APPENDIX A

AVAILABLE MANAGEMENT TECHNIQUES

TABLE OF CONTENTS

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Appendix A: Available Management Techniques

A wide range of techniques is available to create, protect, enhance, and manage aquatic habitat both directly and through those riparian and upland processes which influence aquatic habitat. This section summarizes some of the primary techniques that may be implemented under the Model Watershed Program and other efforts under the Northwest Power Planning Council to mitigate and restore lost fisheries habitat in the Columbia River Basin. USEPA (1993) is a primary source for many of these techniques. The techniques are not necessarily appropriate for all watersheds or for BPA funding; indeed, misapplication of these techniques could result in worsened habitat conditions. However, all of these techniques can be a viable part of a sound watershed management plan, and properly implemented alone and with other techniques, can result in improvements in the quantity and quality of aquatic habitat.

The techniques are classified in this EIS into 11 major categories:

- In-channel Modifications and Habitat Enhancement Techniques
- Special Vegetation Treatment Techniques, including Techniques for Wetlands and Riparian Areas
- Agricultural Management Techniques--Crops
- Agricultural Management Techniques--Irrigation
- Agricultural Management Techniques--Animal Facilities
- Agricultural Management Techniques--Grazing
- Road Management Techniques
- Forest Management Techniques
- Community Development and Management Techniques
- Recreation Management Techniques
- Mining and Mine Reclamation Techniques

For each major category, a series of specific management techniques is listed and described below. Each technique includes an overview of the technique followed by a brief listing of some general benefits and drawbacks inherent to the technique.

1 IN-CHANNEL MODIFICATIONS AND HABITAT ENHANCEMENT TECHNIQUES

1.1 MODELING THE EFFECTS OF RIVER CHANNELIZATION

1.1.1 Overview of Technique

Use available computer models to evaluate effects of proposed channelization and channel modification projects on physical channel characteristics and flow regimes. Similarly, hydraulic models can be used to aid in the design of natural channel conditions for the restoration of channelized reaches and the removal of control structures. Simulation models can integrate physical transport processes and other parameters over time to aid in decision making during planning level evaluations.

1.1.2 General Benefits

- both physically-based and empirical models force consideration of a variety of factors (input parameters)
- choice of models already developed and in use for many applications
- allows proactive management through predictive capability of modeling

1.1.3 General Drawbacks

- assumptions behind a model may not apply to a site-specific project
- can be difficult and expensive to apply to smaller projects

1.2 PROHIBIT FURTHER CHANNELIZATION

1.2.1 Overview of Technique

Discourage or prohibit any projects that result in increased channelization including channel relocation, dredging, permanent bank armoring with rip-rap or concrete, and disruption of high-flow or side channels.

1.2.2 General Benefits

- maintains naturally operating processes necessary to creation and maintenance of channel structure and fish habitat
- natural channel systems usually result in an optimum configuration unless the river regularly leaves the channel or creates new channels.
- maintains a greater quality and quantity of fish and riparian habitat

1.2.3 General Drawbacks

- some heavily impacted or less resilient systems may require very long periods of time to recover
- dynamic river beds with extreme floods or new channel development are unpredictable

1.3 RESTORATION OF CHANNELIZED RIVER AND STREAM REACHES

1.3.1 Overview of Technique

Channels which have been modified or "trained" using control structures to meet flood control and other land use concerns often experience a reduction in the quantity and/or quality of fish habitat they contain. Where land uses have changed or occur in areas where fish habitat restoration is a priority, restoring channelized reaches may be an appropriate technique.

This technique involves the careful design of natural channel conditions, the removal of control structures (dikes, levees, structural bank protection, other engineered or created stuctures), and the reclamation of the natural, active floodplain. Good design considers data and results from current and historic aerial photos, maps, hydraulic models, original channelization plans, local knowledge of historic conditions, and recent literature. Heavy equipment excavates the current conditions into a chanel and floodplain which mimics natural conditions for gradient, width, sinuosity, and other hydraulic parameters. Bioengineering methods are employed to help stabilize the banks and floodplain as the new channel performs minor self-adjustments during bankfull (and larger) flood events.

1.3.2 General Benefits

- restores naturally operating processes necessary to the sustaining of channel structure and fish habitat
- natural channel systems usually result in an optimum configuration unless the channel frequently convulses (high sinuosity or braided channels)
- maintains a greater quality and quantity of fish and riparian habitat

1.3.3 General Drawbacks

- conflicts with existing land uses
- may require significant land area (channel and floodplain)
- dynamic river beds with extreme floods or new channel development are unpredictable

1.4 PRE-IMPLEMENTATION EVALUATION OF PROPOSED ENHANCEMENTS

1.4.1 Overview of Technique

Proposed enhancements should be based on observed and documented resource conditions and processes. Assess conditions and impacts of enhancements before project design and implementation using any of a number of biological and channel stability check lists and methodologies. Examples include: Habitat Evaluation Procedures (Cooperrider et al., 1986); Rapid Bioassessment Protocols (Plafkin et al. 1989); Rosgen Stream Classification (Rosgen 1994; Rosgen and Fittante 1986); Pfankuch Channel Stability (Pfankuch 1978).

1.4.2 General Benefits

- fosters understanding of habitat-limiting factors
- matches suitability of enhancement methods to habitat needs
- characterizes baseline or reference conditions for post-enhancement habitat evaluation

1.4.3 General Drawbacks

- none

1.5 INSTALL GRADE CONTROL STRUCTURES AND CHECK DAMS

1.5.1 Overview of Technique

Grade control structures are hydraulic barriers placed in a channel to provide stability by controlling headcuts, scour of the stream bed, and upstream degradation. Examples include gabions and concrete weirs, which generally do not impound water, and check dams, which do.

1.5.2 General Benefits

- useful in controlling stream flow velocity and direction
- stabilizes sediments behind structure
- retards gully advancement
- enhances fish habitat by creating deeper pools and holding areas

1.5.3 General Drawbacks

- gradient alterations influence many other channel parameters (width, depth, etc.) and may cause detrimental changes to channel morphology
- can affect sediment transport processes resulting in deposition of fine sediment through a reduction in channel steepness (aggradation)
- could inhibit fish passage if improperly designed

1.6 INSTALL LARGE WOODY DEBRIS STRUCTURES

1.6.1 Overview of Technique

Large woody debris (LWD) in stream channels provides hydraulic roughness which promotes grade control, complex velocity distributions, localized scour, and a variety of naturally maintained stream bed and bank forms. This hydraulic and structural diversity provides an array of habitat features including clean spawning gravel, pools, and protective cover. A reduction in instream LWD through riparian harvest and stream "cleaning" may lead to a simplification and degradation of fish habitat. LWD structures, such as wing deflectors, bank protection logs, and upstream and downstream vee log weirs, can restore lost habitat.

1.6.2 General Benefits

- provides hydraulic and structural diversity
- mimics natural processes
- slow, long-term decay of structures can provide transitional return to natural conditions

1.6.3 General Drawbacks

- LWD insertion requires anchoring either through cabling, or bed/bank disturbance and partial burial, or both
- improperly designed structures can create adverse hydraulic conditions and exacerbate flooding and local bank erosion
- flooding can displace structures to less optimal location

1.7 INSTALL OTHER HABITAT COMPLEXITY STRUCTURES

1.7.1 Overview of Technique

Boulders and concrete structures can be installed in longer reaches with higher stream flow velocities to provide localized scour pools and resting areas. They can also provide additional cover or direct streamflow to preferred channel areas (spawning gravels, side channels, etc.).

1.7.2 General Benefits

- enhances existing habitat
- encourages upstream migration through higher velocity reaches

1.7.3 General Drawbacks

- improperly designed structures can create adverse hydraulic conditions (flooding or scour)
- some bed/bank disturbance may accompany placement or construction of structures

1.8 BANK PROTECTION THROUGH VEGETATION MANAGEMENT

1.8.1 Overview of Technique

Maintenance of existing and/or natural streambank vegetation and replanting of native vegetation are non-structural techniques of protecting streambanks and the habitat features they provide. Trees and shrubs (woody plants) offer the most protection and provide cover to habitat; herbaceous plants retain surface soils on-site; aquatic (under the waterline) vegetation stabilizes banks and absorbs stream energy otherwise directed at soil particles in the bank. This method relies on the rooting strength of streamside plants to stabilize streambank soils.

1.8.2 General Benefits

- promotes natural processes (e.g., repairs itself when damaged, eventually replenishes instream woody debris)
- inexpensive
- visually attractive

1.8.3 General Drawbacks

- vegetation--natural or planted--may be inadequate for natural or man-made reasons
- seasonal limitations and time to effective cover
- high-value property may be lost to rapidly eroding streambanks

1.9 STRUCTURAL BANK PROTECTION USING BIOENGINEERING METHODS

1.9.1 Overview of Technique

Tree boles and root wads installed in the river bed at the banks are effective in stabilizing streambanks by absorbing stream energy otherwise directed to streambank soils. They are especially useful on the outside of curves such as meander bends, where stream energy is greatest. They generally require the use of heavy equipment to either push sharpened boles into the banks, or to excavate, partially bury, and backfill around them.

Other soil bioengineering methods are useful where steep, eroding slopes abut streambanks. Live brush cuttings in bundles (fascines) on narrow contour terraces are effective in reducing sheet and rill erosion and shallow sliding. Branch packing of cuttings and backfill in deeper slumps perpendicular to the slope are effective in reinforcing soil and increasing slope stability.

Bioengineering methods are usually accompanied by planting of trees and shrubs.

1.9.2 General Benefits

- natural materials, often obtainable in riparian stands
- mimics natural processes of LWD recruitment
- gradual decay provides transition to naturally stable banks
- also provides excellent bank cover and localized scour pools for fish

1.9.3 General Drawbacks

- soil disturbance during installation
- heavy equipment near or possibly in stream
- may disrupt natural channel migration

1.10 STRUCTURAL BANK PROTECTION USING ENGINEERED STRUCTURES

1.10.1 Overview of Technique

Direct protection of streambanks may be obtained by lining banks with stone riprap, geotextiles, burlap or jute fabric, and/or bulkhead walls constructed of wood or concrete. Structures provide indirect protection by redirecting stream flow and include dikes, gabions, and fences.

1.10.2 General Benefits

- helpful in highly disturbed areas, or where high quality habitat and high value property require immediate protection
- generally long design life

1.10.3 General Drawbacks

- expensive
- design, labor, and resource intensive
- may require greater maintenance than other measures
- visually unattractive
- disrupts natural channel migration
- inhibits development of vegetative cover
- may simply "transfer" problems downstream
- may result in increased channelization

1.11 REMOVE DEBRIS FUNCTIONING AS BARRIERS TO PASSAGE

1.11.1 Overview of Technique

Some accumulations of debris in channels can be large enough and configured in such a way as to preclude passage by migrating adults or access by rearing juvenile fish to preferred habitats. Examples include large jams of introduced large woody debris at channel constrictions, landslide deposits, and beaver dams.

1.11.2 General Benefits

- access to critical or high quality habitat

1.11.3 General Drawbacks

- hydraulic "side-effects" can create higher flow velocities and downstream scour
- loss of slower-water habitat and cover provided by debris to existing fish population

1.12 HARDENED FORDS

1.12.1 Overview of Technique

Where livestock, farm equipment, and other machinery must cross stream channels only occasionally, and then at low flows, culvert installation or bridge construction may not be warranted. Hardened fords (cobbles, concrete blocks, geotextiles, concrete) at established pathways may adequately protect channel structure (Saskatchewan Environment and Resource Management 1995a).

1.12.2 General Benefits

- resists bank trampling and destruction
- generally easier to install (compared to culverts)
- less resource damage if/when removed

1.12.3 General Drawbacks

- allows direct contact of equipment/livestock with stream
- no sideboards to encourage/require use

1.13 CULVERT REMOVAL/REPLACEMENT TO IMPROVE FISH PASSAGE

1.13.1 Overview of Technique

Improperly installed, designed, or damaged stream crossing structures (culverts, etc.) can cause partial or complete barriers to fish migration. Replacement with properly sized sructures, placed at gradients and depths conducive to fish passage, can restore fish migration routes. Generally, preferred structures are, in order: no structure at all (avoid crossing); bridges; bottomless arch culverts; oversized culverts; temporary culverts; and permanent culverts (whether pipes or boxes; whether metal, concrete, or plastic; etc.). Replacement with properly sized structures, placed at gradients and depths conducive to fish passage, can restore fish migration routes (Baker and Votapka, 1990).

1.13.2 General Benefits

- restored fish migration
- improved capacity

1.13.3 General Drawbacks

- temporary impacts due to instream construction

1.14 REDUCE SCOUR AND DEPOSITION AT HYDRAULIC STRUCTURES

1.14.1 Overview of Technique

Improperly installed, designed, or damaged stream crossing structures (culverts, bridges) can result in the scour of the streambed, stream banks, and road fills, and/or the deposition of both fine and coarse sediments. Deleterious effects may include the removal of spawning gravels, sedimentation of spawning gravels, the fill of downstream soils, the perching of culverts precluding fish passage, and the influences of catastrophic road failures after clogging or undermining of the structures. Removal and/or replacement of poorly functioning structures can alleviate such chronic and potentially catastrophic conditions (Saskatchewan Environment and Resource Management 1995a).

1.14.2 General Benefits

- reduces in-channel erosion and sedimentation
- maintains clean spawning gravels
- reduces pool filling
- maintains road and crossing structure investment

1.14.3 General Drawbacks

- temporary sediment increase due to construction

1.15 FISH PASSAGE ENHANCEMENT—FISHWAYS

1.15.1 Overview of Technique

The enhancement of fish passage over or around natural barriers and man-made structures may provide the highest and most immediate benefit to the fisheries resource (Rainey, 1991; Powers and Orsborn, 1985). Barriers may be effective for all or some fish, all or various ages of fish, and at all or some of the time (and stage of flow). Barriers and other deterrents to fish passage associated with fast water include waterfalls, velocity chutes, boulder-strewn reaches, and extremely turbulent areas. Braided reaches and streams with wide, shallow flows can be slow water barriers. Debris-laden reaches may also limit fish passage by creating frequent obstacles. Culverts, dams and diversions, other instream structures, fill areas, and ponds can be human-made obstacles to passage by physically blocking or dewatering streamcourses.

Fish passage enhancement projects include the construction of fish ladders, fish screens, side channels, baffled culverts, fish locks and fish elevators (Rainey, 1991). Simpler approaches may include blasting to remove barriers or create pools. The removal of roughness elements and obstacles such as debris, beaver dams, boulders, and sediment may be appropriate in some cases (see Technique 1.10). Existing culverts may also be replaced to correct passage problems (see Technique 1.12) (Baker and Votapka, 1990).

Design criteria for passage enhancement will include biological, engineering, and hydraulic considerations. Biological considerations should include fish capabilities such as swimming and burst speeds, endurance, and leaping abilities, quality and quantity of upstream habitat, relative frequency of other barriers upstream and downstream, upstream channel stability, and upstream management activities. Engineering considerations should include elements such as structure selection, construction materials, streambed foundation, site access, regulatory and arbitrary design constraints, and the desired life expectancy of the structure. Hydraulic considerations should include design peak flows, hydraulic parameters such as gradient, cross-section, and roughness coefficient, bedload, expected debris load and type, and water storage capacities at the upstream and downstream ends of the structure. Plans should be submitted for peer technical review prior to approval and implementation.

1.15.2 General Benefits

- facilitates increased fish migration
- provides access to unused or under utilized habitat

1.15.3 General Drawbacks

- temporary increase in construction related sediment
- increased maintenance requirements (e.g., cleaning trash racks, etc)
- potential adverse effects by changing channel hydraulics
- potential adverse effects on individuals and fish populations isolated or protected by existing barriers (e.g., introduction of anadromous fish to trophy trout waters)

1.16 SPAWNING HABITAT ENHANCEMENTS

1.16.1 Overview of Technique

Where available spawning area is limiting in areas of otherwise good potential production, enhancement projects may be implemented to increase the quantity or improve the quality of spawning habitat. Approaches to spawning habitat enhancement include placement of log or rock structures to function as gravel traps (see Technique 1.6), augmentation of riffled areas with clean river gravel, and the construction of side spawning channels accessible from natural streams (Seehorn, 1992; Bonnell, 1991). The appropriate method depends on the channel type of the enhancement reach (Rosgen and Fittante, 1986).

1.16.2 General Benefits

- increased or improved available spawning area
- potential to increase spawning success

1.16.3 General Drawbacks

- increased or improved habitat may remain under utilized
- useful design life can be shortened by peak flow events or sedimentation
- some improvements may require maintenance or repeated applications

1.17 REARING HABITAT ENHANCEMENTS

1.17.1 Overview of Technique

Where available rearing area is limiting in areas of otherwise good potential production, enhancement projects may be implemented to increase the quantity or improve the quality of rearing habitat. Approaches to rearing habitat enhancement include using log structures to create pools and glides; enhancing bank cover through riparian planting and the use of log structures; improving access of juvenile fish to tributary channels adjacent to mainstem rivers and spawning areas; reconnecting streams to remnant channels, ponds, oxbow lakes, and perhaps reclaimed borrow pits; and the creation of small side channels to provide accessible rearing habitat (Seehorn, 1992; Cedarholm and Scarlett, 1991). The appropriate method is depends on the channel type of the enhancement reach (Rosgen and Fittante, 1986).

1.17.2 General Benefits

- increased or improved available rearing area
- potential to increase rearing success

1.17.3 General Drawbacks

- increased or improved habitat may remain under-utilized
- useful design life can be shortened by peak flow events or sedimentation
- some improvements may require maintenance or repeated applications

2 SPECIAL VEGETATION TREATMENT TECHNIQUES, INCLUDING TECHNIQUES FOR WETLANDS AND RIPARIAN AREAS

2.1 MAINTAIN HEALTHY RIPARIAN PLANT COMMUNITIES

2.1.1 Overview of Technique

Maintaining a streamside vegetation zone with a complex of woody and herbaceous riparian plants has multiple benefits. Avoid clearing riparian vegetation to support other land uses. Where riparian vegetation has been cleared, seed and/or plant herbaceous and woody vegetation as appropriate to address resource needs. Consider the use of rooted stock and protection of plantings from animal damage to accelerate vegetation establishment and site stabilization. Revegetation efforts should be part of project implementation plans on projects requiring soil disturbance. Project managers should take advantage of heavy equipment used during project implementation while it is still on-site to facilitate the planting of rooted-stock.

2.1.2 General Benefits

- sustains minimum flows in summer
- shades stream to maintain cool water temperatures
- filters sediment, nutrients and other pollutants from upland sources
- retains sediment, nutrients and other pollutants deposited during overbank flow events
- preserves off-channel habitats frequently used by rearing fish (remnant channels, pocket pools)
- provides for recruitment of large woody debris
- provides detritus and primary food production
- protects upland areas where channels tend to migrate

2.1.3 General Drawbacks

- requires commitment of land

2.2 PLANT/PROTECT CONIFERS IN RIPARIAN AREAS FOR THERMAL COVER

2.2.1 Overview of Technique

In addition to the benefits listed under 2.1.2 above, conifers can provide important thermal cover to sensitive stream reaches prone to ice development. Whereas deciduous plants allow greater winter temperature extremes, conifers can moderate riparian temperatures and reduce gravel and pool freezing and the development of ice flows. Large trees can also slow and break up ice flows.

2.2.2 General Benefits

- temperature moderation
- less freezing of fish eggs in spawning gravel
- less freezing of overwintering fry and juvenile fish
- reduced bank and riparian damage from ice floes

2.2.3 General Drawbacks

- some conifers may not adapt to excessively wet sites

2.3 CREATION OF WETLANDS TO PROVIDE NEAR-CHANNEL HABITAT AND STORE WATER FOR LATER USE

2.3.1 Overview of Technique

Constructed wetlands are designed to imitate the water filtering and purification processes of natural wetlands. Upland or riparian sites are converted to wetlands by creating poorly drained soil conditions. Near streams, small shallow channels can be constructed to encourage seasonal filling and access of aquatic species between the channel and adjacent wetland. This water slowly replenishes ground water and helps to sustain low flows later in the summer. Wetland functions such as wildlife habitat may exist in created wetlands, and they may function to moderate stormflows and filter sediment. This water may also be made available for agricultural uses given other resource protections.

2.3.2 General Benefits

- ground water recharge
- improved water quality
- possible rearing habitat enhancement
- possible duel benefit to wildlife and agriculture

2.3.3 General Drawbacks

- difficulty in wetland plant establishment after ground disturbance may result in sediment source and water quality degradation
- requires commitment of land

2.4 PROVIDE FILTER STRIPS TO CATCH SEDIMENT AND OTHER POLLUTANTS

2.4.1 Overview of Technique

Vegetated strips encircle a potential pollution source, or form a barrier between it and a receiving water body. Surface water entering the vegetated filter strip loses (reduces) sediment, nutrients, and bacteria through several processes. These may include filtration, deposition, infiltration, adsorption, absorption, decomposition, and volatilization. Vegetation can consist of an array of close-growing ground cover species. Soil conditions remain in aerobic condition (as compared to the anaerobic conditions of wetlands).

Shrubs and herbaceous cover should be encouraged along the perimeter of roads, including cutslopes, fillslopes, ditches, and adjacent topography. Sediment generated from the road surface, ditches, cutslopes, and fillslopes will, with adequate cover, remain stabilized on or near the road prism. Maintenance may be required where growth is vigorous, especially in ditches, in order to retain the hydraulic capacity to transport water downslope of the road.

2.4.2 General Benefits

- reductions in sediment reaching receiving waters
- nutrients taken up by vegetation
- ancillary benefits for wildlife forage and nesting
- road prism erosion is reduced
- running surface erosion is retained roadside

2.4.3 General Drawbacks

- may require maintenance or removal of sediment
- roadside vegetation can be slow to establish on eroding cutslopes
- may require continued maintenance to meet transportation safety requirements

2.5 PLANT WINDBREAKS

2.5.1 Overview of Technique

Tightly spaced trees planted on field borders can decrease wind shear on the soil surface and reduce the mass of soil removed by the wind. Detached sediment may be stored where it can be secondarily transported by water, or it may deposited directly in surface waters.

2.5.2 General Benefits

- soil stays on site; productivity maintained
- reduced deposit of/transplant of sediment to surface waters

2.5.3 General Drawbacks

- commitment of land
- transpiration of soil water that might otherwise be used by deeper-rooted crops

2.6 NATIVE SEEDS INVENTORIES

2.6.1 Overview of Technique

Local sources of seeds for grasses and legumes ensure plants adaptedto local climate and soil chemistry. Hardiness of plants selected for restoration is assured.

Tree and shrub cuttings selected for slope stabilization should also beobtained from local sources-preferably near to the site.

2.6.2 General Benefits

- sources available for immediate needs
- seeds and plants well-suited to local or area ecosystems

2.6.3 General Drawbacks

- some seed types difficult or expensive to obtain and/or germinate

2.7 AVOID EXOTIC SPECIES

2.7.1 Overview of Technique

While nonnative plants can have positive stabilizing influence on a disturbed site, they can also overtake native species. Negative effects include increased maintenance problems, a reduction in plant diversity, increased disease and pest problems, and detrimental secondary effecs on coexisting plants and wildlife. Avoidance measures may include using only approved native seed mixes, planting only mature plants. removal of existing non-native plants through hand/mechanical means, and eradication of existing non-native plants through chemical means

2.7.2 General Benefits

- ecosystem interactions not interrupted
- benefits of native plant species maintained

2.7.3 General Drawbacks

- mechanical removal may generate temporary sediment source (see 2.10)
- chemical eradication can have toxic side-effects (see 3.29)

2.8 CONSTRUCT WETLANDS TREATMENT SYSTEMS

2.8.1 Overview of Technique

Constructed wetlands are designed to imitate the water filtering and purification processes of natural wetlands. Upland sites are usually converted to wetlands by creating poorly drained soil conditions. Vegetation is generally not as diverse as in natural wetlands. Though other wetland functions such as wildlife habitat may exist in created wetlands, they are primarily managed in this context to treat agricultural wastewater. Pollutant removal occurs through sediment trapping, assimilation by plants, bacterial decomposition, and adsorption.

2.8.2 General Benefits

- pollutant removal
- sediment retention
- wildlife habitat

2.8.3 General Drawbacks

- if underdesigned, contaminated stormflows may be discharged from the wetland (before pollutants are stabilized)
- land commitment required
- maintenance may require harvest of overgrowth or sediment removal

2.9 MECHANICAL VEGETATION REMOVAL

2.9.1 Overview of Technique

Mechanical removal of vegetation typically involves the use of tractors or other heavy machinery equipped with a blade, mower, or other device to remove vegetation. Cables and chains attached between vehicles may also be used to clear vegetation.

While the degree of disturbance depends on the type of equipment used, mechanical removal breaks the surface of the soil and can remove some or all of the parts of plants, including roots.

Mechanical removal can be carried out over large areas or can be confined to smaller areas (known as scalping). Vegetation is sometimes removed in strips rather than clearing all areas (known as contouring or furrowing).

2.9.2 General Benefits

- generally high efficiency
- no chemicals

2.9.3 General Drawbacks

- can disturb soils
- typically nonselective
- use can be restricted by steep slopes or other uneven topography
- plants may resprout if the whole plant is not removed

2.10 BIOLOGICAL VEGETATION CONTROL

2.10.1 Overview of Technique

Biological control of vegetation involves the use of disease, insects, other parasites, and desirable plants to inhibit growth and spreading of unwanted vegetation. Insect adults or larvae can be used to attack seedheads, stems, or flowers of target plants. In many cases, host-specific species of insects can be found.

Bacteria, viruses, fungi, and other microbes can also be used to control vegetation, but these techniques are mostly experimental at this time (USFS 1988). Another experimental approach involves the use of chemicals naturally produced by plants to inhibit or repel other plants. Traditional knowledge of tribal cultures can be very useful in identifying competitive relationships among plants.

Extreme care is required to effectively apply biological control. When selecting a specific type of control agent, such as a species of insect, managers must research and consider (1) the agent's known effectiveness against the target plant species, (2) the agent's ability to survive site conditions, and (3) the specificity of damage the agent will cause.

Use of any biological agent requires close coordination and consultation with local, state, and federal agencies as well as adjacent landowners. In particular, the USDA Agricultural Research Service and local weed control boards should be consulted prior to considering the use of biological controls.

2.10.2 General Benefits

- involves fewer risks to water quality than chemical removal methods

2.10.3 General Drawbacks

- requires intensive monitoring
- may be difficult to obtain appropriate insects or other control agents
- potential risk of disrupting natural systems

2.11 HAND PULLING

2.11.1 Overview of Technique

Hand pulling of vegetation can be effective on small areas targeted for plant control, and on areas sensitive to chemical or mechanical treatment.

2.11.2 General Benefits

- target specific species
- involves much less disturbance of soils

2.11.3 General Drawbacks

- labor intensive
- not practical for covering large areas

2.12 PRESCRIBED BURNING

2.12.1 Overview of Technique

Prescribed burning is the intentional use of fire to create desired changes, such as wildlife habitat improvement, within a specific treatment area. There are three types of prescribed burns: (1) broadcast burning, (2) pile burning, and (3) underburning.

Broadcast burning involves general ignition of essentially all flammable materials within the treatment area. Hand-held or helicopter-borne drip torches are used to quickly ignite fuels. Sites are sometimes cleared or otherwise disturbed prior to igniting a broadcast burn. An example of broadcast burning is slash burning, where woody residuals from logging are burned to prepare a recently harvested timber site for regeneration.

Pile burning involves collecting and piling fuels to be burned in place. This technique allows a more selective approach to burning but is also more labor intensive.

Underburning involves burning only the lower layer of vegetation, while avoiding burning in the overstory (such as the tree canopy). It is used to reduce fuel loads (to avoid wildfires), eliminate unwanted brush, or stimulate forage production.

Properly planned prescribed burns (e.g., USFWS 1995) can be used to:

- increase forage abundance and accessibility
- reduce unwanted vegetation
- prepare an area for replanting, especially where soils, topography, or slope limit the use of other methods
- create habitat for edge or early seral species
- maintain early seral stages
- increase vegetative diversity and associated wildlife communities
- simulate natural disturbance regimes
- reduce fuel load and risk of catastrophic fire
- alter distribution patterns of animals (such as wintering deer)

2.12.2 General Benefits

- can simulate the natural role fire plays in the development of most vegetation communities
- can cause desired changes in vegetation relatively inexpensively, compared with chemical or mechanical techniques

- can have minimal impact on surface soils, when compared with mechanical methods, thereby reducing the exposure of mineral soils and associated encouragement of invasive weeds

2.12.3 General Drawbacks

- possible air pollution and soil erosion
- increased nutrient transplant to stream
- risk of fire escaping
- can be difficult to control because of the complex and unpredictable factors involved
- not selective within treatment area; may harm beneficial or desirable plants and animals
- effects can be severe and long term if burns are too hot or if fire escapes to sensitive areas

2.13 REDUCE SHADE TO INCREASE PRIMARY FOOD PRODUCTION

2.13.1 Overview of Technique

Energy from the sun is a significant driver in primary food web production. Opening formerly shaded lakes and stream reaches to sunlight by vegetation removal can result in the growth of food organisms favored by some species of fish. This practice probably occurs most often coincidentally with, for example, single tree or small group selection timber harvest, or after mass wasting events in headwaters areas.

If lakes and stream reaches are marginally temperature sensitive, however, shade removal can cause temperatures to rise to stressful and lethal levels for fish and other aquatic organisms. Further, even if temperatures are adequately maintained on-site, effects can be translated to temperature sensitive reaches downstream. This practice is not recommended at large scales within a watershed.

2.13.2 General Benefits

- increased primary production
- greater food supply available to fish

2.13.3 General Drawbacks

- disrupts the natural energy flowthrough small streams
- gains in productivity are often localized and short lived
- increases in temperature extremes may more than compensate for fisheries benefits derived from primary productivity

2.14 ENHANCE LARGE WOODY DEBRIS RECRUITMENT

2.14.1 Overview of Technique

This technique is similar to Technique 1.5, which addresses installation of large woody debris structures for structural and habitat enhancement of channels. The intent of this technique is to enhance the natural recruitment of streamside trees with the potential of becoming large woody debris. Approaches include:

- planting trees in floodplains and riparian areas

- riparian harvest restrictions on individually marked trees, trees leaning toward or over streams, or other appropriate restrictions
- falling select trees to bridge across streams
- girdling select trees with strong potential as large woody debris
- selective harvest of trees to increase size of remaining trees

2.14.2 General Benefits

- ensures long-term supply of large woody debris
- mimics natural processes and allows for an element of "natural selection" in the placement of large woody debris
- can provide transitional return to natural conditions
- minor implementation impacts relative to large woody debris placement per Technique 1.5

2.14.3 General Drawbacks

- long time frames for effectiveness
- effectiveness uncertain

2.15 ACQUISITION OF SENSITIVE RIPARIAN RESOURCES

2.15.1 Overview of Technique

Sensitive riparian areas may be specifically acquired and designated as a riparian management "set-aside" using fee-title, easement and leasing approaches.

Fee-title acquisition and transfer is a three-step process: (1) directly purchasing property (Brumback and Brumback 1990), (2) placing restrictions or protective covenants on the title, and (3) reselling or transferring ownership of the property. For the Watershed Management Program, properties would most likely be transferred as trust lands to Tribal or state fish and wildlife agencies. Terms and conditions of long-term funding and management would be formally stipulated in a signed agreement between BPA and the management entity.

Easement acquisition is the purchase of partial rights to a property (Brumback and Brumback 1990). Easements may be temporary, but typically perpetual easements are acquired for habitat management. The purchaser, referred to as the dominant tenant, owns the rights to specific aspects of use on the subject property, such as timber, grazing, mineral, or development rights. The seller, referred to as the servient tenant, retains the right for other uses of the land. The cost of the easement is derived from the difference between the assessed value of the property with and without the easement. Easements can be a very cost-effective approach to protecting habitat.

Long-term leases involve leasing a property over a long period, generally for 50 years or more. The Canadian Wildlife Service has used this method to protect waterfowl habitat on private farmland in the prairie potholes of central Canada (Gilbert and Dodds 1987).

2.15.2 General Benefits

- allows restrictive yet flexible use of sensitive riparian areas
- can provide for management/protection of wildlife as well as aquatic species/habitat

2.15.3 General Drawbacks

- may diminish local property tax base on commodity revenue generation

Note: Please also see Section 3. 29 for Herbicide/Pesticide Applicaton that would apply to Special Vegetation Treatment Techniques as well.

3 AGRICULTURAL MANAGEMENT TECHNIQUES--CROPS AND GENERAL

3.1 PLANT/PROTECT VEGETATIVE/CONSERVATION COVER

3.1.1 Overview of Technique

On lands withdrawn from crop production, establish and maintain perennial vegetative cover.

3.1.2 General Benefits

- maximizes infiltration
- minimizes erosion caused by raindrop splash, sheetwash, and overland flow
- sustains minimum flows by encouraging groundwater recharge
- maintenance of soil productivity

3.1.3 General Drawbacks

- maintenance costs of nonproductive land

3.2 CONSERVATION CROPPING SEQUENCE

3.2.1 Overview of Technique

Crop rotations which alternate a variety of crop types provide adequate organic residue and improve soil tilth. Erosion is decreased due to surface roughness and deeper infiltration because of increased soil organic matter.

3.2.2 General Benefits

- sediment and associated nutrients remain on-site
- the need for pesticides may decline with use
- the need for nitrogen fertilizer may be reduced

3.2.3 General Drawbacks

- deep percolation may carry nutrients and other pollutants to ground water

3.3 CONSERVATION TILLAGE

3.3.1 Overview of Technique

Where water erosion is a primary concern, maintain at least 30% of the soil surface covered by residue after planting. Where wind erosion is the primary concern, maintain 1,000 pounds or more of flat, small-grain residue on the surface during critical erosion periods. Surface residues reduce the impact of raindrop energy and increase surface soil roughness, simultaneously increasing infiltration and reducing the amount of water available to runoff.

3.3.2 General Benefits

- additional organic matter at the surface reduces erosion
- reduced tillage systems (as compared to no-till methods) break down preferred flow pathways (macropores) which develop under no-till methods; the result is reduced runoff with reduced pollutants in the runoff

3.3.3 General Drawbacks

- by reducing incorporation of organic matter into the soil, applied pesticides and fertilizers in/on vegetative material may be subject to removal by surface runoff
- increased infiltration may transport nutrients and other soluble substances to groundwater

3.4 CONTOUR FARMING

3.4.1 Overview of Technique

Following the established grades of hillslopes and terraces, prepare, plant, and cultivate farm land on the contour.

3.4.2 General Benefits

- reduces erosion
- decrease in sediment and related pollutants reaching surface waters

3.4.3 General Drawbacks

- increased infiltration may transport nutrients and other soluble substances to groundwater

3.5 CONTOUR ORCHARDS AND FRUIT CROPS

3.5.1 Overview of Technique

All cultural operations should be done on the contour. This may include creation of inward sloping terraces for planting.

3.5.2 General Benefits

- erosion, sediment yield, and pesticide concentrations in runoff are decreased

3.5.3 General Drawbacks

- increased pesticide and fertilizer applications which accompany orchard management may reach ground water with increased infiltration

3.6 COVER AND GREEN MANURE CROP

3.6.1 Overview of Technique

Plant grasses, legumes, or small grains (close-grown plants) for seasonal protection and soil improvement. These are usually grown as an alternate crop for less than one year. Erosion resulting from conventional tillage practices can decrease due to the extended period vegetation covers the soil.

3.6.2 General Benefits

- plants take up available nitrogen and prevent its leaching to ground water and surface waters
- organic nutrients are added to the soil and may reduce the volume of fertilizer needed for application
- reduced erosion and soil loss

3.6.3 General Drawbacks

- extra work/cost in planting

3.7 CRITICAL AREA PLANTING

3.7.1 Overview of Technique

Plant trees, shrubs, vines, grasses, or legumes on severe, actively eroding areas, and areas with high erosion potential.

3.7.2 General Benefits

- reduce erosion and sediment yield
- nutrient loss to surface and ground waters is reduced

3.7.3 General Drawbacks

- no immediate effects - erosion and chemical loss from site prior to plant establishment

3.8 DELAYED SEED BED PREPARATION

3.8.1 Overview of Technique

Maintain crop residue and volunteer vegetation on soil surface until about 3 weeks before planting. The period that bare seed beds occur during critical erosion periods is therefore reduced.

3.8.2 General Benefits

- raindrop splash and surface runoff during the spring erosion period are reduced
- soil moisture is conserved for crop use and sustaining stream flow

3.8.3 General Drawbacks

- risk of additional weather delays
- risk of encroachment of weeds or undesirable species

3.9 GRASSES AND LEGUMES IN ROTATION

3.9.1 Overview of Technique

Establish a mixture of grasses and/or legumes and maintain the stand for several years as part of a conservation cropping system.

3.9.2 General Benefits

- reduced erosion and sediment yield
- crops supply organic nitrogen reducing need for nitrogen fertilizer
- grasses and legumes take up phosphorus reducing phosphorus loading to lakes and streams
- decreased pesticide applications
- opportunities for animal waste management because manures are applied for longer periods on/with established vegetation

3.9.3 General Drawbacks

- commitment of land

3.10 CONTOUR STRIPCROPPING

3.10.1 Overview of Technique

Arrange crops so that close growing crops or grasses alternate with bands of clean-tilled crops which follow the contour

3.10.2 General Benefits

- reduced erosion and sediment yield
- increased infiltration

3.10.3 General Drawbacks

- increased infiltration during wet periods may result in the leaching of soluble substances to ground water

3.11 FIELD STRIPCROPPING

3.11.1 Overview of Technique

This method is similar to contour stripcropping (3.10) but the bands cross the general slope and not necessarily the contour.

3.11.2 General Benefits

- reduced erosion and sediment yield
- increased infiltration

3.11 3 General Drawbacks

- increased infiltration during wet periods may result in the leaching of soluble substances to ground water

3.12 TERRACING

3.12.1 Overview of Technique

Terraces are earthen embankments constructed across a slope. A slope with several terraces takes on a stair-step or inclining ridge and swale appearance. Terraces reduce erosion by shortening the length of slope down which water and sediment can flow once concentrated in a rill. A terrace with negative or no slope (relative to the original unterraced hillslope) intercepts and slows water causing the deposition of any sediment it might be carrying. With appropriate soil maintenance, the water can infiltrate and be stored in the soil.

3.12.2 General Benefits

- the erosive energy of the overland flow of water is abated
- sediment and associated nutrients remain on the slope and available to crops

3.12.3 General Drawbacks

- increased infiltration during wet periods may result in the leaching of soluble substances to ground water

3.13 DIVERSION DITCH

3.13.1 Overview of Technique

Similar to terraces, diversions are channels constructed across a slope with a supporting berm on the downslope side. Placed intermittently on a slope, they reduce the slope length on which sheet and rill erosion might otherwise develop into gullies. The slope distance between diversion ditches is a function of the steepness of the slope and the cover crop.

3.13.2 General Benefits

- the erosive energy of the overland flow of water is abated
- sediment and associated nutrients remain on the slope
- easier to construct than terraces

3.13.3 General Drawbacks

- oversteep diversion ditches can accelerate rill and gully erosion by concentrating runoff

3.14 FIELD BORDER

3.14.1 Overview of Technique

A field border is strip of perennial vegetation along the edge of a field consisting of shrub and or herbaceous cover. It may have been converted from trees or cropland. They are the end points for contour features (terraces, diversions, strip crops) and should contain any lateral water movement from a contour feature. They also prevent the parallel-with-slope furrows that might be created when a contour feature is turned to return back across the slope.

3.14.2 General Benefits

- concentrated flow in furrows is reduced
- water and sediment flow across slope, if any, is filtered

3.14.3 General Drawbacks

- reduced tillable area

3.15 FILTER STRIP

3.15.1 Overview of Technique

Vegetated filter strips encircle a potential pollution source, or form a barrier between it and a receiving water body. Surface water entering the vegetated filter strip loses (reduces) sediment, nutrients, and bacteria through several processes. These may include filtration, deposition, infiltration, adsorption, absorption, decomposition, and volatilization. Vegetation can consist of an array of close-growing ground cover species. Soil conditions remain in aerobic condition (as compared to the anaerobic conditions of wetlands). This technique is the same as 2.4.

3.15.2 General Benefits

- reductions in sediment reaching receiving waters
- nutrients taken up by vegetation

3.15.3 General Drawbacks

- may require mowing or removal of sediment
- may be less effective with suspended sediments and soluble materials
- when flooded they may release a large load of pollutants into surface waters

3.16 GRASSED WATERWAY

3.16.1 Overview of Technique

A grassed waterway is natural or constructed waterway, often with a swale cross-section to assure bank stability and retain vegetation, with vegetation suitable for conveyance of runoff. The filtering of coarser materials is seen as a secondary benefit.

3.16.2 General Benefits

- stable drainage system
- nutrient uptake
- waterfowl habitat
- reduces erosion in concentrated flow areas
- reduced sediment yield to receiving waters

3.16.3 General Drawbacks

- chemical treatments applied to fields are easily transported to streams and/or ground water
- may deliver dissolved and suspended substances which might otherwise be incorporated on an unchanneled slope to streams

3.17 SEDIMENT BASINS

3.17.1 Overview of Technique

These basins are constructed to decrease flow velocity of runoff and allow sedimentation. Detention time of water is relatively short before it is passed on downstream.

3.17.2 General Benefits

- removal of sediments and debris, especially coarser sediments

3.17.3 General Drawbacks

- may not dampen significant storm event
- not as effective in sediment removal at higher flows
- opportunity for leaching soluble materials to ground water
- regular maintenance required

3.18 SEDIMENT AND WATER CONTROL BASINS

3.18.1 Overview of Technique

These larger basins are formed from earthen embankments and are designed to detain stormflow volumes and encourage the settlement of sediment. Overflow and drain pipes are placed to allow the discharge of the cleanest water. Storage and gradual release of stormflow is an advantage over simple sediment basins.

3.18.2 General Benefits

- removal of sediments and debris
- storage and slow release of stormflow
- wildlife habitat

3.18.3 General Drawbacks

- opportunity for leaching soluble materials to ground water
- regular maintenance required; basin cleaning may generate some sediment laden runoff
- discharge temperatures may increase due to longer exposure of water to warming during its impoundment

3.19 ZONING/LAND USE PLANNING

3.19.1 Overview of Technique

Zoning ordinances based on land use plans can alleviate future demands for withdrawal (fresh) and discharge (exhaust) of agricultural water from surface and ground water sources.

3.19.2 General Benefits

- adequate water supplies
- estimated pollutant loadings within capacity of system to recover

3.19.3 General Drawbacks

- limits use of land

3.20 PLANT WINDBREAKS

3.20.1 Overview of Technique

Tightly spaced trees planted on field borders can decrease wind shear on the soil surface and reduce the mass of soil removed by the wind. Detached sediment may be stored where it can be secondarily transported by water, or it may deposited directly in surface waters. This technique is the same as 2.5.

3.20.2 General Benefits

- soil stays on site; productivity maintained

3.20.3 General Drawbacks

- transpiration of soil water that may be used by deeper-rooted crops

3.21 AVOID IMPOUNDING NEEDED FLUSHING FLOW

3.21.1 Overview of Technique

Impounded water obtained from streams for later agricultural uses incurs an opportunity cost of cleaning spawning gravels. On a watershed scale, impounded water that would have been left in the stream could have increased the "winnowing" capacity of higher streamflows to flush fine sediments from around larger gravels and cobbles containing fertilized eggs and alevins. This often occurs in conjunction with spring melt events after a period of winter low flows.

3.21.2 General Benefits

- water remains available to flush gravels
- increased spawning success is assumed

3.21.3 General Drawbacks

- seasonal uses of impounded water must be obtained from other sources
- excessive peak flows may be detrimental--flushing out eggs as well as fine sediment
- flood recurrences may increase with loss of storage

3.22 RELEASE IMPOUNDED WATER TO FLUSH GRAVELS

3.22.1 Overview of Technique

Release of water that is already impounded (as compared to not impounding streamflow in 3.21) can be made available to flush spawning gravels for the same opportunity costs. The release of impounded water, given high seasonal streamflow, may result in higher peak flows and greater scour than without the release of impounded water. Most scour effects are likely to be localized near the outlet of farm impoundments, however.

3.22.2 General Benefits

- water remains available to flush gravels
- increased spawning success is assumed

3.22.3 General Drawbacks

- seasonal uses of impounded water must be obtained from other sources
- excessive peak flows may be detrimental--flushing out eggs as well as fine sediment

3.23 CHEMICAL MANAGEMENT PLANS

3.23.1 Overview of Technique

Management plans for nutrients, fertilizers, pesticides, and other chemicals should be developed, implemented, monitored, and updated periodically for all agricultural operations and some intensive forestry operations. Such a plan should specify, at a minimum, nutrient loading rates needed to achieve realistic crop yields, the recommended fertilizer, the best time for application, and crop production technology useful for increasing the nutrient use efficiency of managed vegetation.

Spill contingency planning (Section 7.15) should coincide with the development of these plans.

3.23.2 General Benefits

- information/data needs are identified

3.23.3 General Drawbacks

- none

3.24 FERTILIZER APPLICATION: RATES AND TIMING

3.24.1 Overview of Technique

Use of fertilizers should be regularly preceded by soil testing for Ph, phosphorus, potassium, and nitrogen; plant tissue testing; manure, sludge, compost, and effluent testing; consideration of site factors; and consideration of timing, formulation and application methods. Also consider:

- split applications,
- banding of nutrients,
- use of nitrification inhibitors and slow-release fertilizers, and
- incorporation or injection of fertilizers, manures, etc.

3.24.2 General Benefits

- maximize plant utilization of nutrients
- minimize nutrient loss to surface water and ground water

3.24.3 General Drawbacks

- analytical costs

3.25 FERTILIZER RECOVERY AND STABILIZATION

3.25.1 Overview of Technique

Consider the use of small grain cover crops to scavenge remaining nutrients that remain in the soil after harvest of the principal crop. Establish cover crops on highly permeable land receiving animal manure and sludge.

3.25.2 General Benefits

- reduced leaching of soluble nutrients to ground water
- "year-round" vegetative cover reduces erosion and sediment yield

3.25.3 General Drawbacks

- none

3.26 EVALUATE FIELD LIMITATIONS

3.26.1 Overview of Technique

An evaluation of areas at high-risk to chemical applications should occur before application. These high-risk areas include:

- karst topography,
- land adjacent to surface water,
- soils with high leaching ability,
- irrigated land in humid areas,
- highly erodible soils,
- lands prone to surface loss of nutrients, and
- shallow aquifers.

3.26.2 General Benefits

- maximize plant utilization of nutrients
- minimize nutrient loss to surface water and ground water

3.26.3 General Drawbacks

- none

3.27 EQUIPMENT CALIBRATION AND USE

3.27.1 Overview of Technique

Assure that equipment used for spray or other application of chemicals are properly maintained. This includes not improperly mixing chemical compounds, calibrating equipment, and training workers in their application. Backflow prevention devices should be used (see Section 4.16). Environmental conditions for application should be met, including the avoidance of windy and excessively wet weather.

3.27.2 General Benefits

- correct concentrations of fertilizers and pesticides applied
- risk of ground water and surface water contamination is reduced

3.27.3 General Drawbacks

- none

3.28 ALTERNATIVE PEST MANAGEMENT STRATEGIES

3.28.1 Overview of Technique

Pesticides are only one means of controlling unwanted vegetation or bothersome, detrimental pests. Many alternatives exist to minimize the amount of pesticides applied to a land parcel. A common approach is to combine one to several alternatives into one integrated pest management (IPM) strategy. Some of the many alternatives listed in EPA (1993) are:

- Use of biological controls:
  - introduction and fostering of natural enemies
  - preservation of predator habitats
  - release of sterilized male insects
- Use of pheromones:
  - for monitoring populations
  - for mass trapping
  - for disrupting mating and other behaviors of pests
  - to attract predators/parasites
- Use of crop rotations to reduce pest problems
- Use of resistant crop strains
- Use of more efficient application methods
  - spot spraying
  - banding

3.28.2 General Benefits

- pesticide application is reduced or avoided
- risk of ground water and surface water contamination is reduced

- farmers can receive higher price for organically grown crops

3.28.3 General Drawbacks

- pesticides may be the most effective and timely method of preserving existing vegetation and its soil stabilizing capability
- some IPM strategies may involve mechanical tillage resulting in increased erosion and sediment yield
- if methods are ineffective at stopping pests, inadequate vegetative cover and increased soil loss could occur

3.29 HERBICIDE/PESTICIDE APPLICATION

3.29.1 Overview of Technique

Herbicides are chemicals applied to kill plants; pesticides control unwanted vegetation or bothersome, detrimental pests. They are typically applied in liquid form via: (1) aircraft; (2) wand or broom sprayers mounted on trucks; and (3) backpack equipment containing a pressurized container with an agitation device. Herbicides can also be hand applied by injection, daubing cut surfaces, and ground application of granular formulas.

Typical uses of herbicides and pesticides are site preparation for planting, control of undesirable plants that are competing with desirable plants, noxious weed control, pest control, right-of-way maintenance, and recreation site and facility maintenance.

Each of the wide variety of herbicides and pesticides carries its own risks, benefits and drawbacks. An analysis of each type is beyond the scope of this assessment. Refer to the USFS (1988) and BPA (1983) for additional considerations.

3.29.2 General Benefits

- in certain situations, can be less expensive and more effective than other methods
- large areas can be covered in a short time
- can be targeted by taking advantage of the seasonal vulnerability of specific species
- has little direct impact on soil surface integrity

3.29.3 General Drawbacks

- can carry substantial risk to environmental and human health, including impacts on water quality
- can kill non-target species
- can be controversial
- concern over risks may require extensive permitting or environmental review.

Note that Category 3.29 also applies to Special Vegetation Techniques (Section 2.0), including techniques for Wetland and Riparian Areas.

3.30 APPLY HERBICIDES/PESTICIDES SELECTIVELY

3.30.1 Overview of Technique

Where the potential for herbicide or pesticide loss from a site is high, seek to minimize losses by consideration of the following physical characteristics:

- karst topography,
- proximity to surface water,
- potential to generate runoff,
- wind erosion and prevailing wind direction,
- highly erodible soils,
- wetlands and water tables near the soil surface, and
- wellhead protection areas.

3.30.2 General Benefits

- maximize chemical efficiency
- minimize chemical loss to surface water and ground water

3.30.3 General Drawbacks

- can carry substantial risk to environmental and human health, including impacts on water quality
- can kill non-target species
- can be controversial
- concern over risks may require extensive permitting or environmental review

3.31 HERBICIDE/PESTICIDE APPLICATION RATES

3.31.1 Overview of Technique

When pests must be addressed and pesticide application is deemed necessary, or when herbicides are used for vegetation control, consider the persistence, toxicity, and runoff and leaching potential in selecting a pesticide. Follow label recommendations for application rates.

3.31.2 General Benefits

- maximize chemical efficiency
- minimize chemical loss to surface water and ground water

3.31.3 General Drawbacks

- can carry substantial risk to environmental and human health, including impacts on water quality
- can kill non-target species
- can be controversial
- concern over risks may require extensive permitting or environmental review

3.32 ANTI-BACKFLOW DEVICES ON HOSES

3.32.1 Overview of Technique

Fertilizers, various pesticides, and other chemicals may be applied to farmland directly through irrigation water in a process known as "chemigation". They can also be applied by special equipment filled from appropriate chemical storage facilities. In both cases precautions should be taken to prevent backflow of chemicals to the irrigation water source, or backflow and spillage at tank filling locations. Several systems used to prevent backflow are available.

3.32.2 General Benefits

- for irrigation surface water sources, risk of chemical contamination is reduced
- for irrigation ground water sources, risk of aquifer pollution is reduced
- for tank filling locations, risk of both surface water and ground water contamination is reduced

3.32.3 General Drawbacks

- none

3.33 ENFORCE CURRENT HERBICIDE/PESTICIDE USE REGULATIONS

3.33.1 Overview of Technique

Many local, state, and federal regulations adequately address and protect aquatic resource concerns but are not implemented or enforced. If these regulations are adhered to, however, soil and water resources and fisheries habitat enhancement efforts should be protected.

3.33.2 General Benefits

- reduced risk of surface water and ground water contamination

3.33.3 General Drawbacks

- assumes regulations are adequate

3.34 AERIAL SPRAY APPLICATIONS: BUFFER ZONES

3.34.1 Overview of Technique

When applying fertilizers and pesticides via aerial methods, assure that appropriate setbacks are observed and boundaries clearly identified on the ground. Appropriate buffer widths would generally be 100 feet from surface waters and riparian areas, but may vary by state.

3.34.2 General Benefits

- reduced chemical loading near surface water supplies

3.34.3 General Drawbacks

- none

3.35 AERIAL SPRAY APPLICATIONS: ATMOSPHERIC CONDITIONS

3.35.1 Overview of Technique

When applying fertilizers and pesticides via aerial methods, assure that appropriate weather conditions are observed. Aerial applications should not be attempted under very wet or very windy conditions in an effort to minimize surface runoff and windblown drift.

3.35.2 General Benefits

- reduced surface runoff and reduced surface water contamination
- reduced windblown drift to inappropriate areas, including direct deposition in surface waters

3.35.3 General Drawbacks

- marginal weather conditions could be adequate but the decision to apply chemicals should err conservatively--do not apply

3.36 SLOW-RELEASE FERTILIZERS

3.36.1 Overview of Technique

The use of slow-release fertilizers should be considered.

3.36.2 General Benefits

- application rates automatically controlled
- risk of surface water contamination is reduced
- risk of nutrient leaching to ground water is reduced

3.36.3 General Drawbacks

- none

3.37 SPILL CONTINGENCY PLANNING

3.37.1 Overview of Technique

Any storage and/or application of chemical compounds should be subsequent to preparation of a spill contingency plan. The plan should include, at a minimum, identificaion of potential hazards; designation of responsible parties, technical assistants, and reporting agencies; an incident management plan including spill containment and recovery, access restriction, and incident termination criteria; and inventory and monitoring plan.

3.37.2 General Benefits

- risk of surface water contamination is reduced
- risk of nutrient leaching to ground water is reduced

3.37.3 General Drawbacks

- none

4 AGRICULTURAL MANAGEMENT TECHNIQUES--IRRIGATION

4.1 IRRIGATION WATER MANAGEMENT

4.1.1 Overview of Technique

Careful planning and a good land and crop knowledge base is needed to determine and control (Canessa and Hermanson 1994; Saskatchewan Environment and Resource Management 1995b):

- the amount of irrigation water to apply,
- the rate at which it is applied, and
- when it should be applied.

Irrigation water management should seek to effectively use the available water supply to:

- control the soil water available to crops,
- promote the desired crop response,
- minimize soil erosion,
- minimize the loss of nutrients,
- minimize water loss, and
- protect water quality.

4.1.2 General Benefits

- water loss minimized
- sediment yield (to streams) minimized
- other sediment-attached and soluble pollutants (e.g., nutrients, herbicides) minimized

4.1.3 General Drawbacks

- increased water temperatures downstream of irrigation return
- percolation of salts and pollutants may reach ground water

4.2 WATER MEASURING DEVICES

4.2.1 Overview of Technique

Depending on the irrigation method used, a metering device should be installed on delivery lines between the diversion and the field distribution system to document volume and rate of irrigation water applied. For example, flumes or weirs can be installed on ditches or canals; various water meters can be installed on water pipelines.

4.2.2 General Benefits

- the total amount of water applied is known and controlled
- the rate at which water is applied is known and controlled
- useful in application of proper chemical concentrations through irrigation water
- monitors water rights allocations

4.2.3 General Drawbacks

- cost and maintenance (relatively small)

4.3 SOIL AND CROP WATER USE DATA

4.3.1 Overview of Technique

Information is available from various publications regarding the characteristic soil water content profiles of the rooting zones of various soils and the water use information of various crops. With this information, both the available water-holding capacity of the soil and the amount of water that can be extracted by a crop can be estimated. Soil moisture contents can be validated through monitoring using bulk samples, or a variety of sensors including probes and gypsum blocks. When the crop demand is calculated to be greater than the available soil water, the decision to irrigate is made (Canessa and Hermanson 1994).

4.3.2 General Benefits

- water loss is reduced
- loading rates of nutrients, chemicals can be calculated
- rooting zone leaching can be estimated

4.3.3 General Drawbacks

- published data is often not site-specific, and may include generalizations or assumptions not appropriate to some lands and crop

4.4 SOIL WATER BY TENSIOMETERS

4.4.1 Overview of Technique

This technique follows that of 4.3 above, but uses tensiometers or other devices and methods of determining soil water content. Variation and error associated with published information is bypassed and site specific data is used in irrigation scheduling.

4.4.2 General Benefits

- water loss is minimized
- loading rates of nutrients, chemicals can be calculated
- rooting zone leaching can be estimated

4.4.3 General Drawbacks

- expense and maintenance of tensiometers

4.5 DRIP OR TRICKLE IRRIGATION

4.5.1 Overview of Technique

Drip irrigation and trickle irrigation are water conservation approaches to watering crops. Irrigation water that may normally be lost to evaporation, transpiration by non-crop plants, and overland flow (without benefit to the crop) is conserved as water is applied directly to the rooting zone of the crop. Applicators such as porous tubing or perforated pipe installed on or just beneath the soil surface transport and deliver the water under low pressure so surface ponding and runoff is reduced.

4.5.2 General Benefits

- water use (quantity) vastly reduced
- reduced sediment and chemical losses from soil

4.5.3 General Drawbacks

- salts and chemicals may not be adequately leached causing increased concentrations in the rooting zone
- more appropriate for row crops than broadcast-seeded crops

4.6 SPRINKLER IRRIGATION

4.6.1 Overview of Technique

Sprinkler irrigation involves the application of water under pressure in a network of perforated pipes or nozzles. This pipe network can be fixed or mobile, as with central pivot irrigation. The area of application depends on the range covered by the pipes plus the reach of the pressurized sprinklers or jets.

4.6.2 General Benefits

- commonly used

4.6.3 General Drawbacks

- water loss (and perhaps chemical transfer) by wind drift
- easier to over-irrigate

4.7 IRRIGATION BY SURFACE OR SUBSURFACE MEANS

4.7.1 Overview of Technique

Irrigation by surface methods includes furrows, contour ditches, and portable gated pipes. Subsurface methods include piped delivery with low-pressure individual or multiple-orifice risers. Area of application includes the pipe network and furrows, ditches, or depressions which carry the irrigation water downslope.

4.7.2 General Benefits

- commonly used

4.7.3 General Drawbacks

- water concentrated in furrows can gain velocity and erode soils
- water in furrows is subject to loss through evaporation

4.8 WATER CONVEYANCE: DITCHES AND CANALS

4.8.1 Overview of Technique

Ditches and canals are generally permanent features used to convey irrigation water from the supply source to the fields. They are most often formed in/with earthen materials. A design discharge of 25 ft^3/second is frequently used.

4.8.2 General Benefits

- water available to wildlife

4.8.3 General Drawbacks

- some water lost to soil through ditch/canal
- some water lost to evaporation
- water susceptible to contamination between source and target areas
- scour and erosion of conveyance channel can lower water quality and increase maintenance requirements
- saline seeps can occur beneath channels due to leaching processes

4.9 WATER CONVEYANCE: DITCH AND CANAL LINING

4.9.1 Overview of Technique

This technique improves the method in 4.8 by lining conveyance channels in permeable, well-drained soils with impermeable (or less permeable) materials to reduce water loss through the wetted perimeter of the channel. Options include applications of paving, concrete blocks, plastic, clay liners, and "time-release" bentonite clay pellets to the bed and/or banks of the channel.

4.9.2 General Benefits

- reduced water loss through seepage
- salt concentrations available to leaching processes are reduced

4.9.3 General Drawbacks

- water lost to evaporation
- water susceptible to contamination between source and target areas
- scour and erosion of conveyance channel may wear or remove some liners, and can lower water quality

4.10 WATER CONVEYANCE: PIPELINE

4.10.1 Overview of Technique

Water can be delivered from an irrigation source to the application system or directly to the field under pressure in a contained pipeline.

4.10.2 General Benefits

- no water losses to seepage or evaporation
- quality of source water is maintained
- maintenance requirements are reduced

4.10.3 General Drawbacks

- ancillary benefit as a wildlife water supply is lost

4.11 TAILWATER RECOVERY

4.11.1 Overview of Technique

Water reaching the downslope end of a field has basically gone unused in satisfying the water needs of a crop. Irrigation efficiency can be improved with a means to recycle this recoverable tailwater for reuse in the irrigation distribution system.

4.11.2 General Benefits

- downstream surface water yields of sediment and pollutants are reduced
- water from the irrigation source is augmented by recycled tailwater resulting in decreased demand on the supply source

4.11.3 General Drawbacks

- accumulation of contaminated sediments in collection ponds will require proper treatment and/or disposal

4.12 FILTER STRIP

4.12.1 Overview of Technique

Vegetated filter strips near field borders, tailwater areas, and intermittently across fields function as a filter between concentrated irrigation water and a receiving water body. Surface water entering the vegetated filter strip loses (reduces) sediment, nutrients, and bacteria through several processes. These may include filtration, deposition, infiltration, adsorption, absorption, decomposition, and volatilization. Vegetation can consist of an array of close-growing ground cover species. Soil conditions remain in aerobic condition (as compared to the anaerobic conditions of wetlands).

4.12.2 General Benefits

- reductions in sediment reaching receiving waters
- nutrients taken up by vegetation

4.12.3 General Drawbacks

- may require mowing or removal of sediment
- may be less effective with suspended sediments and soluble materials
- when flooded they may release a large load of pollutants into surface waters

4.13 SURFACE DRAINAGE DITCH

4.13.1 Overview of Technique

This is simply a graded ditch for collecting excess water in a field. Field characteristics such as slope and soil erodibility and the density of drainage ditches in a field influence the usefulness and effectiveness of this technique.

4.13.2 General Benefits

- reduction in sheet, rill, or gully erosion if ditch placement reduces erodible slope length
- water concentrated in ditch can be more easily collected and treated or reused

4.13.3 General Drawbacks

- possible increased sediment yield to downstream receiving waters when draining highly erosive soils or steep slopes
- increase in salinity and pollutant loading in receiving waters

4.14 SUBSURFACE DRAINAGE COLLECTION

4.14.1 Overview of Technique

Perforated conduit or gravel-filled trenches can be installed beneath the ground surface to collect and/or convey excess drainage.

4.14.2 General Benefits

- discharges to surface waters are generally low in sediment and sediment-related pollutants
- water temperature in receiving streams may be reduced by subsurface-source discharges
- water can be collected and reused

4.14.3 General Drawbacks

- soluble pollutants (e.g., nitrates) can be high and detrimental to either surface or ground water
- excavation required

4.15 WATER TABLE CONTROL

4.15.1 Overview of Technique

The water table (depth at which ground water saturation occurs) influences the distribution of irrigation water and the removal of drainage water; it can be controlled through the proper, combined use of subsurface drains, water control structures, and water conveyance systems. Runoff from fields with controlled water tables is generally reduced, but when drainage does increase, water quality will decrease due to the increase in soluble substances. Seasonal control of the water table can both benefit crops and improve soil water quality by removing nitrates and reducing soil salinity. Seasonally controlled drainage to downstream surface waters offers some control over the effects of saline or nutrient-rich discharges.

4.15.2 General Benefits

- increased control of water available to crops
- control of drainage water quality

4.15.3 General Drawbacks

- erosion and sediment-yield hazards associated with system installation
- may alter ground water regime of nearby wetlands and riparian areas
- can affect low flow conditions of adjacent and downstream channels
- high-cost, intensive management

4.16 BACKFLOW SAFETY DEVICES

4.16.1 Overview of Technique

Fertilizers, various pesticides, and other chemicals may be applied to farmland directly through irrigation water in a process known as "chemigation". Precautions should be taken to prevent backflow of chemicals to the water source whenever the irrigation pump is shut down. Several systems used to prevent backflow are available.

4.16.2 General Benefits

- for surface water sources, risk of chemical contamination is reduced
- for ground water sources, risk of aquifer pollution is reduced

4.16.3 General Drawbacks

- none

4.17 LIMIT INTERWATERSHED DIVERSIONS AND RETURNS

4.17.1 Overview of Technique

With large-scale landscape modifications to terrace hillsides, install irrigation facilities (including pumps), excavate contour drainage ditches, and perform other soil and water conservation measures, it is not uncommon for irrigation water diverted from a source in one watershed to be returned to another adjacent watershed. This may happen as water applied to land near a divide seeps to the adjacent watershed, or irrigation water pumped uphill in canals and furrows across a divide can flow downhill by gravity.

This practice can upset the natural water balance under which aquatic life (as well as human and wildlife communities) in each of the watersheds developed. Streams in the source watershed may suffer from declining or no flows during low flow periods. Streams in the target watershed may or may not be impacted. Changes in riparian vegetation in each of the watersheds may also be observed.

Opportunities to correct existing interwatershed diversions should be studied. Proposed interwatershed diversions should be avoided or mitigated to the fullest extent possible.

4.17.2 General Benefits

- natural water balances are maintained or restored

4.17.3 General Drawbacks

- some areas may be irrigated only with great difficulty and expense (both financial and resource disturbance)
- water rights are difficult to modify

4.18 PURCHASE/NEGOTIATE WATER RIGHT

4.18.1 Overview of Technique

Adequate water supplies for current and future water supplies should be assured by water rights. When a water right is not owned, it is possible that one may be secured through negotiation, purchase, or written agreement with a legal water rights holder. This is particularly true where the owner of a perennial water right requires only seasonal use of the water. "Off season" use may be had for alternate seasonal purposes.

4.18.2 General Benefits

- water rights should provide for instream uses

4.18.3 General Drawbacks

- water rights may be over-allocated
- competing uses may limit available options
- water rights are difficult to modify

4.19 FILE FOR INSTREAM WATER RIGHT

4.19.1 Overview of Technique

Adequate water supplies for current and future water supplies should be assured by water rights. When a water right is owned, water availability is secured to the extent possible by law. Filing for an instream water right is a first step to documenting need and intent of use.

4.19.2 General Benefits

- water rights should provide for instream uses

4.19.3 General Drawbacks

- water rights may be over-allocated and actual supply or quality is not guaranteed

4.20 WELL CONSTRUCTION FOR PRIMARY WATER SOURCE

4.20.1 Overview of Technique

Using a well as a primary water source for irrigation water may alleviate demands on surface sources such as streams. Wells can be preferred water sources for the long term as long as regional or subregional watershed planning occurs. Unchecked ground water pumping can reduce the quantity and quality of both surface water and ground water resources.

If wells tap deep aquifers, effects on streamflows in the near term should be negligible. Over years and decades, however, ground water elevations may be lowered resulting in reduced quality and higher access costs.

If wells tap shallow aquifers, dry season pumping may result in a lowered water table, increased leaching of salts and other pollutants to ground water, and vegetation impacts in wetlands and riparian areas. These impacts may be negligible at first, or undetectable for one or more years

4.20.2 General Benefits

- local, generally clean and reliable water supply
- alleviates immediate need for surface water supplies, leaving streamflow for instream beneficial uses
- may reduce the length of ground-disturbing pipelines needed for an irrigation system

4.20.3 General Drawbacks

- pump costs
- can hurt ground water and surface supplies if mismanaged on the watershed scale
- can modify wetland and riparian areas where the water table is lowered

4.21 IMPOUNDMENTS FOR WATER SOURCE

4.21.1 Overview of Technique

Impoundments can be an irrigation water source that is both self-sustaining and one step removed from well water, surface water, and piped in sources. Properly located, some impoundments can be filled by collecting ground water, soil water seepage, and precipitation. They may also be filled with water from wells or pumped from streams at a time when water is available and demands are reduced, then used at a later date with risk of loss to seepage and evaporation.

4.21.2 General Benefits

- water collected as available and used when needed
- leaves streamflow for instream beneficial uses
- can create additional fish and wildlife habitat

4.21.3 General Drawbacks

- surface water sources more easily contaminated
- seepage water may leach pollutants to ground water
- may require additional filtering before use to preserve irrigation system integrity

4.22 AVOID EXCESS IRRIGATION FLOWS

4.22.1 Overview of Technique

Water applied to furrows, conveyance channels, and drainage ditches in excess of plant needs and minimum delivery requirements functions only to maintain hydraulic head in the channels and account for obstructions or irregularities that may reduce delivery accuracy and efficiency. Some of this water is necessary for successful irrigation.

Too much water can have negative effects. Excess water can result in scouring of furrows and ditches and an increase in sediment transport off site. Filter strips and tailwater systems may be inundated above their capacity, reducing their effectiveness. In permeable areas, excess water can flush needed nutrients and chemicals out of the rooting zone and can contaminate ground water supplies.

Excess irrigation flows can be avoided by good irrigation planning, understanding crop requirements, knowing existing soil water conditions, metering application lines, and recording times of application.

4.22.2 General Benefits

- water loss is minimized
- sediment yield is reduced
- ground water and surface water quality is maintained
- system design capacities are not stressed

4.22.3 General Drawbacks

- none

4.23 INTAKE AND RETURN DIVERSION SCREENS

4.23.1 Overview of Technique

Where irrigation diversion intake and return points coincide with surface water supplies and aquatic habitat, these contacts should be designed to prevent fish and other aquatic organisms of all lifestages from accessing the irrigation system. Protection often takes the form of screens across intake pipes or discharge channels (Saskatchewan Environment and Resource Management 1995b; Canada Department of Fisheries and Oceans 1995). Monitoring and maintenance of these barrier devices should occur on a regular basis.

4.23.2 General Benefits

- fish mortality due to stranding and/or temperature and oxygen stress is reduced

4.23.3 General Drawbacks

- maintenance required

4.24 PROTECT SPRINGS

4.24.1 Overview of Technique

Where springs are known to exist, they should be given special protection. They may be capped and used as a water supply for agricultural uses. Where a spring occurs near a stream, protect the spring from modification and maintain/create discharge to the stream channel. Protection should also include the avoidance or reduction in use of pesticides and fertilizers and ground disturbance near the spring. Springs generally produce clean and cool water effective in enhancing the quality of receiving streams.

4.24.2 General Benefits

- improved water quality
- decreased stream temperatures

4.24.3 General Drawbacks

- fewer land management options near the spring

4.25 CONSOLIDATE/REPLACE IRRIGATION DIVERSION DAMS

4.25.1 Overview of Technique

Not uncommonly, older diversion dams used for irrigation supplies are undesigned structures created through the bulldozing of river rock, earth, or fill material into embankments, or the placement of log cribs. Habitat modifications, barriers to fish passage, and water capacity and demand may not have been considerations during construction of these diversion dams.

Where diversion dams are barriers to fish passage, have created unacceptable habitat modifications, or are causing sediment concerns through deposition behind the dam or downstream scour, and where diversion dams are abandoned, are in need of repair, are considered unnecessary to meet demand, dams should be removed, consolidated, or replaced with structures designed for fish passage and habitat considerations. Projects should be supported by watershed-based analyses with the involvement of multiple owners and users. Coordinate with appropriate local governments, irrigation districts, and state and federal agencies.

4.25.2 General Benefits

- improved fish passage
- where dams are removed, increase in natural habitats
- removal/reduction of erosion source
- reduction in maintenance costs

4.25.3 General Drawbacks

- where removed, sediment retention function is lost
- construction effects on water quality

5 AGRICULTURAL MANAGEMENT TECHNIQUES--ANIMAL FACILITIES

5.1 HEAVY USE AREA PROTECTION

5.1.1 Overview of Technique

Areas that are intensively used by farm animals and livestock should be protected by establishing vegetative cover, by surfacing with other suitable materials, and/or by installing drainage, treatment, and access structures.

5.1.2 General Benefits

- reduced erosion improves surface water quality

5.1.3 General Drawbacks

- erosion and sedimentation accompanying initial construction of structures
- increased runoff from impervious areas discharges nutrients, chemicals, oils, bacteria, and organic matter to receiving waters

5.2 MANAGE RUNOFF FROM IMPERVIOUS SURFACES

5.2.1 Overview of Technique

Whether from paving, destruction of soil structure by compaction, sealing the ground surface with fine sediment and organic matter, or the construction of water repellent structures such as roofs, impervious areas can compound water quality problems by rapidly concentrating water from a large area. Managing this overland flow can be preventative (implement designs to minimize area, volume, and direction of flow) or corrective (assuring its treatment and/or dispersal).

5.2.2 General Benefits

- erosion and downstream sediment yields reduced
- volume of water polluted by animal wastes is reduced

- nutrient and pesticide loadings in discharges are decreased
- risk of local flooding reduced as drainage is improved

5.2.3 General Drawbacks

- infiltration in highly permeable areas may result in pollutants leaching to ground water

5.3 WASTE MANAGEMENT PLAN

5.3.1 Overview of Technique

A waste management plan should be developed for the various waste "streams" associated with confined animal facilities and other agricultural sources. Wastes should be characterized and alternative utilization, treatment, and disposal methods identified. Recycling and reuse of wastes are preferred.

Waste management should be tiered to a nutrient management plan developed for all agricultural operations on a parcel of land. Management options and techniques are subject to state regulations.

5.3.2 General Benefits

- the most environmentally acceptable and financially feasible alternatives for use or disposal are identified

5.3.3 General Drawbacks

- none

5.4 WASTE STORAGE AND TREATMENT

5.4.1 Overview of Technique

Earthen impoundments or fabricated structures are used to contain and temporarily store animal and other agricultural wastes. Some impoundments may serve as lagoons for the long-term biological treatment of wastes.

5.4.2 General Benefits

- reduces direct delivery and loading of nutrients, pathogens, and chemicals to surface water
- in lagoons, sediments and some insoluble nutrients settle and form sludge before runoff is discharged

5.4.3 General Drawbacks

- dissolved pollutants may leach with seepage to ground water supplies
- long-term maintenance and cleaning still results in a use/disposal issue

5.5 LAND APPLICATION OF WASTES

5.5.1 Overview of Technique

Agricultural wastes such as manure and runoff water can be used as a soil amendment beneficial to improve soil fertility and tilth. Proper site selection, rate and timing of application, and other BMPs can lower the risk of surface water and ground water degradation. Increased microbial activity near the soil surface may also assist in controlling pesticides and other pollutants.

5.5.2 General Benefits

- plant growth increased
- increased infiltration and decreased erosion
- fixing of pesticides near the soil surface

5.5.3 General Drawbacks

- risk of pollutants discharged to surface waters
- nutrients available for leaching to ground water are increased (e.g., nitrates)

5.6 COMPOSTING FACILITY

5.6.1 Overview of Technique

A facility for composting agricultural organic wastes may be built. This process uses biological decay by microorganisms to produce a stable humus-like material that may then be used as a soil amendment or mulch and a substitute for fertilizer. State regulations may apply.

5.6.2 General Benefits

- natural, biological process
- yields stable, nutrient rich product
- can improve soil tilth and infiltration when used

5.6.3 General Drawbacks

- can be time consuming
- may require large area requiring its own drainage management

5.7 CONSTRUCTED WETLANDS FOR TREATMENT OF AGRICULTURAL WASTES

5.7.1 Overview of Technique

Constructed wetlands are designed to imitate the water filtering and purification processes of natural wetlands. Upland sites are usually converted to wetlands by creating poorly drained soil conditions.

Vegetation is generally not as diverse as in natural wetlands. Though other wetland functions such as wildlife habitat may exist in created wetlands, they are primarily managed in this context to treat agricultural wastewater. Pollutant removal occurs through sediment trapping, assimilation by plants, bacterial decomposition, and adsorption.

5.7.2 General Benefits

- pollutant removal
- sediment retention
- wildlife habitat

5.7.3 General Drawbacks

- if underdesigned, contaminated stormflows may be discharged from the wetland (before pollutants are stabilized)

5.8 COMMERCIAL DISPOSAL SERVICE

5.8.1 Overview of Technique

A commercial disposal service may be best equipped to handle the disposal or treatment and recycling of agricultural wastes in an environmentally acceptable manner.

5.8.2 General Benefits

- ease
- service transports and disposes of wastes at approved sites

5.8.3 General Drawbacks

- expense
- reuse as soil amendment is an opportunity cost
- fertilizer requirements may increase
- disposal at some location is still required

5.9 LANDFILL BURIAL OF WASTES

5.9.1 Overview of Technique

Some landfills may be approved to accept agricultural wastes where disposal is favored over reuse. State regulations apply.

5.9.2 General Benefits

- ease

5.9.3 General Drawbacks

- limited landfill capacity
- expense
- reuse as soil amendment is an opportunity cost
- fertilizer requirements may increase

5.10 INCINERATE WASTES

5.10.1 Overview of Technique

Agricultural wastes can be incinerated when large volumes of waste exceed the capacity to handled by other means.

5.10.2 General Benefits

- waste reduction
- ash may yield some nutrient value

5.10.3 General Drawbacks

- reuse as soil amendment is an opportunity cost
- fertilizer requirements may increase
- air quality issues

5.11 HARDENED FORDS FOR LIVESTOCK CROSSINGS OF STREAMS

5.11.1 Overview of Technique

Where livestock and other farm animals are required to access and cross a stream channel on a somewhat infrequent basis, hardened fords can be used to reduce trampling pressure and streambank and bed damage. (Use culverts or bridges for frequent crossing locations.) Methods may include paving with concrete or placing cobbles, concrete blocks, or geotextiles at established pathways.

5.11.2 General Benefits

- resists bank trampling and destruction
- generally easier to install (compared to culverts)
- less resource damage if/when removed

5.11.3 General Drawbacks

- allows direct contact of equipment/livestock with stream
- no sideboards to encourage/require use
- temporary concrete leaching in stream channel

5.12 SEASONAL USE OF FORDS AND SURFACE WATERS

5.12.1 Overview of Technique

Where livestock or farm animals do access surface waters for drinking, or where they cross surface waters at fords, limit access to seasons when preferred fish species are not present. Additional use of fences may reduce straying off fords or watering areas into spawning gravels or large rearing pools.

5.12.2 General Benefits

- mortality and injury to fish remain low
- water quality maximized when fish are present

5.12.3 General Drawbacks

- may result in lengthy exclusions
- some fish may be present during open use-windows

5.13 ALTERNATIVE WATER SOURCES

5.13.1 Overview of Technique

Provide alternative and/or supplemental water sources to surface water supplies for livestock and farm animals. (This option is considered in greater detail as grazing techniques 6.6 through 6.10.)

5.13.2 General Benefits

- preserves stream channel or lake bed structure
- prevents direct contact of animal wastes and disturbance-generated sediments with surface water and maintains high water quality

5.13.3 General Drawbacks

- alternatives may be impractical

6 AGRICULTURAL MANAGEMENT TECHNIQUES--GRAZING

Grazing involves releasing livestock onto rangeland for the purpose of providing forage and shelter to the animals. Grazing can also be used as a management tool to manipulate vegetation and has been used to reduce shrub density, thus releasing trees from competition and reducing fire fuels. Grazing can also be used to create habitat diversity between grazed and ungrazed areas. Conversely, range improvements can improve water quality as well as increase annual production (Johnson 1992).

Riparian grazing, however, has been linked to decreased stream bank stability, increased sediment yields to streams, and declining water tables and the recharge of aquifers. Modern grazing management (primarily cattle and sheep) addresses these concerns with intensive grazing systens that utilize fencing, rotation of use, and control of movements (Elmore 1992).

Related management techniques that may be employed under a grazing management system include control of undesirable plants, seeding, fertilization, water improvements and pipelines, and construction of holding corrals, cattleguards, and fences.

Range management on public lands is usually carried out through range allotments. Range allotments are essentially lease arrangements for a specific number, kind, and timing of livestock use within a designated area. An allotment is typically implemented under an allotment management plan that specifies how and when the allotment area is to be grazed.

The grazing techniques below are typical of those used to reduce nonpoint source pollution from farms and rangeland.

6.1 DEFERRED GRAZING

6.1.1 Overview of Technique

This management technique "rests the land" by postponing grazing for a prescribed period. With time, vegetative ground cover should increase, ground disturbance decreases, soil bulk density characteristics improve, and infiltration rates increase. The filtering qualities of the land are also improved with the establishment of vegetation as sediments are trapped and secured and available nutrients are utilized by plants. Animal waste loading is drastically reduced with less risk of adverse effects on surface water and ground water quality.

6.1.2 General Benefits

- soil conditions improve
- sediment yields and related pollutants in receiving waters are reduced
- runoff from site is reduced and slowed

6.1.3 General Drawbacks

- if not monitored or observed periodically, restoration needs or deferred grazing lands may go unnoticed or unmet

6.2 PLANNED GRAZING SYSTEM

6.2.1 Overview of Technique

This management technique involves the grazing of two or more landunits in an alternating graze and rest sequence for several years or more. The duration of the periods may be annually or during the growing season of key plants.

6.2.2 General Benefits

- quantity and quality of vegetation is increased
- rates of manure decomposition, dependent on vegetation quality, should increase and therefore reduce pollution potential
- sediment and nutrient yields are maintained at low rates compared to continual grazing

6.2.3 General Drawbacks

- commitment of land (doubling land requirements over a system of continuous grazing)

6.3 CONTROL GRAZING INTENSITY

6.3.1 Overview of Technique

Grazing should be managed and controlled at an intensity that will maintain soil conditions and sustain healthy vegetative cover. In woodland areas, grazing should be managed and controlled at an intensity that will maintain soil conditions and sustain both trees and forage vegetation. A grazing plan should document a justifiable grazing intensity.

6.3.2 General Benefits

- quantity and quality of vegetation is increased or sustained
- sediment and nutrients in runoff remain low

6.3.3 General Drawbacks

- large herds may be dispersed across several allotments or pastures

6.4 PASTURE AND HAYLAND MANAGEMENT

6.4.1 Overview of Technique

Whether grazed or harvested, pastures and hayland should be managed on a sustainable basis where vegetation is encouraged and soil disturbance is minimized.

6.4.2 General Benefits

- erosion and sediment yields are reduced as infiltration is encouraged
- more water remains on site; runoff is reduced

6.4.3 General Drawbacks

- increased infiltration may result in an increase of soluble nutrients and pesticides being leached into the ground water

6.5 WATER SUPPLY: PIPELINE

6.5.1 Overview of Technique

Pipelines are an alternative water supply method to surface water sources. Water is piped (and usually pumped) from any appropriate source to watering areas located away from stream channels or other sensitive areas. Pipes generally range from 0.5 to 4 inches, but may exceed 12 inches in diameter. They can be placed in the ground or above. Placement in the ground typically involves minor trenching using a backhoe or similar equipment.

6.5.2 General Benefits

- minimizes water losses from infiltration and evaporation

6.5.3 General Drawbacks

- requires more initial investment to install and can require more effort to maintain
- disturbs vegetation
- trenching may affect archeological resources

6.6 WATER SUPPLY: PONDS

6.6.1 Overview of Technique

Impoundments can be one of the simplest ways to create a water feature. Several scales and designs of impoundments are available to the farmer or range manager. Impoundments can range from simple earthen levees to elaborate concrete dams. Examples include simple embankments made from on-site soils; clay-core dams, which contain a hard clay center; and diaphragm dikes, which contain an outer layer of concrete, steel, or wood to hold back water.

The level of construction required depends upon the magnitude of the impoundment. Simple soil berms require relatively little construction work while an elaborate concrete dam would require larger crews. Construction of dikes and levees typically involves heavy equipment, including a front-end loader, excavator, dump truck, bulldozer, and grader. Blasting may be required to remove rock or stumps or to dig out the foundation area.

Impoundments usually require spillways to allow excess water to pass during heavy flows. Spillways may be constructed from concrete, wood, steel, or earth. On smaller impoundments, simple overflow tubes may be sufficient to release potential floodwaters.

6.6.2 General Benefits

- provides controllable water features
- ponds trap sediment and sediment-related pollutants
- may store or moderate stormflows from/on the area

6.6.3 General Drawbacks

- surface water subject to direct contamination from livestock
- impounded water from streams may prevent adequate flushing of fine sediments from spawning gravels downstream
- seepage can leach pollutants to ground water
- water temperatures will increase in ponds
- design can require extensive engineering considerations
- excavation may affect archeological resources

6.7 WATER SUPPLY: TROUGH

6.7.1 Overview of Technique

Troughs can be filled by water pipelines or wells in order to provide an alternative watering site to a stream channel.

6.7.2 General Benefits

- sediment and pollutant yields are reduced
- channel structure is maintained as bank and bed trampling are reduced
- location of troughs can help distribute grazing livestock

6.7.3 General Drawbacks

- none

6.8 WATER SUPPLY: WELL

6.8.1 Overview of Technique

Well systems involve drilling to and tapping into ground water sources to provide an alternative water supply to stream channels. Construction usually involves a small drilling rig which is typically mounted on a vehicle. Following access to the well, pipe is installed to transport water from the well, and a pump and distribution assembly is placed at the well head and housed in a small structure. Distribution lines are then established. The diameter of pipe and distribution lines depends on water demand but is typically much less than 12 inches.

6.8.2 General Benefits

- sediment and pollutant yields are reduced
- channel structure is maintained as bank and bed trampling are reduced
- location of wells and associated watering sites can help distribute grazing livestock
- obtaining water rights for a well can sometimes be easier than obtaining surface water rights

6.8.3 General Drawbacks

- wells immediately adjacent to watering areas may be prone to surface contamination (e.g., bacteria, nitrates)
- may raise concerns regarding aquifer depletion

6.9 WATER SUPPLY: SPRING DEVELOPMENT

6.9.1 Overview of Technique

Springs and seeps occur where groundwater escapes to the surface. Ingeneral, springs provide greater amounts of water than seeps. Both can be tapped and collected to provide water to livestock.

Spring or seep development requires (1) a field of gravel or sand to colect water, (2) a pipe to drain the field, (3) a storage area or head box to collect and temporarily store water, and (4) a pipe connected to a trough to serve as a drinking basin for livestock.

In most cases, development of a spring requires excavation to install the drainage field and, if necessary, an impermeable barrier to prevent flowthrough.

6.9.2 General Benefits

- sediment and pollutant yields are reduced
- channel structure is maintained as bank and bed trampling are reduced
- can provide water for wildlife

6.9.3 General Drawbacks

- source water for springs can change naturally or by disturbance caused during spring development
- for springs near stream channels, the cooling effect of the spring on stream water temperature, if any, may be decreased

6.10 ACCESS: FENCING

6.10.1 Overview of Technique

Permanent and/or temporary fencing may be constructed to serve as a containment feature or barrier to livestock. Streambanks, lake shores, riparian areas, and wetlands are some areas which can be excluded from livestock access. Physical disturbance to these features is reduced as a result.

Fence lines will typically contain taller grass and some shrubs. Fencesthat are constructed on the contour may therefore slow surface runoff and result in deposition of coarser sediment.

Where fencelines cross roads, simple wire gates or cattle guards may be installed.

6.10.2 General Benefits

- sediment and pollutant yields to streams are reduced
- channel structure is maintained as bank and bed trampling are reduced

6.10.3 General Drawbacks

- livestock tend to walk along fences, creating soil-worn paths
- fences may create a concentrating effect by placing many livestock in a smaller area near fencelines--erosion and livestock waste problems may result
- seasonal access may be desired, thus requiring frequent maintenance
- abandoned fences may create access or solid waste problems

6.11 ACCESS: TRAILS/FORDS AT STREAM CROSSINGS

6.11.1 Overview of Technique

Where livestock and other farm animals are required to access and cross a stream channel on a somewhat infrequent basis, hardened fords can be used to reduce trampling pressure and streambank and bed damage. (Use culverts or bridges for frequent crossing locations.) Methods may include paving with concrete or placing cobbles, concrete blocks, or geotextiles at established pathways.

Where livestock or farm animals do access surface waters for drinking, or where they cross surface waters at fords, limit access to seasons when preferred fish species are not present. Additional use of fences may reduce straying off fords or watering areas into spawning gravels or large rearing pools.

6.11.2 General Benefits

- resists bank trampling and destruction
- generally easier to install (compared to culverts)
- less resource damage if/when removed
- mortality and injury to fish remain low
- water quality maximized when fish are present

6.11.3 General Drawbacks

- allows direct contact of equipment/livestock with stream
- unless fenced, there are no sideboards to encourage/require use of established fords
- may result in lengthy exclusions from streams
- some fish may be present during open use-windows

6.12 VEGETATION STABILIZATION: PASTURE PLANTING

6.12.1 Overview of Technique

Improve the quantity and quality of vegetative cover on pastureland by establishing or reestablishing stands of native or adapted perennial, biannual, or reseeding forage plants.

6.12.2 General Benefits

- reduced erosion and sediment yield
- increased surface water quality

6.12.3 General Drawbacks

- leaching of soluble substances to ground water may increase vith increased infiltration (this is countered, however, by healthy, vigorous vegetative cover)

6.13 VEGETATION STABILIZATION: RANGE SEEDING

6.13.1 Overview of Technique

Improve the quantity and quality of vegetative cover on rangeland by seeding and establishing native or adapted forage plants. Some ground scarification may be necessary. Application of fertilizer or some herbicides may be desired.

6.13.2 General Benefits

- reduced runoff after vegetation establishment
- reduced erosion and sediment yield over the long term
- increased surface water quality

6.13.3 General Drawbacks

- temporary minor erosion and sediment increases may result ifthe ground is scarified
- risk of fertilizer or chemical transport to surface water, or leaching to ground water

6.14 VEGETATION STABILIZATION: CRITICAL AREA PLANTING

6.14.1 Overview of Technique

Plant trees, shrubs, vines, grasses, or legumes on severe, actively erodng areas, and areas with high erosion potential.

6.14.2 General Benefits

- reduce erosion and sediment yield
- nutrient loss to surface and ground waters is reduced

6.14.3 General Drawbacks

- not immediate in effect - erosion and chemical loss may occur from the site prior to plant establishment

6.15 VEGETATION STABILIZATION: BRUSH/WEED MANAGEMENT

6.15.1 Overview of Technique

Noxious weeds, nonnative invasive plants, and aggressive, weedy species can take over disturbed lands and degrade range values. Much of the Columbia River Basin has been disturbed by intensive grazing, farming, and other human activities; therefore, some mitigation areas are expected to contain relatively poor range and wildlife habitat dominated by undesirable plant species. The control of such unwanted vegetation can encourage the establishment and water quality benefits of native plants.

Techniques available to control vegetation includes herbicides, mechanical removal, biological control, hand pulling, and prescribed burning. These are described in Sections 3.29 and in Sections 2.9 through 2.12, respectively. Water level manipulation is also a vegetation management tool. See Section 4.15.

6.15.2 General Benefits

- various (see referenced sections above)

6.15.3 General Drawbacks

- various (see referenced sections above)

6.16 MONITOR WILDLIFE

6.16.1 Overview of Technique

Study wildlife (e.g., deer, elk) and domestic livestock land use patterns, identify problems and develop mitigation strategies. For example, wildlife may be herded away from domestic feedlots if they exacerbate existing poor conditions.

6.16.2 General Benefits

- problem sources properly identified
- reduced erosion and waste generation
- sound basis for management

6.16.3 General Drawbacks

- may be difficult or costly to implement

6.17 WILDLIFE HARVESTING

6.17.1 Overview of Technique

Encourage proper wildlife harvesting to ensure proper population densities and forage balances.

6.17.2 General Benefits

- maintain vegetative cover and stable soil conditions

6.17.3 General Drawbacks

- secondary disturbance effects created by hunters/hunting pressure

6.18 HEAVY USE AREA MANAGEMENT

6.18.1 Overview of Technique

Areas that are intensively used by livestock (feedlots, temporary herding pens) should be protected by establishing vegetative cover; by surfacing with other suitable materials; by installing drainage, treatment, and access structures; by creating filter strips around problem areas; and/or by removal or relocation of attracting structures.

6.18.2 General Benefits

- vegetation re-establishment
- patterned dispersal and recovery of disturbed areas
- increase infiltration and reduced runoff from most areas
- reduced erosion improves surface water quality

6.18.3 General Drawbacks

- erosion and sedimentation accompanying initial construction of some structures
- leaching of soluble nutrients may reach ground water
- increased runoff from impervious areas (if created) may discharge nutrients, chemicals, oils, bacteria, and organic matter to receiving waters

7 ROAD MANAGEMENT TECHNIQUES

7.1 PRE-PLAN ROAD LOCATION

7.1.1 Overview of Technique

In addition to user safety, the avoidance of unstable, sensitive, or fragile areas are a primary consideration incorporated into the best location of roads and other transportation facilities (such as landings). Forest roads are often chronic sediment sources degrading water quality and devaluing habitat which may often be prevented by planning including aerial and on-the-ground reconnaissance, surveying, design, and the implementation of various other BMPs.

7.1.2 General Benefits

- road crossings of floodplains and alluvial fans can be minimized, and when they are required, crossing impacts can be minimized by locating roads in the narrowest, most stable locations
- unstable slopes can be avoided
- well-designed roads provide adequate drainage and reduce the erosive impact of water on road surfaces
- direct sediment inputs from roads to streams are reduced

7.1.3 General Drawbacks

- few drawbacks, if any, as well-planned roads can pay for themselves in reduced road maintenance and sustained quality habitat in adjacent streams

7.2 INSTALL HYDRAULIC STRUCTURES AT LOW STREAMFLOWS

7.2.1 Overview of Technique

Low flows have a reduced capacity for sediment transport. Therefore, in order to retain the maximum amount of disturbed sediments at the crossing site, schedule construction or installation of all stream crossing structures for low flow periods. Be prepared to suspend work or perform weather-contingent work during dry-season stormflow events.

7.2.2 General Benefits

- reduced sediment generation
- reduced downstream sediment transport during construction
- sediments have an opportunity to be stabilized in construction fills
- downstream habitat preserved--spawning gravels are less impacted by fine sediment, and loss of pool volume through pool filling is minimized

7.2.3 General Drawbacks

- construction delays and higher construction costs may result during wet weather

7.3 MINIMIZE EROSION AND SEDIMENTATION DURING STREAM CROSSING CONSTRUCTION

7.3.1 Overview of Technique

Reduce the generation of sediments during stream crossing construction. This can be accomplished through the implementation of various techniques. Examples include:

- working machinery from one side of the stream where possible (minimize unnecessary construction crossings),

- when crossing channels during construction, use pioneering techniques such as using "log culverts" to protect banks, minimize bed disturbance, and prevent contact of equipment oils with streamflow,
- construction of temporary cribs to reduce water velocities,
- using silt fences, hay bales, etc. immediately downstream of construction to retain as much sediment on site as possible, and
- using graded material less than 4 inches diameter as compacted backfill around culverts to prevent piping and continued erosion after construction.

7.3.2 General Benefits

- reduced sediment generation
- reduced downstream sediment transport during construction
- sediments have an opportunity to be stabilized in construction fills
- downstream habitat preserved--spawning gravels are less impacted by fine sediment, and loss of pool volume through pool filling is minimized

7.3.3 General Drawbacks

- short time delays

7.4 DIVERT WATER AROUND CONSTRUCTION OF LARGER STRUCTURES

7.4.1 Overview of Technique

Construction of large structures requires the diversion of streamflow around the crossing site in order to minimize sediment entrainment and water quality degradation from construction equipment. This may be accomplished by damming flow with a coffer or crib dam and pumping sediment-free water around the construction to a stable point downstream. Water may also be diverted to a temporary culvert laid adjacent and parallel to the channel. On wider streams, it may be possible to complete half the construction with weirs directing flow to the other half of the channel. The second half of the stream can then be dewatered by diverting streamflow through the newly installed structure (culvert, bridge piling). All diverted flows should be restored as soon as practicable.

7.4.2 General Benefits

- reduced downstream sediment transport during construction
- sediments have an opportunity to be stabilized in construction fills
- downstream habitat preserved--spawning gravels are less impacted by fine sediment, and loss of pool volume through pool filling is minimized
- water quality degradation by petroleum products minimized

7.4.3 General Drawbacks

- temporary impedance of fish migration
- potential for fish mortality if pumped

7.5 AVOID STREAM CROSSINGS OUTSIDE OF CONSTRUCTION WINDOWS

7.5.1 Overview of Technique

Avoid construction outside of allowable "windows" which reflect the typical lifestages of salmon and steelhead trout. Adults are protected to reduce pre-spawning mortality. Eggs should have hatched and fry emerged from spawning gravels so they may avoid active construction impacts. This window may vary by river basin and seasonal runs, but often approximates a mid-June to mid-September time frame. State fisheries departments are involved in the identification of appropriate windows for site specific stream reaches.

Other timing windows may be appropriate to ensure stable road construction. For example, blasting should not occur when soils are saturated, particularly near streams. Also, road fill should not be placed over snow which may settle and cause failure of fills and drainage structures. If these windows are neglected when appropriate, wide-spread habitat destruction may result.

7.5.2 General Benefits

- increased adult survival and spawning success
- increased fry survival
- reduced risk of road and slope failures

7.5.3 General Drawbacks

- limited construction periods requiring careful planning and resolution of conflicts

7.6 REDUCE RISK OF ROAD-RELATED MASS FAILURES

7.6.1 Overview of Technique

Where practicable, steep and unstable slopes should be avoided through the planning process. When construction occurs on steeper slopes, several guidelines can be followed to minimize the risk of road-related mass failures. These include:

- conduct subsurface investigations and stability analyses on slopes and stream crossings where stability may be suspect,
- roads on slopes should be constructed with a balanced cut/fill design to reduce the size of excavation and fill volumes,
- strictly control blasting--avoid overloading explosives, and do not blast under saturated soil conditions,
- manage road runoff to avoid concentration of water on unstable slopes,
- limit clearing widths to the minimum needed for driver safety,
- locate overburden disposal areas away from steep slopes in more stable locations,
- minimize fill slopes adjacent to designated stream courses, and
- avoid or minimize loading of steep or unstable slopes by excavating roadbed into hillslope and avoiding sidecast or fill material by "end-hauling" it to a stable location.

7.6.2 General Benefits

- reduced risk of mass-failures which may degrade streams
- reduced long-term road maintenance costs (compared to replacement)

7.6.3 General Drawbacks

- cost

7.7 REDUCE RISK OF ROAD-RELATED SURFACE EROSION

7.7.1 Overview of Technique

Linear road features on variable slopes increase the risk of sheet, rill, and gully erosion by subjecting long, bare, and compacted slope lengths to the erosive action of water. Roads and ditches near stream channels tend to function as extensions of the drainage network during wet weather and may transport sediment and other pollutants from roads directly into stream channels. Water allowed to concentrate and remain on the road surface or in an adjacent ditch or flow across a cut or fill slope will increase downstream sediment yields and cause costly maintenance problems.

Techniques to minimize the production of surface erosion from roads may include:

- sealing road surfaces with water and compaction roller, oil treatments, chip-sealing, aggregate surfacing, and paving;
- water, oil, or other treatments for dust control;
- creating rolling dips or water bars in the road surface to reduce water velocities on the road surface;
- planting bare cut and fill slopes and ditchlines;
- limiting wet weather traffic;
- using low tire pressure systems on heavy trucks ("central tire inflation" systems);
- providing adequate road drainage through the frequent use of ditch relief culverts or cross-drains; and/or
- outsloping roads or using a permeable rock overlay to preclude the need to concentrate water in a ditch.

7.7.2 General Benefits

- reduced risk of mass-failures which may degrade streams
- reduced long-term road maintenance costs (compared to replacement)

7.7.3 General Drawbacks

- cost

7.8 DRAINAGE CONTROL TO MINIMIZE EROSION AND SEDIMENTATION

7.8.1 Overview of Technique

In addition to properly sizing stream crossing structures and placing relief culverts, several other drainage control techniques may be implemented to prevent the erosion and entrainment of sediment from road-related surfaces. These may include:

- assuring culverts are placed deep enough in the road fill to prevent crushing, deformation, and a loss of capacity;
- designing water velocities in ditches so that they are fast enough to carry sediment (prevent filling), but slow enough to not scour the ditch;
- armoring ditches with coarse material;
- placing ditch blocks at relief culverts to divert water to culvert and prevent water from running down ditch line;
- using trash racks, drop inlets, and aprons at culvert inlets to prevent clogging and scour;
- dissipating discharge energy (velocities) from culverts using riprap; and
- protecting fill slopes with mechanical measures, including riprap, geo-textiles, hay bales, terracing, or application of soil tackifers.

7.8.2 General Benefits

- reduced risk of surface erosion which may degrade streams
- reduced long-term road maintenance costs

7.8.3 General Drawbacks

- cost

7.9 AVOID CONSTRUCTION DURING INCLEMENT WEATHER

7.9.1 Overview of Technique

Wet weather construction leads to an increase in the amount of sediment generated and available for runoff. Simultaneously, a water supply is present to transport the sediment toward stream channels. Construction on unstable and potentially unstable slopes is also more prone to create mass failures during wet or saturated conditions.

7.9.2 General Benefits

- reduced risk of downstream sediment yield surface erosion and mass erosion processes

7.9.3 General Drawbacks

- construction delays

7.10 EROSION CONTROL AND REVEGETATON AT PROJECT COMPLETION

7.10.1 Overview of Technique

Use grass-seeding, hydro-mulching, straw mulching, straw bales, planting of shrubs and trees, and other revegetation and erosion control techniques to complete road consruction. The goal is to protect freshly disturbed soils until natural vegetation can be established. Rough soil surfaces will help retain planted seed and help to maximize germination and establishment of vegetation

7.10.2 General Benefits

- exposure of bare soils to raindrop energy and concentrated water is reduced
- sediments are retained on site
- instream sediment yields and sediment-attached pollutantsare reduced

7.10.3 General Drawbacks

- vegetation establishment may not occur (or may be incomplete) prior to the wet/runoff season
- non-native plants may be slow to transition back to nativespecies

7.11 SLASH MANAGEMENT

7.11.1 Overview of Technique

Debris generated during road construction should be prevented from obstructing channels. Provided it is stable, large woody debris encountered at stream crossings shouldbe left in place if at all possible. Construction debris generated from rights-of-way should be disposed of by one or means to prevent the formation of slash jams and culvert blocks. These include:

- windrowing (sediment control capabilities),
- scattering.
- chipping,
- piling and burning, and
- bucked into manageable lengths and piled roadside for firewood.

7.11.2 General Benefits

- instream disturbance due to removal of natural large woody debris is prevented
- instream disturbance due to removal of introduced woody debris is prevented
- risk of unnatural debris jams and related dam-break flood events is reduced

7.11.3 General Drawbacks

- none

7.12 INTERSECTIONS WITH PAVED ROADS

7.12.1 Overview of Technique

Where sediment may be tracked from forest roads on to public highways or other paved surfaces, protect the intersections and limit the sediment transfer by paving back from intersection, using corduroy logs, wood chips or similar materials on forest roads.

7.12.2 General Benefits

- tracked and airborne sediment transfer off roads is reduced
- less sediment on impervious paved roads to be entrained in runoff

7.12.3 General Drawbacks

- maintenance required

7.13 GRADE ROAD

7.13.1 Overview of Technique

Road surfaces should be maintained by grading as needed to:

- retain a crowned or sloping cross-section to shed water,
- remove unwanted dips or berms to prevent downslope movement of concentrated water, and
- conserve road materials which might otherwise be transported and deposited in streams.

7.13.2 General Benefits

- improved road drainage
- reduced sediment generation from road surfaces
- reduced instream sediment yields

7.13.3 General Drawbacks

- maintenance costs
- risk of ditch filling with road material or incidental damage to culverts

7.14 DITCH AND CULVERT CLEANING

7.14.1 Overview of Technique

Ditches, culverts, catch basins, and other road crossing structures should be regularly cleaned of obstructions to maintain optimum drainage across the road surface and prism. Maintenance efforts should take care to minimize disturbance of ditches and roadside vegetation, especially during wet weather.

7.14.2 General Benefits

- reduced risk of structural failure and failure of road prism or adjacent slope

7.14.3 General Drawbacks

- risk of disturbing ditches or removing stabilizing vegetation

7.15 GRASSED ROAD SURFACE MANAGEMENT

7.15.1 Overview of Technique

Low use-volume roads may be kept in a vegetated state by sowing grass seed or allowing the encroachment of natural vegetation. Annual maintenance may require mowing or shrub control, especially in more arid areas where fire ignition may be a problem.

7.15.2 General Benefits

- surface erosion processes minimized

7.15.3 General Drawbacks

- coarse or rapid shrub growth may close road or reduce access

7.16 REMOVE TEMPORARY STREAM CROSSINGS

7.16.1 Overview of Technique

When roads are to be closed, or when intensity of use of a road will diminish, remove stream crossing structures which may plug and fail when abandoned. Dips and water bars should be established where culverts are removed. This reduces the risk of channel scour and downstream sediment transport should a culvert plug and fail.

7.16.2 General Benefits

- reduces maintenance requirements
- reduced risk of culvert failure

7.16.3 General Drawbacks

- water bars may become erosion sites if not constructed properly or if not maintained

7.17 ACCESS MANAGEMENT

7.17.1 Overview of Technique

Restriction of access or selected access is a preventive practice implemented on roads that are not adequate for all-weather/all-season use. Where the quality and durability of a road surface is poor and results in rutting and ponding of water during periods of wet weather or high water tables, erosion of the road prism and sediment transport is likely. Roads not constructed for or not suited for all-weather use should be closed during these saturated or thaw conditions. This can be performed by gating, cabling, posting notices, and/or placing barriers such as logs or boulders at the roadhead.

Restricting access also may benefit fish and fish habitat by reducing human pressures on sensitive areas. Seasonal or periodic closures can give chronic problem areas like trails, remote campsites, and eroding stream banks a chance to recover through a natural process of revegetation and stabilization. Also, closure of stream crossings at fords during spawning season should be prohibited to reduce damage to fish and sedimentation of spawning gravels.

7.17.2 General Benefits

- road erosion is not accelerated by mechanical disturbance
- sensitive or chronically disturbed areas recover more quickly
- not a permanent measure--applied easily and only when necessary

7.17.3 General Drawbacks

- public sentiment may resent some closures
- not easily enforced

7.18 ROAD CLOSURE

7.18.1 Overview of Technique

Road closure or road obliteration is both a preventive and corrective practice intended to reduce sediment generated from temporary or unnecessary roads and to return the land to natural production. Temporary roads allowed to remain in use beyond their prescribed time may be subject to damage, and can become chronic sediment sources.

Effective obliteration is achieved by blocking access, removing all culverts and bridges, restoring the natural surface and subsurface drainage patterns, and revegetating all surfaces to reduce surface erosion of bare soils. These efforts may also include any or all of the following: reshaping and stabilizing side slopes, removing rock overlay down to the elevation of the adjacent terrain, ripping the subgrade where compaction is identified as a problem, installing water bars where necessary, and planting both herbaceous cover and trees and shrubs.

7.18.2 General Benefits

- removal of potential (and often active) sediment sources in a watershed reduce sediment yields to streams and fish habitat
- time and cost savings through reduced maintenance requirements

7.18.3 General Drawbacks

- untraveled roads easily become un-monitored roads--it may be possible for eventual failure of even obliterated roads to go unnoticed for a long period of time

7.19 WATER BARS

7.19.1 Overview of Technique

Placement of water bars on closed roads, or water bars, broad-based dips, or hardened fords on infrequently used, low maintenance roads may be preferable to the installation of culverts to pass streams and road drainage downslope. Culverts may clog (especially where unstable slopes, undercut stream banks, or high bed load transport rates are observed or suspected upslope) and divert water down or across the road surface resulting in greater erosion and sediment generation. Maintaining water bars with armored material on infrequently used, dry season roads may generate smaller sediment yields over the life of the road. Steepness of slope is a factor to be considered in both the decision to place water bars on roads, as well as the frequency of their placement.

Roads of this nature, though sometimes warranted, should be reviewed periodically and considered for complete road closure.

7.19.2 General Benefits

- low maintenance
- reduced risk of large failures where large bed load volumes are expected
- can be armored with coarser substrate to result in minimal road erosion

7.19.3 General Drawbacks

- permits channeled water to be in contact with road prism--a potentially highly erosive situation

7.20 INSPECT CLOSED ROADS

7.20.1 Overview of Technique

Closed roads may remain unstable for years after their closure because of unobserved subsurface modifications created by the road, or by failure of revegetation efforts. Obliterated roads should be scheduled for initial inspection for mass movements, surface erosion, and the adequacy of cover of pioneering vegetation after the first winter or wet season after closure. Depending on the results of such an inspection, one, two, or more inventories can be scheduled at annual or biannual intervals. Conduct re-seeding or restoration work as needed.

Where opportunities exist, roads may be only partially closed and transformed into recreational trails. The creation of trails increases the frequency of monitoring as well as provides a recreational benefit.

7.20.2 General Benefits

- ensures the long-term reduction of sediment sources in a watershed
- recreational benefit of trails is a possibility

7.20.3 General Drawbacks

- none

7.21 RELOCATE ROADS

7.21.1 Overview of Technique

Existing, poorly located or constructed roads may be relocated if road closure is not warranted but chronic sedimentation or habitat degradation persist. Other Best Management Practices will apply.

7.21.2 General Benefits

- correction of chronic sediment problems
- opportunities for improved access

7.21.3 General Drawbacks

- relocation is a permanent access restriction

8 FOREST MANAGEMENT TECHNIQUES

Practices located in Section 2 "Special Vegetative Treatments" may also apply to this section, and vice versa.

8.1 SMA WIDTHS

8.1.1 Overview of Technique

Riparian areas should be managed in relation to various legal mandates of federal and state governments. Federal requirements include the Inland Native Fish Strategy (USFS 1995) and the Eastside Ecosystem Management Plan. State requirements include, but are not limited to, those associated with floodplains, wetlands, water quality, dredged and fill material, endangered species, wild and scenic rivers, and cultural resources.

Width of the managed riparian area is subject to state and federal regulations, but should consider site-specific factors in a determination of adequacy. These factors include: slope steepness, class of watercourse, depth to water table, soil type, type of vegetation, and intensity of management. SMAs should be delineated and evaluated on the ground before implementing any project activity.

8.1.2 General Benefits

- protection of streamcourse and influences on the streamcourse such as large woody debris recruitment, shade, detritus, slope stability, microclimate control, etc.
- protection of riparian-dependent wildlife habitat

8.1.3 General Drawbacks

- limited land management practices available within SMAs

8.2 MINIMIZE DISTURBANCES WITHIN SMA

8.2.1 Overview of Technique

Disturbances that would expose mineral soil within the SMA should be minimized. Possible disturbances include both human-induced and natural causes. Regardless of the cause, soil exposed in SMAs is subject to scour and the entrainment of sediment during periods of high flow, or it may be subject to surface erosion by water and gravity. Soil compaction and puddling can also lead to long-term changes in protective vegetative cover.

Human-induced causes of soil disturbance include the use of skidders or heavy machinery within the SMA, the ground skidding of logs within SMAs, improper road and landing location, and fire initiated by sparks from harvest equipment. Adverse effects can be avoided through the implementation of BMPs and the administration of state and federal forest practices code. These activities include, but are not limited to, proper forest harvest planning, inspection of harvest units before and after logging, proper maintenance of equipment, weather restrictions on operations, and the obliteration of temporary roads.

More "natural" causes of soil disturbance in SMAs include the windthrow of riparian trees weakened by adjacent harvest and resulting higher wind speeds, scour of floodplains and terraces by deep, fast-flowing waters at floodstage. These disturbances can be reduced by consideration of the prevailing winds and storm dynamics known about an area when designing buffers. Additional "transition buffers" of variable density may be useful in "feathering" buffer SMA boundaries to increase windfirmness. Floodplain boundaries that extend beyond regulated SMA widths may also warrant conditional management design and practices.

8.2.2 General Benefits

- reduction in soil available for entrainment by flood flows or downslope movement to streams
- maintenance of stable side slopes

8.2.3 General Drawbacks

- none

8.3 LOCATE LANDINGS AND ROADS OUTSIDE SMA

8.3.1 Overview of Technique

Roads and landings should be located outside SMAs except as noted in technique 8.1.

8.3.2 General Benefits

- reduction of bare soil and active disturbance areas adjacent to streams

8.3.3 General Drawbacks

- road location restrictions (some variances may be granted where short lengths of well-maintained road in SMAs may reduce greater road lengths on more unstable slopes or other sensitive areas)

8.4 APPROPRIATE CHEMICAL USAGE IN SMA

8.4.1 Overview of Technique

Avoid or limit use of chemicals such as pesticides and fertilizers in SMAs, particularly those where seasonal flood flows or rapid through-flow of soil water may result in transport of these chemicals or nutrients directly into streams.

There are other chemical management practices included with the agriculture/crops techniques in Section 3 of this appendix. Most apply directly to forest management situations as well; a few would require minor modifications for implementation in a forest environment. Reference the following techniques when considering chemical usage in SMAs: 3.23 Chemical Management Plans; 3.24 Fertilizer Application: Rates and Timing; 3.26 Evaluate Field Limitations; 3.27 Equipment Calibration and Use; 3.28 Alternative Pest Management Strategies; 3.29 Herbicide/Pesticide Application, 3.30 Apply Herbicides/Pesticides Selectively; 3.31 Herbicide/Pesticide Application Rates; 3.33 Enforce Current Herbicide/Pesticide Use Regulations; 3.34 Aerial Spray Applications: Buffer Zones; 3.35 Aerial Spray Applications: Atmospheric Conditions; 3.37 Spill Contingency Planning; and 8.12 Fertilization.

8.4.2 General Benefits

- risk of water quality degradation is reduced

8.4.3 General Drawbacks

- higher cost, more labor intensive techniques may need to be applied to achieve similar results

8.5 DIRECTIONAL FALLING OF TREES

8.5.1 Overview of Technique

When falling trees in/near stream channels and SMAs, fall trees away from these courses so that generation of slash from bucking and soil disturbance by skidding is minimized in the SMA. Jacking and cabling trees may be used to assist in directional falling. Appropriate responses to incidental introduction of trees and slash into streams and SMAs should be handled on a case-by-case basis. Debris may be removed by the least disturbing method, or left in place if removal will exacerbate channel instability or interfere with SMA functions.

8.5.2 General Benefits

- disturbance prevention

8.5.3 General Drawbacks

- none

8.6 HARVESTING RESTRICTIONS

8.6.1 Overview of Technique

Timber harvest in SMAs should be consistent with applicable federal and state forest practices regulations. Avoid or limit timber harvest when possible, except where safety concerns predominate. Some selective timber harvest (individual tree selection, small group selection, commercial or pre-commercial thinning) can improve riparian and instream habitat if appropriately implemented.

8.6.2 General Benefits

- maintenance of riparian vegetation functions

8.6.3 General Drawbacks

- land use restrictions

8.7 REMOVAL OF INTRODUCED TREES AND SLASH

8.7.1 Overview of Technique

Appropriate responses to incidental introduction of trees and slash into streams and SMAs should be handled on a case-by-case basis. Debris may be removed by the least disturbing method, or left in place if removal will exacerbate channel instability or interfere with SMA functions. Debris deposited in fish streams should be addressed as soon after introduction as practicable. Debris deposited into non-fish-bearing streams should be addressed before the completion of the project, or before the commencement of winter storm events or other high streamflow seasons.

8.7.2 General Benefits

- disturbance prevention

8.7.3 General Drawbacks

- none

8.8 TIMBER HARVEST UNIT DESIGN

8.8.1 Overview of Technique

This is an administrative and preventive practice in which proposed timber harvest units are evaluated to estimate site-specific impacts and determine appropriate techniques for minimizing soil erosion and water quality degradation. Harvest unit design incorporates site-specific information and field verification in order to consider:

- stream channel protection (channel incision depth and width),
- potential slope instability and erosion hazard (slope angle and soils),
- size and shape of unit,
- landform characteristics,
- road and skid trail network,
- logging system design,
- relative risk of windthrow (including local wind direction and intensity),
- wetland and riparian protection (composition and canopy structure), and
- other special watershed protection needs.

Where adverse water quality and soil productivity impacts, or undesirable streamflows may result, the harvest unit design should be modified.

8.8.2 General Benefits

- stream channel protection
- reduced sediment production from roads and skid trails
- wetland and riparian protection

8.8.3 General Drawbacks

- none

8.9 DETERMINING GUIDELINES FOR YARDING OPERATIONS

8.9.1 Overview of Technique

Yarding systems and operational guidelines are selected to protect soil and water resources and meet management objectives. In addition to silvicultural treatments and transportation systems, yarding suitability must be determined after consideration of soil and landform inventories and hydrologic information. Watershed factors to consider include:

- slope gradient and aspect,
- soil and slope stability,
- erodibility and compactability,
- vegetative cover,
- streamcourse protection needs,
- riparian areas, wetlands, and meadows, and
- other factors affecting water quality, flood, and sediment yield potential.

Yarding operations may include either or both ground-based and cable methods.

Ground-based methods include dragging (skidding) logs behind rubber-tired or tracked tractor equipped with a grapple and/or short cable and winch. Another method uses a tracked shovel to pass or "leap-frog" logs toward a landing using motion that provides more lift and less soil disturbance than conventional skidding.

Considerations for groundskidding include:

- limit skidding to slopes less than 35% to 40%;
- skid along the slope contour wherever possible;
- landings should be located upslope wherever possible;
- skid logs with one end suspended to reduce rutting or gouging;
- avoid skid trail layouts that concentrate runoff into draws and streams;
- use cables or grapple reach to winch (endlining) or pull logs out of sensitive areas where the encroachment of heavy equipment may disturb soils or impair water quality; and
- logging over frozen ground and/or snow with adequate depth can protect both the soil and residual vegetation, thereby preventing soil and water quality degradation.

Considerations for shovel yarding include:

- limit shovel yarding to slopes of about 20% or less;
- avoid broken, uneven topography and areas which are frequently dissected by deeply incised streams;
- on soils of low bearing strength, support tracks with logging slash;
- the number of turns on shovel trails should be limited, depending on soil type and vegetative cover;
- wide arc turns can reduce soil disturbance on shovel trails; and
- live streams should not be crossed without the use of a temporary structure, such as a log mat.

Cable methods are best used on steeper slopes, or in broken topography, or where yarding occurs over long distances. Cable systems such as highlead yarding and skyline yarding offer some degree of log suspension, thereby reducing soil disturbance. A special type of cable method, helicopter yarding, is a true aerial system where logs are fully suspended from the pick-up point to the landing.

Considerations for highlead yarding include:

- appropriate where resource protection does not require full or partial log suspension and where ground-based systems are inadequate or inappropriate,

- use on slopes in excess of about 40%,
- yard logs uphill wherever possible for greater control, and
- avoid yarding in or across streams by using stream courses as setting boundaries for each landing

Considerations for skyline yarding include:
- use on slopes in excess of about 40%;
- appropriate where log suspension may be required on steep or unstable slopes, over sensitive soil, and in riparian areas or wetlands;
- perform a suspension feasibility analysis and field verification, if necessary to determine required and obtainable deflection;
- partial suspension is the norm, but full suspension can be obtained where terrain is favorable;
- use lift or tail trees to increase suspension and payload; and
- yard logs uphill wherever possible for greater control.

Considerations for helicopter yarding include:

- full-suspension assures soil and water protection;
- applicable to all terrain conditions and suitable for most silvicultural prescriptions;
- requires less road construction, and may be suitable for providing access across unstable terrain; and
- time-sensitive operation which must optimize weight-yarded per unit time to be cost effective.

8.9.2 General Benefits

- method dependent, see 10.3.1
- potential benefits include reducing soil erosion, soil compaction, gullying and the disruption of sensitive vegetation

8.9.3 General Drawbacks

- method dependent, see 10.3.1

8.10 STREAM CHANNEL PROTECTION DURING TIMBER HARVEST

8.10.1 Overview of Technique

Stream channels should be protected during harvest operations to:

- maintain the natural flow regime,
- provide for unobstructed passage of stormflows,
- maintain the integrity of the riparian area to filter sediment and other pollutants,
- restore the natural course of any stream that has been diverted as soon as practicable,
- maintain natural channel integrity to protect aquatic habitat and other beneficial uses, and
- prevent adverse changes to the natural stream temperature regime.

Various other techniques included in this section and in Sections 2, 8, 9, and 11 may be applicable specifically to streamcourse protection and should be implemented to meet these objectives.

8.10.2 General Benefits

- many; see specific techniques

8.10.3 General Drawbacks

- few, variable; see specific techniques

8.11 EQUIPMENT SERVICING

8.11.1 Overview of Technique

During the servicing or refueling of logging, road construction, and other equipment, petroleum products may be spilled and potentially enter a water course. This risk is minimized by locating service and refueling sites 100 feet from stream channels and wetlands (or per state/federal regulations). Minor oil spills can be prevented by using good housekeeping techniques including:

- collecting used oil, oil filters, and grease tubes;
- requiring equipment operators to carry oil absorbent pads;
- providing containment and cleanup for portable fuel tanks;
- following approved disposal methods for waste products; and
- repairing equipment leaks promptly.

When spills do occur, it is important to contain and clean up the spill quickly and notify all proper authorities. It is important to have a written spill contingency plan before spills occur to assure these procedures are done promptly and properly without omissions. A spill contingency plan should be prepared for each project requiring the operation of heavy equipment.

8.11.2 General Benefits

- reduced risk of contaminating surface water and ground water with petroleum products

8.11.3 General Drawbacks

- none

8.12 PRESCRIBED BURNING

8.12.1 Overview of Technique

Prescribed burning is the intentional use of fire to create desired changes, such as wildlife habitat improvement, within a specific treatment area. There are three types of prescribed burns: (1) broadcast burning, (2) pile burning, and (3) underburning.

Broadcast burning involves general ignition of essentially all flammable materials within the treatment area. Hand-held or helicopter-borne drip torches are used to quickly ignite fuels. Sites are sometimes cleared or otherwise disturbed prior to igniting a broadcast burn. An example of broadcast burning is slash burning, where woody residuals from logging are burned to prepare a recently harvested timber site for regeneration.

Pile burning involves collecting and piling fuels to be burned in place. This technique allows a more selective approach to burning but is also more labor intensive.
Underburning involves burning only the lower layer of vegetation, while avoiding burning in the overstory (such as the tree canopy). It is used to reduce fuel loads (to avoid wildfires), eliminate unwanted brush, or stimulate forage production.

Prescribed burns can be used to:

- increase forage abundance and accessibility
- reduce unwanted vegetation
- prepare an area for replanting, especially where soils, topography, or slope limit the use of other methods
- create habitat for edge or early seral species
- maintain early seral stage
- increase vegetative diversity and associated wildlife communities
- simulate natural disturbance regimes
- reduce fuel load and risk of catastrophic fire
- alter distribution patterns of animals (such as wintering deer)

8.12.2 General Benefits

- can simulate the natural role fire plays in the development of most vegetation communities
- can cause desired changes in vegetation relatively inexpensively, compared with chemical or mechanical techniques
- can have minimal impact on surface soils, when compared with mechanical methods, thereby reducing the exposure of mineral soils and associated encouragement of invasive weeds

8.12.3 General Drawbacks

- possible air pollution and soil erosion
- risk of fire escaping
- can be difficult to control because of the complex and unpredictable factors involved
- not selective within treatment area; may harm beneficial or desirable plants and animals
- effects can be severe and long term

8.13 STAND THINNING

8.13.1 Overview of Technique

Commercial or pre-commercial thinning may have benefits in addition to the added-value of timber. Forest stand characteristics may be modified through thinning to provide benefits to:

- understory vegetation, including shrub and herbaceous cover of soil;
- primary aquatic food production;
- size of trees available for large woody debris recruitment; and

- wildlife habitat, including the production of snags and multi-story canopies.

Thinning operations should follow other best management practices including timber falling, slash management, and yarding practices, if appropriate.

8.13.2 General Benefits

- soils protected against surface erosion as well as mass movements
- increased solar energy input supports primary food production
- large wood available for large woody debris recruitment

8.13.3 General Drawbacks

- impacts from harvest/thinning on soils and residual trees
- potential for slash to enter streams from riparian areas

8.14 PLANT/PRESERVE TREES IN UNDERSTOCKED AREAS

8.14.1 Overview of Technique

Depending on management objectives, harvested forestland should be returned to natural or optimum production of trees. Stocking characteristics (density, spacing, canopy development) vary by site (climate, elevation, aspect, soils, and species) and management objective. Sites which are understocked or unstocked are both less than fully productive and generally subject to increased surface erosion and/or mass movements.

Where forestland is understocked or unstocked following timber harvest or other land clearing, reforestation by tree planting may be an option for stabilizing sites. On a watershed scale, reforestation can influence the hydrology of the basin by moderating extreme hydrologic events (e.g., decreasing peak flows and increasing summer base flows).

Reforestation in riparian areas has other benefits to the aquatic environment. See techniques 2.1, 2.2, and 9.1.

Some land may be "understocked" or marginally productive for natural reasons (e.g., unproductive soils, harsh climates at high elevations, etc.). In these areas planting may have limited success. In these cases preserve existing trees as natural seed sources, and consider planting along the perimeter (especially the downslope perimeter) to help stabilize sediments moved off-site.

Planting may be done mechanically, with wheeled or tractor-pulled planting machines, or by hand. Planting machines should be limited to flatter slopes and should be done on the contour where possible.

8.14.2 General Benefits

- improved soil protection through rooting strength, wind and raindrop energy dissipation, and development of organic soil horizons.
- maintained site productivity
- reduction in downslope sediment yields

8.14.3 General Drawbacks

- planting machines may cause some site disturbance

8.15 MANAGE STANDS TO ENHANCE SNOWPACK

8.15.1 Overview of Technique

The amount snow under a dense forest canopy is extremely limited by the interception and ablation of snow in the canopy. The depth of snow in an open field is similarly limited by ablation (and re-distribution) driven by sun and wind. Managing forest stands at densities which increase canopy openings intermediate to these two situations can increase both the depth of the snowpack and the length of time that it is stored on the ground surface. Ablation of the snowpack is slowed by the reduction in direct solar radiation received by the snowpack (it is transmitted to the tree crowns) and the reduction in wind shear at the snow surface (wind speed reduced by forest vegetation). With the snowpack slowly feeding ground water as it melts, as compared to surface runoff of rapid snow melt, ground water supplies to support summer base flows is increased.

8.15.2 General Benefits

- risk of surface erosion generated by rapid runoff is reduced
- risk of degraded channel conditions as a result of increased peak flows is reduced
- increased ground water to support base flow conditions

8.15.3 General Drawbacks

- requires relatively large areas to generate significant results
- requires changes in the silviculture and rotation of the managed stands
- controversial

8.16 STUDY REWARD/PENALTY SYSTEM

8.16.1 Overview of Technique

The impacts of many forest practices are in a large way dependent directly on the skill and care with which they are implemented. A prescribed "best management practice" may be ineffective solely for reasons of incompetence or apathy on the part of the forest worker. An "acceptable practice" implemented on the same site may be extremely effective and environmentally sound when performed by a skilled, knowledgeable, individual.

Currently there are no known avenues or standards for recognizing the quality of work done in a forest environment. A system which recognizes good forest work and rewards or penalizes performance may increase the standard by which work is accomplished and result in reduced environmental impacts. The design and implementation of such a system may be warranted.

8.16.2 General Benefits

- potential to reduce environmental impacts

8.16.3 General Drawbacks

- difficulty in administration

8.17 SEED AND SPECIES SELECTION

8.17.1 Overview of Technique

Disturbed areas with exposed bare soil need to be protected by vegetation as soon as practical. Herbaceous seed mixtures (generally grasses and legumes) should be adapted to the site. Exotic species should be avoided. Once the site is "secured" by herbaceous cover, the goal is succession of natural shrubs and trees. Therefore seed mixtures should include a proportion of annuals which will stabilize soils for the first year, but yield to natural, native vegetation in successive years. Seed selection for late growing season applications should include a high proportion of annuals with plans to seed again in the spring.

8.17.2 General Benefits

- established vegetation stabilizes or secures soil in place
- seed selection can be adapted to seasonal variability
- native species are adapted to climate and soil conditions and are hardy

8.17.3 General Drawbacks

- none

8.18 PRIORITY AREAS

8.18.1 Overview of Technique

Disturbed areas should be prioritized for revegetation based on severity of disturbance, disturbed area, slope steepness and slope length, soil erodibility, season, expected success of natural revegetation, expected success of seeded or planted vegetation, availability of suitable seed mixtures, and the quantity and quality of potentially degraded habitat.

8.18.2 General Benefits

- maximized reduction in erodible area

8.18.3 General Drawbacks

- risk of failure to germinate often tied to site-specific factors

8.19 OPTIMUM SEEDING PERIODS

8.19.1 Overview of Technique

Seed at the start of optimum periods for growth and establishment. Timing will depend on the site location, species planted, and, for disturbances associated with proposed projects, scheduled completion date.

8.19.2 General Benefits

- maximize chances for establishment; maximize quality of cover

8.19.3 General Drawbacks

- none

8.20 MULCHING

8.20.1 Overview of Technique

Reseeded areas should be mulched to prevent translocation of seed by wind or water, reduce erosion by raindrop splash, and maintain soil moisture. Mulches can also be used to temporarily stabilize unseeded slopes until seeding or other stabilization techniques are implemented. Type and amount of mulch varies by region, erosion potential, and available materials.

Native, biodegradable materials should be used wherever possible. Mulch should be free of noxious weeds and other non-native seed.

8.20.2 General Benefits

- maximize vegetation establishment
- reduce erosion potential of recovering sites

8.20.3 General Drawbacks

- none

8.21 FERTILIZATION

8.21.1 Overview of Technique

Fertilization is probably necessary to help establish vegetation on disturbed forested areas, especially along roads and on mass wasting slopes and deposits, where often thin topsoil is removed or buried. Sampling soils to be planted or seeded for available nitrogen, phosphorus, potassium, and sulphur will verify that fertilization will satisfy the requirements of the seed mixture to be sown. Fertilization may be applied in lifts--at seeding, at germination, and then periodically thereafter until establishment.

8.21.2 General Benefits

- increased quantity and quality of vegetative cover
- shortened time to establishment

8.21.3 General Drawbacks

- risk of nutrient fluxes to streams or ground water given wet weather conditions

8.22 SITE PROTECTION

8.22.1 Overview of Technique

Seeded or planted areas should be protected from disturbance by foot and vehicle traffic, cattle grazing, and the like. Protection options may include the use of flagging, rope fencing, conventional fencing, and/or posting of notices. Re-seeding vegetation may be necessary if disturbance occurs before establishment is sufficient.

8.22.2 General Benefits

- increased quantity and quality of vegetative cover
- shortened time to establishment

8.22.3 General Drawbacks

- none

8.23 MONITOR REVEGETATED AREAS

8.23.1 Overview of Technique

All seeded areas should be inspected for establishment on a regular basis, including a germination inventory about 2 weeks after seeding. Where failures are evident, implement additional stabilization techniques, if necessary, and reseed.

8.23.2 General Benefits

- assure quantity and quality of vegetative cover

8.23.3 General Drawbacks

- none

8.24 VEGETATE STEEP SLOPES

8.24.1 Overview of Technique

Grass seeding may have limited success in preventing surface erosion from slopes exceeding the angle of repose. Additional stabilization techniques may need to be implemented and supported by planting and seeding efforts. Native woody plants should also be planted as sprigs, cordons, or wattles in rows on slope contours.

8.24.2 General Benefits

- assure quantity and quality of vegetative cover
- faster establishment of larger roots and adventitious roots
- maximized reduction in erodible area

8.24.3 General Drawbacks

- none

8.25 INTERIM STABILIZATION METHODS

8.25.1 Overview of Technique

Implement interim surface stabilization methods to control surface erosion during non-growing seasons. Methods may include mulching, installation of erosion-control fabric, and terracing or other mechanical methods. Seeding should occur as soon into the growing season as practicable.

8.25.2 General Benefits

- reduction in surface erosion
- reduction in offsite removal of eroded material which may be stabilized by subsequent vegetation

8.25.3 General Drawbacks

- requires additional site visit

8.26 AGGRESSIVE FIRE SUPPRESSION

8.26.1 Overview of Technique

This technique involves active management to replace the role that natural fire regimes play in rangeland and forest ecosystems. Methods employed include direct and aggressive attack of most unplanned fires. Prescribed burns may be used to reduce fuel loads (see the section on prescribed burning under "Vegetation Management" below). Thinning and other silvicultural methods in forested areas may also be used to reduce fuels.

8.26.2 General Benefits

- more predictable and controllable than natural fire
- can be used to protect developed areas or other areas where fire would be detrimental

8.26.3 General Drawbacks

- requires relatively high devotion of resources
- requires thorough understanding of natural systems and processes, some of which may not be fully understood

8.27 NATURAL FIRE CONTROL

8.27.1 Overview of Technique

Natural fire management allows naturally caused fires to burn with minimum suppression. Few if any agencies widely use this technique, although it is applicable to certain wilderness or natural areas. Fire suppression under such a management approach is aimed primarily at protection of life, property, or valuable resources. Fuel reduction and fuel breaks may be implemented near homes and other developments near areas where natural fire management is applied. Otherwise, fire is allowed to occur naturally.

8.27.2 General Benefits

- allows natural processes to occur
- if natural fires occur frequently, then the severity of each fire may be relatively low

8.27.3 General Drawbacks

- difficult to implement in areas where previous fire suppression or other events have significantly altered fuel loads and natural vegetative structure, composition, and condition
- fire behavior and occurrence can be unpredictable
- substantial risk of property damage, loss of human life, or injury

8.28 PRESCRIBED BURNING TO REDUCE FUELS

8.28.1 Overview of Technique

Prescribed burning is the intentional use of fire to create desired changes, such as wildlife habitat improvement, within a specific treatment area. There are three types of prescribed burns: (1) broadcast burning, (2) pile burning, and (3) underburning.

Broadcast burning involves general ignition of essentially all flammable materials within the treatment area. Hand-held or helicopter-borne drip torches are used to quickly ignite fuels. Sites are sometimes cleared or otherwise disturbed prior to igniting a broadcast burn. An example of broadcast burning is slash burning, where woody residuals from logging are burned to prepare a recently harvested timber site for regeneration.

Pile burning involves collecting and piling fuels to be burned in place. This technique allows a more selective approach to burning but is also more labor intensive.

Underburning involves burning only the lower layer of vegetation, while avoiding burning in the overstory (such as the tree canopy). It is used to reduce fuel loads (to avoid wildfires), eliminate unwanted brush, or stimulate forage production.

Prescribed burns can be used to:

- increase forage abundance and accessibility
- reduce unwanted vegetation
- prepare an area for replanting, especially where soils, topography, or slope limit the use of other methods
- create habitat for edge or early seral species
- maintain early seral stage
- increase vegetative diversity and associated wildlife communities
- simulate natural disturbance regimes
- reduce fuel load and risk of catastrophic fire
- alter distribution patterns of animals (such as wintering deer)

8.28.2 General Benefits

- can simulate the natural role fire plays in the development of most vegetation communities
- can cause desired changes in vegetation relatively inexpensively, compared with chemical or mechanical techniques
- can have minimal impact on surface soils, when compared with mechanical methods, thereby reducing the exposure of mineral soils and associated encouragement of invasive weeds

8.28.3 General Drawbacks

- possible air pollution and soil erosion
- risk of fire escaping
- can be difficult to control because of the complex and unpredictable factors involved
- not selective within treatment area; may harm beneficial or desirable plants and animals
- effects can be severe and long term

8.29 SEASONAL GRAZING MANAGEMENT TO REDUCE FUELS

8.29.1 Overview of Technique

Grazing involves releasing livestock onto rangeland for the purpose of providing forage and shelter to the animals. As an ancillary benefit, grazing serves as a vegetation manipulation management tool. Shrub density is reduced, thus releasing trees from competition and reducing fire fuels.

Modern grazing management involves intensive grazing systems that utilize fencing, rotation of use, and control of movements. These same strategies applied on a time scale of 2 to several years can minimize the buildup of fire fuels while sustaining adequate vegetative cover.

8.29.2 General Benefits

- can cause desired changes in vegetation relatively inexpensively, compared with chemical or mechanical techniques
- reduces need for prescribed burning

8.29.3 General Drawbacks

- land and water resources may sustain damage from livestock

8.30 WILDFIRE CONTINGENCY WATERSHED RESTORATION PLANS

8.30.1 Overview of Technique

Good watershed management plans will include contingency wildfire restoration plans. Plans will include at a minimum:

- revegetation plans including seeding, planting, and fertilizing
- temporary erosion control measures such as water bars, windrowing, mulching, etc.
- stream channel clearing to prevent debris damming
- sources of materials, supplies, equipment, and manpower for the above measures

8.30.2 General Benefits

- interagency support as consultants
- rapid response to minimize erosion and reduce sediment yields

8.30.3 General Drawbacks

- fire fighting efforts are outside the scope of plan
- complex land ownership patterns will make implementation difficult

9 URBAN AREA TECHNIQUES

9.1 ZONING/LAND USE PLANNING

9.1.1 Overview of Technique

Zoning ordinances based on land use plans can alleviate future demands for withdrawal and discharge of water from surface and groundwater sources for urban, suburban, and rural uses. Zoning for low-intensity land use can be a sound and successful method for protecting fish and wildlife habitat.

9.1.2 General Benefits

- adequate water supplies
- estimated pollutant loadings may be maintained within capacity of system to recover, (or exceedences may be anticipated, monitored, and mitigated)

9.1.3 General Drawbacks

- limits use of land

9.2 URBAN RUNOFF FACILITIES

9.2.1 Overview of Technique

This technique involves the operation and maintenance of runoff facilities, such as infiltration basins and trenches, vegetated filter strips, grassed swales, constructed wetlands, porous pavement and concrete grids, and detention ponds (Puget Sound Water Quality Authority 1989).

9.2.2 General Benefits

- increased infiltration and reduced runoff
- pollutant loading to storm drains and receiving waters is reduced

9.2.3 General Drawbacks

- increased infiltration may enable pollutant leaching to reach the water table

9.3 LIMIT FUTURE DEVELOPMENT OF SEWER SYSTEMS

9.3.1 Overview of Technique

Within the context of Section 12.1, sewer system construction may be replaced by the construction of septic systems in selected areas.

9.3.2 General Benefits

- natural treatment and dispersal of wastes
- construction disturbance consists of localized trenches rather than lengthy continuous trenches--sediment yields may be decreased

9.3.3 General Drawbacks

- septic maintenance problems may result in release of contaminants to surface water and/or ground water

9.4 IMPROVE EXISTING SEWER SYSTEMS

9.4.1 Overview of Technique

Where problems with existing sewer systems, such as leaks or capacity shortages are known, make repair of these systems a priority.

9.4.2 General Benefits

- reduced loading of organic and bacterial wastes to surface water

9.4.3 General Drawbacks

- localized and temporary ground disturbance to repair sewer lines and facilities

9.5 INDUSTRIAL/CONSTRUCTION CHEMICALS/FUELS

9.5.1 Overview of Technique

This technique, or collection of techniques, expands on the Chemical Management Techniques of Section 7. Industrial and construction chemicals concerns in urban areas may include the generation, transfer and transport, storage, and release of large quantities of pesticides, fertilizers, petroleum products, solvents, paints, and other pollutants.

After spill prevention, containment and collection of spilled pollutants on-site is the preferred technique for maintaining high water quality. Safe containment and recycling features should be designed and constructed, for example, at industrial plants, gas stations, car washes, and heavy construction fueling and maintenance areas. Containment design should consider maximize storage volume, 100-year or greater design storm for the size (area) and location of the facility, and an additional factor of safety. Such features should be required on all new construction and retrofitted on existing facilities. State and federal regulations apply.

9.5.2 General Benefits

- reduced risk of accidental introduction of pollutants to surface and groundwaters
- recycle/save recovered chemicals

9.5.3 General Drawbacks

- high cost for design and implementation
- continued maintenance required
- additional treatment of spilled material required

9.6 PROHIBIT FURTHER CHANNELIZATION

9.6.1 Overview of Technique

Natural channel systems, including natural variability in physical channel structure, know how to best maintain themselves and do not need to be "trained". New construction should occur outside of the zone lateral migration. Minimal channel "training" should occur, and then to protect existing infrastructure. Habitat enhancement structures may be a satisfactory alternative to channel "training".

9.6.2 General Benefits

- maintains as much as possible the naturally operating processes necessary to creation and maintenance of channel structure and fish habitat

9.6.3 General Drawbacks

- existing infrastructure may limit success of desired channel condition and management goals

9.7 AVOID BUILDING ON FLOODPLAINS

9.7.1 Overview of Technique

Floodplains belong to the domain of the fluvial channel. Any structures, debris, or activity occurring on the floodplain is subject to inundation and scour and deposition by the channel. Conversely, these features may reduce the water quality of the overbank stream. Avoiding construction on floodplains minimizes the risk of water quality degradation.

9.7.2 General Benefits

- risk of water quality degradation and property damage is reduced
- peak flow events are moderated to the maximum extent possible
- sediment yield is reduced

9.7.3 General Drawbacks

- many floodplains already contain structures

9.8 PUBLIC EDUCATION PROGRAMS

9.8.1 Overview of Technique

Teach proper use and disposal of household supplies hazardous to the environment (Puget Sound Water Quality Authority 1989).

9.8.2 General Benefits

- risk to water quality degradation from storm drains and sewes is reduced

9.8.3 General Drawbacks

- public education often may not reach the "worst offenders"

9.9 RECYCLING PROGRAMS

9.9.1 Overview of Technique

Used motor oil, antifreeze, paint, cleaning supplies, and other hazardous household chemical recycling programs should be implemented for the protection of the aquatic resource and the public's convenience.

9.9.2 General Benefits

- volume reduction in public waste stream of materials which frequently are deposited in or near storm drains
- improved downstream water quality

9.9.3 General Drawbacks

- none

9.10 LAWN CARE AND LANDSCAPING

9.10.1 Overview of Technique

The cumulative impacts of individual lawn care practices for entire urban areas can contribute significantly to nonpoint source pollution. Broad based educational efforts are necessary to encourage proper lawn management and landscaping. All of the following practices are applcable to home and yard owners in the Columbia River Basin:

- proper pesticide and herbicide use, including reduced applications;
- implement Integrated Pest Management (IPM) methods (see Technique 3.28 and scale as appropriate for single owner or subdivision lawncare);
- reduced rates of fertilizer application and improved timing;
- limited lawn watering;
- xeriscaping;
- reducing runoff by increasing infiltration; and
- training and certification programs for lawn care professionals.

9.10.2 General Benefits

- nutrient concentrations available to lawns remain high
- reduced runoff

- chemicals available to runoff are reduced
- water quality remains high

9.10.3 General Drawbacks

- public education often may not reach the "worst offenders"

9.11 ENCOURAGE ONSITE RECYCLING OF YARD TRIMMINGS

9.11.1 Overview of Technique

Nutrients contained in yard trimmings can be recycled in a home composting program. Compost releases nutrients more slowly than many fertilizers, increases organic matter in the soil, increases infiltration, decreases runoff, sustains high moisture contents in the soil, and contains trace metals and other nutrients. Home composting programs may include features such as:

- free composting bins,
- pamphlets explaining the process and its benefits,
- workshops, and
- waste reduction credits (financial) to composters.

9.11.2 General Benefits

- reduced fertilizer loading
- increased infiltration
- decreased need for lawn watering
- decrease in nutrients available for leaching to ground water

9.11.3 General Drawbacks

- compost piles near waterways can result in surface water contamination through leaching

9.12 BIODEGRADABLE CLEANERS

9.12.1 Overview of Technique

Biodegradable cleaners should be encouraged through community education efforts.

9.12.2 General Benefits

- reduction in chemical pollutant loading to surface waters
- reduction in compounds toxic to aquatic organisms

9.12.3 General Drawbacks

- none

9.13 PET EXCREMENT

9.13.1 Overview of Technique

Implement programs to manage pet excrement in order to minimize pollutant runoff to surface waters. Programs may include, for example, "pooper-scooper" laws, zoning ordinances to control horses, and public education efforts.

9.13.2 General Benefits

- reduced bacteria and nutrient loading in surface water
- reduction in "grazing pressure" (vegetation and soil disturbance) by animals in high public visibility areas

9.13.3 General Drawbacks

- public education often may not reach the "worst offenders"

9.14 STORM DRAIN STENCILING

9.14.1 Overview of Technique

Storm drain stenciling of downstream beneficial uses can be an effective tool in preventing the input of toxic, other chemical, and organic wastes into the environment. Stenciling serves as a continual, educational lesson that downstream beneficial uses are directly influenced by a local storm drain.

9.14.2 General Benefits

- reduced pollutant loading at storm drains
- improved downstream water quality

9.14.3 General Drawbacks

- none

9.15 PARKING LOT DESIGN AND STREET MAINTENANCE

9.15.1 Overview of Technique

Sediments which collect on parking lots, streets, and other impervious surfaces can have many pollutants adsorbed to the individual particles. Street sweeping can actually reduce aquatic pollution by removing the sediment before it has a chance to be entrained in stormflow in street gutters and storm drains. Other features such as rectangular designs and the removal of parking space bumpers can increase the efficiency of street sweepers.

Other efforts which achieve similar goals include wet-sweeping for the removal of oil and grease from streets, and grassy swales designed to filter water as it infiltrates.

9.15.2 General Benefits

- reduced pollutant loading at storm drains
- improved downstream water quality
- reduction in downstream sediment yield

9.15.3 General Drawbacks

- none

9.16 WATER CONSERVATION PROGRAMS

9.16.1 Overview of Technique

Water overuse can directly affect the quantity and quality of runoff in streams, especially during the dry season when low flow quantities are unable to dilute polluted runoff. Conservation techniques range from volunteer lawn watering to required water rationing.

9.16.2 General Benefits

- increased water available for low flows
- improved assimilation and dilution of polluted waters

9.16.3 General Drawbacks

- educational efforts may do little to change private habits (as opposed to public habits)

9.17 SEPTIC SYSTEM ADDITIVES

9.17.1 Overview of Technique

Discourage the use and dumping of septic system additives, such as household cleaners, down household drains. This chemicals are persistent in ground water.

9.17.2 General Benefits

- reduction in the loading of toxic pollutants to ground water
- improved downstream water quality

9.17.3 General Drawbacks

- educational efforts may do little to change private habits (as opposed to public habits)

9.18 LITTER CONTROL

9.18.1 Overview of Technique

Litter control can improve the quality of urban runoff where regular sweeping or litter disposal is of low quality. Some common litter control programs include:

- "green" business practices,
- mandatory recycling laws,
- providing technical and financial assistance in establishing community waste collection programs, and
- developing user-friendly recycling programs (curbside pickup, volunteer efforts).

9.18.2 General Benefits

- reduced litter
- improved quality of urban runoff
- visually pleasing

9.18.3 General Drawbacks

- none

9.19 ADOPT-A-STREAM PROGRAMS

9.19.1 Overview of Technique

Communities may promote Adopt-a-Stream programs to provide local citizens an opportunity to focus on watershed influences on a stream. Opportunities include litter pickup, riparian vegetation planting, fish habitat enhancement structures, aquatic insect surveys and other methods of improving and monitoring stream health.

9.19.2 General Benefits

- improved, watershed-scale consideration of the limiting factors on a stream
- improved water quality
- monitoring may detect changes early

9.19.3 General Drawbacks

- un-mentored groups may do more harm than good for a stream's overall health

9.20 DIRECT POLLUTANTS AWAY FROM BRIDGES

9.20.1 Overview of Technique

Design or redesign bridge decks to direct storm water away from stream channels. Divert collected stormflow to land for treatment in vegetated filter areas or storm drains. Adequately design bridge stormflows for 50-year, 24-hour event.

9.20.2 General Benefits

- reduced loading of sediment and other pollutants directly in stream

9.20.3 General Drawbacks

- may be impractical or result in high flow velocities on long bridges

9.21 RESTRICT USE OF BRIDGE SCUPPER DRAINS

9.21.1 Overview of Technique

Scupper drains allow direct discharge of storm water from bridge decks to stream channels below. Restrict the use of scupper drains on all bridges less than 400 feet in length, especially those bridges across high quality habitat.

9.21.2 General Benefits

- reduced loading of sediment and other pollutants directly in stream

9.21.3 General Drawbacks

- may require periodic bridge deck cleaning

9.22 CONSTRUCTION: EROSION AND SEDIMENT CONTROL PLANS

9.22.1 Overview of Technique

All construction efforts with ground-disturbing activity should develop an erosion and sediment control (ESC) plan in accordance with state regulations. The plan should contain erosion and sediment control provisions to reduce erosion and contain sediment on site. The following elements should provide the minimum requirements for an effective ESC plan:

- predominant soil types and known hazards,
- site grading details, including existing and proposed contours,
- structural controls--location and design (mulching, sediment basins, filter fabric, etc.),
- topsoil management,
- stabilization measures--both temporary and permanent, and
- construction plan of work (sequential).

9.22.2 General Benefits

- documented contingency plans/instructions
- reduced runoff and reduced sediment yields

9.22.3 General Drawbacks

- construction staff may not be knowledgeable about plan

9.23 CONSTRUCTION: EROSION AND SEDIMENT CONTROL STRUCTURES

9.23.1 Overview of Technique

Implement structural controls to help reduce erosion and contain sediment on site. Structural controls may include:

- wind erosion controls such as snow fences and hay bales,
- runoff interception structures such as dikes and drainage ditches,
- contour benches, terraces, or ditches across long slopes,
- retaining walls,
- lined conveyance channels,
- check dams,
- seeding and fertilizing,
- mulch/mats,
- sod,
- sediment basins or traps,
- filter fabric fence,
- straw bale barriers,
- storm drain inlet protection,
- paved or graveled construction entrances, and
- vegetated filter strips.

9.23.2 General Benefits

- reduced erosion
- reduced water velocities and increased sediment deposition on site
- sediment-related pollutant loading is decreased

9.23.3 General Drawbacks

- structures are not 100% effective
- frequent maintenance required

9.24 CONSTRUCTION: INSPECT EROSION AND SEDIMENT CONTROL STRUCTURES

9.24.1 Overview of Technique

Monitoring and maintenance of the structures listed under 12.24.1 must occur on a daily basis, especially during inclement weather.

9.24.2 General Benefits

- frequency of structure maintenance is increased
- effectiveness of structures increased

9.24.3 General Drawbacks

- structures are not 100% effective

9.25 CONSTRUCTION: MINIMIZE RUNOFF TO/FROM SITE

9.25.1 Overview of Technique

This preventive erosion control measure seeks to minimize water flowing through or near construction sites. A series diversion and storage structures such as dikes, diversion ditches and water and sediment detention basins may be constructed upslope of a planned construction site. Similar downslope facilities also exist for collecting site runoff. With a reduction in the volume and velocity of runoff and the length of the slope it travels on, erosion of construction sediments is minimized.

9.25.2 General Benefits

- reduced runoff
- reduced erosion
- sediment yields are reduced

9.25.3 General Drawbacks

- structures are not 100% effective (efficiency increased with implementation of multiple structures)

9.26 ROAD SALT STORAGE AND APPLICATION

9.26.1 Overview of Technique

Salt storage piles and other deicing materials should be located outside the 100-year floodplain. Keep them covered when not in use to reduce contamination of surface waters.

Regulate the application of deicing salts to prevent oversalting of pavement and to minimize saline runoff to streams.

9.26.2 General Benefits

- surface water quality is maintained

9.26.3 General Drawbacks

- moderate to high risk of salt leaching into ground water under large storage piles

9.27 ALTERNATIVE DEICING MATERIALS

9.27.1 Overview of Technique

Where high quality fish habitat and other sensitive ecosystems occur immediately adjacent roads or bridges, or lie within a short distance downstream but are without undeveloped tributaries, use alternative deicing materials. Examples include sand or salt substitutes.

9.27.2 General Benefits

- maintain high quality water quality and related habitat

9.27.3 General Drawbacks

- fine sediments can clog spawning gravels

9.28 ACCUMULATED SNOW DISPOSAL

9.28.1 Overview of Technique

Accumulated snow along roadsides and in urban areas may be high in sand, salts, and other debris and pollutants. Prevent dumping of this snow into surface waters.

9.28.2 General Benefits

- maintain high quality water quality and related habitat

9.28.3 General Drawbacks

- spring snowmelt runoff from impervious areas can be very poor quality; high flow velocities may scour the bed and banks of receiving streams

10 RECREATION MANAGEMENT TECHNIQUES

10.1 RELOCATE TRAILS AND CAMPGROUNDS

10.1.1 Overview of Technique

Trails, campgrounds, and other recreational facilities may in some areas provide user benefits at high cost to fisheries and/or resources which affect the quantity or quality of fish habitat. Concentrating fishermen or hikers on trails near sensitive streambanks may accelerate bank erosion and loss of undercut banks. Campgrounds in riparian areas may alter the hydrology of a site by compacting soils with normally high infiltration rates. The same campgrounds could encourage harvest of dead and/or downed trees that are potential sources of instream large woody debris. And wherever a concentration of people exists, the likelihood for water pollution by litter, fecal coliform, and petroleum products is high.

When such conditions exist, an obvious improvement technique is the relocation of the faulty facilities to more stable, less sensitive sites. Relocation would include both construction of new facilities and restoration of the re-located sites. New construction may generate temporary conditions conducive to water quality degradation, but correction of long-term chronic conditions should offset these impacts. Approved relocation plans should precede any construction activity.

10.1.2 General Benefits

- improved water quality
- improved habitat conditions

10.1.3 General Drawbacks

- variable construction-related impacts associated with relocation
- public sentiment for preferred recreation sites may be high
- relocation of facilities does not necessarily guarantee relocation of former users

10.2 IMPLEMENT RECREATIONAL PERMIT SYSTEM

10.2.1 Overview of Technique

Where concentrated recreational pressure is having a negative impact on fisheries and fish habitat, the problem may be alleviated by implementation of a recreational permit system. The permit system would limit the intensity of resource impacts by controlling the number and frequency of users into an area of degraded habitat.

10.2.2 General Benefits

- recreational opportunities remain within an area
- impacted areas may recover naturally and/or faster once recreational use is at or below some "carrying capacity"

10.2.3 General Drawbacks

- public sentiment for preferred recreation sites may be high
- administration and enforcement costs

10.3 IMPROVE CAMPGROUND DESIGN

10.3.1 Overview of Technique

Design criteria for new and existing campgrounds, parks, and other recreational facilities may be improved as needs and opportunities are identified. Opportunities may include, for example, dispersal of user sites (campsites), (re-)location of campsites within a campground, improvedtoilet and sanitation facilities, and control-of-flow structures such as gates, fences, and trails.

10.3.2 General Benefits

- recreational opportunities remain within an area
- reduced fish habitat impacts

10.3.3 General Drawbacks

- none for new facilities
- variable reconstruction-related impacts for existing facilities

10.4 OUTDOORS EDUCATION PROGRAMS

10.4.1 Overview of Technique

Many negative impacts on fisheries and fish habitat can be overcome through effective educational outreaches to recreationists active within a watershed. Many impacts vill be prevented if users are made aware of the causes and effects. Some users will work to mitigate impcts and/or restore degraded sites if informed of the opportunities.

Education programs can cover a range of detail from unstaffed interprdive trails to support of local outdoors and scout groups to funding for interpreters in parks and campgrounds.

10.4.2 General Benefits

- preventive and proactive in nature
- improved habitat conditions
- restoration needs and opportunities publicized
- generally long term in its effect if sustained

10.4.3 General Drawbacks

- may be slow in creating positive effects
- difficult to sustain due to tumover of personnel

10.5 FENCE SENSITIVE AREAS FROM RECREATIONISTS

10.5.1 Overview of Technique

Because concentrations of people can cause resource damage in ways similar to concentrations of livestock (e.g., trampling of streambanks), exclusion of recreationists from sensitive areas by fences and barricades may be an effective enhancement technique.

10.5.2 General Benefits

- reduced physical damage to habitat-influencing structures and processes
- reduced water quality degradation
- improved habitat conditions

10.5.3 General Drawbacks

- exclusion by design does not necessarily guarantee exclusion of all recreationists
- potential negative impacts on wildlife movements
- unsightly

10.6 IMPLEMENT PACK IN/PACK OUT POLICY

10.6.1 Overview of Technique

Where recreational facilities are remote, or where resources to fund sanitation serves are inadequate, implement and enforce a Pack In/Pack Out policy. Inducements for implementation may include providing suitable litter or waste bags, providing a minimum of collection points, and/or levying severe fines on violators.

10.6.2 General Benefits

- reduction in water pollution due to litter reduction

10.6.3 General Drawbacks

- already a "standard" of ethical outdoor conduct
- difficult to enforce

10.7 SANITATION SERVICES

10.7.1 Overview of Technique

Sanitation services include the removal or treatment of both garbage and human wastes in recreational areas. The courses of action available for both these pollution problems varies based on location and available funding.

Garbage may be collected in receptacles on-site and collected on a regular or intermittent basis. It may also be requested that users pack garbage to either home or a nearby receptacle. The spatial coverage of garbage pickup can be limited to heavy-use areas, or expanded, for example, to include infrequently used roadside rest stops.

Facilities for treatment of human wastes range from no facilities whatsoever to flush systems connected to wastewater treatment plants. Intermediate options may include pit toilets; advanced, contained toilet designs; incinerating toilets; and septic systems.

10.7.2 General Benefits

- reduction in litter with increase in services
- reduction in fecal coliform, nitrate, etc. loading with increase in services
- improved water quality

10.7.3 General Drawbacks

- cost of implementation
- cost and difficulty of maintenance and operations

10.8 INSTALL PUMP OR SELF-COMPOSTING TOILETS

10.8.1 Overview of Technique

Pit toilet designs are replaced with contained toilet systems in which waste is easily pumped to removal trucks or treatment facilities. Another design includes a contained, self-composting toilet which minimizes the need for cleaning and maintenance. These contained designs minimize the risk of water quality degradation through contact with shallow ground water.

10.8.2 General Benefits

- reduced risk of water quality degradation
- reduced maintenance requirements

10.8.3 General Drawbacks

- construction impacts
- cost to implement

10.9 CLOSE STREAM TO FISHING TO PROTECT SENSITIVE FISH SPECIES

10.9.1 Overview of Technique

Recreational fishing in some streams may lead to the harassment and/or incidental catch of non-target fish. To reduce the risk of incidental losses or incidental stressing of protected fisheries, certain streams may be closed to all fishing.

10.9.2 General Benefits

- target stocks are clearly protected
- potential impacts on habitat features through increased recreational pressure are reduced

10.9.3 General Drawbacks

- may be unpopular with some fishermen
- may concentrate fishermen in other sensitive streams/reaches resulting in worse habitat degradation

10.10 SEASONAL SPORT FISHERY CLOSURES

10.10.1 Overview of Technique

Recreational fishing in some streams may lead to the harassment, overfishing, and/or incidental catch of non-target fish or of target fish during sensitive life stages. Certain streams may be seasonally closed to prevent impacts to fish resources.

All closures of streams to fishing are subject to state and federal resource agencies.

10.10.2 General Benefits

- target stocks are clearly protected
- potential impacts on habitat features through increased recreational pressure are reduced
- perhaps more acceptable to fisherman than complete closure

10.10.3 General Drawbacks

- may be unpopular with some fishermen
- may concentrate fishermen in other sensitive streams/reaches resulting in worse habitat degradation

10.11 PROVIDE ALTERNATIVE SPORT FISHING LOCATIONS

10.11.1 Overview of Technique

Other sport fishing locations may be promoted as alternatives to popular stream reaches. Closure of the more popular stream reaches may or may not be necessary.

10.11.2 General Benefits

- relieves and/or distributes pressure on both fish and fish habitat
- may expand fishing opportunities

10.11.3 General Drawbacks

- may spread disturbances to otherwise protected areas

10.12 CONSTRUCT WELL TO PROVIDE WATER TO RECREATIONISTS

10.12.1 Overview of Technique

In heavy recreational use areas where some users may frequent stream banks, lakes, or wetlands to collect water for drinking or other uses, alternative water sources may need to be provided. These include well construction, water lines, or spring development (if appropriate) away from the sensitive areas.

10.12.2 General Benefits

- reduction in structural damage of habitat features
- improved water quality due to decrease in human influences on sensitive areas
- safer water supply for recreationists

10.12.3 General Drawbacks

- assumes primary draw to surface water sources is potable or auxiliary water; other attributes may sustain pressure despite alternative water supplies

10.13 MANAGEMENT OF OFF ROAD VEHICLE (ORV) USE

10.13.1 Overview of Technique

Corrective measures may be required where ORV use is causing unacceptable soil erosion and adverse effects on water quality or fish and fish habitat. Corrective measures on disturbed areas may include development of a travel plan, signing or barriers to redistribute use, partial closure during wet weather or to certain vehicle types, total closure, and structural solutions such as culverts and bridges.

10.13.2 General Benefits

- reduction in soil erosion
- water quality and habitat improvement

10.13.3 General Drawbacks

- potential economic loss to recreation-based employment where closures are enforced
- potential pressure on other areas from redistribution

11 MINING AND MINE RECLAMATION TECHNIQUES

Many of the techniques in this section are directed at the inventory and cleanup of abandoned acid-generating mine waste disposal areas in order to prevent further loss of aquatic habitat to Acid Mine Drainage. Under the Watershed Management Program, they are necessarily not intended as operating guidelines for active mines (though many techniques may be applicable). Two techniques speak directly to in-channel dredging operations.

Acid Mine Drainage is produced when sulphide-bearing minerals in rock are exposed to air and water, changing the sulphide sulphur to sulfuric acid. This acid then dissolves heavy metals, such as lead, zinc, copper, and arsenic, which are leached into ground and surface water. Acid Mine Drainage and heavy metals poison drinking water supplies, and can destroy aquatic life and habitat. Acid Mine Drainage can develop in association with underground mines, open pit mines, waste rock dumps, tailings deposits, and ore stockpiles (collectively called mine waste materials in the discussions which follow). Once begun, Acid Mine Drainage can persist for decades, centuries, or longer.

11.1 CONTROL OF RAINFALL LEACHING

11.1.1 Overview of Technique

This technique implements measures to prevent excessive precipitation from entering spent cyanide-leaching heaps and mining spoil areas. The most common approach generally includes the capping of waste piles with low permeability clay liners or other impermeable synthetic or geotextile fabric.

11.1.2 General Benefits

- reduced water supply reduces Acid Mine Drainage
- reduced toxicity and improved water quality
- decreased mortality of fish and aquatic organisms

11.1.3 General Drawbacks

- none

11.2 SURFACE WATER CONTROL

11.2.1 Overview of Technique

Control surface water to prevent contact of water with mined material. Divert streams around the area. Slope surrounding terrain away from storage areas and centers of mine activity. Placing small streams in culverts made of resistant materials can decrease risk of leachate entering surface water supplies. Contour ditches minimize surface runoff and can discharge affected waters into treatment ponds.

11.2.2 General Benefits

- reduced water supply reduces Acid Mine Drainage
- reduced toxicity and improved water quality
- decreased mortality of fish and aquatic organisms
- reduction in sediment delivered from streams

11.2.3 General Drawbacks

- annual maintenance may be required

11.3 FISH AND WILDLIFE PROTECTION

11.3.1 Overview of Technique

Prevent access of fish and wildlife to cyanide solution ponds and treatment or detention ponds in mined areas. This may be accomplished through removal of mined materials.stream diversions, and/or fencing of ponds to exclude wildlife. All discharges from treatment areas to surface waters should be safe for fish and people.

11.3.2 General Benefits

- decreased toxicity of surface waters
- prevent fish and wildlife mortality

11.3.3 General Drawbacks

- none

11.4 TREATMENT OF MINE WASTE

11.4.1 Overview of Technique

Location of waste disposal sites should maximize the distance to surface waters, minimize transport to ground water (consider water table depth, soil type), and minimize risl to beneficial uses (aquifers, fisheries, high quality waters). Where feasible, relocate waste disposa sites to identified low-risk locations. Mill tailings should be retumed underground if the risk of ground watr contamination is low. Stabilize waste material to prevent physical movement toward surface waters.

Many heavy metals are leached from waste rock and ore under acid conditions. For these metals, treat mined waste material with lime or caustic soda to neutralize the wastestream and prevent leaching into surface or ground waters. A detailed chemical composition of the wase material should be determined prior to treatment since some metals, such as molybdenum, are releasel into solution in basic environments.

11.4.2 General Benefits

- "neutral" environment decreases Acid Mine Drainage producton
- improved quality (decreased toxicity) of surface and ground water
- decreased mortality of fish and aquatic life

11.4.3 General Drawbacks

- none

11.5 TREATMENT OF MINE WASTE RUNOFF

11.5.1 Overview of Technique

An internal drainage system and detention ponds should be constructed to collect runoff and leachate from stockpiled waste material. Ponds should be constructed using synthetic or impermeable clay liners to prevent leaching to ground water. Treat this effluent as required in NPDES and other permits. This effluent may be treated with lime to reduce acidity. Use decanting systems, as appropriate, to remove water from the ponds after solids separation. Secondary treatment and dilution of this water may be necessary to reduce toxicity to levels safe for fish and people. Slowly discharge treated effluent to receiving streams to reduce deposition of suspended matter and to avoid depressing dissolved oxygen. Mine water may be directly used in mill boilers where it may be recycled to reduce contamination of surface waters.

11.5.2 General Benefits

- increased quality of effluent
- improved surface and ground water quality
- decreased mortality of fish and aquatic life

11.5.3 General Drawbacks

- none

11.6 REVEGETATION OF WASTE DISPOSAL SITES

11.6.1 Overview of Technique

Mined waste material should be limed and capped as discussed in techniques above. Additional reclamation should include the addition of some topsoil, recontouring to provide proper surface drainage, revegetation with native grasses, shrubs, and trees, and the implementation of erosion control structures.

Where stockpiles are located on floodplains or adjacent to streams, they should be relocated to areas with less risk of contaminating surface and ground waters. All such disposal sites should be monitored to assure surface and ground water quality is maintained or improved.

11.6.2 General Benefits

- reduced risk of leachate movement into surface and ground water
- vegetation accelerates site recovery
- well-implemented "closure" reduces long-term maintenance costs

11.6.3 General Drawbacks

- regular, long-term maintenance, especially where repeated revegetation attempts are necessary

11.7 MONITORING MINE WASTE DISPOSAL SITES

11.7.1 Overview of Technique

A plan for the long-term monitoring and evaluation of surface and ground water quality should be developed and implemented. Parameters will vary based on the characeristics of the mined waste material, but should include pH, electrical conductivity, and heavy metals and organic compounds, as appropriate. Macroinvertebrate collection and analysis and/or live bioassays shouldalso be considered for biological monitoring. Threshold of concem criteria, potential corrective actions,responsible authorities, and agency contacts should be identified before monitoring commences.

11.7.2 General Benefits

- reduced risk of long-term surface and ground water contamination

11.7.3 General Drawbacks

- none

11.8 LEACHING FOR REMEDIATION

11.8.1 Overview of Technique

Leaching has potential for clean up of Acid Mine Drainage in soils beneath mined waste material stockpiles. The capacity and quality of the aquifer, the depth to a water table, the presence of confining layers in the formation, and the uses of the aquifer below these sites should be considered. There should be no lateral dispersal of the contaminants to adjacent areas. A well should be sited in the region of highest concentration of the contaminant. The well is pumped to a treatment tank at the surface. Once treated, the leachate is pumped back into the ground through injection wells located around the center of highest concentration. Other injection wells around the outermost periphery of the site pump clean water into the ground to create higher pressure and prevent flow of the contaminant literally out of the site.

11.8.2 General Benefits

- dilution and confinement of contaminant plume beneath the ground surface
- some metals and contaminants removed during treatment at surface

11.8.3 General Drawbacks

- treats the effects of Acid Mine Drainage, not the source
- difficulty in extracting and treating adequate quantities of concentrated contaminants may make it hard to justify the expense

11.9 GRAVEL MINING WINDOW

11.9.1 Overview of Technique

Limit gravel mining in streams to window prescribed by fish and wildlife agency.

11.9.2 General Benefits

- gravel extraction limited to known period when eggs are not in stream gravels
- rearing fish have opportunity to escape disturbance

11.9.3 General Drawbacks

- turbid water created by dredging can cause mortality by clogging gills
- some rearing fish will be physically injured

11.10 REGULATE STREAM DREDGING

11.10.1 Overview of Technique

Gravel mining in streams is not permitted. Some limited extraction from previously disturbed floodplains and terraces may be permitted given habitat protection guidelines are employed (Saskatchewan Environment and Resource Management 1995a).

11.10.2 General Benefits

- complete protection for all fish of all lifestages

11.10.3 General Drawbacks

- economic impact on gravel extraction businesses