CHAPTER 9

LONG-TERM SITE MANAGEMENT

Frequent inspection and maintenance of project sites is important so that any damage that occurs can be repaired before it progresses to major failure. Streambank erosion inventories can be updated by identifying new erosion sites and re-evaluating old sites. It also provides an opportunity to identify potential sites for habitat improvement that might be implemented during routine maintenance operations. Inspections also provide an opportunity to observe untreated banks.

9.1 INSPECTIONS AND MONITORING

Regular periodic inspections should be made after bank stabilization measures have been installed. All projects should be inspected at least annually; newly installed projects should be inspected after the first major high flow. Each project should be monitored to evaluate changes occurring at the site. Ground photos should be taken periodically at established photo points. These may be supplemented by aerial photos on large projects. Photos should be taken at least twice a year, ideally in the spring and in the fall. To allow comparisons among repeated photographs, photographs should be taken during low water periods and at corresponding water levels. Overlays made from these and subsequent photographs will assist in identifying changes. Photogrammetric measurements can then be made on the overlays to document the extent of plant growth or areas lost to erosion after project installation. If post-project erosion is present, an evaluation of its mode and cause should occur while collecting ground photos.

9.1.1 ROCK STRUCTURES

Most conventional bank protection structures fail because of undermining. Careful inspection of the toe area can help prevent failures by identifying damage before it progresses to failure. Inspection of the toe zone should occur during low water periods when the toe is more likely to be exposed to view.

Areas below the ordinary high water mark should be inspected for evidence of stone movement along the toe or streambank erosion that could undermine the toe. The following conditions may suggest a need for repairs:

- Areas of bare soil within the toe zone;
- Horizontal displacement of individual rocks or sections of rock within the toe zone;
- Scour along the toe that results in loss of support to the upper bank;
- Evidence of bed degradation, headcuts, or scour holes that might undermine the toe; and
- Movement or loss of large rock protecting the foundation of cribwalls or movement (settling, tilt, or horizontal displacement) of the structure.

The loss of rock from rock revetments and levee faces should be monitored at least yearly (prior to the flood season) and after each major flood. This inspection may include quantifying the loss of rock from the face and toe of the facility. Estimates of missing toe rock can be made visually from the bank or boat. Deep depths or turbid water along the toe area may require the use of a fathometer to delineate the extent of erosion.

9.1.2 VEGETATIVE SYSTEMS

The development of the vegetation should be monitored and correlated, at least visually, to the degree of or lack of erosion occurring on the treated streambank. Plantings are assumed to be effective if the vegetation is growing well in all bank areas of the project and aerial or ground

reconnaissance suggests erosion is not occurring. The frequency of monitoring plant survival should be a minimum of once per growing season (preferably near the end of summer) for at least three consecutive years. Vegetation, especially unrooted cuttings, may take three years or more to become fully established.

Successful plant establishment, which may be defined by the percentage survival and total ground cover, may vary among projects. General success criteria are listed in Table 9.1. Common problems encountered in establishing vegetation, their diagnosis, and general remedies are listed in Table 9.2. Coppin and Richards (1990) offer the following advice for evaluating growth performance of vegetation:

> Color is a widely used indicator but must be interpreted with care. Yellowing leaves indicate nutrient deficiency, particularly of nitrogen, which may be due to infertility in the soil. It can also be due to impaired functioning of the roots in absorbing nutrients, resulting from low or high pH, waterlogging, soil compaction or disease. Brown and papery leaf edges indicate that the plant is suffering from drought, either directly through lack of soil moisture or indirectly through the inability of the roots to exploit a sufficiently large volume of soil. Competition from surrounding dense vegetation is also a frequent cause of drought stress. Dark green, or sometimes reddish, leaves associated with poor growth may indicate phosphate deficiency. In unseasonably cold weather many plants take on a bluish or reddish tinge, which disappears when normal conditions return.
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> Poor growth is caused by many factors but is usually associated with poor soil and root development. Trees that put on very little shoot growth in the first year after planting will probably never grow well, as the root system may by permanently damaged. Pruning back the top growth to reduce the demands on the faltering root system can sometimes help.

Woody plants should be monitored for survival and vigor in each bank area on the treated streambank. This may be accomplished by marking 10 percent of the woody vegetation in each area with a stake. Each marked plant is revisited

Table 9.1 Evaluation criteria for streambank vegetation.

CATEGORY	DESCRIPTION
Good	Ninety (90) percent or more of the bank is protected by vegetative cover and at least seventy-five (75) percent of the cover consists of woody plants. Plants are growing vigorously (new growth, green stem and leaves, no yellowing of leaves).
Fair	Fifty (50) to ninety (90) percent of the bank is protected by vegetative cover and at least fifty (50) percent of the cover consists of woody plants. Plants are growing, but stable (no new growth, just green).
Poor	Less than fifty (50) percent of the bank is protected by vegetation and less than twenty-five (25) percent of the cover consists of woody plants. Plants are declining in vigor (stem deteriorating, leaves dropping, yellowing of leaves).

Table 9.2 Common problems of vegetation establishment, their diagnosis and remedies. (Adapted from Coppin and Richards 1990.)

SYMPTOMS	CAUSE	DIAGNOSIS	REMEDIES
Ground covers			
Legumes disappear	Acidity	pH <5.5	Liming
	Low phosphorus	Extractable P test	P-fertilizer
	Grass competition	Grass height > 12 in.	Graze or cut
Poor growth, prone to drought in summer; shallow rooting; pale color	Soil compaction	Packing density [1] > 1.75 (mg/m^3)	Cultivation
	Waterlogging	Water table <15 in. from surface	Drainage, use tolerant species
Poor growth, moribund	Nutrient deficiency	Extractable nutrient low	Add fertilizer, use legumes
		Low cation exchange	Add organic ameliorants
	Acidity	pH <5.5	Add lime, use tolerant species
	Drought	Low AWC[2], coarse soil texture	Add organic ameliorant
Thick matted grass, moribund, no decomposition	Nutrient deficiency	as above	as above
	Acidity	as above	as above
	Low N in vegetation	C/N ratio >25	Add N-fertilizer, grazing
Growth too dense and vigorous	Soil too fertile	Presence of aggressive weed species	Cut regularly and remove herbage to reduce soil fertility
Trees and Shrubs			
Failure to establish	Poor stock or bad handling and planting	All site factors are satisfactory	Replant
Dieback or death, poor root growth, foliage colored or sickly	Excessive soil compaction	Packing density >1.75 (mg/m^3)	Cultivate
		Planting pit impermeable	Replant
	Waterlogging	High water table < 2 ft. deep	Drainage
Poor growth rates	Nutrient deficiency	Foliar and/or soil analysis	Fertilize
	Acidity	pH outside preferred range	Lime
	Drought	Low rainfall; low AWC, coarse soil texture	Mulches; watering
	Competition from ground cover	Dense vegetation around trees	Amelioration with organic matter Mulch or herbicide to suppress
Damaged, disfigured or discolored foliage, buds and stems	Disease	Symptoms of fungi or insect attack	Pest control; prune or fell affected trees, remove and burn

[1] Packing Density = Dry bulk density of soil in situ (mg/m^3) + (0.009 x % clay)
[2] AWC = Available water capacity

periodically to decide whether it is live or dead and observe the vigor of its growth. The percent survival can be determined by dividing the number of live plants by the original number staked. Vigor can be determined subjectively by assigning each marked live plant a vigor class suggested in Table 9.1. In general, growth should be continuous, with no open spaces greater than two feet in dimension. Areas smaller than this will generally fill in and not hamper the integrity of the vegetative system.

A periodic measurement of ground cover will determine if vegetation, herbs in particular, is successfully spreading across the site. Measurements of stem densities are needed to find if woody cuttings and fascines are sprouting and adding to the vegetative composition and density. Both factors can be measured by establishing one square meter plots randomly throughout the bank area until a one percent sample is achieved. These plots should be permanently established immediately after planting and delineated by well-marked stakes.

Ground cover for each plot can be determined by using visual estimates of live vegetation in different cover classes. Each cover class is assigned a number and recorded on the data sheet for that plot. Once the percent ground cover has been determined for each plot, composition by dominant species is estimated and a list of the dominant plant species for each plot prepared. Stem densities of woody plants are determined by species for each plot by counting the number of stems. This gives an estimate of number of stems per species per square meter.

9.2 MAINTENANCE

Damage to the toe zone usually is repaired by adding rock or by replacing lost or displaced rock. Rock can be individually placed with equipment having a "rock-picker" implement or dumped; when possible, individual placement is recommended because it allows better keying. Large rock, D_{100} or larger, should be used for replacement. If the filter layer has been damaged, it should be repaired before the rock is replaced. Depending on the severity of undercutting, scour holes that might undermine the toe of a structure may need to be filled with rock. If the integrity of the structure is threatened, the cause of the scour should be corrected as well.

Permanent access roads for inspection and maintenance should be provided at the time projects are constructed. Access roads should be maintained to allow movement of heavy equipment and materials that might be needed in repair work. In situations where a setback levee has been constructed, the bench area functions as an access route for heavy equipment when toe key repairs are required. Locked gates may be desired to restrict public entry to dangerous or sensitive areas.

Most plant losses occur the first year with fewer losses in successive years. Irrigation, disease and pest control, and replacement of damaged structures improves slope stabilization projects by increasing plant density and allowing identification and prompt correction of minor damage. Vegetative repairs should be performed during the dormant season following the first year's growth. Dead plant material should be replaced where possible. Seriously damaged areas (e.g., gullies, rills, and washouts) should be repaired by restocking or reconstruction. Insect and disease infestations should be controlled.

Other procedures for maintaining existing vegetation involve pruning, selective cutting, and selective spraying. Pruning is usually performed to eliminate shade and encourage growth of plants that need direct sunlight. Undesirable plants are removed by selective cutting.

A program of selective vegetative management should be developed to preserve vegetation with good existing habitat value and to promote development of fish and wildlife habitat in selected areas. Vegetation management strategies should identify targeted fish and wildlife species, plant species with appropriate habitat characteristics, and a vegetative management plan that will preserve and promote growth of the selected plants. Chapter 6 provides information about the habitat value of various plants. Because habitat food and cover values depend on plant form and growth stage, habitat programs often take longer to estab-

lish than other project components (up to 10 years is not uncommon).

In recent years restrictive federal vegetation standards for revetments have been relaxed to allow for some growth of woody vegetation. The Portland District of the Corps of Engineers (USAED, Portland, 1980) revised maintenance criteria for Willamette River revetments following the discontinuation of broadcast spraying for vegetation control. The adopted selective clearing criteria called for removal of woody growth two inches or more in diameter or six feet or more in height and the removal of all vines. Similarly, the Seattle District (USAED, Seattle, 1982) adopted a modified vegetative management plan for riprapped levee slopes on the Green River in King County that allows dogwood, willow, and wild rose on the upper portion of the levee. Similar changes are being developed for the Sammamish River.

RECOMMENDED SOURCES FOR ADDITIONAL INFORMATION

Coppin, N.J. and I.G. Richards. 1990. Use of Vegetation in Civil Engineering. Butterworths. London, England.

Gray, D.H. and A.T. Leiser. Biotechnical Slope Protection and Erosion Control. Van Nostrand Reinhold Company. New York, N.Y.

Schiechtl, H. 1980. Bioengineering for Land Reclamation and Conservation. University of Alberta Press. Edmonton.