CHAPTER 12

Evaluation of Techniques to Extend Maintenance Cycles

12.1 Introduction to Extended Maintenance Cycles (Goal 11)

Erosion is a fundamental and complex natural process that is strongly modified (generally increased) by agricultural activities (Osterkamp et al. 1991; Osterkamp and Schumm 1996). The general erosion control principles are to limit disturbance of the existing site during construction, stabilize disturbed soils, retain eroded sediment on site, and control stormwater runoff (Federal Highway Administration 1995). Sediment deposition has been identified as a problem in many of King County's agricultural waterways. Sedimentation reduces the carrying capacity of the channel directly by physical obstruction and indirectly by providing a more desirable substrate for RCG growth. Removal of sediments is a costly process in terms of time, labor, and environmental impact so determining methods for extending the maintenance cycle is an important issue. Controlling sediment sources to the maximum extent practicable is the most effective approach for minimizing the deposition of sediments in channels within and downstream of dredge areas (Wolman and Riggs 1990; Schumm et al. 1984). In other words, it is critical to prevent sediment from eroding and entering the drainage channel.

The solution to this problem depends on the relative magnitudes of the various sources of sediment. If the majority of sediment is from upstream sources, preventing sediment should be done by adopting best land management practices (BMPs) throughout the watershed, which is generally beyond the control of individual landowners. However, if the majority of the sediments deposited within the channel are from agricultural areas adjacent to the agricultural watercourse, or from on-site bank erosion sources, then minimizing soil loss from and across the channel banks will extent the maintenance cycle. On-site BMPs can be used to mitigate erosion in both these cases.

With the assistance of KCDNRP staff, the following initial research hypotheses were posed in relation to this study component:

> Hypothesis 1: Upstream erosion sources contribute a minor amount of depositional sediments in agricultural watercourses in the study areas.
>
> Hypothesis 2: There is no statistically significant difference in rill erosion immediately after maintenance (as measured in rills per square meter) between slopes reshaped at several slope angles, and between slopes with and without mid-slope benches.
>
> Hypothesis 3: Increasing the existing standard seeding and mulching requirements by 50 percent will not affect bank erosion.

Hypothesis 4: There is no difference in rill formation on channel slopes that are hand seeded compared to those that are hydro-seeded.

The remainder of this chapter discusses the methods used to evaluate these hypotheses.

12.2 Methods

12.2.1 Test Procedures

A thorough literature review did not reveal any similar research or policy decision based on science related to this specific maintenance cycle application. Although dredging is a mature subject with entire texts being devoted to the subject (Herbich 2000), most operations and methodologies are designed for larger waterways and were not deemed appropriate for agricultural watercourses. 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.

To investigate the first hypothesis, the amount of sediment deposition was measured over a certain period of time after the maintenance. The total deposited sediment was measured. At the same time, erosion from the banks of the watercourse was estimated based on observation of rill formation on the banks. The difference between the total amount of sediment deposited in the channel and that from bank erosion was considered as the amount resulting from upstream sources. The first hypothesis would pass the test if upstream erosion sources contributed less than 10% of the depositional sediments in each of the agricultural drainage watercourses selected in this study.

Quantitative measurement of deposited sediments in the channel was conducted by using a system of steel rods. Figure 12-1 illustrates the typical configuration of the rods. The steel rods were installed at the channel bottom centers, close to the Petri dishes installed for measuring sediment resulting from first significant rainfall event after excavation (See Chapter 11 for details of Petri dish experiments). Horizontal steel bases 9.5 mm thick with sides measuring 40.6 cm x 40.6 cm (3/8 in x 16 in x 16 in) with a 12.7 mm (½ in) diameter center hole were installed to hold the rods. The rods were inserted through the holes until the lowest cross bars reach the bases (See Figure 12-2). Cumulative sediment was measured by counting the number of visible horizontal bars that were not buried by sediment. In addition to the measurements of cumulative sediment in the watercourses, the effectiveness of the bank stabilization techniques were evaluated through monitoring and quantification of rills.

The second hypothesis was tested by measuring rill density, in terms of the number of rills per square meter, on the channel banks prior to the establishment of grass or permanent crop cover. The lengths, widths and depths of rills were measured at representative sites along the mitigation treatment reaches approximately two to three months after the maintenance activity. Digital photographs were taken to document the relative severity of rills.

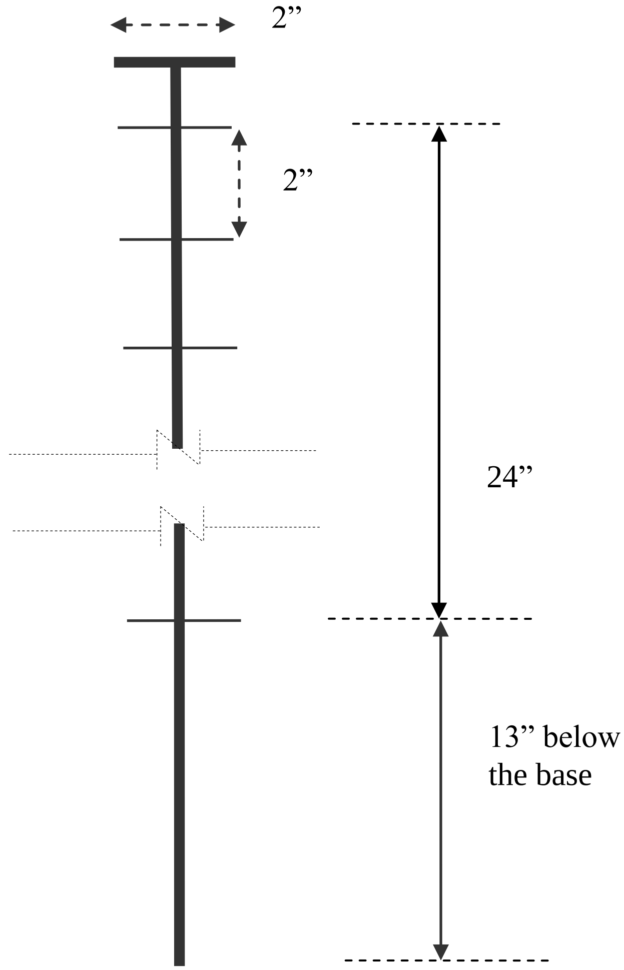


Figure 12-1. Structure of steel rods for measuring cumulative sediment

Because of mitigation requirements for maintenance activities, it was impossible to isolate the last two hypotheses (hypothesis #3 and #4). It would be nearly impossible, for example, to obtain permit exemptions from the Washington State Department of Fish and Wildlife and King County to leave an exposed bank cut without any mulch or reseeding in order to investigate the relative effectiveness of various mulch and grass seed treatments. As a result, the testing procedures were developed to answer both questions with specific weights to each hypothesis assigned by comparing the degree of erosion ensuing from excavated agricultural watercourse segments with varying types of vegetative cover and bank slopes.

Figure 12-2. Typical installation of Petri dishes and steel rods

12.2.2 Erosion Control Treatments

Site-specific bank stabilization techniques were utilized to reduce sediment deposition in or downstream from the treated channel reach due to bank erosion. Both temporary and permanent stabilization methodologies were evaluated as well as the impact of these stabilization procedures as a function of bank slope.

The general experimental design for meeting all the objectives in this phase of the project is presented in Table 12-1. The following paragraphs will provide comprehensive information on the experimental designs and test procedures for the selected test sites. It should be noted that testing of all possible combinations at any individual site was not feasible due to the limitation of watercourse length.

Table 12-1. Parameters and combinations of experimental design for erosion control

Side slope angle	Bank stabilization technique
2:1	No treatment was applied
3:1	Hydro-seeding (100% and 150%) Hand-seeding Sod Erosion control fabrics Mulching (100% and 150%) Moss Soil Binder (wheat straw)
3.55:1 ~ 6.09:1 (Composite channel)	Hydro-seeding (100% and 150%) Hand-seeding Sod Erosion control fabrics Mulching (100% and 150%) Moss Soil Binder (wheat straw)

The following descriptions of the materials listed in Table 12-2 are provided for clarity:

(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.

12.2.3 Experimental Sites

The three sites used to conduct this portion of the sediment study included the Watercress Creek (also referred to as Josie-Wetzel) and Ray Ewing sites in Enumclaw and the 124th Street (also referred to as Pickering) site in Duvall. Figure 12-3 illustrates the general study area within King County. The two Enumclaw study site locations are presented in Figure 12-4. The Watercress (Josie-Wetzel) site is between Josie-Wetzel-1 and Josie-Wetzel-2 on the map. Similarly, the Ewing site is between Ewing-1 and Ewing-2. The Duvall site at 124th Street is shown as the Pickering A-1 to Pickering B-2 reach in Figure 12-5. Table 12-1 shows the general experimental designs of bank stabilization techniques at these sites. Details of the sites are provided below.

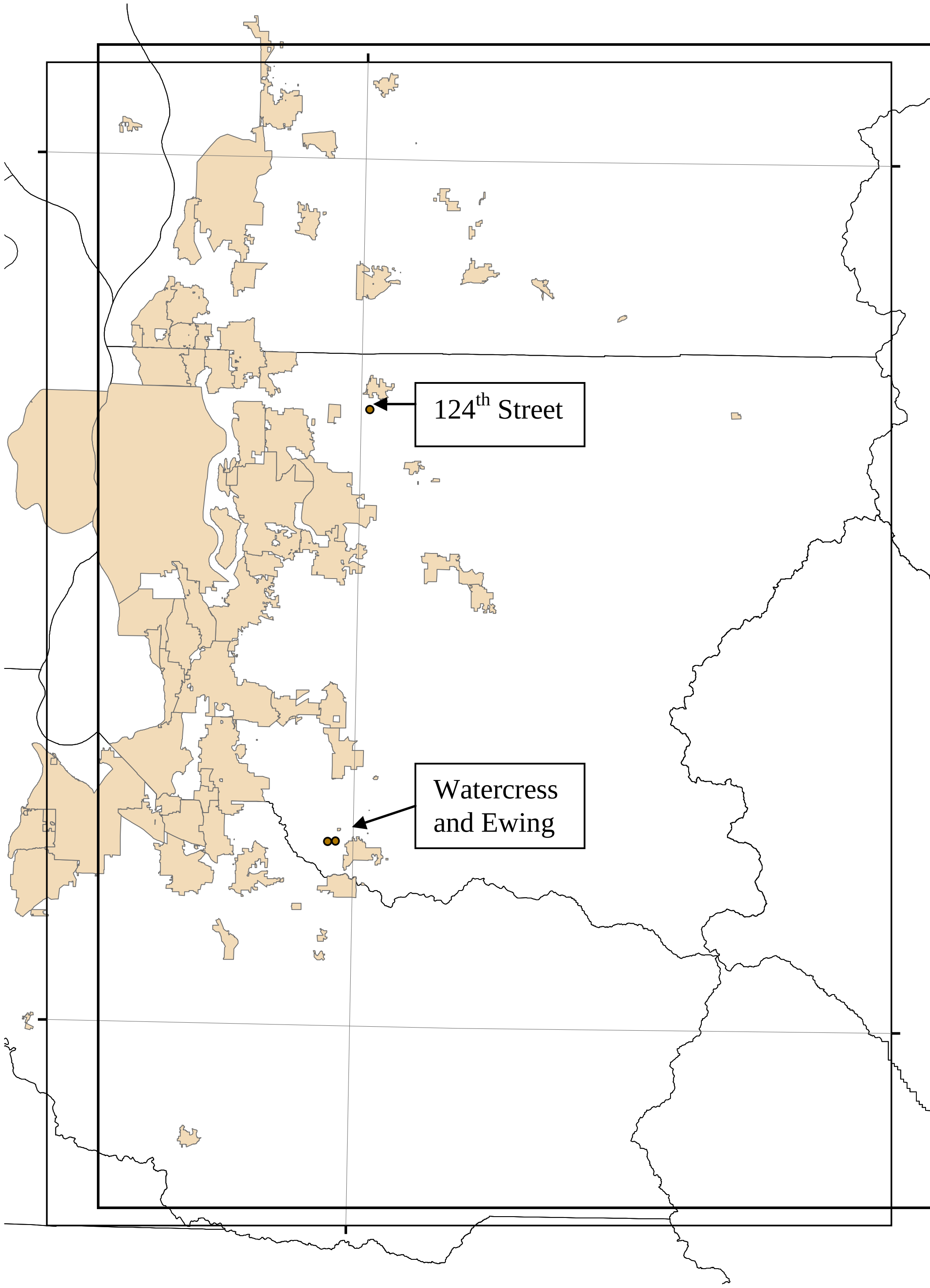


Figure 12-3. Geographic location of the experiment sites
(See site diagrams for GPS location information)

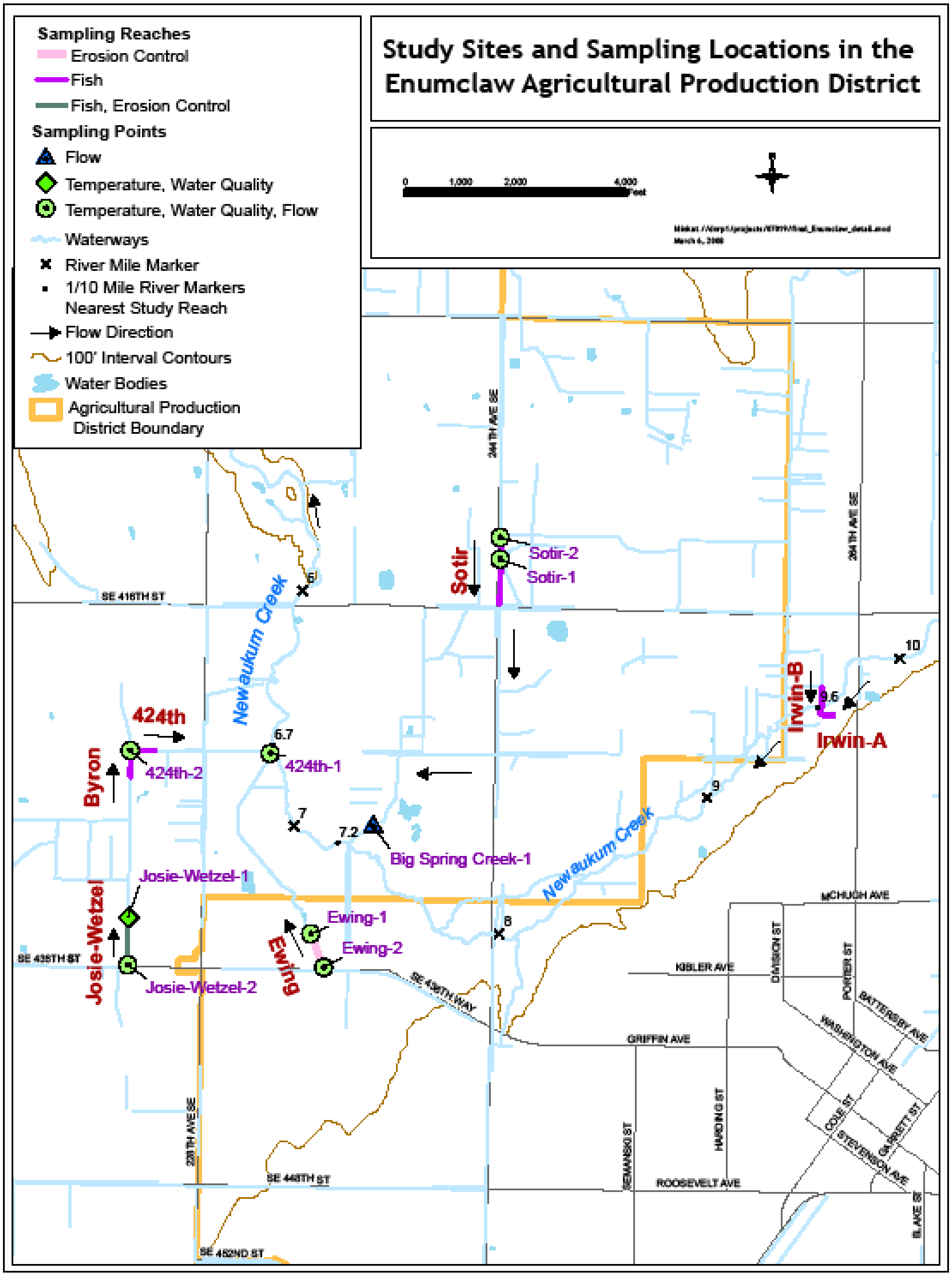


Figure 12-4. Detailed map of Enumclaw study sites

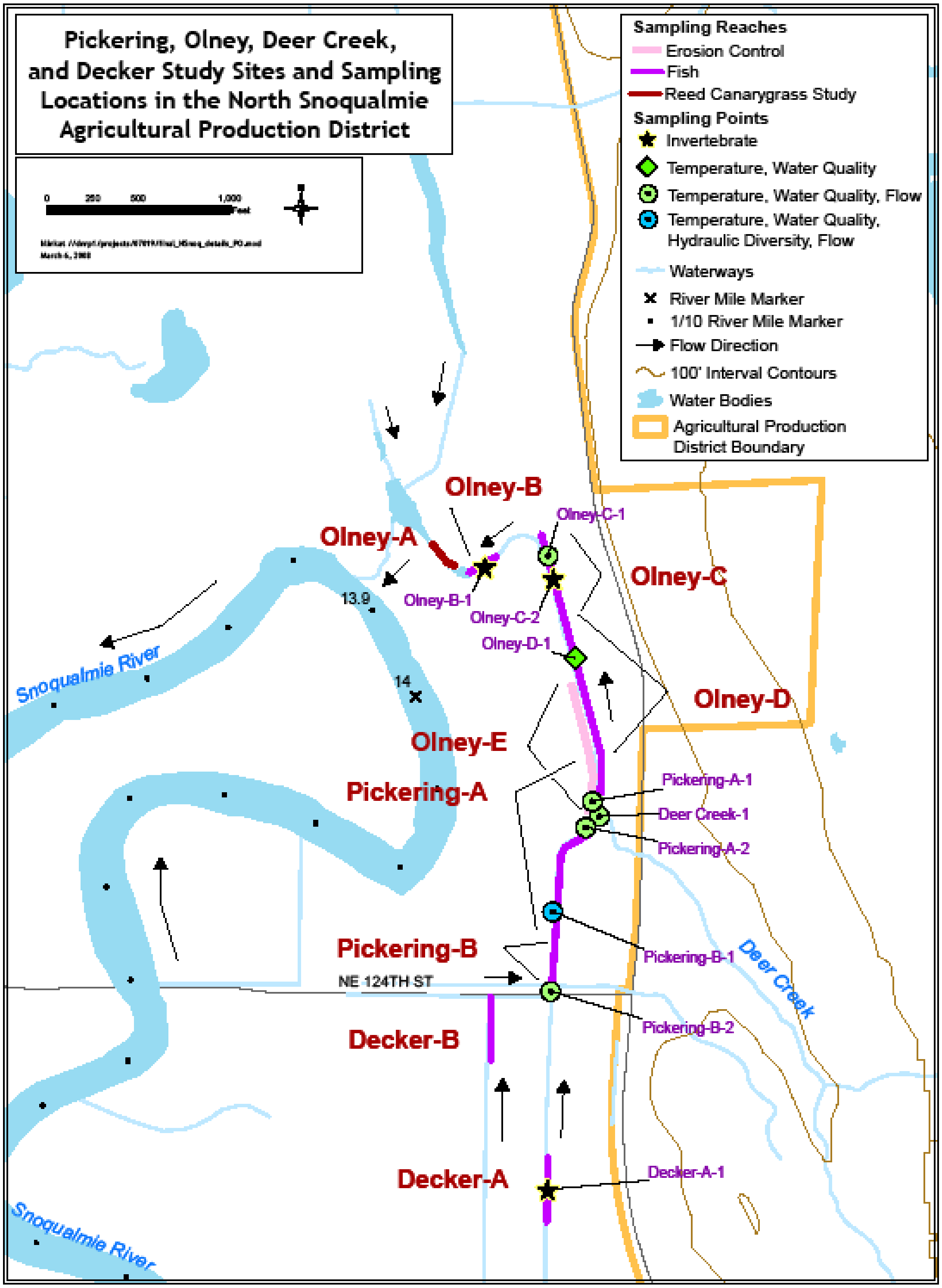


Figure 12-5. Detailed map of 124th Street site

12.2.3.1 Experimental design at the site of Watercress Creek

The Watercress Creek (Josie-Wetzel) site is located on a tributary to the Newaukum Creek drainage on the Enumclaw Plateau (Figure 12-4). There was no bank treatments employed at the Watercress Creek site since the side slopes were too steep for economical erosion control (2:1). The total length of the watercourse was approximately 274.3 m (900 ft) although the effective length for measuring cumulative sediment was about 201.2 m (660 ft) after excluding the possible interferences from two ends of the watercourse. Steel rods were placed at seven locations using 30.5 m (100 ft) spacing intervals as illustrated in Figure 12-6. The steel rods were installed on August 2004 and cumulative sediment depths were measured twice (August 2005 and September 2005).

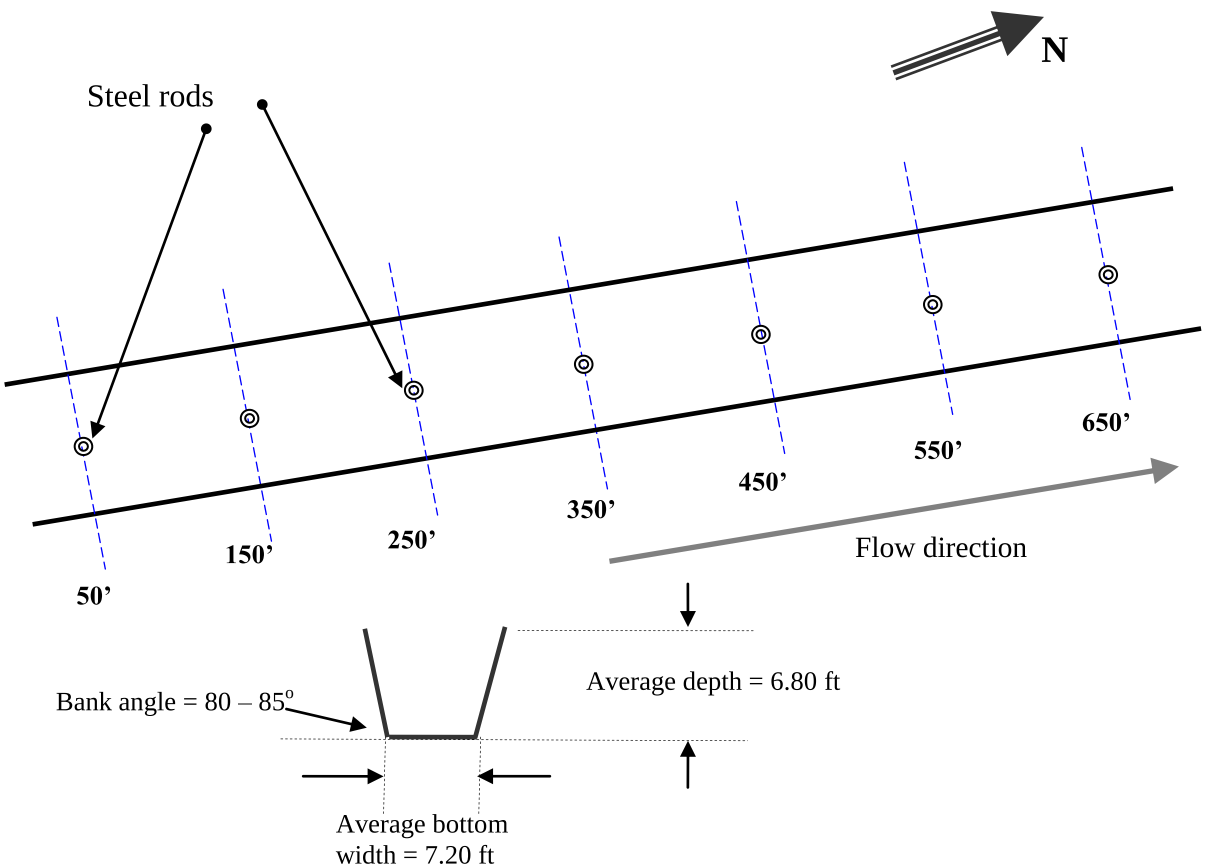


Figure 12-6. Steel rods placement at Watercress Creek site

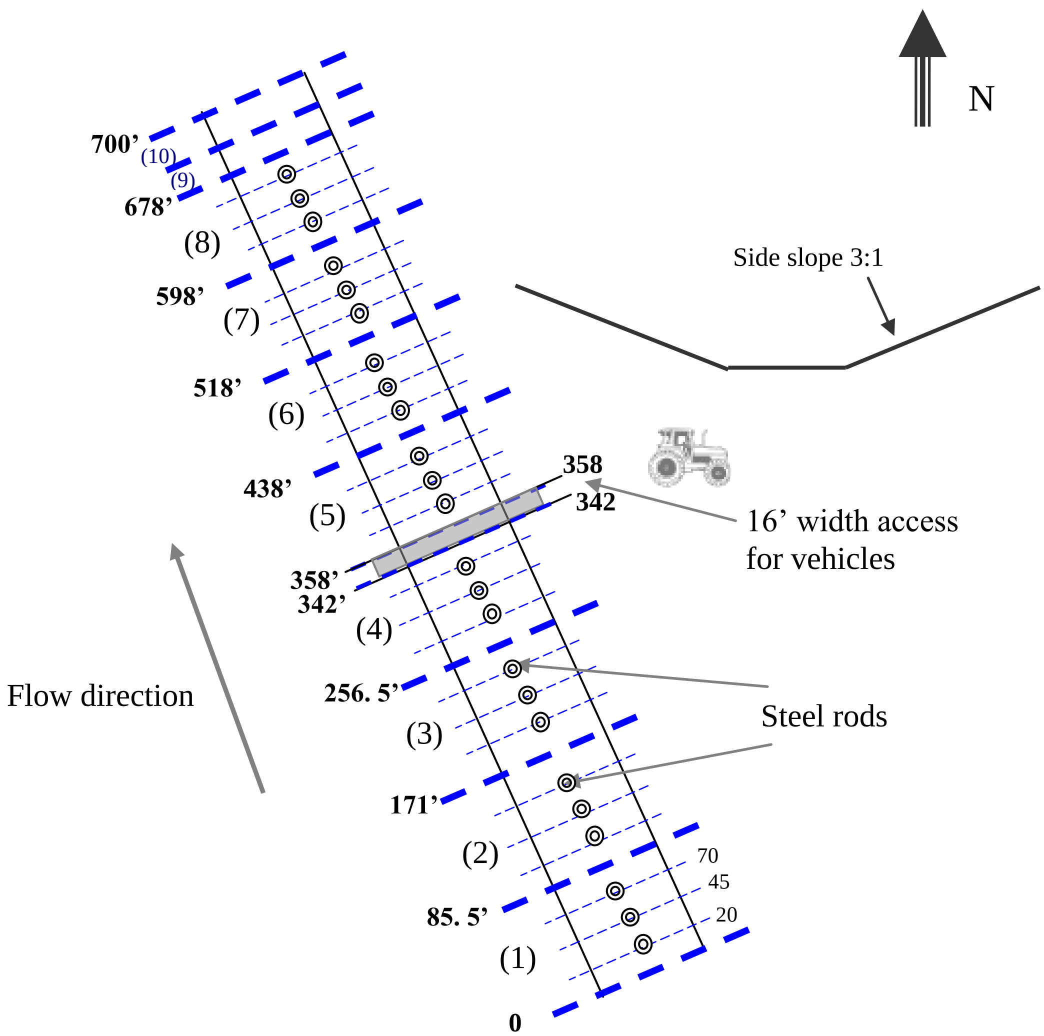
GPS location N 47 12.756 W122 02.573

12.2.3.2 Experimental design at the Ray Ewing site

The experimental design for monitoring cumulative sediments in the Ray Ewing site is illustrated in Figure 12-7. The total length of the watercourse used in the 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) Hogfuel (200%, depth of 4”), and
(10) Hogfuel (100%, depth of 2”)

Wheat straw was used as a substitute for both sod and soil binder at this site for economic and maintenance reasons. The length for the treatment plots (1)-(4) was 85.5 ft, while that for treatment plots (5)-(8) was 80.0 ft. Within each of the treatment plots (1)-(8), steel rods were placed in the channel center at distances of 20, 45, and 70 ft measured from the upstream boundary of the treatment area (See Figure 12-7). Cumulative sediments were measured in January, April, and August of 2005. The length for treatments (9) and (10) was 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 12-7. Steel rods placement at the 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

12.2.3.3 Experimental design at the 124th Street site

The assigned watercourse length for the sediment experiment at the 124th Street site was 230.1 m (755 ft) which included a 16.8 m (55 ft) separator strip in the middle. Eight mitigation treatments were applied on the left bank of the watercourse at this site. Along the direction of water flow (upstream to downstream), the treatments were:

(1) Peat moss,
(2) CF-900 coir mat,
(3) Woodchips (100%, depth of 2"),
(4) Woodchips (200%, depth of 4"),
(5) Sod
(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).

Treatment plots 1-4 each had lengths of 85.0 ft while treatment plots 5-8 each had lengths of 90.0 ft. Within each treatment plot (1-8), steel rods were placed in the channel center at distances of 30, 50, and 70 ft from the upstream beginning of the treatment. Figure 12-8 illustrates the layout of the experiments. The cumulative sediment measurements were collected in October 2004, January 2005, April 2005, and August 2005 at the 124th Street site.

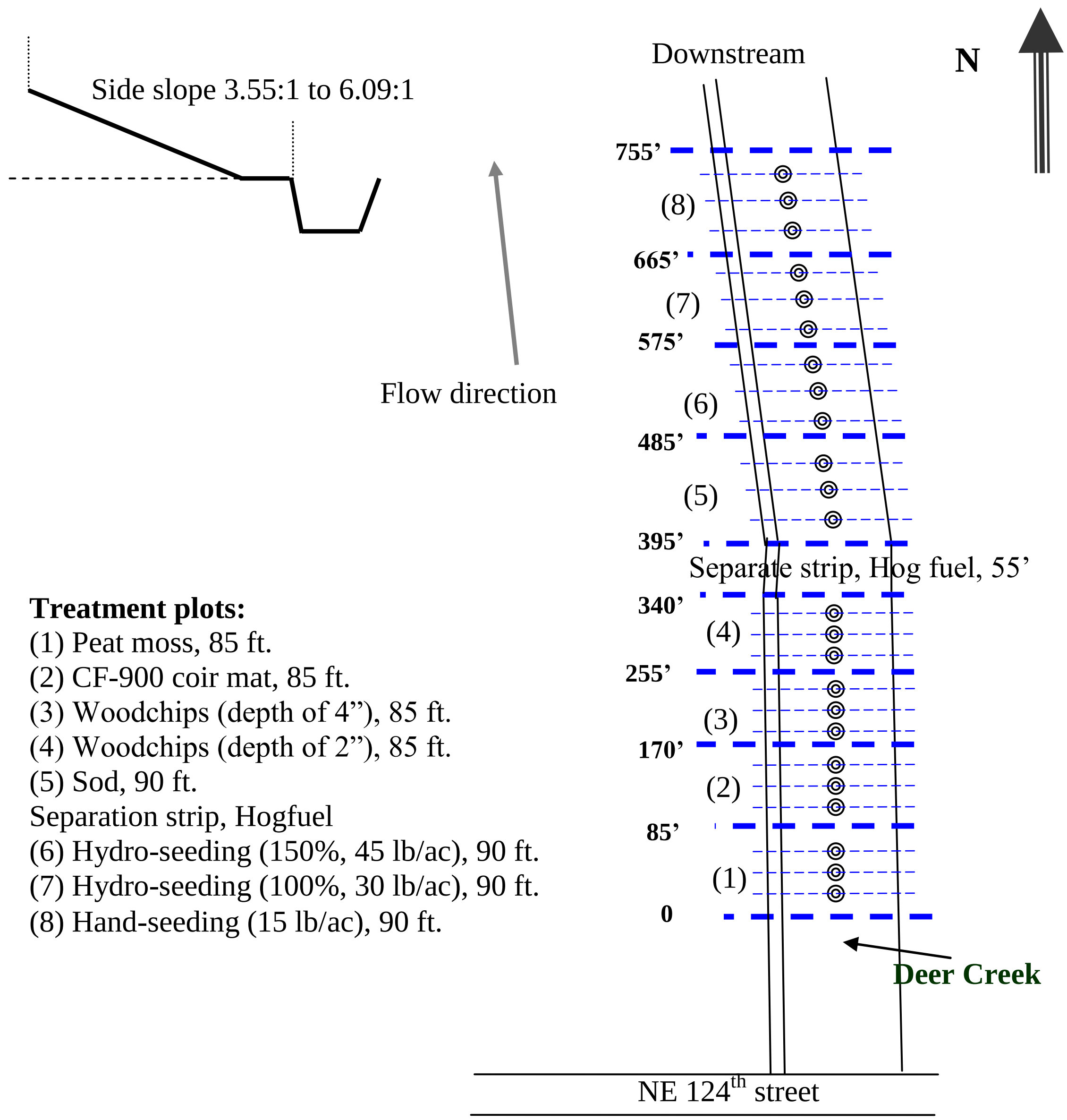


Figure 12-8. Steel rod placements at 124th Street site

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

12.3 Results

Shown in Figure 12-9 and Table 12-2 are the cumulative sediment depths at Watercress Creek, from August 2004 to August 2005 and from August 2005 to December 2005, respectively. The cumulative sediments amounts were much higher than the sediment resulting from the first significant rainfall event after excavation discussed in Chapter 11.

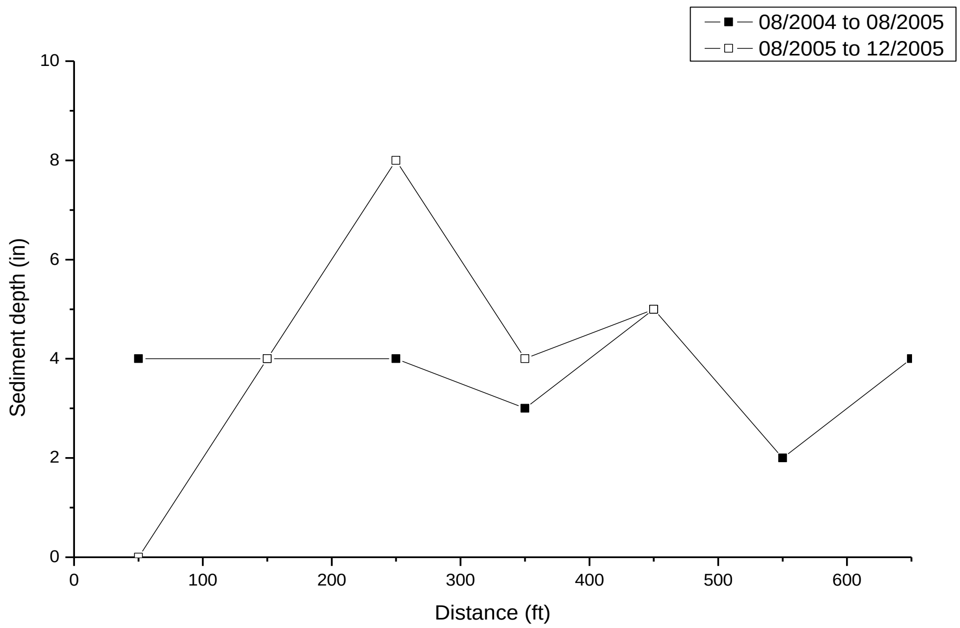


Figure 12-9. Cumulative sediment at the Watercress Creek site, starting from August 2004

Table 12-2. Cumulative sediment at the Watercress Creek site, starting from August 2004

Distance		Cumulative sediment (mm and inches)	
(m)	(ft)	August 2004 to August 2005	August 2005 to December 2005
15.2	50.0	101.6 mm (4.0 in)	0.0 mm (0.0 in)
45.7	150.0	101.6 mm (4.0 in)	101.6 mm (4.0 in)
76.2	250.0	101.6 mm (4.0 in)	203.2 mm (8.0 in)
106.7	350.0	76.2 mm (3.0 in)	101.6 mm (4.0 in)
137.2	450.0	127.0 mm (5.0 in)	127.0 mm (5.0 in)
167.6	550.0	50.8 mm (2.0 in)	50.8 mm (2.0 in)
198.1	650.0	101.6 mm (4.0 in)	101.6 mm (4.0 in)

The following are some observations on the results of cumulative sediment measurements at the Ray Ewing property. It is noteworthy that a highway drainage watercourse adjacent to this property inlet was blocked by mud and gravel which resulted in unusually high runoff through the Ray Ewing property. High water flows in December 2004 caused scouring effects on the channel bottom and washed away the previously deposited sediment at this site as illustrated in Figure 12-10. Hog fuel installed in treatments (9) and (10) were also washed out during the flood event. Of the twenty-four steel rods installed, positive cumulative sediment measurements were only observed at the seven rods located from 152.4 m to 182.9 m (500 ft to 600 ft) along the watercourse. This area was about 36.6 m (120 ft) upstream from the watercourse outlet (Figure 12-11). Based on the site inspection conducted by WSU researchers, the stream flow appeared to be impeded by a debris laden fence before the stream exited the property. During large runoff events this blockage created a pond-like area that allowed solids to settle out of suspension (Figure 12-12 and Table 12-3). Therefore, sediment accumulated in the lower section of this watercourse (treatment plot #7). As shown in the photos, a high water table was observed where woody matter (hog fuel) remained.

Figure 12-10. High water flow washed away the previously deposited sediment at the 124th Street site as depicted in this photograph taken on January 28, 2005

Figure 12-11. Example of sediment deposited near the watercourse outlet at the Ray Ewing property on January 28, 2005

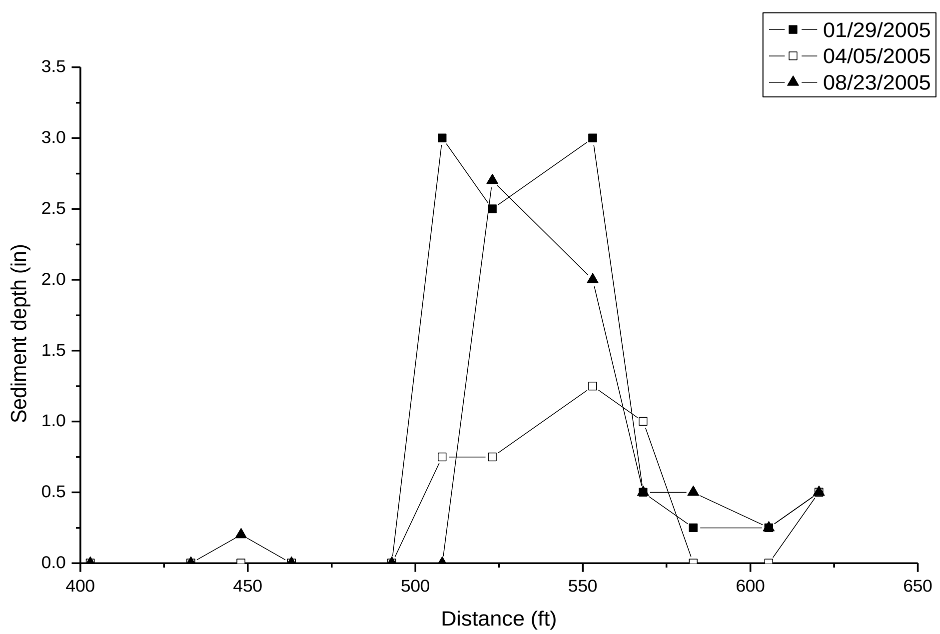


Figure 12-12. Sediment depths at the site of Ray Ewing property

Table 12-3. Cumulative sediment at the site of Ray Ewing property, starting from October 2004

Distance		Cumulative Sediment (inches)		
(m)	(ft)	01/29/2005	04/05/2005	08/23/2005
6.1	20.0	0	0	0
13.7	45.0	0	0	0
21.3	70.0	0	0	0
32.2	105.5	0	0	0
39.8	130.5	0	0	0
47.4	155.5	0	0	0
58.2	191.0	0	0	0
65.8	216.0	0	0	0
73.5	241.0	0	0	0
84.3	276.5	0	0	0
91.9	301.5	0	0	0.2
99.5	326.5	0	0	0
113.7	373.0	0	0	0
118.3	388.0	0	0	0
122.8	403.0	0	0	0
132.0	433.0	0	0	0
136.6	448.0	0	0	0.2
141.1	463.0	0	0	0
150.3	493.0	0	0	0
154.8	508.0	3.0	0.75	0
159.4	523.0	2.5	0.75	2.7
168.6	553.0	3.0	1.25	2.0
173.1	568.0	0.5	1.0	0.5
177.7	583.0	0.25	0	0.5
184.6	605.5	0.25	0	0.25
189.1	620.5	0.5	0.5	0.5

The cumulative sediment collected on April 5, 2005 reflected a loss of previously deposited sediment in the lower reaches (treatment plots #7 and #8) of this property. This occurred because the landowner performed maintenance on a fence that had impounded the flow through the outlet and because partially blocked highway watercourses above the property inlet were cleared. These activities allowed the channel to flow freely which washed away some of the previously deposited sediments.

Sediment accumulated rapidly at the 124th Street site. The cumulative sediment depth increased somewhat sporadically from15.2 cm (6.0 in) in August 2004 to 40.6 cm (16.0 in) in August 2005. This trend is shown in Figure 12-13 and

Table 12-4. Based on our observations, the predominate sediment sources were from upstream. The sediment loss from the left bank of this watercourse with treatment was insignificant, and there was no measurable rill formation on the bank as determined by visual inspection (Figure 12-10). Similarly, there was no visible evidence of rill erosion at the treated sites (Figure 12-14). A close-up of the Coir mat erosion control effectiveness is shown in Figure 12-15.

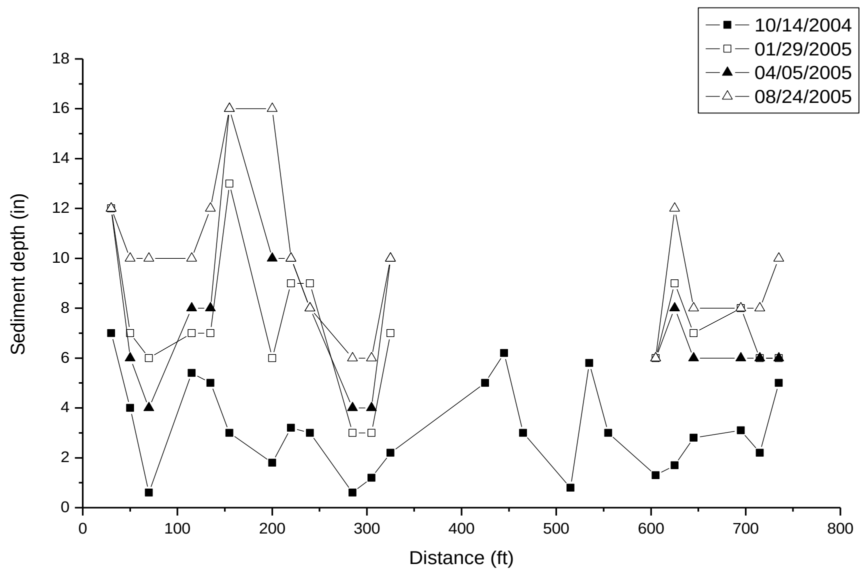


Figure 12-13. Sediment depths at the site of the 124th Street

Table 12-4. Sediment measurements at the 124th Street site in Duvall from August 2004 to August 2005 (Measurements taken from the South to the North).

Distance		Cumulative Sediment (inches)			
(m)	(ft)	10/14/2004	01/29/2005	04/05/2005	08/24/2005
9.1	30	7	12	12	12
15.2	50	4	7	6	10
21.3	70	0.6	6	4	10
35.1	115	5.4	7	8	10
41.1	135	5	7	8	12
47.2	155	3	13	16	16
61.0	200	1.8	6	10	16
67.1	220	3.2	9	10	10
73.2	240	3	9	8	8
86.9	285	0.6	3	4	6
93.0	305	1.2	3	4	6
99.1	325	2.2	7	10	10
129.5	425	5	N/A	N/A	N/A
135.6	445	6.2	N/A	N/A	N/A
141.7	465	3	N/A	N/A	N/A
157.0	515	0.8	N/A	N/A	N/A
163.1	535	5.8	N/A	N/A	N/A
169.2	555	3	N/A	N/A	N/A
184.4	605	1.3	6	6	6
190.5	625	1.7	9	8	12
196.6	645	2.8	7	6	8
211.8	695	3.1	8	6	8
217.9	715	2.2	6	6	8
224.0	735	5	6	6	10

(a)

(b)

Figure 12-14. No rill formation in the treated bank at the 124th Street site, (a) treatment (1) peat moss, and (b) treatment (2) Coir mat

Figure 12-15. Visual evidence of erosion control provided by Coir fiber mat

12.4 Conclusion

The first hypothesis was rejected at the 124th Street site in Duvall. At this site, the measurement of rill formation indicated that the rills from the treated banks were immeasurable and insignificant as illustrated in Figure 12-14. Upstream erosion sources were the primary contributor of the deposited sediment at this site. Therefore, locations similar to the 124th Street site, it is suggested that the most effective practices to extend the maintenance cycle of the watercourse would be to implement effective soil erosion control treatment in the upstream regions. Alternatively, a settling pond could be installed at the beginning of each long watercourse at this site. Sediment from upstream flows would settle out in such ponds due to slower flow velocities and increased hydraulic residence time. Economically, the cost for settling ponds should be much less than the cost of dredging a long watercourse on a frequent basis.

Due to the unusual stream flow pattern during the measurements at the Ray Ewing property, it was difficult to determine the individual contribution on the cumulative sediment from bottom erosion, watercourse banks, or upstream sources.

The second hypothesis was generally accepted although maintenances were only applied at two sites (the Ray Ewing property and the 124th Street site). At both sites, there was no rill formation prior to the establishment of grass or permanent crop cover. For further investigation, more experimental sites should be used to determine the effects of slope angles and slope benches on the rill erosion immediately after maintenance.

The last two hypotheses were accepted based on the experiments and observations in this study. Since there was no significant difference of rill erosion on the treated banks, we concluded that (1) increasing the existing standard seeding and mulching requirements by 50% would not affect bank erosion, and (2) there was not difference in rill formation on channel slopes that were hand-seeded compared to those that were hydro-seeded. Therefore, hydro-seeding with standard seeding rate (30 lb/ac) is recommended for extending maintenance cycles in erosion control.

The results of the research demonstrated that sediment runoff from the watershed upstream was the main source for the sediment buildup in the watercourse. Potential sediment sources include, but not limited to development, improper farming practices, loss of vegetative cover on land, etc. Therefore, a more comprehensive approach should be taken in evaluating strategies for extending the period between excavations. One possible option is using sedimentation basin (trap), a specifically designed pool area that fits into the watercourse configuration. This basin can intercept and store the sediment. Removing the sediment from an easily accessible basin will be less costly than dredging the watercourse.

12.5 References

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