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Environmental Design for Northern Road Developments

Environmental Impact and Assessment Report EPS 8-EC-76-3

Environmental Impact Control Directorate

ENVIRONMENTAL DESIGN
FOR
NORTHERN ROAD DEVELOPMENTS

by

H. J. BRIAN CURRAN P. ENG.

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H. M. ETTER*, PH.D., P.AG.

ENVIRONMENTAL PROTECTION SERVICE
NORTHWEST REGION
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* Present Address: Thurber Consultants Limited, 1623 McKenzie Avenue, Victoria, British Columbia.

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ABSTRACT

This report recommends environmental protection measures to minimize adverse effects on the environment from northern road developments. The measures presented are based on experience gained in the environmental review of the Mackenzie Highway and proposed Mackenzie Valley Pipeline projects and on the advice of environmental and engineering experts.

The road development process is presented in six sequential phases: preliminary route selection, the environmental survey, the alignment selection and route field survey, design, construction and finally, maintenance. In the initial phases of development the participation of those responsible for environmental protection is emphasized. In the latter phases specific measures for environmental protection are given for individual highway activities.

RÉSUMÉ

Ce rapport recommende une série de mesures destinées à protéger l'environnement contre les effets causés par la construction de voies routiéres dans le nord du Canada. Ces recommendations sont basées sur l'expérience acquise lors de l'examen environnemental de la voie routière du Mackenzie et du pipeline proposé pour le bassin du Mackenzie, ainsi que sur l'avis d'experts de l'environnement et des ponts et chaussées.

La méthode de développement de la voie routière est réduite à six opérations constructives: choix préliminaire de la route à suivre, étude environnementale, alignement final, levée de plans, construction et finalement l'entretien. La nécessité de la participation de gens responsable de la protection de l'environnement pendant les phases initiales est soulignée. Des mesures spécifiques de protection de l'environnement sont proposées pour les opérations finales de la construction.

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INTRODUCTION

There is a general concern today that efforts must be made to maintain and enhance the quality of our environment. Many individuals have a certain skepticism however, in accepting the need for environmental protection measures. This is especially true if past projects have never been assessed as to their environmental impact. New stipulations which regulate hitherto unrestricted actions often meet with opposition and are considered intrusions from outside agencies.

Road development in Canada has seldom been scrutinized for adverse effects on the environment. This holds for northern roads as well. In recent years, however, large-scale development plans have been unveiled for the north with attention being focused not only on the economic costs and benefits but also on the environmental effects of these projects.

Northern roads have been built and will continue to be built for some time principally to support resource development. But there are other uses that occur from the construction of these roads. Northern residents benefit by obtaining an additional mode of transportation. The hardier tourists gain access to relatively unspoiled wilderness areas. Even though a highway may be developed for one prime objective, it ultimately has several uses.

Although there is no environmental control legislation pertaining specifically to highway development, legislation does exist which covers certain aspects of its effects. The Fisheries Act has a relevancy to highway development in requiring that fishways be constructed, where necessary, around obstructions in streams; that one third of the width of any stream always be left open; that eggs or fish fry on spawning grounds not be destroyed; and, that there be no deposit of deleterious substances into water frequented by fish. The Northern Inland Waters Act requires that an application be made to obtain authorization to use water in the Yukon and Northwest Territories. It is encumbent upon the applicant to demonstrate to the appropriate Territorial Water Board that the proposed use of the water will not adversely affect a watercourse. The Territorial Lands Act and Land-Use Regulations set general and specific regulations for land-use operations in both Territories. The Migratory Birds Convention Act gives provision for the establishment of regulations to protect migratory birds and their nesting areas. Finally, the Federal Government has instituted a policy that requires all federally-funded projects to be screened, before they commence, for potentially adverse environmental effects. Environmental design, monitoring and surveillance are also important steps in this review function.

Aside from the legislative requirements, conditions in the north require special consideration in highway design and construction. There are limitations imposed by the extreme climatic conditions and by soils containing permafrost. Terrain and water relationships are in sensitive equilibrium and can be easily unbalanced. Terrain restoration after disturbance is slow; biomass productivity is low. Despite the fact that there are areas in the North which support little wildlife, certain areas do contain high densities of animals and unique habitats. Major watercourses contain generally productive fisheries. Vast areas are virtually undeveloped and culturally unaffected by large-scale developments.

There is a definite need to see that the north retains its character and uniqueness. However, controls to ensure environmental protection must be developed in a scientific rather than emotional

manner. Sensitive areas where development should be prevented or closely scrutinized must be determined and categorized. Acceptable levels of disturbance must be defined and appropriate environmental protection measures clearly explained.

For their part, the highway developer must design and construct a road for multi-purpose use. With the exception of some private roads, highway developments are funded by government agencies. It follows, therefore, that wherever possible, all segments of the population should derive some benefit from the road. Although resource developers will be the prime users of most highways in the north for the foreseeable future, some consideration must be given to their use by the northern residents and tourists. Finally, consideration must be given to the general citizen who will eventually benefit materially from northern development but who desires that wilderness areas be protected and remain a heritage for future generations.

This report is presented in a guidelines format. It is intended to create an awareness on the part of road builders and designers of ways and means to minimize the effects of road developments on the natural environment; to identify potential environmental hazards that must be considered, and the consequences if they are not; and to suggest methods that can be employed to avoid or minimize environmental disturbances.

The recommendations contained in this report are based on recommendations made during the environmental review of the Mackenzie Highway, on results of studies carried out to assess the environmental impact of the Mackenzie Valley Highway and Pipeline, on field observations of current highway construction practices, and on advice from environmental and engineering experts.

1. PHASE I PRELIMINARY ROUTE SELECTION

1.1 Selecting a Corridor

Function, economics, environmental quality and aesthetics are the main factors to be considered in selecting a preliminary highway route. While function and economics are the primary concerns of the highway engineer, some thought must also be given to the environment and aesthetic considerations, not only because they relate to economics, but because they are important in themselves. A multi-disciplinary approach is required to ensure that these factors are included in their proper perspective during corridor selection.

Consultation with local people and govenment agencies concerned with the land-use potential of the areas along possible highway corridors is required so that adequate consideration can be given to long-term use of the highway and related facilities before its overall function and standard are decided upon.

Officials responsible for environmental protection should be consulted at this stage so that known or suspected critical environmental factors can be identified and studied, and areas which could require special environmental protection measures can be delineated. Knowing the nature of these constraints, a better decision can be made as to the location of the corridor.

1.2 Selecting a Right-of-Way

Each area within a corridor will have its own unique terrain, habitats and biological systems. It is essential that those involved in route selection assess all available data on the environmental, geotechnical and hydrological characteristics of the highway corridor. Careful consideration of all factors in route selection will ultimately save time and effort in the subsequent highway development phases.

To minimize terrain disturbance extensive muskeg areas such as unfrozen peatlands should be avoided, where practical, because of the poor drainage and low bearing capacity of peat soils. If the road runs along a contour, cross-drainage and groundwater seepage areas often produce icing and surface water problems. If these areas cannot be avoided, special design or maintenance measures will have to be taken to protect the highway.

The presence of permafrost in soils demands special considerations. In the warmer regions of the discontinuous zones, sporadic areas of permafrost can possibly be avoided. In the colder reaches of the discontinuous zones and throughout the continuous zone the properties of permafrost must be accommodated. Ice-rich soils indicated by thermokarst terrain and patterned ground (Fig. 1 and 2) however, should be avoided wherever they are encountered unless it is known that the highway will not degrade the permafrost.

To minimize the need for deep cuts and the possible occurrence of slumping and excessive icing, the right-of-way should avoid steep gradients. Areas selected for borrow should contain soils that are believed to be ice free and not susceptible to excessive frost action (Fig. 3).

To minimize disturbance to significant watercourses, no part of the highway system should pass within 300 feet of a high-water mark. Streams should not be parallelled before being crossed. Nor should crossings be considered where actively eroding banks are evident or suspected (Fig. 4). Material should not be considered for borrow if it is located in an active flood plain, on a lake shore or in stream channel. Where natural barriers to fish passage such as waterfalls exist, the route should cross up-stream of the barrier where fish passage would not be affected by bridge or culvert installations. Where spawning grounds are concerned, crossings should be downstream of these areas to avoid their disturbance and possible sedimentation.

A 457.2 metre (1,500 foot) buffer zone should be maintained between the highway system and a designated critical wildlife habitat, an established or potential recreational area, or the boundary of a biological reserve.

Before proceeding to Phase II of the development, the following should have been accomplished:

1) A concensus on the long-term function and required standards for the highway.
2) General identification of the nature and location of materials for construction.
3) Identification of environmentally critical areas which prohibit highway development and selection of routes that avoid them.

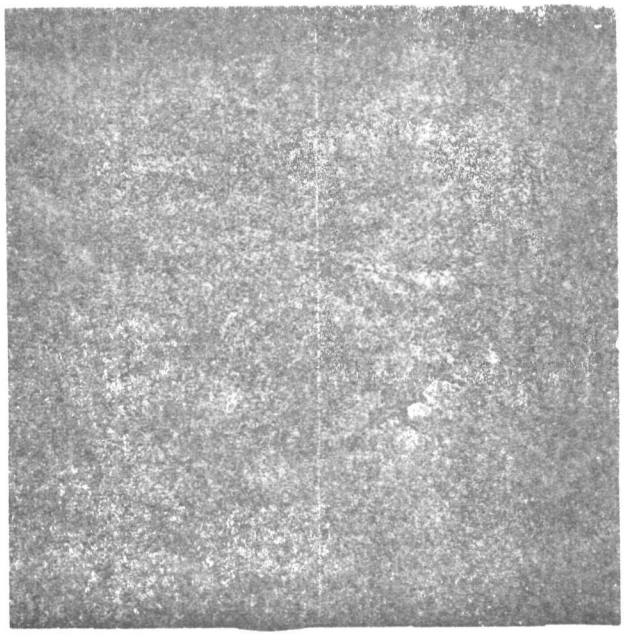

Fig. 1 Patterned ground surface, characteristics of ice-rich, organic soils.

Fig. 2 Thermokarst lakes with actively eroding lake shores. Note trees inclining into lake.

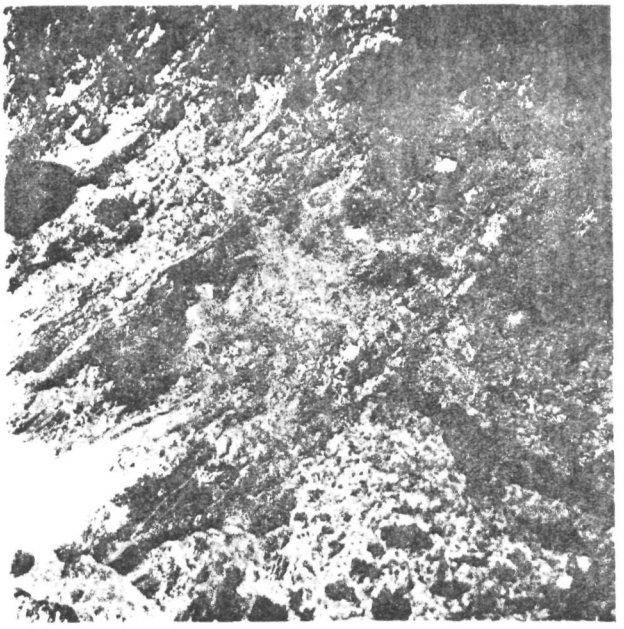

Fig. 3 Massive ground ice in fine grain soil unexpectedly exposed in a borrow pit. The vein of ice is 1.8 metres (6 feet thick) vertically. Melt from overlying soil has allowed a thin coating of fluid silt to flow over the ice and partially obscure it.

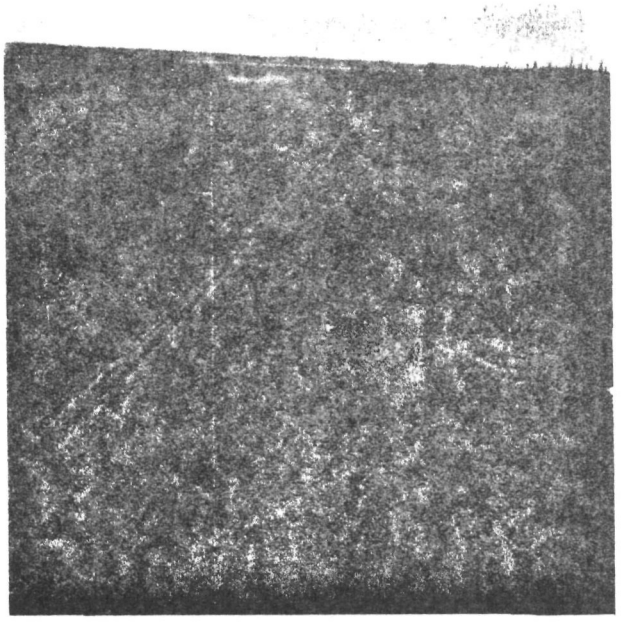

Fig. 4 Road located too close to actively eroding stream bank. Highway relocation or stabilization of stream bank may ultimately be required.

4) An awareness of the protection measures required in traversing environmentally sensitive areas.

5) Selection of tentative alternate alignments connecting terminal points in a given corridor.

Careful planning, close communication among all interested groups and adequate lead time for proper consideration of environmental factors involved in route selection will pay dividends in the subsequent phases of development and throughout the life of the highway.

2. PHASE II THE ENVIRONMENTAL SURVEY OF THE PROPOSED ROUTE

2.1 Objectives

All proposed highway routes should be surveyed to verify decisions made in Phase I and to gather the environmental base-line data needed for final route selection and preliminary design. The survey should include an analysis of available information and advice on wildlife, fisheries, archeology, recreation potential and terrain that would be affected by the highway.

Objectives of the survey would be to make observations and collect sufficient data to identify sensitive areas along alternate right-of-ways and rate them according to their susceptibility to disturbance. The survey should also identify the nature of controls that will be required to minimize adverse effects if a sensitive area must be traversed. To attain these objectives, the survey team should be multi-disciplinary in skills and training and their efforts should be coordinated with preliminary engineering studies. Capability of assessing terrain, wildlife, fisheries, vegetation, and recreational potential would be basic, and an ability to conduct archeological, historical, aesthetic and landscape investigations would be valuable in the survey.

2.2 Terrain

The terrain sensitivity study would primarily verify assumptions made in preliminary route selections that were based on air-photo interpretation. This study would also investigate route alternatives that would avoid sensitive and critical biological areas, important historic sites, or take advantage of scenic landscapes. Shallow excavations would be made to visually classify surficial soils and determine the thickness of insulating mats in permafrost areas. The thickness of the active layer would also be determined and estimates made of the apparent stability of stream banks and natural slopes.

2.3 Fisheries

Watercourses to be crossed or approached by the highway should be rated as to sensitivity to disturbance according to such criteria as spawning potential; fish type, abundance and distribution; rearing and over-wintering areas; migration patterns; and resiliency of the populations to siltation or altered stream velocities. Significant locations such as spawning, rearing or overwintering areas should be noted, as should species life-history aspects which might be considered atypical. The impact on fisheries due to increased fishing pressure would be estimated, and the importance to the welfare of local communities of domestic and sport fishing would also be determined wherever appropriate.

Fishery protection measures appropriate to each stream should be stipulated for fish passage, stream bed protection, siltation control, and scheduling of construction. Locations for continual monitoring and surveillance could be identified.

2.4 Wildlife

Wildlife investigations should determine the patterns and seasonal ranges of migratory animals such as caribou; prime moose habitats and wintering ranges; waterfowl nesting, rearing and staging areas; denning sites for bears; locations of rare and endangered species; and, the distribution of economically important fur-bearing animals such as muskrat and beaver. As in the fisheries studies, the effect of increased accessibility to hunting or trapping areas on the economy of the local communities should be evaluated.

The results of wildlife investigations should provide the basis for identifying the extent of critical and sensitive wildlife areas. Changes to the preliminary route alignment can be suggested to avoid critical areas, and protection measures required in the sensitive areas can be stated.

NOTE: THE NEED FOR EXTENSIVE ROUTE ADJUSTMENTS AND COSTLY CONTROL MEASURES MUST BE SUPPORTED BY FACTUAL DATA.

Although these studies are primarily required to assess and minimize the impact of the highway, they will have a significant secondary benefit by providing valuable information for wildlife and fisheries management in the area after the highway has been built.

2.5 Conduct of Field Crews

In carrying out the environmental survey, activities of the field parties should be planned with care to avoid minor environmental disturbances. Tracked vehicles should not be used where the terrain is obviously susceptible to thermal erosion (Fig. 5). Stream crossings by vehicles and equipment should be kept to a minimum. Although the survey camps would not be large, human refuse and faecal wastes should be buried as a general sanitation measure and to avoid attracting wildlife.

2.6 Results

The environmental survey should produce a factual estimate of the fisheries and wildlife resources in the area affected by highway development as well as their existing and potential use. Areas of special concern should be delineated on topographic maps and designated as to sensitivity. Archeological and potential recreation sites as well as areas of visual quality would also be shown.

After the first two phases of the highway development process have been completed the area along the route corridor should be completely classified as to probable terrain sensitivity and wildlife and fisheries importance. The engineering survey can now be undertaken knowing what areas must be avoided and the special requirements for sensitive locations.

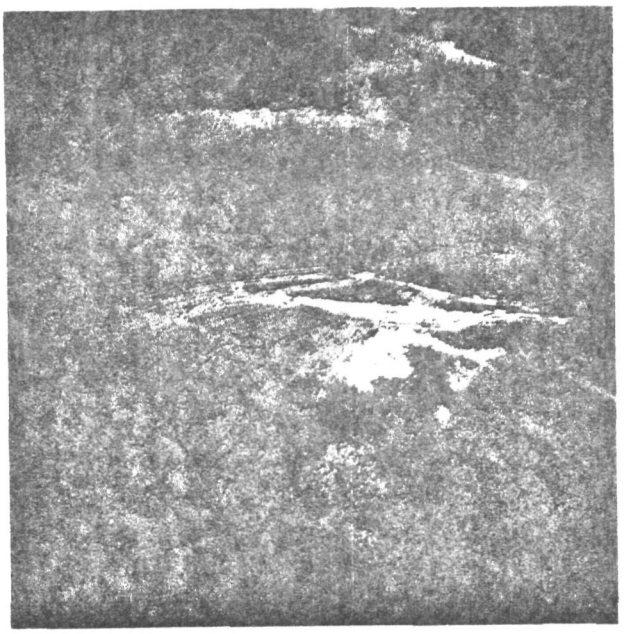

Fig. 5 Track imprints from terrain vehicles in surface of permafrost soils.

Fig. 6 The road at this site dammed the subsurface flow. The water pressure raised the entire frozen vegetation mat in the area. When the surface was punctured the mat collapsed stripping the trees as a result. Piles in background are of stripped trees.

3. PHASE III ALIGNMENT SELECTION AND SURVEY

The objectives of this phase are to identify the best possible alignment and collect data required for design of the highway. Route selection is basically an iterative process with promising sections reconnoitred and geotechnical sampling carried out. Alignments which may prove troublesome from an engineering viewpoint are abandoned and alternate routes investigated.

Although the intuition and experience of the highway designer are important and indeed essential attributes, they are no substitutes for factual information. The more complete the survey, the more sound the design. Design based largely upon "guesstimates" may result in construction and maintenance difficulties. Expenditures incurred for a thorough survey will be well spent, reducing the likelihood of unforseen problems arising in construction and during the long-term highway maintenance operations.

The field survey follows the routes previously selected in the preceding development phases. The location engineer in charge of the survey has at his disposal geologic and topographic maps, air photos of the route and the interpretation of the photos by those who selected the preliminary route. Information collected in the environmental survey must also be consulted at this time.

Methods employed in the field survey to collect required data for design and to select the final route include, in addition to air-photo and map interpretation, ground reconnaissance, transit and level surveys of the centreline profile and alignment cross sections, geotechnical and hydrological surveys.

3.1 Ground Reconnaissance

3.1.1 ***Terrain.*** The accuracy of all information obtained from air photo interpretation must be confirmed by ground reconnaissance. In undertaking this reconnaissance an awareness of the relationships which exist in the elements of terrain must be possessed; an understanding of the function of vegetation in relation to erosion, wildlife habitat and aesthetics is vital.

Vegetation is not only a habitat component, it provides protection to the soil against wind and water erosion and modulates the heat transfer between the air and subsoil. Removal of the vegetation mat from soils containing permafrost, changes the thermal regime and may cause the permafrost to melt.

Terrain and vegetation in the north are in a state of dynamic equilibrium under natural conditions Plant growth is slow in the arctic and sub-arctic environment, and establishment after disturbance is often a slow process. Natural vegetation re-established immediately after disturbance is usually a poor insulator by comparison to the organic mats that originally covered the soil and does little to dampen geothermal fluctuations (7). These factors must be taken into account in assessing areas where cut and fill sections are anticipated in potentially ice-rich soils.

In evaluating the terrain, consideration must be given to areas that are susceptible to ground icing. Ground icing will occur where groundwater, forced to the surface by an underlying impermeable

stratum, forms seasonal or perennial seepages (31). Road embankments may promote icing in areas where there is no evidence of previous occurrence. This will happen in the colder areas of the permafrost zones if the fill compresses the vegetation, reducing its insulating character and allowing the permafrost to aggrade into the embankment. The subsurface flow is obstructed by the frozen impermeable barrier beneath the roadway, and water is forced to the surface. When seasonal frost penetrates the saturated portion of the active layer, water may be expelled to the surface where it will freeze in layers (Fig. 6). The buildup will continue until the saturated zone becomes completely frozen.

3.1.2 ***Landscape.*** The ground reconnaissance is perhaps the best means of evaluating landscape features for their scenic value. Aesthetic considerations should not be left to chance. "Beauty along the road must be deliberately sought. It seldom comes by accident."(22).

Incorporation of prime natural features in the development of the road will reduce driving monotony and increase the scenic value of the route. Landscape architects suggest that natural features should not be avoided as if they were obstructions. The alignment should begin to curve before such features come into view.

Panoramic views over broad expanses of landscape are most enjoyable driving pleasures. Sites should be selected along such stretches for view points as a first step in planning secondary facilities along the route.

Locating the alignment to skirt open areas of muskeg or to view the expanse of lakes would add to scenic enjoyment and reduce driver fatique (23). Long horizontal radius curves combined with gentle vertical curves are preferable to short curves with long tangents (3) (4) (Fig. 7). However, unnecessarily close approaches to sensitive areas should not occur.

Taking advantage of the natural scenic qualities of the landscape is usually not without additional cost to the construction of the highway. In deciding what expenses are justified, the function of the road, both immediate and long term, must be considered. In addition, driver safety and environmental protection must always supercede aesthetic considerations.

3.1.3 ***Watercourses.*** Particular attention must be given to the infringement of the highway on watercourses. The environmental survey will have designated these areas and provision should be made to ensure that no highway activities, except for stream crossings, encroach within 91.4 metres (300 feet) of the high-water mark of a lake, stream, river or productive marsh. This requirement forces the alignment onto higher and drier sites in many cases.

Where crossings are being contemplated, stream banks must be extensively inspected for tendencies to failure. Dendrochronological investigations, i.e. the use of tree ring data to indicate the stability of a slope, may be useful in studying the history of slope failures along the banks at proposed stream crossings. Such investigations can also provide required information on flooding, ice jamming, sedimentation and erosion, permafrost and climate (28). Sections of the river upstream and downstream from the proposed crossings should be investigated for possible failures. Although such failures may not directly affect the crossing structure they may promote the formation of ice jams or channel changes which could jeopardize the crossing or cause bank erosion downstream (2).

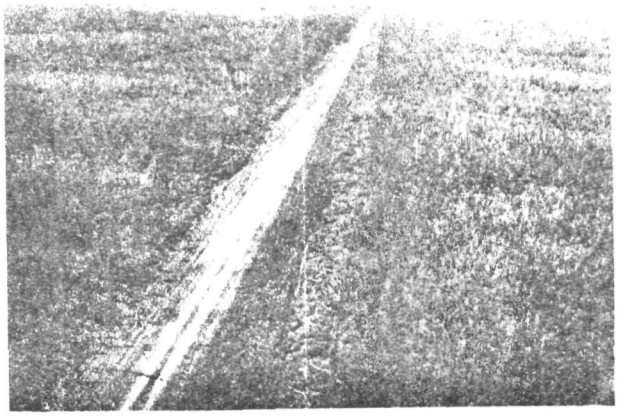

Fig. 7 Several horizontal curves designed into this road during the engineering survey would have reduced the monotony of the landscape.

In assessing potential river scour in areas where bridges are required, mapping from air photos of false parallax caused by the flow of ice after breakup may be helpful (1) (25). Dye studies may also be employed using non toxic dyes to determine channel configuration and probable areas of scour and fill.

The survey should endeavour to recognize potential icing sites in streams. Streams that are susceptible to icing are characteristically shallow with low winter flows maintained by groundwater discharge. In such streams, sudden changes of channel width from narrow to wide or abrupt flattening of the gradient often indicate icing areas (31). Icings are also likely to occur where a deep lake is drained by a braided stream with boulder and gravel flats. Indications that previous icings may have occurred at a particular location may be seen in a flood plain where gravel and boulders are scattered irregularly in low heaps, and vegetation, including lichens, is conspicuously absent (30). Such locations should be avoided or provisions made in design or during maintenance operations to resolve the icing problem.

Designated fish-spawning areas, especially in clear-water streams, should not be considered as suitable crossing sites. If it is unavoidable, the use of a bridge with a high approach rather than a culvert will have to be specified to limit disturbance to the channel; otherwise the alignment should be placed at least 457.2 metres (1500 feet) downstream from the spawning areas with adequate provision for safe passage of fish.

3.1.4 ***Erosion.*** The erodability of soils should be assessed where the quality of watercourses may be seriously impaired by sedimentation and where dust and maintenance problems are anticipated along

the right-of-way. Application of the Universal Soil Loss Equation developed by the U.S. Soil Conservation Service may be useful in estimating potential soil losses from highway construction sites and the resulting silt concentration in a stream. The equation (developed in English units only) is:

$$A = RKLS \quad (19)$$

where
- A = computed soil loss in tons per acre
- R = the average annual rainfall erosion index
- K = the soil erodability factor
- L = the slope length factor
- S = slope gradient factor

These factors are determined empirically and are dependent upon rainfall intensity, duration and frequency, and on soil horizon composition, thickness and texture. The equation only predicts sheet erosion. Soil losses from gulley and hill erosion are not included; however, for exposed fills and excavations the equation should be useful in determining the need for proper control of soil erosion (See *reference* 19 *for details on application*).

3.1.5 ***Drainage.*** The ground reconnaissance, together with air-photo interpretation, must determine the location of cross-drainage culverts to carry overland runoff and seepage. Where soil conditions do not permit contiguous or offset collector ditches, the proper locations of culverts may be determined by inspecting air photos for narrow lines extending downslope from ridges. These lines are small surface runoff channels and, although visible from the air, they are difficult to sight on the ground because of the slight topographic relief between the drainage channels. Vegetation helps to delineate drainage channels since they often contain tamarack and black spruce with a variable cover of willows, grasses and mosses. Between channels, the vegetation is characteristic of imperfectly drained slopes: open stands of black spruce with abundant ground lichens (7).

3.1.6 **Wildlife.** The environmental survey will have designated areas of critical concentrations of wildlife and sensitive habitat components. These areas should be avoided. Caribou are particularly sensitive to large-scale activity. Stream crossings used traditionally by caribou should not be distrubed or intersected by the highway (22).

Nesting waterfowl are extremely intolerant to disturbance (2). To minimize disturbance to waterfowl, the highway alignment should not be located for long stretches on the boundaries of productive marshes. Raptor nesting sites need to be given a wide berth. As a precaution against washouts, the highway should be located upstream of beaver dams where possible.

Although gravel materials may be scarce, not all available deposits along the route should be slated for use. These soils provide prime denning sites for bears (22). Several deposits should remain untouched along the route, especially those containing known denning sites.

3.2 Geotechnical Survey

Once a visual inspection of the alignment has been completed, and assumptions made in earlier phases verified by field observation, an intensive geotechnical survey can be carried out along the final alignment.

This survey would indicate, in addition to the availability of acceptable roadway material, possible areas of excessive settlement, stability problems on side hills and at proposed excavations, liquefaction and frost-heave problems, erosion potential and seepage problems. Soil data will confirm or disprove the assumptions made during air-photo interpretation and ground reconnaissance. These findings may require reconsideration of the proposed alignment and the selection of an alternate route. Such changes may also require reconsideration of environmental constraints along a given alignment.

Generally, drill holes along the centre of the right-of-way are spaced at a maximum of 304.8 metres (1,000 feet), with additional holes in critical areas such as stream crossings or where excavations are required in suspected ice-rich soils. The holes are normally drilled to a maximum depth of 4.6 to 6.1 metres (15 to 20 feet) where overlay fills are expected. Where major fills are anticipated, the holes should be drilled to a 9.1 metre (30-foot) depth. In areas where an excavation is anticipated, the holes should be drilled 4.6 to 6.1 metres (15 to 20 feet) below the expected grade elevation. Along sections where side-hill cuts will be required, offset holes should be drilled to the same depth as those on the highway centre line (24). Test holes must also be drilled in stream channels for design of the crossing structure.

Data from the geotechnical survey should include the *in situ* density of the soil, grain size analysis and true ice content and ice type classified according to the manual, *Guide to a Field Description of Permafrost* (36). If the survey is conducted in the summer the depth to the permafrost table should be noted if it is encountered. The presence of thawed layers (taliks) within the permafrost must be recorded especially in sections where cuts are expected.

The susceptibility to frost heaving and ice-lens formation should also be estimated. The standard test procedure is by grain-size analysis but a newly developed and possibly more efficient technique is available. The new technique measures the pore pressures in a rapidly freezing sample (27). This technique may be quite useful in evaluating borrow material and predicting maintenance requirements.

The agronomic properties of the soil in selected areas should also be noted so that a revegetation programme can be planned. Information on texture, pH, and the nitrogen and phosphorous concentrations of the final surface layer will assist in specifying seed and fertilizer requirements. These measurements may not, however, be possible until construction begins.

3.3 Hydrology Survey

Only a limited number of northern rivers have had their flows monitored for periods long enough to enable statistical analyses of design discharges. An engineering survey can only collect rudimentary hydrological data on which to base the design of a bridge or culvert, but estimates of peak

flows can be calculated using rational or empirical methods. Flow-duration and flow-recession curves for streams on which data are nonexistent can be derived using data from streams having similar basin morphology and rainfall characteristics.

The hydrology survey should obtain a profile of both the stream bed and water surface to at least 45.7 metres (150 feet) from each toe of the slope of the proposed approach fills, at least three complete cross sections within the right-of-way of the crossing, and if possible, a stage reading during spring runoff at one of the cross sections. Data on velocity gradients in the streams at cross sections are also useful.

Observations should be made of the debris carried in the river, especially during spring flood. The elevations of the estimated high-water and ice-shove marks should be recorded. In alluvial rivers, the lowest undistrubed stream-bed elevation at or near a bridge crossing can be used as a reference level in setting the scour elevation for principal piers in or near the main channel (21).

3.4 Survey Operation Constraints

These early field activities must be carried out with as little environmental disturbance as possible. The two most important concerns are terrain damage by vehicles and stream blockages and siltation due to improper construction or siting of temporary stream crossings.

Due to the short periods of sunlight in the winter, most surveys are conducted between March and October. This requires that vehicles be restricted to terrain that is not susceptible to thermal erosion by the compaction or removal of the vegtative mat. Where there is a possibility of severe thermokarst effects from terrain-vehicle activity, helicopters must be used for transportation.

In the geotechnical investigations, abandoned drill holes should be plugged. This is easily done and will avoid the possibility of water collecting in the holes and initiating possible subsidence.

Where soil conditions permit the use of tracked vehicles, they should not be used outside of the proposed right-of-way. During winter, centre-line clearing can be carried out by bulldozer, provided there is adequate snow cover to protect the vegtative mat from compaction or other disturbance and the soil has frozen to a sufficient depth to support heavy equipment. Bulldozers should be equipped with inverted mushroom pods at each end of their blades so that the blades are kept six to eight inches above the ground. Where the terrain is hummocky and bulldozers cannot operate without shearing the tops off the hummocks, centre-line clearing should be done by hand.

Temporary stream-crossing sites should be located on the centre-line of the proposed alignment (3). In summer, fording sites should be limited to one crossing, 15.2 metres (50 feet) in width.

Temporary crossings during winter should be constructed of ice or snow. The next material preference is granular soil which must be removed before breakup. Limbed trees are acceptable but must also be removed prior to breakup. If channel or bank modifications are required for crossings, they should be finished and stabilized upon installation of the crossing (2).

All stream-crossing locations, their description and duration of use should be provided to the appropriate government agency responsible for fisheries management and protection.

Distrubance to wildlife, especially sheep and grizzly bears by aircraft must be avoided. Aircraft should not fly lower than 304.8 metres (1,000 feet) above animal concentrations and, if possible, these concentrations should be detoured.

General sanitation practices in survey camps must be followed in the interest of public health. Sewage wastes must be disposed of in a manner that is not hazardous to health or disruptive to local aquatic habitats. Refuse must be regularly burned and/or buried.

4 PHASE IV DESIGN

4.1 General

The design team for the highway should include individuals who have participated in Phases I - III of the development process. This will ensure that the large quantity of data which is available for design can be interpreted from a firsthand knowledge of observed field conditions.

Geometric standards are normally followed in the design of a highway. Horizontal curves, vertical gradients and road widths are set according to the design speed. However, economics and function must not be the only criteria in design. The information available from the environmental survey must also be considered.

4.2 Right-of-Way Clearing Operations

The width of right-of-way clearing is dependent upon requirements for embankment and ditch sections, the necessity for adequate stopping and passing-sight distances and the need to moderate the tunnel effect in dense timber.

The method of clearing and timber disposal which can be employed along a given section is a function of terrain sensitivity, the nature of the tree cover, time of year, quality of timber, and the need to use slash material for insulating materials.

Acceptable clearing and disposal methods include (1) knocking down and piling of timber with bulldozers; burning and stoking with hand labour; (2) hand clearing and piling by hand or with light equipment; burning and stoking with hand labour; (3) knocking down with heavy equipment; chipping and spreading over the cleared right-of-way or stockpiling; (4) knocking down with equipment or hand labour and laying flat along the centre line where fills are deep and the permafrost will rise into the embankment (Fig. 8).

The loss of forest habitat is an obvious consequence of right-of-way clearing. Disturbance of the vegetation mat by terrain vehicles and burning are less obvious but may cause melting of the permafrost and localized slumping (Fig. 9). Surface runoff over cleared areas will increase and snow accumulation will be greater but there will be a reduction in moisture withdrawal from the soil by

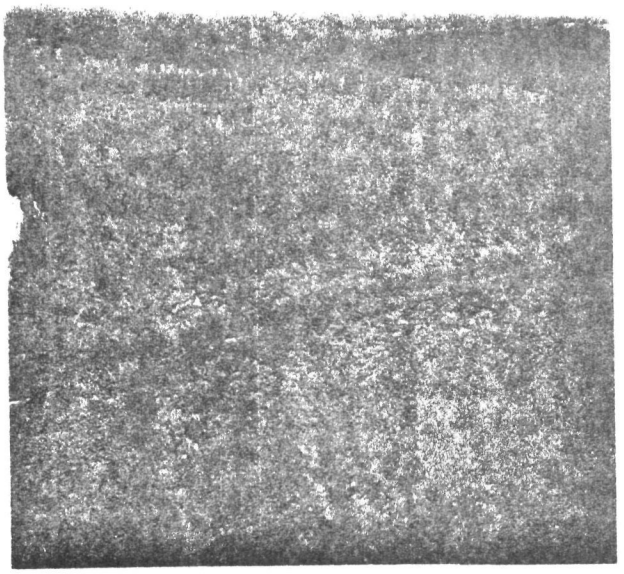

Fig. 8 Hand-cut timber placed in center of future road. Depression covered by the timber was caused by terrain-vehicle traffic.

Fig. 9 Slopes of river bank cleared of timber too far in advance of construction. Disturbed terrain in foreground was ice-rich and began to slump. Cut timber placed over the disturbed area retards melting.

transpiration. Trees at the edge of the right-of-way will become subject to wind blowdown. If cut timber is not disposed of, insect infestations can result (24).

4.2.1 Design Stipulations for Clearing. Before the methods for clearing and disposal of slash are selected, local settlements in the area should be advised of the impending operation. If the timber is of any value to them, local residents should be given the opportunity of collecting the cleared timber. If the timber is to be salvaged, hand clearing and piling along the right-of-way for subsequent pickup is required.

Clearing widths should be kept to a minimum (Fig. 10). The right-of-way should be cleared for road embankment and drainage requirements and to maintain safe passing and stopping-sight distances. This should result in a variable clearing width and would help moderate the tunnel effect in dense timber.

Clearing should not be undertaken too far in advance of construction in sensitive terrain. It may have a detrimental effect on the permafrost condition, resulting in erosion which cannot be controlled until the construction crews reach the location. As a general rule, clearing should not be initiated on stream crossings except to provide for vehicle passage until embankment construction is about to commence.

Since most timber disposal is by burning, clearing operations are usually carried out in winter to alleviate forest fire hazard. Heavy equipment may be used for clearing and piling provided blades are fitted with invert mushroom pods and are kept 15 to 20 centimetres (6 to 8 inches) above the ground surface to avoid scuffing of the vegtation mat. Heavy equipment must only be employed when the ground is frozen to a sufficient depth to provide the necessary bearing capacity, and the ground has an adequate snow cover to protect the vegetation mat.

In areas of extreme sensitivity, clearing should be done by hand. In winter, however, it is difficult to cut timber close to the ground surface because of the snow cover (Fig. 11). This may result in the necessity of cutting the long stumps down in the summer.

Where the terrain has ice-rich soils, felled timber should be stacked and burned where the embankments are to be located. The embankment will then cover burned areas and prevent the establishment of small ponds along the right-of-way.

Small trees and slash in the far northerly areas near the tree line need not be burnt but can simply be placed along the centre-line of the highway. The permafrost table will rise into the embankment and prevent decay of the timber and any resulting subsidence in the road bed.

Although burning is the most economical method for disposing of cleared timber (32), consideration may also be given to using mechanical chippers in local situations. Wood chips are a good insulation material and are suitable for re-insulating ice-rich soils from which the vegetation cover has been accidentally removed. The extensive use of wood chips is not recommended, however, because they may hinder or prevent natural revegetation for a considerable time. Only where quick re-insulation of ice-rich soils is required should wood chips be applied.

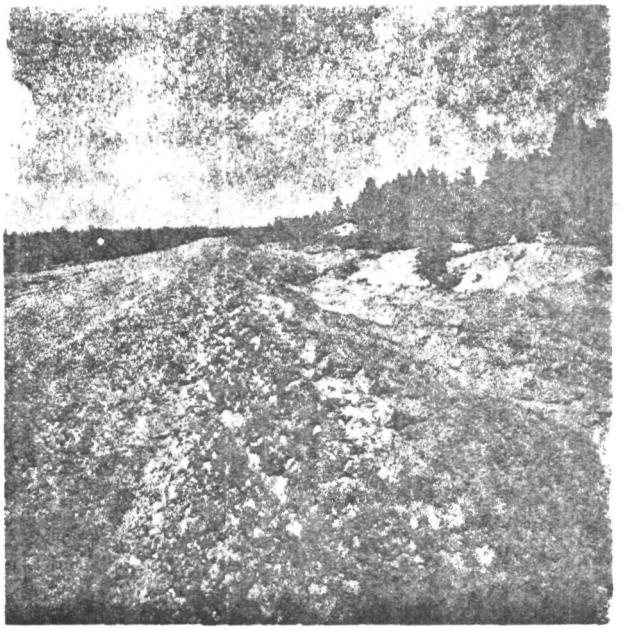

Fig. 10 Clearing and grubbing all roadside vegetation is poor conservation. These ditches are now susceptible to wind and water erosion.

Fig. 11 High stumps - a drawback of hand clearing during winter when deep snow prevents cutting flush with the ground surface.

4.3 Grubbing Operations

Grubbing is often required to remove materials which are unsatisfactory construction material, such as large tree trunks and roots, from the soil. The extent of grubbing required is dependent upon the height of embankment or width of excavation. The operation must be carried out in summer to allow a bulldozer to rip up trunks and large roots from the soil.

Grubbing results in the complete destruction of the vegetation mat, causes recession of the permafrost, and increases the susceptibility of the soil to erosion. If the whole right-of-way is grubbed, the root systems of standing trees along the edge are usually damaged making them susceptible to wind blow down (Fig. 12).

Fig. 12 Right-of-way grubbed to edge of the standing timber causing root damage and blow down.

Grubbing operations should be carried out only where soil conditions are known to be stable. They should be specified only where required to ensure subgrade support for shallow road fills and to remove unsatisfactory materials from soil required for embankment construction. The vegetation mat should not be stripped routinely right up to the edge of the clearing, but only within the limits required for earth work.

4.4 Earthwork Operations

Excavation and fill requirements along any section of highway are dependent upon the terrain and the proposed geometric standards for the highway. The most economical method of

construction is to balance cut and fill sections, and where right-of-way material is insufficient, short hauls from borrow pits.

Road fills and embankments upset the natural movement of surface and subsurface water. They cause changes in the thermal regime of the soil. Areas stripped for borrow become a visual distraction if not redressed or hidden. Another environmental effect of road fills and cuts is to greatly increase the exposed area of easily erodable soil.

4.4.1 Design of Earthworks. Generally, a passive approach to road design in the north results in the least environmental problems (Fig. 13 and 14). Changes in thickness of the active layer may cause heaving, settling, and sliding of the road as well as icing problems (13). In the northern continuous permafrost areas, the permafrost table may eventually rise into the embankment, giving it more structural stability. However, this action will also alter the subsurface drainage patterns and as a result may cause cross-drainage problems.

In the southern discontinuous zone, overlay construction will compress the vegetation cover and locally depress the permafrost table. This cannot be avoided and must be accounted for in design. Embankments should therefore be designed with adequate consideration for the thermal properties of the fill and underlying soil to estimate the magnitude of subsidence that can be expected from increasing the thickness of the active layer.

Allowance must also be made for soil consolidation if frozen material is placed in an embankment. The original embankment must be above the design grade to allow for subsequent settling when the material thaws and consolidates.

Where cuts are absolutely required in ice-rich soil, vertical backslopes should be considered. A wide ditch should be provided to handle the material which will eventually subside after thawing has commenced (Fig. 15). Brush and trees must be hand cleared back from the top of the slope to a distance equal to one and a half times the depth of the cut. This will allow the top mat to subside with the soil without becoming detached. The mat will retard the rate of thaw and a new stable thermal regime will quickly re-establish itself. Where vertical slopes are planned, slope stability must be considered to prevent unexpected massive slope failures. On cuts approaching stream crossings, the use of sediment catch-basins in the ditches may be required to prevent a heavy sediment load from discharging into the stream.

Backslopes with non-vertical gradients may also be excavated in ice-rich soils but some type of insulation, such as wood chips or gravel may be required over the surface to retard thawing. A thin cover of soil may be needed over light particulate insulation to keep it from blowing or washing away.

In areas of overlay construction, consideration should be given to building up to the desired grade with several shallow lifts rather than with just one. Construction vehicles travelling near the edges of the lift will give some compaction to the shoulders. This cannot be accomplished by constructing in one lift. Soft shoulders may result and increase maintenance operations in the future.

Fig. 13 Overlay fill construction is desirable in terrain with ice-rich soil. Foreground shows result of tracked-vehicle traffic.

Fig. 14 This road alignment, although somewhat lacking in aesthetic appeal because of its straightness follows the natural topography. Result: No interceptor ditches, no disturbance to vegetation mat, no ponded water

Fig. 15 Result of cut in ice-rich soil possibly a fossil icewedge. Wide ditches, however, accommodate mud flow without affecting the road embankment.

In locating borrow pits the designer must ensure that they will not adversely affect any significant nearby watercourses. A minimum of 30.5 metres (100 feet) of undisturbed terrain should be left between the edge of the right-of-way and a borrow pit (Fig. 16). The same requirement applies for areas where waste soil will be stockpiled. Where waste piles are specified, they should be as deep and as compact as possible to minimize exposed surface area. Waste areas should be covered with coarse material to prevent wind and water erosion, or revegetated if visible from the roadside.

The subsequent use of abandoned borrow pits should also be considered during design. Specifications should be given to have the top soil, which is stripped from the surface of the pit, stockpiled for recovery when the pit is closed. If material is to be stockpiled in a borrow pit as a ready source of unfrozen material for maintenance purposes, it should be placed in well-drained areas. Precautions should be taken to ensure that the permafrost does not aggrade into the stockpile and defeat its purpose.

4.5 Drainage and Erosion Control

Drainage facilities employed in the construction of a highway include contiguous ditches, interceptor ditches, offtake and intake ditches and culverts. Erosion control measures that can be used in construction include rock rip rap, ditch checks and ditch blocks; revegetation with shrubs, trees and grasses, benching to dissipate sheetflow on long steep slopes; serrated slopes; application of materials to bind soil particles; blanketing of slopes and ditch bottoms with stable, free-draining materials; asphalt, polyethylene and concrete liners in ditches; and, minimizing the area of excavated and fill sections which remain exposed before revegetation.

Fig. 16 Poorly located borrow pit. No revegetation of slopes carried out and no screening exits between roadway and pit.

Drainage requirements over particular sections of the highway are normally dependent upon precipitation characteristics, rate of snow melt, size of drainage basins, local topography, soil properties, vegetation cover and road gradients. Erosion control requirements are dependent upon the same factors as drainage requirements but they are also a function of the need to protect watercourses from sedimentation, reduce dust and improve the appearance of the roadway.

The consequences of inadequate drainage and erosion control measures are extensive. They include ponding, flooding, washouts, inundation of vegetation, subsidence melting of permafrost, the creation of icing conditions and increased highway maintenance. Flooding of marshes can result in the reduction of shallow shoreline and a decrease in the willow-alder communities used by wildlife (Fig. 17) (2). It will also reduce the area for waterfowl nesting. Conversely, the drawdown of marshes, especially in fall, could allow sufficient frost penetration to cause winter kill of beaver or muskrat (2). Ponding at the inlet and outlet of culverts may cause local softness in the roadway.

Improper erosion control works may cause damage to ditches and roadways, the undermining of road structures, sedimentation in watercourses and blockage of culverts and even local failure of the road embankment (Fig. 18, 19, 20, 21).

4.6 Design of Drainage and Erosion Control Works

4.6.1 ***Drainage***. Highways cannot avoid altering natural drainage patterns within a drainage basin. In designing drainage structures the objective should be, therefore, to minimize such changes to

Fig. 17 Inadequate cross-drainage has caused the water level in the swamp to rise and drown a large number of trees.

Fig. 18 Eroded ditch leading to creek. Note absence of vegetation.

Fig. 19 This gulley was eroded after an intermittent stream was diverted without consideration of erosion control requirements.

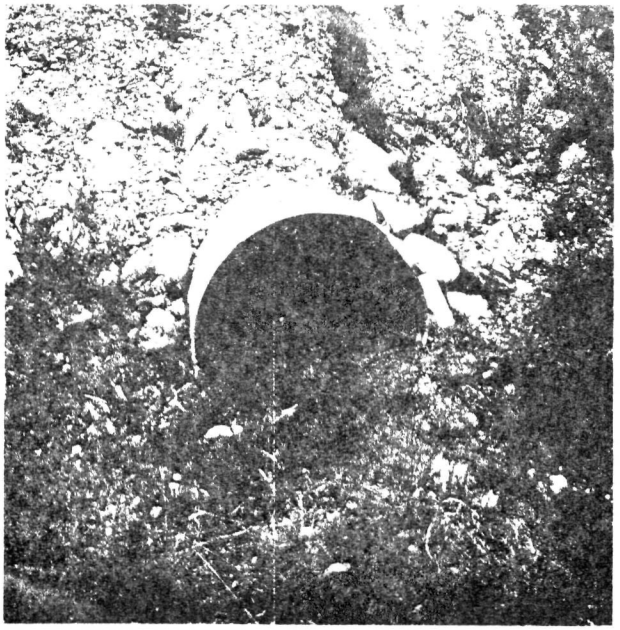

Fig. 20 Inadequate erosion control measures and sediment catch basins have resulted in clogging of culvert with sediment.

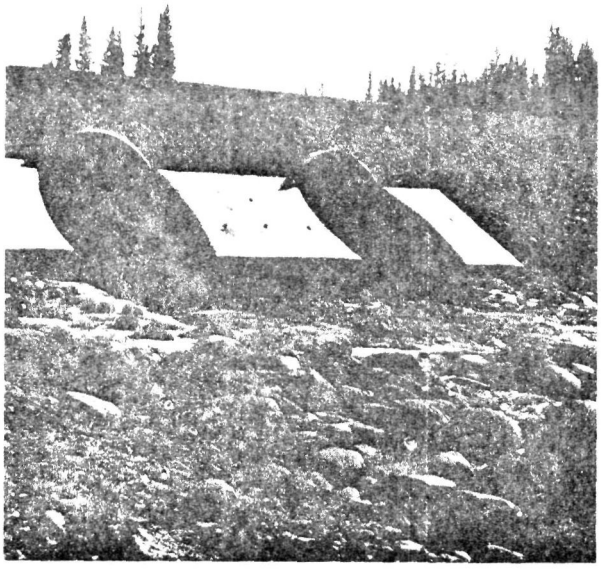

Fig. 23 This culvert has been well placed and is adequately protected with a concrete apron. Note that this outlet is at the same elevation as the natural stream bed.

natural conditions. All cross-drainage structures must be sized from accurate topographic information and knowledge of runoff potential, storm frequencies and intensities. Where terrain conditions allow the use of ditches, the natural drainage flow should not be redirected away from a marsh that supports wildlife.

Where ice-rich soils do not permit the use of ditches, culverts should be place wherever a natural cross-drainage channel exists. Ditch blocks should be placed beside culverts in terrain sensitive areas to direct flow into the culvert. Depressions contiguous to the road between cross-drainage culverts should be filled to prevent standing water from thawing permafrost and weakening the road shoulders. The ground surface around culvert inlets and outlets should be brought to culvert invert elevation thus avoiding ponding, sediment build-up in the culverts or plunge pools (Fig. 22 and 23).

Potential icing problems at culverts must be considered. Although ground-icing locations are difficult to predict, potential areas include: crossings over streams with low winter discharges; sideslopes where frost may aggrade into the road bed and dam water movement along the surface of the permafrost; in culverts beneath large fills where permafrost will aggrade and surround the pipes.

Although icing is primarily a maintenance problem, there are several measures that can be incorporated in the design to counteract icing occurrence. Surface area in and around the culvert can be minimized thereby increasing the velocity of discharge. A dyke or cross ditch can be placed upslope of the culvert to deliberately create an icing condition away from the road. Upslope icing intercepts the

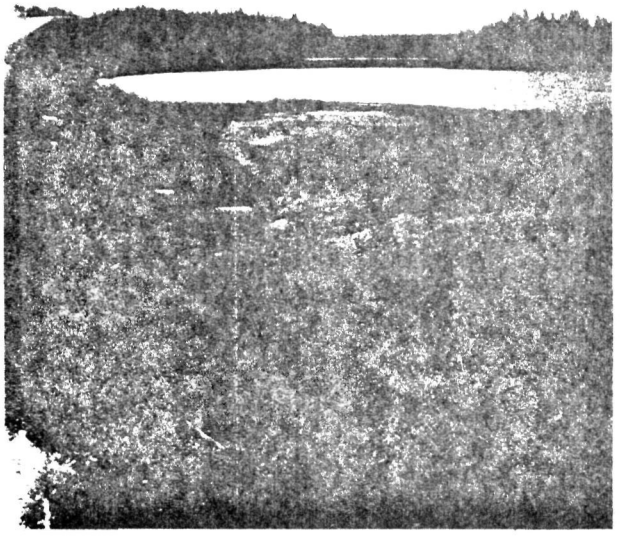

Fig. 21 Culverts discharging directly into a lake have caused the formation of a small delta.

Fig. 22 The height of this culvert outlet above the stream channel may prevent fish passage during periods of low flow.

winter flow keeping culverts open for the spring runoff. Step culverts or french drains can also be specified. A diagram of a typical french drain is contained in Appendix B (Fig. B-1 and B-2).

4.6.2 ***Erosion Control.*** Estimates of possible soil losses from fills and excavations should be used to determine the intensity of protection required for proper control of erosion and sediment transport.

Velocities in ditches can be reduced by limiting ditch gradients and by selecting appropriate cross sections. A trapezoidal or parabolic cross section should be specified; V-shaped ditches are prone to erosion and should not be considered unless protected with coarse granular material. Rock rip rap for ditch checks should be placed up both sides of the ditch so that water will not flow around them. Timber may also be used in the same fashion where rock is unavailable. Provision should be made in the contract for the clean out of temporary sediment catch basins during construction. Diagrams of typical erosion control structures are shown in Appendix B.

The need for erosion control structures and attendant maintenance requirements can be reduced by erosion prevention through revegetation. In addition to its soil stabilization effects, it also increases the aesthetic quality of the road considerably (Fig. 24 and 25). By planting grasses and low-growing shrubs, trees and brushes are prevented from encroaching into the cleared right-of-way, reducing the passing and stopping-sight distances (Fig. 26).

Factors that must be considered in revegetation include soil texture and chemical composition, rainfall and drainage, extremes of temperature, and the slope of cut or fill. The direction that the embankment will be facing is also important. North-facing slopes may be much more difficult to revegetate than south-facing slopes. If more than one type of soil is encountered in a cut, changes in seeding and fertilizer formulations may be required.

Where vertical cuts are not prescribed, the tops of cuts and fills should be rounded (19). Soil from beneath unrounded turf caps at the top of a cut could slough and cover over new vegetation.

The designer can also limit the maximum surface area of erodable soil that is exposed at one time. Erodable slopes should not be left bare for more than one season or they will require refinishing before seeding. Appendix A gives some standard revegetation practices, seeding and fertilizer formulations.

4.7 Stream Crossings

The scarcity of hydrological data on northern streams is a serious problem facing the designer. With only a very limited amount of information, he is required to design structurally sound and economic crossings which will not interfere with fish passage. Because of the scarcity of hydrological data, the safety factors in designing crossings will have to be large (2).

The decision on whether to install a bridge or culvert over the smaller streams is a difficult one. Over streams with a known fishery resource, bridges are preferred. Culverts, however, are usually

Fig. 24 Abandoned borrow pit with unstable slopes. No trees were left standing to screen the pit from the road.

Fig. 25 The natural beauty of this cascade could be enhanced if the slopes of the highway were revegetated with grasses and shrubs.

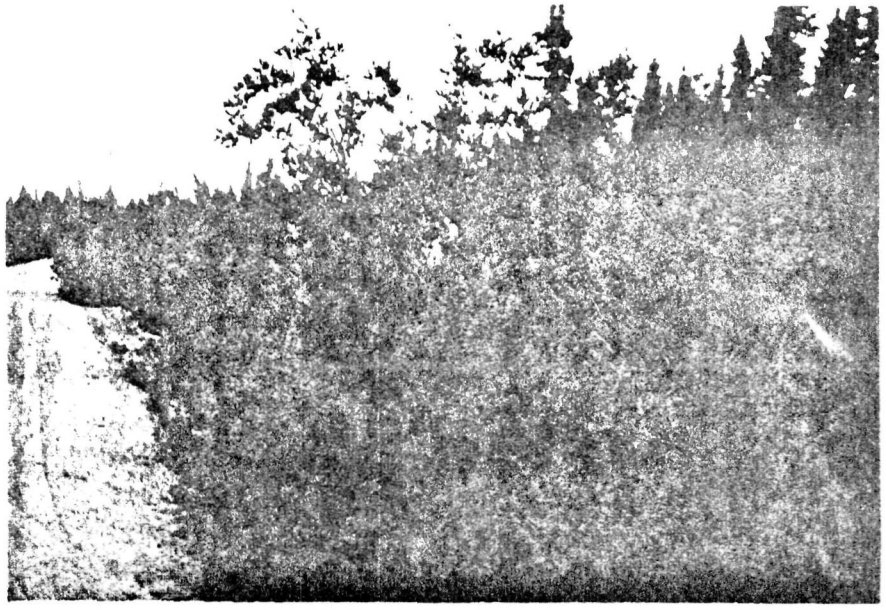

Fig. 26 Brush has encroached upon roadway, hiding road signs and reducing sight distances. Grass revegetation and routine roadside mowings would prevent this and improve aesthetics of the highway.

much less expensive. The final decision must consider hydrological conditions, costs and potential disruption to the fishery resource.

The environmental consequences of poorly designed stream crossings manifest themselves in upstream flooding and drowning of vegetation, blockages to fish migration either by insufficient cross-sectional area or debris accumulation and, in some cases, blockage of the movement of people and wildlife along the watercourse. Crossings may increase scour and downstream siltation, and create favorable conditions for icing. Stresses built up around inadequate crossings may lead to failures and washouts.

The main criteria in designing a stream crossing, whether bridge or culvert, must be that while providing a structurally sound overpass, it does not create undue sedimentation problems, obstruct fish and wildlife passage along the watercourse or unduly alter the hydrological properties of the watercourse.

4.7.1 ***Culvert Design.*** Design can be based upon hydrological principles or empirical methods. As a check, several methods should be used to obtain values for design discharge. For major streams the design discharge is taken as the flow which will occur only once in 100 years. For minor streams, the 50 year design discharge should be used.

If a stream is known to have a fish potential, culverts must be designed to allow fish passage. Guidelines are available from Fisheries and Marine Service of Environment Canada (39). These guidelines

are contained in Appendix C and copies may be obtained from the Director of Fisheries Operations, Fisheries and Marine Service, 501 University Crescent, Winnipeg, Manitoba.

Other considerations in culvert sizing include requirements for sufficient free board for debris and ice passage and the prevention of ponding above the top of the upstream culvert end. Culvert inverts should be placed at or slightly below mean stream bed to minimize outlet velocities. Plunge pools are to be avoided because they promote downstream erosion and are an obstruction to fish. If the culvert entrance is placed below the original stream channel, rip rap of the channel bottom in front of the culvert is required to prevent upstream erosion.

Although cut-back end sections are hydraulically more efficient and aesthetically more pleasing than projecting entrances, they weaken the pipe structurally and allow debris from the roadside to easily enter the culvert. If cut-back sections are used, provision must be made to prevent debris from the roadside entering the culvert.

Where icing problems are anticipated, measures must be taken to prevent them. French drains may be constructed underneath the culverts. Step culverts may be designated or steam lines built into the culverts. (See Figures B-1 and B-2).

All culverts should be rip rapped with concrete aprons or heavy rock to the ice scour line. Rip rapping should also be required downstream from the culvert. To minimize subsidence of the culvert structure, the subgrade should be excavated and replaced with well compacted granular material. Granular material free of large rocks should be place in shallow, well compacted lifts around the culvert.

Culverts, if placed in the natural stream channel requiring stream diversion, should be installed in the fall when the stream is at low flow. Although the insertion of a culvert into a stream diversion will require more erosion control work, it is preferable to installing one in the natural stream bed, because the stream remains untouched until the culvert is in place and the diversion is opened to carry the flow (Fig. 27).

4.7.2 ***Bridge Considerations.*** Determination of velocity in streams that are to be bridged is useful for scour assessment. Generally, bridges do not greatly constrict channel cross sections and increase the velocity of the stream at peak flow as a result. Predictions should be made of the stage versus discharge relation at bridge crossings.

The effects of scour protection devices such as dykes and rip rap must be evaluated. Their sizes, shapes, spacing, number, geometry, and orientation with respect to channel alignment and flow direction must be evaluated for the influences on scour action and changes in flow direction causing streambank erosion (21). Geotechnical information from the streambanks must be carefully analyzed to assess stability.

Approaches to bridges should not constrict the flood plain by more than 20%. Long-span bridges are more desirable than short spans because the latter collect more debris which, when caught against the piers, increases their effective size, concentrates the flow, causes deeper scour and can place

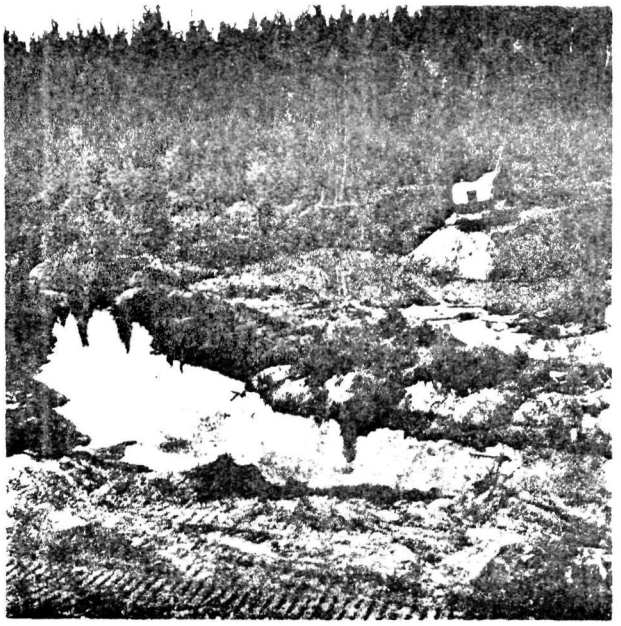

Fig. 27 Considerable disturbance to the stream is evident at this location where a culvert is to be installed. Leaving the natural stream channel untouched until the culvert is in place would reduce disturbance to the watercourse.

unacceptable stresses on the bridge structure (21). Adequate clearance must be given to allow debris and ice passage under the bridge.

Rip rap is essential around the bridge approaches and possibly around some piers. However, the extent of rip rapping must be specified, for indiscrimanate use can lead to scour and changes in stream cross section outside of the protected zone and even to eventual failure of the protective blanket (21).

Bridges do not have to be completely constructed on site. Preference should be given to prefabricated structures that can be transported to the site to minimize work areas adjacent to the watercourse.

4.7.3 ***Temporary Stream Crossings.*** Temporary stream crossings must be shown on contract plans. Acceptable crossing structures should also be illustrated in the contract plans. Major but temporary crossing structures such as Baily bridges should be constructed according to the same criteria as permanent crossings (Fig. 28 and 29).

Note: All plans for stream crossings, both temporary and permanent should be submitted for review to the appropriate government agency responsible for fisheries management and protection.

Fig. 28 Temporary bridge crossing. Long spans allow for passage of debris but note absence of erosion control in the temporary road side ditch.

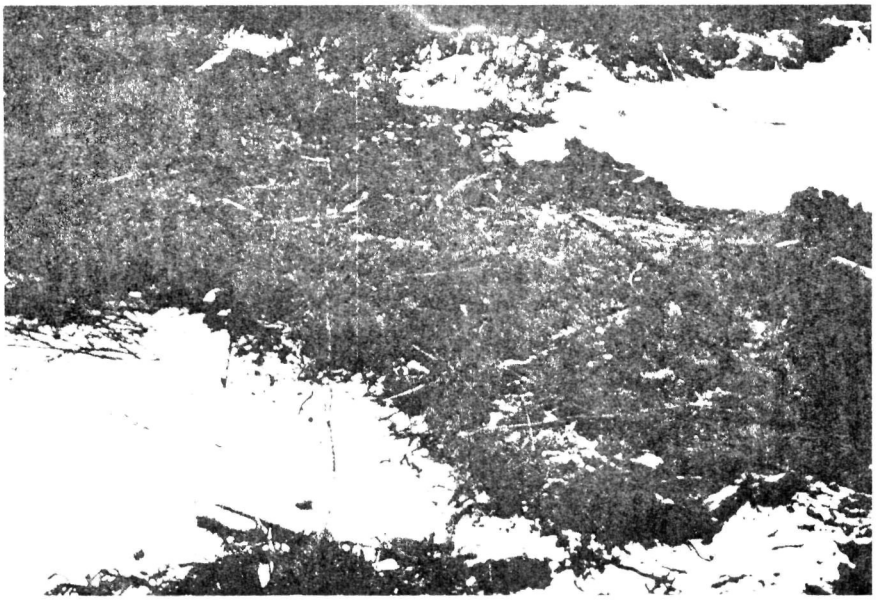

Fig. 29 Unacceptable temporary stream crossing. Fine grained sois in stream banks have been excavated to form crossing. Streambank erosion can be expected during spring runoff.

4.8 Work Camps

Specifications should be prepared in the design phase which will advise contractors of their responsibilities to minimize environmental disturbance due to camp activities. Technical guidelines for work camps are contained in Appendix D.

Some constraints must be placed on where a contractor is allowed to set up his camp. Acceptable areas should be designated on plans. These areas should make use of previously cleared land wherever possible. Suggested camp layouts that maximize sequential land-use alternatives after the camp is removed should be given to contractors (Fig. 30).

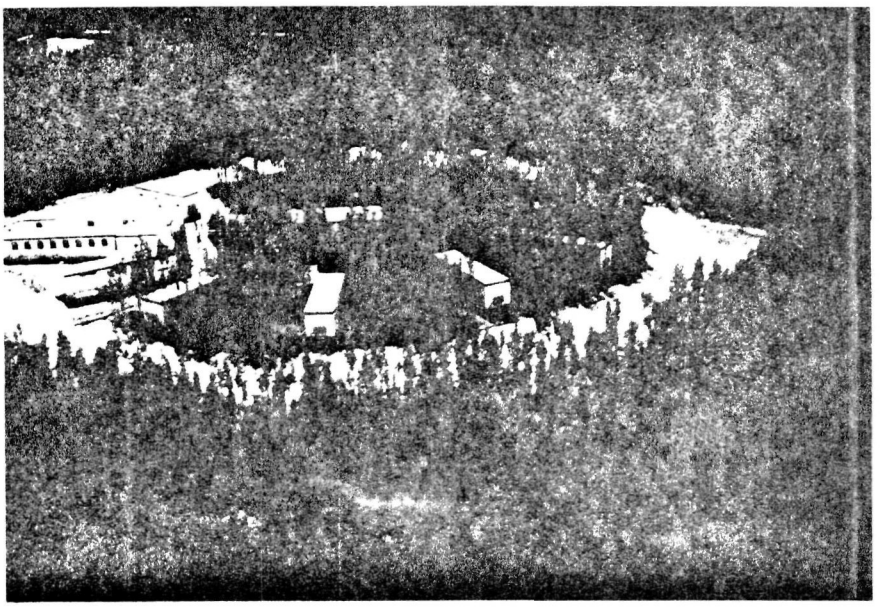

Fig. 30 A well laid out work camp site.

5 PHASE V CONSTRUCTION

The major responsibilities of engineers supervising construction activities on behalf of a government agency are to ensure that design specifications and plans are rigidly adhered to and to resolve any unforeseen problems which may arise during construction. Because the natural elements of soil and water are so heterogeneous in character over a long stretch of highway, it is not possible, even on the most carefully planned, surveyed, and designed road to predict the exact nature and magnitude of their response to highway construction. The construction engineer must therefore have the knowledge and ability to analyze and evaluate unforeseen problems and solve them quickly.

The work of the field engineer is considerably lessened if contractors are aware of, and have an appreciation for, special circumstances that relate to northern road development. It is most beneficial, therefore, to brief each contractor after tenders are awarded, on the objectives of the highway development and his responsibilities in helping to achieve those goals.

5.1 Briefing Sessions

Prior to commencement of any construction activity, the design personnel along with the engineer in charge of construction should discuss with the contractor's supervisory and management staff, details of the highway project. Sensitive areas where terrain, wildlife or watercourses will be affected by construction operations should be pointed out. The considerations behind the design of particular elements of the highway which are critical to the preservation of a particular area should be explained. Contract specifications and land use regulations that are intended to provide environmental protection need to be made the responsibility of the contractor.

These briefings should be followed by general briefings for machine operators after the first work camp has been set up. The consequences of disturbance to the vegetation mat by heavy vehicles should be described and illustrated and off right-of-way travel appropriately restricted (Fig. 31). The effects of erosion and improper temporary stream crossings should be pointed out. Any restrictions concerning hunting and fishing activities must be brought to their attention and the reasons behind the restrictions explained. The fact that the individual equipment operator has an important role to play in the environmental protection effort should be brought out.

Fig. 31 Dressing shoulders without disturbing the natural terrain.

Strict enforcement of existing fish and wildlife regulations are preferred to individual restriction. Recreational pursuits are severely limited in isolated work camps and curtailment of hunting and fishing would eliminate a popular recreational outlet for camp personnel.

5.2 Clearing and Grubbing Operations

Wherever restrictions are contained in specifications for terrain vehicles and heavy equipment operation, clearing operations must be closely supervised. The vegetation mat over ice-rich soils is not to be removed or disturbed. Trees should be felled into the right-of-way and cut flush with the ground. This latter requirement must be watched closely in hand-clearing operations during the winter, when snow cover will make it difficult to get close to the ground surface. Trees felled outside of the right-of-way or into a watercourse should be recovered.

In any areas that are mistakenly grubbed, or disturbed, the contractor should be required to spread slash material over the distrubed area. Grubbing should not be carried out within four feet of standing timber at the edge of the right-of-way.

5.3 Embankment Construction and Excavation Requirements

Again the field engineer must ensure that heavy equipment does not unnecessarily disturb the terrain. Work on stream banks should be delayed until the crossing is ready to be constructed.

Borrow pits should be excavated so that the final contours blend with the natural landscape. All topsoil stripped from the surface before the pit was opened should be piled and later spread onto the slopes of the abandoned pit.

Wherever practical, topsoil from excavated sections of the highway should be stockpiled for subsequent application to side slopes requiring revegetation.

5.4 Drainage and Erosion Control Operations

The field engineer should instruct contractors to construct appropriate sediment catch basins and to clean out sediment when they are 1/2 to 2/3 full.

Rip rap for channel protection should be placed as soon as channel work is complete. Sand bag rip rap for temporary protection may be useful where rock cannot be easily obtained. Revegetation should be carried out as soon as an embankment or cut is complete. Surfaces which have been compacted may need to be roughened or ripped prior to seeding. The engineer should check to see if proper seed and fertilizer formulations are being used and applied correctly. Post-seeding inspections should be carried out to record the effectiveness of the methods being used.

5.5 Stream Crossings

Any temporary stream crossings which block fish passage should be removed immediately. The engineer should ensure that river banks and beds are re-shaped and stabilized upon installation of temporary or permanent crossings.

Activities in stream channels for the construction of crossings should be curtailed during spawning periods, and major channel revisions or blasting should not be carried out at this time. If blasting is to be carried out in a watercourse federal fishery regulations require that a permit be obtained.

5.6 Support Activities

Waste disposal operations should conform to the requirements in Appendix D. Proper refuse collection and disposal will lessen the attraction of wildlife to the work camp. Camps should be equipped with exploding shot or flare guns to frighten bears which may approach the camp (2). The use of pesticides to control flies in the vicinity of camps should be limited to living and refuse areas.

With increased activity, forest fires and chemical spills are a potential hazard. Contingency plans should be developed for fighting forest fires and cleaning up spills of fuel and other hazardous or toxic materials. All crews should have some instruction in fire fighting and spill clean up. Special techniques for fire fighting in permafrost areas should be developed so that the control efforts do not cause more damage than the forest fires themselves.

5.7 Environmental Monitoring and Surveillance

Agencies responsible for environmental protection should institute a routine monitoring programme to record the actual effects of the highway. Changes can be measured by comparison with data collected in the environmental survey. Streams should be monitored for increased siltation, and obstructions to fish passage. Any evidence of serious adverse reactions should be relayed to the field engineer for corrective action.

Changes in any wildlife populations or migratory patterns should also be noted.

6 PHASE V MAINTENANCE

All-weather gravel roads require constant attention if their standard is to be maintained. The amount of maintenance required to sustain the standard of a highway depends on its use, the care taken in route selection, the competency of its design, and the manner of construction.

Although regular maintenance is required over the life of the highway, it is particularly important immediately after the highway is constructed. Even completed sections of a highway which have not been opened to regular traffic must be maintained immediately after construction as problem

areas begin to develop. Quick action at this time, such as reinsulating exposed cuts or reinforcing erosion control structures, may prevent more serious and costly problems in the future.

Prior to the commencement of the maintenance programme and immediately after construction has been completed, those responsible for construction should brief maintenance supervisory personnel on difficult areas of construction where maintenance problems may arise. Sensitive wildlife or aquatic habitat locations should be pointed out, the reasons for their sensitivity explained and the necessary precautions to avoid or minimize disturbances detailed. The location of erosion control structures and their maintenance requirements should be made known. Seed and fertilizer formulations for revegetation should be provided.

6.1 Roadway and Right-of-Way Maintenance

Grading and maintaining the road surface is the principal maintenance operation. In reworking the gravel on the driving surface, the operator should be careful not to blade it onto the shoulders of the road. Ridges should not be left on the edge of the roadway. Such ridges act as berms to water draining from the crown of the road. On long vertical curve sections, large quantities of water will drain against the gravel ridge, pond at the bottom of the hill and eventually spill over. Unless the embankment has slope drains, erosion will be severe in fine grain and granular soils (Fig. 32).

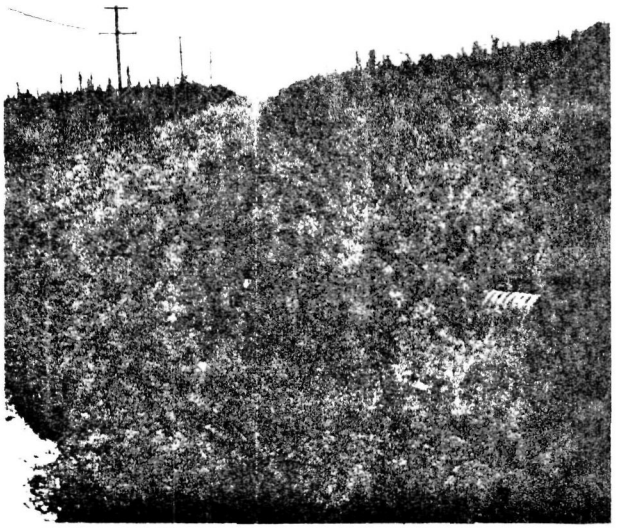

Fig. 32 Berm on edge of road concentrates road surface runoff. Severe erosion has resulted where runoff has breached the berm. Slope drains would mitigate such erosion.

Dust control by oil or chemicals will increase driving enjoyment and safety. However, the application must be done carefully and only after the road surface has thawed adequately to absorb the

dust control material. Spillages must be avoided, especially near watercourses. If they occur, cleanup must be immediate. Oils containing contaminants, such as phosphate tricresol, must not be used for dust control.

Borrow and gravel pits that were opened during construction should be used until they are depleted to repair road sections. Stockpiles of material should be built up in the summer for ready use in the spring when it will be most needed and the ground is still frozen and difficult to excavate.

The right-of-way must be kept clear of tall-growing bushes and trees to maintain safe stopping and passing-site distances. Bulldozers should not be used for clearing because of the damage they do to the terrain. Light equipment with rotary mowers or sicklebars should be used where terrain conditions permit. Hand clearing should be done on terrain not negotiable by light equipment.

The aesthetics of the highway may be increased with vista clearing and selected thinning of trees along the right-of-way. This activity is best left until after construction so that the finished highway can be observed and the required improvements in clearing made in conjunction with other planned roadside developments.

All stopping points along the highway, such as picnic and camping areas and scenic viewpoints, should have refuse containers. A regular refuse collection service should be conducted to keep these areas clean.

Because of the dust problem, picnic and camping areas should be located away from the right-of-way with perhaps a 61.0 metre (200 foot) separation of trees and upwind, or on higher terrain, where possible. Although toilet facilities at such sites would be quite rudimentary, probably privies, they should be carefully located not to affect nearby watercourses or wells. Many other design features need to be considered for roadside recreational developments that are outside the scope of this report.

6.2 Drainage and Erosion Control Maintenance

Sediment basins must be cleaned out when 1/2 to 2/3 full. Revegetated slopes must be watched carefully and fertilized, if required, to ensure plant establishment. Culverts must be checked for obstruction by debris or the accumulation of sediment.

Icing is a common problem to northern road maintenance. It creates hazards to driving safety and causes serious stresses to the roadway itself. Such situations must be closely watched and remedial action quickly taken when required. Measures can be taken to mitigate the effects of icing or to eliminate them completely.

Passive measures to control icing include steaming out frozen culverts, placing hessian cloth dams upstream of drainage structures, draping the entrances of culverts with hessian cloth, blasting or grading ice accumulations, and fire pots (31). The use of hessian cloth dams is to prevent icing from reaching the roadway or plugging culverts. The hessian cloth barriers turn into impermeable dams when the water soaks the cloth and rises slightly through capillary action. The wet cloth freezes and water begins to back up behind the barrier. This action continues until spring, unless the top of the cloth is

breached. The cloth produces the same action when dropped over the end of a culvert. Although the entrance to the culvert may eventually be completely covered, the inside is ice-free. In the spring, a small hole can be steamed or cut through the ice to carry the first runoff. These methods can only be used where the area upstream of the culvert is flat enough to contain the ice build-up and not allow it to breach the road surface.

Active measures can be taken to eliminate icing situations. Underdrains can be constructed to prevent seepage from coming to the ground surface (see Appendix B for diagram of underdrains). French drains and stepped culverts can be installed to prevent icing. Freezing belts can be created above the road by keeping the ground cleared of snow and causing the frost to penetrate down and eventually block the flow. This will force the seeping water to the surface at that location and create an icing condition there rather than at the road. Care must be taken, however, not to severely damage the vegetation mat over sensitive terrain (31). Ponding areas created upslope from the drainage structures by dyking or ditching will also create icing conditions away from the highway (Fig. 33).

6.3 Stream Crossings

Stream-bed elevations should be taken periodically around piers to assess scour and deposition. Measurements should be taken as soon as conditions permit after the spring runoff and before deposition around the structures begins.

Debris caught on piers and at the entrance to culverts should be removed as quickly as possible to prevent upstream flooding and to reduce stresses imposed upon crossing structures. Beaver which dam culverts should be trapped and transported to a region where their activities will not affect the highway.

6.4 Environmental Monitoring Programme

The monitoring programme begun in the construction phase should be continued for some period into the maintenance phase to assess the efficiency of the environmental design in protecting environmental conditions. Wildlife concentrations and patterns should be studied for adverse changes. Where large herds of caribou migrate across the highway it might be necessary to close down the highway until they have passed. Surveillance of the herds will be needed to predict the time, location and duration of the crossing event.

Watercourses should continue to be monitored for a year or two after construction is completed to determine any adverse effects on fish populations.

The knowledge obtained in this programme can be applied to future highway projects and may indicate areas where constraints could be eased or more rigidly applied.

Figure 33 Dam constructed across drainage to induce icing upstream of road

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APPENDIX A

REVEGETATION PROCEDURES

This appendix consists primarily of a selection of material from "A Vegetative Guide for Alaska" U.S.D.A. Soil Conservation Service Publication M7-N-22612, Portland, Oregon 1972 (38). Recommendations selected are mainly those for interior Alaska. Some additional material is included from recent studies in the Canadian and Alaskan arctic and sub-arctic.)

A. CULTURE AND MANAGEMENT FOR ESTABLISHING GRASSES AND LEGUMES

1. Soils

The upper 31 centimetres (12 inches) of soil should consist of a loamy material and be able to hold at least 1.9 centimetres (0.75 inches) of water to permit the establishment of good vegetative cover. The soil must be porous enough to allow root penetration, and tillable for good seedbed preparation. In areas where good turf is desired, it may be necessary to replace the soil material. At least 10 centimetres (4 inches) of loamy material should be available as topsoil before seeding.

2. Seedbed Preparation

Proper seedbed preparation is an important factor in establishing a good stand of grass. In many areas incorporation of dead vegetation and organic matter by intensive cultivation is necessary in order to get a satisfactory seedbed. After tilling and packing, the seedbed should be firm; a heel imprint should barely show after walking over the ground. The soil should be weed-free and moist. When the seedbed is well prepared, the amount of seed needed will be less and the success of the planting will be greater. On steep sloping land or construction sites where tillage implements cannot be used, the soil should remain in a rough condition. Slopes should be prepared as well as possible and roughened with construction equipment so the broadcast seed will have a chance to remain in place long enough to germinate and produce a stand.

3. Seed Specifications

Certified seed should be used whenever it is available. Germination and purity tests should be used to determine the proper seeding rates for each grass or legume variety. Legumes should be scarified if necessary and inoculated with the proper strain of nitrogen-fixing bacteria before seeding. Use only northern strains of grasses and legumes.

4. Time of Seeding

For best results seedings should be made in early June. Successful seedings can be made later in the summer but grass and legumes should not be seeded later than mid August to avoid winterkill. Annual ryegrass or cereal grain can be seeded until September 1 to secure a temporary cover to reduce erosion. The area should then be seeded to a perennial grass the next spring.

5. Seeding Methods

a. Drill

A grass drill is the best method of seeding on nearly level to sloping land, but the preferred method will depend on slope, and conditions of the planting site. Very small seed must be seeded no more than 0.6 to 1.3 centimetres (0.25 to 0.50 inches) deep. A packer should be pulled behind the drill unless the equipment already has a packer combination. On steep slopes where drilling is not

feasible, the hydroseeder method is preferred. When applying seed, fertilizer or mulch materials with the hydroseeder, use not more than 45.3-68.0 kilograms (100-150 pounds) of solids per 378.5 litres (100 gallons) of water. It is best to apply seed or seed and fertilizer first, to ensure seed contact with the soil, followed by the mulch. Fertilizer can be added to the water slurry as long as the material is used within a few hours after mixing, preferably when the soil is already moist.

b. ***Hydroseeding***

Hydroseeder Operation 3,785 litre (1,000 gallon) tank

1. Seeding – 0.8 hectares (2 acres)
   - Seed: 18.1–45.3 kilograms (40–100 pounds)
   - Fertilizer: 800–1, 90.6 kilograms (200 pounds)
   - Water: 3,785 litres (1,000 gallons)

2. Mulching – 0.2 hectares (0.5 acres)
   - Fiber mulch: 226.5–271.8 kilograms (500–600 pounds)
   - Water: 3,785 litres (1,000 gallons)

If necessary to seed, fertilize, and mulch in one operation, each 3,785 litre (1,000 gallon) load should cover 0.13 hectares (0.33 acres) and the mixture for each load would be as follows:

Seed:	3.2–7.7 kilograms (7–17 pounds)
Mulch:	15.0–181.2 kilograms (33–400 pounds)
Fertilizer:	61.2–90.6 kilograms (135–200 pounds)
Water:	3,785 litres (1,000 gallons)

Caution: Add seed and fertilizer first and mix thoroughly in tank at least 1/3 full of water before adding mulch.

c. ***Broadcast***

If the broadcast method of seeding is used, rates of seed application should be twice that recommended for drilling.

d. ***Sprigging***

Sprigging (planting a shoot, root or sprout of a plant) and sodding (covering with sections of sod) are special methods which are costly, but necessary for some grasses. Sodding and sprigging may be preferable to seeding in critical situations.

6. Fertilization

Fertilization is important to ensure a good growth of grass. Grass should be fertilized each year for best results.

The general recommendations for fertilizer are 27.2 kilograms (60 pounds) N (nitrogen) - 27.2 kilograms (60 pounds) P_2O_5 (phosphate) - 27.2 kilograms (60 pounds) K_2O (potash) per 0.41

hectares (1 acre) the first year and a maintenance application of 30-60-30 each ensuing year on construction sites. Where soil testing service is available fertilizer application should be based on soil tests. Some possible combinations of commercially available fertilizers to obtain the indicated amounts of N, P, and K are:

60-60-60-	135.9 kilograms (300 pounds) of 10-20-20 plus 45.3 kilograms (100 pounds) of 33-0-0 or 135.9 kilograms (300 pounds) of 10-20-10 plus 45.3 kilograms (100 pounds) of 33-0-0 plus 22.7 kilograms (50 pounds) of 0-0-60
120-60-60	135.9 kilograms (300 pounds) of 10-20-20 plus 135.9 kilograms (300 pounds) of 33-0-0 or 135.9 kilograms (300 pounds) of 10-20-10 plus 135.9 kilograms (300 pounds) of 33-0-0 plus 22.7 kilograms (50 pounds) of 0-0-60
30-60-30	135.9 kilograms (300 pounds) of 10-20-10

Many other combinations are possible. For best results, at least one-half of the nitrogen added should be in the form of nitrate. Urea is not generally recommended because of its slow release of nitrogen in northern soils.

7. Maintenance

Grass seedings must be kept moist after seeding and until the grass has reached a height of 3-6 centimetres (1-2 inches). If possible, supplement water should be supplied especially during prolonged periods of drought while grass is becoming established. Critical sites may need watering, some reseeding or sodding, and maintenance applications of mulch and fertilizer.

8. Mulching

Mulching is important in establishing vegetation on steep construction sites or other critical areas. A mulch cover will help hold moisture, protect the soil from erosion, hold seed in place and keep soil temperatures more constant. It should be applied uniformly by mechanical means or by hand after seeding. Common types of mulching material used in critical-area plantings are hay, small grain straw, straw-asphalt, wood-fiber mulches, peat moss, and jute matting. Grass seed straw, or native bluejoint hay, cut when seed is about mature, often contains viable seed and is excellent for mulching. Some bare soil should still be visible through a straw mulch. Mulching is necessary on steep and critical areas, but is expensive and not always necessary to establish grass stands on favorable sites. Very early spring applications may retard the rate at which soils may warm up.

On north-facing slopes a dark colored binder with a mulch will increase the surface temperature and promote early growth. Care must be taken in applying a binder simultaneously with

mulch and seed to ensure that there is contact between the seed and the soil. Seeds coated with binder may be slow to germinate or fail completely (35).

Methods of anchoring mulch are important. They include pressing the mulch into the soil with a mulch anchoring tool, tacking with various binders, and tying down with cotton netting or wire mesh.

9. Annual Seedings

Annual ryegrass (Lolium multiflorum) is recommended for a quick catch on burned or critical areas for erosion control. Seedings at rates of 11.1-27.9 kilograms per hectare (10-25 pounds per acre) or more for thick growth should be made before August 1 for best results. Plan on seeding to perennial species the following spring. Annual ryegrass is also recommended for seeding with a perennial grass mixture to control erosion until the perennial grass becomes established.

10. Native Seeds

Native bluejoint (Calamagrostis canadensis) and fall arctic-grass (Arctagrostis latifolia) have been found to be excellent colonizers of distrubed areas of the northern forest and tundra although they are not as fast growing as some of the hardier agronomic grasses (34). Unfortunately seed for these grasses is in limited supply and may not yet be available in commercial quantities.

B. SOIL AND SITE GROUPS AND RECOMMENDED PLANTS

1. Soils and Sites with Few or No Limitations

These soils and sites are well drained and have slopes of 20% or less. They consist of silt loam to sandy loam, moderately permeable materials ranging from 51 centimetres (20 inches) to more than 152 centimetres (60 inches) thick. The natural substrate or subgrade materials may be very porous gravel deposits, moderately fine textured sediments, bedrock, or rock fill.

With adequate fertilization these soils and sites are generally suitable for a wide range of climatically adapted species.

Major soil Limitations	Drainage Class	Depth centimetres (inches)	USDA Texture	Engineering Classification Unified	AASHO	Water Holding capacity centimetres (inches)
None	Well and moderately well drained	More than 51 (20)	Silt Loam, fine sandy loam,	ML CL SM	A2 A-4 A-6 Some A-7	13 to 20 (5 to 8)

	Mixtures and Species in Numbered Order	Variety name in Order of Preference	Drill Seeding Rate kgm/ha. (lbs/Ac)
Mix 1	Red Fescue	Arctared	11.2 (10)
	Alside or White Dutch clover	or Olds	3.4 (3)
Mix 2	Smooth Brome	Polar or	16.8 (15)
		Manchar	11.2 (10)
	Alsike or White Dutch clover		3.4 (3)
Mix 3	Smooth Brome	Polar or	9.0 (8)
		Manchar	5.6 (5)
	Kentucky bluegrass	Nugget or	5.6 (5)
		Merion	5.6 (5)
	Alsike or White Dutch clover		3.4 (3)

* Annual ryegrass may be added to any single species or mixture for quick cover, at a rate not to exceed 5.6 kilograms per hectare (5 pounds per acre).

2. Soils and Sites with Limitations Due to Low Water Holding Capacity

These soils and sites consist of well-drained silt loam to sandy loam materials, ranging from 25 to 51 centimetres (10 to 20 inches) in depth, and generally underlain by gravel or sandy deposits. In places they may be underlain by bedrock or rock fill. Slopes are 20% or less. The permeability is moderate. The soils and sites in this group have a tendency to be droughty.

On these soils and sites the use of drought tolerant species is usually necessary.

Major soil Limitations	Drainage Class	Depth centimetres (inches)	USDA Texture	Engineering Classification Unified	AASHO	Available Water Holding Capacity centimetres (inches)
Drought-iness	Well-drained	25 to 51 (10 to 20)	Silt loam fine sandy loam, sandy loam	ML CL SM	A-2, A-4 A-6 Some A-7	8 to 13 (3 to 5)
		Sub-strate	Very gravelly sand or shattered rock	GW, GP GM, SW SP	A-1, A-3	

	Mixtures and Species in Order of Preference	Variety name in order of Preference	Drill Rate kgm/ha. (lbs/Ac.)
Mix 1	Smooth Brome	Polar or	9.0 (8)
		Manchar	5.6 (5)
	Hard Fescue	Durar	5.6 (5)
	Alsike or White Dutch clover		3.4 (3)
Mix 2	Smooth Brome	Polar or	16.8 (15)
		Manchar	11.2 (10)
	Alsike or White Dutch clover		3.4 (3)
Mix 3	Smooth Brome	Polar or Manchar	9.0 (8)
		Manchar	5.6 (5)
	Red fescue	Arctared	9.0 (8)
		Olds or Boreal	5.6 (5)
	Alsike or White Dutch clover		3.4 (3)

3. Soils and Sites with Severe Limitation Due to Very Low Water Holding Capacity or Steep Slopes

These soils and sites are well drained or excessively drained and are very shallow or steep. Many construction sites, road cuts and fills, and distrubed or compacted sites are included.

The very shallow soils have less than 26 centimetres (10 inches) of loamy materials over gravel, sand or bedrock. The water supplying capacity is less than 8 centimetres (3 inches). On steep slopes the soils may be deep or shallow over gravel, sand, or bedrock, but the water supply capacity is equally low because of excessive run-off. On the deep soils, especially those high in silt, the erosion hazard is high.

The choice of plants for this group is usually limited to species that are adapted to droughty condition, and form a dense root mass.

Major soil Limitations	Drainage Class	Depth centimetres (inches)	USDA Texture	Engineering Classification United	AASHO	Available Water Holding Capacity centimetres (Inches)
Drought-iness or high erosion	Well and excessively drained	25 to 51 (10 to 20)	Silt loam sandy loam sand	ML CL SM	A-2, A-4 A-6	less than 8(3)
		Sub-strate	Very gravelly sand or shattered rock	GW, GP GM, SW SP	A-1, A-3	

	Mixtures or Species in Order of Preference*	Variety name in order of Preference	Drill Seeding Rate kgm/ha. (lbs/Ac.)
Mix 1	Smooth Brome	Polar or Manchar	9.0 (8) 5.6 (5)
	Hard Fescue	Durar	5.6 (5)
Mix 2	Crested wheat-grass	Nordan	5.6 (5)
	Hard fescue	Durar	5.6 (5)
Mix 3	Streambank wheatgrass	Sodar	16.8 (15)
Mix 4	Smooth Brome	Polar or Manchar	16.8 (15) 11.2 (10)

* Yellow or White sweet clover may be added at rate of 5.6 kgm./ha. (5 lbs/Ac.) to the above mixtures.

4. Soils and Sites with Moderate Limitations Due to Excess Moisture

These soils and sites have textures ranging from silty clay loam to fine sandy loam. The natural drainage may be impeded by layers of low permeability in the substrate, by permafrost, or low relief terrain. The water table is usually more than two feet below the surface but may fluctuate to higher levels for short periods of time during the growing season.

If these soils and sites are drained, they are generally suitable for plant growth. If they are undrained, plant choices will be limited to those that are tolerant to cool, moist conditions.

Major soil limitations	Drainage Class	Depth centimetres (inches)	USDA Texture	Engineering Classification Unified	AASHO	Available Water Holding Capacity centimetres (inches)
Impeded drainage	Somewhat poorly drained or poorly drained	More than 51(20)	Silty clay loam, silt loam sandy loam, fine sandy loam	MML CL SM	A-2, A-4 A-6 Some A-7	More than 13(5) (may be water logged for short periods)

	Mixtures and Species in Order of Preference	Variety name in Order of Preference	Drill Seeding Rate Kgm/La. (lbs/Ac.)
Mix 1	Creeping foxtail	Garrison	11.2 (10)
	White Dutch or Alsike clover		3.4 (3)
Mix 2	Creeping foxtail	Garrison	11.2 (10)
	Kentucky bluegrass	Nugget or	5.6 (5)
		Merion	5.6 (5)
	White Dutch or Alsike clover		3.4 (3)
Mix 3	Timothy	Engmo	6.7 (6)
	Creeping Red fescue	Arctared or	9.0 (8)
		Olds	5.6 (5)
	White Dutch or Alsike clover		3.4 (3)
Mix 4	Smooth Brome	Manchar or	11.2 (10)
		Polar	16.8 (15)
	White Dutch or Alsike clover		3.4 (3)

5. Soils and Sites with Severe Limitations due to Excess Moisture

These soils and sites have a wide range of textures and are generally wet throughout the growing season. The water table is usually within two feet of the surface. These wet conditions may be due to materials with poor permeability, high permafrost tables, slow surface runoff, or seepage from adjacent areas.

Many of these soils and sites are not feasible to drain, and plant choices are limited to those that are the most tolerant to cold, wet soil conditions. If they can be drained to maintain the water table at a depth of two feet or more, the choice of plants can be widened.

Major soil limitations	Drainage class	Depth centimetres (inches)	USDA texture	Engineering Classification Unified	AASHO	Available Water Holding Capacity centimetres (inches)
Wetness (high water table)	Poorly drained	More than 51 (20) May have up to 41 centimetres (16 inches) of peat or surface	Very wide range			Usually waterlogged

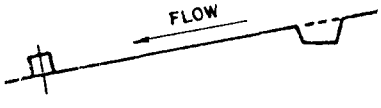
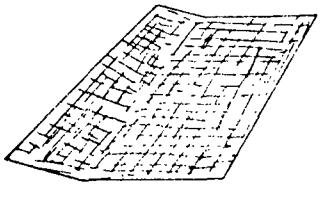
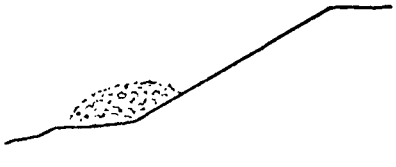
	Mixtures and Species in Order of Preference	Variety name in Order of Preference	Drill Seeding Rates Kgm./ha. (lbs/Ac.)
Mix 1	Creeping foxtail	Garrison	11.2 (10)
	Kentucky blue-grass	Nugget or Merion	5.6 (5) 5.6 (5)
	White Dutch or Alsike clover		3.4 (3)
Mix 2	Creeping foxtail	Garrison	11.2 (10)
	White Dutch or Alsike clover		3.4 (3)
Mix 3	Timothy	Engmo	6.7 (6)
	Kentucky blue-grass	Nugget or Merion	5.6 (5) 5.6 (5)
	White Dutch or Alsike clover		3.4 (3)

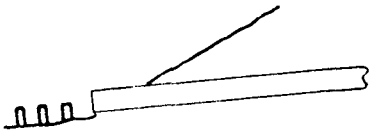
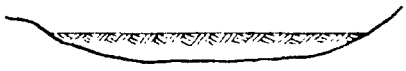
APPENDIX B

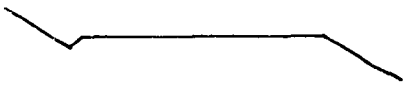
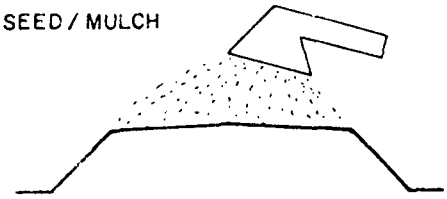
EROSION AND DRAINAGE CONTROL PRACTICES

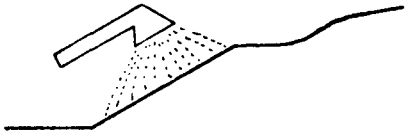
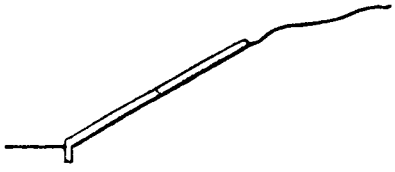
EROSION CONTROL PRACTICES

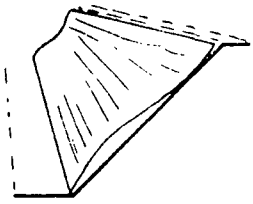
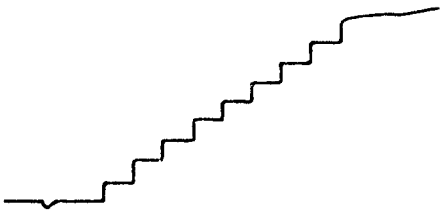
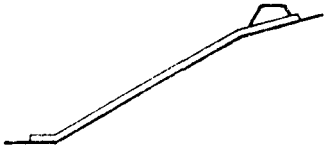
(taken with amendments from "Erosion Control on Highway Construction", Highway Research Board, U.S. N.R.C., 1973)(19)

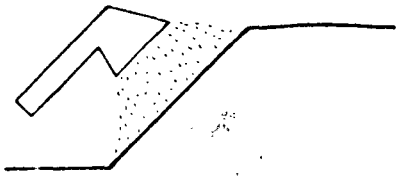
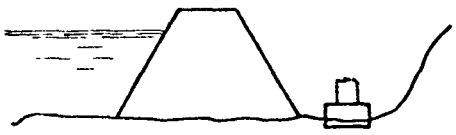
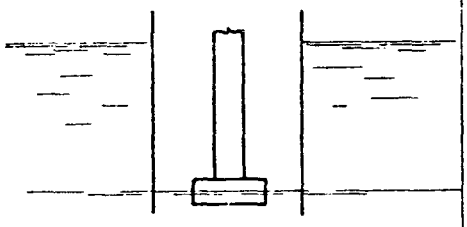
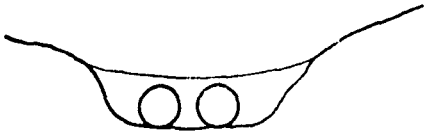
TREATMENT PRACTICE	BENEFITS	PROBLEMS
ROADWAY DITCHES		
CHECK DAMS 	Maintain low velocities Retain sediment Can be constructed of logs, shot rock, lumber, masonry or concrete	Require close spacing on steep grades Require periodic clean-out Unless keyed at sides and bottom erosion may occur
SEDIMENT TRAPS / STRAW BALE FILTERS 	Can be located as necessary to collect sediment during construction Clean-out often can be done with on-the-job equipment Simple to construct Straw bale filters not usually required	Sediment disposal may be difficult Specification must include provisions for periodic clean-out May require seeding, or pavement if removed during final cleanup
SEEDING WITH MULCH & MATTING 	Effective for ditches with low flow velocities Easily placed in small quantities by inexperienced personnel	Will not withstand medium to high velocity unless tacked to ground
PAVING, RIPRAP, RUBBLE 	Effective for high velocities May be part of the permanent erosion control effect	Cannot always be placed when needed because of construction traffic and final grading and dressing Initial cost is high
BRUSH BARRIERS 	Can use slashing and logs from clearing operation Can be covered and seeded rather than removed	May be considered unsightly in urban areas

TREATMENT PRACTICE	BENEFITS	PROBLEMS
ROADWAY DITCHES		
STRAW BALE BARRIERS 	Straw is readily available in many agricultural areas When properly installed, they filter sediment and some turbidity from runoff	Require removal Subject to vandal damage Flow is slow through straw requiring considerable area Shipment costs may be prohibitive to northern locations
SEDIMENT POOLS 	Can be designed to handle large volumes of flow Both sediment and turbidity are removed May be incorporated into permanent erosion control plan	Clean-out volumes can be large Access for clean-out not always convenient
TEMPORARY RIPRAP 	Sacked sand with cement or stone easy to stockpile and place Can be installed in increments as needed	Expensive
ENERGY DISSIPATORS 	Slow velocity to permit sediment collection and to minimize channel erosion off project	Collect debris and require cleaning Require special design and construction of large shot rock or other suitable material from project
LEVEL SPREADERS 	Convert collected channel or pipe flow back to sheet flow Avoid channel easements and construction off project Simple to construct	Adequate spreader length may not be available Must be a part of the permanent erosion control effort Maintenance forces must maintain spreader until no longer required

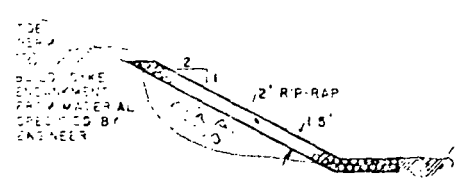
TREATMENT PRACTICE	BENEFITS	PROBLEMS
ROADWAY SURFACE		
CROWNING TO DITCH OR SLOPING TO SINGLE BERM 	Directs the surface water to a prepared or protected ditch, and minimizes erosion	None - should be part of good construction procedures
COMPACTION	Part of good construction procedures	None
AGGREGATE COVER 	Minimizes surface erosion Permits construction traffic during adverse weather May be used as part of permanent base construction	Requires reworking and compaction if exposed for long periods of time Loss of surface aggregates can be anticipated
SEED/MULCH 	Minimizes surface erosion	Must be removed or is lost when construction of pavement is commenced Should only be considered if roadway abandoned or closed for a long period
CUT SLOPES		
BERM AT TOP OF CUT 	Diverts water from cut Collects water for slope drains/paved ditches May be constructed before grading is started	Difficult to build on steep natural slope or rock surface Concentrates water and may require channel protection or energy dissipation devices Can cause water to enter ground, resulting in sloughing of the cut slope

TREATMENT PRACTICE	BENEFITS	PROBLEMS
CUT SLOPES		
DIVERSION DYKE 	Collects and diverts water at a location selected to reduce erosion potential May be incorporated in the permanent project drainage	Access for construction May be continuing maintenance problem if not paved or protected Disturbed material or berm is easily eroded
SLOPE BENCHES 	Slows velocity of surface runoff Collects sediment Provides access to slope for seeding, mulching, and maintenance Collects water for slope drains or may divert water to natural ground	May cause sloughing of slopes if water infiltrates Require additional ROW Requires maintenance to be effective Increases excavation quantities
SLOPE DRAINS (PIPE, PAVED, ETC.) 	Prevents erosion on the slope Can be temporary or part of permanent construction Can be constructed or extended as grading progresses	Require supporting effort to collect water Permanent construction is not always compatible with other project work Usually requires some type of energy dissipation
SEEDING / MULCHING 	The end objective is to have a completely grassed slope. Early placement is a step in this direction. The mulch provides temporary erosion protection until grass is rooted. Temporary or permanent seeding may be used. Mulch should be anchored. Larger slopes can be seeded and mulched with smaller equipment if stage techniques are used.	Difficult to schedule high production units for small increments. Time of year may be less than desirable May require supplemental water Contractor may perform this operation with untrained or unexperienced personnel and inadequate equipment if stage seeding is required.
SLOPE PAVEMENT, RIPRAP 	Provides immediate protection for high risk areas and under structures May be cast in place or off site	Expensive Difficult to place on high slopes May be difficult to maintain

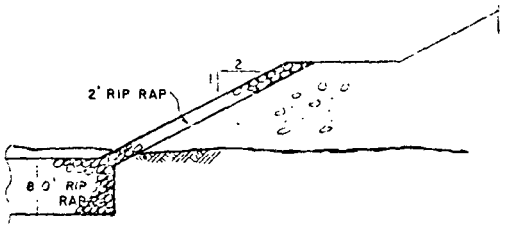
TREATMENT PRACTICE	BENEFITS	PROBLEMS
CUT SLOPES		
TEMPORARY COVER 	Plastics are available in wide rolls and large sheets that may be used to provide temporary protection for cut or fill slopes Easy to place and remove Useful to protect high risk areas from temporary erosion	Provides only temporary protection Original surface usually requires additional treatment when plastic is removed Must be anchored to prevent wind damage
SERRATED SLOPE 	Lowers velocity of surface runoff Collects sediment Holds moisture Minimizes amount of sediment reaching roadside ditch	May cause minor sloughing if water infiltrates
FILL SLOPES		
BERMS AT TOP OF EMBANKMENT 	Prevent runoff from embankment surface from flowing over face of fill Collect runoff for slope drains or protected ditch Can be placed as a part of the normal construction operation and incorporated into fill or shoulders	Requires cooperation of construction operators to place final lifts at edge for shoping into berm Failure to compact outside lift when work is resumed is common Sediment buildup and berm failure possible
SLOPE DRAINS 	Prevent fill slope erosion caused by embankment surface runoff Can be constructed of full or half section pipe, bituminous, metal, concrete, plastic, or other waterproof material Can be extended as construction progresses May be either temporary or permanent	Permanent construction as needed may not be considered desirable by contractor Removal of temporary drains may disturb growing vegetation Energy dissipation devices are required at the outlets
FILL BERMS OR BENCHES 	Slows velocity of slope runoff Collects sediment Provides access for maintenance Collects water for slope drains May utilize waste	Require additional fill material if waste soil is not available May cause sloughing Additional ROW may be needed

TREATMENT PRACTICE	BENEFITS	PROBLEMS
FILL SLOPES		
SEEDING/MULCHING 	Timely application of mulch and seeding decreases the period a slope is subject to severe erosion Mulch that is cut in or otherwise anchored will collect sediment. The furrows made will also hold water and sediment. This is good for seed germination.	Seeding season may not be favorable Not 100 percent effective in preventing erosion Watering may be necessary Steep slopes or locations with low velocities may require supplemental treatment Contractor may perform this operation with untrained personnel or inadequate equipment if stage seeding is required
PROTECTION OF STREAM		
CONSTRUCTION DYKE 	Permits work to continue during normal stream stages Controlled flooding can be accomplished during periods of inactivity	Usually requires pumping of work site water into sediment pond Subject to erosion from stream and from direct rainfall on dike
COFFERDAM 	Work can be continued during most anticipated stream conditions No material deposited in stream	Expensive
TEMPORARY STEAM CHANNEL CHANGE	Prepared channel keeps normal flows away from construction	New channel usually will require protection Stream must be returned to old channel and temporary channel refilled
TEMPORARY CULVERTS 	Eliminate stream turbulence and turbidity Provide unobstructed passage for fish and other water life	Space not always available without conflicting with permanent structure work May be expensive, especially for larger sizes of pipe Subject to washout

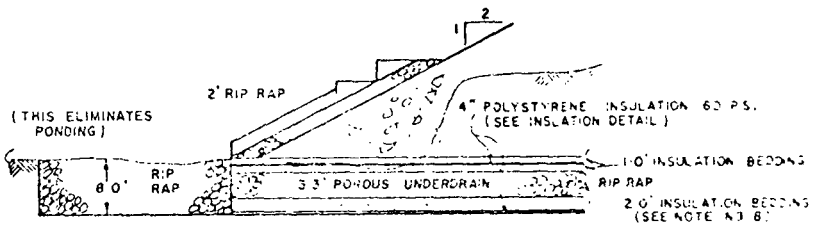
TREATMENT PRACTICE	BENEFITS	PROBLEMS
PROTECTION OF STREAM		
RIPRAP RUBBLE	See Roadway Ditches	See Roadway Ditches
BORROW AREAS		
SELECTIVE GRADING & SHAPING	Water can be directed to minimize off-site damage Flatter slopes enable mulch to be cut into soil	May not be most economical work method for contractor
STRIPPING & REPLACING OF TOPSOIL	Provides better seed bed Conventional equipment can be used to stockpile and spread topsoil	May restrict volume of material that can be obtained for a site Topsoil stockpiles must be located to minimize sediment damage Cost of rehandling material
DYKES, BERMS DIVERSION DITCHES SETTLING BASINS SEDIMENT TRAPS SEEDING & MULCHING	See other practices	See other practices



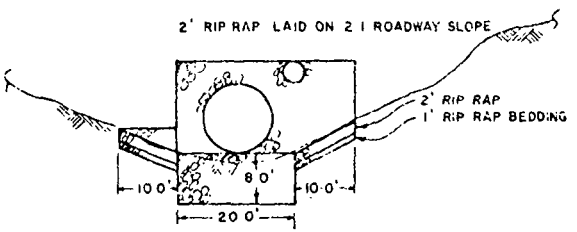
SECTION A-A



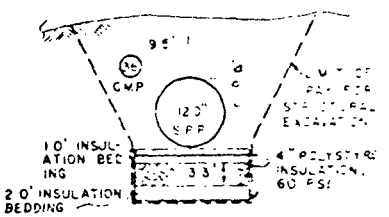
SECTION B-B



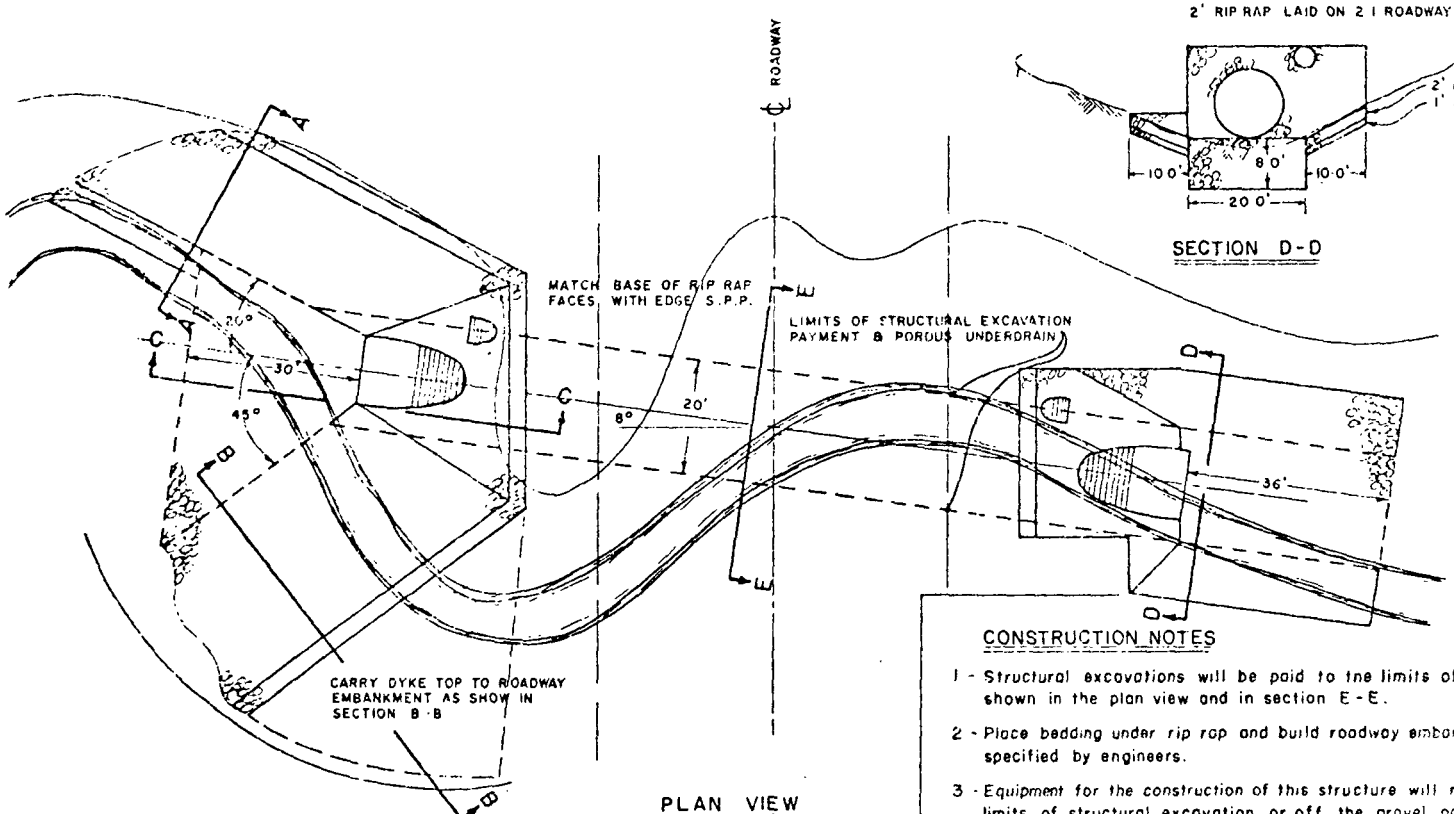
SECTION C-C



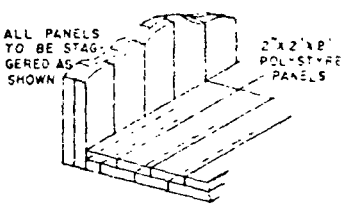
SECTION D-D



SECTION E-E



PLAN VIEW



INSULATION DETAIL

B-8

CONSTRUCTION NOTES

1 - Structural excavations will be paid to the limits of the porous underdrain and natural ground line as shown in the plan view and in section E-E.

2 - Place bedding under rip rap and build roadway embankment to an elevation ≤ HWL (aprox. 5.0') with materials specified by engineers.

3 - Equipment for the construction of this structure will not be allowed in the hand cleared area outside the limits of structural excavation or off the gravel pad placed under the roadway embankment

4 - Rip rapped inlet dykes will extend from the structural plate pipe and tie into the stream banks.

5 - 120" structural pipe : inlet invert elevation is higher than (aprox. 1.0') outlet invert elevation.

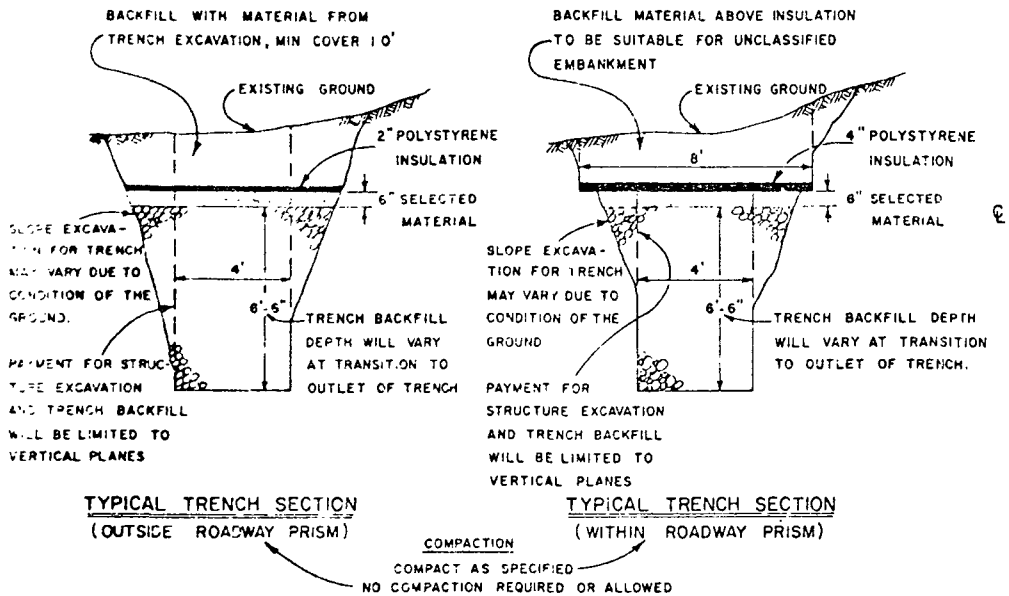
6 - All excavation for this structure will be wasted as directed by the engineer.

7 - Slopped rip rap on channel sides to conform to natural ground at pipe outlet as shown in section D-D.

8 - Bedding material, specified by engineer with no rocks larger than 4" placed directly against insulation or conduit.

FIGURE B-1. STEP CULVERT INSTALLATION WITH FRENCH DRAIN UNDERLAY

(DEPT. OF HIGHWAYS - STATE OF ALASKA)



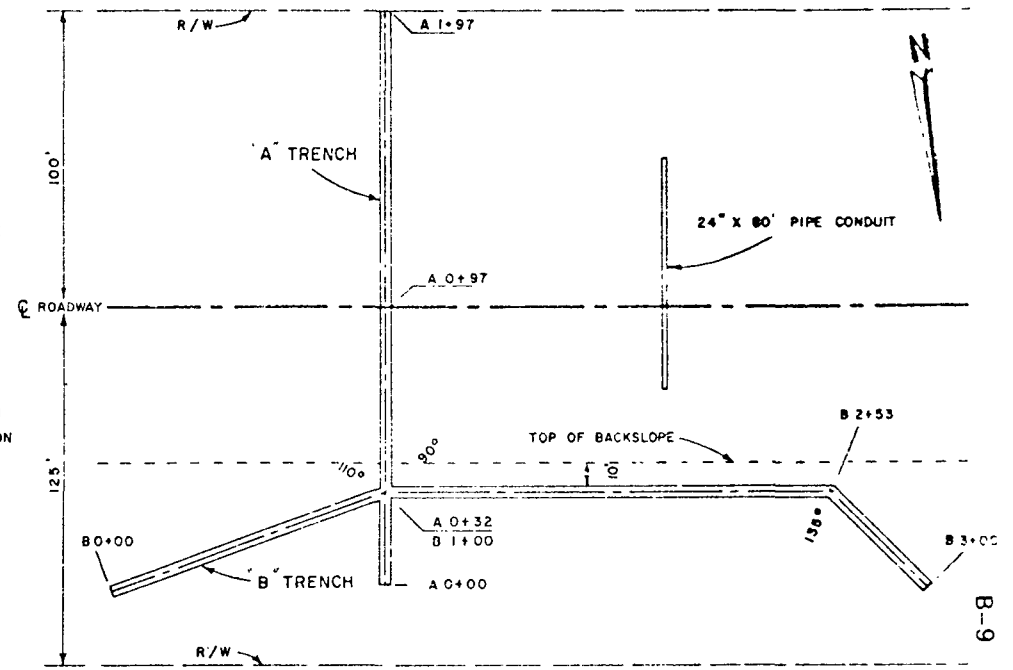
TYPICAL TRENCH SECTION (OUTSIDE ROADWAY PRISM)

TYPICAL TRENCH SECTION (WITHIN ROADWAY PRISM)

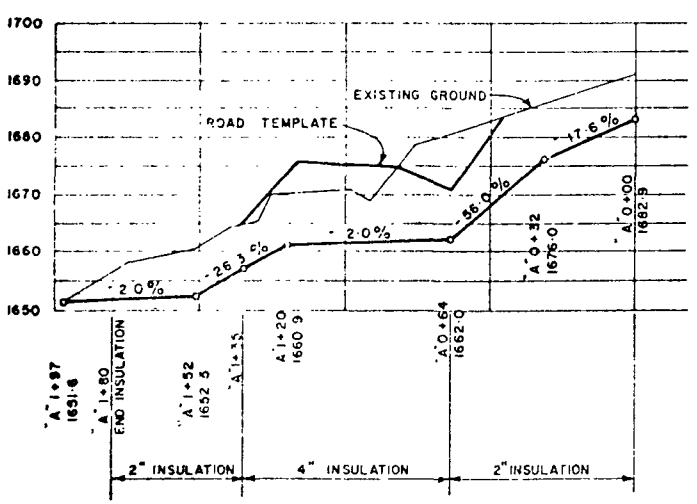
COMPACTION

COMPACT AS SPECIFIED

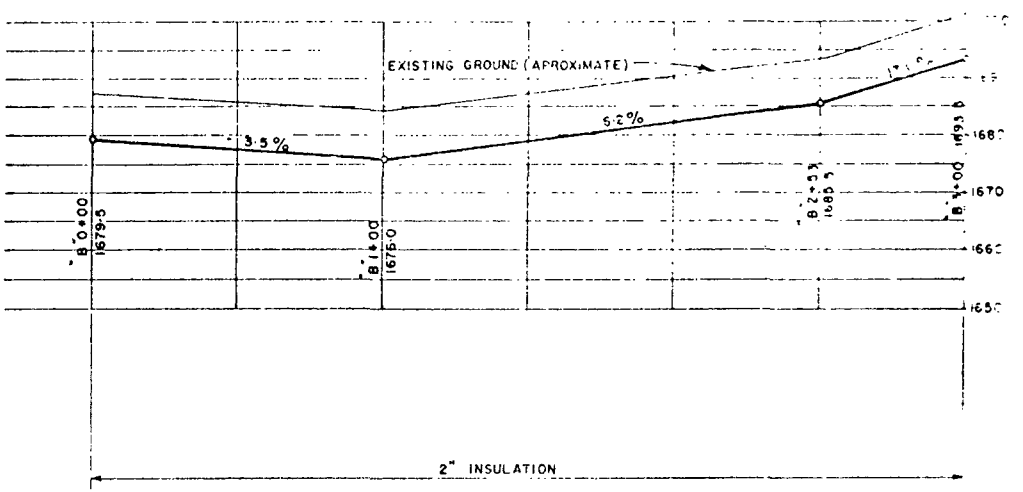
NO COMPACTION REQUIRED OR ALLOWED



PLAN VIEW



"A" TRENCH – PROFILE GRADE



"B" TRENCH – PROFILE GRADE

FIGURE B-2 SUBDRAIN FOR PREVENTION OF ICINGS (DEPT. OF HIGHWAYS - STATE OF ALASKA)

APPENDIX C

GUIDELINES FOR FISH PASSAGE THROUGH CULVERTS

(excerpt with amendments taken from Report: "Guidelines for the Protection of the Fish Resources of the Northwest Territories During Highway Construction and Operations" by R.L. Dryden and J.N. Stein, Technical Report Series No. CEN/T-75-1, Fisheries and Marine Service, Department of the Environment. (39))

1. FISH PASSAGE REQUIREMENTS

1.1 Culvert Velocities

Selection of maximum culvert velocities, in order to accommodate fish swimming performance, should ideally be conducted on an individual stream basis. Consideration would then be given to the hydrographic characteristics of the system, its fish species composition and the purposes for which the fish are utilizing the stream. However, for most of the Northwest Territories, these data are lacking. Therefore, to derive a maximum velocity figure for the purpose of preliminary highway design, consideration was given to three fish species considered typical for the area of concern. The selection of these species was based on the following:

1) That they are widely distributed throughout the Northwest Territories.
2) That they represent the full spectrum of swimming performance determined for northern fish species by Jones (1973).

The species selected were northern pike, humpback whitefish and longnose sucker. Table 2 lists the minimum age at maturity, the percentage of the spawning run represented by each age group and the size range by age for the three species. These data were obtained by pooling information collected from the Fort Simpson, Norman Wells, Arctic Red River and Aklavik areas during the Mackenzie Valley Pipeline Study (Stein *et al.,* 1973).

The ideal highway stream crossing should permit the passage of all fish attempting to move upstream. However, many such migrations frequently include a small number of fish which are not fully mature and are therefore not essential to the successful spawning of the population.

If the mid-lengths for the size ranges shown, at minimum age at maturity, are taken for the three representative species, the maximum culvert velocity (based on a maximum culvert length of approximately 100 metres/328 feet) which these fish might be expected to pass can be determined from the results presented in Jones (1973) (Table 3).

Considerable variation appears to exist between the critical velocity laboratory results obtained by Jones using a swimming chamber, and those observed under field conditions. For example, Dryden and Jessop (1974) attempted to monitor the culvert passage success of northern pike, the species selected as representative of fish displaying a poor swimming performance. An individual fish was noted to pass the culvert at centre-line (inlet/outlet) velocities of 1.8 to 2.2 m/s (6.0 to 7.1 fps). However, this instance was considered to be atypical and it was not felt that passage was generally possible until centre-line velocities reached 0.9 to 1.6 m/s (3.1 to 5.2 fps). Water velocities along the culvert sides would have been somewhat slower and it was felt that these areas of slower current were used to obtain passage.

A possible reason for the data variation is that Jones' estimates were based on the swimming time required to negotiate culverts up to 100 metres (328 feet), while the culvert studied by Dryden and Jessop was 70.6 metres (231.6 feet) in length. It is also known that those fish which were initially

Table 3 **Maximum culvert velocities passable by representative fish species at age of maturity, based on the critical velocity equations determined by Jones (1973)**

Species	Approx. Size at Maturity mm (in.)	*Critical Velocity Equation (Jones, 1973)	Maximum Passable Velocity cm/sec (ft/sec)
Northern pike	338.5 (13.3)	$V = 4.9L^{0.55}$	33.85 (1.11 ft/se
Humpback whitefish	385.5 (15.2)	$V = 18.2L^{0.35}$	65.52 (2.15 ft/se
Longnose sucker	287.0 (11.3)	$V = 11.03L^{0.529}$	65.13 (2.14 ft/se

*V = critical velocity (cm/sec)
L = fork length (cm)

successful were considerably larger than those at minimum age of maturity and were therefore capable of a stronger swimming performance.

Schultz (1974) graphically demonstrated that fish passage through the Caribou Creek culvert improved drastically when average cross-sectional velocities within the culvert dropped below .9 m/s (3 fps).

On the basis of the above, it is recommended that highway culverts be designed such that the average cross-sectional velocity through any culvert section shall not exceed 0.9 m/s (3 fps) during fish migration periods, unless it can be satisfactorily demonstrated that the culvert design includes a selected region wherein velocities are low enough to permit fish passage. This selected region must be continuous throughout the culvert length and of sufficient size to permit the fish to locate it and to swim through it. Velocity criteria need not be adhered to during the delay period in which culverts are permitted to be impassable to fish.

In the event that culvert velocity criteria cannot be met during migration periods then alternative provisions for fish passage must be employed. "Constructing a fish passage device through a culvert essentially opposes the entire basic idea of the culvert. The culvert is made to pass water downstream at the highest possible rate, whereas the fish passage facility built into it must afford a relatively easy upstream path for migrating fish" (McKinley and Webb, 1956). In-culvert energy dissipation baffles create a localized region of reduced velocities along the culvert bottom or sides. The same hydraulics principles utilized in fish-way design (Clay, 1961) must be applied to baffle design if fish passage is to be effective.

Some of the factors which must be considered in baffle design are the decrease in baffle effectiveness with increases in culvert gradient, silt and debris accumulation, reduced culvert capacity and aggravated icing. "Any provision of facilities for fish passage in the barrel of a culvert, that is not accompanied by consideration of ingress and egress from the culvert may be of little value." (McClellan, 1971). For instance, baffle provision within a culvert having an elevated exit (waterfall), which prevents fish entry, is futile.

The study conducted by Engel (1974) contains baffle objectives, test results and suggested baffle designs based on laboratory model studies. It must be remembered, however, that a baffle configuration cannot be considered successful until fish passage under field conditions is determined.

In many instances culvert velocities and gradient will permit natural river bottom materials to be deposited along the culvert bottom. Such deposition, if retained during high-flow periods, will increase the bottom roughness factor and provide a localized region of slower velocities. In situations where the natural deposition is not coarse enough, the placement of an artifical rock substrate (material size being dependent on water velocities and culvert gradient) may slow bottom velocities enough to permit fish passage. Such rock placements will generally be advantageous only in borderline situations where the culvert velocities just exceed the recommended fish migration design velocities.

1.2 Period of Delay

As mentioned previously, little information exists on the physiological effects of delay to fish during spawning migrations. If a run should be blocked for an extended time period, the fish will probably resort to spawning in marginal areas below the blockage, with limited success (Dryden and Jessop, 1974). Consideration should also be given to the proximity of the spawning grounds. If the spawning grounds for a fish population are located immediately upstream of a highway crossing, the period of time during which migration is blocked would likely be much more critical than it would if the spawning areas were located several miles upstream and spawning less imminent. However, the longer that fish migrations are impeded, the more susceptible the fish will be to physical damage and thus more vulnerable to disease and predation. It is estimated that a spawning migration could tolerate a 3-day delay without serious biological consequences.

The discharge at which the culvert becomes impassable to fish is defined as the "critical fish migration discharge". It is recommended that a 7-day impassable period should not be exceeded more than once in the design period of 50 years. A 3-day impassable period should not be exceeded during the average annual flood, defined as a flood having a recurrence interval of 2.33 years. The 7-day delay discharge is that discharge being represented on the design flood (generally a 1 in 50 year recurrence interval) hydrograph by a straight line projected between both limbs of the hydrograph and parallel to the time axis for a period of 7 days. The 3-day delay discharge is represented on the average annual flood hydrograph and encompasses a time period of 3 days. For culvert designs to satisfy these criteria, neither the 7-day nor the 3-day delay discharges should exceed the critical fish migration discharge.

It should be pointed out that the 3-day or 7-day delay period is intended to coincide with the timing of fish migration past the culvert site. If it can be satisfactorily demonstrated that peak flows and fish movement at the culvert do not coincide then it may be possible to adjust the design procedure to accomodate fish movement at the non-peak period. It will, however, generally require several years data on each individual stream in order to properly define the fish movement vs. flood peak time-frame.

1.3 Minimum Water Levels

The water levels within culverts are most likely to be critical during fall, since this is usually a period of low runoff from watersheds and is also the spawning period for a great number of fish species, especially the Coregonids. In all cases, the depth of water in a culvert should be sufficient to submerge the largest fish to use the structure. Metsker (1970) recommends a minimum water depth for Pacific salmon and steelhead of 20.3 to 25.4 centimetres (8 to 10 inches). Since the size ranges of many northern species are similar to those of salmon (especially inconnu), 20.3 centimetres (8 inches) is considered the minimal water level permissible in culverts at any time during the openwater season, unless it can be shown that there is no requirement for fish movement through the culvert.

2. CULVERT DESIGN

The ideal river crossing will attempt to minimize interference with natural river conditions. The much preferred solution from the environmental view involves bridging each stream. However, there are many situations in which both economics and terrain may dictate that a culvert crossing is more realistic than a bridge. Just as there are different bridge designs there is also a variety of culvert types.

2.1 Culvert Shapes

The following culvert shapes are listed in order of preference to Fisheries and Marine Service.

i) ***Arch Culvert.*** This type of culvert may have either an open or a closed bottom. The open bottom type allows for natural riverbed material to be retained. The use of this type of culvert is dependent on suitable foundation conditions and depth of fill.

ii) ***Horizontal Ellipse.*** By lowering the culvert invert below the stream bed elevation it is possible to take advantage of the wide middle portion of this culvert for maintaining stream flow width and at the same time maintain natural river bed material in the culvert. Small barrier dams placed on the culvert bottom will provide some protection against the material washing out.

iii) ***Circular.*** This is the most familiar culvert shape. It is very impractical for fish passage, however, due to the circular geometry. As river flows decrease, the flow area within the culvert also decreases and the high water velocities are retained.

The following conditions all contribute to good culvert design. All of these conditions, where applicable, should be detailed on drawings and plans submitted for Fisheries and Marine Service approval or comments.

2.2 Installation and Gradient

Culvert inverts must be laid a minimum of 15 centimetres (6 inches) below normal stream bed elevation. When foundation conditions are such that a sagging of the central portion of the culvert is anticipated, the central portion should be installed with an upward camber design. Anticipated sag will then tend to reform the culvert to a constant gradient. Sag in a non-camberted culvert can impose a passage problem for fish due to the increased culvert gradient on the upstream side of the sag.

Inverts must be designed to prevent hydrostatic uplift at the downstream or upstream end.

The culvert gradient is to be kept as close to 0% gradient as foundations and stream conditions permit, with the condition that upstream or downstream velocity barriers are not formed as a result. The maximum culvert slope that should be installed when employing a baffle configuration is

5%. Beyond the 5% slope, baffle effectiveness is inversely proportional to any increase in slope (Engel, 1974).

If construction procedures permit, the bolt connections should be installed with the bolt head on the culvert interior. This will help prevent fish being damaged on the sharp, nut and bolt end.

2.3 Capacity

The culvert(s) should have sufficient capacity to pass the design flood (generally a 1 in 50 year flood) with no backwatering or ponding at the upstream end of the culvert(s). There should also be a freeboard allowance for passage of debris.

When water flow enters (inlet) or leaves (outlet) a culvert it generally undergoes an abrupt and localized change in water surface elevation. This "draw down" of water levels is a result of the design and capacity characteristics of the culvert. An abrupt reduction of water levels causes an abrupt increase in water velocities which can form a localized velocity barrier to upstream fish movement. The maximum "draw down" through any section of the culvert should not exceed 0.3 metres (1 foot).

2.4 Culvert Location

Culvert designers should keep stream cut-offs or diversions to a minimum. Bypassing the natural stream loop (meander loop) increases the stream gradient within the diversion channel, which in most cases is the culvert. The increased gradient causes higher velocities and a greater potential for erosion.

The upstream end of the new channel, in the case of diversions, must remain closed off until the channel is fully excavated to the desired width, depth and length; then the stream flow may be diverted into the new channel. The existing channel shall not be filled and blocked by excavated material until diversion into the new channel is completed.

In order to prevent fish becoming trapped in the old channel during high water, the old channel should be filled with excavated material. If it is not feasible to fill the old channel a suitable means of egress must be provided such as an outlet or culvert pipe.

The degree of skew of the highway crossing should be kept to a minimum, so as to minimize both culvert lengths and construction area.

2.5 Erosion Prevention

The stream bed at the downstream end of the culvet may require armouring with heavy rip rap material to prevent bed scour. This end treatment should extend at least 2 pipe diameters past the culvert outlet. A suggested method of treatment would involve a 0.6 metre (2 foot) thick rip rap blanket placed on top of a 0.3 metre (1 foot) thick graded gravel blanket. If bed scour cannot be controlled by armouring of the stream bed, then artificial controls such as downstream rock weirs or gabions may be used. Such controls must, however, allow for fish passage. Both the upstream and downstream faces of

the roadway embankment must be resistant to erosion through turbulence and back eddies. The upstream end treatment must allow for floating debris.

Fill material should not contain any appreciable quantity of vegetation, roots, large rocks, frozen soil or other foreign substances. Special care should be taken during backfilling operations to ensure that uplifting or side movement of the culvert does not occur.

The culvert should be positioned so that its discharge is not directed at a potentially unstable riverbank. If proper direction is not possible then riverbank protection methods must be employed along the susceptible portions.

2.6 Multiple Culverts

It is suggested that a minimum of 1.8 metres (6 feet) be established between adjacent culvert walls in a multiple culvert arrangement. This spacing will provide a backwater area (downstream end) for the fish to rest in before attempting passage.

APPENDIX D

ENVIRONMENTAL PROTECTION MEASURES FOR HIGHWAY CAMPS

1. OBJECTIVES

These environmental protection measures have been prepared with the following aims in mind:

a) to avoid the degradation of local environmental quality factors or the creation of health hazards;

b) to minimize disruption of local ecosystems by work camp facilities and activities;

c) to help minimize alterations and distrubances to the landscape by camp activities and to encourage restoration of the site after camp removal;

d) to outline the best practicable technology and methods that can be employed in the disposal of camp wastes.

2. AREAS OF CONCERN

These environmental protection measures indicate the desired degree of waste effluent quality and methods of collection, storage, transportation, and processing of sewage and solid wastes. Also included are precautions which should be taken for fuel handling and storage facilities and requirements for site restoration after removal of camp facilities.

3. APPLICATION

These measures can be applied to all work-camp operations including those of government agencies, contractors, and subcontractors. Firms who intend to bid on contracts for work on the construction of highway system should be made aware of the content and applicability of these measures.

Prior to installation, all designs of and operating procedures for any waste disposal operation as well as information on fuel storage and handling sites and plans for restoration of the campsites after their removal should be made available to the appropriate government agency responsible for environmental protection.

4. SPECIAL CONSIDERATIONS

It is realized that the highway camps established for construction of the highway will be removed within approximately two to three years of being set up. However, the temporary nature of the camps does not in any way obviate the need for comprehensive environmental protection measures covering camp operations and facilities.

The majority of work camps will undoubtedly be located where access to an adequate water supply is convenient and supply by both aircraft and river craft is possible. Because of their ideal locations,

the camp sites will be attractive for future developments such as resource exploration camps, staging areas, highway maintenance camps, and small recreation and commercial centres. Consequently, it is imperative that camp facilities and activities are properly controlled, not only to avoid any immediate adverse environmental effects, but also as an example of what is required of future developers.

Although these measures should be made applicable to all highway construction camp facilities and activities, exception should be given to small mobile camps. Such camps would consist of three to four men using tent accommodation. These campsites are normally moved every four or five days and it would not be practical to insist upon a high degree of treatment for wastes. Therefore, small mobile camps should not be required to follow these measures although they are expected, as are all the camps, to follow all applicable health and sanitation ordinances and regulations.

5. ENVIRONMENTAL COMPATIBILITY

In planning or operating work-camp facilities all aspects of environmental protection must be taken into account. Efforts should be made to preserve natural beauty, wildlife, recreational areas, historic sites and private property. Attention must be given to the prevention of possible odour problems and the breeding of disease vectors.

6. SEWAGE EFFLUENT AND WASTEWATER TREATMENT OBJECTIVES

6.1 Effluent Limits

6.1.1 ***General.*** No effluent should be discharged unless it can meet the following conditions:

(1) free from anything that will settle forming putrescent or otherwise objectional sludge deposits;

(2) free from floating debris, oil, scum and other floating materials in amounts sufficient to be unsightly or deleterious;

(3) free from materials producing colour, turbidity or odour in such a degree as to create a nuisance;

(4) free from substances in concentrations or combinations which are toxic or harmful to human, animal or aquatic life.

6.1.2 ***Specific Limits.*** Treatment should produce an effluent of the following quality:

Total 5-day Biochemical Oxygen Demand - 20 mg/l maximum,
Total Suspended Solids - 25 mg/l maximum,
Fecal Coliforms - 400 per 100 ml maximum,
Chlorine Residual - 0.50 mg/l minimum and
1.50 mg/l maximum
after minimum 30 minutes contact time[1],
pH - 6 to 9,

Phenols - .02 mg/l maximum,
Oils and greases - 15 mg/l maximum,

[1]Applicable where disinfection is necessary and chlorination is used for disinfection purposes. The above limits must be met without dilution of an effluent either from a treatment works or from any wastewater source.

6.1.3 Mixing of Effluent with Receiving Body. The zone of mixing of the treated effluent with a stream should be so designed as to ensure a reasonable zone of passage for all indigenous aquatic life. Every precaution should be taken to ensure that at least two thirds of the total cross sectional area of stream remains favourable to the aquatic community at all times. The water quality in this section of stream should meet the following requirements downstream from the point of discharge:

Dissolved Oxygen - minimum 5 mg/l or 60% of Saturation - whichever is lesser
Biochemical Oxygen Demand - 4 mg/l - maximum unless background levels are higher.

7. WASTEWATER TREATMENT METHODS

Usually, secondary treatment or equivalent is the minimum level of treatment which can produce an effluent of the quality specified in Section 6. Specific treatment systems, when properly designed, operated and maintained, that are capable of producing such an effluent include activated sludge plants, plastic media trickling filters, independent physical-chemical plants, lagoons with annual retention, incineration, subsurface disposal systems and rotating biological contactors. Septic tanks or imhoff tanks discharging directly to surface waters are not to be considered desirable.

Discharge in close proximity to public water supply sources, or recreation areas should be avoided. Where such discharges are unavoidable, chlorination operations must be checked daily to ensure proper treatment. Wherever such arrangements are economically feasible and the municipal system itself complies with federal and provincial or territorial objectives and regulations, the work camps should discharge their wastes into municipal systems.

8. SPECIFIC WASTE TREATMENT SYSTEMS

8.1 Packaged Treatment Plants

Biological and physical-chemical package treatment plants can produce an effluent described in Section 6. To do so, however, they must be operated and maintained by properly trained operators.

In addition to routine maintenance on plant equipment, the operator should be expected to perform simple quality control tests, record daily the quantities of any chemicals used in treating sewage, and periodically collect samples of influent and effluent for biochemical and bacteriological analysis.

An adequate, heated, ventilated shelter should be provided for any package treatment facility. The building must have sufficient space where the routine quality control tests can be carried out. A flow measurement device complete with meter should be installed to record effluent discharge. Daily flow records should be kept by the operator.

8.2 Lagoons

A lagoon system should have sufficient capacity for the storage of work camp sewage for at least one year.

The shape of the lagoon cells is not critical but short-circuiting and irregularly shaped pockets must be avoided. The maximum depth of lagoons should not be less than 1.2 metres (4 feet) nor greater than 2.4 metres (8 feet). The berms should have a minimum 3:1 slope and the bottom of the lagoon should be level. Drain inlets should be installed 15 centimetres (6 inches) above the lagoon bottom. The height of freeboard in lagoons should be a minimum of 46 centimetres (18 inches). Trees, brush and topsoil must be removed from the immediate lagoon area.

Lagoons must not be located in areas where their presence would result in soil instability due to the degradation of permafrost nor within 91.4 metres (300 feet) of a watercourse or the work camp proper. A separation of 304.8 metres (1,000 feet) is required from any residence not connected with the work camp. The minimum distance between a lagoon and any road should be at least 30.5 metres (100 feet) and preferably 91.4 metres (300 feet). Generally, lagoons should be lined with impervious material.

8.3 Subsurface Disposal

The design of any subsurface disposal system, (septic tank with tile field, leach pits), should be based on the results of percolation tests performed in the soil where the system is to be installed. If a septic tank is used, it should be sufficiently large to provide a 24-hour detention period for the raw sewage and an equal volume for sludge storage. If leach pits only are constructed, they should have two compartments connected in series. The first cell would settle out solids and the second cell would be for percolation.

The soil must be capable of leaching action throughout the winter. To keep the soil around the system from freezing, the warm kitchen wastewater and washwater should be discharged into the same system that is used for toilet wastes. A 46 centimetre (18 inch) cover over the top of a leach pit should be adequate to conserve heat. Weeping tile may have to be laid at a depth of 0.9 metres (3 feet) below the surface and in addition, an insulating layer of straw or wood chips may be required to keep the field from freezing.

The leachate that percolates from the system through the soil must not contaminate groundwater which may have value as a public or private water supply. The disposal system must also be constructed in such a manner that odour problems do not occur. Although the ground surface over

the system should not be used as a thoroughfare, it should be able to support pedestrian traffic but clearly delineated so that heavy vehicles are not inadvertently driven on top.

The minimum recommended distances of subsurface disposal facilities from sources of water supply and natural water bodies are as follows:

(a) Water tight septic tanks or pumpout tanks:
3.0 metres (10 feet) from any cistern,
7.6 metres (25 feet) from any well.

(b) Leach pits:
15.2 metres (50 feet) from any dwelling having a subsurface foundation
15.2 metres (50 feet) from any cistern,
45.7 metres (150 feet) from any well, spring or watercourse.

(c) Weeping tile fields:
30.5 metres (100 feet) from any well,
45.7 metres (150 feet) from any spring or watercourse.

The required separation between a particular subsurface disposal system and a water supply or watercourse will depend upon soil characteristics, sewage flow, direction of drainage, etc.

Since leaching and percolation are not possible in permafrost soil, this method of treatment shall not be used in camps that are operated throughout winter where such soil conditions are present.

8.4 Holding Tanks

All holding tanks should be adequately vented and, if not located in a heated enclosure, insulated to prevent sewage freezing on the walls of the tank. The tanks should have sufficient capacity to contain sewage flow over two days. Consideration should be given to using minimum flush toilets in conjunction with holding tanks to reduce water consumption and tank size.

Sewage trucks should be used solely for the purpose of hauling sewage. Pump-out and hauling operations should be carried out in a manner that does not expose the driver or people in the area where the tanks are emptied to any health hazard. Every effort should be taken to avoid spillage when holding tanks are emptied, when the sewage truck is in transit, and when the truck contents are discharged into a treatment facility. If camp sewage is to be hauled to a municipal treatment facility, prior approval must be obtained from the municipality.

8.5 Incineration

If an incinerator is used to dispose of all or part of the camp sewage, it should meet the following conditions:

(a) be approved by the appropriate government agency for adherence to atmospheric emission objectives,

(b) comply with all safety regulations,

(c) be adequately housed to ensure operation during inclement weather,

(d) produce a sterile residue free of putrescible material,

(e) be operated by designated, responsible and properly trained personnel.

9. SOLID WASTE DISPOSAL

The collection, storage, conveyance, and disposal operations should be carried out in such a manner as to ensure that:

(1) scavengers and wildlife are not attracted to the camp refuse either prior to collection or at the ultimate disposal site,

(2) wind blown trash is minimized,

(3) no odour emission problems are produced by disposal or processing operations (open pit burning should be avoided),

(4) no public health hazards are created,

(5) upon closure of the site, restoration of the disposal site, as close as possible to original conditions,

(6) hazardous and toxic wastes are disposed of on site in a safe manner or transported out of the region.

10. SOLID WASTE TREATMENT METHODS

Sanitary landfill and incineration followed by burial of the incinerated residue are the most commonly used methods for disposal of solid wastes. Providing soil conditions are favourable, permafrost is absent, and the ground water table is low, sanitary landfill is perhaps the more economical method. Incineration, although considerably more expensive than landfill, is a convenient processing method provided the equipment is well designed and properly operated and maintained. The distance that the collected refuse is hauled is minimized and due to volume reduction, only a small area of land is required to bury the incinerated residue.

Other less frequently used and more expensive methods include composting, pyrolysis, recycling, grinding and discharge into sanitary sewers, and shredding or baling followed by sanitary landfill. With the exception of the last two, these methods are not considered practical for disposing of camp solid wastes. Shredding or baling may prove to be economical where permafrost is widespread and suitable landfill areas are limited. Using a garburator for grinding and discharging putrescible kitchen wastes into the camp sewerage systems may prove to be a suitable method of disposal since it would eliminate the storage and disposal of wastes which attract bears, foxes, etc.

11. SOLID WASTE COLLECTION AND DISPOSAL PRACTICES

11.1 Collection, Storage, and Conveyance

Putrescible wastes that attract scavengers should be placed in suitable containers that have tight-fitting lids. When full, the containers should be placed in an enclosed ventilated area to prevent access by wildlife. This type of refuse should be picked up and hauled to the disposal site every day. Other non-putrescible refuse should be picked up when required.

If a conveyance is required, it should transport refuse without causing litter between the disposal site and the collection area. Between uses, it should be kept clean and free of refuse material.

11.2 Sanitary Landfill

11.2.1 Site Selection and Preparation. The site for any sanitary landfill should be selected so that there is a minimum of 91.4 metres (300 feet) or more from the edge of the site to any water body or the work camp. The objective should be 304.8 metres (1,000 feet). A distance of at least 304.8 metres (1000 feet) should be maintained between the landfill and any habitation not connected with the work camp. Whether a trench or area fill method of operation is employed, the bottom of the landfill should be a minimum of 1.5 metres (5 feet) above the ground water table. Surface runoff should be diverted away from the site, if required, to keep the working area dry. For access, an all season road should be constructed to the site. There should be a minimum of 30.5 metres (100 feet) of natural undisturbed growth between the edge of the site and any highway. Any topsoil that is excavated for site preparation should be pushed to one side for pit restoration.

11.2.2 Methods of Operation. The two common methods of operation of a sanitary landfill are the trench and area fill. The objectives of both methods are identical; to compact refuse thoroughly and cover it promptly and completely.

The area fill method (or progressive slope or ramp) is used for low elevation sites such as quarries, pits, ravines and canyons.

The following operating techniques for area fill are recommended:

1. Deposit refuse at bottom of slope for best compaction and control of blowing litter.
2. Spread and compact refuse against slope of previous lift, progressing horizontally along slope.
3. Cover with earth excavated from adjacent area or from off-site borrow area and compact. The thickness of the compacted layer should be at least 16 centimetres (6 inches).
4. A uniform layer of suitable cover material compacted to a minimum depth of 0.6 metres (2 feet) should be placed over the entire surface of each portion of the final lift, not later than one week following the placement of refuse within that portion.

A sketch of the area fill method is shown in Figure D-1.

The trench method is adapted to flat terrain. The following operation techniques for the trench method are recommended:

1. Excavate the trenches to a maximum depth of 2.4 metres (8 feet). This will result in a more economical use of the area for landfill operation. Trenches should be excavated on the windward edge of the site and perpendicular to the prevailing wind direction to minimize the scattering of paper. The width of the trench should be about two times the width of a crawler tractor to allow for maximum compaction. Trenches should be parallel to each other and cover material should be obtained either from excavation of the trench or from the adjacent trench which will be filled next.

2. Dump the refuse, preferably at the bottom of the trench, and spread and compact in layers. Cover layers with at least 15 centimetres (6 inches) of compacted earth.

3. A uniform layer of suitable cover material compacted to a minimum depth of 0.6 metres (2 feet) should be placed over the entire surface of each portion of the final lift, not later than one week following the placement of refuse within that portion.

A sketch of the trench method is shown in Figure D-2. If the trench method is used, a large enough trench to contain refuse during the winter months should be excavated before freeze-up.

In both methods of operation it may be impossible to cover refuse during the winter when soil cannot reasonably be obtained. During this time, adequate controls must be maintained to prevent refuse from blowing about the site. Snow fences around trenches or around the working faces, if area fill is used, should considerably reduce blowing litter. Immediately after the soil has thawed and covering is possible, the whole area should be cleaned up and the required soil cover put in place.

Except during the winter, all putrescible refuse should be covered and compacted, as directed in the manner above, the same day that the refuse is hauled to the landfill site. In order to reduce cover operations, a separate area of the site may be set aside for the deposition of inert refuse, such as wood, metal, abandoned vehicles and equipment, etc. Coverage of such refuse would only be required once a year.

11.2.3 Closing the Sanitary Landfill Site. When the work camps are to be removed or when all available area has been used in the landfill site, the entire site and access road should be restored as close as possible to natural conditions. The final surface of the fill should be graded to a slope of at least one percent and free of depressions that would cause ponding. No surface slope should be so steep as to cause erosion of the cover.

Top soil should be placed over the site and seeded to grass. All access to the site should be removed.

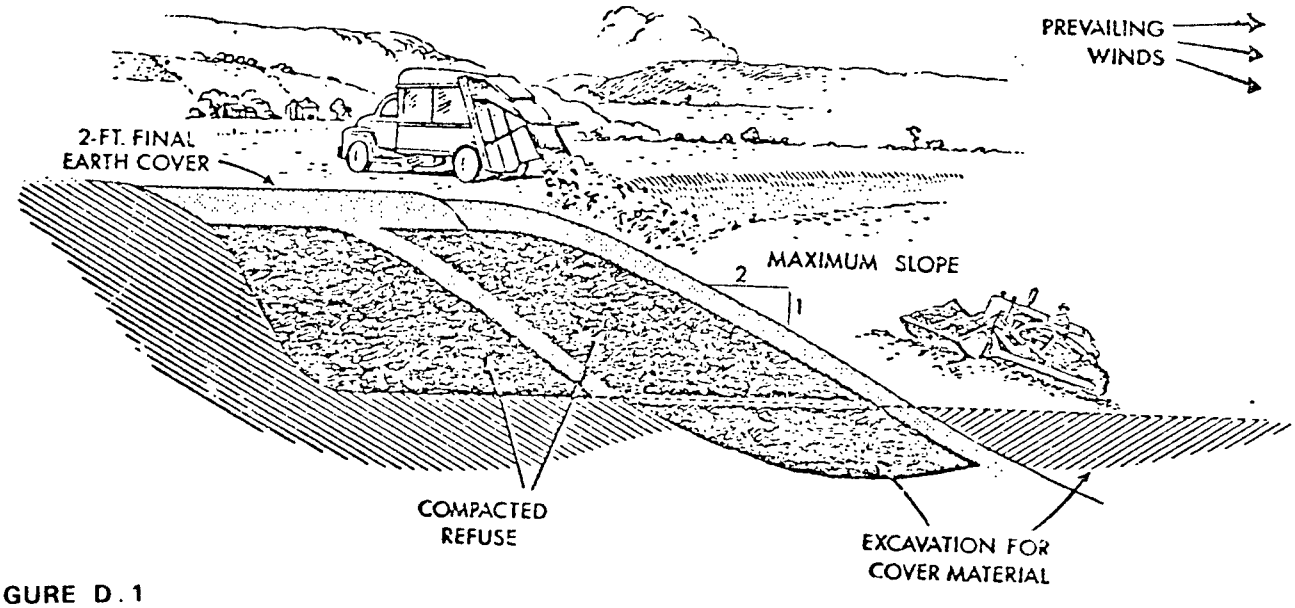


FIGURE D.1

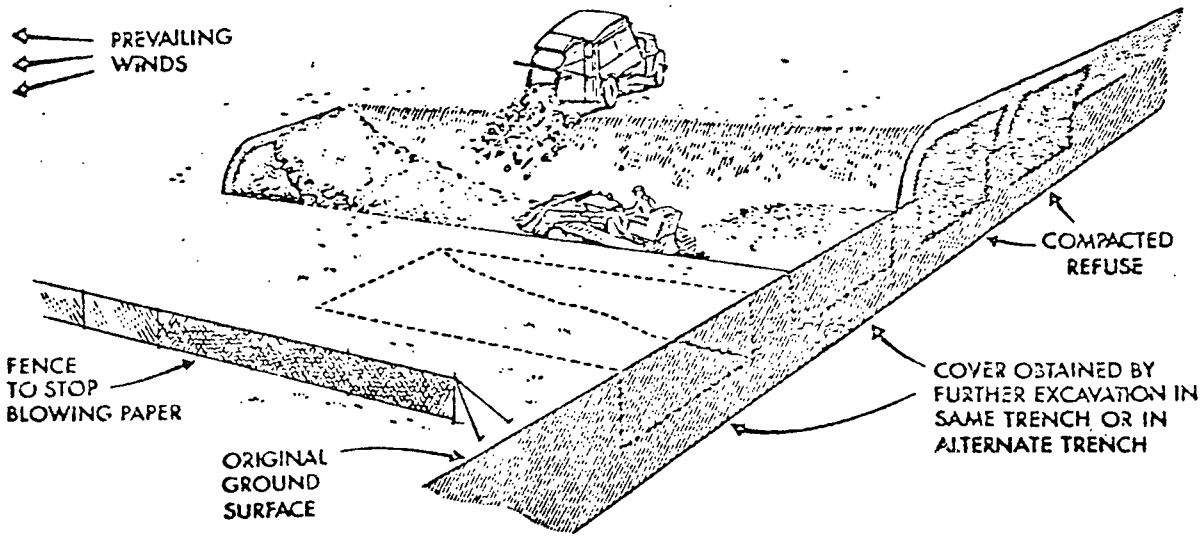


FIGURE D.2

11.3 Incineration

All incinerating equipment should:

1. be approved by the appropriate government agency for adherence to atmospheric emission objectives,
2. comply with all safety regulations,
3. be housed or enclosed in a manner so that it can be operated during all inclement weather,
4. be capable of operating on a 24-hour basis,
5. produce an ash which contains little or no incineratable material,
6. be operated by designated responsible, properly trained personnel.

The incinerated residue may be buried in a suitable location which is above the water table and covered over with at least 0.6 metres (2 feet) of soil.

11.4 Disposal of Waste Oil and Hazardous and Toxic Wastes

Waste oil and other petroleum products, as well as hazardous and toxic wastes, such as pesticides, poisons, solvents, greases, etc., should not be disposed of in a sanitary landfill. Waste oil may be used for dust control, provided that approval has been granted for its application in specified areas after consultation with environmental protection authorities. Waste oil and other petroleum products not disposed of in this manner must be incinerated in approved incinerator facilities. All hazardous and toxic wastes and waste oil not burned or used for dust control should be transported out of the region along with the hazardous wastes.

12. FUEL HANDLING AND STORAGE FACILITIES

In addition to complying with all federal and provincial or territorial safety regulations and conditions contained in land use authorizations, compliance with the following is also recommended:

(1) all above-ground bulk storage, with the exception of mobile tank trucks having a capacity greater than 3785 litres (1,000 Imperial gallons), should be adequately bermed with impervious material to contain any spillages, and the volume of the bermed enclosure should be at least 100% of the bulk storage capacity,

(2) bulk storage sites should be a minimum of 91.4 metres (300 feet) or more from any natural water body, (the objective should be 304.8 metres/1,000 feet),

(3) bulk storage units should be equipped with level indicators,

(4) caches of fuel oil drums should also be kept at least 91.4 metres (300 feet) from any natural watercourse,

(5) the area around storage sites and fuel lines from the handling to the storage facilities should be distinctly marked and kept clear of snow and debris to allow for routine

inspection for possible leaks and to eliminate the risk of vehicles crossing over fuel lines,

(6) all bulk handling operations must be closely supervised at all times,

(7) contingency plans should be developed to contain and clean up spills before any watercourses are affected,

(8) all accidental spills greater than 378.5 litres (100 Imperial gallons) must be reported immediately to the Environmental Protection Service, Department of the Environment.

13. RESTORATION OF LANDSCAPE AFFECTED BY CAMP FACILITIES AND ACTIVITIES

Upon completion of highway construction and the removal of camps and all related facilities, the landscape affected by the camp operation should be restored, as closely as possible, to original conditions unless otherwise requested by a government department.

The restoration of the landscape should include revegetation of the area with grasses, shrubs, and trees native to the area. Where required, the compacted soil must be broken up prior to seeding. Recommendations outlined in Appendix A on revegetation procedures should be followed.

All timber not disposed of after the campsites were initially cleared should be disposed of by burial or burning. The latter is permitted only when no fire hazard exists, and weather conditions are favourable. All buildings, trailers, machinery, equipment, materials, and storage containers should be hauled out, all litter cleaned up, and access roads from the highway to the campsites removed. Abandoned equipment should either be hauled out or buried in a landfill site according to the conditions stated herein.

If a subsurface disposal system has been used for sewage treatment, precautions should be taken to ensure that, should the system collapse within a few years, it will not be a hazard to health.