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Stream Restoration and Slope Stabilization of a Ravine Landslide

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Introduction

In October 1996, a slope failure occurred at the alignment of a storm drain that traverses a steeply-sloping southern bank of Kendale Ravine in a residential area in northwestern Delta, British Columbia (see Figure 1). The slope failure (shown in Figure 2) occurred within approximately 6 m of a residence situated on a flat-lying, upland plateau area located to the south of the steeply-sloping bank of the ravine. The failure also affected a small fish-bearing stream.

Area Overview

Kendale ravine is a broad, 'U-shaped' valley. It is vegetated with mixed coniferous and deciduous trees as well as mixed shrubs and other low cover plants typical of riparian zones in the Lower Mainland area. Kendale Creek lies at the valley floor of the ravine and flows westward from an area of residential development. The stream flows under River Road in a culvert to a junction box; it is redirected through another culvert to a small tributary joined by a canal to the Fraser River. The invert level of the culvert that empties into the canal is about 0.5 m above the water level in the canal under low tide conditions in the Fraser River. The combination of culverts, junction box and elevated culvert invert are not considered total obstructions to upstream fish passage, although no anadromous fish have been reported in Kendale Creek upstream of River Road in recent times. The creek at present contains resident cutthroat trout. Other species, including stickleback and sculpin, have also been reported (MELP files).

Kendale Creek Before Restoration

Upstream of the River Road culvert, the creek has two distinct reaches. The first extends upstream from River Road for approximately 100 m. It consists of three pools separated by gradients of approximately

18% (Figure 1). Reach 2 extends from the last pool approximately 100 m upstream to the slope failure area. Gradient separations in Reach 1 consisted of rip rap (approximately 200 to 600 mm diameter) which formed a series of small pools that allowed fish passage extending about 100 m upstream to an obstruction. The pools ranged in length from 5 to 35 m long, 3 to 5 m wide and between 0.3 and 0.5 m in depth. The right bank of the pools were densely vegetated with ferns, shrubs, mature coniferous (cedar and fir) and deciduous (principally alder) trees. The left bank of the pools lacked vegetation with the exception of low cover grasses. An existing access road ran parallel to the pools along the left bank and was maintained to provide access for the periodic cleaning of sediments from the pools. The right and left banks of Pool 3 were oversteepened, reflecting previous excavation works that had created the three pools some years ago to provide flood and sediment control. The pools all had considerable accumulations of sediment, presumably as a result of past upstream bank and slope failures. Disposal of household refuse in and adjacent to the pools was also apparent.

The obstruction occurred between the two reaches, located about 100 m upstream from River Road (Figure 1). The obstruction was about 1.5 m in height and was the inferred limit of upstream fish movements, given that no fish were captured or observed above this point. The creek width upstream of the obstruction ranged from 1 to 3 m. Both banks were densely vegetated with shrubs, ferns and deciduous trees (broadleaf maple and red alder). Stream gradients were less than 5%. Reach 2 continues to the bank failure zone approximately 100 m upstream of the obstruction. The creek displays similar characteristics above the failure zone, but limited surveys were undertaken above this zone and the extent to which

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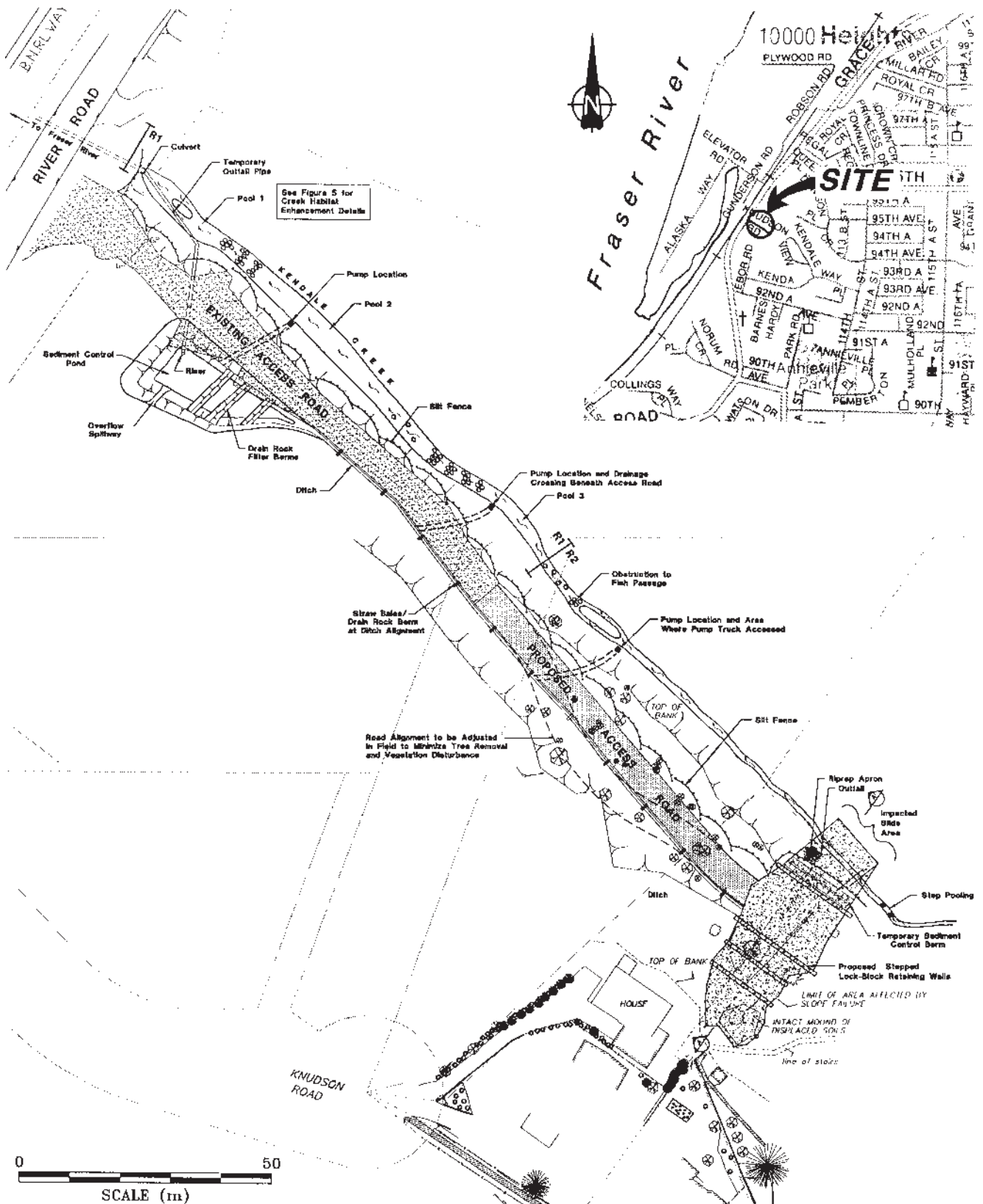


Figure 1. Location and plan of slope failure, access road and characteristics of Kendale Creek in North Delta before site rehabilitation.

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Figure 2. Slope failure in Kendale Creek ravine, North Delta, BC.

Reach 2 continues upstream was not defined.

The slope failure deposited bank materials into the creek channel adjacent to the failure zone, damaging the fish habitat. The creek subsequently eroded a narrow channel through the fine, deposited materials. There may have been some velocity barriers created by focused flows in the narrow channel, causing further damages to habitat. The deposited materials were a source of sediment; these materials were transported downstream during higher flow events. Downstream deposition further limited fish habitat by partially infilling the pools.

Prior to repair of the failed bank, Kendale Creek provided poor habitat due to extensive sediment deposition and general lack of riparian vegetation within Reach 1. Fish surveys conducted by electro-shocking prior to construction indicated that fish were restricted to the three pools and gradient separations of Reach 1. Rearing and spawning habitat were limiting to production. Overall habitat values could be improved if sources of sediment were removed and/or controlled, upstream access improved, pools cleaned, and subsequent re-vegetation established along the left bank.

In addition to fish habitat, the riparian and slope areas of Kendale ravine are very important habitat for three species of Caudatans (native amphibians), found only in ravine environments in their Delta distributions.

Issues Associated with Slope Failure

The slope failure and subsequent erosion resulted in regression of the ravine slope crest to a position that posed a potential threat to an adjacent residence located near the crest of the slope. The failure also resulted in the downstream deposition of soil/sediment into the creek, causing the infilling of pool and riffle

habitat. Both of these conditions required mitigation to protect property and rehabilitate habitat of Kendale Creek adjacent to, and downstream of, the failure zone. The slide area could not be left unrepaired as further slope crest regression and new slope failures could occur due to the weak and highly erodible nature of the saturated, surficial soils that mantle the ravine slopes. The wet weather conditions at the time of the failure complicated the planning and implementation of restoration works. There were concerns that the heavy construction operations required to permanently stabilize the site had the potential to inadvertently destabilize other steeply sloping portions of the ravine banks.

Solutions

To address these problems, the Corporation of Delta:

- introduced an immediate bypass of the storm sewer system to redirect flows away from the slope failure area;
- implemented a program of regular visual inspections and survey monitoring of reference points established within the ravine to monitor the slope condition;
- selected and organized a team of professionals to promptly address the problem. The team, hereinafter referred to as the Project Team, included key members of the Corporation of Delta staff, geotechnical and civil engineers (Golder Associates Ltd.), aquatic biologists (Golder Associates Ltd.) and an experienced contractor (Risling Services Ltd.) which also contributed as an active design participant;
- assessed possible remediation alternatives, including construction of slope stabilization works at the failure site and rehabilitation of the affected segments of the creek channel; and
- constructed remedial works on a priority basis to eliminate the risk of damage to adjacent private property while minimizing long-term adverse impacts on the Kendale Creek system.

Several options were considered to effect permanent restoration of the failure area, including:

1. Re-vegetating the site using specialized planting hydro-seeding techniques.
2. Infilling the failure zone using granular fills.
3. Constructing a permanently tied-back, anchored concrete wall.
4. Constructing a series of stepped or terraced, modular retaining walls.
5. Combining the above alternatives.

The proximity of the potentially threatened residence to the failure zone precluded the use of Options 1 and 2 due to the need for permanent slope support and site access requirements. Option 3 was eliminated due to its significant cost and the requirement to reinstate vegetation that was lost within the failure zone.

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Option 4 was eventually selected due to the speed with which construction could be undertaken, cost considerations, and the ease with which this system could be adapted and modified on site to suit the challenging site conditions.

Problems and Challenges

Access

Extension of the temporary access road approximately 100 m through the riparian zone along the left bank of Kendale Creek was necessary to provide access for construction of a series of stepped or terraced Lock-Block retaining walls (schematically detailed in Figure 3). The temporary access roadway, although initially disruptive, allowed access to the creek channel for selected rehabilitation, restoration and enhancement works which would not have been possible without the use of heavy equipment. Removal of vegetation from a riparian zone for any construction-related purposes is not generally recommended or accepted, but was considered the only viable option for remediating the slope failure in this case. Stringent sediment control measures were implemented to minimize further impact to the creek. Combined with the cooperation of personnel at Ministry of Environment, Lands and Parks (MELP), the Department of Fisheries and Oceans (DFO), the Project Team and adjacent land-owners, these measures permitted all construction activities and restoration works to be completed within three weeks.

Riparian zone/disturbance

Approximately 800 m² of riparian zone vegetation and topsoil was removed for access road construction. A tree survey was undertaken prior to the commencement of road construction to document the size and species of trees that would need to be removed and subsequently replaced (in accordance with the tree replacement criteria established by MELP), and to identify any danger trees that would need to be removed to ensure worker safety. Removal of this vegetation increased the potential for erosion and soil deposition into the creek, and resulted in the disturbance of native amphibian habitat. Topsoil was removed and stockpiled off-site so that it could be replaced following construction. Small to medium bore woody debris, rotten logs, and rootwads were also saved so that they could be returned to provide important continuity to the site for fish and amphibian habitat.

Soil conditions (wetness)

Soil conditions at the site consist of a surficial mantle of softened and disturbed fine-grained and organic sediments. These have developed due to weathering and mass wasting processes at the steeply sloping banks of the ravine. Site conditions are very wet due to abundant surface water drainage, heavy groundwater seepage and the dense forest canopy that prevents evaporation after rainfalls. These wet conditions increased potential for soil/sediment mobilization and

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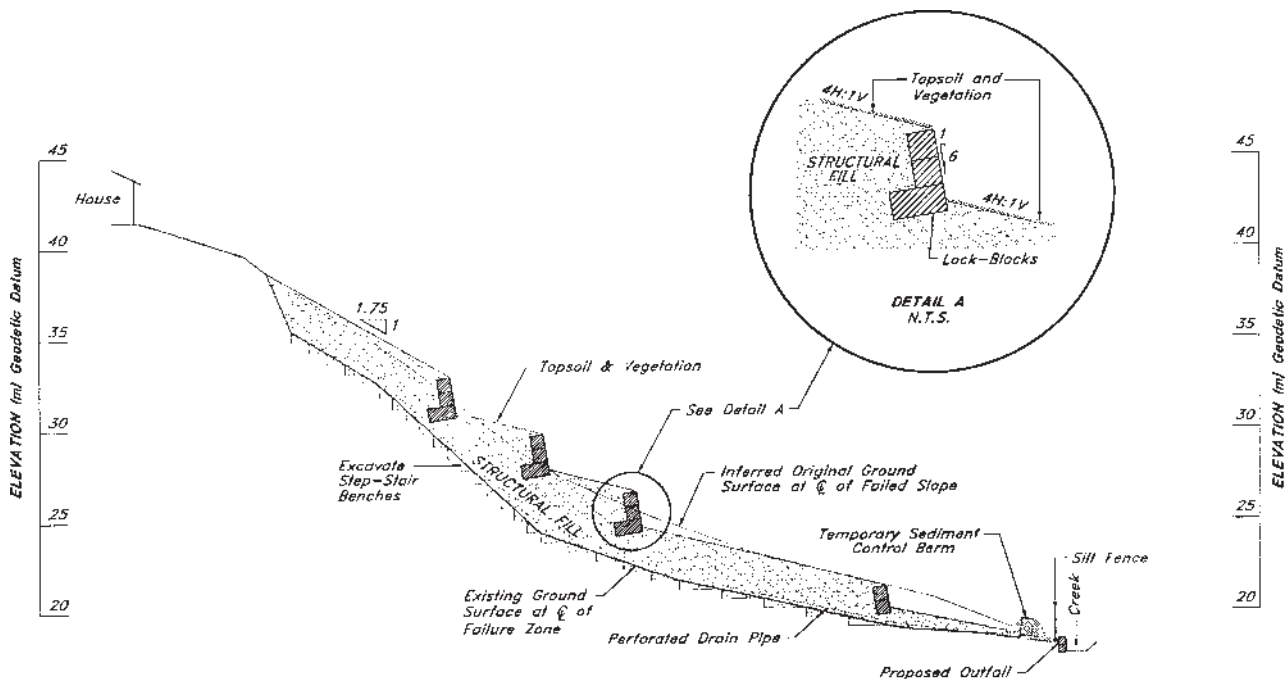


Figure 3. Slope stabilization measures.

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subsequent transport during and following construction, which provided appreciable challenges for completing the work on time and minimizing and/or avoiding adverse impacts on habitat.

Landowner approval

The failure zone and the general study area are on privately owned land. Therefore, in addition to those permits required under the Provincial *Water Act*, it was also necessary to obtain permission for access from landowners adjacent to Kendale Creek. Prior to the submission of any applications to MELP, the Project Team met with local residents and landowners to discuss the nature of the project as well as the regulatory framework that would apply.

Effective environmental protection

The proposed slope stabilization method had to provide for effective re-vegetation and ensure minimal potential surface erosion and sediment transport. During construction of the access roadway sediment control measures and slope stabilization works followed the Land Development Guidelines (DFO/MELP 1993) These included: the installation of silt fencing along the entire length of the existing and proposed access roadway; creation of a temporary sediment pond and outlet works to the creek; and the connection of drainage works between the start of the new access roadway and sedimentation pond (Figure 1). A sedimentation pond was designed by a water resource engineer to provide a minimum detention period of two hours. The discharge from the sediment pond was placed in the culvert running under River Road to avoid fish and habitat.

Facilitating Agency Approval

In sensitive areas such as Kendale ravine, several pieces of legislation require that work proceed in consultation with government agencies. The Provincial *Water Act* requires approval from MELP whenever “works in and about a stream” are proposed. As well, the Federal *Fisheries Act* prohibits the harmful alteration of fish habitat, and the deposition of a deleterious substance (such as silt) into water frequented by fish. As defined under the *Fisheries Act*, the entire Kendale Ravine is considered to be fish habitat, and therefore any proposed works within the ravine were subject to DFO/MELP approval.

Urban developments present some unique challenges not often seen in forestry watershed rehabilitation. In the forest setting, a creek meandering a few meters or even backwatering due to an instream enhancement project is normally of little consequence. However, in the urban landscape, even minor changes to urban streams can have adverse impacts on adjacent properties,

and can result in litigation between landowners. For this reason, MELP has an intensive review process in which Water Management, the DFO, and Habitat Protection all review proposed instream works. This process normally requires a minimum of six weeks. Unfortunately, this project was not submitted for review until August 27, 1997 leaving just over one month for the application to be reviewed and implemented.

To expedite the project, aquatic biologists met on-site with a MELP Regional Habitat Protection Officer prior to developing the final plan. During the site visit held on August 19, it became apparent that for the project to proceed before the September 30 instream work deadline window expired, project planners would have to immediately submit a comprehensive application package for review. This package included all necessary plans, application forms, a detailed description of the entire project including mitigation and compensation, as well as the standard conditions of approval that a habitat officer would normally include in an approval letter. By providing all of the necessary information initially, the agencies’ review time was greatly reduced and project approval was granted in just over one week. This left three weeks to complete the project before the instream work window expired.

A project of this nature usually requires a DFO Section 35(2) *Fisheries Act* Authorization to harmfully alter fish habitat. In proposing to completely rehabilitate the site following stabilization works, and to enhance the creek over its pre-disturbance state, project staff effectively illustrated to the agencies that the project would result in a substantial net gain for the fish habitat, despite the lag time of the lost mature riparian vegetation. Combined with the relatively urgent nature of the project, this allowed the DFO to waive the requirement for an authorization under Section 35(2) of the *Fisheries Act*, thus allowing approved work to proceed unusually quickly.

Undertaking the Work

Few projects entail such a rapid application and approval process as was made possible through the cooperation and experience of the diverse group of companies and individuals that worked on this project. The Corporation of Delta selected the contractor based upon its ability to undertake and complete challenging projects. The project biologists undertook a series of additional steps to optimize environmental protection. These included on-site orientation of environmental issues and concerns to provide awareness of the following:

- the significance and relevance of regulations and legislation applicable to the instream approval;
- individual and company responsibilities to

- environmental protection (*Fisheries Act*);
- responsibilities of the Environmental Monitor;
- the importance of reviewing of equipment and techniques to prevent and manage spills;
- reporting responsibilities in the event of a fuel or lubricant spill (Provincial Emergency program, Spill Reporting Regulation); and,
- general discussions of the importance of undertaking instream works diligently.

On-site Mitigation Strategies

To minimize short- and long-term impacts from the slope failure and remedial construction a number of on-site strategies were used during work in the creek and in the riparian zone, including:

- construction of the temporary access roadway using coarse rockfill, geotextile fabric and Lock-Blocks to minimize the road width and site disturbance while still providing adequate access for heavy equipment and material delivery;
- construction of the terraced Lock-Block walls to approximate the original slope configuration;
- salvage of the soils excavated from the access roadway alignment and failure zone and subsequent re-use after decommissioning the temporary access road; and
- implementation of aggressive sediment and runoff control measures at all parts of the site, consisting of:
 - construction of an appropriately designed sedimentation pond,
 - installation of water pumps so that water containing suspended solids could be diverted around habitat and pumped into the sedimentation pond,
 - installation of silt fencing and hay bails to manage suspended solids,
 - extensive tree and shrub plantings and use of TERRASOL's Sediment-Lok™ to facilitate and optimize site re-vegetation,
 - a tree survey prior to construction, and
 - fish salvage using electrofishing and minnow trapping prior to instream works.

Control of suspended solids

The site plan (Figure 1) shows the location of the sediment control pond as well as pumps and their respective discharge lines. As work proceeded, it became clear that suspended solids could not be effectively controlled by instream placements of hay bails or silt fencing. Attempts to filter sediment-laden water by placing berms of clean crushed gravel instream were moderately effective, but not to the extent necessary for the protection of fish and habitat. Consequently, high volume portable pumps were used to divert sediment-laden water from instream activities to the ditch line along the temporary access road, and ultimately to the sediment control pond. This proved

very effective and made it possible to employ these methods for several hours without compromising downstream water quality in Reach 1, where fish had yet to be salvaged. Pumps were used in this manner during placement of the outfall structure adjacent to the slope failure zone and during instream habitat restoration activities.

Fish salvage

Surviving fish were salvaged from below the active work area prior to undertaking any works. Salvage was undertaken with a backpack electroshocker as well as with minnow traps – the latter technique was not effective. Electroshocking was used only twice throughout the entire construction project; once to determine species presence and distribution and, once to move them for salvage. As discussed above, pumps were used to isolate and divert sediment-laden water around Reach 1 where fish were located.

Once these upstream activities were completed, rehabilitation in Pool 3 was initiated. Fish salvage in Pool 3 was not necessary as no fish were found in it. Salvage of fish from Pools 1 and 2 commenced only after works in Pool 3 were completed, and followed pool filling with upstream flows and when water was deemed to be of suitable clarity and quality. The rehabilitation and isolation of Pool 3 minimized the stress on fish. They had not yet been moved from Pools 1 and 2 after considerable instream construction had been undertaken for a number of days. Pools 1 and 2 were too large and deep to undertake effective electro-shocking, and a decision was taken to lower stage levels by pumping. Pump intakes were screened to prevent entrapment, and pumping continued until water levels had adequately declined so that salvage could proceed. Salvage was complicated by loose, organic sediments that reduced visibility and mobility. However, salvage was quickly and successfully completed and all fish were transferred upstream to Pool 3. Two age classes of cutthroat trout were salvaged, indicating that there was some reproduction and recruitment in Kendale Creek notwithstanding the reported limitations in habitat. Salvage and isolation of Pools 1 and 2 in this manner allowed restoration and rehabilitation activities to commence in the remainder of Reach 1.

Import/export ballast

To support the heavy construction equipment on the saturated ravine soil, a stable access road had to be constructed. Clean ballast was trucked in and spread as the temporary access road was constructed. The road meandered around large trees, and was just wide enough to permit dump trucks to reverse to the stabilization site. One stipulation of the approval was complete reclamation of the access road. For this

Feature

reason, the original topsoil was scalped and stockpiled, and rootwads, small woody debris and rotten logs were saved. Upon completion of the stabilization works, the road ballast was removed, and the original topsoil was spread and seeded where the road had been only the day before. To permanently stabilize portions of the ravine slope, some Lock-blocks remaining from the road edge were left in place and buried. Stockpiling the topsoil was not only cost-effective, but gave reclamation a head start by providing a rich, native seed bank. Throughout the site, exposed soil was hydro-seeded to stabilize the surface and to prevent erosion. TERRASOL's Sediment-Lok™ was used to stabilize the soil within the failure area, and was found to be an effective erosion control and reclamation tool (Figure 4). No rivulet formation was noted, and dense, widespread germination was seen within the first week following application. The edges of topsoil were lined with a silt fence at the project outset, and will remain in place until the next growing season is complete.



Figure 4. Base of rehabilitated slope, vegetation and Sediment-Lok™. Background shows restabilized stream channel.

Access cleaning for streams

Following reclamation, each of the lower-end pools was left accessible to a long-reach excavator to facilitate periodic maintenance of the habitat. This process included planting low-growth shrubs at the access points and installing berms within the pools to promote sediment deposition near the entrance of each pool. A site inspection in the spring of 1998 revealed that sediments are settling out exactly as planned.

Rehabilitation and Restoration Improvements

A number of rehabilitation and restoration improvements were undertaken as part of this project, including:

- stabilization and re-vegetation of the slope failure area, road and riparian zones;

- removal of deposited sediments in selected areas of Reach 2 and from the three pools in Reach 1;
- placement of LWD and rip rap in selected locations in Reach 1 to improve its complexity and the amount of three-dimensional habitat;
- placement of LWD, removal of deposited sediment and re-establishment of cobble substrate within Reach 2 adjacent to the failure zone; and,
- removal of an obstruction between Reach 1 and 2 to improve upstream fish access.

Stabilization and Re-vegetation

To evaluate and develop objectives for re-vegetation, the construction site was segregated into various zones reflecting site-specific conditions and features such as soils, slopes, proximity to the creek, and habitat characteristics. Several zones were identified for the purpose of facilitating development of a re-vegetation plan: (1) failure zone (535 m²), (2) upper access road area (between the upstream limit of Pool 3 to the end of the access road, 724 m²), (3) riparian zone areas adjacent to Pools 1 to 3 (500 m²) and, (4) sediment pond area (400 m²). The principal objectives for the re-vegetation plan was to select appropriate species and size of plants so as to optimize survival. This was undertaken in consultation with MELP and DFO, to conform to the ecological associations, re-vegetation, and tree replacement criteria. Robert Glenn Native Plant Nursery provided the plants, and the company took an active role in evaluating site conditions, plant selection as well as layout and planting at the site. Project team members also visited the nursery to select quality plants.

A total of 1,680 native shrubs, trees and ground cover species were specifically selected and planted in the zones listed above. The average density was 0.79 plants/m²; actual densities ranged from 0.5 plants/m² on the sediment pond to 1.2 plants/m² on the slope failure zone. Densities adjacent to Reach 1 were 0.75 plants/m² and were deemed adequate. These figures generally exceed those provided by the MELP and DFO criteria, and such densities were planned to maximize survivability and stabilization of the area, and to minimize further adverse impacts associated with slope failures and sediment deposition. Plants selected at the nursery were the most healthy and vigorous individuals.

Creek restoration adjacent to the failure zone

The slope failure caused deposition of a large amount of sediment in a 12 m wide zone in the creek channel adjacent to the failure zone (see Figure 1). When these deposited materials were mobilized at higher flows, they damaged habitat downstream by reducing water quality and depositing in pool habitat. It was also observed that the channel was relatively narrow

Feature

through the failure zone and the native cobble substrate was obscured by fine deposited materials.

The creek channel was excavated to install an outfall structure. Cobble-sized, angular rocks were placed as a base. At the same time, a fisheries biologist oversaw the excavation works and provided recommendations for the subsequent removal of additional materials from the channel in order to re-establish the natural drainage pattern. Materials were removed by a track-mounted excavator and the channel was re-established to dimensions similar to those observed immediately upstream of the impacted area. A water resources engineer undertook a field reconnaissance of the impacted area before and after rehabilitation to evaluate the work and confirm that it was appropriately completed.

More than 15 m of stream was rehabilitated through the removal of about 8 m³ of deposited materials and the subsequent placement of angular rip rap (400 to 600 mm diameter), as well as LWD. Materials were removed from the stream that contained growing and established vegetation and were consequently placed along the bank to promote stabilization. A series of

step pools were created, by hand and with the excavator, through the failure zone. Access was improved about 5 m upstream of the failure zone where a small obstruction was removed. Re-vegetation of the riparian zone was completed as discussed above and consisted mainly of shrubs, ferns and vine maple, consistent with naturally occurring species in the area.

Hay bails, sand bags and silt fencing were placed downstream of the failure zone to minimize the downstream transport of suspended solids. Field crews then hand-removed accumulated silts and sand, some of which were due to previous upstream events. Once creek restoration was completed in this area and the outfall installed, the sand bags, hay bails and silt fencing were removed. The end result was the removal of a substantial amount of accumulated materials, exposure of native cobble substrate in the stream channel and an overall improvement in habitat. A suction pump truck was selectively used in some areas to remove deposited materials. This proved effective given that access was possible and the truck could be used site-specifically. More than 6 m³ of material was removed by this combination of methods.

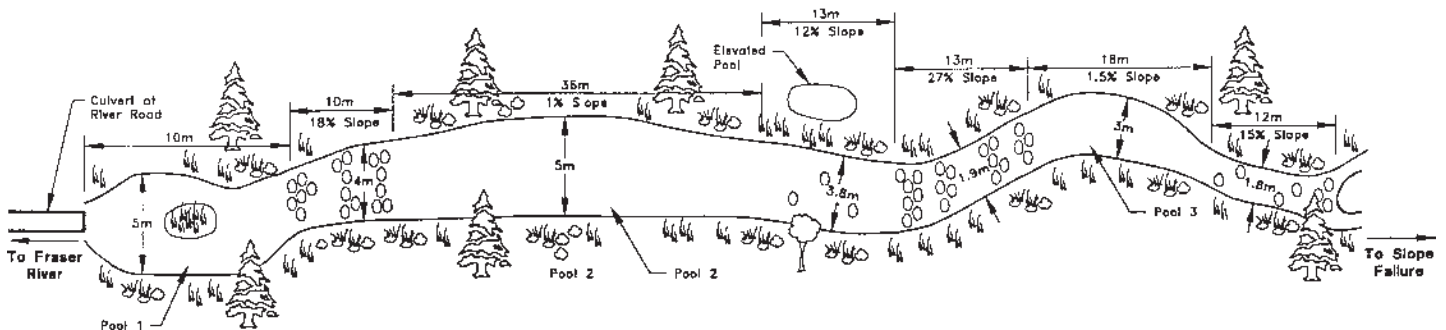


Figure 5a. Kendale Creek prior to rehabilitation. This section of the creek runs from the culvert at River road 112 m upstream towards the slope failure (not drawn to scale).

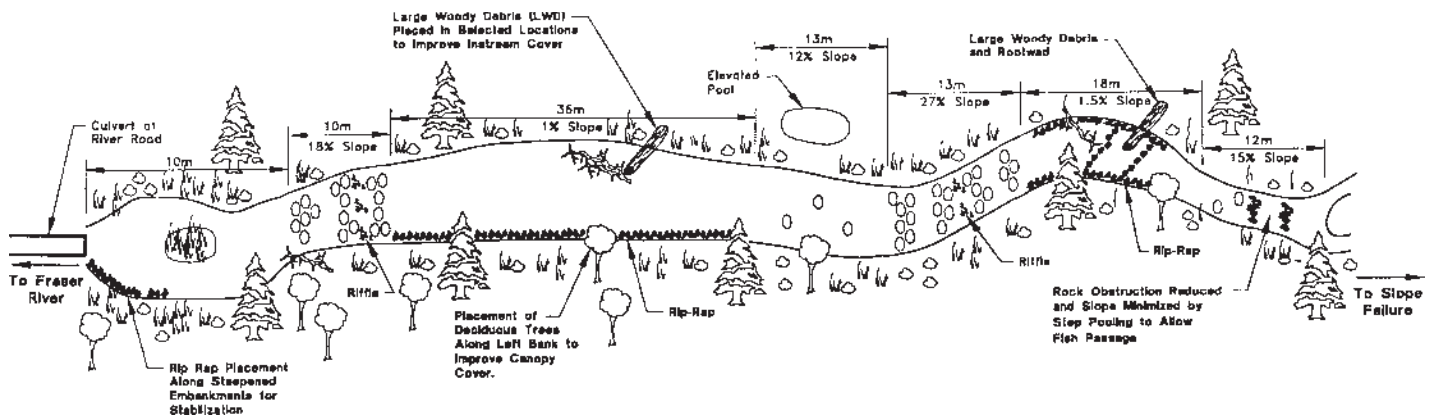


Figure 5b. Rehabilitation of Kendale Creek included the addition of rootwads and rip rap in 3 pools, constructions of a step-pool to allow fish passage at the obstruction and planting of riparian vegetation (not drawn to scale).

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Habitat Improvements in Reach 1

Reach 1 is principally characterized by three man-made pools which had been affected by deposited materials and increased solar radiation along the left bank. Stream characteristics of Reach 1 before and after rehabilitation are shown in Figure 5. The most significant improvements undertaken in association with this project included removal of deposited materials, selective placement of instream LWD, bank restabilization, revegetation, and placement of rip rap.

Although no increase in surface area resulted from the rehabilitation works, the volume of three-dimensional, useable habitat was more than doubled in Pools 1 and 2 and more than quadrupled in Pool 3. Over 50 m³ of deposited materials were removed from the pools (Figure 6) and complexity was greatly improved by adding LWD and rip rap (Figure 7). Rip rap was carefully and selectively placed, with guidance of a biologist at the base and bottom of the pools. The principal objective was to improve bank stability and complexity by developing refugia without compromising overall habitat volume and quality. A rip rap berm (Figure 7) was placed near the upper two thirds of Pool 3 to act as a sediment trap. Recent field observations have confirmed that this berm is functioning as designed and that overall habitat values have been protected downstream.

Summary and Conclusions

Through the rehabilitation efforts recited above, Kendale Creek is now much more complex, stable, and accessible to salmonids than it has been in recent times. Although some temporary riparian loss occurred, the long-term stability of the site now should ensure that disturbances of this nature are not repeated.

Other important factors that contributed to the success



Figure 7. Restoration of Pool 3 showing placement of rip rap to stabilize undercut banks and of LWD to increase rearing habitat.

of this project included:

1. *Minimizing impacts:* Much emphasis was placed on minimizing impacts and maximizing benefits to the creek and ravine system. This built confidence amongst the Project Team members and allowed construction to proceed efficiently and cooperatively.
2. *The client:* The Corporation of Delta recognized the importance of the problem and promptly selected and organized a team of professionals to address the problem.
3. *The contractor:* Rissling Services Ltd. worked cooperatively and closely with the consultants and agencies in the design process and made suggestions for modifications and improvements throughout the construction phase.
4. *Integration of services:* Integration of geotechnical engineering, civil engineering, and environmental and biological sciences proved a successful combination.
5. *Proactive planning:* The project's planning and submission of applications were efficient, resulting in minimal agency review time prior to approval.
6. *Applicability to forest industry:* It can be cost-effective to properly reclaim access roads and minimize impacts to the aquatic habitat; compensation planning requires ingenuity, as the land base can be limited, particularly in an urban setting.
7. *Resource evaluation:* A thorough initial review of the project identified actual limiting habitat components rather than a standard rehabilitation prescription with questionable results. For this reason, the compensation addressed the stream's needs by priority, and left a healthy, stabilized ecosystem when the project was complete.
8. *Social network:* communication between all parties resulted in a well-orchestrated project that satisfied

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the concerns of the local Delta residents, and minimized both the impact to fish and wildlife and the cost to stakeholders.

The success of this project can be attributed to the commitment of the qualified, skilled and competent individuals who contributed to the project.

Acknowledgments

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Technical Tips

Habitat Rehabilitation: How Much Off-Channel Coho Habitat?

Pat Slaney and Matt Foy

In aquatic watershed restoration projects, the objective may be to develop fish habitat prescriptions for a coho stream and implement habitat rehabilitation within a logged watershed. If, for example, a prospective project area's timber had been logged to both banks >50 years ago along a 10 km fish-bearing stream (assuming hillslopes are intact or restoration is largely completed) there is likely to be several opportunities for restoring off-channel habitats cut off by old roads, and also some potential on the floodplain for developing cost-effective mitigative off-channel habitats. Instream work may appear too risky in most or all of the stream channel because of excessive channel instability on a wide alluvial floodplain. The questions that then arise are: 1. How much off-channel habitat is reasonably needed given the historical impacts to coho salmon habitat? 2. Will two ponds and two channels do the job or is the requirement for several times this to restore coho production capability?

Earlier research in S. E Alaska, Washington's Olympic Peninsula and at B.C.'s Carnation Creek showed that coho are very dependent on overwinter refuges.

Hence pools with complex LWD and suitable off-channel habitats are needed to obtain high survival rates from the fry to the parr or smolt stage (Figure 1). Carnation Creek research, in particular, showed: that overwinter survival of juvenile coho is positively correlated with the size of fingerlings reached upon entering the fall freshet period, and coho juveniles that had moved into or remained in off-channel habitats had up to three times the overwinter survival to the smolt and parr stage of those that remained in the mainstem of this "flashy" west coast stream (75% vs. 25%). [A key reason coho have been somewhat resilient to date is that no roads were built on the floodplain, thus preserving all off-channel habitats plus LWD still exists in the mainstem.] Evidence that coho are dependent on off-channel wetlands, ponds, lakes and small nursery tributaries can also be inferred from whole river fertilization of the mainstem Keogh River, which only resulted in about a 20% increase (peak, 30%) in coho smolt output compared to 65% (peak, 150%) for steelhead smolts. Also, at the Clearwater River in Washington, the number of coho