Diam. ______ Slot Size ______ from ______ ft. to ______ ft.

Gravel/Filter packed: [ ] Yes [x] No [ ] Size of gravel/sand ______

Materials placed from ______ ft. to ______ ft.

Surface Seal: [x] Yes [ ] No To what depth? 18 ft

Materials used in seal 3/8 hole plug

Did any strata contain unusable water? [ ] Yes [x] No

Type of water? ______ Depth of strata ______

Method of sealing strata off ______

PUMP: Manufacturer's Name ______

Type: ______ H.P. ______

WATER LEVELS: Land-surface elevation above mean sea level 1900 ft.

Static level 50 ft. below top of well Date 8/2/06

Artesian pressure ______ lbs. per square inch Date ______

Artesian water is controlled by ______ (cap,valve, etc.)

WELL TESTS: Drawdown is amount water level is lowered below static level.

Was a pump test made? [ ] Yes [x] No If yes, by whom? ______

Yield: ______ gal./min. with ______ ft. drawdown after ______ hrs.

Yield: ______ gal./min. with ______ ft. drawdown after ______ hrs.

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 50+ gal./min. with 4 ft. drawdown after 2 hrs.

Airtest ______ gal./min. with stem set at ______ ft. for ______ hrs.

Artesian flow ______ g.p.m. Date ______

Temperature of water 56° Was a chemical analysis made? [ ] Yes [x] No

CONSTRUCTION OR DECOMMISSION PROCEDURE

Formation: Describe by color, character, size of material and structure, and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of information. Indicate all water encountered. (USE ADDITIONAL SHEETS IF NECESSARY.)

MATERIAL	FROM	TO
Light Brown sand	0	75
Blue clay/sand	75	100
Fine/sand/wb	100	110

RECEIVED
AUG 16 2006
DEPARTMENT OF ECOLOGY
WELL DRILLING UNIT

DEPT OF ECOLOGY Received AUG 21 2006 CENTRAL REGION OFFICE

DEPT. OF ECOLOGY FISCAL & BUDGET 06 AUG 14 AM 11:31

Start Date 7/26/06 Completed Date 8/2/06

WELL CONSTRUCTION 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.

[x] Driller [ ] Engineer [ ] Trainee Name (Print) JAMES TREPANIER

Driller/Engineer/Trainee Signature James Trepanier

Driller or Trainee License No. 2287

If trainee, licensed driller's Signature and License no. ______

Drilling Company Aquamen Well Specialists

Address PO BOX 468

City, State, Zip TONASKET WA. 98855

Contractor's Registration No. AQUAMWS958KB Date ______

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. 26039
UNIQUE WELL I.D. # AAK 683
Water Right Permit No. ______

The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.

(1) OWNER: Name Vince Hines Address Tonasket Wa

(2) LOCATION OF WELL: County Okanogan SW 1/4 NW 1/4 Sec 26 T. 39 N., R. 27 W.M. E

(2a) STREET ADDRESS OF WELL (or nearest address) Lt 1 Dixon Tracts Short plat

(3) PROPOSED USE: [X] Domestic [ ] Irrigation [ ] DeWater Industrial [ ] Test Well [ ] Municipal [ ] Other [ ]

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

(5) DIMENSIONS: Diameter of well 6" inches.
Drilled 50 feet. Depth of completed well 50' ft.

(6) CONSTRUCTION DETAILS:
Casing installed: 6" Diam. from +2 ft. to 45' ft.
Welded [X] Liner installed [ ] Threaded [ ]
" Diam. from ______ ft. to ______ ft.
" 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 [X] No [ ]
Manufacturer's Name Huston
Type Free Flow Model No. ______
Diam. 6 Slot size 20 from 45 ft. to 50 ft.
Diam. ______ Slot size ______ from ______ ft. to ______ ft.

Gravel packed: Yes [ ] No [X] Size of gravel ______
Gravel placed from ______ ft. to ______ ft.

Surface seal: Yes [X] No [ ] To what depth? 19 ft.
Material used in seal Volclay Grout
Did any strata contain unusable water? Yes [ ] No [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 11-16-94
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 [X] 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 50+ gal./min. with 0 ft. drawdown after 4 hrs.
Airtest ______ gal./min. with stem set at ______ ft. for ______ hrs.
Artesian flow ______ g.p.m. Date 11-15-94
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
TOP Soil Silty Sand	0	3'
Sand some silt	3	21'
Washed Sand Water	21	40
Sand some small Gravel	40	50

DEC 5 [redacted]

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 Moomaw Drilling (PERSON, FIRM, OR CORPORATION) (TYPE OR PRINT)
Address PO Box 3652 Omak 98841
(Signed) Bill R Moomaw (WELL DRILLER) License No. 1523
Contractor's Registration No. MoomaD*070DD Date 11-16-94, 19__

(USE ADDITIONAL SHEETS IF NECESSARY)

Ecology is an Equal Opportunity and Affirmative Action employer. For special accommodation needs, contact the Water Resources Program at (206) 407-6600. The TDD number is (206) 407-6006.

STATE OF WASHINGTO
DEPARTMENT OF CONSERVATION
AND DEVELOPMENT

WELL LOG Appl. No. 6726

Date February 13, 19 63

Record by driller

Source driller's record

Location State of WASHINGTON

County Okanogan

Area

Map

SW ¼ NW ¼ sec 26 T 39 N, R 27 E. E/W

Diagram of Section

Drilling Co. Bud Henneman, Well contractor

Address Oroville, Washington

Method of Drilling dug Date 2-10, 19 63

Owner Authur J. Lehrman

Address Route 1, Box 294, Oroville, Wn.

Land surface, datum ft above/below

Correlation	Material	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	0	28
	Gravel and water	28	38
	Casing: 48" from 0 - 6'		
	36" from 6 - 28'		
	30" from 28' to 38'		
	Perforated: 3/4" holes in concrete tile		
	from 28' to 38'		
	No screen		
	Gravel not packed		
	S.W.L.: 28 feet		
	No well test made, but well has been in use		
	for 2 yrs. and produces 150 g.p.m.		
	Pump: Turbine, 5 HP		

Turn up Sheet of sheets

The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.

WATER WELL REPORT

Original & 1st copy – Ecology, 2nd copy – owner, 3rd copy – driller

Construction/Decommission ("x" in circle)
☒ Construction 402556
○ Decommission ORIGINAL INSTALLATION Notice of Intent Number

CURRENT
Notice of Intent No. W271107
Unique Ecology Well ID Tag No. BAP 098
Water Right Permit No.
Property Owner Name Rich McKinney
Well Street Address 31 VerBeck RD
City Oroville County Okanogan
Location NE 1/4-1/4 NW 1/4 Sec 23 Twn 39 R 27 EWM (circle one) or WWM
Lat/Long (s, t, r Still REQUIRED) Lat Deg ___ Lat Min/Sec ___ Long Deg ___ Long Min/Sec ___
Tax Parcel No. 3927232005

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

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

DIMENSIONS: Diameter of well 8"-6" inches, drilled 110 ft. 206
Depth of completed well 206 ft. 8" 6"

CONSTRUCTION DETAILS
Casing Installed: ☒ Welded 8" Diam. from +2 ft. to 110 ft.
☒ Liner installed 4 1/2 Diam. from 86 ft. to 206 ft.
☐ Threaded Diam. from ft. to ft.

Perforations: ☒ Yes ☐ No
Type of perforator used Skilsaw
SIZE of perfs 1/8 in. by 6 in. and no. of perfs 30 from 160 ft. to 206 ft.

Screens: ☐ Yes ☒ No ☐ K-Pac Location
Manufacturer's Name
Type Model No.
Diam. Slot size from ft. to ft.
Diam. Slot size from ft. to ft.

Gravel/Filter packed: ☐ Yes ☒ No ☐ Size of gravel/sand
Materials placed from ft. to ft.

Surface Seal: ☒ Yes ☐ No To what depth? 19 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

PUMP: Manufacturer's Name NA
Type: H.P.

WATER LEVELS: Land-surface elevation above mean sea level ft.
Static level 30 ft. below top of well Date Dec 21-10
Artesian pressure lbs. per square inch Date
Artesian water is controlled by (cap, valve, etc.)

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.
Yield: gal./min. with ft. drawdown after hrs.
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 Dec 20-10
Bailer test gal./min. with ft. drawdown after hrs.
Airtest 5 gal./min. with stem set at 204 ft. for 4 hrs.
Artesian flow g.p.m. Date
Temperature of water Was a chemical analysis made? ☐ Yes ☒ No

CONSTRUCTION OR DECOMMISSION PROCEDURE

Formation: Describe by color, character, size of material and structure, and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of information. (USE ADDITIONAL SHEETS IF NECESSARY.)

MATERIAL	FROM	TO
Brown Sand	0	17
Clay Gravel	17	36
Gray Clay Sand	36	72
Brown Clay with Gravel	72	108
Granite Gray med	108	163
Decomposed Granite Water soft	163	167
Gray Granite med	167	183
Hard Granite	183	206

RECEIVED
JAN 14 2011
DEPARTMENT OF ECOLOGY - CENTRAL REGIONAL OFFICE

Start Date Dec 6-10 Completed Date Dec 21-10

WELL CONSTRUCTION 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.

☒ Driller ☐ Engineer ☐ Trainee Name (Print) Bill Moomaw
Driller/Engineer/Trainee Signature Bill Moomaw
Driller or trainee License No. 1573

If TRAINEE,
Driller's Licensed No.
Driller's Signature

Drilling Company Moomaw Drilling
Address PO Box 3652
City, State, Zip Omak WA 98841
Contractor's Registration No. MOOMAD*070DD Date 12-21-10

Ecology is an Equal Opportunity Employer.

ECY 050-1-20 (Rev 3/05) The Department of Ecology does NOT warranty the Data and/or Information on this Well Report.

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

6547

WATER WELL REPORT

STATE OF WASHINGTON

Start Card No. 021039

Water Right Permit No. ______

(1) OWNER: Name B.J. POTTER Address RT 2 BOX 804 OROVILLE WA

(2) LOCATION OF WELL: County OKANOGAN NE ¼ SW ¼ Sec 26 T. 39 N., R. 27 W.M.

(2a) STREET ADDDRESS OF WELL (or nearest address) ______

(3) PROPOSED USE: [X] Domestic [ ] Irrigation [ ] DeWater Industrial [ ] Test Well [ ] Municipal [ ] Other [ ]

(4) TYPE OF WORK: Owner's number of well (if more than one) ——
Abandoned [ ] New well [X] Deepened [ ] Reconditioned [ ]
Method: Dug [ ] Cable [X] Rotary [ ] Bored [ ] Driven [ ] Jetted [ ]

(5) DIMENSIONS: Diameter of well 6 inches.
Drilled 145 feet. Depth of completed well 144 ft.

(6) CONSTRUCTION DETAILS:
Casing Installed: ______ " Diam. from ______ ft. to ______ ft.
Welded [X] 6 " Diam. from +1 ft. to 139 ft.
Liner installed [ ]
Threaded [ ] ______ " 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 [X] No [ ]
Manufacturer's Name JOHNSONN
Type STAINLESS Model No. ——
Diam. 6 Slot size .015 from 139 ft. to 144 ft.
Diam. ______ Slot size ______ from ______ ft. to ______ ft.

Gravel packed: Yes [ ] No [X] Size of gravel ______
Gravel placed from ______ ft. to ______ ft.

Surface seal: Yes [X] No [ ] To what depth? 18 ft.
Material used in seal SODIUM BENTONITE
Did any strata contain unusable water? Yes [ ] No [X]
Type of water? ______ Depth of strata ______
Method of sealing strata off ______

(7) PUMP: Manufacturer's Name STA-RITE
Type: SUBMERSIBLE H.P. 1 HP

(8) WATER LEVELS: Land-surface elevation above mean sea level +700 ft.
Static level 60 ft. below top of well Date 5/1/92
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 [X] 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 20+ gal./min. with ______ ft. drawdown after ______ hrs.
Airtest ______ gal./min. with stem set at ______ ft. for ______ hrs.
Artesian flow ______ g.p.m. Date 5/1/92
Temperature of water ______ Was a chemical analysis made? Yes [ ] No [X]

(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
BRN. DRY SAND	0'	75'
BROWN DRY CLAY	75'	80'
GRAY DRY CLAY	80'	100'
SILTY GRAY CLAY	100'	131'
BLACK/GRAY SAND H_2O	131'	145'
PICKING UP SMALL GRAVEL AND BLACK SAND	145'	→
SCREEN INSTALLED WITH K PACKER AND A 1 FOOT RISER PIPE.		

RECEIVED
MAY 18 1992
DEPARTMENT OF ECOLOGY
CENTRAL REGION OFFICE

Work started 4/19/92 Completed 5/1/1992

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 ALPINE DRILLING (PERSON, FIRM, OR CORPORATION) (TYPE OR PRINT)

Address RT 1 BOX 153-1 OMAK

(Signed) [signature] (WELL DRILLER) License No. 0804

Contractor's Registration No. ALPINDI314QB Date 5/1/92, 19

(USE ADDITIONAL SHEETS IF NECESSARY)

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

The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.

1705

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. 016516

Water Right Permit No. —

(1) OWNER: Name Siegfried Scharf Address 916 McCartney Rd. Kelowna, B.C.

(2) LOCATION OF WELL: County Okanogan NE ¼ SW ¼ Sec. 26 T. 39 N., R. 27 W.M.

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

(3) PROPOSED USE: [X] Domestic [ ] Irrigation [ ] DeWater Industrial [ ] Test Well [ ] Municipal [ ] Other [ ]

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

(5) DIMENSIONS: Diameter of well 6" inches.
Drilled 160 feet. Depth of completed well 160 ft.

(6) CONSTRUCTION DETAILS:
Casing installed: 6" Diam. from +2 ft. to 160 ft.
Welded [X] " Diam. from ft. to ft.
Liner installed [ ] " Diam. from ft. to ft.
Threaded [ ]

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 [ ] No [X]
Manufacturer's Name
Type Model No.
Diam. Slot size from ft. to ft.
Diam. Slot size from ft. to ft.

Gravel packed: Yes [ ] No [X] Size of gravel
Gravel placed from ft. to ft.

Surface seal: Yes [X] No [ ] To what depth? 18 ft.
Material used in seal Bentonite
Did any strata contain unusable water? Yes [ ] No [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 N/A 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: Dry 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
Top Soil	0	3
Sand	3	10
Sand & Gravel	10	30
cemented sand & gravel	30	38
Sand Stone	38	63
Fine Sand- heaving	63	140
Blue Clay	140	160

Note: Stopped drilling at owners request may continue drilling at a later date. welded cap to top of casing.

RECEIVED
JUL 5 1989
DEPARTMENT OF ECOLOGY
CENTRAL REGION OFFICE

Work started May 8, 1989 Completed May 24, 1989

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 CCT Well Drilling (PERSON, FIRM, OR CORPORATION) (TYPE OR PRINT)

Address Route 2, Box 395, Okanogan, Wash.

(Signed) (WELL DRILLER) License No. 1331

Contractor's Registration No. CCTWED*175KZ Date May 26, 1989

(USE ADDITIONAL SHEETS IF NECESSARY)

The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.

ECY 050-1-20 (10/87) -1329- 3

4740

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.
Water Right Permit No.

(1) OWNER: Name Siegfried Schaf Address 916 McCartney RD. Kelowna B.C

(2) LOCATION OF WELL: County Okanogan NE ¼ SW ¼ Sec 26 T 39 N., R 27 W.M.

(2a) STREET ADDRESS OF WELL (or nearest address)

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

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

(5) DIMENSIONS: Diameter of well 6 inches.
Drilled 80 feet. Depth of completed well 80 ft.

(6) CONSTRUCTION DETAILS:
Casing installed: 6" Diam. from 0 ft. to 80 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 Cook
Type Model No.
Diam. 5" Slot size 8 the from 75 ft. to 80 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? 18 ft.
Material used in seal
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 60 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
top soil	0	1
sand	1	25
sand & clay	25	40
gravel & sand	40	45
sand	45	65
mud	65	70
fine sand	70	80

RECEIVED APR 30
DEPARTMENT OF ECOLOGY CENTRAL REGIONAL OFFICE

ENTERED

Work started 4/4 19 Completed 4/18 1991

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 Hubbard Well drilling (PERSON, FIRM, OR CORPORATION) (TYPE OR PRINT)
Address P.O. Box 12
(Signed) Joe Hubbard (WELL DRILLER) License No. 0882
Contractor's Registration No. HUBBAWD120NA Date 4/28/ 1991

(USE ADDITIONAL SHEETS IF NECESSARY)

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

The Department of Ecology does NOT Warranty the Data and/or the Information on this 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

Start Card No. W-050467
UNIQUE WELL I.D. # ABL-891
Water Right Permit No.

(1) OWNER: Name RAY WALKER Address RT 2 BOX 803 OROVILLE WASH

(2) LOCATION OF WELL: County OKANOGAN [redacted] NE 1/4 NW 1/4 Sec 26 T. 39 N., R 27 W.M.

(2a) STREET ADDRESS OF WELL (or nearest address)

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

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

(5) DIMENSIONS: Diameter of well 6 inches.
Drilled 90 feet. Depth of completed well 90 ft.

(6) CONSTRUCTION DETAILS:
Casing Installed: 6 " Diam. from +1 ft. to 85 ft.
☑ Welded ☐ Liner installed ☐ Threaded
" Diam. from ft. to ft.
" 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 Houston
Type Stainless Model No.
Diam. 5 1/4 Slot size .010 from 85 ft. to 90 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? 18 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 62 ft. below top of well Date 5-5
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? T.M.
Yield: 20 gal./min. with 23 ft. drawdown after 1 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
Fine Sand & Gravel Brown	0	38
Gray Sand Gravel	38	80
Fine Gray Sand & H2O	80	90

RECEIVED
MAY 29 1986
DEPARTMENT OF ECOLOGY
CENTRAL REGION OFFICE

Work Started 5-3-, 19. Completed 5-5, 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 M M Well Drilling (PERSON, FIRM, OR CORPORATION) (TYPE OR PRINT)
Address 6 Airport Rd Oroville 9884
(Signed) Tom M... (WELL DRILLER) License No. 2131

Contractor's Registration No. MMWELLD088DN Date 5-5-86, 19

(USE ADDITIONAL SHEETS IF NECESSARY)

Ecology is an Equal Opportunity and Affirmative Action employer. For special accommodation needs, contact the Water Resources Program at (206) 407-6600. The TDD number is (206) 407-6006.

ECY 050-1-20 (9/93)

APPENDIX C

Well Test Work Plan

Pumping Test Work Plan

Wildhorse Spring Creek

1.0 Purpose

This work plan was developed to document planning of methods, required equipment and responsibilities supporting a pumping test at the domestic well 26D01, Wildhorse Spring Creek, near Oroville, Washington. This pumping test will measure well and aquifer performance and assess impacts to stream flow and temperature from discharging groundwater to Wildhorse Spring Creek. This work is being performed as part of the Wildhorse Spring Creek Habitat Enhancement project under contract with Colville Confederated Tribes Anadromous Fisheries Program, Aspect Project No. 100073.

2.0 Overview

The Wildhorse Spring Creek pumping test will assess the nature of the groundwater to surface water connection and determine if pumping will reduce baseflow in the stream.

Pumping tests typically involve pumping water from a well, and monitoring changes in head and/or water quality in the pumping well and observation wells. These tests are performed to determine larger-scale aquifer parameters, measure well and/or pump performance, assess the magnitude of contaminant transport, and design infrastructure for dewatering or ASR. Step-rate pumping tests are typically performed to determine the optimal pumping rate for constant-rate pumping tests, and have also been used to assess well vs. aquifer losses and sea water intrusion. A step-rate test usually starts with a low pumping rate. Once drawdown in the well has stabilized, the pumping rate is increased. Each step typically lasts between 30 minutes and 2 hours, and there may be 3 to 5 steps in all. Constant-rate tests are typically 24 hours long, with additional recovery monitoring.

Characteristics of the pumping well include:

- Well used for domestic purposes for two residences and for garden/lawn irrigation
- Irrigation also provided to the site by OTID
- Dug well with 48” concrete tile
- Total depth = 26 feet
- Expected formation (no well log available) is fine sand/sand + gravel
- Pump intake should be set near bottom of well, but not below domestic pump
- Minimum flow requirement = 10 gpm
- Maximum flow requirement = 200 gpm
- Anticipated sustainable yield = 30 gpm

3.0 Timeline

The pumping test will proceed along the following general timeline:

<u>Tuesday 30 August, 2011</u>

0800-1000

Set up pumping and discharge equipment

Measure antecedent water levels in the pumping well and piezometers, streamflow and surface water quality parameters

1000-1200

Begin step-rate pumping test

1200-1400

Monitor recovery

1400

Begin constant-rate pumping test

<u>Wednesday 31 August, 2011</u>

1400

End constant-rate pumping test

1400-1700

Monitor recovery

1700

Equipment tear down

<u>Thursday 01 September, 2011</u>

0800-1000

Continued monitoring: piezometers, well SWL, stage heights

4.0 Staffing

Bill Sullivan, Hydrogeologist, Aspect, will be present on 31 August and 01 September and available via cell phone at all other times.

Steve Southmayd, Temporary Field Staff, Aspect Consulting, will make antecedent field measurements on Tuesday 30 August and for continuous periodic measurements on Wednesday 31 August and Thursday 01 September.

Fogle Pump will be present for the duration of the set up/take down and pumping test

5.0 Contacts

Contact information including cell phone numbers for Aspect Consulting, Colville Tribes, Fogle Pump and property owners was included in the work plan (not shown here).

6.0 Planning Checklist

- Workplan
- H&S Plan
- Driller estimation of well capacity
- Point of discharge:
    - Agency approval (Ecology, DOT, irrigation district, county, and/or municipality)
    - Erosion controls
- Specifications for contractor:
    - Equipment disinfection
    - Depth to water
    - Required maximum pumping rate,
    - Pump depth
    - Check valve above pump
    - Flow control
    - Flow metering
    - Sample port
    - 2 – 1-inch sound tubes
    - Length of run to point of discharge
    - Elevation of point of discharge relative to wellhead
    - Required test and recovery periods
- Contract
- Observation wells;
    - Identification of possible wells
    - Owner permission
    - Evaluation for manual and electronic WL measurement
- Instrumentation required (see also Equipment List below)

7.0 Equipment List

____Properly installed, developed, and disinfected well

Existing well; driller to disinfect equipment

____Observation well(s)

None identified as feasible

____Pump and power supply (typically provided by drilling/pump contractor)

____Check valve installed above the pump

____Flow measuring equipment (flow meter, manometer, or weir provided by contractor)

____Sounding tubes (ideally two 1-inch Schedule 40 pipes, installed by contractor to top of pump)

____Sample port

____Approved point of discharge

No permit required for discharge of groundwater to surface water

____Well construction log and workplan (including health & safety forms)

____Pumping test field forms:

- Pumping Test Data
- Flow Test Data
- Groundwater Sampling Record

____Semi-log graph paper

____Clipboards and pens

____Pressure transducer(s) with datalogger

____Communication cable for datalogger/laptop

____Barometric pressure sensor and datalogger

____Laptop computer

____Water level indicator(s)

____Weighted tape to measure total depth of well, and sand production during testing

____Imhoff cone to measure sand production during testing

____Turbidimeter

____Water quality instruments

YSI: temperature, DO, conductivity, pH, ORP (if available)

Temperature/conductivity and pH dipsticks (back up)

PT2X transducer at Staff B provides continuous temperature record at that location

____Tool kit

____Decontamination kit

____Water level meter (2)

____Streamflow velocity meter and measuring tape

____Transit level and rod

____GPS

____Camera

____Fresh batteries

____Calculator

8.0 Procedures for Pumping Test

A. Collect antecedent data:

- ☐ Discharge at Staff A-C (day before on 30 August and morning of 31 August prior to test)
- ☐ Stage height at Staff A-C (day before on 30 August and morning of 31 August prior to test)
- ☐ Water quality at Staff A-C, P-4 and P-5 (temperature, conductivity, pH, ORP)
- ☐ Verify PT2X transducer at Staff B is operational; change recording period to 1 minutes
- ☐ Water levels Piezometers P-1-P-7 (day before on 30 August and morning of 31 August prior to test)
- ☐ Water levels in domestic well 26C01 (pumping well); unused well 26B02 (at P-6); unused well 26C04 (at P-4);
- ☐ Weather conditions
- ☐ Terminus of stream flow
- ☐ Surface water turbidity at Staff A-C and at -P4 and P-5

B. Set up/ Tear down

<u>Verify the following set up by Aspect Consulting:</u>

- ☐ Decontaminate well tape and transducer to be used in pumping well; Driller will decontaminate all other equipment to be used in the well (pump, discharge pipe, sounding tube)
- ☐ Deploy transducer in pumping well to depth greater than pump set; program logger to record on 10 second intervals; record in-air pressure readings (for error and offset) and temperature.
- ☐ Synchronize watches among all participants and equipment (data loggers, laptop)
- ☐ Program and deploy tidbit temperature loggers downstream of discharge at P-5, P-4 and upstream at P-6.

- ☐ Calibrate YSI and set up flow-through cell for groundwater quality monitoring
- ☐ Instruct the driller's crew on data collection and use of field forms

Verify the following set up by Fogle Pump

- ☐ Decontaminate well tape and transducer to be used in pumping well; Driller will decontaminate all other equipment to be used in the well (pump, discharge pipe, sounding tube)
- ☐ Set submsersible pump
- ☐ Power generator
- ☐ Discharge piping with check valve
- ☐ Discharge to stream 100 ft upstream of Piezometer 5 (P-5); discharge to be constructed to avoid erosion or streambed/bank and minimize turbidity. A perforated pipe will be used to minimize erosion at the discharge point and will be monitored throughout the test. Additional measures will be taken as needed to minimize erosion.
- ☐ Sampling port with ¼ tubing adapter located outside of well house
- ☐ Set two 1" sounding tubes
- ☐ Flow meter with totalizer
- ☐ Two 1-inch sounding tubes with screened interval

Verify the following tear down by Aspect Consulting

- ☐ Remove well tape, transducer removed from pumping well
- ☐ Caps replaced on all piezometers
- ☐ Download Staff B transducer
- ☐ Retrieve Tidbit temperature loggers
- ☐ Collect all field forms
- ☐ Notify property owner when testing completed (after recovery monitoring)

Verify the following tear down by Fogle Pump

- ☐ All equipment removed from pumping well and well house. Pump to remain in well for at least 24 hours following conclusion of pumping test or 95% recovery of SWL.
- ☐ Discharge piping removed
- ☐ Domestic water system at well 26C01 restored to fully functional (check at hydrant next to well house)
- ☐ Well house door securely shut

C. Run step-rate test

- Program/start the datalogger in pumping well.
- Start and run the step-rate test
  - Pump at 20 gpm for 30 minutes
  - Pump at 60 gpm for 30 minutes as applicable
  - Pump at 100 gpm for 30 minutes as applicable
  - Pump at rate to be determined (4th rate) after first three completed (30 minutes)
  - Determine optimal pumping rate for continuous-pumping test
- Allow well to recover
- Monitoring during the step-rate test
  - Record SWL in pumping well prior to start
  - Every **1 minute for first five minutes** of each new step:
    - pumping well WL
  - Every **10 minutes** after for each new step:
    - pumping well WL
  - Periodically check stream bed for erosion at discharge location
  - Every **1 minute for first five** minutes of recovery:
    - pumping well WL
  - Every **15 minutes** for remainder of recovery:
    - pumping well WL

- Surface water monitoring will include dissolved oxygen content to ensure DO levels do not meet the following parameters:

DO min 5 mg/L
DO max 9-15 mg/L

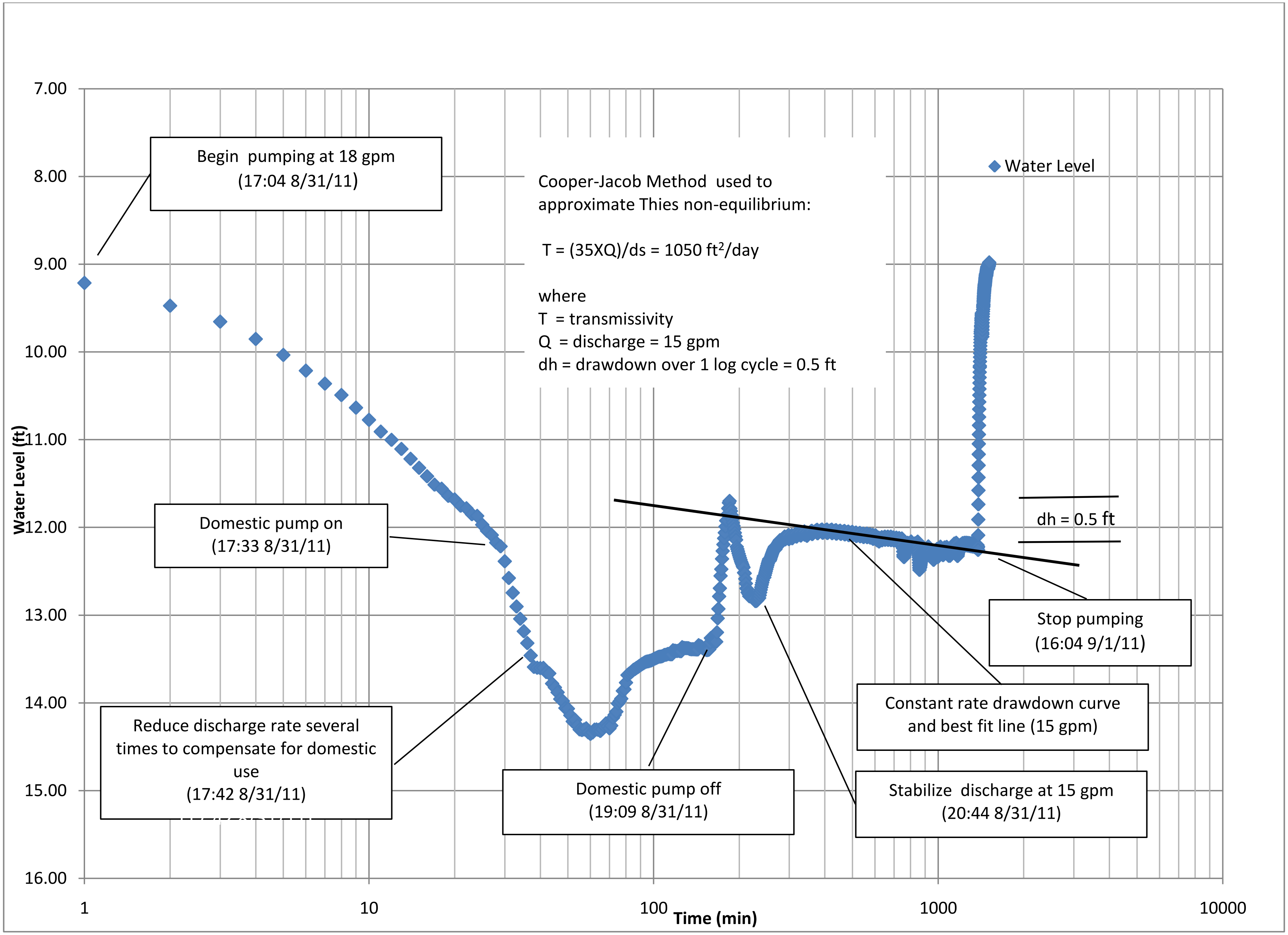
These parameters are expected to be met at all times. Should they not be met, the pumping test will be ceased.

D. Run constant-rate test.

- Download and reprogram datalogger.
- Start the test. Adjust flow rate and check discharge.
- Once pumping starts, increasing pumping head will likely lower the pumping rate. Aim for the targeted rate, but limit the amount of rate manipulation as much as possible. Be aware that much of the drawdown in the pumping well at the beginning of the test is typically boring storage, and is not useful for aquifer parameter analysis.
- Monitoring during constant-rate pumping test
  - Record SWL in pumping well prior to start
  - Every **1 minute until first five minutes** after constant flow rate established:
    - pumping well WL
  - Every **15 minutes after:**
    - pumping well WL, flow rate, totalized flow
    - pumping well water quality (temperature, conductivity, pH, ORP, turbidity) for first one hour
  - Every **1 hour**:
    - pumping well water quality
  - Every **1 hour** while Aspect Staff onsite:
    - stage height at Staff B
    - water level and water quality at P-5
  - Every **2 hours** while Aspect Staff onsite:
    - water levels in P-1 through P-7; unused wells 26B02 and 26C04
    - water quality at P-1 through P-7
    - stage height staff A-C
    - GPS terminus of streamflow
  - Every **4 hours** while Aspect Staff onsite:
    - Volumetric measurement at Staff B
  - Every **1 minute for first five** minutes of recovery:
    - pumping well WL
  - Every **15 minutes** for remainder of recovery:
    - pumping well WL
- Once pumping ends, the pump should stay in the well for 24 hours or 95% of recovery.
- Download dataloggers and remove instrumentation.

APPENDIX D

Well Test Analysis



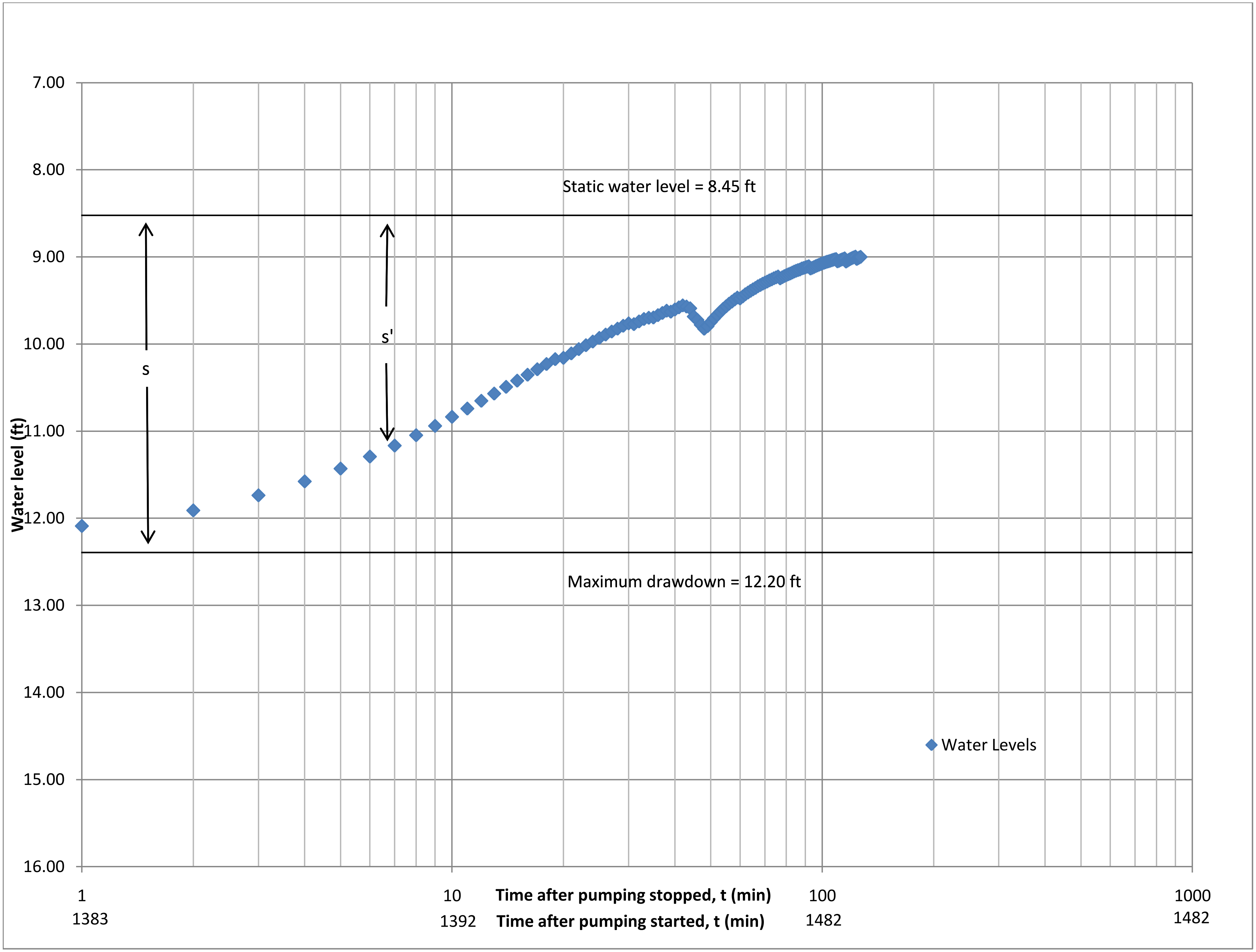
Aspect Consulting

4/2/2012

Well Test Drawdown Curve

Wildhorse Spring Creek Hydrologic Study

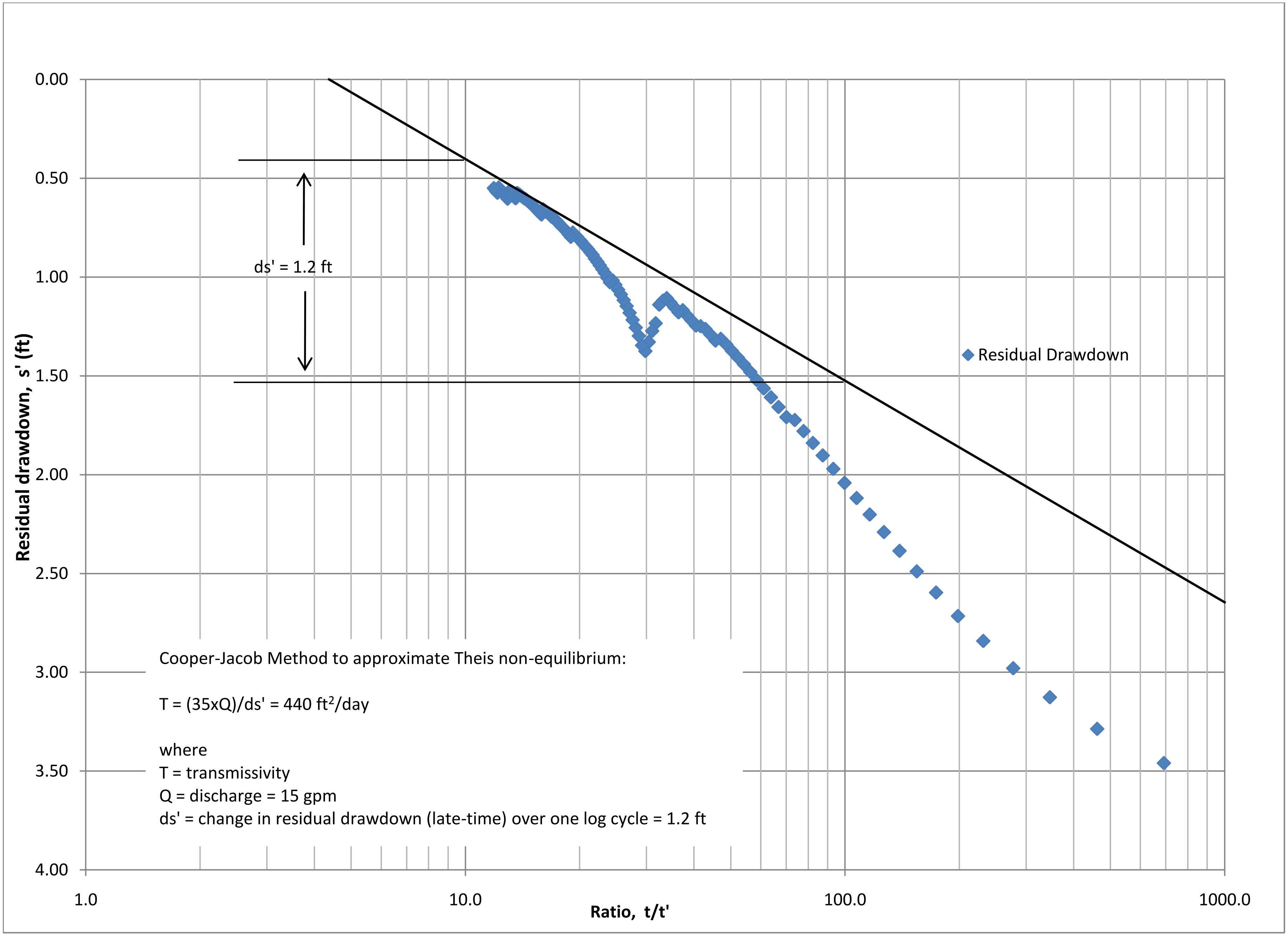
Okanogan County, WA



Well Test Recovery Curve

Wildhorse Spring Creek Hydrologic Study
Okanogan County, WA

Aspect Consulting
4/2/2012



Well Test Time-Recovery Plot

Wildhorse Spring Creek Hydrologic Study

Okanogan County, WA

Aspect Consulting

4/2/2012

Aspect
CONSULTING