CHAPTER 11

Develop Technology to Minimize Sediment Mobilization after Channel Excavation

11.1 Introduction to Sediment Mobilization (Goal 10)

Although there is little published information on salmonid use of small watercourses associated with agricultural areas in King County's riverine floodplains and on the Enumclaw Plateau, waterways within these areas are known to be used by salmonid species. As presented in Chapter 1, the overall objective of this entire study was to determine effective and economical means to maintain agricultural watercourses while protecting fish habitat as described in the Sampling and Analysis Plan developed by Washington State University and the University of Washington (2006) and approved by KCDNRP. In support of that mission, the goal of this chapter is to investigate several important questions related to sediment control during and after channel maintenance. With the assistance of KCDNRP staff, the following research hypotheses were posed in relation to this study component:

> Hypothesis 1. All recommended standard practices for bank stabilization function equally in all situations.
>
> Hypothesis 2. Sediment concentrations in the channel after channel maintenance will be affected by the maintenance activity for a certain period of time.

Erosion estimates are essential to issues related to land and water management, including sediment transport and storage in agricultural watercourses (Foster and Lane 1987; Renard et al. 1997). The effective life of any watercourse maintenance activity will ultimately be determined by the re-sedimentation rate to the channel. Therefore, it is important to adopt reliable erosion control measures after channel excavation. The current best management practices (BMPs) for agricultural waterways provide a list of options for erosion control of channel banks and surrounding land areas including vegetated strips. The effectiveness of these BMPs needs to be documented and better specified for future deployment. Thus, it is necessary to develop a simple tool that allows such predictions.

There are several potential sources of sediment at maintained waterways. Johnson and Stypula (1993) present a comprehensive review of bank failures that lead to sediment accumulation in streams. The British Columbia Ministry of Agriculture, Food and Fisheries produced a schematic illustrating the likelihood of bank failure as a function of slope (Figure 11-1).

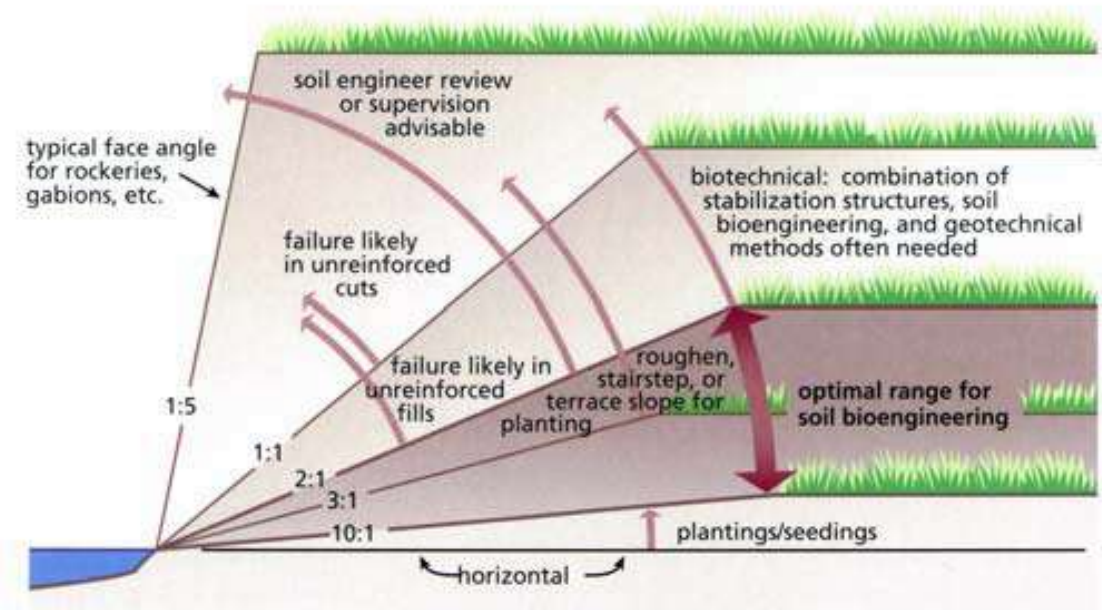


Figure 11-1. Impact of bank slope on erosion potential
(Minister of Agriculture, Food and Fisheries, 2004)

Rilling is one of the most common forms of erosion. Rill erosion is the removal of soil by concentrated water running through little streamlets, or headcuts. Detachment in a rill occurs if the sediment in the flow is below the amount the load can transport and if the flow exceeds the soil's resistance to detachment. As detachment continues or flow increases, rills will become wider and deeper. The rill channels can temporarily be obliterated by tillage. Tillage loosens the soil making it more susceptible to rill erosion. Thus, every time they are destroyed - the rills can reform, resulting in much more soil lost. BMPs must be in place to reduce the occurrence of these rills.

Although streambank mitigation measures are required after maintenance of agricultural watercourses, several important questions related to sediment control during and after channel maintenance need to be investigated. This chapter of the study was aimed at determining the impacts of sediment loading after excavation and evaluating the mitigation measures for erosion control. The objective of the experiments was to evaluate and recommend the best treatment in terms of cost effectiveness and minimizing the sediment mobilization after the excavation. The metric used to evaluate erosion control was the long-term cumulative sediment collected after dredging. Other objectives of this study included the assessment of sediment propagation and the evaluation of the dependence of erosion effects on precipitation.

11.2 Study Area

Measurements of cumulative sediment after the excavation were conducted at three sites coincident with maintenance projects. The three sites used to conduct the sediment study included the Watercress Creek site, the Ray Ewing site in Enumclaw, and the 124th Street site in Duvall (Figure 11-2). The GPS locations of these sites are given in the detailed site maps later in the report. No erosion control treatments were applied in the Watercress Creek in Enumclaw because its side slopes were too steep (2:1, Figure 11-3). Table 11-1 indicates the site locations and treatment practices to be applied at each site.

Table 11-1. Experimental design for testing soil erosion resulting after excavation

Name of reaches	Total effective length of reaches (ft)	Side slopes	TESC treatments	Length of mitigation treatment (ft)
Watercress	850-900	2:1	n/a	660
Ewing	700	3:1	(Treatment on both banks) coir mat, hydro-seeding, hand-seeding, and hog fuel	70
Pickering/Olney-124th	700	3.55:1 to 6.09:1	(Treatment on left bank) peat moss, coir mat, wood chips, hog fuel, sod, hydro-seeding, and hand-seeding	85-90

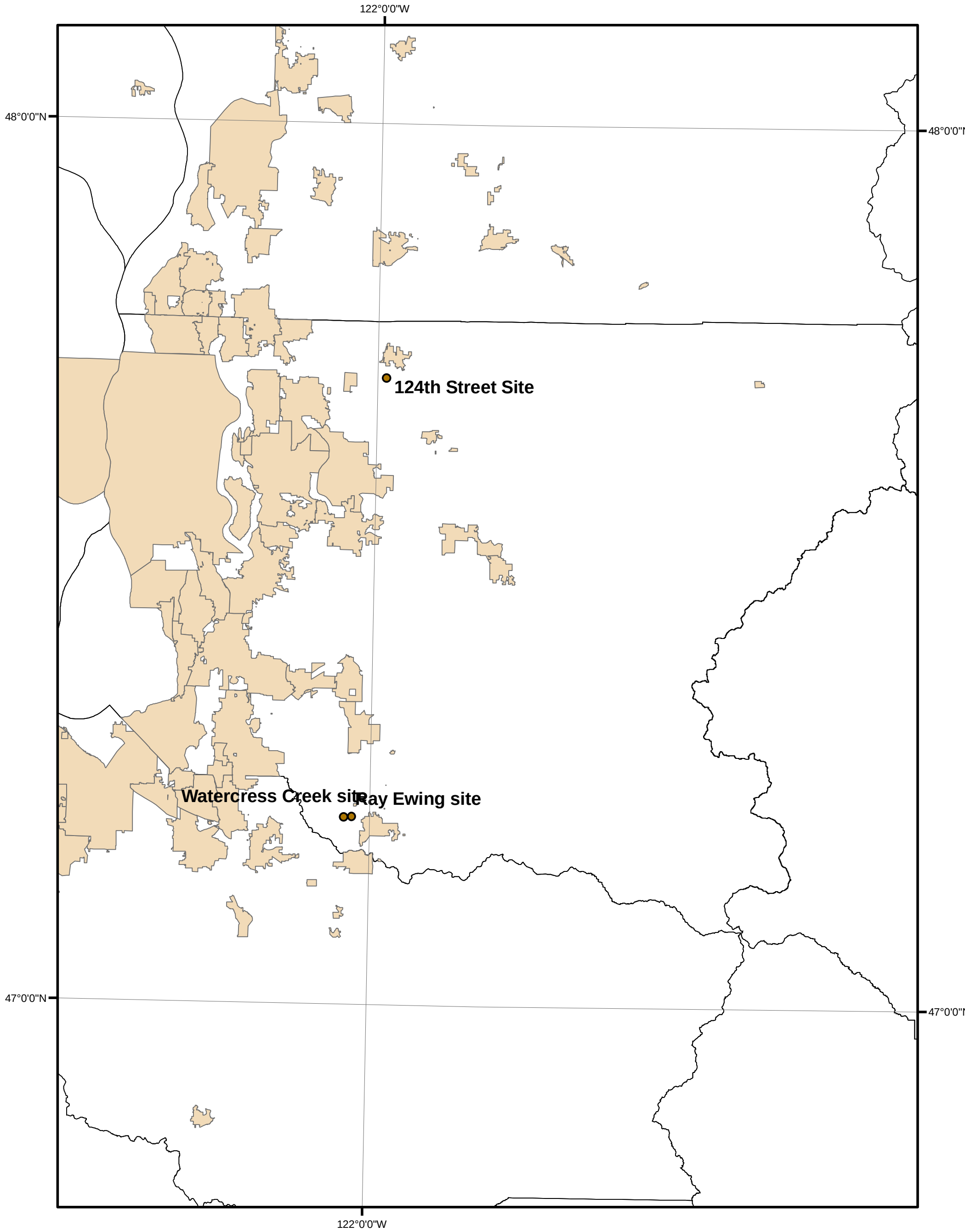


Figure 11-2. Geographic location of the experiment sites
(Detailed GPS locations are specified in the site maps below).

Figure 11-3. Installation of Petri dishes and steel rods at Watercress Creek on August 08, 2004

11.3 Methods

11.3.1 Measurement of sediment

A thorough review of the erosion literature included comprehensive erosion studies by the Federal Highways Administration (1995), Osterkamp and Schumm (1996), and Fifield (2002). Because of the uniqueness of this project, no other method was identified as directly adoptable to this application. A special procedure was devised that utilized unique sediment measuring rods, wire retaining hooks for Petri dishes and the installation protocol.

Field measurements and samples were taken to determine the amount of sedimentation of the agricultural watercourse resulting from the first significant precipitation event. Because maintenance operations in King County are typically conducted during the dry season, heavy rainfall may not occur during the seven days following dredging. Therefore, sample collection was designed to examine long-term cumulative sediment mobilization after excavation.

The long-term sediment measurements were carried out using circular Petri dishes with diameter of 10.0 cm (4 in) and depth of 1.5 cm (1/2 in). Petri dishes were placed in the watercourse bottoms perpendicular to the flow. One dish was installed in the channel center and one dish on each edge of the channel as illustrated in Figure 11-4. The arrangement of Petri dishes allowed sediment measurements to be conducted at three locations for each TESC sub-treatment. The Petri dishes were secured to the watercourse bottom with fashioned wire hold downs. Total solids in the Petri dishes were collected, dried, and weighted. In addition, site visits and inspections were also performed along with associated photographs to quantify the density and sizes of rills developed on the banks, and determine the sedimentation contribution from channel banks.

Turbidity was not measurement for the erosion control of the sediment mobilization after excavation. The relationship between turbidity and TSS is generally poor, especially when water velocities are low, and turbidity is also strongly affected by sampling depth.

Figure 11-4. Typical installation of Petri dishes and steel rods

11.3.2 Erosion control treatments

Erosion control treatments, and their combinations, were utilized in the experiments. From upstream to downstream in a test reach, the following potential temporary erosion and sediment control (TESC) practices were evaluated:

(1) Soil binders – Wheat straw was utilized as a soil binder in lieu of other more expensive material. The straw bales were broken apart and applied on the sites by pitchfork and raked to a uniform depth. We obtained straw at King Feed in Enumclaw, WA.

(2) Erosion control fabric – Coir mat (coconut fiber) was unrolled along the watercourse bank(s) and pinned to the soil with sod staples. We purchased the mat from Terra Enterprises and the sod staples from SYG nursery in Pullman, WA.

(3) Mulching – Wood chips (also called play chips) were applied by J and B Sod. The chips are blown out of a truck by a special blower at a uniform depth. Hog fuel was also employed as a mulch. Hog fuel is a name for chipped residue from tree\shrub removal. The material was applied with pitchforks and was free of blackberry vegetation. The materials were locally supplied.

(4) Sod – The sod was delivered by J and B Sod. The sod was unrolled on the bank and pinned to the bank using wire sod staples. We used a gasoline powered pump to water the sod after installation.

(5) Hydro-seeding grass – Hydro-seeding was applied by J and B Instant Lawn. The seed applied was 100% perennial ryegrass. The seed is mixed with a binder and sprayed on the watercourse bank.

(6) Hand-seeding grass with straw cover – Prior to seeding the soil on the bank was rotor-tilled and raked smooth. The seed was 100% perennial ryegrass and was broadcast with a mechanical hand crank type spreader. Straw was broadcast over the seed. The seed was purchased from Seedland.

(7) Peat moss - Bales of compressed sphagnum peat moss were purchased from Sky Nursery. The peat was hand broadcast and incorporated into the soil surface with a steel rake.

The order in which the above treatments were listed is in accordance with the direction of flow. Erosion control fabric was applied in the section of influent while mulch was in the section of effluent. This arrangement was intended to minimize the interference of upstream treatments with those applied further downstream. For example, if mulch had been applied on the channel bank in the upstream section, it would have tented to get flushed into the channel and float on the water surface thereby potentially impacting downstream treatments. Because of the reach length needed to test the effects of each treatment, not all sites were suitable for test all above treatment. The following paragraphs will provide comprehensive information on the experimental designs and test procedures for the selected test sites.

11.3.2.1 Experimental design at the site of Watercress Creek

There were no bank treatments employed at the Watercress Creek site. As previously stated and illustrated in Figure 11-3, the side slopes were too steep for economical erosion control. The total length of the watercourse was 274 m (900 ft) and the effective length for the experiment was about 201 m (660 ft) by excluding the possible interferences from both ends of the watercourse. Petri dishes were placed at seven cross-section locations with 30.5 m (100 ft) spacing interval. At each location, the three Petri dishes were installed by placing one in the middle of the watercourse and one at each edge along the watercourse bottom. The locations of Petri dishes at this site are shown in Figure 11-5. The Petri dishes were installed on August 9, 2004 and sediment samples were collected on October 13, 2004, for a total duration of about two months, in order to estimate the long-term sediment after excavation. Data collected in the Petri dishes is shown later in Table 11-2.

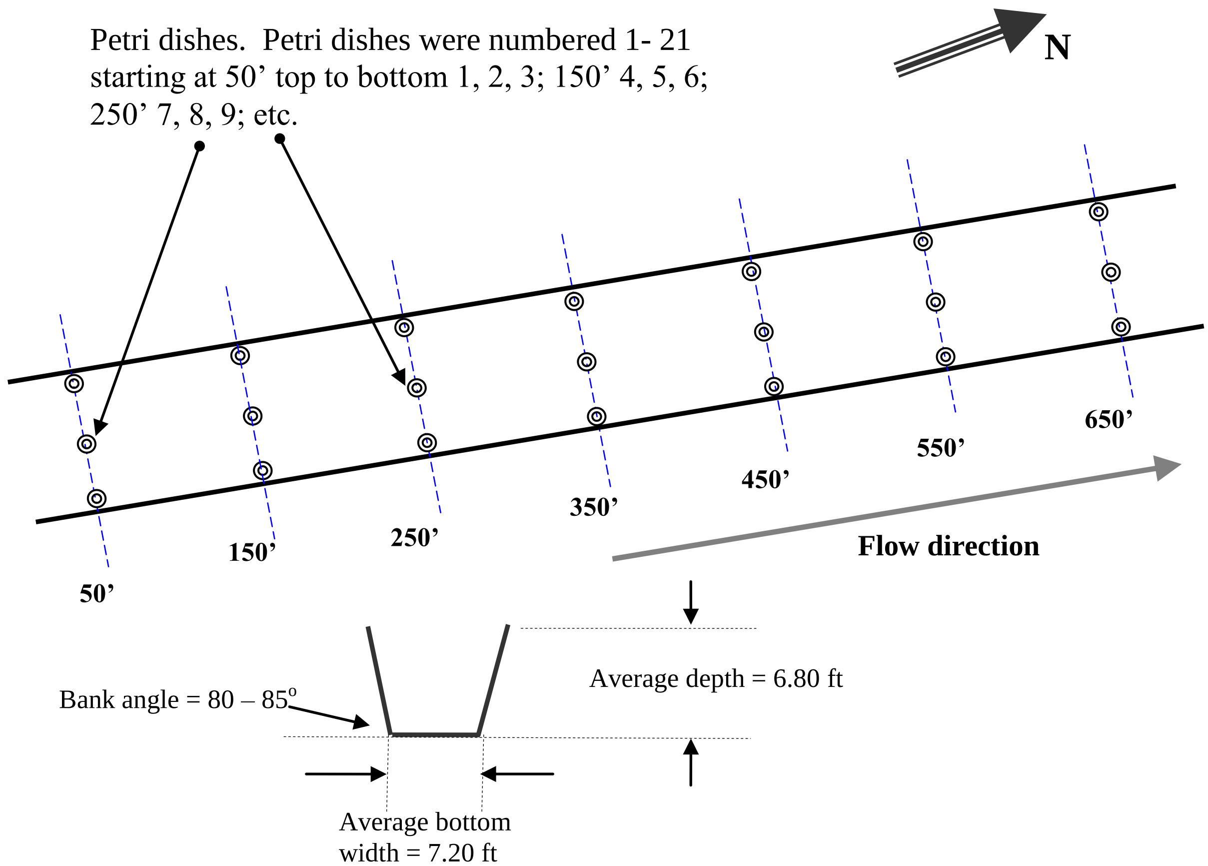


Figure 11-5. Petri dishes placement at Watercress Creek site

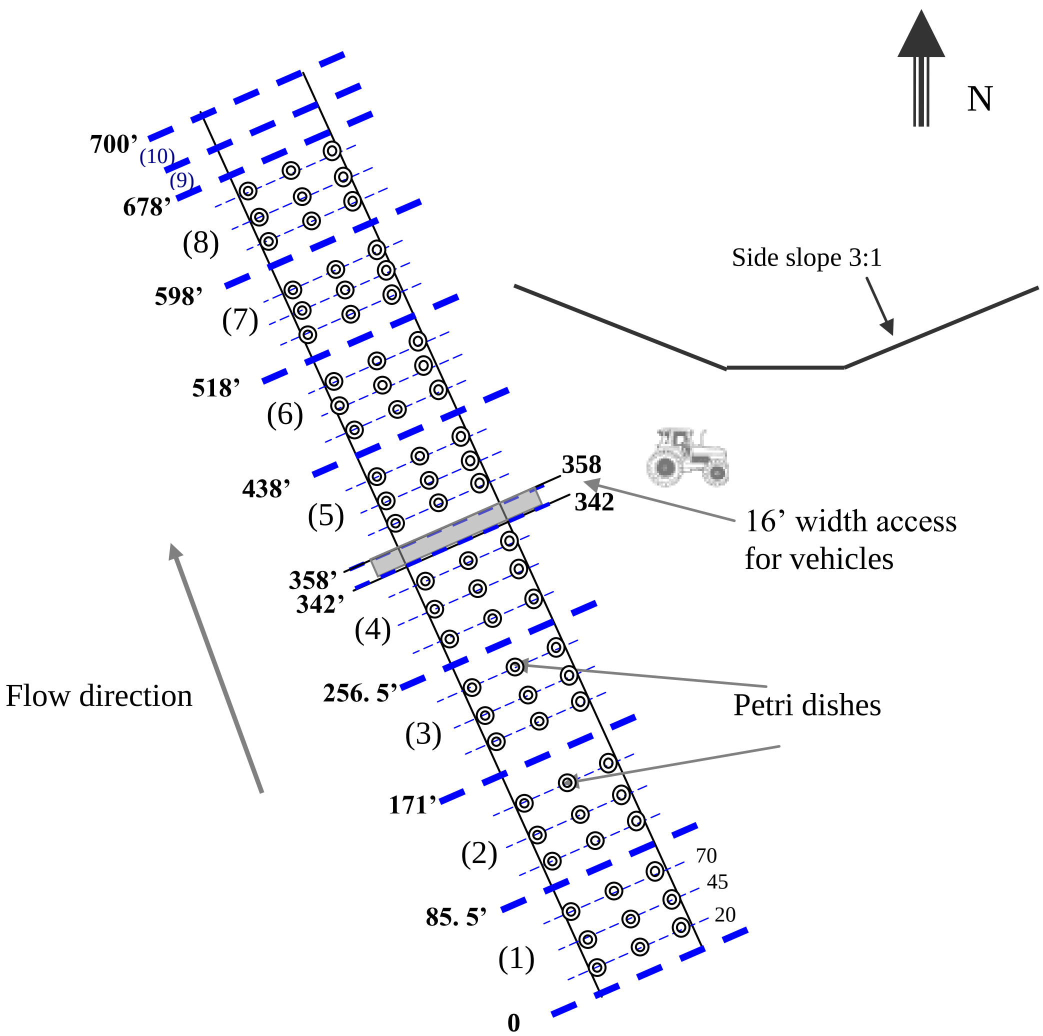
GPS location - N 47 12.756 W122 02.573

11.3.2.2 Experimental design at the Ray Ewing site

Temporary erosion and sediment control practices were applied at the Ray Ewing property. The experimental design for monitoring soil erosion after dredging in the Ray Ewing reach is illustrated in Figure 11-6. The total length of the watercourse in this experiment was 213.4 m (700 ft). The side slope was 3:1 for the entire reach. Ten mitigation treatments were used in the Ray Ewing site on both banks. Along the direction of water flow, the applied treatments were:

(1) CF-900 coir mat,
(2) Hydro-seeding (150%, seeding rate of 45 lb/ac),
(3) Hydro-seeding (100%, seeding rate of 30 lb/ac),
(4) Hand-seeding (seeding rate of 15 lb/ac),
(5) Wheat straw (200%, depth of 4”),
(6) Wheat straw (100%, depth of 2”),
(7) Hydro-seeding (150%, seeding rate of 45 lb/ac) + 100 lb/ac soil binder,
(8) Hydro-seeding (100%, seeding rate of 30 lb/ac) + 100 lb/ac soil binder,
(9) Hog fuel (200%, depth of 4”), and
(10) Hog fuel (100%, depth of 2”).

Wheat straw was used as a substitute for both the sod and soil binder at this site for economic and maintenance reasons. The length for the treatment plots (1)-(4) was 26 m (85.5 ft), while that for treatment plots (5)-(8) was 24.4 m (80.0 ft). Within each plot of treatments (1)-(8), nine Petri dishes were placed in three lines in the center and both edges of the watercourse bottom. The length for treatments (9) and (10) was 3.35 m (11.0 ft). These two plots were designed to visually test the efficiency of hog fuel in bank treatment.



Treatment plots:
(1) CF-900 coir mat, 85.5 ft.
(2) Hydro-seeding (150%, seeding rate of 45 lb/ac), 85.5 ft.
(3) Hydro-seeding (100%, seeding rate of 30 lb/ac), 85.5 ft.
(4) Hand-seeding (seeding rate of 15 lb/ac), cover with straw, 85.5 ft.
(5) Straw (200%, depth of 4”), 80 ft.
(6) Straw (100%, depth of 2”), 80 ft.
(7) Hydro-seeding (150%, seeding rate of 45 lb/ac) + 100 lb/ac soil binder, 80 ft L.
(8) Hydro-seeding (100%, seeding rate of 30 lb/ac) + 100 lb/ac soil binder, 80 ft L.
(9) Hog fuel (200%, depth of 4”), stabilized with nylon netting, 10ft.
(10) Hog Fuel (100%, depth of 2”), stabilized with nylon netting, 10 ft.

Figure 11-6. Petri dishes placement at Ray Ewing site

GPS coordinates
Plot #1: N 47 12.798   W 122 01. 769
Plot #10: N 47 12.614 W 122 01.711

11.3.2.3 Experimental design at the site of 124th Street

The assigned length of the watercourse for the sediment experiment at the 124th Street site was 213.4 m (700 ft) plus a 16.8 m (55 ft) separator strip in the middle of the reach. Eight mitigation treatments were applied on the left bank of the watercourse at this site. Along the direction of water flow, they were:

(1) Peat moss,
(2) CF-900 coir mat,
(3) Woodchips (100%, depth of 2”),
(4) Woodchips (200%, depth of 4”),
(5) Sodding,
(6) Hydro-seeding (150%, seeding rate of 45 lb/ac),
(7) Hydro-seeding (100%, seeding rate of 30 lb/ac), and
(8) Hand-seeding (seeding rate of 15 lb/ac).

The length for the treatment plots (1)-(4) was 25.9 m (85.0 ft), while that for treatment plots (5)-(8) was 27.4 m (90.0 ft). Within each plot of treatments (1)-(8), nine Petri dishes were placed in three lines in the center and both edges of the watercourse bottom on August 19, 2004. The configuration of the dishes is illustrated in Figure 11-7. Silt fencing was erected along the treatment plots at the toe of the bank slope.

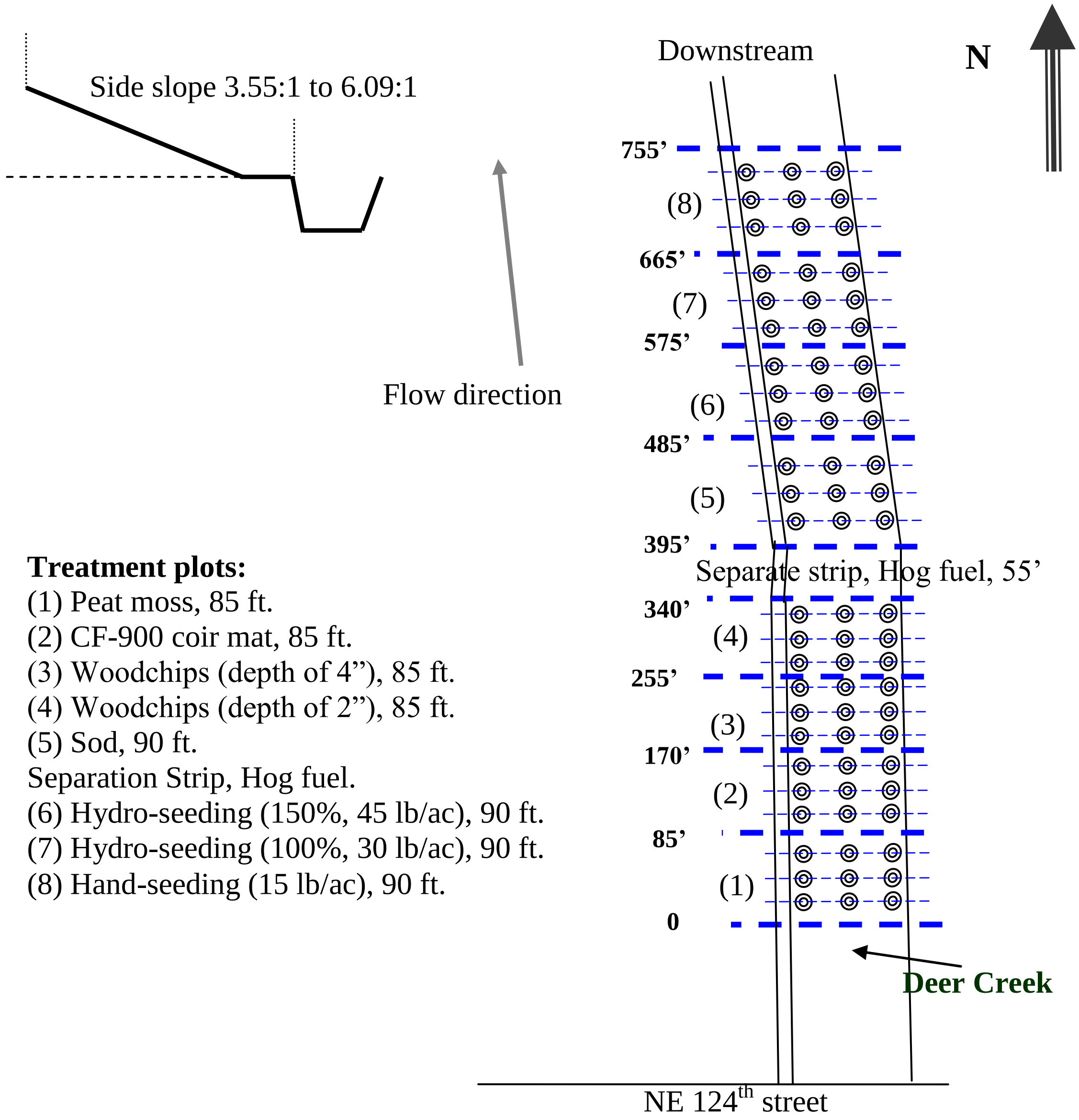


Figure 11-7. Petri dishes placement at 124th Street site

GPS coordinates
Plot #1: N 47 42.700 W 121 59.111
Plot #8: N 47 42.820 W 121 59.155

11.4 Results

Figure 11-8 shows the cumulative sediments collected at the Watercress Creek site during the time frame from August 8, 2004 through October 13, 2004. The collected sediment depth ranged from 0.38 to 2.34 mm (0.015 to 0.092 in) with an average depth of 0.95 mm (0.0374 in) over the 66-day sampling period. The sample analysis results are shown in Table 11-2. In calculating sediment depth, the surface area of Petri dish was 78.54 cm^2, while the solid density was set as 1.30 g/cm^3. Compared to the 1-year cumulative sediment reported in the next chapter (Chapter 12), the long-term sediment depths occurring immediately after dredging were significantly smaller.

It should be noted that the overall effectiveness of the silt fence was poor. Initially the silt fence helped to contain some of the mulch materials from washing downstream, but was rendered ineffective as later occurring flood waters were higher in elevation than the fence.

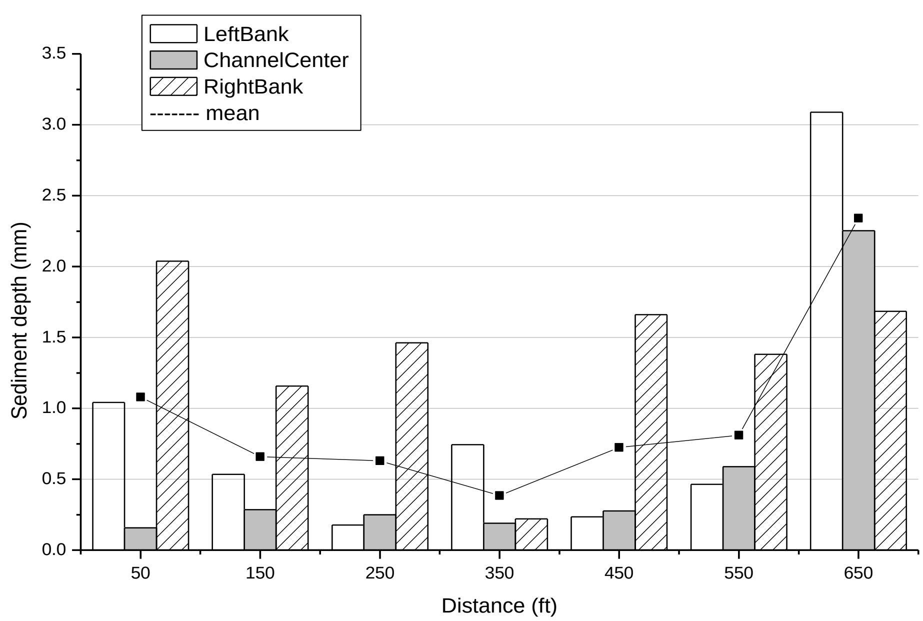


Figure 11-8. Long-term sediment after excavation along the watercourse in Watercress Creek site, during August 8, 2004 through October 13, 2004

Table 11-2. Data sheet for measurements of the sediment after excavation at Watercress

Sample ID	Weight of Dish (g)	Total Weight (g)	Weight of Solids (g)	Notes	Equivalent Depth (mm)
1	40.2888	47.7301	17.1958	Oily	1.68
	40.0005	49.755			
2	42.8189	48.6062	23.0044	Oily	2.25
	44.8900	62.1071			
3	42.7623	65.3878	31.5276	Oily	3.09
	40.8928	49.7949			
4	40.7610	49.4346	14.0891	Oily	1.38
	41.4790	46.8945			
5	41.9138	47.9261	6.0123	Oily	0.59
6	39.1538	43.8914	4.7376	Oily	0.46
7	43.4113	60.3677	16.9564		1.66
8	50.4259	53.2425	2.8166	Mold	0.28
9	50.1284	52.519	2.3906	large amount of algae/mold	0.23
10	50.8454	53.0841	2.2387		0.22
11	77.4939	79.4239	1.9300		0.19
12	81.2298	88.825	7.5952		0.74
13	81.8870	96.8214	14.9344	large pebble removed	1.46
14	76.6201	79.1559	2.5358		0.25
15	78.8984	80.6962	1.7978	3 large twigs removed	0.18
16	77.0803	88.8905	11.8102		1.16
17	77.2627	80.1876	2.9249	Snail	0.29
18	76.8309	82.2909	5.46		0.53
19	74.7369	95.5466	20.8097		2.04
20	81.8186	83.4204	1.6018		0.16
21	77.8167	88.4543	10.6376		1.04

At the Ray Ewing site, the wire hold downs failed to retain the Petri dishes during the large flood flow event that occurred on December 14, 2005. Most of the Petri dishes located at stations from 0 to 121.9 m (0 to 400 ft) were washed away, and those below 121.9 m (400 ft) were displaced, overturned, or buried in soil debris. Therefore, measurements for the sediment after excavation were invalid. Hog fuel installed in treatments (9) and (10) were also washed out during the flood event.

For the site at the 124th Street, we observed higher than usual water runoff out of Deer Creek. This was caused by a leaking bypass hose upstream of the property. This hose was originally designed to divert water around the property during construction. Due to the leakage, an unplanned release of water washed large amounts of sediment into the Petri dishes before an actual rainfall event even occurred. The sand sedimentation flushed down immediately from Deer Creek and quickly buried the Petri dishes that were installed on August 19, 2004. During the field trip on October 14, 2004, the Petri dishes were already found to be deeply buried into the sediment.

11.5 Conclusions

The first null hypothesis is rejected as all the bank treatments were not the same. Among all treatment practices for soil erosion control applied in this study, hydro-seeding has proven to be the best mitigation, based on the considerations of its effectiveness and cost (Table 11-3). The obvious advantage of hydro-seeding is that before the grass is fully developed, the mulch or binder plays an important role in soil erosion control. As the grass becomes developed, the mulch or binder decays away. However, there appeared to be an upper limit beyond with additional hydro-seeding did not provide any additional benefit. Exceeding the recommended application rate (150%) seemed to show little difference photographically or in apparent resistance to flood waters. A second choice after hydro-seeding would be sod. Despite higher cost and labor consumption in the installation, sod can withstand flood water as demonstrated at site of the 124th Street (Figure 11-9). Hand seeding can be a good candidate for watercourse banks which are not prone to flooding. The newly sown seed needs protective cover with materials such as peat moss and wheat straw which were readily flushed away by high water conditions in this study. The other treatment practices tested in this study were not proposed as suitable mitigation plans. For example, buoyant materials such as woodchips, hog fuel, and wheat straw were highly prone to be flushed or blown away even with a cover of netting materials. Coir mat was too expensive, and peat moss should be rotor tilled into the soil to be beneficial, but this action can cause the loosened soil to be easily stripped away in the condition of high water flows.

Table 11-3. Cost evaluation for various treatment practices in this study.

Materials	Amount	Cost
CF-900 Mat [1]	280 ft	$2,142
Grass seed [2]	71.9 lb	$88.50
Hydro-seeding		$815.00
Straw bales		$46.33
Mulching (Hog Fuel)	2,250 ft^3	free
Sod and staples	5,600 ft^2	$1,462
Peat moss	4,507 ft^2	$742.50

[1] Erosion control fabrics, 900g/sqm, 26.4oz
[2] Type: PRG-BrightStar II

Figure 11-9. Sod (treatment plot #5) was undamaged while woodchips (treatment #4) were washed out at the 124th Street site

To determine the dependence of the sediment mobilization after excavation effects on precipitation, more measurements should be conducted. Site inspection indicted that the TESC practices applied in the sites of Ray Ewing and the 124th street were effective in controlling the erosion from watercourse banks. For example, although the depth of cumulative sediment reached up to one foot at the site of the 124th street in Duvall by August 2005, sediment from the watercourse bank was negligible (**Error! Reference source not found.Error! Reference source not found.**). To evaluate the relationship between precipitation and erosion effects, measurements of multiple years are required.

Overall, hydro-seeding is recommended as the best choice because it is faster to emerge, less labor and easier to apply on newly excavated slopes. Preparation, seeding, and mulching took two people, two days of labor installation. The hand seeded plots and the grass took longer to emerge. Assuming that a 1 mile long watercourse had vehicular access along one side, we feel hydro- seeding would be the best choice for bank stabilization.

The second null hypothesis is also rejected because the clogging potential of the maintenance activity was not significant in terms of amount of sediment delivered compared with that received from upstream. Although bank erosion prevention was important for bank stabilization, the finding of the other part of the project (Chapter 12) indicated that the main sediment source that clogs the watercourse came from upstream runoff. Therefore when determining what erosion control measures to use, one should not consider to use the measure as a tool for preventing the watercourse, but for bank stabilization.

Petri dishes were installed to measure the long-term sediment resulting from rainfall event after excavation. However, only the experiment at the site of Watercress Creek generated valid measurements. The sediment collected over 66-day period was significantly smaller, compared to the 1-year cumulative sediments. Although there were no valid measurements for the cumulative sediments after excavation at the sites of Ray Ewing and the 124 street, the results of site inspection also indicated that sediment from the treated banks of these watercourses were insignificant and immeasurable, as shown in Figure 11-10 and Figure 11-11.

Figure 11-10. RCG breaking through coir mat at the 124th Street site

Figure 11-11. No rill formation in the treated bank at the 124th Street site

11.6 References

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