Whychus Creek Restoration Project at Camp Polk Meadow Preserve

June 29, 2007

A collaborative project of the:

Upper Deschutes Watershed Council
Deschutes Basin Land Trust
Deschutes National Forest

Project design funding provided by the Oregon Watershed Enhancement Board, Confederated Tribes of the Warm Springs Reservation, Deschutes River Conservancy and The Nature Conservancy.

Technical design prepared for the Upper Deschutes Watershed Council by the Deschutes National Forest under Collection Agreement No. 06-CO-11060120-011.
Please direct project inquiries to Ryan Houston, Upper Deschutes Watershed Council, www.RestoreTheDeschutes.org

TABLE OF CONTENTS

FIGURES

TABLES

APPENDICES

EXECUTIVE SUMMARY

Land management activities in the lower Whychus Creek watershed and stream alterations within Camp Polk Meadow have resulted in significant degradation to Whychus Creek. Since European settlement began in the 1860's, there has been an estimated net loss of 4,200 feet of mainstem stream channel, 4,800 feet of side channels, 75 acres of wetland area and a lowering of the groundwater elevation by three to 10 feet within Camp Polk Meadow.

The Deschutes Basin Land Trust, owners of the 145-acre Camp Polk Meadow Preserve, have partnered with the Upper Deschutes Watershed Council to restore the 1.5 mile reach of Whychus Creek that flows through Camp Polk Meadow to enhance stream function and fish and wildlife habitat. The project is specifically focused on restoring a naturally functioning stream channel through the historic meadow to provide high quality in-stream and riparian wetland habitat for the benefit of native fish and wildlife. A particular emphasis is placed on improving conditions for native fish, including existing redband trout and the summer steelhead and spring chinook that are being reintroduced with the fish passage restoration at Pelton and Round Butte Dams.

The Upper Deschutes Watershed Council employed the technical expertise of the Deschutes National Forest to assess restoration options for Whychus Creek and to design the selected alternative. Team members evaluated relic channels in the meadow, stream flow, sediment regimes and channel pattern and dimensions. All analyses, results and design were reviewed with a multi-disciplinary Technical Advisory Committee. The analyses indicate that restoring a highly sinuous meadow channel is feasible under the current flow and sediment regimes, and that the restoration effort will result in a properly functioning and stable stream channel.

The restored meadow channel will restore 1.7 miles of stream channel (including an increase of 2,646 feet), increase side channel habitat by more than 500 feet, increase wetland area by approximately 73 acres, reduce stream temperatures and increase late season flow.

INTRODUCTION

Background

The Deschutes Basin Land Trust (Land Trust) purchased the 145-acre Camp Polk Meadow Preserve (Camp Polk Meadow) in 2000 to protect and restore fish and wildlife habitat along approximately 1.5 miles of Whychus Creek (river mile 15.3 to 16.6). Camp Polk Meadow is located approximately four miles northeast of the town of Sisters, Oregon and includes a variety of wetlands, meadows, aspen groves and ponderosa pine stands (T14S R10E SEC 34) (**Figure 1**). Camp Polk Meadow is home to a variety of plant and wildlife species and is one of Central Oregon's birding hot spots, with more than 135 species identified on site. Camp Polk Meadow also has a long and illustrious history as a crossroads for Native Americans, explorers, soldiers and settlers (Winch 2006). The Hindman barn on Camp Polk Meadow is Deschutes County's oldest structure.

Whychus Creek originates on the Deschutes National Forest in the Three Sisters Wilderness, on the east slope of the Cascade Range. The stream flows approximately 40 miles northeast, through Sisters, and ultimately into the Deschutes River at river mile 123. Although the upper watershed is in undisturbed wilderness, the lower watershed around the community of Sisters has been managed for timber production and livestock grazing since 1870 (Inter-Fluve 2002). Diversions from Whychus Creek have been used to provide irrigation water for agriculture since the late 1800's (Inter-Fluve 2002). Current water withdrawals on Whychus Creek reduce peak summer discharge volumes by an average of 150 cubic feet per second (cfs) between April 1 and September 30. With recent conservation efforts, in-stream flow leasing and purchases, the average summer low flow was approximately 15 cfs in 2006. In-stream flow restoration efforts are ongoing and it is expected that summer base flow will continue to increase over the next five to ten years.

Fish species currently inhabiting Whychus Creek at Camp Polk Meadow include the following native species: redband trout (*Oncorhynchus mykiss*), bridgelip sucker (*Catostomus columbianus*), longnose dace (*Rhinichthys cataractae*), speckled dace (*Rhinichthys osculus*) and shorthead sculpin (*Cottus* confuses). Mountain whitefish (*Prosopium williamsoni*) and federally-listed bull trout (*Salvelinus confluentus*) are found downstream, near the mouth of Whychus Creek in the vicinity of Alder Springs. Non-native fish species include brook trout (*Salvelinus fontinalis*), brown trout (*Salmo trutta*) and one domestic goldfish (*Carassius auratus*). Brown trout densities appear to be increasing in recent history as this species is now occupying habitats where it was not found in 1997 (**Appendix E**).

Prior to the purchase of Camp Polk Meadow, Whychus Creek had been drained, ditched, straightened and diked to make the meadow more suitable for settling

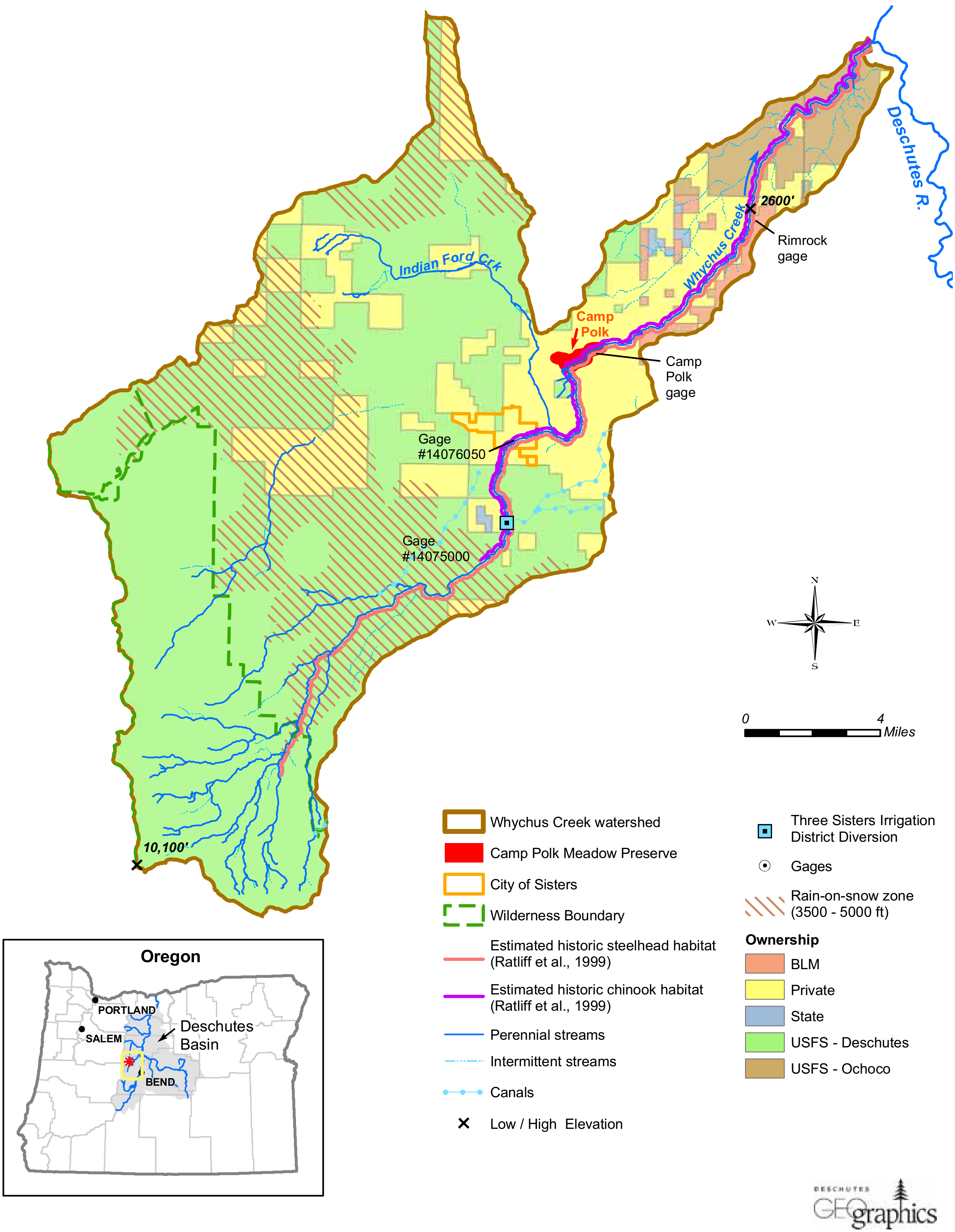


Figure 1. Project location.

and grazing. Although it is not known exactly when these modifications began, some initial channelization is visible in the earliest known aerial photo from 1943. At this time, Whychus Creek had been placed into a drainage ditch along the southern boundary of the valley, and a storage pond had been constructed in the meadow. Since 1943, channel sinuosity has continued to decrease as the straightened Whychus Creek downcut and became more incised. As a result, much of the meadow is now dry, no longer supporting riparian vegetation and the stream channel is deeply incised and dominated by riffle habitat with little vegetative cover or diversity. This reach of stream does not meet temperature standards and is on the State of Oregon's 303(d) impaired water bodies list as directed by the Clean Water Act.

Camp Polk Meadow has historically provided important habitat for native redband trout and, prior to fish passage blockage at the Pelton Round Butte Dams, habitat for spring chinook salmon and summer steelhead trout. Whychus Creek within Camp Polk Meadow provided significant habitat for spawning steelhead, likely due to appropriate sized substrate and cold water influx from springs (Riehle personal communication). The installation of Pelton and Round Butte Dams created passage barriers for anadromous fish species, and therefore chinook and steelhead have not reached the Upper Deschutes Basin in the past 40 years.   Due to pending fish passage restoration activities at Pelton and Round Butte Dams, it is expected that steelhead and chinook will once again have access to the upper Deschutes River, Metolius River and the Crooked River drainages, including Whychus Creek. Current habitat conditions within Camp Polk Meadow are poor, providing little for either chinook or steelhead.

Development and Planning

The Land Trust and Upper Deschutes Watershed Council (Watershed Council) entered a partnership in 2004 to evaluate potential restoration alternatives, develop a restoration design and, ultimately, implement a comprehensive restoration project designed to improve stream function and fish and wildlife habitat at Camp Polk Meadow. Under this partnership the Watershed Council agreed to oversee the funding, design, management and implementation of the restoration project as part of its mission to support habitat restoration on private land in the Whychus Creek watershed.

After securing project design funding from the Oregon Watershed Enhancement Board, Deschutes River Conservancy, Confederated Tribes of the Warm Springs Reservation and The Nature Conservancy, the Watershed Council established a Project Team to conduct the project evaluation and design. The Project Team consists of:

- Ryan Houston, Upper Deschutes Watershed Council (Project Manager)
- Kristine Senkier, Upper Deschutes Watershed Council (Hydrologist)
- Paul Powers, Deschutes National Forest (Fisheries Biologist)
- Cari McCown, Deschutes National Forest (Hydrologist)

- Karen Allen, private consultant (Botanist, Wetlands Biologist)
- Amanda Egertson, Deschutes Basin Land Trust (Land Steward)
- Sherry Berrin, Deschutes Basin Land Trust (Assistant Land Steward)

The Watershed Council employed the technical expertise of the Deschutes National Forest to assist with the restoration planning under Agreement #0601-06-CO-011. This partnership was built upon more than five years of a close working relationship between the Deschutes National Forest and the Watershed Council on several stream restoration projects, including Trapper Creek (restoration of federally-listed bull trout habitat on the Crescent Ranger District), Tumalo Creek (three miles of channel reconstruction for Regionally Sensitive redband trout on the Bend/Fort-Rock Ranger District), and Middle Fork Lake Creek (channel realignment, habitat restoration for federally-listed bull trout on property owned by the Lake Creek Lodge).

The partnership between the Watershed Council and Deschutes National Forest has been developed under the Wyden Amendment, which encourages the Forest Service to partner with private landowners on watershed restoration projects. The Whychus Creek project fits under the Wyden Authority as Forest Service Administered Lands are located upstream of the project area and the Forest Service has a vested interest in improving watershed conditions. Habitat improvements downstream of Forest Service managed lands will improve fish stock health and improve the probability of returning anadromous fish to the Deschutes National Forest.

In addition to the Project Team members listed above, Dan Rife, Mike Riehle, Nate Dachtler (fish biologists), David Bates, Chris Yamasaki (fisheries technicians), Peter Sussman (soil scientist), Louis Wasniewski, Marc Wilcox, and Rob Tanner (hydrologists) all provided important input during the restoration planning.

The Watershed Council also established a Technical Advisory Committee (TAC) to provide feedback, guidance, peer review and other assistance with the project design process. This TAC includes:

- Leslie Bach, The Nature Conservancy
- Rod Bonacker, Deschutes National Forest
- Mollie Chaudet, Deschutes Basin Land Trust Board of Directors
- Jennifer O'Reilly, U.S. Fish and Wildlife Service
- Matt Orr, University of Oregon
- Maret Pajutee, Deschutes National Forest
- Mike Riehle, Deschutes National Forest
- Darcy McNamara, Watershed Council Board of Directors
- Dan Rife, Deschutes National Forest
- Matt Shinderman, Oregon State University

- Scott Turo, Confederated Tribes of Warm Springs
- Louis Wasniewski, Deschutes National Forest
- Marc Wilcox, Deschutes National Forest
- Ted Wise, Oregon Department of Fish and Wildlife
- Mark Yinger, Hydrologist

Project Goal and Objectives

Through the planning process, the Project Team and TAC identified that the goal of the project is to restore the key functions and values of the historic wet meadow and associated in-stream and riparian habitat. The intent is to benefit fish and wildlife, including neotropical migratory birds, mammals, amphibians, and native resident and anadromous salmonids. The project seeks to restore historic summer steelhead and spring chinook spawning areas at Camp Polk Meadow to support the anadromous fish reintroduction efforts in this watershed.

Based on a review of similar restoration projects in the western United States, the restoration of a meandering stream channel and meadow hydrology should greatly improve aquatic habitat quantity and quality in Whychus Creek (Hogervorst and Schmalenberg 2005; Lindquist and Wilcox 2000; Plumas Corp 2004; Loheide and Gorelick 2005; Loheide Gorelick 2006). A restored meadow channel will result in increased off channel refugia, decreased peak velocities, increased cover, increased food production and increased groundwater storage available for delayed release during summer low flow periods. Delayed releases will dampen the flashy flow regime at Camp Polk Meadow, decrease maximum water temperatures and increase the quality of spawning habitat by providing cold water upwelling through hyporheic exchange. In addition, the project will provide an outstanding opportunity to connect local residents with habitat restoration through tours, volunteer projects and other activities that coincide with a large-scale restoration project.

Project goals and objectives include:

<u>Goal 1:</u> Provide 1.7 miles of high quality redband trout, chinook and steelhead spawning and rearing habitat.

<u>Objective 1</u>: Increase length of channel by 2,646 feet, increase number of pools from 14 to 27, and create more than 500 feet of new side channel habitat.

<u>Goal 2:</u> Restore functioning meadow hydrology, including floodplain connectivity, an increase in the groundwater table and enhanced summer base flow.

<u>Objective 2</u>: Increase the entrenchment ratio from the existing 1.5 to a minimum of 23.

<u>Objective 3</u>: Increase average groundwater elevation a minimum of three feet in the meadow.

Goal 3: Restore and enhance high quality riparian wetland habitat along the stream corridor.

Objective 4: Establish a minimum of 70 acres of wetland and riparian plant communities.

Goal 4: Provide natural channel stability, including dimension, pattern and profile that meets reference conditions;

Objective 4: Restore channel that meets the 36 dimension, pattern and profile design criteria established in this Restoration Plan.

Goal 5: Reduce stream temperatures to help meet state water quality criteria.

Objective 5: Reduce temperature in the project reach by 2°C (3.5°F) to assist in meeting the 18°C (64.4°F) maximum stream temperature [redband trout] and 13°C (55.4°F) maximum stream temperature [steelhead trout] established by the Oregon Department of Environmental Quality.

Alternatives

During the feasibility assessment and development of the restoration design, the Project Team evaluated two alternatives (**Figure 2** and **Appendix A**):

1. Meadow Channel: Restore a sinuous channel on the meadow, and
2. Enhanced Existing Channel: Improve aquatic habitat conditions within the current channel alignment

Alternative 1 (Meadow Channel Alternative) would significantly increase channel sinuosity (+0.5), length (+2,646 ft), pools (+13), cover, and side-channel habitat (+ >500 ft), thereby increasing both adult and juvenile salmonid habitat quantity and quality. In addition, the creation of a meadow channel would provide early rearing and spawning habitat for both steelhead trout and chinook salmon (see discussion in **Appendix B**) and improve habitat for resident redband trout. In this alternative, the bankfull elevation would match the valley floor/meadow, allowing flood waters to spill over the banks and fully access the floodplain, reducing bed and bank shear stress. This would greatly increase wetland acres and groundwater storage (see discussion in **Appendix C**), reduce maximum stream temperatures and increase late season streamflow (Loheide and Gorelick 2005; Loheide and Gorelick 2006). This alternative fully meets project goals and restores not only aquatic habitat but the ecological function of the entire meadow, including hydrologic function and wildlife habitat.

Alternative 2 (Enhanced Existing Channel) would include developing additional meanders within the current alignment where feasible, constructing structures within the bed to develop and maintain pool habitat, and constructing lateral log complexes for habitat and hydrologic complexity. Due to the degree of entrenchment, meander opportunities are limited without creating a great deal of bank instability and, therefore, a much less sinuous channel would be

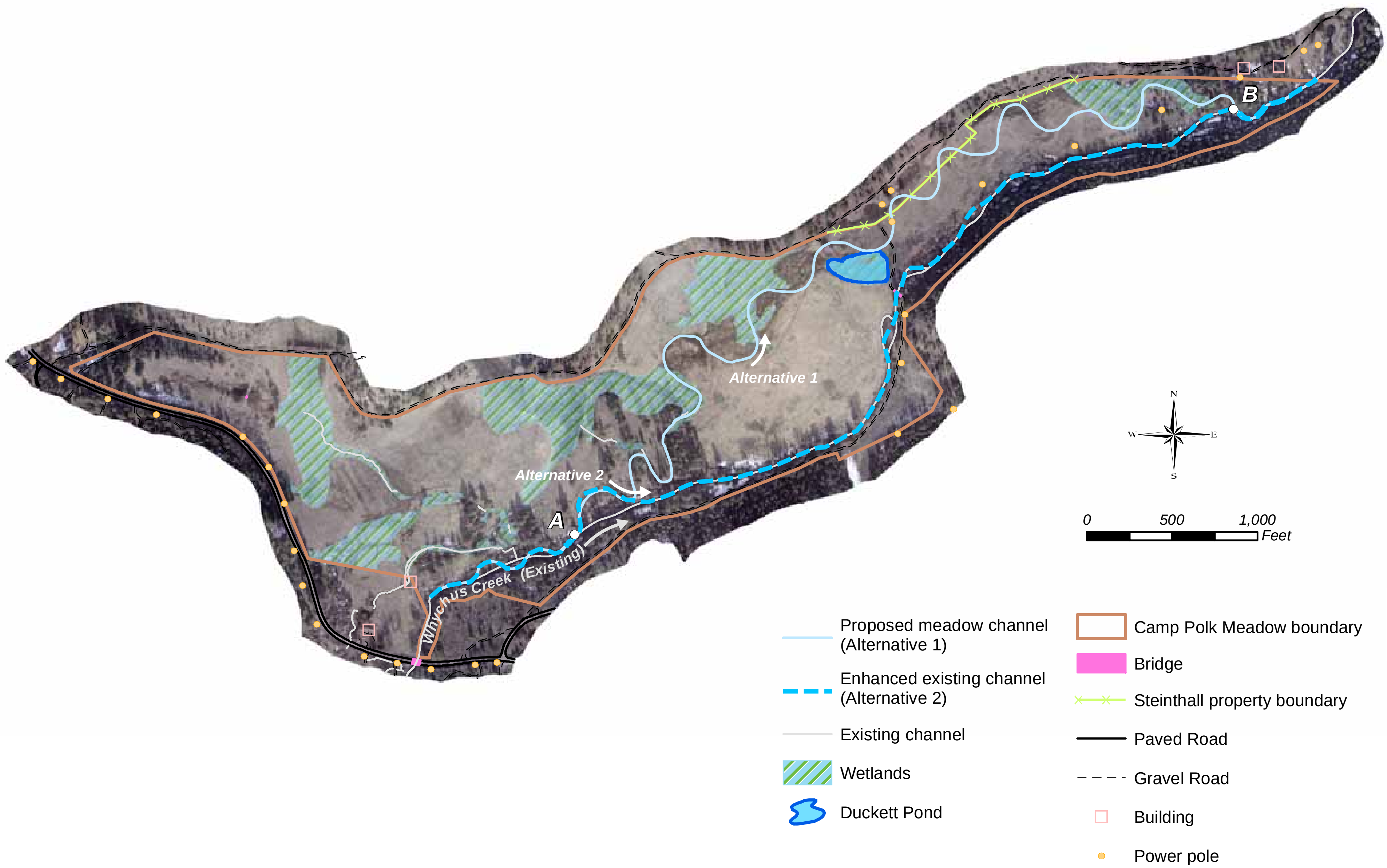


Figure 2.

Restoration alternatives.

Source: 2/11/06 Aerial Photo

cpm_mapping\alternatives.mxd, dquinlan, 6/7/07

DESCHUTES GEOgraphics

constructed.   This alternative would not reconnect Whychus Creek with its floodplain or elevate the groundwater table. Whychus Creek would remain entrenched and dominated by riffle habitat. Alternative 2 does not fully meet all of the restoration goals for the project.

Two meetings and a site visit were held in 2006 with the TAC to discuss the merits and feasibility of each alternative. Members of the TAC were in agreement with the Project Team that the meadow alternative was both feasible and the preferred restoration alternative. Following a presentation by the Project Team, the Board of Directors of the Land Trust formally voted on October 19, 2006 to pursue the restored meadow alternative.

PROJECT ANALYSIS

Previous Assessments

The US Army Corps of Engineers conducted a flow analysis at Camp Polk Meadow in 2001 (USACE 2001). This report concluded that due to flow and sediment regime alterations resulting from irrigation diversions upstream, pre-settlement conditions could not be restored at Camp Polk Meadow.

Inter-Fluve, a hydrologic consulting group based in Hood River, Oregon, conducted a sediment analysis for the US Army Corps of Engineers in 2002 (Inter-Fluve 2002). The purpose of their analysis was to determine if irrigation withdrawals upstream of Camp Polk Meadow were responsible for current conditions in the meadow, and/or if current sediment supplies would allow for the restoration of a stable meandering meadow channel. The analysis suggests that irrigation withdrawals have very little influence on the sediment supply (removing 2-8% of sediment) and the conditions observed in Camp Polk Meadow are the result of land management activities (*e.g.*, diking and berming, channel straightening, grazing, logging, filling of wetlands and relic channels, *etc.*).

Inter-Fluve (2002) describes that there are two options for decreasing channel slope, improving riparian/wetland complexity and re-grading the channel. One is to fill the current channel and restore flows onto the meadow. The second option would be to create sinuosity within the current alignment by excavating the banks and reforming the channel at a lower base elevation. Restoring flows onto Camp Polk Meadow would maximize groundwater storage and improve wetland hydrology.

Inter-Fluve (2002) also cautions that any work at Camp Polk will be exposed to potential elevated sediment from degrading stream banks upstream. A new channel that decreases slope by adding channel length or sinuosity will have to ensure that the new channel can transport sediment loads. Lateral bank and floodplain roughness that maintains a deep, narrow channel efficient at transporting sediment at bankfull and higher discharges should be a design criteria if the goal is to elevate the current channel to historic bed elevations and gradient. Restoring a meadow channel will result in a reduction in transport capacity where the transition in slope occurs from the current to the new channel bed. This transition point will be vulnerable to sediment deposition created by the loss of gradient and bed shear stress. Sediment deposition could result in meander cut-offs, over land flow, chute development or degradation.

The Project Team agrees with Inter-Fluve (2002) that changing from a high slope (*i.e.*, sediment transport reach) to a low slope new channel will result in sediment deposition. However, this issue can be addressed by designing the channel to facilitate sediment deposition prior to reaching the meadow. This will allow sediment deposition to migrate headward, reducing bed slope and potentially improving floodplain connectivity upstream. This will also allow the average bed slope upstream of the meadow to more closely meet the bed slope of the channel in the meadow, creating a smooth transition without a great deal of sediment deposition at this location.

Project Team Assessment

The Project Team evaluated soils, flow regime, channel dimension and pattern, sediment regime, vegetation and fish habitat to determine the feasibility of restoring a channel in the meadow and to develop the final design.

As part of the assessment, a one-foot contour map of the project area was created from aerial photo analysis during the spring of 2006 and incorporated into both CAD and GIS. A longitudinal profile survey of Whychus Creek was completed within Camp Polk Meadow during April 2006 using a total station. Additional survey work was completed in the fall 2006 to accurately capture channel dimensions of stable, pool/riffle sequences. A laser level was used to measure cross sections at stable locations and within portions of the relic channel.

Soils and Groundwater

Soils throughout the meadow are mapped as Omahaling fine sandy loam (USDA 1992). These soils are derived from a parent material of ash over alluvium, occur on floodplains between 2,800 and 4,000 feet elevation, and have a ‘somewhat poorly drained’ drainage class. The typical soil profile description consists of a fine sandy loam texture in the upper ~20 inches under which silt loam, gravelly sand and gravelly course sand is found. Limited investigation of surface soils in the meadow confirms a texture of fine sandy loam or sandy loam, with old stream gravels in places.

A field assessment conducted November 2006 identified the groundwater level in the meadow at 6.5 feet and groundwater monitoring in June 2007 identified groundwater depths varying between 4.8 and 7.5 feet. However, these data represent only limited sampling so continue monitoring in 2007 and beyond will be used to identify average depth to groundwater and potential seasonal fluctuations. These data will be collected as part of the project monitoring discussed later in this document.

In addition, a soil and groundwater assessment completed in June of 2006 concluded that the soils of Camp Polk are capable of storing 104,000 gallons of water per acre for every foot of rise in water table elevation, suggesting that the restoration of the meadow channel will result in improved water storage and late season releases (**Appendix C**). This is consistent with published findings for other similar projects in the west (Lindquist and Wilcox 2000; Plumas Corp 2004; Loheide and Gorelick 2005; Loheide Gorelick 2006)

Flow Regime

Stream flow was analyzed at Camp Polk Meadow to determine bankfull flow, which was critical for assessing whether the meadow channel could accommodate the existing flow regime and for designing this channel.

Whychus Creek flows have been measured at an upstream gage (14075000) since 1906. This gage site lies approximately nine miles upstream of Camp Polk Meadow, just above the Three Sisters Irrigation District diversion (**Figure 1**). This water withdrawal is operated seasonally from April through the end of September. A second gage (14076050), downstream of the Three Sisters Irrigation District Diversion has been operated near the town of Sisters by the Bureau of Reclamation since 2000. Flows at Camp Polk Meadow are assumed to be roughly comparable to the Sisters gage (14076050) because the only significant tributaries between the gage and Camp Polk Meadow are Indian Ford Creek (a small spring-fed stream) and a few other small springs that contribute a sum total of approximately three cfs. A third gage has recently been installed at Camp Polk Meadow by the Land Trust and Deschutes River Conservancy (DRC) to monitor base flows; however this gage is new and not fully calibrated for peak flows and therefore was not used for calculations and analysis. The Land Trust and DRC have installed a fourth gage at Rimrock Ranch, seven miles downstream of Camp Polk Meadow. This gage is also too new to be fully calibrated for peak flows.

The typical hydrograph for Whychus Creek both above and below the Three Creeks Irrigation Diversion is bimodal and flashy (**Figure 3**). Large, short duration rain-on-snow events occur during winter months and lower magnitude, more sustained elevated flows resulting from upland snowmelt occur during the spring months. Within the past 100 years, flows have fluctuated from 2,000 cfs during rain-on-snow events (1964) to zero cfs during summer months when 100% of the instream water was diverted for irrigation purposes.

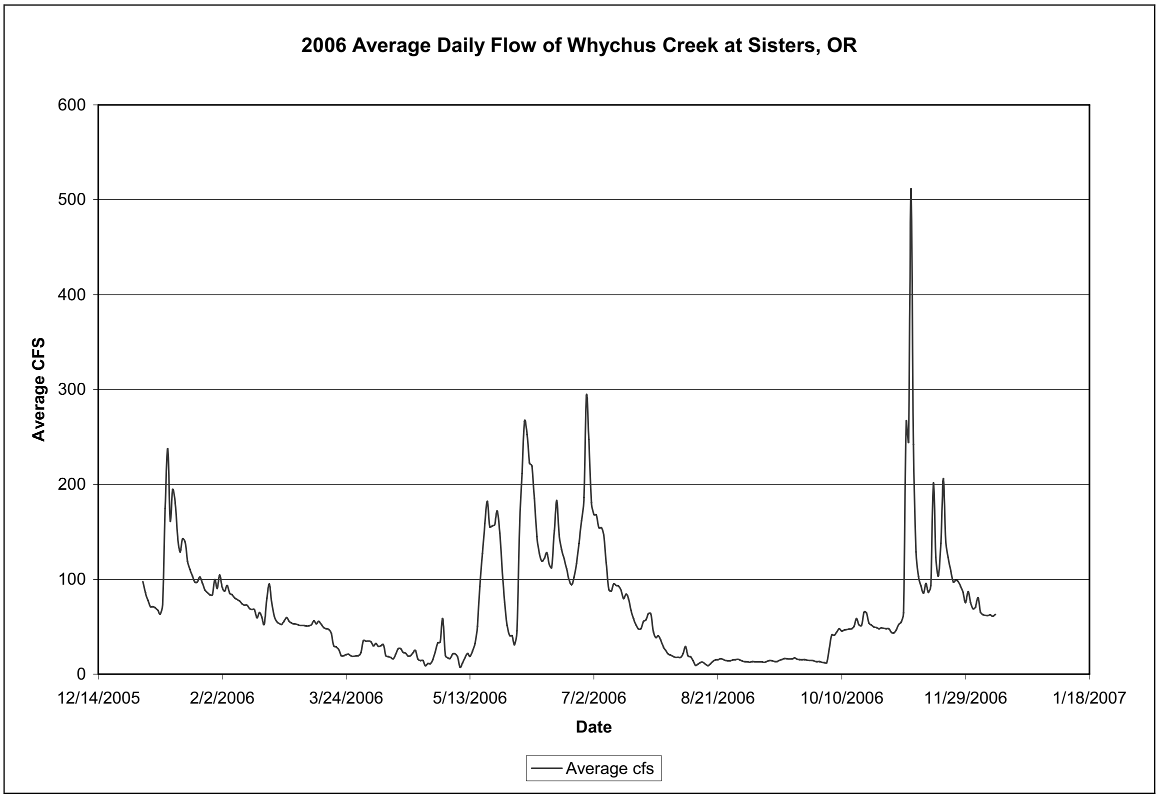


Figure 3. 2006 average daily flow of Whychus Creek.
Flow data collected at Sisters, Oregon (#14076050).

Large scale flow events appear to be more frequent in recent history and may be a result of climate change and/or changing weather patterns. For example, four of the ten largest peak flows on record (40%) have occurred within the past ten years. On November 7, 2006, the Project Team observed a rain-on-snow event that brought Whychus Creek at Sisters up to nearly 1,200 cfs, corresponding to an 11-year recurrence interval (RI) event.

The effects of the bimodal discharge regime are most pronounced downstream of the Three Sisters Irrigation District Diversion. Indicators of the bimodal discharge are displayed on the ground in the form of cross sectional dimension and vegetative structure. At Camp Polk Meadow and on the Cyrus property (immediately upstream of Camp Polk Road) there is a grade break and larger sized alder indicator at an elevation that fits the RI of 1.9 and calculated discharge of 375 cfs. There is also a lower elevation grade break and smaller willow/alder line that correlates with a RI of 1.5 and a discharge of 288 cfs (**Figure 4**).

Figure 4. Photo of Whychus Creek at Cyrus property.
This photo shows the bimodal indicators with an upper break and a lower terrace which likely has formed at spring snow melt discharges.

In reviewing stream gage data dating back to 1906, it appears that the primary irrigation diversion upstream of the project area is significantly reducing the longer-duration, spring snowmelt flows, but has had little influence on the highest and flashiest instantaneous peak flows, which are often associated with rain-on-snow events. Seventy-eight percent of the peak flows greater than 600 cfs occurred outside the irrigation season as rain-on-snow events. A little more than half (55%) of the annual instantaneous peak flows have occurred during the irrigation season (April – September), which is the period when the annual snow-melt peak occurs. These peaks have been reduced by 37% due to the irrigation canal diverting on average 146 cfs.

The average instantaneous peak occurring outside of the irrigation season (rain-on-snow) was 917 cfs as compared to the average of approximately 336 cfs occurring during the irrigation season (snow melt/summer thunderstorm) (**Figure 5**). In addition to the reductions in peak flow caused by the upstream irrigation diversion, summer base flows are significantly reduced as well. Summer low flow in Whychus Creek at Camp Polk Meadow is generally approximately 15 cfs, which is considerably more than in the past. In recent years conservation efforts and water right leasing and purchasing for instream flows have kept Whychus Creek from going dry as it flows through Sisters.

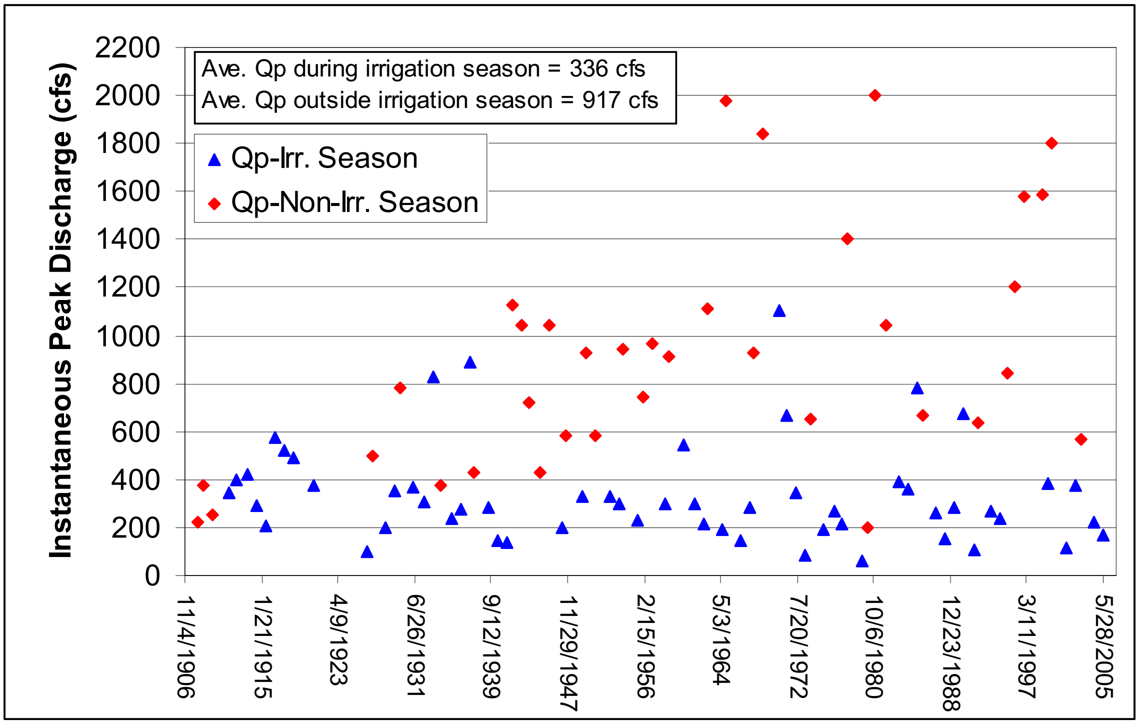


Figure 5. Annual instantaneous peak discharges, 1909-1994.
Flow gauge located downstream of primary diversion. Red diamonds indicate peak flow for the water year occurring outside the irrigation season (October through March) while blue triangles indicate a peak flow that occurred during the irrigation season (April through September). Note the consistency of snow melt flows (blue triangles).

As a result of irrigation diversions, bankfull flow at Camp Polk Meadow is less than bankfull flow measured upstream of the project area. For example, bankfull discharge upstream of the diversion (approximately nine miles upstream of Camp Polk Meadow) was calculated at 467 cfs (RI = 1.9), while the same 1.9 year RI at Camp Polk Meadow is estimated to be 374 cfs. Daily stream flow data between 1924 and 2005 showed that flows greater than 400 cfs occurred 96 days during the primary irrigation season upstream of the diversion, and only nine days downstream of the diversion.

Although there are two peaks that occur at Camp Polk Meadow, the restored meadow channel would be designed to carry the sustained, spring snow-melt peak as bankfull. The snow-melt peak at Camp Polk Meadow is associated with a flow of 288 cfs and a 1.5 year RI. The channel would be designed to accommodate this flow verses the higher, rain-on-snow peak because it is predictable (occurs nearly every year), sustained and most consistent with a channel forming flow. In contrast the high volume, short duration rain-on-snow events are less predictable in their recurrence or frequency and they are generally short lived pulses. Designing a channel with bankfull dimensions to match sustained flows that have only occurred nine times within the past 82 years would not achieve the desired hydrologic function. Therefore, the regularly recurring, sustained snow-melt discharge is the channel forming flow and the flashy short lived rain-on-snow pulses can be released onto the floodplain to dissipate stream energy.

Bankfull discharge in Whychus Creek at Camp Polk Meadow was calculated using Manning's Equation ($V=1.4865*R^{2/3}*S^{1/2}/n$) multiplied by the cross-sectional area at the high flow field indicators ($Q=A*V$), where,

Q=Discharge (ft^3/sec)
A=Cross Section Area (ft^2)
V=Velocity (ft/s)
R=Hydraulic radius (ft) = Area/Wetted perimeter
S=Water slope (ft/ft)

The "n", roughness coefficient, in Manning's Equation was estimated using two methods. One method used measured discharge at a known cross-sectional area to back-calculate the roughness coefficient "n". The other method used Limerino's equation based on empirical data and the Friction Factor, a function of hydraulic radius divided by the 84^{th} percentile stream substrate size (R/D84), to estimate "n". Limerino's equation is:

$n = (0.0926 * R^{1/6})/(1.16 + 2.0\log_{10}(R/D84))$ and was calculated in RiverMorph software.

The high flow discharges obtained using the two different methods for calculating "n" were compared to the discharges generally associated with bankfull RI (generally 1.2 – 2). Recurrence intervals for streamflow intervals at Camp Polk Meadow were determined by subtracting out the amount of flow diverted from the annual peak flows at gage 14075000 and then recalculating the RI downstream of the diversion. Bankfull flow at the gage upstream of the diversion (14075000) is associated with the 1.9 RI. Downstream of the diversion high flows estimated using the two methods for obtaining "n" values were close to the 1.9 RI. Because these estimates closely matched the calculated RI for the higher rain-on-snow events upstream of the diversion, the Limerino's equation was used to back-calculate the discharge associated with the snow-melt field indicators (lower grade break) at Camp Polk Meadow. These corresponded to a 1.5 RI, which best represented bankfull flow at Camp Polk Meadow. Therefore, bankfull flow at Camp Polk Meadow is thought to be 288 cfs, matching a 1.5 year RI.

Channel Pattern and Dimension

Channel pattern and dimension in the relic channel, the existing channel and at off-site reference reaches were analyzed to determine if a meadow channel could accommodate a bankfull flow of 288 cfs and to help design the proposed meadow channel.

Relic Channel

A sequence of the earliest aerial photos (1943, 1951, 1959, and 1967) available for the Camp Polk Meadow area were obtained and analyzed to help assess historic conditions in Whychus Creek.

In the 1943 photo, it is evident that Whychus Creek had already been pushed to the side of the valley and that relic meadow channel was being used as an irrigation canal to fill the Duckett Pond in the middle of the meadow (**Figure 6**; **Figure 7**). Based on the 1943 air photo, a survey cap dated 1938 in a relic channel, and the age of conifers within the bankfull elevation of the relic channel (80-85 years), it appears that Whychus Creek had probably been moved to the edge of the meadow prior to the 1930s.

Figure 6. 1943 aerial photo

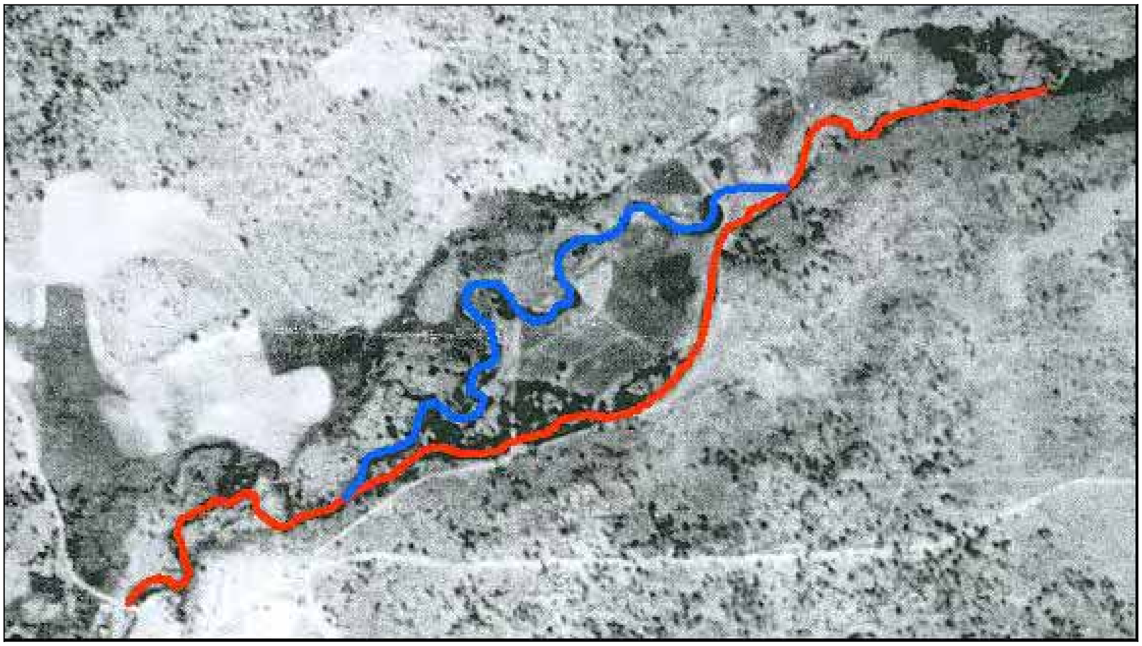


Figure 7. 1943 aerial photo (showing modifications).
The main channel is shown in red and the old channel alignment in blue. The old channel is being used as an irrigation feed line.

A majority of the old stream channel alignment has since been filled in and leveled to match the grade of the surrounding meadow. This was likely done with excavated materials from the Duckett Pond to make the property more suitable for farming and ranching. Portions of the relic channel remain visible through a ponderosa pine stand in the upper third of the meadow. This relic channel was analyzed as a reference condition for channel pattern and dimension.

Three cross-sections and a longitudinal profile were surveyed in the relic channel to determine if it would be entrenched under the current flow regime (**Figure 8**, **Figure 9**). Historic streambed elevations were determined by excavating pits to the old streambed and then surveying the substrate bed elevation. Based on these surveys, the relic channel (where visible) is not entrenched and was used as a reference for some parameters of the designed meadow channel.

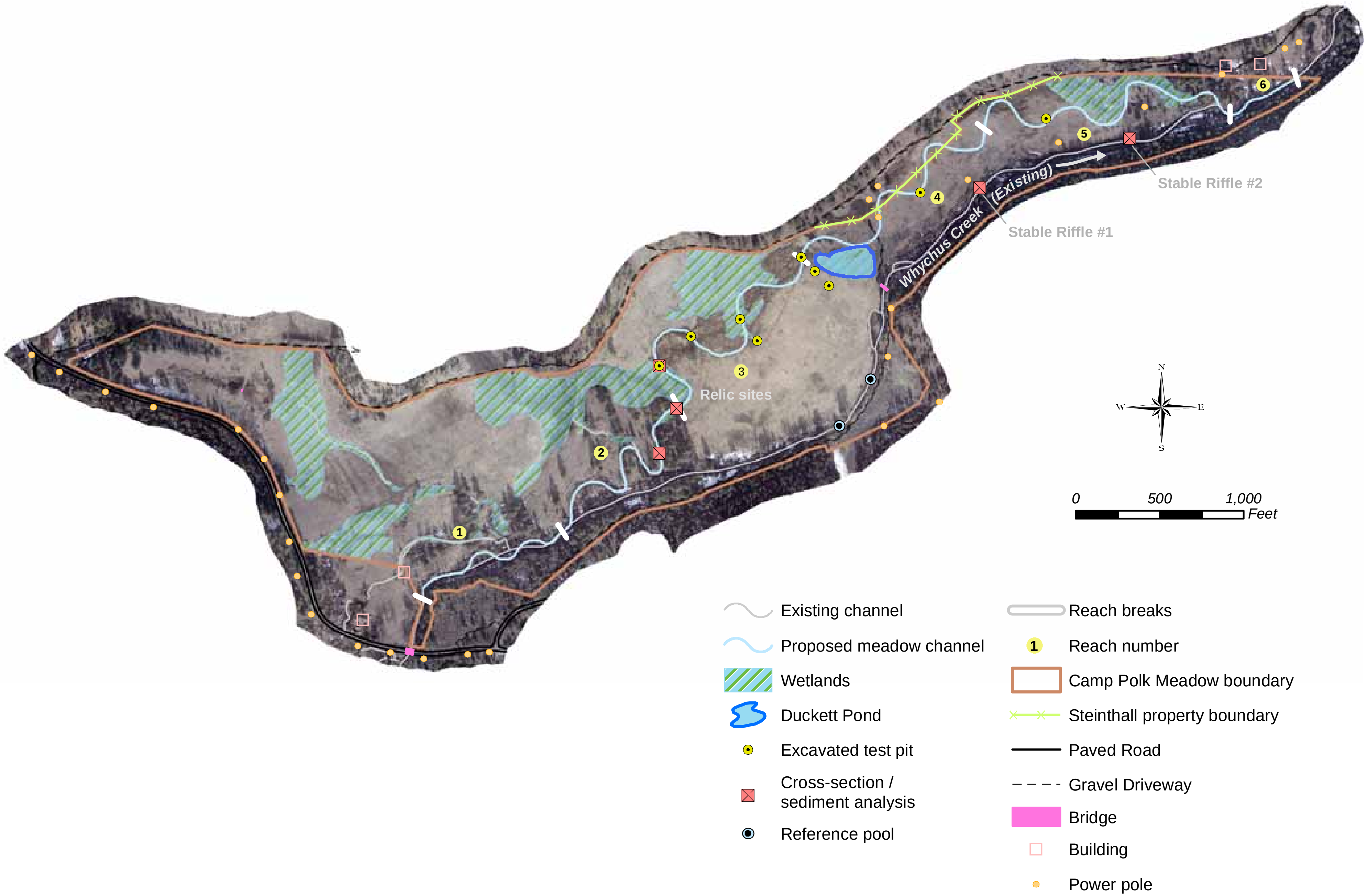


Figure 8.

Study sites in the Camp Polk Meadow area.

Source: 2/11/06 aerial photo

cpm_mapping\study_area.mxd, dquinlan, 6/7/07

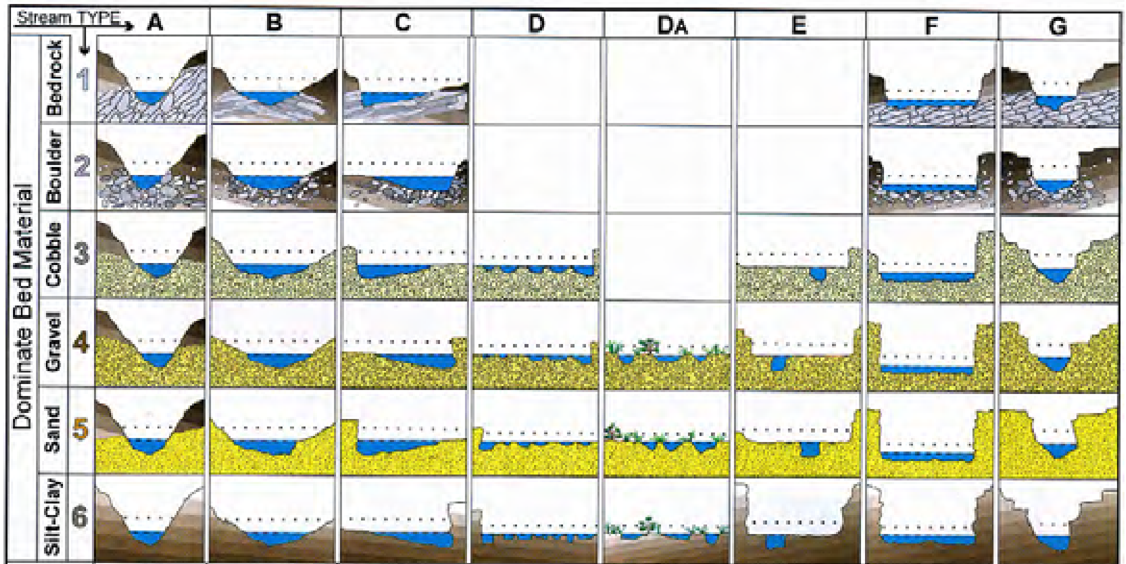
DESCHUTES GEOgraphics

Figure 9. Downstream view of cross section #1 in the relic channel.
The red line indicates the calculated area occupied by a discharge of 375 cfs (1.9 RI) with soil excavated to native bed material; pink line marks a discharge of 288 cfs (1.5 RI)

<u>Existing Channel</u>
Whychus Creek within the Camp Polk Preserve is dominated by long, homogenous riffle habitat. As a result of past ditching, diking and land management activities, the stream has become straightened and entrenched. The highest level of entrenchment is found at the upstream end of the property, where the average slope is steepest and Whychus Creek has downcut to bedrock. At the lower end of the property, the average slope is less, alluvial substrate remains and the level of entrenchment is lower.

Whychus Creek has been in this condition for several decades, and despite generally poor habitat conditions, the stream has stabilized. There is one exception, found approximately midway through the property. At this site a sediment wedge has formed upstream of a footbridge. Lateral instability at this site has resulted in erosion of the left bank. The current stream condition exhibits B, C and F channel type characteristics (**Figure 10**).

Only four stable habitat features that were found in the existing channel within reaches with stream types and slopes similar to the design channel. Although the existing channel is slightly incised at these sites (less than one foot), the habitat features still provided useful dimension data for developing a range of reference conditions because the reaches are low gradient and stable. The channel dimensions from these sites were compared to dimensions derived using empirical equations based on meander geometry, cross-sectional area, and bankfull width to insure they were within the range of other stable C stream type channels.



Stream TYPE	A	B	C	D	DA	E	F	G
Entrchmnt	< 1.4	1.4 - 2.2	> 2.2	n/a	> 4.0	> 2.2	< 1.4	< 1.4
W/D Ratio	< 12	> 12	> 12	> 40	< 40	< 12	> 12	< 12
Sinuosity	1 - 1.2	> 1.2	> 1.2	n/a	variable	>1.5	> 1.2	>1.2
Slope	.04-.099	.02-.039	< .02	< .04	< .005	< .02	< .02	.02-.039

Figure 10. Delineative criteria and characteristics for the major stream types (Rosgen and Silvey 1996).

Within the existing channel, four stable and properly functioning riffles and two stable pools with residual depths greater than three feet were extensively surveyed for channel dimension reference conditions (**Figure 8**). These sites were selected based on average slope and long term stability (see longitudinal profile discussion). These sites were used to compare observations in the relic channel against areas that are properly functioning under the current flow and sediment regimes. This provided an important crosswalk for comparing and assessing cross sectional area, bankfull slope, average riffle slope, pool dimensions, and substrate size. If the current channel is capable of maintaining stable pool/riffle sequences at these sites without aggrading or degrading the bed or eroding the banks, we know that the meadow channel should also be stable and properly functioning with similar channel dimensions and slope.

<u>Off Site Reference Reaches</u>
Conditions were evaluated at three sites, including the Cyrus Property, Rimrock Ranch and the Middle Fork of Lake Creek:

Three cross-sections and longitudinal profiles were surveyed on the Cyrus property, located immediately upstream of Camp Polk Meadow. These surveys were completed to assess upstream conditions and to evaluate the degree of erosion, lateral instability and mobile bed load coming into Camp Polk Meadow. These data were only relevant for assessment purposes and for determining bankfull cross-sectional area for the design. The Cyrus site does not provide a good reference for channel pattern as it had also been straightened and remains unstable. This reach of stream has experienced a significant degree of lateral movement as it is reclaiming a sinuous pattern. Bank erosion and mid-channel bar deposits are common features. Entrenchment on the Cyrus property is generally less than what is observed at Camp Polk Meadow, and due to the lateral channel movement, the belt width is greater and the riparian area is in better condition.

A field assessment of Whychus Creek at Rimrock Ranch was completed in October of 2006. Rimrock Ranch lies on Whychus Creek, approximately seven miles downstream of Camp Polk Meadow. Rimrock Ranch has a similar history to the Camp Polk and Cyrus properties. The stream flowing through this meadow has been confined to a single thread channel and straightened to make the adjacent wetland/meadow/marsh accessible to ranching and farming. Portions of the Rimrock Ranch property provided an excellent example of a recovering, functioning riparian area; however, due to the degree of past disturbance at this site, it does not provide a good reference condition for channel pattern. Aerial photo analysis shows that this site remains much less sinuous than it had been prior to ditching.

Reference conditions on Middle Fork Lake Creek (C4/E4 stream type) were extensively surveyed and used in the design of the channel through the Lake Creek Lodge property (Wasniewski 2005). Lake Creek has a similar average channel slope, sinuosity and channel pattern to the proposed meadow channel, and therefore provides some reference data for Whychus Creek. However, Lake Creek originates as outflow from Suttle Lake and maintains a much more consistent hydrograph than does Whychus Creek. Lake Creek is also smaller than Whychus Creek, with a bankfull discharge of only 90 cfs as compared to 288 at Camp Polk Meadow.

Because a single, undisturbed reference site with a similar hydrograph as Whychus Creek was not available as a reference, appropriate reference conditions were obtained from various sources and compiled to form a range of variability. Specific parameters are discussed in the Restoration Design section of this document.

Sediment Regime

Channel capacity (volume) and competence (particle size) were analyzed to design a meadow channel that could effectively route the existing sediment load. Capacity of the meadow channel was determined by evaluating the stability (*i.e.*, over-time neither aggrading nor degrading) of reference riffles in the existing channel with the same slope as the average slope of the proposed meadow channel. Longitudinal profiles from 2000 (USACE 2001) and 2006 were compared to verify that these sites had neither aggraded nor degraded within the past six years. If there was an imbalance of sediment and more sediment was coming in than the stream could transport out, the stream bed would aggrade.

Conversely, if the stream was transporting out more sediment than it was receiving from an upstream source, the stream bed would degrade. These sites have not changed; therefore, the existing channel at the stable riffle sites has the capacity to route the sediment load (**Figure 11**). Likewise, the meadow channel would have the capacity to route the sediment load because the meadow channel dimensions and substrate are within the range of the stable riffles in the existing channel.

Channel competence was analyzed by collecting and wet sieving pavement / sub-pavement samples at three sites within the visible portion of the relic channel (
Figure 12). The stream sub-pavement represents the average size of bedload available for transport once mobilization of the bed material occurs. Stable riffles with slopes ranging from 0.5% to 1% in the project area and upstream on the Cyrus property were sampled to determine the particle size mobile during a bankfull discharge. Pebble counts were conducted at each pavement / sub-pavement site (relic channel values were extrapolated from the low gradient stable riffles in the existing channel) and used in the entrainment calculations.

In locations where the relic channel had been filled and is no longer visible, nine test pits were excavated with a backhoe to locate the depth and composition of the old streambed. Pits were excavated along the proposed channel alignment in Reaches 2, 3 and 4; the depth and size of the former streambed substrate was recorded (**Figure 13**).The uppermost pit in Reach 2 is immediately downstream of a pavement/sub-pavement sample site in the visible portion of the relic channel. This pit was dug as a quality assurance procedure to check that the sub-pavement sample had not included any fill material from past agricultural practices. The substrate in this pit was similar to the substrate in the reference reaches and was approximately three feet below the valley elevation (1.5 feet below the soil surface in the relic channel).

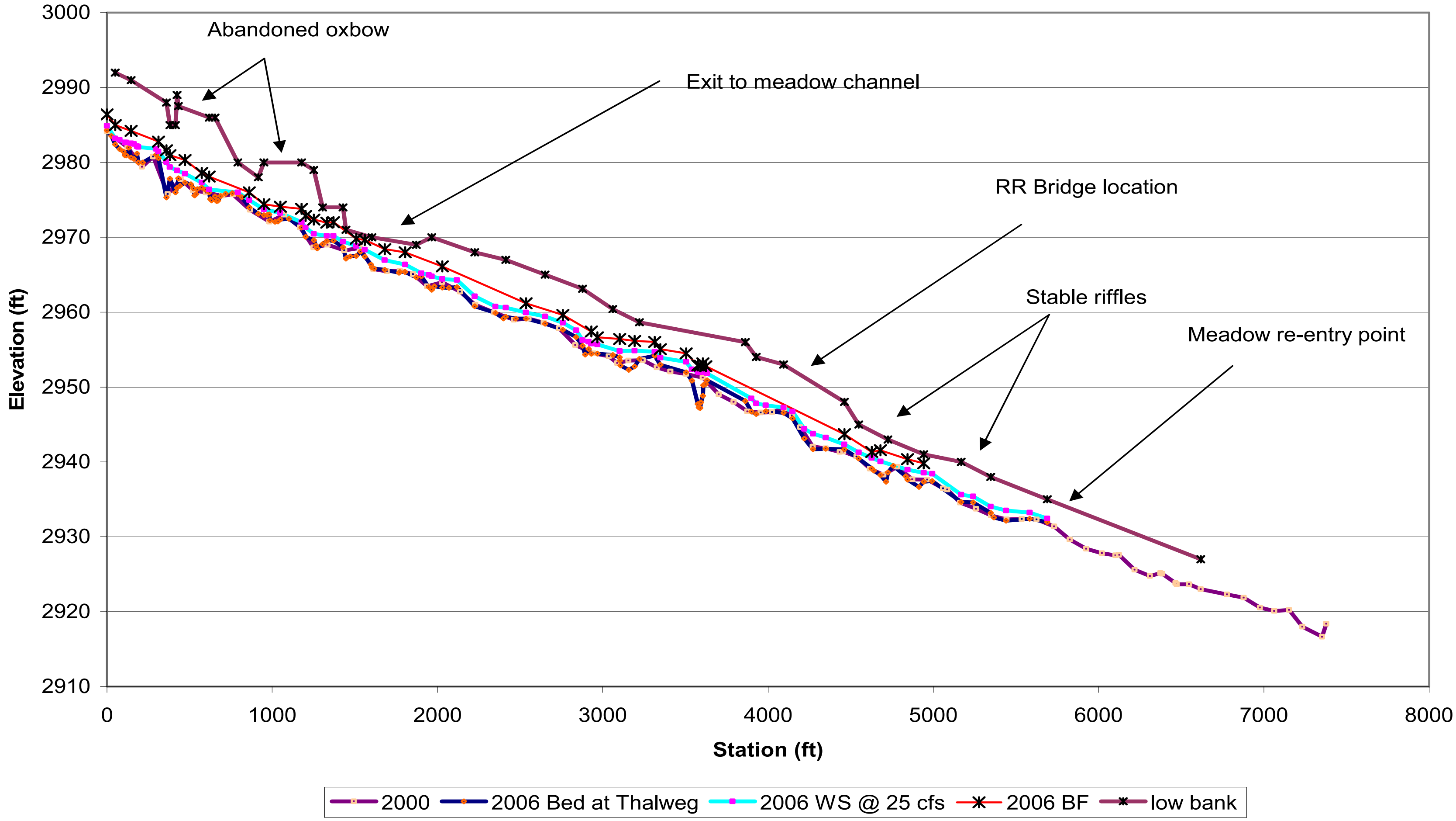


Figure 11. Comparison of 2000 and 2006 longitudinal profiles.

Figure 12. Pavement / sub-pavement samples in the relic channel. Excavating pavement / sub-pavement samples (top), (bottom left) sieved pavement on left, sieved sub-pavement on right, and (bottom right) five inches beneath surface of meadow.

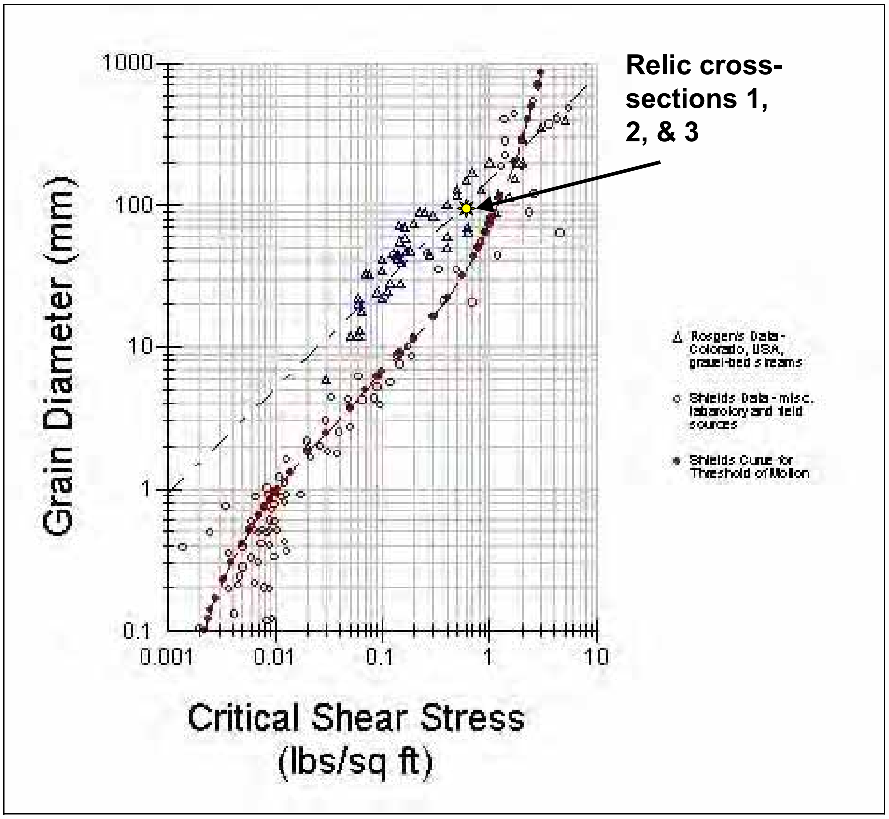


Figure 13. Modified Shields diagram.

Diagram includes empirical data from Colorado gravel-bed streams showing average largest sub-pavement diameter and critical shear stress within the relic channel at Camp Polk Meadow (Rosgen and Silvey 1996).

The substrate observed in the pits above Duckett Pond (Reach 3) was generally small (*i.e*., small gravels and sand), and found approximately 3.5 feet below the valley elevation (**Figure 14**). Pits in the upper part of this reach were excavated across the valley. Substrate was relatively uniform through this cross section with the exception of fill material over the bed in some locations. This indicates that the relic channel in this location may have been more of an E4/5 stream type, with high sinuosity and lower width-to-depth ratio (deeper and narrower). Down valley of the Duckett Pond, the substrate in the relic channel was similar in size to the existing channel (gravel and cobble) and approximately 1.5 ft below the valley elevation, suggesting that this reach may have been more characteristic of a C3/4 stream type (**Figure 15**).

Figure 14. Soil pit in Reach 3.
Pit located above Duckett Pond showing the depth and size of relic channel bed.

Figure 15. Soil pit in Reach 4.
Pit located below Duckett Pond showing the depth and size of relic channel bed.

Entrainment calculations based on the Rosgen methodology (Rosgen 2005) indicated that the shear stress on the bed of the proposed meadow channel will be within the acceptable range (**Figure 13**).Analysis of sub-pavement samples and test pits collected at Camp Polk indicate that substrate size in the relic channel is similar to stable riffles in the low gradient portion of the existing channel. Therefore, if a riffle in the current channel is stable (not aggrading or degrading) with an average bankfull (1.5 year RI) area of 60ft^2, average depth of 1.9 feet, and a sub-pavement D84 particle size of approximately 45 mm, the proposed meadow channel would also be stable given the same dimensions.

Based on the observed particle sizes, both in the test pits and in the pavement / sub-pavement samples, and the design channel dimensions, the meadow channel is fully capable of transporting the bedload of Whychus Creek under the current sediment regime. Degradation is not anticipated because substrate of similar size to the current channel (low slope areas) is present through most of the meadow, and bed shear stress will be reduced through floodplain connectivity. The meadow channel between the ponderosa pine stand and the Duckett Pond (Reach 3) is designed to be more similar to an E4/5 channel type. Riffles within this reach will probably be seeded with substrate of the same size as the upper meadow to prevent degradation. Significant aggradation is not anticipated; however, some will occur and is encouraged for the future creation of side channel habitat. Effective sediment transport and sorting through Camp Polk Meadow should result in the deposition of spawning substrate of appropriate size for steelhead in pool tail-outs.

Vegetation

Historic Vegetation

Camp Polk Meadow was first used by the military in 1864 and homesteaded soon thereafter in the early 1870s. These early settlers brought livestock and planted alfalfa, potatoes, grains and hay grasses (Winch 2006). These introduced grasses still thrive in the meadow today. By the time the first aerial photograph was taken in 1943, changes to the pre-settlement landscape were well underway. The black and white 1943 aerial shows areas of wet vegetation, a multi-channeled stream running through the meadow, cleared areas under cultivation, and irrigation lines (**Figure 6**). Because there are no known ground photos, drawings, or written accounts from early settlers, no baseline data about vegetation in the meadow at the time of settlement exists (Winch 2006).

Prior to European settlement, the meadow was used for thousands of years by eight different tribal groups who migrated across it seasonally. Native women dug roots and tubers, and collected berries, nuts, flowers, and seeds to use for food, baskets, shelter, tools and ceremonies. They camped in the meadow, erecting round tipis covered in woven tule and dogbane mats (Winch 2006). Tule, also known as softstem bulrush (*Schoenoplectus tabernaemontani*, synonym: *Scirpus validus)* is an aquatic plant found today in the Duckett Pond. Great Basin wild rye (*Leymus cinereus*), a native bunchgrass, was called "se-see-qua" by the native Pauite who ground its seeds into flour (Winch 2006). Also known as tall ryegrass, it can be found growing along the margins of the Upper Meadow. Willow was used to make baskets and may have been used to frame sweat lodges. Berries of riparian species such as chokecherry, red osier dogwood, blue elderberry, gooseberry, and serviceberry were collected, eaten fresh or preserved for later use (Winch 2006).

The blue blossoms of camas (*Camassia quamash*) were observed when they bloom in the Spring to avoid the deadly white or green flowering camas. The bulbs were harvested in fall, eaten fresh or dried in the sun. Wild mint or field mint (*Mentha arvensis*), a native perennial forb, is a common circumboreal species that tends to readily spread (OSU 1980). While both species thrive in open wet meadows, neither is known to currently grow at Camp Polk Meadow.

Relic pieces of woody material and root masses of grasses, rushes or sedges were observed throughout the depth of soil profiles dug along the relic channel. It was unclear as to whether the roots observed more than three feet deep were still living and viable or if they were from decadent plants. Due to the very fine structure of the roots and the fact that they had not decomposed, it has been assumed that they were from living plants.

<u>Existing Conditions</u>
Native wetland and riparian plant species that occur at Camp Polk Meadow today provide insight into future restoration opportunities. Most plants growing in wet areas are native perennials. This is encouraging, as it suggests that when the meadow is recharged, native perennial plants will be favored. In addition, most have extensive root networks, important for soil stability, and spread vegetatively through rhizomes, creeping underground horizontal stems.

Plant community composition was investigated in five locations during the 2006 growing season:

- Along Whychus Creek;
- Surrounding and within Duckett Pond;
- In the mid-meadow above the Duckett Pond;
- In the relict channel located down valley from the mid-meadow ponderosa pine grove; and
- In the spring-fed wetland near the large aspen grove at the upper end of the mid-meadow.

Species found at Camp Polk Meadow, their location (near creek, far from creek, in wettest part of wetland, on edge of pond, *etc.*), and elevation (relative to Whychus Creek flows) were noted. **Appendix D** includes a list of species known to occur at Camp Polk Meadow and photos of existing conditions (photos D-1 to D-5).

A formal wetland delineation was conducted in 2006 and 2007 (Allen 2007); data from this delineation is used in the wetland layer shown on figures in this Restoration Plan. A riparian assessment was conducted on October 23, 2006 along Whychus Creek in order to understand the species present along the channel, relative abundance of each, and where each species grows relative to base and bankfull flow. The overall proportions of each shrub species present along the channel was estimated as follows: Alder: 70%, Willow: 20%, Birch: 5%; Dogwood: 1%, Spirea: 1%, Cottonwood: 2%. Rose: <1%. No aspen were found along the current channel. Herbaceous wetland plants are rooted in the channel, on the bank, and on the floodplain, providing the primary bank stability (**Appendix D**).

Plants surrounding and within Duckett Pond, located in the mid-meadow above the pond, in the relict channel, and in the spring-fed wetland near the large aspen grove at the upper end of the mid-meadow were identified throughout the 2006 growing season. Those growing in and near the pond are primarily native perennial and annual plants, providing excellent seed sources and nursery stock for transplanting to other similar habitats (backwater or groundwater-fed wetlands) created by a recharged meadow. The list of species identified in the mid-meadow is by no means comprehensive, but it does show a mix of native and introduced grasses and forbs, giving some indication of the seed source present and future potential management concerns. Those species identified in the relict channel and in the upper wetland are all native perennial wetland species, and all are included in the revegetation plan discussed later in this document.

The Land Trust's most current weed inventory, completed in 2006, includes maps of the location and infestation levels of high priority species. This weed inventory indicates the following species occur in the vicinity of the new channel:

Priority 1 (High): Small infestations, relatively easy to control, active control efforts, greatest risk to native ecosystem, require immediate action:

Bull thistle (*Cirsium vulgare*)
Canada thistle (*Cirsium arvense*)
Spotted knapweed (*Centaurea maculosa*)
Reed canarygrass (*Phalaris arundinacea*)
Teasel (*Dipsacus sylvestris*)

Priority 2 (Medium): Easier to eradicate than Priority 1, less competitive, or both. Mapped and monitored closely; may move up to Priority 1 at any time.

Mullein (*Verbascum thapsus*)
Cheatgrass (*Bromus tectorum*)

Priority 3 (Low): Well-established or occupy large area to make control efforts unreasonable; or less competitive than Priority 1 and 2.

St. John's Wort (*Hypericum perforatum*)
Quackgrass (*Agropyron repens*)
Kentucky bluegrass (*Poa pratensis*)

The five priority 1 species currently found in the project area occur in low densities. Spotted knapweed has occurred in much higher densities in the mid-meadow in years past. Canada thistle occurs in two known isolated patches in the mid- and lower- meadow, but is more common in the Upper Meadow and near Hindman Springs where human disturbance likely favored its spread. Although teasel was prolific around Hindman Springs in 2000, its population is now greatly reduced by consistent control efforts. Very little teasel currently exists in the vicinity of the new channel. Reed canarygrass occurs along Whychus Creek upstream of Camp Polk in unknown abundance, and in mapped patches on the Preserve. In fall 2006 it was cut back and herbicides were applied with a wick applicator along the creek on the property to kill the plant.

Two Priority 2 species occur in the project area: mullein and cheatgrass. Mullein is easily pulled by hand as resources are available and does not pose a great threat. Cheatgrass is well-established throughout the project area and tends to grow in dry sites.

Three Priority 3 species grow in the project area. St. John's Wort occurs in low abundance. Kentucky bluegrass and quackgrass are both well-established and will likely spread. Other introduced grasses that are well-established in the meadow include meadow foxtail (*Alopecurus pratensis*) and dense silkybent (*Apera interrupta*). All four of these grasses grow in or on the edge of wet meadows.

<u>Plant Associations</u>
Native riparian and wetland plant associations for Central and Eastern Oregon integrate potential natural vegetation, soil characteristics, fluvial geomorphology, hydrology, and climate (Crowe *et al*. 2004). Of all the potential natural vegetation associations identified by Crowe *et al*. (2004), none seem to be an ideal fit to the project site.

The *Shining willow (Salix lucida ssp. lasiandra) / wet graminoid* Association may be the most appropriate potential community described, although it has been documented at slightly higher elevations. This association occurs at moderate elevations in the East Cascades Ecoregion on floodplains along Rosgen E4, E6 and B2 stream reach types. Shining willow dominates the shrub overstory, although it is unclear if this species also occurs at Camp Polk Meadow. A variety of moist graminoids comprise most of the herbaceous layer, supported by wet conditions during the growing season. These include Nebraska sedge, creeping spikerush, small-fruited bulrush, Baltic rush, and other sedges.

Other associations similar to that proposed and expected to have the potential to develop include *Salix boothii-Salix geyeriana / Carex utriculata* Association and *Salix geyeriana / Deschampsia cespitosa-Carex nebrascensis* Assocation (Crowe *et al*. 2004).

<u>Off-Site Reference Areas</u>
Examination of reference riparian plant communities provides information on the composition and distribution of species along streams with similar channel geometry as the new channel through Camp Polk Meadow. Three reference sites were investigated including Lake Creek, Indian Ford Creek, and Rimrock Ranch. **Appendix D** includes photographs of these reference sites.

Lake Creek, a tributary of the Metolius River, has channel dimensions similar to the new channel through Camp Polk Meadow. The vegetation along low gradient, meandering reaches of Lake Creek at the Metolius Meadows and the Lake Creek Lodge properties consists of a dense cover of small-fruited bulrush and sedges, with a patchy distribution of alder and shrubs throughout the floodplain (Photos D-6 and D-7). In places, ninebark and spirea overhang the banks, providing shade and nutrients (Photo D-8). Downstream of Lake Creek Lodge, the cover of overhanging shrubs along the bank is greater than that above (Photos D-9 and D-10). The cover and distribution of shrubs present here are more important reference conditions than the actual species present. Due to its location just east of the Cascade crest, the Metolius Basin has a different mosaic of species than that present in the Whychus Creek watershed. For instance, Pacific ninebark (*Physocarpus capitatus*) is common in the Metolius Basin and willow is uncommon, whereas ninebark is uncommon and willow is more common in the Whychus Creek watershed. Off-channel spring fed wetlands support scattered willow and alder among dense sedges, offering a glimpse at what the spring fed wetlands at Camp Polk could look like once flows are restored through the meadow (Photo D-11).

Indian Ford Creek, a tributary of Whychus Creek, near USFS Road 2058 was used as a reference because of its proximity to the project site, its low gradient, sinuous channel and intact riparian vegetation. Although flow volumes are lower and bed size smaller than the proposed channel, the species diversity and abundance in relation to water levels and topography provide an indication of what the new channel might support.

Upstream of Road 2058, the floodplain supports nearly 100% cover of sedges and approximately 70-80% cover of shrubs (Photo D-12). The shrub community is composed of willow (~80%), spirea (~15%), and alder (~5%). Willows occur in clumps approximately three to six feet in diameter on average, with 10 to 50 plus stems per clump, spaced an estimated six to 20 feet apart (Photo D-13). Banks are vegetated with ~50% cover of willows and spirea overhanging the water and 50% cover of herbaceous wetland plants, primarily sedges. Alder is relatively sparse throughout the floodplain and aspen tower along the south upper edge of the floodplain margin (Photo D-14). Shrub species growing topographically higher on the banks above the floodplain include dogwood, ninebark, and rose.

A rise of six inches at the outer margin of the floodplain results in a completely different, drier plant community. These observations provide insight into the opportunities created by micro-relief to diversify with species whose roots prefer shorter periods of inundation. Downstream of the road, willow clumps tend to be larger, approximately 15 to 20 feet in diameter and spaced from 20 to 50 plus feet apart (Photo D-15). Indian Ford Creek offers an excellent source of willow, spirea, and twinberry cutting material for the project.

Portions of Rimrock Ranch, located downstream of Camp Polk Meadow Preserve on Whychus Creek, provide an ideal snapshot of a mature riparian forest within the watershed. Like Camp Polk, it occupies a wide place in the canyon and has a broad floodplain across which the stream has historically meandered. The riparian species found at Rimrock also occur at Camp Polk Meadow. A notable aspect of the riparian community on Rimrock is the presence of old cottonwood galleries. Mature trees tower over the creek and the floodplain (Photo D-16).

A University of Oregon Ecological Restoration Field Course surveyed the riparian tree and shrub community at Rimrock Ranch in June 2006 and found the following species and estimated proportions: Alder: 39%, Cottonwood: 19%, Birch: 13%, Spirea: 7%, Willow: 2%, Rose: 2%. Other species present in their survey (making up the difference between 100%) include ponderosa pine, western juniper, mock orange, and sagebrush. Dogwood and twinberry are found in low abundance amidst the thick riparian forest, especially at the upper end of the property, but were not documented. Water-loving sedges and grasses offer protection during flood flows (Photo D-17).

Fisheries

The existing habitat conditions and fish populations are documented in **Appendix E**. to provide a baseline condition for the pre-project condition. The report indicates that existing habitat conditions are generally poor, with much of the area dominated by riffle habitat. Pools are infrequent, lack cover and most have shallow residual depths. Large woody material and habitat complexity are limited.

Fish surveys revealed that brown trout were the most common trout species in the upper two reaches and long nosed dace were the most common non salmonid species sampled. The number of brook trout captured increased from 5 and 10 in reaches 1 and 2, respectively to 40 in reach 3. Redband trout ranged from 38 mm to 305 mm with a range of fish representing different size classes.

A few larger brown trout were sampled in all three reaches. However, the majority (93 %) of brown trout were between 51 and 100 mm most likely representing 0+ or 1+ age classes (**Appendix E**).

As noted previously, **Appendix B** compares the aquatic benefits of the restoration alternatives for fish based on fish habitat parameters from the literature. The most important benefits of the meadow alternative would be the increase in habitat area, increase in pool area and depth, increase in undercut bank and increase in spawning habitat (*i.e.*, pool tailouts). Both steelhead and chinook could use the site for spawning and early rearing and may use the downstream reaches for rearing as they grow older and disperse. Added pools and increased undercut banks would also increase winter rearing habitat.

Floodplain development would add stability to the channel and would be most effective in the meadow channel. At least 500 feet of side channels and flood channels will be developed in the meadow channel, providing off channel refugia for fish during floods. Boulders and large wood could be added to the existing channel instead of creating a meadow channel, but due to the restriction of the flood plain, little protection from winter peak flows may be provided by this alternative.

Riparian plantings in both alternatives would reduce summer stream temperatures and would add to the habitat diversity as trees and shrubs fall into the stream and add cover. With the meadow channel, stream temperatures may decrease during summer from riparian plantings and increased groundwater interactions. Existing stream temperatures can range over 20°C some years and reducing the maximum temperatures will benefit steelhead and resident trout.

Peer Review

Dave Rosgen (Wildland Hydrology) visited Camp Polk on August 27, 2005, during the initial conceptual stage of the project and prior to any surveys having been completed. During this initial evaluation, Mr. Rosgen identified that the existing channel is stable and that there is potential for some in-stream improvements to enhance fish habitat. When discussing the restoration of the historic meadow channel, Mr. Rosgen summarized several key issues that he felt needed to be addressed before considering this approach. These included:

- Evaluation of core samples in the relic channel to identify depth to gravels and degree of entrenchment;
- Evaluation of upstream sediment conditions to determine potential size and volume of bedload at Camp Polk Meadow;
- Hydraulic calculations to determine competency in the restored meadow channel; and
- Evaluation of the downstream tie-in location to ensure no upstream headcutting after construction.

A second review was conducted on July 9, 2006, and all survey data and analysis conducted by the Project Team to that point was presented. Following this meeting, Mr. Rosgen felt that some improvements could be made in the existing alignment for fish habitat, but to fully accomplish the goals of the project, meadow restoration would be required. Mr. Rosgen was comfortable with the analysis presented and agreed that meadow restoration appeared to be feasible.

The Region 6 Restoration Assistance Team (RAT) visited the project site in June of 2006 and submitted a report of their recommendations (**Appendix F**). The RAT is composed of members (generally fish biologists and hydrologists) with experience in analyzing, designing and implementing complex restoration projects. Team members Johan Hogervorst (Willamette National Forest) and Paul Boehne (Wallowa-Whitman National Forest) reviewed project data and spent a day in the field. As described in **Appendix F**, the RAT was confident that the meadow alternative was both feasible and clearly the preferred ecological alternative.

As discussed earlier in this document, the Project Team has presented their findings to a TAC made up of biologists, hydrologists, ecologists, planners and other specialists from a diversity of non-profits, universities and agency partners (see previous discussion in Development and Planning section). After reviewing the data and analyses, the TAC unanimously supported restoring a meandering channel to the meadow provided that adequate vegetation could be established during project implementation to ensure that channel erosion would not occur because vegetation (as opposed to rock, log jams or other structures) would be the primary source of stream channel stability in the meadow. A strong focus on the use of vegetation has been integrated into the project design and planning as discussed in the Restoration Design section of this document.

RESTORATION DESIGN

Overview

The proposed restoration project includes approximately 1,500 feet of enhancement of the current channel alignment as well as constructing approximately 7,300 feet (1.4 miles) of highly sinuous new channel in the meadow, resulting in a total restoration project length of 8,800 feet (1.7 miles) on Camp Polk Meadow. The design includes a minimum of 500 feet of high flow channels that are accessible to flows greater than 288 cfs (1.5 RI), providing off-channel refugia. Although flow and sediment regimes have been significantly altered by irrigation diversions and anthropogenic disturbances, the processes of a properly functioning meadow channel can be restored based on the above-described analysis of stable conditions in the current channel alignment, relic channel patterns and analysis of the current flow and sediment regimes.

The restoration plan consists of creating a meadow channel, enhancing the upper and lower reaches of the existing channel, adding floodplain roughness (*i.e.*, addition of wood and vegetation), revegetating the meadow, and plugging the middle reach of the existing channel. The upper portion of the proposed channel would be in the existing channel and a portion of the upper, incised section of this reach would be re-aligned. This would improve fish habitat by creating pools and it would provide a more gradual transition zone between the steep "B" channel type in the upper reach and the proposed meadow channel which is a "C" channel type. The proposed meadow channel will exit the current channel alignment at a site that is feasible based on the degree of entrenchment and utilizes an existing relic channel. The proposed meadow channel will meander for approximately 1.4 miles before connecting with a highly vegetated, intact relic channel and re-entering the current channel at the lower end of Camp Polk Meadow.

The design includes creating high flow access to side channels to enhance habitat and help recharge the groundwater in the meadow. Within the central portion of the meadow more than over 500 feet of side channel length can be achieved by allowing peak flows to access existing relic channels. Additional side channels could develop naturally in the future when riparian vegetation has become well established across the valley.

Design Principles

Channel pattern and dimension for the restored channel were derived based on historic aerial photos, use of equations, and evaluation of reference conditions in the relic channel, stable pools and riffles in the existing channel, Whychus Creek at Rimrock Ranch, and Middle Fork of Lake Creek downstream of Lake Creek Lodge as described previously. Historic aerial photos of Camp Polk Meadow were used to identify former channel alignments and evaluate changes. The dimension of the relic channel provided a gross dimension of the proposed meadow channel but was adjusted based on other reference conditions. Relic channel dimensions were adjusted because in many places the channel was over-widened from decades of bank collapse/failure following the diversion of Whychus Creek and because of changes in flow and sediment regimes. The sources of the design parameters are summarized in **Table 1** and the specific values used in the design are listed in **Table 2**. Ranges for the various reference reaches are found in **Appendix G** and proposed channel design schematics and typical drawings are found in **Appendices H** and **I**.

As described in the Flow Regime section, above, the Project Team identified that the channel should be designed to the 1.5 year RI. While bankfull at the gage site (#14075000) upstream of the Three Sisters Irrigation District Diversion has been calculated as having a 1.9 year RI, the 1.5 year RI at Camp Polk is more accurate for Camp Polk Meadow site because of the irrigation withdrawls. The bimodal indicators observed in the current channel alignment have likely developed as a result of the high level of entrenchment for a long period of time. The stream has had to adjust and create two terraces (matching 1.9 and 1.5 year RI). In contrast, the meadow channel could be developed to allow flows greater than a 1.5 year RI to be released onto the floodplain and/or side channels. Overbuilding the new channel (too large of a cross sectional area) would contain Whychus Creek during bankfull events, making it entrenched. In contrast, slightly under building the channel dimensions (reduced cross sectional area) would allow the stream to make fine tuning adjustments while still allowing the stream to easily flood during peak events, reducing bed and bank shear stress. With the apparent increasing trend for more frequent large scale discharge events, it is desirable to maximize floodplain connectivity. Therefore, developing the new channel to accommodate a bankfull flow of 288 cfs (1.5 RI) rather than 375 cfs (1.9 RI) is advised.

Table 1. Source of design parameters

Feature	Source
Average channel slope	Relic channel pattern, valley length and slope
Average riffle slope	Relic channel pattern, stable riffles in existing channel, Middle Fork Lake Creek
Sinuosity	Relic channel, air photos, Middle Fork Lake Creek
Average bankfull width	Stable pools and riffles in existing channel
Average bankfull depth	Stable riffles in existing channel
Bankfull width/depth	Stable riffles in existing channel, Middle Fork Lake Creek,
Riffle cross sectional area	Stable riffles in existing channel
Entrenchment	Rosgen C & E channel types, valley width
Meander Geometry	Relic channel, historic photos, Rimrock 1943 photo, Equations.
Riffle dimensions	Stable riffles in existing channel, relic channel pattern
Run Dimensions	Stable runs in existing channel, relic channel pattern
Pool Dimensions	Stable pools in existing channel, relic channel pattern
Glide Dimensions	Stable glides in existing channel, Middle Fork Lake Creek

Table 2. Channel dimension and pattern design parameters

Variables	Existing	Restored Channel	
	Mean	Mean	Range
Stream Type	F1-4, B3, C4	C4/E4	C4-E4
Bankfull width (W_{bkf})	33	30	<28-35
Bankfull mean depth (d_{bkf})	1.6	1.9	1.3 -3
Width/Depth ratio (W_{dkf}/d_{bkf})	20	15.8	15-30
Bankfull X-sect. Area (A_{bkf}) (ft^2)	60	60	42-64
Bankfull discharge, cfs (Q_{bkf})	288	288	----------
Bankfull Max. depth (d_{max}) (ft)	2.2	2.4	1.9-2.8
Width of flood prone area (W_{fpa}) (ft)	50	1000	700-1300
Entrenchment ratio (W_{fpa}/W_{bkf})	1.5	33	23-43
Valley Width (ft)	1000	1000	700-1300
Meander length (L_m)	----------	390	275-545
Meander length / Bankfull width	----------	13	9.1-18.1
Radius of curvature (R_c) (ft)	----------	96	52-146
Radius of curvature/Bankfull Width	----------	3.2	1.7-4.8
Belt width (W_{blt}) (ft)	----------	223	102-377
Belt width/Bankfull Width	----------	7.43	3.4-12.5
Sinuosity (str. Length/valley dist.(k))	1.1	1.6	-------
Valley slope (ft/ft)	0.01	0.01	-------
Average slope ($S_{avg}=S_{valley/k}$) (ft/ft)	0.009	0.006	-------
Max pool depth (d_{pool}) (ft)	3	6	4 to 7
Pool width (W_{pool}) (ft)	30	28	25-33
Pool head width (ft)	----------	<28	26-30
Pool tail width (ft)	----------	>30	32-35
Pool Length (ft)	----------	161	100-244
Pool Length/Riffle Length	----------	1.2	1 -2
Pool to pool spacing (p-p)	----------	130	48-225
Pool to pool spacing/Riffle Width	----------	4.3	1.6-7.5
Riffle slope (S_{riff}) (ft/ft)	0.0095	0.014	.007-.03
Riffle slope/ave. water surface slope	1.05	2.3	1.16-5
Riffle Length (ft)	----------	130	49-225
Run slope (ft/ft)	0.084	0.084	0.02-0.4
Run slope/ave. water surface slope	9.3	14	3.3-66
Run Length (ft)	10	10	3 - 18
Glide Slope (ft/ft)	-0.04	-0.05	-0.0014 - -0.12
Glide Slope/ave. water surface slope	0.044	-8.3	-0.23 - -20
Glide Length (ft)	20	29	6 - 52

Note: Cross-section area values provided are for final dimensions, not build to dimensions.

The proposed meadow channel would be classified as a C4 (the 4 refers to a gravel bed) type with characteristics of an E channel type. The predominantly higher vegetated point bars and the riffle features, typical in a C channel type, would be replaced with longer, deeper glide features characteristic of an E channel, with a lesser degree of incision. The designed channel stream type was determined based on valley type, slope, historic aerial photos of Camp Polk Meadow, and reference conditions in the relic and existing channels.

The primary morphological features of the “C” stream type are the sinuous, low relief channel, the well developed floodplains built by the river, and characteristic unvegetated “point bars” within the active channel (Rosgen and Silvey 1996). These streams have a well-developed floodplain (slightly entrenched), are relatively sinuous (>1.2) with a channel slope of 2% or less, and width to depth ratios generally exceed 12. Bed form morphology is indicative of a riffle/pool configuration. As is the case at Camp Polk Meadow, these streams can be significantly altered and rapidly de-stabilized when changes in bank stability, watershed condition, or flow regime are combined to exceed the channel stability threshold.

The E4 stream types are channel systems with low to moderate sinuosity (>1.5), gentle to moderately steep channel gradients (< 2%), with very low channel width/depth ratios (<12). The E4 type is a riffle/pool stream found in a variety of land forms including high mountain meadows, alpine tundra, deltas, and broad alluvial valleys with well developed floodplains. Due to the inherently stable nature of the bed and banks, this stream type can develop with a wide range of channel slopes. Sinuosities and meander width ratios decrease, however, with an increase in slope. Streambanks are composed of materials finer than that of the dominant channel bed materials and are typically stabilized with extensive riparian or wetland vegetation that form densely rooted sod mats from grasses and grass like plants as well as woody species (Rosgen and Silvey 1996).

Channel Restoration Reaches

For the purposes of discussion and planning, the channel design has been divided into six reaches with the first and sixth reaches located in the existing channel alignment (**Figure 16, Figure 17, Figure 18**). Channel design for each of the six reaches is based on channel pattern and dimension ranges from reference reaches and empirical equations.

Reach 1

Reach 1,located at the upstream end of the Camp Polk property in the existing channel alignment (**Figure 19, Figure 20**), includes approximately 1,100 feet of channel. The lower 1,000 feet of Reach 1 would become a C3/4 channel type with lateral or apex logjams. Meander and pool construction are recommended in this reach to aggrade the bed, increase sinuosity, decrease slope and provide quality aquatic habitat. Side cast material from the time the current channel alignment was excavated remains on site in the form of a stream-side berm / dike. This material would be returned to the stream bed, thus raising the base elevation and opening floodplain access. Reducing the existing channel slope from 1.1% to 0.7% would make the transition to the 0.64% slope of the proposed meadow channel easier and less likely to cause lateral erosion around the first plug (the first plug would be constructed at the beginning of Reach 2).

In addition, the floodprone width in Reach 1 would be increased from 50 feet to 220 feet. Relic meander bends and oxbows upstream of the entrance to the meadow would be reactivated, which would add 120 feet of stream length, decrease average slope, and increase sinuosity. The transition point between the existing channel and the proposed meadow channel would be at a pool and this feature would be enhanced with a rock and log structure. Grade control structures at the head and tail-out of this pool would provide stability at this transition. An existing relief channel may be accessed by peak flows, adding at least 500 feet of side channel habitat.

Source: 2/11/06 aerial photo

cpm_mapping\design.mxd, dquinlan, 6/7/07

Figure 16. Proposed meadow channel.

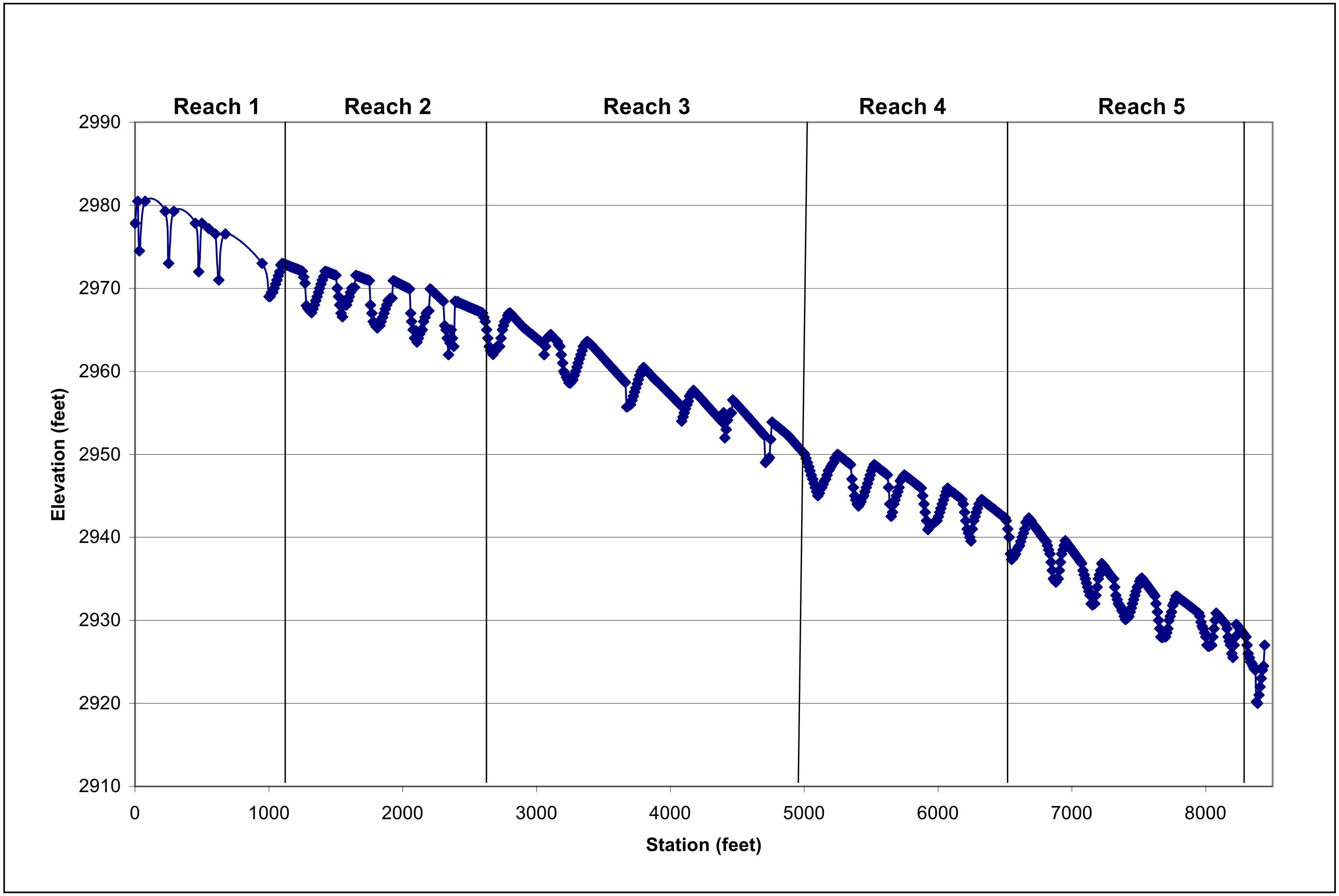


Figure 17. Longitudinal profile of meadow channel

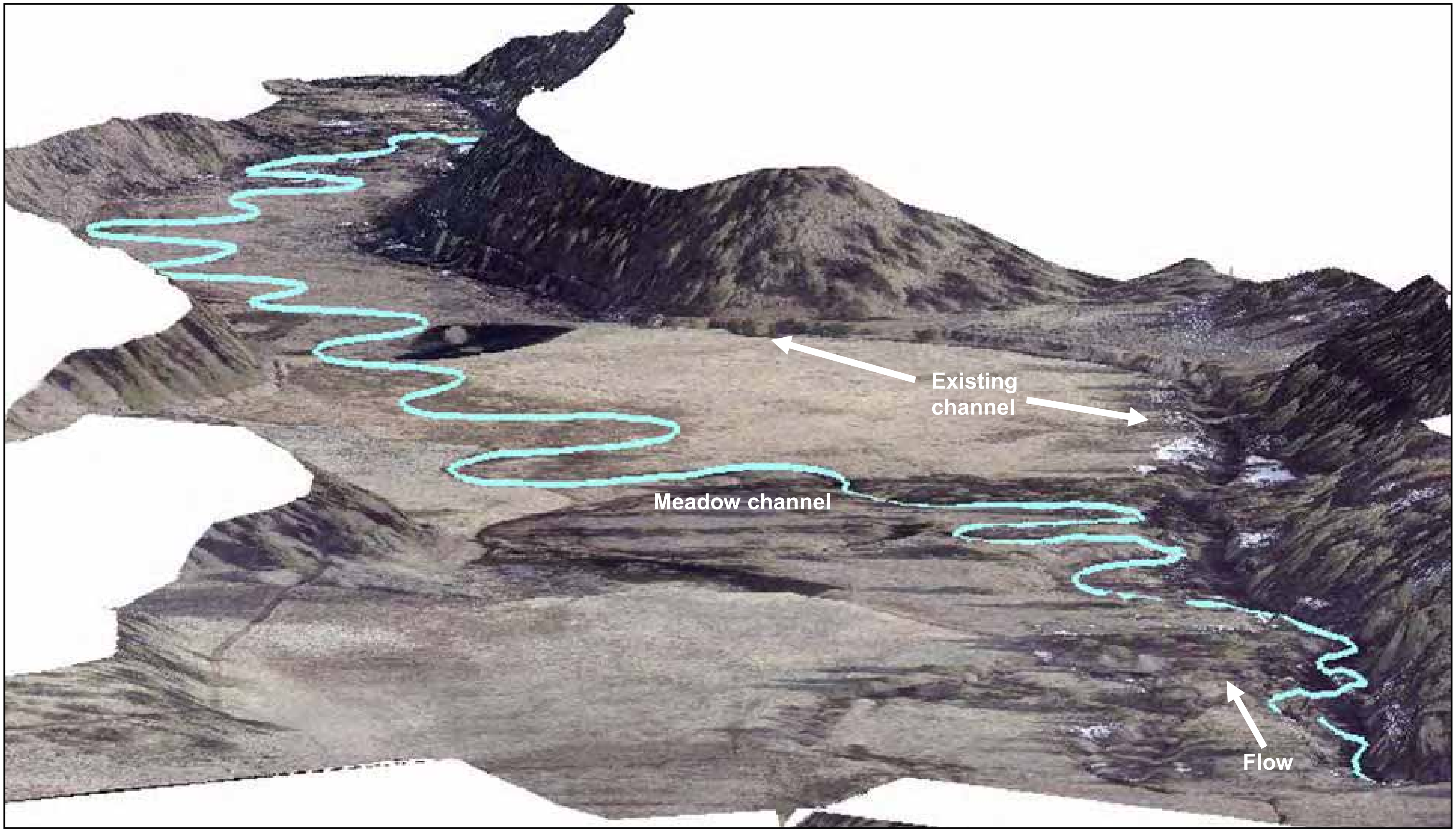


Figure 18. Three dimensional schematic of meadow channel

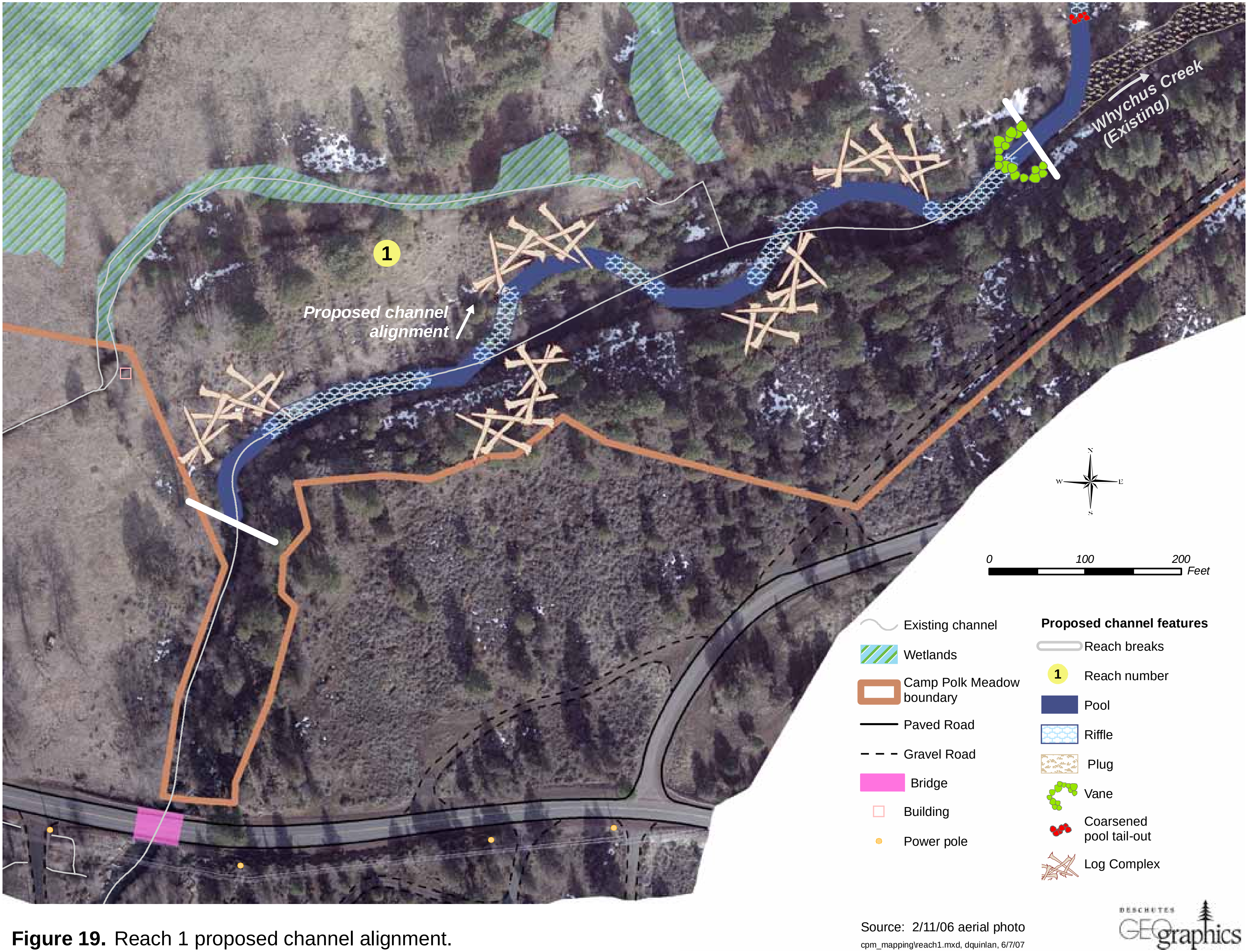


Figure 19. Reach 1 proposed channel alignment.

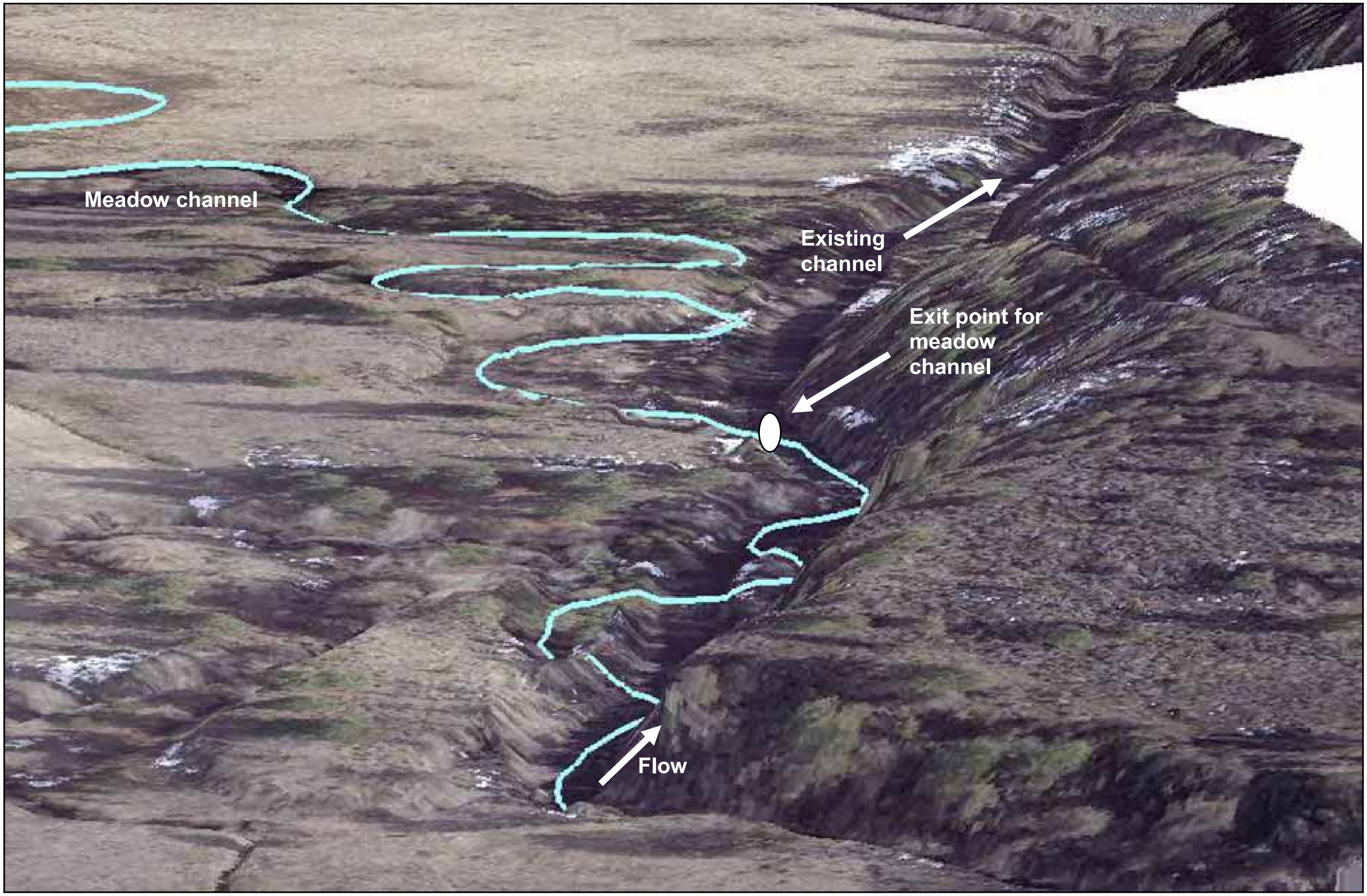


Figure 20. Reach 1 three dimensional schematic.

Reach 2

Reach 2, including approximately 1,600 feet of channel, is located in the visible portion of the relic channel as it meanders through the 80-year-old ponderosa pines (**Figure 21**). This reach would be maintained as a C4 stream type. The channel would follow the relic alignment and banks would be shaped to provide a low flow channel and a bankfull cross-sectional area of approximately 40 feet^2 (note: designed cross sectional area is 60feet^2, however under-building is recommended to avoid creating an entrenched channel and to allow fine tuning adjustments over time). However, the uppermost part of this reach will be constructed with a cross sectional area of 60 feet^2 and be reduced towards 40 feet^2 lower in the reach. This will allow Whychus Creek to access the new channel without causing damage to the banks at the transition. Bankfull would be located at the top of the low bank. Wood complexes would be added at pools to provide roughness, cover, and bank complexity. In addition, wood complexes would be constructed on the floodplain between the proposed meadow channel and the existing channel to help prevent the proposed meadow channel from being recaptured by the current channel.

As in all reaches, the bed would be shaped to have narrow pool heads, wide pool tailouts, and max pool depths at meander apexes. The tailout of the pool at the transition from the existing channel (Reach 1) to the proposed meadow channel (beginning of meadow channel) would be coarsened with a grade control structure to help prevent a lowering of the tail-out at the change in grade. Before the proposed meadow channel would carry the full flow of Whychus Creek, the current channel alignment would be plugged. Plugging the current channel will reduce the risk of stream recapture and allow the recovery of the water table in the meadow. If the current channel were to remain un-plugged, it would continue to be the low point in the valley, draining groundwater from the meadow, preventing recharge and vegetative recovery.

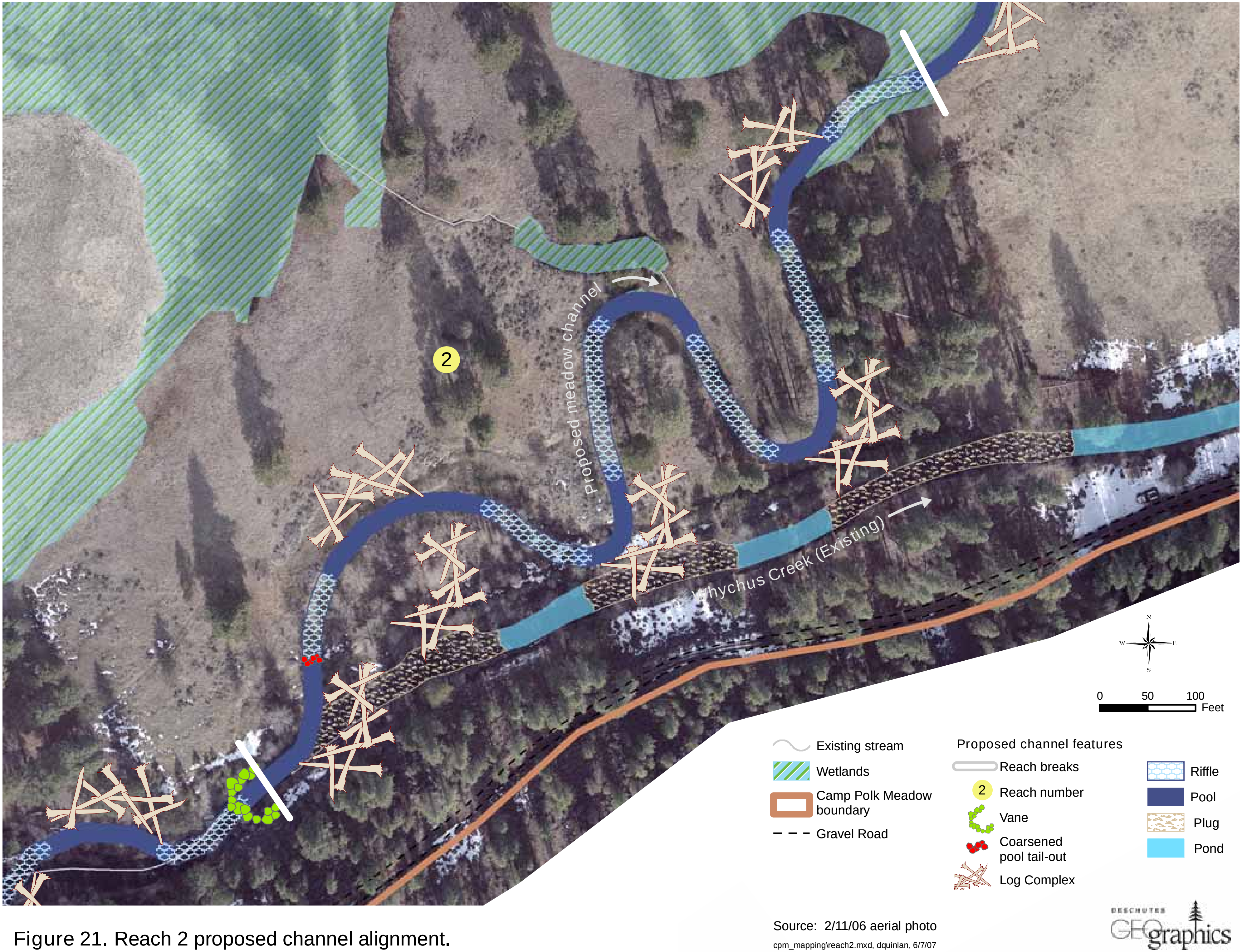


Figure 21. Reach 2 proposed channel alignment.

Reach 3

Reach 3, including approximately 1,900 feet of channel, is located between the visible portion of the relic channel and Duckett Pond (**Figure 22**). The existing substrate in this reach lies approximately 3.5 feet below the surface and is predominantly small gravels and sand. Historically, this reach was probably a C/E or E stream type, as is evident by the depth and size of the substrate and tortuous meander pattern. This reach has been designed to mimic historic conditions; however, the streambed may be seeded with slightly larger gravel to coarsen riffles. Material available for seeding the proposed meadow channel is available up valley at an old gravel mining site (abandoned oxbow on the property) and from side cast berms.

In general, Reach 3 would be narrower and deeper than the other reaches and the transition between the pools and riffles would be less distinct (*i.e.*, long pools and glides). Wood would be added into the banks and the channel to mimic historic conditions when cottonwood and alders would have fallen into the stream. Wood additions would be low profile, adding complexity to the banks and channel while providing much needed cover for aquatic organisms.

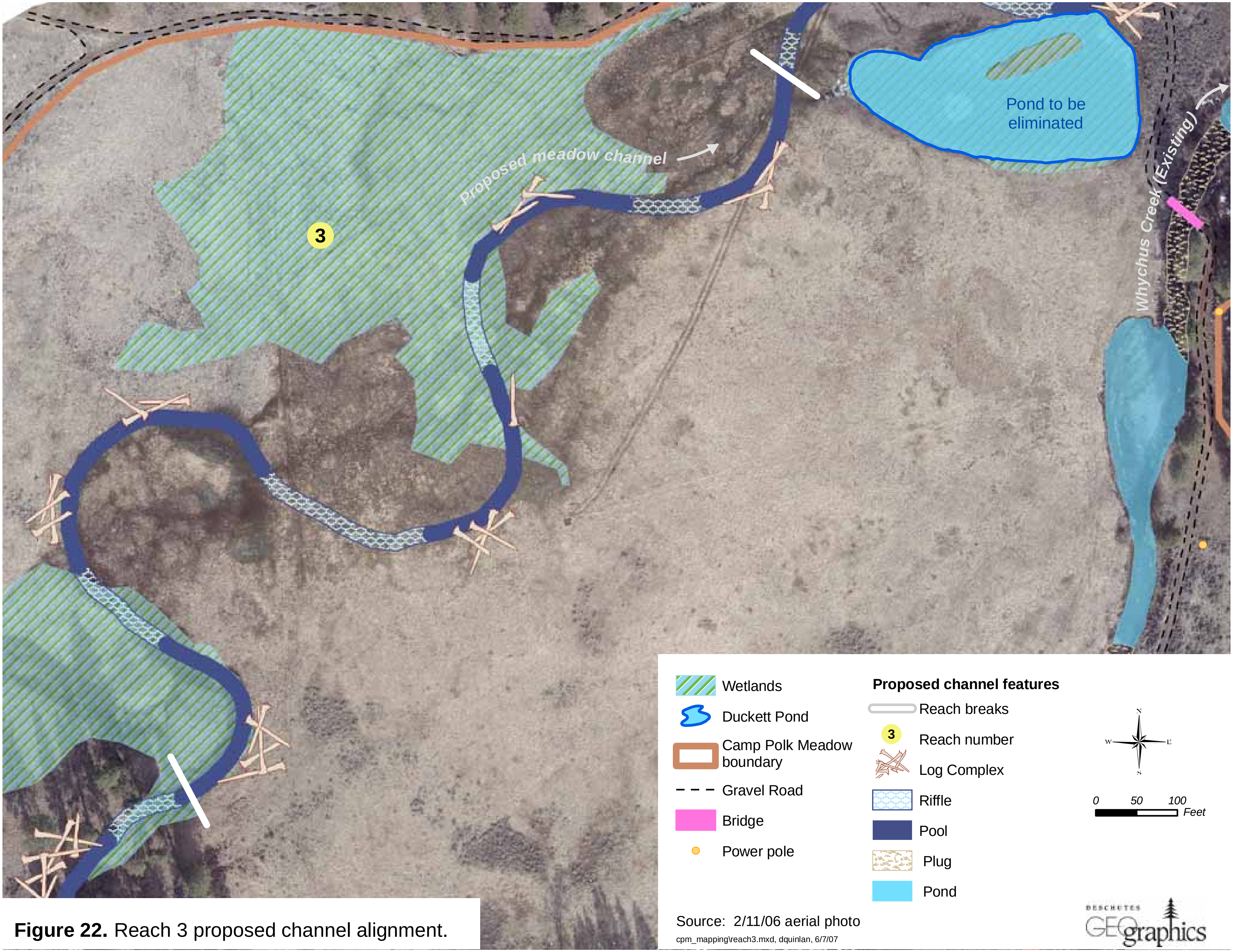


Figure 22. Reach 3 proposed channel alignment.

Reach 4

Reach 4, including approximately 1,700 feet of channel, is located below Duckett Pond and is different than the upstream reaches in that the relic channel pattern is no longer visible on the landscape (**Figure 23**). Therefore, the channel pattern of this reach has been derived by maintaining a meander length and belt width consistent with the design of the other reaches and positioning the channel in a location that most effectively ties together remaining portions of the relic channel. The proposed meadow channel is designed as a C4 channel type and a small portion of this reach would meander onto the Steinthal property at their consent. Seeding the proposed meadow channel with gravel will not be required because gravel substrate was found extensively throughout this reach at 1.5 feet below the surface. A wood complex will be created just below Duckett Pond to coarsen the floodplain and help keep the stream from rerouting into the old alignment. Other low profile wood structures would be incorporated into the channel to provide complexity, similar to Reach 3.

Reach 5

Reach 5, including approximately 2,000 feet of channel, extends from immediately up-valley of the aspen stand to the exit at the existing channel along the east-end of the property (**Figure 24**). The channel is designed as a C4 stream type and will meander around the aspen stand before entering a relic channel immediately southeast of the stand. The channel skirts the aspen stand because this area provides abundant habitat for neotropical birds and other wildlife and should be preserved intact. This relic channel is heavily vegetated and will provide excellent bank stability, which is particularly important near the transition back into the existing channel. Existing vegetation on the channel bottom will be transplanted along the channel banks in reaches 2, 3, and 4. This would salvage existing vegetation and provide mature vegetation to raw stream banks. Gravel substrate is already present and any seeding is expected to be minimal. Wood complexes will be constructed on the outside of meander bends to help maintain the new channel alignment, maintain pools, and provide habitat complexity.

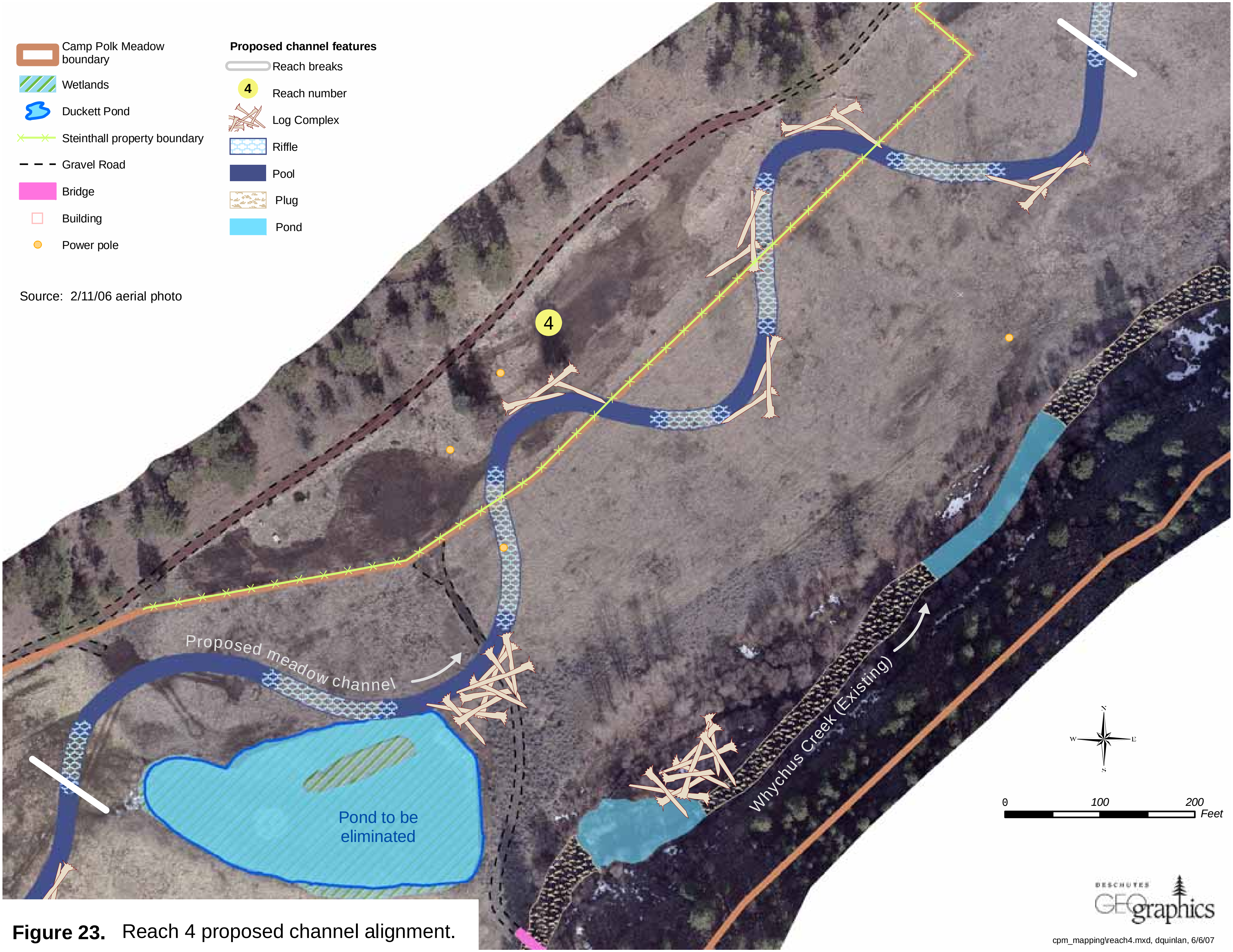


Figure 23. Reach 4 proposed channel alignment.

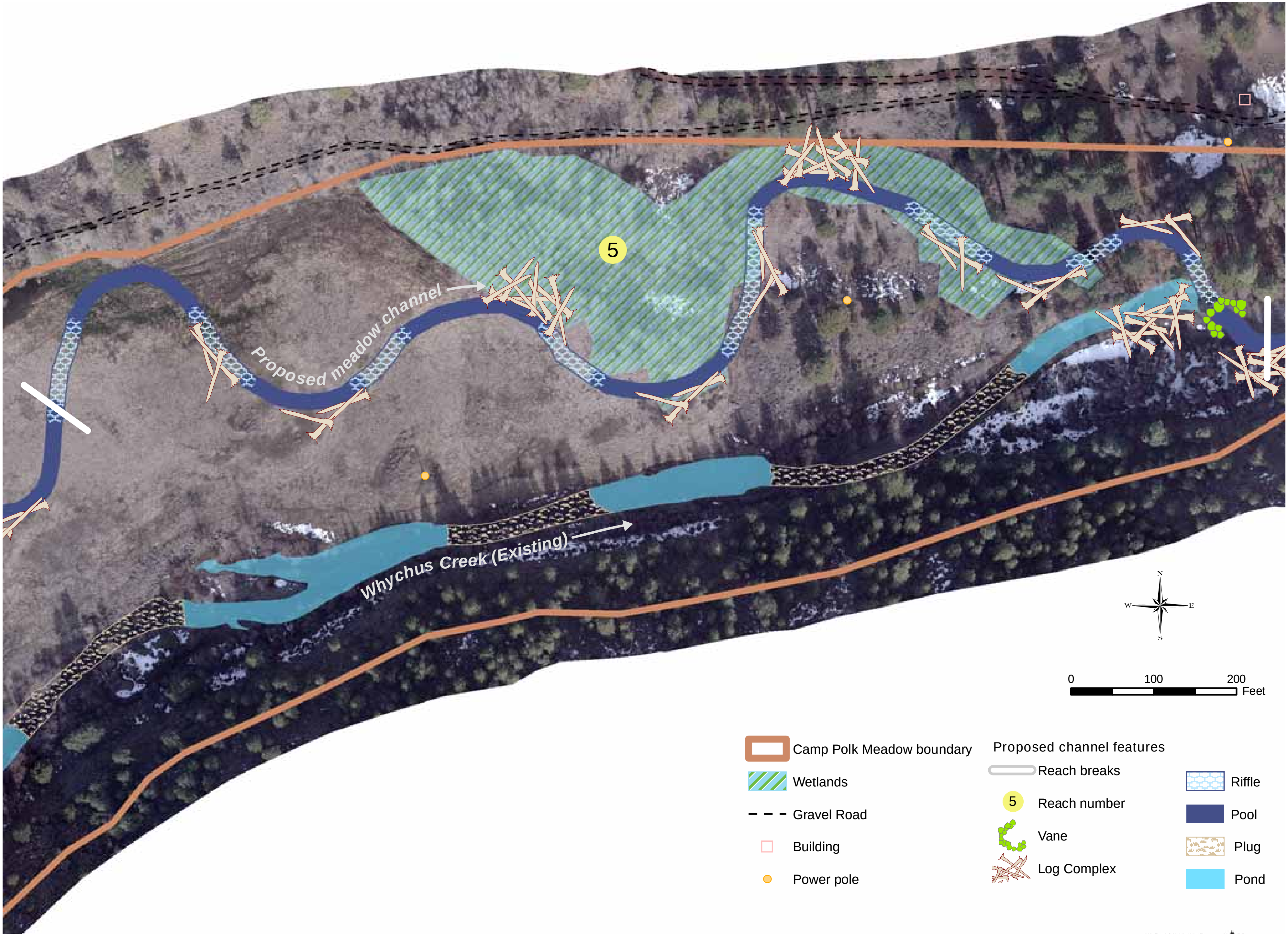


Figure 24. Reach 5 proposed channel alignment.

Source: 2/11/06 aerial photo

cpm_mapping\reach5.mxd, dquinlan, 6/7/07

DESCHUTES GEOgraphics

Reach 6

Reach 6, including approximately 500 feet of channel, lies within the existing channel alignment and extends from the meadow re-entry point to the downstream end of the Camp Polk Meadow property (**Figure 25**). This reach is currently a C4 channel type and will remain so with some minor enhancements. The average bed slope of Reach 6 is 0.7%, which is close to the proposed meadow channel slope of 0.64%. A rock vein will be constructed at the pool head at the transition into the existing channel to maintain the pool and help prevent headcutting into the meadow. Likewise, the pool-tail crest will be coarsened to prevent a drop in base elevation. Wood complexes will be constructed on the outside of three meander bends to help maintain deep pools and provide cover. This location was selected because the elevation difference between the proposed meadow channel and the existing channel is only 1.5 feet, the existing channel is stable at this point and the slopes of the two reaches are similar.

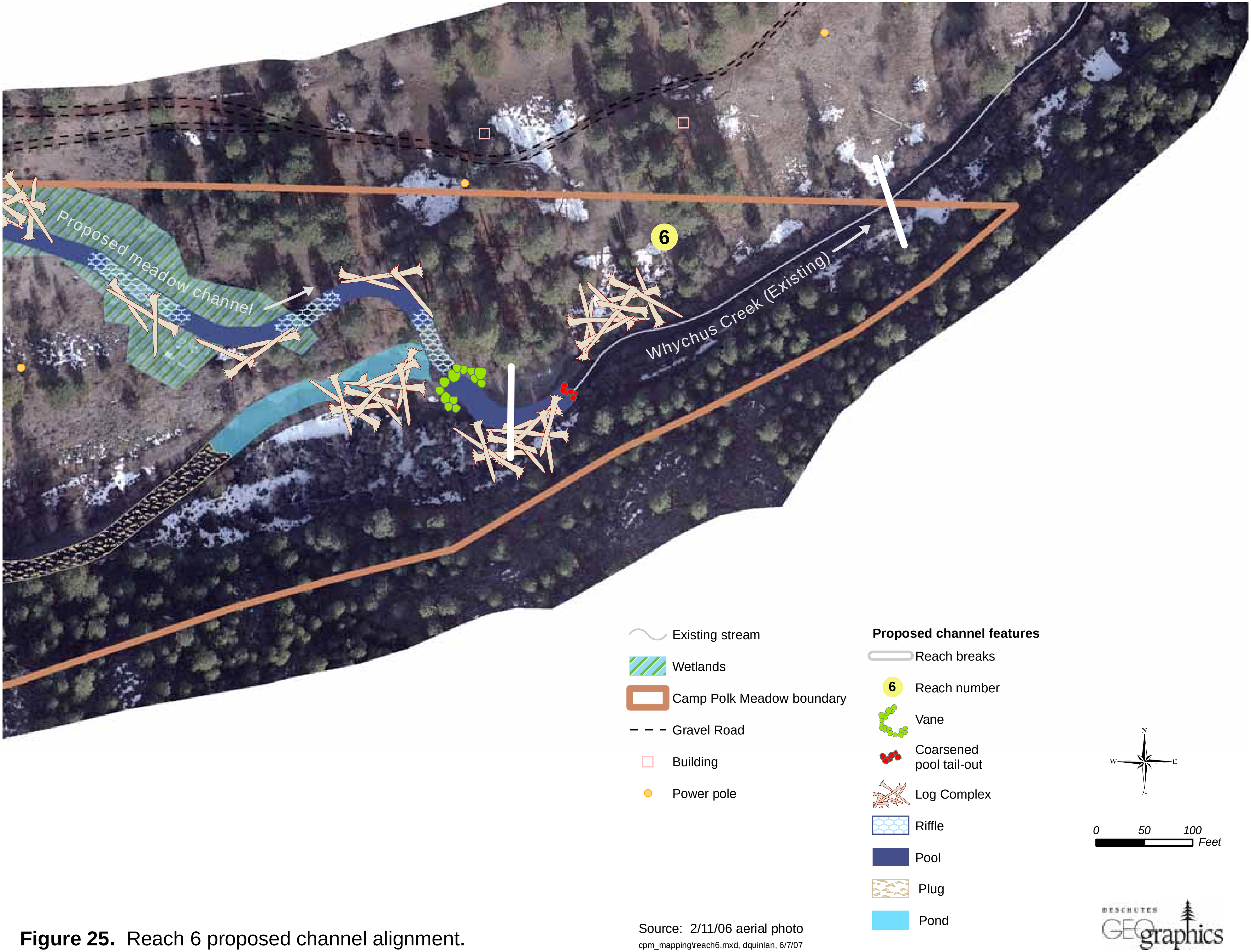


Figure 25. Reach 6 proposed channel alignment.

Eliminating the Existing Channel

Prior to directing flow into the constructed meadow channel, plugs will be constructed in the existing channel alignment between the meadow entrance and exit (**Figure 16**; **Appendix I**). Plugs will be constructed at regular intervals at sites requiring the least amount of fill and at locations where the proposed meadow channel meanders close to the current channel. These plugs will reduce the potential for channel recapture by blocking surface flow, increasing roughness and connecting high flows to the floodplain.

Approximately 13 plugs between 100 and 200 feet long will be constructed starting at the transition point between the existing channel and the proposed meadow channel. The elevation of the first plug will match the bankfull elevation of the new channel, allowing peak flows to be released; thereby, reducing the risk of plug failure. The elevation of all remaining plugs will match the elevation of the adjacent meadow. Plugs will be constructed of boulders, cobbles and gravels from the berms, bed, and material stockpiled from the construction of the proposed meadow channel. The streambed between plugs may be excavated to generate additional fill material, thus creating groundwater-fed ponds. These ponds will serve as wetland habitat that will benefit many wildlife species. Wood will be incorporated into the plugs to provide roughness and habitat in the wetlands between plugs. In addition, plugs will be planted with native riparian vegetation to promote stability and increase their value as wetland habitats. With increased roughness in the form of plugs and the densely vegetated ponds between them, the current channel alignment will no longer be the course of least resistance, preventing recapture during high flow events.

Revegetation

Vegetation is an extremely important component of this project because the restored meadow channel will rely heavily on vegetation for bank stability and floodplain roughness. The revegetation component of the project will include planting the banks and floodplain surrounding the restored channel as well as the plugs used to eliminate the existing channel.

The revegetation plan is based on achieving a desired percent cover of specific species to mimic naturally-occurring species composition, and meeting distribution and abundance observed at Camp Polk Meadow and at off-site reference locations.

Planting Zones and Species

Planting will occur in four zones, differentiated largely by the density of plantings and the importance of sedges and other wetland species (**Figure 26** to **Figure 31**, **Tables 3** and **4**).

<u>Zone 1: Meadow Channel Margins</u>
A 60-foot-wide corridor along both sides of the restored channel will be densely planted with a mix of sedges, trees and shrubs. The primary objective in planting this zone is creating root strength to prevent bank erosion, overhanging vegetation to enhance stream habitat and reduce temperature, and provide floodplain roughness to prevent erosion during high flow events.

As shown in **Table 3**, Zone 1 will be comprised of 10% tree, 30% shrub, and 100% herbaceous wetland plant cover in reaches 2 through 5. The percentages by species shown in **Table 3** refer to the proposed percent cover of that species within the strata (*i.e.*, trees, shrubs, or herbaceous) that they occur. For instance, of the 100% cover of herbaceous wetland plants to be planted, 30% small-fruited bulrush and 30% Nebraska sedge are proposed. Within the 10% of Zone 1 that will be covered by trees, 40% of the trees will be alder, 10% willow, 10% birch, 40% cottonwood and <1% chokecherry. Within the 30% of Zone 1 that will be shrubs, 60% of all shrubs will be willow, 30% spirea, 5% rose, 2.5% dogwood, and 2.5% blue elderberry.

Zone 1 will rely heavily on wetland plants for their strong root systems to provide the primary stabilizing force on the banks and floodplain. Manning *et al*. (1989) found that baltic rush produced 72 feet/inch^3 of roots and Nebraska sedge produced 212 feet/inch^3 of roots in the top 16 inches of the soil profile (reported in Hoag 2000). The fibrous root systems of the herbaceous wetland plants combined with the woody roots of shrubs and trees will hold the soil together better than woody plantings alone. Baltic rush and alder also serve the important ecological function of fixing atmospheric nitrogen, making it available in the soil.

Proposed spacing for sedges is one foot on center. Hoag (no date) documents that a plug spacing of 10 to 12 inch for Baltic rush and one to 1.5 foot for Nebraska sedge will fill in within one growing season. Hoag clarified that his research was conducted in an area with a longer growing season than Central Oregon and that “fill in” means there will be root tillers moving out but the ground will not be covered with vegetation (Hoag personal communication). For uniform ground cover of baltic rush, Nebraska sedge, and beaked sedge in one year after planting, a spacing of 0.5 feet on center is recommended; for uniform cover in two years, one foot on center; and in three years, two feet on center. Creeping spikerush has an even higher growth rate, creating uniform ground cover in one year if planted at one foot on center, in two years if planted at two foot on center and in three years at three foot on center (USDA 2001).

Trees and shrubs will be planted in small clumps to mimic natural colonization patterns found in nearby reference sites. Trees will be planted at six-foot spacing in 10% of Zone 1. Shrubs will be planted at three-foot spacing in 30% of Zone 1. Individual trees and shrubs will be planted along the banks to provide bank stability, shade, and inputs of organic matter, with higher densities planted above pools. Salvaged alder, willow, dogwood, and cottonwood will be buried on the outside of meander bends. Trees and shrubs will need to grow for a number of years before providing optimal shade.

There are two exceptions to the Zone 1 width and plant palette. In reach 1, the width of Zone 1 will be variable, based on the topography and area of disturbance caused by removing berms. Less herbaceous wetland plants and more shrubs and trees will be planted here since the substrate is coarser and the stream currently supports primarily trees and shrubs with sedges and grasses on the point bars. In reach 1, Zone 1 will be comprised of 30% tree, 60% shrub, and 10% herbaceous wetland plant cover. Trees will be at six-foot spacing, shrubs at a three-foot spacing, and sedges at 15-inch spacing.

In reach 5, where the channel will be constructed adjacent to the aspen grove, Zone 1 will be 60 feet wide on the right bank and only 20 feet wide on the left bank as far down as shrubs are present. Downstream of this, Zone 1 on both sides will widen to 60 feet. The same Zone 1 plant palette proposed for reaches 2 through 5 will be used.

Zones 2 and 4: Floodplain

Zone 2 includes that portion of the floodplain that will be planted and irrigated along with Zone 1. Zone 4 includes that portion of the floodplain that will be planted later in the project timeline once groundwater elevations have increased and irrigation is not needed.

Prior to planting the floodplain, whole trees will be added to create additional roughness. These whole trees, when combined with the restored vegetation, will reduce flood velocities and initiate deposition of mobilized sediments when floods occur.

Five percent (5%) of the floodplain area will be planted with trees, 10% with shrubs, 10% with herbaceous wetland plants, 5% with forbs, and 100% seeded with native perennial grass seed. All recommended forbs are native perennial plants known to occur at Camp Polk Meadow. Species proposed to be seeded either occur in wet areas today or are native to the area and suitable to plant in the anticipated hydrologic conditions. Micro-relief, either existing or created, will be utilized to increase the diversity of species planted. For example, dogwood and rose seem to prefer higher, drier areas. Areas of coarser soil texture in the greater meadow can be used in a similar way.

Overflow channels, side channels, and backwater areas will all be planted with species appropriate to the hydrologic conditions at each site. During implementation, the indicator status will be used to identify where best to plant relative to water levels.

Zone 2 will be planted along with Zone 1 during phase 1 of project implementation. Both Zones 1 and 2 will be irrigated. Zone 4 will be planted during phase 2, once flows have been restored to the new channel and groundwater levels have risen.

<u>Zone 3: Earthen Plugs in Existing Channel</u>

Phase 2 also includes planting the earthen plugs constructed in the existing channel at the time flows are diverted to the new meadow channel. The 13 plugs will each be approximately 50 feet wide by 150 feet long. A string of ponds and wetlands will develop along the existing channel between the earthen plugs. Prior to the construction of each plug, the herbaceous riparian vegetation on both sides of the existing channel along the length of the plug will be salvaged and temporarily set aside. Once the plug is constructed, the salvaged plant material will be transplanted along the upstream and downstream edges of the plug, adjacent to each pond. No additional herbaceous plant material will be brought in. In general, the plugs will be constructed up to the base of the riparian shrub vegetation (*i.e.*, approximately bankfull elevation) along the existing channel and these shrubs will be left alone. All the riparian vegetation (herbs, shrubs, trees) in the existing channel adjacent to the ponds and wetlands will also be left alone.

Each plug will be planted with shrubs and trees (**Table 3**). (*e.g.*, 'Total area to restore' generated from 50 feet x 150 feet x 13 plugs = 97,500 $feet^2$). A total of 55% of the plug area will be planted in trees (*e.g.*, alder, cottonwood, aspen, and birch) and a total of 45% will be planted in shrubs (*e.g.*,willow, spirea, dogwood). Plant quantities were derived using two-foot spacing. A native seed mix is also proposed in order to help out-compete weeds on the newly constructed plugs.

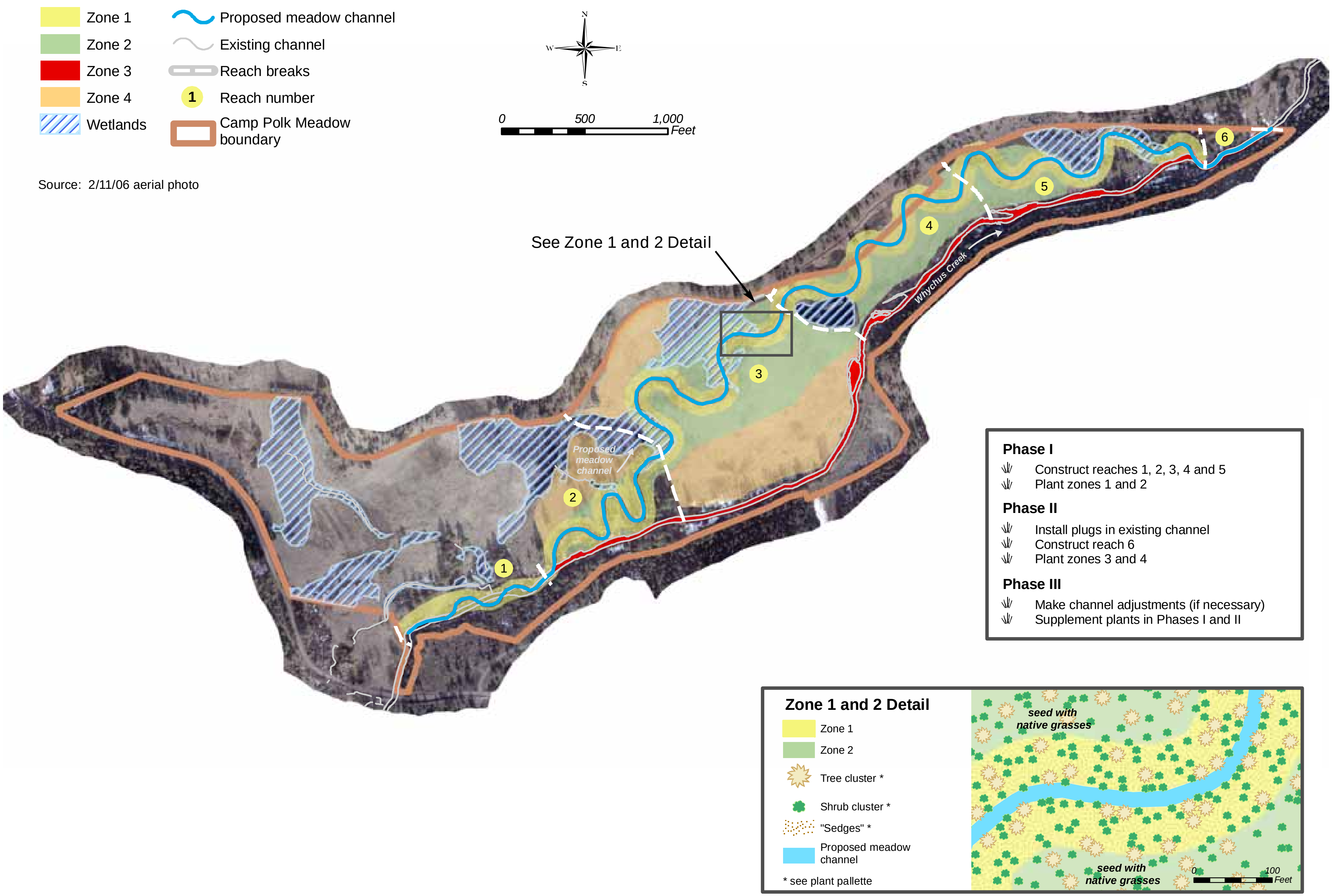


Figure 26. Revegetation Plan: Overview

DESCHUTES GEOgraphics

cpm_mapping\reveg_plan.mxd, dquinlan, 6/7/07

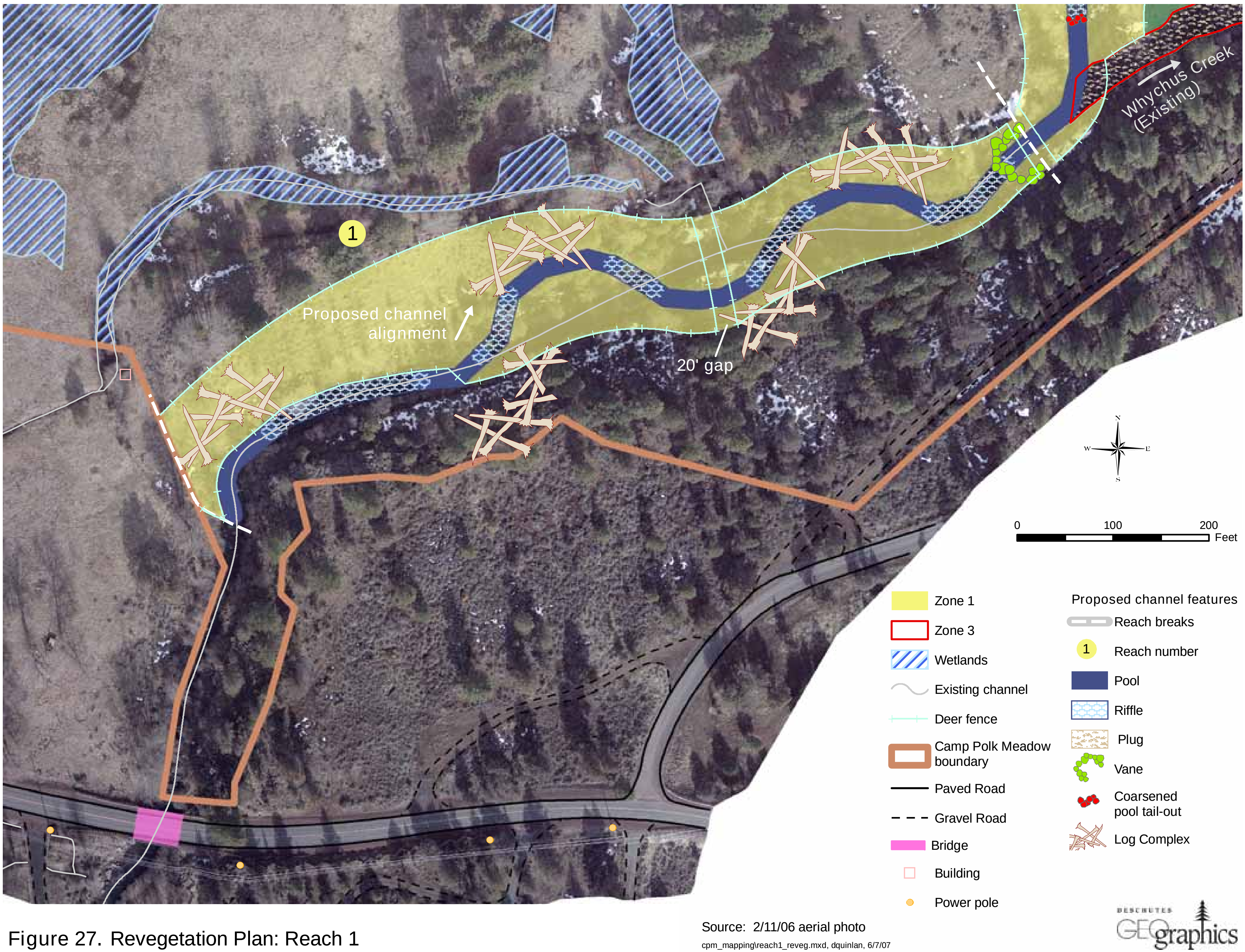


Figure 27. Revegetation Plan: Reach 1

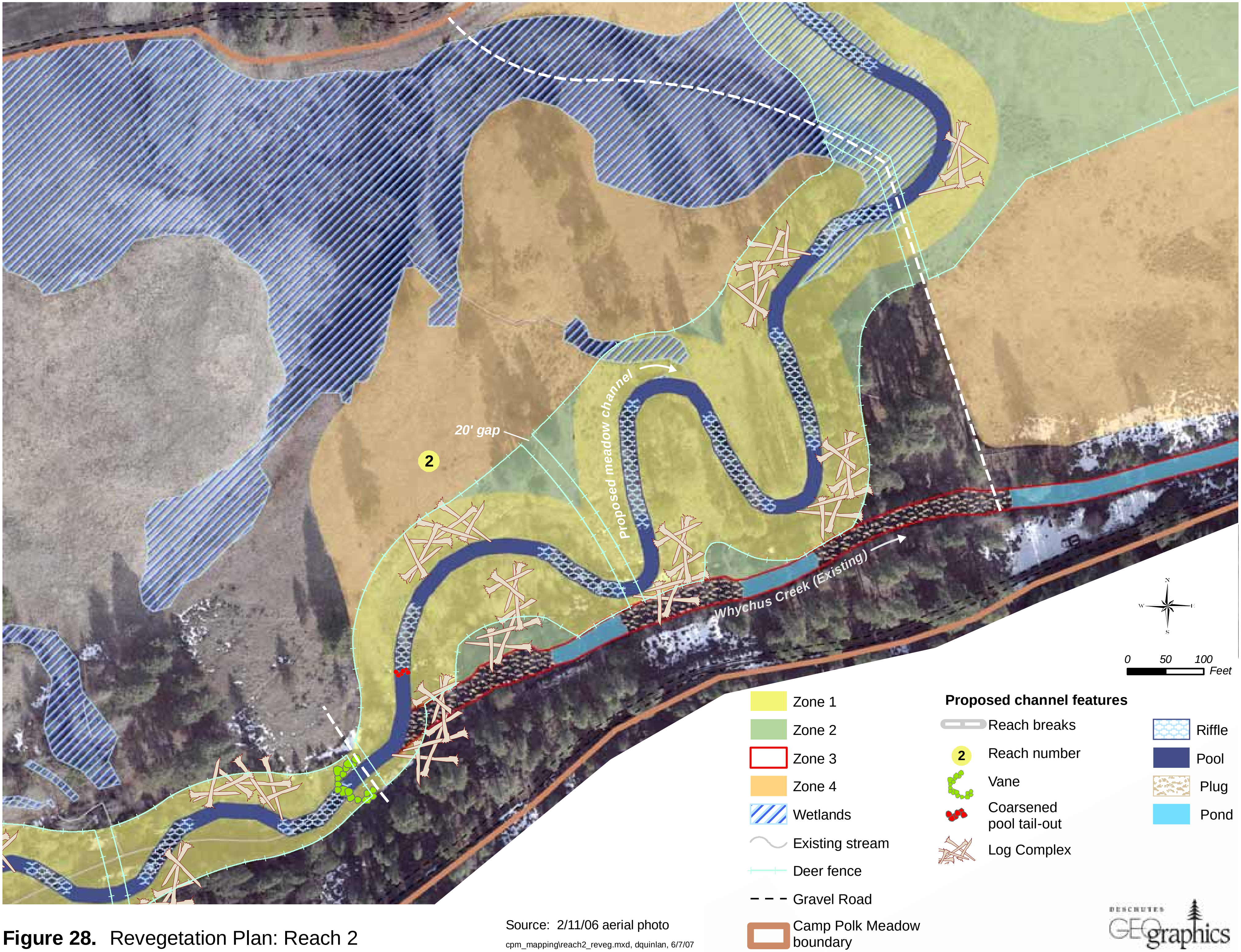


Figure 28. Revegetation Plan: Reach 2

Source: 2/11/06 aerial photo

cpm_mapping\reach2_reveg.mxd, dquinlan, 6/7/07

Figure 29. Revegetation Plan: Reach 3

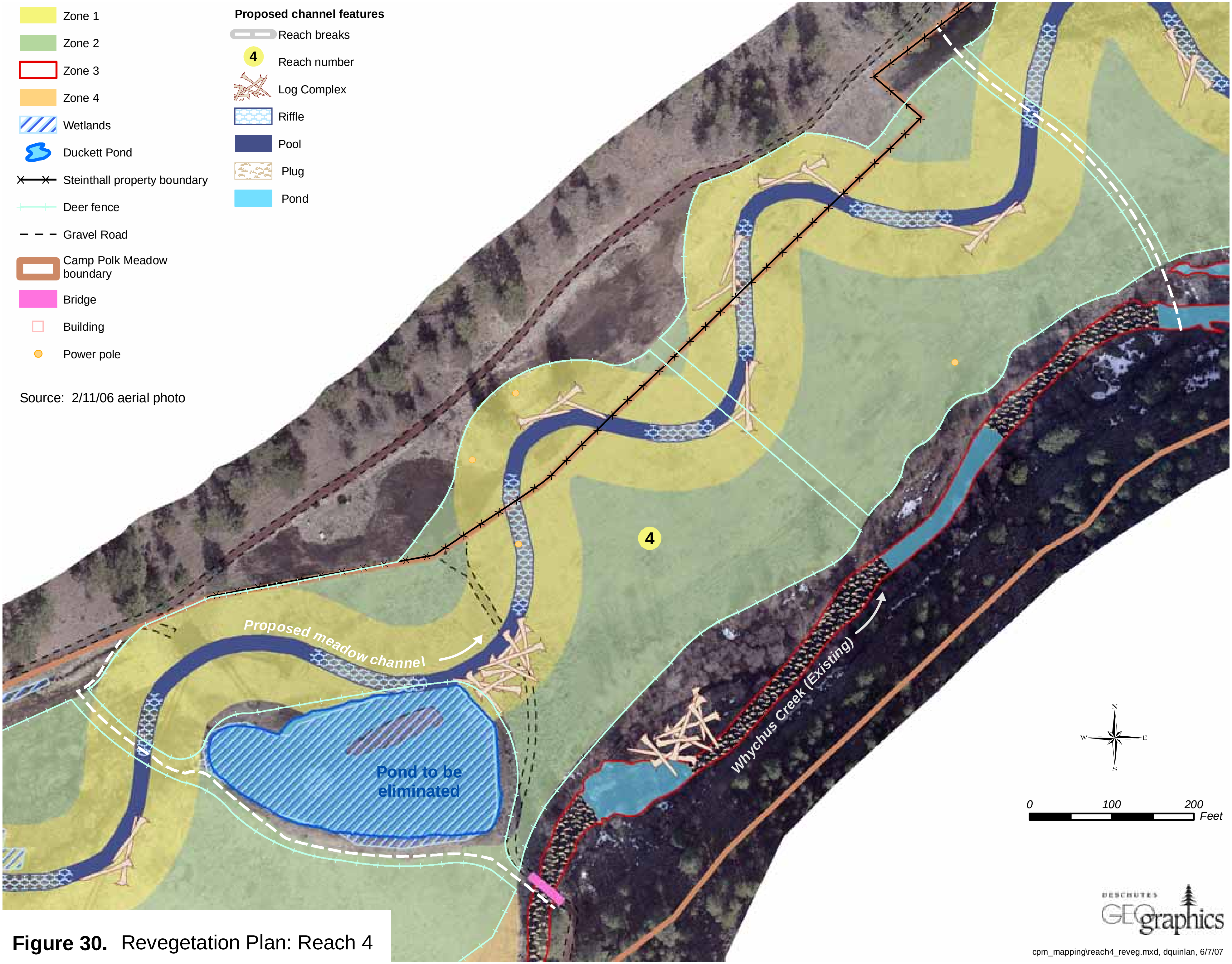


Figure 30. Revegetation Plan: Reach 4

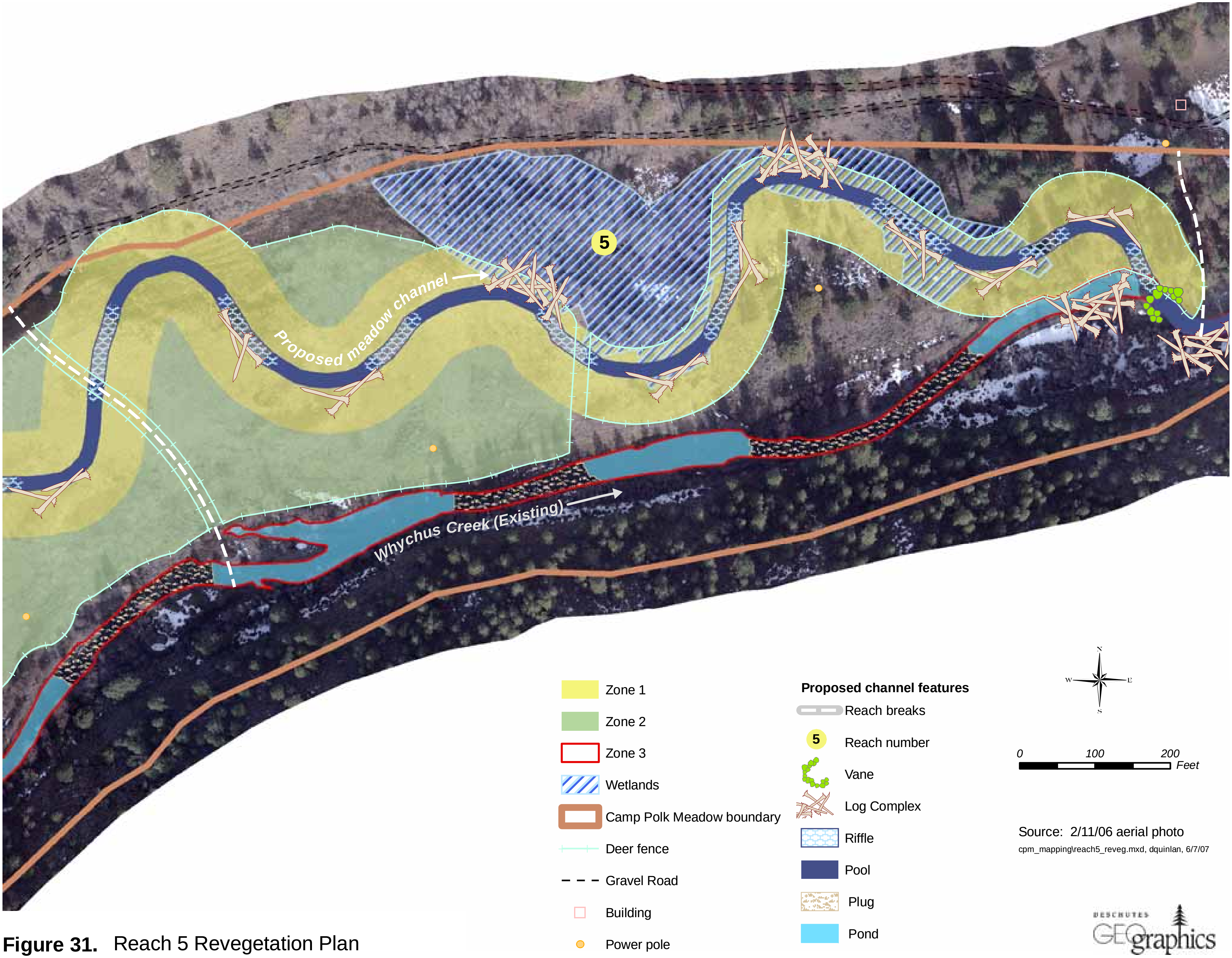


Figure 31. Reach 5 Revegetation Plan

Table 3. Plant Palette

Scientific Name	Common Name	Indicator Status	Spacing (feet)	Desired % Cover	Total Area to Restore (acres / feet^2)	Cover (feet^2 / plant)	Quantity
Zone 1: Channel Margins - Reach 1 (2.1 ac total area)							
Trees			**6**	**30% total**	**0.64 / 27,878**	**36**	**770**
Alnus incana	Alder	FACW		40%			
Salix sp.	Willow (tree)			10%			
Betula occidentalis	Birch	FACW		10%			
Populus trichocarpa	Cottonwood	FAC+		40%			
Prunus virginiana	Chokecherry	FACU		<1%			
Shrubs			**3**	**60% total**	**1.27 / 55,321**	**9**	**6,156**
Salix sp. (S. geyeriana)	Willow (shrub)	FACW+		60%			
Spiraea douglasii	Spirea	FACW		30%			
Rosa woodsii	Rose	FACU		5%			
Cornus sericea	Redosier dogwood	FACW		2.5%			
Sambucus cerulea	Blue elderberry	FACU		2.5%			
Herbaceous Wetland			**1**	**10% total**	**0.21 / 9,147**	**1.56**	**5,920**
Scirpus microcarpus	Small-fruited bulrush	OBL		30%			
Carex nebrascensis	Nebraska sedge	OBL		30%			
Carex rostrata var. utriculata	beaked sedge	OBL		20%			
Juncus sp.	Rush	OBL		10%			
Carex athrostachya	Slenderbeaked sedge	FACW		5%			
Juncus balticus	Baltic rush	FACW+		4%			
Eleocharis palustris	Common spikerush	OBL		1%			

Scientific Name	Common Name	Indicator Status	Spacing (feet)	Desired % Cover	Total Area to Restore (acres / feet^2)	Cover (feet^2 / plant)	Quantity
Zone 1: Channel Margins - Reaches 2-5 (18.4 ac total area)							
Trees			**6**	**10% total**	**1.84 / 80,150**	**36**	**2,226**
Alnus incana	Alder	FACW		40%			
Salix sp.	Willow (tree)			10%			
Betula occidentalis	Birch	FACW		10%			
Populus trichocarpa	Cottonwood	FAC+		40%			
Prunus virginiana	Chokecherry	FACU		<1%			
Shrubs			**3**	**30% total**	**5.52 / 240,451**	**9**	**26,717**
Salix sp. (S. geyeriana)	Willow (shrub)	FACW+		60%			
Spiraea douglasii	Spirea	FACW		30%			
Rosa woodsii	Rose	FACU		5%			
Cornus sericea	Redosier dogwood	FACW		2.5%			
Sambucus cerulea	Blue elderberry	FACU		2.5%			
Herbaceous Wetland			**1**	**100% total**	**18.40 / 801,504**	**1.56**	**513,785**
Scirpus microcarpus	Small-fruited bulrush	OBL		30%			
Carex nebrascensis	Nebraska sedge	OBL		30%			
Carex rostrata var. utriculata	beaked sedge	OBL		20%			
Juncus sp.	Rush	OBL		10%			
Carex athrostachya	Slenderbeaked sedge	FACW		5%			
Juncus balticus	Baltic rush	FACW+		4%			
Eleocharis palustris	Common spikerush	OBL		1%			

Scientific Name	Common Name	Indicator Status	Spacing (feet)	Desired % Cover	Total Area to Restore (acres / feet^2)	Cover (feet^2 / plant)	Quantity
Zone 2: Irrigated Floodplain (17.6 ac total area)							
Trees			**6**	**5% total**	**0.88 / 38,332**	**36**	**1,065**
Alnus incana	Alder	FACW		10%			
Salix sp.	Willow (tree)			10%			
Betula occidentalis	Birch	FACW		10%			
Populus trichocarpa	Black cottonwood	FAC		35%			
Populus tremuloides	Aspen	FAC+		35%			
Prunus virginiana	Chokecherry	FACU		1%			
Shrubs			**3**	**10% total**	**1.76**	**9**	**8,520**
Salix sp. (S. geyeriana)	Willow (shrub)	FACW+		70%			
Spiraea douglasii	Spirea	FACW		20%			
Cornus sericea	Redosier dogwood	FACW		5%			
Rosa woodsii	Rose	FACU		2%			
Lonicera involucrata	Twinberry	FAC+		2%			
Ribes sp. (lacustre?)	Prickly currant	FAC+		1%			
Amelanchier alnifolia	Serviceberry	FACU		<1%			
Herbaceous			**3**	**10% total**	**1.76 / 76,665**	**9**	**8,520**
Scirpus microcarpus	Small-fruited bulrush	OBL		20%			
Carex nebrascensis	Nebraska sedge	OBL		20%			
Carex rostrata var. utriculata	Beaked sedge	OBL		10%			
Juncus sp.	Rush	OBL		5%			
Carex athrostachya	Slenderbeaked sedge	FACW		15%			
Juncus balticus	Baltic rush	FACW+		20%			

Scientific Name	Common Name	Indicator Status	Spacing (feet)	Desired % Cover	Total Area to Restore (acres / $feet^2$)	Cover ($feet^2$ / plant)	Quantity
Zone 2: Irrigated Floodplain (17.6 ac total area) (Continued)							
Herbaceous (Continued)			**3**	**10% total**	**1.76 / 76,665**	**9**	**8,520**
Eleocharis palustris	Common spikerush	OBL		5%			
Scirpus validus	Soft-stem bulrush	OBL		1%			
Carex sp. (C. aquatilis, C. utriculata, C. vesicaria)	Sedges	OBL		4%			
Forbs			**3**	**5% total**	**0.88 / 38,332**	**9**	**4,260**
Camassia quamash	Camas	FACW		<1%			
Geum macrophyllum	Largeleaf avens	FACW-		<1%			
Iris missouriensis	Rocky Mountain Iris	FACW+		<1%			
Mimulus guttatus	Common monkeyflower	OBL	Interplant in banks	<1%			
Penstemon rydbergii	Rydberg's beardtongue	FACU		<1%			
Potentilla anserina	Silverweed cinquefoil	OBL		<1%			
Sisyrinchium idahoense	Idaho blue-eyed grass	FACW		<1%			
Lupinus polyphyllus	Bigleaf lupine	FAC+		<1%			
Sidalcea oregana	Oregon checkerbloom	FACW-		<1%			
Polemonium occidentale	Western polemonium	FACW		<1%			
Aquilegia formosa	Western columbine	FAC		<1%			
Potentilla gracilis	Slender cinquefoil	FAC		<1%			

Scientific Name	Common Name	Indicator Status	Spacing (feet)	Desired % Cover	Total Area to Restore (acres / feet^2)	Cover (feet^2 / plant)	Quantity
Zone 2: Irrigated Floodplain (17.6 ac total area) (Continued)							
Native Seed Mix				**100% total**			Depends on availability and seeding rate per species
Deschampsia cespitosa	Tufted hairgrass	FACW					
Deschampsia elongata	Slender hairgrass	FACW-					
Calamagrostis stricta (C. neglecta)	Slimstem reedgrass	OBL					
Poa palustris	Fowl bluegrass	FAC					
Muhlenbergia racemosa	Green muhly	FACW					
Glyceria sp.	Mannagrass	OBL					
Elymus glaucous	Blue wildrye	FACU					
Elymus cinereus	Basin wild-rye	FAC	(plugs)				

Scientific Name	Common Name	Indicator Status	Spacing (feet)	Desired % Cover	Total Area to Restore (acres / feet^2)	Cover (feet^2 / plant)	Quantity
Zone 3: Earthen Plugs (2.24 ac total area)							
Trees			**2**	**55% total**	**1.23 / 53,940**	**4**	**13,407**
Alnus incana	Alder			5%			
Populus trichocarpa	Cottonwood			20%			
Populus tremuloides	Aspen			20%			
Betula occidentalis	Birch			10%			
Shrubs			**2**	**45% total**	**1.00 / 43,560**	**4**	**10,968**
Salix sp. (S. geyeriana)	Willow			10%			
Spiraea douglasii	Spirea			20%			
Cornus sericea	Dogwood			15%			
Native Seed Mix				**100% total**	**2.23 / 97,500**		Depends on availability and seeding rate per species
Deschampsia cespitosa	Tufted hairgrass	FACW					
Deschampsia elongata	Slender hairgrass	FACW-					
Poa palustris	Fowl bluegrass	FAC					
Muhlenbergia racemosa	Green muhly	FACW					

Scientific Name	Common Name	Indicator Status	Spacing (feet)	Desired % Cover	Total Area to Restore (acres / feet^2)	Cover (feet^2 / plant)	Quantity
Zone 4: Non-Irrigated Floodplain (17.4 ac total area)							
Trees			**6**	**5% total**	**0.87 / 37,897**	**36**	**1,053**
Alnus incana	Alder	FACW		10%			
Salix sp.	Willow (tree)			10%			
Betula occidentalis	Birch	FACW		10%			
Populus trichocarpa	Black cottonwood	FAC		35%			
Populus tremuloides	Aspen	FAC+		35%			
Prunus virginiana	Chokecherry	FACU		1%			
Shrubs			**3**	**10% total**	**1.74 / 75,794**	**9**	**8,422**
Salix sp. (S. geyeriana)	Willow (shrub)	FACW+		70%			
Spiraea douglasii	Spirea	FACW		20%			
Cornus sericea	Redosier dogwood	FACW		5%			
Rosa woodsii	Rose	FACU		2%			
Lonicera involucrata	Twinberry	FAC+		2%			
Ribes sp. (lacustre?)	Prickly currant	FAC+		1%			
Amelanchier alnifolia	Serviceberry	FACU		<1%			
Herbaceous			**3**	**10% total**	**1.74 / 75,794**	**9**	**8,422**
Scirpus microcarpus	Small-fruited bulrush	OBL		20%			
Carex nebrascensis	Nebraska sedge	OBL		20%			
Carex rostrata var. utriculata	beaked sedge	OBL		10%			
Juncus sp.	Rush	OBL		5%			
Carex athrostachya	Slenderbeaked sedge	FACW		15%			
Juncus balticus	Baltic rush	FACW+		20%			

Scientific Name	Common Name	Indicator Status	Spacing (feet)	Desired % Cover	Total Area to Restore (acres / $feet^2$)	Cover ($feet^2$ / plant)	Quantity
Zone 4: Non-Irrigated Floodplain (17.4 ac total area) (Continued)							
Herbaceous (Continued)			**3**	**10% total**	**1.74 / 75,794**	**9**	**8,422**
Eleocharis palustris	Common spikerush	OBL		5%			
Scirpus validus	Soft-stem bulrush	OBL		1%			
Carex sp. (C. aquatilis, C. utriculata, C. vesicaria)	Sedges	OBL		4%			
Forbs			**3**	**5% total**	**0.87 / 37,897**	**9**	**4,210**
Camassia quamash	Camas	FACW		<1%			
Geum macrophyllum	Largeleaf avens	FACW-		<1%			
Iris missouriensis	Rocky Mountain Iris	FACW+		<1%			
Mimulus guttatus	Common monkeyflower	OBL	Interplant in banks	<1%			
Penstemon rydbergii	Rydberg's beardtongue	FACU		<1%			
Potentilla anserina	Silverweed cinquefoil	OBL		<1%			
Sisyrinchium idahoense	Idaho blue-eyed grass	FACW		<1%			
Lupinus polyphyllus	Bigleaf lupine	FAC+		<1%			
Sidalcea oregana	Oregon checkerbloom	FACW-		<1%			
Polemonium occidentale	Western polemonium	FACW		<1%			
Aquilegia formosa	Western columbine	FAC		<1%			
Potentilla gracilis	Slender cinquefoil	FAC		<1%			

Zone 4: Non-Irrigated Floodplain (17.4 ac total area) (Continued)							
Native Seed Mix				**100% total**	**17.4 / 757,944**		Depends on availability and seeding rate per species
Deschampsia cespitosa	Tufted hairgrass	FACW					
Deschampsia elongata	Slender hairgrass	FACW-					
Calamagrostis stricta (C. neglecta)	Slimstem reedgrass	OBL					
Poa palustris	Fowl bluegrass	FAC					
Muhlenbergia racemosa	Green muhly	FACW					
Glyceria sp.	Mannagrass	OBL					
Elymus glaucous	Blue wildrye	FACU					
Elymus cinereus	Basin wild-rye	FAC	(plugs)				

Table 4. Plant Indicator Status

Plant Indicator Status Categories[1]		
Category	**Indicator Symbol**	**Definition**
Obligate Wetland Plants	OBL	Plants that occur almost always (estimated probability >99 percent) in wetlands under natural conditions, but which may also occur rarely (estimated probability <1 percent) in non-wetlands.
Facultative Wetland Plants	FACW	Plants that occur usually (estimated probability >67 percent to 99 percent) in wetlands, but also occur (estimated probability 1 percent to 33 percent) in non-wetlands.
Facultative Plants	FAC	Plants with a similar likelihood (estimated probability 33 percent to 67 percent) of occurring in both wetlands and non-wetlands.
Facultative Upland Plants	FACU	Plants that occur sometimes (estimated probability 1 percent to <33 percent) in wetlands, but occur more often (estimated probability >67 percent to 99 percent) in non-wetlands.
Obligate Upland Plants	UPL	Plants that occur rarely (estimated probability <1 percent) in wetlands, but occur almost always (estimated probability >99 percent) in non-wetlands under natural conditions.

[1]Categories were originally developed and defined by the USFWS National Wetlands Inventory and subsequently modified by the National Plant List Panel. The three facultative categories are subdivided by (+) and (-) modifiers. A FAC+ plant grows in slightly wetter conditions than a FAC plant but not as wet as a FACW plant; a FAC- plant grows in drier conditions than a FAC plant, but not as dry as a FACU plant.

Potential Wetland Creation

The reconnection of the floodplain in Camp Polk Meadow is expected to significantly increase groundwater elevations similar to what has been seen in other restoration projects around the western United States (Hogervorst and Schmalenberg 2005; Lindquist and Wilcox 2000; Plumas Corp 2004; Loheide and Gorelick 2005; Loheide Gorelick 2006). With an increase in groundwater levels, areas adjacent to existing wetlands that have similar soils with a relatively high water-holding capacity will support slightly wetter plant communities. Over time, wetland hydrology, soils, and vegetation are expected to develop.

The location of potential future wetlands was estimated based on the location of existing wetlands, topography, soils, vegetation, and the location of springs. An estimate of the wetland creation area is shown in **Figure 32**.

.

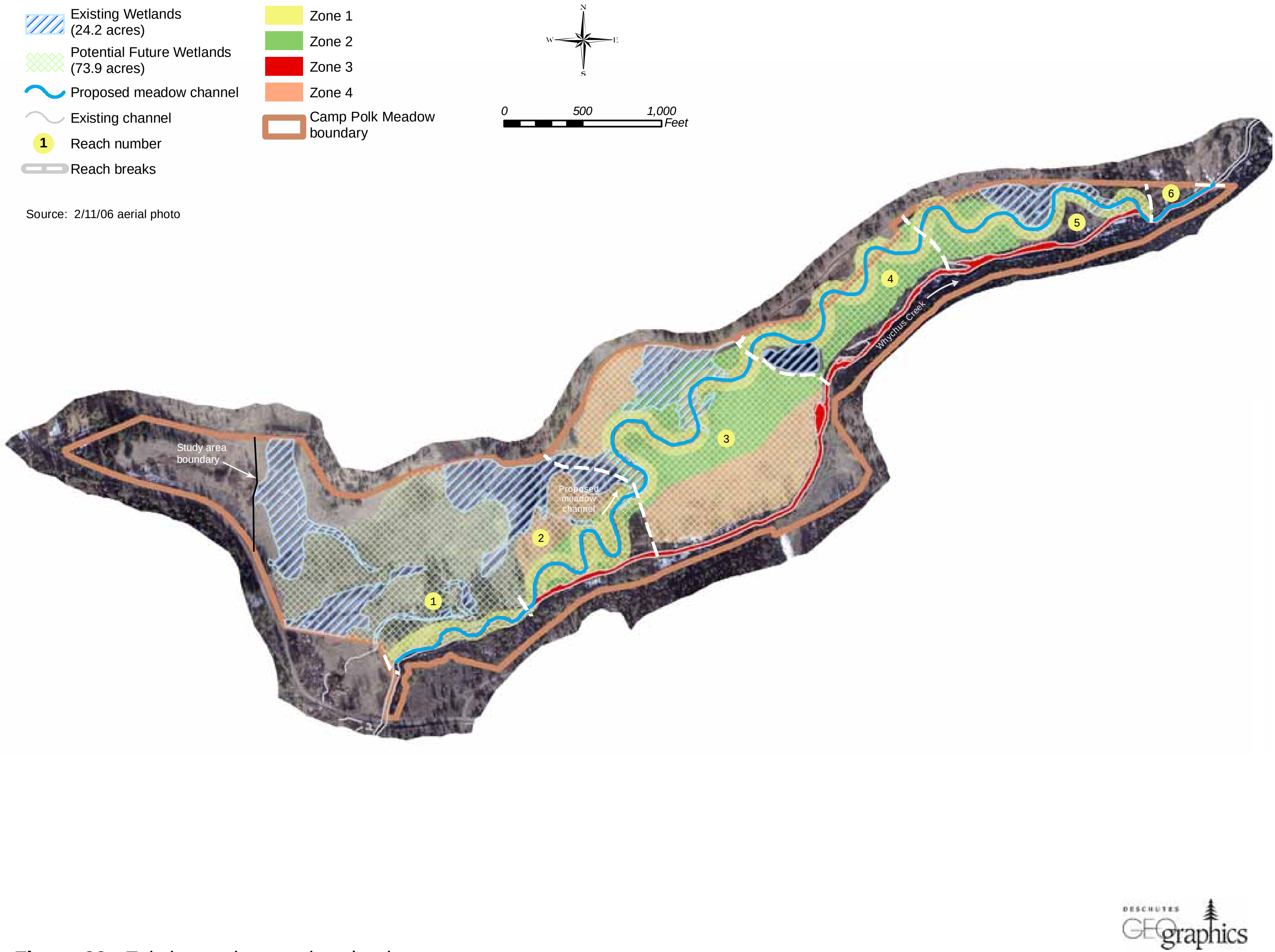


Figure 32. Existing and created wetlands.

cpm_mapping\extg_fut_wtlnd.mxd, dquinlan, 6/7/07

Transplanting

During channel construction, shrubs and herbaceous riparian plants will be salvaged and transplanted to the greatest extent possible. This effort will help introduce larger plant material to the restored channel and recycle much of the high quality vegetation that exists in pockets throughout the project area. In reaches 1, 2, and 5, shrubs and trees will be salvaged and transplanted nearby into the new channel banks. In reach 5, approximately 6,800 $feet^2$ of riparian shrubs will be transplanted to the upstream banks of reach 5. In reach 3 approximately 10,500 $feet^2$ of native, perennial herbaceous wetland plants will be transplanted to nearby banks.

Past experience on other local projects has shown that wetland plants and riparian shrubs will transplant very well provided that they are given enough water. When transplanting herbaceous wetland plants, wetland mats will be dug less than six inches, which gets most of root mass but also leaves enough roots to grow back into the hole. If large mats are moved with an excavator, dividing the wetland mat into 3.5 inch by 3.5 inch plugs, planted at one foot spacing, will make them go further and help cover larger areas. The tops should be cut off to six inches above the root mass where new sprouts will emerge; uncut plants take longer to establish and the tops will generally die off any way (Hoag 1994).

Research has shown willow, alder, birch, spirea, dogwood, cottonwood, and rose can all be successfully transplanted. Because the root system inevitably gets torn when transplanted, the stems will be down to 1/3 or ½ of their original length (Hoag personal communication). Transplanting success is improved if done when dormant in the late fall, winter, or early spring before bud break.

Care will be taken to avoid transplanting any reed canarygrass or other noxious weeds. Surveys prior to construction will identify areas where transplanting should be avoided to prevent the accidental spread of weeds.

Browse Protection

Many willows, alder, birch, and spirea along Whychus Creek and elsewhere at Camp Polk Meadow show evidence of heavy browsing by deer. In spring 2002, over 2,200 willow and dogwood were planted in the Hindman Springs and Upper Meadow area by the Land Trust. Annual monitoring showed that those not protected were heavily browsed and many died, while those protected with vexar tubes survived. Subsequent monitoring showed that vexar, while protecting the plant from herbivory, limited growth to the size of the vexar (*i.e.*, typically less than three feet tall). In 2003, nearly 6,000 willow, cottonwood, and dogwood were planted in circular patches and enclosed in four-foot-tall wire erected with Tposts. Results of monitoring in 2006 showed excellent survival and growth, presumably a result of successful browse protection. These past experiences have shown the importance of browse protection at Camp Polk Meadow.

Deer fence will be erected around the perimeter of Phase 1 plantings, with 20-foot wide gaps for wildlife passage. A total length of 18,700 feet (3.54 miles) of fencing will be required. See **Figures 27** to **31** for proposed locations of deer fence.

Irrigation

Although the meadow will ultimately be recharged and groundwater elevations will increase as flows are reintroduced into the restored channel, the meadow is currently too dry to support successful establishment of riparian vegetation. Therefore, phase 1 plantings (Zones 1 and 2) in reaches 2 through 5 along the channel margins and floodplain will be irrigated with a temporary irrigation system during at least the first three years of establishment. This 36-acre area will need to be watered with up to one inch of water per week during the summer months.

The specific design and operation of the irrigation system will be developed as project planning proceeds and temporary water rights are secured.

Weed Control

The spread of non-native invasive species following the disturbance caused during implementation will be monitored and weed populations will be controlled. Due to a number of life history characteristics that give weeds a competitive advantage on newly disturbed ground, a flush of invasive non-native weeds is anticipated to occur in the first year or two following construction. Weed populations will be aggressively controlled while native plants become established.

The Land Trust has inventoried, mapped, and actively controlled invasive plant species on the Preserve since it acquired the property in 2000. Since 2001, weed management priorities have followed the *Weed Management Plan for Camp Polk Meadow Preserve* (DBLT 2001). This document includes species descriptions, biology and ecology, as well as control plans. In 2002, noxious weeds were inventoried and mapped.

In the summer of 2006, weeds were re-inventoried and weed maps were updated with current distributions and infestation levels of each species. The *2006 Weed Monitoring and Evaluation – Camp Polk Meadow Preserve* (Berrin 2006) describes this monitoring effort, results, and includes updated control plans for each species. The number of plants encountered was given an infestation level, used in the text below: Trace = less than five plants (<1% cover); Low = 6-15 plants (1-5% cover); Moderate = 16-30 plants (6-25% cover); High = >30 plants (>25% cover).

Table 5 shows the weed species found in the vicinity of the new channel that will need to be controlled.

Table 5. Weed species known to occur in project area

Common Name	**Scientific Name**	**Priority**
Reed canarygrass	*Phalaris arundinacea*	1
Spotted knapweed	*Centaurea maculosa*	1
Diffuse knapweed	*Centaurea diffusa*	1
Bull thistle	*Cirsium vulgare*	1
Canada thistle	*Cirsium arvense*	1
Teasel	*Dipsacus sylvestris*	1
Mullein	*Verbascum thapsus*	2
St. John's Wort	Hypericum perforatum	3

<u>Pre-Construction Treatment</u>
The Land Trust plans to treat all these weeds during the 2007 growing season, as outlined in the 2006 report. In addition, pre-construction treatment of quackgrass and other pasture grasses should be considered in the Phase 1 planting areas. This could include using chemicals, and will have to be discussed with the Land Trust. Without pre-construction treatment and with irrigation, these grasses will likely spread rapidly.

<u>Post-Construction Treatment</u>
Post-construction control strategies, briefly described below, are identical to the Land Trust's updated control plans. For more details, refer to the Berrin (2006). **Table 6** provides an overview of the treatment plan for each species.

During the first year after construction, weed infestations will be monitored weekly by a walk-through the project area. Plants that can be easily removed by hand will be, while additional resources necessary to remove larger infestations and limit their spread will be identified.

Table 6. Weed control summary

Species	Season	Treatment
Reed canarygrass	April-May	Apply Killz-All/surfactant mix to all infestations
	June-July	Re-check known sites; clip and remove flower heads
	Sept-Oct	Re-check known sites; clip and remove seed heads; apply Killz-All/surfactant to new growth
Knapweeds (diffuse and spotted)	April-May	Hand-pull rosettes prior to flowering; remove roots from property. Hand pull and remove plants that have initiated flowering. Burn seed heads.
	July-Sept	Re-check known sites; remove any new plants.
Bull thistle	May-June	Hand pull rosettes and break or remove root (OK to leave on site)
	July-August	Remove flowering stalks and seed heads; Hand pull rosettes and break or remove root
Canada thistle	June-July	Clip plants close to ground.
	August-October	At least 4 weeks after cutting, treat new growth with glyphosate (better to do early to avoid overgrown native plants near thistle)
Teasel	May-Sept	dig and remove rosettes and taproot from the ground; cut and remove flowering heads from property
Mullein	May-September	Hand pull rosettes; remove flowering stalks and seed heads from property
St. John's Wort	May	Hand dig plants; remove roots from property
	June-July	remove flowering stalks and seed heads from property
	September	Apply Killz-All to cut plants.

<u>Reed canarygrass</u>
Twenty-five low to moderate infestations of reed canarygrass were mapped along Wychus Creek in 2006. Seed heads were clipped and all were treated with Killz-All (aquatic Round-up) in September 2006 and again in May 2007. This is the Land Trust's highest priority weed during the 2007 growing season.

There is a high likelihood of reed canarygrass spreading into the restoration area. In late April or May, new growth will be killed with Killz-All (aquatic Round-up). In June and July, known infestations will be revisited and the flower heads will be clipped and removed from the property. In late September and October, seed heads will be clipped and removed, and Killz-All will be applied to any new growth.

Spotted and Diffuse knapweed

Spotted knapweed is more abundant than diffuse knapweed on the Preserve. The two species were mapped together in 2006. Seventy-eight occurrences of knapweeds were mapped in 2006, 71 of which were trace infestations (1-5 plants). Most were located downstream of the railroad bridge along Wychus Creek. Spotted knapweed has occurred in much higher densities in the mid-meadow in years past, and has been successfully controlled by hand pulling. Exceptionally long seed viability raises concern about its future spread in the project area. Since it tends to grow on drier sites, the degree to which spotted knapweed will be competitive once the meadow is recharged is unclear.

To remove either of the knapweeds, rosettes and the entire root will be hand pulled in April and May prior to flowering. Plants that have initiated flowering will also be hand pulled, and seed heads burned to prevent spread to other areas. From July through September, known sites will be revisited and treated, as above. Control efforts should begin at the edge of the population and work inward. Chemical treatment is not preferred.

Bull thistle

Bull thistle was found throughout the property in trace or low infestations. The highest concentration of rosettes was found along the edge of the aspen grove at the lower end of the property. As a biennial, bull thistle produces a basal rosette the first year and a flowering stalk the second.

Bull thistle is relatively easy to control by breaking the taproot with a shovel or hand pulling. In May and June, rosettes will be pulled and the root removed from the ground. In July and August, flower stalks will be cut and removed from the property, and any new rosettes will be pulled. Chemical treatment will be considered only if hand pulling does not keep pace with its spread. If chemical treatment is necessary, 2,4-D will be sprayed on new rosettes.

Canada thistle

Canada thistle is commonly found in disturbed wetland areas and along edges throughout Central Oregon. It occurs in two known isolated patches in the mid- and lower- meadow, but is more common in the Upper Meadow and near Hindman Springs where human disturbance likely favored its spread. The plant was found in 46 places, 27 of which were trace infestations (1-5 plants). Three dense patches were found: one in the upper meadow near the willow plantings;

one near the aspen grove in the mid-meadow; and a third just south of the Preserve boundary.

Canada thistle has a high potential to spread in the project area. Since it propagates readily from stem and root fragments, soil disturbance favors its growth. An aggressive control strategy ought to be employed to prevent the rapid spread of Canada thistle. In June and July, plants will be cut to ground level. Plant should not be pulled since this can stimulate sprouting of new plants. From August through October, at least 4 weeks after cutting, new growth will be treated with glyphosate. The Land Trust is experimenting in 2007 with cutting plants in May and June, then covering the plants with boards for the summer. In October, the boards will be removed and the area reseeded with native plants.

<u>Teasel</u>
Although teasel was prolific around Hindman Springs in 2000, its population has been greatly reduced by consistent control efforts. It is still found in trace infestations in the Hindman Springs area and in a high infestation near the aspen grove in the lower meadow. These infestations will be treated in summer 2007. Teasel is commonly found along disturbed wetland edges throughout Central Oregon and it will likely spread in the project area.

As a biennial (or short-lived perennial) plant, teasel produces a basal rosette with a thick taproot in its first year of growth and a flowering stalk in the second year. From May through September, rosettes will be pulled and the taproot removed in order to prevent resprouting. If the plant has already flowered, stalks will be cut and removed from the site. If the teasel population explodes beyond the capacity to hand pull, glyphosate or 2,4-D herbicide can be used in spring, summer, or fall.

<u>Mullein</u>
Mullein was found in 2006 throughout the Preserve in 178 infestations. Most were trace infestations and 13 were high densities. As a biennial, it is easily pulled by hand. From May through September, rosettes will be pulled and flowering or seeding stalks will be removed from the property. Chemical treatment is not recommended.

<u>St. John’s wort</u>
Only 11 patches of St. John’s wort were found on the Preserve in 2006. These few infestations will be controlled in 2007. There is potential for rapid spread of the plant due to its high seed production (15,000-30,000 seeds/plant per season). Once well-established, St. John’s wort can be difficult to eradicate due to its long-lived seed and extensive root system.

A combination of hand-puling, cutting and chemical treatment is recommended. In May, plants will be dug up, and underground rhizomes removed from the property. In June and July, any flowering or seeding stems will be cut and removed from the site. In September, Killz-All will be applied to cut plants.

<u>Other Weeds</u>
Three other Priority 3 weeds grow in the project area: cheatgrass (*Bromus tectorum*), Kentucky bluegrass (*Poa pratensis*), and quackgrass (*Elymus repens*). Cheatgrass is well-established throughout the project area and tends to grow in dry sites. The degree to which cheatgrass will be competitive once the meadow is recharged is unclear. Research into the hydrologic tolerance of cheatgrass may shed some light on this potential threat. Other hydrophytic plants adapted to wetter conditions may have a competitive advantage over cheatgrass. Kentucky bluegrass and quackgrass are both well-established and will likely spread. Other introduced grasses that are well-established in the meadow include meadow foxtail (*Alopecurus pratensis*) and dense silkybent (*Apera interrupta).* All of these grasses except cheatgrass grow in or on the edge of wet meadows. As mentioned above, pre-construction treatment will be further explored.

Seeding of native grasses in the project area is intended to establish a cover of native perennial grasses that will help outcompete non-native invasive weeds.

Implementation Phasing

Project implementation will include three phases spanning at least five years **Figure 33**. This extended implementation schedule is necessary for project success because the proper function and stability of the new stream channel will depend upon strong vegetation establishment.

Phase I: New Channel Construction (Years 1-3 or more)

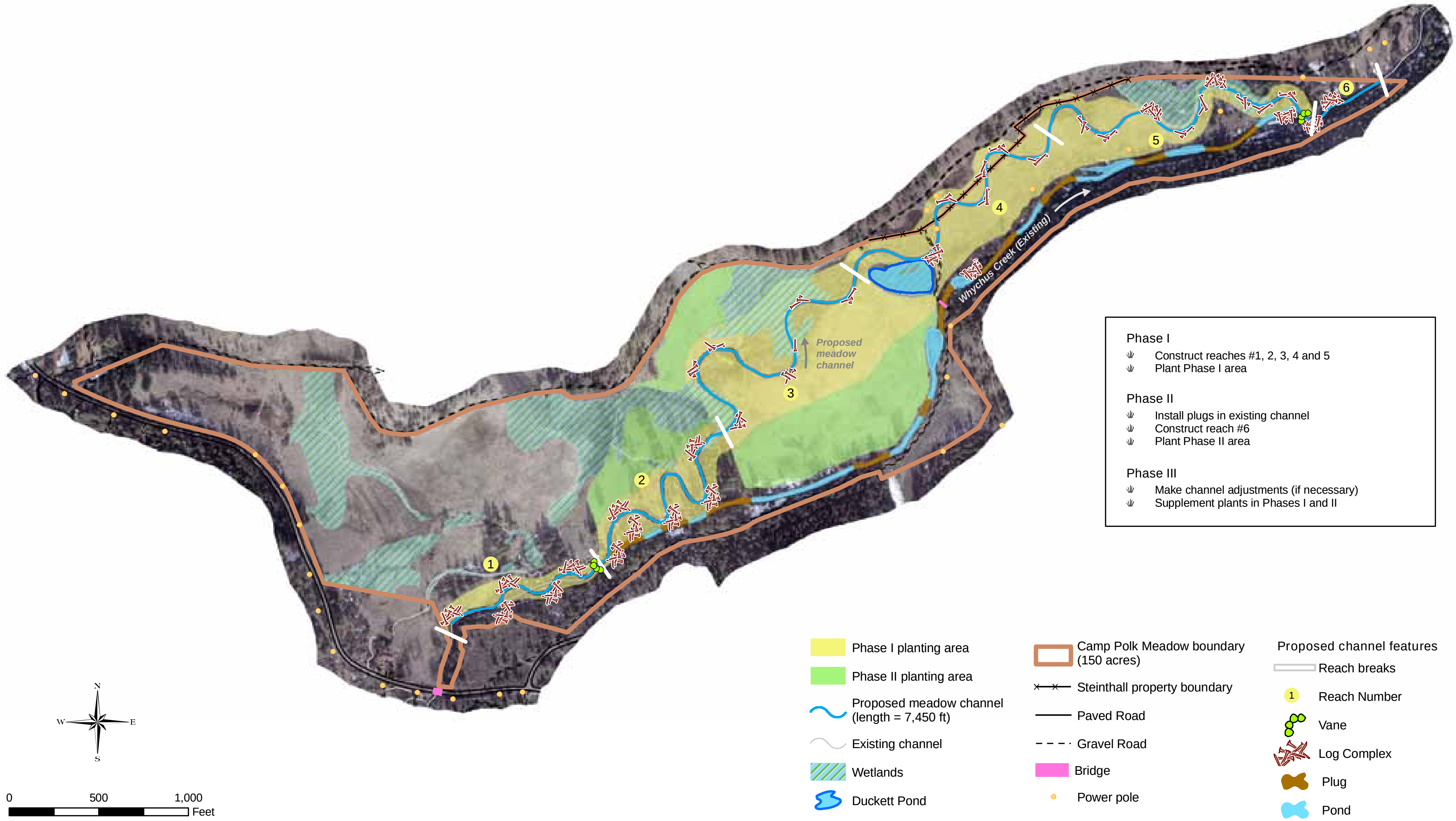
- Reach 1: Reach 1 in-stream enhancements will be completed during Phase I to allow Whychus Creek to sort unconsolidated bed materials before the current channel alignment is plugged. This will reduce the risk of plugging the entrance to the proposed meadow channel with deposits. Also, it will allow Whychus Creek in Reach 1 to aggrade and stabilize prior to transitioning to the proposed meadow channel. Working within the active channel will allow the Project Team to test their assumptions and make any necessary adjustments to the proposed meadow channel prior to re-routing the flows of Whychus Creek into the restored meadow channel.

- Reaches 2, 3, 4 and 5: Reaches 2, 3, 4 and 5 will be excavated to match design parameters, including placement of structures and logjams / complexes, adding woody material to the floodplain and supplementing riffle sections with appropriate sized substrate where needed. Materials such as gravel, boulders, fill material and trees will be stockpiled adjacent to the existing stream channel to be used in Phase II for creating plugs.

- Irrigation System: A temporary irrigation system will be installed to support revegetation efforts. This includes installation of a temporary pond, pump and sprinkler system to support irrigation needs for newly planted riparian and floodplain vegetation.

- Revegetation: Planting will occur throughout Zone 1 (channel margins) and Zone 2 (floodplain) on Reaches 1, 2, 3, 4 and 5. Vegetation will be allowed to establish for *at least* one to five years before Phase I is considered complete. Ongoing vegetation monitoring will be used to determine when establishment is considered to be adequate to support channel stability

The channel construction of this phase will take approximately two months to implement, with the planting adding an additional month. It is expected that summer months would be best for heavy equipment work (because the soil would be dry) and, based on past experience, fall and spring would be the best time to begin planting. Reach 1 instream work will need to occur during the instream work window of July 15 through October 15.



Source: 2/11/06 aerial photo

cpm_mapping\imple_plan.mxd, dquinlan, 6/7/07

Figure 33. Project implementation phases.

Planting will occur in both the spring and fall. Zone 1 and the inner portions of Zone 2 will be planted in the fall. In order for plants to survive through the winter, plants will need to be planted early enough to have some root establishment in the soil before going dormant and receive irrigation immediately after planting. Based on past experience at Tumalo Creek, Lake Creek and other project sites, planting in early October provides the best opportunity for plant survivorship for a fall planting. Planting will be immediately followed with irrigation and potentially filling of the stream channel to ensure that plants enter winter dormancy with adequate soil moisture. Limited winter flows may need to be introduced periodically into the channel to retain soil moisture over the winter season.

The outer portions of Zone 2 will be planted in the following spring. Planting will be immediately preceded and followed with irrigation to ensure that plants are being introduced into soils with adequate moisture. Based on past experience at Farewell Bend Park and other sites, spring planting is best when conducted immediately after ground thaw and before plants emerge from dormancy, likely to be late March or early April.

Phase II: Existing Channel Elimination (approximately Year 4)

Phase II will be initiated after riparian vegetation has been established along the length of the newly created channel and the banks of the newly constructed meadow channel are considered to be stable enough to withstand streamflow. Phase II includes:

- Constructing earthen plugs in the existing channel alignment with fill, rock and woody material;
- Planting Zone 3 (earthen plugs);
- Introducing Whychus Creek into the proposed meadow channel; and
- Planting Zone 4 (floodplain).

Phase III: Maintenance and Monitoring (approximately Years 5-10)

Phase III focuses on channel and vegetation maintenance, including:

- Planting additional material in Zones 1 to 4 as needed;
- Completing any adjustments to the new channel or the earthen plugs;
- Conducting weed control; and
- Site monitoring.

Phase III is expected to continue for the duration of the monitoring effort, as described below.

Monitoring

Project monitoring is critically important for tracking the long-term success of the project. The complete monitoring plan included in **Appendix J** includes provisions for monitoring the following elements:

- Discharge;
- Groundwater recovery;
- Surface water temperature;
- Stream channel dimension, pattern and profile;
- Streambed composition;
- Riparian vegetation success and cover;
- Wetland creation;
- Invasive weeds;
- Fish habitat, spawning and populations; and
- Photopoints.

REFERENCES

Allen, K. 2007. Wetland Delineation for the Camp Polk Meadow Preserve. Prepared for Upper Deschutes Watershed Council.

Berrin, S. 2006. 2006 Weed Monitoring and Evaluation – Camp Polk Meadow Preserve. Deschutes Basin Land Trust, December 2006.

Crowe, E. A., B.L. Kovalchik, and M.J. Kerr. 2004. Riparian and Wetland Vegetation of Central and Eastern Oregon. Oregon State University, Portland, OR. 473 pp.

DBLT, 2001. Weed Management Plan for Camp Polk Meadow Preserve, Deschutes Basin Land Trust, 2001-2005.

Hoag, J.C. no date. Wetland Plant Fact Sheets. Baltic Rush and Nebraska sedge. Interagency Riparian/Wetland Project, USDA, NRCS, Plant Materials Center.

Hoag, J.C. 1994. Riparian/Wetland Project Information Series No. 6. Seed and Live Transplant Collection Procedures for 7 Wetland Plant Species, June 1994.

Hoag, J.C. 2000. Riparian/Wetland Project Information Series No. 14. Harvesting, Propagating, and Planting Wetland Plants. July, 2002.

Hoag, J.C. 2006. Personal communication with Karen Allen. Wetland Plant Ecologist, USDA, NRCS, Plant Materials Center, Aberdeen, Idaho.

Hogervorst, J.B and Schmalenberg, J. 2005. 2004 Monitoring Report for Enchanted Valley Stream Restoration. Unpublished technical report. March.

Inter-Fluve. 2002. Qualitative Assessment of Sediment Transport and Downstream Channel Stability of Squaw Creek near Camp Polk Meadows below the Squaw Creek Diversion Canal. Unpublished report prepared for the US Army Corps of Engineers.

Lindquist, S. and Wilcox, J. 2000. New Concepts for Meadow Restoration in the Northern Sierra Nevada. Unpublished technical report.

Loheide, S. P. II and S. M. Gorelick. 2005. A local-scale, high-resolution evapotranspiration mapping algorithmn (ETMA) with hydroecological applications at riparian meadow restoration sites. Remote Sensing of Environment. 98: 182 – 200.

Loheide, S. P. II and S. M. Gorelick. 2006. Quantifying stream-aquifer interactions through the analysis of remotely sensed thermographic profiles and in situ temperature histories. Environmental Science and Technology. 40(10):3336-3341.

Manning, M.E., S.R. Sawnson, T. Svejcar, and J. Trent. 1989. Rooting Characteristics of Four Intermountain meadow community types. Journal of Range Management 42:309-312.

OSU 1980. Nutritive Values of Native Foods of Warm Springs Indians. Oregon State University Extension Circular 809.

Plumas Corp. 2004. Last Chance Watershed Restoration Project, CalFed Agreement #2000-E01. December.

Riehle, M. 2006. Personal communication in regards to anadromous fish use in Whychus Creek. Fish Biologist. US Forest Service, Deschutes NF, Sisters, OR.

Rosgen, Dave and Hilton Lee Silvey. 1996. Applied River Morphology, second edition. Wildland Hydrology, Pagosa Springs, CO.

Rosgen, D. 2005. Flowsed/Powersed-Prediction Models for Suspended and Bedload Sediment Transport.

United States Army Corps of Engineers. 2001. Analysis of Flow Data for Squaw (Whychus) Creek Near Sisters, OR. Unpublished report prepared for the Upper Deschutes Watershed Council. Bend, Oregon.

USDA (United States Department of Agriculture) 1992. Soil Survey of Upper Deschutes River Area, Oregon, including parts of Deschutes, Jefferson, and Klamath Counties.

Williams, G.P., 1986. River meanders and channel size. Journal of Hydrology, 88 pp.147-164.

Wasniewski, L. 2005. Middle Fork Lake Creek Restoration Plan at Lake Creek Lodge. Prepared for Upper Deschutes Watershed Council.

Winch, M. 2006. Biography of a Place: Passages through a Central Oregon Meadow. Bend, OR: Deschutes County Historical Society.

Appendix: A
Title: Alternative Comparison: General
Prepared by: Paul Powers
Fish Biologist
Crescent Ranger District

Cari McCown
Hydrologist
Sisters Ranger District
Date: January 22, 2007

Channel and Implementation Parameter Comparison

Two general restoration alternatives were evaluated. The first alternative and the one preferred by the Forest Service team, is to restore a meandering channel on the meadow. The second alternative would be to improve aquatic habitat within the current channel. Due to substantial channel incision (up to 10 feet in places) and fine texture soils in the banks, channel enhancements to create sinuosity would be limited to areas that could access former meander bends. Creating new meander bends within this confined, fine-grained system would put the channel at risk of failure. For the purpose of quantifying one alternative versus the other, the analysis area starts where the proposed meadow channel would leave the existing channel and ends where it would rejoin the current channel (Figure B-1). Both alternatives would include rehabilitation activities within the current channel alignment above and below these points.

Alternative 1 (Restored Meadow Alternative)

Pros
Alternative 1 would dramatically improve aquatic habitat quality and quantity as well as restore mesic meadow conditions. Restoring a meandering meadow channel would increase channel length by over 30%, increase high quality pool habitat (>1m residual depth) by approximately 450%, convert a xeric, weed-infested pasture to a mesic wet meadow, create 100 acres of wetland and probably most importantly, reconnect Whychus Creek to its floodplain in one of the few locations where this is possible. Elevating the stream channel and recharging the meadow would result in dramatic changes to vegetation, wildlife, fish and hydrologic function. Two recent studies in California documented a 3°C decrease in maximum summer stream temperatures through a 1.7 km restored meadow reach and an increase in delayed streamflow release which supplements base summer discharge (Loheide and Gorelick, 2006). Four rehabilitated meadows studied by Loheide and Gorlick (2005) responded within one or two seasons after project implementation. The rising water table

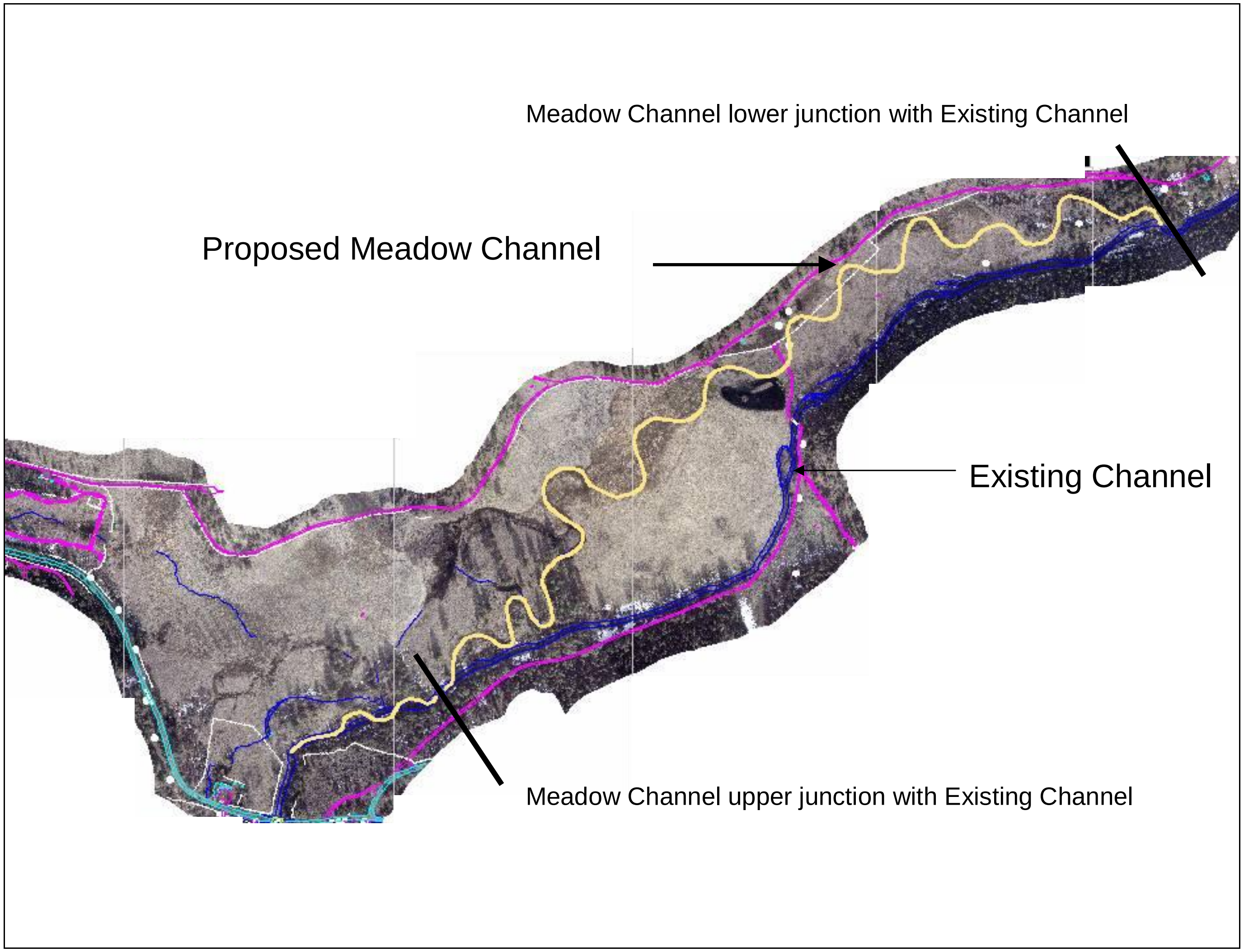


Figure A-1. Alternative comparison reaches for the Camp Polk Restoration Project shown by the black lines.

increased soil moisture killing xeric vegetation and initiated the succession of riparian dependant vegetation.

Alternative 1 would greatly improve habitat for ESA listed steelhead and chinook salmon as well as regionally sensitive redband trout, sculpin, suckers, and non-native brook trout and brown trout. Camp Polk Meadow, the new stream channel and the abundant off channel habitat would provide refuge during winter peak flows and thermal refuge during summer low flow periods. This reach may once again become significant for spawning steelhead and redband trout. The increased level of hyporheic exchange between the stream and the meadow may result in improved spawning habitat in areas of cold water upwelling.

Cons

The disadvantages of Alternative 1 are the increased complexity of designing and preparing the new channel, increased cost, a longer timeline for implementation and potentially increased risk of unanticipated results (erosion). The ability of the stream to move its bedload and not significantly aggrade the meadow or more importantly not degrade is critical to the stability of this option. Aggradation of mobilized bedload would likely occur in some areas and should not be viewed as a project failure, but rather a success. Accumulations of gravels will likely result in the development of sidechannels and provide areas of high quality spawning habitat.

The worst case scenario that could result from selecting Alternative 1 would be to create a meadow channel that is not stable, resulting in a downcut or incised channel. This would occur if the stream power were too great for the channel and more sediment were being transported out than was being replaced from upstream. This would result in an incised, entrenched mid-meadow channel that resembles the current alignment. This would be detrimental to water quality and fisheries resources downstream as high volumes of fine sediment would be contributed to the channel. Based on channel geometry, low slopes, floodplain connectivity, upstream channel stability and sediment analysis, we do not expect this to occur.

If the newly designed channel were receiving more sediment than it could pass, channel aggradation would occur. This could result in lateral instability (bank erosion) and braiding of the channel. If riparian vegetation is established this could result in the creation of stable braids or side channel habitat. It should be made clear that if stable channel braiding of the channel were to occur in the meadow that would not be viewed by the Forest Service team as a project failure. If a meadow channel is designed it will include side channels. This is a natural feature of properly functioning meadow channels that reduces stream power, increases available habitat and facilitates groundwater recharge.

Alternative 2 (Enhanced Existing Channel Alternative)

Pros

The most significant advantages to enhancing the existing channel are the low risk of project failure, lower cost and a shorter timeline for implementation. The current stream channel has already eroded down to bedrock in areas, so the risk of further incision is low. A comparison of a thalweg profile from 2000 versus that surveyed in 2006 shows little change; therefore, it is believed that the project area is now relatively stable. In addition, the channel location appears to have changed little since 1976. This alternative would provide improved pool habitat and channel complexity over the current condition. Implementation of this alternative would be relatively easy in terms of time, money, and complexity.

Cons

The major disadvantage is that this alternative does not fully restore or rehabilitate the stream and/or meadow and does not restore floodplain connectivity. Sinuosity would remain relatively low (1.15) and riffle habitat would still dominate the reach. Within the comparison reach, only four new pools would be created in this alternative verses the creation of 24 new pools in Alternative 1. The water table would remain low; therefore, no new wetlands would be created and the meadow at Camp Polk would remain a xeric pasture. Due to the level of entrenchment and higher slope, grade control structures would be engineered and be less natural in appearance and function.

Figure A-2. Picture of sediment wedge and associated left bank channel erosion in Whychus Creek at Camp Polk meadows (2006).

Table A-1. Comparison of channel dimensions by alternative for the Camp Polk restoration project.

Measure	Existing Channel	Enhanced Existing Channel	Restored Meadow Channel	Desired Condition
Rosgen channel type	C3/4	C3/4	C4/E4	
Channel Length (feet)	5358	5630	7450	
Riffle Length (feet)	4018	4220	3262	
Pool Length (feet)	1232	1300	4188	
Estimated Pool Area (ft^2)	31,389	35,000	170,000	
Percent of Reach as Pool Habitat	23	43	57	
Number of Pools	6	10	27	20-28* (existing and enhanced channel) 33-46* (meadow channel)
Sinuosity	1.08	1.15	1.6	>1.2
Average Slope	0.9%	0.83%	0.6%	
Entrenchment	1-2	1-5	9-26	>2.2
Bankfull W/D	20	19	17-30	

Note: Channel length in this table is calculated only from the point of the meadow channel bifurcation to the confluence with the current channel.
* estimate based on a pool every 5-7 channel widths

Table A-2. Comparison of fish habitat and project implementation parameters by alternatives for the Camp Polk restoration project.

Comparison Parameters	**No Action Alternative**	**Enhance Existing Channel Alternative**	**Meadow Alternative**
Increase in (adult – main channel) fish habitat (ft)	0	472	2092
Increase in side channels (juvenile habitat?) (ft)	0	0	>500
Increase in sub-surface water storage (gal/ac-ft of elevation)	0	0	104,000
Increase in wetlands maintained through summer months (ac)	0	0	115
Decrease in stream temperature	0	0	3-10 ºC
Increase in flow during low flow season	0	0	yes
When would project be completed	Done	1 year	Multi-year
Cost	None	Inexpensive	Expensive
DBLT goals accomplished	None	Some fish habitat	All
Short-term effects from implementation	None	Low	High

Table A-3. Comparison of risks associated with the Camp Polk restoration project alternatives.

Meadow Alternative Risks		Enhance Existing Channel Alternative Risks	
Degradation	We don't expect this to occur based on particle size and channel dimensions	Bank Erosion	Localized bank erosion could occur adjacent to structures.
Recapture	This would be the greatest concern. Plugs would need to be deep (down the TW) and substantial		
Bank Erosion	Riparian vegetation would require a couple growing seasons before subjecting it to the flows of Whychus Creek		
Aggradation	This could occur, resulting in the deposition of gravel sized material and possibly initiating sidechannel creation.		

Appendix:	**B**
Title:	**Alternative Comparison: Anadromous Fish Habitat** **Changes in steelhead trout and chinook salmon habitat resulting from proposed channel restoration.**
Prepared by:	**Mike Riehle** **Fish Biologist** **Sisters Ranger District**
Date:	**January 22, 2007**

Introduction

Whychus Creek, a tributary to the Deschutes River, was historic habitat for summer steelhead and spring chinook salmon prior to the abandonment of upstream fish passage at Round Butte Dam in 1968 (Nelhsen 1995). Historically an important steelhead stream in the upper Deschutes Basin, Whychus Creek is now habitat for resident redband trout, and non-native brook trout and brown trout. With fish passage being restored at Pelton Round Butte Dams, steelhead and chinook salmon will again have access to Whychus Creek, possibly starting in 2011.

The Deschutes Basin Land Trust (DBLT) manages the lands along Whychus Creek near Camp Polk Road, upstream of the Pelton Round Butte Dam Complex. Two alternatives were evaluated for potential effects on the quality of steelhead trout and chinook habitat. The fish habitat quality in the existing channel was compared to enhancing the habitat in its existing location and relocating the channel by routing it into the abandoned channel in the adjacent meadow (Figure 1).

Study Area

The study area is downstream of Camp Polk Road in T14S R10E S26 on DBLT lands. Habitat surveys were performed on 8/2/06 using USFS protocol (USFS 2006) on the entire 2.3 kilometers of Whychus Creek on DBLT lands. Reach boundaries were defined as the upper junction of the existing channel and meadow channel alternative (A) and the lower junction (B) of the existing and meadow channel (Figure 1). The enhanced existing channel alternative had the same boundaries as the existing channel. Additional channel work upstream of the meadow channel junction was not considered in the assessment because it was proposed in both restoration alternatives.

Historic use of Whychus Creek at Camp Polk by summer steelhead trout was documented by King (1966) in the 1950s and 1960s by trapping near Camp Polk and counting redds downstream of the trap. As many as 1000 steelhead were estimated to spawn in Whychus Creek in 1953 (Montgomery 1952 and 1953 as cited by Nelhsen 1995). Those fish counted in the trap would likely have spawned in the Camp Polk area or upstream. The upper extent of steelhead spawning upstream of Camp Polk is not mentioned in the historic reports reviewed. The upstream extent of steelhead spawning in Whychus Creek is considered the lower falls, near the boundary of the Three Sisters Wilderness Area at RM 35 (Ratliff 1999).

Spring Chinook were reported to use the lower few miles of Whychus Creek for spawning during the 1950s (Nehlsen 1995). It was clear that their upstream migration was limited in the fall by the reduced flows in Whychuc Creek upstream of Alder Springs. Since chinook salmon are fall spawners, poor water quality due to low summer flows in the 1950s would have presented a significant barrier to spawning chinook. It was estimated that upper Whychus Creek could support 1000 spawning Chinook Salmon if gravel was the only limiting factor (OSGC 1960 as cited by Nelhsen 1995). By the 1950s, little water flowed in Whychus Creek between Camp Polk Springs and Alder Springs due to water withdrawals for irrigation.

Chinook salmon may have historically used the middle reaches of Whychus Creek for spawning prior to major irrigation withdrawals in the early 1900s. Chinook spawning may have occurred as far up as RM 24 (2 miles upstream of Sisters), where the gradient becomes steeper and there are short cascades and minor waterfalls.

Methods

The fish habitat survey followed USFS (2006) Region 6 stream habitat inventory protocol. A modification to the habitat protocol was pebble counts for substrate quantification were performed on pool tail-outs instead of riffle habitats. This was done to determine the amounts of fine sediments and gravel in potential spawning areas. In addition, undercut banks had to be undercut 0.3 meters or greater to be counted. Boulders 1 meter diameter or larger were also counted.

Criteria for a habitat assessment called HabRate were developed to rate habitat quality in the Upper Deschutes Basin for steelhead trout and chinook salmon (Burke et al. 2003). For this report, only the habitat criteria for selected habitat attributes were used to compare the alternatives of the Camp Polk Project. The overall habitat rating system in HabRate was not used in order to focus on the individual habitat attributes. Criteria used by Cramer and Beamesderfer (2002) were also used to evaluate steelhead habitat quality.

Key habitat attributes for chinook salmon used from HabRate were percent pool, pool complexity and gravel. Pool complexity is a combined score of pool depth, large wood densities and densities of key pieces of large wood that were high enough to be considered good quality. These habitat attributes were found to be important in a habitat assessment for anadromous fish above Pelton Round Butte Dams (Riehle 2001).

It is important to note that the criteria used to describe good steelhead habitat was based on studies of fish densities in relation to habitat quality. I used HabRate criteria for the good habitat category for individual habitat attributes. The criteria used in this assessment should not be viewed as a threshold, but more as a goal. For example, if the measure of habitat quality falls just below the criteria used in this report, the resulting fish densities would be similar to habitat which falls just above the criteria.

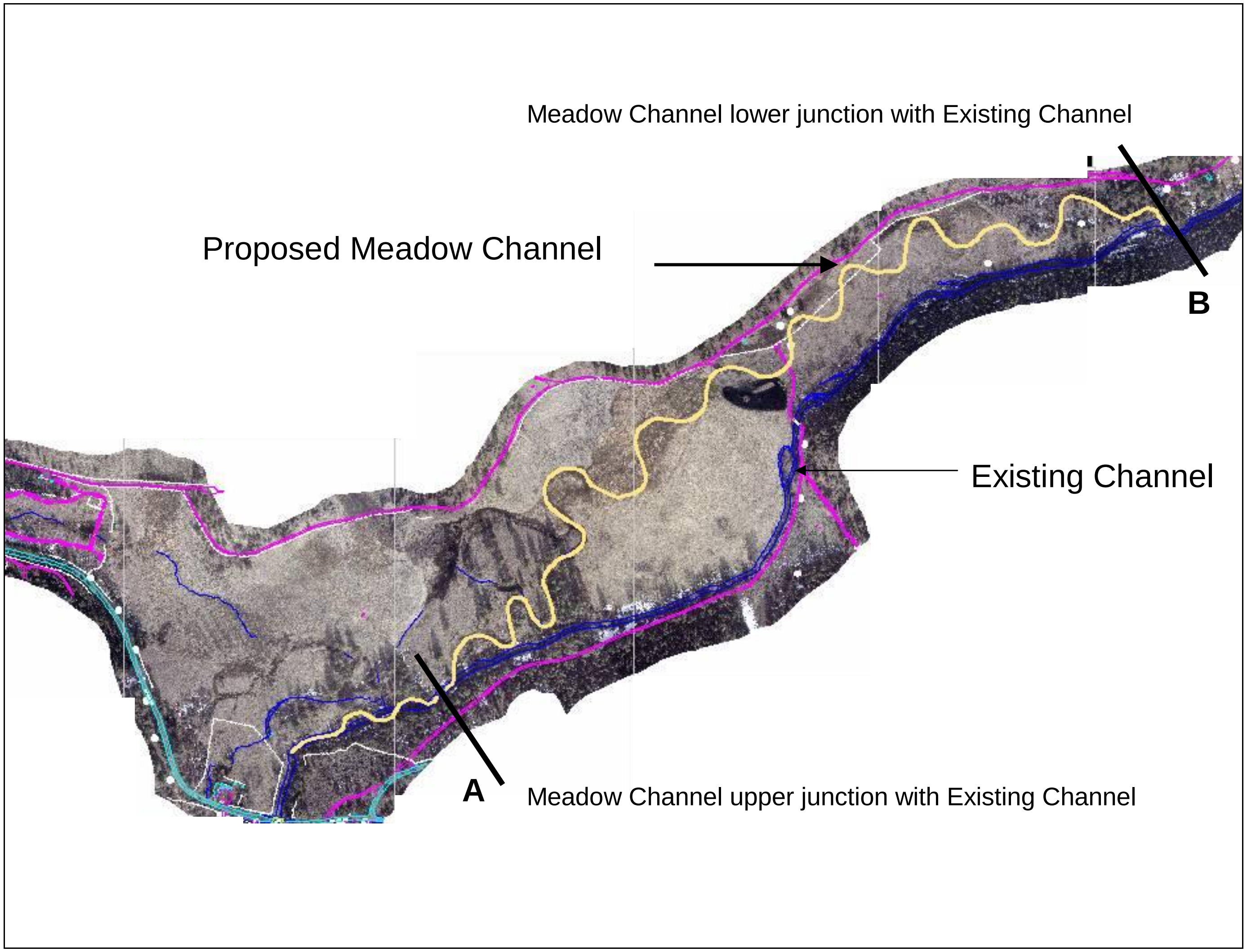


Figure 1. Map of proposed channel restoration and the upper (A) and lower (B) extent of the existing channel and the proposed meadow channel used for the habitat assessment.

Results

Steelhead Trout Habitat Comparison

Existing Conditions
Existing habitat conditions for steelhead trout is poor to fair. The substrate of this reach had little substrate complexity for rearing but an adequate proportion of cobble (17 to 21%) (Table 1 and Table 2) Gravel was abundant in pool tailouts (59%) and the percentage of fines was 21%, which was higher than desired for good spawning habitat and rearing habitat (Suttle et al. 2004). Spawning habitat was in fair condition, other than the percent fines and low number of pool tailouts.

Riffles had low fine sediment, low number of boulders, and an adequate proportion of cobble. (Table 2). Low fine sediment allows for spaces in the gravel and could provide hiding cover for juvenile fish in winter. For summer rearing, large cobble and boulders in riffles provide good feeding and hiding cover for juvenile steelhead. Large boulders were infrequent in the existing channel. Boulders were primarily located in the upper portion of the reach and at the old flatcar bridge (used as riprap).

Pool habitat is lacking in the existing channel (23%), and was almost half the number of pools required for good habitat (Table 2). Cover and depth in pools were also lacking. Riffle depth, a key attribute to steelhead summer habitat, was poor (0.2 m) (Table 3). Overall cover in the reach was low for undercut banks, large wood and boulders. Pool complexity was poor when considering pool depth, large wood density and key pieces of large wood density(greater that 20 inch diameter). Therefore, pool complexity was poor in the existing channel for steelhead.

Enhanced Existing Channel
In the proposed alternative where enhancements would be made to the existing channel, the habitat quality for steelhead would be improved. Although substrate would not be changed, the number and quality of pools would be improved (Table 1). Undercut banks would not be increased substantially due to the steep gradient and confined floodplain (Table 2). Even though large wood would be added to the channel, the number of boulders or percent cobble would not be increased. Channel complexity would be moderate quality for steelhead habitat. Habitat attributes that were most improved by the addition of wood were pool depth and pool complexity (Table 3 and Table 4).

Riffle depth would be improved greatly with enhancements to the existing channel, providing good quality riffle habitat in a reach that is now considered poor (Table 4). Boulders would remain below what is considered good for steelhead rearing habitat.

Meadow Channel Alternative

The meadow channel alternative would provide the largest improvements in habitat by doubling the pool area and by increasing pool quality. The number of pools would greatly increase (14 to 27 pools), creating more feeding stations and habitat for larger age classes of steelhead (Table 5). In addition, the quality of the pools would improve by adding large wood and undercut banks to the stream margins (Table 2 and Table 3). Although the amount of cobble would remain the same and boulders would remain low, the increased undercut bank habitat in the meadow would improve habitat for the early rearing steelhead fry. Riffle depth would increase and provide good rearing habitat compared to the existing poor riffle conditions.

The overall habitat area of the meadow alternative would nearly double (Table 5). Pool habitat area would increase from 2511 to 13,173m^2 and channel length in the assessment reach would increase from 1670 to 2395m. The number of pools would double (14 to 27 pools) and pool quality would increase greatly from the addition of wood and greater depth.

Adding pools would also increase the area of spawning habitat in the pool tailouts. With increased spawning sites in the meadow alterative, combined with improved undercut banks and pool complexity for rearing habitat, the meadow alternative would improve steelhead habitat quality the most, especially for spawning and summer rearing. With increased pools in the meadow channel, there would be an increased need for riparian shade in order to maintain and possibly reduce summer water temperatures.

The increase in pool habitat would greatly increase winter rearing habitat quality in the meadow channel alternative. Without a prevalence of large substrate for intergravel cover in the winter, there would be an increased importance for undercut banks, large wood and boulders. An estimated 500ft of side channels and flood channels will be developed in the Meadow Alternative, providing off channel refugia for fish during winter floods.

Chinook Salmon Habitat Comparison

Although the project may not be targeted to improve chinook salmon habitat, there would be benefits to this species. Once reported to spawn in Whychus Creek, primarily near Alder Springs, the Camp Polk reach may serve to provide spawning and early rearing habitat for chinook salmon once they are reintroduced. The water quality at the site is improving with the recent increases in instream water rights and water leasing. Reduced water quality upstream of

Alder Springs may have been what limited upstream use of Whychus Creek by spring chinook historically.

Habitat criteria developed by Burke et al. (2003) and used by Riehle (2001) identified pool habitat attributes and gravel as key habitat attributes for chinook salmon. The existing channel does not provide good chinook habitat based on the percent pools, pool complexity and residual pool depth (Table 6). Gravel in pool tailouts is considered good quality (>30%). If the existing channel is improved, the residual pool depth could be raised to be good quality but the percent of main channel pools would not be considered good chinook habitat. The meadow alternative would raise the habitat quality for chinook habitat into the good range for pool depth and percent pools.

Given habitat improvements in the Camp Polk property, chinook salmon would be more likely to use the area for spawning and rearing because of the increase in pool habitat and spawning habitat in the pool tailouts. Increasing cover in the form of undercut banks and large wood and floodplain roughness would further improve the habitat for winter rearing chinook.

The meadow alternative provides the best chinook salmon habitat for spawning and rearing because of the improvements to pools density and pool depth. Added cover in the pools will greatly increase the pool quality over that of the existing channel.

Resident Trout Habitat Changes

Native resident redband trout, being the same species as steelhead trout may respond to the proposed habitat changesin a similar way. Cramer and Beamesderfer (2004) suggested that there may be a temperature range that favors the anadromous steelhead trout compared to the resident redband trout. Mean August temperatures below 15^{o}C may favor resident redband trout. Dachtler (2007) found densities of redband trout in the Camp Polk area to be on the low range compared to other redband trout populations in the basin. The low habitat quality of the existing channel and high summer temperature may be related. If water temperatures were reduced as much as 5 ^{o}C in the proposed restoration project, they may still favor the anadromous steelhead trout.

Brown trout were as numerous as redband trout in the Camp Polk area (Dachtler 2007). Brown trout can tolerate warm summer temperatures in this reach (Scott and Crossman 1973). Increased shade and groundwater exchange in the Meadow Alternative could provide more favorable conditions for redband trout and steelhead trout.

Table 1. Criteria adapted from Burke et al. (2003) for steelhead spawning to emergence habitat.

Spawning, egg survival, emergence	Criteria for Good Habitat	Existing	Enhanced Existing Channel Alternative	Meadow Alternative
Fines (%)- pool tailout	**≤10**	21	21	21
Gravel (%)- pool tailout	**≥30**	59	59	59
Cobble (%)- pool tailout	**≥10 τo ≤ 30**	17	17	17
Pool area (% pools)	**≥40 τo 60**	23	30	55
Residual Pool Depth (m)	**≥0.2**	0.5	0.8	1.0

Table 2. Criteria adapted from Burke et al. (2003) for steelhead rearing habitat.

Rearing	Criteria for Good Habitat	Existing	Enhanced Existing Channel Alternative	Meadow Alternative
Fines (%)- reach	**≤10**	2.3	2.3	2.3
Cobble and boulder (%)- reach	**≥20**	21	21	21
Pool Area (% pools) -reach	**≥40 τo ≤60**	22.9	30	□□
Pool complexity	**3**	1	3	3
Depth in fast water (m) - reach	**≥0.45**	0.2	0.4	□□□
Additional Cover				
% undercut	**≥15**	1.3	10	15
LWD / 100m	**≥20**	0.01	1.25	1.25
boulders / 100m	**≥20**	0.54	7	0

Table 3. Criteria adapted from Burke et al. (2003) for steelhead pool complexity rating.

Pool Complexity	Criteria for Good Habitat	Existing Channel	Enhanced Existing Channel Alternative	Meadow Alternative
Depth (*min. at summer flow*)				
<= 10m wetted width	**>0.6**	**0.5**	0.8	1
LWD				
Keypieces of LWD/ 100m	**≥2**	**0**	0.62	0.62
Pieces of LWD / 100m	**≥20**	**0.01**	1.25	1.25

Table 4. Criteria for steelhead parr based on Cramer and Beamsderfer (2004).

	Good parr rearing habitat	Existing Channel	Enhanced Existing Channel Alternative	Meadow Alternative
Depth	>0.75m	0.3-1.0	0.66 -1.0	1.0 -1.3
Riffle depth	>0.25m	0.06	0.39	0.48
Large wood	Complexity rating (4=high)	0	3	2-3
Substrate	Boulders/100m	5.5	7	0

Table 5. Habitat attribute comparison for the project alternatives.

Measure	Existing Channel	Enhanced Existing Channel Alternative	Meadow Alternative
Length m	1670	1706	2395
Width m	10	10	9
Number of pools	14	15	27
Pool Area m^2	2511	5118	13,173
Riffle Area m^2	10,500	11,260	10,299

Table 6. Chinook salmon selected rearing habitat attributes by alterative based on Burke et al. (2003).

Attribute	Criteria for good habitat	Existing Channel	Enhanced Existing Channel Alternative	Meadow Alternative
Percent Pool	**40-60**	23	30	55
Pool Complexity Score	**3**	1	1	1
Residual Pool Depth (m)	**0.6**	0.5	0.8	1.0

Discussion

The most important benefits of the meadow alternative would be the increase in habitat area, increase in pool area and depth, increase in undercut bank and increase in spawning habitat (pool tailouts). Both steelhead and chinook could use the site for spawning and early rearing and may use the downstream reaches for rearing as they grow older and disperse. Added pools and increased undercut banks would also increase winter rearing habitat.

Floodplain development would add stability to the channel and would be most effective in the Meadow Alternative. An estimated 500ft of side channels and flood channels will be developed in the Meadow Alternative, providing off channel refugia for fish during floods. Boulders and large wood could be added to the existing channel, but due to the restriction of the flood plain, little protection from winter peak flows may be provided by the enhanced existing channel alternative.

Riparian plantings in both alternatives would reduce summer stream temperatures and would add to the habitat diversity as trees and shrubs fall into the stream and add cover. With the Meadow Alternative, stream temperatures may decrease during summer from riparian plantings and increased groundwater interactions. Existing stream temperatures can range over 20^{o}C some years and reducing the maximum temperatures will benefit steelhead and resident trout. Optimum water temperatures for rearing steelhead are 10-13 ^{o}C (Burke et al. 2003). The existing channel is down cut below the existing water table and may serve to drain the meadow of groundwater (Sussmann 2006). The meadow alternative may restore the historic water table and the reach may release the groundwater into the channel during the summer. Similar meadow restoration projects have been shown to reduce summertime maximum stream temperatures by greater than 3 ^{o}C (Loheide and Gorelick 2006). This connection to groundwater, combined with added pool tailouts, may attract fish to spawn in this reach more than the other alternatives.

Literature Cited

Burke, J.L., K.K. Jones and J.M. Dambacher. 2003. HabRate: A stream habitat evaluation methodology for assessing potential production of anadromous fish salmon and steelhead in the Middle Deschutes River Basin. Oregon Department of Fish and Wildlife. Portland, Oregon.

Cramer, S.P. and R.C.P. Beamesderfer. 2002. Population dynamics, habitat capacity, and life history simulation model for steelhead in the Deschutes River, Oregon. S.P. Cramer and Associates, Inc. Gresham, OR. Prepared for Portland General Electric, Portland OR.

Dachtler, N. 2007. Whychus Creek fish habitat and population surveys prior to channel restoration on Deschutes Basin Land Trust Property, at Camp Polk, Oregon. Deschutes National Forest, Bend, Oregon.

King, D.N. 1966. Central Region Administrative Report No. 66-3. Deschutes River Summer Steelhead. March. Oregon State Game Commission. Portland, Oregon.

Loheide S.P. and S.M. Gorelick. 2006. Quantifying stream-aquifer interactions through the analysis of remotely sensed thermagraphic profiles and insitu temperature histories. Environmental Science and Technology. In Press. Published on the web at http://pubs.acs.org/jornals/esthag/index.html.

Mongomery, M.L. 1952. Deschutes River Investigations, Central Region. River Basin Investigations, Oregon State Game Commission.

Mongomery, M.L. 1953. Deschutes River Investigations, Central Region. River Basin Investigations, Oregon State Game Commission.

Nehlsen, W. 1995. Historical Salmon and Steelhead Runs of the Upper Deschutes River and Their Environments. Portland General Electric. Portland, OR.

Oregon State Game Commission. 1960. Statement concerning the fish and wildlife resources of the Deschutes Basin for presentation at the State Water Resources Public Hearing. March 1.

Ratliff, D., Schultz E., and S. Padula. 1999. Pelton Round Butte Project Fish Passage Plan. Portland General Electric. Portland, Oregon.

Riehle, M.D. 2001. Habitat Availability and limiting factors for anadromous fish habitat upstream of Pelton Round Butte Dams- Progress Report. *In* Annual Fisheries Workshop, March 7, 2001. Portland General Electric. Portland, Oregon.

Scott, W.B., and E.J. Crossman. 1973 Freshwater fishes of Canada. Fisheries Research Board of Canada. Bulletin 184.

Sussmann, P. 2006. Camp Polk Reconnaissance and Groundwater Assessment. Deschutes National Forest. Bend, OR.

Suttle, K.B., Power M.E., Levine J.M. and C. McNeely. 2004. How fine sediment in riverbeds impairs growth and survival of juvenile salmonids. Ecological Applications. 14(4): 969-974p.

USFS. 2006. Region 6 Level II Steam Inventory Protocol. USDA Forest Service. Pacific Northwest Region. Portland, OR.

Appendix: C
Title: Soil and Groundwater Report
Prepared by: Peter Sussmann
Soil Scientist
Deschutes National Forest
Date: June 9, 2006

Soils in the Camp Polk Meadow area are primarily Mollisols developed in airfall ash overlying waterlain volcanic ash, sands and gravels. Glacial outwash currently exposed in the existing channel bottom of Wychus creek consists of large gravels and cobbles and likely underlies the majority of the meadow area. Smaller sized gravel and sand deposits are also present throughout the meadow approximately four to five feet below the current surface. This material appears to be waterlain deposits indicative of a meandering stream channel system.

Wet meadow plant communities are present in lower lying areas where seasonal water tables are closer to the surface. Soils underneath these communities have developed additional organic horizons within the soil profile from the higher production of plant biomass and the slower decomposition rates. **Figure C-1** shows the different horizons of a soil underneath a wet meadow Carex/Juncus community (photo **Figure C-2**). Surface horizons are silt loam in texture and high in organic matter. Subsurface horizons include a diatomaceous silt loam likely deposited in slack water, a buried organic layer developed as a surface horizon, waterlain loamy sands, and waterlain sands and gravels. The water table was encountered approximately three feet below the surface in this profile.

Figure C-1. Soil profile of Carex/Juncus relict channel site (left to right).

Figure C-2. Carex/Juncus wet meadow site in low lying ‘relict’ channel location.

Contribution to groundwater within this system appears to be driven primarily by surface springs emanating at the west end of the meadow and subsurface irrigation throughout the area. The existing stream channel of Wychus Creek is incised below the level of groundwater present in the meadow and is likely not currently contributing a substantial amount to the groundwater system in the meadow beyond the immediate hyporheic zone influence.

Figure C-3. Eastern meadow soil profile along Wychus Creek with historic drain.

Groundwater storage in the meadow appears to perch on consolidated outwash material deposited from multiple glacial events and likely flows laterally on a west to east gradient. The storage capacity of the soil substrate within the meadow is relatively high, based primarily on the porosities provided by the loamy sand textures of subsurface horizons and the somewhat uncompacted silt loam textures of the surface horizons. Rock content of the soil profiles is also quite low. Estimated average porosity of the soil profiles within the meadow is between 30 and 40%. Storage capacity based on an average porosity of 35% would be approximately 2.6 gallons per cubic foot of soil or 104,000 gallons per acre for every foot of rise in water table elevation.

Appendix: D
Title: **Existing Condition Stream Survey and Fish Population Report**
Prepared by: **Nate Dachtler**
Fish Biologist
Sisters Ranger District
Date: **January 7, 2007**

Introduction

The headwaters of Whychus Creek (formerly Squaw Creek) originate in the Three Sisters Wilderness and flows Northeast approximately 65 kilometers before meeting the Deschutes River. Historically Steelhead *Oncorhynchus mykiss* used the stream for spawning and rearing up to Whychus Falls located just inside the Three Sisters Wilderness boundary. Small numbers of spring chinook *O. tshawytscha* were also documented near the mouth in the Alder Springs area (Nehlsen 1995). Anadromous fish were cut off from this stream and other tributaries in the basin when upstream fish passage was terminated around Round Butte, Pelton and associated reregulating dams. Native fish species found in the creek include redband trout *O. mykiss*, bridgelip suckers *Catostomus columbianus,* longnose dace *Rhinichthys cataractae*, speckled dace *R. osculus* and shorthead sculpins *Cottus confuses.* Bull Trout *Salvelinus confluentus* and mountain whitefish *Prosopium williamsoni* are found near the mouth below Alder Springs. Nonnative fish species include brown trout *Salmo trutta*, brook trout *S. fontinalis* and one goldfish *Carassius auratus* was found during this study. As part of a relicensing agreement PGE (Portland General Electric) will begin the reintroduction of steelhead and possibly spring chinook in the next five years.

The land currently managed by the DBLT (Deschutes Basin Land Trust) near Camp Polk was historically modified to improve agriculture and grazing. The stream was rerouted into a straight channel along the southern edge of the property. Old channels in the meadow indicate it once meandered through the meadow. A restoration plan and pre project hydrology data has been collected in the last few years. A decision has to be made to either improve the channel in its existing location or reroute it through the meadow.

This report will focus on the results of preproject instream fish habitat survey and fish population estimates. This will allow assessment of changes to instream fish habitat and fish populations after the restoration project has been completed.

Study Area

The study area is downstream of Camp Polk Road in T14S R10E S26 on DBLT lands. Habitat surveys were performed on the entire 2.3 kilometers of Whychus Creek, on DBLT lands. Fish surveys were conducted on three 300 meter reaches. Two 300 meter reaches were within the proposed restoration project area and one was a control reach located at the downstream end of the property mostly below the proposed restoration project (Figure 1).

Methods

The fish habitat survey followed USFS (2006) Region 6 stream habitat inventory protocol. Additions or changes to the standard protocol are as follows: A modification to the habitat protocol was pebble counts for substrate quantification were performed on pool tail-outs instead of riffle habitats. This should help determine amounts of fine sediments and gravel in potential spawning areas. Length of undercut banks was measured and banks had to be undercut 0.3 meters or greater to be counted. Boulders equal or greater than 1 meter diameter in the wetted channel were also counted. Habitat surveys were conducted Aug. 2, 2006.

Two pass Peterson mark recapture population estimates were performed in three reaches. Reaches were measured out to be 300 meters each and flagged at upstream and downstream ends. Two reaches were located within the proposed restoration project area and another was located mostly downstream of the project and was intended as a control reach. However part of this reach was located within the proposed project area because the distance between the downstream end of the DRC property and bottom of the proposed project was only about 200 meters. The fish population estimates were performed with a crew of five people and two Smith Root battery powered backpack electrofishers working upstream. All fish were captured and all trout species were marked with a caudal clip and then redistributed throughout the survey reach. Other species were identified, counted and released. The same reach was electrofished the following day and fish were captured and identified as being marked or unmarked. Fish were marked on Aug 8, 2006 in reaches 1 and 2 and recaptured the following day. Fish in reach 3 were marked on Sep. 5, 2006 and recaptured the following day.

Redband redd counts were conducted on the DRC Camp Polk property and the private property upstream of it during the winter and spring of 2005-2006. Reaches were also surveyed downstream near Alder Springs and up to Rimrock Ranch by PGE during the same time period. Redd counts were conducted every two weeks, flow and water clarity permitting.

Figure 1. Whychus Creek fish and habitat survey reach locations in relation to proposed stream channel restoration reach on DBLT land.

Results and Discussion

Habitat Survey

A complete habitat survey of Whychus Creek was performed in 1997. ODFW (Oregon Department of Fish and Wildlife) surveyed reaches from the mouth to the main TSID (Three Sisters Irrigation District) diversion dam (ODFW 1997). The Forest Service surveyed from the town of Sisters to the first major falls on Whychus Creek (Dachtler 1997). A comparison between agency survey methods and results were made on the reach between Sisters and the TSID dam. The result from this comparison and a summary of the entire survey was completed by Burke and Dachtler (1998). The ODFW survey took place on The Crooked River National Grasslands and private land. Landowner permission to survey on private land was granted in most areas but the previous owners of the DBLT property did not grant ODFW permission to survey so no data for this reach from the 1997 ODFW survey was available for comparison with this survey.

During this habitat survey a flow of 27.3 cfs was recorded on 8/3/2006 with a Marsh McBirney flow meter just upstream of the Camp Polk Road Bridge. Flow readings at the BOR (Bureau of Reclamation) Gauge in Sisters, Oregon showed approximately 8.5 cfs less and the additional flow mainly comes from springs located upstream of Camp Polk Road. A small thunderstorm increased flows in Whychus Creek the 1st day of the fish population sampling on 8/8/2006 (Table A-1)

Table D-1. Daily average flows from draft data at the BOR gauge in the City of Sisters and estimated flows for Camp Polk based on flow measurement done on 8/3/2006.

Date	Camp Polk flow (cfs)	City of Sisters flow (cfs)
8/2/2006	28.4	19.9
8/3/2006	27.3*	18.8
8/8/2006	37.8	29.3
8/9/2006	27.9	19.4
9/5/2006	21.6	13.1
9/6/2006	21.6	13.1

* Actual flow measurement, all other flows for Camp Polk are estimates.

The channel length within the proposed habitat project was slightly less than three quarters the channel length of the entire DBLT land surveyed. A small amount of side channel habitat was located entirely within the project area and percentages of pool and riffle habitat for the project area and the all the DBLT property were very similar (Table A-2).

Table D-2. Survey length and pool, riffle and side channel percent and area for entire survey and areas within the proposed restoration project.

Reach	Survey Length m	% Pool	% Riffle	% Side Channel	Pool Area m²	Riffle Area m²	Side Channel Area m²
All DBLT Land	2,298	22.9	75.4	1.7	4,107	13,509	302
Project Area	1,670	19.0	79.6	2.3	2,510	10,500	302

Pools were generally infrequent and shallow, with most pools less than one meter deep. Pools were often separated by long stretches of riffle habitat (Table A-3). The two areas that contained pools closer together separated by short riffles were located outside the proposed restoration project at the furthest upstream and downstream ends of the DBLT land. Pools were formed mostly by bedrock outcrops with only a few as a result of LWD (Large Woody Debris).

Table D-3. Pool and riffle habitat variables for entire survey and areas within the proposed restoration project.

Reach	Number of Pools	Avg. Residual Pool Depth m	Avg. Pool Max Depth	Avg. Riffle Depth	Pools Per 100m	Pools ≥ 1m Max. Depth Per 100m
All DBLT Land	23	0.5	0.8	0.2	0.98	0.09
Project Area	14	0.4	0.8	0.2	0.24	0.12

Instream habitat was lacking with very few pieces of LWD over the entire reach and only four pieces located within the proposed project area (Table A-4). Because much of the DBLT lands are a meadow habitat there are only a few areas where direct recruitment of LWD is possible. In areas that do have trees there are primarily smaller second growth ponderosa pines with limited numbers of larger pines and cottonwood along the creek for future recruitment. Whychus Creek is prone to flashy high flow event that could have historically brought more wood into this area. However because of private land, the City of Sisters and several irrigation diversions upstream it is likely that wood has been removed in the past to protect structures such as houses, bridges and dams. Boulders ≥ 1 meter were almost exclusively located in the upper 1/3 of the DRC lands except for some rip rap associated with the old flat car bridge approximately half way through the reach.

Table D-4. LWD and boulder habitat variables for entire survey and areas within the proposed restoration project.

Reach	Pieces Small LWD	Pieces Med. LWD	Pieces Large LWD	Large and Med. LWD per 100m	All LWD per 100m	Num. of Boulders ≥1m	Boulders ≥1m Per 100m
All DBLT Land	4	3	1	0.2	0.4	130	5.7
Project Area	2	2	0	0.1	0.2	91	5.5

Bankfull and floodprone measurements were done on the five measured riffles within the project and three outside of it. Channel geometry such as bankfull and entrenchment ratios was slightly greater within the project area. Percent undercut bank and unstable bank were also slightly higher within the project area than for the entire reach (Table A-5).

Table D-5. Channel morphology and bank condition for entire survey and areas within the proposed restoration project.

Reach	Avg. Bankfull Width m	Avg. Flood Prone Width m	Entrench. Ratio	Width to Depth Ratio	Length Undercut Bank m	% Undercut Bank	Length Unstable Bank m	% Unstable Bank
All DBLT Land	9.7	22.9	2.36	19.9	58	1.3	139	3.0
Project Area	9.8	25.7	2.63	20.0	54	1.6	120	3.6

Modified Wolmann pebble counts sampled substrate within the bankfull channel at three pool tail out locations. Amount of gravel decreased towards the upstream (top) of the DBLT lands while boulders and cobbles increased (Table A-6). Fine sediments decreased toward the bottom of the reach. This is surprising because one would expect fines to increase in the lower end because the gradient is slightly less and overall substrate size decreased. Bedrock was not sampled during the pebble counts but was present in the upstream portions of the DBLT land.

Table D-6. Substrate percentages from three pebble counts at pool tail outs, performed on the lower, middle and upper portions of Whychus Creek on DBLT land.

Channel Unit and Location	% Sand/Silt	% Gravel	% Cobble	% Boulder
2 (bottom)	14.7	69.7	15.6	0.0
23 (middle)	23.7	67.5	8.8	0.0
42 (top)	24.6	40.4	25.4	9.6
Avg.	21.2	59.1	16.6	3.3

Although ODFW did not survey this section in 1997 they did survey private land reaches above and below the DBLT land. ODFW found slightly less pool habitat but slightly more pools per 100 meters than was present on DBLT land, although these pools were generally shallower (Table A-7). ODFW key pieces are similar to the USFS large size class. Less key wood was counted during this survey then what was found by ODFW in 1997 but amounts above and below DBLT land were still low. ODFW also had high amounts of actively eroding banks with 39.3% downstream and 33.9% upstream. However their classification and calculation of percent eroding banks differ from USFS unstable banks.

Table D-7. Selected attributes from ODFW (1997) survey downstream (reach 3) and upstream (reach 5) of DRC land

Reach	All LWD/100m	Key LWD/100m	Percent Pool	Pools/100m	Pools ≥ 1m deep per 100m	Boulders ≥ 1m per 100m
3	2.1	0.3	18.3	0.62	0.29	4.5
5	1.5	0.9	13.6	0.65	0.28	7.6

Fish Population Surveys

Fish surveys revealed that brown trout were the most common trout species in the upper two reaches and long nosed dace were the most common non salmonid species sampled (Figures 2-4). The number of brook trout captured increased from 5 and 10 in reaches 1 and 2, respectively to 40 in reach 3. Groves et al. (1999) also found brook trout more prevalent near the springs upstream of Camp Polk Road during her sampling.

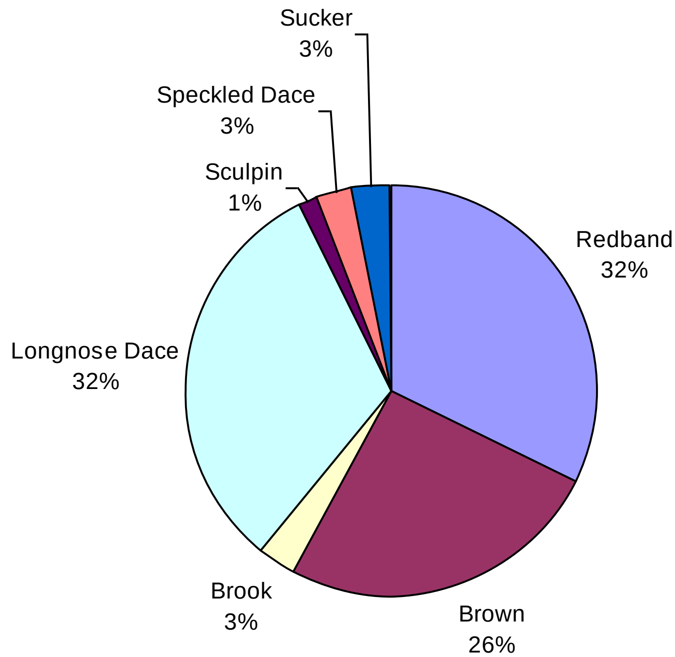


Figure 2. Whychus Creek species composition at (lower) reach 1 on DBLT Camp Polk property.

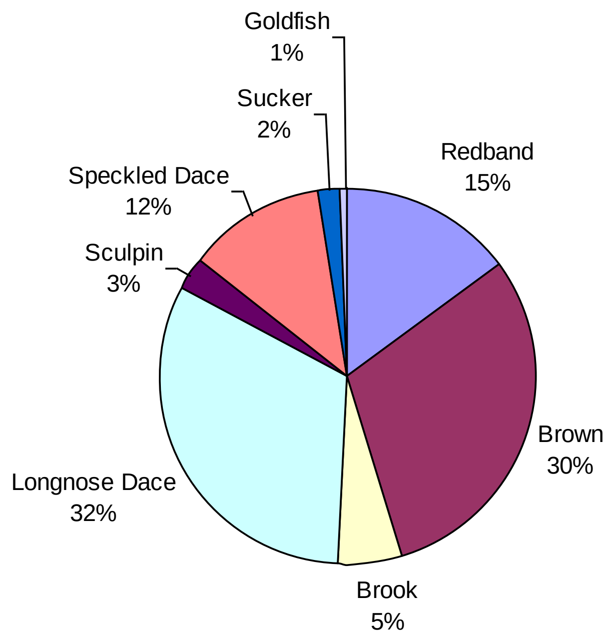


Figure 3. Whychus Creek fish composition at (middle) reach 2 on DBLT Camp Polk property

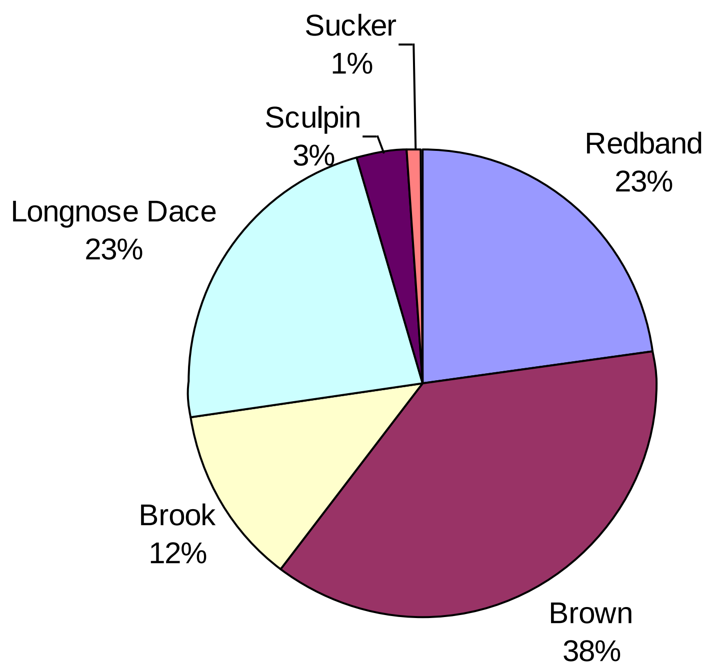


Figure 4. Whychus Creek species composition at (upper) reach 3 on DBLT Camp Polk property.

Redband trout (Figure 5) ranged from 38 mm to 305 mm with a range of fish representing different size classes (Figure 6) A few larger brown trout (Figure 7) were sampled in all three reaches but the overall majority (93 %) of brown trout were between 51 and 100 mm most likely representing 0+ or 1+ age classes (Figure 8). The abundance of small sized brown trout with a few very large individuals and virtually no intermediate age classes indicates this portion of Whychus Creek may be a spawning and rearing area for this species. Juvenile brown trout may migrate out to the Deschutes River or even Lake Billy Chinook after reaching a certain age. Although brown trout have not been the focus of recent studies in the Deschutes River, LBC (Lake Billy Chinook), Whychus Creek or the Metolius River it appears that they may be becoming more numerous in these systems and occupying habitats they were not previously found in. During the ODFW fish survey in 1997 a site was sampled approximately 0.8 km downstream of DBLT property and no brown trout were found. Also brown trout were not present at the town of Sisters during ODFW surveys in 1997 or USFS surveys in 1999 (Riehle and Lovtang 2000). However PGE found brown trout in Sisters during 2003, 2004, and 2005 indicating this species may have colonizing upstream after restoration of flows in this section of Whychus Creek (PGE 2006 unpublished data). In recent years brown trout have been observed in streams such as Canyon Creek (Metolius River tributary) and Street Creek (LBC tributary) where they had not been previously documented (USFS data on file).

Figure 5. Typical redband trout sampled from Whychus Creek on DBLT land.

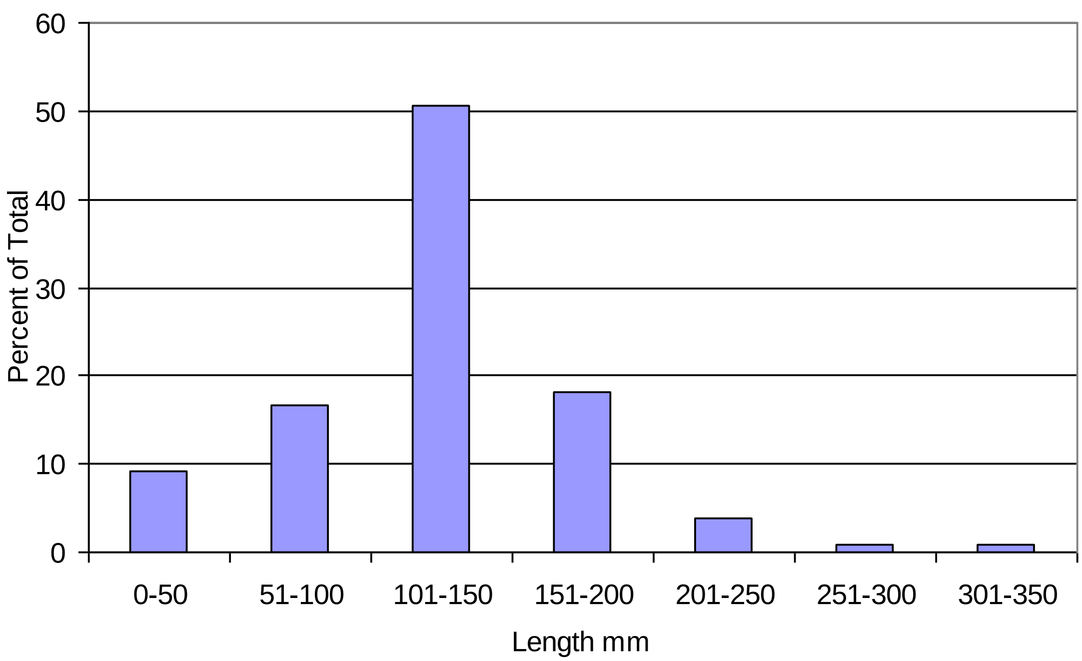


Figure 6. Length frequency of redband trout captured at all sites (N=132).

Figure 7. A large 550 mm brown trout sampled in Whychus Creek on DBLT land.

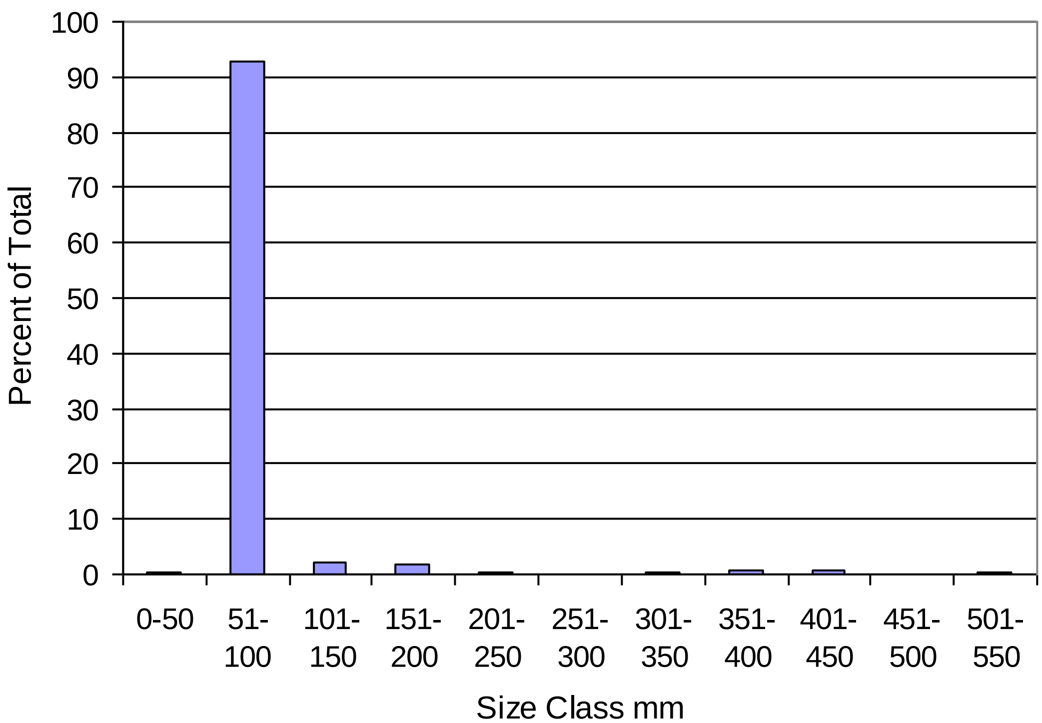


Figure 8. Length frequency of brown trout for all sites (N =238).

The most common non game fish was long nosed dace which made up from 23 % to 32 % of the total species composition depending on the reach. Longnose dace (Figure 9) and juvenile trout are likely important prey species for larger brown trout. A seemingly healthy 110 mm goldfish (Figure 10) was sampled in reach 2.

Figure 9. Typical long nosed dace from Whychus Creek on DBLT land.

Figure 10. Goldfish sampled in Whychus Creek on DBLT land.

Population estimates from the mark recapture survey found similar numbers of trout in reaches 1 and 2 with an almost two fold increase in the upper reach 3 (Table A-8). Although a slight increase in redband trout was seen in reach 3 much of the increase came from brown and brook trout (Tables A-9 and A-10). Reach 3 was the only reach with enough brook trout recaptured to make a population estimate for this species.

Some possible reasons for the upper reach having higher population estimates than the lower reaches could be closer proximity to the springs above Camp Polk and if increased spawning is associated with these springs increased fish densities might be expected. The habitat in reach 3 had more riffle habitat but the main difference was that more cobble and boulder substrate was present. The larger substrate could add more hiding and resting habitat niches for juvenile trout than the gravel dominated streambed in reaches 1 and 2. Unfortunately, the amount of large boulders ≥1m in reach 3 could not be extrapolated because the lower end of the fish sampling reach started in the middle of a long riffle. Amounts of LWD were very low in all fish sampling reaches but reach 1 had three of the eight countable pieces of LWD for the entire survey while reach 2 had no countable pieces of LWD. Amounts of LWD for reach 3 could not be extrapolated for the same reasons as the boulders.

Table D-8. Mark recapture population estimates for all trout species, reaches 1-3.

Reach	N fish marked (1st Pass)	N fish captured (2nd pass)	N fish recaptured (2nd pass)	Population estimate N	Lower and upper 95 % confidence interval N	Density fish/100m²
1	49	46	7	294	153 – 618	12.9
2	59	34	7	263	136 – 553	12.8
3	122	159	41	469	348 – 647	17.1

Table D-9. Redband trout mark recapture population estimates for reaches 1-3.

Reach	N fish marked (1st Pass)	N fish captured (2nd pass)	N fish recaptured (2nd pass)	Population estimate N	Lower and upper 95 % confidence interval N	Density fish/100m²
1	25	24	6	93	46 – 203	4.1
2*	16	11	1	102	31 – 185	5.0
3	32	44	12	114	68 – 206	4.2

* Estimate for this reach biased because of low recapture rate.

Table D-10. Brown trout mark recapture population estimates for reaches 1-3.

Reach	N fish marked	N fish captured	N fish recaptured	Population estimate	Lower and upper 95 %	Density fish/100m²

	(1st Pass)	(2nd pass)	(2nd pass)	N	confidence interval N	
1*	20	21	1	231	70 – 420	10.2
2	40	18	5	130	61 – 300	6.4
3	76	89	21	315	210 – 495	11.5

* Estimate for this reach biased because of low recapture rate.

Table D-11. Brook trout mark recapture population estimates for reach 3.

Reach	N fish marked (1st Pass)	N fish captured (2nd pass)	N fish recaptured (2nd pass)	Population estimate N	Lower and upper 95 % confidence interval N	Density fish/$100m^2$
3	14	26	8	45	24 – 92	1.6

Reach 3 with the most riffle habitat (Table A-12) had the largest population of all trout species and of redband trout. Other snorkel and electrofishing studies of redband trout have found more fish in pool habitat than riffles or glides (Cramer et al. 1999, Thurow 1986). It is possible that electrofishing in deeper pools is less effective in Whychus Creek than other systems because of low conductivity (58-60 µS/cm). Pools sampled in all three reaches generally lacked habitat complexity because of the minimal amounts of LWD or boulders.

Table D-12. General habitat characteristics of fish reaches sampled on DBLT lands.

Fish Reach	% Pool	% Riffle	% Side Channel	Pools N	Avg. Riffle Depth
1	46.6	53.4	0.0	6	0.7
2	38.1	57.5	4.4	6	0.9
3	13.4	86.6	0.0	1	1.0

Past fish surveys on Whychus Creek include some single pass electrofishing and snorkeling at various locations during the ODFW and USFS habitat surveys in 1997. The redband study by Groves et al. (1999) did four pass depletion electrofishing and single pass snorkeling in 1989 and 1999 at three locations from Alder Springs to Camp Polk. The Forest Service did some single pass snorkeling and multiple pass depletion electrofishing in 1999 at 5 sites from Alder Springs up to the TSID diversion (Riehle and Lovtang 2000). PGE has been conducting annual single pass electrofishing and snorkeling at five sites from Alder Springs to the City of Sisters during years 2002 to 2006 (PGE 2006 unpublished data).

Previous surveys found similar species to what this survey found with mountain whitefish and bull trout sampled near the mouth below alder springs. These surveys also found redband trout to be the dominant trout species at all sites and for all years. ODFW (1997) sampled a site approximately 0.8 kilometers downstream of the DBLT property and found redband trout, brook trout, sculpin, and longnose dace. Interestingly, they found no brown trout at that time.

Redband trout densities based on population estimates for this study ranged from 4-5 fish per $100m^2$ Brown trout densities ranged from 6-12 fish per $100m^2$ and brook trout densities in reach 3 were around 2 fish per $100m^2$. Redband densities were similar to what other studies found for Whychus Creek except Groves (1998) found less fish at the 6360 road ford (Table A-13).

Table D-13. Comparison of 2006 redband trout densities with other Whychus Creek studies for various locations and years.

Comparable Study Author and Year Sampled	Density of Comparison Study	Location of Comparison Study	Method Used
Riehle and Lovtang 1999	5-7 fish/$100m^2$	Gauge above TSID, Camp Polk Rd and 6360 Rd ford	Electrofish, Multiple Pass, Sum of all Fish Caught
Groves et al. 1998	6 fish/$100m^2$	Alder Springs	Electrofish, 4 Pass Depletion Est.
Groves et al. 1998	2 fish/$100m^2$	6360 Road Crossing	Electrofish, 4 Pass Depletion Est.

Densities of redband trout in most streams on the ONF (Ochoco National Forest) were higher than what were found in Whychus Creek (Table A-14). Many of these streams do not have other introduced trout species to compete with the native redband trout. Tumalo Creek had similar densities to what was found on DBLT lands (Table A-14) and is probably a better comparison to Whychus Creek because it is similar in size and flows out of the Cascades which keeps temperatures colder and flows higher during the summer. Tumalo Creek also has introduced brook trout which made up 68-70 % of the fish population in two sites sampled below Tumalo Falls (Dachtler 2004).

Table D-14. Comparison of Whychus Creek 2006 redband trout densities with three redband trout population studies on the Deschutes and Ochoco National Forest for various years that used 2-4 pass electrofishing depletion methods. All streams except Tumalo Creek are on the Ochoco National Forest.

Comparable Study Author and Year	Year of Estimate	Density of Comparison Study fish/$100m^2$	Location of Comparison Study
Groves et al. 1999	1997	24	Mckay Creek
Groves et al. 1999	1998, 1999	11	Mckay Creek
Groves et al.	1997	39	Little Mckay Creek

1999			
Groves et al. 1999	1998, 1999	17	Little Mckay Creek
Stuart et al. 2000	1992	26	Canyon Creek
Stuart et al. 2000	1992	27	Ochoco Cr
Stuart et al. 2000	1994	1	Gray Cr
Stuart et al. 2000	1991	8	Lookout Creek
Stuart et al. 2000	1991	8	Howard Creek
Stuart et al. 2000	1992	14	Brush Creek
Stuart et al. 2000	1992	4	Porter Creek
Stuart et al. 2000	1992	10	Dipping Vat Creek
Stuart et al. 2000	1992	2	Roba Creek
Dachtler 2004	2004	5	Tumalo Creek

<u>Redband Redd Counts</u>

Redd counts were conducted three times on DBLT land from late March to late April. Only four redband redds were observed on DBLT lands all in the last week of April. After the last count in April the water became too turbid to see redds and counts were not attempted but it is possible more spawning took place after this time. One pair of small redband trout were observed spawning at the upper end of DBLT lands and these fish were estimated to be around 250 mm in length.

Conclusions and Recommendations

Current fish habitat conditions on DBLT lands in the Camp Polk area are poor with very little instream LWD or other sources of instream or overhead cover. Any additional instream habitat complexity and cover will most likely help fish populations of all species. Although a diverse mix of fish species are present, introduced brown trout may be becoming more numerous and competing for food and space with redband trout. Larger brown trout most likely prey upon redband trout and other fish species in the stream. The population of brown and redband trout should continue to be monitored to determine if brown trout densities are increasing from what they are now and if redband trout densities are decreasing. ODFW (2005) set benchmarks for redband trout densities of the great basin with a low population density of ≤ 0.059 fish per m^2 (≤ 5.9 fish per $100m^2$) and moderate population density of 0.06 - 0.19 fish per m^2 (6-19 fish per $100m^2$) Densities found in this survey and other studies on Whychus Creek fall in the low density category or slightly above it.

Upstream distribution of brown trout should be checked to see if brown trout are now present upstream of Sisters. Brown trout were not found in the Sisters area during 1997 (ODFW) or by survey conducted in 1999 (Riehle and Lovtang 2000). They were first documented in Sisters by PGE in 2003. With increased flows in the stream and essentially no barriers until the TSID diversion dam approximately five kilometers upstream of Sisters there is the potential for brown trout to become established in this section of stream.

Studies have observed that redband trout prefer pools with cover in the form LWD or large substrate (Thurow 1987, Cramer 1999). Thurow (1987) also found pools in side channels to contain the highest densities of redband trout and that trout densities increased as instream cover increased. The restoration of DBLT land at Camp Polk should try to improve on these habitat features to ensure redband and steelhead have suitable habitats they can thrive in. Currently amounts of LWD and side channel habitat on DBLT land are very low. Another key for over wintering of juvenile redband and steelhead would be interstitial spaces between larger substrate especially during periods of cold water temperatures (Hillman et al. 1987). During the winter Whychus Creek often experiences anchor ice and water temperatures near freezing. Off channel areas with slower velocities and gravel sized substrate or larger so fish could avoid high flows would also be beneficial. Larger substrate is now primarily found in the upper 1/3 of the DBLT land.

Another concern for stocking of steelhead fry into Whychus Creek will be the potential effects of this on existing redband trout populations. Although the two life history forms coexisted before steelhead were extirpated from the system studies raise this as a major concern when reintroducing steelhead (Bjorn 1978, Chapman et al. 1990). These are the same species with different life histories so both steelhead and redband would essentially compete for the same food and habitat resources. The lower Deschutes River is one of the few areas that large redband trout and steelhead populations coexist. However, a study by Zimmerman (2002) using otolith microchemisty found almost all juvenile fish sampled in the mainstem Deschutes River were progeny of resident redband trout while fish examined in two tributaries below anadromous barriers were almost all progeny of steelhead. This indicates these two life history forms may be primarily using two different rearing habitats. In most other situations such as the Hood River when steelhead are present resident trout populations are insignificant and above anadromous barriers populations of resident trout are present in numbers that reflect available habitat and resources (Pribyl 1995 in Larson and Bawdon 1995).

To determine changes in fish habitat and populations after the restoration project these surveys should be repeated five years after the project is completed. The habitat portion could be surveyed 1-2 years after the project is completed but waiting at least up to five years would allow the channel to adjust and allow fish populations to colonize and respond to the new habitat.

To increase mark recapture efficiencies during electrofishing it is recommended that electrofishing be done at the lowest summer flows possible similar to the September 5th and 6th sampling of reach 3. The use of a raft mounted electrofisher could possibly improve the catch rate by increasing the effective area of the electrofisher. Another method that should also be tried would be using a seine just downstream of the electrofishers to capture fish that are trying to escape. This would require two more persons while sampling. This method has been reported to work well in other areas (A. Reischauer, 2006 personal communication).

Literature Cited

Bjorn, T.C. 1978. Survival, production, and yield of trout and Chinook salmon in the Lemhi River, Idaho. Idaho Cooperative Fishery Research Unit. Bulletin number 27.

Chapman, D., Platts, W. and M. Hill. 1990. Evaluation of introduction of anadromous salmonids upstream from Condit Dam in the White Salmon River, Washington.

Cramer, S.P., Witty, K.L., Romey B.T. and K.P. O'Neal. 1999. Distribution, life history and abundance of redband trout in the great basin. Submitted to Lake, Harney and Grant Counties. S. P. Cramer and Associates, Inc. Gresham, OR.

Dachtler, N. 1997. Squaw Creek level II stream habitat inventory. USDA Forest Service. Deschutes National Forest. Sisters Ranger District. Sisters, OR

Dachtler N. and J. Burke. 1998. Squaw Creek habitat survey summary. USDA Forest Service. Deschutes National Forest and Oregon Department of Fish and Wildlife. Bend, OR.

Dachtler, N. 2004 Tumalo Creek pre restoration project fish population and fish condition survey. Deschutes National Forest. Bend Fort Rock Ranger District. Bend, OR

Groves, K., B. Shields and A. Gonyaw. 1999. Lake Billy Chinook rainbow (redband) trout life history study – final report. Pelton Round Butte Hydroelectric Project FERC No. 2030. Portland General Electric. Madras, OR.

Hillman, T.W., J.S. Griffith, and W.S. Platts. 1987. Summer and winter habitat selection by juvenile chinook salmon in a highly sedimented Idaho stream. Trans. Amer. Fish. Soc. 116:185-195.

Larson, R.J. and D.B. Bawdon. 1995. Potential interactions between resident trout and anadromous salmonids. USDA Forest Service. Pacific Northwest Region. Columbia River Gorge National Scenic Area. Hood River, OR

Riehle, M.D. and J. Lovtang. 2000. Squaw Creek Education and Restoration Project 1998-1999. Deschutes National Forest. Sisters, OR.

Stuart, A.M., D. Grover, T.K. Nelson, S.L. Thiesfeld. 2002 Draft report: Redband Trout investigations in the Crooked River Basin. Oregon Department of Fish and Wildlife. High Dessert Region, Prineville, Oregon.

Thurow, R.F. 1987. Effects of stream alterations on rainbow trout in the Big Wood River, Idaho. Idaho Department of Fish and Game.

Nehlsen, W. 1995. Historical Salmon and Steelhead Runs of the Upper Deschutes River and Their Environments. Portland General Electric. Portland, OR.

ODFW. 2005. Oregon native fish status report. Volume II, Assessment methods and population results. Oregon Department of Fish and Wildlife. Salem, OR.

ODFW. 1997. Squaw Creek ODFW aquatic inventory and fish survey, stream report. Oregon Department of Fish and Wildlife. High Desert Region. Bend, OR.

USFS. 2006. Region 6 Level II Steam Inventory Protocol. USDA Forest Service. Pacific Northwest Region. Portland, OR.

Zimmerman, C.E. and G. H. Reeves. 2002. Identification of steelhead and resident rainbow trout progeny in the Deschutes River, Oregon, revealed with otolith microchemistry. Trans. Amer. Fish. Soc. 131:986-993.

Appendix: E

Title: USFS Region 6 Restoration Review

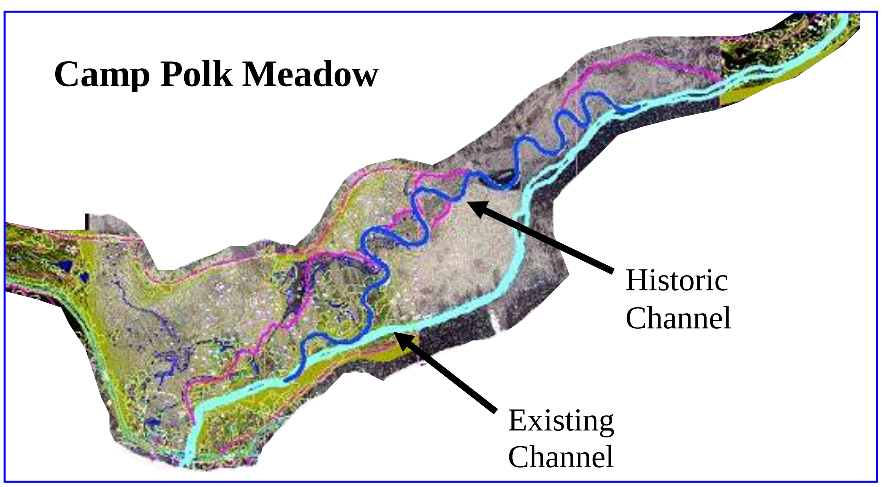
Prepared by: Paul Boehne
Forest Fisheries Biologist
Wallowa-Whitman National Forest

Johan Hogervorst
Central Coast District Hydrologist
Siuslaw National Forest

Date: August 1, 2006

We would first like to thank you for the opportunity to return to the Deschutes National Forest to see Camp Polk Meadow, a potential project with the Deschutes Basin Land Trust. We were hosted by Paul Powers and Cari McCown~~,~~ and were also able to meet Cindy Quezada visiting from the Paulina District. Although this project is at the conceptual stage, we commend Paul and Cari for the work they have done to gather data and known information in advance of this large-scale effort.

We visited the site as members of the Regional Restoration Assistance Team (RATs) that has been established to assist in all aspects of stream restoration (planning, design, implementation, and monitoring). Our intent is not to take the place of skilled aquatic resources on the forest (service staff?), but to assist and advise the local staff during the initial conceptual stage to determine the feasibility of a number of options at Camp Polk Meadow. The short-term goal as we understand it is to complete a feasibility study for the site by mid-summer (year?), and then to begin planning and design shortly thereafter. What follows is a brief discussion of the conversations that took place in the field on June 13th~~,~~ and our recommendations for the best course of action to restore Camp Polk Meadow.



Background

The project area is located in the Deschutes National Forest, 4.5 miles northwest of Sisters, Oregon in the Central Cascades. Whychus Creek originates from springs on the east side of the Cascades in the Three Sisters Wilderness and carries peak flows of the year in early summer during snowmelt. The historic peak flow is approximately 2,000 cubic feet per second while summer low flow has been recorded as low as 12 cubic feet per second. Between April 1 and September 30, water withdrawals for irrigation remove an average of 150 cubic feet per second from this stream. Bi-modal (bimodal is not hyphenated in main document) flow patterns are greatly exaggerated by the water diversions

upstream of Camp Polk Meadow as evidenced by bi-modal bankful indicators seen in the photo below.

Since homesteading began in the 1870s near the town of Sisters, long-term grazing, timber management and water withdrawal have and continue to affect Whychus Creek in the watershed above Camp Polk. More recently, there ~~are~~ have been additional heavy impacts from ATV use and dispersed campsites in the Sisters area as well as naturally occurring ice dams. In Camp Polk Meadow itself, ditching and diking before 1943 have caused loss of water table with subsequent change in vegetation from what was likely a cottonwood/willow gallery wetland complex to a drier sagebrush, ponderosa pine and grass pasture. Also lost from the site are the historic high quality spawning and rearing habitat for summer steelhead.

It is the objective of the Deschutes Basin Land Trust to rehabilitate both native vegetation and aquatic species in Camp Polk Meadow. Future alterations to the Pelton Round Butte Dam will restore access for summer steelhead and spring chinook to the Whychus, and the Camp Polk Meadow Restoration project has potential to provide habitat in the largest low gradient valley in the Whychus Creek system. Partners working with the Deschutes Basin Land Trust include the Upper Deschutes Watershed Council and the Deschutes National Forest. The Forest Service is being contracted to provide the technical expertise for design and implementation on the project.

Alternatives being considered

Two alternatives are being considered for active restoration of Camp Polk Meadow. The first would be to work with the existing channel to either partially or fully recreate meandering conditions and floodplain connection needed for recovery of habitat. The second option would be to prepare the existing remnant channel to be able to accept flow and to eventually divert permanent flow into this channel. We would favor alternative #2, reinitiating the old channel. What follows is a discussion of both alternatives including lessons learned on other projects in the region:

Alternative #1 – Work with the existing ditch

Currently, the straightened, incised channel on the south side of the meadow has high velocity and associated high near-bank shear stresses during peak flows of the year. There are some limited vegetated floodplains that provide some energy dissipation at this time, but only a fraction of the historic floodplains and wetlands that once existed.

The objective of working on this channel would be to reestablish an historic meander pattern and floodplain connection, both of which could provide needed dissipation of energy and habitat conditions favorable for steelhead spawning and rearing. With a down-cut channel such as this, you would be required to bring up the bed level three to five feet in places, just to assure that water could connect with the existing valley floor and the historic water table could be restored. The only other option would be to create a floodplain at a lower elevation and the valley floor would become a terrace, but discussions in the field seemed to indicate that water table recovery and associated vegetation changes were very desirable for this project.

Another problem is that you would be trying to recreate a natural meander pattern in a location where it did not historically exist. Although meander construction would provide some of the fill material needed to raise the bed elevation, significant amounts of substrate would also need to be brought in as well, given that banks of the existing channel will not likely contain the substrate needed.

Dealing with flow diversion during the implementation can also be complex, though not impossible to deal with in this alternative. Also consider that any temporary diversion of flow done at low flow would have to be turned directly into the new construction without any rest time for vegetative establishment. This may be an important factor here if there are Chinook spawning gravels below this site needing protection from temporary sediment influx.

Alternative #2 – Reinitiate the Historic Channel

In general, it is the opinion of these reviewers that if you have a meander pattern that is at least partially intact, this template is closest to the natural condition and should therefore be priority. Putting the stream back into the middle of the valley also provides the best opportunity to re-colonize historic cobble/gravel beds on site as opposed to bringing in substrate and trying to recreate channel beds. Sub-pavement samples taken by Paul and Cari in the existing remnant channel indicate that the proper sized substrates do exist in much of the channel. Augmentation may be needed and certain meanders will require reconstruction, but you would not be starting from scratch. It will likely be necessary to mine gravels from the existing ditch and sort them to acquire the needed substrate where augmentation is needed.

The advantage of having the entire valley bottom as your floodplain should not be minimized in selection of alternative #2. In terms of meadow restoration, it is our view that the entire valley bottom should be considered in order for this restoration to be considered complete. As part of alternative #2, the wetland seed bank is likely intact in the valley and will be reinitiated once the water table is brought up again. Paul also discussed with us in the field the possibility of using existing wetlands on site as sources of willow and other wetland vegetation for transplanting to the new channel. Some of this transplanting may not be feasible until water table changes have occurred after diversion into the historic channel.

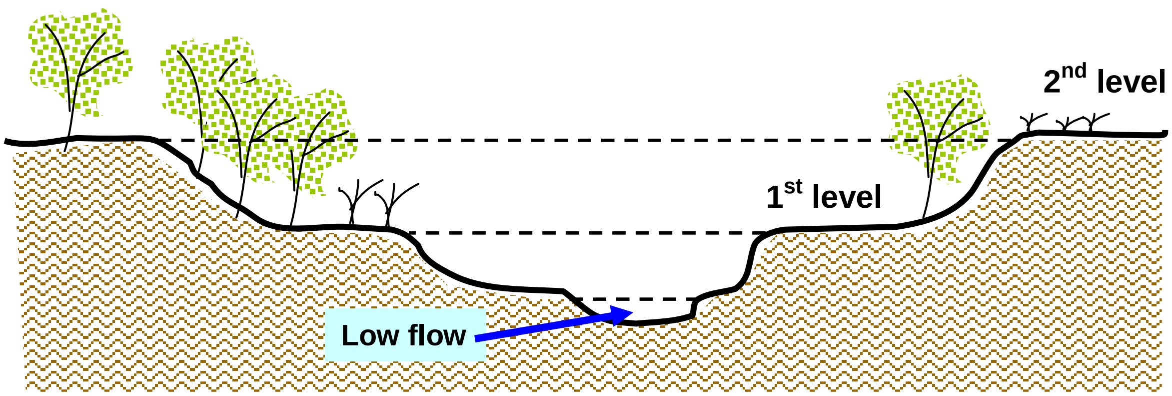
Existing wetland on site with native wetland species

Design Considerations for Alternative #2

In the field we talked about several design considerations related to the re-initiation of the historic channel. As mentioned above, the importance of proper substrate size is key to reestablishing spawning substrates in particular, and the Deschutes team has this analysis in hand. We also talked about the need to nail down bankful width and depth, and the design team is currently measuring cross sections in both the historic channel and existing ditch.

Width depth ratio is very important. In the Enchanted Valley stream restoration project, a stream reconstruction on the Siuslaw National Forest, bankful considerations were based on flow modeling and bankful measurement in a highly degraded ditch with heavy reed canary grass. As a result of uncertain field measurements, estimates of channel cross sectional area were inflated, and floodplain connection after flow initiation did not occur as frequently as predicted. Although the channel in Enchanted Valley is currently correcting itself, reducing cross sectional area through deposition, recovery of water table and subsequent establishment of vegetation have been greatly slowed. With so much floodplain in Camp Polk Meadow available to help dissipate energy, assume undersizing the cross sectional area is preferable to oversizing if there is any doubt.

Additionally, the current bi-modal distribution of flow should be considered in design. You may want to consider designing a low-flow channel, a first level floodplain and a second level floodplain (valley floor). Opinions differ on whether a low-flow channel needs to be built or will form on its own. In any case, you need to know where water would be at both 12 cfs and 2,000 cfs, your extremes of record. You could create a sample riffle cross section similar to the drawing below, give it a slope and sampled D50, and then play with it in a program like WinXSPro to see what shear stresses would be incurred under various flows. This would



Conceptual drawing of a riffle cross section with multiple floodplain levels.

also allow you to play with different slopes to determine design riffle gradient. Pursue constructing or reconnecting old side channels which would serve as additional release valves during peak flow.

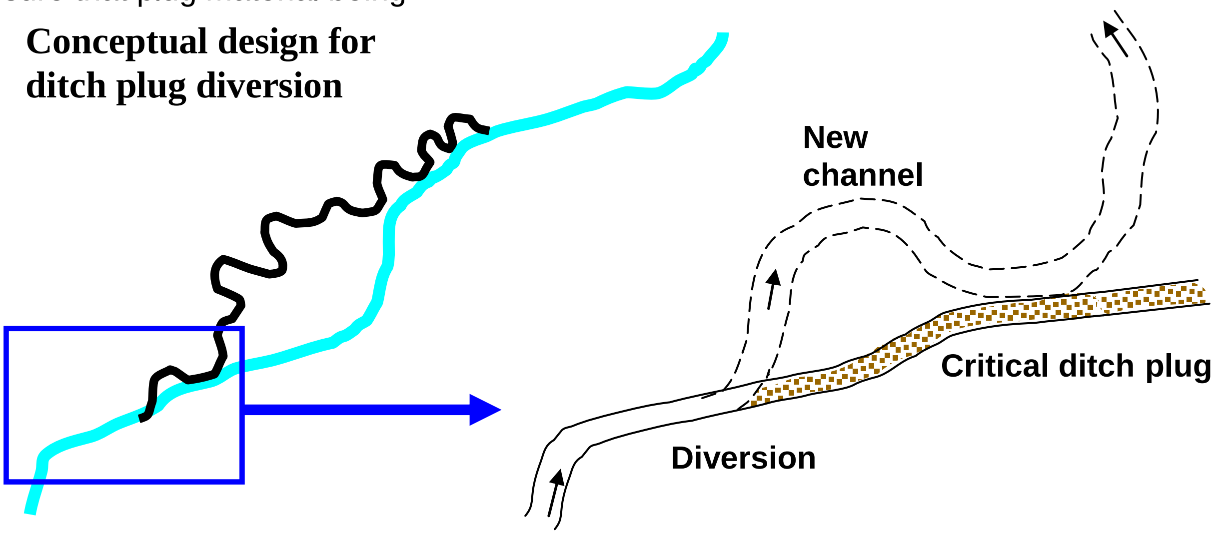
Also in the field, we talked about options for what to do with the old ditch and how to initiate the flow in the new/historic channel. Similar to the Wind River Old Growth Channel on the Gifford Pinchot National Forest, Paul expressed a desire to install several jams in succession in the current ditch, and let them fill behind over time to eventually ease the channel into the newly reconstructed channel. The idea would be to build the bottom jams at the highest elevation, allowing material to fill from the bottom up. These reviewers would discourage this approach for the following reasons:

1. Given the incision of the current ditch, shear stresses are far too high to

fight with wood jams. The filling would take some time to occur and during this time, flanking of placed wood jams would be a lingering threat. You would also likely get ditch widening as filling would begin to take hold, increasing the potential for avulsion.

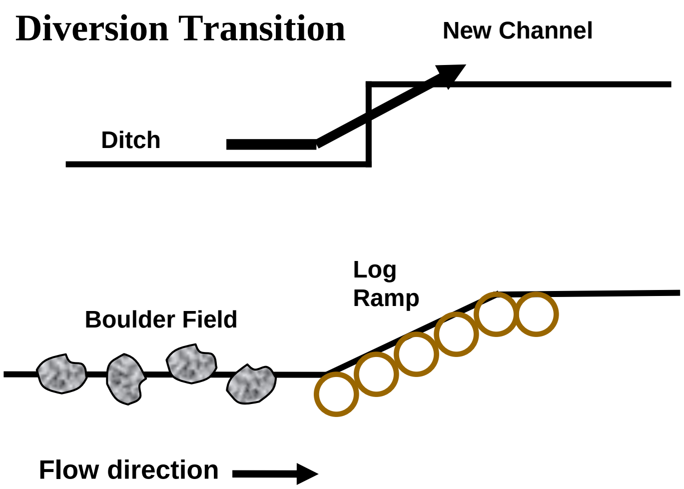
2. Filling the existing ditch (or plugging it at strategic locations) would greatly reduce the threat of losing your restoration investment. Instead of defending several structures throughout the entire length of ditch, put your efforts into one well-engineered diversion plug.
3. At some point in the diversion process, there would be split flow between the old and new channels. Your bi-modal distribution of flow is already complicated enough without having to design a channel that will ease into various flow patterns over time. Also, flow changes over time increase the likelihood of fish stranding and death, which does not bode well for public and partner support, not to mention consulting agency support.
4. The likelihood of the entire ditch not filling up is very high under the “let fill” model. Unless filled later, low spots in the abandoned ditch would be long-term head cut potential if water diverts to these low spots and starts cutting back to the historic channel.

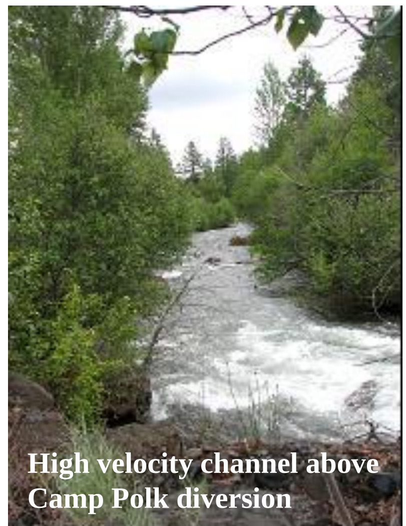
Diversion Structure Considerations for Alternative #2
There are many things to consider to assure that water does not flow back into the abandoned ditch once water has been diverted to the historic channel. Make sure that plug material being



used is completely free of organic material to avoid piping potential. The plug should be of sufficient elevation to guarantee that water will never flow over top of this plug. In the case of this particular project, this first plug should probably extend well below the diversion site and past the next meander since there is a ditch proximity problem with the second meander as well. During implementation, layer place material with a dozer in a maximum of one-foot lifts to assure proper compaction.

Given that there is a 4-5-foot difference in elevation between the current channel bed and the historic channel to be reinitiated, water will pond at this transition before flowing into the new channel. From experience on the Enchanted Valley stream restoration project, the Siuslaw National Forest found that if this transition is not hardened, severe erosion can occur downstream as the force of flow comes down a long straight incised ditch and hits the transition. As shown in the diagram below, building a log ramp up into the new channel and placing a boulder field just above the transition can help to dissipate this high energy. Make sure that logs are well keyed into the bank on the outside of this turn into the new channel. Eventually, this transition will fill with sediment and both the boulders and log ramp will disappear underneath the deposition.




High velocity channel above Camp Polk diversion

With regard to wood placement in channel, there would likely have been some large wood in this natural meadow (cottonwood, alder, aspen) but not a great deal of wood in a cottonwood/willow complex. We recommend some small complexes in pools for cover and pool maintenance, but not large, bank stabilizing structure complexes like in Tumalo Creek. Also, consider spreading wood on valley floor floodplains for future wood recruitment and for microclimate for planted riparian vegetation. We would not expect wood to be a driving morphological factor, particularly out in the middle of the meadow away from hill slope influence. Beaver dams would have been the most influential factor in habitat maintenance, causing multiple channels, high water table and natural rearing ponds.

Irrigation pond in lower valley

Dike below pond

Plugging the old ditch should be done strategically to minimize head cut potential to the greatest extent possible. Pay attention to low spots in the valley where overland flow could run to in a big storm and begin a head cut. Fill or block these areas if needed. The biggest challenge for the project will be to obtain the amount of fill needed to adequately plug the ditch and the pond at the bottom of the valley. The pond volume is particularly extensive, and the large dike built with the fill material originally excavated from the pond can be pushed back in to help fill it. Make sure to plan for aquatic species rescue as part of this filling. This may include pre-shocking and someone to watch and capture during fill placement. Also, you can stockpile wetland vegetation sod from the pond fringes and spread it on top of the filled area. This works well to replace the seed source after construction.

It may be that you as designers choose to leave the pond on site and work the channel through it or around it. Once again, consider seriously the potential for a head cut to develop from the pond up valley and armor transitions with natural materials if the pond is retained. Also consider that the existing dike is a hydrologic impediment to down valley surface and possibly subsurface flow. If the dike is removed and put back into the pond area, make sure to deeply de-compact the remaining valley floor beneath the dike to help restore hydrologic pathways.

It will be most expedient to find one or more large toe slopes or alluvial fans that can serve as borrow areas for large amounts of fill. Borrow areas will leave long-term scars but are a necessary sacrifice for the project to succeed. Consider what can be seen from adjacent hilltop residences in choosing these sites and designate routes for trucks to take so that these routes can be de-compacted upon project completion. For at least the diversion plug, you will need to stockpile fill material. Make sure that you have adequate erosion control measures around these stockpiles to prevent surface erosion from them during storage. Your permits will likely require these measures if over winter stockpiling is planned and they would include coverage seeding and silt fence around the base of each pile.

In terms of plug locations in the ditch, consider that what will be left between plugs will be ponds that will fluctuate with the water table. Consulting agencies will be very concerned about stranding fish, so depending on the input of springs for each of these ponds, design overflow channels that connect back into the valley and historic channel if needed.

There was talk in the field about the possibility of a reference condition at the Rim Rock Ranch, nearby. If at all possible, we would encourage you to look at this site and characterize both channel and vegetative conditions for use in your design. It could make your project design even stronger.

Finally, based on experience on other large-scale projects in the region, consider spending some budget on a vegetation plan designed specifically for this site. The diagram below is a portion of the planting plan for the Karnowsky Creek stream restoration project. A graduate student was contracted to put this plan together for 80 acres of this project. This plan has been implemented over the last four years with two grants from the National Forest Foundation, totaling $100,000.
The results have exceeded expectations for vegetative restoration in this

meadow, showing that
specific expertise in vegetative reestablishment can greatly benefit a meadow restoration project.

In conclusion, we heartily commend the Deschutes National Forest for being the technical arm of the partnership on this project. Given the personnel involved, we feel there is a high likelihood of success in a location with great potential for restoration. This is no surprise, given the Deschutes National Forest's reputation and accomplishments. Feel free to contact us if there are any questions concerning our report.

Appendix:	**F**
Title:	**Channel Design Parameters**
Prepared by:	**Paul Powers** **Fish Biologist** **Crescent Ranger District** **Cari McCown** **Hydrologist** **Sisters Ranger District**
Date:	**January 22, 2007**

Table F-1. Values for various channel parameters used for the Camp Polk Restoration Project from the existing channel, proposed meadow channel, and reference channels.

Variables	Existing	Proposed		Reference w/in existing or Relic Channel		MF Lake Ck		Williams Equations	
	Mean	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**
Stream Type	F1-4, B3, C4	C4/E4	C4-E4	C4	C4-E4	C_4 (E_4)	----------	-------	--------
Bankfull width (W_{bkf})	33	30	<28-35	31	28-35	20.05	19.1-21	41**	25 - 70
Bankfull mean depth (d_{bkf})	1.6	1.9	1.3 -3	1.6	1.3 -3	1.15	1-1.3	2	1.8 - 2.2
Width/Depth ratio (W_{dkf}/d_{bkf})	20	15.8	15-30	19.375	12 to 25	18	15.1-21	20	----------
Bankfull X-sect. Area (A_{bkf}) (ft^2)	60	60	42-64	60	42-64	22.5	21-24.1	112**	50 - 300
Bankfull discharge, cfs (Q_{bkf})	288	288	----------	288	----------	90.8	----------	-------	--------
Bankfull Max. depth (d_{max}) (ft)	2.2	2.4	1.9-2.8	2.4	2.1-2.9	1.7	1.6-1.8	-------	--------
Width of flood prone area (W_{fpa}) (ft)	50	1000	700-1300	-------	--------	250	200-400	-------	--------
Entrenchment ratio (W_{fpa}/W_{bkf})	1.5	33	23-43	-------	--------	12.5	8.7-19	-------	--------
Valley Width (ft)	1000	1000	700-1300	1000	700-1300		200-440	-------	--------
Meander length (L_m)	----------	449	275-545	449*	275 - 545	195	140-253	371	140 - 828
Meander length / Bankfull width	----------	15.5	7.7-19.5	-------	--------	9.7	7 - 12.6	9.3	3.5 - 21
Radius of curvature (R_c) (ft)	----------	96	52-146	96*	52 - 146	33.9	20-48	73	23 - 162
Radius of curvature/Bankfull Width	----------	3.2	2.13-4.86	-------	--------	1.7	1 - 102.1	1.8	0.6 - 4
Belt width (W_{blt}) (ft)	----------	223	102-377	224*	102 - 377	112	53-173	191	97 - 456
Belt width/Bankfull Width	----------	7.43	3.4-12.5	-------	--------	5.6	2.6 - 8.6	4.8	2.5 - 11
Sinuosity (str. Length/valley dist.(k))	1.1	1.6	-------	-------	--------	1.36	----------	-------	--------
Valley slope (ft/ft)	0.01	0.01	'-------	-------	--------	0.008	----------	-------	--------
Average slope ($S_{avg}=S_{valley/k}$) (ft/ft)	0.009	0.006	'-------	-------	--------	0.0055	----------	-------	--------
Max pool depth (d_{pool}) (ft)	3	5	4 to 7	4.8	3.6 - 6	3.7	2.9-4.2	-------	--------
Pool width (W_{pool}) (ft)	30	28	25-33	28	25-33	19.5	18-21	-------	--------
Pool head width (ft)	----------	<28	26-30	28	26-28			-------	--------

Variables	Existing	Proposed		Reference w/in existing or Relic Channel		MF Lake Ck		Williams Equations	
	Mean	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Pool tail width (ft)	----------	>30	32-35	35	32-35			-------	--------
Pool Length (ft)	----------	161	100-244	----------	100-200	26.2	16.5-31.1	-------	--------
Pool Length/Riffle Length	----------	1.2	1 -2	----------	----------	0.92	1.2 - 0.75	-------	--------
Pool to pool spacing (p-p)	----------	130	48-225	130*	48-225	79.7	50.9-123.3	-------	--------
Pool to pool spacing/Riffle Width	----------	4.3	1.6-7.5	---------	---------	3.98	2.7 - 5.9	-------	--------
Riffle slope (S_{riff}) (ft/ft)	0.0095	0.014	.007-.03	---------	---------	0.028	0.01-0.059	-------	--------
Riffle slope/ave. water surface slope	1.05	2.3	1.16-5	---------	---------	5.1	1.8 - 10.7	-------	--------
Riffle Length (ft)	----------	130	49-225	---------	---------	28.4	13.7-41.0	-------	--------
Run slope (ft/ft)	0.084	0.084	0.02-0.4	---------	---------	0.078	0.032-0.125	-------	--------
Run slope/ave. water surface slope	9.3	14	3.3-66	---------	---------	14.2	5.8 - 22.7	-------	--------
Run Length (ft)	10	10	3 - 18	---------	---------	13.5	7-24.5	-------	--------
Glide Slope (ft/ft)	-0.04	-0.05	-0.0014 - -0.12	---------	---------	-0.0355	-0.0014--0.0828	-------	--------
Glide Slope/ave. water surface slope	0.044	-8.3	-0.23 - -20	---------	---------	-6.5	-0.25 - -15.1	-------	--------
Glide Length (ft)	20	29	6 - 52	---------	---------	28	18.8-51.8	-------	--------
D_{16} (mm) (pebble count)	-------	14***	-------	14	-------	20.4	-------	-------	--------
D_{35} (mm)	-------	28***	-------	28	-------	38.05	-------	-------	--------
D_{50} (mm)	-------	40***	-------	40	-------	51.8	-------	-------	--------
D_{84} (mm)	-------	83***	-------	83	-------	88	-------	-------	--------
D_{95} (mm)	-------	133***	-------	133	-------	130	-------	-------	--------

* taken from the 1994 aerial photo of the historic meadow channel pattern
** Williams equations are for a “C” stream type and values are slightly wider and shallower than the values we would expect for the proposed Camp Polk meadow channel (C/E)
*** estimated to be the same as substrate diameters in the reference riffles in the existing channel

Table F-2. Channel dimension design parameters for the Camp Polk Restoration Project.

Habitat Type	Width (ft)	Depth (ft)	Area (ft2)	W/D	Slope (%)	Length (ft)
Riffle	27-36	1.5-1.7	45-52	17-20	0.68-3	49 - 225
Pool Head	28	1.6	45	17	0.02-0.4	**
Max Pool Depth	26	1.8	47	15	0	100 - 244
Pool Tail Crest	35	1.15	42	30	-0.0014 to -0.12	**

** these values are included in the pool length

Appendix:	**G**
Title:	**Channel Design Schematics**
Prepared by:	**Paul Powers** **Fish Biologist** **Crescent Ranger District** **Cari McCown** **Hydrologist** **Sisters Ranger District**
Date:	**January 22, 2007**

Figure G-1. Proposed meadow channel for Camp Polk Rehabilitation Project (see attached 22” x 34” map)

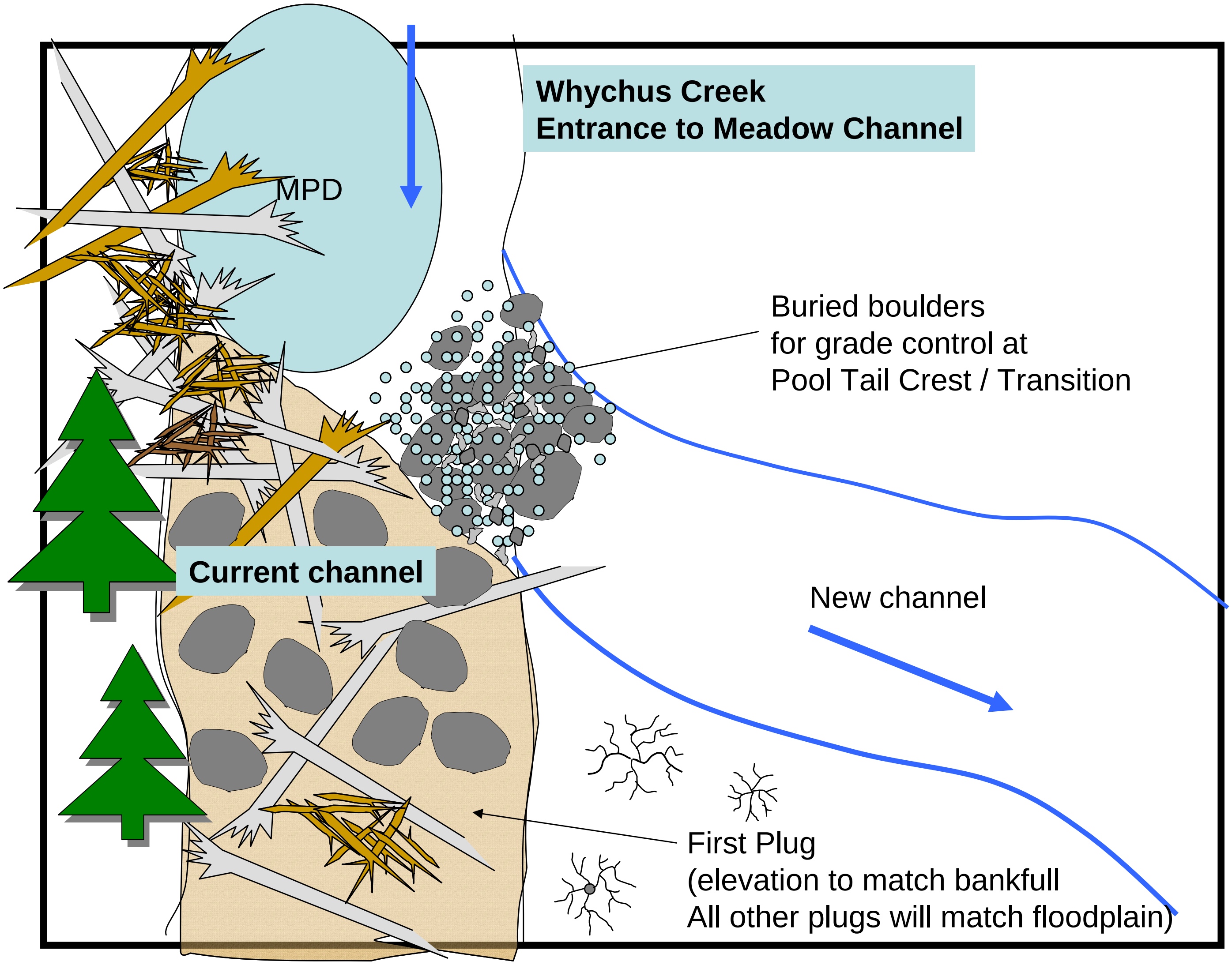


Figure G-2. Schematic of proposed entrance from the existing channel to the meadow channel at Camp Polk meadows.

Figure G-3. View of current channel looking upstream from the proposed entrance to the meadow channel. Note the side cast pile of gravel on the river left bank.

Figure G-4. View of relic meander looking down valley from the proposed entrance to the meadow channel.

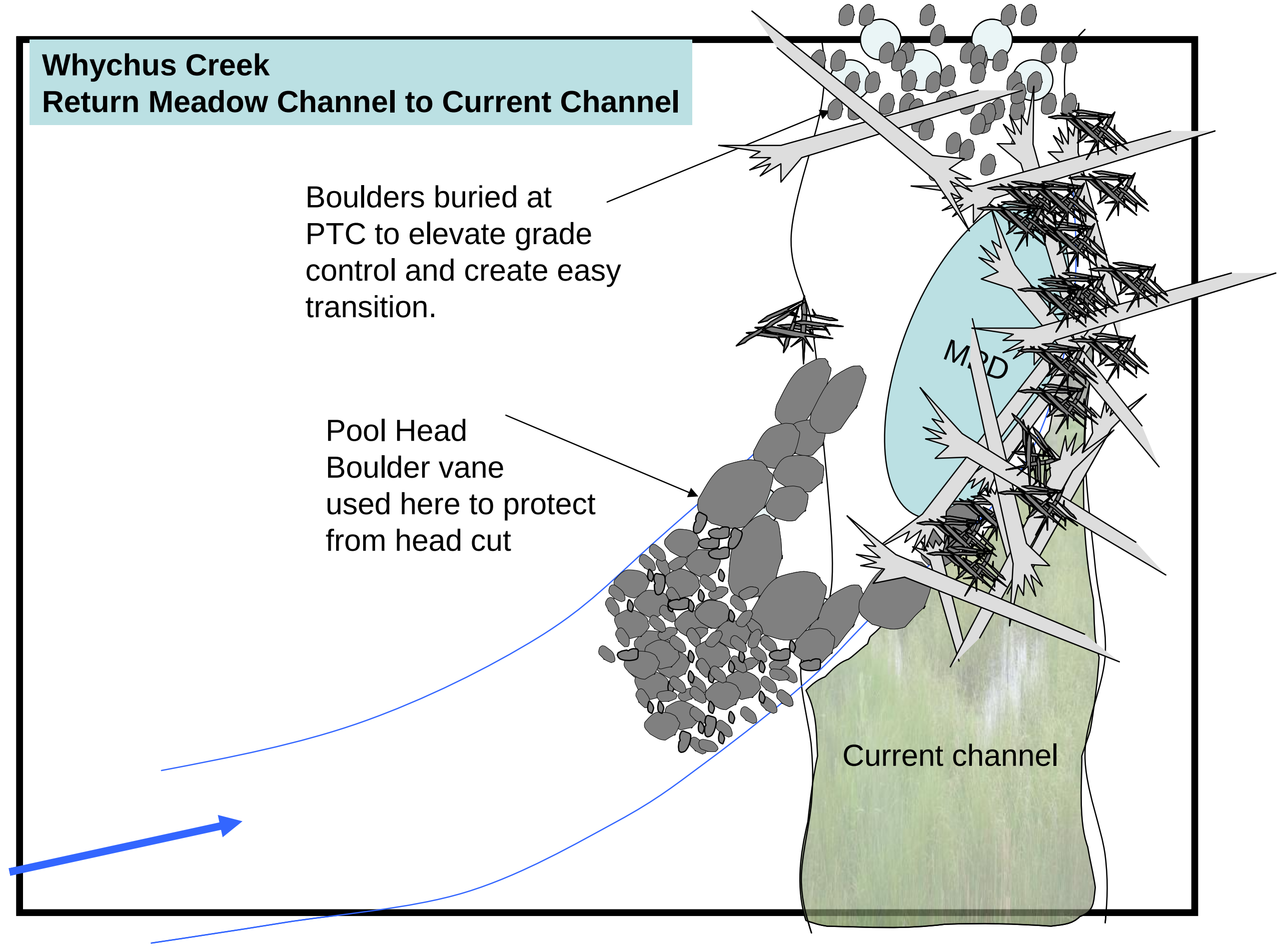


Figure G-5. Schematic of proposed exit from the meadow channel back into the existing channel at Camp Polk meadows.

Figure G-6. View of current channel looking upstream from the location where the proposed meadow channel would reenter the existing channel. Note the existing vegetation that would provide important bank stability.

Figure G-7. Reach 1 cross section at a relic meander location.

Figure H-7. Reach 1 cross-section at a relic meander location.

Source: 2/11/06 aerial photo
cpm_mapping\reach1_xsec.mxd, dquinlan, 1/18/07

DESCHUTES GEOgraphics

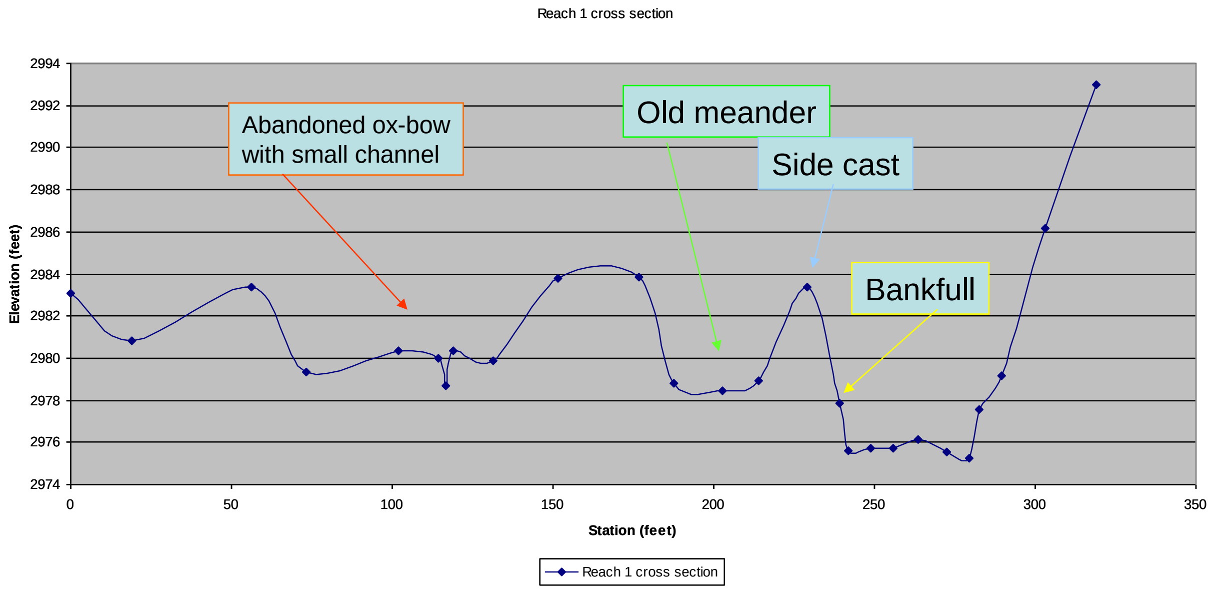


Figure G-8. Cross-section at a potential re-meander location in reach 1 of the Whychus Creek at Camp Polk.

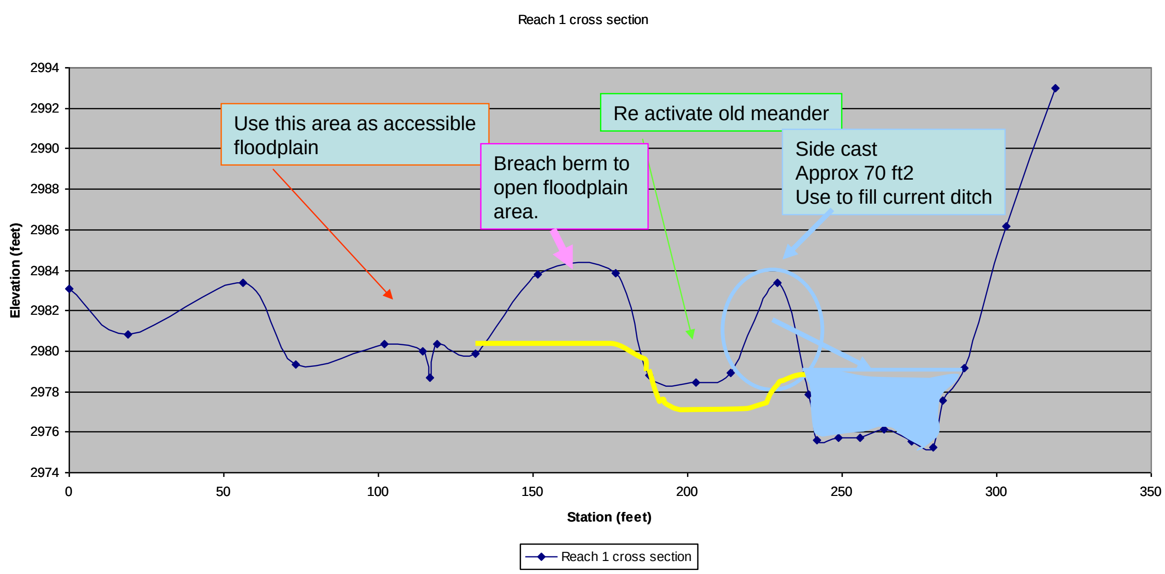


Figure G-9. Cross section showing how to create a meander in reach 1 of Whychus Creek at Camp Polk.