Carney Lake Sub-Basin Assessment Report

Ueland Tree Farm, LLC

September 2007

Parametrix

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ACRONYMS

BMPs	Best Management Practices
DO	Dissolved oxygen
LID	Low Impact Development
UTF	Ueland Tree Farm
WDFW	Washington Department of Fish and Wildlife

1. INTRODUCTION

Ueland Tree Farm (UTF) is proposing to develop portions of a 280-acre parcel of land located near Carney Lake in unincorporated south Kitsap County, Washington (Figure 1-1). This sub-basin assessment has been prepared to assist UTF in developing project plans that reflect natural resource values, as well as identify potential limiting factors within the Rocky Creek watershed.

1.1 PURPOSE AND SCOPE

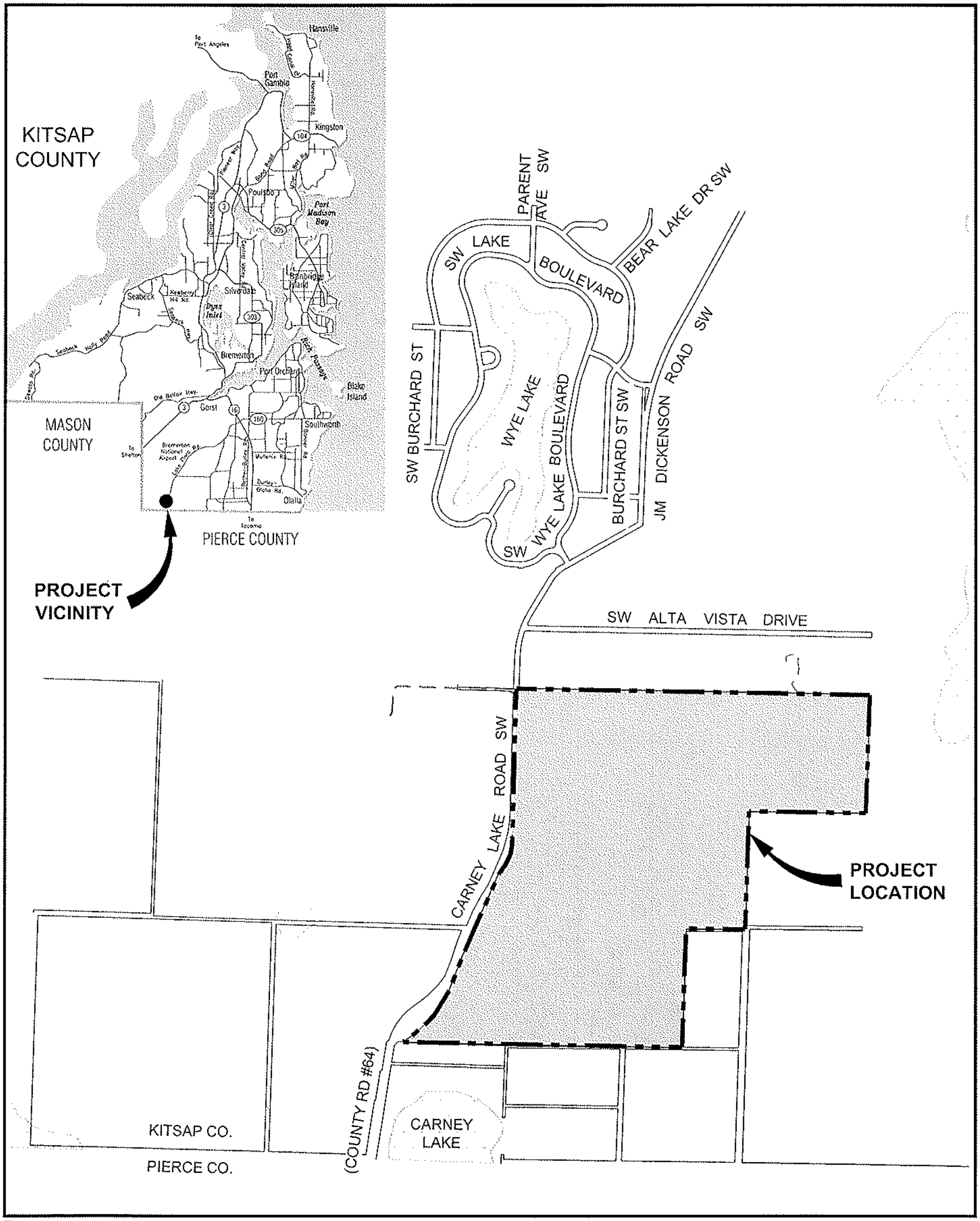
The purpose of this sub-basin assessment is to identify existing conditions and limiting factors within the property boundaries of UTF, located on approximately 280-acres of forest land situated to the northeast of Carney Lake in unincorporated south Kitsap County near the Kitsap County and Pierce County line. The UTF project consists of planning, permitting, and design of mineral resource extraction and future residential development.

This sub-basin assessment consists of a review of existing watershed data to characterize natural resources and significant limiting factors for fish and wildlife habitat. The report also includes the identification of Best Management Practices (BMPs) that could potentially be used on the property to minimize project impacts on natural resources.

The assessment provides a summary description of the Rocky Creek watershed and the UTF site including hydrology, fish and wildlife habitat, and water resources. Potential limiting factors are identified, as are general recommendations for the design of future projects.

1.2 LIMITATIONS

Information contained in this report is intended to be used as an aid in making decisions about proposed activities on the UTF property. This document is not a substitute for an EIS or other required environmental information.



Parametrix DATE: Sep 14, 2007 FILE: BR5528002P01T06F-01

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0 1,500

SCALE IN FEET

Figure 1-1
Ueland Tree Farm
Carney Lake Property
Project Location

2. PROPERTY DESCRIPTION

The UTF property consists of three parcels that encompass approximately 280-acres of forested land that is currently zoned as Rural Wooded (Figure 2-1). The western edge of the property borders Carney Lake Road SW. The southwestern corner abuts property zoned Rural Residential, as does the entire northern border. The eastern side of the property borders land owned by Alpine Evergreen, LLC. Three access roads stemming from Carney Lake Road SW provide entrance points to the property, with various forest access roads winding through the parcel.

The property is located entirely within the Rocky Creek watershed located in both Kitsap and Pierce Counties (Figure 2-2). Several small intermittent drainages run through the property, two of which drain into Carney Lake to the south. One small tributary of Rocky Creek begins on the western side of the property close to Carney Lake Road SW. Depressional areas exist on the property that also support seasonal creeks and wetlands.

2.1 PROJECT DESCRIPTION

Ueland Tree Farm has preliminary development plans that include one sand and gravel surface mine and large-lot residential development (Figure 2-3). The sand and gravel mine consists of approximately 71-acres of land in the northeastern section of the property, with future plans to reclaim the mine into commercial forest. The residential lots will be approximately 20-acres each. Approximately 14 lots for future single-family residences are proposed.

2.2 HISTORY OF CARNEY LAKE AREA

The following brief historical description of the Carney Lake area, and the photographs shown on the cover of this report were provided by Evelyn and Willard Wright.

> "My great-grandfather, Willard Carney, was born in Cambria, New York. He served in a New York regiment in the Civil War. After the war, he lived in Kansas. In 1888, he brought his family and homesteaded near Vaughn, Washington at Carney Lake on the Kitsap County side. My grandmother Minnie Carney, the oldest of three children, would have been age 16 at the time. She married another homesteader, Elmer E. Wright in Sidney (now Port Orchard), Washington in 1897 and moved to Tacoma.
>
> I am attaching scans of some old faded photos you might find interesting. The cabin and lake photos are not dated. I have guessed the time on the apparent age of the people in the photo. The aerial view of Carney Lake is dated February 1940.
>
> The property surrounding the lake was subdivided into lots probably in the early 1940s. I have fond memories of visits to the lake as a child. I remember my grandfather having to cut small trees from the center of the 2-track road so our car could pass – about 1932-1934.
>
> My parents bought two lots on the south (Pierce County) end of the lake in 1945, and I bought the intervening lot while still overseas in the army during World War II. We erected a cabin in 1964, and just added our current home last year. We are not on the original

homestead, but at least on the lake that bears my grandfather's name."

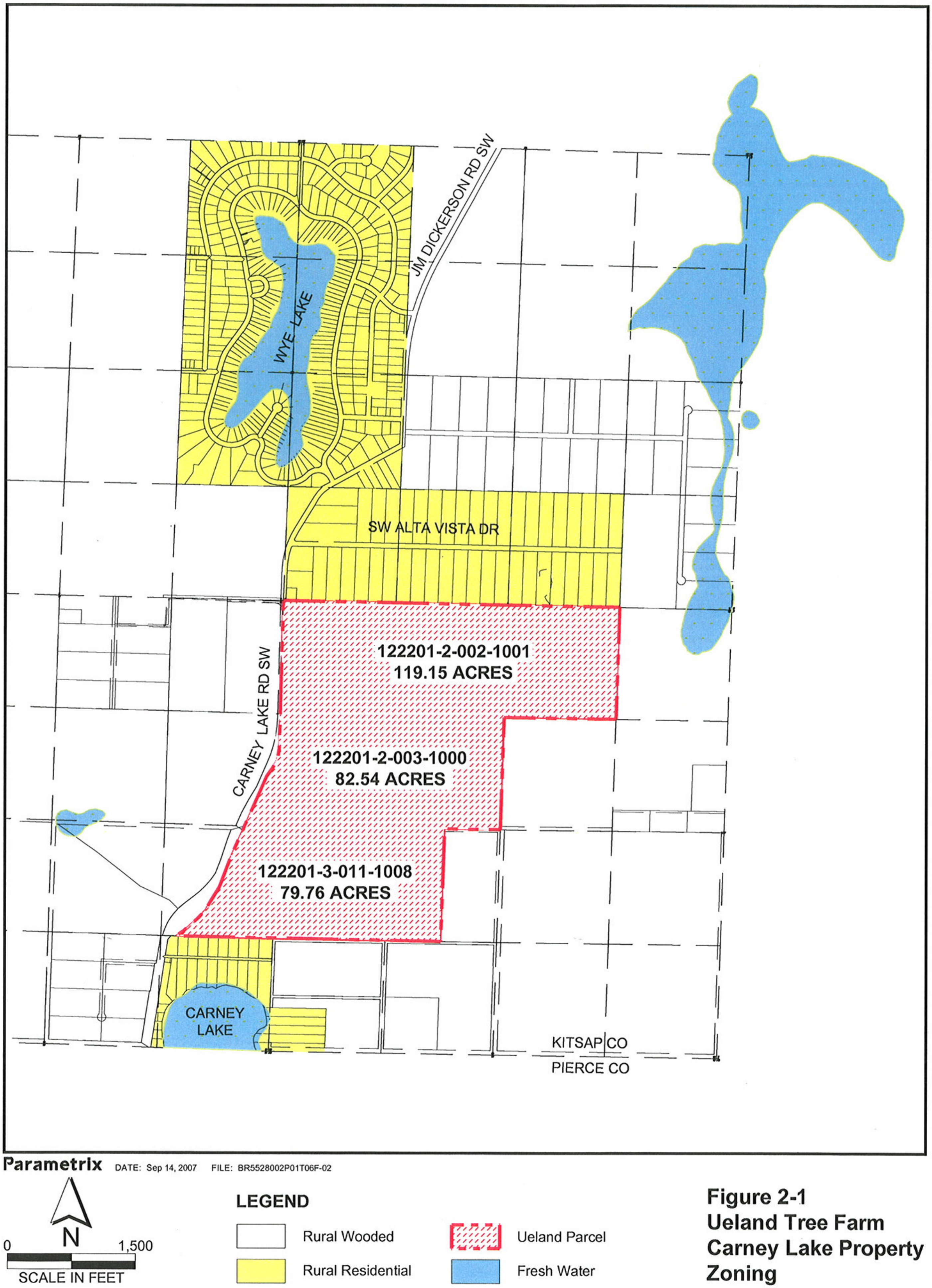
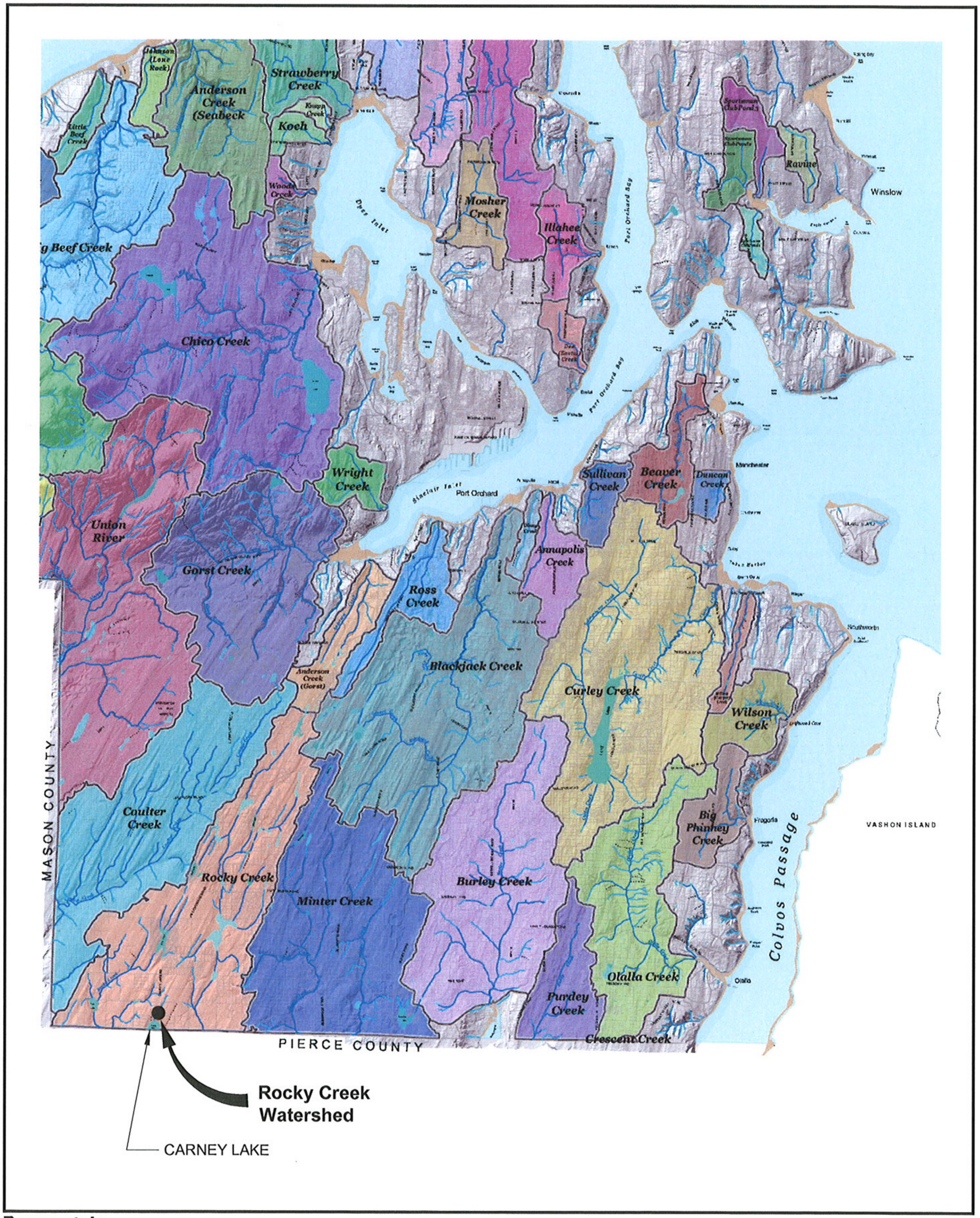


Figure 2-1
Ueland Tree Farm
Carney Lake Property
Zoning



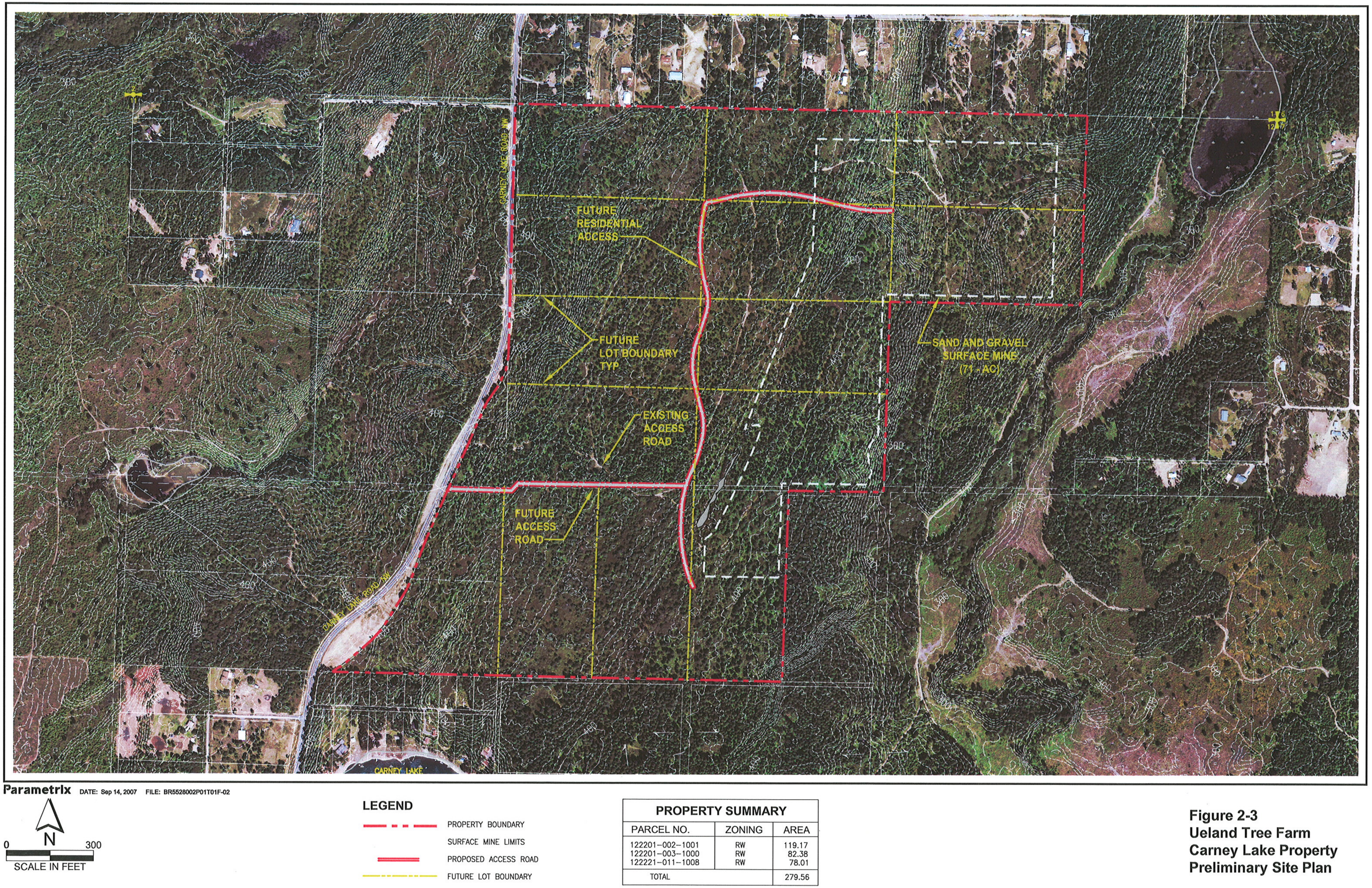
Parametrix DATE: Sep 14, 2007 FILE: BR5528002P01T06F-03

N

0

NO SCALE

Figure 2-2
Ueland Tree Farm
Carney Lake Property
Watershed Map



PROPERTY SUMMARY

PARCEL NO.	ZONING	AREA
122201-002-1001	RW	119.17
122201-003-1000	RW	82.38
122221-011-1008	RW	78.01
TOTAL		279.56

Figure 2-3
Ueland Tree Farm
Carney Lake Property
Preliminary Site Plan

3. SUB-BASIN DESCRIPTION

3.1 ROCKY CREEK SUB-BASIN DESCRIPTION

The entire project is within the Rocky Creek watershed, which is located in southern Kitsap County and extends south into Pierce County where the creek and its associated tributaries ultimately flow out to Rocky Bay on Case Inlet. The mainstem is approximately five miles long, with tributaries contributing an additional ten to twelve miles of channel length. The Rocky Creek drainage contains approximately 12,000 acres of land in both Kitsap and Pierce counties (May 2003).

The headwaters of Rocky Creek lie in sparsely developed lowland hills of the southern Kitsap Peninsula. The stream flows in a southerly direction through moderately sloped valleys covered with second growth timber and ultimately drains into Rocky Bay. Land development is generally limited in the sub-basin except for communities around Wye Lake, Carney Lake and the marine shoreline.

Rocky Creek does not flow through the project area; however, it is located less than one mile from the northwest property boundary. The property itself is divided by two ridgelines that run north to south, and ultimately determine the flow of water within the property. Because the western edge of the property abuts Carney Lake Road SW, water flowing from the western ridgeline will drain into the ditches along the side of the road, and flow south to Carney Lake (Figure 3-1). The northeastern portion of the property drains toward the eastern tributary of Rocky Creek while a small portion of the site in the northwest corner discharges to the Rocky Creek mainstream basin to the west.

3.2 CARNEY LAKE SUB-BASIN

Carney Lake is located just south of the project boundary and is surrounded by single-family homes. Two small tributaries located within the southern property limits drain into Carney Lake, which has no outlet except for infiltration. Periodic flooding has been identified as a concern around Carney Lake. The mining operation will use infiltration for stormwater management to prevent flooding impacts.

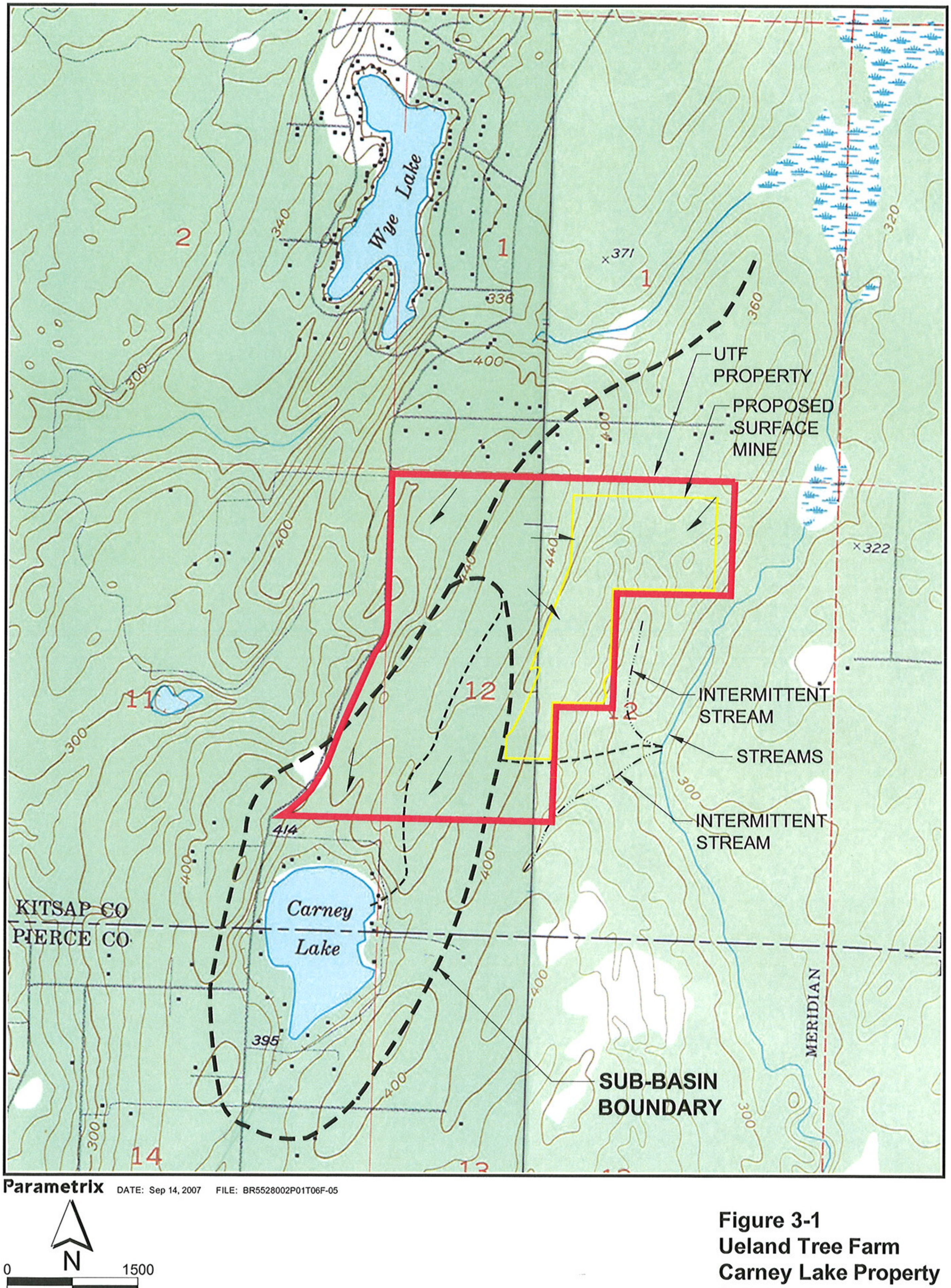


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Figure 3-1
Ueland Tree Farm
Carney Lake Property
Sub-Basins

4. CRITICAL AREAS

Critical areas on the site consist of several wetlands and intermittent streams. The location of wetland and stream critical areas is shown in Figure 4-1 and was determined by field investigations conducted in 2007 (Parametrix 2007).

4.1 WATER QUALITY

Kitsap County does not maintain a database on water quality within the Rocky Creek watershed. However, Pierce County has been monitoring a site on Rocky Creek less than a mile upstream of its mouth. Samples taken since 1995 have shown that the creek is well within state water quality standards for fecal coliform. Water quality samples taken by Stream Team volunteers and Pierce County Water Programs have generally found the creek to be in very good condition. Temperatures have ranged between 5°C and 14°C, and the average pH is 7. Dissolved oxygen (DO) readings have ranged between 7 and 14.88 mg/l. The state water quality standard for minimum DO is 8 mg/l for Class A waters, indicating a potential problem during portions of the year for Rocky Creek (Haring 2000).

4.2 WATER QUANTITY

The Department of Ecology has determined that Rocky Creek and its tributaries exhibit low summer flows and have the potential for drying up or inhibiting anadromous fish passage during critical life stages; therefore, no further water is available for consumptive appropriation from June 1 – October 31 per WAC 173-515-040. Applications for consumptive water appropriation at other times of the year are subject to minimum instream flows established in WAC 173-515-030 (Haring 2000).

Instream flow data for Rocky Creek taken at the outlet to Fern Lake shows a low flow of four cubic feet per second on June 10, 1995, to a high of 9.4 cubic feet per second on October 29, 1996. A flow survey performed by Pierce County Water Programs on September 12, 1997, calculated a total quantity of 9.8 cubic feet per second with a velocity of 1.58 feet per second (Haring 2000).

4.3 FISH SPECIES AND HABITAT

Rocky Creek supports coho, chum, cutthroat, steelhead, and chinook, and is used year round for spawning and rearing. The extent of anadromous fish along Rocky Creek stops approximately three quarters of a mile south of Wye Lake. Its main unnamed tributary located east of the property is utilized by coho and chum salmon. Anadromous fish presence in this tributary to the east extends approximately three miles past the northern boundary of the property. No anadromous fish presence is documented within Carney Lake or any of its tributaries (Figure 4-2).

Stream areas within this sub-basin are producing close to their maximum natural potential, with the exception of sections depleted through recent poaching activities. Maintaining these levels can only be achieved if the habitat remains in its present, undisturbed condition (Haring 2000).

4.4 WILDLIFE SPECIES AND HABITAT

Wildlife species common to the watershed include black bear, bobcat, deer, coyote and other mammals typical to conifer forests.

4.5 SPECIAL STATUS SPECIES

According to the Washington Department of Fish and Wildlife (WDFW), no heritage points exist on the property or within a mile of the project boundary. However, mountain quail, a Washington State priority species, has been documented within a two mile radius of the project site. Additionally, priority anadromous fish including chinook, chum, coho salmon and steelhead, as well as resident fish, including cutthroat and largemouth bass, reside within Rocky Creek to the west and in the unnamed tributary to Rocky Creek to the east of the property (Figure 4-2).

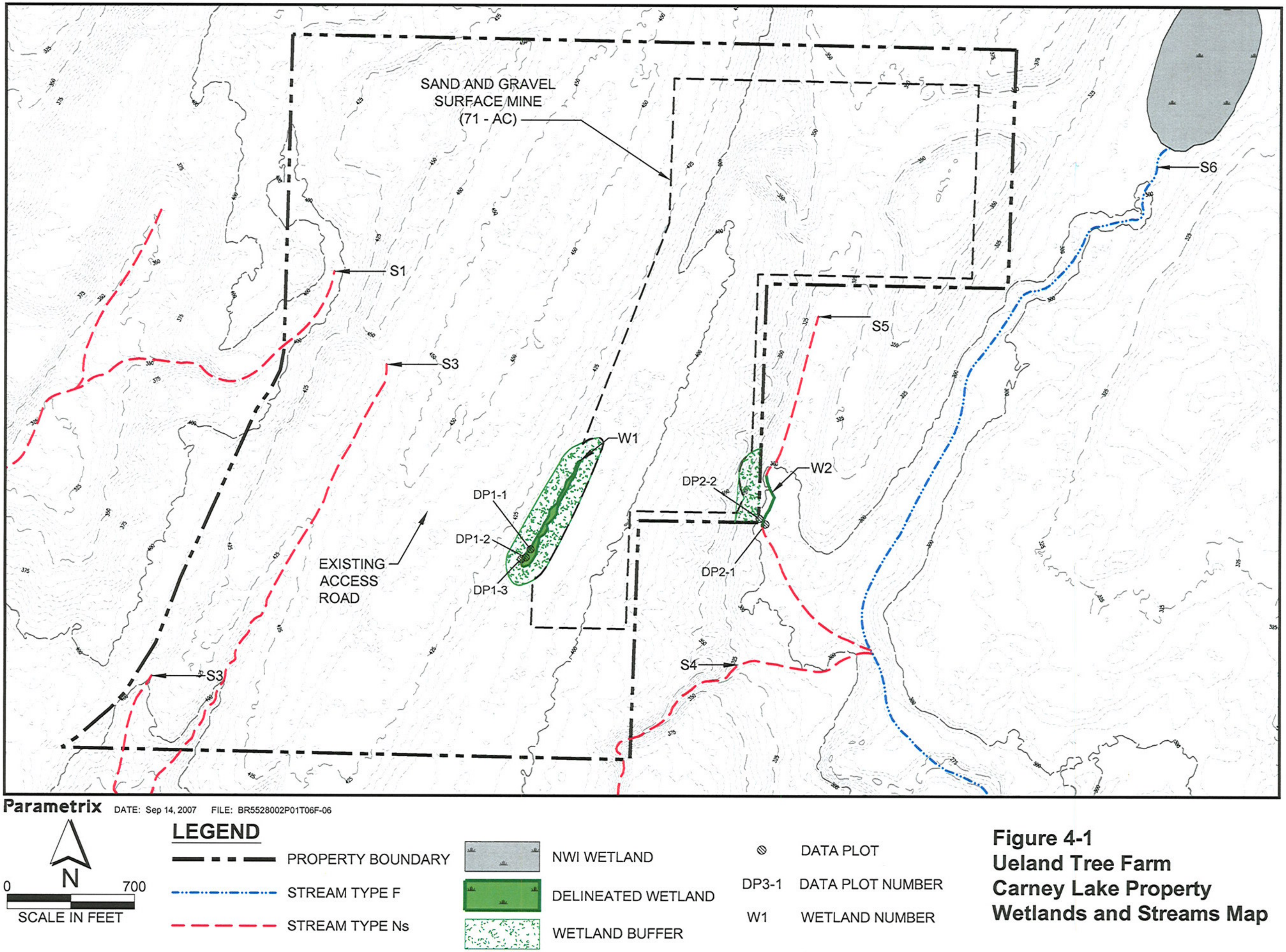
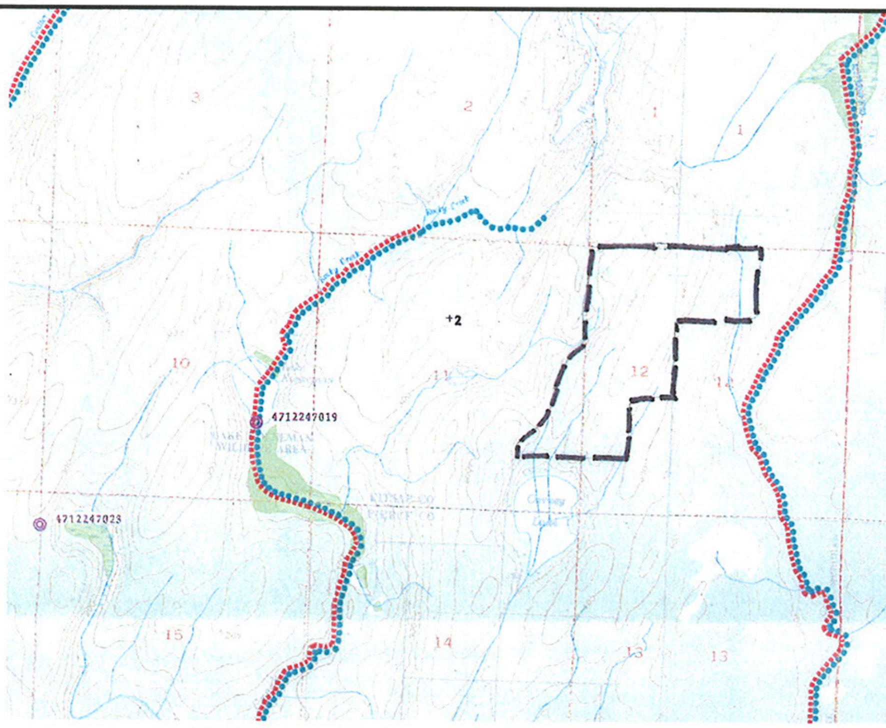


Figure 4-1
Ueland Tree Farm
Carney Lake Property
Wetlands and Streams Map



Washington Department Of Fish and Wildlife

HABITATS AND SPECIES MAP

IN THE VICINITY OF T22R01W SECTION 11

Coordinate System - State Plane South Zone 5626 (NAD27)
Production Date - November 28, 2006
Map Designed by WDFW Information Technology Services GIS

PLEASE NOTE

This map and the accompanying reports are not for general distribution. Washington State law (RCW 42.17.310) exempts Sensitive Fish and Wildlife information from public inspection and copying.

Washington Department of Fish and Wildlife (WDFW) considers sensitive species and habitat locations displayed on this map and accompanying reports to be confidential. WDFW is the exclusive owner of the Sensitive Fish and Wildlife Information and locations shall in all respects be treated as proprietary information in accordance with all procedures reasonably necessary to protect WDFW's proprietary rights therein.

This map may contain some species and habitats that are not considered priority. Accompanying this map are reports that provide information on displayed wildlife points and polygons. These reports do not include information for displayed spotted owls and marbled murrelet occurrences.

Some legend classes and symbols may not be present within the mapped area.

DISCLAIMER

This map and the accompanying reports only include information that the Washington Department of Fish and Wildlife (WDFW) maintains in a central computer database. It is not an attempt to provide you with an official agency response as to the impacts of your project on fish and wildlife. This information only documents the location of fish and wildlife resources to the best of our knowledge. It is not a complete inventory and it is important to note that fish and wildlife resources may occur in areas not currently known to WDFW biologists, or in areas for which comprehensive surveys have not been conducted. Site specific surveys are frequently necessary to rule out the presence of priority resources.

Locations of mapped wildlife and habitat features are generally within a quarter mile of the locations displayed on this map. Locations of fish and wildlife resources are subject to variation caused by disturbance, changes in season and weather, and other factors. WDFW does not recommend using maps more than six months old and information should not be used for future projects.

To insure appropriate use of this information, users are encouraged to consult with WDFW biologists.

MAIN DATA SOURCES

Priority Habitats and Species polygon, Habitat point, Klickitat County Oak Wildlife Heritage, Spotted Owls, Marbled Murrelet, Seal/Sea Lion Haulouts
1:24,000 streams and fish presence data : Wa. Dept. of Fish and Wildlife.
Wetlands data: US Fish and Wildlife Service, National Wetlands Inventory.
Seabird Colony data: US National Oceanic and Atmospheric Administration.
Kelp Bed, Oak Stand, Eelgrass, Turf Algae and Township/Section data: Wa. Dept. of Natural Resouces.
Columbia River Tidal Marsh data: Oregon State Service Center for Geographi Information Systems (1988).
7.5-minute quadrangle image from US Geological Survey.

MAP LEGEND

Priority Habitats/Species:

- Priority Habitats and Species (PHS) Polygon Borders
- Priority Wildlife Heritage Points
- Priority Habitat Points
- Marbled Murrelet Points (Occupancy Sites)
- Spotted Owl Site Centers (Official Status 1-3)
- Spotted Owl Site Centers (Official Status 4)
- Priority Anadromous Fish Presence
- Priority Resident Fish Presence
- National Wetlands Inventory

Other Habitats/Species:

- Other Wildlife Heritage Points
- Spotted Owl Management Circles Established Territory
- Spotted Owl Management Circles Insufficient Data To Establish Territory

Other Symbols:

- Rivers and Streams at 1:24,000 Scale Resolution
- Township Lines
- Section Lines

Washington Department of FISH and WILDLIFE

AREA LOCATION

Parametrix DATE: Sep 14, 2007 FILE: BR5528002P01T06F-03

N

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SCALE IN FEET

Figure 4-2
Ueland Tree Farm
Carney Lake Property
WDFW Priority Habitat & Species Map

5. SUMMARY AND CONCLUSIONS

The UTF property is a relatively undisturbed parcel of land located in an area of commercial forest and low-density residential development. No major streams run through the property; however, seasonal creeks and wetlands do exist within the property boundary. Due to the topography of the land, stormwater runoff will flow in a southerly direction either to the east or west of the ridgelines located on the property or into Carney Lake or a tributary of Rocky Creek where priority anadromous and resident fish exist.

The sand and gravel surface mine and the future residential development could have potential for both short and long term impacts if proper BMPs are not put in place. Potential impacts from the surface mine could occur during mineral extraction activities and would end once the resources have been removed and the site is reclaimed. Long-term impacts at the site will be mitigated through reclamation of the surface mine and revegetation with native plants. Residential development, however, may cause long-term effects by creating permanent alterations to the site primarily through the increase in impervious surfaces. Development of the property for future residential communities will remove existing habitat and contribute to habitat fragmentation. It is therefore important that both mining and residential developments are designed in a way to eliminate short term impacts to water quantity and wildlife habitat.

5.1 POTENTIAL LIMITING FACTORS

Limiting factors refer to conditions that lead to a loss or reduction of the environment's fish production potential, excluding harvest or exploitation. They include only those conditions presently considered alterable. Within the Rocky Creek watershed, the only major limiting factor identified is low summer flow (Haring 2000).

5.2 BEST MANAGEMENT PRACTICES

In planning and designing future development on the property, UTF intends to follow BMPs that reduce the amount of impact on the land, work with existing natural systems, and require a minimum of intervention and ongoing maintenance. Specific BMPs are summarized in the following sections and described in detail in Appendix A.

5.2.1 Surface Water Management

Development should utilize most recent surface water management techniques for the sand and gravel surface mine along with low impact development (LID) techniques for residential development, which should provide adequate protection for the Rocky Creek drainage system. Specific BMPs include those related to erosion control, pollution prevention, water quantity control, and water quality treatment. Detailed descriptions of these BMPs are provided in Appendix A.

5.2.2 Water Quality

Water quality BMPs will include conducting periodic surface water quality monitoring of the mining operation to evaluate performance of stormwater treatment BMPs, and adhering to all water quality standards. Additionally, the development should endeavor to provide enhanced treatment of surface water runoff through implementation of the BMPs shown in Appendix A.

5.2.3 Water Quantity

Water quality BMPs will include providing infiltration of stormwater for the surface mine development to reduce potential contribution to flooding near Carney Lake, and to provide aquifer recharge, thereby maintaining stream hydrology. The mine operation should also recycle water used for aggregate processing at the sand and gravel site.

5.2.4 Fish Habitat Recommendations

Fish habitat BMPs will include providing stormwater infiltration to maintain aquifer recharge and stream hydrology and prevent impacts to seasonal low stream flows. To reduce potential temperature impacts, maintain mature vegetation, including conifers where possible, in streams and wetland buffer areas.

5.2.5 Wildlife Recommendations

Wildlife BMPs should include maintaining and protecting designated critical areas and buffers, and revegetating reclaimed sand and gravel mine with native plant material.

Reclamation plans for the sand and gravel mine should provide wildlife habitat potential by ensuring variable topography, vegetation, and surface water features.

6. REFERENCES

Haring, Donald. 2000. Salmonid Habitat Limiting Factors. Water Resource Inventory Area 15 (East) Final Report. Washington State Conservation Commission.

Kitsap County Department of Community Development and Public Works. 2007. Kitsap County Comprehensive Plan. (http://www.mykitsap.org).

May, C.W. and G. Peterson. 2003. Kitsap Salmonid Refugia Report. Kitsap County.

Parametrix. 2007. Ueland Tree Farm Carney Lake Property Wetland Delineation Report. Prepared for Ueland Tree Farm, LLC. September.

APPENDIX A

Best Management Practices

3.3 Infiltration Facilities for Flow Control and for Treatment

3.3.1 Purpose

To provide infiltration capacity for stormwater runoff quantity and flow control, and for water quality treatment.

3.3.2 Description

An infiltration BMP is typically an open basin (pond), trench, or buried perforated pipe used for distributing the stormwater runoff into the underlying soil (See Figure 3.25). Stormwater dry-wells receiving uncontaminated or properly treated stormwater can also be considered as infiltration facilities. (See Underground Injection Control Program, Chapter 173-218 WAC).

Coarser more permeable soils can be used for quantity control provided that the stormwater discharge does not cause a violation of ground water quality criteria. Typically, treatment for removal of TSS, oil, and/or soluble pollutants is necessary prior to conveyance to an infiltration BMP.

Use of the soil for treatment purposes is also an option as long as it is preceded by a pre-settling basin or a basic treatment BMP. This section highlights design criteria that are applicable to infiltration facilities serving a treatment function.

3.3.3 Applications

Infiltration facilities for flow control are used to convey stormwater runoff from new development or redevelopment to the ground and ground water after appropriate treatment. Infiltration facilities for treatment purposes rely on the soil profile to provide treatment. In either case, runoff in excess of the infiltration capacity of the facilities must be managed to comply with the flow control requirement in Volume I, if flow control applies to the project.

Infiltration facilities can help accomplish the following:

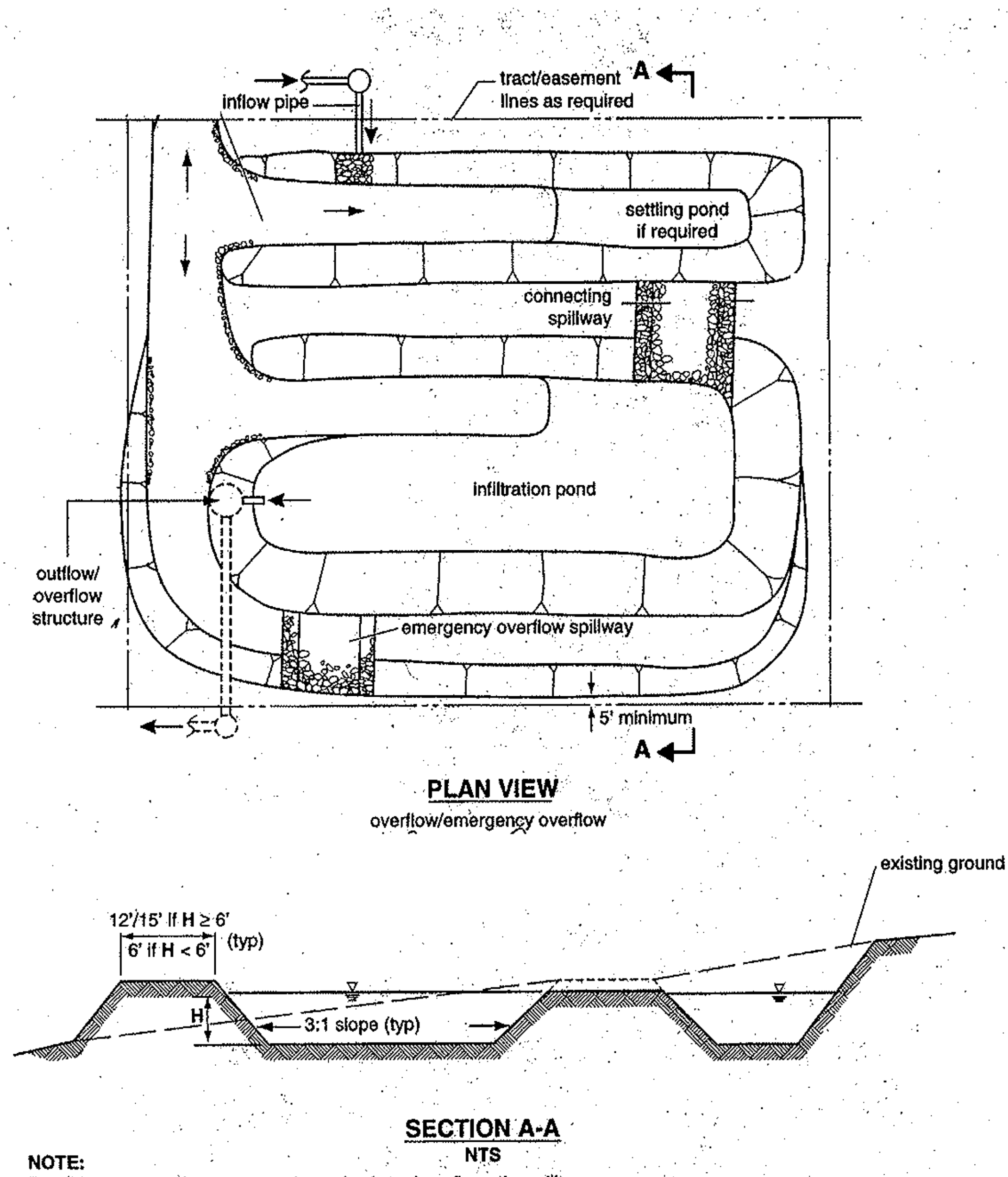
Ground water recharge

Discharge of uncontaminated or properly treated stormwater to dry-wells in compliance with Ecology's UIC regulations (Chapter 173-218 WAC)

Retrofits in limited land areas: Infiltration trenches can be considered for residential lots, commercial areas, parking lots, and open space areas.

Flood control

Streambank erosion control



NOTE:
Detail is a schematic representation only. Actual configuration will vary depending on specific site constraints and applicable design criteria.

Figure 3.25 Typical Infiltration Pond/Basin

3.3.9 General Design, Maintenance, and Construction Criteria for Infiltration Facilities

This section covers design, construction and maintenance criteria that apply to infiltration basins and trenches.

Design Criteria – Sizing Facilities

The size of the infiltration facility can be determined by routing the influent runoff file generated by the continuous runoff model through it. To prevent the onset of anaerobic conditions, an infiltration facility designed for treatment purposes must be designed to drain the 91st percentile, 24-hour runoff volume within 48 hours (see explanation under simplified or detailed design procedures. In general, an infiltration facility would have 2 discharge modes. The primary mode of discharge from an infiltration facility is infiltration into the ground. However, when the infiltration capacity of the facility is reached, additional runoff to the facility will cause the facility to overflow. Overflows from an infiltration facility must comply with the Minimum Requirement #7 for flow control in Volume I. Infiltration facilities used for runoff treatment must not overflow more than 9% of the influent runoff file.

In order to determine compliance with the flow control requirements, the Western Washington Hydrology Model (WWHM), or an appropriately calibrated continuous simulation model based on HSPF, must be used. When using WWHM for simulating flow through an infiltrating facility, the facility is represented by using the Pond Icon and entering the pre-determined infiltration rates. Below are the procedures for sizing a pond (A) to completely infiltrate 100% of runoff; (B) to treat 91% of runoff to meet the water quality treatment requirements, and (C) to partially infiltrate runoff to meet flow duration standard.

(A) For 100% infiltration

(1) Input dimensions of your infiltration pond,

(2) Input infiltration rate and safety (rate reduction) factor,

(3) Input a riser height and diameter (any flow through the riser indicates that you have less than 100% infiltration and must increase your infiltration pond dimensions).

(4) Run only HSPF for Developed Mitigated Scenario (if that is where you put the infiltration pond). Don't need to run duration.

(5) Go back to your infiltration pond and look at the Percentage Infiltrated at the bottom right. If less than 100% infiltrated, increase pond dimension until you get 100%.

(B) For 91% infiltration (water quality treatment volume)

The procedure is the same as above, except that your target is 91%.

Infiltration facilities for treatment can be located upstream or downstream of detention and can be off-line or on-line.

On-line treatment facilities placed ***upstream or downstream*** of a detention facility must be sized to infiltrate 91% of the runoff file volume directed to it.

Off-line treatment facilities placed ***upstream*** of a detention facility must have a flow splitter designed to send all flows at or below the 15-minute water quality flow rate, as predicted by WWHM (or other approved continuous runoff model), to the treatment facility. Within the WWHM, the flow splitter icon is placed ahead of the pond icon which represents the infiltration basin. The treatment facility must be sized to infiltrate all the runoff sent to it (no overflows from the treatment facility are allowed).

Off-line treatment facilities placed ***downstream*** of a detention facility must have a flow splitter designed to send all flows at or below the 2-year flow frequency from the detention pond, as predicted by WWHM (or other approved continuous runoff model), to the treatment facility. Within the WWHM, the flow splitter icon is placed ahead of the pond icon which represents the infiltration basin. The treatment facility must be sized to infiltrate all the runoff sent to it (no overflows from the treatment facility are allowed).

See Chapter 4 for flow splitter design details.

(C) To meet flow duration standard with infiltration ponds

This design will allow something less than 100% infiltration as long as any overflows will meet the flow duration standard. You would need a discharge structure with orifices and risers similar to a detention facility except that, in addition, you also have infiltration occurring from the pond.

Additional Design Criteria

- Slope of the base of the infiltration facility should be <3 percent.
- Spillways/overflow structures – A nonerodible outlet or spillway with a firmly established elevation must be constructed to discharge overflow. Ponding depth, drawdown time, and storage volume are calculated from that reference point. Overflow Structure-Refer to Chapter 2 for design details
- For infiltration treatment facilities, side-wall seepage is not a concern if seepage occurs through the same stratum as the bottom of the facility. However, for engineered soils or for soils with very low permeability, the potential to bypass the treatment soil through the side-walls may be significant. In those cases, the side-walls must be lined, either with an impervious liner or with at least 18 inches of

treatment soil, to prevent seepage of untreated flows through the side walls.

Construction Criteria

- Initial basin excavation should be conducted to within 1-foot of the final elevation of the basin floor. Excavate infiltration trenches and basins to final grade only after all disturbed areas in the upgradient project drainage area have been permanently stabilized. The final phase of excavation should remove all accumulation of silt in the infiltration facility before putting it in service. After construction is completed, prevent sediment from entering the infiltration facility by first conveying the runoff water through an appropriate pretreatment system such as a pre-settling basin, wet pond, or sand filter.
- Infiltration facilities should generally not be used as temporary sediment traps during construction. If an infiltration facility is to be used as a sediment trap, it must not be excavated to final grade until after the upgradient drainage area has been stabilized. Any accumulation of silt in the basin must be removed before putting it in service.
- Traffic Control – Relatively light-tracked equipment is recommended for this operation to avoid compaction of the basin floor. The use of draglines and trackhoes should be considered for constructing infiltration basins. The infiltration area should be flagged or marked to keep heavy equipment away.

Maintenance Criteria

Provision should be made for regular and perpetual maintenance of the infiltration basin/trench, including replacement and/or reconstruction of the any media that are relied upon for treatment purposes. Maintenance should be conducted when water remains in the basin or trench for more than 24 hours after the end of a rainfall event, or when overflows occur more frequently than planned. For example, off-line infiltration facilities should not have any overflows. Infiltration facilities designed to completely infiltrate all flows to meet flow control standards should not overflow. An Operation and Maintenance Plan, approved by the local jurisdiction, should ensure maintaining the desired infiltration rate.

Adequate access for operation and maintenance must be included in the design of infiltration basins and trenches.

Removal of accumulated debris/sediment in the basin/trench should be conducted every 6 months or as needed to prevent clogging, or when water remains in the pond for greater than 24 hours after the end of a rainfall event.

9.4 Best Management Practices

This Chapter presents the following Biofiltration Treatment BMPs:

BMP T9.10 – Basic Biofiltration Swale
BMP T9.20 - Wet Biofiltration Swale
BMP T9.30 – Continuous Inflow Biofiltration Swale
BMP T9.40 – Basic Filter Strip & Compost-Amended Filter Strip
BMP T9.50 – Narrow Area Filter Strip

BMP T9.10 Basic Biofiltration Swale

Description:

Biofiltration swales are typically shaped as a trapezoid or a parabola as shown in Figure 9.1.

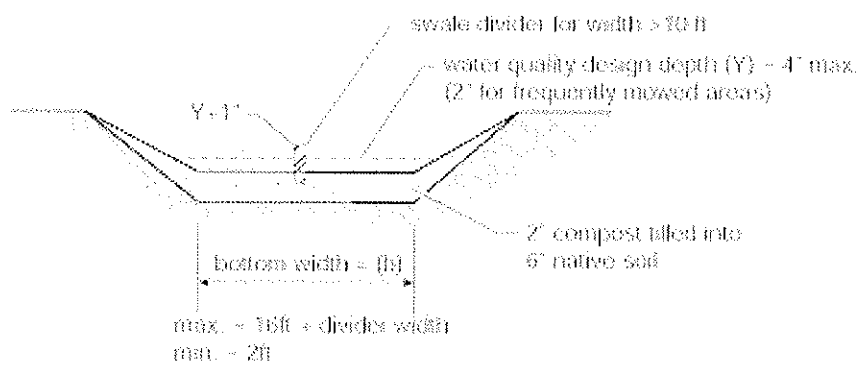


Figure 9.1 – Typical Swale Section

Limitations:

Data suggest that the performance of biofiltration swales is highly variable from storm to storm. It is therefore recommended that treatment methods providing more consistent performance, such as sand filters and wet ponds, be considered first. Swales downstream of devices of equal or greater effectiveness can convey runoff but should not be expected to offer a treatment benefit. (Horner, 2000)

Design Calculations for Biofiltration Swale

There are a number of ways of applying the design procedure introduced by Chow (Chow, 1959). These variations depend on the order in which steps are performed, what constants are established at the beginning of the process and which ones are calculated, and what values are assigned to the variables selected initially.

The procedure recommended here is an adaptation appropriate for biofiltration applications of the type being installed in the Puget Sound region. This procedure reverses Chow's order, designing first for capacity and then for stability. The capacity analysis emphasizes the promotion of biofiltration, rather than transporting flow with the greatest possible hydraulic efficiency. Therefore, it is based on criteria that promote sedimentation, filtration, and other pollutant removal mechanisms. Because these criteria include a lower maximum velocity than permitted for stability, the biofilter dimensions usually do not have to be modified after a stability check.

Design Steps (D):

D-1. Select the type of vegetation, and design depth of flow (based on frequency of mowing and type of vegetation). (Table 9.1)

D-2. Select a value of Manning's n (Table 9.1 with footnote #3).

Table 9.1 – Sizing Criteria

Design parameter	BMP T 9.10-Biofiltration swale	BMP T 9.40-Filter strip
Longitudinal Slope	0.015 - 0.025[1]	0.01 - 0.15
Maximum velocity	1 ft / sec (@ K multiplied by the WQ design flow rate ; for stability, 3 ft/sec max.	0.5 ft / sec
Maximum water depth[2]	2"- if mowed frequently; 4" if mowed infrequently	1-inch max.
Manning coefficient (22)	(0.2 – 0.3)[3](0.24 if mowed infrequently)	0.35 (0.45 if compost-amended, and mowed to maintain grass height ≤ 4")
Bed width (bottom)	(2 - 10 ft)[4]	---
Freeboard height	0.5 ft	---
Minimum hydraulic residence time at Water Quality Design Flow Rate	9 minutes (18 minutes for continuous inflow) (See Volume I, Appendix B)	9 minutes
Minimum length	100 ft	Sufficient to achieve hydraulic residence time in the filter strip
Maximum sideslope	3 H : 1 V 4H:1V preferred	Inlet edge ≥ 1" lower than contributing paved area
Max. tributary drainage flowpath	---	150 feet
Max. longitudinal slope of contributing area	---	0.05 (steeper than 0.05 need upslope flow spreading and energy dissipation)
Max. lateral slope of contributing area	---	0.02 (at the edge of the strip inlet)

1. For swales, if the slope is less than 1.5% install an underdrain using a perforated pipe, or equivalent. Amend the soil if necessary to allow effective percolation of water to the underdrain. Install the low-flow drain 6" deep in the soil. Slopes greater than 2.5% need check dams (riprap) at vertical drops of 12-15 inches. Underdrains can be made of 6 inch Schedule 40 PVC perforated pipe with 6" of drain gravel on the pipe. The gravel and pipe must be enclosed by geotextile fabric. (See Figures 9.2 and 9.3)

2 Below the design water depth install an erosion control blanket, at least 4" of topsoil, and the selected biofiltration mix. Above the water line use a straw mulch or sod.

3. This range of Manning's n can be used in the equation; b = Qn/1.49y(1.67) s(0.5) – Zy with wider bottom width b, and lower depth, y, at the same flow. This provides the designer with the option of varying the bottom width of the swale depending on space limitations. Designing at the higher n within this range at the same flow decreases the hydraulic design depth, thus placing the pollutants in closer contact with the vegetation and the soil.

4. For swale widths up to 16 feet the cross-section can be divided with a berm (concrete, plastic, compacted earthfill) using a flow spreader at the inlet (Figure 9.4)

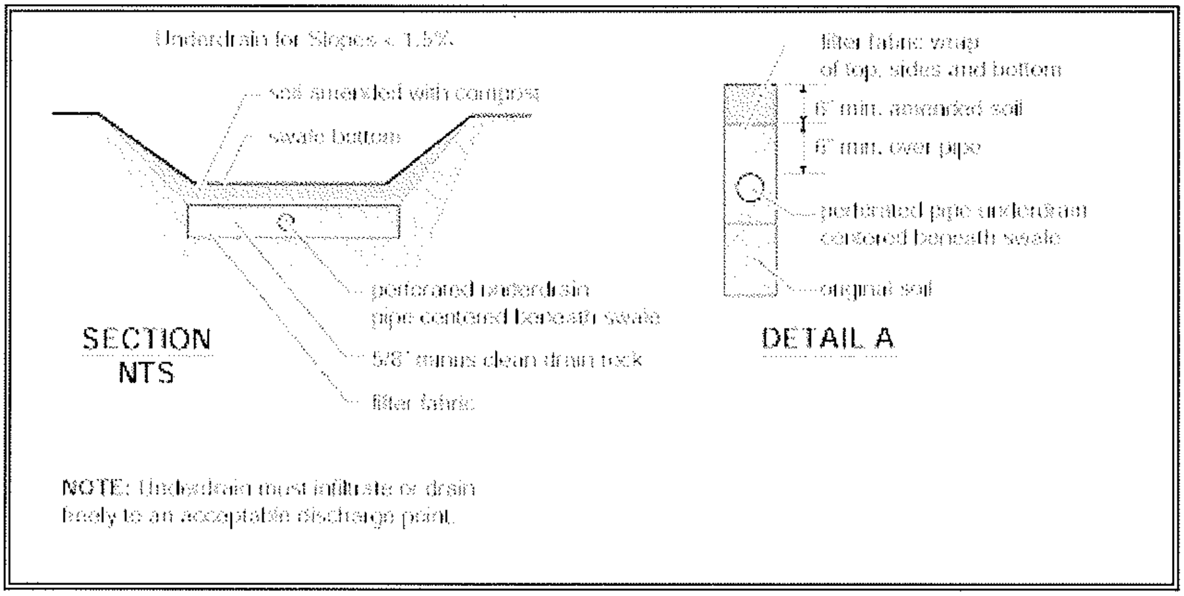


Figure 9.2 – Biofiltration Swale Underdrain Detail

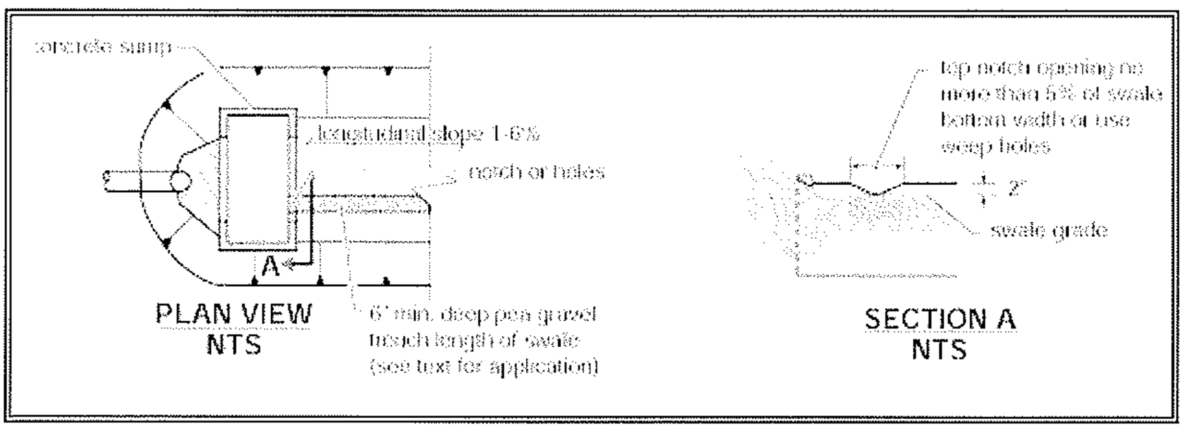


Figure 9.3 – Biofiltration Swale Low-Flow Drain Detail

- Stabilize soil areas upslope of the biofilter to prevent erosion
- Fertilizing a biofilter should be avoided if at all possible in any application where nutrient control is an objective. Test the soil for nitrogen, phosphorous, and potassium and consult with a landscape professional about the need for fertilizer in relation to soil nutrition and vegetation requirements. If use of a fertilizer cannot be avoided, use a slow-release fertilizer formulation in the least amount needed.

Recommended grasses (see Tables 9.3 and 9.4 below)

Table 9.3 – Grass Seed Mixes Suitable for Biofiltration Swale Treatment Areas

Mix 1		Mix 2	
75-80 percent	tall or meadow fescue	60-70 percent	tall fescue
10-15 percent	seaside/colonial bentgrass	10-15 percent	seaside/colonial bentgrass
5-10 percent	Redtop	10-15 percent	meadow foxtail
		6-10 percent	alsike clover
		1-5 percent	marshfield big trefoil
		1-6 percent	Redtop

Note: *all percentages are by weight. * based on Briargreen, Inc.*

Table 9.4 – Groundcovers And Grasses Suitable for the Upper Side Slopes of a Biofiltration Swale in Western Washington

Groundcovers	
kinnikinnick*	*Arctostaphylos uva-ursi*
St. John's-wort	*Hypericum perforatum*
Epimedium	*Epimedium grandiflorum*
creeping forget-me-not	*Omphalodes verna*
--	*Euonymus lanceolata*
yellow-root	*Xanthorhiza simplissima*
--	*Genista*
white lawn clover	*Trifolium repens*
white sweet clover*	*Melilotus alba*
-------	*Rubus calycinoides*
strawberry*	*Fragaria chiloensis*
broadleaf lupine*	*Lupinus latifolius*
Grasses (drought-tolerant, minimum mowing)	
dwarf tall fescues	*Festuca* spp. (e.g., Many Mustang, Silverado)
hard fescue	*Festuca ovina duriuscula* (e.g., Reliant, Aurora)
tufted fescue	*Festuca amethystine*
buffalo grass	*Buchloe dactyloides*
red fescue*	*Festuca rubra*
tall fescue grass*	*Festuca arundinacea*
blue oatgrass	*Helictotrichon sempervirens*

Construction Criteria

The biofiltration swale should not be put into operation until areas of exposed soil in the contributing drainage catchment have been sufficiently stabilized. Deposition of eroded soils can impede the growth of grass in the swale and reduce swale treatment effectiveness. Thus, effective erosion and sediment control measures should remain in place until the swale vegetation is established (see Volume II for erosion and sediment control BMPs). Avoid compaction during construction. Grade biofilters to attain uniform longitudinal and lateral slopes

Maintenance Criteria

- Inspect biofilters at least once every 6 months, preferably during storm events, and also after storm events of > 0.5 inch rainfall/ 24 hours. Maintain adequate grass growth and eliminate bare spots.
- Mow grasses, if needed for good growth {typically maintain at 4 – 9 inches and not below design flow level (King County, 1998)}.
- Remove sediment as needed at head of the swale if grass growth is inhibited in greater than 10 percent of the swale, or if the sediment is blocking the distribution and entry of the water (King County, 1998).
- Remove leaves, litter, and oily materials, and re-seed or resod, and regrade, as needed. Clean curb cuts and level spreaders as needed.

Prevent scouring and soil erosion in the biofilter. If flow channeling occurs, regrade and reseed the biofilter, as necessary.

Maintain access to biofilter inlet, outlet, and to mowing (Figure 9.8)

- If a swale is equipped with underdrains, vehicular traffic on the swale bottom (other than grass mowing equipment) should be avoided to prevent damage to the drainpipes.

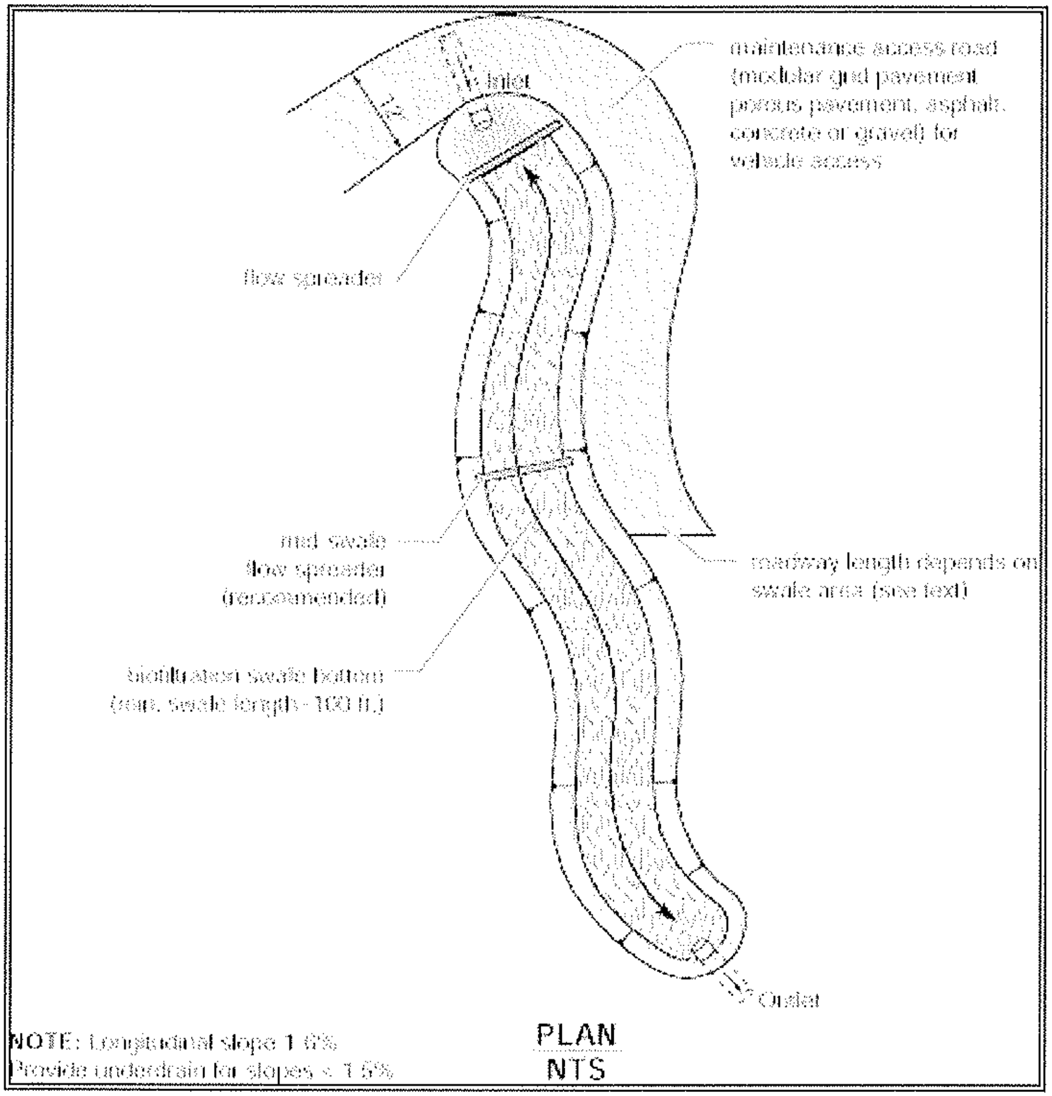


Figure 9.8 – Biofiltration Swale Access Features

BMPs for Dust Control at Disturbed Land Areas and Unpaved Roadways and Parking Lots

Description of Pollutant Sources: Dust can cause air and water pollution problems particularly at demolition sites and in arid areas where reduced rainfall exposes soil particles to transport by air.

Pollutant Control Approach: Minimize dust generation and apply environmentally friendly and government approved dust suppressant chemicals, if necessary.

Applicable Operational BMPs:

- Sprinkle or wet down soil or dust with water as long as it does not result in a wastewater discharge.
- Use only local and/or state government approved dust suppressant chemicals such as those listed in Ecology Publication #96-433, "Techniques for Dust Prevention and Suppression."
- Avoid excessive and repeated applications of dust suppressant chemicals. Time the application of dust suppressants to avoid or minimize their wash-off by rainfall or human activity such as irrigation.
- Apply stormwater containment to prevent the conveyance of stormwater TSS into storm drains or receiving waters.
- The use of motor oil for dust control is prohibited. Care should be taken when using lignin derivatives and other high BOD chemicals in excavations or areas easily accessible to surface water or ground water.
- Consult with the Ecology Regional Office in your area on discharge permit requirements if the dust suppression process results in a wastewater discharge to the ground, ground water, storm drain, or surface water.

Recommended Additional Operational BMPs for Roadways and Other Trafficked Areas:

- Consider limiting use of off-road recreational vehicles on dust generating land.
- Consider paving unpaved permanent roads and other trafficked areas at municipal, commercial, and industrial areas.
- Consider paving or stabilizing shoulders of paved roads with gravel, vegetation, or local government approved chemicals.
- Encourage use of alternate paved routes, if available.
- Vacuum or wet sweep fine dirt and skid control materials from paved roads soon after winter weather ends or when needed.
- Consider using traction sand that is pre-washed to reduce dust emissions.

Additional Recommended Operational BMPs for Dust Generating Areas:

- Prepare a dust control plan. Helpful references include: Control of Open Fugitive Dust Sources (EPA-450/3-88-088), and Fugitive Dust Background Document and Technical Information Document for Best Available Control Measures (EPA-450/2-92-004)
- Limit exposure of soil (dust source) as much as feasible.
- Stabilize dust-generating soil by growing and maintaining vegetation, mulching, topsoiling, and/or applying stone, sand, or gravel.
- Apply windbreaks in the soil such as trees, board fences, tarp curtains, bales of hay, etc.
- Cover dust-generating piles with wind-impervious fabric, or equivalent material.

BMPs for Loading and Unloading Areas for Liquid or Solid Material

Description of Pollutant Sources: Loading/unloading of liquid and solid materials at industrial and commercial facilities are typically conducted at shipping and receiving, outside storage, fueling areas, etc. Materials transferred can include products, raw materials, intermediate products, waste materials, fuels, scrap metals, etc. Leaks and spills of fuels, oils, powders, organics, heavy metals, salts, acids, alkalis, etc. during transfer are potential causes of stormwater contamination. Spills from hydraulic line breaks are a common problem at loading docks.

Pollutant Control Approach: Cover and contain the loading/ unloading area where necessary to prevent run-on of stormwater and runoff of contaminated stormwater.

Applicable Operational BMPs:

At All Loading/ Unloading Areas:

- *A* significant amount of debris can accumulate at outside, uncovered loading/unloading areas. Sweep these surfaces frequently to remove material that could otherwise be washed off by stormwater. Sweep outside areas that are covered for a period of time by containers, logs, or other material after the areas are cleared.
- Place drip pans, or other appropriate temporary containment device, at locations where leaks or spills may occur such as hose connections, hose reels and filler nozzles. Drip pans shall always be used when making and breaking connections (see Figure 2.2). Check loading/ unloading equipment such as valves, pumps, flanges, and connections regularly for leaks and repair as needed.

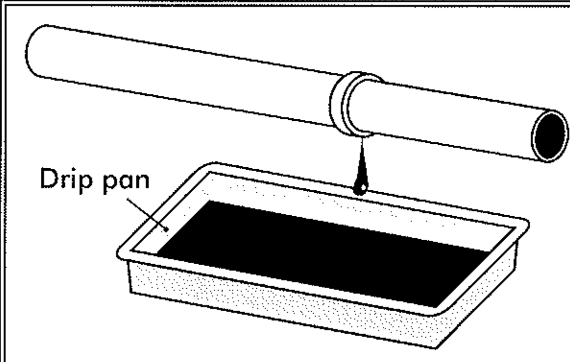


Figure 2.2 – Drip Pan

At Tanker Truck and Rail Transfer Areas to Above/Below-ground Storage Tanks:

- To minimize the risk of accidental spillage, prepare an "Operations Plan" that describes procedures for loading/unloading. Train the employees, especially fork lift operators, in its execution and post it or otherwise have it readily available to employees.
- Report spills of reportable quantities to Ecology (refer to Section 2.1 for telephone numbers of Ecology Regional Offices).
- Prepare and implement an Emergency Spill Cleanup Plan for the facility (BMP Spills of Oil and Hazardous Substances) which includes the following BMPs:
  - Ensure the clean up of liquid/solid spills in the loading/ unloading area immediately, if a significant spill occurs, and, upon completion of the loading/unloading activity, or, at the end of the working day.
  - Retain and maintain an appropriate oil spill cleanup kit on-site for rapid cleanup of material spills. (See BMP Spills of Oil and Hazardous Substances).
  - Ensure that an employee trained in spill containment and cleanup is present during loading/unloading.

At Rail Transfer Areas to Above/below-ground Storage Tanks: *Install* a drip pan system as illustrated (see Figure 2.3) within the rails to collect spills/leaks from tank cars and hose connections, hose reels, and filler nozzles.

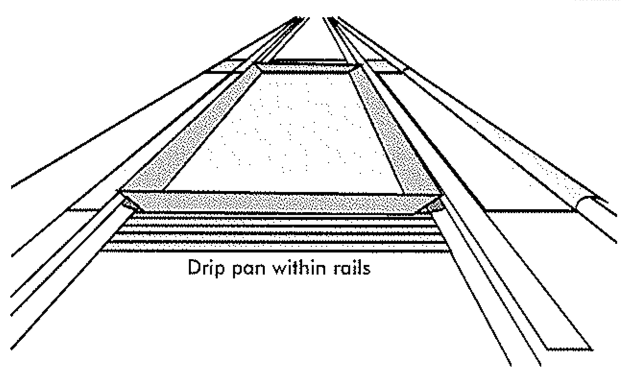


Figure 2.3 – Drip Pan Within Rails

Loading/Unloading from/to Marine Vessels: Facilities and procedures for the loading or unloading of petroleum products must comply with Coast Guard requirements specified in Appendix IV-D R.5.

Transfer of Small Quantities from Tanks and Containers: Refer to BMPs Storage of Liquids in Permanent Above-Ground Tanks, and Storage of Liquid, Food Waste, or Dangerous Waste Containers, for requirements on the transfer of small quantities from tanks and containers, respectively.

Applicable Structural Source Control BMPs:

At All Loading/ Unloading Areas:

- Consistent with Uniform Fire Code requirements (Appendix IV-D R.2) and to the extent practicable, conduct unloading or loading of solids and liquids in a manufacturing building, under a roof, or lean-to, or other appropriate cover.
- Berm, dike, and/or slope the loading/unloading area to prevent run-on of stormwater and to prevent the runoff or loss of any spilled material from the area.
- Large loading areas frequently are not curbed along the shoreline. As a result, stormwater passes directly off the paved surface into surface water. Place curbs along the edge, or slope the edge such that the stormwater can flow to an internal storm drain system that leads to an approved treatment BMP.
- Pave and slope loading/unloading areas to prevent the pooling of water. The use of catch basins and drain lines within the interior of the paved area must be minimized as they will frequently be covered by material, or they should be placed in designated "alleyways" that are not covered by material, containers or equipment.

Recommended Structural Source Control BMP: For the transfer of pollutant liquids in areas that cannot contain a catastrophic spill, install an automatic shutoff system in case of unanticipated off-loading interruption (e.g. coupling break, hose rupture, overfill, etc.).

At Loading and Unloading Docks:

- Install/maintain overhangs, or door skirts that enclose the trailer end (see Figures 2.4 and 2.5) to prevent contact with rainwater.
- Design the loading/unloading area with berms, sloping, etc. to prevent the run-on of stormwater.
- Retain on-site the necessary materials for rapid cleanup of spills.

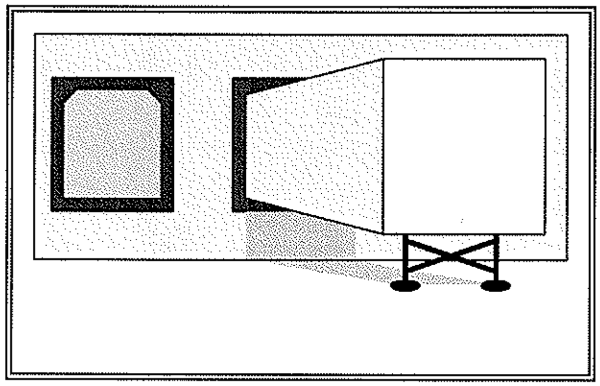


Figure 2.4 – Loading Dock with Door Skirt

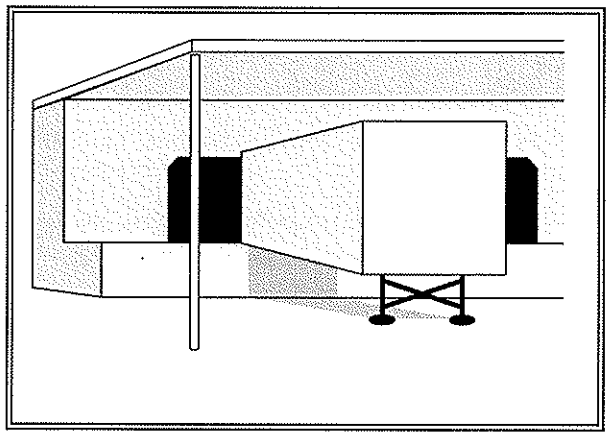


Figure 2.5 – Loading Dock with Overhang

At Tanker Truck Transfer Areas to Above/Below-Ground Storage Tanks:

- Pave the area on which the transfer takes place. If any transferred liquid, such as gasoline, is reactive with asphalt pave the area with Portland cement concrete.
- Slope, berm, or dike the transfer area to a dead-end sump, spill containment sump, a spill control (SC) oil/water separator, or other spill control device. The minimum spill retention time should be 15 minutes at the greater flow rate of the highest fuel dispenser nozzle through-put rate, or the peak flow rate of the 6-month, 24-hour storm event over the surface of the containment pad, whichever is greater. The volume of the spill containment sump should be a minimum of 50 gallons with an adequate grit sedimentation volume.

BMPs for Maintenance and Repair of Vehicles and Equipment

Description of Pollutant Sources: Pollutant sources include parts/vehicle cleaning, spills/leaks of fuel and other liquids, replacement of liquids, outdoor storage of batteries/liquids/parts, and vehicle parking.

Pollutant Control Approach: Control of leaks and spills of fluids using good housekeeping and cover and containment BMPs.

Applicable Operational BMPs:

- Inspect for leaks all incoming vehicles, parts, and equipment stored temporarily outside.
- Use drip pans or containers under parts or vehicles that drip or that are likely to drip liquids, such as during dismantling of liquid containing parts or removal or transfer of liquids.
- Remove batteries and liquids from vehicles and equipment in designated areas designed to prevent stormwater contamination. Store cracked batteries in a covered non-leaking secondary containment system.
- Empty oil and fuel filters before disposal. Provide for proper disposal of waste oil and fuel.
- Do not pour/convey washwater, liquid waste, or other pollutant into storm drains or to surface water. Check with the local sanitary sewer authority for approval to convey to a sanitary sewer.
- Do not connect maintenance and repair shop floor drains to storm drains or to surface water. To allow for snowmelt during the winter a drainage trench with a sump for particulate collection can be installed and used only for draining the snowmelt and not for discharging any vehicular or shop pollutants.

Applicable Structural Source Control BMPs:

- Conduct all maintenance and repair of vehicles and equipment in a building, or other covered impervious containment area that is sloped to prevent run-on of uncontaminated stormwater and runoff of contaminated stormwater.
- The maintenance of refrigeration engines in refrigerated trailers may be conducted in the parking area with due caution to avoid the release of engine or refrigeration fluids to storm drains or surface water.
- Park large mobile equipment, such as log stackers, in a designated contained area.

For additional applicable BMPs refer to the following BMPs: Fueling at Dedicated Stations; Washing and Steam Cleaning Vehicle/Equipment/Building Structures; Loading and Unloading Areas for Liquid or Solid Material; Storage of Liquids in Permanent Above-Ground Tanks; Storage of Liquid, Food Waste, or Dangerous Waste Containers;

Storage or Transfer (Outside) of Solid Raw Materials, By-Products, or Finished Products; Spills of Oil and Hazardous Substances; Illicit Connections to Storm Drains; and other BMPs provided in this chapter.

Note that a treatment BMP is applicable for contaminated stormwater.

Applicable Treatment BMPs: Contaminated stormwater runoff from vehicle staging and maintenance areas must be conveyed to a sanitary sewer, if allowed by the local sewer authority, or to an API or CP oil and water separator followed by a basic treatment BMP (See Volume V), applicable filter, or other equivalent oil treatment system.

Recommended Additional Operational BMPs:

- Consider storing damaged vehicles inside a building or other covered containment, until all liquids are removed. Remove liquids from vehicles retired for scrap.
- Clean parts with aqueous detergent based solutions or non-chlorinated solvents such as kerosene or high flash mineral spirits, and/or use wire brushing or sand blasting whenever practicable. Avoid using toxic liquid cleaners such as methylene chloride, 1,1,1-trichloroethane, trichloroethylene or similar chlorinated solvents. Choose cleaning agents that can be recycled.
- Inspect all BMPs regularly, particularly after a significant storm. Identify and correct deficiencies to ensure that the BMPs are functioning as intended.
- Avoid hosing down work areas. Use dry methods for cleaning leaked fluids.
- Recycle greases, used oil, oil filters, antifreeze, cleaning solutions, automotive batteries, hydraulic fluids, transmission fluids, and engine oils (see Appendix IV-C).
- Do not mix dissimilar or incompatible waste liquids stored for recycling.

BMPs for Maintenance of Roadside Ditches

Description of Pollutant Sources: Common road debris including eroded soil, oils, vegetative particles, and heavy metals can be sources of stormwater pollutants.

Pollutant Control Approach: Roadside ditches should be maintained to preserve the condition and capacity for which they were originally constructed, and to minimize bare or thinly vegetated ground surfaces. Maintenance practices should provide for erosion and sediment control (Refer to BMP Landscaping and Lawn/Vegetation Management).

Applicable Operational BMPs:

- Inspect roadside ditches regularly, as needed, to identify sediment accumulations and localized erosion.
- Clean ditches on a regular basis, as needed. Ditches should be kept free of rubbish and debris.
- Vegetation in ditches often prevents erosion and cleanses runoff waters. Remove vegetation only when flow is blocked or excess sediments have accumulated. Conduct ditch maintenance (seeding, fertilizer application, harvesting) in late spring and/or early fall, where possible. This allows vegetative cover to be re-established by the next wet season thereby minimizing erosion of the ditch as well as making the ditch effective as a biofilter.
- In the area between the edge of the pavement and the bottom of the ditch, commonly known as the "bare earth zone," use grass vegetation, wherever possible. Vegetation should be established from the edge of the pavement if possible, or at least from the top of the slope of the ditch.
- Diversion ditches on top of cut slopes that are constructed to prevent slope erosion by intercepting surface drainage must be maintained to retain their diversion shape and capability.
- Ditch cleanings are not to be left on the roadway surfaces. Sweep dirt and debris remaining on the pavement at the completion of ditch cleaning operations.
- Roadside ditch cleanings, not contaminated by spills or other releases and not associated with a stormwater treatment system such as a bioswale, may be screened to remove litter and separated into soil and vegetative matter (leaves, grass, needles, branches, etc.). The soil fraction may be handled as 'clean soils' and the vegetative matter can be composted or disposed of in a municipal waste landfill. For more information, please see "Recommendations for Management of Street Wastes," in Appendix IV-G of this volume.
- Roadside ditch cleanings contaminated by spills or other releases known or suspected to contain dangerous waste must be handled

following the Dangerous Waste Regulations (Chapter 173-303 WAC) unless testing determines it is not dangerous waste.

- Examine culverts on a regular basis for scour or sedimentation at the inlet and outlet, and repair as necessary. Give priority to those culverts conveying perennial and/or salmon-bearing streams and culverts near streams in areas of high sediment load, such as those near subdivisions during construction.

Recommended Treatment BMPs:

Install biofiltration swales and filter strips –See Chapter 9, Volume V) to treat roadside runoff wherever practicable and use engineered topsoils wherever necessary to maintain adequate vegetation (CH2M Hill, 2000). These systems can improve infiltration and stormwater pollutant control upstream of roadside ditches.

BMPs for Maintenance of Stormwater Drainage and Treatment Systems

Description of Pollutant Sources: Facilities include roadside catch basins on arterials and within residential areas, conveyance systems, detention facilities such as ponds and vaults, oil and water separators, biofilters, settling basins, infiltration systems, and all other types of stormwater treatment systems presented in Volume V. Roadside catch basins can remove from 5 to 15 percent of the pollutants present in stormwater. When catch basins are about 60 percent full of sediment, they cease removing sediments. Oil and grease, hydrocarbons, debris, heavy metals, sediments and contaminated water are found in catch basins, oil and water separators, settling basins, etc.

Pollutant Control Approach: Provide maintenance and cleaning of debris, sediments, and oil from stormwater collection, conveyance, and treatment systems to obtain proper operation.

Applicable Operational BMPs:

Maintain stormwater treatment facilities according to the O & M procedures presented in Section 4.6 of Volume V in addition to the following BMPs:

- Inspect and clean treatment BMPs, conveyance systems, and catch basins as needed, and determine whether improvements in O & M are needed.
- Promptly repair any deterioration threatening the structural integrity of the facilities. These include replacement of clean-out gates, catch basin lids, and rock in emergency spillways.
- Ensure that storm sewer capacities are not exceeded and that heavy sediment discharges to the sewer system are prevented.
- Regularly remove debris and sludge from BMPs used for peak-rate control, treatment, etc. and discharge to a sanitary sewer if approved by the sewer authority, or truck to a local or state government approved disposal site.
- Clean catch basins when the depth of deposits reaches 60 percent of the sump depth as measured from the bottom of basin to the invert of the lowest pipe into or out of the basin. However, in no case should there be less than six inches clearance from the debris surface to the invert of the lowest pipe. Some catch basins (for example, WSDOT Type 1L basins) may have as little as 12 inches sediment storage below the invert. These catch basins will need more frequent inspection and cleaning to prevent scouring. Where these catch basins are part of a stormwater collection and treatment system, the system owner/operator may choose to concentrate maintenance efforts on downstream control devices as part of a systems approach.

- Clean woody debris in a catch basin as frequently as needed to ensure proper operation of the catchbasin.
- Post warning signs; "Dump No Waste - Drains to Ground Water," "Streams," "Lakes," or emboss on or adjacent to all storm drain inlets *where practical.*
- Disposal of sediments and liquids from the catch basins must comply with "Recommendations for Management of Street Wastes" described in Appendix IV-G of this volume.

Additional Applicable BMPs: Select additional applicable BMPs from this chapter depending on the pollutant sources and activities conducted at the facility. Those BMPs include:

- BMPs for Soil Erosion and Sediment Control at Industrial Sites
- BMPs for Storage of Liquid, Food Waste, or Dangerous Waste Containers
- BMPs for Spills of Oil and Hazardous Substances
- BMPs for Illicit Connections to Storm Drains
- BMPs for Urban Streets.

BMPs for Parking and Storage of Vehicles and Equipment

Description of Pollutant Sources: Public and commercial parking lots such as retail store, fleet vehicle (including rent-a-car lots and car dealerships), equipment sale and rental parking lots, and parking lot driveways, can be sources of toxic hydrocarbons and other organic compounds, oils and greases, metals, and suspended solids caused by the parked vehicles.

Pollutant Control Approach: If the parking lot is a **high-use site** as defined below, provide appropriate oil removal equipment for the contaminated stormwater runoff.

Applicable Operational BMPs:

- If washing of a parking lot is conducted, discharge the washwater to a sanitary sewer, if allowed by the local sewer authority, or other approved wastewater treatment system, or collect it for off-site disposal.
- Do not hose down the area to a storm drain or to a receiving water. Sweep parking lots, storage areas, and driveways, regularly to collect dirt, waste, and debris.

Applicable Treatment BMPs: An oil removal system such as an API or CP oil and water separator, catch basin filter, or equivalent BMP, approved by the local jurisdiction, is applicable for parking lots meeting the threshold vehicle traffic intensity level of a *high-use site.*

Vehicle High-Use Sites

Establishments subject to a vehicle high-use intensity have been determined to be significant sources of oil contamination of stormwater. Examples of potential high use areas include customer parking lots at fast food stores, grocery stores, taverns, restaurants, large shopping malls, discount warehouse stores, quick-lube shops, and banks. If the PGIS for a high-use site exceeds 5,000 square feet in a threshold discharge area, and oil control BMP from the Oil Control Menu is necessary. A high-use site at a commercial or industrial establishment has one of the following characteristics: (Gaus/King County, 1994)

- Is subject to an expected average daily vehicle traffic (ADT) count equal to or greater than 100 vehicles per 1,000 square feet of gross building area: or
- Is subject to storage of a fleet of 25 or more diesel vehicles that are over 10 tons gross weight (trucks, buses, trains, heavy equipment, etc.).

BMPs for Soil Erosion and Sediment Control at Industrial Sites

Description of Pollutant Sources: Industrial activities on soil areas; exposed and disturbed soils; steep grading; etc. can be sources of sediments that can contaminate stormwater runoff.

Pollutant Control Approach: Limit the exposure of erodible soil, stabilize or cover erodible soil where necessary to prevent erosion, and/or provide treatment for stormwater contaminated with TSS caused by eroded soil.

Applicable BMPs:

Cover Practice Options:

- Vegetative cover such as grass, trees, shrubs, on erodible soil areas; or,
- Covering with mats such as clear plastic, jute, synthetic fiber; and/or,
- Preservation of natural vegetation including grass, trees, shrubs, and vines,

Structural Practice Options:

Vegetated swale, dike, silt fence, check dam, gravel filter berm, sedimentation basin, and proper grading. (For design information refer to Volume II, "Standards and Specifications for BMPs").

BMPs for Spills of Oil and Hazardous Substances

Description of Pollutant Sources: Owners or operators of facilities engaged in drilling, producing, gathering, storing, processing, transferring, distributing, refining or consuming oil and/or oil products are required by Federal Law to have a Spill Prevention and Control Plan if the storage capacity of the facility, which is not buried, is 1,320 gallons or more of oil, or any single container with a capacity in excess of 660 gallons and which, due to their location, could reasonably be expected to discharge oil in harmful quantities, as defined in 40 CFR Part 110, into or upon the navigable waters of the United States or adjoining shorelines {40 CFR 112.1 (b)}. Onshore and offshore facilities, which, due to their location, could not reasonably be expected to discharge oil into or upon the navigable waters of the United States or adjoining shorelines are exempt from these regulations {40 CFR 112.1(1)(i)}. Owners of businesses that produce Dangerous Wastes are also required by State Law to have a spill control plan. These businesses should refer to Appendix IV-D R.6. The federal definition of oil is oil of any kind or any form, including, but not limited to petroleum, fuel oil, sludge, oil refuse, and oil mixed with wastes other than dredged spoil.

Pollutant Control Approach: Maintain, update, and implement an oil spill prevention/cleanup plan.

Applicable Operational BMPs: The businesses and public agencies identified in Appendix IV-A that are required to prepare and implement an Emergency Spill Cleanup Plan shall implement the following:

- Prepare an Emergency Spill Control Plan (SCP), which includes:
  - A description of the facility including the owner's name and address;
  - The nature of the activity at the facility;
  - The general types of chemicals used or stored at the facility;
  - A site plan showing the location of storage areas for chemicals, the locations of storm drains, the areas draining to them, and the location and description of any devices to stop spills from leaving the site such as positive control valves;
  - Cleanup procedures;
  - Notification procedures to be used in the event of a spill, such as notifying key personnel. Agencies such as Ecology, local fire department, Washington State Patrol, and the local Sewer Authority, shall be notified;
  - The name of the designated person with overall spill cleanup and notification responsibility;

- Train key personnel in the implementation of the Emergency SCP. Prepare a summary of the plan and post it at appropriate points in the building, identifying the spill cleanup coordinators, location of cleanup kits, and phone numbers of regulatory agencies to be contacted in the event of a spill;
- Update the SCP regularly;
- Immediately notify Ecology and the local Sewer Authority if a spill may reach sanitary or storm sewers, ground water, or surface water, in accordance with federal and Ecology spill reporting requirements;
- Immediately clean up spills. Do not use emulsifiers for cleanup unless an appropriate disposal method for the resulting oily wastewater is implemented. Absorbent material shall not be washed down a floor drain or storm sewer; and,
- Locate emergency spill containment and cleanup kit(s) in high potential spill areas. The contents of the kit shall be appropriate for the type and quantities of chemical liquids stored at the facility.

Recommended Additional Operational BMP: Spill kits should include appropriately lined drums, absorbent pads, and granular or powdered materials for neutralizing acids or alkaline liquids where applicable. In fueling areas: absorbent should be packaged in small bags for easy use and small drums should be available for storage of absorbent and/or used absorbent. Spill kits should be deployed in a manner that allows rapid access and use by employees.

STORM-WATER AND EROSION-CONTROL STRUCTURES

The techniques discussed above and the structures described below can be organized in many different ways. The erosion/sedimentation controls at a site will likely change over time as the configuration of the site changes. Examples of storm-water control systems for an upland processing area and a quarry floor are shown in Figures 2.10 and 2.11, respectively. The profile shown in Figure 2.10 illustrates possible proper drainage techniques in a processing area. The location and choice of the various structures and techniques are site- specific.

Conveyance Channels and Ditches

Channels and ditches are permanent, designed waterways shaped and lined with appropriate vegetation or structural material to safely convey runoff to a sediment pond, vegetated area, or drainage. The advantages of open channels are that they are generally inexpensive to construct, can be lined with vegetation, and make it easy to trace the water. One disadvantage of grass-lined channels is that they may, if improperly designed, erode during high flows and become a source of sediment themselves.

The design of a channel or ditch cross section and lining is based primarily on the volume and velocity of flow expected in the channel. If flow is low and slow, grass channels are preferred to riprap or concrete lining. Although concrete channels are efficient and easy to maintain, they allow runoff to move so quickly that channel erosion and flooding can result downstream. Grass-lined or riprap channels (Fig. 2.12) more closely duplicate a natural system. Riprap and grass-lined channels, if designed properly, also remove pollutants via biofiltration (removal of pollution by plants). Engineered channels are recommended when the discharge will be greater than 50 cubic feet per second.

In addition to the primary design considerations of capacity and velocity, other important factors to consider when selecting a cross section and lining are land availability, compatibility with surrounding environment, safety, maintenance requirements, and outlet conditions.

Slash Windrows and Brush Sediment Barriers

Most mine sites have to be cleared of woody vegetation prior to mining. Slash windrows and brush barriers can be easily and inexpensively constructed with the vegetative debris. These are effective for filtering coarse sediment and reducing water velocity.

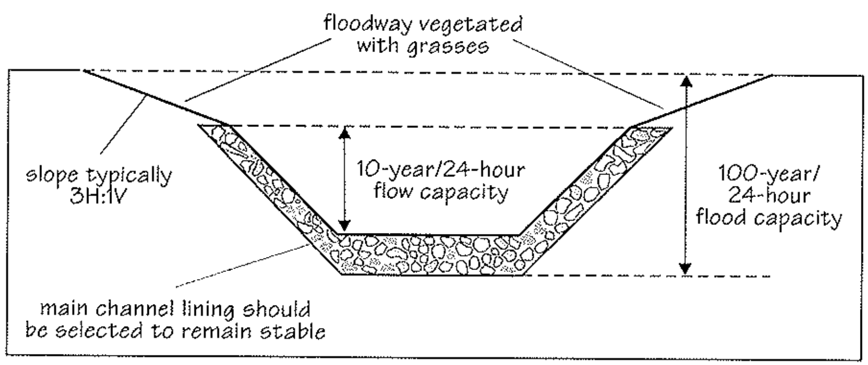


Figure 2.12. Details of construction for a rock-lined diversion ditch.

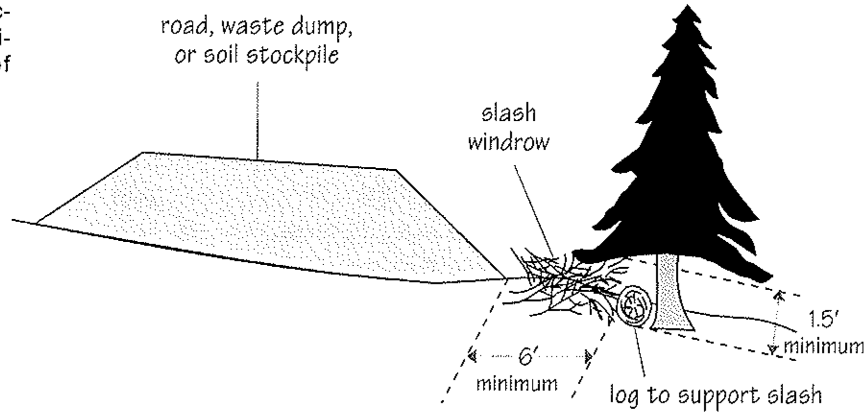


Figure 2.13. Details of construction of a slash windrow filter. (Modified from Idaho Department of Lands, 1992.)

Slash windrows are constructed by piling brush, sticks, and branches into long rows below the area of concern. The windrow may be supported at the base by large logs or rocks (Fig. 2.13).

Brush sediment barriers require somewhat more effort, planning, and expense, but they are generally more effective than slash windrows. Brush sediment barriers are linear piles of slash, typically wrapped in filter fabric or wire mesh. Construction details are provided in Figure 2.14.

- Slash windrows should be used below roads, overburden and soil stockpiles, and any other bare areas that have short, moderate to steep slopes.
- Brush sediment barriers are most effective on open slopes where flow is not concentrated; they can help prevent sheet flow and rill and gully erosion during heavy rains.

Straw Bales

Straw bales are a well-known temporary erosion-control method (Fig. 2.15). They are fairly cheap and readily available. However, they are frequently installed incorrectly, making them ineffective.

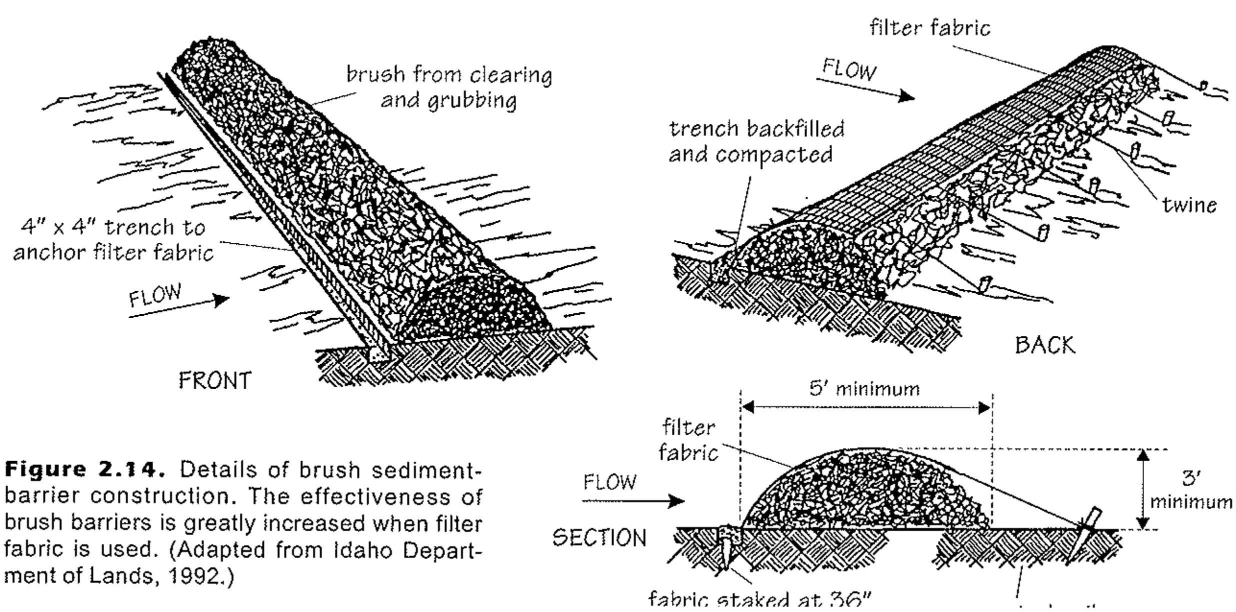
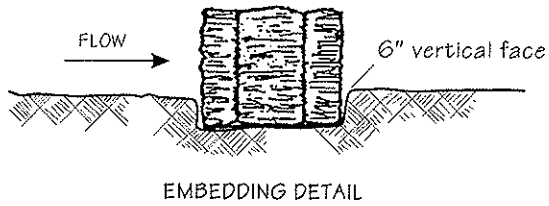


Figure 2.14. Details of brush sediment-barrier construction. The effectiveness of brush barriers is greatly increased when filter fabric is used. (Adapted from Idaho Department of Lands, 1992.)



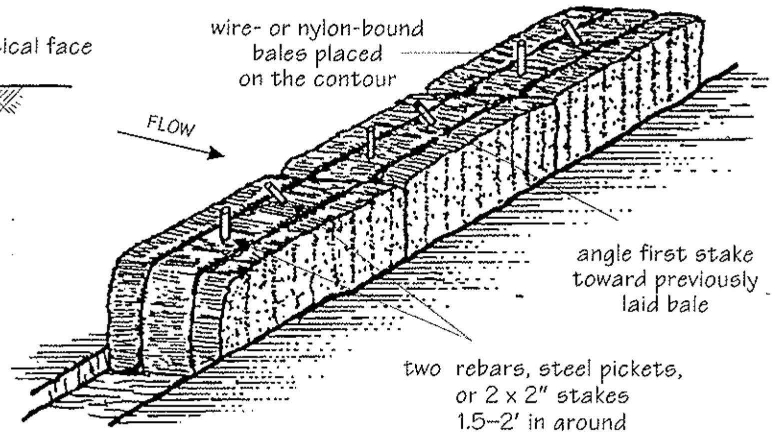


Figure 2.15. Details of straw-bale sediment barrier construction. (Adapted from Idaho Department of Lands, 1992.)

Simply placing straw bales on the ground surface without proper anchoring and trenching will provide only minimal erosion control. Proper ground preparation, placement, and staking are necessary to provide a stable sediment barrier. Straw bales also require frequent repair and replacement as they become clogged with sediment. Only certified weed-free straw should be used.

Straw bales used in conjunction with a check dam or filter berm constructed of sand and gravel, as shown in Figure 2.16, provide a more effective erosion-control system that requires less maintenance and can handle larger volume flows.

- ☛ Straw bales are most practical below disturbed areas where rill erosion occurs from sheet runoff.
- ☛ Straw bales may be used in minor swales and ditch lines where the drainage area is smaller than 2 acres and/or where effectiveness is required for less than 3 months.

Bio Bags Bio bags are woven nylon net bags filled with bark chips. They are about the size of straw bales and can be used as an alternative to straw bales for erosion control. Bio bags are much lighter than straw

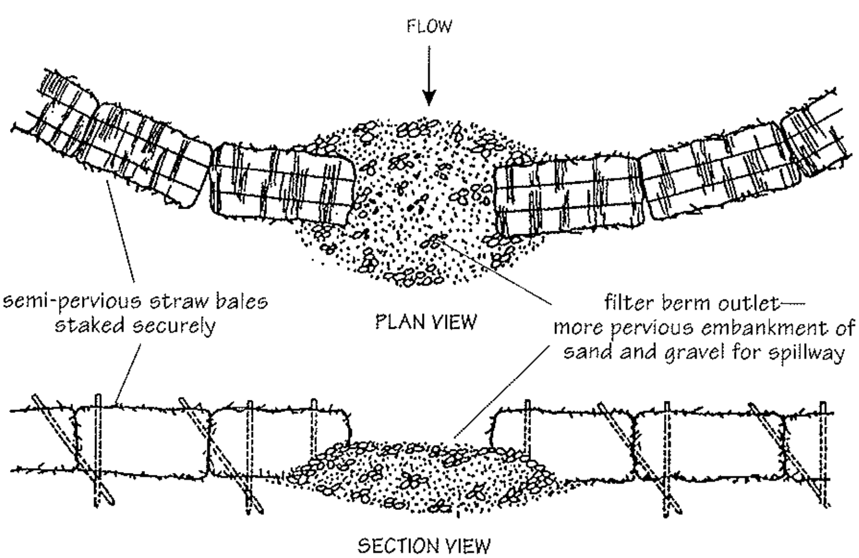


Figure 2.16. Details of construction for a straw-bale barrier combined with a gravel check dam. (Adapted from Idaho Department of Lands, 1992.)

bales; they must be staked down to keep them in place. They are more permeable, but slow water sufficiently to cause sand, silt, and clay to drop out. They fit the contours of the land, avoiding the bridging problem of straw bales. They hold together better and can therefore be removed more easily when saturated. Wildlife won't tear them apart to eat them, and they will not introduce grass and weed seeds to the site.

Bio bags may not be as readily available as straw bales. Their unit price is comparable to that of straw bales, but because they are smaller, more units are needed per application, making them slightly more expensive. They are not as biodegradable as straw bales.

Burlap Bags Filled with Drain Rock

Woven burlap bags filled with drain rock can be used as an alternative to bio bags. They conform well to irregular ground and are easily installed. They do not need to be staked down and are less prone to washing away than bio bags. They can easily be created using recycled burlap bags and the aggregate that is already present on most mine sites.

Silt Fences

A silt fence is made of filter fabric that allows water to pass through. Woven fabric is generally best. Depending on its pore size, filter fabric will trap different particle sizes. The fence is placed perpendicular to the flow direction and is held upright by stakes (Fig. 2.17). A more durable construction uses chicken wire and T-posts to support the fabric vertically.

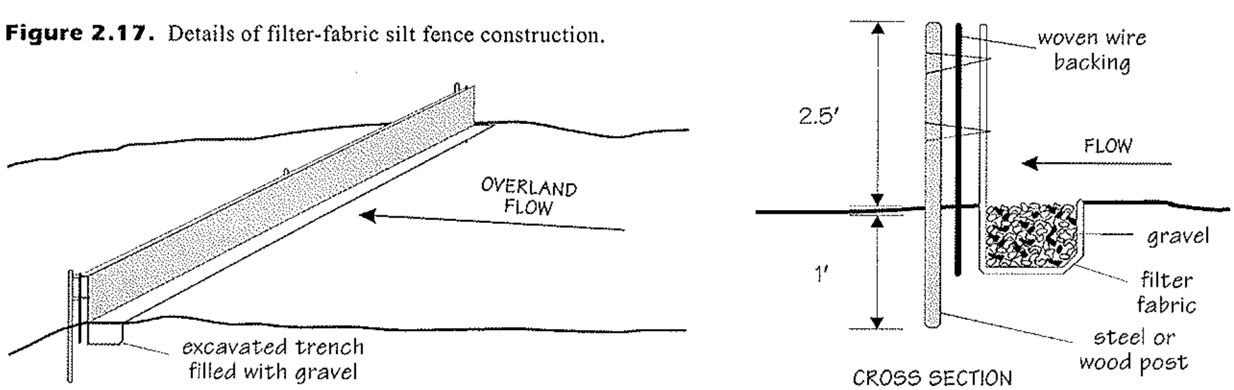
It is essential to bury the bottom of the filter fabric to prevent flow under or around the fence. Maintenance is required to keep the fence functioning properly. Rock check dams or other methods may be needed to slow water enough to allow it to pass through the fence. Although silt fences are more complicated and expensive to install than straw bales, they provide better erosion control in some situations, for example, in coastal climates where hay bales decay rapidly or in locations that are difficult to access with vehicles.

☛ Silt fences should be used below disturbed areas where runoff may occur in the form of sheet and rill erosion.

Erosion-Control Blankets

Erosion-control blankets are made of a variety of artificial and natural materials, including jute, coconut husk fibers, straw, synthetic

Figure 2.17. Details of filter-fabric silt fence construction.



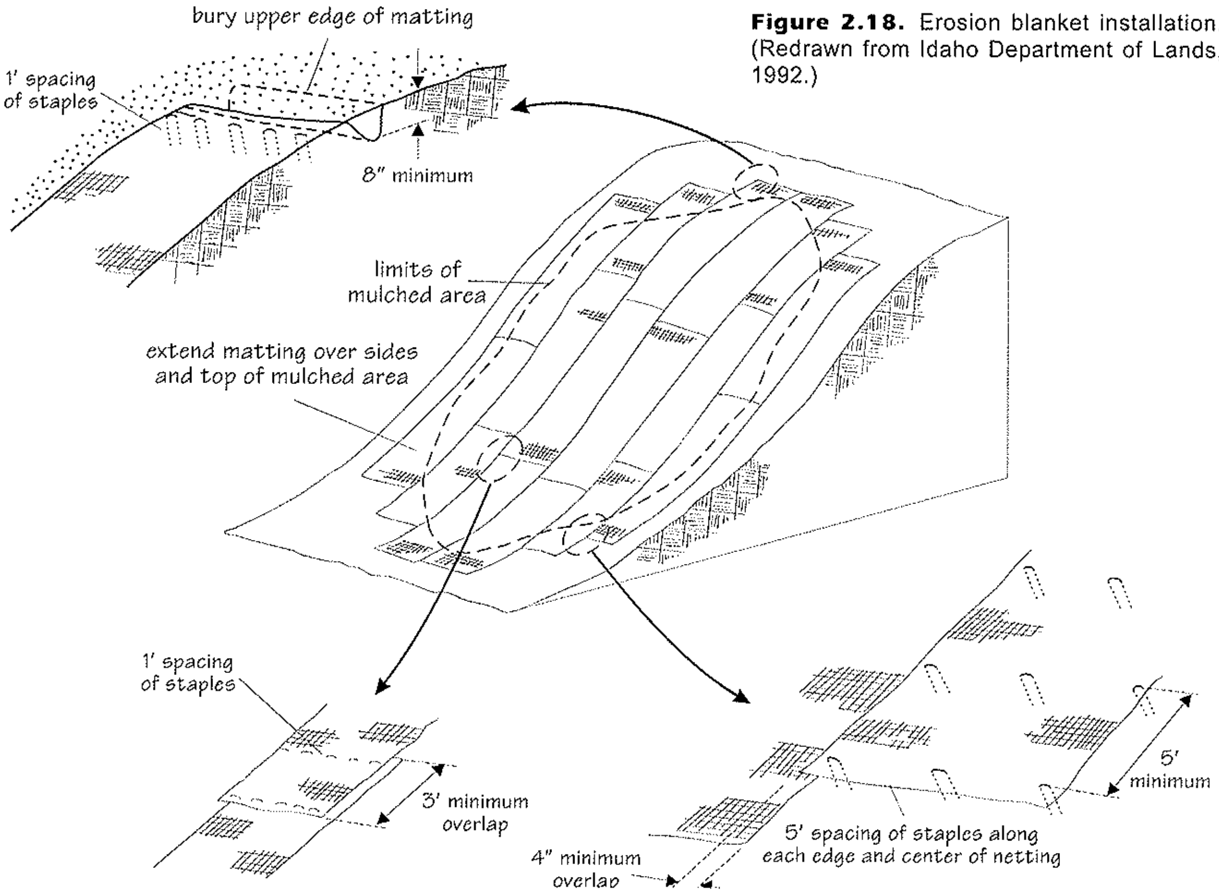


Figure 2.18. Erosion blanket installation. (Redrawn from Idaho Department of Lands, 1992.)

fabrics, plastic, or combinations (Fig. 2.18). Applying erosion blankets over large areas can be prohibitively expensive. However, small applications in areas that are oversteepened and/or prone to erosion, in conjunction with cheaper methods such as hydromulching and/or hay mulch and netting, can be very effective. The effectiveness of jute netting and mulch fabrics is greatly reduced if rills and gullies form beneath these fabrics. Therefore, proper anchoring and ground preparation are essential.

☛ Erosion-control blankets can be used on steep slopes where severe erosion-control problems are anticipated.

Where water infiltration is not desirable, for example, on the surface of an active landslide, an impermeable erosion blanket may be appropriate. In this situation, special care must be taken to provide a place where the energy the water has gained can dissipate, such as a slash windrow, brush sediment barrier, or rock blanket at the base of the slope.

Vegetation Vegetation absorbs some of the energy of falling rain, hold soils in place, maintains the moisture-holding capacity of the soil, and reduces surface flow velocities (Fig. 2.19).

☛ The most effective way to use vegetation is to leave it undisturbed to prevent erosion and reduce the speed of surface water flows.

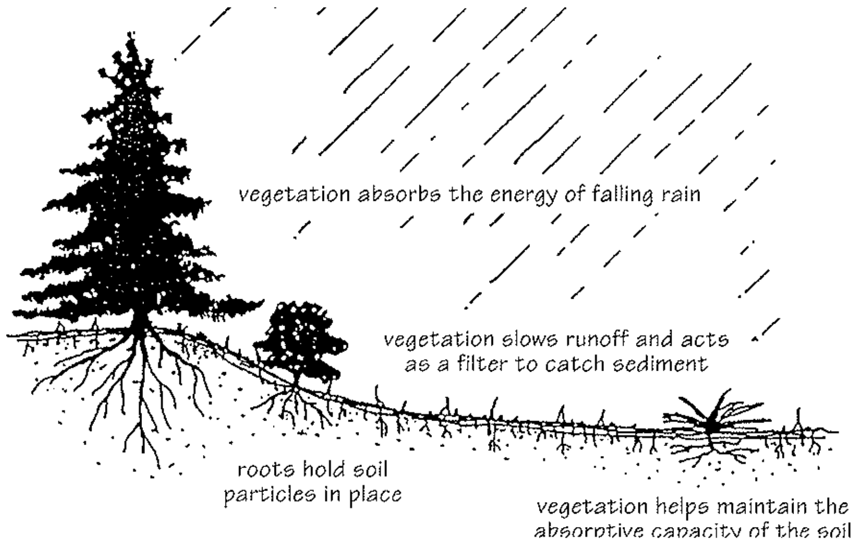


Figure 2.19. Effect of vegetation on storm-water runoff. (Modified from Washington State Department of Ecology, 1992.)

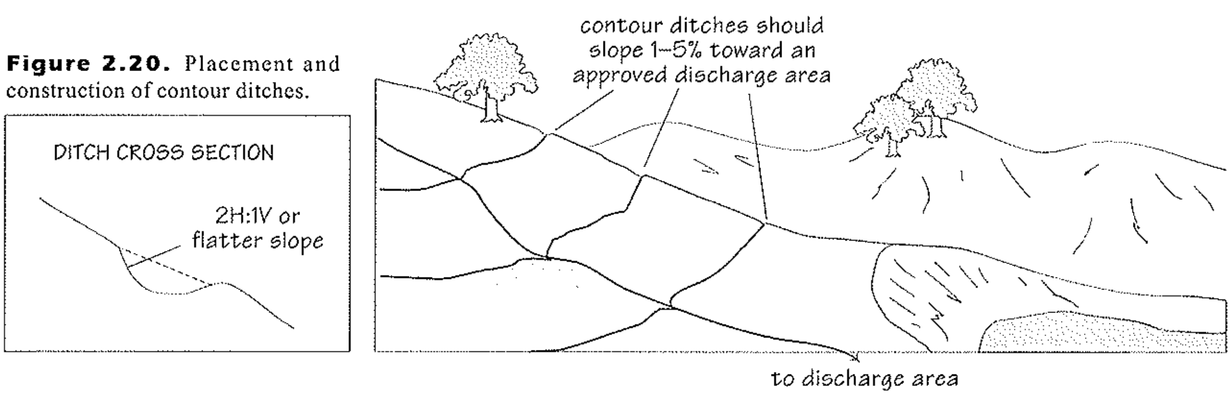
- If a new area must be cleared for mining, clear only the amount needed for expansion within one year.
- As an area is cleared of vegetation, save the sod or slash and stake it down across the cleared slopes to temporarily reduce storm-water runoff until the area is mined.
- Replace topsoil and replant mined areas as soon as possible.
- Revegetate overburden and topsoil stockpiles over the winter or when they will remain unused for more than six months. (Topsoil should not be replaced in this situation; see Interim Reclamation, p. 3.1.)

Contour and Diversion Ditches

Contour ditches are constructed along a line of approximately equal elevation across the slope (Fig. 2.20). Diversion ditches guide water around unstable areas to prevent both erosion and saturation with water (Fig. 2.21), reducing the likelihood of slope failure. Both types of ditches should have a 1 to 5 percent grade directed away from steep slopes to the appropriate drainage or vegetated areas.

Ditch channels may need to be lined to prevent scouring and minimize sediment transport. When their slope is greater than 5 per-

Figure 2.20. Placement and construction of contour ditches.



cent, ditches are typically lined with rock. Where slope stability is of concern, impermeable liners may be used. Rock check dams, described below, should be placed in diversion and contour ditches at decreasing intervals as the slope increases.

☛ Contour and diversion ditches should be used to direct surface runoff away from disturbed areas and prevent rills and gullies from forming.

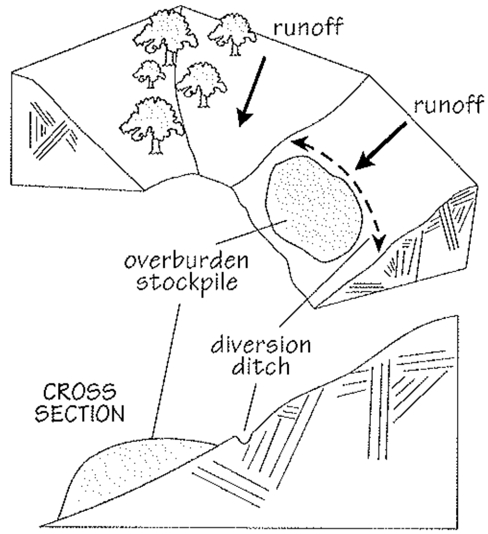


Figure 2.21. A diversion ditch can be placed upslope from an overburden pile to prevent saturation of the pile.

Rock and Log Check Dams

Check dams are typically constructed from coarse crushed rock ranging from about 2 to 4 inches in diameter, depending on the water velocities anticipated. A check dam can generally withstand higher velocity flows than a silt fence, and the integrity of the structure will not be affected if it is overtopped in a large storm event. The tops of check dams are lower than the channel margins so that water can spill over (instead of around the sides) during heavy storms (Fig. 2.22).

The effectiveness of rock check dams for trapping sediment can be improved by applying filter fabric on the upstream side. The bottom of the fabric must be anchored by excavating a trench, applying the fabric, and then filling the trench with coarse rock. This structure functions like a silt fence, but it is more durable. Choosing the proper size of filter fabric mesh is important to minimize clogging.

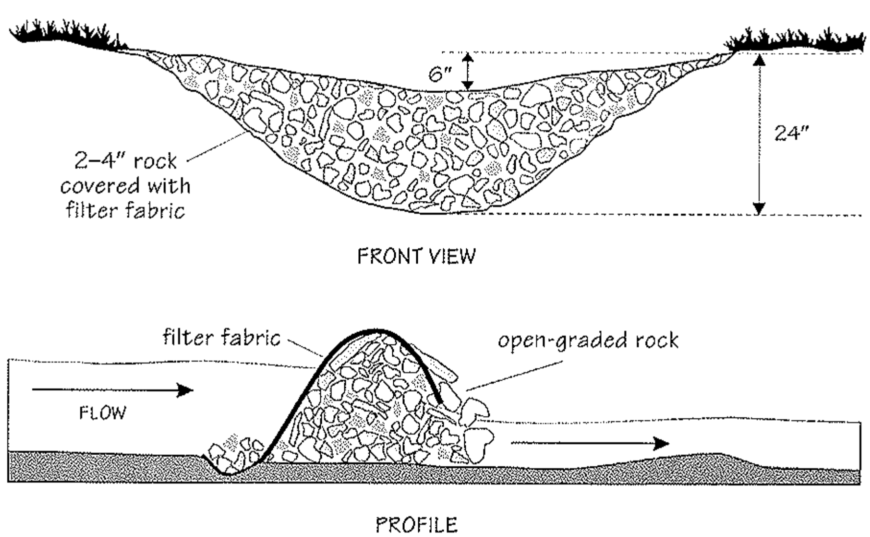
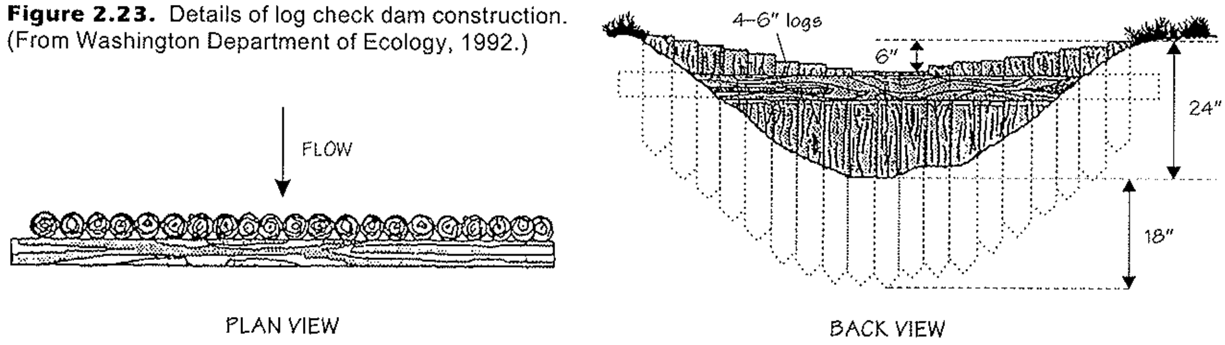


Figure 2.22. Details of rock check dam construction.

Figure 2.23. Details of log check dam construction. (From Washington Department of Ecology, 1992.)



The filter fabric must be replaced when it becomes clogged. Gabions (wire baskets filled with coarse rock) and filter fabric would function in the same manner.

Where they are readily available, logs can be used to construct check dams instead of rock (Fig. 2.23).

- ☛ Check dams can be used to slow surface flow in ditches.
- ☛ Check dams are a common means of establishing grade control in a drainage to minimize downcutting.

Concrete Check Dams

Concrete check dams (Fig. 2.24) can be an effective long-term alternative to straw bales, bio bags, and rock-filled burlap bags. They can often be constructed from waste concrete that is cleaned out of mixer trucks, but time constraints may prevent this. Concrete check dams are most appropriate along ditches that are relatively permanent.

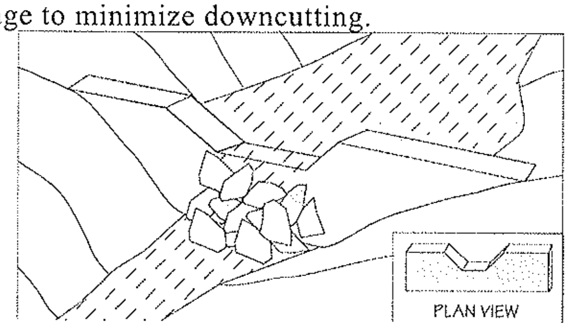


Figure 2.24. Waste concrete check dam. It should be a minimum of 4 inches thick; length and width vary to fit application.

Filter Berm

A filter berm (Fig. 2.25) allows the passage of water but not soil particles. It can be constructed of sand and gravel or crushed and screened quarry rock free of 200-mesh or smaller material. Using pit-run sand and gravel or quarry rock is not recommended because silt and clay will be present. In the ideal berm, fine sand, coarse sand, and gravel are placed sequentially from the upstream side to

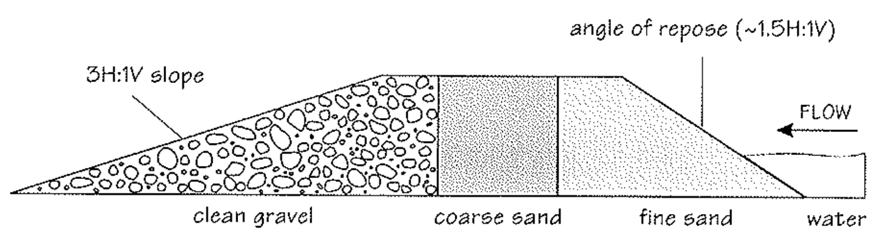


Figure 2.25. Idealized cross section of a filter berm showing details of construction.

the downstream end of the berm. The sand may need periodic replacement as it becomes clogged with sediment.

☛ Filter berms should be used in channels with low flow.

Trench Subdrains and French Drains

The terms 'trench subdrain' and 'French drain' are sometimes used interchangeably. A French drain is a ditch partially backfilled with loose, coarse rock to provide quick subsurface drainage and covered with a compacted clay cap. A trench subdrain is a ditch backfilled all the way to the top with loose, coarse rock, which allows water to enter more freely (Fig. 2.26). Both types of drains are designed to allow the movement of water while preventing or minimizing the movement of soil particles, and both require an outlet to remove water. Either can be improved by placing perforated pipe in the drain. (See also Figs. 3.11 and 6.6.)

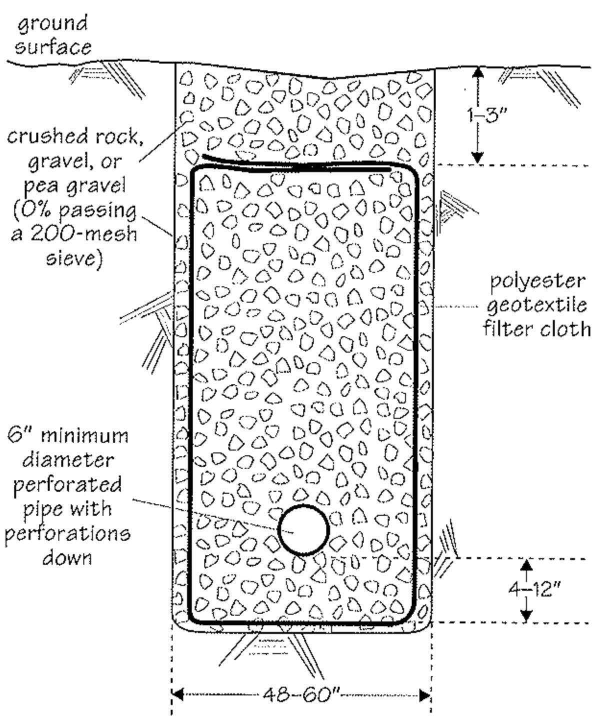


Figure 2.26. Details of trench subdrain construction.

Several filtering methods can improve the long-term effectiveness of these drains. Early applications relied on open-graded aggregate free of 200-mesh or smaller material, but this may eventually become clogged. Current practice is to wrap the perforated pipe in filter fabric so that sediment is trapped on the surface of the fabric rather than in the pore spaces. Because maintenance may eventually be required for subdrains, placement of clean-outs along the pipes is recommended.

☛ Drains are used for dewatering landslides and agricultural lands and stabilizing highway road cuts.

☛ Drains are also well suited for storm-water control.

Infiltration Galleries and Dry Wells

Infiltration galleries (or dry wells) are similar to trench subdrains and French drains except that there is no direct outlet for the water that enters them. These drains are deeper than they are long.

Infiltration galleries are created by excavating a hole— the deeper the better—which is then backfilled with coarse rock (Fig. 2.27). Typically, the holes are dug to the maximum reach (≈20′ of the backhoe used. If possible, water percolation should be improved by fracturing the bottom of the hole. This may require drilling and shooting. Backfilling to the sur-

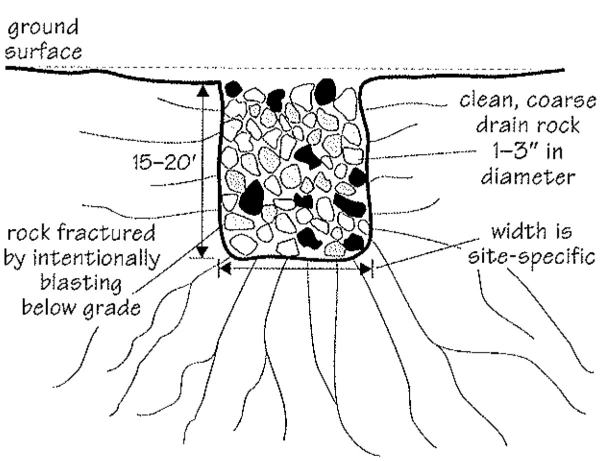


Figure 2.27. Details of infiltration gallery construction. (See also Fig. 2.9.)

face with coarse rock allows heavy equipment to pass safely over these structures, making them well suited for installation around a crusher or screening plant. Because there is no outlet for water, these galleries should be located where fines and storm water accumulate. Grading should direct storm-water runoff to them. The exact size and number of infiltration galleries needed is site specific. Maintenance is typically limited to periodic replacement of the fill with clean rock.

- ☛ Infiltration galleries are best suited for quarry sites or areas where natural infiltration of storm water is minimal and the water table is low enough to allow drainage. They should be used alone only where grades prevent connection to a gravity-flow subdrain or where volumes of storm water are small.
- ☛ Infiltration galleries should not be used if oil and grease are present to contaminate the ground water.

Wheel Washes

Tracking of mud and rocks onto roads can become a problem at many mine sites during the winter. A permanent wheel wash can be installed near the exit to wash excess dirt and mud off truck tires. A series of railroad rails spaced 2 to 8 inches apart can be used to shake loose rocks and dirt while the vehicle is driving through the wheel wash (Fig. 2.28). Make sure that water used to wash trucks is treated to remove solids and turbidity before being discharged from the site.

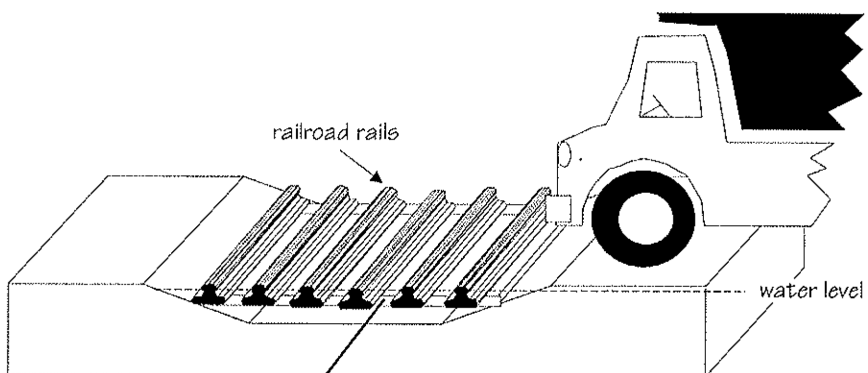


Figure 2.28. Wheel washes can be used to keep mud and rocks from being tracked onto roads. Dirty water can be sent to a settling pond, or the wheel wash can be cleaned out with an excavator.

STORM-WATER SETTLING PONDS

Most mine operations cannot rely solely on passive storm-water control methods and must employ settling ponds as an integral part of their storm-water system. These flat-bottomed excavations can range from small hand-dug sumps to ponds covering several acres. They slow water velocities enough to allow sediment to settle out of suspension. The number and size of ponds needed will depend on the site conditions. Construction of numerous ponds in the upper part of the drainage systems enhances effective trapping of sediments. For example, upper quarry benches and floors can be bermed so that they function as sediment basins during the rainy season.

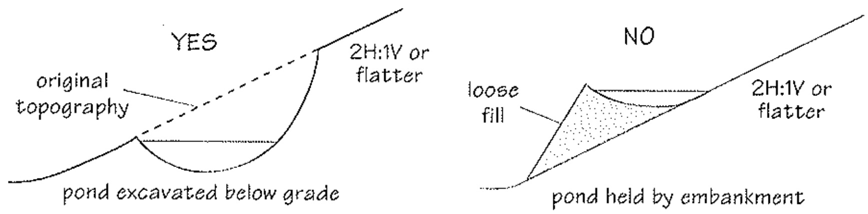


Figure 2.29. Details of settling-pond construction. The excavation method on the left is preferred because it is less likely to fail and cause flooding than an constructed embankment (right).

Two types of ponds are commonly used—detention and retention. Detention ponds reduce the velocity of storm water, allowing sediment to settle before it moves off-site. Retention ponds are large enough to accept all storm water without surface discharge.

Ponds can be developed by building embankments or by excavating below grade. Excavated ponds are preferable because they are less likely to fail than embankments (Fig. 2.29). Embankments have to be carefully constructed using the same techniques that would be used for constructing waste and overburden dumps and stockpiles (see p. 3.15). Ideally, ponds should be situated at the bottom of a slope. Soil or geotextile liners may be required where stability is a concern. Many ponds are designed for the life of the operation, whereas others are used for only a short time.

☛ Settling ponds are the best method of gathering turbid water to allow sediment to settle out.

In Washington, water impoundments that contain more than 10 acre-feet of water must be approved by the Dam Safety Section of the Department of Ecology.

In Oregon, water impoundments with dams more than 10 feet high or with a capacity of more than 9.2 acre-feet of water must be approved by the Dam Safety Section of the Oregon Water Resources Department.

Configuration, Location, and Size

Storm-water detention ponds should be designed to maximize both velocity reduction and storage time. That is, storm water entering a pond should spread out and migrate as slowly as possible toward the discharge point. Baffles constructed across the pond (Fig. 2.30) can reduce flow rates. A good rule of thumb is that the flow path of the pond should be at least five times the length of the pond. The inlet and outlet should be located so as to minimize the velocity and maximize the residence time.

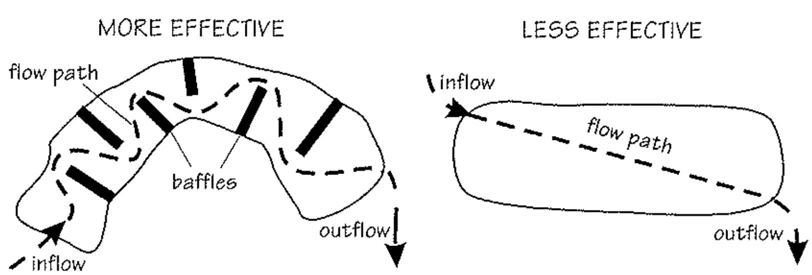


Figure 2.30. Details of detention pond design. The pond on the left, which maximizes the length of the flow path, is preferable to the pond on the right, which does not keep water in the pond long enough for optimum settling.

If ponds are to be placed in the lowest area of the watershed, several should be constructed in a series. This will enable the first pond to slow the high-velocity waters coming into it and allow subsequent ponds to settle out sediments more effectively. For maximum treatment effectiveness, ponds should be placed as close as possible to those areas most likely to contribute sediment, such as the pit floor, the processing plant, and other areas of heavy equipment activity.

There are several widely used methods for determining the appropriate size of storm-water ponds for a given site. Most methods begin with estimating the size of the watershed and estimating runoff using infiltration rates. This information is then used to calculate the amount of runoff on the basis of annual precipitation or a storm event of a certain size. Observations of flow characteristics and locations made near the mine during storm events can be invaluable in developing a good storm-water pond system.

However, choosing an appropriate size for storm-water ponds can be difficult without site-specific information such as a storm hydrograph—a graph of the volume of water flowing past a certain point during a storm event. When hydrographic information is not available, theoretical calculations are used to estimate the flow volume for a given storm event. The calculations quickly become complicated because storm intensity and duration can have a significant effect on the amount of runoff. Also important, but even more complicated, are determining the influence of road systems, vegetative cover, and amount of compaction on runoff volumes.

The Natural Resources Conservation Service (formerly Soil Conservation Service) has developed a simplified method for estimating storm-water runoff. This method can work well if the limitations are understood, and it yields a good starting point for determining pond size. For more information, contact the local office of the Natural Resources Conservation Service.

There are many resources for information on designing storm-water ponds. (See the list of references at the end of the chapter.) For determining spillway designs and diversion ditch liner specifications, Urban Hydrology for Small Watersheds (Soil Conservation Service, 1986) is a good resource.

☛ For most mining situations, storm-water ponds should be designed to handle at least a 25-year/24-hour event or larger.

In Washington, RCW 78.44 sets a standard for water control: "Diversion ditches, including but not limited to channels, flumes, tightlines and retention ponds, shall be capable of carrying the peak flow at the mine site that has the probable recurrence frequency of once in 25 years as determined from data for the 25-year, 24-hour precipitation event published by the National Oceanic and Atmospheric Administration." The data for 25-year, 24-hour precipitation events can be found in Miller and others, 1973. Furthermore, if the site is located in a watershed that is prone to erosion, heavy storms, and/or flooding, design specifications may require planning for a 100-year storm event.

Maintenance Settling ponds must be cleaned out regularly to remain effective. Spillways should be kept open and ready to receive overflow during large storms. Settling ponds should be constructed and placed so that onsite equipment can be used to maintain them. In some situations, sediment can be pumped out of settling ponds as a slurry instead of being removed with heavy equipment. Regardless of the method of sediment removal, all sediment removed should be placed in a stable location so that it will not enter waterways.

Drainage The method of releasing water from storm-water ponds can be critical in determining their efficiency. Standpipes, spillways, and infiltration are the most common release methods.

Standpipes are vertical pipes rising from the bottom of the pond and connected to a gently sloping pipe that passes through the side of the pond to the discharge point (Fig. 2.31). Antiseep collars must be attached to the pipe where it passes through the dam or settling pond wall to prevent water from flowing along the outside of the pipe. A grate or screen should be placed over the standpipe intake to prevent debris from clogging it.

Spillways are overflow channels that are part of the construction of all water impoundments. For small settling ponds used intermittently and designed for low maintenance, spillways may handle all water discharged from the pond. Where water is recirculated to the processing plant or where discharge is through a standpipe or subdrain, a spillway allows overflow during extremely wet weather or when the primary drain system becomes clogged.

Spillways should be located in undisturbed material and not over the face of a constructed dam. If the spillway is placed on erodible material, it must be rock lined to limit erosion that would compromise the safety of the dam.

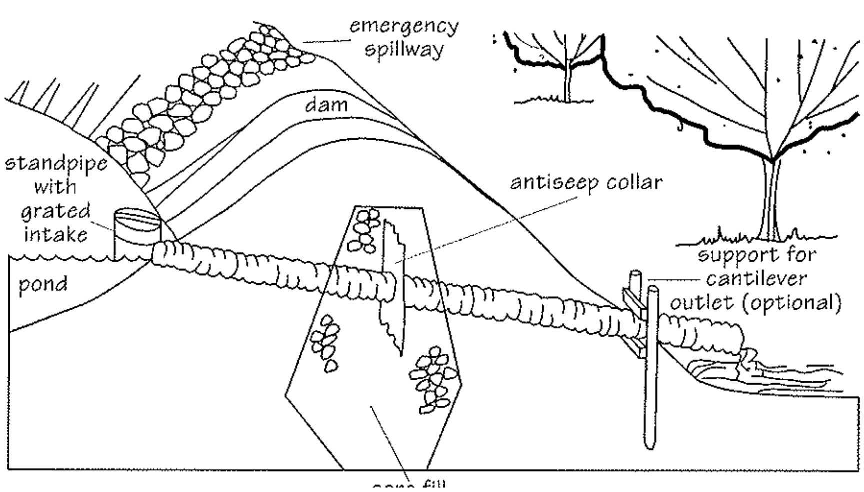


Figure 2.31. Section through a berm showing standpipe with antiseep collar. (Modified from U.S. Soil Conservation Service, 1982.)

3 Operation and Reclamation Strategies

INTRODUCTION

Four general strategies can be used in surface-mine reclamation. Some mines may use all four of these strategies:

Post-mining reclamation – reclamation only after all resources have been depleted from the entire mine.

Interim reclamation – temporary reclamation to stabilize disturbed areas.

Concurrent (progressive or continuous) reclamation – reclamation as minerals are removed; overburden and soil are immediately replaced.

Segmental reclamation – reclamation following depletion of minerals in a sector of the mine (Norman and Lingley, 1992).

In Washington, the Department of Natural Resources (DNR) encourages segmental reclamation wherever site conditions permit.

In Oregon, segmental reclamation is considered a variant of concurrent reclamation. The Department of Geology and Mineral Industries (DOGAMI) encourages concurrent reclamation wherever possible.

POST-MINING RECLAMATION

Reclaiming after all resources have been depleted from the entire mine is generally discouraged by regulating agencies because it results in large areas being left unreclaimed for long periods, but it may be necessary at many quarries and metal mines and at some sand and gravel deposits (Fig. 3.1).

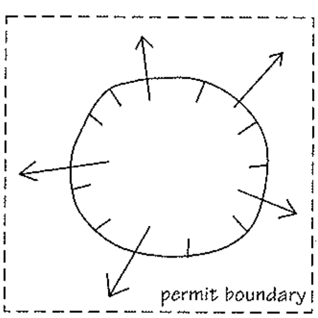


Figure 3.1. For a mine site beginning a center-outward excavation, the preferred segmental reclamation method is not possible, and post-mining reclamation then becomes the method by default.

Advantage

- Complete resource depletion is more easily attainable in some instances.

Disadvantages

- Stockpiled soils will have deteriorated during the mine's life and will not be as fertile as the soils in place.
- Revegetation will probably be more expensive and take longer.
- The site generates negative public opinion for a long period.
- The land is not providing a beneficial use while unreclaimed.
- No reclaimed segments are available as test plots for revegetation.
- Bonding liability is very high.

INTERIM RECLAMATION

Interim reclamation is done seasonally to stabilize mined areas or stockpiles and to prevent erosion. If a mine is to remain inactive for more than 2 years or if a stockpile, excavated slope, or storage area needs rapid stabilization, it may be appropriate to temporarily reclaim it by doing earthwork and using fast-growing vegetation, such as cereal grains or legumes that establish quickly, to stabilize the site. However, topsoil should not be moved for interim reclamation; significant amounts are lost each time topsoil is moved. (See The Soil Resource, p. 3.10.)

Advantages

- Soil viability is maintained.
- Fewer storm-water control structures are needed because the erosion-prone area is vegetated.
- Air and water quality are improved in the short term.
- Sites that use interim reclamation are often easier to convert to final reclamation than those that do not.

Disadvantages

- Areas may be redisturbed as plans change.
- Cost may be greater than when material is moved only once.

CONCURRENT OR PROGRESSIVE RECLAMATION

Concurrent or progressive reclamation typically involves transporting material from the new mining area to the reclamation area in one circuit (Fig. 3.2). This is the method used in strip mining minerals such as coal where a small amount of mineral is mined compared to a large amount of overburden moved.

Concurrent reclamation is viewed by the public as the preferred technique. However, progressively reclaiming land that overlies known mineral resources can be wasteful. Thin soils may render progressive reclamation impractical or impossible on some sites. It is also impractical for those operations that must blend different sand and gravel sizes from various parts of the mine site to achieve product specifications.

Advantages

- Soil is immediately moved to the reclamation area.
- Soil and subsoil profile are more easily reproduced than in other types of reclamation.
- Materials are moved only once.

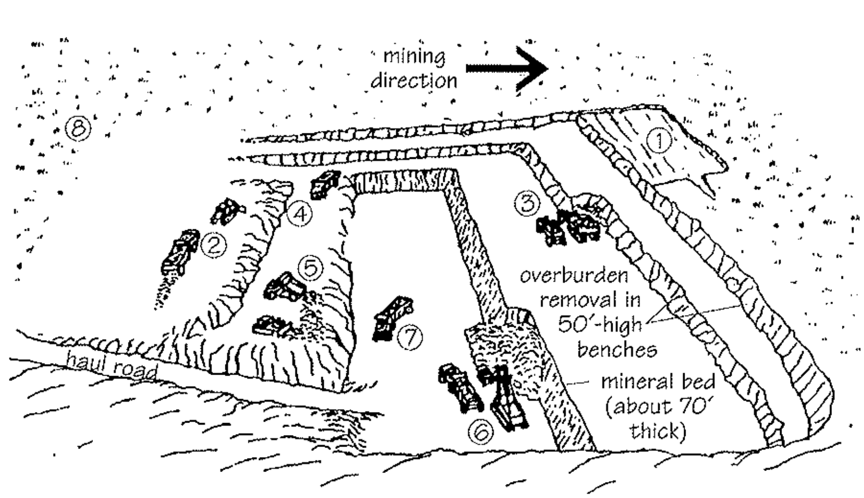


Figure 3.2. Concurrent or progressive extraction and reclamation of a shallow dry pit.
1, removal of topsoil;
2, spreading topsoil on graded wastes;
3, loading of overburden;
4, hauling of overburden;
5, dumping of overburden;
6, loading of product;
7, hauling of product;
8, reclaimed land.

(Modified from U.S. Bureau of Land Management, 1992.)

- Disturbance at any given time is minimized.
- Offsite impacts are minimized in any given area.
- Mined land can be reclaimed earlier for agriculture or grazing.
- Bond liability tends to be low.

Disadvantages

- Progressive reclamation is generally not feasible in quarries or deep gravel deposits.
- Progressive reclamation typically does not work if the water table is above the excavation depth.

SEGMENTAL RECLAMATION

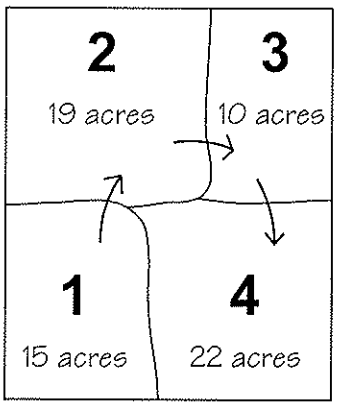


Figure 3.3. A segmental reclamation plan with four segments showing segment size and direction of working.

In segmental reclamation, the mine is divided into segments with fairly uniform characteristics and the order of mining and reclaiming these segments is determined (Fig. 3.3). Prior to mining, soil in the first segment is stockpiled to minimize handling and protect the resource. After resource extraction from the first segment, its slopes are reshaped according to the reclamation plan. Soil is then stripped from the second segment and spread on the slopes of the first segment.

Revegetation of the floor of the first segment does not occur until the area is no longer needed for mineral processing or maneuvering trucks. Immediately prior to replacing topsoil and planting, the pit floor is plowed or ripped because most plants cannot grow in soils that have been overcompacted by heavy machinery. Prompt planting in the correct season with grasses, legumes, and trees will quickly produce a cover that reduces erosion, retains moisture, and moderates soil temperature.

Segmental reclamation works best in homogenous deposits where aggregate mining proceeds in increments. Typical working cells or segments will be larger in heterogeneous deposits (for example, fluvial deposits) where blending minerals from many places in the mine may be required (Norman and Lingley, 1992).

Advantages

- Topsoil for most segments is handled only once and is not stored. This reduces reclamation cost and preserves soil quality.
- Final slope angles and shapes can be established during excavation rather than as a separate operation.
- Clay and silt, which are critical for retaining the moisture and nutrients essential for vegetation, are less likely to be washed away because they are immediately revegetated.
- The potential for establishing a diverse self-sustaining soil/plant ecosystem is enhanced because revegetation of reclaimed segments will be monitored as mining continues.
- Restoration of chemical, physical, and biological processes is less expensive when reclamation is started as soon as possible and spread over the life of the mine.

- Reclamation is less expensive because it does not require mobilization of personnel or equipment for the sole purpose of reclamation.
- Short-term environmental impacts are reduced.
- Bonding liability at any given time is minimized.

Disadvantages

- Thin soils may render this technique impractical.
- It is impractical for those operations that must blend different sand and gravel sizes from various parts of the mine site in order to achieve product specifications.
- Poorly planned segmental reclamation may result in disturbing more land per unit of mineral produced.

By law (RCW 78.44) in Washington, a segment is defined as a 7-acre area with more than 500 linear feet of working face. Larger segments must be approved by DNR in a segmental reclamation agreement.

MINING TO RECLAIM

Mining the slope to the final contours reduces reclamation costs by eliminating some of the earthwork necessary for final reclamation. This can result in reclamation being completed earlier, the performance security being reduced, and operating costs being lower in the long run.

SITE PREPARATION

Before mining begins, steps must be taken to mark permit boundaries, setbacks, buffers, segments, and storage and processing areas. Setbacks, buffers, and storage areas should remain undisturbed until reclamation. Keeping equipment and stockpiled materials out of these areas will help preserve them. Flagging, fences, or monuments will alert operators to areas to be avoided. If vegetation is present on slopes that might be unstable if bare, then those plants should be protected. Activity near trees and shrubs should be kept outside the area below the longest branches (or drip line).

Permit and Disturbed Area Boundaries

Permit boundaries and the limits of the area to be disturbed (permit boundary minus setbacks and buffers) should be identified with clearly visible permanent markers. Markers should be maintained until the reclamation permit is terminated.

Permanent Setbacks or Buffers

Permanent setbacks or buffers are necessary at many mines (Fig. 3.4). They are lands (that may or may not have vegetation) that remain undisturbed during mining to provide habitat and/or visual and noise screening.

In Washington, the minimum permanent setback for quarries (mines in consolidated deposits) permitted after June 30, 1993, is 30 feet. This area cannot be mined, and the material cannot be used for reclamation. Permanent setbacks are not required for gravel pits (unconsolidated deposits) but may still be useful if the mine has close

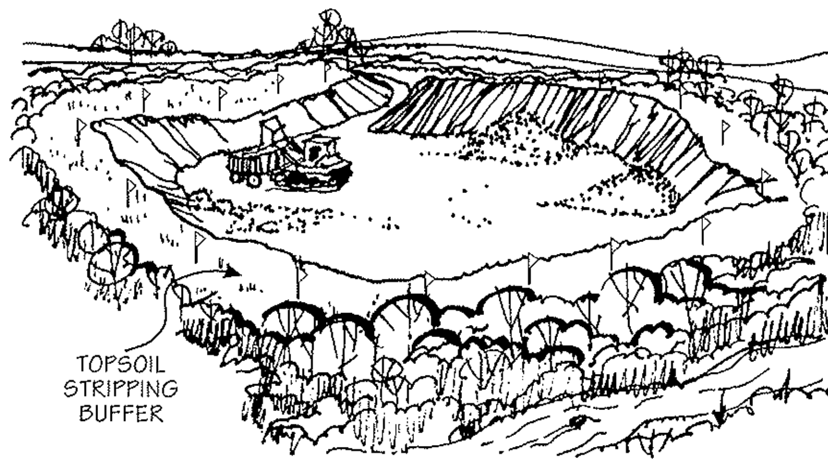


Figure 3.4. Buffer strips of native vegetation protect adjacent land and water and visually screen the operation. Note that the flags marking the limits of the disturbed area show employees where to stop mining. (Modified from Green and others, 1992.)

neighbors or adjacent scenic resources. However, setbacks may still be required by local government.

In Oregon, mine setbacks are site-specific and designed to provide lateral support for adjacent lands. Setbacks for the purpose of minimizing conflicting land uses are determined by the local land-use authority.

Reclamation Setbacks

Reclamation setbacks are lands along the margins of surface mines that must be preserved to provide enough material to accomplish reclamation. If the cut-and-fill method will be used to restore slopes (rather than mining to a final slope), the reclamation setback from the property boundary (or permanent setback, where used) should be wide enough to ensure that sufficient material is available for reclamation.

In Washington, the width of the reclamation setback for pits (mines in unconsolidated deposits) permitted after June 30, 1993, must equal or exceed the maximum anticipated height of the adjacent working face.

Note: A setback equal to the working face will provide only enough material for a 2:1 slope. To meet the standards of the law for slopes of between 2:1 and 3:1, a setback of 1.5 times the vertical height of the working face is required.

Setbacks to Protect Streams and Flood Plains

Streams and flood plains are dynamic locations that frequently experience dramatic changes during flooding. They are prone to damage by, and slow to fully recover from, improperly planned and executed mining operations. Mining in or near streams and flood plains requires greater care on the part of the operator and is subject to closer regulation than mining in less sensitive areas.

In Washington, no mine, including haul roads, stockpiles, and equipment storage, may be located within 200 feet of or on the 100-year flood plain of a stream that has a flow greater than 20 cubic feet per second unless a Shoreline Permit is issued by the local jurisdiction (Washington Department of Ecology, 1992). Wide setbacks may be necessary for stream and flood-plain stability to preserve riparian zones and to prevent breaching of the pit at a later date. The depth of excavation and pit size may be limited in these areas.

In Oregon, mining is not explicitly prohibited on the 100-year flood plain. Setbacks are site-specific to protect riparian areas and stream integrity. Depending on flood frequency, bank stability, and the potential for lateral migration of the river channel, wider setbacks may be required or depth of excavation may be limited.

Conservation Setbacks In special instances, setbacks that will not be mined or disturbed may be necessary to protect unstable slopes, wildlife habitat, riparian zones, wetlands, or other sensitive areas or to limit turbid water discharge from areas that will be disturbed.

Topsoil and Overburden Storage Areas Prior to mining a segment, all available topsoil and overburden should be stockpiled in separate, stable storage areas for later use in reclamation or immediately moved to reclaim adjacent depleted segments. Topsoil needed for reclamation cannot be sold, removed from the site or mixed with sterile soils.

In Washington, topsoil should not be used to create screening berms required by local government because this may preclude its timely use for reclamation.

VISUAL AND NOISE SCREENS

The value of visual and noise screens cannot be overstated. The adage 'out of sight, out of mind' is particularly applicable to mine sites. The more the public can be screened from the unpleasant aspects of mining, such as dust, noise, and an unsightly view, the less likely they are to aggressively oppose mining operations.

The following are some ways to reduce the noise and visual impacts of mining (Figs. 3.5 and 3.6):

- Plan mine development to minimize offsite impacts.

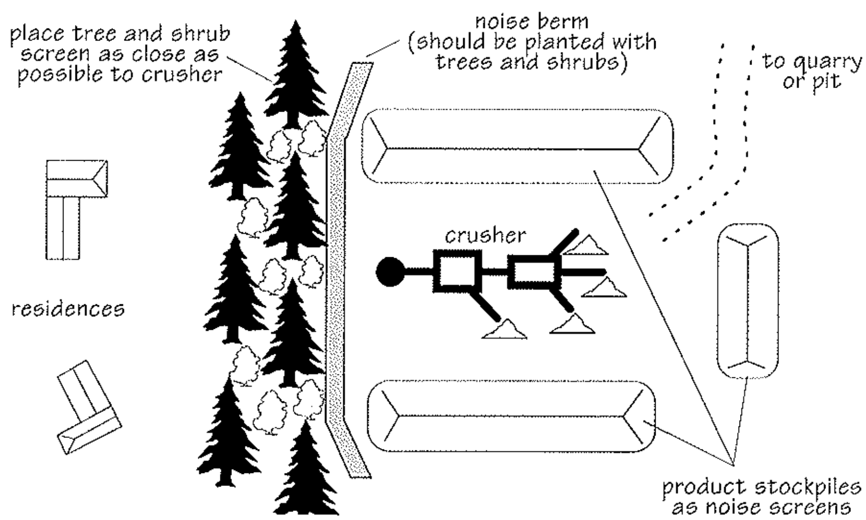


Figure 3.5. Visual and noise screening techniques used at a processing area.

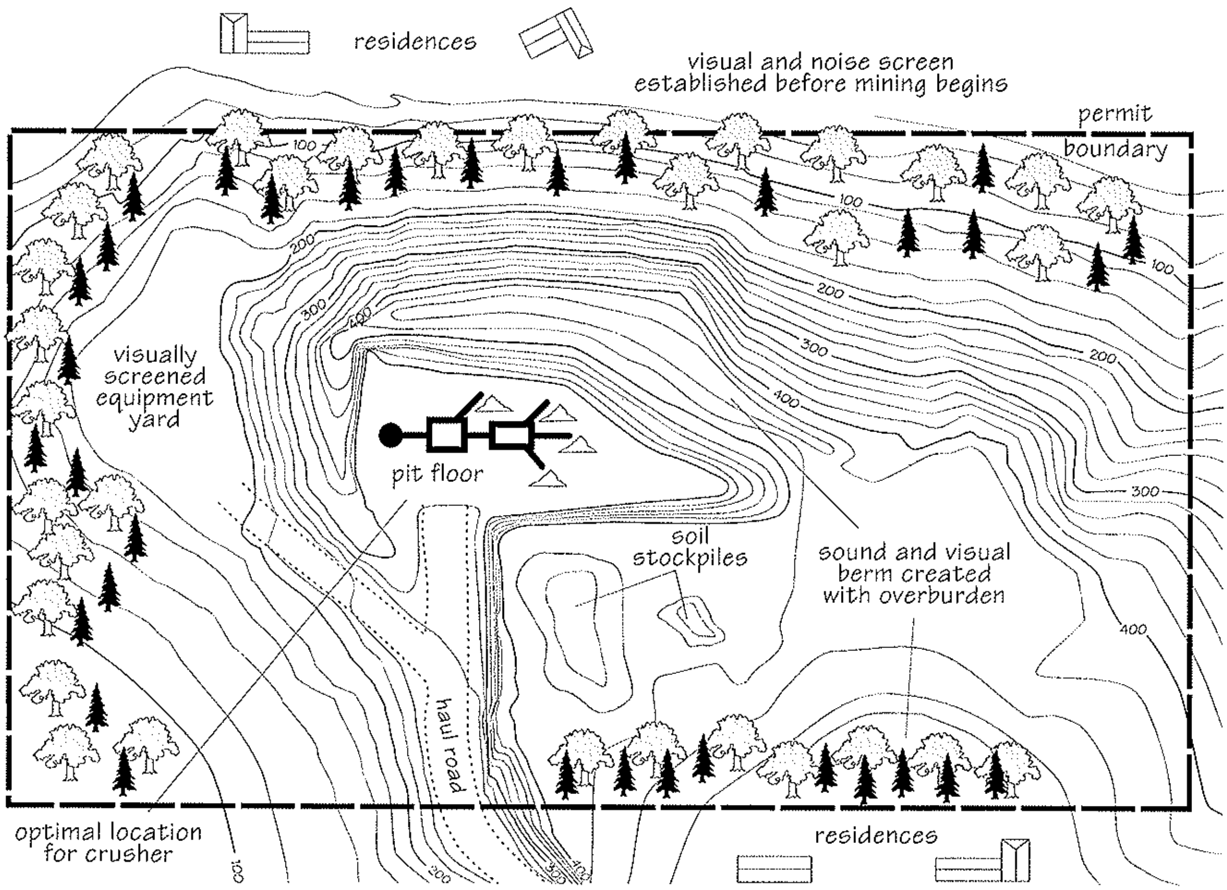


Figure 3.6. Visual and noise screening techniques used at a quarry site. Figure 2.11 shows the storm-water control system at the same site.

- Use existing topography as a noise and visual screen.
- Store overburden in berms along the site perimeter. Plant vegetation on them immediately to reduce noise.
- Plant trees and other visual screens—the denser and wider the better—well ahead of the mining to give them time to establish before they are needed.
- Plant tree barriers as close to the noise source as possible and between noise sources and the neighbors.
- Plant trees that will quickly grow tall enough to screen the mine. Plant shrubs to fill in the gaps, particularly if the foliage is sparse on the lower parts of the trees. Use evergreens if the site will be operated year round.
- Reduce noise by placing loud stationary equipment, such as the crusher, in an excavated area below the surrounding terrain.
- Surround the crusher with product stockpiles to reduce noise.
- Enclose the crusher in a building.
- Muffle the exhaust systems on trucks and other equipment.

Figure 3.7. Noise levels and human response for some common noise sources. (Modified from Barksdale, 1991.)

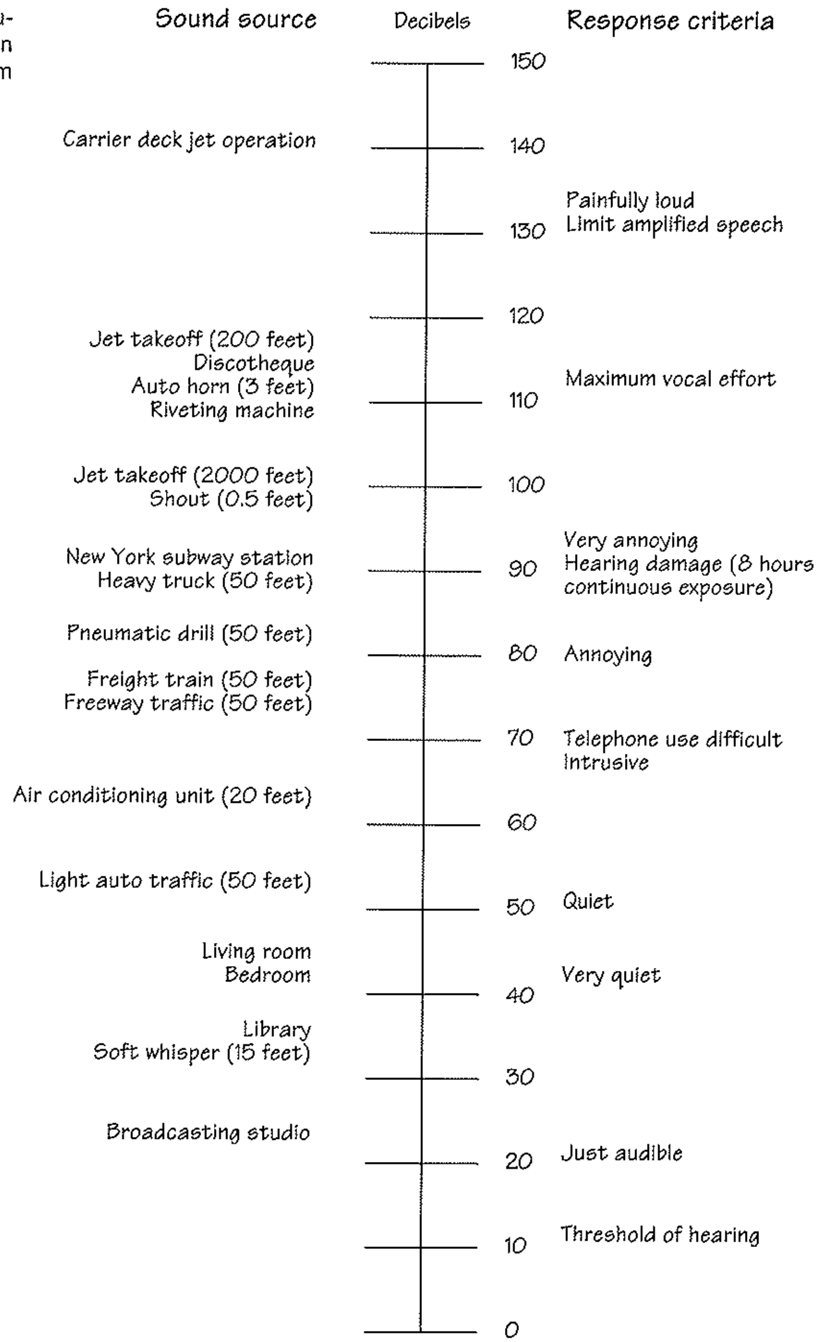


Table 3.1. Summary of noise measurements and projected noise levels in decibels (dBA) for common mining equipment (Barksdale, 1991)

Noise source	Measurements	Projected noise levels 1,000 ft	2,000 ft	3,000 ft
Primary and secondary crusher	89 dBA at 100 ft	69.0 dBA	63.0 dBA	59.5 dBA
Hitachi 501 shovel, loading	92 dBA at 50 ft	66.0 dBA	60.0 dBA	56.5 dBA
Euclid R-50 pit truck, loaded	90 dBA at 50 ft	64.0 dBA	58.0 dBA	54.4 dBA
Caterpillar 988 loader	80 dBA at 300 ft	69.5 dBA	63.5 dBA	60.0 dBA

- Use screens coated with rubber in the crusher, and line dump trucks beds with rubber.

How Noisy Is It? Figure 3.7 summarizes the noise level, in decibels (dBA), from some common sources. Table 3.1 summarizes noise measurements for common mining equipment.

Noise-Control Methods Noise-control measures, such as berms and tree barriers, can reduce the noise experienced by adjacent landowners by as much as 12 dBA, whereas earthen berms with vegetation can reduce noise up to 15 dBA, depending on the size and configuration of the berms, the type and density of vegetation, and the distance to the listener.

Visual Screens The least expensive visual screen is the existing topography and vegetation on the site. Plan to leave large buffer zones of trees and vegetation between the mining site and nearby roads and buildings. Narrower buffer screens can be created with vegetation (preferably native evergreens), walls, fences, or berms, although they are generally less effective than buffer zones, which rely on distance for their effectiveness.

REMOVING VEGETATION

In a well-planned operation, vegetation is removed from areas to be mined only as needed and is preserved when possible to screen the site and limit erosion that may result in turbid water discharge.

Disposing of Vegetation Grass and small shrubs can be incorporated into the topsoil stockpile, and larger material can be chipped and used as mulch or to add organic matter to the soil. Burial of large volumes of woody debris is permissible only in areas above the water table because anaerobic decomposition of woody debris produces nitrates, which can degrade water quality. Vegetation should not be buried in areas where building construction is planned because the soil may settle as the vegetation decays.

In Washington, a permit from the county health district is required for burial of more than 2,000 cubic yards of debris. If burning will take place, a burning permit may be necessary.

In Oregon, a permit from the Department of Environmental Quality is generally required for burial of debris and may be required for burning.

Transplanting Vegetation Bushes and small trees, together with some surrounding soil, can be scooped up using backhoes or front-end loaders with tree spades and transplanted to mined-out segments or areas to be used as screens. (See p. 7.9.) This technique is a cost-effective means of quickly establishing a natural appearance in reclaimed segments, introducing seed trees, and providing screening. These plants are already adapted to the area. Moving the soil along with the plant protects rootlets and microorganisms that are important to plant health. Additionally, the soil may contain seeds or shoots of other vegetation, which may spread across nearby areas.

Using Vegetation for Habitat

Vegetation that cannot be transplanted live can be set aside (with leaves, needles, and roots intact) for future use as fish and wildlife habitat. Placed in ponds, it can provide shelter for small fish, and collected into piles, it can provide shelter for small animals. (See Structures That Enhance Habitat, p. 4.12.) Salvaged coarse woody material, such as logs, should be distributed across a regraded area at the rate of about 8 tons per acre.

THE SOIL RESOURCE

Soil is one of the most important components of successful reclamation. Without soil, vegetation cannot be established. A typical soil is composed of approximately 45 percent minerals (sand, silt, and clay particles), 5 percent organic matter, and 50 percent pore space for air and water. Organic matter, air, and water in a soil allow it to support a tremendous amount of animal and plant life, most of which is invisible to the naked eye.

The word 'topsoil' is often used to describe a broad range of soil types. It may refer to high-quality river-bottom loams suitable for intensive agriculture or to the top layer of the soil resource, generally the most fertile slice.

In Washington, topsoil is defined in the reclamation law [RCW 78.44] as the "naturally occurring upper part of a soil profile, including the soil horizon that is rich in humus and capable of supporting vegetation together with other sediments within four vertical feet of the ground surface".

In Oregon, soil salvage requirements are determined on a site- specific basis.

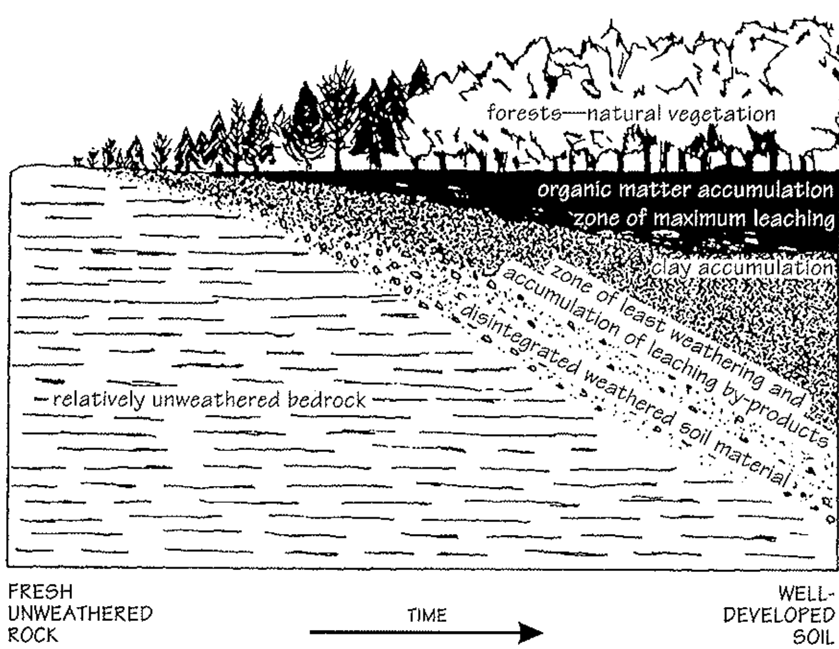


Figure 3.8. Soil profile development over time. Organic matter accumulates in the upper horizons, and the rate of accumulation is dependent on the type and amount of vegetation present. Clay and the by-products of chemical leaching accumulate in the lower horizons. (Modified from THE NATURE AND PROPERTIES OF SOILS, 8/E by Brady, ©1974. Reprinted by permission of Prentice-Hall, Inc., Upper Saddle River, NJ.)

Survey map, even though the depth of the individual soils in the group may be significantly different.

For mine development and reclamation, it is important to know how much soil is present and where it is in the project area. Order I and Order II soil surveys can provide this information. They are commonly available for areas of intensive agricultural production and can be obtained from the NRCS, DOGAMI, or DNR.

On-site soils investigations can be accomplished with a backhoe or a shovel and a hand auger. If the mine operator is doing the soil investigation, the NRCS, DOGAMI, or DNR should be contacted for information about soil types at the mine site and for recommendations on how to handle them. Understanding the approximate fertility level of each soil type and different soil horizons will contribute to wise use of the resource.

REMOVING AND STORING TOPSOIL AND SUBSOILS

Topsoil, subsoil, and overburden should be removed separately before mining and retained for reclamation. Placing several inches of soil with elevated organic matter over a lower quality subsoil material can make a dramatic difference in revegetation success. If adequate soils are not reserved to accomplish the approved reclamation plan, miners may need to import soil—often at considerable expense. It is important to ensure that soil resources are protected and used to their maximum potential, because few mine operations can afford to import soils.

The pore space in soil is essential for the proliferation of bacteria, fungi, algae, and soil-dwelling insects and worms. One gram of soil may contain as many as 3 billion soil bacteria. Consequently, soils must be properly handled and stored to protect both the pore spaces and soil organisms. Porosity, or structure, can be permanently damaged if soils are stripped when they are excessively wet or dry. This is a particular problem with clay-rich soils and loams. Stockpiling aggregate on top of a soil stockpile, compaction caused by the passage of heavy equipment, burial by overburden, or creation of large soil stockpiles can destroy the dynamic qualities of a soil.

Live Topsoiling

'Live topsoiling' means placing stripped soil directly onto an area that has been mined out or backfilled or on a reshaped surface for reclamation (Fig. 3.10). Soil should be spread with a minimum of equipment traffic to avoid compaction and protect pore spaces. Because the soil contains viable seeds and the soil organisms are relocated to the same ecological niche, revegetation can occur within a short time (Munshower, 1994).

In both Washington and Oregon, live topsoiling is recommended wherever possible. However, live topsoiling may not be practical, particularly in quarry operations where concurrent reclamation opportunities are limited or where the soil contains noxious or undesirable weeds and the site is being reclaimed to cultivated cropland.

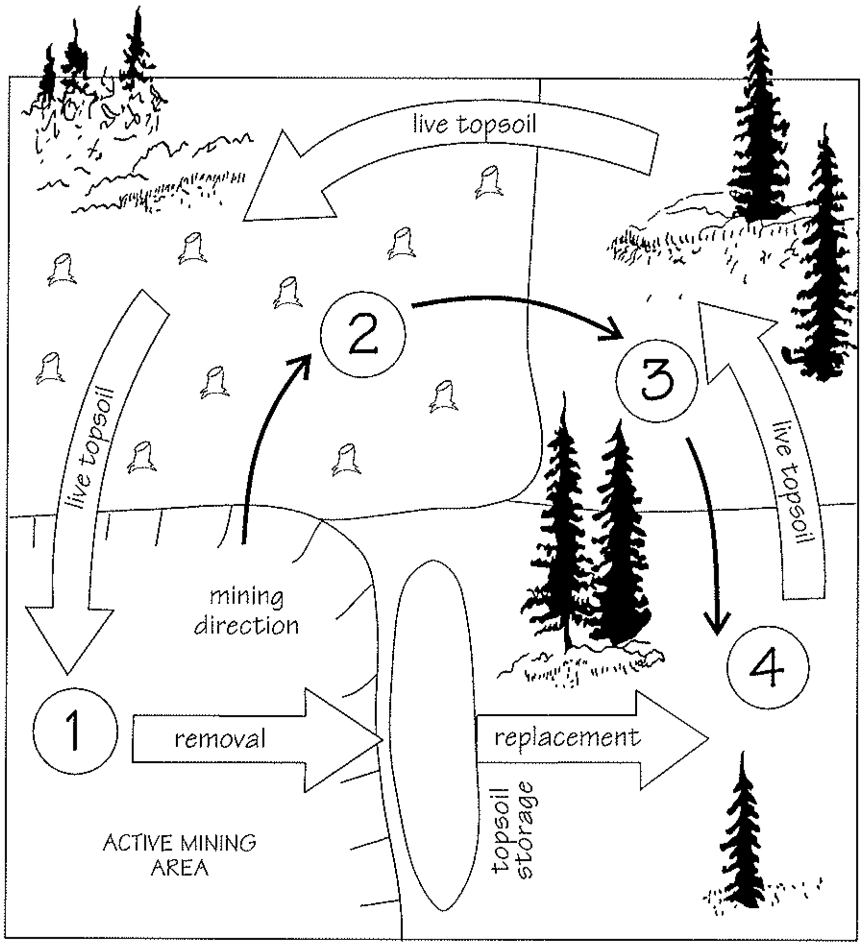


Figure 3.10. Topsoil handling in a four-segment mine. Segment 1 is the first to be mined. Its topsoil is removed and stored just inside segment 4. When mining of segment 1 is finished, topsoil is taken from segment 2 and place directly on segment 1 (live topsoiling). The topsoil from segment 3 is placed on segment 2. The topsoil from segment 4 is placed on segment 3. When mining is completed, the stockpiled topsoil from segment 1 is used to reclaim segment 4.

Stripping and Salvage

Before soils can be stripped and stockpiled, areas to be stripped and storage areas should be marked. (See Fig. 1.3.) Equipment operators who are stripping soils by horizon or separating soils from subsoils should have enough information to identify and segregate topsoil, subsoil, and overburden. A color change is typically the most obvious indicator of a change in soil horizons. Soil horizons that contain a fairly large amount of organic matter can generally be recognized in the field by their darker color and position at the top of the soil profile. Another technique is to identify stripping depths on survey stakes placed on 100 to 200 foot centers. It is best to move the soil only once. This also reduces operating costs.

By law in Washington [RCW 78.44], topsoil needed for reclamation cannot be sold or mixed with sterile soil unless specific authority has been granted in the permit documents. Subsoils capable of supporting vegetation must be salvaged to a depth of 4 feet and stored in a stable area if not immediately used for reclamation.

In Oregon, subsoil salvage depth must be adequate to accomplish reclamation according to the approved plan.

Constructing Storage Piles

Choosing an appropriate method for storage pile construction is also important. Continually driving heavy equipment over the soil while constructing scraper-built or end-dump piles can permanently damage soil structure and reduce the pore space essential for micro-organisms. This type of construction should be avoided.

Soil storage piles should be constructed to minimize size and compaction so soil organisms can 'breathe'. Extensive experience and research have shown that the size of soil storage piles can significantly affect soil viability (Allen and Friese, 1992). Soil storage piles should be no more than 25 feet in height. Available plant material such as grasses, shrubs, and chipped tree limbs should be incorporated into the piles. However, if large amounts of woody material are added, soil may become nitrogen deficient.

Soil storage piles should be revegetated. They are good areas to do test seedings to prepare for final revegetation. To retain soil microbes deep in the soil pile, it can be aerated by deep ripping, discing, and tilling every 2 or 3 years.

Recent research (Allen and Friese, 1992) has shown that soil microbes can be regenerated in sterile soils by spotting live soil throughout the area and by using inoculated trees and shrubs. Microbes will spread to other areas in a relatively short time (weeks to a few months).

WASTE AND OVERBURDEN DUMPS AND STOCKPILES

Large amounts of overburden exist at many mine sites, and operations frequently create large volumes of waste rock. Dumps and stockpiles are created to temporarily or permanently store both overburden and unwanted material separated from the salable product on the site, for example, crusher scalpings, oversize material, and reject fines. During reclamation, overburden and waste can be used to create landscape diversity. It is important to plan the location of overburden or waste piles so they can be used in reclamation.

Site Selection

Dumps and stockpiles can result in landslides and increased sediment load that may pollute nearby waters if they are not properly designed and maintained. Careful planning is necessary to ensure that dumps and stockpiles are placed in a geologically stable location, and that they can be revegetated successfully. Locations next to waterways or springs or seeps will probably not be acceptable. Ideally, from both construction and water-quality protection standpoints, these materials should be removed and placed only during dry periods.

Site Preparation

Storage sites for overburden and waste rock should be properly prepared. All vegetation, soil, and subsoil must be stripped from the site prior to dump construction. Any buried vegetation will rot; this soft material provides little resistance to sliding and increases the potential for downslope movement. Slash cleared from the stockpile area can be used below the stockpile to filter runoff. (See Slash Windrows and Brush Sediment Barriers, p. 2.12.)

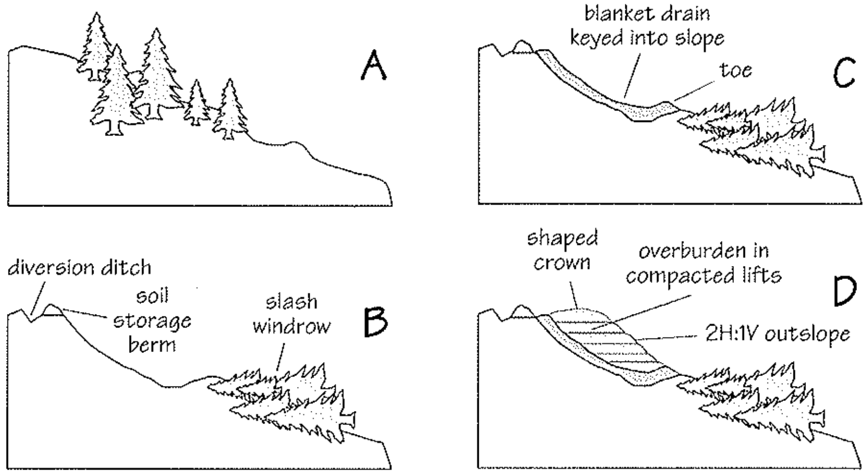


Figure 3.11. Proper procedures for waste dump construction. Trees removed from the site are used to construct a slash windrow to filter runoff. A blanket drain (a French drain that covers a slope instead of being confined to a trench; see Trench Subdrains and French drains, p. 2.20 and Fig. 6.6.) is laid down first to prevent the buildup of water, and the dump itself is constructed of thin, compacted layers.

Before overburden is stockpiled, all vegetation should be cleared, and the drainage for the pile must be prepared. Undrained and uncompacted fill dumped over vegetation without drainage is prone to mass wasting and landslides that waste topsoil. Soil placed over permanent waste piles will promote self-sustaining vegetation. (See Topsoil and Overburden Storage Areas, p. 3.6.)

Large dumps and stockpiles or those located on steep ground should have diversion ditches constructed above them (Fig. 3.11B). (See Contour and Diversion Ditches, p. 2.17.) A blanket drain should be installed on any slopes where drainage problems are anticipated (Fig. 3.11C). (See also Trench Subdrains and French Drains, p. 2.20.)

Dump and Stockpile Construction

Stability is important, particularly for dumps that will become permanent features. Both dumps and stockpiles should be constructed using thin, compacted layers (Fig. 3.11D). Before compaction, layers may be as thin as 12 to 18 inches. When compacted by rubber-tired equipment, they will result in a much more stable dump than one prepared by simply end-dumping or pushing with a bulldozer.

Dumps and stockpiles on hillsides or filling ravines need a properly constructed toe to key the pile into competent material. The toe should have a blanket drain to prevent the buildup of water. (See Fig. 6.6.)

Dumps and stockpiles should be shaped to prevent water from ponding. The top should be sloped to direct runoff to a drainage system and to avoid critical areas, or it should be crowned to disperse runoff around the perimeter. The slopes of the dump or stockpile should be constructed with appropriate runoff control structures. The top and overall shape should be rounded off to blend into the natural topography. (See Slope Stabilization, p. 6.6.)

Most final slopes should be between 2H:1V and 3H:1V. Generally, the flatter the slope, the more stable it will be and the easier to access for reclamation. Terraces should be constructed at 30-foot intervals vertically, or other methods of slope shaping should be use to reduce water velocities.

When shaping is complete, the dump or stockpile should be seeded and mulched to establish vegetation.

DUST CONTROL

Neighbors often complain about dust from mining operations. Dust is generated by the crusher, rock drills, and other mining equipment, and from disturbed areas, including haul roads and stockpiles.

In Washington, the Department of Ecology or the local air pollution control authority has review and permit authority over rock crushers, batch plants, fugitive dust emissions from mining operations, and haul roads. Contact these agencies for further information.

In Oregon, emissions from on-site processing require a permit from the Department of Environmental Quality.

Controlling Dust with Water

Controlling fugitive dust is usually a matter of frequent application of water or chemicals. Water trucks are typically used for conveying these liquids. However, sprinklers and irrigation pipe installed in the berms alongside haul roads can significantly decrease dust without the expense of using a water truck several times a day.

Controlling Dust with Chemicals

Chemical dust suppressants, such as magnesium chloride, are appropriate where water is in short supply. Most chemical dust suppressants require repeated application. There are numerous chemical dust suppressants designed for a variety of uses. The local and state water-quality agency can provide information about appropriate chemicals and how to apply them.

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4 Restoring Landforms

INTRODUCTION

Land shaping is an important but often underemphasized part of the reclamation process. Common objectives for land shaping include:

- minimizing erosion,
- reducing slope angles to provide stability for post-mining development,
- contouring aesthetically pleasing landforms to blend with the surrounding area,
- forming shapes and slopes consistent with the subsequent use planned for the site (Fig. 4.1),
- increasing revegetation success, and
- providing diverse wildlife and fish habitat.

SUBSEQUENT USE

Reclamation of a mine site, and thus its subsequent use, can be driven by high land values, zoning, and/or environmental protection and the state regulations that set minimum standards for reclamation and water quality.

In urban areas, high land values motivate miners to reclaim for intensive use. For example, in Portland, Oregon, gravel pits are typically backfilled with construction waste and developed as building sites. Building sites can also be developed directly without backfilling. Government-owned sites where the water table is high often become parks with ponds. In rural areas, less intensive uses such as wildlife habitat, agriculture, or timber production can also be profitable. (See Agricultural and Forestry Subsequent Uses, p. 7.17.)

Imagination and careful planning can yield a wide variety of landforms that make the site better for a specific use than it was prior to mining. For example, wetlands and fishing ponds can be created from rock quarries and gravel pits if proper water conditions exist. Many agricultural sites have been enhanced by selective gravel removal, making them easier to irrigate or till after gravel-rich knobs

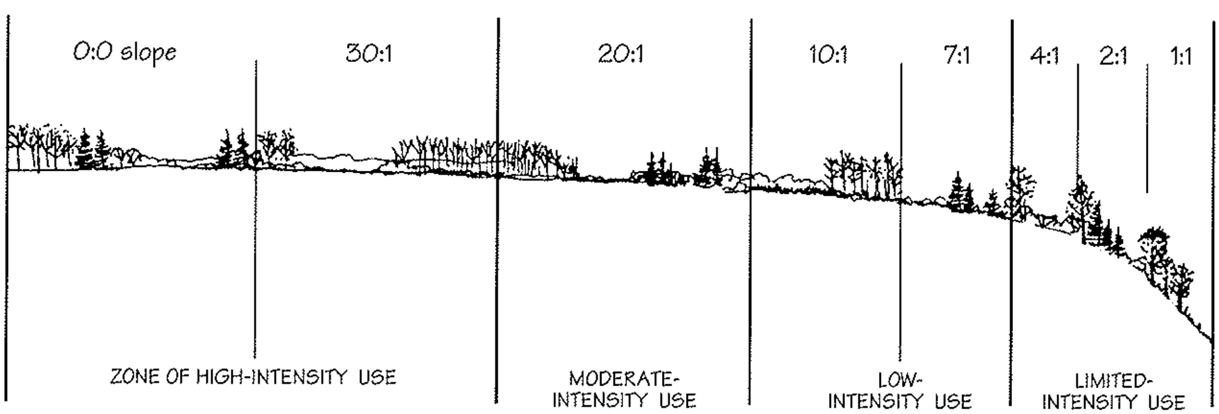


Figure 4.1. The steepness of the final slope strongly influences the intensity of proposed land use for reclaimed mine sites. Fewer options are available on steeper slopes. (From Green and others, 1992.)

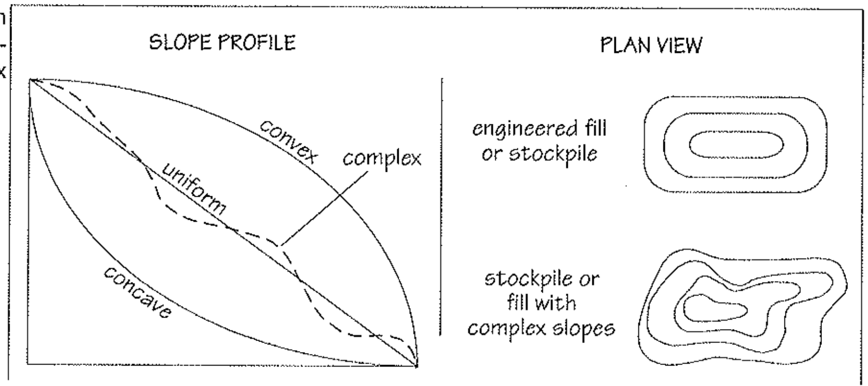


Figure 4.2. **A**, profile of common slope types. **B**, plan view of different stockpile designs. Complex slopes are preferred.

have been selectively removed from the fields. Mining can level areas of hilly topography making them more suitable for agricultural or industrial uses. In eastern Oregon and Washington, many of the mine sites developed on rangeland are returned to their previous condition by revegetation, generally with native species.

In Washington, RCW 78.44.031 identifies subsequent use as a criterion for guiding the reclamation scheme, while RCW 78.44.141 sets forth reclamation standards that must be met for various uses.

In Oregon, the subsequent use of the mined land must be compatible with the local comprehensive land-use plan.

SLOPE TYPES

Profiles of four basic slope types are shown in Figure 4.2. Convex slopes erode rapidly and yield the most sediment. Concave slopes are less affected by erosion and typically yield less sediment than convex slopes. The steepness of the slope is a major factor influencing the amount of sediment production. Surface-water runoff velocities are higher on longer, steeper slopes, and more soil particles are typically dislodged and transported. Sediment production on uniform slopes is intermediate between concave and convex slopes. Long uniform slopes should be avoided because they can be severely eroded in a single storm event.

☛ Complex slopes generally produce the least sediment and are the most stable. Complex slopes are preferred for mine site reclamation.

CREATING SLOPES

Where the goal of reclamation is to restore natural slopes that blend with surrounding landforms, sinuous slopes that are curved in plan and section and irregular in profile should be created (Fig. 4.3). Irregular slopes will intercept more runoff and reduce its velocity, trap seeds, and speed revegetation. Rectilinear slopes should be avoided because they are prone to sheet erosion and gullying and because they look unnatural.

Natural-looking topography can be achieved early on through a well-planned extraction operation and equipment operators who fully understand the post-mining use of the site. Sinuous slopes can be formed by mining to the prescribed angles (generally the most

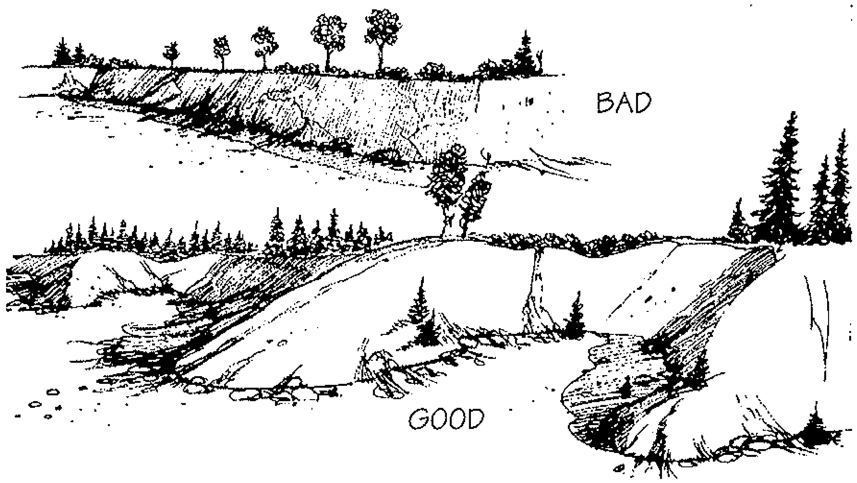


Figure 4.3. A key element in restoring topography is creating natural-looking slopes that blend with the surrounding landforms. Rectilinear slopes (top) are inappropriate for reclamation in unconsolidated materials. Slopes should be curved in plan and section and irregular in profile (bottom). (Redrawn from Green and others, 1992.)

inexpensive means of reclamation) or by using the cut-and-fill method, which requires a reclamation setback or material from overburden stockpiles. (See Reclamation Setbacks, p. 3.5.) Backfilling to create appropriate slopes can be the most expensive reclamation technique when it is done after mining.

A reclaimed site should consist entirely of stable slopes. A rule of thumb is that slopes are unstable if pioneer plants cannot establish themselves naturally, if the slopes ravel or show signs of soil creep and tension cracks, or if landsliding is noted. (See Identifying Unstable Slope Conditions, p. 6.3.) In general, unconsolidated materials are stable and can sustain vegetation at slopes of 3 feet horizontal to 1 foot vertical (commonly expressed as 3H:1V) (Fig. 4.4) (Norman and Lingley, 1992).

For variety, a few locally steeper areas (1.5H:1V to 2H:1V) may be created (if stable), especially if they mimic locally steeper slopes nearby. However, steep slopes greatly increase the potential for erosion. Long, steep slopes produce more and faster runoff and allow less infiltration than a series of short, gentle slopes separated by

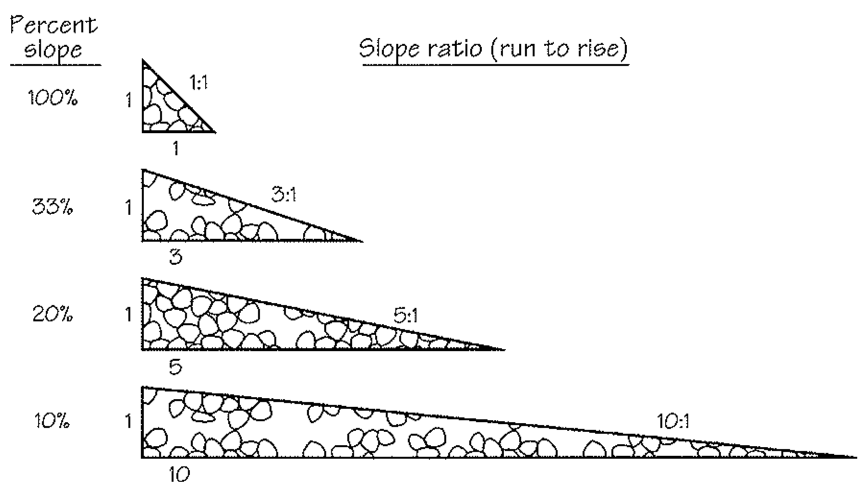
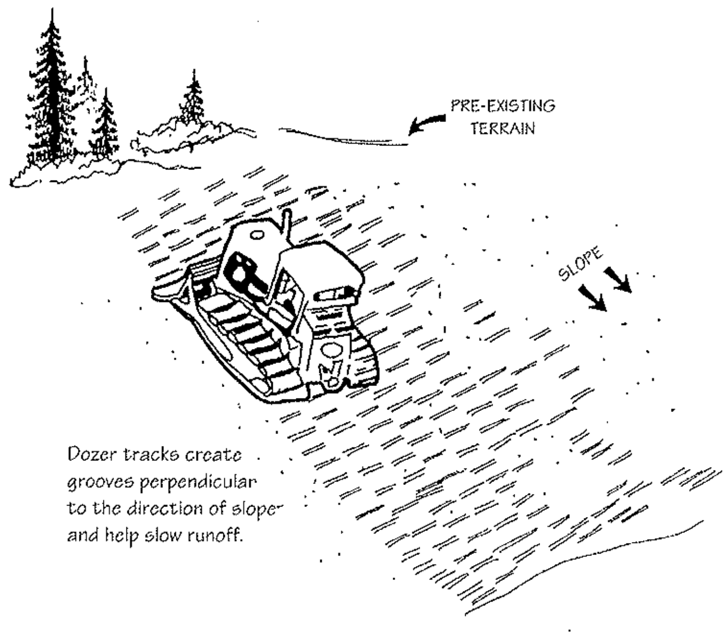


Figure 4.4. Slopes are expressed as the ratio of horizontal run to vertical rise. This diagram shows the percent slope of several common ratios. (Redrawn from Green and others, 1992.)

Figure 4.5. Dozer tracking can reduce runoff and enhance revegetation. Tracked equipment should be run up and down a slope, not across, to increase slope roughness. (Modified from Law, 1984.)



benches or terraces. New drainages or contour ditches should be established within the reclaimed area to contain the expected surface water runoff. Any water diverted during reclamation or land shaping should be directed to the drainage it occupied before mining to prevent drying up or flooding of areas downstream. This water should have approximately the same velocity, volume, and quality as the drainage it is entering.

Some guidelines for slope shaping are:

- Slopes steeper than 3H:1V should be kept shorter than 75 feet by creating breaks in slope, such as irregular terraces, berms, or basins. (See Figs. 2.3 and 2.4.)
- If the site is to be dry after mining, then pit floors should be graded to a slope of 2 to 5 percent to promote drainage.
- Some mounds, hills, and depressions can be left on pit floors to vary the topography for subsequent use (Norman and Lingley, 1992).
- In the final grading, bulldozers or other tracked equipment should be run up and down a slope, not across it, to increase slope roughness (Fig. 4.5). (Older bulldozers are generally unable to back up sand and gravel slopes steeper than 3H:1V.)
- Final slopes should be revegetated immediately to minimize erosion.

REGRADING

After the land has been shaped, it should be regraded to produce a rough, irregular surface, particularly on slopes (Fig. 4.5). This ensures that replaced soil is keyed into the substrate to slow erosion.

Roads, pit floors, and stockpile areas should be ripped at close intervals to provide drainage prior to replacing the soil. Placing a loose, friable soil over a compacted base does not increase soil moisture-holding capacity, drainage, or slope stability and will result in inadequate root development and penetration. A good rule of thumb is that ripper spacing should be less than or equal to the depth of ripping.

REPLACING TOPSOIL AND SUBSOIL

Understanding the soil resources of a site and the post-mining land use will lead to effective site development, using the best management practices for soil replacement. The type of vegetation planned for reclamation may dictate soil replacement depth. Deeper soils will be needed for agricultural production or establishing trees, particularly for timber production. More important than the depth of the replaced soil is how replacement is done. Soils should not be compacted. The less equipment is run over soils, the better. The most skilled and experienced equipment operators should be used for soil replacement—their skill will pay off.

Topsoil should be replaced on slopes as soon as possible after restoring topography. Soil horizons from stockpiles should be replaced separately in the proper order for best use of the resource. After the topsoil is spread, it should be tilled to construct a proper seed bed.

A minimum soil replacement depth of 12 inches of topsoil is recommended for reclamation for most post-mine uses. Upland sites may have soil depths, prior to mining, of 6 inches or less. On these sites, reject soil fines and rock fines produced during rock processing may be used to supplement pre-existing soil resources as a growth medium. Generally fines would be mixed with organic material and put in place before the topsoil is added.

The minimum recommended soil depth for timber production is 4 feet over rock and 2 feet over gravel or soft overburden to establish an effective rooting depth of 4 feet. Timber growth rates are generally directly related to the depth of the soil available.

A common problem in reapplying topsoil and subsoil is spreading them too thickly initially so that little is left for remaining areas. If the volume of topsoil at the site is limited, its application should be restricted to low areas or excavated depressions that will conserve soil, retain moisture, and catch wind-blown pioneer seeds. These low areas are also ideal sites for planting trees.

Varied soil replacement depths mimic natural soil-forming processes and should be incorporated into reclamation strategies where possible. Thinner layers of soil on the upslope areas and thicker layers on the lower slopes may naturally encourage different vegetation types. These parts of the slopes should be planted differently to encourage post-mining vegetation diversity.

In Washington, topsoil is defined as the naturally occurring upper part of a soil profile, including the soil horizon that is rich in humus

Chemical Fertilizers. If a quick cover of vegetation is needed to provide erosion control or if the soil or manufactured soil substitute is of poor quality, applying a fertilizer is recommended. Organic matter should be added to achieve a long-term response before seeding directly into soil substitutes. Avoid applying fertilizers in areas where runoff into streams could occur.

Some research shows that native plants do not respond well to chemical fertilization, and fertilizers are not generally needed for the long-term survival of these species. Fertilization tends to depress plant community diversity by indirectly decreasing desirable native plant populations such as warm season grasses and legumes. Fertilizers tend to give a competitive advantage to opportunistic species such as annual grasses and herbaceous plants, many of which are weeds.

RESTORING DRAINAGE

Where the pit or quarry is mined below the water table or surface drainage collects on the mined property, productive ponds and wetlands can be formed with careful water management.

Where appropriate to the subsequent use, a pond creates additional plant and habitat diversity, even though it may contain water only on a seasonal basis. Shallow process-water ponds, as well as low places on excavation floors and in stockpile areas at upland sites, can be developed as seasonal wetlands, even in arid areas east of the Cascades.

Extraction ponds (ponds being mined for gravel) and some upland rock pits with a permanent water source make ideal sites for constructing wetlands if the water table is shallow. Sediment from washing and screening rock can be deposited to form shallow deltas that, when combined with the permanent water supply, can easily be revegetated with wetlands species.

CREATING PONDS FOR WILDLIFE

Ponds for wildlife habitat should have irregular outlines (Fig. 4.6). The bottom of the pond should also be irregular so as to offer a variety of habitat possibilities for plants, bottom dwellers, and fish (Fig. 4.7). Both water deeper than 10 feet and benches and bars with water depths less than 2 feet should be provided. As a general rule, 25 percent of the pond should be less than 2 feet deep, 25 percent 2–6 feet deep, and 50 percent deeper than 10 feet. Water deeper than 15

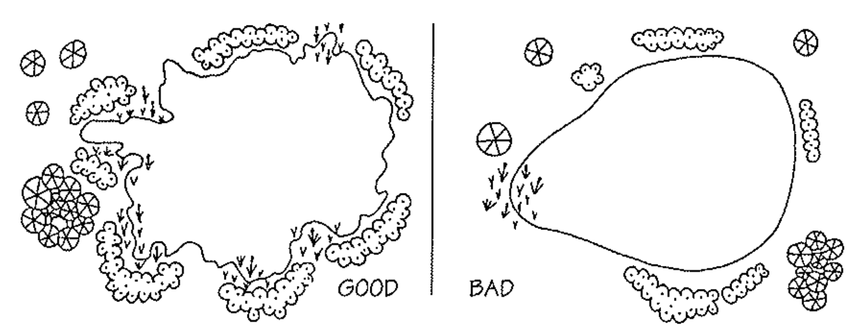


Figure 4.6. The shoreline of ponds used for wildlife habitat should be irregular and planted for cover with a mixture of open meadows and shrubs in the surrounding area. The shape of the pond on the left is better suited to supporting wildlife than that of the pond on the right. (Redrawn from Szafoni, 1982.)

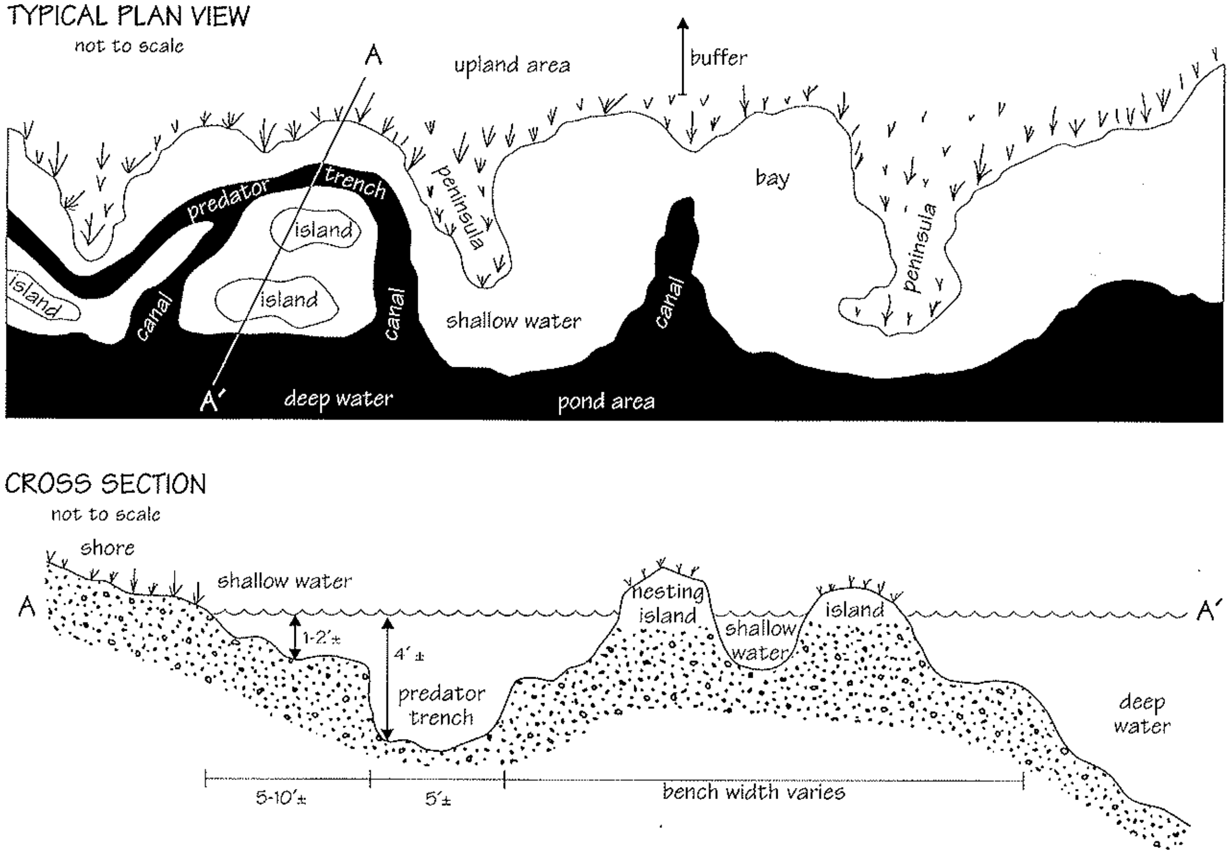


Figure 4.7. Plan view and cross section of a well-designed irregular wetland or pond shoreline. Note the large areas of shallow water. Steep slopes along parts of the shore will discourage the growth of wetland plants and provide clear access to the pond. Bird nesting sites are provided. The trench discourages predators, but the shallow water offers sites for food for fish and cover plantings. Islands can be constructed from fill, unmined material, or sediments saved from digging the trench.

feet can provide a cool summer refuge for fish (Norman and Lingley, 1992).

In-Water Slopes

Slopes should be very gentle, 5H:1V or flatter, to allow development of wetland plant species (Fig. 4.8). In general, the more shallow areas, the better. Slope variations will enhance the plant diversity in created wetlands.

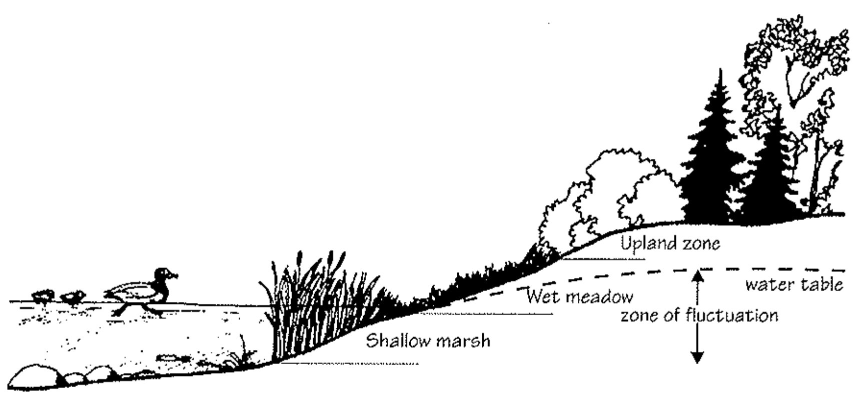


Figure 4.8. Slope variations will enhance the habitat diversity of created wetlands. To successfully establish wetland vegetation, seeds and transplants must be placed in sites with the correct water depth. (Modified from Green and others, 1992.)

7 Revegetation

INTRODUCTION

Mines west of the Cascades in Washington and Oregon are fairly easy to reclaim because they typically have deeper soil horizons due to abundant precipitation. Mined areas east of the Cascades are more difficult to reclaim because soils are thinner, the region is drier, and temperatures are more extreme. Therefore, successful revegetation in the eastern part of the state is more dependent on proper plant selection, appropriate timing of planting, adequate fertilization, presence of organic matter in the soil, and irrigation.

West of the Cascades, even though revegetation can be accomplished without separately salvaging and replacing the soil because of the abundant moisture, species diversity will be limited until a soil horizon rebuilds, and this may take decades. Additionally, plant vigor may quickly decline after the first planting if ample amounts of organic matter are not provided or supplemental chemical fertilizers are not added to initiate the cycle of plant growth, decomposition, and nutrient recycling. Amounts of fertilizer should be based on site-specific needs determined by soil tests. (See Amending or Manufacturing Soil, p. 4.6.)

Natural plant communities develop through a succession from pioneer species to climax species (Fig. 7.1). Pioneer species are aggressive and tend to grow rapidly to fill disturbed areas, whereas climax plant communities develop over longer periods and tend to be slower growing. Each phase in the plant succession prepares the ground for the next. Nitrogen-fixing legumes, shrubs, and trees may play a crucial role in soil reconstruction.

It is tempting, particularly with trees, to plant only climax species (for example, Douglas fir) even if the ground is not fully prepared. However, natural communities develop slowly in a succes-

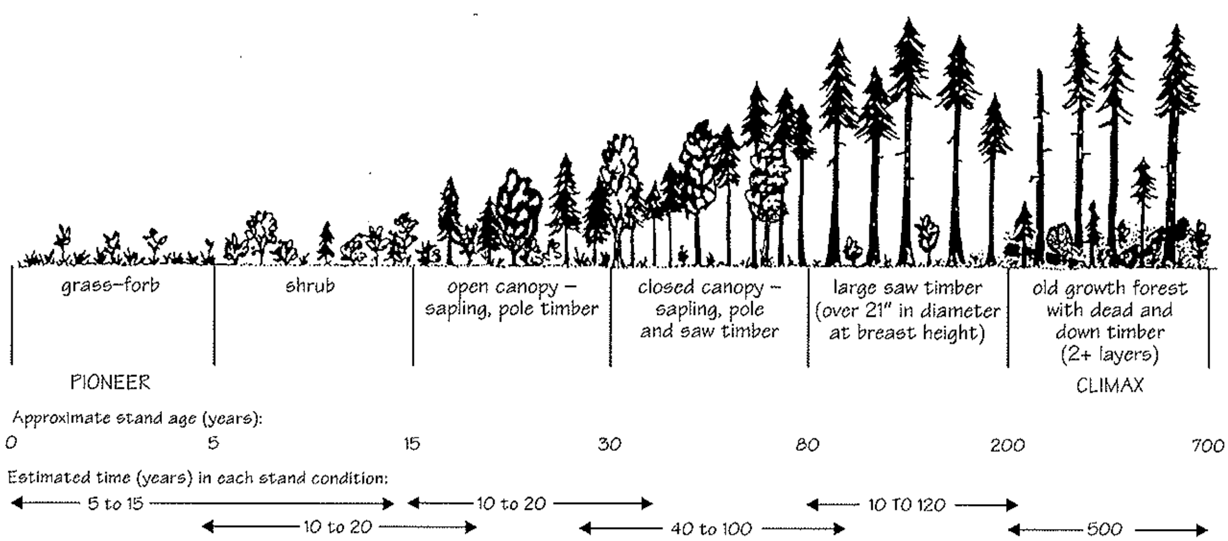


Figure 7.1. Sequence from pioneer to climax vegetation for a Douglas fir forest after clear cutting. The same recovery process occurs naturally in mined areas. (From Brown, 1985.)

sion. Mimicking this progression during reclamation is impractical, but planning a phased succession for both ground cover and trees will establish a good climax mix (Norman and Lingley, 1992).

Grasses may be appropriate as either quick pioneer soil builders under developing woodland or as climax species for rangeland. Pioneer trees will act as fast-growing nurse trees for slowly maturing forest trees that find it difficult to establish in disturbed ground or in areas with no canopy.

Revegetation is important because it:

- reduces erosion,
- reduces storm-water runoff,
- provides habitat and forage for animals,
- reduces visual and noise impacts,
- reduces reclamation liability, and
- increases the value of property by returning it to agriculture, forestry, or other beneficial use.

Note: While vegetation significantly reduces erosion, it cannot prevent slippage of a soil that is not stable due to improper placement techniques. For example, soil placed on steep slopes requires additional stabilization techniques to ensure revegetation success. (See Chapter 6.)

SPECIAL PROBLEMS AT MINE SITES

Plants need fertile soil, sunlight or protection from the sun, and water to thrive. Mining often removes fertile soil. (Salvaging and replacing soil is discussed in The Soil Resource, p. 3..) Even in the best of conditions, plant growth cannot be guaranteed immediately after mining. Mine sites generally offer harsh conditions that make it difficult to establish vegetation. Some common problems affecting revegetation are:

- high surface temperature (especially on south-facing slopes),
- steep slopes,
- poor water retention,
- lack of adequate soil,
- erosion before seedlings establish,
- only limited periods during the year suitable for seeding,
- lack of water
- poor conditions for germination,
- slopes inaccessible to equipment, and
- grazing impacts.

By being aware of these potential problems, an operator can improve the quality of reclamation and save money by being successful on the first attempt. Revegetation early in the reclamation process is critical because it may take several seasons to establish widespread healthy vegetation. For example, by planning ahead and choosing appropriate techniques, an operator can place young trees in strategic locations to provide a significant visual screen within a few years.

SUCCESSFUL REVEGETATION STRATEGIES

Trial-and-error revegetation that relies on natural precipitation and hardier natural pioneer species (such as alder) is generally less expensive, uses less labor, and is more effective than waiting until mining is complete to plant the entire site with commercial plants. Segmental mining results in fairly small areas on which to begin this process. Test plots can be used to determine which species will be successful. Areas in which plants fail to establish can be reseeded with more appropriate vegetation (Norman and Lingley, 1992).

Steps to successful revegetation of mined land can be summarized as follows:

- *Plan before you start.* Know in advance what has to be done, but allow for modification if necessary.
- *Strip and store the topsoil, subsoil, and overburden separately.* Minimize handling and storage.
- *Strip a small area at a time.* Strip only the area that can be revegetated within a reasonable time to minimize erosion.
- *Move soil materials under dry conditions (June–September).* Wet soils are easily damaged.
- *Carefully calculate volumes of soils necessary for reclamation to ensure that sufficient amounts are retained.*
- *Reclaim the mine in segments.* Segmental reclamation allows for 'live topsoil' replacement, which often enhances revegetation.
- *Shape slopes for subsequent use.* Slopes between 40H:1V and 20H:1V are desirable for agriculture purposes. For forestry, the slopes can be steeper.
- *Replace overburden (if any), subsoil, and topsoil in the correct sequence.*
- *Eliminate compacted soil.* Where compaction has occurred, rip the mine floor as deeply as possible before reapplication of stored overburden, subsoil, and topsoil.
- *Develop a post-reclamation management program.* Choose plants that increase soil fertility and improve soil structure, such as deep-rooted nitrogen-fixing legumes, for the first plantings. Monitor progress and determine why plants did not thrive.
- *Get good advice from the experts.* Take advantage of the expertise available in various government agencies and though local farmers.
- *Be patient.* Successful revegetation may be a slow process taking several seasons or years.

roots are above the water table. Table 7.1 is a plant selection guide listing plant growth characteristics, requirements, and planting conditions necessary for propagation. (For more information on wetlands vegetation selection, see Vegetation, p. 4.15.)

AGRICULTURAL AND FORESTRY SUBSEQUENT USES

Often the post-mining use calls for commercial agriculture or reforestation. For those situations, the operator may want to plan reclamation with a professional forester or an extension service agent. The Oregon Departments of Forestry or Agriculture and the Washington Department of Natural Resources are other good sources of information.

Topsoil

For a mine site to be reclaimed for agriculture or forestry, topsoil must be replaced. Operators who have not saved topsoil and subsoil for reclamation will generally not be able to use the site for agriculture or forestry because topsoil replacement would be too costly.

Other conditions to avoid are excessively stony soils resulting from mixing soils and subsoils with the sand and gravel deposit, compacted pit floors, and inadequate treatment of applied topsoil and subsoil to ameliorate compaction problems. In addition, slopes steeper than 3H:1V will not be as productive for agriculture or forestry.

Segmental reclamation and live topsoiling increase the chances of productive agricultural and forestry land after mining. Detailed knowledge of the sand and gravel deposit is also necessary. The composition of the pit floor is an important component in developing a reclamation plan. For example, if the pit floor is on impermeable or compressible silty and clayey material, severe soil compaction will occur, soil drainage will be impeded, and a perched water table causing excessive wetness will result.

Factors to Consider

From an agricultural standpoint, at least 8 inches of topsoil with suitable subsoils or a minimum of 3 feet of combined topsoil and subsoil overlying a zone saturated with water is needed for most plants during the growing season. Therefore mineral extraction should not occur below the water table. Knowledge of the hydrologic conditions of the site is necessary for reclamation to be successful.

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