TECK COMINCO RIVERBANK RESTORATION PROJECT:
CASE STUDY, TRAIL, BRITISH COLUMBIA

Pierre Raymond
Thor Smestad, MSc

Terra Erosion Control Ltd.,
2304 Silver King Road,
Nelson, BC, Canada
info@terraerosion.com

ABSTRACT

Teck Cominco Metals Ltd has operated a lead-zinc smelter in Trail, British Columbia, Canada for over 100 years. A number of attempts to re-vegetate the high bank of the Columbia River below this smelter have been made; however, these have met with poor to, at best, moderate success.

This project combines two essential features to re-vegetate this slope: soil bioengineering to stabilize the slope surface and the use of pioneering plants to initiate natural vegetation succession processes on the site. The primary objectives were to stabilize the site by establishing well-rooted permanent native vegetation, and to improve the aesthetics of the hillside. Other objectives were to reduce sediment delivery into the Columbia River, and to improve riparian habitat. Live cuttings used in the soil bioengineering structures were collected locally near the project area.

In the spring and fall of 2006 soil bioengineering structures were installed on approximately 860 metres of the lower, active bank of the Columbia River. These consist of brush layers with protective layers and live cutting pockets installed within rip-rap, as well as brush sills and fascines within a gravel bank. The cuttings used consisted of a mixture of *Salix scouleriana, S. bebbiana, S. exigua and S. lasiandra, Populus balsamifera ssp. trichocarpa* and *Cornus sericea*. Planting was machine-assisted using excavators and survival and growth of the structures was assessed as good to excellent.

The upper riverbank, or hillside site has a total width of 700 m and an average slope length of 80 m. Slope gradients range from 20 to 85% (10 to 40^{o}) and the aspect is to the east/north-east. The slope surficial material consists of glacio-fluvial sand mixed with historical smelter waste materials such as brick and slag.

The hillside units were reclaimed during the fall of 2006 and springs of 2007/08. On slope gradients greater than 40% (22 ^{o}), which is the majority of the hillside, machine-assisted planting was done using a Schaeff Walking Excavator (Spyder Hoe). On slopes greater than 60% (31^{o}), this machine was tethered to a skidder located at the top of the slope. Materials were transported onto the slope using a skyline cable system.

The soil bioengineering structures on the hillside units consist of brush layers, using a species mixture of approximately 80% *Populus balsamifera ssp. trichocarpa* and 20% *Salix scouleriana* and *S. bebbiana*, with a minor component of *Salix lasiandra*. During planting of the brush layers a custom soil amendment was utilized to increase soil fertility, retain moisture and regulate pH. Straw wattles were also installed

across the slope to control surface erosion. Survival and growth of planted areas was mostly good to excellent, but with some areas of high mortality due to soil contamination and/or lack of irrigation.

The hillside units were also planted with container type native shrubs and trees and hydro-seeded with native grasses using pulp mill bio solids as mulch. An irrigation system was installed and a five-year monitoring program, which includes excavation of root systems and compost tea applications, was initiated in the summer of 2007.

INTRODUCTION

In the fall of 2004 Terra Erosion Control Ltd submitted a joint proposal with AMEC Earth and Environment for the development of site prescription and cost estimate on the Riverbank Restoration Project for Teck Cominco Metals Ltd in Trail, British Columbia, Canada. The design was approved in summer 2005 and the work was conducted from the fall of 2005 to spring of 2008. A five year monitoring program and compost tea application began in the fall of 2007 which included establishment of permanent sampling plots, soil and foliage lab analysis, and compost tea application.

The objective of this project is to establish vegetation on the hillside and adjacent riverbank area, reduce/control soil erosion on the slope, and improve visual and wildlife/fish habitat values in this area below the Teck Cominco smelter in Trail, British Columbia, Canada.

For the purpose of treatment design, the hillside was divided into four units (Units 1 to 4, referred to as the Hillside below), and the adjacent riverbank below these units and existing road was divided into five sections (Sections 1A, 1, 2, 3A and 3, referred to as the Riverbank Sections below). The project was administrated by AMEC Americas on behalf of Teck Cominco Metals Ltd.

SITE DESCRIPTION AND HISTORY

Teck Cominco and its predecessor have operated a smelter at the present site on the bench above the Columbia River in Trail since the late 1800's. Evidence of the long operation of the smelter can be found on the slope below the smelter with the presence of bricks, smelter slag, metal bits and a variety of other materials. A desire to establish a vegetation cover on the slope has lead to a series of trials, tests and reports. Old irrigation systems as well as small fences and a variety of plantings are evidence of these trials – which in general have met with poor to at best moderate success. The current project is expected to be a more satisfactory solution to re-vegetation of this slope and adjacent riverbank. This project combines two essential features that have not previously been utilized in attempts to re-vegetate this slope: soil bioengineering techniques to stabilize the slope surface, and the use of pioneering plants with both ecto and endo mycorrhizal fungi to initiate natural vegetation successional processes on the site.

<u>Site Description</u>

The riverbank sections lie along the bank of the Columbia River, below the slope that comprises 5 Sections; 1, 1A, 2, 3 and 3A. The substrate here consists of a variety of native fluvial materials (sands, gravels, stones), and in some areas, various amounts of historical smelter waste materials such as brick and slag. Portions of area planted in Sections 1A, 1 and 3 lie below the river high water line during peak flood years (these areas flooded in May/June of 2006). Section 1A starts at the south end of the riverbank access road and continues

160m south below a concrete wall on Teck Cominco property. All of the sections lie along the bank of the Columbia River.

Hillside units are located between the Teck Cominco smelter and the riverbank. The hillside was divided in 4 units based on topography similarity, access logistics and existing vegetation. The units have a number of features that make establishment of vegetation difficult. The slope is often very steep (over 38 degrees), well over the natural angle of repose. This results in surface instability, making it difficult for small seedlings and herbaceous vegetation to become established. The slope contains a variety of materials, including historical waste materials from the smelter, such as scrap metals and old bricks that were used in the smelter furnaces and as part of the lead stack component. In the case of Units 2 and 3, there are areas with a preponderance of brick, located at the base of the slope. The slope is east to north-east facing, with significant heating and drying often occurring during summer mornings. Random pockets of vegetation have established over the years, either naturally or through past planting trials.

RESTORATION MEASURES

Section 1A (Riverbank Brush Sills): Spring 2006/Spring 2008

Implementation of soil bioengineering treatments in Section 1A was done in April of 2006. The structures were installed as shown in Figure 1. Layout of brush sill locations was done prior to treatment. Machine-assisted planting using insertion technique (i.e. forcing of excavator bucket into the ground and creation of an opening to insert live cuttings and soil amendment) for sills was done using an excavator. A total of 27 nine-meter long brush sills and adjacent fascines were planted. Each sill/fascine pair begins at the base of the concrete wall and extends out at an angle of approximately 30 degrees from the wall. All the Pacific willow designated for Section 1A were planted in the first 1 m of each brush sill closest to the wall (these are expected to grow as medium size trees, 9-15m, up against the wall). The willow, red-osier dogwood and cottonwood were mixed evenly along the remainder of each sill. The fascines were planted in shallow trenches approximately 0.5-1m up stream from the sills, using one willow fascine and one cottonwood fascine along each sill. In the spring of 2008 the riverbank access road was extended 110 meters south into Section 1A. A single vegetated brush layer using 2.3m long cuttings was installed along this new section of road, similar to that installed in Section 1 below. The species component for this additional work was; 40% willow, 30% Pacific willow, 20% cottonwood, 10% red-osier dogwood.

Section 1 (Vegetated Rip-Rap Toe Protection): Spring 2006

Implementation of soil bioengineering treatments in Section 1 was carried out in May 2006. The structures were installed as shown in Figure 2. Machine-assisted planting was done using excavators. Installation began with construction of a rip-rap toe apron, above which four rows of live pockets were located, each pocket had a 30 cm layer of top soil placed within the existing substrate to provide suitable rooting material.

The four rows of pockets were completed consecutively, with approximately 0.5 m (vertical spacing distance) of rip-rap placed between each row. Each pocket consists of six cuttings contained within two protective sleeves made from 4” Big-O pipe. In addition to growing medium, one bucket (20L) of topsoil was added to each pocket.

A final layer of rip-rap was placed above the fourth (highest) row of pockets. Section 1 brush layer was installed behind this rip-rap. To install the brush layer a trench was first prepared for the cuttings. The cuttings were laid out along this trench so that the tips protruded about 30 cm above the adjacent rip-rap. Growing medium was applied and then the topsoil was spread over the base of the cuttings prior to backfilling to 1 m depth using native soil material. After backfilling, 1.3 m of the cuttings remained exposed. Protective OSB (Oriented Strand Board) sheets (1 m width) were placed over the lower 1 m of the exposed cuttings; rock was then placed to raise the road grade.

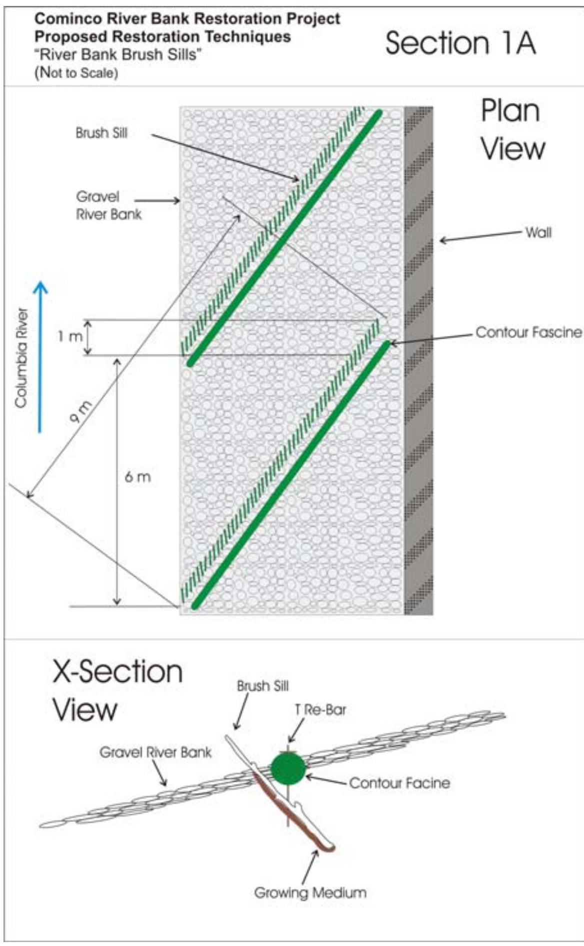

Figure 1: Section 1A

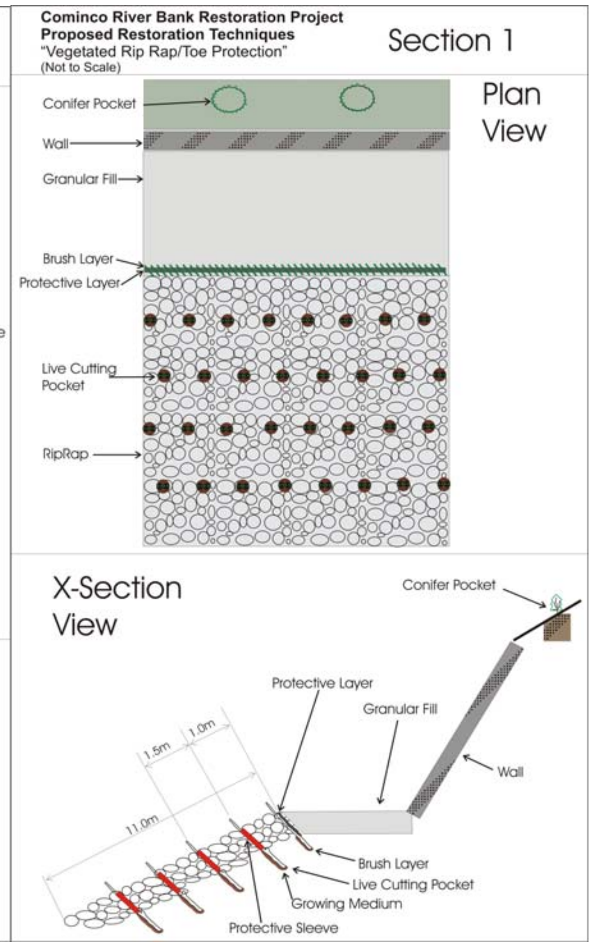

Figure 2: Section 1

<u>Section 2 (Brush Layer below Mechanically Stabilized Earth (MSE) Wall): Fall 2006</u>

Work in this section was postponed until October 2006 due to continued high flood levels. This prevented upgrades to the road and construction of the MSE wall. The structures were installed as shown in Figure 3. Machine-assisted planting was carried out using excavators. The procedure followed was the same as that used for the brush layer in Section 1- growing medium was applied with little to no topsoil prior to backfilling. Following back filling of brush layers, OSB sheets were placed, road grade was raised and MSE wall was constructed. The Pacific willow was planted in 1 m long brush layer sections (clumps), located at intervals of about 15 m.

Section 3A (Brush Layer below Road): Fall 2006

Implementation of soil bioengineering treatments in Section 3A was carried out in October of 2006. The structures were similar to those installed in Section 3 (see Figure 1-5) with one continuous row and one partial row of brush layer for a total length of 29 m. The Pacific willow was planted in 1.2 m wide sections (clumps), at intervals of about 15 m as in Section 2.

Section 3 (Brush Layer below Road): Spring 2006

Implementation of soil bioengineering treatments in Section 3 commenced in May 2006 (concurrent with work in Section 1), however, implementation had to be terminated after May 19th due to high flood levels on the Columbia River. Work in Section 3 was continued and completed in June. Pacific willow was planted in 1.3 m sections (clumps), spaced approximately every 15 m along the riverbank

Soil bioengineering structures were installed as show in Figure 1-5 with the exception of additional brush layers installed in some areas planted as two intermittent rows above the main brush layer.

A Summary of Soil Bioengineering Treatments Installed on Riverbank Sections in 2006/2008 is shown in Table1.

Table 1 – Soil Bioengineering Treatments in Riverbank Sections

Riverbank Section	Meters of Brush Layer / Sill Planted	No. Pockets Planted	Meters of Fascines Planted	Length of Brush Layer / Sill Cuttings (m)	Species Planted			
					Pacific Willow (%)	Brush Layer / Sill Species Composition in % (between Pacific Willow clumps)		
						Willow	Red-Osier Dogwood	Cotton-wood
1A	243	---	243	1.5	2	52	31	17
1A (2008)	110			2.3	30	40	10	20
1	100	250	---	2.3	4	61	16	23
2	114	---	---	2.3	4	52	32	16
3A	40	---	---	1.5	2	52	32	16
3	414	---	---	1.5	2	50	29	21
3 (extra work)	225	---	---	1.5	5	65	30	5

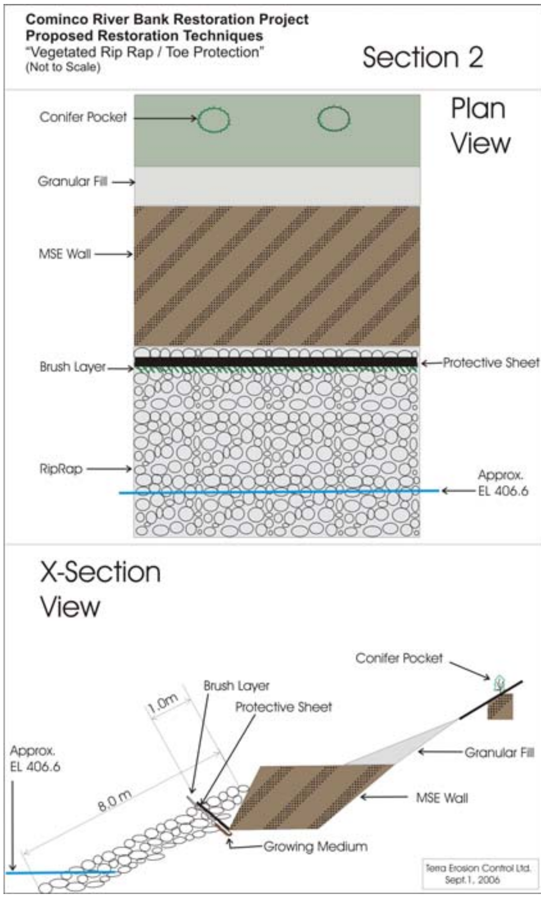

Figure 3: Section 2

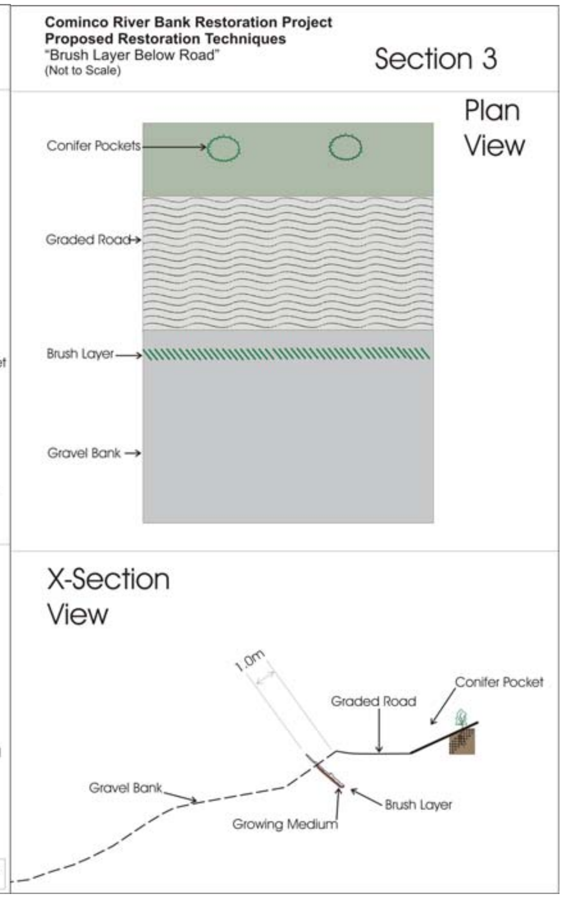

Figure 4: Section 3

Total estimated live cuttings planted in riverbank sections are shown in Table 2.

Table 2 –Cuttings Planted and Area of Riverbank Sections Treated

Riverbank Section	Total Live cuttings Planted/ Sections	Estimated Area (ha)
1A	5245	0.14
1A	1665	0.1
1	3500	0.06
2	1824	0.022
3A	640	0.017
3	8280	0.21
3 (extra work)	5625	(included in section 3)
Total	**25,114**	**~ 0.5**

Summary of Treatments Installed in Hillside Slopes of Riverbank Units during Fall 2006, Spring 2007-08

The restoration prescription for Units 1 to 4 called for the planting of brush layers, using 8 cuttings per linear meter, along with the installation of 9" straw wattles approximately 0.5 m above every second brush layer (see Figure 1-6). A constant 1.15 m vertical distance between all brush layers was used for layout. In order to keep the planting of each brush layer at the correct elevation (on the contour), survey stakes, located using a level, were placed periodically at the end of each brush layer as planting proceeded. A summary of soil bioengineering treatments installed in Units 1, 2, 3 and 4 for 2006, 2007 and 2008 is shown in Table 3.

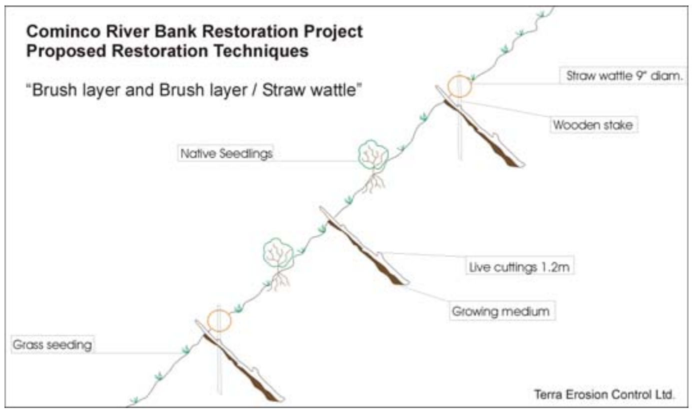

Figure 5: Hillside slope treatment

1-7 Machine assisted planting, Unit 3 Nov. 2006.

1-8 Placement of cuttings in trench. Unit 3 Nov. 2006.

The hillside units were also planted with container type native shrubs and trees (Table 4) and hydro-seeded with native grasses using pulp mill bio solids as mulch.

Spyder Hoe Planting Procedures

Machine assisted planting was done in Units 1 to 4 using a Schaeff Walking Excavator (Spyder Hoe). Planting with this machine involves placement of cuttings in the trench formed behind the bucket, simultaneously as the bucket is pulled laterally through the soil (referred to as a "trench-pull") as show in

Figures 1-7 and 1-8. In order to reduce the extent to which soil collapsed into the trench as the bucket was dragged and thereby allowing more time to insert cuttings, a specialized fin attachment was designed by the personnel of Terra Erosion Control Limited and the operator. Growing medium and other required soil amendments were spread over the excavated trench where the cuttings were placed during and/or after

Table 3 – Summary of Soil BioEngineering Treatments on Hillside Units

Unit	Meters of Brush Layer Planted (all cuttings 1.2m in length)	Species Composition of Brush Layers (%)		Meters of Straw Wattle Installed
		Willow	Cottonwood	
Unit 1 (2008)	3150	20	77	1650
Unit 2 (2007)	4900	10	90	2600
3 (2006)	2900	20	80	650
3 (2007)	3400	10	90	2100
Total Unit 3	6300			2750
4 (2006)	2600	20	80	750
4 (2007)	0	---	---	400
Total Unit 4	2600			1150

Unit	Total cuttings planted	Estimated area covered (ha)
Unit 1 (2008)	**29,300**	**0.65**
Unit 2 (2007)	46,000	0.86
Unit 2 (2008)	160	**----**
Total Unit 2	**46,160**	**0.86**
Unit 3 (2006)	23,200	0.50
Unit 3 (2007)	27,200	0.63
Unit 3 (2008)	160	-----
Total Unit 3	**50,560**	**1.13**
Unit 4 (2006)	20,800	0.6
Unit 4 (2008)	1,350	0.05
Total Unit 4	**22,150**	**0.65**
Total cuttings planted for Units 2, 3, 4	**148,170**	**3.29**

each "trench-pull". Water was also added at the same time. The machine then back-filled the trench using adjacent soil material, prior to repositioning up the slope for the next "trench-pull" On slopes over about 60% the Spyder hoe was tethered to a skidder located at the top of the slope. In some locations where space was confined (e.g., slide chutes in Unit 4), planting with the Spyder hoe was carried out using insertion technique, similar to the method used when planting cuttings using an excavator.

Straw Wattle Installation

Straw wattles (9" diameter) were installed using the following procedure; the location of each wattle line is painted on the slope using a laser level. A shallow trench (approximately 20 cm depth) is dug manually just above the marked line. An appropriate length of straw wattle is laid-out in the trench, and then the wattle is secured using wooded stakes at about 1.5 m intervals. Adjacent wattle lengths should overlap at both ends by 30 cm. The wattles are back-filled (up slope) ensuring that $^1/_2$ to $^2/_3$ of the wattles remain exposed. The ends of each wattle section were tucked into the slope or closed (dammed) off, so that the finished wattles could act as a sediment trap.

Portable Cable System

In order to facilitate the movement of materials (only) on the slope during this project, a portable engineered cable system was used. The cable system consists of top and bottom tripod stations, over which runs a rail cable line (3/8" cable). The station and cable are anchored to concrete blocks. Materials are attached to a universal carriage board that is suspended from a carriage which is moving on a rail line. The loading board is moved up or down the slope using a haul-line (1/4" cable) and electric winch. Due to an approximately 12 m vertical concrete wall located at the bottom of Unit 1, the cable system was modified in the spring of 2008. In replacement of a skyline system, a four wheeled buggy was attached to the winch cable, which was secured to the station/tripod system located at the top of the slope. Live cuttings and other materials were transported on the slope using the buggy.

Table 4 – Summary of Shrub and Tree Species Planted

Species Common Name	Latin Name	Stock Type	No. Planted				
			Unit 1	Unit 2	Unit 3	Unit 4	Total
Saskatoon	Amelanchier alnifolia	415B		130	130	40	300
Saskatoon	Amelanchier alnifolia	1 gal	50				50
Mallow Ninebark	Physocarpus alnifolia	415B		160	150	40	350
Chokecherry	Prunus virginiana	415B	150	115	120	40	425
Western Mtn. Ash	Sorbus scopulina	415B		130	200	90	420
Falsebox	Pachistima myrsinites	615		65	95	40	200
Mock Orange	Philadelphus lewisii	615		65	160	85	310
Redstem ceanothus	Ceanothus sanguineus	615		260	405	170	835
Oregon grape	Mahonia aquifolium	615		65	95	40	200
Oregon grape	Mahonia aquifolium	1 gal	50				50
Yellowstem Ceanothus	Ceanothus velutinus	615		30	160	100	290
Paper birch	Betula papyrifera	415B	200	65	95	40	400
Common juniper	Juniperus communis	1 gal		0	60	40	100
Aspen	Populus tremuloides	1 gal		40	20	0	60
Rose	Rosa ssp.	1 pint		40	80	45	165
Rose	Rosa woodsii.	615B	250			70	320
Black hawthorn	Crataegus douglasii	615		35	60	30	125
Soopolallie	Shepherdia canadensis	415	5	35	45	20	105
Beaked hazelnut	Corylus cornuta	615B	43			14	57
Red-osier dogwood	Cornus stolonifera[d]	415B		60	190	150	400
Wolf willow	Eleagnus commutata	615B	75				75
Sitka alder	Alnus viridis[e]	415B		0	120	100	220
Ponderosa pine	Pinus ponderosa	410		260	350	150	760
Ponderosa pine	Pinus ponderosa	615A	310	230	320	175	1035
Western Larch	Larix occidentatlis	615A	390	480	630	400	1900
Douglas fir	Pseudotsuga menziesii var. glauca	615A	445	550	720	450	2165
Hybrid Spruce	Picea glauca x engelmanii	615D	110	140	180	120	550
Totals			2078	2955	4385	2449	**11,867**

GENERAL IMPLEMENTATION PROCEDURES

Live Material Harvest and Soaking

Harvest of live cuttings for the riverbank sections was carried out within the Creston Wildlife Management Area (CWMA) near Creston, BC (area located near the project site) in November 2005. Sufficient material was harvested for all five riverbank sections and stored for the winter under snow at the Salmo-Creston summit (1800 m elevation).

Live cuttings (cottonwood and willow) were harvested for Units 3 and 4 starting the fall of 2006. At the end of each week of harvest, the cuttings were transported to the site for installation. Additional live cuttings for Unit 2 were harvested in December 2006, from an area of private land near the project area. This material was also stored at high elevation.

All live cuttings were soaked in water for approximately a week prior to planting. Soaking was carried out using tanks constructed from a 20-foot shipping container, cut in half as show in Figure 1-9. A constant flow of clean water was provided into each of the tanks during the soaking process. The tanks were covered with silva-cool tarps to keep the water temperature cold.

Figure 1-9 Live cutting soaking tanks.

Growing Medium

During installation of live cuttings, a custom growing medium was spread over the area where the cuttings were placed in the soil. This soil amendment consists of a mix of peat, organic fertilizer, a mycorrhizal fungi inoculant, and natural humic complexes. Varying quantities of lime were also added.

Watering of Cuttings during Planting

Live cuttings were watered during planting, either using a gas pump drawing water from the Columbia River or a gravity-feed. This was done to ensure that growing medium was saturated and soil moisture was fully charged around the planted cuttings, minimizing the risk of desiccation.

Painting of Cuttings

The protruding distal end of all cuttings was painted with diluted latex paint prior to planting (50% paint/ 50% water). This will reduce desiccation and disease entry.

Irrigation of Planted Areas

An irrigation system was installed in July 2006 over the areas completed during the spring of 2006, and on the hillside units by early to mid summer 2007.

Lime Application

Dolomite lime application was carried out on Units 2, 3 and 4 using a hydro-seeding truck . The quantity of lime applied to each area was based on the results of lime requirement analysis from soil samples. These lime requirement values provide the quantity of lime needed to increase soil pH to 6.0 in the top 20 cm. Two forms of dolomite lime (# 30 and # 0) were added in equal amounts to the growing medium used in brush layer planting in Units 2, 3 and 4.

Compost Tea Application

Aerated compost tea will be applied as a soil drench three times each year (spring/summer/fall) – the first application occurred on completed units in the fall of 2007. This will help restore and replenish soil and foliar microbiology, which is seen as especially important since elevated metal levels on this site could potentially cause toxicity to soil and foliar microbiology. The recommended application rate is 50 US gallons/ha (based on Soil Foodweb training held in Vulcan, Alberta, March 2007). In the case of Units 2-4, with a total area of 2.7 ha, 135 gallons of tea are required (2007 application). When tea is applied to all four units (starting in 2008), with a total area of 3.4 ha, 170 gallons are required.

Soils under deciduous forest have soil bacteria biomass to fungi biomass ratios in the order of 5:1 to 100:1 (Soil Foodweb Training 2007). According to Ingham (2005), compost tea brewed for application on sandy sites with deciduous trees should have two to ten times more (beneficial) fungal biomass than bacterial biomass.

In order to ensure a high quality fungal tea is used a combination of qualitative assessment will be caried out by sending one tea sample each year for detailed lab analysis as well as in-house analysis to be carried out by Terra Erosion Control using a light microscope.

The compost tea, combined with irrigation water, is injected into an irrigation system with a 45 gallon per run capacity.

CONCLUSION

The Riverbank Re-habilitation project demonstrates the logistics involved in successfully developing and implementing a large site re-habilitation project on a site with challenging soil conditions and extreme steep slope gradient, using a portable cable system to efficiently transport material on slope, as well as the use of a spyder hoe excavator to assist the installation of soil bioengineering structures. This project also shows innovative ways of installing vegetated class 1 & 2 riprap (woody vegetation within the riprap) which soften the rock appearance, create fish habitat by providing shade, and provide cover and small organic debris input into the river. Also demonstrated is the process of stabilizing and improving aesthetics on an industrial (mostly) bare slope using soil bioengineering techniques, the results of one and two growing seasons on the various units/sections, as well as the summary of first sampled data gathered during the fall of 2007 as part of the Cominco Riverbank Restoration Monitoring Program.

Teck Cominco Metals Ltd was awarded a ”citation for reclamation” for the riverbank project at the BC Mine Reclamation Symposium, organized by the Technical and Research Committee on Reclamation on September 19, 2007 held in Squamish, BC.

REFERENCES

Schiechtl, H.M. and R. Stern 1996. Ground Bioengineering Techniques for Slope Protection and Erosion Control. 146p. Blackwell Science Inc., Cambridge, MA.

Soil Foodweb Training 2007. Course Materials from Soil Foodweb Canada Training Program, Vulcan, AB. March 2007.

Gray, D.H. and R.B. Sotir 1996. Biotechnical and Soil Bioengineering Slope Stabilization: A Practical Guide for Erosion Control. 378p. A Wiley-Interscience Publication, NewYork.

Ingham, E. 2005. The Compost Tea Brewing Manual, 5th edition. Soil Foodweb Incorporated, Corvallis, Oregon.

Leeters, E.E.J.M. and W.de Vries 2001. Chemical composition of the humus layer, mineral soil and soil solution of 200 forest stands in the Netherlands in 1995. www.library.wur.nl/wasp/bestanden/LUWPUBRD_00316187_A502_001.pdf.