North Umpqua Habitat Restoration/Creation Project Feasibility Report

Prepared for
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Coordination Committee
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1 BACKGROUND AND PURPOSE

The 2001 North Umpqua Settlement Agreement (Agreement) established the goal of maximizing spawning habitat for anadromous fish in the mainstem North Umpqua River, with a priority given to chinook salmon spawning habitat (Section 8.1 of the Agreement). Approximately 450 to 1,400 m^2 (5,000 to 15,000 ft^2) of spawning habitat were to be created in the Soda Springs Bypass Reach (Section 8.3 of the Agreement). It was recognized that potential project benefits will be limited by little coarse sediment supply and by the natural constraints of the river channels to store sediment. Measures to restore, create, and/or enhance spawning habitat in the Soda Springs Bypass Reach were initially to be focused in the lower end of the Soda Springs Bypass Reach at a location referred to as an alluvial feature.

Based on field work conducted by Stillwater Sciences at the original project site in early 2002, the feasibility of completing the original project and achieving goals for restoration of spawning habitat as described in the Agreement were questioned. Preliminary surveys of the referenced reach indicated a steeper gradient than originally thought, with less potential to store sediment of the size and quantity necessary to provide the desired amount of spawning habitat.

After a site visit and a series of meetings in 2002 by a technical work group (TWG)(See Appendix 1 for list of members) of the Resource Coordination Committee (RCC), a work plan to identify and evaluate alternatives to the original site was developed in late August 2002. Based on criteria developed during the TWG discussions, 10 potential enhancement sites were identified that potentially met the objective of capturing the original intent and scope of the project. Using a set of criteria approved by the RCC (Appendix 2), the TWG conducted site visits in September and October 2002, narrowing the list of potential sites and identifying a preferred site (Appendix 3).

An amendment to the Agreement reflecting this additional information and describing changes to Section 8.3 was filed with the Federal Energy Regulatory Commission on 1 November 2002. This amendment reflects the Agreement Parties' willingness to expand the area considered for habitat projects, in order to achieve the broader goals of the Agreement and establishes a maximum of $410,000 to accomplish the goals. The work required under the amended Section 8.3 would restore or create salmonid spawning habitat in an assessment area encompassing the Soda Springs Bypass Reach and the mainstem North Umpqua River and its tributaries downstream of Soda Springs Dam.

Under the amendment to the Agreement, the TWG developed a scope of work to identify potential enhancement opportunities in the expanded area of interest. The scope of work included developing a feasibility assessment evaluating four sites (one preferred and three potential sites) selected by the TWG, as well as developing an implementation plan (including preliminary construction design), monitoring plan, and baseline habitat survey for the selected site(s). This document fulfills the requirements described under Task 1 (Feasibility Assessment) of the scope of work to accomplish amended Section 8.3.1 of the Agreement.

2 DESCRIPTION OF REACH

The area encompassed by the feasibility assessment extends from Soda Springs Dam downstream to Steamboat Creek, including tributaries (Figure 1). The mainstem North Umpqua River from Soda Springs Dam downstream to Steamboat Creek is confined by steep bedrock walls and is largely characterized by forced pool-riffle and plane-bed morphology. Channel gradients are predominately less than 1 percent, with local gradients greater than 1 percent in short sections of the reach, mostly between Soda Springs Dam and Boulder Creek. Large boulders and bedrock outcrops create pools and provide features that create channel complexity. Gravel deposits in this reach are generally associated with boulder and bedrock obstructions and larger planform features, such as point bars associated with curvature of the channel. Introduction of bedload sediment into the reach between Soda Springs Dam and Boulder Creek has been reduced by an estimated 95-100 percent (Stillwater Sciences 2000). Large woody debris is not a major influence on channel form in this reach due to the large channel size, coarse bed material, and abundance of bedrock.

Tributaries to the North Umpqua River between Soda Springs Dam and Steamboat Creek have confined channels with moderately steep gradients (1–4 percent) in lower reaches and forced pool-riffle bed morphology. Reaches with gradients of 4–8 percent generally exhibit forced pool-riffle and step-pool bed morphology. The spawning distribution of chinook and coho salmon in tributaries is generally restricted to reaches where gradients are generally less than 2 percent and where adequate stream flow exist during September and October when spawning occurs. Spring chinook spawning distribution is very limited in most tributaries because of the low flow conditions during September and early October. Steelhead distribution in tributaries generally extends upstream into reaches where stream gradients remain less than 8 percent.

3 SITE SELECTION

3.1 Approach

Site selection involved an iterative process in which information was obtained and synthesized, assessment tools were identified and developed, and potential sites were evaluated and prioritized. This process was developed to be initially inclusive in considering potential enhancement sites and progressively confirm or exclude sites based on well-defined and appropriate criteria (Appendix 2) in order to increase potential for success.

3.2 Methods

The TWG considered the mainstem North Umpqua River in close proximity to Soda Springs Dam a higher priority for enhancement efforts than tributary reaches or the mainstem river farther downstream. A GIS-based map of the river channel and its tributaries from Soda Springs Dam to the confluence with Steamboat Creek was developed to support site selection by the TWG. The map included mainstem channel planform, reach designations, stream habitat units (e.g., pool-riffle-glide), and geomorphic units provided by the USDA Forest Service (USDA-FS); road network provided by USDA-FS and PacifiCorp and merged by Stillwater Sciences; spawning redd counts by reach for 1993 provided by PacifiCorp (PacifiCorp 1995); contour lines; and stream network provided by Stillwater Sciences. In September 2002, the TWG identified and visited 10 potential enhancement sites on the mainstem North Umpqua River from Soda Springs Dam downstream to the confluence with Steamboat Creek.

The TWG used a matrix developed by the USDA-FS to evaluate the suitability of potential enhancement sites and to prioritize the sites (Appendix 3). Criteria used to evaluate potential sites included distance from soda Springs dam (closer sites received higher priority), accessibility for construction equipment, existing habitat value, existing infrastructure, Wild and Scenic River status, possibility of conflicts with other river users, and the estimated area of spawning habitat created by enhancement activities (Appendix 2 and 3). The TWG assigned a qualitative ranking (high, medium-to-high, medium, medium-to-low, and low) to each potential site based on the cumulative scores from these criteria (Appendix 3). Four sites were recommended as high priority sites. On October 4, 2002, the TWG revisited the four high priority sites with the objective of reaching consensus on an initial preferred site.

In April 2003 an additional 10 potential enhancement sites were identified by Stillwater Sciences using 1:6,000 scale aerial photography of the mainstem North Umpqua River taken in July 2001. The evaluation included the reach from Soda Springs Dam downstream to Horseshoe Bend. Criteria used to identify potential enhancement sites from the aerial photographs included: presence of existing bars or gravel patches, existing hydraulic roughness elements, favorable hydraulics and hydraulic complexity, favorable channel planform (e.g., curvature, widening), low local slope, existing spawning utilization, local upstream sediment supply, and degree to which anthropogenic disturbances influence existing conditions.

A field evaluation of geomorphic conditions at the sites was then conducted by Stillwater Sciences on April 17 and 18, 2003. The purpose of the field evaluation was to assess the potential for increasing spawning gravels at each site without degrading the spawning habitat that currently exists, develop conceptual enhancement designs, and estimate the potential increase of spawning habitat area.

Preliminary results from the Stillwater Sciences' geomorphic field evaluation were reviewed by the TWG, and a TWG meeting to finalize site prioritization and discuss preliminary conceptual site designs took place on April 30, 2003.

3.3 Results

The following 10 potential enhancement sites were identified by the TWG during the site visit on September 20, 2002:

- Site 1. Upper Soda Springs Bypass Reach
- Site 2. Lower Soda Springs Bypass Reach
- Site 3. North Umpqua at Boulder Flat Campground
- Site 4. North Umpqua below mouth of Copeland Creek
- Site 5. Lower Copeland Creek
- Site 6. North Umpqua above Marsters Bridge
- Site 7. North Umpqua below Marsters Bridge
- Site 8. North Umpqua at old bridge site (below Marsters Bridge)
- Site 9. Otter Island side channel (Horseshoe Bend Campground)
- Site 10. Gravel Bin side channel

The following four potential enhancement sites were initially prioritized and agreed upon during a site visit by the TWG on October 4, 2002:

- Site 1. Upper Soda Springs bypass Reach (preferred)
- Site 9. Otter Island side channel (Horseshoe Bend Campground)
- Site 3. North Umpqua at Boulder Flat Campground
- Site 6. North Umpqua above Marsters Bridge

The ten additional sites identified by Stillwater Sciences using aerial photographs include:

- Site 11. Eagle Creek confluence
- Site 12a. Eagle Rock Campground (upstream)
- Site 12b. Eagle Rock Campground (downstream)
- Site 13. Upstream of Wilson Creek
- Site 14. Upstream of Deception Creek
- Site 15. Charcoal Point
- Site 16. Upstream of Dry Creek
- Site 17. Downstream of Dry Creek confluence
- Site 18. Upstream of Calf Creek confluence

Site 19. Downstream of Calf Creek confluence

The final priority sites identified by the TWG include (Figure 2):

Site 1. Upper Soda Springs Bypass Reach (TWG recommended preferred site)
Site 3. North Umpqua at Boulder Flat Campground
Site 12b. Eagle Rock Campground (downstream)
Site 9. Otter Island side channel (Horseshoe Bend Campground)

4 EVALUATION OF SCOUR AT SITES 1 AND 9

4.1 Approach

Uncertainty regarding the frequency and magnitude of bed scour at Sites 1 and 9, and the potential effects of scour on developing salmonids, was identified as a concern warranting further evaluation. Bed scour is defined here as movement of the surface layer of gravel and coarser material. Bed mobility is a function of the size of the sediment grains, both individually and in their aggregate distribution, and by the shear stress imparted by the flow. A patch of coarse sediment will typically mobilize once the shear stress exceeds a threshold value. Monitoring scour is important for assessing the feasibility of habitat enhancement because it provides an indication of the relative mobility and re-supply of sediment supply to a site. If an existing gravel patch is mobilized frequently yet persists, it is reasonable to assume that the site is regularly re-supplied. If a patch is not regularly re-supplied, then we would not expect gravel to persist at that site. Scour monitoring is also useful for identifying sites that are poor candidates for enhancement by indicating where bed mobilization is too frequent and/or too extensive (e.g., deep), which would result in the destruction of redds and loss of eggs.

Site 1 extends from the concrete weir near Soda Springs Dam downstream approximately 140 m (450 ft) to the ODFW gravel retention structures near the pool tail. This site currently provides from 110 to 140 m^2 (1,200 to 1,500 ft^2) of spawning habitat for spring chinook and coho salmon, as well as steelhead. Scour at Site 1 was evaluated using two methods: (1) painted rocks to assess bed scour, and (2) topographic surveys to assess the depth of scour.

Site 9 is located on the right bank side channel at Horseshoe Bend Campground and is approximately 150 m (500 ft) in length. An evaluation of scour was conducted at Site 9 because initial reconnaissance at this site indicated that a relatively thin veneer of gravel (< 0.3 m or approximately 1 ft) overlain bedrock was present at this site, and if bed scour occurred here, it would likely scour to bedrock and eliminate the habitat value for spawning and incubation. Painted rocks were placed on the bed surface at this site to assess bed scour. The painted rocks placed at Sites 1 and 9 were monitored following winter peak flows.

4.2 Methods

At Site 1, two separate patches of painted rocks were deployed on February 26, 2003, when flows at Copeland gage were 1,330 cfs (Figure 3), one near the middle of the reach near the right bank portion of the site (site/patch 1a) and the other at the pool tail upstream of the v-log weir gravel retention structure (site/patch 1b). A total of 138 and 153 painted rocks were placed on the bed surface at patches 1a and 1b, respectively (Figures 4–8). At Site 9, 102 painted rocks were placed on the bed surface on February 26, 2003 (Figures 9–12).

To evaluate the potential extent and degree of bed scour, painted rocks were placed on the bed surface in a grid pattern and monitored subsequent to peak winter flow events. The rocks selected for painting were local to the North Umpqua River and ranged in size within ±0.5 Φ of the D_{84} (68–124 mm). To avoid biasing the marked rocks at Site 1 toward a larger particle size, and therefore a larger threshold of mobility, the size distribution of the marked rocks was determined by sampling clasts from the surface of the large right bank bar at the downstream end of the pool where the surface particle size distribution is relatively unaffected by prior high flows following augmentation. Rocks were painted white using oil-based exterior house paint and allowed to dry before being placed onto the bed surface. Once the grid pattern was laid out on the bed surface, the painted rocks were forced into the bed by stepping on them until they were even with the surrounding bed surface. This technique ensures that painted rocks are mobilized under similar conditions as the surrounding bed. A sketch of the pattern of painted rocks was made (Figures 8 and 12), and photographs were taken to document changes in the distribution of painted rocks over time. Painted rocks that are mobilized, evidenced as being moved or missing, provide an indication of the spatial pattern of bed mobility. Any bed mobilization that occurs can also be correlated to a discharge, and therefore, a probability of exceedance or frequency (e.g., recurrence interval), so that the magnitude and periodicity of flows that would scour the site may be estimated.

Streamflow at Site 1 is regulated by releases at Soda Springs Dam. During most of the year, flow in the Soda Springs Bypass Reach is regulated to meet the minimum flow requirements; however, flows in the bypass reach increase through releases from the spill gates at the dam when inflows exceed the diversion capacity of the penstock (1,600 cfs) plus the minimum instream flow, and also when the diversion is shutdown for maintenance or emergencies. Relative to natural conditions, this results in the reduction in the frequency of relatively low-magnitude high flows (e.g., 1.5-yr flood), and little effect on high-magnitude, low frequency high flows. High flows in this reach were calculated as the flow measured at the USGS gage upstream of Copeland Creek minus the flow from Boulder Creek and Soda Springs powerhouse.

Instream flows at Site 9 are not substantially altered by the project. The USGS gage upstream of Copeland Creek provides a relatively accurate depiction of conditions at Site 9. Contributing discharge from tributaries such as Copeland and Calf Creek are not included due to their relatively small contributing drainage area. Peak discharges reported here for Site 9 are based on the Copeland gage and therefore slightly underestimate the actual flow at Site 9.

The painted rocks at Site 1 were monitored on April 7, 2003, subsequent to a peak flow of approximately 2,300 cfs occurring on March 26, 2003, and high flows approaching 2,000 cfs stemming from scheduled maintenance of the Soda Springs hydroelectric development during the week of March 31 to April 4, 2003. The painted rocks at Site 9 were monitored on March 20, 2003 subsequent to a peak flow of approximately 2,220 cfs that occurred on March 16, 2003. They were monitored again on April 7, 2003 subsequent to a peak flow of approximately 4,630 cfs that occurred on March 26, 2003. Stage at the site on April 7, 2003 was estimated to be 15 to 30 cm (6 to 12 inches) higher than flows observed on March 20, 2003.

A topographic survey was conducted at Site 1 on February 25 and 27, 2003 to document current conditions and assess the depth of bed scour. A total station was used to collect topographic data, which were then used to create a topographic depiction of the surface of the channel bed and banks.

4.3 Results

4.3.1 Site 1 – Upper Soda Springs Bypass Reach

Approximately 36 of the 138 rocks at Site 1a moved (Figures 4–6), most of which were considered by the TWG monitoring team to have been moved by steelhead during spawning activity. Similarly, approximately 20 of the 153 painted rocks placed at Site 1b had moved (Figures 7–8), all of which were considered to have been moved by spawning steelhead. The marked rocks were pressed into the existing gravel deposit, and thus, their mobility closely approximates existing bed surface mobility. Because the results of monitoring indicated that the spawning substrate at Site 1 had not been scoured by recent high flows, no follow-up topographic survey was conducted to assess depth of scour.

The peak flows occurring in the Soda Springs bypass reach during winter 2002/2003 were relatively high frequency, low-magnitude flows with an estimated recurrence interval slightly higher than 1.2 years. A summary of estimated flood frequency in the Soda Springs bypass reach over a range of discharges is provided below in Table 1.

Table 1. Flood recurrence estimates related to various discharges in the Soda Springs Bypass Reach.

Return Period (year)	Discharge (cfs)
1.2	2,100
1.5	3,500
2	5,000
5	9,700
10	13,700

Results from the scour assessment indicate that spawning gravels were relatively stable at flows less than 2,300 cfs and that enhancement have a high likelihood of success when experiencing flows of similar or lesser magnitude. The extent to which the proposed spawning gravel enhancements will remain stable during greater magnitude floods is uncertain.

4.3.2 Site 9 - Otter Island side channel (Horseshoe Bend Campground)

By the first monitoring visit on March 20, 2003, 38 of the 102 painted rocks at Site 9 had moved (Figures 9–12). Eighteen were transported only a short distance and remained within the patch, and 20 were transported out of the site. Observations indicated that painted rock movement was concentrated at the upstream end of the site (top 7.6 m [25 ft]) and in the two rows farthest from the right bank. The row closest to the bank exhibited little movement. On the 7 April 2003 monitoring visit, only 19 of the original 102 rocks were estimated to be in their original location, of which 13 occurred in the row closest to the right bank (Figures 9–12).

The peak flows occurring at Site 9 (4,630 cfs) during winter 2002/2003 were relatively low. A summary of flood frequency in the North Umpqua River at the USGS gage upstream of Copeland Creek is given below in Table 2 for reference.

Table 2. Flood recurrence estimates related to various discharges for USGS gage upstream of Copeland Creek.

Return Period (year)	Discharge (cfs)
1.2	4,000
1.5	5,500
2	7,100
5	12,100
10	16,400

Evidence of bed particle mobilization observed at Site 9 suggests that bed scour occurs rather frequently, which substantially limits incubation success, and that any enhancement design should consider reducing scour potential while maintaining and/or enhancing sediment delivery and retention (including patch depth). With high sediment transport potential and the presence of a post-high-flow gravel deposit, it is evident that the sediment supply to the area is relatively high, which may offer opportunities for enhancement.

5 CONCEPTUAL DESIGNS

5.1 Site 1 – Upper Soda Springs Bypass Reach

5.1.1 Site description and design

Site 1 extends from the concrete weir located approximately 150 m [500 ft] downstream of Soda Springs Dam (immediately below the access bridge), downstream approximately 140 m (460 ft) to the ODFW gravel retention structures near the pool tail. The channel is restricted by a 30-m high (100-ft), vertical bedrock wall on the left bank and rip-rap on the right bank associated with the access road. This site currently provides 110–140 m (1,200–1,500 ft^2) of spawning habitat for spring chinook, coho, and steelhead, most of which is at the pool tail and along the right bank.

The conceptual design for this site calls for constructing a new log weir downstream and at a higher elevation than the existing log structure at the pool tail (Figures 13–14). Design is based on a minimum in-stream flow release of 275 cfs (to be implemented September 1, 2005, for the duration of the license period). The new log weir would function as the new hydraulic control for the pool and as a retention structure for augmented gravel.

The new weir is intended to make use of the increased flow (275 cfs) by placing the weir relatively horizontal, and therefore, increasing the width of the inundated area. The new weir would be placed between the two existing weirs with a crest elevation approximately 0.45 m (1.5 ft) higher than the lowest crest elevation of the existing upstream weir. Raising the water surface may also increase the pool volume, which would help to dissipate energy of turbulent flow released from the spillway. The weir would be an inverted "V" in plan view, similar the two existing weirs at the site. The slope upstream of the weir will be initially graded to a slope of approximately 0.002, thus maintaining a depth of 1.2 to 1.5 ft and a velocity of 2.2 to 2.5 ft during instream flow of 275 cfs. To secure the log structure during high flow events and to facilitate upstream fish passage, large boulders would be placed along the downstream edge of the new log weir. Boulders will also be placed near the right bank to deflect water away from and protect the access road from erosion. Part of the gravel bar at the right bank upstream of the existing log weir will be excavated to further increase the pool volume and help to dissipate energy of turbulent flow released from the spillway. Please note that Figure13 is a schematic of the conceptual design and does not reflect specific details of the design. A more detailed site design will be developed during the engineering design phase of the project.

Gravel suitable for spawning would be augmented during low flows to maintain spawning habitat at this site. The augmented gravel would be placed near the pool tail upstream of the enhanced spawning habitat, as shown in Figures 13 and 14. Gravel would be placed in the pool at depths greater than 1.5 m (5 ft) in order to promote low water velocity and discourage salmon and steelhead from spawning in the augmentation area during low flow. The primary function of the augmented gravel would be to supplement downstream spawning habitat during high-flow events, reduce scour of downstream spawning habitat, and thereby reduce the potential for egg loss. The augmented gravel is intended to be mobilized during high flows and transported only a short distance as bedload to the enhanced spawning area, where reduced water depths and lower bed sheer stresses would increase the probability of deposition. In addition, the equilibrium between bedload transport and augmented gravel supply to the enhanced spawning area would reduce the potential depth of scour. Peak high flows capable of mobilizing the bed surface generally occur during the period of November to May. This partially overlaps with the spawning and incubation periods of salmon and steelhead expected to use the site. However, based on the scour evaluation at Site 1 flows capable of mobilizing bedload at the enhancement site, and potentially scouring redds, is not expected to occur each year

Gravel would need to be periodically augmented to the area upstream of the spawning habitat to maintain bedload supply to the spawning area (e.g., every 3 to 8 years, depending on degree of scour). The periodic augmentation at the site would be determined through initial monitoring conducted after a specified threshold flow magnitude and duration (e.g., 2.5-year recurrence interval for 1 day). If substantial bed surface changes are apparent during initial monitoring, an assessment of useable spawning habitat area, and a topographic survey of the enhancement and augmentation areas will be conducted to determine the functionality of the existing gravel deposit and the volume of gravel lost since augmentation previous augmentation. Infrequent maintenance of the spawning habitat (e.g., contouring) may be necessary to maintain optimal spawning water depths and velocities. Detailed monitoring methods will be discussed in a forthcoming monitoring plan.

5.1.2 Assumptions

- The large scour pool immediately downstream of Soda Springs Dam dissipates sufficient energy from turbulent flow released from the spillway to allow the enhanced spawning gravel deposit to persist.
- Pool volume will be increased by raising the water surface elevation and excavating part of the gravel bar on the right bank.
- Increasing pool volume will reduce scour of the spawning gravel near the pool tail during high flows.
- Augmented gravel can be placed in a location where few fish will spawn on it until it gets naturally transported by high flows and is re-deposited in the enhanced spawning area at the pool tail.

5.1.3 Pros and cons

Pros

- Site 1 was the highest priority site identified by the TWG due to its proximity to Soda Springs Dam, intensively regulated flow regime, location upstream of the Wild and Scenic River reach and no conflicts with other river users.
- The site currently provides excellent access.
- Gravel augmentation already occurs at the site.

- Chinook salmon, coho salmon, and steelhead currently spawn in the area.
- The site has the largest potential spawning habitat gain of any of the identified sites.
- The site configuration offers design flexibility.
- Any substrate transported out of this site will provide potential bedload supply to downstream sites.

Cons

- Gravel augmentation would be required periodically due to lack of natural gravel recruitment and scour of placed gravel during high flows in the Soda Springs bypass reach.
- Habitat enhancement may require additional costs to re-rate or move and rate the existing compliance gaging station for the Soda Bypass Reach, which is located in the same pool as Site 1.

5.1.4 Expected outcome

A net increase of approximately 370 to 465 m^2 (4,000 to 5,000 ft^2) of spawning habitat compared with existing conditions may be created as a result of the proposed enhancement design.

5.2 Site 3 - North Umpqua River at Boulder Flat Campground

5.2.1 Site description

Site 3 is located 100 m (300 ft) downstream of the Boulder Creek confluence near the Boulder Creek Campground at River Mile (RM) 67.9. The site encompasses several large boulders (>25 m^3 [1,000 ft^3]) spanning the channel at the head of a pool and a large gravel deposit at the downstream pool tail (Figure 15). The three large boulders, one on each bank and one in the channel center, create the hydraulic conditions necessary for gravel deposition. The submerged gravel deposit forms the upstream edge of a larger sub-aerial mid-channel bar. The channel planform through the site has limited curvature. Site 3 currently provides about 140 m^2 (1,500 ft^2) of spawning habitat. Spring chinook salmon and steelhead spawn in the existing deposit.

The conceptual design calls for 90–140 m^2 (1,000–1,500 ft^2) of gravel augmentation in a patch on the left bank approximately 6 m (20 ft) downstream of the large mid-channel boulder and 15 m (50 ft) upstream of the flow split around the mid-channel bar. The augmentation would increase the aerial extent of the existing gravel deposit. The proposed patch is on the left bank of the river where access is easily obtained through the Boulder Creek Campground. Augmentation would ideally lead to feedback mechanisms that increase natural deposition in the vicinity. It is uncertain how much bedload would be supplied to the enhancement site. The conceptual design for habitat enhancement at this site is limited to gravel augmentation in order to minimize disruption of the existing spawning habitat. Gravel augmentation potentially could be implemented after evaluation/monitoring of the gravel pulse experiment scheduled for 2004 as described in Section 7.2 of the Settlement Agreement (see Section 8 below).

5.2.2 Assumptions

- Boulder Creek is the primary source of gravel maintaining the existing gravel deposits.
- Augmented gravel will be relatively stable and will therefore sustain additional spawning habitat. This assumption is supported by the existence of a relatively large gravel deposit.
- The existing gravel deposit was historically more extensive prior to reduction in bedload supply by construction of Soda Springs Dam.

5.2.3 Pros and cons

Pros

- The Boulder Creek Campground provides excellent access.
- Since no grade control structures are required, construction costs would be minimized.
- Enhancement activities would not negatively influence existing downstream spawning habitat when augmented gravel is mobilized during high flow events.
- Gravel augmentation can be discontinued at any time if it does not produce the desired effects.

Cons

- The site will likely require regular augmentation to replenish the gravel patch.
- Restricted recreational access to the site may be required in order to protect spawning beds created by enhancements.
- Enhancement may conflict with river recreational activities (e.g., whitewater boating).
- The site is located in the Wild and Scenic River Reach.

5.2.4 Expected outcome

Approximately 90 to 140 m^2 (1,000 to 1,500 ft^2) of spawning habitat may be created as a result of the enhancements.

5.3 Site 12b - Eagle Rock Campground

5.3.1 Site description

Site 12b is located near the Eagle Rock Campground at RM 66.3. A split channel converges around a mid-channel bar at the upstream end of the site. At the downstream end of the site, a large transverse cobble bar oriented obliquely upstream routes bedload toward the left bank. A large bedrock outcrop at the upstream end of the bar also influences flow direction. As a result, a large cobble-gravel deposit has developed along the left bank at the downstream end of the transverse bar. The deposit forms a partially submerged gravel bar separated from the left bank by a left-bank side channel. This channel geometry creates two opportunities for spawning habitat enhancement, one upstream of the transverse bar and one downstream.

The conceptual design for the upstream part of the site is to place a large boulder cluster approximately 4.5 m (15 ft) river-left of the area of convergent flow at the downstream end of the mid-channel bar (Figure 16). The boulders would increase roughness and enhance local flow separation. The slower, divergent flow would promote gravel deposition near the left bank downstream of the boulder cluster. The conceptual design for the downstream part of the site is to place several boulders near the left bank to form an oblique step or spur dike located downstream and oriented parallel to the transverse bar. This oblique spur dike would create a zone of potential gravel deposition within the assumed path of bedload transport toward the left bank. Gravel would be augmented in the areas of anticipated deposition at the time of construction. These enhancement activities would be constructed in a way that will not negatively impact existing habitat in the left bank side channel and does not obstruct the path taken by boaters.

5.3.2 Assumptions

- The oblique transverse bar in the middle of the site routes bedload to the left bank where it is stored in the left bank gravel bar.
- Trapping efficiency may be enhanced by increasing roughness along the relatively narrow path of bedload transport along the downstream margin of the bar.

- At the upstream end of the site, increased roughness and enhanced local flow separation near where flow converges around the mid-channel bar would reduce shear stresses and facilitate gravel deposition.

5.3.3 Pros and cons

Pros:

- The Eagle Rock Campground provides excellent access.
- The existing planform provides hydraulic conditions and concentrated bedload transport paths suitable for gravel deposition with the addition of large roughness elements.

Cons:

- The impact of the downstream boulder spur on the existing left bank side channel is uncertain.
- The gravel deposits may not provide suitable spawning habitat due to small patch size, shallow patch depth, and/or unfavorable hydraulics.
- Enhancement may conflict with river recreational activities (e.g., whitewater boating).
- The site is located in the Wild and Scenic River Reach.

5.3.4 Expected outcome

A total of approximately 40–90 m^2 (400–1,000 ft^2) of gravel is expected to develop at the two proposed boulder clusters.

5.4 Site 9 - Otter Island side channel (Horseshoe Bend Campground)

5.4.1 Site description

This site is located in a right-bank side channel along the inside of Horseshoe Bend at RM 60.8. Flow enters the side channel via two low-flow paths through a dissected point bar terrace creating an island during periods of low flow. Upstream of the second opening, the side channel slope is steep (approximately 3 percent) and narrow (approximately 7.5 m [25 ft] wide). The bed is primarily comprised of boulder and bedrock with occasional thin gravel-cobble deposits along the channel margins. Downstream of the second opening to the side channel, the slope is lower (approximately 1 percent) and the channel widens to approximately 15 m (50 ft). Thin gravel-cobble deposits are more extensive in this portion of the site.

The conceptual design is to enlarge two existing, natural bank irregularities that create some flow separation and promote gravel deposition (Figure 17). The upstream gravel patch is associated with a bedrock outcrop along the right bank of the side channel. Boulders would be placed to increase roughness in the vicinity of the existing bedrock outcrop. Downstream, the naturally occurring bank irregularity is associated with several trees rooted in the left bank of the side channel. Similarly, a boulder cluster would be constructed to increase roughness, enhance flow separation, and induce gravel deposition. Gravel would be augmented in the areas of anticipated deposition at the time of construction.

5.4.2 Assumptions

- The scour evaluation described above in Section 4 suggests that the substrate mobility and relatively high gravel supply to this portion of the site may be suitable for creating persistent gravel deposits.

5.4.3 Pros and cons

Pros:

- The existing Horseshoe Bend Campground provides excellent access to the site.

Cons:

- Boulder clusters in the side channel at Horseshoe Bend could create a potential hazard for whitewater boating. This is of greater concern here than at other sites because if a boat were to get into the narrow side channel, there would be little room to maneuver around boulders.
- Gravel deposits may not be thick enough to provide high quality spawning habitat.
- Although gravel appears to be persistent because of re-supply, the apparent high mobility could reduce redd viability.
- The side channel to could naturally "close off" and dewater at some future date.

5.4.4 Expected outcome

The two proposed boulder clusters may create 25–55 m^2 (250–600 ft^2) of spawning habitat each for a total increase of approximately 45–90 m^2 (500–1,200 ft^2).

6 COST ESTIMATES, CONSTRUCTION TIMELINES, AND PERMITTING/NEPA REQUIREMENTS/CONSULTATION

6.1 Cost Estimates

6.1.1 Assumptions

- All cost estimates are reported in 2003 dollars.
- Permitting cost includes limited support by the designated contractor (e.g., production of text and figures for permitting effort). Costs for the PacifiCorp and the TWG to perform the majority of work in support of permitting are not included.
- NEPA costs are for preparation of an environmental assessment by the Forest Service. For Sites 3, 9 and 12b cost estimates reflect the possibility of multiple sites being selected, resulting in lower per site cost. Cost estimates are for initial project construction and maintenance within the first ten years of the Project. Maintenance actions after the first ten years may need additional NEPA (at minimum additional scoping) if additional environmental issues emerge.
- Engineering design cost includes the engineering design and engineering oversight during the initial construction phase.
- The construction cost includes purchase and transportation of construction material (e.g., boulders, gravel, and logs), and transportation and operation of construction equipment. The cost of acquisition and transport for boulders and gravel was based on enhancements constructed in the Slide Creek Bypass Reach in 2002.
- Baseline monitoring cost includes a topographic survey of the enhancement area and field evaluation of useable spawning habitat area, with which subsequent monitoring efforts will be compared. [Note: this is a preliminary estimate; baseline monitoring will be scoped in more detail in cooperation with the TWG during development of the Monitoring Plan and Baseline Habitat Survey components.]
- Periodic monitoring cost includes a site visit to evaluate the area of useable spawning habitat, estimate the volume of gravel transported out of the site since the previous implementation, evaluate the configuration of the of the bed relative to intended design, and assess the integrity of

the enhancement. [Note: this a preliminary estimate; periodic monitoring will be scoped in greater detail in cooperation with the TWG during development of the Monitoring Plan.]

- Periodic maintenance cost includes limited permitting support by the designated contractor, the purchase and transportation of gravel, the transportation and operation of construction equipment, and project oversight.
- The feasibility study costs ($45,238) is included in the maximum available funding ($410,000) for this project, but are not reflected in the following cost estimates.
- Total cost over the term of the license includes permitting, engineering, construction, monitoring, maintenance, and other cost considerations expected during the 35-year license term. Estimated monitoring costs provided here assume 14 monitoring visits (approximately once every 2.5 years). Maintenance costs assume 6 maintenance visits (approximately once every five years). [Note: this a preliminary estimate; periodic monitoring will be scoped in greater detail in cooperation with the TWG during development of the Monitoring Plan.]

6.1.2 Site 1

Implementation Costs:	
Permitting and NEPA	$15,000
Engineering design	$7,100
Construction	$65,800
	$87,900
Baseline monitoring	**$6,400**
Ongoing Costs:	
Periodic monitoring	**$6,200**
Periodic maintenance	**$26,400**
Other Cost Considerations	
Periodically re-rate monitoring gage	**$7,500**
Total Cost Over Life of the License:	**$347,000**

Cost Considerations at Site 1:
An instream flow compliance gage is currently located in the Soda Springs Bypass Reach within the vicinity of Site 1 and is required to remain accurate and functional during implementation of the new license. Site construction and gravel augmentation activities that would be conducted as part of the proposed design at Site 1 are expected to affect the accuracy of the gage, although it is not anticipated to disturb the gage infrastructure. The need to move the gage to a new location is not anticipated. Installation of the new log weir, boulder cascade, and augmented gravel will alter the elevation and configuration of the hydraulic control of the gage pool, and necessitate re-rating the gage. The gage currently requires periodic rating to ensure accurate discharge measurements. If enhancements at Site 1 are conducted, the timing of rating visits may need to be modified to be coordinated with construction activities to maintain accurate gage readings at this location. This may increase the number of visits required and, therefore, the overall cost of maintaining the gage may be increased compared with existing maintenance costs. The estimated cost of each rating visit is approximately $1,000 to $2,000. If it is determined that the gage needs to be moved, the gage could be relocated upstream to a location that would not be affected by construction and gravel augmentation at Site 1. The estimated cost of relocating the gage is approximately $10,000, and would not negate the need to rate the station periodically. The $7,500 cost estimate referred to above includes 5 site visits to re-rate the gage at an estimated cost of

$1,500 per visit. The need to relocate the compliance gage will be evaluated in further detail during the engineering design phase of the project.

6.1.3 Site 3

Implementation Costs:	
Permitting and NEPA	$9,600
Engineering Design	$2,500
Construction	$18,200
	$30,300
Baseline monitoring	**$5,000**
Ongoing Costs:	
Periodic monitoring	**$3,500**
Periodic maintenance	**$15,100**
Total Cost Over Life of the License:	**$175,000**

6.1.4 Site 12b

Implementation Costs:	
Permitting and NEPA	$9,600
Engineering Design	$2,700
Construction	$23,700
	$36,000
Baseline monitoring	**$5,000**
Ongoing Costs:	
Periodic monitoring (cost/visit)	**$3,500**
Periodic maintenance (cost/visit)	**$13,900**
Total Cost Over Life of the License:	**$136,000**

6.1.5 Site 9

Implementation Costs:	
Permitting and NEPA	$9,600
Engineering Design	$2,700
Construction	$19,600
	$31,900
Baseline monitoring	**$5,000**
Ongoing Costs:	
Annual monitoring	**$ 2,700**
Periodic maintenance	**$10,700**
Total Cost Over Life of the License:	**$139,000**

6.2 Construction Timelines

It is anticipated that a final selection of site(s) for habitat restoration/creation will be made by the RCC during summer 2003. An implementation plan (including construction designs), monitoring plan, and baseline habitat survey would then be prepared in summer/fall 2003. Permitting, National Environmental Policy Act (NEPA) analysis, and Endangered Species Act (ESA) Section 7 consultation would need to begin in 2003 such that construction would occur in August 2004 (during the state-approved in-channel work period). Construction of this project will be coordinated with the gravel augmentation project (Settlement Agreement Amendment Section 7.2), also scheduled for August 2004, to maximize resource benefits and reduce impacts from both activities.

6.3 Permitting/NEPA/Consultation Requirements

It is anticipated that permitting/NEPA and consultation will take three to twelve months. Section 404 permits, Aquatic Conservation Strategy findings under the Northwest Forest Plan, and any necessary ESA Section 7 consultation would have to be completed for any of the four sites. Wild and Scenic River findings will have to be completed by the USDA-FS. Oregon Department of Environmental Quality will require a turbidity monitoring plan as part of the U.S. Army Corps of Engineer Section 404 permit.

6.3.1 Federal and state permitting

Permits under Section 404 of the Clean Water Act would be needed for any of the four sites. Section 404 permits are issued by the U.S. Army Corps of Engineers and the Oregon Division of State Lands. The time required to issue permits is from three to six months.

6.3.2 National Environmental Policy Act (NEPA) analysis

The environmental effects of implementing the project on the selected site(s) would need to be analyzed. This process, and the USDA-FS appeals process, can take up to 12 months to complete. The environmental analysis must meet the criteria set forth in the USDA-FS regulations for NEPA. Any contractor selected by PacifiCorp to conduct the NEPA process must be approved by the USDA-FS in advance of any work. The NEPA decision document and any determination or findings (i.e., Wild & Scenic River Determinations, Aquatic Conservation Strategy Findings) are the sole responsibility of the USDA-FS.

6.3.3 Endangered Species Act (ESA) consultation

Depending on the specific action taken, the proposed project could by covered by an ongoing programmatic Biological Opinion (in which case, no additional consultation would be needed).
If ESA Section 7 consultation with National Oceanic and Atmospheric Administration (NOAA) Fisheries (for listed anadromous salmonids) and/or the U.S. Fish and Wildlife Service (for terrestrial species and resident fish) may need to be completed, this process may take three to six months. This time estimate includes Level 1 team discussions, submittal of the consultation document(s) to the Services, and completion of the appropriate consultation document by the Services (Letter of Concurrence or Biological Opinion). Letters of Concurrence normally have a 30-day turn-around from the Services; Biological Opinions normally have a 60-day turn around from acceptance of the final, adequate Biological Assessment.

6.3.4 North Umpqua Wild and Scenic River Determination

The North Umpqua Wild and Scenic River Reach extends from Soda Springs Powerhouse downstream to the confluence with Rock Creek. This reach was designated as Wild and Scenic River (WSR) in October 1988 and is protected under Section 7 of the Wild and Scenic Rivers Act, which provides a specific standard for review of developments below or above a designated river. Potential enhancement Sites 3, 12b, and 9 occur within the North Umpqua WSR reach, while Site 1 occurs upstream of it.

Developments below or above a designated river may occur as long as the project will not invade the area or unreasonably diminish the scenic, recreational, and fish and wildlife values present in the area as of the date of designation. This standard applies to projects outside the river corridor but on the same river or tributary, as is the case with Site 1 on the North Umpqua River.

In June 2002, the Section 7(a) determination was issued by the USDA Forest Service and USDI Bureau of Land Management in response to the Draft Environmental Impact Statement for the North Umpqua Hydroelectric Project (FERC 2002). Section 2.2.2 addresses Section 8.3 of the Agreement. The determination is provided below:

> "The FERC DEIS does not disclose any additional adverse effects or any greater magnitude of adverse effect than those already considered in the detailed analysis completed to support the February 2001 preliminary Section 7(a) determination prepared in response to the final license application. None of the alternatives propose construction of any project works in the WSR corridor; therefore, none will invade the designated river area... Therefore, we find that none of the action alternatives will invade the designated river area or unreasonably diminish its scenery, recreation, fish or wildlife values as present on the date of designation (October 1988)."
>
> "This determination is based on the North Umpqua Hydroelectric Project as it is proposed to operate in the alternatives that are evaluated in the FERC DEIS. In cooperation, the Forest Service and Bureau of Land Management will make a final determination under Section 7(a) coincident with the timing of submittal of the final 4(e) terms and conditions and informed by evaluation of the project in FERC's final environmental impact statement."

7 COST-BENEFIT SUMMARY

The costs, potential increase in spawning habitat area, estimated cost per unit area, confidence in success, and risk of adverse effects at each site are summarized in Table 3.

Table 3. Cost-benefit summary for priority enhancement sites.

Site	1	3	12b	9
TWG preference	Preferred	--	--	--
Total cost over license term *	$347,000	$175,000	$136,000	$139,000
Wild & Scenic River	No	Yes	Yes	Yes
Permitting and NEPA	$ 15,000	$ 9,600	$ 9,600	$ 9,600
Engineering design	$ 7,100	$ 2,500	$ 2,700	$ 2,700
Construction	$ 65,800	$ 18,200	$ 23,700	$ 19,600
Baseline monitoring	$ 6,400	$ 5,000	$ 5,000	$ 5,000
Periodic monitoring	$ 6,200	$ 3,500	$ 3,500	$ 2,700
Periodic maintenance	$ 26,400	$ 15,100	$ 13,900	$ 10,700
Potential net increase in habitat (ft^2)	4,000 – 5,000	1,000 – 1,500	400 – 1,000	500 – 1,200
Cost per unit area ($/$ft^2$)**	$69 - $87	$117 - $175	$136 - $340	$116 - $278
Confidence in success	High	Moderate	Moderate	Low
Risk of adverse effects	Low	Low	Moderate	Low

* See assumptions in Section 6
** Based on estimated total cost

8 RELATIONSHIP BETWEEN MAINSTEM RIVER ENHHANCEMENT PROJECTS

Section 8.3 of the Settlement Agreement provides for the restoration or creation of salmonid spawning habitat in the Soda Springs Bypass Reach and the mainstem North Umpqua River and its tributaries, downstream of Soda Springs Dam. In support of this effort, the four priority enhancement sites discussed above were identified. Section 7.2 of the Settlement Agreement amendment provides for a gravel augmentation program that supplements gravel below Soda Springs Dam, to address the geomorphic effects of reduced sediment load downstream of Soda Springs Dam. Section 7.2.1 provides for an estimated 20 tons of gravel to be augmented at up to five sites (100 tons total) a total of seven times over the course of the license. Given the evident overlap of goals, location, and methodology (i.e., gravel augmentation), potential enhancements identified here under Section 8.3 may be supported by gravel augmentation actions under Section 7.2. Also, the proposed design at Site 3 calls for gravel augmentation that may be more appropriate for implementation under Section 7.2 of the amended Agreement.

9 REFERENCES

PacifiCorp. 1995. Application for new license for major modified project. North Umpqua Hydroelectric Project, FERC Project No. 1927, Douglas County, Oregon. Portland, Oregon.

Stillwater Sciences (2000). Geomorphic effects of Soda Springs dam and potential effects on aquatic habitat, Prepared by Stillwater Sciences, Berkeley, California for PacifiCorp, Portland, Oregon.

Appendix 1. Technical Work Group Members

NAME	AFFILIATION	PHONE #
Craig Tuss	USFWS	541-957-3470
Janine Castro	USFWS	503-231-6179
Dave Loomis	ODFW	541-440-3353
Ken Homolka	ODFW	541-440-3353
Larry Broeker	USFS	541-957-3403
Dean Grover	USFS	541-416-6673
Pam Sichting	USFS	541-957-3342
Craig Street	USFS	541-498-2531
Rich Grost	PacifiCorp	541-498-2617
Eric Lesko	PacifiCorp	503-813-6624

Appendix 2. Spawning Enhancement Below Soda Springs Site Criteria. Reviewed and concurred with by RCC September 17, 2002.

1. Location
   - θ Near the original project sites are preferred
   - θ Site selected incrementally downstream in the mainstem N. Umpqua, and then in the tributaries as needed

2. Engineering Intensity
   - θ Natural materials preferred over construction materials

3. Sustainability
   - θ Minimize need for ongoing maintenance

4. Confidence of Success
   - θ Selection based on professional judgment
   - θ Selection not experimental

5. Access to the site

6. Wild and Scenic
   - θ Few conflicts with Wild and Scenic
   - θ Size: Appropriate log size
   - θ Type: Boulders preferred over wood
   - θ Rafter safety

7. Good Cost/Benefit Ratio

8. Low Total Cost

9. Species Benefits
   - θ Contributes to restoration of Spring Chinook
   - θ Aids others species without jeopardizing endangered species (Coho Salmon)

10. Existing Habitat not Negatively Affected

11. Impact on Infrastructure
    - θ Low impact to Highway 138, Twin Lakes Road, and bridges

12. Hydrologic/Geomorphic Appropriateness

13. Special Considerations if Site is in Soda Springs Bypass
    - θ Multispecies and flow issues considered

Appendix 3. Potential Spawning Gravel Enhancement Sites in the Mainstem North Umpqua River Between Soda Springs Dam and Horseshoe Bend. Key to Symbols *=Sites also identified by the Technical Work Group, s=Spawning habitat, h=Holding habitat, r=Rearing habitat.

Criteria	Site Numbers for Potential Enhancement Sites														
	1*	3*	4*	6*	7*	9*	11	12 a & b	13	14	15	16	17	18	19
Presence of existing bars patches (particle size distribution)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Existing hydraulic roughness elements	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Favorable hydraulics/hydraulic complexity	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Channel planform (e.g., curvature, widening)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Local slope	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Existing spawning utilization	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Local upstream sediment supply	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	yes	Yes	Yes	Yes
Anthropogenic disturbance (e.g., reduced, altered hydrology)	Yes														
TWG Priority	High	Med-High	Low	Med-High	Med-High	High	Low	Low	Low	Low	Low	Low	Med-Low	Low	Low
Distance from Soda Springs Dam	0.1 mi														
Access	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N
Existing habitat values	$CH_{s,h,}$	$CH_{s,h}$	$_{r}$	$CH_{s,h}$	$CH_{s,h}$	$_{r}$	CH_hS_h		CH_r,S_r	CH_s	CH_r,C_r				
Existing infrastructure	Bridge, road	None	None	Bridge	Bridge, road	None	None	None	None	Road	None	None	None	None	none
Wild and Scenic	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Potential habitat (Sq.Ft.)	4,000-5,000	1,000	1,000-1,500	1,000 - 2,000	1,000	1,000-2,000	N/A	N/A	Micro-sites 500	N/A	N/A	2,000 - 4,000	N/A	N/A	N/A
Recreation considerations	No	Yes	Yes	Yes	Yes	N/A	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

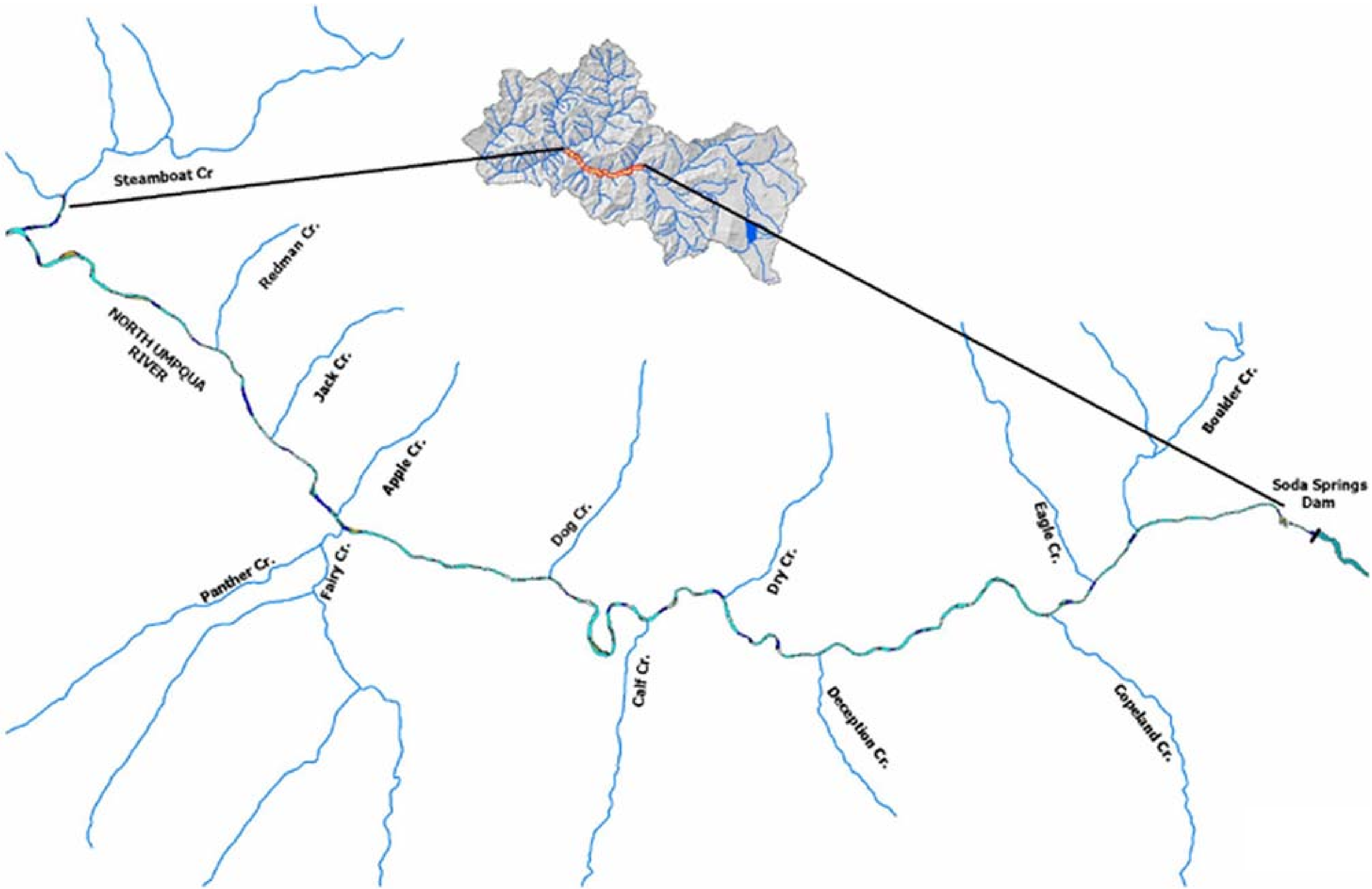


Figure 1. Assessment area.

Stillwater Sciences

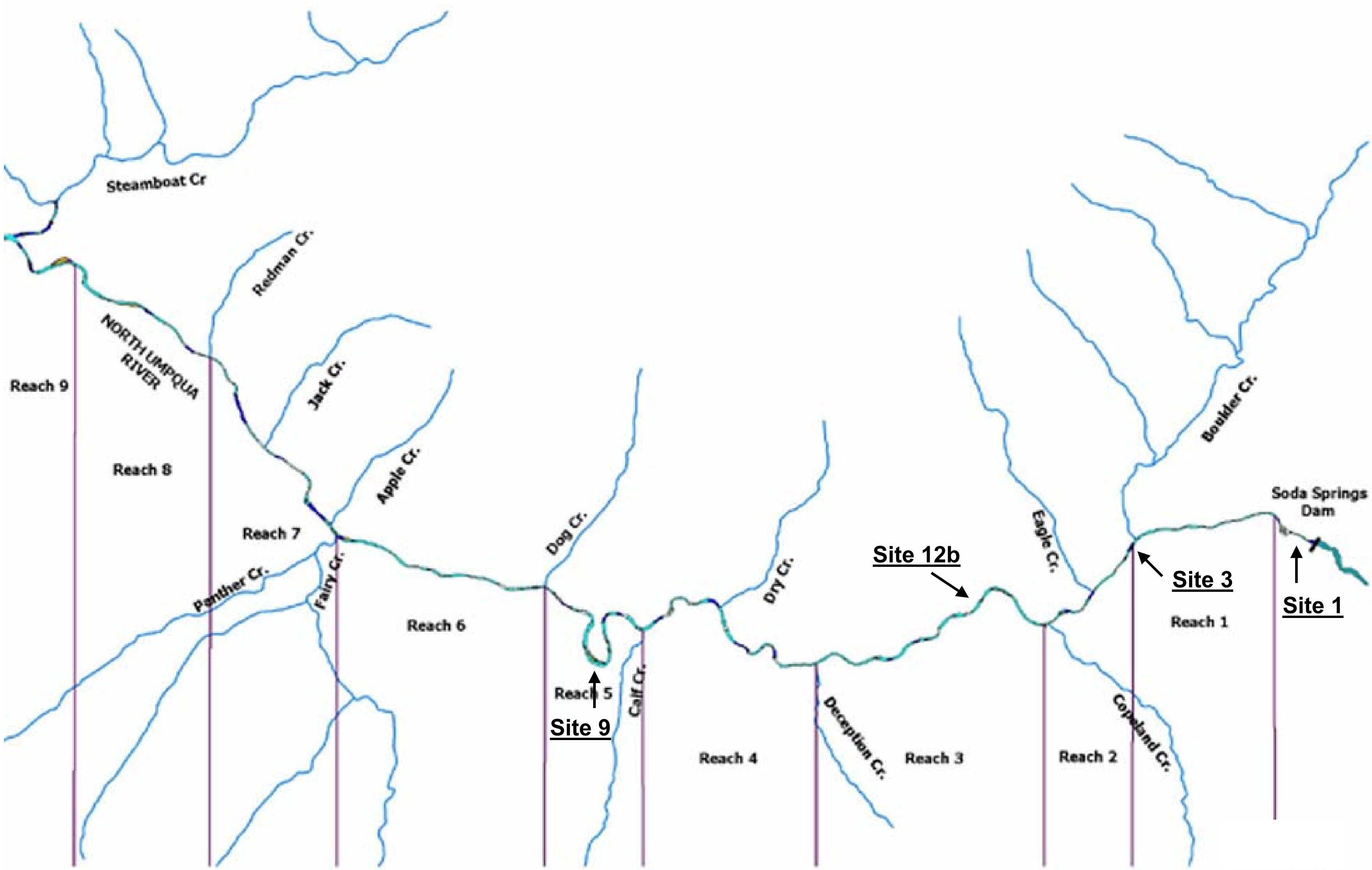


Figure 2. Four priority enhancement sites identified by the Technical Work Group.

Stillwater Sciences

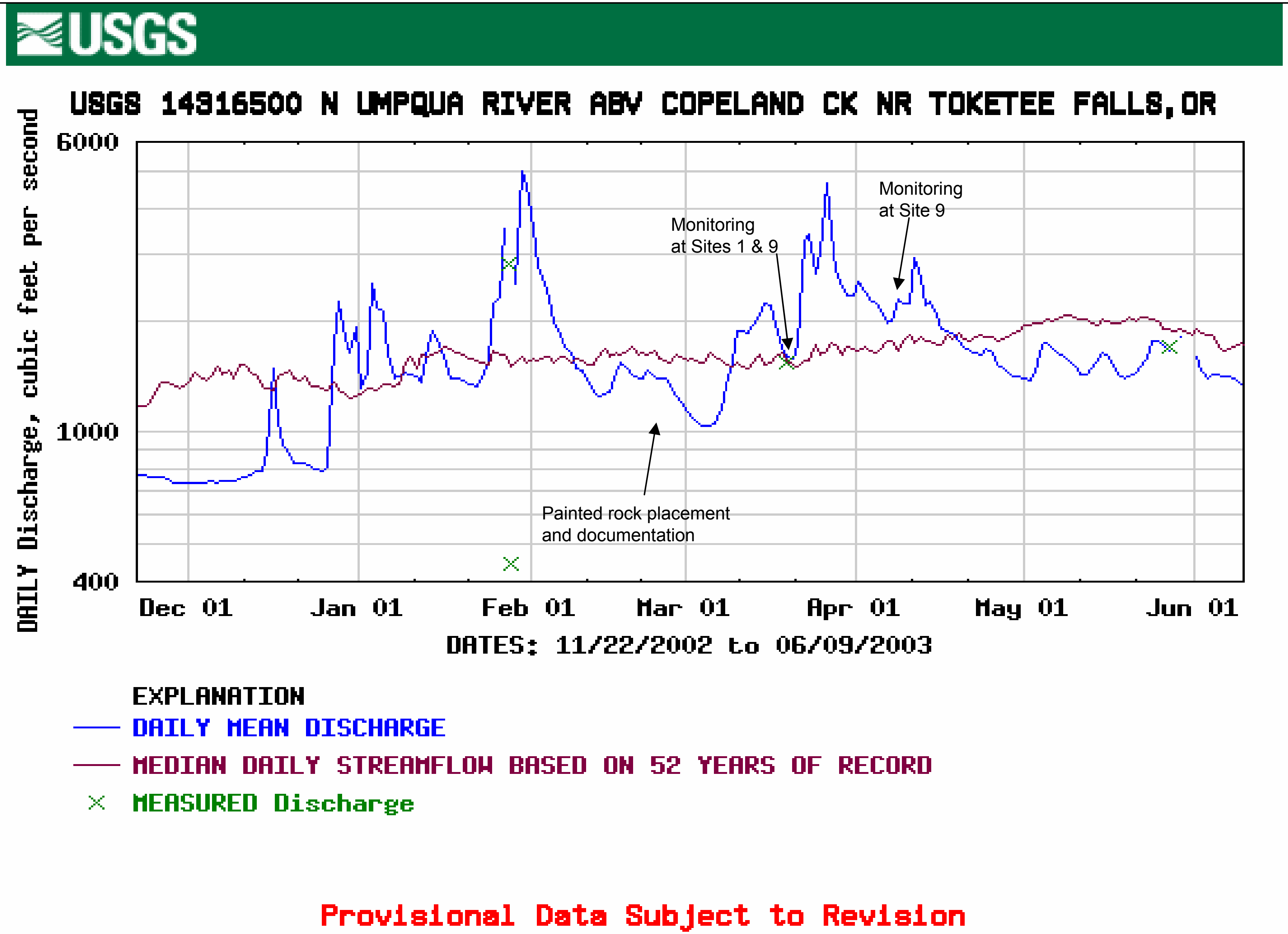


Figure 3. USGS hydrograph of daily mean discharge at the Copeland gage, indicating when painted rocks at Sites 1 and 9 were placed and monitored.

26 February 2003, installation of painted rocks

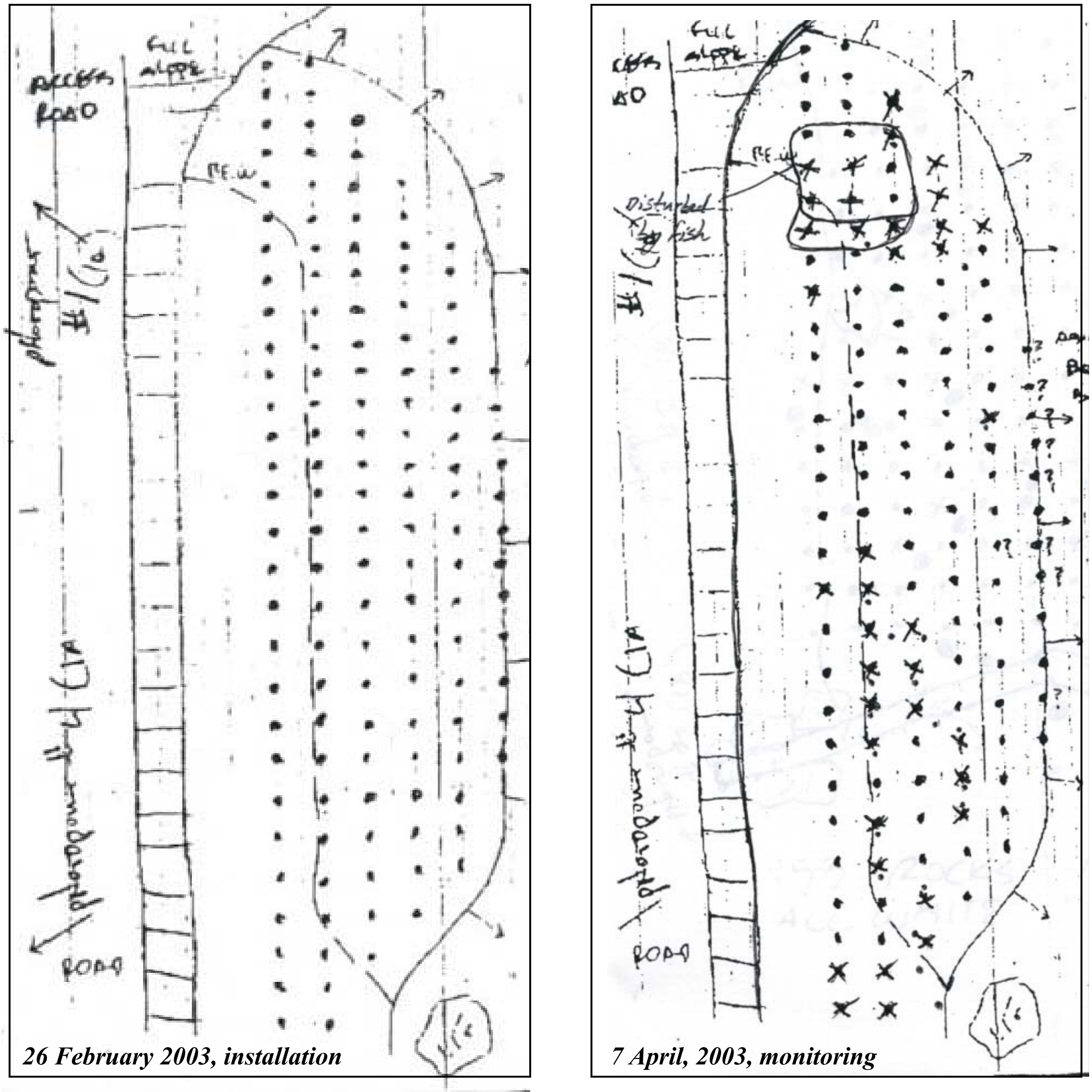
7 April 2003, monitoring of painted rocks

Figure 4. Site 1a from photo point 1 during winter and spring 2003.

26 February 2003, installation of painted rocks

7 April 2003, monitoring of painted rocks

Figure 5. Site 1a from photo point 4 during winter and spring 2003.



26 February 2003, installation

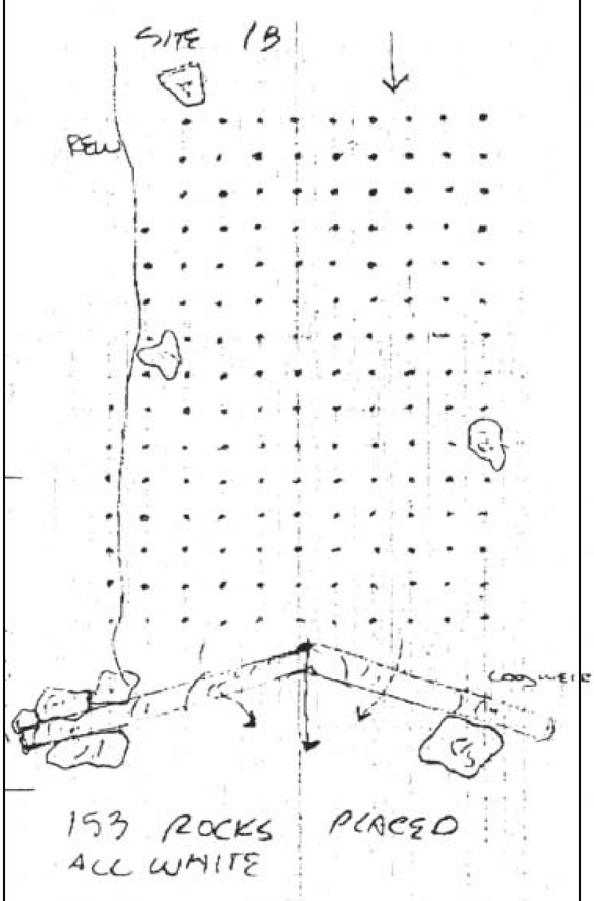
7 April, 2003, monitoring

Figure 6. Site sketches of site 1a during installation and monitoring.

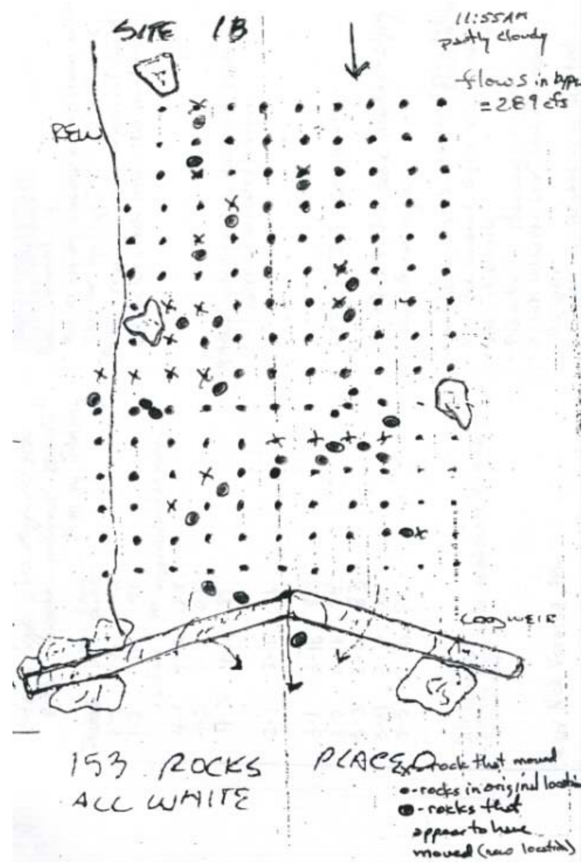
26 February 2003, installation of painted rocks

7 April 2003, monitoring of painted rocks

Figure 7. Site 1b from photo point 2 during winter and spring 2003.



26 February 2003, installation



7 April 2003, monitoring

Figure 8. Site sketches of site 1b during installation and monitoring

26 February 2003
installation of painted rocks

20 March 2003
monitoring of painted rocks

7 April 2003
monitoring of painted rocks

Figure 9. Site 9 from photo point 1 during winter and spring 2003.

26 February 2003
installation of painted rocks

20 March 2003
monitoring of painted rocks

7 April 2003
monitoring of painted rocks

Figure 10. Site 9 from photo point 5 during winter and spring 2003.

26 February 2003
installation of painted rocks

20 March 2003
monitoring of painted rocks

7 April 2003
monitoring of painted rocks

Figure 11. Site 9 from photo point 4 during winter and spring 2003.

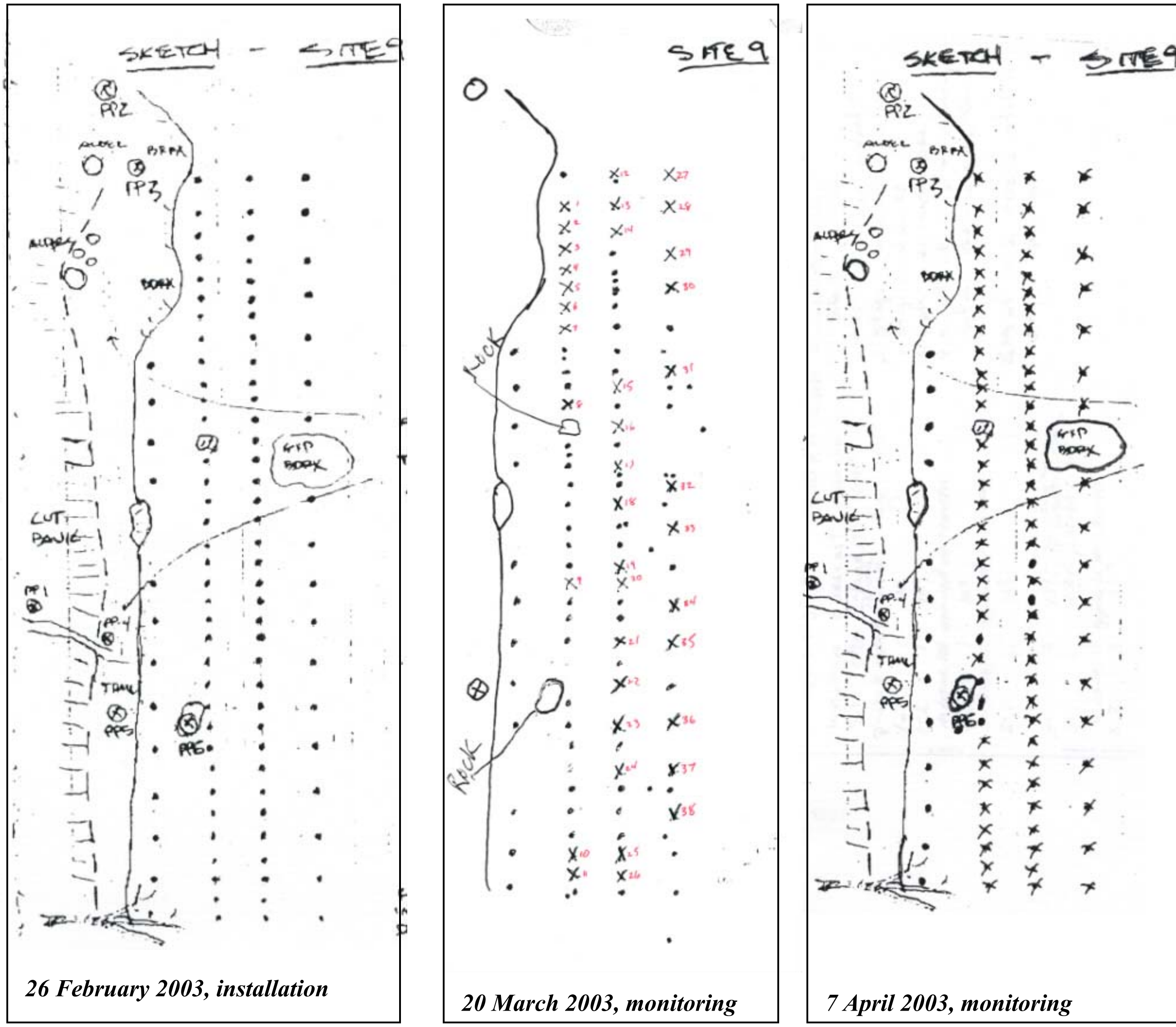


Figure 12. Site sketches of site 9 during installation and monitoring.

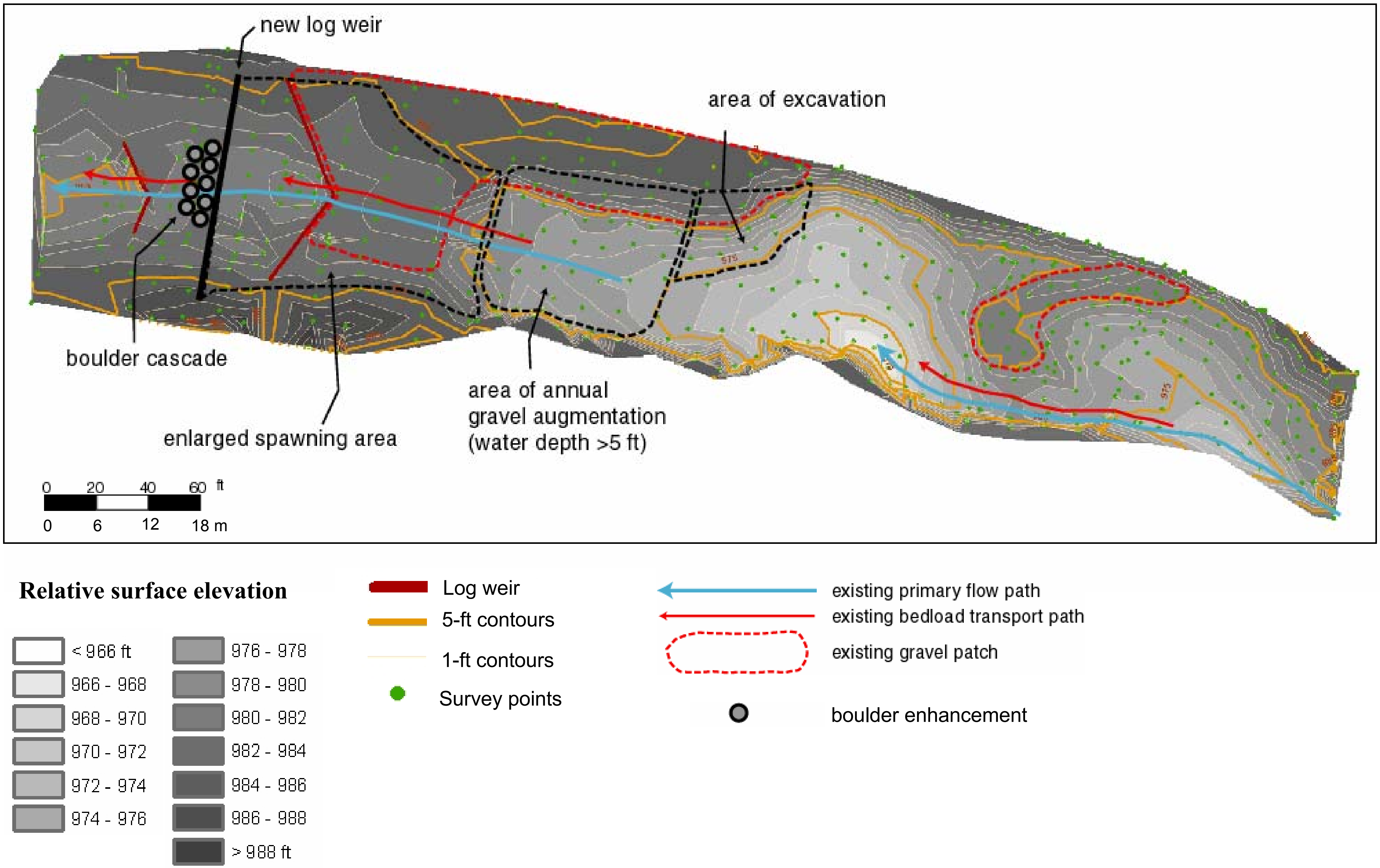


Figure 13. Site 1 existing conditions and proposed conceptual design.

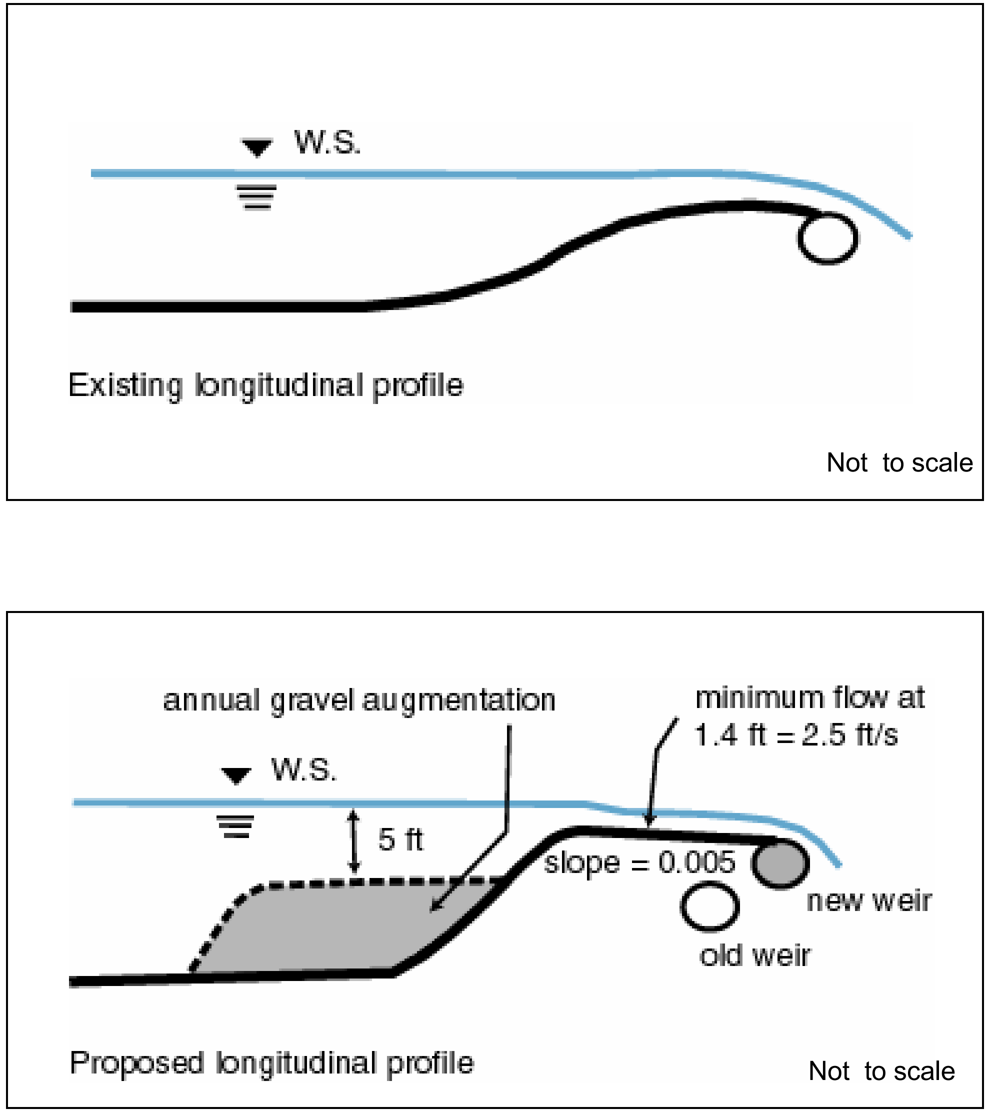


Figure 14. Schematic of Site 1 existing and proposed longitudinal profile.

Stillwater Sciences

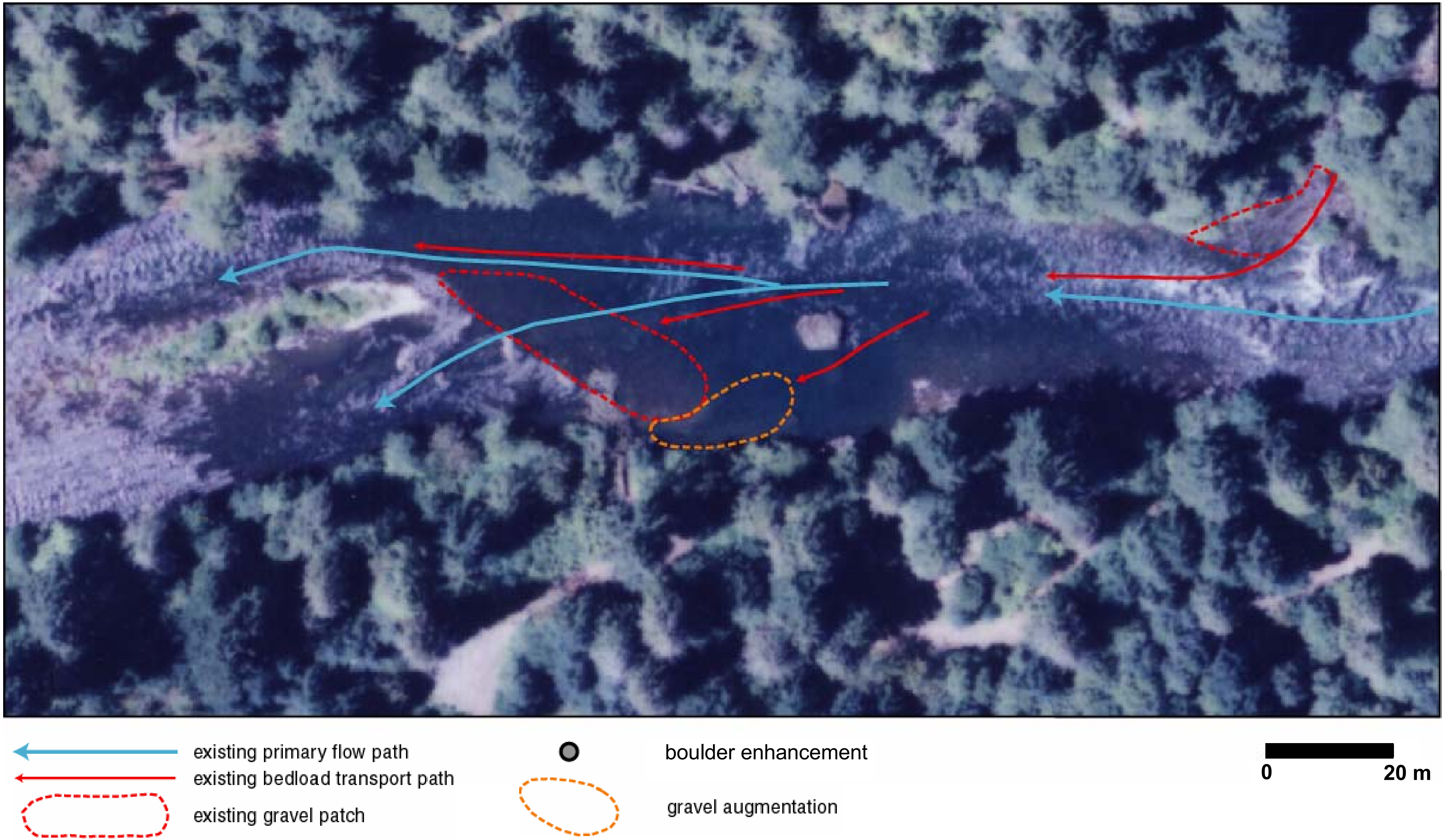


Figure 15. Site 3 existing conditions and proposed conceptual design.

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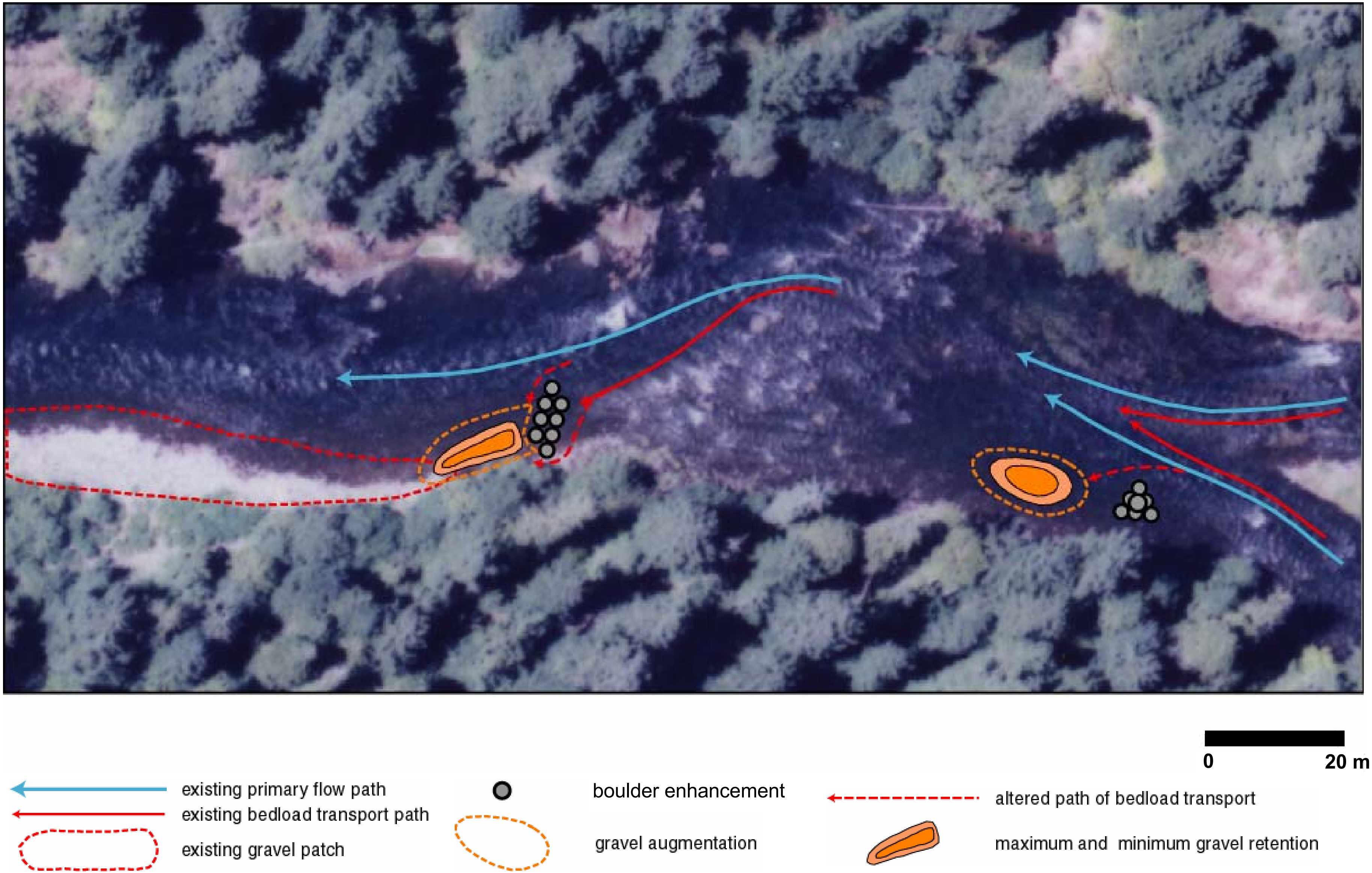

Figure 16. Site 12b existing conditions and proposed conceptual design.

Stillwater Sciences

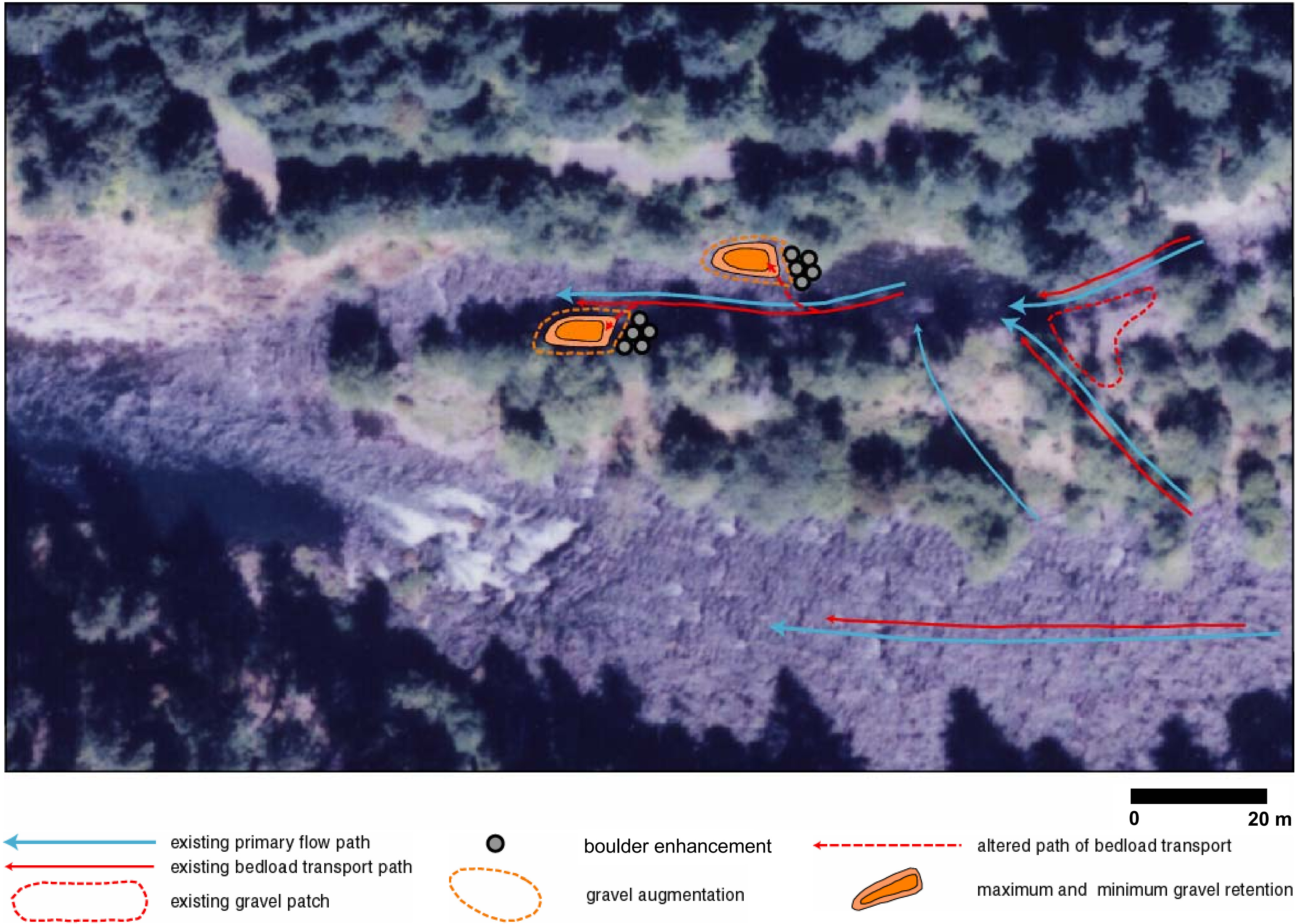

Figure 17. Site 9 existing conditions and proposed conceptual design.