BIG HANAFORD CREEK FLOODPLAIN AND WETLAND RESTORATION PROJECT AS MITIGATION FOR A SURFACE COAL MINE PROJECT

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Abstract. This paper presents the restoration design process and construction activities associated with the Big Hanaford Creek restoration project. The project was completed as part of required wetland mitigation to compensate for adjacent plant and mine activities requiring state and federal wetland permits. Big Hanaford Creek is a tributary to the Skookumchuck River in Lewis County, Washington, with its headwaters in the foothills of the Cascade Mountains, and with lower reaches in low gradient floodplain valleys. Within its lower reaches, a 4800-meter portion of the creek was straightened and deepened approximately 90 years ago when the valley was drained for agricultural purposes. Most recently, the floodplain surrounding the creek was used for grazing and mowing of pasture grasses for hay production. In an effort to rehabilitate in-stream habitat, reconnect the creek to the floodplain, and return native floodplain vegetation to the valley, a 61-hectare restoration project is underway. The project includes excavating 63,460 cubic meters of soil to relocate 2,286 linear meters of the stream back to a historical channel alignment; installing in stream wood structures for fish habitat; creating a new channel cross section with a bench at spring water surface elevations; planting willows along the reconfigured channel; creating low lying floodplain swales, and planting over 290,000 native trees, shrubs, and sedge plugs in the floodplain. Aerial photographs were used to identify a past historical meander pattern to serve as the new stream alignment and Government Land Survey Office field notes from 1867 were used to identify the historical wetland floodplain plant community. Construction occurred over an 18-month period to allow for channel excavation and included construction of approximately 150 in-stream wood structures during the dry season; and installation of plants the following spring. A 10-year monitoring program is being developed to monitor hydrologic performance and establishment of the native vegetation. This project is located immediately west of the TransAlta Centralia Generation Plant and Mine operations on land currently owned by the TransAlta Corporation.

Additional Key Words: stream relocation, fish habitat improvement, wetland restoration, floodplain connectivity, wetland mitigation.

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Introduction

TransAlta Centralia Mining LLC (TCM) owns and operates a 5,848-hectare (14,450-acre) coal mine as permitted by the Office of Surface Mining Reclamation and Enforcement (OSM). The mine is located in the low foothills of the Cascade Mountains in Southwestern Washington State. In 2005, TCM proposed the Kopiah project which included the extraction of overburden and coal from the existing Kopiah Pit with the resultant spoils to be placed in a new area called the Kopiah Excess Spoils Area (KESA). KESA was designed to receive approximately 940,402 cubic meters (123 million cubic yards) of excess spoils. In addition, the Kopiah Project also included the development of a sedimentation pond to collect runoff from new mining activities associated with the Kopiah Pit.

Average rainfall at the mine is approximately 122 centimeters (48 inches) per year with many of the floodplain areas being large wetlands regulated by the U.S. Army Corps of Engineers, Washington Department of Ecology, and local counties. Due to the prevalence of wetlands in the permit area, the Kopiah project impacted 8.8 hectares (21.7 acres) of regulated wetlands, 2,784 meters (9,134 linear feet) of low gradient streams, and 8,839 meters (29,000 linear feet) of high gradient intermittent drainage channels. Other resource agencies with regulatory status over the project included Washington Department of Fish and Wildlife for in-stream water impacts and U.S. Fish and Wildlife Service and National Marine Fisheries Service for compliance with the Endangered Species Act.

TCM submitted a Joint Aquatics Resource Application to the wetland regulatory agencies to place fill in the wetlands and streams for the Kopiah project. At the time of submission, this was one of the largest wetland fill applications received by the Seattle Corps District. A series of meetings between TCM and the resource agencies were held over a 12-month period to discuss the project's wetland and stream impacts and mitigation requirements. Wetland and stream permits were issued to TCM in September 2005 based on the agencies' acceptance of a mitigation plan TCM was required to implement. The primary element of the mitigation involved the rehabilitation of approximately 44.5 hectares (110 acres) of degraded wetland floodplain and realignment of 2,286 meters (7,500 linear feet) of a straightened, channelized stream back to a historical alignment.

Project Impacts

Numerous field studies were conducted to characterize the condition of wetlands to be filled by the project. Project impacts occurred within the Packwood Creek and South Hanaford Creek subbasins, tributaries to Big Hanaford Creek. Wetland delineations identified the acreage of wetlands, and wetland functions were evaluated utilizing Ecology's Functional Assessment Methodology (Hruby et al., 1999). The Kopiah project filled a total of 8.8 hectares (21.7 acres) of emergent, scrub-shrub, and forested wetlands that provided a variety of hydrologic, water quality, and habitat functions. The primary wetland functions affected by the Kopiah project were sediment/nutrient removal, reduction of peak flows, groundwater recharge, wildlife habitat, and native plant species richness. An analysis of stream functions was conducted using the Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers (EPA, 1990). The results of this assessment showed that sedimentation in the existing streams limited use by macroinvertebrates, and downstream obstructions limited use by coho salmon, steelhead, and resident fish species. Riparian habitat was present to provide cover and use by wetland and riparian-associated species. The primary function of high gradient intermittent drainages was to convey seasonal runoff into associated wetlands.

Mitigation Approach

To receive wetland and stream fill permits, TCM developed a mitigation approach to compensate for the wetland and stream impacts to meet state and federal mitigation regulations. To achieve the goal of compensating for the impacts, a site selection study was conducted to identify a mitigation site within the same watershed that had a high potential for restoration. The study included site reconnaissance of potential wetland mitigation sites, and use of Ecosystem Diagnosis Treatment (EDT) (Lestelle et al., 2004). EDT is a habitat model that can be used to assess current stream habitat potential, identify limiting factors, and evaluate potential restoration alternatives within a watershed.

Based on the site reconnaissance and EDT analysis, the highest priority area for wetland and stream restoration in the Hanaford Creek watershed was lower Big Hanaford Creek. Lower Big Hanaford Creek was selected because the site had limited wetland and stream habitat functions such as the lack of native floodplain wetland plant communities, channelized/straightened stream reaches, lack of connectivity of stream flow to surrounding floodplain, lack of in stream habitat structures, lack of riparian cover and high stream temperatures, and lack of off channel aquatic habitat.

The lower Big Hanaford Creek site represented a site with high potential for restoration opportunities. The mitigation site was also was consistent with the Corps' surface coal mining mitigation guidance for mitigating within the same local watershed, to the extent possible, where the project impacts occur. Lower Big Hanaford Creek also provided long-term restoration opportunities since it would not be affected by future mining activities (located outside of the OSM mine permit area) and would be located on land owned by TCM. The mitigation site selected was a 44.5-hectare (110-acre) parcel that had been used for many years for livestock grazing and mowing of pasture grasses for straw bales. Big Hanaford Creek flowed through the middle of the site in a linear channel straightened in the early 1900's to help drain water and facilitate agricultural land use.

The mitigation approach consisted of filling the existing straightened channel and realigning Big Hanaford Creek to follow a historical alignment as observed on aerial photographs. The new stream's cross section was also shaped to improve connection of high stream flows to the adjacent floodplain. Off channel aquatic habitat was created and approximately 42.5 hectares (105 acres) of the adjacent floodplain were planted with native wetland herbaceous, shrub, and tree species.

Methods for Restoration Design

The restoration method was based on designing a project that would increase the mitigation site's hydrologic, habitat, and water quality functions. Four objectives associated with this goal were:

- Improve hydrologic functions by increasing flood storage capacity, connecting the stream flows and adjacent floodplain, and increasing the flooded wetland area and width relative to Big Hanaford Creek;
- Improve water quality functions by increasing the width ratio of flooded wetland relative to the creek and increasing the area or duration of flooded clay soils;
- Improve habitat functions by increasing canopy closure on the floodplain and riparian stream cover, increase number of vegetation classes, improve vegetation structure and

number of strata, increase number of snags and large woody debris on the floodplain and in the creek; and

- Improve fish passage for anadromous fish and improve in stream habitat conditions for aquatic organisms.

Methods for designing the restoration project are described below and included evaluating the pre-mitigation site conditions, designing the new stream channel alignment, and developing a vegetation planting plan.

Pre-Mitigation Project Site Conditions

Developing the restoration design required an understanding of the mitigation site's pre-construction conditions. An ecological site assessment of the channelized stream and surrounding pastureland floodplain was conducted to assess the pre-mitigation channel characteristics and wetland vegetation, soil, and hydrologic functions.

Hydrologic analysis of Big Hanaford Creek identified a watershed area of 74.1 square kilometers (28.6 square miles) at the mitigation site. The lower reaches of Big Hanaford Creek can be considered a response reach based on its position within the watershed and the relative balance of transport capacity to sediment supply (Montgomery and Buffington, 1998). In the early twentieth century Big Hanaford Creek was channelized along a 4.8-kilometer (3-mile) segment to improve drainage for agricultural purposes. Despite channelization, the pre-mitigation stream gradient at the mitigation site was about 0.0002. The valley bottom areas of Big Hanaford Creek are typically featureless pastureland, characterized by poorly drained conditions due to silty clay subsoil horizons. The channel ranges from approximately 12.2 to 13.7 meters (40 to 45 feet) wide at the top of bank and up to 3.96 meter (13 feet) deep when dredged spoils berms adjacent to the creek are considered. These berms isolated much of the channel from the floodplain. The channel cross section is typically trapezoidal with steep banks and very little to no woody riparian cover.

A 33-year data set of daily precipitation records and monthly spot stream flow data was also used to develop continuous rainfall/runoff models and hydrologic and hydraulic models using Mike 11 and HEC RAS to better understand stream flow conditions. Using a continuous rainfall/runoff model, flow measurements of Big Hanaford Creek from 1972 to present indicate mean monthly flows range from about 0.28 cubic meter per second (cms) (10 cubic feet per second (cfs)) during dry summer months to a monthly mean peak of 4.56 cms (161 cfs) in December. Maximum flows as measured from monthly spot data occur periodically with a peak of 28.3 cms (1000 cfs) and flows of greater than 17 cms (600 cfs) measured twelve times since 1972. Hydrologic model simulations (Mike 11 and HEC RAS) indicate that the previous straightened channel condition had an average bank full capacity ranging from approximately 22.66 cms (800 cfs) (upstream) to 25.5 cms (900 cfs) (downstream). Valley wide flooding would occur at these flows. Some localized flooding would occur next to the creek at slightly lower flows 17-22.7 cms (600-800 cfs) where several side drainage channels were connected to the creek through the sidecast berm. Silty clay subsoils, overbank flooding, and ponding of water from rainfall and overland runoff would create saturated soil conditions to support wetlands in the pasture lands in pre-mitigation project conditions.

Although native floodplain soils are present and soil profiles are generally consistent with those described in local soil surveys, the vegetation was dominated by nonnative pasture grasses such as reed canarygrass (*Phalaris arundinacea*), bentgrass (*Agrostis tenuis*), and fescue (*Festuca arundinacea*). Remnant patches of native shrubs and scattered ash trees were present on the site.

Stream Channel Design.

The primary components of the restoration design were the realignment of 2,286 meters (7,500 linear feet) of Big Hanaford Creek and the planting of native wetland vegetation along the channel and adjacent floodplain. Figure 1 shows the project site's restoration design with the alignment for the constructed channel and the associated vegetation communities.

Stream channel design focused on construction of a new channel to support wetland and riparian vegetation and rehabilitate quality rearing and over-wintering habitat for anadromous and resident salmonids. Realignment of the constructed channel used aerial photographs to identify a past historical stream planform alignment, combined with field investigations where swale-like topography coincided with the patterns on the aerial photograph. The remnant historical channel generally matched the location of Big Hanaford Creek on USGS topography maps of the early 1900s and Government Land Survey notes from 1867. Comparison of geomorphic characteristics of the straightened channel condition and the restored stream conditions are shown in Table 1.

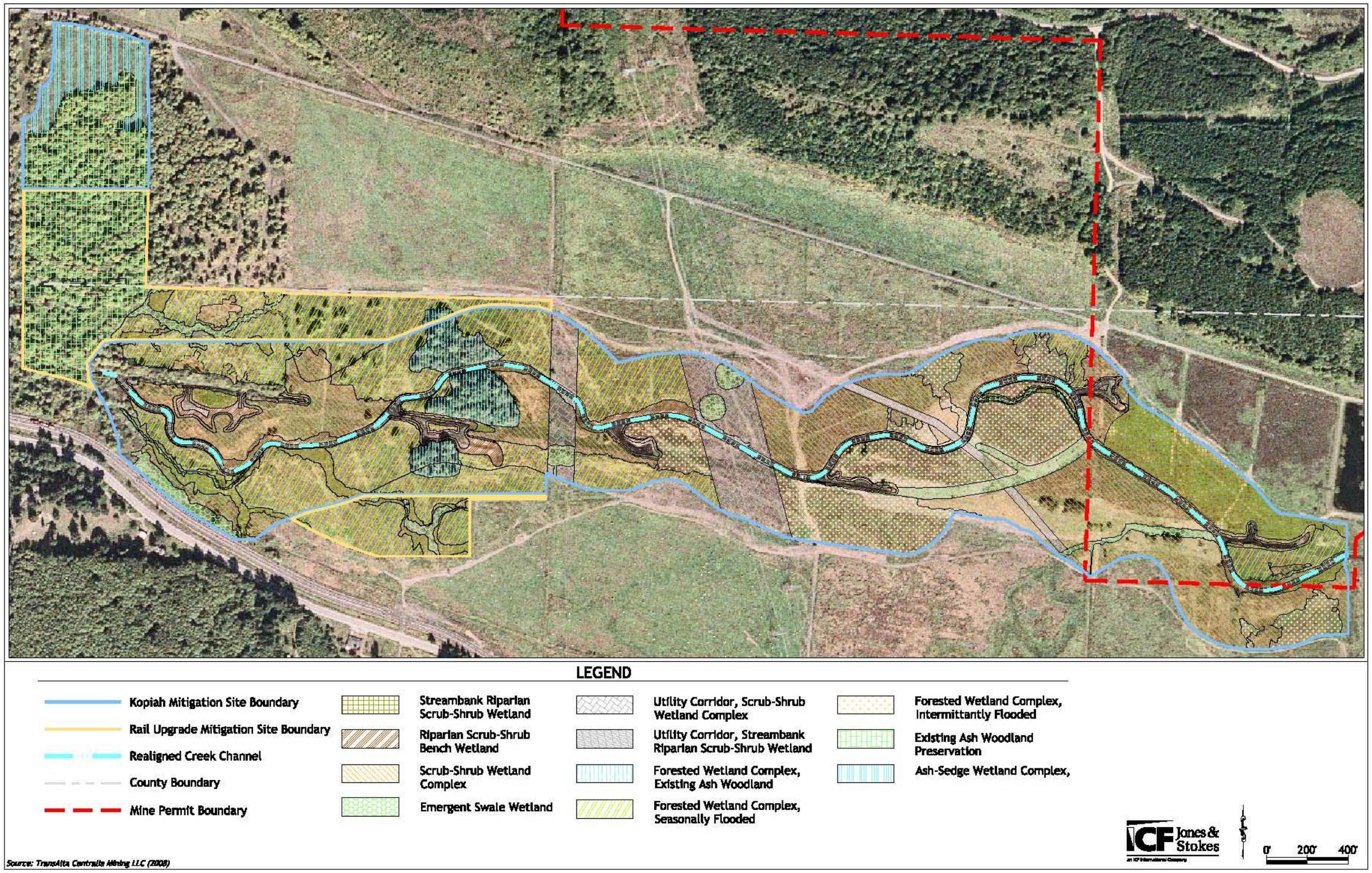

Figure 1. Mitigation site showing stream realignment and associated plant communities.

Table 1. Comparison of geomorphic characteristics of existing and proposed stream channels.

Geomorphic Characteristic	Straightened Alignment	Restored Alignment
Characteristics similar between both channels (not likely to change significantly as a result of mitigation)		
Average sediment size	Small (predominantly clay)	Small (predominantly clay)
Average sediment load	~4.1mtons/km^2 (~ 11.7 ton/mi^2)	~4.1mtons/km^2 (~ 11.7 ton/mi^2)
Bed load/total load ratio	Low	Low
Valley slope	0.0002	0.0002
Stream slope	0.0002	0.00036
Valley width	610-762 m (2,000 - 2,500’)	610-762 m (2,000 - 2,500’)
Top width	12.2-13.7 m (40-45’)	~ -13.7 – 14.8 m (45-48)’
Characteristics dissimilar (changed as a result of mitigation)		
Channel length	1,898 m (6,228’)	2,286 m (7,500’)
Bottom width	3.0 – 4.6 m (10-15’)	1.8 m (6’)
Width of channel forming flow	~ 4.6 - 6.1 m (~ 15-20’)	~7.6 m(~ 25’)
Depth of channel forming flow	~2.1 – 3.9 m(~ 7-13’)	~ 1.5 – 2.1 m (~ 5’-7’)
Width:depth ratio for geomorphic bankfull surface	1.5-2 (somewhat deep)	5 (somewhat shallow)
Sinuousity	1.0 for upper reach (straight); 1.0 for lower reach (straight)	1.3 for upper reach (slightly sinuous); 1.2 for lower reach (slightly sinuous)
Average meander belt width	n/a	55.5 m (182’) in upper reach; 64.9 m (213’) in lower reach
Average bend radius	n/a	26.2 m (86’) in upper reach; 15.8 m (52’) in lower reach
Average meander wavelength	n/a	277 m (909’) in upper reach; 254 m (834’) in lower reach
Average channel curvature (average bend radius / average channel width at bankfull discharge)	n/a	3.4 in upper reach; 1.4 in lower reach
Riparian vegetation condition	Absent or low cover from native shrubs in upper reach, moderate cover in lower reach	High cover from willow and other shrub species along full channel
Channel bed variability and type	Low (mostly long glides with some pools)	Medium (glides with approximately 27 created pools)
Bank stability	Low	Moderate during initial period of vegetation establishment; high afterwards
Degree of incision	High	Low
Relative stability	Moderate	High

Note = Proposed alignment in this table refers to the "upper reach" - upper reach is defined as the 1,036 meter (3,400 foot) portion of Big Hanaford Creek. The "lower reach" is defined as the western downstream 1,250-meter (4,100 - foot) portion. Both are presented to demonstrate the designs are compatible from a landscape-scale perspective.

Stream channel cross section design was developed through an iterative design process that used hydrologic data generated by HEC RAS models to identify channel geometry to meet geomorphic, fisheries, and vegetation objectives. Critical discharges/stages were identified for riparian and wetland vegetation and salmonids. Channel width and depth were developed based on flood frequency requirements (i.e., at least once every two years), existing topography, and channel bed slope. The newly constructed channel cross section was designed to increase the frequency of overbank flow onto the floodplain and restore hydrologic connectivity between the channel and the floodplain.

The primary channel design constraint was that the channel thalweg elevation within the 2,286-meter (7,500-foot) realigned channel had to meet channel thalweg elevations at the upstream and downstream connection points to the existing creek. Although the channel had been artificially deepened many years ago, a shallower channel depth for the constructed channel was determined not to be a viable option since a raised elevation to the channel bed would have created a hydraulic "pinch point" and increased potential for upstream flooding that could interfere with existing mining or generation plant operations. Therefore, the constructed channel has a maximum channel depth of 2.7 to 3 meters (9 to 10 feet) to match the existing channel with a maximum top of channel width of 13.7 meters (45 feet). (Note: the maximum channel depth is a different measurement than the channel forming flow identified in Table 1; channel forming flow depth is considered the depth at which flows do the most geomorphic work within the channel.) However, the constructed channel cross section is improved over the previous condition by constructing a low flow 1.8-meter- (6-foot-) wide channel bottom, the inclusion of a 1.2 to 2.4-meter- (4 to-8-foot-) wide planting bench located on inside bends to facilitate riparian willow plantings adjacent to the low flow channel, and gradual sloping connections to the surrounding floodplain. The channel bench is located approximately 1.1 to 1.4 meters (3.5 to 4.5 feet) above the channel bottom, which correlates to approximately 0.3 meter (1 foot) above summer low flow conditions, to support willow plantings on the benches. Hydrologic modeling confirmed channel velocities would be sufficient to support fisheries habitat during low flow, and not be excessive during high flow to erode channel banks in the silty clay subsoils.

Fish habitat improvements included the construction of 130 in stream large woody habitat structures including single root wads, multiple interconnected root wads, and undercut bank structures. In addition, 184 branch bundles were installed along the banks to provide additional fish cover and macroinvertebrate refugia/habitat. In-stream structures were designed to withstand 100-year flow velocities and were anchored by burying in the channel banks and with soil anchors. Additional fish habitat was created by constructing six off channel alcoves with root wads installed along the sides and large logs anchored in the middle of the alcoves.

Vegetation Planting Plan

The vegetation planting plan was designed to restore wetland vegetation communities along a 182.9- to 304.8-meter- (600- to 1,000-foot-) wide corridor along the restored creek. Forest and scrub-shrub wetlands were planted on the floodplain, and emergent wetlands communities were planted on the floodplain in linear swales that drain into the creek. Plant species selected for the forest, scrub-shrub, and emergent communities were based on observations of existing native species growing in remnant patches along the Big Hanaford Creek floodplain. Additionally, the target plant communities are consistent with plant species growing in these soils on the Big Hanaford Creek floodplain as noted in the 1867 Government Land Survey notes. Common species mentioned in "swamp" areas from the Land Survey notes include willow, alder, ash, crabapple, "briars", and cedar. Plants were installed in the native topsoil to facilitate plant growth and establishment. Table 2 identifies the plant species used for the different plant communities. Riparian scrub-shrub bench wetlands refer to the plant community along the bench constructed adjacent to the low flow channel, and streambank riparian scrub-shrub wetlands refer to the plant community along the upper slopes of the stream channel banks above the bench.

Locations of the plant communities were based on the anticipated hydrologic conditions on the floodplain using Mike 11 modeling of flooding scenarios. Although the floodplain is generally featureless with respect to obvious topographic changes, subtle differences in topography create areas that are more seasonally flooded vs. areas not as wet and are less frequently flooded or flooded/ponded for shorter periods. Scrub-shrub wetlands and intermittently flooded wetlands were considered the "drier" plant communities.

Table 2. Proposed plant species for Big Hanaford Creek wetland/riparian plant communities.

Common Name	**Scientific Name**	**Indicator Status[1]**
Riparian Scrub-Shrub Bench Wetland – 2.14 hectares (5.31 acres)		
Pacific willow	*Salix lucida ssp. lasiandra*	FACW
Sitka willow	*Salix sitchensis*	FACW
Streambank Riparian Scrub-Shrub Wetland -4.49 hectares (11.09 acres)		
Red-osier dogwood	*Cornus stolonifera*	FACW
Pacific willow	*Salix lucida ssp. lasiandra*	FACW
Sitka willow	*Salix sitchensis*	FACW
Nootka rose	*Rosa nutkana*	FAC
Forested Wetland Complex - Seasonally Flooded 11.51 hectares (28.44 acres)		
Black cottonwood	*Populus trichocarpa*	FAC
Oregon ash	*Fraxinus latifolia*	FACW
Western red cedar	*Thuja plicata*	FAC
Crabapple	*Malus fusca*	FAC
Salmonberry	*Rubus spectabilis*	FACW
Sitka willow	*Salix sitchensis*	FACW
Pacific willow	*Salix lucida ssp. lasiandra*	FACW
Douglas' hawthorne	Crataegus douglasii	FAC
Nootka rose	*Rosa nutkana*	FAC
Forested Wetland Complex - Intermittently Flooded – 6.72 hectares (16.59 acres)		
Black Cottonwood	*Populus trichocarpa*	FAC
Oregon Ash	*Franxinus latifolia*	FACW
Western red cedar	*Thuja plicata*	FAC
Nootka rose	*Rosa nutkana*	FAC
Pacific ninebark	*Physocarpus capitatus*	FAC
Douglas' hawthorne	*Crataegus douglasii*	FAC
Crabapple	*Malus fusca*	FAC
Forested Wetland Complex - Existing Ash Forest – 1.76 hectares (4.36 acres)		
Oregon Ash	*Franxinus latifolia*	FACW
Western red cedar	*Thuja plicata*	FAC
Nootka rose	*Rosa nutkana*	FAC
Salmonberry	*Rubus spectabilis*	FACW
Snowberry	*Symphoricarpos alba*	FACU
Ash-Sedge Wetland Complex 1.66 hectares (4.1 acres)		

Common Name	Scientific Name	Indicator Status[1]
Oregon Ash	*Fraxinus latifolia*	FACW
Scrub-Shrub Wetland Complex 12.29 hectares (30.35 acres)		
Crabapple	*Malus fusca*	FAC
Pacific ninebark	*Physocarpus capitatus*	FAC
Salmonberry	*Rubus spectabilis*	FACW
Sitka willow	*Salix sitchensis*	FACW
Nootka rose	*Rosa nutkana*	FAC
Douglas' Hawthorne	*Crataegus douglasii*	FAC
Utility Corridor Scrub-Shrub (Riparian and Palustrine)[2] – 3.36 hectares (8.29 acres)		
Crabapple	*Malus fusca*	FAC
Pacific ninebark	*Physocarpus capitatus*	FAC
Nootka rose	*Rosa nutkana*	FAC
Salmonberry	*Rubus spectabilis*	FACW
Sitka willow	*Salix sitchensis*	FACW
Emergent Swale Wetland 1.03 hectares (2.55 acres)[3]		
Slough Sedge	*Carex obnupta*	OBL
Small-fruited Bulrush	*Scripus microcarpus*	OBL

[1] Indictor status refers to one of the categories used by the U.S. Army Corps of Engineers that describes the estimated probability of a plant species occurring in wetlands. FACU = facultative upland plant, FAC = facultative plant, FACW = facultative wetland plant, OBL = obligate wetland plant
[2] Only Pacific ninebark, Nootka rose, and Salmonberry will be planted in Puget Sound Energy right of way per PSE's plant height restrictions.
[3] Does not include 0.8 hectare (1.94 acres) of emergent wetland seeded with native wetland grasses.

Based on the mitigation actions described above for the stream design and planting program, it was important to demonstrate to the regulatory agencies that the mitigation would increase the wetland and stream functions compared to "pre" mitigation site conditions. Table 3 summarizes the comparison of the pre and post function attributes for the mitigation site.

Table 3. Overall comparison of existing and proposed function attributes for the Big Hanaford Creek mitigation site.

Function Attribute	Pre Mitigation Condition	Mitigation Work	Proposed Condition**
Water Quality Improvement Function Attributes			
Vegetation classes	**Poor –** Predominantly non-native herbaceous species present. Existing vegetation grazed and hayed.	Plant native woody and herbaceous vegetation, control non-natives. Remove grazing and haying.	**Good** – Vegetation classes increase as shrub and forested communities establish. Increase native species cover. Protect with conservation easement and fencing.
Water Quality Improvement Function Attributes			
Understory vegetation	**Poor -** Minimal canopy present. Existing vegetation grazed and hayed.	Create overstory. Seed native grasses. Remove grazing and haying.	**Medium –** Understory vegetation increases as shrub and forested communities establish and understory develops. Protect with conservation easement and fencing.
Width ratio of *flooded wetland to stream**	**None –** Creek does not flood sufficiently to maintain riverine conditions.	Earthwork will re-introduce creek flooding and restore riverine conditions.	**Good –** Big Hanaford Creek will reconnect to floodplain annually via overbank flooding.
Area of *flooded inundated clay soils to provide treatment of potential contaminants**	**None –** Creek does not flood. Clay soils are not inundated by potentially contaminated floodwaters.	Earthwork will enlarge flooded area, exposing floodwater and any potential contaminants to clay soils.	**Good** – Flooded area will be increased, allowing for potential contaminants in creek flow to inundate clay soils. Hydroperiod will be increased, providing increased treatment.
Hydrologic Functions Attributes			
Storage capacity	**None –** Creek is channelized and wetland cannot store water during peak flows.	Earthwork will reconnect creek flow to surrounding wetland.	**Good –** Storage capacity will be increased.
Size ratio of wetland relative to basin	**N/A –**Wetland conditions currently provided by precipitation and groundwater.	Earthwork will re-introduce surface water flooding from Big Hanaford Creek to wetland area.	**Good –** Wetland on site will be capable of providing hydrologic functions for Big Hanaford Creek Basin.
Ratio of *flooded wetland to stream**	**Poor –** Flooding limited to creek channel area only.	Earthwork will enlarge flooded wetland area.	**Good** – Ratio of flooded wetland to stream increases.
Cover by woody vegetation	**Poor –** Woody cover is low (8%) and mostly non-native blackberry.	Plant woody vegetation.	**Good** – Woody species establish and woody cover increases, ultimately contributing approx. 75% cover.

Flow path (length of stream relative to wetland)	**Poor** – Creek is straightened.	Restore creek channel.	**Good** – Creek channel length restored to historical condition.
Habitat Functions Attributes			
Buffer condition	**Poor –** Woody cover is low (8%) and mostly non-native blackberry.	Plant woody vegetation.	**Good –** Buffer condition improves as woody species establish.
Canopy closure	**Poor** – Woody cover is low (8%) and mostly non-native blackberry.	Plant woody vegetation.	**Good –** Canopy closure improves as woody species establish, providing 75% cover.
Number of vegetation strata	**Poor –** Only small amount of woody cover present, and predominantly non-native.	Plant woody vegetation.	**Good –** More vegetation strata as woody species establish.
Number of snags	**Poor –** No snags or woody cover present for recruitment.	Install snags (plant woody vegetation).	**Good** – Number of snags and potential recruitment increase.
Number of LWD	**Poor** – No LWD or woody cover present for recruitment.	Install LWD (plant woody vegetation).	**Good** – Number of LWD and potential recruitment increase.
Vegetation interspersion	**Poor –** Woody cover is low (8%) and mostly non-native blackberry.	Plant woody vegetation.	**Medium/Good –** Vegetation interspersion increases as shrub and forested communities establish.
Number of hydrologic regimes	**Poor - ** Site artificially drained. Majority of site is rarely inundated.	Grade micro-topography; relocate stream.	**Good –** Restored creek provides increased area and duration of inundation. Drainage removed.
Number of water depth classes	**Poor –** Creek present on site, site artificially drained.	Grade micro-topography; relocate creek, restore flooding.	**Good –** Relocated stream includes numerous water depth classes, such as alcoves and benches. Drainage removed.
Species richness	**Poor** – No woody cover present. High non-native cover	Plant woody vegetation.	**Medium/Good** – Species richness increases as shrub and forested communities establish and non-natives are controlled.
Mature woody vegetation	**Poor** – No mature woody cover present.	Plant woody vegetation.	**Medium/Good –** Mature vegetation develops from established woody species.

* The word "flooded" was added to clarify the existing condition. The riverine flowthrough model assumes a wetland is flooded. (Hruby, 1999).

** Proposed conditions are based on the Big Hanaford Creek mitigation concept; presented here to facilitate a comparison of pre and post function conditions.

Construction Process

After TCM received permits from the resource agencies to proceed with the Kopiah mining project, a full set of mitigation construction grading and planting plans were prepared. Restoration contractors submitted bids and TCM selected Jansen Inc. to construct the project, including construction of the new creek alignment, installation of in-stream structures, and installation of plants. TCM released a separate contract to a local native plant grower, Watershed Garden Works, to be responsible for collecting seed from local sites and growing the trees, shrubs, and emergent plantings required for the project.

Stream Channel Construction

Construction of the mitigation project began in May 2007 and continued through spring 2008. The construction process began by surveying in the centerline of the realigned channel, fencing existing native vegetation to be preserved, constructing a temporary access road, and staking limits of the project boundary. Topsoil was stockpiled from the excavated channel, stored on site, and reused on the in-stream planting bench. Topsoil was also used to cover subsoil used as backfill in the straightened channel.

The constructed channel was excavated in four separate segments working downstream to upstream. Before connecting the straightened channel to a new constructed segment, all in-stream habitat wood structures were constructed in a segment. After all structures were completed, the plug of soil separating the straightened channel from the constructed channel segment was gradually opened, allowing water to backwater the constructed segment. After the water level stabilized, the upstream connection was made by excavating 15-centimeter (6-inch) lifts of soil for the stream to be redirected into the constructed channel. After all soil was removed, the stream flowed through both the constructed segment and the original straight channel for 24 to 36 hours before a plug was placed in the original channel to completely divert flow into the new channel segment. The 24 to36 hour period provided sufficient time for sediment delivery to stabilize and water quality at the upstream and downstream reach of the constructed channel to be equivalent. Given the very low gradient of the new channel (0.00036), low channel velocities (approximately 0.3 meter per second (1 foot per second)) and the silty clay subsoils, erosion in the constructed channel was minimal. Stream flow was progressively diverted into the full length of the constructed channel after excavation of the four segments of the constructed channel was completed.

Spoils from the excavated channel were temporarily placed along the straightened channel segments and used to fill the old channel after the plugs were placed in upstream and downstream locations. (Fish block nets were strategically placed to allow biologists to remove fish before construction and diversion occurred in the new channel and old channel.) Channel construction occurred between June 1 and September 1, the designated work window for in water work to avoid impacts on coho salmon and steelhead that migrate through this system.

As the new stream channel excavation and filling of old channel segments occurred, weed control activities on the adjacent floodplain were also completed. Nonnative pasture grasses were treated following a program developed by the U.S. Fish and Wildlife Service at a study site near Vancouver, Washington (Killbride and Paveglio, 1999). A combination of early treatment with glyphosate labeled for aquatic sites had occurred during the summer of 2006, followed by disking later in the season, and a second application the following growing season of 2007. After the second application, the entire mitigation site floodplain was disked and a cultipacker was used to break up clods and prepare the site for hydroseeding with a native grass seed mix. A hydroseed mix was applied to the floodplain and stream banks during late summer 2007 to prepare the site for fall and winter rains.

Excavation of the stream channel created excess spoils material beyond what was used to fill the old linear creek channel. Spoils were hauled to an inactive coal pit as agreed to with OSM via permit revisions. This provided a cost efficient means to dispose of excess material.

Plant Installation

Installation of woody plant material (1-gallon container plants) and live willow cuttings and emergent plugs of *Carex obnupta* and *Scirpus microcarpus* occurred between November 2007 and June 2008. Planting occurred over this extended period because of the large quantity of plants that had to be installed and the seasonal flooding/ponding that interfered with site access and plant installation. Container plants were used rather than bare root material to allow for flexibility in timing of planting. Live willows were collected from nearby locations and planting started on the streambanks in November 2007 and continued until heavy rains and site flooding halted the planting. Planting was re-initiated in late January when site access allowed and sufficient area was available for planting. A total of 105 acres of floodplain and streambanks were planted with 130,000 container plants, 54,000 live willow stakes, and 98,000 *Carex* and *Scirpus* plugs. Planting of the plugs occurred in May and June when the lower lying swales were relatively free of water. A planting crew foreman and approximately 20 laborers were used to install the plants.

Although the site is very wet through the spring with ponded water and saturated soil, the site becomes dry in summer when rainfall is generally less than 2.5 centimeter (1 inch) per month. The site was irrigated during July and August via two spray guns with an effective 300-foot radius. Water was applied at a rate of 2.5 centimeters (1 inch) per week using water from a nearby sediment pond. Water quality in the sediment pond was good other than high summer temperatures which limited discharge from the pond to drainages connected to Big Hanaford Creek. This approach provided an effective means to help the establishment of plant materials as summers in the Pacific Northwest are dry and warm with very little precipitation.

Restoration biologists conducted weekly site visits to observe the planting effort and review the layout of the different plant communities and distribution of plants within each community. The planting plans provided typical planting patterns and spacing to create a random placement of plants to avoid an orchard-like planting pattern.

Trees and shrub installation on the floodplain included the placement of a coir weed mat. No fertilizers or soil amendments were used since plants were installed in native topsoil. Mychorrhizal inoculants were not used since some native plant restoration contractors do not recommend use of mycorrhizal inoculants because the Pacific Northwest has been reported to have a very high concentration of mycorrhizal spores in the air.

Summary

The Big Hanaford Creek stream and floodplain restoration project has been a successful project to date by reestablishing almost 2.4 kilometers (1.5 miles) of stream into a historical stream alignment and planting over 42.5 hectares (105 acres) of adjacent wetland floodplain with native plants. Observations of the stream hydraulics and floodplain hydrology from the 2007–2008 winter and early observations of 2008-2009 winter indicate the stream is performing as designed. (As noted below a 10-year monitoring period will begin in the summer of 2009 to monitor success for vegetation establishment and hydrologic conditions.)

During periods when heavy rainfall is constant for three or more days, the creek has exceeded its banks and spills out onto the floodplain as designed. This occurred twice during the 2007–2008 winter and has already occurred once during 2008–2009 rainy season. The basic process of flooding on site starts as the floodplain soils become saturated and ponding occurs in depressions and low areas. Surface flows in the stream rise and floodwaters encroach on the valley from the creek through gentle overbank flooding via the swales and alcoves that were constructed and disperse onto the floodplain (as opposed to the past condition when there was more of an immediate overbank flooding once the sidecast berm was topped adjacent to the channel and via several linear ditches). Floodwater gradually receded in approximately 7 to 10 days via the created swales and alcoves constructed along the length of the constructed channel. In addition, there have been several periods when the floodplain did not entirely flood, but localized flooding occurred adjacent to the channel in the lower areas where the constructed channel has a broad general gradation toward the floodplain and around the six constructed alcoves. Figure 2 shows a portion of the floodplain several days after a high spring flow that exceeded the top of channel, spread out onto the floodplain, and has begun to recede back to the channel. High water can still be seen in the channel and alcoves and swales connected to the channel along with surface water present in depressions.

Figure 2. Aerial view showing localized flooding still remained after high flows receded back into the creek.

Cross sections of the newly constructed channel with the riparian planting bench appear to be providing the function as designed. The riparian planting bench along the inside bends of the creek channel is approximately 0.3 meter (1 foot) above the low flow summer elevations. This bench is expected to provide an excellent location for willow growth as a source for aquatic shading. Figure 3 shows a typical section of the constructed channel during summer conditions with a planting bench on one side where willows will be planted.

Figure 3. Planting bench on left side of creek will provide location for riparian willow growth.

Some sloughing along the low flow channel banks has occurred but has not changed the course of the stream or created a loss of planting bench area. Low flow summer velocities are approximately 0.3 meter per second (1 foot per second) and depths are approximately 0.9 meter (3 feet). Based on visual observations from qualitative site visits after construction there has been minimal erosion from channel flows. No slumps or bank failures in the constructed channel have been observed and only in several places have small rills formed along the channel banks where ponded water drains back into the creek. During the winter months flow depths are great enough to submerge the planting bench by 0.6 to 0.9 meter (2 to 3 feet) with flow velocities of

0.6 to 0.9 meter per second (2 to 3 feet per second). Summer flows are typically around 0.7 cms (25 cfs) and winter flows within the channel are 2.1 to 3.54 cms (75 to 125 cfs).

Native grass seed formed dense stands with cover values ranging from 65-90% absolute cover on the majority of the floodplain the first growing season after application (Fig. 4). Native grasses included *Agrostis errata*, *Deschampsia caespitosa*, and *Hordeum brachyantherum*. However, native grasses did not establish well in narrow swales where other weed control efforts were more difficult to implement due to prolonged wetness. Monitoring of vegetation as required by agency permits is scheduled to begin in summer 2009 to determine how well the native grasses continue to establish in subsequent growing seasons, as well as monitoring survival of planted trees and shrubs. Plant installation was just completed in spring 2008 and monitoring in 2009 will assess how plants are responding to the site conditions.

The 10-year monitoring program scheduled to begin in 2009 is designed to assess the channel flow depth and stream velocities throughout the year, quantify the extent and frequency of overbank flooding, and monitor vegetation survival, native species richness, and native species plant cover. There are also performance standards to ensure invasive weed cover does not exceed certain thresholds.

Figure 4. Successful establishment of native grasses on floodplain one season after seeding.

As the project transitions into the site management and monitoring phase, it is important to reflect on the recent construction process and the applicability of the project to other restoration sites of this scale. Positive attributes and lessons learned from this restoration project included:

- Conducting frequent on-site observations by the restoration engineer and plant biologist to be able to observe the construction process and be available to quickly respond to questions from the contractor for on-site decision making.
- Identifying contacts for the project sponsor, restoration contractor, and restoration designer for efficient communication and implementation of action items agreed to in the field or at project meetings. Establishing clear roles and responsibilities between the project sponsor, contractor, and construction observer is important so all three have the same expectations.
- Providing sufficient project planning time to allow for plant collection and propagation well in advance of the construction project to ensure container plants are available for the contractor.
- Identifying a wide planting window to allow for flexibility of plant installation given the site conditions, high likelihood of flooding, and the large number of plants that were installed.
- Sequencing of construction of the new creek channel in segments and diverting flow without the need for routing flow through piping or other artificial means.
- Utilizing on-site areas to dispose of excavated soil.
- Engaging regulatory agencies early and often so they are aware of the project goals to facilitate project modifications that will not have adverse affects but can greatly improve constructability.

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