AL DEPARTMENT OF ENVIRONMENTAL CONSERVATION

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TRANSPORTATION and WATER QUALITY

Final Report

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Section 208, PL 92-500, 95-217

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MANUAL OF RECOMMENDED PRACTICES

FOR

TRANSPORTATION CORRIDOR DEVELOPMENT

ROADS, RAILROADS, PIPELINES, SUBDIVISIONS

Prepared by the Alaska Department of Environmental Conservation Water Quality Planning Program pursuant to Section 208 PL 92-500 as amended. This project was assisted by a grant from U.S. Environmental Protection Agency.

Prepared in part by
R&M Consultants, Inc.

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INTRODUCTION

This is a manual of recommendations for controlling erosion and sedimentation in development of transportation facilities, roads, railroads, pipelines, and subdivisions. Recommendations apply to design, construction and maintenance.

Construction activities are classified by the headings, GROUP and PRACTICE. Each PRACTICE is described under a series of subsequent headings. Many of the PRACTICES (construction activities) serve some primary purpose other than erosion and sediment control; but discussions under the subheadings (PURPOSE, SITE CHARACTERISTICS, DESCRIPTION) refer only to those applications which in some way control erosion and sediment.

The selection of alternative design features, such as bridges or culverts for stream crossings, is not directly addressed here. Those decisions should be made on the basis of sound engineering judgement applied to specific sites and situations. This manual does, however, provide information and suggestions on how to protect water quality in the design, installation and maintenance of such structures. Trade-offs will occur between such things as initial cost, maintenance required, project life, and right of way required. Frequently several other professional disciplines should also be included in decision making.

Guidelines presented here are not intended to serve as design standards. A number of design publications already are available; these are reviewed and referenced on the appropriate procedure sheets.

No attempt is made to represent all possible solutions. Many of these procedures are intended only as examples. Innovative engineering solutions are encouraged. The PRACTICES will be modified or supplemented periodically; the format is expandable.

Recommendations refer mainly to roads, because land-based transportation systems in Alaska are primarily roads. These, therefore, provide the most information. However, the same basic design and construction methods are used whether an embankment is intended to support a roadway, rails, or a pipeline workpad.

For several PRACTICES it is indicated that to use a specified erosion control measure will result in some additional cost. However, expenses necessary for meeting water quality standards should be considered as a normal cost of doing business.

It will suffice to mention administrative requirements (permits, etc.) once, in this introduction, to avoid repeating the list each time a procedure touches on an agency's responsibility. The state and federal programs most frequently affecting highways and other transportation corridors are:

<u>Federal</u>

U.S. Army Corps of Engineers
   Section 404 permits (P.L. 92-500, Clean Water Act). Required for placing dredge spoils or fill in navigable waters and wetlands. Section 10 permits (Rivers and Harbors Act). Required for obstruction, alteration or improvement in navigable water.

U.S. Coast Guard
   Section 9 permit (Rivers and Harbors Act). For construction, modification, or removal of bridge or causeway in navigable water.

State

Department of Environmental Conservation

Section 401 Certification (P.L. 92-500). U.S. Army Corps of Engineers permits require certification from the state that they comply with other provisions of the Clean Water Act (SECS. 301, 302, 306, 307).

Water Quality Standards (AS 46.03). Apply to all activities which result in point or non-point source discharges into state waters.

Department of Fish and Game

Anadromous Fish Protection Permits (AS 16.05.870). Requires ADF&G approval before conducting activities which impact anadromous fish streams.

Department of Natural Resources

Water use permits (AS 46.15). Require permit before constructing water impoundment or diversion.

Division of Policy Development and Planning

Coastal Management (AS 44.19.891-894, AS 46.35). Requires determination of project consistency with district and state coastal programs.

State Clearinghouse (Circular A-95). Federally funded projects require review of numerous agencies through the state clearinghouse.

For a more complete list, please contact the ADEC permit coordination center in either Anchorage or Juneau for the Directory of Permits.

Nothing in this manual limits responsibility for compliance with any law or regulations.

GROUP Earthwork

PRACTICE Clearing, Grubbling and Slash Disposal (Guidelines)

PURPOSE

To prevent erosion of areas disturbed by clearing and excavation.

SITE CHARACTERISTICS

The following set of guidelines apply to all areas where vegetation and timber are removed, topsoil stripped and soils excavated for construction. Permafrost areas may require special techniques to avoid thermal degradation.

ADVANTAGES

1. Minimizes erosion and sedimentation from disturbed areas.

DESCRIPTION

Guidelines for clearing, grubbling and early construction phase.

1. Minimizing Disturbed Area

Clearing should immediately precede excavation activities to minimize exposed, unprotected surfaces.

Erodible cutslopes, fills and other exposed soils should not be left over winter unprotected by vegetation, or coarse, adhesive or blanketing materials.

Equipment should not be operated outside of the designated area within the R-O-W. In permafrost terrain, unless snow roaded even a single pass by a wheeled vehicle can damage the organic layer, resulting in thermal erosion.

Preserve the organic mat above cuts. Handclearing should be done on ice rich permafrost (for summer construction) and at the top of cut banks. Any disturbance which may lead to erosion should be promptly reported and treated (See section 7 for further discussion of permafrost).

In muskegs, slash can be used as a mat for overlay materials.

2. Conservation of Topsoil

Organic soils stripped from the R-O-W should be stockpiled whenever possible for later use, or immediately respread over surfaces to be revegetated. Proper staging can prevent double handling.

DESCRIPTION CONTINUED

3. Slash Disposal

Slash should not be mixed into fill.

- Salvage all merchantable timber.
- Slash can be used for ditch checks, sediment filters, or can be chipped for mulch.

4. Stream Crossings

Equipment operation instreams should be kept to an absolute minimum for crossing anadromous streams with equipment.

Buffer strips at the approach to streams should be maintained until actual construction is to proceed.

Avoid felling trees or allowing other debris to enter streams. In some case this may be unavoidable. Remove such debris within 48 hours. Avoid damaging natural streambanks.

MAINTENANCE

If these activities are carried out properly, very little maintenance should be needed, particularly if excavation and final construction follow closely behind.

REFERENCE

1) Tourbier, J. Water Resources Protection Measures in Land Development, Water Resources Center, Univ. of Delaware, April 1974. 2) Environmental Protection Agency Guidelines for Erosion and Sediment Control Planning and Implementation August 1972. 3) Environmental Protection Agency. Logging Roads and Protection of Water Quality, EPA 910/9-75-007 March 1975.

GROUP
Earthwork

PRACTICE
Surface Preparation

PURPOSE

To promote revegetation efforts and reduce erosion from disturbed areas as well as from driving surfaces.

SITE CHARACTERISTICS

Applicable to any areas to be revegetated, particularly sloping terrain. May be used to reduce wind and water erosion of exposed areas and stabilize driving surfaces.

ADVANTAGES

1. Promotes seed germination.
2. Helps increase soil moisture retention and reduces movement of seed and fertilizer.
3. Increased runoff infiltration.
4. Stable driving surfaces.

DISADVANTAGES

None - should be a part of recommended practices.

DESCRIPTION

Surface preparation includes a variety of techniques to stabilize exposed areas, promote revegetation and reduce erosion from construction areas. Some techniques apply to the surface treatment and others to its configuration.

Scarification Many types of equipment can be used to "roughen" a surface prior to revegetation. The roughened surface helps infiltration and moisture retention, which promotes germination. "Cat-tracking" consists of running tracked vehicles up and down or along slopes creating mini-benches. This can usually be done on slopes up to 2:1. Discs, harrows, sheepsfoot rollers are also used to roughen surfaces.

Serrated Cuts Slopes in certain materials can be cut or serrated into mini-benches along the contours. This also improves infiltration.

Topsoiling Although not always economical, topsoil stripped during clearing should be stockpiled and later respread over areas to be revegetated. This provides a more effective seed bed, particularly in dry soils areas.

Roadbed Construction

Aggregate Cover A surface dressing of clean aggregate provides a good driving surface, even in wet weather and minimizes surface erosion. It can be used as a base for final surfacing (such as asphalt) or simply for heavily travelled access roads or pipeline R-O-W's to reduce soil tracking.

DESCRIPTION CONTINUED

Surface Configuration The geometry of the roadbed is critical to providing surface drainage and in minimizing surface saturation and runoff of eroded soils.

Compaction The final lift of each day's work should be compacted and shaped to drain.

Crowning or Sloping The surface should be crowned or cross-sloped to direct runoff to ditches, berms or other stabilized areas.

Aggregate Cover, Temporary Seed and Mulch If the surface is to remain unused for extended periods, such as for final completion the following season, a treatment of temporary revegetation (see 5.A.) or aggregate cover will minimize erosion.

EXAMPLE

Highway fill slope shown was 'cat-walked' prior to revegetation. Grass was beginning to germinate in cleat tracks. Other slopes in the area which had not been scarified showed rilling and gullying erosion.

Location: Glenn Highway, Eklutna, Alaska

Source: R&M Consultants, Inc., Anchorage, Alaska

REFERENCE

1) Environmental Protection Agency. Guidelines for Erosion and Sediment Control Planning and Implementation, August 1972. 2) Fairfax County, Virginia. Erosion and Sediment Control Handbook. Dec. 1974. 3) Environmental Protection Agency. Logging Roads and Protection of Water Quality. EPA 910/9-75-007. March 1975.

GROUP
Earthwork

PRACTICE
Borrow and Disposal Practices

PURPOSE

To prevent erosion from mining and disposal sites during and after construction.

SITE CHARACTERISTICS

Recommendations are applicable to all disposal sites, and all upland and floodplain borrow sites.

ADVANTAGES

1. Protection of water resources from mining and disposal activities.

DISADVANTAGES

1. None - cost of erosion control should be considered part of normal expense.

DESCRIPTION

BORROW AREAS

1. Mining Plan

Each site will impose special requirements to prevent or minimize sedimentation from mining activities. Before and during mining a detailed mining plan should be on site. The plan should include:

site sketch to scale;
mining procedures;
stockpiling and overburden handling procedures;
erosion and sedimentation control procedures;
overburden depth;
material properties quantity and depth;
buffer areas;
excavation dimensions;
plan modifications;
time frames;
traffic routes; and
final restoration measures.

Time frames should be determined well in advance so that the contractor will have proper equipment on hand.

Mining Plans should be changed as field conditions change.

DESCRIPTION CONTINUED

2. Sediment Control During Operation of Upland Borrow Sources

Mining should take place wherever possible in upland areas rather than in floodplains.

Pits should be located out of the path of heavy seepage. Avoid locations where pit backwalls adjoin steep slopes (recommend less than 40%) except where pit adjoins solid rock slopes.

Floodplain Sites

Mining should not go deeper than a foot or more above the water table to prevent hydraulic changes and siltation.

Gravel washing should be avoided. If there isn't an alternative, effluents should be passed through settling basins with low energy exits. If possible, direct effluents away from streams to vegetated areas, provided that energy can be dissipated to prevent erosion.

Remove borrow materials from floodplain sites as soon as possible. When removal is not feasible, stockpiling materials in rows in the direction of flow lessens the potential for erosion.

Avoid vegetated portions of the floodplain, especially inside meanders. Locations inside meanders have high potential for short cutting stream flow, and may have high potential for fish entrapment.

Avoid work in active channels, especially spawning and overwintering areas.

Where floodplain sites are used, scalping and crowning unvegetated bars have the following advantages.

No vegetation would be disturbed;
Mining does not enter the water table;
By crowning, fish are not trapped by receding flood waters.

However, maintaining bank integrity is important to prevent change in stream configuration (prevent braiding). Scalping and crowning should not be done where banks are unstable and could be damaged at high flows if bars are removed.

All Borrow Sites

Runoff upslope/upstream of any borrow sources should be diverted with dikes or ditches. Runoff from the pit should pass through sediment basins or revegetated buffer strips before entering a watercourse.

Keep equipment operation within approved working limits.

3. Preventing Channel Charges

Floodplain Sites

Retrain undercut and vegetated banks.
Avoid borrow in streams where banks are unstable.
Avoid disturbing edge of active channel - subsequent floods could establish braiding.

DESCRIPTION CONTINUED

For pits in the floodplain, locate where buffer zone is stable. A flow path through the pit should be a greater distance than existing channels.

High Water Channels

Maintain channel shape in material site similar to shape of the channel as it enters and leaves the site.

Retain bed slope in site not greater than naturally occurring slopes.

4. Phased Development

Phased development borrow sources can minimize disturbed area. As use of one segment is completed, it may be stabilized while the next is developed. By mining in an upslope or upstream direction the portions first developed may be used as settling basins for higher portions.

5. Fish Entrapment

This is often a potential hazard when borrow sources are in floodplains. Sites should not be left so that fish can be trapped when floodwaters recede. If settling basins are used the final outlet should be perched.

Maintain fish passage in active channels. Avoid constriction of flows which would increase velocity.

6. Restoration

Upland sites

Stockpiling, and respreading overburden following operation greatly assists in borrow pit restoration.

Floodplains

Remove overburden immediately to a location above high water for disposal, stockpiling or rehabilitation of other sites.

If settling basins were required fine solids should be removed beyond the floodplain or the basin should be rehabilitated such that fine solids will not be introduced into the stream.

All borrow sources

All sites should be stabilized by returning to stable angles and revegetating. (See Section 5 on revegetation)

DISPOSAL AREAS

Disposal of organic soils, ice-rich soils, slash and other materials requires careful planning. Spoil areas should be graded to stable conditions and should provide for impoundment of waterborne sediment. Some waste materials can be used to restore old haul roads being "put to bed." Disposal areas should mulched and seeded as in Section 5.

Both borrow and disposal area plans should incorporate appropriate tracking and dust control procedures as discussed in Section 10.

EXAMPLE

A portion of this borrow site where mining was completed has been final graded and revegetated.

Location: Trans-Alaska Pipeline

Source: R&M Consultants, Inc.
Anchorage, Alaska

REFERENCE

1) Burger, C., Swenson, L. Environmental Surveillance of Gravel Removal on the Trans-Alaska Pipeline System with Recommendation for Future Gravel Mining. Joint State/Federal Fish and Wildlife Advisory Team. Special Rpt. No. 13. 1977.
2) Highway Research Board. Erosion Control on Highway Construction. 1973.
3) Soil Conservation Service. Field Manual for Conservation Practices. 1969.
4) Woodward-Clyde Consultants. Gravel Removal Studies in Arctic and Sub-Arctic Floodplains in Alaska. Draft Technical Report. U.S. Fish and Wildlife Service. November, 1979.

GROUP
Drainage - Structures

PRACTICE
Culverts

PURPOSE

To provide non-erosive passage of stream flow on temporary and permanent roads.

SITE CHARACTERISTICS

Used on any roadway section where continuous access is required and where flow volume, gradient and/or length of span do not mandate bridging.

ADVANTAGES

1. Permanent or temporary installation.
2. Allows continuous access.
3. Can be designed to allow fish passage.
4. Relatively inexpensive and quick.

DISADVANTAGES

1. Requires regular maintenance.
2. If maintenance is discontinued usually requires removal to prevent eventual plugging and washout.
3. Requires accurate staking for proper installation.
4. May plug and wash out due to icing. (See procedures 8A and 8B, Icing control).

DESCRIPTION

DESIGN CRITERIA AND OUTLINE SPECIFICATIONS:

Different sets of procedures are needed for fish streams and non-fish streams. They are separated accordingly below. "Fish streams" include streams which support resident migratory, or anadromous fishes during some part of the year.*

<u>All Streams</u>

1. The natural stream path should be normal (90°) to the road, insofar as possible. Culverted flows should not involve stream realignment.

*Intermittent streams (those that flow only part of the year), common to interior Alaska, often provide significant habitat for resident fishes. For example, grayling sometimes spawn and hatch in streams that are dry by midsummer (Hickman, G.L. Asst. Area Director, USFWS. Letter to E.I. Lipson. August, 1978).

DESCRIPTION CONTINUED

2. Depth of headwater at design flow should be no greater than 1½ times the culvert diameter. Design should not allow culvert headwaters to exist on fish where high flow could coincide with fish migrations.

3. In permafrost areas where ice rich soils could occur, culverts should be designed with particular care to avoid ponding.

4. Install cross drains to intercept flows in ditches on upstream side so that outlet is downstream of main bridge or culvert.

Non-Fish Stream (Includes roadside drainage)

1. Culvert should match the gradient of the natural channel.

2. If grade is steep or culvert outlet is above streambed, energy dissipation may be required (see procedure 2.C.).

Fish Stream

A goal of maintaining culvert flow velocity under 1.5 fps for "fish streams"* at least half the time is recommended, and was used in preparing some of the specific guidelines given below. Higher velocities reduce or eliminate the use of upstream locations as rearing areas for juvenile salmonids and as spawning and rearing areas for grayling.

1. Embankment slope in the vicinity of the upper end of culverts should be armored as necessary to prevent erosion.

2. Minimum culvert size for a fish stream should be 24 inches (larger depending on flow rate). Arch- or open-bottomed culverts with comparable cross section and natural-bottom conditions are also acceptable.

3. Culverts in fish streams should be buried to one-fifth of their diameter below the natural stream grade, or the invert of the culvert should be buried six inches below the stream bottom.

4. Culvert slopes should match stream gradient unless:

   a) outfall armoring is designed, constructed and maintained to prevent outlet erosion and resultant perching of outfall;

   b) armor allows minimum water depth and velocity for fish passage.

   In general, if the stream gradient is too steep to match with culvert slope, then a bridge is preferred.

   The recommended culvert slopes to approximate the 1.5 fps goal for fish streams are as follows:

Diameter (in)	Slope (%)
24	1.0
36	0.6
48	0.4
60	0.2

(From: U.S.F.S. Alaska Region Fish/Culvert Roadway Drainage Guide. 1977), (Hickman, G.L. Asst. Area Director, USFWS. Letter to E.I. Lipson. Aug, 1978)

DESCRIPTION CONTINUED

Experimental structures such as baffled culverts may pass fish (including fry) at much steeper gradients. However, baffles are debris collectors. They should seldom be used as they require maintenance attention to prevent blockage not available in most areas.

5. All drainage structures should be of sufficient size to prevent scouring. All drainage structures and related facilities should be armoured with sufficient rip rap to preclude erosion.
6. The embankments above the culvert ends should not wash sediment into the stream.
7. Culverts should be properly bedded to prevent undermining and eroding seepage flows.
8. The jumping ability of juvenile salmonids is assumed to be zero, so there must be no dropoff at the culvert outlet.
9. Reach of the stream should be chosen that has a low gradient.
10. Consider bridging as an alternative if proper culvert design results in too high a cost.

MAINTENANCE

1. Culverts require periodic inspection and may require cleaning, especially after storms.
2. Culverts may require thawing.

REFERENCE

1) State of Alaska, Department of Highways. Hydraulics Manual. 2) U. .S. Department of Agriculture, Forest Service. Roadway Drainage Guide for Installing Culverts to Accommodate Fish. Alaska Region Report No. 42. Juneau. September, 1979. 3) American Iron and Steel Institute. Handbook of Steel Drainage and Highway Construction Material.

GROUP Drainage -- Structures

PRACTICE Low Water Crossings

PURPOSE

To provide passage of stream flow on roads having low traffic volumes.

SITE CHARACTERISTICS

Can be used on forest roads or pipeline work pads where traffic volume is low and continuous access is not required.

ADVANTAGES

1. Inexpensive to install.
2. Less susceptable than culverts to damage from debris or icing.

DISADVANTAGES

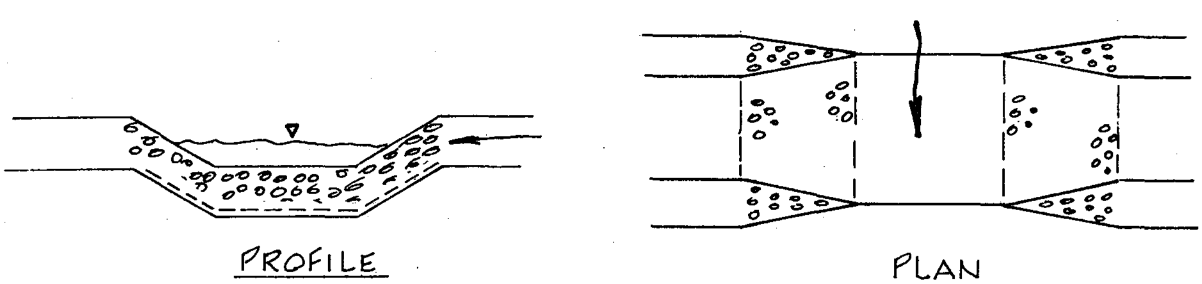
1. Not usable during high stream flows.
2. May be washed out.
3. Not suitable for heavy construction traffic.
4. Not suitable for deeply incised streams. Such streams may require excessive disturbance during construction.
5. Not suitable for some fish streams. For any fish stream, necessary maintenance would be greater. Access should be restricted or denied during periods of migration or spawning, which would usually coincide with construction.
6. May be subject to icing.

DESCRIPTION

The intent of the low water crossing is to match the natural geometry as closely as possible; therefore, it is only applicable in situations where stream banks are low and approach grades are flat. Configuration of the crossing varies with stream geometry and streambed material.

Side slopes of crossing should match natural geometry as closely as possible and still provide trafficability.

Size of rock armor required is determined by maximum anticipated flow velocity. (See Appendix 2.B.3)



DESCRIPTION CONTINUED

Application of low water crossings has frequently resulted in more maintenance costs than initial installation costs for temporary bridges. Fish blockage, sedimentations, traffic lane failure and icing were continuous problems along taps. (Logan, R. Chief, ADF&G Habitat Protection. Memo to B. Walker. Apr. 18, 1980).

EXAMPLE

A low water crossing for a small drainage along the Trans-Alaska Pipeline workpad.

Source: R&M Consultants.

MAINTENANCE

Will require periodic, perhaps frequent, regrading. More frequent regrading will be necessary for fish streams.

REFERENCE

1) Environmental Protection Agency. Logging Roads and Protection of Water Quality. EPA 910/9-75-007. Seattle, March, 1975. 2) Highway Research Board. Erosion Control on Highway Construction. 1973. 3) Alaska Dept. of Highways. Hydraulics Manual. 1972.

GROUP

Drainage - Non-Paved Road Surfaces

PRACTICE

Grading, Cross Drains

PURPOSE

To prevent erosion of unpaved road surfaces.

SITE CHARACTERISTICS

Being in constant use, construction service and access roads are an important source of pollution. All are susceptable. Steep slopes and highly erodible soils are especially vulnerable. All unpaved road surfaces must be provided with adequate drainage.

ADVANTAGES

1. Reduces on-site erosion.
2. Can avoid immobilizing machinery and generally improve site efficiency and working conditions during adverse weather.
3. Minimize regrading.
4. Economical to build.

DISADVANTAGES

1. Measures must be inexpensive both to install and to remove if they would interfere with eventual surfacing.
2. Outlets must be stable.

DESCRIPTION

1. Grading

Temporary and other unpaved roadways should be carefully graded for cross drainage. Otherwise runoff will build up and gullying will occur. A cross fall of ½" per foot is recommended. Roadside drainage is also required.

Use dips and rolls in the grade, where practical, to break up surface flows on or parallel to the road.

2. Cross Drains

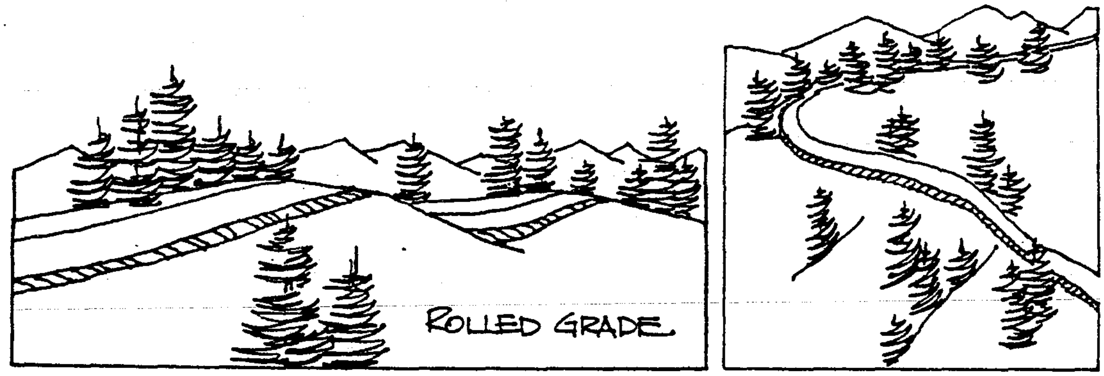
For cross drainage dips or installations such as open culverts the following spacings are recommended.

For other soils distance between cross drainage dips or installations such as open culverts, should be less than 100 feet for slopes over 5 percent. In silt soils intervals should be: 10 percent slope, 55 feet, 8 percent, 65 feet; 6 percent, 70 feet; 4 percent 80 feet; 2 percent, 95 feet. (Adopted from Ref. 2).

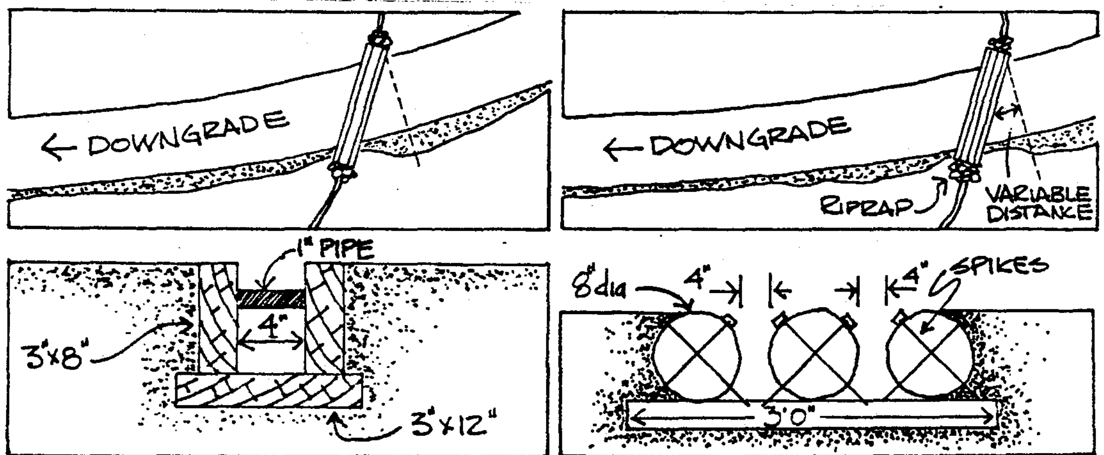
Install crossdrains (usually round culverts) to intercept flows in ditches on the upstream side so that outlet is downstream of a main bridge or culvert.

Examples shown below are box or pole open culverts, dip gravel trench drain, and for less highly traveled roads simple gravel berms.

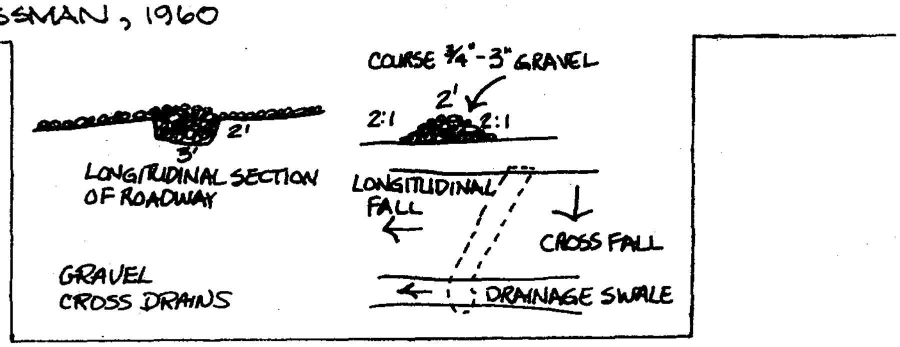
EXAMPLE



FROM PACKER & CHRISTENSEN



FROM HAUSSMAN, 1960



MAINTENANCE

Berms and tracks which prevent desired cross drainage should be graded out.

Drainage structures should be inspected periodically. On haul roads used in winter, snow berms should be removed before breakup to permit lateral drainage.

REFERENCE

1) Haussman, R. F. 1960. Permanent Logging Roads for Better Woodlot Management. USDA Forest Service, Division of State and Private Forestry, Eastern Region, Upper Darby, Pa. 2) Packer, P. E., Christianson, G. F. (pre 1964) Guides for Controlling Sediment from Secondary Logging Roads. USDA Forest Service, Intermountain Forest and Research Experiment Station, Ogden, Utah and Northern Region Missoula, Montana 42 p. 3) EPA. Control of Erosion and Sediment Deposition from Construction of Highways and Land Development. 1971 4) EPA. Guidelines for Erosion and Sediment Control Planning and Implementation. 1972.

GROUP
Drainage Control - Runoff

PRACTICE
Grass Channels

PURPOSE

To economically provide drainage with grass lined channels.

SITE CHARACTERISTICS

Runoff from roadside ditches and other graded areas can be handled by grass channels for velocities up to 8 fps. Maximum allowable velocity depends on soil and species of cover. Usually restricted to channel gradients less than 10%.

ADVANTAGES

1. Grass lined channels are less expensive than those lined with concrete or stabilized by a 'bio-technical' measure (see section 2.B.3).
2. Grass will delay runoff and consequently reduce its erosive capacity.
3. Grass channels are visually more acceptable than those lined with concrete or rip rap.
4. A vegetated channel reduces surface runoff through infiltration.

DISADVANTAGES

1. Very careful design and good maintenance are necessary to prevent gully erosion.
2. New areas of impermeable surfacing upstream/upslope of grassed channels may increase runoff volume and velocity to exceed design capacity.
3. Channels should not be constructed for maximum flow velocity. In practice vegetation may not be well maintained. Actual vegetation would then provide inadequate protection against erosion at design velocity.

DESCRIPTION

Channel flow velocities on well established soil of good quality generally should not exceed 5-6 fps except for special situations. Respreading topsoil may be essential.

Most waterways are constructed to accommodate the peak flow from a storm of at least 10 years frequency before overbank flow occurs.

The flow retarding factor of different vegetation should be considered in the design.

Construction

Avoid excessive compaction during construction, as it will result in an inferior sward. Between the time of seeding and the time of actual establishment, the waterway will be unprotected and subject to damage. Provision should be made to divert flows during construction.

DESCRIPTION CONTINUED

Channel sections may be V-shaped, trapezoidal or parabolic. Parabolic cross sections have proven most satisfactory. Trapezoidal sections tend to revert to a parabolic shape. Due to flow velocity distribution, v-shaped channels should not be used if the channel side slopes would exceed 6:1.

To maintain a good turf the channel should not be continuously wet. A tile drain can help. Recommended placement is offset from the center of the channel by at least ¼ channel width.

Permissible Velocity

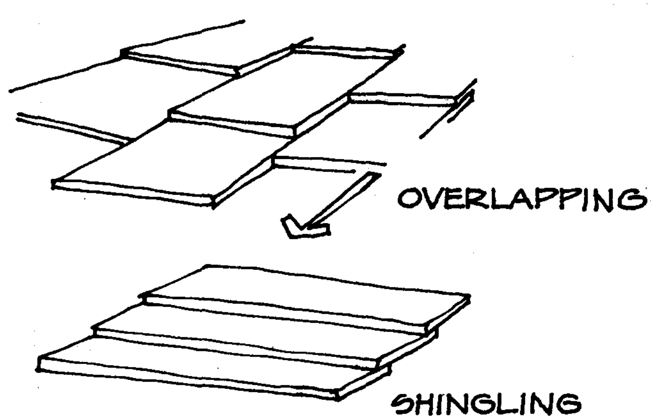
Cover Species	Slope (%)	Erosion Resistant Soils (fps)	Easily Eroded Soils (fps)
Kentucky bluegrass	0-5	7	5
Smooth brome	5-10	6	4
Tall fescue	over 10	5	3
Grass mixture	0-10	5	4
Red fiscue	0-5	3.5	2.5

The Rural Development Council's Revegetative Guide gives other species which can be used for channel vegetation.

Sodding

Sodding can be expensive, but may be required for immediate stabilizing. Overlapping involves the placement of sod strips parallel to the water flow and is used in relatively flat ditches that carry large volumes. Shingling can be used on short grades that are steeper than 10%. Grass strips are laid perpendicular to flow. Staking overlapped portions will increase the effectiveness in both cases.

SODDING



MAINTENANCE

Maintenance can increase capacity of grassed waterways. A yearly dressing of fertilizer may be helpful if applied so that it will not be carried away by runoff. Regular mowing encourages a tight sward.

REFERENCE

1) Soil Conservation Service. Field Manual for Conservation Practices. 1969. 2) Minnesota Department of Highways, Conservation Division. Erosion prevention and Turf Establishment Manual. 1970. 3) Alaska Department of Highways. Hydraulics Manual. 1972. 4) Alaska Rural Development Council. A Revegetative Guide for Alaska. 1977.

APPENDIX 2.B.1.
Calculation of Channel Size

The discharge capacity of a channel (Q in cfs) is determined from V, the velocity in the channel (in fps) and a, the end area of the channel (sq. ft.) by the formula

$$Q = Va \qquad \text{EQUATION 1}$$

V varies according to the 'coefficient of roughness', n, of the channel which is normally 0.04 for grass-lined channels, the hydraulic radius, r, (end area, a, divided by wetted perimeter, p) and the slope or gradient of channel, s. This relationship is expressed by the formula

$$V = \frac{1.486}{n}\left(r^{2/3}\right)\left(s^{1/2}\right) \qquad \text{EQUATION 2}$$

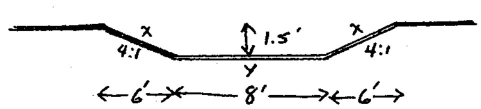
Substituting V in Equation 1

$$Q = \frac{1.486}{n}\left(r^{2/3}\right)\left(s^{1/2}\right)a \qquad \text{EQUATION 3}$$

The selection of channel size using the above equations is a trial-and-error process of selecting for a channel, checking whether its velocity is within the safety limits for the type of grass lining (Table 7) and whether the cross section is sufficient for the discharge of runoff from the area drained.

Example A1

Select a channel alignment and cross section to drain an area with a peak discharge, Q, of 160 cfs. An ideal alignment for the channel has a slope, s, of 0.03 and it is decided that the side slopes should be a maximum of 4:1 to allow high speed maintenance by mowing. Soil conditions are very good and it is anticipated that the quality of turf will allow a maximum velocity, V, of 6 fps.



Step i) Select ideal channel section (for ease of calculation, this is trapezoidal).

Step ii) Calculate area of section.

$$a = 21 \ ft^2$$

Step iii) Calculate hydraulic radius.

$$r = a \div p \quad p = y + 2x = 8 + 2\sqrt{6^2 + 1.5^2} = 20.18$$

$$\therefore \; r = 21 \div 20.18 = 1.03$$

Step iv) Calculate discharge capacity of channel.

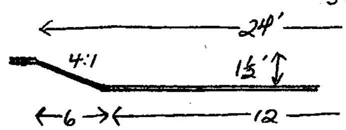
$$Q = \frac{1.486}{n}\left(r^{2/3}\right)\left(s^{1/2}\right)$$

$$Q = \frac{1.486}{0.04} \times 1.02 \times .1732 \times 21 = \underline{137.8 \text{ cfs}}$$

This is not sufficient to carry the peak discharge of 160 cfs.

Step v) Select a larger cross section.

Note that both a deeper or a wider channel will increase capacity but a deeper channel will result in a higher velocity of flow.



$$a = 27 \text{ ft}^2$$

$$r = 27 \div 24.36 = 1.11$$

$$Q = \frac{1.486}{0.04} \times 1.072 \times 0.1732 \times 27 = \underline{186 \text{ cfs}}$$

This is sufficient with a safety margin to take 160 cfs discharge.

Step vi) Check that the velocity of flow will not be too great for the grass lining.

$$V = \frac{Q}{a} \qquad \text{EQUATION 1}$$

$$V = \frac{186}{27} = \underline{6.8 \text{ fps}}$$

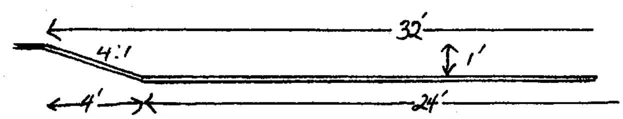
But this is too great (the maximum velocity decided on was 6 fps). One velocity decided on was 6 fps) One could argue that peak discharge is 160 cfs.

Maximum design velocity = $\frac{160}{27}$ = <u>5.9 fps</u>

and is 0.K

However, if not considered safe, then:

Step vii) If velocity is too great, make the channel <u>wider</u> but <u>shallower</u>.



$$a = 28\ ft^3$$

$$r = \frac{28}{32.24} = 0.87$$

$$Q = \frac{1.486}{0.04} \times 0.911 \times 0.1732 \times 28 = \underline{164.1\ cfs}$$

Channel is sufficient to take discharge of 160 cfs.

Step viii) Check that <u>velocity of flow in channel (step vii) is not too great</u>.

$$V = \frac{Q}{a} \qquad \text{EQUATION 1}$$

$$V = \frac{160}{28} = \underline{5.7}\ fps \qquad \text{WHICH IS O.K.}$$

The same technique may be applied to a parabolic or 'V' shaped section; this just makes the calculation slightly more complex.

Note: One could have done this example a different way. For instances, if space were very tight one could start by finding the minimum cross section for a velocity of 6 fps to take a discharge of 160 cfs, thus:

$$a = \frac{Q}{V} \qquad \text{EQUATION 1}$$

$$a = \frac{160}{6} = 26.7\ ft^2$$

Say, then, that only 24' is available; we know from Steps v and vi above that a 24' channel width will give too great a velocity. Therefore, the gradient must be decreased. Note that if the gradient is the same but the side slopes are increased, it effectively increases (a) but also Q, and therefore is not advisable.

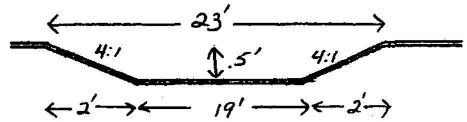
Note: About 10% should be added to width and 0.5' to depth for freeboard in permanent channels.

Example A2

Design a channel with a macimum velocity, V, of 3 fps and a slope, s, of 0.05 with a peak discharge Q of 30 cfs. On Table 3 enter the chart on line reading 30 cfs, follow to right in column reading 5% (0.05) slope. For a velocity of 3 fps, top width is 45' and depth of 0.4' (add 4' to width and 0.5' to depth for freeboard in permanent channels).

Note: The dimensions given in this example are for a parabolic section for a Manning's coefficient of 0.04. If the maximum allowable velocity had been 4 fps, the width could be reduced to 23' and depth increased to 0.5'; and if 5 fps, a 13' width and 0.7' depth would have been permissible.

Using Method A for the above example,



$$r = a \div p = 10.5 \div 23.1 = 0.45$$

$$Q = \frac{1.486}{0.04} \times 0.587 \times 0.2236 \times 10.5 = \frac{2.0475}{0.04}$$

$$Q = 51.198 \text{ cfs}$$

$$V = \frac{51.2}{10.5} = 4.876 \text{ (TOO HIGH) BUT IF}$$

$$Q = 30 \text{ cfs}, \quad V = \frac{30}{10.5} = 2.9 \text{ fps (O.K.)}$$

Reference

URS Company. Stormwater Management, Procedures and Methods. Snohomish County, King County, City of Everett. EPA Grant Id. No. P-000091. September 1977.

GROUP
Drainage Control - Runoff

PRACTICE
Ditch Checks, Checkdams -- Temporary Measures

PURPOSE

To slow velocities within a ditch to reduce erosion or trap eroded sediments.

SITE CHARACTERISTICS

Used in any small ditch or channel (not used as fish habitat) where soils may be eroded by expected flows. Required more often for poorly drained soils where more runoff occurs.

On steeply sloping channels, checks may be used as gradient breaks to reduce slope. They are helpful while establishing vegetative channel liners. (See 2.B.1.)

ADVANTAGES

1. Reduces flow velocities.
2. Traps eroded sediments and prevents gullying of the channel.
3. Economical. Can be built with scrap or native materials.

DISADVANTAGES

1. May require clean out to maintain effectiveness. If they silt up, percolation through permeable structures will be reduced and flow may go over banks.
2. These are usually temporary measures. Long term protection will require more substantial measures and design.
3. May need to be removed.

DESCRIPTION

DESIGN CRITERIA AND OUTLINE SPECIFICATIONS:

These procedures are suited for use during construction as ditching proceeds or to protect natural channels. They can help control gully erosion until permanent liners such as vegetation or stone can be established. (See 2.B.1, 2.B.3)

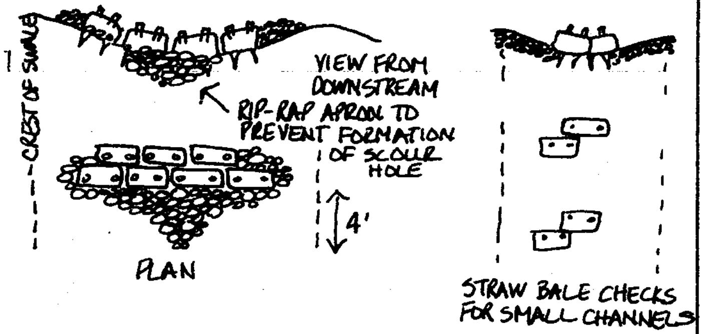
Straw Bale Checks

1. Channels over 9' wide. Bales are staked down with two 2½' wooden or metal stakes, and tied, preferably with nylon or wire. Place rip rap downstream for a minimum of 4', and at the edges to bring its height level with the crest of channel.

DESCRIPTION CONTINUED

2. On channels less than 9'. The small checks shown may be used without rip rap. They should be spaced about 50' apart.

   Both these checks must be removed before final channel stabilization.



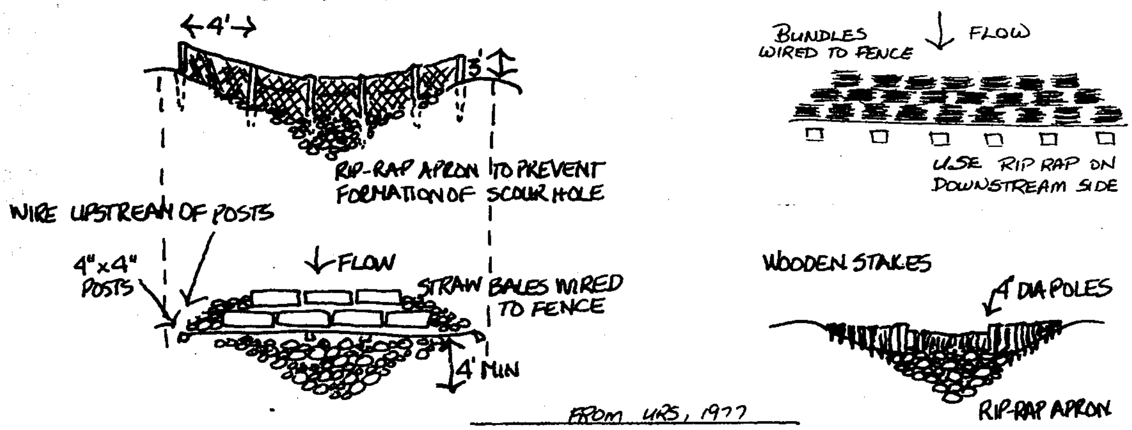
Wire Fence Check with Straw Bales

A 3' cyclone fence is nailed on the upstream side of 4" x 4" wooden stakes across the channel. Straw bales are placed on the upstream side as shown. These are wired together and to the fence.

Rip rap is placed as in the Straw Bale Checks section. In some cases the straw bales may be covered in crushed stone.

This installation must be removed prior to final channel stabilization.

This is prefered over the first method shown above when protection is required for longer than 6 months, as straw bales may be quickly and easily replaced without disturbing rip rap.



Wire Fence Check with Brushwood Bundles

When straw is not available but where there are large quantities of brushwood on site, brushwood bundles approximately 28" in diameter can be made up with #9 wire laid in stagged formation upstream of the fence and wired together and to the fence. Rip rap is placed as in the Straw Bale Checks.

This installation must be removed prior to final channel stabilization.

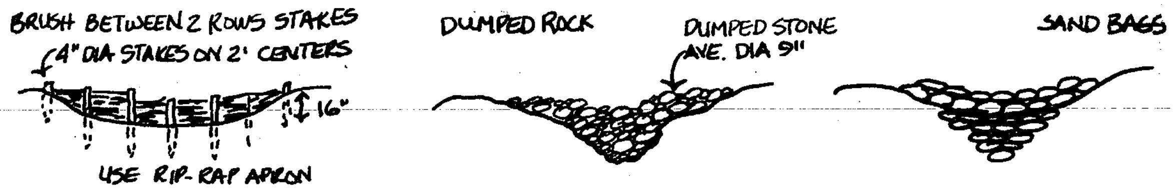
Wooden Stakes

4" minimum diameter wooden poles or stakes are driven in across the swale. Rip rap protection is used downstream. Permeability of structure may be reduced by nailing polyethylene sheeting on upstream side.

DESCRIPTION CONTINUED

Brush Between 2 Rows of Stakes

4" minimum diameter stakes are driven at 2'6" centers in 2 rows 2'6" apart. Brush is packed between, and wired down securely by criss-crossing #9 wire between stakes.



FROM URS, 1977

Dumped Rock

A semi-permeable check may be constructed of dumped rock. (9" diameter is sufficient for velocities of up to 8 fps which is the maximum for grass channels.) The installation may become permanent.

Sandbags

100 pound sandbags may also be used as a temporary check in a swales. An apron should extend at least 4' downstream. This type is useful in areas where rock is unavailable.

MAINTENANCE

The ditch checks may require periodic clean-out or replacement, particularly to remain effective in filtering out sediments from flows.

REFERENCE

1) North Carolina State Highway Commission. Temporary Erosion and Pollution Measures. 1972. 2) Environmental Protection Agency. Guidelines for Erosion and Sediment Control Planning and Implementation. 1972. 3) Pennsylvania Department of Environmental Resources. Soil Erosion and Sedimentation Control Manual. September, 1972. 4) URS Company. Stormwater Management, Procedures and Methods. Snohomid County, King County, City of Everett. EPA Grant ID. No. P-000091. September 1977.

GROUP
Drainage Control - Runoff

PRACTICE
Mechanical Channel Liners

PURPOSE

To carry surface runoff in stable waterways where flow velocities exceed those acceptable for vegetated channels (2.B.1).

SITE CHARACTERISTICS

To carry runoff in stable waterways where flow velocities are excessive for channels with vegetation alone, or to protect channels before vegetation becomes established.

ADVANTAGES

1. Stone liners are effective for higher flow velocities.
2. Some mechanical measures can aid in establishment of vegetation on sites that would otherwise be unsuitable. The use of vegetation in combination will slow flow velocity and increase infiltration.

DISADVANTAGES

1. Initial cost may be higher.
2. Checkdams and drop structures are prone to damage during high velocity flows. Netting should be used only with low velocities.
3. Energy dissipators in drop spillways collect silt and debris and require cleaning.
4. Plastic nettings should not be used where they could wash into fish streams, as they can act as gill nets.

DESCRIPTION

Mechanical liners provide several levels of protection based on channel configuration, runoff quantities and velocities and soil conditions. Consult Alaska Division of Highways Hydraulics Manual and SCS Field Manual for detailed design considerations.

<u>Netting and Seeding</u>

A variety of materials, such as jute and plastic nettings are available. They are often used with vegetation but do offer some protection of their own.

In larger channels, where several widths of netting are required, they should overlap 2". Overlaps should be stapled 4-10' apart. Ends of rolls should also be overlapped. The top ends should be buried in trenches 4" deep, and stapled 10" apart. (Hairpin-shaped wire staples recommended.)

After completion, water ways should be rolled to insure contact with soil. Nettings are effective for medium velocities up to 6 fps. (See procedure on nettings.)

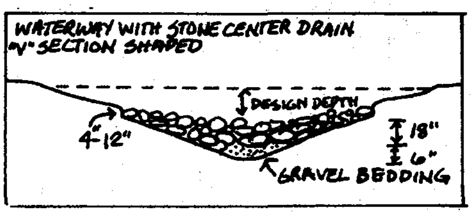
DESCRIPTION CONTINUED

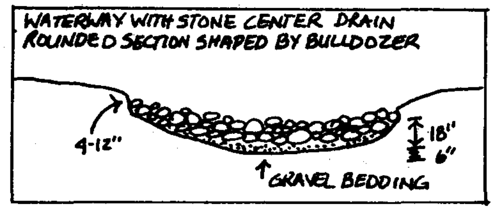
Erosion Checks

Erosion checks are usually constructed of fiberglass which are installed across drainage swales and function as a spreader, avoiding the formation of gullies and aiding in the establishment of vegetation. Preferably they are installed at changes in gradient and downstream from confluence of tributaries. Construction: 1) excavate trench of 1' depth; 2) install vertical membrane and secure with staples, backfill, compact, and trim flush with surface; 3) center netting or mat on top of vertical strip to form cap to extend ½' above design flow elevation and staple on 6" centers.

Stone Center Drains

Are used in drainage channels that experience prolonged flow and wetness, preventing the growth of adequate turf. Gravel bedding and packed stone provide for drainage in the center of the grassed swale. Acceptable flow velocities and gradients are determined by standard rip rap specifications. (See Appendix to this procedure.)





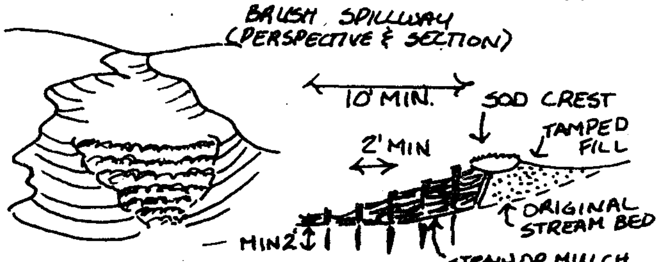
FROM URS, 1977

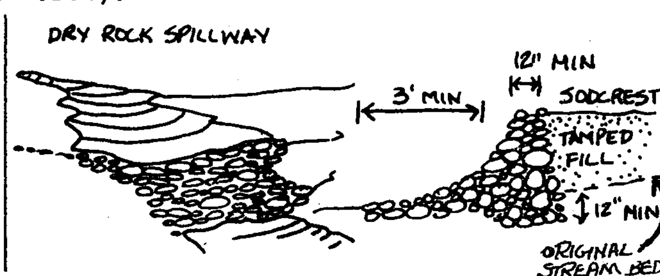
Latticework Concrete Blocks

Can be used to stabilize the banks of waterways that experience high velocity flows. Gaps in the concrete blocks are backfilled with soil, compacted, and seeded with grass. Other materials used as channel liners include paving, sacked sand, and concrete filled mattresses.

Drop Structures and Checkdams

Counteract gully erosion in waterways by reducing that gradient of the channel. These should be used rather than impermeable concrete or asphalt linings, when physical conditons are too severe for the satisfactory establishment of vegetative cover. Selection of materials will depend on strength requirements, cost, permanence and aesthetic aspects (temporary checkdams were considered in procedure 2.B.2.). Structures can be divided into rigid or slightly flexible and into straight drop spillways and chute-type spillways. Material can consist of timber, rock, gabions, concrete, and brush or sod. To prevent undercutting at the toe, all structures should extend several feet or more below the existing ground surface. The selected design capacity should be for a storm of greater frequency than the one used for the drainage channel because of the damage that could be done to the structure if it were to overtop. (A method for calculating channel sizes and capacities is given in Appendix 2.B.1).





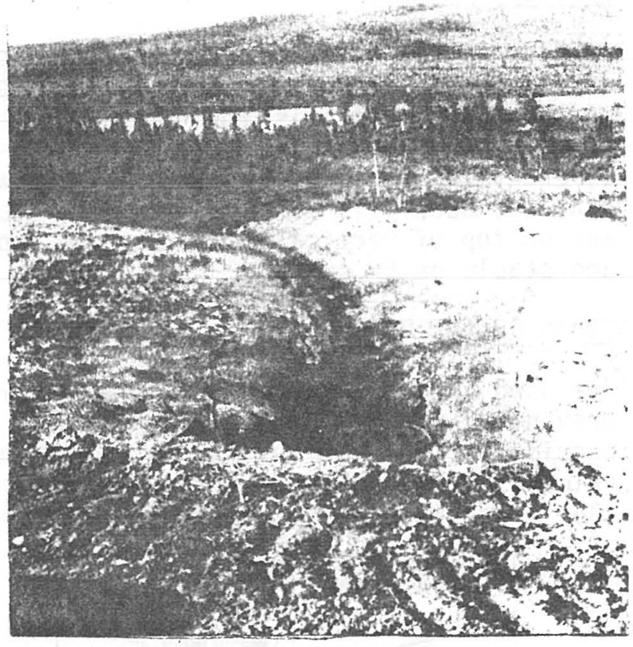
FROM URS, 1977

EXAMPLE

Outlet channel of this drainage structure in highly erodible fill has been treated with straw mulch, jute netting and seeded.

Location: Trans-Alaska Pipeline

Source: R&M Consultants, Inc.



MAINTENANCE

Methods require some maintenance due to scour, although with proper design and construction, many structures have long life effectiveness.

REFERENCE

1) USDA, Soil Conservation Service. Engineering Field Manual for Conservation Practices. 1969. 2) Soil Conservation District, Montgomery County, Pennsylvania. Erosion and Sediment Control Handbook. 3) USDA. Controlling Erosion on Construction Sites. Soil Conservation Service Agriculture Information Bulletin #347. 1970. 4) Environmental Protection Agency. Guidelines for Erosion and Sediment Control and Planning and Implementation. 1972. 5) Brandt, G. H. and others. An Economic Analysis of Erosion and Sediment Control Methods for Watersheds Undergoing Urbanization. USDI. OWRR. 1972. 6) Alaska Department of Highways. Hydraulics Manual. 1972. 7) Tourbier, J. Water Resources Protection Measures in Land Development. University of Delaware. April 1974. 8) URS Company. Stormwater Management, Procedures and Methods. Snohomish County, King County, City of Everett. EPA Grant Id. No. P-000091. September 1977.

APPENDIX 2.B.3

Calculation of Required Stone Size to Prevent Channel Erosion and Estimation of Scour for Waterways

Calculation of Stone Size for Waterway with Stone Center Drain

Use the nomography below (Figure 1) to determine the size of stone for waterways with stone center drains (used where there is a problem with prolonged flow and wetness).

Example: Design grass waterway in the normal way, determining the top width and the depth of flow (See Appendix 2.B.1). For a design depth of 1.0' and a longitudinal slope (gradient) of 5.5% (0.05), 25% of the rock should be in sizes slightly larger than 7.9" and the remainder should be well-graded material of less than 7.9", including sufficient sands and gravels to fill the voids between larger rocks.

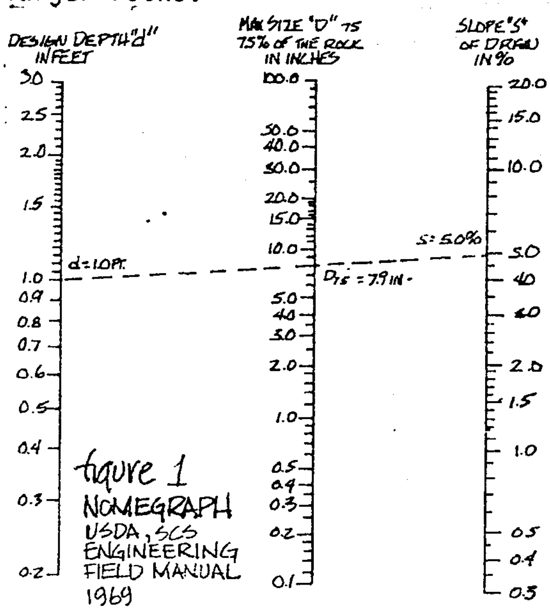


figure 1
NOMEGRAPH
USDA, SCS
ENGINEERING
FIELD MANUAL
1969

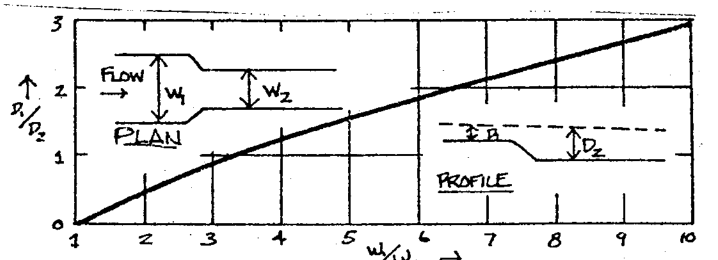


figure 2
ESTIMATION OF DEPTH OF SCOUR AT LONG CONSTRICTIONS[1]

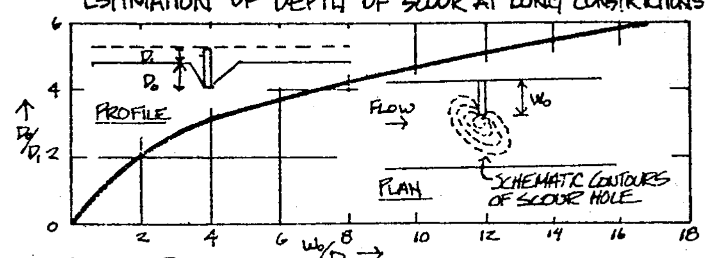


figure 3
ESTIMATION OF DEPTH OF SCOUR AT SHORT CONSTRICTIONS[1]

Estimation of Depth of Scour at Channel Construction

Note: This technique gives only a very rough indication of depth of scour and should be used only with extreme caution. In practice, scour depth depends on soil erodibility and other variables.

a) Depth of Scour at Long Channel Constrictions.

Step i) Determine reduction in channel width at point of construction. Determine ratio of W_1/W_2.

Step ii) On Figure 2 read equivalent value of D_1/D_2 for width of channel ratio.

---

[1] New York Dept. of Trans., Div. of Design and Constrcution. "Bank and Channel Lining Procedures." 1971.

Step iii) Knowing design depth of flow D_1, estimate depth of scour D_2.

b) Depth of Scour at Short Channel Constrictions

Step i) Determine the extent of the construction W_0.

Step ii) Determine design depth of flow upstream of constriction D_1. Determine ratio W_0/D_1.

Step iii) On Figure 3 read equivalent value of D_0/D_1.

Step iv) Knowing D_1, estimate depth of scour D_0.

Reference:

URS Company. Stormwater Management, Procedures and Methods. Snohomish County, King County, City of Everett. EPA Grant Id. No. P-000091. September 1977.

GROUP Drainage - Structures

PRACTICE Outlet Protection [for roadside drainage]

PURPOSE

To slow flow velocity at drainage structure outlets.

SITE CHARACTERISTICS

The velocity of flow is nearly always speeded during passage through a culvert, and always when passing down a chute. A scour hole or pluge pool will develop, unless protection is provided. Headward erosion of the fill may also result.

ADVANTAGES

1. Reduce or eliminate erosion of stream and fill material.
2. Some structures can permit sediment collection through stilling process.

DISADVANTAGES

1. Requires special design and suitable rock or other armor.
2. Some types of structures may be unsightly.
4. In permafrost soils, structures which impound water should not be used.

DESCRIPTION

Several examples are shown for outlet protection for roadside drainage. Choice depends on 1) soil and topography of the site; 2) anticipated flows; 3) height of fill or outlet.

Structures which impound water should not be used in permafrost soils.

The increase in water velocity through a culvert will tend to form a plunge pool where it flows into an unlined channel.

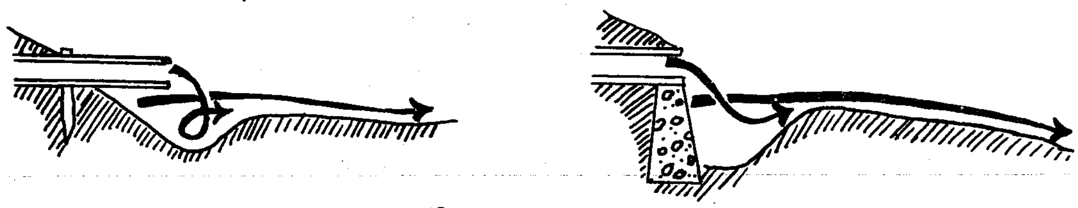
1. Plunge Pools

   A plunge pool will dissipate a large amount of excess energy, but could undermine the toe of the embankment if not adequately armored. Not to be used in permafrost soils.

   When plunge pool is acceptable may choose from three measures:

DESCRIPTION CONTINUED

a. Cantillver the end section of the culvert and support with wood (temporary), or concrete (permanent). Not aesthetically desirable.



FROM URS, 1977

b. A cut-off wall extending below anticipated depth of scour will prevent undermining .

c. Use armor layer in pool. Depending on natural soil conditions one or more filter layers may be required below armor.

2. Protective Aprons

Dumped rock, hand-placed rip rap or rock-filled gabion baskets or mats may be used.

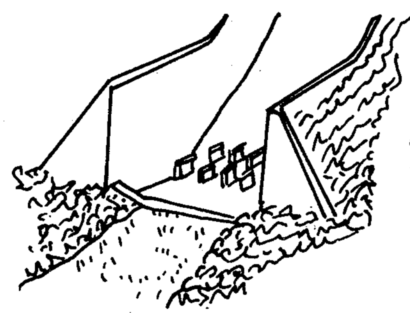
Width of apron should be at least one culvert width each side of culvert. Height should be to or above design high water.

Dumped stone is most effective due to roughness. A plunge pool will often form beyond a concrete apron lacking baffles.

3. Stilling Basins

For flows that are excessive for available stone size. The function is similar to a plunge pool. See reference 4 for design details.

Outlets are shaped to conform to the receiving channel.



STILLING BASIN WITH BAFFLES TO DISSIPATE ENERGY AT BASE OF CONCRETE CHUTE SPILLWAY.

MAINTENANCE

1. Outlets should be inspected periodically for damage, such as undercutting.

2. Pools and basins require periodic clean out of sediment and debris.

REFERENCE

1) U.S. Dept of Transportation. Highways in the River Environment, Hydraulic and Environmental Design Considerations. May 1975. 2) Tourbier, J. Water Resources Protection Measures in Land Development. Water Resources Center, University of Delaware. 1974. 3) Environmental Protection Agency. Logging Roads and Protection of Water Quaity. EPA 910/9-75-007. March, 1975. 4) State of Alaska, Department of Highways. Hydraulics Manual. 1972. 5) URS Company. Stormwater Management, Procedures and Methods. Snohmish County, King County, City of Everett. EPA Grant Id. No. P-000091. September 1977.

GROUP Drainage - Structures

PRACTICE Inlet Protection

PURPOSE

To prevent accumulation of debris at culvert inlets.

SITE CHARACTERISTICS

Structures can be used at culvert installations where debris presents a problem, to avoid plugging. Therefore avoid resulting flooding and potential erosion of roadway section.

ADVANTAGES

1. Avoids need to clean out culvert barrels.
2. Provides full culvert capacity during high flows.

DISADVANTAGES

1. Requires regular maintenance.
2. High initial cost.

DESCRIPTION

Debris - Control structures can have many shapes and can be constructed of a variety of materials. Some typical examples are:

1. Debris Deflectors

   Structures placed at the culvert inlet to deflect the major portion of the debris away from the culvert entrance. Normally "V"-shaped with apex upstream.

2. Debris Racks

   Structures placed across the stream channel to collect debris before it reaches the culvert entrance. Usually vertical and at right angles to the stream flow.

3. Debris Risers

   Closed-type structure placed directly over the culvert inlet in log-cabin fashion to prevent inflow of coarse bed load and light floating debris.

4. Debris Fins

   Walls built in the stream channel upstream of the culvert, and aligned with the direction of flow. Their purpose is to align debris, such as logs, with the culvert axis so that debris will pass through the culvert barrel. Sometimes used on bridge piers to deflect drift.

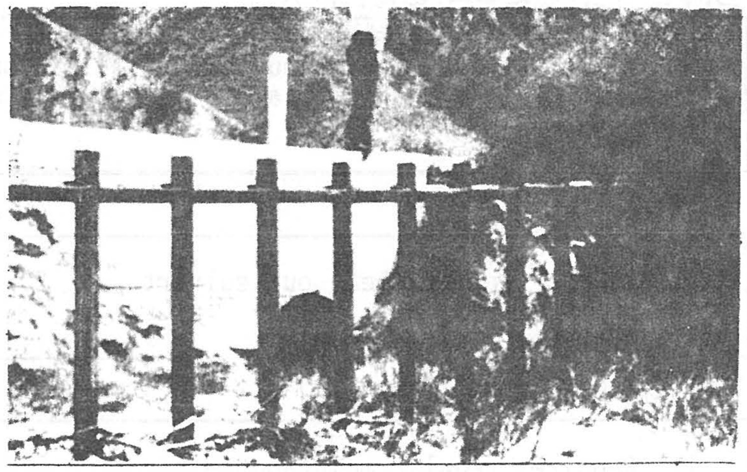
DESCRIPTION CONTINUED

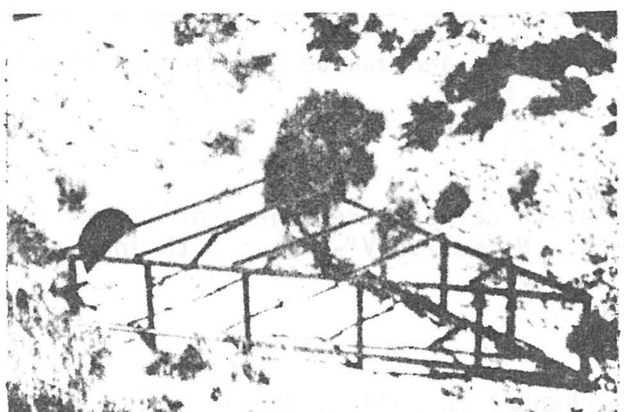
6. Debris Dams and Basins

Structures placed across well-defined channels to form basins which impede the stream flow and provide storage space for deposition of detritus and debris (see also Procedure 3.A).

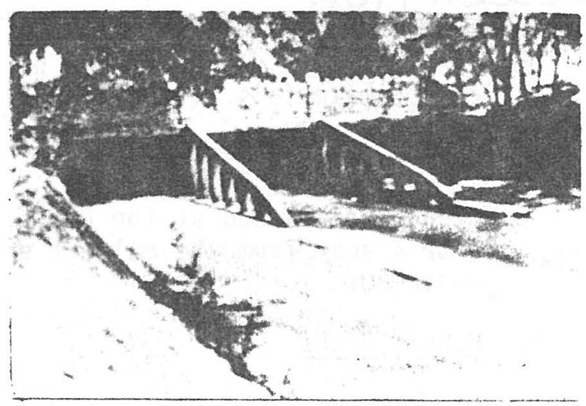
EXAMPLES

RAIL DEBRIS RACK





STEEL RAIL DEBRIS RACK



CONCRETE DEBRIS FINS

MAINTENANCE

Requires regular clean-out to maintain effectiveness. Ease of access should be considered during design.

REFERENCE

1) U.S. Department of Transporation, Federal Highway Administration, "Hydraulic Engineering Circular No. 9, Highways, Debris-Control Structures." 2) Alaska Department of Highways, Hydraulics Manual, 1972.

GROUP
Sediment Retention

PRACTICE
Sediment Basins -- Permanent and Temporary

PURPOSE

To retain runoff waters and remove sediments generated from construction areas, preventing deposition into drainage ways and property below the site.

SITE CHARACTERISTICS

While erosion control reduces sediment in runoff from construction sites, developers should also use impoundments to precipitate sediments before runoff leaves the site. Particularly important on steep and highly erodible sites, and on poorly drained sites where the erosive potential of rainfall and melting snow will be greater.

ADVANTAGES

1. Downstream riparian properties will not be damaged by sediment deposits originating from that development.
2. Prevents sediment deposits downstream which would reduce the capacity of the stream channel.
3. Can be incorporated into the permanent erosion control plan.
4. Can be designed for large flows.

DISADVANTAGES

1. May require additional R-O-W or flow easements.
2. Periodic clean-out and disposal is required.
3. Can be aesthetically unsatisfactory or a safety hazard if not designed or maintained properly.

DESCRIPTION

Large permanent-type basins will require full design consideration and would normally be included in construction plans. Small basins and traps for temporary retention should be included in construction plans also, but can be field located as needed by the project engineer when temporary sediment retention is required.

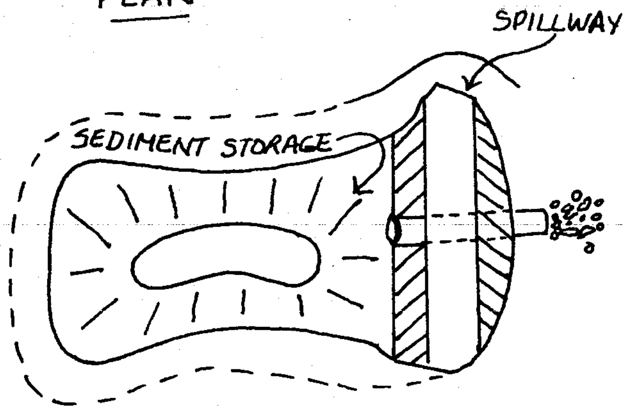
The SCS Field Manual (Ref. 3) provides detailed design information for permanent sediment basins. Generally, the basin consists of a dam, a pit or a combination of the two.

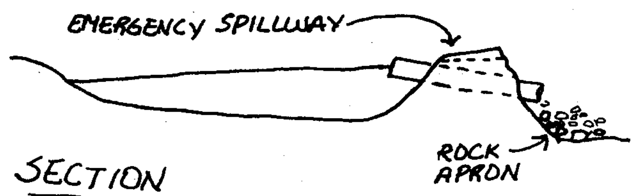
DESCRIPTION CONTINUED

Pond Size

The effectiveness of a sediment pond depends upon the settling velocity of sediment particles. Settling velocity can be calculated from the volume, size, and density of the particle and the density of the fluid. This velocity is then compared with the geometry and retention time of the planned pond. The effectiveness of a pond will increase as its surface area increases. Assuming that construction costs increase as the volume of the pond is increased, a relatively shallow pond with a large surface area appears to be the most economical design (1). Appendix 3.A.1 shows that the economics of sediment ponds depends primarily on particle size. For particle sizes of less than 10 microns, the size of the sediment basins required suddenly becomes very large.

PLAN





SECTION

Storage Capacity

Basins are commonly maintained at a minimum depth of 5'-8'. This allows sufficient space above the flood storage zone for settling to occur in a low velocity boundary zone between the surface (where flow is close to the average overflow rate) and the static bottom layer.

Spillway

Sloped culverts are less expensive than perforated risers. An emergency spillway should be incorporated.

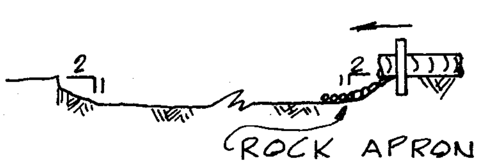
Embankment

Fill is built in compacted lifts. Normally top width equals height. Embankment should be stabilized against erosion.

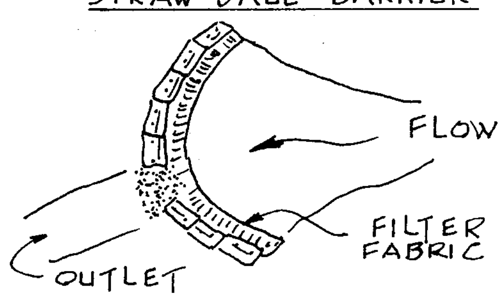
Temporary Basins

These range from very simple ditch checks, as in 2.B.2., to structures similar to the permanent basins. Shown below are two simple but effective techniques which could be used at outlets of drainage structures, ditches or other areas.

STILLING BASIN



STRAW-BALE BARRIER



MAINTENANCE

Periodic inspection and cleanout will be necessary. Sediment basins must not be left where they could eventually wash out and become a long term sediment source.

REFERENCE

1) Thronson, R.E. Comparative Costs of Erosion and Sediment Control, Construction Activities. Washington, D.C. EPA - 430/9-73-016. July, 1973. 2) Tourbier, J. Water Resources Protection Measures in Land Development. Univ. of Delaware. 1974. 3) Soil Conservation Service. Engineering Field Manual for Conservation Practices. 1975. 4) U.S. Dept. of Transportation. Suggestions for Temporary Erosion and Siltration Control Measures. Feb, 1973. 5) Mallony, C. W. the Beneficial Use of Stormwater. Office of Research and Monitoring. 1973.

APPENDIX 3.A.1
Settling Pond Sizing

To determine the theoretical size of pond to be used:

1) Obtain representative particle size distribution for the suspended solids in the inflow water.

2) Determine the size of particle that must be removed to meet the state water quality standards.

3) The settling velocity associated with the selected particle size can be obtained by using Stokes Law:

$$V_s = \frac{g}{18\mu} (S - 1) D^2$$

Where:

V_s = Settling velocity, cm/sec.
g = Acceleration of gravity, 980 cm/sec^2.
μ = Kinematic viscosity of fluid, cm^2/sec
S = Specific gravity of particle
D = Diameter, cm.

4) Next, the anticipated flow rate to the pond should be determined and then the area can be calculated by:

$$A = \frac{Q}{V_s}$$

Where:

A = required basin size in m^2 (or ft^2)
Q = Flow rate through the pond, m^3/sec (or ft^3/sec)
V_s = Critical settling velocity, m/sec (or ft/sec)
(1 m/sec = 3.28 ft/sec)

5) Apply correction factor to account for non-ideal settling:

$$A\,(\text{adjusted}) = 1.2\,A\,(\text{required}).$$ [1]

It should be noted that the settling velocity, V_s, is inversely proportional to the kinematic viscosity, u. That is, as the viscosity increases, the velocity decreases. For a given pressure, the viscosity of liquids decreases with an increase in temperature. The decrease per degree is much greater at low than at high temperatures. This is illustrated in the following list of kinematic viscosities of water at various temperatures:

Temperature (F°)	Viscosity (cm²/sec)
32	0.017939
39.2	0.015672
50	0.013099
60	0.011306
70	0.009838
80	0.008640
100	0.006865

In practical application the settling velocity is reduced due to turbulence resulting from wave action, or due to interaction between suspsended particles. This lower settling velocity, or rate, significantly affects the particle size that will settle in a pond of a given area.

(Huber[3], in testimony prepared for the adjudicatory hearing on NPDES permits for placer miners, computed the hindered settling velocities at a variety of concentrations of suspended solids. At the high suspended solids concentrations found in mining operations hindered velocity was predicted to be 0.73 to 0.85 of the free velocity.)

The following table was given in reference (4). Water temperature and particle specific gravities assumed in the computations were not given. The table shows that for particle sizes less than 10 microns required basin size suddenly becomes very large.

	Material	Diameter (micron)	Settling Rate cm/sec
1.	Coarse Sand	1000	10.0
2.	Coarse Sand	200	2.1
3.	Fine Sand	100	0.8
4.	Fine Sand	60	0.38
5.	Fine Sand	40	0.21
6.	Silt	10	0.015
7.	Coarse Clay	1	0.00015
8.	Fine Clay	0.1	0.0000015

---

1) Environmental Protection Agency. Erosion and Sediment Control, Surface Mining in Eastern U.S. EPA-625/3-76-006, October 1976. 2) King, H.W.; Brater E. J. Handbook of Hydraulics. New York: McGraw-Hill Book Co. 1954. 3) Huber, M. E. Testimony in the Matter of NPDES Placer Mining Adjudicatory Hearing Docket No. X WP7630C. August 1977. Appended to testimony of A. L. Renshaw, Jr. Available from EPA, Seattle. 4) URS Co. Stormwater Management Procedures and Methods. Snohomish County, King County, City of Everett. EPA Grant Id. #P-000091. September 1977.

GROUP Sediment Retention

PRACTICE Buffer Strips, Barriers and Fences

PURPOSE

To retard runoff, increase infiltration and contain sediments eroded from construction areas.

SITE CHARACTERISTICS

Almost any stand of vegetation or other materials will retain some amount of sediments. These techniques are used at inlets and outlets of drainage structures, in ditches and any other area where sediments are being eroded. See also 5.A.

ADVANTAGES

1. Can be incorporated into the permanent erosion control plan
2. Most techniques are very economical. No cost with undisturbed strips.

DISADVANTAGES

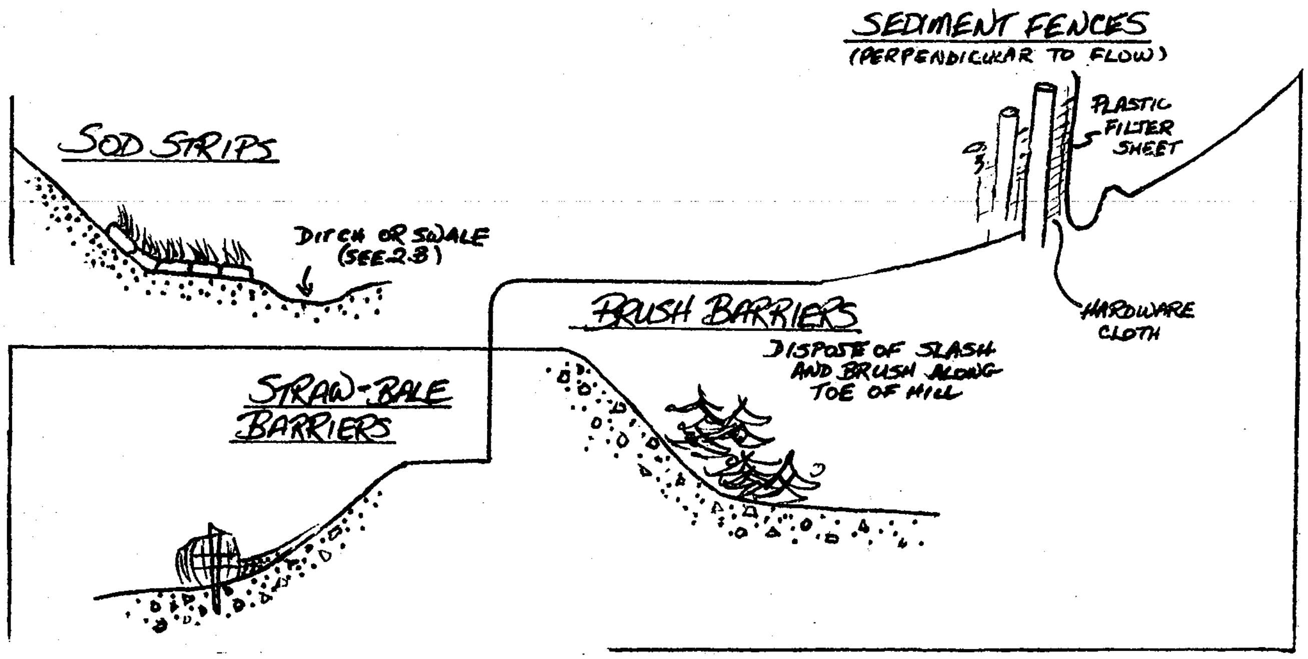
1. Some maintenance required to remove sediments accumulated.

DESCRIPTION

Areas commonly subject to erosion include cut slopes, embankments, drainage outlets, and ditches. If buffer strips of undisturbed vegetation are left, these can filter out much of the runoff sediments which are generated. Stands of timber, brush or grass between streams and roadways should be kept intact. Barriers at the toes of slopes are also recommended. Straw bales or brush can be placed to trap or filter sediment from runoff waters.

DESCRIPTION CONTINUED

The following illustrate some simple techniques.



Vegetative Buffer Strip

It costs virtually nothing to leave a buffer zone between construction areas and small drainages or other water bodies. Studies have shown these buffer strips to be effective in filtering sediment and increasing infiltration. This idea not only pertains to roadways adjacent to streams but to all construction areas.

MAINTENANCE

If long-term use is desired, accumulated sediments should be removed, taking care to avoid damage to vegetation.

REFERENCE

1) Environmental Protection Agency. Guidelines for Erosion and Sediment Control Planning and Implementation. Aug. 1972. 2) Environmental Protection Agency. Logging Roads and Protection of Water Qualtiy. EPA 910/9-75-007. March 1975.

GROUP
Sediment Retention - Temporary Measures

PRACTICE
Traps and Filters for Storm Drain Inlets

PURPOSE

To prevent eroded sediments from entering natural or constructed drainageways, storm sewers or drainage structures.

SITE CHARACTERISTICS

Normally applied as a temporary measure until exposed construction surfaces are stabilized. Used to remove sediment from small flows.

For Urbanizing Areas Where permanent roads or roadbeds are used during construction and inlets have already been installed, sediment laden water should not enter an incomplete storm sewer system. Dry wells, seepage pits etc. should also be protected.

ADVANTAGES

1. Usually economical to build and maintain.
2. Prevents clogging of storm sewers or drainage structures.
3. Can be built as needed.
4. Easily cleaned with available equipment.

DISADVANTAGES

1. Will not usually remove all sediments.
2. Usually requires removal after construction.
3. Subject to vandalism or damage during clean-out.

DESCRIPTION

A number of methods, vegetative and mechanical can be employed, largely depending on available materials. Economy of these procedures allows liberal use at all suitable locations. Choice should consider: 1) size of structure, 2) anticipated flows and sediment quantities, 3) clean-out requirements, 4) cost, 5) availability of materials.

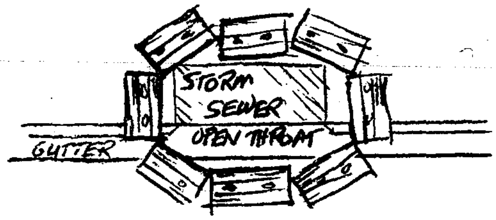
1. Protection of Storm Sewer Inlets

Whenever permanent roads are used during construction and storm systems or other drainage structure are installed, measures should be taken to prevent sediment laden waters from entering inlets.

DESCRIPTION CONTINUED

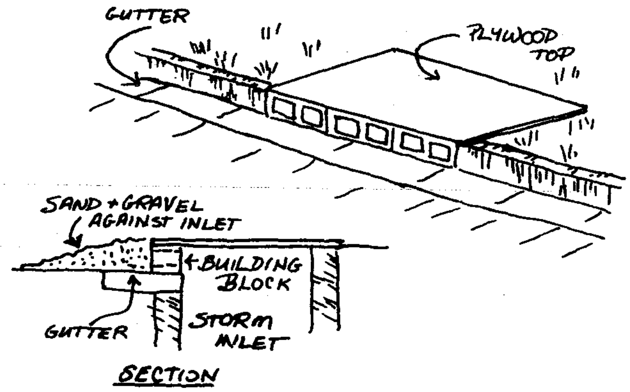
Straw-bale Barrier

Used before paving, stake to ground and wire together. Bale can be used off paved surfaces to slow overland flow.

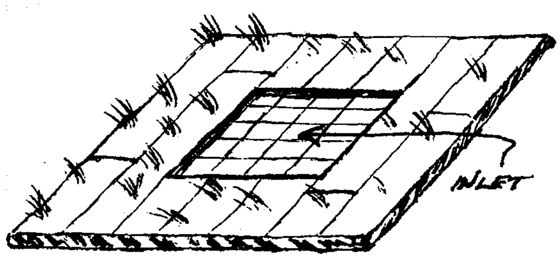


Sand and Gravel Filter

Used before or after paving.

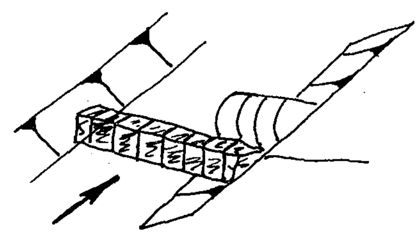


Sod filter Strip



2. Protection of Drainage Inlets

To prevent sediment-laden waters from entering culverts, ditches and other drainage transport structures. Other examples applicable to drainage inlets are shown in 2.B.2. See procedure 2.D for examples of debris control.



MAINTENANCE

Accumulated sediments must be removed periodically to maintain sediment trap effectiveness.

REFERENCE

1) County of Fairfax, Va. Erosion and Sediment Control Handbook. Dec. 1974. 2) Environmental Protection Agency. Guidelines for Erosion and Sediment Control Planning and Implementation. 1972. 3) U.S. Dept. of Transportation. Erosion and Sediment Control in Highway Construction Projects. Feb, 1973. 4) URS Co. Stormwater Management, Procedures and Methods. Snohomish County, King County, City of Everett. EPA Grant ID. No. P-000091. September 1977.

GROUP
Sediment Retention

PRACTICE
Silt Curtain

PURPOSE

To prevent sedimentation of water bodies adjacent to construction activity.

SITE CHARACTERISTICS

Where construction abuts or encroaches on a lake. Not effective for stream where turbulent flow will prevent settling. Also ineffective for deep lakes, or where there is wind induced mixing.

ADVANTAGES

1. Retains sediments which were not held within the work area.
2. Construction is relatively easy and inexpensive--a cost effective method of maintaining water quality.

DISADVANTAGES

1. Temporary only.
2. Requires regular maintenance.
3. May require permit.

DESCRIPTION

Occassionally, the route selection process cannot avoid the necessity of construction activity encroaching on a body of water. One of the more common examples is the widening of a roadway section immediately adjacent to a lake or stream. The intent of the curtain is to prevent muddied water caused by the construction activity from spreading over the entire body of water.

The curtain is generally fastened at both ends and fitted with anchors and flotation devices in such a manner that it remains as much as possible in a vertical position. The curtain can be constructed of heavy plastic, canvas, or any other suitable material, but should be of sufficient strength and density to withstand wave action and infiltration of fine-grained material.

Some space must be allowed below the curtain to allow escape of runoff entering the enclosed area. The curtain is effective for silt size particles and larger. Turbulence in the enclosed area will keep particles in suspension.

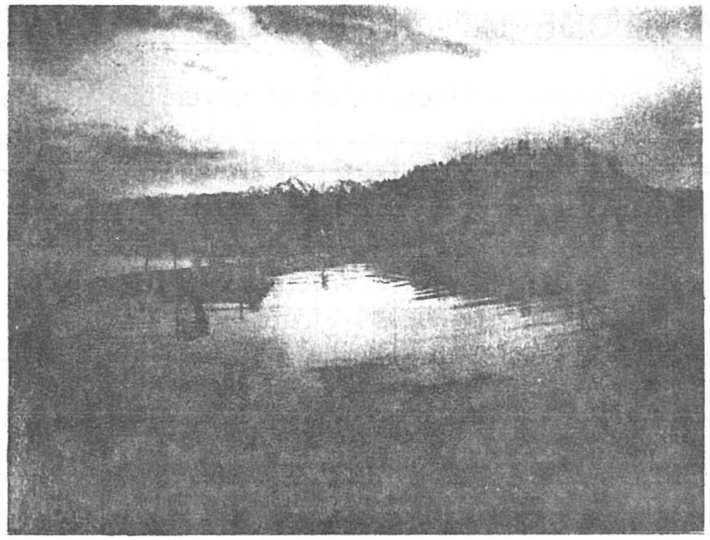
If the curtain is placed in a body of navigable water, warning devices should be placed with the flotation devices, with sufficient visibility to prevent any problem for boaters.

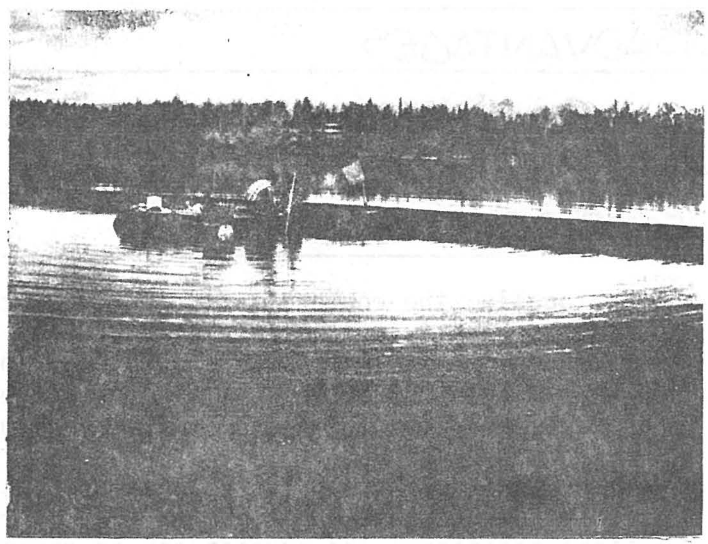
EXAMPLE

The two photos show the installation of a filter fabric silt curtain used during 1973 construction work on the Parks Highway.

Location: Wasilla Lake
Wasilla, Alaska

Source: J. Henry
A&G Construction
Anchorage, Alaska





MAINTENANCE

Subject to damage by floating objects. Should have regular surveillance.

GROUP
Slope Stabilization

PRACTICE
General -- Non-Permafrost Areas

PURPOSE

To prevent erosion and sloughing of cut and fill slopes by one or more vegetative or mechanical means.

SITE CHARACTERISTICS

Methods below require knowledge of soils, ground water hydrology and hydrology of receiving waters.

If soils are saturated and have a tendency to liquify or slump it is desirable to convey water quickly away with minimal infiltration. This could include, paving slopes or ditches, and constructing diversion ditches for maximum non-erodible velocities.

If soils are not saturated and slumping is not anticipated practices should be chosen to maximize infiltration to reduce downstream flood flow and erosive power and to delay peak flow (peak would then be smaller).

ADVANTAGES

See Below

DISADVANTAGES

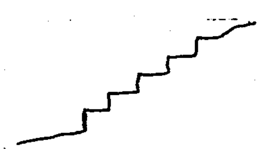
See Below

DESCRIPTION

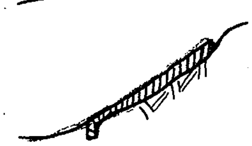
A number of techniques, both vegetative and mechanical, are available to provide temporary cover or permanent stabilization of cut and fill slopes, or other sloping areas. The following illustrated examples demonstrate a few choices.

Cut Slopes

Serrated Cuts - lower velocity of runoff and collect sediment. Minor sloughing possible if saturated. Generally for fragmented rock or shale materials.



Pavement or Rip-Rap - immediate protection for high risk slopes. Expensive and may be difficult to install and maintain.



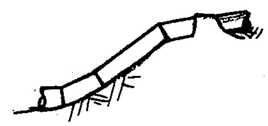
DESCRIPTION CONTINUED

<u>Diversion Ditch</u> - good for cut slopes in erodible soils. Diverts runoff through stable channels and outlets. Requires sufficient slope to prevent ponding and saturation. See 4.C. for further discussion.

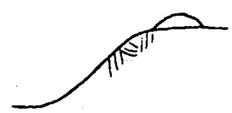
<u>Cut or Fill Slopes</u>

<u>Benches or Fill Berms</u> - slows runoff and helps seeding and maintenance programs. Additional R-O-W may be needed for increased slope lengths.

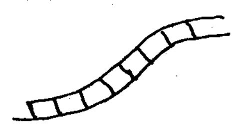
<u>Slope Drains</u> - prevents gullying erosion of slope by carrying runoff through slope drain. Energy dissipation needed at outlet. Procedures 4.B. provide further details.



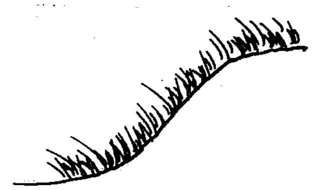
<u>Diversion Berms</u> - diverts runoff away from face of slope. Berm material must be stable. Either temporary or permanent protection. Procedures 4.C. provide greater detail for this technique.



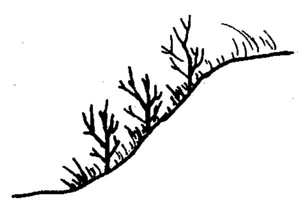
<u>Sodding</u> - immediate cover for critical slopes. Is usually expensive but will give permanent protection.



<u>Seeding and Mulch</u> - either temporary cover or permanent stabilization. Must be watered and fertilized until grass is established. Mulch needed on steeper slopes. Revegetation procedures 5.A. and 5.B. give further recommendations.



<u>Woody Vegetation</u> - in combination with grass ground cover where root mass is necessary to stabilize slope.



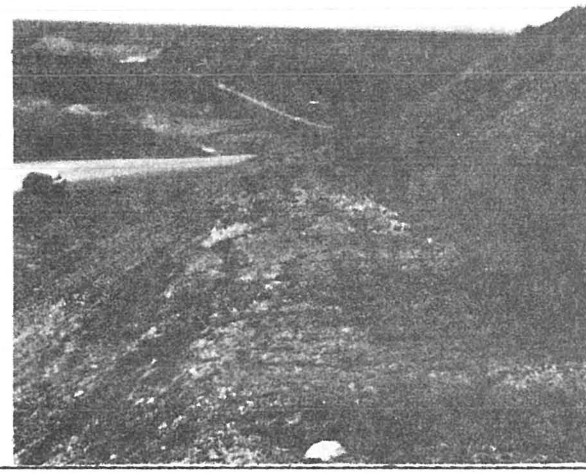
<u>Temporary Cover</u> - other materials such as netting, plastic sheeting and others can be used to cover slopes left exposed until final procedures are performed. Plastic sheeting may be difficult to keep in place.

EXAMPLE

Large benched cut slope. Benches are 10 feet wide, placed at every 20 foot increment in slope height. When originally excavated, permafrost with visible ice was encountered.

Location: Simpson Hill
Mile 113
Richardson Highway

Source: R&M Consultants, Inc.
Anchorage, Alaska



MAINTENANCE

All slopes should be maintained periodically. Materials eroded from the slope should be removed to prevent eventual sedimentation of water courses or clogging of culverts.

REFERENCE

1) Highway Research Board. Erosion Control on Highway Construction. 1973.
2) Tourbier, J. Water Resources Protection Measures in Land Development. Water Resources Center, Univ. of Delaware. April 1974.

GROUP Slope Stabilization

PRACTICE Revegetation -- Biotechnical Methods

PURPOSE

To prevent erosion and sloughing of cut and fill slopes through a combination of vegetative and technical means.

SITE CHARACTERISTICS

Revegetation can take the following forms:

Seeding to prevent sheet or rill erosion (Section 5);

Using woody plants (usually willow or alder) to provide additional root mass. This is necessary for steeper, less stable slopes (Section 5);

Biotechnical methods are also used for steep, unstable slopes, especially where regeneration may be difficult, and where there is greater risk of damage to water related resources, or of economic loss such as in urbanizing areas. Biotechnical methods combine vegetation with mechanical methods.

ADVANTAGES

1. Vegetation reduces sheet erosion on slopes and impedes sediment at the toe of the slope.
2. Shrubs and trees shelter slopes against the impact of rainstorms, and the humus formed by decaying leaves further helps to impede runoff.
3. Where soils are unstable and liable to slip due to wet conditions, use of soil moisture by vegetation can reduce the problem.
4. Mechanical measures help to stabilize soil long enough to allow vegetation to become established.

DISADVANTAGES

1. There is a general reluctance to work with live material where its planting cannot be highly mechanized.
2. Knowledge of soil, hydrology and other physical data is required to design measures that will adequately solve the problem and stand up to the test of time.

DESCRIPTION

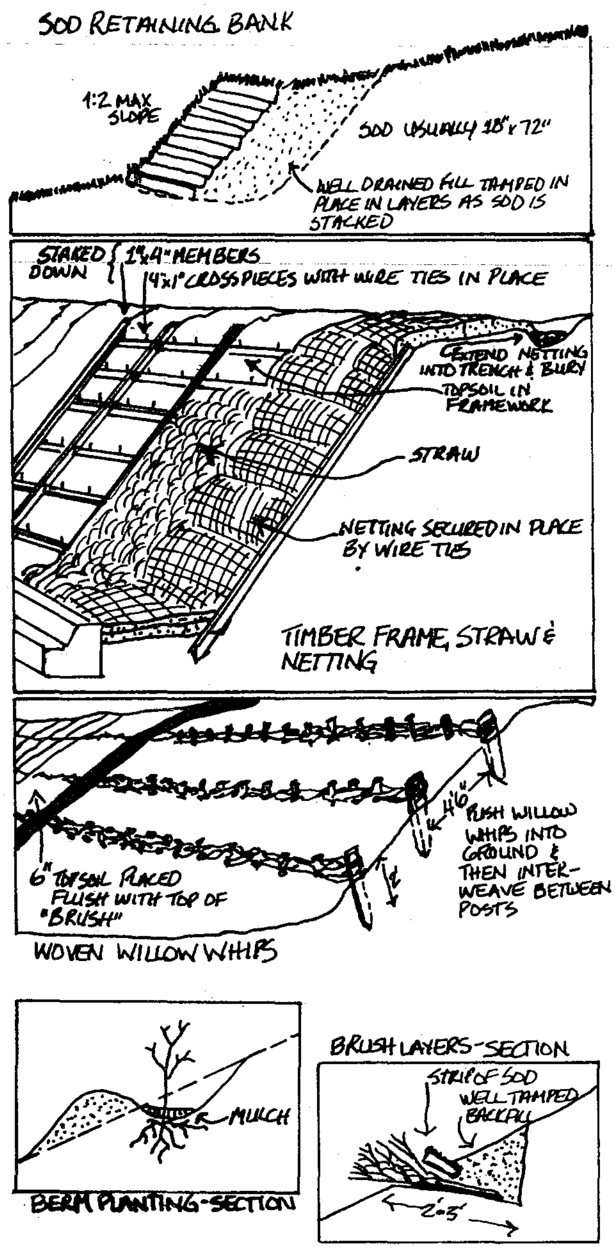
(See also Section 5, Revegetation.)

DESCRIPTION CONTINUED

1. Sod walls or retaining banks are used to stabilize terraces. Sod is piled by tilting it slightly toward the slope and should be backfilled with soil and compacted as they are built up. Sod walls can be as steep as 1:2 but should not be higher than 5'.

2. Timber frame stabilization is effective on gradients up to 1:1 and involves the following steps in construction: 1) Lay soil retarding frames of 2 x 4" vertical members and 1 x 4" horizontal members on slopes. Frames on slopes over 15' in length need to be anchored to slope to prevent buckling. 2) Attach 14 gauge galvanized tie wires for anchoring wire mesh. 3) Fill frames with moist topsoil and compact the soil.
4) Spread straw 6" deep over slope.
5) Cover straw with 14 gauge 4" mesh galvanized reinforced wire.
6) Secure wire mesh at least 6' back of top slope. 7) Plant ground cover plants through straw into topsoil.

3. Woven willow whips may be used to form live barriers for immediate erosion control. Construction: 1) 3' poles are spaced at 5' distances and driven into the slope to a depth of 2'. 2) 2' willow sticks are inserted between poles at 1' distances. 3) Live willow branches of 5' length are sunk to a depth of 1" and interwoven with poles and sticks.
4) Spaces between the woven 'fences' are filled with topsoil. Fences are generally arranged parallel to the slope or in a grid pattern diagonal to the direction of the slope.



FROM URS, 1977

4. Berm Planting 1) Excavate ditches at 3-5' distance along the slope and shape berm on the downslope side. Construct ditches with 5% longitudinal slope.
2) Plant rooted cuttings on 3' centers and mulch. Suitable trees are willow, alder, birch, pine and selected shrubs. In extremely dry situations, rooted cuttings can be planted in bio-degradable plastic bags that are watered at the time of planting.

5. Brush Layers 1) Prepare 3' "niches" as shown. 2) Lay unrooted 5' live branches of willow or poplar at close spacing. 3) Starting at foot of slope, backfill lower ditch with excavated material from ditch above it. Operation should be carried out during dormant season.

REFERENCE

1) URS Company. Stormwater Management, Procedures and Methods. Snohomish County, King County, City of Everett. EPA Grant Id. No. P-000091. September 1977.
2) Alaska Rural Development Council. A Revegetative Guide for Alaska. Alaska Cooperative Extension Service. March 1977.

GROUP
Slope Stabilization - Structures

PRACTICE
Temporary Downdrains

PURPOSE

A temporary structure to safely convey a concentration of runoff from one elevation to another without erosion of the slope.

SITE CHARACTERISTICS

All sites are vulnerable to erosion during construction but particularly steep slopes and highly erodible soils. Fill slopes are very susceptible. Temporary downdrains can be used as a gradient break to reduce velocities; they can be extended as construction of the slope progresses.

Also can serve as an inlet to channels or a transition from grassed to open waterways.

ADVANTAGES

1. Eliminates saturation of slopes and R-O-W.
2. An efficient temporary drainage system minimizes the delays caused by severe storms during the construction period.
3. An efficient temporary drainage system minimizes the amount of regrading, etc. needed to repair erosion during the construction period.
4. Can be built and extended as construction proceeds.

DISADVANTAGES

1. Removing temporary structures can cause additional disturbance and will entail some costs.
2. Diversion while reducing soil saturation in some areas may increase seepage in others, causing local soil instability.

DESCRIPTION

Temporary downdrains can be effective during construction to protect the slopes until permanent stabilization, such as revegetation and mulching, is possible.

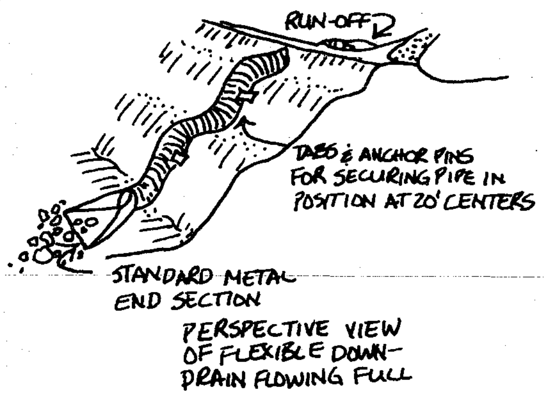
These structures usually require a diversion and collection system to direct runoff to the inlet (See 4.C.)

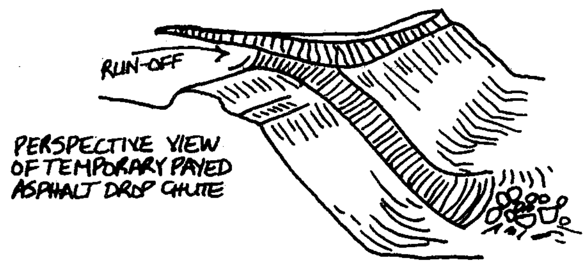
Energy dissipators are required at the outlet (See 2.C.).

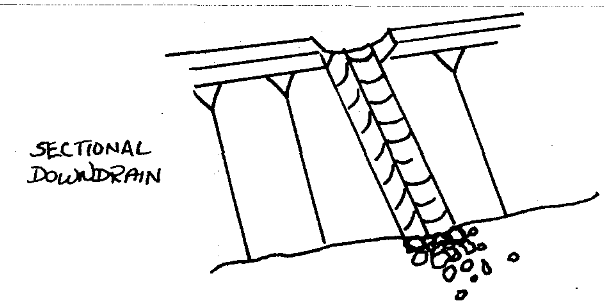
<u>Sectional Downdrain</u>

1/2 or 1/3 round culvert sections are normally used. These can easily be extended as slope length is increased during construction. The sections must be securely fastened and anchored to prevent leaking and erosion under the pipe.

DESCRIPTION CONTINUED







<u>Paved Chute</u>

Asphalt is commonly used. These are best used on cut slopes rather than fills. Asphalt apron should extend at least 3' beyond the toe of the slope. Inlet should be constructed to prevent runoff piping under the structure -- a very common problem.

<u>Flexible Downdrain</u>

Consists of a flexible conduit of heavy fabric or other material. Must be well anchored to prevent movement. Flexibility allows use on benched or terraced slopes and is easily removed. Fabric conduit usually not recommended for use through the winter as freezing could damage the fabric and result in leaking.

Calculate sizes from SCS Engineering Field Manual for Conservation Practices.

EXAMPLE

Location: Glenn Highway, near Mirror Lake. This half-round downdrain was set in the fill slope. Runoff is collected by curbs and diverted to the structure. Note rock energy dissipitator at the outlet.

Source: R&M Consultants, Inc.
Anchorage, Alaska

MAINTENANCE

Each structure should be inspected periodically and damage quickly repaired. Inlets should be checked for piping which could undermine the slope. Care should also be taken to prevent damage by equipment, such as during snow removal operations. If the structures are removed, the area must be restabilized to prevent erosion.

REFERENCE

1) Tourbier, J. Water Resources Protection Measures in Land Development. Water Resources Center, University of Delaware. 1974. 2) Alaska Dept. of Highways. Hydraulics Manual. 1972. 3) Soil Conservaton Service. Field Manual for Conservation Practices. 1971. 4) URS Company. Stormwater Management, Procedures and Methods. Snohomish County, King County, City of Everett. EPA Grant Id. No. P-000091. September 1977.

GROUP	Grade Stabilization Structures
PRACTICE	Permanent Downdrains

PURPOSE

A permanent structure to carry runoff water from one elevation to another without erosion of the slope or channel.

SITE CHARACTERISTICS

Can be applied to cut or fill slopes or to provide a gradient break in a channel to reduce velocities. Usually applied when flows are continuous or runoff quantities dictate a permanent level of protection.

ADVANTAGES

1. Prevents erosion or saturation of slopes.
2. Provides permanent protection of channels and slopes.

DISADVANTAGES

1. Will require full design consideration.
2. More expensive than temporary structures.

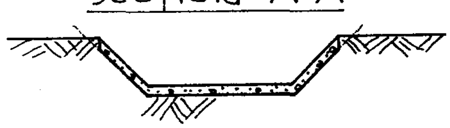
DESCRIPTION

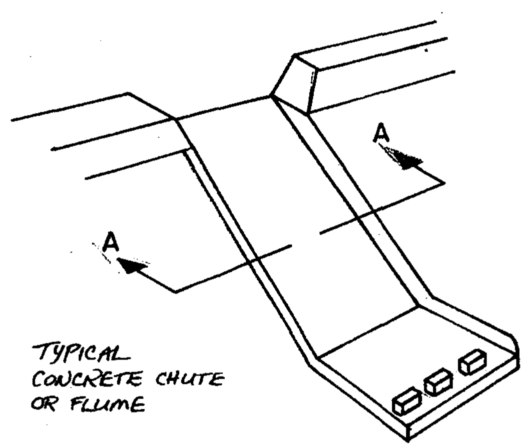
These types of structures can have many applications besides simply transporting runoff down cut and fill slopes. They are used as inlets or transition structures for transporting water from a channel at a higher elevation to a lower one. They can also be used to make non-erosive gradient breaks to reduce channel velocities.

For slope stabilization purposes, corrugated pipe, bituminous concrete or cement are often used for these structures. A collection system (4.D.1.) is needed to direct runoff flow. Refer to the Alaska Hydraulics Manual or the SCS Field Manual for actual design criteria and specifications.

Generally, the design is similar to that for channels. Cross-section can be trapezoidal, parabolic or U-shaped. An energy dissipator is usually needed at the outlets. These structures should be included in the permanent erosion control design for the site.

SECTION A-A



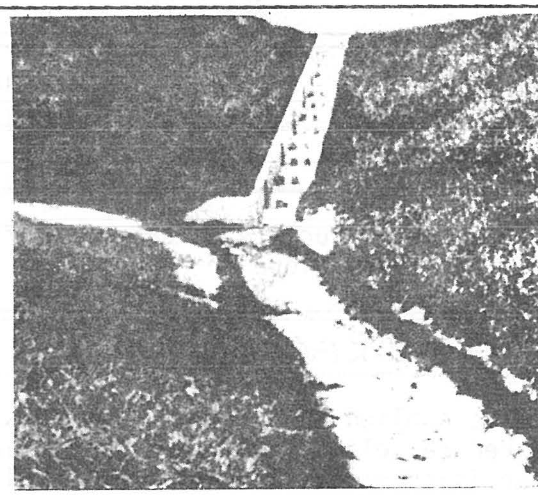


TYPICAL CONCRETE CHUTE OR FLUME

EXAMPLE

One type of concrete flume with continuous energy dissipators in the channel.

Source: EPA, Guidelines for Erosion and Sediment Control Planning and Implementation, 1972.



MAINTENANCE

If properly built, these structures are virtually maintenance-free. Inlets and outlets should be checked periodically for undermining and erosion. Debris which could clog the structure should be removed.

REFERENCE

1) Alaska Dept. of Highways. Hydraulics Manual. 1972. 2) Soil Conservation Service. Field Manual for Conservation Practices. 1971. 3) County of Fairfax, Va. Erosion and Sediment Control Handbook. 1974. 4) Environmental Protection Agency. Guidelines for Erosion and Sediment Control Planning and Implementation 1972.

GROUP
Slope Stabilization

PRACTICE
Diversions and Benches

PURPOSE

To divert runoff waters and sediments away from critical areas and convey it to stable outlets.

SITE CHARACTERISTICS

Can be used on any site to keep runoff away from exposed construction areas or as a part of a permanent stabilization plan. It can break up concentrations on long, gentle slopes or keep runoff flows away from steeper, erodible areas. Recently constructed fill slopes are especially susceptable to damage.

ADVANTAGES

1. Increased infiltration of runoff.
2. Diversion of storm runoff may minimize construction delays.
3. Protects erodible, steep sloping sites.
4. Can provide permanent protection.
5. Can delay runoff by increasing overland flow distance. This will reduce downstream storm peaks.

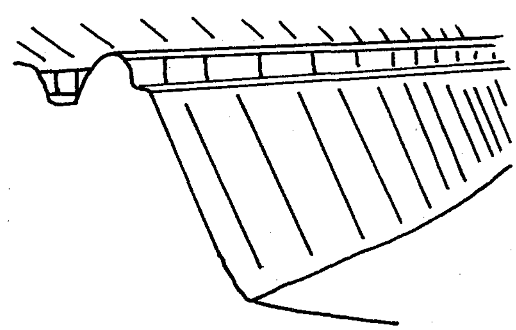
DISADVANTAGES

1. Increased infiltration of slopes or other areas may temporarily prevent access.
2. Channels may require additional protection such as regular maintenance of channel vegetation or use of rock lining.
3. Channel may act as a sediment basin and require cleanout, especially while drainage area is undergoing construction.

DESCRIPTION

1. Types

Diversions are generally of three types.

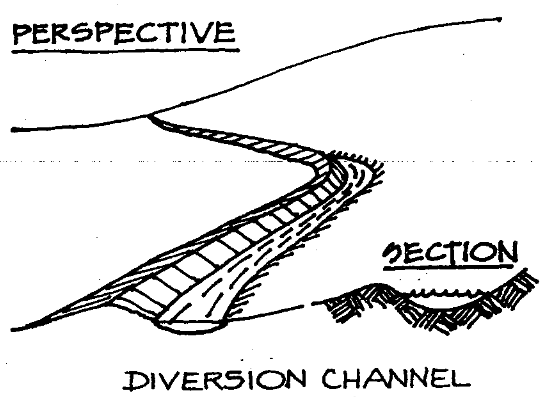


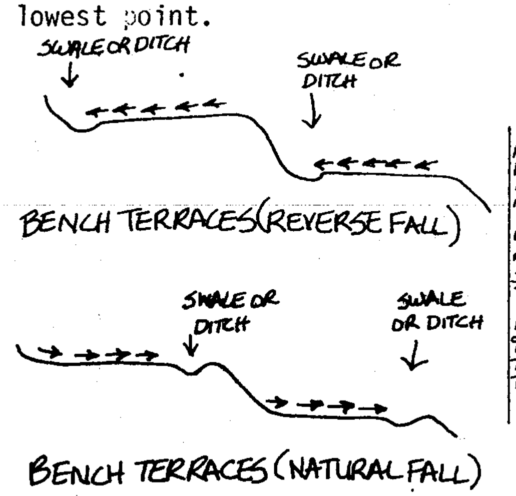
Diversion Levees - are compacted earth ridges normally placed along the top of steep slopes or cut sections. Usually a diversion ditch is associated. Runoff can be conveyed to downdrains (4.C.) or stable outlet.

Diversion channel - consists of a channel with a supporting berm on the lower side constructed across sloping areas. Runoff is conveyed laterally at slow velocity to protected area or outlet channel.

DESCRIPTION CONTINUED

Benches - are flat areas constructed along the contours of the slope. If wide enough, access for equipment can be provided. Benches can be built with a natural or reverse fall, often with a small swale at the lowest point.





2. Design

The design storm frequency should provide protection compatible with the hazard if the diversion should overtop. There should be an emergency path where runoff which overtops the facility will not cause too much damage. Where overflow may cause very limited erosion damage a ten year frequency would be appropriate with a freeboard of 0.3'. If overflow would be a hazard to water related resources or structures, frequencies of as much as 50 years may be needed, with a freeboard of 0.5'.

References 1 and 2 provide design details for runoff estimation and channel design.

Design velocities may be determined from the tables below.

Average Length of Veg., Inches	Retardance Good Stand	Retardance Fair Stand
11-24	B	C
6-10	C	D
2-6	D	D

	Rermissible Velocity - Ft./Sec.				
	Bare	Channel Vegetation			
Soil Texture	Channel	Retardance	Poor	Fair	Good
Sand, silt,		B		3.0	4.0
Sandy loam and	1.5	C	1.5	2.5	3.5
Silty loam		D		2.0	3.0
		B		4.0	5.0
Silty clay loam	2.0	C	2.5	3.5	4.5
Sandy clay loam		D		3.0	4.0
		B		4.0	5.0
Clay	2.5.	C	3.0	4.5	5.5
		D		4.0	5.0

Tables from References 3 and 4.

DESCRIPTION CONTINUED

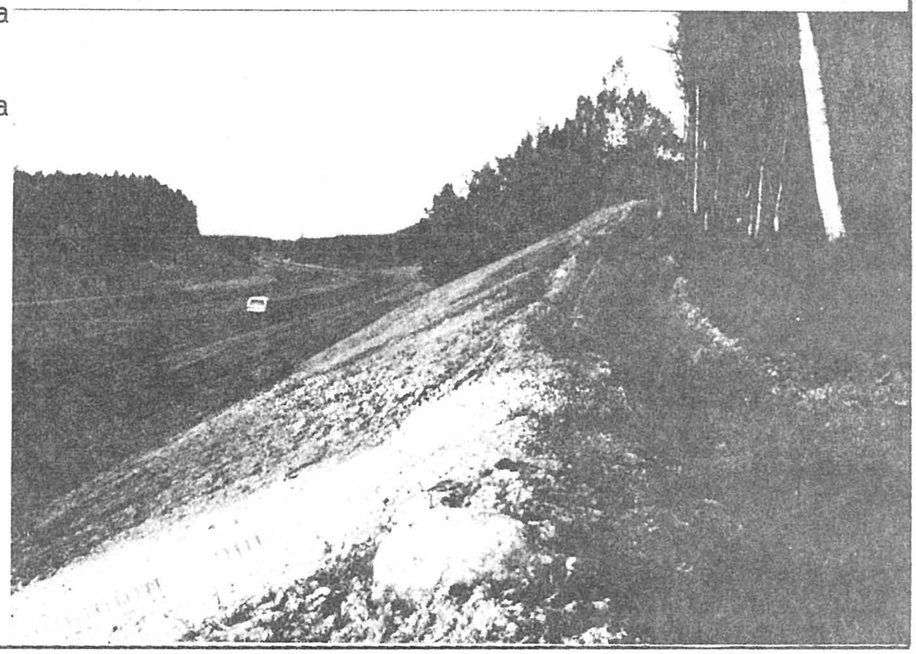
Location and spacing of diversions will depend on slope, soils and estimated runoff. Channel gradients are normally 0.5-1.0% but can be higher in resistant soils. For channel protection see 2.B.1-2.B.3. Outlets for diversions can be vegetated channels, natural water courses, level spreaders, etc. If flows are carrying sediment eroded from the site, sediment retention techniques, as shown in section three are necessary.

EXAMPLE

A diversion ditch along the top of the cut slope directs flow to sectional downdrain (lower left).

Location: Glenn Highway
Eklutna, Alaska

Source: R&M Consultants,
Anchorage, Alaska



MAINTENANCE

Sediment may need to be removed from channels.

Vegetation in channels may require maintenance to remain effective in controlling erosion.

REFERENCE

1) Alaska Dept. of Highways. Hydraulics Manual. 1972. 2) Soil Conservation Service. Field Manual for Conservaton Practices. 1971. 3) URS Company. Stormwater Management, Procedures and Methods. Snohomish County, King County, City of Everett. EPA Grant Id. No. P-000091. September 1977. 4) Northeast Regional Technical Service Center, SCS. Guidelines for the Control of Erosion and Sediment in Urban Areas of the Northeast. 1970.

GROUP
Slope Stabilization

PRACTICE
Level Spreaders

PURPOSE

To convert concentrated flow to sheet flow at non-erodible velocities over stable areas. Time of concentration of runoff is increased and storm peaks are reduced.

SITE CHARACTERISTICS

Infiltration is increased, so level spreaders should be used where they will outlet to undisturbed stable soils. Spreaders should not be built on fills.

ADVANTAGES

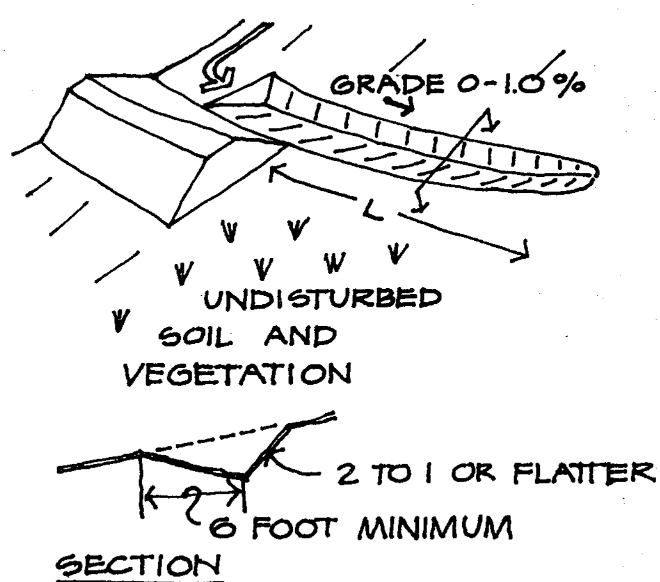
1. Reduced erosion can minimize regrading of completed areas.
2. Increased overland flow time and increased infiltration can reduce storm peaks.

DISADVANTAGES

1. May not be applicable on poorly drained or ice-rich permafrost soils.
2. Spreader lip must be stable and level or flow will concentrate, with high potential for gully erosion.

DESCRIPTION

Runoff spreaders convert concentrated flow to sheet flow where it can be dispersed at non-erosive velocities into undisturbed, vegetated areas. Much of the flow will infiltrate in undisturbed areas. The spreader should outlet to undisturbed soils which are well drained and are not highly erodible. Care must be taken to insure the outlet lip is level. Inflow value (Q) in cfs must be estimated to determine the length of the spreader.



Design Q (CFS)	Length (L)
up to 10	15
10 to 20	20
20 to 30	26
30 to 40	36
40 to 50	44

See Section 4.D.1. for permissible channel velocities for grass lined channels.

MAINTENANCE

Periodic inspection and maintenance is vital. Spreaders should be inspected after storms. Trapped sediments should be removed. If the lip is not kept level gully erosion may result.

REFERENCE

1) USDA, SCS College Park, MD. Detail of Level Spreader. L.S.I., Md. SCS Design Standard. 2) Thronson, R.E. Comparative Costs of Erosion and Sediment Control, Construction Activities. Env. Prot. Agency. EPA-430/9-73-016. Sept. 1973. 3) County of Fairfax, Va. Erosion and Sediment Control Handbook. Dec. 1974.

GROUP

Revegetation and Mulching

PRACTICE

Grasses, Herbaceous and Woody Plants

PURPOSE

To provide vegetation to control runoff and prevent erosion and sedimentation.

SITE CHARACTERISTICS

Applicable to all sites such as cleared or graded areas, slopes and others which require either temporary or long-term protection against erosion.

ADVANTAGES

1. Increases infiltration and can help trap sediment movement.
2. May provide both surface cover and root mass for slope stabilization.
3. Economical form of protection.
4. Once established mostly maintenance free; allows native species of vegetation to return.

DISADVANTAGES

1. Some limitation imposed by soil, topographic and climatic conditions.
2. Commerical sources limited.

DESCRIPTION

The Revegetative Guide for Alaska published by the Rural Development Council provides an excellent guide to selecting grass species, fertilizers, application methods and physiographic limitations. It is also recommended that, where possible, the local Soil Conservation Service be contacted for information to assist any revegetation effort.

GRASSES AND HERBACEOUS PLANTS

1. Site Preparation

Respreading loamy materials will assist revegetation, and in many cases is essential for vegetative recovery. For upland borrow pits stockpiling and respreading topsoil should be standard procedures.

Soils must be porous for root penetration, and friable enough for good seedbed preparation. On construction sites a scarified surface is usually best to help retain seed.

2. Timing

Seeding should normally be done between May 15th and August 15th, as close after disturbance as feasible. Temporary covers such as annual rye can be seeded later.

Disturbed soils should not be left unstabilized over winter.

3. Application Methods

A number of techniques are used, each with limitations.

DRILLING: The Revegetative Guide for Alaska recommends drilling as the best method for nearly level to gently sloping land, where equipment access is not limited.

HYDROSEEDING is preferred for steeper slopes where access is a problem. Seed, and sometimes fertilizer and mulch are applied as a slurry. It is best to apply seed and fertilizer first, to ensure seed contact with the soil, followed by mulch. The guide recommends mixing ratios and application rates.

BROADCAST seeding, such as aerial appreciation offers rapid application for large areas. The guide recommends application rate twice that required for drilling.

SPRIGGING (planting a root shoot or sprout) and SODDING, although expensive may be necessary for critical areas requiring quick ground cover. (See procedures 2.B.1. and 5.A.2.)

4. Fertilization

On many construction sites, fertilization is critical to successful establishment and survival of plantings. Reference 1 provides application rates for various conditions. Fertilizer is often required during initial seeding as well as successive applications to promote growth. Where it is desirable to allow native species to take over areas planted with exotics, the reapplication of fertilizers is gradually reduced during the succeeding seasons until the native species are established.

5. Mulching

Revegetation on sloping terrain, especially with minerals soils will usually require some form of mulching. (See Procedure 5.B.)

WOODY PLANTS

There is advantage to establishing woody plants, most commonly willow or alder, in addition to grass and herbacious ground covers for:

-- slopes where additional root mass would help stabilize soils;
-- stabilizing streambanks by additional root mass and by slowing stream velocity along banks. (See Section 6)

Plants may be started from seed, seedlings, and for some deciduous species, stem cuttings.

Species must be adapted to soil pH. The Revegetative Guide gives pH tolerances.

Timing. Seeding should take advantage of high soil water content, so late fall or early spring seeding is desirable. Transplanting can be early spring or fall. Cuttings can be planted in spring.

DESCRIPTION CONTINUED

Timing for collection of seeds and cuttings is extremely important, and varies with species. (See references 1, 2 for recommended times.) Seeds and cuttings (8-10") should be stored below-freezing as soon as possible after collection. Seedlings should be kept dormant at 35-40°F and should be kept from excessive drying.

For seeding, the discussion under grasses and herbaceous plants applies. For planting seedlings and cuttings there must be close contact with the soil. Cuttings are usually just pushed into the ground.

EXAMPLE

Hydroseeding operation along Yukon to Prudhoe Bay Haul Road

Source: R&M Consultants, Inc.

MAINTENANCE

Seedlings must be kept moist until reaching a height of 1-2 inches. Watering may be required in some areas or during periods of drought. Watering and fertilizing woody plants may be critical during the first year.

REFERENCE

1) U.S. Forest Service. Seeds of Woody Plants in the United States. USDA. Agricultural Handbook No. 450, 1974. 2) Alaska Rural Development Council. A Revegetative Guide for Alaska. Alaska Cooperative Extension Service. March 1977. 3) Erosion and Sediment Control Handbook. Country of Fairfax Virginia. December 1974. 4) Tourbier, J. Water Resources Protection Measures in Land Development. Univ. of Delaware. April 1974.

GROUP
Revegetation - After Final Grading

PRACTICE
Stabilizing Critical Areas with Sod

PURPOSE

To establish a protective layer of vegetation as fast as possible to prevent soil erosion by wind or water.

SITE CHARACTERISTICS

Sodding gives the fastest possible protection by vegetation and, thus is used where immediate protection is essential. It is an expensive operation and should be applied to critical areas only. These include steep slopes, highly erodible soils and disturbed areas in the floodplain, drainage channels and other critical areas.

ADVANTAGES

1. Sod gives immediate vegetative cover which is effective in checking erosion and aesthetically pleasing.
2. Good sod has a high density of growth and this gives superior protection to a recently seeded sward.
3. Sod can be placed at any time that soil moisture is adequate and the ground is not frozen.

DISADVANTAGES

1. Sod is expensive.
2. Sod is heavy and handling costs are high.
3. Good quality sod may be difficult to obtain.
4. Grass species in available sod may not be suitable for site conditions.
5. If mowing is required do not use on slopes steeper than 3:1 (use minimum maintenance ground covers.)

DESCRIPTION

Sod Specifications (Taken from Reference 1)

Local SCS office.

1. Sod should be uniform thickness (approximately 1").
2. Sod should have a dense root mat to give adequate mechanical strength.
4. Sod should be moist and fresh when delivered to the site.

Site Preparation

1. Where possible, grade to allow use of conventional equipment for cultivation, spreading lime, fertilizing and seeding.
2. Apply lime and fertilizer according to soil tests (or according to recommendations in reference 2).
3. Disc harrow to a depth of 2-3" until a uniform, fine, firm bed is attained. Where possible, final cultivation should be along the contour.
4. Irrigate before laying sod.

DESCRIPTION CONTINUED

SOD Placement

1. Lay sod strips along contour, never up and down slope. (See exception, Section 2.B.1.). Start at the bottom of the slope and work up. Stagger joints and make sure joints are snug.
2. Roll or tamp thoroughly after placement.
3. On steep slopes secure sod with wood pegs, wire staples or split shingles (8-10" x 3/4").
4. Use jute or plastic netting to secure sod in place at the crown of very steep slopes, in drainage swales and at other areas where water could undercut sod.
5. Irrigate sod thoroughly until moisture penetrates the soil layer beneath. Maintain optimum moisture for at least two weeks.

Future Developments Outside Alaska rapid progress is being made in growing very high quality sod in shallow pans on a thin bed of polystyrene granules. This product is very light and can be handled in wide rolls, unlike traditional sod. When unrolled onto bare ground which should have received a light dressing of fertilizer and thorough irrigation, the sod will become established very rapidly. This technique, when generally available, will combine the advantages of traditional sod with the advantages of lightweight erosion control blankets.

REFERENCE

1) URS. Co. Stormwater Management, Procedures and Methods. Snohomish County, King County, City of Everett. EPA Grant Id. No. P-000091. September 1977.
2) Alaska Rural Development Council. A Revegetative Guide for Alaska. Alaska Cooperative Extension Service. March 1977. 3) U.S. Soil Conservation Service. Interim Standard and Specification for Critical Area Stabilization with Sod. Somerset, New Jersey.

GROUP
Revegetation - Mulches

PRACTICE
Organic Mulches

PURPOSE

Application of plant residues or other suitable organic material can reduce erosion by reducing impact of rainfall and checking runoff; also will stimulate plant growth by retaining moisture.

SITE CHARACTERISTICS

Especially steep slopes and highly erodible soils, and where large areas of soil are exposed at one time. May be used on any area subject to erosion, particularly where revegetation would otherwise by difficult. May require netting or chemical binders.

ADVANTAGES

1. Improved germination and growth.
2. Helps retain moisture in soil.
3. Helps dissipate rainfall impact and stop soil erosion.

DISADVANTAGES

1. If the area is to be seeded, it must usually be done simultaneously with mulching.
2. Straw mulch, one of cheapest and most effective may be a fire hazard, is subject to wind and is unavailable in some areas.

DESCRIPTION

Organic mulches include straw or hay, wood fiber, wood chips and other plant materials which can be used as protective, soil cover. Level areas and other sites with favorable growth conditions dont generally require mulching. On slopes, erodible soils, very gravelly sites and other critical areas mulching assists revegetation by retaining seeds, moisture and soil and improving survival and growth.

On slopes of 3:1 or less machinery can be used to apply and anchor mulches. Steeper slopes will require hand application or hydroseeding.

Application rates given below are taken from recommendations for Snohomish and King County in Washington State and may require local adjustment. One of the technical agencies should be contacted for local recommendations on appropriate mulch type and application rate.

DESCRIPTION CONTINUED

1. Straw Mulch

Is usually applied by hand or mulch blowing equipement. It requires anchoring against wind blow.

- May be punched into soil by discs, etc., or covered with nettings or chemical agents.
- Effective for more than three months.
- Application: 75-100 lbs. (2-3 bales) 100ft^2 or 15-25 tons (90-100 balls)/acre.

2. Wood Fiber Mulch

A number of commerical products are available, mostly applied by hydroseeding. Mulch is often mixed with seed slurry.

- Does not require anchoring.
- Application 25-30 lbs/100 ft^2 or 1,000-1,500 lbs/acre.

3. Wood Chips

This mulch has been used as a temporary mulch over areas not seeded or over newly seeded areas. Slash and brush from initial clearing can later be processed and spread.

- Limited to fairly level areas as may be subject to movement by runoff.
- Resistant to wind blow.
- Applicaton: 500-900 lbs/100 ft^2 or 10-20 tons/acre with 10 lbs nitrogen/ton recommended.

4. Wood Excelsior

Decomposes slowly and is subject to some windblow.

- Application: 90 lbs/100 ft^2 or 2 tons/acre.

5. Other Mulches

Often a good mulch can be had by stockpiling, respreading and incorporating into soils the organic material removed in clearing. Any number of other materials such as compost, peatmoss, topsoil, etc. can be used in certain construction areas.

MAINTENANCE

Mulched areas should be inspected periodically and damaged areas repaired.

REFERENCE

1) Alaska Rural Development Council, A Revegetative Guide for Alaska, Univ. of Alaska. March 1977. 2) Environmental Protection Agency. Guidelines for Erosion and Sediment Control Planning and Implementation. August 1972. 3) Tourbier, J. Water Resources Protection Measures in Land Development. Univ. of Delaware. April 1974.

GROUP Revegetation and Mulching

PRACTICE Nettings, Mattings and Mulch Blankets

PURPOSE

To prevent soil erosion during establishment of vegetation.

SITE CHARACTERISTICS

These mulches are used mostly on steep slopes, in swales and other critical areas to be revegetated. They do not offer much soil moisture retention, as do organic mulches, so their use is limited to favorable areas or in conjunction with other mulches such as in 5.B.1.

ADVANTAGES

1. Easily installed, by unskilled labor.
2. Resistant to wind and water erosion but must be well anchored.

DISADVANTAGES

1. Will not retain soil moisture, which may limit use.
2. Synthetic nettings should not be used where net could be washed into fish stream.
3. If used in swales where there is high velocity runoff before vegetation is established, netting will cause scouring.

DESCRIPTION

Before installing these mulches, the areas should be stabilized with other procedures such as diversions, perimeter dikes and drainage structures. The surface should be prepared as in 1.B., and 5.A.2. The area can then be covered with any number of commercially available nettings or mattings. Manufacturer's specifications should be followed and it may be desirable to consult with the SCS or other agencies.

1. Nettings

Either natural (such as jute) or synthetic nettings are available. They can be used to tack other mulches such as straw, if mulching effect is desired, or used alone if only erosion prevention is needed. Nettings must be anchored. They are also used as channel liners for vegetated channels (See 2.B.2.). Nettings are usually effective on even steep slopes and most soils types.

2. Mattings

Materials such as Excelsior Blanket are a machine produced mat or curled wood excelsior covered with either a Kraft paper or plastic mesh. The blanket must be stapled, particularly if used in channels or swales. These blankets offer somewhat more of a mulching effect than netting alone. Mattings are fairly resistant to concentrated flows.

DESCRIPTION CONTINUED

3. Mulch Blankets

Consist of wood cellulose fiber bonded with a water soluble binder, forming a homogeneous mat. A plastic net is bonded to the top surface for anchoring. These provide a greater mulching effect than nettings alone although they may not be as resistant to concentrated flows.

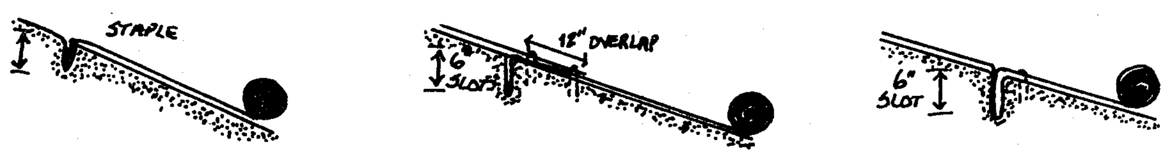
Installation of Matting

Unreel the matting downhill. This is best achieved by placing a hollow shaft (e.g. a metal pipe) through the center of the roll through which is passed a rope. The roll can be unwound slowly down the slope. Most mesh is reeled on a cardboard core and a rope may simply be passed through this. The material should not be stretched nor allowed to lie loosely, but should take up the contours of the ground. The manufacturer's recommendations for overlapping adjacent strips should be followed.

Anchoring Matting

Uphill ends should be buried in a 6" deep slot and stapled across on 12" centers. At joints, the downhill end should be overlapped (shingle fashion).

On very severe slopes check slots should be used (Figure 2). These are 6" deep slots into which a tight fold of matting is inserted. The slot is filled and tamped and staples inserted across on 12" centers) just down slope of the check slot.



FROM URS, 1977

Stapling

Matting should be stapled according to the manufacturer's instructions, generally as above, and on 12" centers down each edge of the mat and down its center line. After installation, mesh mattings should be rolled with a smooth roller to bring into close contact with the soil and to consolidate the seedbed.

MAINTENANCE

Mulched and netted areas should be inspected periodically, especially following storms. Damaged areas should be repaired.

REFERENCE

1) Environmental Protection Agency. Guidelines for Erosion Control Planning and Implementation. August 1972. 2) Tourbier, J. Water Resources Protection Measure in Land Development. Univ. of Delaware. April 1974.

GROUP Revegetation - Mulching

PRACTICE Chemical Stabilizers and Soil Binders

PURPOSE

To bind soils to prevent erosion during revegetation. Some chemicals act as mulches also.

SITE CHARACTERISTICS

Are applicable to any site, particularly steep sloping or highly erodible soils.

ADVANTAGES

1. Many are applied by hydroseeders allowing labor savings, and access to areas inaccessable to other machinery.
2. Binds soil surface against erosion.
3. Acts as a mulch under certain conditions.

DISADVANTAGES

1. Not as effective for fine-grained soils as for sand soils.
2. Requires special equipment for application.
3. Rarely superior to straw.
4. Equipment may be difficult to schedule for small job increments.

DESCRIPTION

Chemical stabilizers include petroleum products, asphalt emulsions, latex emulsions, plastics and many others. Each material has certain limitations, particularly in terms of ambient temperature during application and soil types. Use in Alaska has been rather limited and has had varying success. Technical agencies, such as the Soil Conservation Service, and the manufacturers should be consulted. The surfaces must usually be cultivated prior to application. The following provides general considerations for the use of these materials.

1. <u>Chemical Stabilizers</u>

These materials do not usually penetrate the soil, but rather form a thin crust. Examples are asphalt emulsion and cutback asphalt. They are applied over the seeded area and as they cure, the seedlings can penetrate the cover. The seed bed should be well prepared prior to application of the chemicals.

2. <u>Soil Binders</u>

Are useful where fiber, straw, or other forms of mulches are unavailable. These are most commonly emulsions of resin or latex and check erosion during the establishment of vegetation by stabilizing the seedbed. They also help to retain soil moisture and yet are soluble enough to allow rainwater to reach the soil. Penetration of soil binders is usually about ½'. They are most conveniently applied together with seed and fertilizer with a hydroseeder. Soil conditions at the time should be moist. Soil binders alone, therefore, should only be used in favorable seasons. Binders remain effective on sandy soils longer than on finer textured soils.

DESCRIPTION CONTINUED

In less favorable seasons, soil binders can be hydroseeded with short fiber mulches. More than twice as much stabilizing agent is required. Moisture retention and insulating properties of the mulch are greater when in combination with wood fibers.

These materials would normally not be used in areas subject to concentrated flows, such as in swales or channels.

MAINTENANCE

Damaged areas should be repaired until permanent vegetative cover is achieved.

REFERENCE

1) Tourbier, J. Water Resources Protection Measures in Land Development. Univ. of Delaware. April 1977. 2) Alaska Rural Development Council. A Revegetative Guide for Alaska. Pub. No. 2. Univ. of Alaska Cooperative Extension Service. March 1977. 3) URS Co. Stormwater Management, Procedures and Methods. Snohomish County, King County, City of Everett. EPA Grant Id. No. P-000091. September 1977.

INTRODUCTION
TO GROUP 6, STREAM STABILIZATION

PURPOSE

This introduction described potential grass stream responses to man made changes. It is presented to provide a background against which the procedures in Section 6 can be reviewed.

The following is from Mackin (1937) (Reprinted in Ref. 1). The engineer who alters natural equilibrium relations by diversions or damming or channel improvement measures will often find that he has the bull by the tail and is unable to let go-- as he continues to correct or suppress undesirable phases of the chain reaction of the stream to the initial 'stress' he will necessarily place increasing emphasis on study of the genetic aspects of the equilibrium in order that he may work with rivers, rather than merely on them."

Natural streams are dynamic systems, though often not viewed as such.

DESCRIPTION

1. <u>Variables in a Stream System</u>

A range of effects from induced changes must be carefully considered in attempting engineering solutions, to prevent merely transferring a problem to upstream, downstream, or next year.

In natural alluvial streams the following general relations exist:

- channel width, depth and meander wavelength are directly proportional to discharge;
- Width and wavelength are directly proportional to sediment load;
- Width to depth ratio is directly related to sediment load;
- Gradient is proportional to sediment load and grainsize and inversely proportional to discharge;
- Sinuosity is proportional to valley slope and inversely proportional to sediment load.

Natural alluvial rivers are broadly classified as straight, meandering or braided.

Meandering rivers change channel shape by erosion at the outside of bends, and deposition in straight reaches and point bars at the inside of bends.

Braided streams have wide channels, poorly defined and unstable banks, high velocity and relatively steep gradient, and rapidly shifting subchannels.

Changes in the independent variables (sediment load, grain size, discharge and valley slope) can be expected to cause major channel changes which will stabilize only after considerable length of time.

DESCRIPTION CONTINUED

2. Qualitative Stream Responses

Activity — **Potential Stream Response** (from Richardson, May 1975)

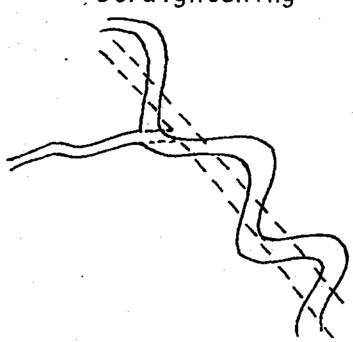
1. Impoundment

Upstream: aggradation of bed (deposition); change in river geometry; increase in flood stage which must be accommodated by upstream structures; raise base level for tributaries.
Downstream: channel degradation (increased erosion of bed and/or banks) to compensate for reduction of sediment load at impoundment; local scour at bridges or culverts; possible change in river form; reduced flood stage; reduced base level for tributaries causing increased velocity, reduced channel stability, headcutting, and local scour at instream structures; tributaries increase sediment transport to main channel.

2. Constriction (e.g. installation of culvert or bridge with abutments between banks)

Increased velocity at the structure; local scour; backwater and aggradation at flood stage.

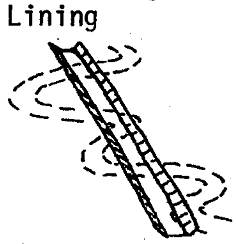
3. Channel Straightening



Increased gradient and velocity; increased sediment transport; channel degradation; banks unstable; river may braid; lowered base level of tributaries straight
Downstream: deposition below straightened channel; loss of channel capacity; increase in flood stage.

If the lower end of the constructed channel outlets to the stream base level such as a lake or reservior the lower portion will first be subject to the above. Then, as a delta forms or increases at the mouth and progresses upstream, the channel will significantly aggrade, and flood levels increase.

4. Channel Straightening and Lining



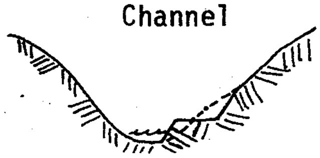
Increased velocity and gradient; unless lining is very rough, velocity increase will be greater than in unlined channel; if only banks are lined scour will occur at the base of the linings.
Downstream: If energy is not dissipated at downstream end of channel there will be scour at outlet and more severe attack at first bend downstream.

5. Longitudinal Encroachment

a. Meandering Channel

Same as 3. above and: Highway fill subject to scour as channel tends to shift to old alignment; headcutting may proceed up from downstream end; adequate lateral drainage must be allowed.

b. Incised Channel

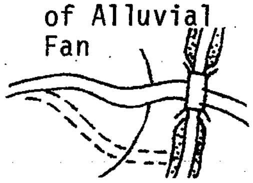


Channel is narrowed, velocity increased; fill subject to erosion, bed degradation induced; lateral drainage may be hindered. Upstream: backwater generated, producing increased flood stage and deposition.
Downstream: large sediment load may cause aggradation; local scour at end of constructed channel.

DESCRIPTION CONTINUED

c. Floodplain — There may be fill erosion during flood; if encroachment is significant, may increase flood stage upstream.

6. Crossing Downstream of Alluvial Fan — Streams through fans are very susceptable to channel shifting. Serious aggradation may occur at bridges; culverts may be blocked; stream crossing structure may be bypassed entirely.



Similar problems may occur at rapidly shifting meandering streams.

The USDOT publication, Highways in the River Environment. . .(1) provides information for predicting qualitative changes in more detail. It gives methods to estimate quantitative effects of instream structures on stream hydrology and on stream crossings.

REFERENCE

1) Richardson, E.V. Highways in the River Environment, Hydraulic and Environmental Design Considerations, Training and Design Manual. U.S. Dept. of Transportation, FHWA, May 1975.

GROUP
Streambank Stabilization

PRACTICE
Vegetative

PURPOSE

For protection of small streams and their banks to prevent or control erosion and sedimentation.

SITE CHARACTERISTICS

Should be restricted to areas which have been disturbed by construction activities or where structures are threatened by degrading banks. Applies to swales, creeks, streams and rivers as well as man-made ditches, canals and impoundments including ponds and storage basins.

ADVANTAGES

1. Retains instream and streambank habitats.
2. The reduction of velocity lowers local erosive power.
3. Plants regenerate and adapt to changing natural situations, offering economic advantage over some mechanical methods.
5. Visually agreeable.

DISADVANTAGES

1. Native plants not carried by nurseries may have to be collected by hand.
2. Effects of lowering velocities on adjacent area must be considered.
3. For severe conditions will not provide resistance to erosion as strong as some mechanical means.
4. Possibly affected by ice or heavy debris.
5. Methods described here will cause temporary disturbance during planting.

DESCRIPTION

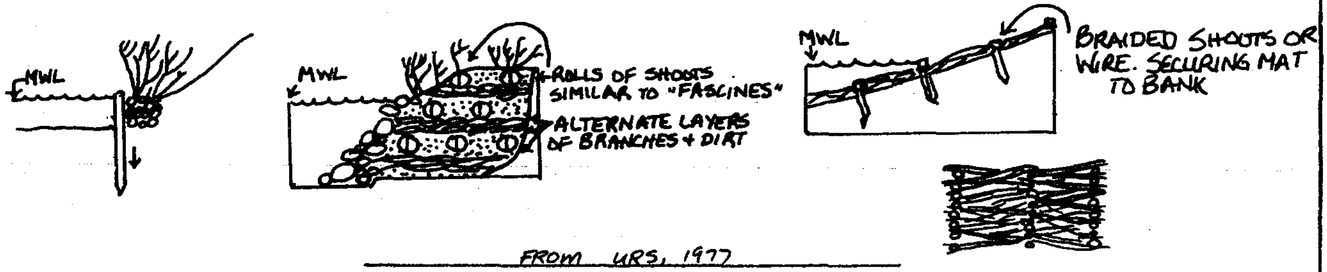
<u>The lower riparian zone</u>

This zone has natural growth of willow, alder and cottonwood. These stabilize stream bank soil with their roots. In periods of high water, their upper branches slow the current and thereby reduce erosive force. Woody plants are planted either as 1) individual cuttings or 2) bound together in various forms. This zone receives primary emphasis in vegetative streambanks protection.

a) Fascines are bundles usually of willow, 3 to 12" in diameter, containing brushwood, sticks, coarse gravel etc. in center tightly wound.

DESCRIPTION CONTINUED

b) A packed fascine work can be employed on cut banks. Alternate 1' layers of branches with rolls of shoots packed with dirt.



FROM URS, 1977

c) Willow mattresses of 4-6' cuttings either braided or wired together, staked down and covered lightly with dirt.

MAINTENANCE

If willows or alders are cut before they reach 2" in diameter, growth of small shoots from the base will be encouraged. Cuttings can be used to stabilize sediment deposits. This also applies to Procedure 6.A.2.

REFERENCE

1) URS Co. Stormwater Management, Procedures and Methods. Snohomish County, King County, City of Everett. Environmental Protection Agency Grant Id. No. P-000091. September 1977.

GROUP Streambank Stabilization

PRACTICE Mechanical Methods - Revetment

PURPOSE

To control streambank erosion in critical areas which cannot be protected by grass (maximum velocity 8 fps) or other vegetation.

SITE CHARACTERISTICS

Mechanical methods are usually reserved for protection of roads, utilities, buildings and other structures located on stream banks. Flexible revetments such as rip rap and mattress-type linings are applicable for protecting banks where heavy scouring at the toe is anticipated. Sites with highly erodible soils will be the most vulnerable. Mattresses can be used where rock is in short supply.

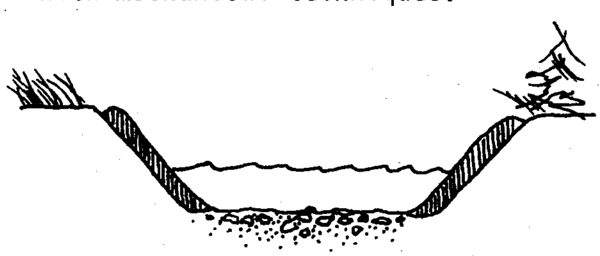
ADVANTAGES

1. Protection of valuable sites from erosion.
2. Most practices listed here maintain channel capacity.
3. Flexible lines: Rip rap blankets and mattresses are not as susceptable to instability or undercutting as rapid linings.
4. Mattress: If carefully designed, a mattress will fall into place after scouring has taken place, providing continuous protection.
5. Gabions: Stone of a considerably smaller size than dumped rock may be used.

DISADVANTAGES

1. Loss of aesthetic values.
2. Reach may be damaged or eliminated as a habitat by eliminating vegetation or changing hydraulic characteristics.
3. A large amount of hand labor may be required.
4. Difficulty in installing in deep water.
5. Streambank linings often result in scour of streambeds by increasing velocity.
6. Some structures such as gabions and groins may be expensive to maintain.
7. Often not a permanent solution.
8. Smooth linings speed flow, which may aggravate scour downstream. Acceptable solutions must be designed to prevent simply shifting problems to other reaches of the stream (See Group 6 Intro.).
9. Rigid revetments are subject to undercutting and collapse.
10. Usually higher cost associated with mechanical techniques.

Revetments consist of any number of bank lining materials such as rip rap, concrete, grouted stone, gabion blankets, and bagged concrete.



DESCRIPTION

1. Gabion Mattresses

These are wire mattresses filled with rock, usually by a backhoe or selective hand packing. To lay in deep water it is necessary to prefill the mattress on a raft and slide into place. The mattress has similar roughness to hand placed stone.

If desired, 6" lengths of willow or alder shoots and some silty gravel may be included during filling. Under favorable conditions this will give a dense growth over protected banks.

2. Gabions

Gabions are wire baskets filled with stone. They can be used when larger stone for rip rap is not available, for lining steeper streambanks than mattresses. Gabions are filled with a backhoe and by selective hand packing. They are available in plastic covered mesh and have life expectancy of over 25 years. However, by that time the rock-fill in the gabions will probably have stabilized itself.

3. Concrete-Filled Nylon Blankets

Blankets are 2 nylon sheets stitched together like a quilt and filled with Portland cement grout after they are fixed in place. Not recommended on slopes steeper than 1:1. The upper layer of fabric deteriorates slowly in sunlight, but this does not greatly reduce its performance. Seams are sewn in the field with a portable air-operated or electric bag closer. Ready-mix concrete is injected with a mortar pump filling the toe first.

Blankets are capable of withstanding small movements unlike concrete linings, so are less susceptible to undercutting, etc. The channel must be dewatered prior to installation, making them frequently impractical. Fabriform blankets have similar applications as mattresses (above) but can be used in areas where stone is unavailable in sufficient quantities. However, they are aesthetically less acceptable than the gabion mattress, which can become covered with vegetation.

4. Sheet Piling

This must be driven to the point of refusal or to at least ½ its length below the maximum depth of scour. Piling would generally be used only where a vertical bank is required, or where deep water is required close to the shore.

5. Rigid Concrete Revetments

These have the following characteristics:

- Dewatering will probably be necessary before placing.
- They are aesthetically unappealing and often have low public acceptance.
- To prevent settling and cracking they should be used only on well compacted soils.
- The lining should extend to the top of the bank where it is stabilized with vegetation. Height should be increased on the outside of bends.
- Reinforcement should extend through all construction joints.
- The toe should be extended to the maximum anticipated scour depth and protected with rip rap.

DESCRIPTION CONTINUED

6. Grouted Stone Revetments

Grouting is sometimes used when large stones are unavailable to stabilize dumped stone linings if movement is occurring. This can be effective, but will reduce roughness of lining. Flow velocity will increase. This can result in a plucking action at any holes or flaws in the grouting, leading to failure. Grouting has the disadvantage of making the protection layer (dumped stone) rigid.

7. Dumped Stone--Linings and Revetments

Dumped stone forms a flexible lining which will gradually slump into any scour holes. It has a very rough surface which results in dissipation of the stream's energy, minimizing scouring problems at the ends of the revetment or lining. For maximum allowable velocities (dependent on stone, size and channel shapes) see Appendices 2.B.1. and 2.B.3.

8. Placed Rip Rap or Bagged Concrete

Linings and revetments of hand placed stone or rip rap generally consists of stones of 100 lbs or more placed in a single layer. They are more subject to damage than dumped stone. Any shifting of the stone layer will expose bare soil. Placed stone has a lower coefficient of roughness than dumped rock and therefore, is more susceptible to scour at the end of lined sections.

Placed stone is aesthetically one of the most acceptable mechanical protection techniques.

MAINTENANCE

Dumped Stone

Shifted stones can be rearranged with backhoe. For large scale movement, dump more stone. Damage to concrete linings MUST BE REPAIRED IMMEDIATELY.

Economic Considerations

1. Access. Rigid linings require good access for construction. Where difficult, cost may increase considerably; in such cases other alternatives should be considered.

2. Materials. The cost of hauling rock will be a significant factor in lining costs. Concrete linings may be required where this is excessive.

3. Labor Costs. Where high and the cost of stone is low, use dumped stone. If vice versa, use hand placed stone.

REFERENCE

1) URS Co. Stormwater Management, Procedures and Methods. Snohomish County, King County, City of Everett. 2) New York Department of Transportation. Division of Design and Construction. Bank and Channel Lining Procedures. 1971. 3) Bross, J.M. Engineering Evaluation of Erosion Protection for Water Courses in New Castle County, Delaware. 1970. 4) Maccaferri Gabions of America, Inc. Technical Literature. Flushing, New York. 5) Construction Techniques, Inc. Fabriform Literature. Cleveland, Ohio. 6) Leep, A.W. California Soil Conservation District Streambank Stabilization Program. J. Soil and Water Conservation. Vol. 20, #1. 7) U.S. Department of Transportation. Use of Rip Rap for Bank Protection. Hydraulic Engineering Circular #11. 8) Soil Conservation Service. Field Manual for Conservation Practices. 1975. 9) Tourbier, J. Water Resources Protection Measures in Land Development. Water Resources Center, Univ. of Delaware. 1974. 10) Alaska Dept. of Highways. Hydraulics Manual. 1972.

GROUP

Stabilization of stream channels and banks.

PRACTICE

Bio-technical methods.

PURPOSE

To provide protection of critical sections of streambank through a combination of vegetative and mechanical means.

SITE CHARACTERISTICS

Due to large initial disruption, should be used only where area has been disrupted by construction activity or where structures are threatened. To be used in streams with swift flow where the flow/soil conditions exceed the stabilizing effect of purely vegetative channel protection.

ADVANTAGES

1. Mechanical materials provide for interim and immediate stabilization until vegetation takes over.
2. Once established, vegetation can outlast mechanical structures and requires little maintenance while regenerating itself.
3. Aesthetic benefits and wildlife propagation.

DISADVANTAGES

1. Slightly higher initial cost and need for professional advice.
2. If possible, methods should be scheduled for time of extreme low water.
3. The methods described require a complete knowledge of soils, hydrology and other physical data to be lasting solutions, and to avoid adverse effects on other streams reaches.
4. Due to cost and initial disturbance involved these procedures would usually be reasonable in urbanizing areas where streamside structures require protection.

DESCRIPTION

Streams in urbanizing settings may carry a great increase in runoff. Bio-technical methods can provide for stabilization without complete visual degradation and higher effectiveness than purely mechanical techniques.

DESCRIPTION CONTINUED

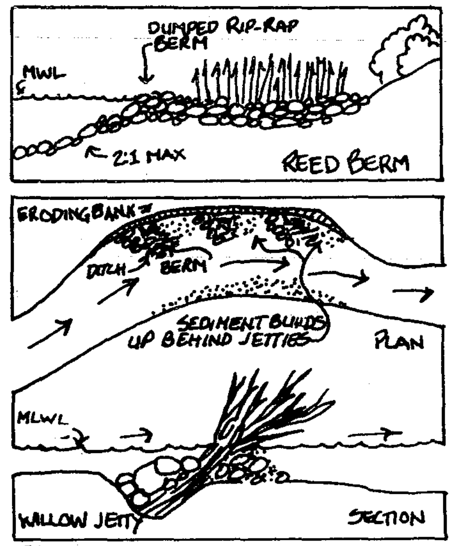
Willow jetties can be constructed at the water level to stabilize a cutbank by deflecting the current and by encouraging deposition of sediment. Steps:

1. Dig ditches diagonally to direction of flow, and place fill to form berm downstream from ditch.

2. Set 2' willow branches at 45° angle and 3" spacing facing downstream.

3. Weight down branches with rip rap extending beyond water level.

In the lower riparian zone efforts should be concentrated on critical areas only:



FROM URS, 1977

1. Rip rap can be supplemented with willows which will bind soil and screen the bank. Willow cuttings in joints need to be long enough to extend 1' into natural soil and should have 2-4 buds above surface. Willow branches and rip rap should be installed simultaneously.

2. Willow branch matt revetment takes the following steps to install:

   a. Grade slope to approximately 2:1 and excavate 3' ditch at toe of slope;
   b. Lay live willow brush with butts up the slope, and anchor mat in the ditch below normal waterline by packing with large stones;
   c. Drive 3' willow stakes 2-½' on center to hold down brush; connect stakes with No. 9 galvanized wire and cover brush slightly with dirt to encourage sprouting.

MAINTENANCE

Costs vary according to local availability of labor. However, there are practically no maintenance costs for the vegetation once it is established.

REFERENCE

1) USDA, Soil Conservation Service. Engineering Field Manual for Conservation Practices. 1969. 2) USDA, Soil Conservation Service. Farm Planners Engineering Handbook for the Upper Mississippi Region, Agricultural Handbook #57. 1953.
3) URS Co. Stormwater Management. Procedures and Methods. Snohmish County, King County, City of Everett. September 1977.

GROUP
Streambank Stabilization

PRACTICE
Mechanical Methods -- Deflector Jetties

PURPOSE

To deflect streamflow away from an eroding bank, causing a buildup of sediment which can then be stabilized.

SITE CHARACTERISTICS

Should not be used on sites where stream cannot compensate for restriction in channel width, either by bed scouring or by scouring on the inside of the bend. Generally, used on the outside of bends, especially where soils are highly erodible or runoff is increased by development upstream.

ADVANTAGES

1. Deflector jetties cause areas of comparatively still water where sediment loads are precipitated.
2. The buildup of sediment against the bank allows it to be stabilized by planting.

DISADVANTAGES

1. As with all structures in this section, potential for causing changes in the stream course upstream or downstream must be fully considered.
2. Deflectors will considerably restrict the channel capacity. They should only be used where the stream's natural tendency to compensate by scouring the bed or the opposite bank will not cause a problem. Structures which would cause bed scouring in a fish spawning area would not be appropriate.
3. Jetties are generally not suitable for glacial streams which carry a larger quantity of bedload and which have a tendency for rapid fluctuations in flow. These fluctuations dump large quantities of bedload in short reaches of the stream.
4. Jetties produce excessive eddying, and therefore may do more harm than good in very sinuous channels.

DESCRIPTION

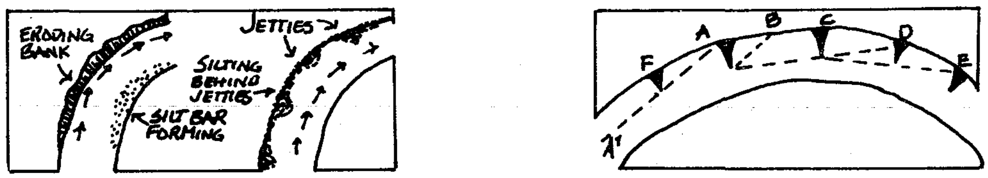
Deflectors and Jetties are used:

1) To deflect stream flow away from an eroding bank, or

2) Prevent meandering and encourage the stream to increase channel capacity by scouring its bed, rather than by lateral cutting.

DESCRIPTION CONTINUED

Because of potential acceleration of up or downstream changes, jetties and deflectors should be designed by a qualified engineer. When curvature of the bend exceeds 30° (190' radius), it is safer and more economical to use a revetment.



FROM URS, 1977

Spacing of Jetties or Deflectors

A rule of thumb should not be applied, but some guidance can be found in the diagram. A'A is the direction of flow against the eroding bank. Draw a line parallel from the end of Jetty A to B. AB = BC, which determines the location of Jetty C. Draw a line from tip of Jetty A to tip of Jetty C and extend it to intersect the bank. This determines the location of Jetty D. Place smaller jetty at F (AF = AC). Jetties should not be placed at 90° to the bank but at one angle to deflect flow with less resistance, causing less turbulence.

Plant willows or insert willow cuttings in the sediment as it builds up behind the jetty.

MAINTENANCE

Cutting willows regularly every 5-7 years, or before they reach 2" in diameter, encourages growth of small shoots from the base.

All instream work should be monitored for success of measures used, and for possible effects on other reaches of the stream.

REFERENCE

1) Soil Conservation Service. Farm Planners Engineering Handbook, Upper Mississippi Region. Milwaukee, Wisconsin. 1953. 2) URS Co. Stormwater Management Procedures and Methods. Snohomish County, King County, City of Everett. EPA Grant Id. No. P-000091. September 1977.

GROUP
Thermal Erosion Control

PRACTICE
Treatment of Disturbed Surfaces, Prevention of Disturbance

PURPOSE

To prevent damage to permafrost areas by construction activities; to prevent or minimize thermal degradation of permafrost areas with disturbed organic layers.

SITE CHARACTERISTICS

In poorly drained permafrost areas, or wherever disturbance of the active layer could result in melting of underlying frozen soils and cause ponding, gully erosion and other self-aggravating conditions.

ADVANTAGES

1. Prevents or minimizes thermal related erosion.
2. Arrests the problem before it can seriously aggravate.

DISADVANTAGES

1. Access to areas may be limited.
2. Can be expensive due to large amount of hand work required.

DESCRIPTION

1. Whenever possible use overlay construction as opposed to cut and fill.

2. When using overlay avoid stripping the organic layer. Conventional wheeled or tracked vehicles should not be used for surveying.

3. Consider winter construction to avoid melting and thermal degradation.

4. Avoid induced drainage or standing water over permafrost areas which can result in rapid thermal degradation. Avoid concentrated discharges from drainage structures onto undisturbed terrain. Attempt to convert to sheet flow to prevent headward cutting.

RESTORATION

After the active layer has been disturbed and left untreated, the sequence of events is : 1) Ponding and minor settlement in the disturbed area; 2) If ground is sloping, minor gully erosion; 3) Eventually, increasing ponding and settlement or development of ravines. Events are influenced by the topography and soils, as well as the season the disturbance occurred.

1. Drainage Control - such means as ditch checks and water bars are used to convey melt and runoff waters safely away from a disturbed area, or control the water within the area. This would be necessary where thawing of the active layer can result in the melt water being drained away.

DESCRIPTION CONTINUED

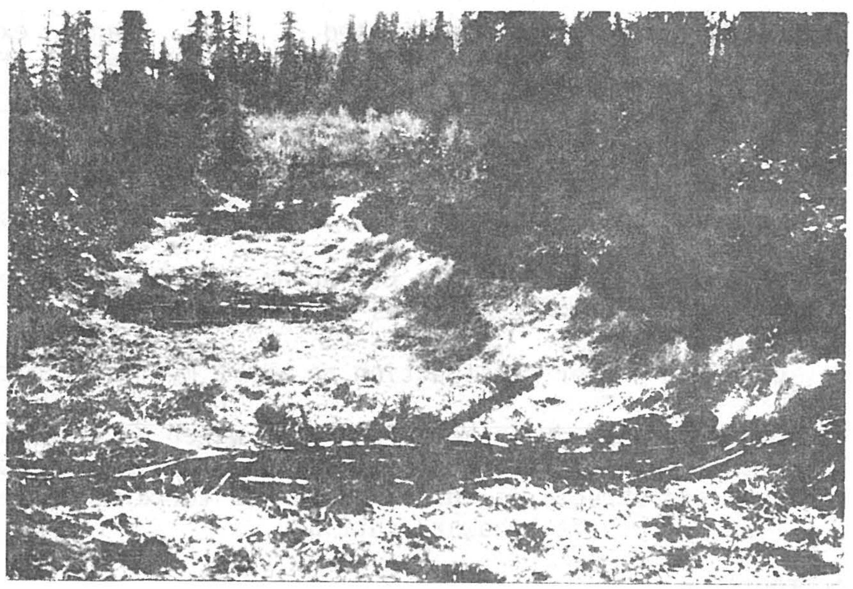
2. Revegetation - the disturbed area should be promptly revegetated to help retard melting of underlying soils. Seeding and fertilizing should normally be done by hand or aerial methods to prevent further disturbance. Transplanting of trees and brushes may be favorable in some areas both for quick cover and erosion control.

3. Insulation - a number of materials can be used to insulate the permafrost. This would normally be used in smaller problem areas where rapid thawing may be occurring. Materials such as straw, excelsior blanket, slash and styrofoam have been used. Typically this technique would be used where the active layer had been significantly disturbed or removed. Certain insulators, such as straw, excelsior or wood chips could also be beneficial to revegetation.

EXAMPLE

Trail area near the Livengood to Yukon Highway. Area was underlain by massive ice. Thawing and erosion was arrested with excelsior blanket cover and slash-log ditch checks.

Source: R&M Consultants, Inc.
Location: Anchorage, Alaska



MAINTENANCE

Disturbed areas should be inspected periodically until completely restored and stabilized. Drainage work and other measures should be performed promptly.

REFERENCE

1) BLM. Influence of Man-Caused Disturbance in Permafrost Areas in Alaska. U.S. Dept. of Interior. 1973. 2) Lotspeich, F.B. Environmental Guidelines for Development Roads in the Subarctic. EPA 660/3-74-009, June 1974.

GROUP	Thermal Eroson Control

PRACTICE	Cut Slope Stabilization

PURPOSE

To prevent erosion as a result of cuts made in permafrost soils.

SITE CHARACTERISTICS

Cut slopes in frozen soils will exhibit varying degrees of thawing, erosion and instability depending on the soils, height of cut, and ice content. These techniques apply to all cut slopes which contain potentially erodible soils, due to melting, surface runoff or sloughing.

ADVANTAGES

1. Prevents or controls erosion from cut slopes.
2. Controls rapid retreat of slopes.
3. Prevents clogging of ditches and drainage structures.

DISADVANTAGES

1. Some techniques, such as buttresses can be expensive.

DESCRIPTION

The general practice for frozen cuts has been to make a fairly steep slope (anywhere from 1.5:1 to 1:4) and leave the slope to self-stabilize. This can result in thawing of ice, release of meltwaters and some degree of sloughing, but eventually the cut will retreat to a stable condition. If a cut continues to retreat and appears that it will not self-stabilize, then the slope should be treated with either a filter buttress or insulation.

Following are several suggestions for application of these techniques:

<u>Vertical Cut</u>

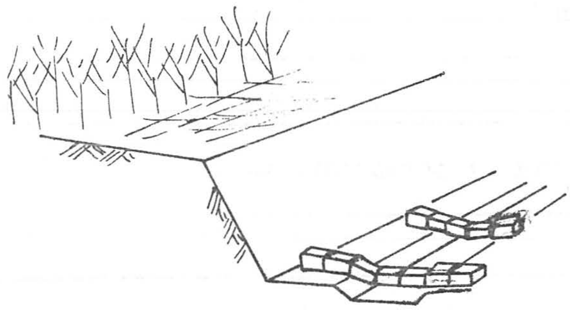
Avoid damaging vegetal mat. Allow to overhang or drape for insulation.

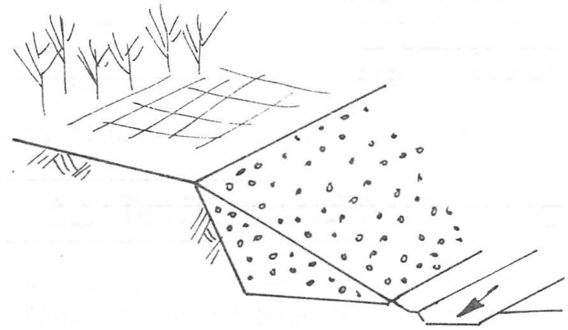
Clear trees by hand far enough back to prevent overhanging on slope. As the bank retreats due to melting, trees would tear the mat and prevent self-stabilization.

Install ditch checks, sediment filters or others to trap sediment eroded from the cut.

Observe periodically for any major erosion and sloughing. Apply remedial measures promptly.

DESCRIPTION CONTINUED

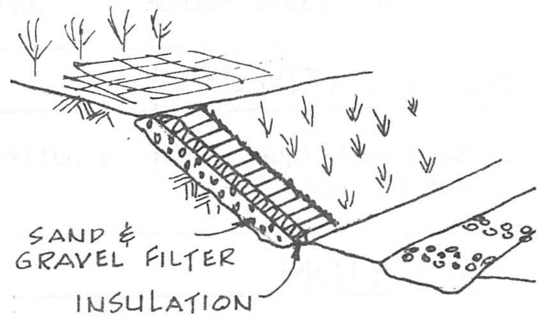




Filter Buttress

If the cut retreats excessively or refuses to stabilize, re-dress slope and place free-draining gravel filter material to insulate and stabilize the cut. The filter material can be placed at an angle steeper than natural repose to eventually settle to a stable repose. Place sediment filters along the toe to contain silts from melt flows. The buttress can be dressed with topsoil and revegetated.

Insulation and Revegetation

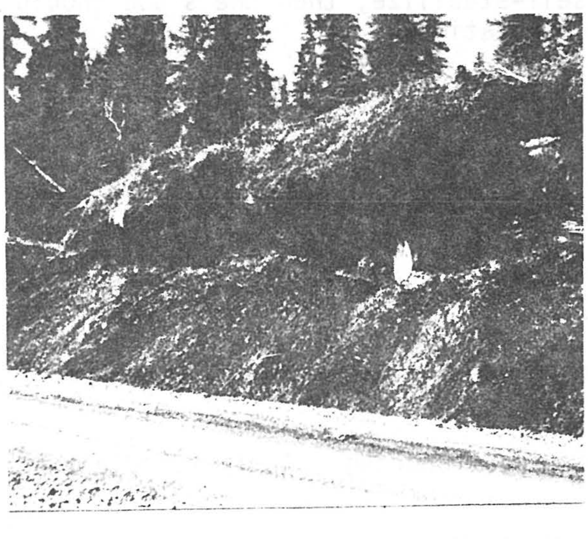


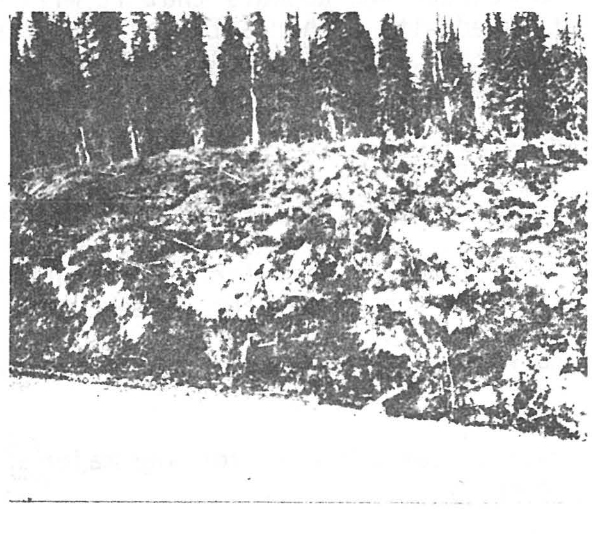
Dress slope to 2:1, overlay with 12" of free-draining sand or gravel.

Cover with urea foam insulation or other similar material.

The insulation can be covered with topsoil, mulched and revegetated.

In some cases, slopes can be simply treated with mulch, such as straw and netting and revegetated. Selection of the above techniques largely depends on the severity of the thermal degradation and resultant slope instability.





A vertical cut made in massive ice along the Yukon to Livengood Highway. Photo at left shows overhanging organic mat as slope retreats. At right, the slope has self-stabilized with new vegetative growth.

Source: R&M Consultants, Inc.

MAINTENANCE

All exposed cuts should be inspected periodically until self-stabilized. Sloughed and eroded materials should be removed from ditches or sediment traps. Remedial slope treatment should be performed promptly.

REFERENCE

1) Pufahl, D.E., Observations on Recent Highway Cuts in Permafrost. Gov't of Canada, March 1974. 2) Lotspeich, F.B., Environmental Guidelines for Road Construction in Alaska. Env. Prot. Agency. EPA-660/3-74-009. June 1974.

GROUP Icing Control

PRACTICE Specialized Drainage Structures

PURPOSE

To provide passage of winter or breakup flow. To avoid icing which encroaches on road surfaces or which blocks culverts and bridges and could result in damage to the structure or the embankment.

SITE CHARACTERISTICS

1. Icings can occur naturally or because of road construction. Natural icings are aggravated by presence of a roadway.

2. Some small streams develop icings only when exposed in the cleared road R-O-W.

3. The greater the thickness of organic ground cover, the greater the incidence of icings; very few develop in regions with no ground cover.

4. Most icings occur in hilly to mountainous terrain.

5. Water may pass upward through frozen soil or through ice along cracks, tree roots or trunks.

ADVANTAGES

1. Reduces or eliminates the need for periodic thawing. This especially helpful during breakup when demands on maintenance personnel are high.
2. Dual and oversize culverts, bridges improve fish passage over standard culverts.
3. Some techniques can prevent road surface icing.

DISADVANTAGES

1. Some increase in initial cost.
2. Dual, oversize culverts--require deeper fill and adequate storage space for ice accumulation.
3. Subsurface drains--must be designed so that outlets don't clog with ice, or outlets must be periodically opened with steam.

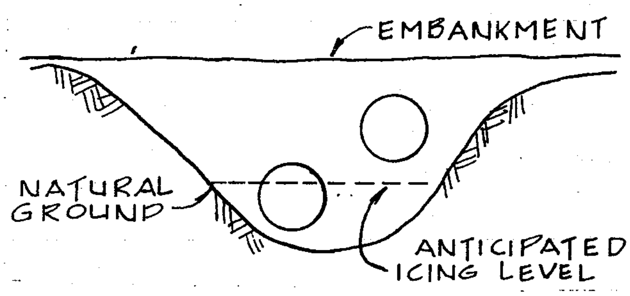
DESCRIPTION

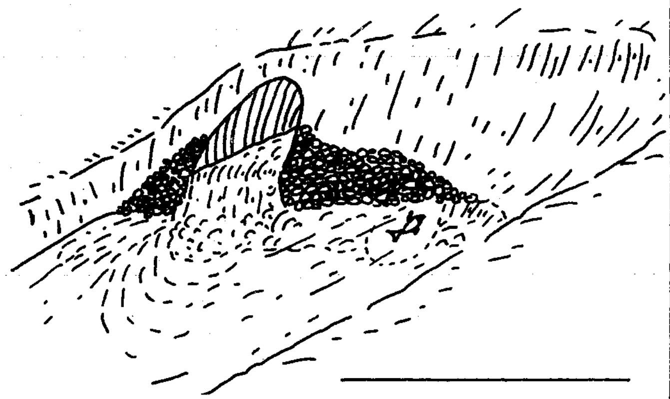
1. <u>Dual Culverts-Stacked</u>

A stacked culvert provides a relief route for meltwater at an ice-dammed culvert, eliminating the need for spring thawing. Requires a deep fill section and sufficient storage area for ice accumulated during winter, without plugging the upper culvert. Offsetting the upper culvert reduces the necessary depth of fill. In streams which experience wide fluctuations in flows, offset culverts can also assist in fish passage. (Lotspeich, 1974).

Use of oversize culverts or bridges can delay or prevent total blocking of the structure.

DESCRIPTION CONTINUED





2. Subsurface Drains

Stream flows - used where topography is steep enough to allow diversion of subsurface flow and exit downslope of structure or roadway. Pipes are placed upstream of the area of icing, across the stream to intercept sub-bed flow and allow filtration of low stream flow. Within the stream channel the trench should be backfilled with coarse material to allow infiltration. Outside of channel banks, insulation should be placed over subdrain backfill.

The subdrain is for low flows only, and should not be used to replace the conventional drainage structure at the roadway.

Road Icing from Ground Seepage - Subsurface drains can be used to: 1) reduce artesian head at the roadside beneath seasonal ice; 2) intercept surface flows. For a subdrain to function surface flows must be intercepted at the source, since icing layer is impermeable, and must be buried below maximum freezing depth. Outlets are downslope from the road embankment.

Subdrain outlets must be designed so they will not freeze or so they can be periodically thawed.

3. Channel Re-alignment - Straightening and deepening channels can increase flow velocity and therefore decrease surface icing.

However:

- It is usually a temporary solution only. The channel may need to be reconstructed fairly often. Channel straightening usually causes instability upstream and/or downstream from the new channel. Chronic maintenance and erosion problems could thereby be created;

- Channelization and any associated chronic erosion/sedimentation problems are destructive of aquatic habitat.

DESCRIPTION CONTINUED

4. Channel Covers

C.R.R.E.L. reports in reference 1 that channel covers are an "unproven technique of limited applicability." Use should be limited to well defined channels of limited surface area. Seepage from banks should be negligible. The purpose of the covers is to accumulate snow and provide insulation. Insulation is frequently insufficient. Covers may be of any material that will hold snow including brush, tar paper, scrap sheet metal, plastic sheets, plywood, burlap, spruce trees. Materials are best suited which provide best insulating effect. Canvas has been used to cover open ends of the structures. If contact is allowed with the ice surface the canvas can act as an ice fence, and could aggravate icing conditions. Any use should follow intensive site study. Channel covers may be useful in combination with other methods such as heat cables (See 8.B).

Locations of highest heat loss of a culvert are at the culvert ends. A variety of materials are used to reduce air flow through culverts and to cover exposed metal at culvert ends. Materials include brush, snow, tar paper. Care must be taken to prevent formation of an ice fence. (See 8.C.)

MAINTENANCE

Drainage structures should be periodically inspected. Proper design of dual and oversize culverts, and subdrains should reduce or eliminate the need for culvert thawing.

REFERENCE

1) Carey, K.L. Prevention and Control of Culvert Icing. U.S. Army C.R.R.E.L. April 1975. 2) Johnson E.G., Esch, D.C. Investigation and Analysis of the Paxton Roadway Icing. 1977. In: Proceedings, 2nd Intl. Symp. on Cold Regions Engineering Fairbanks. Dept. of Civil Engineering Univ. of Alaska, Fairbanks. Aug. 1976.

GROUP Icing Control

PRACTICE Culvert Thawing

PURPOSE

To maintain winter flow or provide an opening for passage of spring meltwater.

SITE CHARACTERISTICS

Suitable for any culverts or small bridges subject to plugging by icing.

ADVANTAGES

1. Technique not limited by expanse of icing.
2. Thaw cables - can be used either to keep open throughout winter or to open before spring.
3. Thaw cables - for maintaining opening throughout winter. More environmentally acceptable than fire pots and should require less maintenance.

DISADVANTAGES

1. Thaw cables: It may be difficult to intercept icing feedwater.
2. Thaw cables: Are limited to locations where electrical power is available.
3. Fire Pots - require continual maintenance.
4. Fire Pots - have high potential for spills into streams.

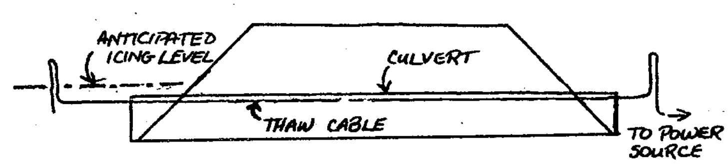
DESCRIPTION

1. Thaw Cables

Most efficient use of electrical heat cables is to maintain a small open passageway through a culvert at low power levels. When roadway surface will not be threatened with icing, they can also be used to open and keep opened a plugged culvert in spring.

Culvert ends require more heat than the center portion to maintain opening. This can be most easily accomplished by doubling back, or tripling the cable (maintain manufacturer's bending radius).

A vertical riser (see figure) can help keep ends open. Operation is most economical when the cable length is short, with risers at the culvert openings. But to collect surface feedwater the riser must be placed at the low point in the icing. If the riser is not well placed, icing will not be prevented, but there will be an escape route for spring meltwater.



DESCRIPTION CONTINUED

Cables are either buried a few inches (3-5") below the culvert and below the streambed at each end, or suspended inside the culvert.

Power source is usually a nearby service pole with a transformer, but a truck-mounted generator may be used for spring thawing.

Specific engineering criteria must be developed for each site. Ice fences or other methods in this section may be used in combination with thaw cables.

This is one of the more environmentally acceptable procedures.

2. Steam Thawing

Steam is used to open ice blocked culverts. Usually done in winter when icing threatens roadway or in spring where winter flow need not be maintained. The method is suitable for any ice blocked culvert accessible to truck mounted boiler. Thawing can be done by probe or permanent piping may be installed. The process is less expensive than thaw cables, but usually must be done more than once.

3. Fire Pots

Unless fuel flow can be automatically and reliably shut off if the flame dies, fire pots should not be used.

A fire pot consists of a large drum holding a fire of fuel oil (or some mixture of liquid fuels) or coal placed at culvert entrance to keep it thawed.

Spills during operation or refilling can have harmful effects on overwintering fish.

Fire pots require continual maintenance to be sure oil is not reaching the stream -- their design requires fuel storage near running water.

These have usually been gravity feed systems. If the flame goes out fuel continues to flow -- into the stream.

The Alaska Railroad uses coal or charcoal fired burners with reported success (1).

MAINTENANCE

Culvert thawing is essentially a maintenance activity. All culverts should be inspected periodically throughout the year.

REFERENCE

1) Carey, K.L. Prevention and Control of Culvert Icing U.S. Army C.R.R.E.L. April, 1975.

GROUP	Icing Control
PRACTICE	Channel Maintenance

PURPOSE

To maintain winter flow, or induce icing at some location which will not require maintenance.

SITE CONDITIONS

Suitable for any small-to-medium size channel at culverts or bridge openings.

ADVANTAGES

1. Frost dam, air ice covers: no material removal is required in spring.
2. Ease of construction.
3. Ice Fence: timing less critical.

DISADVANTAGES

1. Frost dam, air ice covers may become ineffective after warm spell.
2. Frost dam, air ice covers: timing of construction is critical.
3. Ice Fence requires removal in spring.

DESCRIPTION

1. Frost Belts

Constructed by excavating a ditch in the ice 10' - 12' wide to the streambed. The ditch progresses downward as the ice below the ditch thickens. A drainage ditch may be required to remove accumulated water downstream. Frost belts must extend well beyond the stream edges. Extension ditches on the banks may be excavated before freeze up at the selected site, which should be between 600 and 900 feet from the structure. Additional dams should be at least 60 feet apart. Frost belts are best constructed where stream ice usually freezes solid to the bed, as in shallows or near rapids.

2. Air-Ice Covers

This method is essentially the same for all situations where it is used. The intent is to create an insulating layer of air under an ice cover by temporarily damming the stream early in the season and allowing the water to back up through the culvert. The dam is placed a short distance downstream from the culvert and should retain a degree of permeability. After allowing the ice cover to freeze to a 5 or 6 inch thickness, the dam is removed. With the free flow restored, the water level drops so that an 8 to 15 inch air gap remains. The intervening layer of air is generally sufficient to prevent freezing of the flowing water. Extra snow, peat, branches and other available materials may be placed over the ice layer for further insulation. Insulation material must be removed in the spring.

DESCRIPTION CONTINUED

Additional protection is afforded by planting shrubbery along the banks to retain snow over the stream for additional natural insulation. Where a broad channel is encountered, support for the ice cover may be provided in the form of short wooden or concrete posts acting as columns placed before the pond is formed. At a large icing site, several temporary check dams may be required. Spacing should be 150-200'.

3. Ice Fence

Ice Fences are used to store ice accumulation upstream from culverts or bridges.

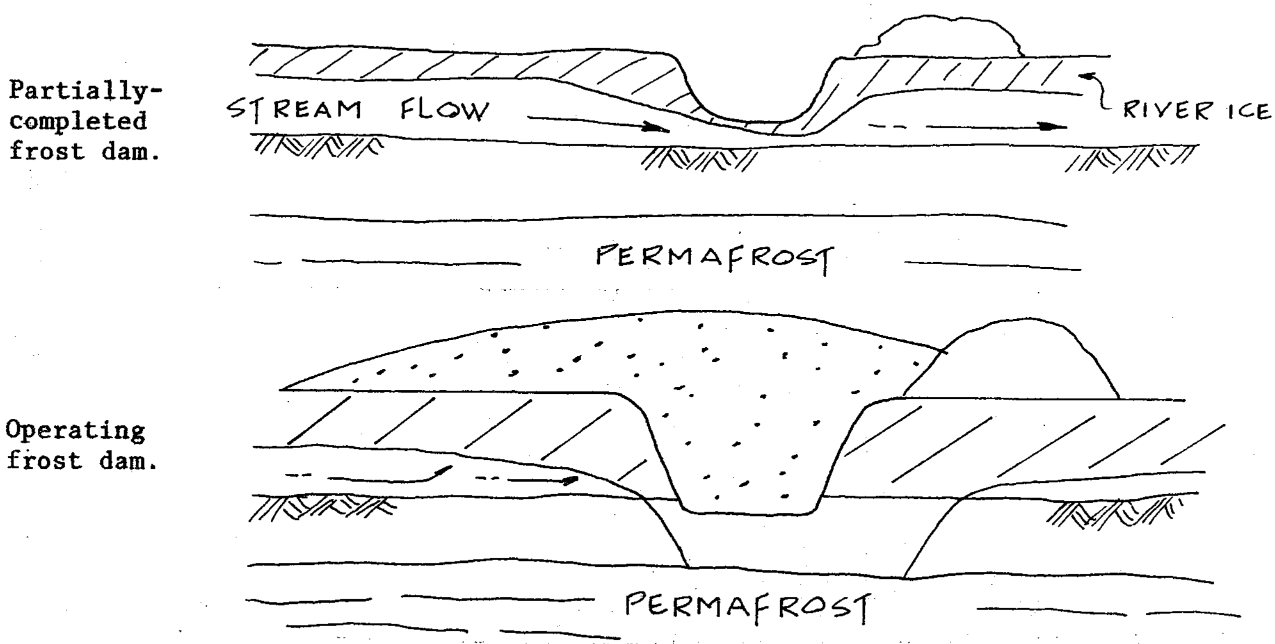
Icing feedwater sources must be upstream of the fence. If avenues open below the fence for water to pass upward through the ice, the fence will be ineffective.

Upstream storage space must be adequate for a winter's accumulation.

May be combined with other measures. With thaw cables fences may help move the lowest point of icing nearer the culvert inlet so a shorter (more economical) cable can be used to intercept surface feedwater.

A wide variety of materials can be used: snow, plastic, canvas, burlap, boards, brush, galvanized sheet metal, tar paper, wire faced with paper, etc.

EXAMPLE



REFERENCE

Ice Fences

1) Carey, K. L. Prevention and Control of Culvert Icing. U.S. Army C.R.R.E.L. Special Rpt. 224. April 1975.

GROUP
Final Restoration

PRACTICE
"Putting to Bed"

PURPOSE

To leave areas used during construction, which are to be no longer used or maintained, in a stable condition.

SITE CHARACTERISTICS

For any location where intended use is complete, and for those to remain unused for extended periods. Includes areas such as unused portions of R-O-W, haul roads, borrow and disposal sites, campsites, storage yards and others.

ADVANTAGES

1. Elimination of maintenance costs for unused facilities.
2. Stabilization against erosion and sedimentation.

DISADVANTAGES

1. Additional cost if facilities or structures are removed.

DESCRIPTION

All slopes should receive appropriate treatment for stabilization. Provisions should be made for access blocks to prevent use of these facilities by unauthorized persons. It should be stressed that all restoration activities should be complete and adequate. It can be extremely expensive to return to the site, particularly in remote areas, to repair that which could have been avoided.

1. Slopes, borrow areas and waste materials should be graded to stable conditions (normally 2:1 or flatter depending on soils) and provisions made for permanent drainage.

2. All open culverts should be removed and sufficient cross-road drainages provided to accommodate runoff at breakup. Culverts in natural drainages should be removed, as their inlets gather debris and gradually plug, resulting in washout over the road. For all streams used as fish habitat, fill material should be removed down to the original stream contour to prevent sediment problems and blockage from icing.

3. Roadways should be shaped to drain by crowning or outsloping. Water bars, checks or other measures should be installed.

4. Disturbed bare areas should be seeded with grass, legumes and/or planted with woody plants and fertilized as necessary (Section 5) with N-P-K mixture, following recommendations in reference 1, to insure initial quick growth to protect bare soil.

DESCRIPTION CONTINUED

5. Install access blocks such as berms or ditches to prevent access and damage to stabilized areas by unauthorized vehicles.

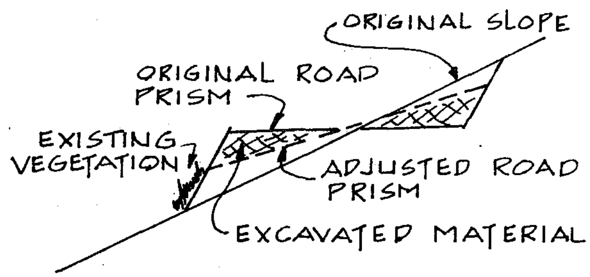
6. Petroleum products, containers, and abandoned equipment should be removed from landings, service areas, and roadsides before the roads are put to bed.

7. On old haul roads and main skidtrails, special attention should be paid to cross draining at points just above steep sections and to the erodibility of the soil.

8. Vegetative debris is usable to stabilize sections likely to erode after abandonment.

One technique suggested in Reference 2 for logging roads, called a "Kaniksu Closure," may be applicable for improving drainage of haul and others which will be reopened at some future date. This technique may have some limitation in high precipitation areas, on surfaced roads and for some soil types. It can be effective to keep traffic off the road. At a future date, the excavated material can be pulled back by an angle blade and reshaped for use.

'KANIKSU CLOSURE'



MAINTENANCE

Restored areas should be inspected periodically until stable and appropriate action is taken.

REFERENCE

1) Alaska Rural Development Council. A Revegetative Guide for Alaska. University of Alaska Cooperative Extension Service. No. 2, P-238. 1977.
2) Environmental Protection Agency. Logging Roads and Protection of Water Quality. EPA 910/9-75-007. March 1975. 3) Lotspeich, F. Environmental Guidelines for Development Roads in the Subarctic. Environmental Protection Agency. EPA 660/3-74-009. June 1974.

GROUP Miscellaneous

PRACTICE Tracking Control

PURPOSE

To prevent tracking sediment from construction areas onto public right-of-way by vehicles or runoff.

SITE CHARACTERISTICS

At points of egress from construction areas (such as haul roads, borrow and disposal areas) where mud-laden vehicles may travel onto public roads, parking lots and private property.

ADVANTAGES

1. Prevents sediment problems in storm drain systems and natural streams.
2. Reduces safety hazard on public roads which can become slick from mud from equipment.

DISADVANTAGES

1. Minor inconvenience for construction equipment.
2. Clean gravel may not always be available.

DESCRIPTION

Construction traffic, such as dump trucks, delivery trucks and others can carry significant amounts of sediment from construction sites, particularly during wet-weather periods. The following is adopted from the Anchorage Management Plan cited in Reference 1 below.

Construction of Stabilized Crushed Aggregate "Wash-Strips" At Entrances to Construction Sites. The purpose of a stabilized construction entrance is to reduce or eliminate soil-tracking or flowing of sediment onto paved streets. This applies to all points of construction ingress and egress in urban areas, and in suburban areas where 60% of the streets are paved, where storm drains are directly involved, or in any location where tracked sediment would reach streams.

Stone size - Crushed only, AASHTO M43, Size No. 2 (2 1/2 to 1 1/2")

Thickness - Minimum 6"
Width - Minimum full width of driveway
Length - Minimum 50'

DESCRIPTION CONTINUED

The entrance shall be maintained in a condition which will prevent soil-tracking onto paved roads. This may require periodic maintenance by adding layers of crushed stone or washing by water. A sediment trap as outlined under sedimentation should be provided and periodically repaired and cleaned. All sediment tracked, spilled, or washed onto paved streets must be removed immediately. When necessary, wheels must be cleaned to remove sediment prior to entrance onto paved public roads. When washing is required, it shall be done on an area stabilized with crushed stone which drains into an approved sediment trap or sediment basin. All sediment shall be prevented from entering any storm drain, ditch, or watercourse through the use of sand bags, gravel berms, boards or other effective methods. (See Section 3.)

MAINTENANCE

The above is a maintenance activity.

REFERENCE

1) Municipality of Anchorage. Soil Erosion and Sediment Control, 208 Areawide Waste Treatment Management Plan. September, 1977. 2) County of Fairfax, Va. Erosion and Sediment Control Handbook. Dec. 1974. 3) Tourbier, J. Water Resources Protection Measures in Land Development. Water Resources Center, Univ. of Delaware. Apr. 1974.

GROUP Miscellaneous

PRACTICE Wind Erosion and Dust Control

PURPOSE

Control of surface and wind movement of dust on construction sites and traffic surfaces.

SITE CHARACTERISTICS

Any areas subject to wind erosion of exposed surfaces or dust generated by vehicles, where eroded materials can cause on-and off-site damage without treatment.

ADVANTAGES

1. Improves visibility, safety and health on site.
2. Prevents sedimentation of nearby water courses.
3. Temporary or permanent control is provided.

DISADVANTAGES

1. Certain materials may be toxic to plants or animals.

DESCRIPTION

TEMPORARY METHODS - for areas still under construction, the following techniques can be used:

1. Mulches - material such as straw, wood chips, soil binders and others described in 5.B. can provide quick cover.
2. Vegetation Cover - quick growing annual grasses (See 5.A.) can be employed if an area is to be left exposed for a period of time.
3. Scarification - as discussed in 1.B., surface roughening can be used as an emergency measure before wind erosion starts. The idea is to bring clods to the surface which will not erode. Plows or harrows can be used.
4. Irrigation - another 'emergency' type technique is to simply spray the site with water. Must be repeated to remain effective.
5. Spray-on Adhesives - a number of chemicals, asphalt emulsions and other materials have been used. Consult current regulations for each material as many can be toxic.
6. Barriers - vertical barriers, such as solid board fences, snow fences, burlap fences and hay bales can control air currents and wind erosion. Generally effective if placed at right angles to prevailing winds and spaced at intervals of approximately 15 times the height of the barrier.

DESCRIPTION CONTINUED

PERMANENT METHODS

1. Vegetation - permanent seeding or sodding (See 5.A.) and mulching (5.B.) after construction is completed. Existing trees and shrubs, if left in place, offer effective protection also.
2. Topsoiling - this means covering the surface with a less erodible soil. Other methods may be preferred.
3. Aggregate Cover - the surface can be covered with crushed stone or gravel. Can be expensive so is mainly applicable to small areas.

MAINTENANCE

Surfaces should be retreated as necessary.

REFERENCE

1) Fairfax County, Virginia. Erosion Sediment Control Handbook. 1974.