Final Report
ER 390

Control of Shoreline Erosion at Sooke Reservoir Using Planted Willow Cuttings

For
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by
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1.0 Abstract

The Capital Regional District Water Department needed to expand the capacity of the Sooke Reservoir in order to meet the future water demands of the Greater Victoria residents. To facilitate this expansion the existing dam was raised and the future shoreline was prepared for flooding. To minimize the impacts of shoreline erosion on drinking water quality during this flooding a shoreline erosion strategy was implemented. One of the strategies implemented to control shoreline erosion was the cutting, processing and planting of over a 100,000 willow cuttings in areas identified to be at high risk for shoreline erosion potential. Both trench and bar planted willow cuttings were installed with varying degrees of success. A number of challenges were presented and milestones reached during the willow planting program which extended over a two year program (2001-2003). The placement and strategies for future willow cutting planting programs needs to be guided by the results of ongoing monitoring.

2.0 Introduction

Sooke Reservoir is located on southern Vancouver Island, British Columbia approximately 30 km west of the city of Victoria at 48° 33’ 0” N and 123° 42’ 30” W (See Appendix I and II). The catchment area is 8613 hectares and is about 98% owned and controlled by the Capital Regional District’s (CRD) Water Department. Sooke Reservoir supplies almost 100 percent of the water used by area residents as well as flows for fisheries in the Sooke River. It is the primary source of drinking water for the Capital Regional District’s (CRD Water) water supply system. The water supply is unusual in that it is completely protected from all other land and is managed strictly for the purpose of supplying drinking water.

Protecting water quality through a “Multi-Barrier Approach” that integrates ecological risk assessment with adaptive management facilitates the supply of high quality, unfiltered drinking water to Greater Victoria residents. A Strategic Plan for Water Management provides the Risk Management Framework, which describes the process for working with potential risks to water quality and secondary values (See Appendix III). This framework provides an overall strategy for assessing risks and minimizing the potential for water quality deterioration. One of the programs identified in the framework is the Terrestrial Ecology Program, which encompasses the vegetation ecology, wildlife ecology, soils, surficial geology, and the reservoir draw down zone.

The Strategic Plan for Watershed Management (1999) sets the direction for the management of the Greater Victoria Water Supply Area (WSA).
Recognizing the primary management goal, of producing an ample supply, of safe, high
demand and water quality for Greater Victoria residents. It also recognizes the secondary goal of
providing regional conservation, and maintenance of biodiversity where these do not
compromise water quality.

Sooke Reservoir is a combination of a natural lake basin and reservoir created by
flooding portions of the surrounding watershed. The first dam was built in 1914 and
formed the Sooke Lake Reservoir. Due to increased water supply demands a new dam
was constructed downstream of the first dam in 1970. In 1990 work began in preparation
to raise this second dam by five meters from 180.75 meters to 185.75m:- Sooke Reservoir
Expansion Project (SREP) (See Appendix IV). The proposed new high water level was
increased an additional meter to 186.75m in 2002 to account for water released into
Sooke River for First Nations and fish habitat and hatchery requirements. At this new
level Sooke Reservoir will be 8.3 kilometers long with a maximum width of 1.6km, a
maximum depth of 75 meters. The reservoir will have a total usable capacity of
approximately 92.7 million cubic metres (20,400 billion gallons) and typically gets drawn
down approximately 7 meters each year.

Sooke Reservoir is a biologically active, but nutrient poor water body (oligotrophic). The
low levels of nutrients help to maintain a high quality drinking water supply that requires
limited treatment. Although annual cycles of algae and other organism are a normal part
of the ecology of Sooke Reservoir, uncharacteristic increases in nutrient levels resulting
from shoreline erosion have the potential to drastically change the biological activity of
the reservoir and thus the high quality of the drinking water supply.

The inherent conditions of a watershed (physical, chemical, biological) and the human
induced uses and management within a watershed determine water quality and water flow
conditions that are essential to ecological functioning. Part of the overall watershed
management guiding principles are to develop, implement, and monitor reservoir
perimeter vegetation plans, to reduce sediment input from draw down zone erosion and
perimeter instability. In preparation for the anticipated raising in the spring of 2003 the
majority of the shoreline stabilization began in October 2001 and was completed just
prior to the water level increasing in April 2003.

Sediment entering an aquatic environment are generated when erosion process are not
controlled at disturbed sites. Thus an integral part of any biological erosion control
strategy is to establish vegetation as soon as possible providing a foundation for
succession to continue with little to no additional inputs. On most natural shorelines,
erosion rates are low due to the development of equilibrium conditions (slope or profile
and sediment size). In a newly created reservoir or in an existing reservoir where the
water level will be raised, erosion of shoreline materials can occur rapidly and will
continue until equilibrium conditions are reached (AXYS 1994).

Bio-engineering is the successful use of vegetation in concert with engineering structures
to increase slope stability against shallow mass wasting (Beese et al. 1994).
The result is efficient erosion control and slope stabilization with minimal soil disturbance. Plant material increases soil strength through the transfer of root tensile strength to soil shear strength. As the plants mature they increase in strength and provide increased resistance to natural forces (Schiechtl 1985). Bioengineering solutions uses native plant species to:

- Enhance slope stability
- Control sediment generation.
- Maintain plant and wildlife biodiversity.
- Establish and enhance microsites for secondary succession.

Pioneering woody species are of particular importance in the successional reclamation of disturbed sites. This group of plants represents the successional bridge between the herbaceous initial colonizers of a disturbed site and the later seral types and thus play a key role in the successional advancement and stabilization of a site (Madrone Consultants).

As part of phase I SREP, the use of planted willow cuttings was integrated into the shoreline stabilization program. The most appropriate woody shrub species for erosion control along the future shoreline was native willow (Salix sp.). Planted willow cuttings will increase in biomass production with moist soils, and will tolerate intermittent flooded soils. The threshold for maximum flooding will depend on the rate, duration and timing of flooding as well as soil conditions, and species. Overall locally collected unrooted willows planted in the fall in high moisture zones are known to be most successful. Stem cuttings from willow species readily root and establish when planted in appropriate sites.

A naturally established band of willow is located just below the old high water level along the existing shoreline of Sooke Reservoir. The structure of this band of willow has helped to control ongoing shoreline erosion potential generated by the annual cycle of reservoir infilling, drawdown and wave action. An SREP willow planting strategy was developed in 2001 in hopes of fast tracking the establishment of a similar band of willow just below the new proposed high water level for the purposes of mimicking its natural erosion control potential and ecological function.

The climate of the Greater Victoria Water Supply Area (WSA) is mild and moist with annual precipitation of approximately 1500mm, warm dry summers seldom exceed 30°C and mild winters typically free from sub-freezing temperatures. The snow pack in the watershed is minimal.

The Greater Victoria WSA is largely comprised of the Nanaimo Lowland Physiographic Region. This region occurs below 600m elevation on the east coast of Vancouver Island from Victoria to Campbell River and includes the Gulf Islands. Within the WSA the terrain is gently rolling and relatively uniform. The northeast portions of Sooke Watershed consist of well rounded and hummocky hills with minor bluffs and cliffs.
2.1 Soils
The bedrock geology of the Sooke Lake Reservoir watershed can be described as rugged, steep, precipitous geomorphic terrain associated with exposed and underlying Wark gneiss occurring on the western side and the northeastern corner of the reservoir (Green 1994).

The rock is considered to be highly competent to erosion. Coquitz gneiss occurs along the east side of the reservoir and in the northwest corner. This is found underlying the well-rounded, yet hilly areas. This rock is also considered to be highly competent to erosion. Leech River schists found on the extreme southern end of the reservoir is the only bedrock considered to be of erosion concern.

The majority of the Sooke watershed is located on a subdued terrain associated with the Nanaimo Lowlands physiographic region (Holland, 1976). Surficial deposits are mainly till or morainal blankets and veneers directly overlying bedrock. Orthic Dystric Brunisols are the most common soil type in the study area (Green 1994). They are found to occur on most well drained sites, as both morainal and fluvio-glacial terrain types. Gleysols are known to occur in some of the low-lying areas, which are subjected to prolonged saturation by ground water. Typic Mesisol organic soils have also been mapped within the study area. They show an intermediate degree of decomposition of Sphagnum moss, or peat.

Because most of the soils in the study area do not have a high inherent erodibility, topography and cover will play an important role in determining relative susceptibilities (Green 1994). Soil erosion impacts will be strongly influenced by erosion control measures used within the expanded draw down zone.

2.2 Vegetation
Coastal Douglas-fir is the dominant tree species in this Coastal Western Hemlock very dry maritime biogeoclimatic subzone (CWHxM). Due to the longevity of this tree and the history of repeated fire and windthrow disturbance in the area, rarely do any sites proceed to a forest dominated by other species. Other tree species that occur are red cedar, pine arbutus, grand fir, alder, and maple. Shrub species include salal, Oregon grape, huckleberry, bald hip rose, ocean spray, false azalea, salmonberry, devil’s club and Labrador tea. Several willow species frequently occur adjacent to Sooke Reservoir’s shoreline in a 2-5m wide band with the dominant species identified as pacific (salix lucida), scoulers (salix scouleriana), and sitka (salix sitchensis). This band is subjected to a fluctuating water table. This area or drawdown zone consists of coarse textured shallow lacustrine over morainal fluvial or bedrock materials.

As part of the SREP planning process, an Environmental Impact Assessment, a Greater Victoria Water District (CRD) Sooke Lake Reservoir Expansion Site Preparation Work Plan, and a Classification and Erodibility Assessment of Sooke Reservoir was undertaken to identify the risks associated with expanding the Sooke Reservoir. Based on the risks identified in the environmental assessment, a detailed site plan for each
shoreline block to be cleared was developed. Water quality protection was the primary criteria in planning all on site activity.

One of the shoreline erosion control techniques recommended and later implemented was the planting of native willow species along the new shoreline. All three planning documents recommended the use of native willow species as part of the overall shoreline erosion control strategy in preparation for raising the water level at Sooke Reservoir. To be successful the willow planting program developed for the SREP needed to provide several functions:

2.3 Planted willow functions

- Roots to bind soil particles to control shoreline erosion
- Shoots to act as a baffle to diffuse wave energy to control shoreline erosion before it acts at shoreline water interface to erode exposed soils
- Exposed planted cutting + shoots developed to trap cwwd at or behind willow bands
- Exposed planted cuttings + shoots developed to trap seed sources
- To quickly enhance/replace the ecological and water quality functions of the existing band of willow.
- To provide the habitat for other native plant and animal species
- Guide future planting strategies in and around the Water Supply Area (WSA)

3.0 Purpose

To control shoreline erosion at selected sites along Sooke Reservoirs shoreline both during and following the raising of the reservoirs water level by 6m (180.75m – 186.75m).

4.0 Objectives

- To identify and harvest the dominant willow species (Salix sp) from the existing shoreline willow band at Sooke Reservoir.
- To document willow harvesting, cutting specifications and planting strategies specific to the SREP.
- To develop and implement experimental willow trials to determine future willow planting prescriptions.
- To establish mixed willow species planting trials at both high wave energy and low wave energy sites.
- To establish three, planted willow, water inundation, species trials at both high wave energy and low energy sites to guide future willow planting strategies.
• To determine the elevation threshold that planted willow cuttings will re-establish at sites with fluctuating water levels and subject to low and high wave erosion.

• To determine the location(s) of the existing shoreline willow band relative to the reservoirs storage cycle and project future location(s) for new reservoir storage cycle.

• To establish two bands of willow around Sooke Reservoir, as quickly as possible, retaining the existing genetic stock by taking cuttings from the current shoreline willow band.

• To establish a planted wall of willow cuttings at a location to dissipate erosive wave energy at the shorelines new high water level interface.

• To identify areas in which willow planting can be used to effectively minimize potential soil erosion and determine the most efficient planting method.

• To establish bands of willow at 185.75m and at the 185.0m elevation line along sections of the shoreline with low to moderate slopes and suitable soils.

• To document and map all SREP willow planting locations

• To evaluate the SREP willow cutting and planting strategies to guide future planting programs.

• To monitor sites where willow cutting, bar planting and, trench planting have taken place and to document the growth rates and soil erosion in response to raising of the Sooke Reservoir.

5.0 Methodology

The stabilization of the new 39 km of Sooke Reservoir shoreline was required to minimize sedimentation that could adversely affect water quality. The stabilization of the future shoreline of Sooke Reservoir involved the planting of suitable vegetation and placement of rock armoring in combinations appropriate to soil types, slope and potential for wave erosion in 25 possible cutblocks (2-26) (See Appendix V).

5.1 Site Selection

Blocks surrounding the Sooke Reservoir were surveyed and rated for potential shoreline erosion during the future raising of the water level at Sooke Reservoir in 2001 (Golder and Associates 2001). High and low wave erosion sites suitable for willow planting transects were identified by a shoreline erosion specialist consultant (Ian Wright), and two willow planting test sites were confirmed.

• Block #9 is a North aspect site subject to moderately low energy wave erosion.
• Block #4 is a South aspect site subject to high-energy wave erosion.

5.2 Willow Harvest Sites
Willow donor sites were identified on the basis of amount of suitable willow, and the ease at which it can be harvested, processed, and loaded for transport. Six main willow donor sites were identified with suitable willow and effective road access: Blocks 2, 23, 13, 14, 21, and 7.

Initially chainsaws with vegetable oil were used to cut larger willow stems and hand loppers were used to cut smaller diameter stems. Once cut the entire stem was pruned using hand pruners and placed in a pile with the butts facing the same direction. When enough stems were pruned and piled usually midday, the crew began to cut and bundle the willow cuttings.

A cutting table was setup with cutting requirements marked for precision. The pruned stems were loaded and fed in the same direct along the length of the table. A chainsaw was used to cut several stems at a time once the ends were squared and positioned at the correct length for processing. Bar planting stock was identified and piled separately. Once enough stems were cut, counted and piled to produce a bundle they were quickly tied. With a five person crew the entire loading, squaring, cutting, and sorting, and bundling could proceed without interruption if enough pruned stems were supplied.

An attempt was made to harvest willow as close as possible to the planting site to reduce transportation time and to maintain any block species variability. The amount of willow harvested from the existing willow band at each site was dependent upon the erosion potential of the harvest site and if rock armor was going to be established at the site.

Willow donor sites that were to be rock armored could be harvested in greater numbers than those that were to rely on the existing willow band to control shoreline erosion at lower elevations. A minimum of a 1 meter wide leave strip of the existing willow band was retained at all donor sites that were not scheduled for rock armoring.

5.3 Establishing Sooke Reservoir Elevations and Experimental Sites
The existing willow band was surveyed for its position relative to the old high water level and this was then projected for the new high water level (See Appendix VI).

Elevation contours were established by survey crews along Sooke Reservoir shoreline in preparation for proposed SREP activities including 185 and 185.75m for willow planting and 175 to 188m for the willow trials.

5.4 Willow Trials
Three dominant species of willow were identified by Axys Environmental Consulting Ltd during ecological site description surveys conducted in 1997. These dominant species were identified and marked at the donor site by the coordinating biologist in preparation for the willow species trials: pacific (Salix lucida), scouler's (Salix scouleriana), and sitka (Salix sitchensis).
Willow transects were installed on Block #4 and Block #9 and marked every half meter in elevation with wooden stakes. These stakes were later replaced with painted re-bar stakes complete with elevation tags. At each of the transects, two types of willow inundation planting trials were installed, one on each side of the transect line. Both types were installed using a steel bar.

**Type #1** Willow species preferences trials (Pacific, Scoulers, and Sitka) (188m to 175m). The species were planted every half meter in elevation starting with Pacific willow on the inside next to the elevation stake, followed by scoulers willow and then sitka willow. Willow cuttings were selected with varying diameters at each elevation stake. Three cuttings of each species were installed, for a total of nine cuttings at each half-meter in elevation.

**Type #2** Mixed willow species and survival under a fluctuating water table (182m-175m). A random mix of willow species and sizes were used for this type. Cuttings were planted in a single line every half meter (horizontal distance).

5.5 Willow Planting

Two types of cuttings were harvested: Bar planting and trench planting.

5.5.1 Bar planting

Four foot by ¼ inch cold rolled steel bars with a pointed tip at one end and sledge hammers were used to plant individual cuttings along designated elevation lines. To increase bar planting efficiency only straight cuttings between 1.5cm and 3cm diameter at the butt were used. Bar planting cuttings were pruned to a target length of 80-100cm.

All willow cuttings greater than 3cm at the butt and with a target length of 100-150cm were utilized in the trench planting. Trench cuttings were not restricted by large size or straightness, as were the bar planting stock.

The target bar planting depth was 70% below ground level unless soil and site conditions did not permit planting to this depth. Five-pound sledgehammers were used to drive the planting bar into the ground to achieve this target planting depth when necessary. Then willow cuttings were placed in the hole, which was immediately closed around the planted cutting. Target bar planting areas were those rated lower for shoreline erosion or where shoreline areas in which site conditions did not permit efficient excavator operation: - rocky, steep, subsurface flows, or access.

5.5.2 Trench planting

A small excavator (John Deere 80) with an 18 inch digging bucket and a 36 inch cleanup bucket was used to dig and backfill, after willow installation, an 80cm to 110cm deep trench parallel to the proposed new high water level. Excavated soils were piled on the topside of the trench, furthest away from the reservoir edge.
Proposed trenched and bar planted willow were installed as close as possible to the identified potential erosion areas at 185.0m and 185.75m, while providing access to areas where other site stabilization work would be carried out.

Also a 5m no trenching buffer was also implemented around known creek and obvious drainage channels to minimize sediment impacts.

5.5.3 Presoaking and Watering
During the 2002/03 planting season willow cuttings were presoaked in nearby wetlands for a minimum of 10 days before planting.
Also in the summer of 2003 as a response to an unusually warm summer all trench planted willow lines were heavily watered using a Wajax fire fighting pumps with 1”-1.5” hose.

5.5.4 Survival surveys
Each year willow planted blocks were surveyed to monitor willow survival and health. Monitoring consisted of walking each block and sampling 50-100 cuttings representative of the site conditions and determining live:dead ratios and average shoot length. Deer browse and or competing vegetation was also noted during site surveys.

6.0 RESULTS
To date shoreline erosion has been minimal at Sooke Reservoir following the recent inundation to 185.75m and drinking water quality has been maintained throughout the entire process. Planted willow has been established in 17 blocks around the reservoir with both the trapping of CWD and the reduction in wave energy at ~185.0m and ~185.75m level (See Appendix V). Planted willow has also provided a platform for the establishment of both herbaceous and shrub pioneer species.

The Sooke Reservoir reached a new high water level of 185.75m in the spring of 2004, and was held at that level as a precautionary measure for additional water quality monitoring. This allowed for a two staged raising process rather than all at once, with the final 1 meter increase to 186.75m expected in late 2004 early 2005.

6.1 SREP Willow Planting Specifications 2001/02
A willow harvesting, bundling, and, planting strategy was developed and implemented for the proposed willow work planned for the SREP 2001/02 Site Stabilization. This strategy was maintained for the 2002/03 season (See Appendix VII).

6.2 Willow Trials
A total of five bar planted trials were installed, three on block 9 and two on block 4.

- Installed Block #9 = transect 1,2, and 3
- Installed Block #4 = transect 4 and 5
Willow harvesting began on November 20th and all five willow trials were installed by December 2nd 2001. It took approximately 30 person days to harvest, process and install the transects and approximately 1500 willow were planted. Willow planting, bar and trench continued to February 18th 2002.

6.3 Willow Planting
The existing willow band was determined to be located between 180.00m-181.00m relative to the old high water level of ~180.75m. The new proposed willow bands were projected to 185.00m and 185.75m for the new proposed water level of 185.75 which later changed to 186.75m.

2001/02
- Proposed SREP planted willow at 185.0m and 185.75m was started on November 20th 2001 and completed on February 15th 2002. Approximately 32,500 willow cuttings were bar planted and approximately 60,000 willow cuttings were trench planted during this time period.

2002/03
- Proposed SREP planted willow at 185.0m and 185.75m was started on November 24th 2002 and completed on March 17th 2003. Approximately 2,500 willow cuttings were bar planted and approximately 55,000 willow cuttings were trench planted during this time period.

SREP 2001/02 and 2002/03 Willow Planting Installations by Block

<table>
<thead>
<tr>
<th>Block #</th>
<th>Willow Installed at 185.0m and 185.75m</th>
<th>Willow Installed at 188m to 175.0m</th>
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• Exposed soils between 185.75m and 185.0m, susceptible to erosion had additional bar planted willow installed. This was not a continuous application across the block and in some cases provided the only opportunity to establish pockets of willow cuttings in otherwise rocky areas (See Appendix VIII).

6.4 Willow Production

6.4.1 Willow Harvesting
On average a five person crew could cut and process between 1000 and 3000 cuttings/day. At times a 15 person crew was used to keep cutting productivity above daily planting requirements.

Also the age of willow stand that was to be harvested also influenced cutting productivity. Older stands generally produced thicker, non-uniform cuttings with fewer total cuttings. Younger stands produced a greater number of uniform cuttings but they were generally smaller in diameter.

6.4.2 Bar Planting
On average one person could bar plant 100+ cuttings a day with an eight person crew planting approximately 1000 cuttings per day. Strict quality control had to be implemented on bar planting stock to ensure efficient planting.

6.4.3 Trench Planting
On average the excavator could dig and backfill approximately 100-200m/day, on flat easy digging blocks such as block#12,13, and 14 it is much closer to 200m/day.

Total productivity
2001/02 approximately 60,000 trenched cuttings + 32,500 bar planted cuttings
2002/03 approximately 55,000 trenched cuttings + 2500 bar planted cuttings

For a total of approximately 150,000 willow cuttings harvested, processed, and planted for approximately 15km of planted willow line.

6.5 Willow Survival

Willow survival for both trench and bar planted cuttings was 90-95% following the first growing season over all willow planted. During the second growing season both trench and bar planted cutting survival decreased. Trench planted cuttings dropped to between 50-70% survival and bar planted cuttings dropped to 30-50% survival. During the third growing season planted willow cuttings have dropped to an overall average of 30-50% for trench planted willow and 10-30% for bar planted willow cuttings.

Blocks with above average survival (50%+)
2, 7, 17, 19, 21

Blocks with average survival (30-50%)
6,12,13,16,17,20,23

Blocks with poor average survival(10-30%)
6.5.1 Willow planting trials
At block 9 trials, (low wave erosion site), willow cuttings have low overall survival 10-20% but willow cuttings have survived at low elevations at which they would be submerged from 3-6 months. Bar planted cuttings have not been undermined at this location and most of the upper organic soil layers have remained in place. Although herbaceous cover is regenerating the only healthy looking shrub species present in the inundation zone is both planted and regenerating willow.

At block 4 trials, (high wave erosion site), willow cuttings have very low overall survival 0-5%. Almost all of the willow cuttings at this location have been undermined or have been badly damaged or girdled by wave erosion activity. All of the upper organic soil layers have been completely stripped away and no live vegetation exists in the lower inundation zone (175m -186.75m) except large natural and planted willow.

Based upon shoot growth initial observations (1 growing season 2002) appeared to indicate that both pacific and sitka willow cuttings had the best survival rates although differences were very minor initially. The 2004 surviving willow appears to be mostly sitka willow, with a very minor component of pacific willow. This is consistent with the non trial planted willow (bar and trench) although species ratio’s planted was not controlled as in the trials. Thus species survival rates may be skewed to what was planted.

6.6 Presoaking and Watering
All 2002/2003 planted willow was initially soaked before planting. Willow soaking sites took advantage of small wetlands adjacent to Sooke Reservoir with good vehicle access close to shoreline blocks scheduled for willow planting. Seven main soaking sites were used: 15s, Joes Corner, 3A Spur rd, ~1.5km Old Leechtown rd, Haflu wetland, abandoned Old 2A road wetland, and 7s wetlands.

All trench planted willow was watered twice in the summer 2003. Where possible, an attempt was made to deliver approximately 1 gallon of water per cutting to the bottom of the trench. Bar planted willow cuttings were watered when the trench watering setup permitted. Each block required an average of 2 person days to deliver the required water to each willow line and took approximately 4 weeks to complete one round of willow watering.

6.7 Shoreline Erosion
Although shoreline erosion is evident at all areas along the new shoreline all planted willow at the target elevations of 185.00 and 185.75m have not been undermined and provide a continuous line of shoreline erosion control.
Some areas not willow planted have exhibited the greatest amount of shoreline erosion for the existing high water level of ~185.75m. Planted and natural willows dominate the new inundation zone with much of the herbaceous and shrub layer dying back following submergence. Planted willow lines have acted as a debris trap, trapping coarse woody debris, eroded vegetation and dispersed seeds.

6.7 Costs

Total Cost for Willow Stabilization

Estimated costs per meter
Bar Planting $2- $3/m
Trenching $3- $6/m (costs do not include low bed transportation costs)

Estimated costs are based upon the following assumptions and should only be used as guides:

- Estimations are assuming no breakdown time or partial days due to weather conditions
- It assumes that a 10 person crew plants a minimum of 1000 cuttings/day at one meter spacing.
- It assumes that a 5-person crew can cut between 1000- 3000 stems/day. This will vary greatly with the type of stems to be cut and willow availability at the donor site.
- It also assumes easy access to the willow at the donor site.
- It does not include the additional time required for cleanup of harvest sites.

To get an accurate cost per meter one would have to survey the willow at each block and determine the total costs at the blocks for cutting, trenching and bar planting. This was conducted for block #6

Block#6

1066 m of willow installation was completed on Block #6 (2001/02)

216m of trenching = $5.07/m
850m of bar planting = $2.49/m

Total cost for the block is $5016.76

An average of ($5016.76/ 1066m) = $4.70/m
An average of ($5016.76/3010 cuttings) = $1.67/cutting

Based upon field observations on other blocks where the majority of the willow was installed by trenching and willow harvesting became limited at the donor site these numbers maybe in fact double for the cost per meter of willow installation. In blocks where the majority of the block was bar planted the cost per meter could be reduced.
Disturbed areas created during trench willow installation were grass seeded with a reservoir mix which was not included in the planting costs. Also the cost of donor site cleanup was not included in the costs. At block#2 this included the rental of an excavator and dump truck for ½ a day for cleanup and transport of the discarded willow material.

7.0 Discussion

Although site plans were developed for each block based upon shoreline erosion potential and proximity to the south basin, until planting began it was difficult to predict soil depth, subsurface flows, and vehicle access while coordinating with ongoing SREP activities. This often required on site adjustment to planting locations and willow requirements. Ongoing activities such as land clearing, road deactivation, culvert removal, rock blasting, transport and placement, and shoreline surveying were just some of the activities that needed to be scheduled around.

Willow harvesting, processing, and planting specifications were effective at controlling willow cutting quality, transportation and productivity requirements. Cutting sizes quoted were often used as minimums and adjustments had to be made to the number of cuttings bundled when large stock were consistently processed due to size and weight restrictions in safely handling bundles. Cutting production was largely influenced by access to the donor willow band at ~180.0m. This access was limiting once the water level at Sooke Reservoir became higher than the elevation of the current band of willow surrounding the shoreline in January 2002 and again in 2003. The water level at Sooke Reservoir typically determined the length of the willow harvest program each year. Although other higher elevation willow donor sites were available they were often too small, off catchment, or with poor vehicle access.

7.1 Willow Harvesting, Cutting and Planting Strategy

The willow harvesting, cutting and planting strategy was effective. The minimum size requirements for harvesting willow was used as an absolute minimum and an attempt was made to randomly distribute both thinner and wider cuttings during both bar planting and trench planting installation. This was an effort to reduce large gaps in the willow lines attributed to cutting size induced mortality. Randomly distributed willow cutting sizes would encourage uniform survival/mortality within the planted line reducing large gaps due to cutting size.

The equipment used to cut the willow seemed to work efficiently although as the reservoir water level began to increase it also limited the area’s in which chainsaws could be safely used without increased risk to water quality from oil leaks. At higher water levels hand saws and pole pruning saws were only allowed for harvesting purposes. This dramatically reduced harvesting and cutting production. As the water level continued to rise at Sooke Reservoir it became necessary for some willow crew members to wear hip waders in order to access the existing donor willow band.
Increasing water levels also reduced the amount and level of existing willow band above water that could easily be harvested.

The large amount of cutting debris was not anticipated initially, and thus clean up costs were not accounted for in budget projections. The bundling of processed cutting allowed for daily productivity to be tracked and ensured that enough willow was transported and distributed along the proposed planting lines in preparation for planting the following morning. Willow cutting production had to out perform planting productivity to ensure crews and heavy equipment were not kept waiting. At times this meant closely monitoring both activities and redistributing the crews when necessary.

Once cut and processed an attempt was made to have willow cuttings planted within 24 hours unless they were stored for 10 days of soaking (2002/03 only). Soaked willow cuttings increased in weight substantially and a tractor with a large bucket was required to effectively reload and redistribute the cuttings on the block to be planted. The tractor also proved to be useful at accessing soaking willow cuttings at sites where the water level had drawn down making vehicle access difficult.

The SREP willow program exhausted the most productive willow sites where harvesting could be conducted without interrupting concurrent SREP work activities. Harvest sites have been surveyed in 2004 during low water and many of the stems cut in 2001/02 have coppiced producing long straight shoots 2m+ tall. Thus long term willow programs should investigate both willow harvesting and production rates for sustainable willow production especially at sites that have good access and productivity. Alternative sites for willow harvesting for future willow installations would include Blocks 18 and 19. Cragg Main is an example of a potential off catchment willow harvesting area that could be investigated for future willow recruitment although it is preferable to use on catchment stock to reduce any introduction of non catchment biological activity to the drinking water supply area.

7.2 Willow Planting Trials

The results from the willow trials installed on block #4 and #9 will guide future willow stabilization work within the WSA. Continued monitoring will help to determine the elevation range of planted willow subjected to fluctuating water levels at Sooke Reservoir. This monitoring will also help to determine if there are species response differences in these elevation ranges and how these results compare across both high energy and low energy wave sites. Monitoring should include the influence of surrounding vegetation. While the occurrence of scotch broom adjacent to planted willow appears to impede growth and subsequently survival (competition for moisture and nutrient resources). The occurrence of grass species adjacent to planted willow lines appears to create an environment for greater planted willow survival (possibly shading during hot weather and less competition for moisture and nutrient resources at depth).

It was difficult to monitor root development in planted willow cuttings without disturbing adjacent cuttings due to the proximity of each cutting with its neighbor.
Also the depth at which the cuttings were planted made it difficult to excavate root systems without disturbance. On the few willow cuttings that were excavated average shoot growth out performed average root growth during all years.

However it was difficult to determine the length of all fine roots developed and comparison were visual only. Willow were found to survive at low elevations submerged for up to six months at block#9 although shoot and leaf development appeared stunted compared to surviving upland cuttings. Willow survival decreased (0-5%) in upland areas that were dominated by scotch broom. Following installation of the willow trials scotch broom plants increase in both height and density; thus willow species trials and inundation trials were heavily influenced by competing vegetation which was not initially controlled or monitored.

Future willow planting activities will be guided by the results of these trials and they will help to determine where willow can be installed with the greatest potential for establishment relative to the proposed new shoreline. Also the need to control competing vegetation will be reviewed as part of future willow planting programs.

7.3 Bar Planting
The planting bars and sledgehammers were effective for installing willow cuttings, although it limited the size of willow cuttings that could be planted. The equipment was fairly inexpensive and required very little maintenance and thus no delays occurred as a result of equipment failure. However due to the small width of the planting bar (3/4”) and the target depth at which they were to be planted (70%) it meant that quality control on selected bar planting stock was imperative to reduce installation time and to ensure target planting depths were achieve when possible.

7.4 Trench Planting
The John Deere 80 excavator was effective for digging and back filling the trench after willow installation. It was able to dig effectively through most substrates although it was limited to flatter dryer sites and it required a low bed truck transport to move it to some of the blocks. The use of the excavator also increased the amount of soil disturbance at the site which required grass seeding following backfilling.

An attempt was made to bury the cuttings as close as possible to 70% during both bar and trench planting, although ground conditions as well as cutting size and straightness often dictated the maximum depth at which willow could be installed especially for bar planted cuttings.

Following the established willow strategy developed in 2001 allowed for the willow program to finish on time and permitted project managers to forecast the time and cost requirements for the 2002 willow planting strategies.
The variation in bar planting production rates was largely due to the following factors:

- Access at the planting site
- Site soil characteristics
- Cutting uniformity

Trenching productivity was greatly influenced by the number of obstacles such as no work areas that had to be maneuvered around. Also productivity was reduced when the excavator was moved between blocks planned for trenching.

Bar planting and trench planting had both advantages and disadvantages.

<table>
<thead>
<tr>
<th>Trenching</th>
<th>Vs.</th>
<th>Bar Planting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cheaper by the stem</td>
<td>Expensive by the stem</td>
<td>Expensive by the stem</td>
</tr>
<tr>
<td>Expensive by the meter</td>
<td>Quick covers the ground (density?)</td>
<td>Cheaper by the meter</td>
</tr>
<tr>
<td>Slow to cover the ground</td>
<td>Limited to smaller, uniform stems</td>
<td>Quickly covers the ground</td>
</tr>
<tr>
<td>Greater use of larger stems</td>
<td>Not limited by slope</td>
<td>Limited to smaller, uniform stems</td>
</tr>
<tr>
<td>Limited to flatter blocks</td>
<td>Can be micro site specific planting</td>
<td>Limited to smaller, uniform stems</td>
</tr>
<tr>
<td>Limited by digging effectiveness</td>
<td>No re-seeding required</td>
<td>Not limited by slope</td>
</tr>
<tr>
<td>Requires re seeding after installation</td>
<td>Approximately 2.00/meter (1 stem)</td>
<td>Approximately 2.00/meter (1 stem)</td>
</tr>
<tr>
<td>Approximately $5.00/meter (10 stems)</td>
<td>Produces a dense wall/baffle of willow</td>
<td>Produces a loose wall of willow</td>
</tr>
<tr>
<td>Limited by excavator breakdowns</td>
<td></td>
<td>Limited by equipment failure</td>
</tr>
</tbody>
</table>

**7.5 Willow Installation**

The planted willow bands should also be monitored for its growth and its ability to control soil erosion at Sooke Reservoir. The results of this ongoing monitoring will help to determine where additional willow installations maybe required in the future. If Sooke Reservoir is to be raised in stages there maybe further opportunities for willow plantings at other elevations or fill in the existing willow bands were survival or growth is non uniform. The height and structure of the existing willow band help to control where shoreline erosion occurred. Following the recent raising of the reservoirs water level observations of increased shoreline erosion occurred at gaps in the existing willow band. Also at block 25, erosion was minimal until water levels had increased past the height of the existing willow band at that site. Following this increase the wave dissipation ability of the existing willow band diminished and shoreline erosion levels increased at higher shoreline elevations.

**7.6 Survival**

Although planted willow cutting survival have decrease each year since installation the size of surviving willow shoots have increase. Thus for some trench planted lines although overall survival appears low a continuous wall of willow exists.
Because cuttings were trench planted with a target density of 10/m a 30-50% survival rate would indicate that approximately 3-5 cuttings/m have survived. Each of which are 1-2m tall, thus as the cuttings age it is expected that some self thinning will occur naturally, but if only 1 cutting survives but it is 5m tall and 3m wide the objective of maintaining a wall of willow has been obtained.

It is expected that the present low level willow band at ~180m will eventually die out. Planted willow cuttings will increase in biomass production with moist soils, and will tolerate intermittent flooded soils, but will start to decrease in biomass production with prolonged flooding. The threshold for maximum flooding will depend on the rate, duration and timing of flooding as well as soil conditions, and species. Researcher’s controlled inundation trials have reported elevated growth at 60 days inundation with a decrease in growth after 90 days inundation of the root crown. Other studies have reported decreased levels of survivorship after 40 days of inundation.

Our inundation trials have willow cutting survival with 6 months inundation but the long-term survival or root growth has not been studied. Most studies have been conducted in controlled areas where factors such as vegetation competition, deer browse, and cutting damage/girdling from wave erosion have not been explored during inundation trials.

The majority of root growth on planted willow cuttings has been reported above the flooding levels on the cuttings, and with prolonged flooding the rooting structure begins to die back at lower levels. The amount and availability of moisture and nutrients resources is more variable with longer cuttings thus enabling the willow to adapt to various site restrictions. With shorter cuttings the available moisture and nutrients are only made available in the topsoil layers, thus in dry or nutrient poor sites, survivorship may be reduced. The reduced moisture and nutrients available at some upper soil locations is one of the rationales for not using nursery plug type stock.

The diameter of the cuttings is also thought to be important for survivorship. The larger the cutting the greater the amount of stored resources that can be used for growth. Initial SREP monitoring results have indicated that willow cutting survival appears to be greatest in those cuttings that are 1-1.5” in diameter. The age of the cutting is thought to have a greater influence on survival than actual size. Thus cuttings taken in between mature stems and recent growth are ~1-1.5” in diameter. Additional monitoring will be required to determine the long term survival trends of planted willow cuttings and how this varies amongst species, size, site soil conditions, competing vegetation, wildlife browse, and reservoir storage cycles.

7.7 Costs

The cost for willow installation can be highly variable. The cost per meter is primarily influenced by the time to produce cuttings. Factors such as accessing the willow during times at which the reservoir level is above the elevation of the current band of shoreline willow at ~180m will greatly increase the cost of producing willow cuttings. Access during low water is the most cost effective as the reservoir level rises harvesting efficiency decreases.
This should be evident with the cost for willow installation both before the Christmas break and after the break when the reservoir level had risen to ~181.5m submerging the roots of the existing willow band located at ~180.0m.

A number of willow planting project challenges existed which influenced project planning and adaptive management.

7.8 Willow Planting Project Challenges
- Access to planting blocks and willow donor sites became limited as culverts were removed and roads rock armored.
- Inundation of willow donor sites restricted access and limited the harvesting period.
- Wx: Rain and snow conditions limited vehicle access and safe working conditions.
- Coordination with ongoing SREP works such as land clearing, culverts+road rehab and construction, rock blasting and transport, and construction activities including rock armoring,
- The transportation of willow cuttings required several trips using a ¼ ton pickup from donor site to soaking or planting sites. Some of the large cutting bundles were in excess of 50lbs when soaked making unloading, loading and distribution on the planting blocks very labor intensive.
- Daily production rates needed to be closely monitored to ensure cut willow was planted as soon as possible and planting crews and the excavator did not run out of willow at any time. This was often challenging due to the great variability in both harvesting and planting productivity each day.
- Subsurface flows limited excavator operation and digging areas and often were not obvious from site plans. The goal of all willow installations was to minimize disturbance and creation of overland sediment flows or disturbances to established water flows.
- Transportation of the excavator often delayed trenching by 2 hours between blocks that were not adjacent. This meant that trenching activities were often rounded to the nearest day permitting startup the following morning at the new location.
- Hardpan and small rock outcrops were also not considered during planting site plans thus often target planting elevations had to be adjusted slightly up or down to facilitate a continuous planting line.
- Although the excavator could operate on steep grades it would often result in unnecessary disturbance thus machine operation was restricted to low grades.
- Did not want to create more erosion prone sites from excavator disturbance.
- An unusually dry summer (2003) created almost drought conditions for the upland willow lines that were not inundated following planting. Thus this lead to increased plant stress for limited moisture and nutrient resources.
- Willow watering was implemented in 2003 following an unusually dry summer conditions. A water source was often 100m+ away from any planted willow line and vehicle access had been further restricted following willow planting.
Approximately 15km of willow were heavily watered twice often requiring the setting up and dismantling of 300m of watering hose on each block.

- Cutting storage locations were chosen for easy access for unloading cuttings but at times when cutting retrieval was required water levels often had dropped dramatically making loading and vehicle access very time consuming.
- The cleanup of willow processing materials was not factored into program costs. An excavator and dump truck were used to clean up discarded materials at block#2. Cleanup of willow processing sites became a necessary part of the program strategy.
- Girdling of planted willow cuttings through wave, suspended gravel and/ or cwd erosion were not expected to contribute to willow mortalities.
- Planted willow lines planning had to ensure access was maintained for future SREP works, thus trench planted lines were discontinued across some spur roads.
- Although some deer browse was expected, the extent that some willow lines were browsed were not. Although deer browse often lead to increased coppicing and stunted initial leaf growth it is not known whether this may be advantageous in dry conditions, rather than have increased shoot growth with large leaves to increase moisture loss.
- Competition from scotch broom on or near planted willow lines was not factored into the willow planting strategy.
- Willow monitoring trials were not set up to provide easy access to root/shoot monitoring. Also the first year survival/growth is not always representative of species or inundation differences.
- Annual drawdown of the Sooke Reservoir by ~ 7m is an unusual circumstance for planting programs.
- Do not want to increase attractiveness to wildlife especially large mammals
- Needed to maintain erosion control function of existing willow band at harvest sites
- All planted willow work was to be completed in preparation for the raising of the reservoir in 2003 and during the window for harvesting and planting Nov – March.
- Willow soaking sites with good access and a stable water level, willow soaking sites were either being flooded or drawn down making cutting retrieval labor intensive.
- At some sites it was more efficient to use a flat deck truck with a small hydraulic lifting arm to load, transportation and unload soaked willow cuttings.
- All willow harvesting, processing and planting activity had to have minimal impact to the reservoirs shoreline and had to follow all water quality protection procedures.
- Large amounts of willow bundle twine was required which doubled when string began to break during bundle handling. Nylon string, doubled and tied at three locations on the bundles were most effective at holding the bundles tightly together during transport.
- All work activity had to abide to the Water Quality Protection Procedures which may not be as strict outside the WSA.
• The installation of elevation markers were required to guide willow planting placements. In blocks with undulating shorelines elevation markers needed to be more frequent.

• Changing of the new proposed high water level from 185.75m-186.75m in second year of the program was unexpected and may lead to impediment/ greater mortality of willow lines especially at the 185.00m level which is now outside the relative range of the existing willow band of 180.00m for high water level of 180.75m.

• If the planting bars were not used correctly they were prone to bending, although this was emphasized early in the planting projects some bars needed straightening. Also the bar tips needed to be sharpened and tops were grinded down flat when they began to mushroom from sledge hammer strikes during willow installation.

• Keeping harvesting and planting continuous was a challenge when access to harvest sites became difficult. Also some harvest stands were not conducive to producing straight bar planting stock and thus more effort was required to harvest selectively to match productivity.

• Bar planting quality had to be monitored closely as achieving desired depth on poor, rocky sites was often difficult, but it had greater impact on cutting survival than moist, nutrient rich sites, where planting depth was easier to achieve.

• The establishment of willow lines in upland areas sometimes 100m+ from the existing shoreline and water sources was a challenge especially during dry program years in which the reservoir did not achieve full pool.

7.9 Milestones
A number of project milestones were achieved throughout the willow planting program:

• ~150,000 willow cuttings cut, pruned, bundled, and planted over approximately 15km shoreline

• ~24 km of willow bundling twine was used

• Willow planted in 19 blocks along the proposed new shoreline of Sooke Reservoir

• Installation of willow planting trials at block#4 and block#9

• Installed willow bands have not been undermined at any block

• Planted and natural willow shrubs dominate the new inundation zone other shrub species have died or appear unhealthy.

• Planted willow cuttings have started to infill sporadic lines

• 1-2m shoot growth within a growing season on some sites

• ~90% survival first year following planting**(less second growing season)

8.0 Conclusion(s) and Recommendation(s)

8.1 Willow Harvesting
Once the existing willow band has gone into dormancy willow harvesting and planting should be conducted as soon as possible. This will help to reduce harvesting costs associated with the increase in water levels at Sooke Reservoir.
If the window of opportunity is too small to achieve both willow harvesting and planting for willow projects, the possibility of cold storing harvested and processed willow bundles should be explored. If a cold storage site/location can be rented willow planting can be delayed while cutting continues until program quotas are obtained.

If harvesting and planting of native species is planned for long term programs such as road rehabilitation, riparian restoration, and soil erosion control, the possibility of cooperating with a local green house should be investigated. The combination of native plant cutting propagation and seed collection and propagation could provide a year round supply of stock. Target planting stock could be harvested throughout the year and prepared for upcoming projects.

For a sustainable willow program willow harvest sites should be selectively harvested to allow coppicing to renew harvested stock following 2 years after cutting. Also discarded willow cutting debris could be buried in rows of shallow trenches to facilitate establishment of a willow donor site not directly influenced by reservoirs shoreline water levels and/or add coarse woody debris benefits to silviculture sites. Rows could be spaced wide enough apart to allow vehicle/tractor to pass between making harvesting and loading more efficient.

8.2 Willow Trials
Monitoring of the willow planting trials and the installed willow at the planted blocks should be documented and continued as long as possible. Where appropriate the growth of planted willow should be monitored for the following:

- Species differences
- Elevation preferences
- Installation type
- Size of the cuttings
- Planting depth
- Aspect
- Erosion risk of the planting site
- Planting density
- Ability to control soil erosion
- Sooke Reservoirs water level(s)
- Weather conditions over the growing season(s)
- Competition from scotch broom
- Vegetation succession at the planting site
- Wildlife browse

The results of continued monitoring will help to determine where improvements to the willow program should be made. The success of planted cuttings will help to determine if the current proposed densities and installation type will meet the required long term objective of establishing a willow band encircling Sooke Reservoir similar to the existing willow band.
Also the growth rates of cuttings with various sizes will help to determine the upper and lower stem size limits for the SREP willow program in future years. Evidence of willow regen establishing between planted willow lines is confirming the trapping ability of planted lines both live and dead cuttings. The growth/survival differences between planted and regenerating willow should be documented to guide future willow planting programs.

8.3 Willow Planting
The use of a production based contract for willow harvesting and planting will help to improve on the inefficiencies of the willow program. Along with the productivity bonus a quality clause should be included similar to current tree planting contracts.

The costs for a particular job would be known before the work is carried out, thus allowing for more accurate budgeting and field staff scheduling. Including productivity levels that must be achieved as part of the contract will limit the CRD field staff supervision time that is required to achieve appropriate productivity to complete the contract objectives. Ongoing planted willow survival monitoring will help to determine if current willow cutting and planting specifications can be fined tuned to improve survival.

8.4 Monitoring
Bar planted cuttings had lower survival rates than trench planted cuttings. This may be due to several factors. Bar planted stock is generally smaller and thus contains less moisture and nutrient reserves relative to surface area. Also bar planted stock were generally planted on steeper, poorer sites where trenching was not possible. Typically these sites had lower moisture and nutrient availability especially during the summer months. To conclusively determine willow cutting erosion control and survival preferences trials needed to be established at each block under similar site conditions in which bar, trench, and no willow planting areas were established and concurrently monitored.

Because monitoring of root growth was both labor intensive and time consuming almost all survival trends were based upon shoot growth only which can be very misleading as moisture and nutrient uptake can be achieved with little to no root development through cut stems. Future willow planting programs should include willow cuttings planted specifically for the purposes of root development monitoring. Root monitoring could be coordinated with excavator/backhoe yearly scheduling.

If time permits dry weights should be used to describe shoot and root production in planted cuttings. Some factors to consider when making conclusions of planted cutting survival/ health are the following:

- What was the health of the donor plant?
- Were all cuttings taken from the same plant or at sites with similar site characteristics?
- Were all cuttings the same age?
• Were all cuttings the same size?
• Have any of the cuttings been browsed?
• Have any of the cuttings been damaged/girdled since planting?
• Available nutrients and moisture? Are all cuttings subjected to the same stresses?

8.5 Cost
Planting willow cuttings can be very expensive but it is both cheaper and more ecologically **viable** at jump starting shoreline succession than rock placement. Planting 1m+ cuttings allows the cuttings to access water and nutrient resources at greater depths than shorter cuttings or plug nursery stock, which are generally cheaper to buy as plugs although an order of 150,000 would require both significant space for storage and advanced notice. Once established though planted cuttings will help to bind soil at greater depths protecting shoreline erosion at greater depths than most typical nursery plug stock.

The harvesting of willow had a large variability on program costs. Both the type of stand and the access to the harvest stand influence production. Although it varied the planting productivity of willow could be controlled with increased on site supervision. Quality control is essential for bar planted stock harvesting and planting efficiency.

8.6 Recommendations
Start any willow planting program as early as possible to ensure adequate time has been allotted for unscheduled delays such as weather or equipment failures. Ensure productivity incentives are included in any harvesting and planting contracts. Ensure planting progress does not exceed harvesting progress and make on site visits to planting blocks “just “ before work is scheduled to make adjustment to planting plans when necessary.

Setting up a willow table where the minimum sizes are clearly marked and an assembly type line is established for pruning, loading stems on to the table, squaring up the willow stems, cutting, sorting, and bundling will be very efficient.

While piling stems reading for processing and when bundling willow “ensure” all stems are facing the same direction. On those few bundles in which cuttings were not all facing the same direction they had to be manually sorted through during installation. Also it is most often much easier to determine stem direction before they are being processed rather than after they have been cut into ~1m sections.

The placement and strategies of future willow installations should be guided by the results of ongoing monitoring of the existing willow program.
9.0 Literature Cited


Acknowledgements
Maps and Orthophoto replications were supplied by the Resource Planning Section of CRD –Water Services.
10. Appendices
Appendix III

Overall Guiding Principles
- Watershed Vision statement
- Watershed Management Principles
- Watershed Management Goals
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Risk Management
- Water Quality Risks
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- Draw down zone

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- Structure maintenance
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- Monitoring stations maintenance

Aquatic Ecology Program
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- Taste and odour prediction
- Short and long term trending

Watershed Protection Program
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Implementation
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- Program Audits

Elements of the Strategic Plan for Watershed Management for the Greater Victoria Water Supply Area
11. Photographs
Existing willow band at Sooke Reservoir: Block #4, and Block #2
Willow Cutting and Processing Block #2: Cutting willow, willow cuttings pruned and bundled X2, and willow and bar planting equipment.
Photo #1: Willow cuttings harvested and processed at Block#2 in preparation for the trials

Photo #2: Willow cuttings and a planting bar and sledge hammer used for installation
Photo #3 Willow bar planting at Block #9 - Willow trials

Photo #4 Willow bar planting at Block #9 - Willow trials
Willow Trench Planting: Excavator trenching, placing the willow in the trench, trench prior to back-filling X2, trenching and back-filling, and back-filled trench X3.
Appendix VII
Willow Planting Strategy

Elevation contours for both the willow planting trials and the 185.00m and 185.75m willow planting were marked in the field along Sooke Reservoir shoreline with marked wooden stakes.

- A 5-meter no work zone area was maintained around all soil transects (black with yellow dots ribbon).
- A no machine zone of 5m for all heavy equipment was maintained around all riparian corridors.

Willow Harvesting
Once cut, all willow processing/pruning took place in a designated area above the 188m line. Willow cuttings were harvested from existing natural stands that border the Sooke Reservoir drawdown zone. Bar plant cuttings had a target length of 70 to 80 centimeters. All bar planting cuttings were selected to be reasonably straight and free of knots, branch whorls, rot, dead wood and mechanical damage. The required cutting diameter at the butt end was 1 to 3 centimeters.

Trench plant cuttings were 100cm in length and a minimum of 1 cm at the butt end. They were not restricted by knots, or straightness, but an attempt should be made to harvest cuttings free of dead wood or disease.

Unless instructed otherwise, all willow cuttings taken from donor sites around the Sooke Reservoir were cut to preserve a minimum of 50% of the existing band, both in thickness and height. Willow was not harvested within a minimum of 5m of all creeks and streams.

Bundling and Packaging
Bar plant willow cuttings were bundled with 50 cuttings per bundle. Trench planted cuttings were bundled in numbers that could be handled easily by all crew persons. All of the butt ends of the cuttings were oriented to the same end within the bundle. The bundles were tied securely with twine, with one binding at each end of the cutting bundle, for a total of two well-spaced twine bindings per bundle. Bundles not planted within 48hrs were covered with tarps to prevent moisture loss from the cuttings and placed in a cool shady location. Reasonable care was exercised in handling the cutting bundles to minimize damage.

Bar Planting Willows
Willow cuttings were singly planted, with at least 70% of the their length in the soil, butt ends oriented down. The loose woody debris removed before creating the willow planting hole. Once the willow stem was planted to the appropriate depth the hole was collapsed around the cutting and compacted to ensure the cutting was “tight” so that it could not be reasonably pulled out. Planting will be undertaken with a pointed steel bar. If the
minimum planting depth cannot be achieved with the bar by hand, it must be driven into the soil substrates to the required depth with a sledgehammer.

Trench Planting Willows
Where feasible an excavator trenched an 80cm- 100cm deep continuous trench for willow planting. Willow cuttings were placed on the Sooke shoreline side of the trench approximately ten cuttings per meter with the butt sides down. A mix of species and sizes was randomly distributed along the trench when possible. Once the willows were installed, the excavator returned to back fill the trench as soon as possible. When necessary in areas where the excavator could not dig a continuous trench to the desired depth a band of singly bar planted willows was installed.