GOVERNMENT OF THE NORTHWEST TERRITORIES, DEPARTMENT OF TRANSPORTATION - EROSION AND SEDIMENT CONTROL MANUAL

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VERSION HISTORY

Version No.	Date	Description

PREFACE

This manual provides guidelines for analysis, design, construction, and maintenance of erosion and sediment control systems for transportation construction projects in the Northwest Territories (NWT). This document was developed with the intent that it would provide a convenient and comprehensive resource and a rational basis for the design of erosion and sediment control systems. It is intended primarily for use by design consultants but also provides valuable information for contractors and field personnel. It is intended to assist and provide direction in the analysis and design of erosion and sediment control structures, but is not intended to preclude innovative or alternative designs.

This manual was adapted for use in the NWT from the Alberta Ministry of Transportation's Erosion and Sediment Control Manual (Alberta Transportation 2011). The intent is for the manual to reflect the climatic and biophysical conditions that influence the processes of erosion and sedimentation in the NWT, in order to design and implement erosion and sediment control in a way that reflects conditions in the territory.

Continuing comment is essential to the regular updating of this document and feedback is welcome. Periodic updates and revisions will be undertaken in response to user feedback, changes in technology, regulatory requirements and many other factors. The most current version of this document will be posted on the Government of the Northwest Territories Department of Transportation (GNWT-DOT) website (www.gov.nt.ca). Inquiries, suggestions for revisions or additions, and comments may be sent to the Planning, Policy and Environment Division, Government of the Northwest Territories, Transportation, PPE, P.O. Box 1320, Yellowknife, NT X1A 2I9.

GNWT-DOT thanks all those who have contributed to the development of this document. Special thanks are expressed to Alberta Transportation and Don Snider, Manager of Transportation Projects and Environmental Services, in particular, who agreed to provide the Alberta ESC manual to the GNWT to form the basis of the current volume. GNWT-DOT also extends its gratitude to the Department of Fisheries and Oceans for its willingness to review and comment on this document during development. The manual was adapted for the GNWT-DOT by Summit Environmental Consultants Inc. of Yellowknife, NT.

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1.0 INTRODUCTION

1.1 Background

Erosion and sedimentation are naturally occurring processes of loosening and transporting soil through the action of wind, water, or ice, and the subsequent transport and deposition of sediment particles. Construction activities can result in increased erosion and sedimentation where soil surfaces are exposed to rainfall and runoff. If uncontrolled, these processes may result in adverse effects on the environment. This includes loss of soil productivity, degradation of surface water quality, damage to adjacent land, and degradation of aquatic habitat. Erosion and sediment control techniques are activities or practices, or a combination of practices, which are designed to:

- Protect an exposed soil surface;
- Prevent or reduce the release of sediment to environmentally sensitive areas;
- Minimize impacts to permafrost; and
- Promote revegetation establishment.

The purpose of this document is to develop a set of guidelines and standard procedures to minimize erosion and sediment transport in transportation construction activities in the Northwest Territories (NWT). The document focuses on minimizing potential impacts to environmentally sensitive areas.

Erosion and Sediment Control (ESC) combines two terms: erosion control, and sediment control. In this document, the term **erosion control** means the prevention of erosion, while **sediment control** refers to preventing or minimizing the transport of eroded sediment away from the construction site.

1.2 Objectives

The objectives of this document are to:

- Outline the regulatory requirements related to ESC in NWT;
- Clarify the roles and responsibilities of the owner [Government of the Northwest Territories – Department of Transportation (GNWT-DOT)], their consultants, and contractors;
- Provide guidelines and standard procedures for selecting, designing and implementing ESC measures for transportation construction and maintenance;
- Provide details of ESC measures commonly required on the NWT construction sites as well as their applications and limitations; and
- Provide a means for the GNWT-DOT to educate consultants and contractors in proper ESC procedures.

1.3 Document Disclaimer

This document is intended for use in the design, construction and maintenance of ESC measures for terrestrial (land-based) infrastructure. The information, guidelines and reference material presented in this document are intended to complement the experience and judgement of the individual or firm responsible for preparing an ESC Plan.

A Field Guide titled "Erosion and Sediment Control Field Guide" has been prepared as a companion to this document. The field guide contains information derived from the ESC Manual for use by field personnel, and includes the following:

- Introduction,
- Objectives
- Regulatory Requirements
- Erosion and Sediment Control Process
- Inspection and Maintenance
- Tables, BMPs, and Inspection Form, and
- Best Management Practices (BMPs) details.

ESC measures for in-stream (water-based) works are provided in this document. This includes works near streams and lakes. In addition to this document, Fisheries and Oceans Canada (DFO) has published a series of Operational Statements guiding in-stream works in the NWT. The Operational Statements and the ESC Manual should be used together when planning and designing work in and near streams, lakes and wetlands.

It is the responsibility of project owners, consultants, and contractors to ensure that they have the appropriate environmental authorizations and regulatory approvals in place for all upland and in-stream works. It is likewise their responsibility to carry out construction works with due diligence and using appropriate procedures to protect the environment.

1.4 Selected Key Terms and Acronyms

There are a number of terms and acronyms from ESC practices that are used throughout this manual. They are defined here to assist the reader.

Active layer	The layer of soil or rock underlain by permafrost that thaws in summer.
BMP	Best Management Practices.
Erosivity	The potential ability of rain to cause erosion. It is a function of the physical characteristics of rainfall including rainfall intensity and duration.
Erodibility	The vulnerability or susceptibility of the soil to erosion. It is a function of both a soil's physical characteristics and the management of the soil.
Ground ice	Ice formed in freezing and frozen ground. It occurs in pores, voids, and other openings in soils and rocks.
Permafrost	Ground that is perennially (all year) frozen.
RUSLE	Revised Universal Soil Loss Equation. An equation used to predict annual soil loss. RUSLE gets employed in ESC planning to assess erosion risk and compare control options.

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2.0 REGULATORY REQUIREMENTS

There are several federal and territorial Acts and Regulations in force that direct construction, maintenance, and closure activities undertaken by or on behalf of the Department of Transportation. These Acts and Regulations contain legal measures designed to mitigate adverse environmental effects associated with various works or undertakings. Of particular relevance to the ESC Manual are those measures intended to limit erosion and/or sedimentation as a result of transportation construction activities.

Most legislation and other types of regulatory instruments make reference to preventing the release of harmful or deleterious substances, including sediment, to the environment. A summary of the Acts and Regulations guiding responsible development and environmental protection in the Northwest Territories is provided below in Sections 2.1, 2.2 and 2.3.

2.1 Federal Legislation

2.1.1 Navigable Waters Protection Act

The *Navigable Waters Protection Act* (NWPA) protects the public right of navigation by regulating works over waterways such as bridges, dams and docks to minimize the overall impact on navigation. NWPA applies to in-stream work involving construction or placement in, on, over, under, through, or across navigable water. The original definition of “navigable water" captured any body of water capable of accommodating any type of floating vessel for transportation, recreation or commercial purpose. The body of water can be navigable periodically, historically, or by facilitating public access.

In 2009, NWPA was amended, in part to narrow the class of works to which it applies. The amendments also granted the Minister of Transportation and Cabinet more power to exempt classes of works and waterways, while increasing the level of inspection and enforcement of the Act.

The Government of Canada is currently (2012) proposing further amendments to the NWPA. The bill is still before Parliament at the time of this report, so a summary of the changes is not possible at this time. It appears likely that the new legislation will change the definition of water bodies that are protected under the Act. However, it is likely that major structures (e.g. bridges, outfalls) will require authorization under the Act.

Subsection 22 of the NWPA contains prohibitions related to the deposition of organic and non-organic materials (e.g., sediment or rubbish) into navigable waters.

2.1.2 Fisheries Act

The Federal *Fisheries Act* is intended to protect fish and fish habitat. The *Fisheries Act* is the most comprehensive piece of environmental legislation in Canada and comes with serious penalties for violators, including substantial fines and/or imprisonment. Subsection 36 (3) of the Act is of most relevance to this manual. This states that no one shall deposit or permit the deposit of a **deleterious substance** of any type in water frequented by fish or in any place under any conditions where the deleterious substance may enter water. Sediment eroded from a construction or development site is considered a deleterious substance under the Act. Under subsection 38 (5) anyone who owns, manages or controls a deleterious substance has a duty to report any deposit out of the normal course of events to a Fishery Inspector or regulatory authority. Under subsection 38(6) these people are also responsible to counteract, mitigate, and as soon as possible, remedy any adverse effects that results or may result from the occurrence. Environment Canada is responsible for the administration and enforcement of the pollution prevention provisions of the *Fisheries Act*. The Department of Fisheries and Oceans Canada (DFO) is responsible for the administration and enforcement of the remaining portions of the *Fisheries Act*.

Transportation construction activities must also take into consideration the protection of fish habitat and sensitive environmental areas. Subsection 35 (1) of the Act prohibits the carrying on of any work or undertaking that results in the **serious harm to fish that are part of a commercial, recreational or Aboriginal fishery, or to fish that support such a fishery,** unless authorized by the Minister [Note: This subsection used to prohibit any harmful alteration, disruption or destruction of fish or fish habitat (HADD), but was revised in 2012 to its current reading].

The removal of fish habitat from the clause may indicate less control over activities in or around water. However, under subsection 38(4), developers or responsible agents are still responsible for notifying authorities about unauthorized harmful alterations, disruptions or destructions of fish habitat. As with deleterious substance deposits, subsection 38 (6) also requires responsible agents to prevent the occurrence or to counteract, mitigate or remedy any adverse effects that result from the occurrence or might reasonably be expected to result from it. Practically speaking, people undertaking transportation construction activities are still responsible for preventing harm to fish habitat and for addressing adverse environmental effects.

Changes to the *Fisheries Act* in 2012 have cast some confusion over what responsible measures one must take when working around water. In the Northwest Territories the changes will need to be considered with respect to the Aboriginal Treaty and Land Claims that cover the entire territory. With fishing a recognized traditional activity amongst Aboriginal beneficiaries, harm to any fish could trigger subsection 35 (1). The harm of non-commercial or non-sport/harvest fish could also violate the modified Act as these ‘other’ fish constitute an important part of the diet for more economically viable fish.

Additional sections of the *Fisheries Act* relevant to transportation construction activities include that the maintenance of fishways; keeping fish passages free; and maintaining sufficient water flow in watercourses.

The condition (Subsection 30) to have an appropriately sized fish screen for all water intakes was repealed in the 2012 changes to the Act. Also repealed was subsection 32, preventing the unauthorized killing of fish by means other than fishing.

2.1.3 Canada National Parks Act

The *National Parks Act* designates and maintains national parks and national park reserves in Canada. The Act guides management decisions in Canada’s National Parks relating to capital re-development of facilities, accommodation and infrastructure. Proposed activities in National Parks must commit to high standards of ecological integrity and be authorized by Parks Canada.

Highway Number 5, the Fort Smith Highway, travels through Wood Buffalo National Park in the Northwest Territories. New road works or renewal of existing licenses or permits along the Park section of Highway 5 will require the authorization of Parks Canada.

2.2 Territorial Legislation

2.2.1 Mackenzie Valley Resource Management Act

The *Mackenzie Valley Resource Management Act* (MVRMA) came into effect in 1998. It governs land and water use in throughout the Northwest Territories. The Inuvialuit Settlement Region (ISR) and Wood Buffalo National Park are excluded from the MVRMA. Other Acts and Regulations, described below, regulate land and water use in the ISR. The Canada National Parks Act guides activities in Wood Buffalo National Park.

The MVRMA establishes public boards to regulate the use of land and water, to prepare regional land use plans to guide development, and to carry out environmental assessment and reviews of proposed projects in the Mackenzie Valley. The Act also makes provisions for monitoring cumulative impacts on the environment, and for periodic, independent environmental audits.

As institutions of public government, the land and water boards regulate all uses of land and water while considering the economic, social and cultural well-being of residents and communities in the Mackenzie Valley.

Through the MVRMA, an integrated co-management structure was created for public and private lands and waters throughout the Mackenzie Valley. Part IV of the Act came into effect in 2000, establishing the Mackenzie Valley Land and Water Board (MVLWB). The MVLWB screens projects for their social and environmental affect and issues water licences and land use permits accordingly.

2.2.2 Mackenzie Valley Land Use Regulations

Section 90 of the *Mackenzie Valley Resource Management Act* established the *Mackenzie Valley Land Use Regulations* (MVLUR). The MVLUR facilitates use of land in the Mackenzie Valley by setting the conditions for land use permits. There are three types of permits under the Regulations: “Type A”, “Type B”, and “Type C”. “Type A” permits are reserved for projects with a greater perceived environmental risk and resource demand. “Type B” permits encompass projects with a lower perceived risk and resource demand. “Type C” permits are reserved for activities occurring on T’licho Government lands for which neither a Type ‘A’ nor ‘B’ permit is required (MVLWB, 2012).

The following activities may require a land use permit:

- Use of explosives
- Use of vehicles
- Drilling
- Hydraulic prospecting
- Earth moving and clearing
- Campsites
- Fuel caches
- Preparation of lines, trails or rights-of-way

The Department of Aboriginal Affairs and Northern Development Canada is responsible for inspecting and enforcing land use permits issued in the NWT.

2.2.3 Northwest Territories Waters Act

The *Northwest Territories Waters Act* (NWTWA) was established in 1992 to regulate the use and disposal of water in special management areas in the NWT that fall **outside of the Mackenzie Valley**. Effectively, the NWTWA governs the use of water in the Inuvialuit Settlement Region (ISR). The NWTWA can also be used to manage trans-boundary waterways: water bodies that flow into or out of the NWT and a neighboring province or territory.

Section 10 of the NWTWA established the NWT Water Board. This Board is tasked with optimizing the conservation, development and utilization of waters for Canadians and NWT residents living within its management areas. The Board accomplishes this by screening development proposals and issuing Type “A” or Type “B” water licences.

2.2.4 Northwest Territories Water Regulations

The *Northwest Territories Water Regulations* (NWTWR) guides the use, disposal, and licensing of water in the Inuvialuit Settlement Region (ISR) of the NWT. Water licences are administered by the NWT Water Board. Water licences include terms and conditions to prevent an adverse impact on waters within a prescribed water management area (AANDC, 2009). The NWTWR are more technical in nature, and provide guidance to NWT Land and Water Boards on when to issue a Type “A” versus a Type “B” water licence.

2.2.5 Type A and Type B Water Licences

Water licences are issued by Land and Water Boards in the Mackenzie Valley, and by the NWT Water Board in the ISR and in special management areas. Some of the activities that require a Water Licence are (MVLWB, 2012):

- 100 m^3 or more of direct water use per day;
- A municipality or camp that uses more than 50 m^3 of water per day;
- Construction of a structure across a water course five or more metres wide at ordinary high water mark;
- Channel and bank alterations, erosion control, diversion of water, alteration of flow or storage of water (dam or storage reservoir);
- Draining or infilling of a water course;
- Any deposit of waste (solid waste, sewage, oil drilling etc.); and
- Industrial or mining and milling activities that use more than 100 m3 of water per day.

Similar to Land Use Permits, Type “A” water licences are required for activities of broad scope, having significant potential for adversely affecting human health or the environment, and/or requiring substantial volumes of water. Type “B” water licences are required for activities of generally limited scope, having less potential for adversely affecting human health or the environment (AANDC, 2009). All development projects that require licences undergo preliminary screenings by the responsible regulatory board. The screening determines if the project must proceed to an environmental assessment (see Section 2.2.1) or go directly into the regulatory phase, which includes a detailed review of the water licence application.

The NWTWA and NWTWR form part of the legal and administrative framework that was established for managing land and water use under the MVRMA (AANDC, 2009). As with the NWTWB, the Minister of AANDC is responsible for approving all Type “A” water licences. Inspectors employed by AANDC are responsible for enforcing the provisions of the NWTWA, NWTWR, and MVRMA (*ibid)*.

2.2.6 Environmental Protection Act

The *Environmental Protection Act* (EPA) was established in 1988 and promotes responsible environmental stewardship in the NWT. The EPA gives the NWT Minister of the Environment and Natural Resources the authority to research knowledge gaps and establish boards, committees, or other bodies to provide advice relating to the preservation, protection or enhancement of the environment. The Minister can also appoint a Chief Environmental Protection Officer for the NWT. The EPA empowers the Chief Environmental Protection Officer (CEPO) to uphold the Act, including authorizing certified members of the Royal Canadian Mounted Police and certified wildlife officers identified under subsection 76(1) of the *Wildlife Act* to be inspectors tasked with upholding the Act.

The EPA makes it an offence to discharge contaminants into the environment that endangers the health of animal life or is likely to cause damage to plant life or property. Sediment eroded from a construction site may be considered a “contaminant”. Officers have the authority to direct persons to put in safeguards to avoid contamination, to cease operations and to repair damage to the environment caused by the contamination. Persons have a duty to report all contaminations and are required to take all reasonable measures to stop and/or contain the contamination.

The EPA also empowers the Minister to appoint a Controller with the authority to issue and revoke permits and licences under this Act. The EPA also establishes the penalties, and identifies the right to reclaim costs and expenses associated with contaminations.

2.3 Due Diligence

Most environmental legislation provides for "due diligence" as a defence to the majority of environmental offences. GNWT-DOT is working to meet its due diligence obligations with respect to erosion and sediment control by taking the following steps:

- Publication of this document for implementation in the transportation construction industry by in-house forces, contractors and consultants;
- Publication of a plain language field manual for workers involved in GNWT-DOT transportation construction activities;
- Increasing awareness of the adverse effects of erosion and sedimentation, regulatory requirements, and penalties for contravention; and
- Requiring the proper use of best management practices for erosion and sediment control for the transportation construction industry through contracts and regulatory terms and conditions.

3.0 EROSION AND SEDIMENT CONTROL MANAGEMENT STRATEGY

3.1 Government of the Northwest Territories – Department of Transportation (GNWT-DOT) Requirements

Erosion and Sediment Control Plans should be prepared by qualified firms or individuals for all GNWT-DOT transportation construction projects. Submitted plans and construction works must comply with the specifications set out in this manual. Construction monitoring is provided as part of the work. Interim audits shall be conducted by the qualified person of record for the construction project or GNWT-DOT.

Parties undertaking phases of works or entire projects for the GNWT-DOT are required to fulfil various requirements concerning environmental protection. Responsibilities pertaining to erosion and sediment control measures form an important part of these requirements. Within the project planning phase, the development of an effective ESC plan is a requirement for GNWT-DOT project managers and contractors, as outlined below.

3.1.1 Design Engineer/Technician Responsibility – Permanent Erosion and Sediment Control (PESC) Plans (Design Phase)

Construction projects should have three levels of development for ESC including: the planning strategies and procedures and the two levels of ESC plans: temporary (construction) and permanent (post-construction).

Planning Strategies and Procedures (Table C-5) in Appendix C are often called minimum requirements which are non-structural methods or procedures that can reduce erosion and sediment transport. Proper planning generally constitutes the minimum requirement for preparing an ESC strategy. The minimum requirements for planning strategies and procedures for an erosion and sediment control plans are presented in Table 7.1.

A **permanent erosion and sediment control** (PESC) plan must be established to minimize erosion and sedimentation once a project is operational. The designer is required to prepare a Permanent Erosion and Sediment Control Plan (PESC Plan) for the project as part of the detailed planning and design phase of a project. The requirements for the PESC are detailed in Section 9.0.

To ensure that erosion is controlled during construction, the PESC is provided to the contractor to guide them in designing the **temporary erosion and sediment control plan** (TESC) plan. The TESC plan becomes part of the Environmental Management Plan (EMP) implemented during construction.

The TESC plan would apply during construction operations, and provide appropriate mitigations when soils are typically exposed to the elements and newly disturbed areas. It is called “temporary” because it focuses on preventing erosion and sediment processes for a short period of time.

During the execution of the contract, the contractor, as the party having ‘care and control’ of the site, will be responsible for environmental protection and minimization of potential environmental hazards resulting from construction activities. The contractor is required to develop and implement an EMP detailing environmental protection measures. The EMP includes an ESC Plan as a core element.

Both the EMP and PESC Plan must be completed by individuals or firms with appropriate training and experience in both construction and ESC practices. Ideal training and designations for the PESC Plan reviewer include:

- Registered Professional Engineer or Geoscientist with appropriate expertise and licenced to practice in the NWT;
- Certified Professional in Erosion and Sediment Control (CPESC); and/or
- Registered Professional Agrologist with expertise in soil and water conservation.

3.2 Overview of Preparation of Erosion and Sediment Control Plans

The process of preparing an erosion and sediment control strategy as well as maintaining and revising the measures contained therein is presented in Figure 3.1. The figure outlines general steps involved in preparing permanent and temporary erosion and sediment control plans for each phase of a transportation construction project.

Design Phase (Pre-construction)

Permanent Erosion & Sediment Control Plan

May Include:
- Soils information
- Environmental and hydrotechnical information
- Identification of erosion and sediment control issues
- Design of permanent erosion and sediment control measures

⇩

Tender Phase

Contract Specifications & Special Provisions may include:
- Specific requirements related to Erosion & Sediment Control

⇩

Construction Phase

Contract Awarded

⇩

EMP Prepared by Contractor
(including the TESC Plan)
Based on:
- Contract Specifications & Special Provisions
- Environmental Management Plan (EMP) Framework
- Erosion and Sediment Control Manual
- Permanent Erosion & Sediment Control Plan
- Design information
- Contractor experience
- Proper construction planning - Scheduling

⇩

Implementation and Maintenance of Measures Contained in EMP

- Update EMP to include information obtained during construction
- Maintain records for interim audits
- Ensure implemented measures result in compliance with environmental regulations

⇩

Implementation of Measures Contained in Permanent Erosion and Sediment Control Plan

- Designer to update permanent measures to include information obtained during construction
- Contractor to implement permanent measures as part of construction as early as possible

⇩

Post-Construction Phase

Post-Construction Monitoring

- GNWT-DOT and maintenance contractor(s) to verify permanent measures implemented result in compliance with environmental regulations

Figure 3.1: GNWT-DOT Management Strategy for Erosion and Sediment Control on Transportation Construction Projects

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4.0 EROSION AND SEDIMENTATION PROCESS

4.1 Mechanics of Erosion

Erosion is the displacement of surface soil by naturally occurring processes that cause the detachment (entrainment) and transport of soil materials from one location to another. The natural processes (e.g., rain, flowing water, wind, and frost) responsible for erosion can be considerably accelerated through human activities.

Water is the predominant agent of erosion on transportation construction sites and on operational infrastructure sites. Wind erosion is not a major contributing factor to erosion on most transportation projects because of the localized nature of the exposed areas and relatively short construction time periods. Thus, methods of controlling water erosion are the principal focus of this manual. However, effective erosion control measures will mitigate both water and wind forces.

The prevention of erosion is critical to the success of the overall ESC Plan. Undisturbed or un-displaced soils behave predictably, are stable, and represent no environmental risk. Once sediment becomes displaced, controlling it becomes very difficult, imprecise and costly. Sediment suspended in flowing water, for example, is difficult to remove. For this reason, the need for prevention through erosion controls cannot be over emphasized. In many cases though, soil disturbance is unavoidable. Thus sediment controls are installed on a construction site to promote sedimentation before being carried off-site.

Sedimentation is the deposition of soil particles by moving water. Sedimentation occurs at locations where the velocity of the water slows down or stops. As the water slows down, energy is taken out of the water, allowing the sediment to settle and come out of suspension. The larger particles such as gravel and sand settle out first. As the flow velocity reduces further, the smaller particles such as fine sand and silt settle, eventually leaving only the clay sized particles as the last to be deposited. In general, the silt and clay particles only settle out in still water bodies likes ponds, lakes, and wetlands; or in treatment facilities such as storm water or sediment control ponds.

Sediment fencing installed across a long slope, slows the water and allows sediment to deposit. Commonly used sediment fencing, with woven material, will filter larger particle sizes such as sand and gravel. Silts and clays are fine enough to pass through the small holes in the woven fabric of this type of fencing. Where the removal of fine silts and clays are required, settling ponds may be necessary to allow water to be still or near still for a period of time.

Two common units are employed when measuring the presence of suspended solids in water: Total Suspended Solids (TSS) and turbidity. TSS is the mass of suspended solids per volume of water (standard units: mg/L). Turbidity is an indication of the ability of light to pass through the water, measured in Nephelometric Turbidity Units (NTU). Turbidity can be measured in the field with portable instruments, while TSS must be analyzed in a lab. TSS and turbidity are correlated but the relationship tends to be site specific. For example, if the suspended material includes fine organic material, analysis can indicate low TSS concentrations but relatively high turbidity. Elevated TSS and turbidity can both have detrimental effects on an aquatic environment. Smothering fish eggs or aquatic plants, gill abrasion, increasing risk of predation, reducing oxygen, or blocking light are some of the adverse aquatic environmental effects posed by fine sediments.

Clay particles will only settle out after extended periods of time (days to weeks) due to their fine particle size. As a result, settling by gravity alone is often ineffective or impractical for clay size particles. Again, this points to the importance of preventing the erosion of fine-grained soils in the first place.

4.2 Types of Water Erosion

There are generally four types of erosion that result from water which are illustrated in Figure 4.1.

1. **Raindrop (Splash) Erosion:** Movement of soil particles caused by the direct impact of raindrops on unprotected exposed soil surfaces.
2. **Sheet Erosion:** Movement of soil particles by runoff flowing over the ground surface as a broad thin sheet layer. Erosion is caused by shear stresses associated with water flow.
3. **Rill and Gully Erosion**: Movement of soil particles due to a concentration of runoff in depressions (rills) in the ground surface. Erosion potential in this situation is greater than with sheet flow due to the greater velocity and depth of flow. Further increases in the velocity and depth of flow will escalate the erosion potential which may gradually enlarge the rills into gullies. Conventionally, rills are defined as small channels on a hill slope that are 75 mm or less in depth. Once the depth exceeds 75 mm, then the eroded channels are referred to as gullies (Fifield 2001).
4. **Stream and Channel Erosion:** Movement of soil particles on the bed and banks of streams and channels due to concentration of runoff. Scouring, another facet of channel erosion, occurs along channels where eddies form as a result of sudden expansion, contraction or change in flow direction. Scouring may lead to rapid soil loss from the channel bed or side slopes.

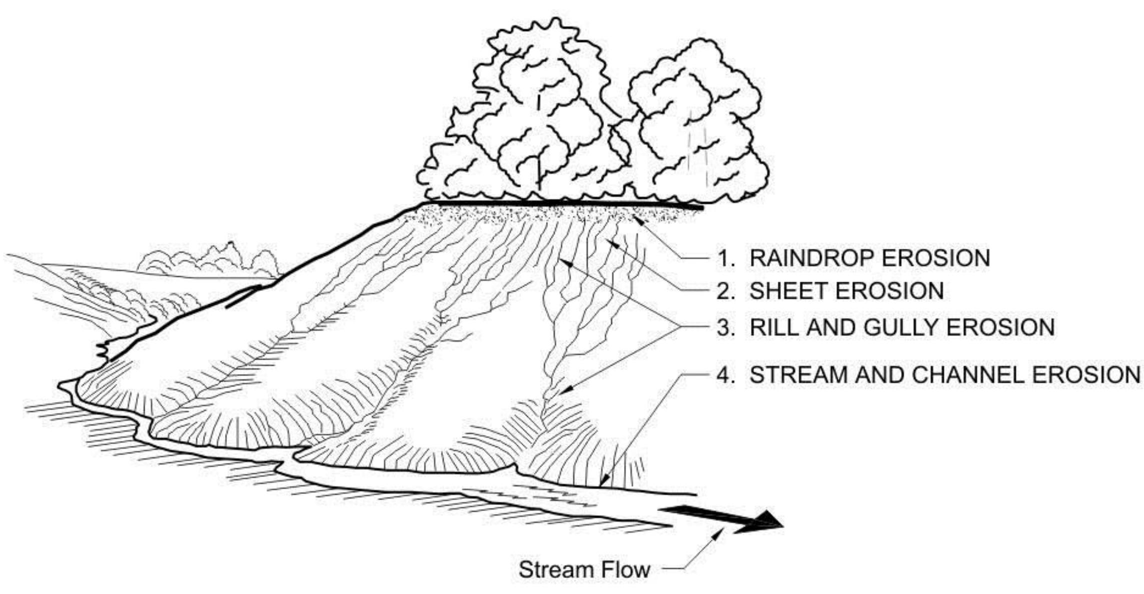


Figure 4.1: Types of Water Erosion

Erosion potential is reduced by minimizing rainfall impact and by reducing the velocity and depth of surface water flow. The erosion potential increases with increasing flow velocity and depth.

4.3 Factors Affecting Erosion

4.3.1 General

Erosion occurs as a result of a number of interacting factors and processes. Four broad factors that affect erosion are as follows:

- Climate;
- Soil characteristics including texture (particle size), structure, and organic matter content
- Vegetative cover; and
- Topography (slope angle, length, aspect and shape).

Each of these factors is described in the following sections.

4.3.2 Climate

The erosive potential of rainfall depends on the intensity (amount per unit of time) and duration of the rainfall event. In general, erosion risk is highest from intense but short duration storms. However, extended periods of less intense rainfall can also create significant erosion because saturated soils have lower strength to resist erosion.

The climate of a location affects the amount and type (rain, snow) of precipitation, the duration of frozen conditions, the length of the growing season, and other factors that affect plant growth and hence the vegetative cover. The climate may have a long term effect on topography, especially in reference to the growth and persistence of permafrost. The climate also affects soil characteristics, where cooler climates have thinner topsoil and deeper weathering.

Climate data are available through Environment Canada, Agriculture Canada, territorial environment agencies, and local communities. Environment Canada is the agency that produces Intensity-Duration-Frequency (IDF) curves from precipitation data[1]. IDF curves are the key climate data tools for ESC planning, especially for the design of sedimentation structures.

The regional climate varies across the NWT. As such, the intensity and duration of precipitation events varies from location to location, as does the erosion hazard.

Rainfall data can be used as a general guideline when considered with other site specific factors such as soil texture and slope gradient and slope length. Table 4.1 provides annual rainfall, snowfall, days with temperature >0°C, and rainfall intensity data for NWT climate stations where there are IDF curves. The rainfall intensity data are given for the 2-year and 25-year return interval one-hour and six-hour storms. Although these numbers provide an indication of the spatial variation in rainfall erosivity, care should be taken in extrapolating between sites. Values from sites in Alberta and Saskatchewan are included in Table 4.1 for comparison.

[1] See http://www.climate.weatheroffice.gc.ca/prods_servs/index_e.html

Station*	Region	Normal** Annual Rainfall (mm)	Normal Annual Snowfall (cm)	Normal Days with Minimum Temp. >0°C	2-year Return Interval Intensity (mm/hr.)		25-year Return Interval Intensity (mm/hr.)	
					1 hour	6 hours	1 hour	6 hours
Yellowknife	Mackenzie Slave Lowlands, Taiga Plains	165	152	143	9.5	3.0	21	6.8
Fort Reliance	Low Subarctic; Taiga Shield	172	147	133	7.2	2.3	17	4.5
Fort Simpson	Mackenzie Slave Lowlands, Taiga Plains	224	170	140	11	3.6	27	7.4
Hay River	Mackenzie Slave Lowlands, Taiga Plains	203	125	144	9.2	3.1	21	6.4
Inuvik	High Subarctic Taiga Plains	117	168	107	5.6	1.9	12	4.1
Norman Wells	Great Bear Plains, Low Subarctic Taiga Plains	166	153	133	7.9	2.7	18	5.4
Tungsten	Cordillera	214	261	n/a	6.9	2.3	11	3.6
Comparison to sites in central and northern Alberta and Saskatchewan								
Fort Chipewyan		252	145	144	12	3.6	27	6.9
Edmonton		375	121	162	16	4.5	30	7.8
Saskatoon		265	97	166	16	n/a	46	n/a

* All sites located at airport
** Normal is the 1971-2000 average, except Tungsten (1961-1990)

Source: Environment Canada (2012)

Table 4.1: Precipitation and Rainfall Intensity Data for Selected Sites in the NWT

4.3.3 Soil Characteristics

Soil characteristics that primarily affect soil erodibility are as follows:

- Particle size distribution (soil texture);
- Soil structure (i.e., how well soil particles are held together)
- Permeability;
- Frozen or unfrozen condition;
- Presence of ground ice in areas with continuous or discontinuous permafrost; and
- Fibrous organic matter content (structure).

A classification of soil erodibility in relationship to soil texture is presented in Figure 4.2. In general, soils containing high proportions of silt and very fine sand are usually the most easily eroded. Soils containing high proportions of clay are usually the least erodible.

In order to use Figure 4.2 to determine erodibility, estimate the amount of sand and clay within the soil sample by hand testing (Figure 4.3) or use laboratory soil texture results. Using the soil texture triangle, locate the percent of clay and sand contained within the sample. Follow the lines until they intersect to locate the soil texture class in the triangle (e.g. 30% sand on horizontal axis, 50% clay on vertical axis is a clay). Once the soil texture class is identified, locate it on the Erodibility Chart to determine the estimated erodibility of the soil (e.g. the erodibility rating for clay is Low). The erodibility factor for clay loam is medium. The large numerals on the texture nomograph are soil texture groups (outlined by the thicker lines on the soil texture triangle), and are not used in the soil erodibility method.

Once eroded, clays are readily transported over potentially long distances in flowing water, even if the velocity is slow. Coarse textured soils (sands and gravelly sands) with little silt content are the least erodible soils.

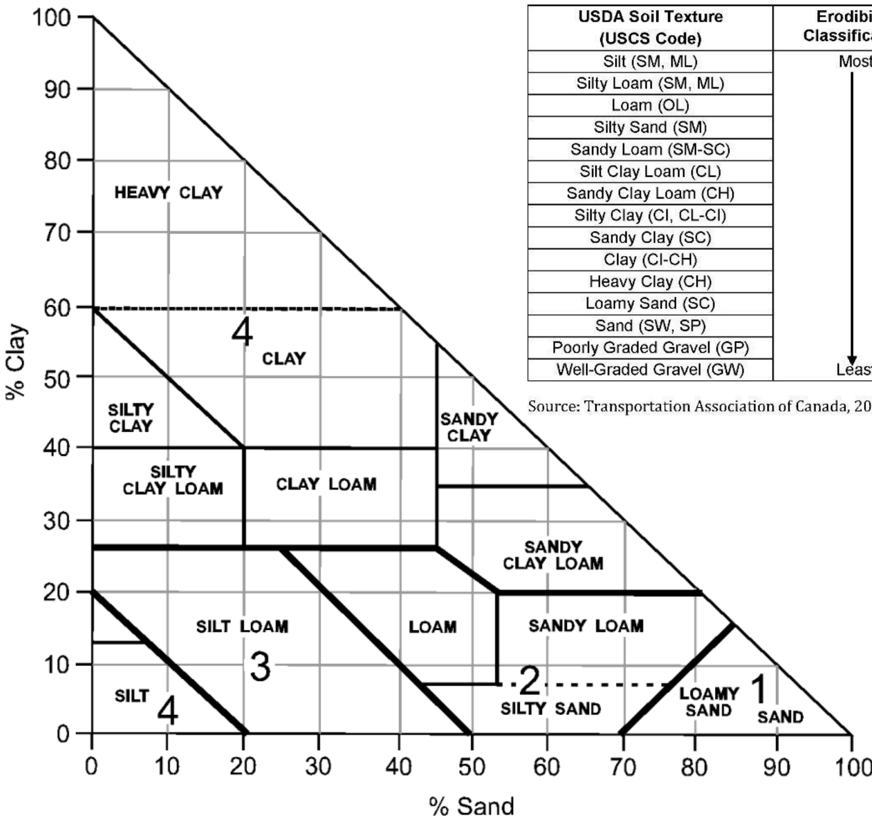
The ability of a soil to absorb rainfall or surface runoff is best characterized by its permeability, which influences the ability of water to infiltrate into the ground. The potential for erosion is smaller in soils that readily absorb rainfall or surface runoff, as this decreases the volume of water available to cause sheet, rill and gully erosion.

A general relationship between soil type and the runoff generated by precipitation is presented in Figure 4.4. This graph indicates the amount of runoff that can be expected for each general soil type in relation to the amount of precipitation during a specific event. This graph provides the user with a quick visual reference as to what they may expect for runoff on their site area.

In general, the presence of topsoil (i.e., the relatively high organic matter upper horizon of a soil) reduces erosion compared to subsoil with similar texture. This observed behaviour is mainly due to the permeability and fibrous nature of the organic material in the topsoil. An organic rich soil placed in an unsaturated condition generally has the ability to absorb a significant amount of water. Furthermore, the various rootlets and fibres present in topsoil act as reinforcement that minimizes the effect of raindrop, sheet or rill and gully erosion.

The presence of permafrost influences soil erodibility. Although a frozen soil is resistant to erosion, infiltration is restricted leading to increased runoff which can affect down-gradient non-frozen soils. Exposure of a frozen soil (e.g., in a road cut) can lead to permafrost melt, soil saturation, and increased erosion potential if rainfall or runoff occurs. Additional information on permafrost and erosion is provided in Section 6.2.

Examples of soil data for typical NWT soil types are presented in Appendix A to illustrate typical textural and organic matter characteristics. This information is included for the purpose of illustrating the variety of soils that could be encountered on the NWT construction sites. It is not intended as a comprehensive list of soil types, nor should it be used to replace or supplement soil testing data for a specific construction sited.



USDA Soil Texture (USCS Code)	Erodibility Classification	Soil Erodibility Rating
Silt (SM, ML)	Most	High
Silty Loam (SM, ML)		High
Loam (OL)		High
Silty Sand (SM)		High
Sandy Loam (SM-SC)		Medium
Silt Clay Loam (CL)		Medium
Sandy Clay Loam (CH)		Medium
Silty Clay (CI, CL-CI)		Medium
Sandy Clay (SC)		Low
Clay (CI-CH)		Low
Heavy Clay (CH)		Low
Loamy Sand (SC)		Low
Sand (SW, SP)		Low
Poorly Graded Gravel (GP)		Low
Well-Graded Gravel (GW)	Least	Low

Source: Transportation Association of Canada, 2005

Figure 4.2: Soil Texture Nomograph and Erodibility Rating

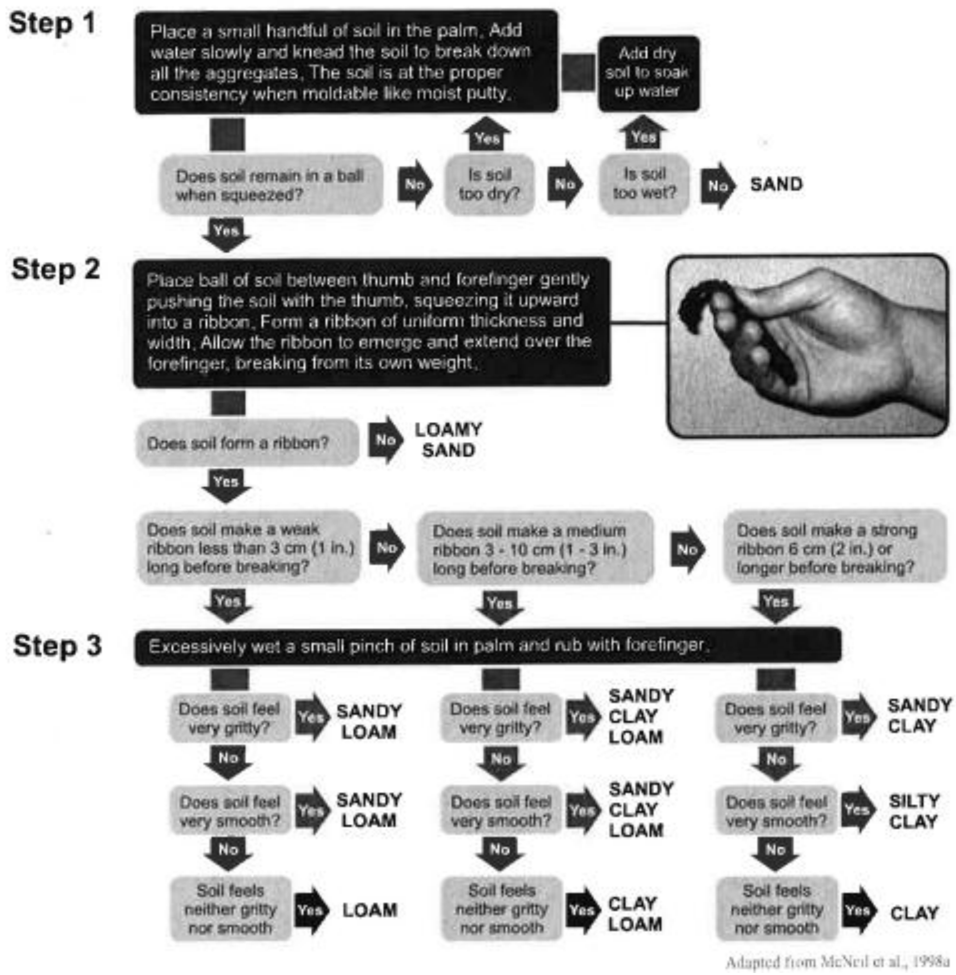


Figure 4.3: Manual Method for Determining Soil Texture[2]

[2] Alberta Agriculture: Nutrient Management Planning Guide, Figure 3.1.5 (Undated)

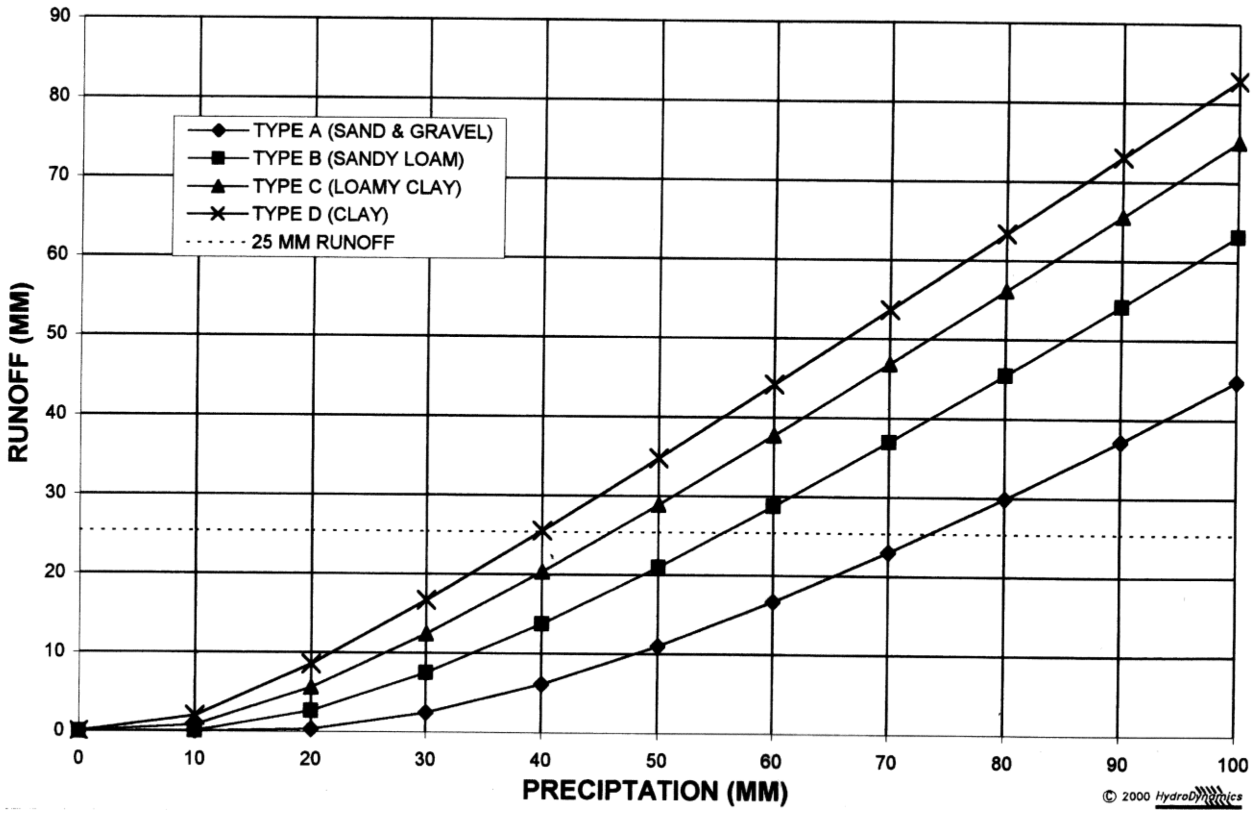


Figure 4.4: Estimated Runoff from Precipitation for Different Soil Types

Source: Fifield, 2001

4.3.4 Vegetative Cover on Soil

Under natural conditions, the amount of vegetation cover is perhaps the major factor controlling natural erosion rates. Vegetative cover is a very durable and a highly effective erosion control measure. Vegetation minimizes erosion by:

- Shielding the ground from direct rainfall impact;
- Improving the soil permeability;
- Reducing velocity of runoff; and
- Holding soil particles in place with the root structure from living and dead vegetation.

Because of its effectiveness in controlling soil erosion, vegetation is usually the primary choice for long-term erosion control (unless there are reasons for doing otherwise). Given the relatively short growing season in the NWT, it can take several years for vegetative cover to be established. ESC Plans should therefore:

- Minimize the removal of vegetation on sloping ground during construction to what is absolutely necessary; and

- Specify plant species for re-vegetation that are climatically suited to the specific ecological region and site characteristics. Indigenous plant species should be considered and some may be transplanted from local areas, if approved by the GNWT-DOT, such as in sod placement treatments, in conjunction with seeding treatments using non-native species (refer to Grass Seed Mix). Caution should be used to ensure low growing species are used where "line-of-sight" is necessary along linear corridors to avoid the need for intense maintenance. Some examples of indigenous species which may be suitable include:
  - Cotton-grass for wet areas;
  - Black Current for moist woody areas;
  - Bog Rosemary for damp or muskeg zones;
  - Crowberry for sandy or rocky areas;
  - Willows or dwarf birch, low growing varieties in most areas;
  - Alder in most disturbed areas. Seed can be easily collected in fall and planted just before snowfall; and
  - Other potential species may include: dogwood, raspberry, rose, Saskatoon, snowberry, kinnikinnick, high-bush cranberry, cinquefoil, blue-jointed reed grass, fowl bluegrass, meadow foxtail, and slender wild rye, any native sedge or rush species depending on the site location and local availability.

4.3.5 Topography

Topography refers to the shape, length, gradient and aspect of a slope. The length and gradient (slope angle) are critical factors, with longer and steeper slopes producing greater soil erosion. The aspect of the slope also affects soil erosion. For example, south-facing slopes tend to thaw more quickly in the spring and the soils can become drier than north-facing slopes in the summer. On north-facing slopes in the NWT, the ground may remain frozen beneath a relatively thin active layer well into the summer.

The shape of a slope also influences the potential extent of erosion; concave slopes with lower gradients at the base are generally less erodible than convex slopes with steeper slopes at the base.

5.0 SITE ASSESSMENT

5.1 General

ESC Plan development begins with a site assessment. The project site assessment provides information needed to assess the erosion potential of a roadway construction site and to identify beneficial features or problem areas on the site. The project site includes the construction area and peripheral areas including temporary roads, quarries, material storage, material disposal, staging and field office areas. The proximity of the site to streams, lakes and other water bodies must be assessed since the consequences of impacting these water bodies play a role in determining the risk of erosion and sedimentation.

The crossing of a water body or other type of encroachment may require Authorization under the *Fisheries Act*. It may also trigger the need for a broader environmental effects analysis under territorial or federal legislation. In cases where works will occur around water, DFO should be contacted to ensure activities are in compliance with the *Fisheries Act*. Submitting a Notification form suffices for works that can be done in conformance with a DFO-approved *Northwest Territories Operational Statement.* For works with a higher risk level or where *Operational Statements* do not apply, DFO should be consulted early in the planning process for project-specific advice. Where works will occur around other sensitive environments or encroach on valued ecosystem components, the appropriate Regulatory Agencies should be consulted.

Identifying the erosion potential of a site and the sensitivity of any downstream values will determine the relative risk represented by the project (see the Risk Assessment section 5.1.8). The project manager can then establish an appropriate level of effort for site specific erosion and sediment control management. An effective ESC Plan will minimize the site disturbance and prevent off-site sediment transport and protect sensitive areas.

Background information for the proposed construction site should be assembled to permit a preliminary assessment of the drainage and erosion potential of the site as well as for identification of environmentally sensitive areas and the presence of fish species for in-stream work windows. Identifying these areas will assist in evaluating the ESC measures to be implemented on and downstream of the proposed construction site.

The key information sources for use in preparing a site assessment are discussed in the following sections. This section is not intended to be an exhaustive list of information sources; it is the responsibility of the individual or firm preparing an erosion control strategy to ensure they have considered the appropriate relevant information.

5.1.1 Review of Construction Drawings

Design drawings will provide some of the information necessary for the preparation of an ESC Plan. This information includes, but is not limited to, the location, size and gradient of grubbing areas and stripping areas, vertical and horizontal road alignments, length and gradient of cut slopes and embankment slopes, ditch lines, culverts, bridges and watercourse crossings, riparian zones, and special sites such as borrow pits, gravel pits, and spoil areas.

5.1.2 Geotechnical Investigation Reports

Geotechnical information such as borehole logs, test pit logs, and accompanying reports are available for some areas in which transportation construction projects may take place in the NWT. This information will likely indicate the type of soils encountered in the area, detailed soil descriptions, the thickness of each unit, moisture content, soil strength values, the presence and type of ground ice associated with permafrost, and water table levels from discrete locations. In some cases, topsoil assessments or slope stability assessments may have been conducted.

Geotechnical investigations for many project designs may include review of aerial photographs, terrain assessment and soil survey investigation for both gradeline and borrow sources where available. An assessment of difficult/adverse site conditions (i.e., highly erodible soils, unstable slopes, soft subgrade, and high groundwater table) may also be conducted.

Current geotechnical investigation requirements are provided in Geotechnical Site Investigation Guidelines for Building Foundations in Permafrost (I. Holubec Consulting Inc., 2010) and may be implemented by the GNWT-DOT for some construction projects. In general, the depths of soil sampling should extend beneath the design grade for cut slopes, ditch bottoms, and to the maximum depths of proposed borrow source areas. Site assessment of riparian and other water bodies, floodplains and river crossings may be undertaken to evaluate stability of fills as well as to identify possible ESC concerns.

For a typical earthwork grading project, the following soil testing information is provided on the design drawings:

- Soil classification according to USCS;
- Moisture content (%);
- Estimated optimum moisture content (%); and
- Estimated maximum dry density from moisture density relationship testing (kg/m^3).

Depending on the scope of work, the geotechnical report may include the following additional information related to ESC concerns:

- A review of the gradeline design from a geotechnical and erosion perspective;
- Laboratory grain size analysis and Atterberg Limit testing results for fine-grained soils;
- Soil permeability; and
- Stability of large cuts and thick fill areas.

Further, additional reports prepared for environmental and hydrotechnical aspects of the project may contain the following information:

- Identification of environmentally sensitive areas including permafrost, riparian zones, wetlands and fish bearing water bodies;
- Identification of recreational, commercial or traditional fisheries; and

- Construction timing restrictions related to fish and wildlife considerations.

5.1.3 Aerial Photography/Imagery Review

A review of available aerial photographs can provide an overview of landforms, drainage and surface features in and adjacent to the construction site. Overlaying a proposed project alignment on the aerial photos may allow the viewer to locate areas of potential high risk conditions such as historical slope instability. Further, a review of aerial photographs is useful in evaluating drainage patterns, such as drainage catchment size, historic drainage features, ephemeral streams and lowlands.

Web-based aerial image technology provides additional information such as type and extent of soil cover, and type and extent of vegetation.

Sources of aerial photographs in the NWT include the following:

- GNWT Environment and Natural Resources (GNWT-ENR) (www.**enr**.gov.nt.ca/*)*;
- GNWT Department of Transportation (GNWT-DOT) (*www.**dot**.gov.nt.ca/);*
- Natural Resources Canada *(www.nrcan.gc.ca);* and
- GNWT Municipal and Community Affairs (MACA) (*www.**maca**.gov.nt.ca/)*: and
- GNWT Industry, Tourism and Investment (ITI) (*www.**iti**.gov.nt.ca/)*

Local communities such as Hay River, Fort Simpson, Fort Liard, Nahanni Butte, Tulita, Fort Good Hope, Fort McPherson, Aklavik and Tuktoyaktuk, may have information on flooding or other local events within their archives that may be beneficial when developing ESC Plans.

5.1.4 Surficial Geology Maps

Surficial geology maps are another soil information source that may be employed during construction. These maps may be used to interpolate soil conditions between drill holes or test pits (with inherent uncertainty) and can assist in delineating boundaries of various soil types.

The type of information found on surficial geology maps may include type and extent of soil, thickness and bedding characteristics of each soil type, stratigraphy, depth to bedrock, and in some instances, the erodibility rating.

Sources for surficial geology maps include:

- Natural Resources Canada *(www.nrcan.gc.ca);* and
- Geological Survey of Canada. *(www.nrcan.gc.ca/earth-sciences/about/organization/organization-structure/geological-survey-of-canada/)*

5.1.5 Vegetative Cover Maps

Vegetative cover maps typically include the dominant plant species as well as information on moisture and nutrient regimes. They can provide information about the type of vegetation that should be used for re-vegetation, considering the drainage class and soil texture.

Information on vegetative cover will help identify the rooting conditions that may be encountered during grubbing and stripping operations. The existing vegetation will provide the designer with a basis for successful revegetation by defining which species are currently growing on the site and indications of the limitations of the site (e.g., arid versus wet conditions).

Vegetative cover maps come in various forms. Some are developed to address specific concerns such as new development and others are developed for inventory purposes. For the purpose of erosion and sediment control planning, site level vegetative cover maps (scale 1:10,000 or less) are the most useful and provide the level of detail required for characterizing a construction site and developing specific erosion and sediment control measures. Overview maps of larger scale may not provide enough detail to plan specific measures, but may be useful for characterizing general site conditions.

Sources for vegetative cover maps include:

- GNWT Environment and Natural Resources (GNWT-ENR) (*www.**enr**.gov.nt.ca)*;
- Natural Resources Canada *(www.nrcan.gc.ca);* and
- Environment Canada (*www.ec.gc.ca/default.asp?lang=en)*.

5.1.6 Floodplain Information

Floodplain information including frequency, duration, and flood levels is important data to identify erosion and deposition processes associated with natural flooding as opposed to sedimentation caused by construction activities. Sources for floodplain information include:

- GNWT Environment and Natural Resources (*www.**enr**.gov.nt.ca/)*;
- GNWT Municipal and Community Affairs (*www.**maca**.gov.nt.ca/*); and
- Environment Canada (*www.ec.gc.ca/default.asp?lang=en)*;

Floodplain information should be shown on the drawings that accompany the documentation for an erosion and sediment control strategy.

5.1.7 Site Inspection (Data Collection)

A site inspection of the proposed construction site is a fundamental step in the preparation of an ESC strategy. Observations of the existing site conditions, such as drainage patterns, existing vegetation and signs of wildlife use, will provide the greatest level of detail for identifying potential erosion and sediment sources and location of drainage structures for temporary diversions and post-construction alignment. A site inspection should be conducted at the time of year with no snow cover and not immediately following a rainfall event, if possible.

Site inspections should be conducted after the background information, such as flood pattern and frequency, climate data, vegetation mapping, and historical aerial photography, is reviewed. A site inspection should involve a reconnaissance of the project footprint to assess and document the following information:

- Soil Properties: The soil properties in an area to be disturbed by construction activities should be described according to the USCS in conjunction with Agriculture Soil Structure Code in the Soil Erodibility Rating table as presented in Figure 4.2. This information may be assessed by inspecting existing soil exposures or by conducting shallow test pits in the area. The focus should be on areas of anticipated high erosion potential.

  Watercourses: Potential areas of concentrated drainage and areas of surface flow or groundwater outflow should be noted on the site plans. The field inspection should focus on determining the potential for sedimentation and associated consequences downstream and downslope of the construction site. Depending on the nature of the construction, an estimate of the bank full elevation of streams may be required. Baseline water quality sampling will be conducted prior to the start of construction and at intervals during the project determined by site activities and outlined in the ESC Plan.

- Water Crossings: Water crossings, including watercourses and drainage ditches, should be noted.

- Fish Habitat Assessments: All water bodies adjacent to work sites should undergo a fish habitat assessment to account for the presence and importance of fish. If fish are present, care must be taken to prevent blocking fish passage, harming fish or their food (e.g. riparian habitat), or allowing sediment to reach the water. Under section 35(1) of the *Fisheries Act,* it is illegal to seriously harm or kill valued fish species.

- Riparian Zones: The location, width from the high water mark, and general descriptions of riparian zones should be noted and marked in the field. For guidance, vegetated riparian areas should be at least 15 m to 30 m wide to reduce sediment delivery potential. Furthermore, the presence of watercourses originating from or passing through the construction site that are buffered by these zones and their respective gradients should be noted. Intrusion into the riparian zone may require approvals from the GNWT-ENR.

- Vegetation: Existing and adjacent vegetation should be noted in terms of location, type and extent.

- Slope Failures: Signs of recent or historic slope failures or evidence of instability should be noted. Assessment by a geotechnical engineer may be required to determine the cause of slope failure.

- Eroded Sites: Areas of recent or past erosion and sedimentation events should be noted.

- Sensitive Sites: Potentially sensitive sites such as permafrost and icing areas, drinking water source areas, fish and wildlife habitat, private property, utilities, and recreational areas should be noted.

5.1.8 Risk Assessment

After the information has been reviewed and a site inspection completed, an erosion and sedimentation **Risk Assessment** is completed. The purpose of the Risk Assessment is to identify and prioritize areas requiring erosion and sedimentation control and to determine the types of Best Management Practices (BMPs) that should be considered as mitigation measures when developing the ESC Plan.

The Canadian Standards Association (CSA) (2009) has prepared a general risk management decision procedure (CAN/CSA Q850-97), including preliminary analysis, and risk assessment. This procedure may be applied to many activities, including erosion and sedimentation risk assessment. Risk is a quantitative or qualitative expression of possible loss that incorporates both the **probability that a hazard will cause harm** (human injury, property damage, environmental damage and/or other things of value) and the **consequences (the damage, loss or change) to the elements affected** (CSA 2009). The probability of erosion and sedimentation above natural levels, due to construction activities, is affected by the factors discussed in Chapter 4, and can be reduced by properly implementing the practices discussed in Chapter 7 of this manual.

ESC failures can result in four types of potential consequences:

- Ecological consequences related to the introduction of sediment to the aquatic environment;
- Project consequences related to the need to respond to and repair erosion damage and the implications for the project schedule and costs;
- Legal consequences associated with the deposition of sediment in receiving water bodies; and
- Professional and social consequences such as loss of reputation and confidence from nearby communities and other government agencies.

Land management practices during construction can significantly influence the risk of erosion. Removal of vegetation, soil compaction, and slope changes can all increase the rate of erosion. The lack of effective ESC measures can result in significant erosion and sediment transport.

Sedimentation can adversely affect the aquatic environment, including fish and fish habitat. These effects can range from behavioural effects (e.g., avoidance behaviour, decreased foraging success) to outright mortality, depending upon the concentration and duration of exposure (Newcombe and Jensen 1996). Depositing fine sediment in spawning areas can smother eggs and make streambed material unusable for spawning.

Erosion at construction sites can affect project costs and timelines. For example, repair or damage due to large soil movement or gully formation may require resources to be diverted from other construction activities. Damage to neighboring property or receiving water bodies, caused by soil leaving the site, can be costly to repair. In extreme cases, this can also affect project completion schedules.

There are legal consequences related to the release of sediment to the aquatic environment. Sediment is considered a deleterious substance under the *Fisheries Act* and a contaminant under the EPA. Any sediment release could result in charges laid under subsection 36(3) of the *Fisheries Act* or subsection 5(1) of the EPA. Substantial penalties may be attached to convictions for the release of sediment into waters frequented by fish (see subsection 40(1) of the *Fisheries Act* and subsection 12.1 of the EPA).

In addition to fines for environmental offences, stop work orders may be issued by regulatory officials. These can require all work to cease until appropriate mitigation measures are properly implemented and incorporated into a development plan.

All of these potential consequences must be considered in determining the best approach to developing ESC plans. Risk assessment is a key element in assessing the degree to which ESC measures are integrated into a development plan.

Integrating risk assessment with ESC planning also demonstrates that reasonable care was taken in addressing ESC issues and can be a consideration in litigation as part of a due diligence defense. If a risk assessment is not included in the ESC Plan development and a HADD or an uncontrolled release of sediment into a watercourse occurs, it will be difficult to prove that reasonable care was taken.

5.1.9 Consultation with Regulatory Agencies

There are several territorial and federal Regulatory Agencies (RAs) that may have specific and/or detailed information or concerns about the construction site. Gathering site specific baseline information is a challenge in northern Canada, and many sources may need contacting for the original site assessment. Information from regulatory agencies may include general fish and wildlife habitat information, historical data (e.g. rainfall records or past slope failures), revegetation limitations or requirements, information on previously implemented erosion and sediment control measures, and permitting requirements. For site specific information, consider contacting local communities and governments for local and traditional knowledge.

Some RAs have guidelines for specific types of works or undertakings. These guidelines can be found on the RA websites. These documents offer proven and accepted mitigation measures for specific low risk activities. Consider the following agency websites as a resource for project planning:

- Fisheries and Oceans Canada (*www.dfo-mpo.gc.ca/regions/central/habitat/os-eo/provinces-territories-territoires/nt/index-eng.htm).*
- AANDC (*www.aandc-aadnc.gc.ca*)*;*
- Environment Canada (*www.ec.gc.ca/default.asp?lang=en)*;
- GNWT Environment and Natural Resources (*www.enr.gov.nt.ca/)*;
- GNWT Water Board *(www.nwtwb.com/*); and
- Regional Boards with responsibility for environmental management.

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6.0 SITE EROSION POTENTIAL AND EVALUATION

6.1 General

Construction activities can increase erosion rates and the transfer of sediment away from the site. Many activities that are undertaken during construction can directly affect erosion and sediment transport. Activities may be linked or can influence more than one of the factors that can affect erosion rates. Using roadway construction as an example, these linkages are shown in Figure 6.1 below.

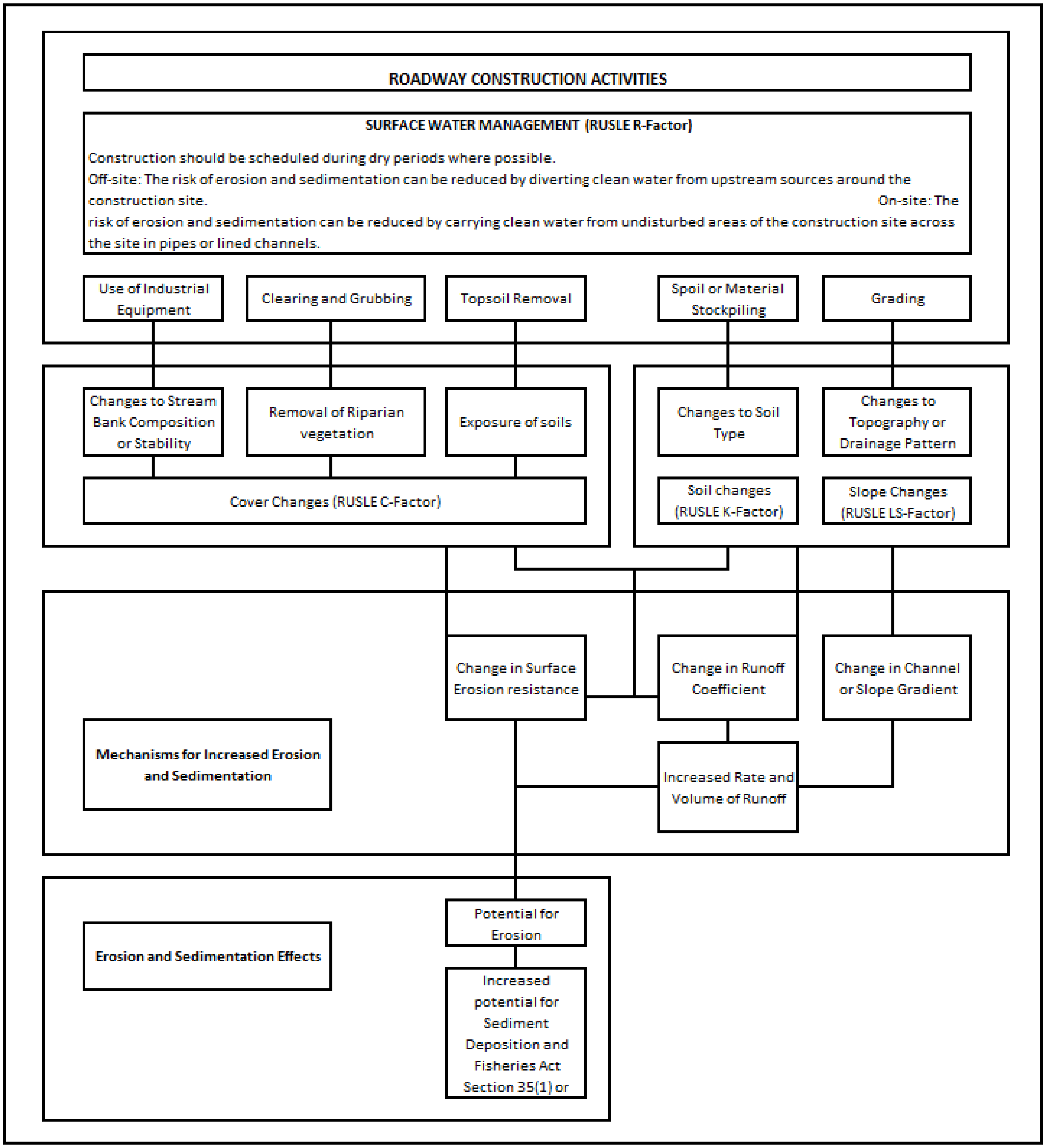

Figure 6.1: Linkage Diagram Relating Construction Activities to Risk of Erosion and Sedimentation

It is important to understand how each type of construction activity affects site erosion potential and the methods for addressing erosion or sediment control, when preparing an ESC Plan. A methodical approach to assessing potential for erosion and sedimentation due to construction activities involves a series of screening evaluations. The following information is required to assess the erosion potential: soil texture, structure, and permeability; topography; climate (e.g. rainfall erosivity and growing season); presence or absence of ground ice or permafrost; cover characteristics (i.e., vegetative, paved, rock etc.), shallow groundwater conditions; and receiving environment sensitivity.

The major challenge facing the designer is to correctly assess the erosion potential resulting from the construction activities. The site erosion potential is an estimate of the quantity of soil that could be removed from the construction site due to erosion and transportation by surface water flow. Soil loss evaluation methods used in agricultural practice have been successfully adapted to construction practices. The estimates produced by using these methods should be supplemented with judgement and experience so that the assessment of site erosion potential is appropriate for the construction site and reflects the level of environmental risk.

6.2 Regional Erosion Potential Issues

This section has been adapted from the Transportation Advisory Committee TAC National Guide to Erosion and Sediment Control for Roadway Projects, May 2005 (TAC Manual). Portions are directly quoted from the TAC Manual.

The NWT has several unique biophysical characteristics that influence ESC planning and practice. The NWT – Protected Area Strategy (PAS) has detailed information on ecoregions which offers the user more specific local information. It is important to be familiar with, and to address, site specific issues when developing an ESC Plan. This section outlines the key differences in ESC in the NWT compared to other parts of Canada.

The NWT is home to a number of flora and fauna species that may be considered at risk or endangered. Lists of species protected by regulations are available through the GNWT - Environment and Natural Resources. That department should be consulted for additional information on the implications for construction projects. Consultation with local First Nations or communities may be a good information source.

Emphasizing proper design of ESC measures, early revegetation of exposed surfaces, protection of impacted permafrost areas, and proactive maintenance programs will help reduce the impacts in these areas. To identify specific regional issues related to ESC, the physiographic regions within the NWT should be considered. These include the Cordillera, Interior Plains, Arctic Canada (Lowlands), Arctic Canada (Innuitian) and the Canadian Shield. A map of the Physiographic Regions of Canada is presented in Figure 6.2. The overview presented here is a brief introduction to regional issues that may be encountered. Local knowledge and additional relevant information should be applied to specific project sites.

Cordillera: The topography of the Cordillera Region is dominated by mountains, plateaus and steep valleys. Erosion potential in the Cordillera is affected by high gradient slopes, large annual rainfall and high runoff resulting from snowmelt and rain-on-snow events. Debris flows should be considered as an important design consideration.

The diverse topography in the Cordillera Region creates a variety of site-specific challenges for ESC. ESC Plan designers should be prepared for rainfall/runoff events, minimize the extent and duration of exposed soil, consider stabilizing temporary stockpiles (seeding or mulching) and be attentive to site sensitivities.

Interior Plains: The Interior Plains Region has an arid climate, low relief and relatively fine-grained soils that are highly susceptible to erosion. Agriculture in this region, limited to the southern portion of the NWT, has created tilled and disturbed soils that are highly susceptible to erosion. Vegetation establishment can be difficult due to arid climate and nutrient poor soils.

Wind erosion may be an issue in the southern plains area due to soil dryness.

Beaver dams may be a common feature on smaller watercourses and they provide critical late summer flows and overwintering habitat to sustain fish. Beaver dam removal should be approached with caution. Dams provide natural ESC and the rapid release of water from a breached dam can cause catastrophic erosion. Proposed beaver dam removal should be reviewed by DFO and GNWT – Environment and Natural Resources.

Canadian Shield: The Canadian Shield is the largest physiographic region in Canada and is a region of exposed rock and glacial features. The Shield is known for its rolling, undulating terrain and its numerous lakes. Some of the biggest challenges in ESC could be intense summer storms and winter storms. Emergency response planning should be incorporated into the ESC. A key consideration in ESC planning should be to minimize the extent and duration of exposed soil and to stabilize temporary stockpiles.

Arctic Canada: The Arctic physiographic region (tundra) generally believed to lie north of the treeline. The short growing season and harsh climate result in short, slow growing vegetation. A large portion of the surface in this region is bare rock and is covered in snow for the majority of the year. The largest runoff events are associated with spring melt.

Typically, large-scale tundra polygons, thaw lakes and depressions, and widespread mass-wasting and patterned-ground phenomena characterize these landscapes. The tundra environment is characterized by the general presence of permafrost (except beneath some lakes and rivers); short summers with almost continuous daylight; long winters and arctic "nights"; low annual precipitation (hence the name polar desert); strong winds and winter blizzards; discontinuous vegetation; unstable, wet SOIL conditions resulting from permafrost and frost action. Tundra plants have developed many adaptations for survival. Their low stature exploits the more favourable microclimate near the ground; small, leathery, hairy leaves prevent desiccation by evaporation.

Perennial life habit, vegetative propagation, short reproductive cycle and effective seed dispersal by wind are common among tundra plants (e.g. lichens, mosses, grasses, and low shrubs). [3]

[3] The Canadian Encyclopedia / Geography / Geography, General/ Physiographic Regions/ Arctic and Sub-Arctic Lands

Major erosion issues related to construction in the arctic are permafrost degradation due to excavation and ditch construction. Constructed infrastructure can change the reflectivity of the ground surface, which affects permafrost by increasing the amount of absorbed solar radiation. The harsh climate may also inhibit revegetation efforts.

Northern Canada: Permafrost degradation is a concern in many of Canada's northern physiographic regions. Refer to Figure 6.3 Permafrost Regions of the Northwest Territories. Construction activities and linear cuts in particular, can remove or disturb insulating soil and vegetation, expose dark soils to reduce the ground surface melt and cause water to flow against frozen ground. These can produce an unfrozen and saturated soil that is susceptible to slope failure and erosion. Proper northern construction techniques and reclamation efforts are required to prevent significant thawing of permafrost soils. For sites constructed on permafrost, available thaw-control BMPs include insulated thermal blankets, gravel buttresses and controlled ablation.

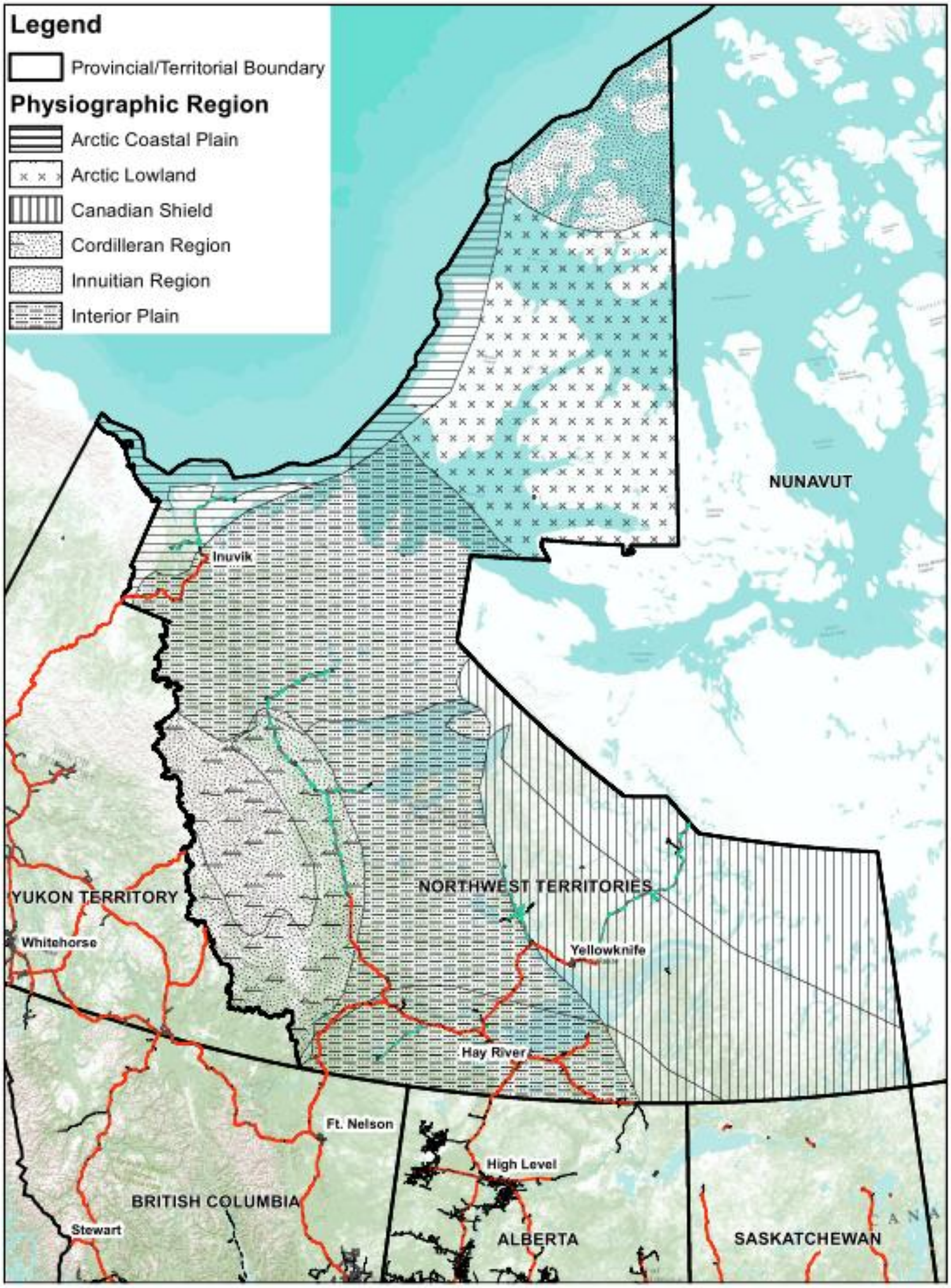

Figure 6-2: Physiographic Regions within the Northwest Territories

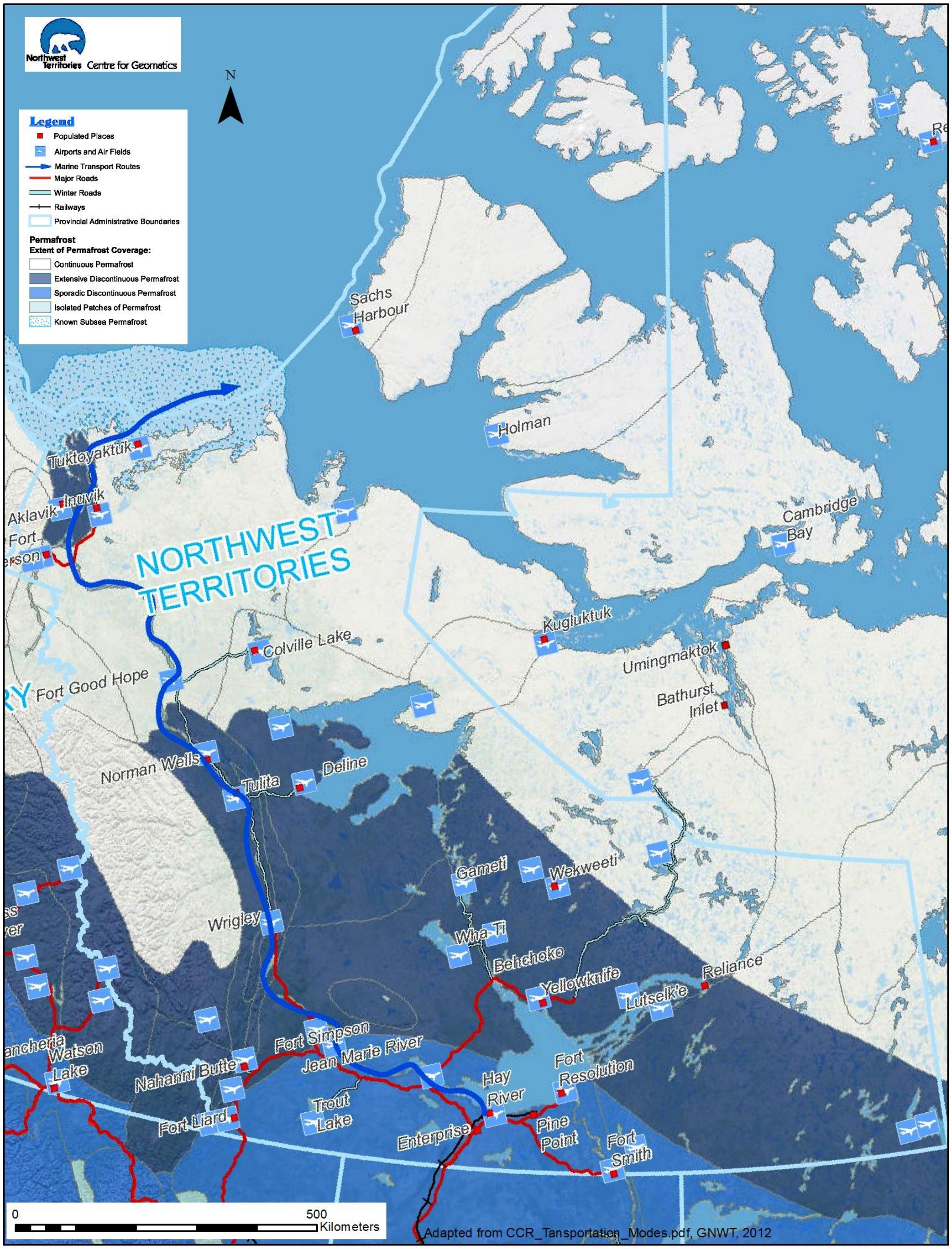

Figure 6-3: Permafrost Regions of the Northwest Territories

In addition to deep organic deposits, northern sites must also contend with very thin topsoil overlaying tills, silts and volcanic ash deposits. Vegetation establishment can be challenging due to the very short growing season, the arid climate, and nutrient poor soils in portions of the north.

Many northern streams, which are very sensitive to sediment deposition, support diverse populations of fish upon which traditional and recreational users rely.

6.3 Revised Universal Soil Loss Equation (RUSLE)

A number of approaches can be used for estimating transportation construction site erosion potential. The primary quantitative tool is the Revised Universal Soil Loss Equation (RUSLE), which is an update of the original Universal Soil Loss Equation (USLE) that was developed in the 1970s. The RUSLE calculations are available in an on-line software package that includes databases of soil erodibility (K) and climate (R) data for all major soils and cities across the United States. As this program was developed in the United States, no data was included for Canadian locations and it should not be used for NWT construction sites. The most recent version is known as RUSLE2 is in Windows format[4].

Agriculture Canada, working with other public agencies and universities, adapted RUSLE so it could be used in Canada, taking into account the factors that influence erosion in Canada. The document Revised Universal Soil Loss Equation for Application in Canada (RUSLE–FAC) (Wall *et al.* 2002) is available online and is the best guide for RUSLE use in Canada. RUSLE-FAC is not currently available in a computerized software and data package.

It is important to note that USLE/RUSLE only predicts the amount of soil loss that results from sheet or rill erosion on a single slope and does not account for additional soil losses that might occur from gully, or wind erosion. Nor does it calculate sediment yield (i.e. the mass of sediment delivered from a watershed). Its primary value is to provide a consistent method of assessing erosion hazard and for determining the potential for specific ESC practices to reduce that hazard to an acceptable level.

For the remainder of this manual, references and examples will focus on RUSLE-FAC, which will be simply referred to as RUSLE for consistency.). For calculating a detailed analysis of soil loss on a project site, the designer should refer to the RUSLE-FAC document (*http://sis.agr.gc.ca/cansis/publications/manuals/2002-92/index.html*).

4 Available from the National Sedimentation Laboratory; http://www.ars.usda.gov/main/site_main.htm?modecode=64-08-05-00

The RUSLE formula is as follows:

$$A = R \times K \times LS \times C \times P \qquad \text{(Equation 6.1)}$$

Where: A = Annual soil loss (tonnes ha^{-1} $year^{-1}$)

R = Rainfall factor (MJ mm ha^{-1} $hour^{-1}$ $year^{-1}$)

K = Soil erodibility factor (tonne hour MJ^{-1} mm^{-1})

LS = L and S are the slope length and steepness factors, respectively (dimensionless)

C = Vegetation and Management Factor (dimensionless)

P = Support Practice Factor (dimensionless)

Supporting information to assist in the selection of these factors is presented in Appendix B.

6.3.1 Rainfall Factor, R

The rainfall factor, R, is a measure of the total annual erosive rainfall for a specific location, combined with the distribution of erosive rainfall throughout the year. The rainfall factor is the average annual sum of the products of the two variables most critical to a storm's erosivity:

- Volume of rainfall and runoff (E); and
- Prolonged-peak rates of detachment and runoff (I) (Wischmeier and Smith, 1978).

EI is the total kinetic energy of a storm multiplied by the maximum 30-minute intensity.

In Canada R is estimated through the use of the following three primary methods:

1. Measured rainstorm EI values. This method is suitable if 22 or more years of rainfall intensity data are available (Wischmeier and Smith, 1978).
2. Equations which rely on an empirical relationship between R and the one-in-two year, 6 hour storm (Canadian adaptations are described in the RUSLE-FAC manual of Wall et al. 2002).
3. Hourly precipitation records, where available to predict R (e.g., Wigham and Stolte 1986).

Estimated R Values have been calculated for Selected Sites in the NWT. (Appendix B: Table B-1 or Section 6 - Table 6.1, Page 6-9)

These three methods have been used to estimate R and produce reference materials for Canadian conditions:

- In southern Canada, isoerodent[5] maps have been developed that indicate annual R values for an area and can be used to calculate average annual soil losses (Refer to the RUSLEFAC Handbook available at: http://sis.agr.gc.ca/cansis/publications/manuals/2002-92/index.html);

5 Isoerodent Maps: A map showing lines of equal soil erosivity which were developed through interpretation of long-term recording-rain gauge records. Maps for lower Canada are available as a result of the development of the RUSLE program in the United States.

- Monthly distribution of R which indicates the proportion of annual erosive rainfall that falls during each month (Table B-2, Appendix B); and
- Mean annual rainfall on frozen soil maps, which may indicate areas where rain falling on frozen soil could pose an erosion risk.

At present, the isoerodent maps are only available for southern Canada (Wall et al. 2002). Climate stations with rainfall intensity data in the NWT are spaced too far apart to generate reliable isoerodent lines, and R values need to be calculated from the best available climate data for a particular site.

Following are estimates of R values for the Environment Canada climate stations in the NWT where there are available Intensity-Duration-Frequency (IDF) data, specifically the rainfall from the 1-in-2 year 6-hour storm. The R estimates were generated using the empirical equation developed by Ateshian (1974) based on directions in the RUSLE-FAC Manual (Wall et al. 2002). The equation is:

$$R = 0.417\ p^{2.17}$$

where p is the normal, one-in-two year, 6 hour storm. The R values in Table 6.1 provide an indication of the spatial variation of erosive rainfall in the NWT. For example, based on the R-value estimates, the annual erosivity in Fort Simpson is almost four times that in Inuvik.

Location*	Normal 1-in-2 year 6-hr intensity (mm/hr.)	Normal 1-in-2 year 6 hr. storm (mm)	R - the Erosivity Index (MJ mm/ha/hr.)
Yellowknife	3.0	18.0	**221**
Fort Reliance	2.3	13.8	**124**
Fort Simpson	3.6	21.6	**328**
Hay River	3.1	18.6	**237**
Inuvik	1.9	11.4	**82**
Norman Wells	2.7	16.2	**176**
Tungsten	2.3	13.8	**124**

*All locations are at the local airport.

Table 6.1: Estimated R Values for Selected Sites in the NWT

It is important to note that the R factor is an index of rainfall erosivity that is used within the RUSLE to estimate annual soil loss. The RUSLE is most useful for comparing the relative effectiveness of conservation of practices rather than for developing precise estimates of soil loss. The lack of more site-specific R values for the NWT is not a serious constraint if the RUSLE is used as intended in this manual, which is to develop an ESC plan. The R values listed above should be used cautiously for any other purpose. For larger projects with significant potential consequences of erosion, users may wish to develop an R value based on local data and the methods specified in the most recent USDA RUSLE Manual (currently Renard et al. 1997)

6.3.2 Soil Erodibility Factor, K

6.3.2.1 Estimation of K

The K factor is a quantitative measure of a soil's inherent susceptibility to erosion. Generally, on the basis of soil characteristics alone, soils with a high percent content of silt and very fine sand particles, as well as low fibrous organic matter content, will be most erodible. A preliminary assessment of soil erodibility was presented earlier in Figure 4.2. K values estimated using the methods detailed herein is appropriate for soils encountered in agricultural practice. As such, a soil erodibility adjustment factor ($Ø_K$) is proposed to facilitate application of the estimated K values to construction sites and is discussed in Section 6.3.2.2.

A K value can be calculated for a specific soil, using the following empirical equation (Wischmeier and Smith, 1978).

$$K = [2.1x10^{-4}(12-a)M^{1.14} + 3.25(b-2)+2.5(c-3)]/100 \qquad \text{(Equation 6.2)}$$

Where: M = (% silt + very fine sand) x (100 - % clay)

a = % organic matter

b = the soil structure code used in soil classification (Figure B-2), and

c = the profile permeability class (Figure B-3)

The input parameters for the aforementioned equation are routinely characterized through standard soil profile descriptions and laboratory analyses. These parameters are listed as follows:

- % silt plus very fine sand (soil particle sizes between 0.05 and 0.10 mm);
- % sand greater than 0.10 mm;
- Soil structure;
- Permeability; and
- Organic matter content.

Of these variables, organic matter content can usually be assumed to be zero in road embankments or deep cuts.

The soil erodibility nomograph (Figure B-1, Appendix B) provides a graphical solution for determining a soil's K value, and can be used if the percent sand and organic matter fractions in a particular soil are known.

The soil erodibility potential is low for high plasticity clayey soil and coarse to medium grained granular soils; therefore, gradation analysis including hydrometer testing of these soils would not usually be required for an erodibility assessment. The soil erodibility can be high to medium for low to non-plastic soil and soil with significant amounts of silt and fine sand. Therefore gradation analysis including hydrometer testing is required.

Where the soil fractions are not known, K factors have been estimated for a number of surface textures and for approximate organic matter content. Major textural groups and their corresponding K values are listed (Table B-3, Appendix B).

6.3.2.2 Soil Erodibility Adjustment Factor ($Ø_K$)

It should be noted that the soil erodibility factor (K) was developed for an agricultural setting where soil are routinely tilled. The level of consolidation and/or compaction of soils encountered on cut and fill areas in a transportation construction setting is usually much greater than that encountered in an agricultural setting, which reduces erodibility for some construction periods. With the possible exception of winter road building, cut slopes in construction will usually or optimally consist of consolidated material and fill slopes that have undergone significant compaction effort and moisture conditioning. For fill embankments, compaction energy was exerted on the soils at thin lifts with moisture conditioning (to moisten or dry the soil to an optimum moisture content) to achieve a maximum dry density (Standard Proctor Density).

Most transportation related fills are constructed with mineral soils with minimal organic content. This situation differs greatly from an agriculture setting where soils have been cultivated to produce loose conditions that promote plant growth. Despite efforts to improve soil strength in a construction setting by compaction, silty and low plasticity fine-grained soils remain highly erodible and must be managed accordingly. The installation of rolled erosion control products (RECP) (e.g. coconut mat) or the replacement of fibrous organic material (Sodding) over highly erodible sites may be beneficial in these areas where feasible. Refer to Sections 7 and 8 of this manual for choosing erosion control measures which may be suitable to the construction site.

Based on the observed differences in the erodibility of construction and agricultural soils, the soil encountered in an industrial scenario would typically have a lower K value. Thus, a modification factor ($Ø_K$) should be applied to lower the K factor for use in RUSLE on construction sites. $Ø_K$ values ranging from 0.5 to 1.0 have been used elsewhere (with an average value of 0.8) to adjust K on construction sites. However, the selection of $Ø_K$ should be done carefully by the qualified person preparing the ESC Plan based on site conditions and the presence or absence of permafrost. If permafrost is not present, a modification factor of 0.8 is reasonable in most situations. If permafrost is present, the K value should <u>not</u> be modified since permafrost melting may increase soil erodibility.

6.3.3 Topographic Factor, LS

6.3.3.1 Estimation of LS

The topographic factor, LS, is a combined factor that accounts for the effect of slope length (L) and slope steepness (S) factors on the site erosion potential. It adjusts the erosion prediction for a given slope length and slope angle to account for differences from slope conditions present at the standard erosion monitoring plot on which the original USLE was based (LS=1 for slopes 22 m long with 9% grade).

For consolidated soil conditions, such as freshly prepared construction sites with minimal vegetative cover, values of LS can be evaluated from the Topographic Factor Chart (Table B-4, Appendix B) for slope lengths varying from 2 to 300 m, and slopes ranging from 0.2 to 60%.

The upper end of a slope can be defined as the top of the slope, or the divide down a ridge in the field. The lower end of a slope can be located by moving down the slope, perpendicular to the contours, until a broad area of deposition or a natural or constructed waterway is reached. Reducing either the length or steepness of a slope can reduce soil loss. However, reducing the steepness of a slope results in an increased slope length, thus the overall reduction of soil erosion may not be significant. Another way to reduce soil loss is to place intercepting berms along the contours. While this procedure will effectively reduce the cross-section to a series of simple slopes, costly earthworks may be required to establish the berms, which may not be justified unless fill material is readily acquired at a nearby location.

Estimation of the LS factor for uniform slopes and irregular slopes is discussed in the following paragraphs.

Uniform Slopes

The equation of the LS factor for a uniform slope is given as follows:

$$\mathbf{LS = (sl/22.13)^{m} \times S} \qquad \text{(Equation 6.3)}$$

The slope factor "S" in RUSLE is given as follows (McCool et al., 1989):

$S = 10.8\sin(\theta) + 0.03$

when slope is <9%, length ≥ 5 m

$S = 16.8\sin(\theta) + 0.50$

when slope ≥ 9%, length ≥ 5 m

$S = 3.0\sin(\theta)^{0.8} + 0.56$

when length <5 m

Where: sl is the slope length of the site (m)

θ is the angle of the slope (in degrees)

m is a coefficient related to the ratio of rill to inter-rill erosion presented in Table B-5.

Irregular Slopes

The RUSLE provides a procedure for separating an irregular slope into segments. This procedure recognizes and adjusts for differences in the type of slope. For example:

- A **convex slope** will have a greater effective LS factor (i.e., a higher erosion estimate) than a uniform slope with the same average gradient; conversely
- A **concave slope** will generally have a lower effective erosion rate than a uniform slope of the same average gradient.

The irregular slope should be divided into a two to five segments that describe varying conditions down slope (i.e., soil type, practices, etc.).

Design examples illustrating evaluation of LS for irregular slope are presented in Appendix H as Examples H.4 and H.5.

6.3.3.2 Topographic Adjustment Factor ($Ø_{LS}$)

The RUSLE Topographic factor (LS) was developed for typical agricultural slopes with loosened surficial soils for most soil types of moderate to low erodibility. For linear construction applications, slopes are generally much steeper than this and the surficial soils are much denser. Typical slopes for a linear construction site in the Northwest Territories range from 3H:1V (33%) to 6H:1V (16%). Using RUSLE for a typical linear construction slope results in a relatively high LS value and subsequently high site erosion potential. Although it steeper slopes are more prone to erosion as a result of increased runoff velocities, the RUSLE classifications for site erosion potential are calibrated or standardized to a much lower slope gradient and therefore should be modified for use on linear construction sites. In the agriculture practice of assessing the erodibility for slope with loose surficial soils, a gentle slope (9% slope, 22 m length) was chosen to calibrate a baseline value for slope factor (LS=1 in RUSLE) with other slope configurations of steepness and length (Wischmeier and Smith, 1978). As a result, the LS factor is dependent on soil conditions, even though it is intended as a modifier for varying slope steepness. In linear construction slopes with compacted soils, the same baseline slope configuration will yield a lower slope (LS) value due to the higher density in linear construction soils.

Based on the differences between a linear construction and agricultural setting, the soils encountered in a linear setting should have a lower slope factor rating. Thus a Topographic Adjustment Factor ($Ø_{LS}$) is applied to lower the LS factor determined as part of the RUSLE approach to estimating soil loss. An $Ø_{LS}$ of 0.8 is suggested to address the inherent differences between transportation construction and agricultural settings. However, the selection of $Ø_{LS}$ is to be conducted at the discretion of the individual or firm estimating soil loss potential based on site conditions, experience and judgement. The adjustment factor has been developed based on judgement for this document and represents a transportation construction specific factor to be used in the RUSLE.

In the NWT where permafrost is encountered, the $Ø_{LS}$ should not be applied due to the melt process and loose soil condition encountered once the water saturation levels dissipate.

6.3.4 Vegetation and Management Factor, C

The C-factor is used to determine the relative effectiveness of soil including natural vegetation, crops, grasses, and/or artificial protection cover (such as mulch, synthetic erosion protection matting) to prevent or reduce soil loss. For bare soil, C=1 is always used (i.e. no reduction in erosion); whereas for soil surface protected by mulch C=0.1 to 0.2 is common. Some construction site C-factor values are shown in Tables B-6a and B-6b (Appendix B).

6.3.5 Support Practice Factor, P (Practice Factor)

The P-factor is a measure of the effects of practices designed to modify the contouring flow pattern, grade, or direction of surface runoff and thus reduce the amount of erosion. Generally, a support practice is most effective when it causes eroded sediments to be deposited far upslope, very close to their source. In the absence of any support practices, P is given a value of 1.0 in the RUSLE formula. With the use of appropriate construction practice, the P factor can be reduced. For example, the practice of track roughening of bare slope (up/down slope) can reduce the P factor from 1.0 to 0.9.

Estimation of P may well be the least accurate and most subject to error of the RUSLE factors, because there are less field data to support the P values compared to other factors in the RUSLE, and because it depends on the practice being implemented properly. The additive effect of multiple ESC practices is also not well understood.

Some construction site P-factor values are provided in Table B-7, Appendix B.

6.4 Empirical[6] Methods for Sediment Storage/Impoundment Design

Sedimentation basins or traps are best designed by a qualified person using local precipitation data and site-specific soils information. For smaller projects or if the supporting data are unavailable, it is reasonable to size ponds using general guidelines based on empirical evidence. For smaller drainage areas (i.e. less than 10 ha), there is a general relationship between the required storage capacity for sediment laden runoff from the construction site and the area of disturbed or exposed soil. Disturbed areas greater than 10 ha or those on long steep slopes must utilize estimating procedures such as the RUSLE to estimate how much sediment could be delivered to the pond. It is important to note that various site specific factors affecting soil erosion rate are taken into account. Therefore, the empirical method should be used with caution. The main advantage of the empirical approach is its simplicity and ease of application.

Other jurisdictions utilize storage volume requirements ranging from 40 to 250 m^3 per hectare of disturbed area. Sediment storage/impoundment ponds are normally designed at 1 m depth with a design volume ranging from 150 m^3 per hectare of disturbed area (minimum) to 250 m^3 per hectare (recommended). It is assumed that vegetation will be established within one to two years of land disturbances or that there will be at least one clean out of the sedimentation facilities per year. If neither is performed, a storage volume of 250 m^3/ha (whenever possible) is recommended for sensitive areas. If 250 m^2/ha cannot be achieved due to restricted space availability, the minimum storage that should be considered in the absence of site-specific design information is 150 m^3/ha. Smaller ponds may be feasible in those parts of the NWT will low rainfall erosivity (see Table 6.1), but the design should be supported by runoff estimates using the Rational Method (Appendix E) or another suitable method.

6.5 Examples for Estimating Site Erosion Potential

Examples using the RUSLE for determining the soil erosion potential are presented in Appendix H as Examples H.1, H.2 and H.3.

6.6 Site Evaluation

Once a site assessment has been completed, the information should be summarized to provide a complete summary evaluation of the slope and drainage conditions. The site evaluation is a critical step in the preparation of an erosion and sediment control plan and the summary information should be clearly indicated on drawings and supporting documents.

[6] Empirical: Information acquired by means of observation or experimentation

6.6.1 Slope Analysis Summary

The slope conditions to be exposed should be assessed to estimate the potential sediment loss from a site. Exposed areas generally include all cut and fill slopes as well as large stockpiles and non-dugout borrow sources. It may be necessary to divide a slope area by drainage breaks and/or soil type. A representative value for each of the following parameters should be indicated on the ESC Plan drawings and supporting documents:

- Soil Type: Each distinctly separate soil type should be delineated by area on the site plan. Where distinct soil type boundaries are not known or cannot be inferred, estimations of soil type areas are acceptable. Information from the site assessment is helpful in defining the various soil types by area. Additional information gathered during construction can be used to update the soil type areas.
- RUSLE Factors: The RUSLE factors (R, K, LS, C, and P) as defined in Section 6.2 should be summarized for the general conditions of the site and for the specific conditions for each distinctly separate soil/ slope area to be encountered on the site.
- Site Erosion Potential / Hazard Class: Using the RUSLE factors, the soil erosion potential (tonnes/ha/year) should be estimated for each distinct area and period of anticipated construction activity. For the soil loss estimated for a particular site, the associated hazard classification can be obtained from Table 6.2.
- Permafrost: Areas with permafrost should be shown on the site plan.
- Special Sites: Any sites of special consideration should be indicated on the site plan, such as locations of potential slope instability, seepage, or borrow sources.

6.6.2 Drainage Analysis Summary

As a minimum, proponents should complete a summary of the drainage conditions to be encountered and included as information on the ESC Plan drawings and support documents.

- Drainage Catchment Areas: A topographic site plan of the construction site and contributing drainage catchment area(s) needs to be divided into smaller drainage areas based on topographic breaks in slope. Then, for each drainage area identified, an estimate of size in hectares (ha) should be provided. Where the site has to be re-graded to final elevations, the direction of sediment-laden flow could change. Overland flow routes, for both initial and final site grade conditions, should be checked to ensure that appropriate on-site and downstream environmental effects have been evaluated.
- Watercourses: If not already shown on the topographic site plan, all watercourses should be identified and labelled. Watercourses consist of all areas of channelized flow (i.e., rivers, streams, creeks, ditches), as well as drainage collection features such as swamps, ponds and lakes. Design drawings should show all proposed ditch lines, catchments and crossings in addition to the natural drainage features including swales. Information on watercourses should extend beyond the limits of the construction site. As a minimum, drainage connectivity should be established to the nearest body of sensitive water downstream of the construction site.

- Floodplain Information: Where applicable, a clear definition of the floodplain limits should be shown on the drawings.
- Special Sites: Sites of special consideration (e.g., permafrost) should be indicated on the drawings.

6.6.3 Site Hazard Classification

Site hazard classification can be obtained from Table 6.2 below based on the estimate of site erosion potential (tonnes / ha / year).

Site Erosion Potential (tonnes / ha / year)	Hazard Class
< 6	Very Low
6-11	Low
11-22	Moderate
22-33	High
> 33	Very High

Source: Wall et al, 2002*

Table 6.2: Site Hazard Classification (RUSLE-FAC *)

6.6.4 Connectivity to Downstream Aquatic Resources

The location of the construction site with respect to downstream aquatic resources is a very important factor in preparing an ESC Plan. Establishing the connectivity of the construction site to downstream water supplies, flood control, fish habitat, navigation, and recreational activities can be conducted using information from the drainage analysis summary.

For the purposes of site evaluation, the most damaging, and therefore monitored, consequences from erosion and sedimentation are 1) the degradation of water quality and 2) the impact on fish habitat. The connectivity rating for each distinct segment on a construction site should be shown on the ESC Plan drawings.

The following table provides ratings based on connectivity to aquatic resources:

Connectivity Rating	Criteria[1]
Direct	Any sediment from a construction site may be transported directly downstream to locations where it may result in adverse effects to water quality or aquatic resources.
Indirect	Sediment laden water from a construction site empties into a secondary watercourse (i.e., stream, ditch, swale) before connecting with any stream with water quality or aquatic resource values. The secondary watercourse may be a non-fish habitat watercourse or a wetland with significant ecological value.
No Connectivity	For no connectivity, the sediment laden runoff flows into a non-significant[*] depressional area and sediment is trapped where water quality or aquatic resources are not a concern, or must terminate before connecting with any stream, or secondary stream, that may have water quality or aquatic resource values.

1 Criteria adapted from British Columbia Ministry of Forests (2001).

Table 6.3: Connectivity Rating to Aquatic Resources

[*] Assessment of the significance of a wetland or pond should be undertaken by an environmental specialist.

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7.0 EROSION AND SEDIMENT CONTROL METHODS

7.1 General

It is important to distinguish between erosion control measures and sediment control measures when preparing an effective erosion and sediment control plan. The difference between erosion and sediment control methods is defined and summarized for the purposes of this document and all related activities on construction sites as follows:

- **Erosion Control** is the process whereby the potential for erosion (displacement of solids by wind, water or ice), is minimized; and
- **Sediment Control** is the process whereby the potential for eroded soil being transported and/or deposited beyond the limits of the construction site is minimized. In this document, the term "sediment control" is synonymous with sedimentation control.

Erosion control is the primary means for preventing the displacement of soils and the subsequent degradation of downstream aquatic resources; sediment control should be viewed as the contingency plan. Most erosion control measures are initiated to implement early re-vegetation as the erosion control method. Primary emphasis must be placed on erosion control, particularly in areas of elevated erosion potential where fine particles are exposed during construction that will not readily settle out in a practical time frame. However, measures to address both erosion control and sediment control are required for most sites.

The design of erosion and sediment control measures should be viewed as a flexible process that responds to new information that is obtained throughout the construction phase and changes to the construction environment. As such, the design of temporary and permanent erosion and sediment control measures should be expected to evolve throughout construction to varying degrees based on site conditions and field performance of the implemented measures.

Erosion and sediment control measures are classified into the following categories:

- Planning Strategy and Procedures ;
- Temporary measures;
- Permanent measures; and
- Best Management Practices (BMP).

Each of these categories and BMPs are described in the following sections.

7.1.1 Temporary and Permanent Control Measures

Erosion and sediment control measures can be classified into two broad categories:

- <u>Temporary Measures:</u> Those measures implemented during the construction phase that will be removed once permanent measures are installed and/or vegetative cover is established; and
- <u>Permanent Measures:</u> Measures incorporated into the overall design to address long-term, post-construction ESC.

Temporary ESC measures should be installed at the start of the construction phase. Additional measures will likely need to be installed throughout the construction phase. Permanent ESC measures can be installed during or at the end of the construction phase.

A listing of ESC control BMPs are presented in Tables C-1, C-2 and C-3 in Appendix C. Examples of temporary measures include top-soiling, seeding, slope texturing, synthetic permeable barrier, mulching, Rolled Erosion Control Product (RECP) coverings, silt fence, rolls, wattles, and straw bale barriers. Examples of permanent measures include diversion ditches, energy dissipaters, berm interceptors, gabions, rock check dams, sediment ponds/basins, etc. Dependent on site conditions, some temporary measures will be retained for a longer time to increase its life span to near permanent. Stream bank protection BMPs are included (Table C-4) in Appendix C.

7.2 Planning Strategy and Procedures

Planning Strategies and Procedures (Table C-5) in Appendix C are often called minimum requirements which are non-structural methods or procedures that can reduce erosion and sediment transport. Proper planning generally constitutes the minimum requirement for preparing an ESC strategy. Proper construction planning includes implementing erosion or sedimentation control BMPs early in construction and recognizing the impact of different seasons on construction sites (e.g., rainfall, snow melt, and freeze-thaw). Various methods of scheduling construction activities can provide the first, best opportunities to help minimize the potential for erosion and sedimentation. However, the minimum requirements are generally not sufficient on their own. As such, many construction projects require site specific ESC measures to be implemented as site conditions dictate. The effectiveness of the ESC measures on a site is highly dependent on proper implementation of a well prepared ESC Plan.

The minimum requirements for planning strategies and procedures for an erosion and sediment control plans are presented in Table 7.1.

7.2.1 ESC Management Based on Diligence and Understanding

Project managers must recognize that successfully implementing ESC measures requires a good understanding of ESC principles and process by design and field staff. Selecting ESC mitigation measures to match the specific site, installing BMPs correctly, and conducting routine maintenance of ESC mitigation measures are essential aspects of ESC management. The planning strategies and procedures and the BMPs presented in this document are as important as the understanding of the implementation principles to achieve good construction performance and protect the environment.

The objectives of the ESC measures begin with education and interaction amongst them project team. This iterative process continues throughout the planning, design, construction and post construction stage of the project.

Table 7.1: Planning Strategies and Procedures for ESC Plans

Planning Strategy or Procedure	Applications				Comments	
	Slopes	Ditches & Channels	Large Flat Surface Areas	Borrow and Stockpile Area	Advantages	Limitations
Minimize Exposed Soils	✓	✓	✓	✓	• Decreases erosion potential; • Decreases area of erosion and sediment control measures required, thus decreasing costs.	• Requires planning and organization of sub-contractors (project phasing); • May require permanent controls be completed on some areas prior to new areas being stripped.
Observe Environmental Timing Restrictions	✓	✓	✓	✓	• Minimizes potential negative impacts on fish and wildlife. • May minimize permitting requirements (e.g. remaining outside of spawning or other critical periods) • Avoid nesting periods	• May affect project schedule.
Maximize Work During Favourable Weather	✓	✓	✓	✓	• Minimizes work in wet soil conditions; • Minimizes amount of storm water to handle or treat on disturbed portion of site; • Promotes seeding (vegetation establishment before wet season and allow establishment in fall for erosion control in late spring).	• May require additional labour and resources to increase scale of production / construction.

Table 7.1: Planning Strategies and Procedures for ESC Plans

Planning Strategy or Procedure	Applications: Slopes	Applications: Ditches & Channels	Applications: Large Flat Surface Areas	Applications: Borrow and Stockpile Area	Comments: Advantages	Comments: Limitations
Protect Permafrost	✓	✓	✓	✓	• Minimizes saturated soils and runoff water; • Reduces long term melting and potential structural damage or slope failure; • Reduces long-term maintenance costs; • Minimizes slope failures along ditches and side cuts.	• Room required to stockpile fibrous organic material (insulation) for redistribution; • Minimizes amount of construction area exposed at one time; • Requires pre-planning and scheduled construction operations; • May require increased drainage structure planning.
Scheduling of Work	✓	✓	✓	✓	• Sets targets for: good housekeeping; earliest construction and installation of erosion and sediment controls; the most preferred work period (dry versus rainy seasons, outside of fisheries windows); preferred timing for topsoil stripping to minimize soil exposure and for protection of permafrost, where applicable; and, opportunities for topsoil and seeding to be completed during rather than following the end of construction; • Avoids conflicts and delays in construction operations and set timeframes for sub-contractors; • Sets target deadlines.	• May require construction to be completed in one area before starting in another.
Implement BMPs Early	✓	✓	✓	✓	• Minimizes erosion and reduces soil loss and potential impacts downslope during construction.	• May need scheduling to avoid conflicts with machine activities.
Avoid Wet	✓	✓	✓	✓	• Minimizes erosion potential;	• Shutdowns may prolong/delay

Table 7.1: Planning Strategies and Procedures for ESC Plans

Planning Strategy or Procedure	Applications				Comments	
	Slopes	Ditches & Channels	Large Flat Surface Areas	Borrow and Stockpile Area	Advantages	Limitations
Weather Periods					• Minimizes soil disturbance and mud tracking.	construction activities.
Direct Surface Water Flow Around Site	✓	✓	✓	✓	• Keeps clean water clean; • Keeps surface water off-site and from causing erosion and sedimentation; • Minimizes the amount of water to be handled on site.	• New diversion structures may require erosion and sediment control measures to be implemented; • Need to be identified and planned for prior to main construction start-up.
Avoid Ponding Water		✓	✓	✓	• Minimizes saturated soils; • Minimizes permafrost melt; • Reduces erosion and potential sedimentation downslope.	• Increased drainage controls (structures) required.
Topsoil and Seed	✓	✓	✓		• Covers exposed soil and reduces erosion potential; • Promotes early revegetation efforts. Use of local native seed will promote revegetation with endemic plants able to survive local conditions; • May provide nutrient source for soils.	• Revegetation is seasonal and erosion may occur before plant growth; • Topsoil supplies may be limited in some areas; • Imported (hauled from other sites) topsoils may contain weed seeds.
Surface Roughening (Slope Texturing)	✓		✓	✓	• Reduces erosion: on fine grained soils, estimated 12% for a dozer ripping on the contour, 52% for track walking up and down the slope, 54% for sheep's foot rolling, and 76% for imprinting (Mike Harding, 2010).	• Equipment may need to be scheduled specifically for this task.

Table 7.1: Planning Strategies and Procedures for ESC Plans

Planning Strategy or Procedure	Applications				Comments	
	Slopes	Ditches & Channels	Large Flat Surface Areas	Borrow and Stockpile Area	Advantages	Limitations
Preserve and Use Existing Drainage Systems	✓	✓	✓	✓	• Minimizes exposed soils and potential erosion in drainage system; • Helps keep clean water clean.	• Requires planning; • May affect scheduling of certain construction activities.
Control Construction Traffic				✓	• Avoids unnecessary heavy traffic in sensitive areas or areas with increased disturbance; • Avoids unwanted soil compaction.	• Forcing traffic into localized areas may increase disturbance or compaction in high-traffic areas.
Signage	✓	✓	✓	✓	• Clearly labelling sensitive zones or areas not to be disturbed identifies restrictions/boundaries for machine operators and other workers; • Helps avoid damages to protected areas or clean water areas; • Identifies hazards for machines and equipment.	• Signage methods and locations will need planning to avoid conflict with operations.
Stockpile Control				✓	• Stockpiles are protected from wind and water erosion, and kept separate to avoid mixing of soils; • Watercourses and environmentally sensitive areas are protected, while piles are close enough to minimize cost for re-application.	• May result in longer haul distances; • Planned for location, number of piles and separation methods; • Planned for reduced erosion and sedimentation.

7.3 Water Management Measures

Water management measures are those which can be implemented on-site or off-site to meet ESC Plan objectives. These measures are intended to control water and reduce erosion potential by following these general principles:

- Keep clean water clean, by temporarily or permanently diverting clean water around the construction or maintenance site and by conveying clean water from undisturbed areas within the site to natural receiving streams;
- Minimize the velocity of any flowing water on site (the erosive power of flowing water increases exponentially with velocity);
- Minimize watercourse disturbance by using existing undisturbed drainages where possible and by integrating on-site drainage into the project design;
- Anticipate and manage groundwater as required;
- Avoid ponding water and plan for increased drainage structures in wet areas;
- Identify areas where icing has previously occurred and anticipate new locations. Plan for multi-level drainage structures where icing is anticipated; and
- Identify permafrost in sub-soils, minimize exposure, plan for additional drainage structures and anticipate required protection strategies.
- If new drainage channels are needed to accommodate design discharges, consider the use of Natural Channel Design (NCD) principles for watercourse diversions. This approach to watercourse restoration and realignment reconstructs channels to match the natural physical form of the stream or drainage that would be appropriate for that location (Toronto and Region Conservation Authority 2009).

Commonly used water management measures are listed in Table 7.2, where the applicability of each to construction site ESC Plans is noted.

Table 7.2: Surface Water Management Measures for ESC Plans

Name	Slopes	Natural Channels	Drainage Channels	Pipes and Culverts	Large Flat Surface	Borrow / Stockpile	Comments and Measures	Temporary	Permanent
Divert Clean Water Around the Site	✓	✓	✓	✓	✓	✓	Clean water drainages from upstream areas should be diverted around the construction site wherever practical to reduce the quantity of water that must be managed on site. This can be done using lined ditches, berms, pipes or culverts.	✓	✓
Keep Clean Water on the Site Clean	✓	✓	✓	✓	✓	✓	Clean water drainages from undisturbed areas within the construction site should be collected and allowed to discharge to receiving streams using lined ditches, pipes and culverts as required, and protect drainage from sediment laden runoff.	✓	✓
Use Existing Drainage		✓	✓	✓			Existing watercourses that are well-vegetated have natural low rates of erosion. Discharges from the construction site containing minimum (close to natural) levels of sediment can be conveyed to existing, undisturbed watercourses. Care must be taken to ensure that peak flows in existing watercourses are not exceeded, as this may cause erosion damage and/or bank failure.	✓	✓
Integrate New Drainage into the Project Design		✓	✓	✓			Where necessary to construct new ditches or use pipes or culverts for on-site surface water management, integrate these features into the permanent project design, where appropriate, to prevent future disturbance due to removal of temporary measures.	✓	✓
Keep Drainage Areas Small	✓	✓	✓	✓	✓	✓	Smaller drainage areas generally require less complex erosion control measures and smaller drainage channels, so they are preferred if local topography permits. By discharging from a number of small discharge points rather than a few large ones, the size of sediment control measures is reduced and the magnitude of potential risk due to failure is reduced.	✓	✓
Design Drainage Channels Appropriately	✓	✓	✓				Drainage channels should be designed with appropriate depths, slopes, cross-sections and linings (armoured or vegetated). NCD is recommended for watercourse diversions.	✓	✓
Manage Shallow Groundwater	✓	✓				✓	Slopes, excavations and areas around retaining walls or tall cuts in fine-grained soil, may be sensitive to piping failure or erosion due to high porewater pressures. These can be managed by temporary dewatering or by incorporating permanent drains to reduce porewater pressures. Gravel blankets can also be installed to protect the ground surface. Dewatering wells, if properly screened, may produce clean water and be suitable for direct discharge to receiving streams.	✓	✓

Source: Modified from Transportation Association of Canada, 2005

7.4 Erosion Control BMPs

BMPs for erosion control are measures that have been proven to work on construction sites when these measures were properly planned and constructed. These measures reduce erosion potential by avoiding exposed soil duration, stabilizing exposed soil or reducing surface flow velocity. There are generally two types of erosion control BMPs included with the minimum requirements:

- Source Control BMPs for protecting exposed surfaces; and
- Runoff Control BMPs for controlling water.

Experience is an important component in the successful selection of the appropriate BMP(s) and in the design and implementation of an ESC plan. It is the designer's responsibility to select BMPs which are appropriate for site conditions.

7.4.1 Controlling Erosion at the Source

The protection of exposed surfaces from the erosive energy of rain splash and surface flows should be the primary goal when selecting appropriate control measures. The maintenance or establishment of vegetative ground cover is the single most effective method of erosion control. Ground cover can include placing topsoil in conjunction with one or more of the following common erosion control methods: seeding, mulching, hydro-seeding, sodding, erosion control blankets, turf reinforcement matting (TRM), and riprap or gabion mats.

Protection of permafrost is a required component of erosion control in northern sites. A covering layer of vegetation and fibrous organic matter naturally creates an insulating thermal layer to minimize permafrost melt and protect the soils from erosive factors of water. Removal of vegetation and the organic protective layer (stripping) should be minimized in permafrost zones. If surface organic material must be removed for construction, it should be stockpiled and re-applied where possible. Melting of permafrost may be detrimental to slope stability and soil structural integrity, resulting in slope or ground failure, and high maintenance and infrastructure costs.

An overview of appropriate BMPs for the protection of exposed surfaces with their respective advantages and limitations is presented in Table 7.3.

7.4.2 Runoff Control

During construction it is not possible or practical to provide surface cover for all disturbed areas. Commonly used methods for runoff control include: the diversion of water which is entering the site; the modification of slope surfaces; the reduction of slope gradients; controlling flow velocity; providing adequate or increased drainage;, diverting flows away from exposed soil areas; and providing adequate containment systems (ponds) for managing sediment laden runoff.

An overview of appropriate BMPs for the runoff control is presented in Table 7.4 with their respective advantages and limitations.

7.4.3 Biotechnical Erosion Control

Erosion control BMPs may involve the use of bio-technical erosion control methods, (sometimes referred to as “bio-engineering”) in combination with other BMPs; however it takes time for woody species to become established (usually 2-3 yrs.) and effective. Bio-technical erosion control methods are best considered as permanent erosion control measures that involve using the roots, stems and leaves of vegetation to reduce the potential for erosion. This is achieved by introducing plants with foliage that decreases impact erosion of rain drops, and plant rooting which anchor (bind) the soil and increase infiltration of moisture into the soil. As the plants grow, the strength of the bio-technical erosion control system strengthens and improves. Typically bio-technical erosion control is used to prevent erosion where there are environmental or aesthetic enhancement requirements; however, if properly selected and implemented, it will provide a simple and cost-effective measure for controlling long-term erosion problems.

Revegetation of exposed soil with local native grasses or plants combined with approved grass seed mixes is the main bio-technical erosion control method utilized in construction. Although native species are preferred the seed may be in short supply and alternative seed sources will need to be addressed.

For transportation projects, the designer should identify the need to establish the appropriate type of vegetation, whether trees/willows/shrubs or grasses/low height plants, since most transportation projects will have a safety/line of sight factor that must be considered. Planting tall plants will have maintenance implications, and the revegetated species may need to be mowed to maintain line-of-sight. There may also be concerns with wildlife foraging, migratory birds or riparian shade requirements which will need to be addressed on a site specific basis by the ESC Plan designer.

Table 7.3: Erosion Control Measures – Source Control

BMP #	BMP Name	Applications				Comments	
		Slopes	Ditches and Channels	Large Flat Surface Areas	Borrow and Stockpile Area	Advantages	Limitations
18	Topsoiling (The application of topsoil over mineral soils to provide a growing medium for seeded vegetation and protect from surface erosion)	✓	✓	✓	✓	• Placing topsoil provides excellent medium for vegetation root structure development; • Organic content promotes plant growth; • Placing stockpiled organic material back on surfaces allows the reuse of these materials (topsoil or peat) stripped from the site at start of grading; • Absorbs raindrop energy to minimize erosion potential; • Insulates frozen soils and may reduce the amount or speed of the thawing process.	• Cannot be effective without seeding and allowing time for plant growth; Not appropriate for slopes steeper than 2H:1V (steep slopes will require geotextile, fabric or rolled erosion control product covering over topsoil and specialized design); • Dry topsoil is particularly susceptible to wind erosion; • Topsoil is susceptible to erosion prior to establishment of vegetation. • Areas with invasive species should be avoided if collecting topsoil.
15	Seeding (Introduction of seed for establishment of vegetation for permanent erosion protection)	✓	✓	✓	✓	• Inexpensive and effective erosion control measure once established; • Promotes even cover and controls seed distribution for higher plant densities as quickly as possible following construction; • Planting locally appropriate species helps reduce weed species establishment. • May be conducted as the project commences without waiting until the	• Requires a prepared surface; • May require soil amendments (topsoil, fertilizers) to be added to poor quality soils; • Grasses may require periodic maintenance (mowing); • Uncut dry grass may be a fire hazard; • Seeding on long steep slopes may be difficult; • Invasive species should be avoided; • Seasonal limitations for seed germination; • Preferred growing periods may not coincide

Table 7.3: Erosion Control Measures – Source Control

BMP #	BMP Name	Applications: Slopes	Applications: Ditches and Channels	Applications: Large Flat Surface Areas	Applications: Borrow and Stockpile Area	Comments: Advantages	Comments: Limitations
						end of the job; • Effectiveness increases with time as vegetation develops; • Aesthetically pleasing; • Enhances terrestrial and aquatic habitat; • Can be used in conjunction with other permanent soil stabilization practices; • Can be applied by installing cocoa matting with embedded seed.	with a delayed construction schedule; • Freshly seeded areas are susceptible to runoff erosion until vegetation is established; • Reseeding may be required to achieve adequate densities; • May attract wildlife thereby creating hazards for the travelling public
16	Mulching (Protective covering applied to protect exposed soils from erosion and protect seed during germination)	✓	✓	✓	✓	• Used alone to protect exposed areas for short periods; • Protects soil from rain splash erosion; • Preserves soil moisture and protects germinating seed from temperature extremes; • Relatively inexpensive measure of promoting plant growth and providing slope protection; • Can utilize vegetative material through on site chipping/mulching and spreading.	• Application of mulch on long steep slopes may be difficult; • May require additional specialized equipment to apply; • Some mulch types may deplete available soil nitrogen; • Slow release fertilizer may need to be added.

Table 7.3: Erosion Control Measures – Source Control

BMP #	BMP Name	Applications				Comments	
		Slopes	Ditches and Channels	Large Flat Surface Areas	Borrow and Stockpile Area	Advantages	Limitations
17a 17b	Hydroseeding / Hydromulching (Seed and mulch mixed with water for application by truck for revegetation and protection of exposed soils)	✓	✓	✓	✓	• Economical and effective on large areas; • Conforms to uneven surfaces; • Retains moisture; • May contain added soil amendments to promote germination and establishment of vegetation; • Mulch with tackifier may be used to provide immediate soil protection until seed germination and vegetation is established; • Allows vegetation of steep slopes where conventional seeding/mulching techniques are very difficult; • Relatively efficient to operate; • Provides wind erosion control.	• Site must be accessible to hydro-seeding / hydromulching equipment (usually mounted on trucks with a maximum hose range of approximately 50 m); • May require subsequent application (reseeding) in areas of low densities as part of maintenance program. • Invasive species should be avoided
19	Soil and Root Mat Replacement (Sodding) (Used where sod mat has been harvested during stripping to be re-applied to protect sensitive sites and insulate soils in permafrost areas.	✓	✓	✓	✓	• Immediate protection for sensitive areas from water and wind erosion; • Aesthetically pleasing. • May contain local seed within fibrous mat	• Expensive due to time required for removing, retaining and replacing the soil and root mat; • Labour intensive to remove and replace; • Soil and root mat may not be readily available; • Soil and root mat cannot be stored on-site for long periods of time. • Harvesting soil and sod in areas with invasive species should be avoided

Table 7.3: Erosion Control Measures – Source Control							
BMP #	BMP Name	Applications				Comments	
		Slopes	Ditches and Channels	Large Flat Surface Areas	Borrow and Stockpile Area	Advantages	Limitations
9	Riprap Armouring (Application of rock lining to provides protection to soils in ditch lines, down-drains, stream channels and slopes)	✓	✓	✓		• Most applicable as a surface soil lining for drainage ditches and down-drains with underlay, and in stream channels without use of fabric underlay • Used for soils where vegetation not easily established or where permanent protection is immediately required; • Effective for high velocities or concentrations; • Permits infiltration; • Dissipates energy of flow from culvert inlets/outlets or other water discharge points; • Easy to install and repair; • Very durable and virtually maintenance free. •	• Expensive; • May require heavy equipment to transport and place rock; • May not be feasible in areas where rock is not readily available; • May be labour intensive to install; • Riprap is usually thicker than gabion mattress requiring additional depth in the channel to be considered in planning.
8	Rolled Erosion Control Products (RECP) (manufactured product used to protect soils from raindrop erosion, and protect seed	✓	✓			• Provides an immediate protective covering to bare soil or topsoil applied to a surface; • Can be used in conjunction with seeding; • Can be more uniform and longer lasting than mulch; • Wide range of commercially available	• Labour intensive to install; • Not suitable for rocky slopes; proper site preparation is required to seat RECP onto soil correctly (requires good soil contact); • Temporary (degrades over time) dependant of type and quality; • Temporary blankets may require removal prior to restarting construction activities.

Table 7.3: Erosion Control Measures – Source Control

BMP #	BMP Name	Applications: Slopes	Applications: Ditches and Channels	Applications: Large Flat Surface Areas	Applications: Borrow and Stockpile Area	Comments: Advantages	Comments: Limitations
	during germination)					products; • Natural product choices available; • May be used for temporary cover protection.	
10	Cellular Confinement System (manufactured product applied to soil surface to reduce rill erosion and provide stabilization of surface soils)	✓	✓			• Lightweight; • Easily installed; • Uses locally available soils for fill to reduce costs.	• Not commonly used in transportation construction projects; • Expensive; • Installation is labour intensive (hand installation); • Not suitable for slopes steeper than 1H:1V.
22	Crushed Rock Buttress for Slopes (Permafrost) (Application of crushed rock to support slope surface material during melt events)	✓				• The cut slope can be rapidly prepared and buttressed to provide support and ensure continued thermal insulation; • Local rock and aggregate materials can be used, if crushing facilities are available; • When ground ice melting occurs, the wetted soils will be held by the buttress and drainage can occur, to increase overall soil stability.	• Obtaining sufficient crushed rock or coarse aggregate for the buttress may be difficult in permafrost areas; • The buttress will require maintenance and replacement of failed buttress material.

Table 7.3: Erosion Control Measures – Source Control

BMP #	BMP Name	Applications: Slopes	Applications: Ditches and Channels	Applications: Large Flat Surface Areas	Applications: Borrow and Stockpile Area	Comments: Advantages	Comments: Limitations
23	Controlled Melt of Cut Slope (Permafrost) (controls natural melting of ice within a slope until slope stabilizes)	✓				• Where no other project configuration is possible to avoid permafrost with high ground ice, this BMP allows controlled melting of the ground ice and stabilization of the cut slope over the long term; • The separation berm can be constructed of local materials if available.	• Construction of the separation berm requires consideration and use of an overflow drainage feature (armoured notch) for extreme rain events or high runoff from snowmelt. Other drainage systems, such as standpipes, may be considered; • Light coloured crushed rock or aggregate will be required for the separation berm to limit thermal degradation of permafrost; • The receding soil failure at the cut slope will require time to come to a slope gradient in balance with water, soil and thermal conditions.
24	Insulated Thermal Blanket on Cut Slope (Permafrost) (application of thermal materials over slope or ground section to reduce/prevent permafrost melt while allowing natural drainage)	✓				• The thermal blanket material can be obtained locally; • The cut slope may regress back from ground ice melt over time but the blanket material will shift and conform to the underlying slope surface, providing support and thermal protection; • For cut slopes with ground ice and in permafrost areas, the cut slope can be prepared at a steep gradient, preserving the natural vegetation and organic deposit cover, and a thermal blanket can be placed over the cut	• Melting of ground ice and permafrost is usually progressive, resulting in loss of soil strength and volume, and may cause retrogressive slope failure behind the blanket; • Climate change with a slow increase in average air temperature, is causing general increase of ground temperatures, melt of permafrost, especially along the belt of discontinuous permafrost where the permafrost is thin, at shallow depth and at a temperature not far below freezing.

Table 7.3: Erosion Control Measures – Source Control

BMP #	BMP Name	Applications				Comments	
		Slopes	Ditches and Channels	Large Flat Surface Areas	Borrow and Stockpile Area	Advantages	Limitations
						slope to reduce ground ice melting and allow water drainage.	
20a	Live Staking (Planting of live cuttings to promote growth of woody vegetation for the purpose of promoting fast establishment of leafy woody vegetation to protect exposed soils from raindrop erosion and bind soils through rooting networks)	✓		✓		• Establishes vegetative cover and root mat; • Once established, vegetation may reduce flow velocities; • May trap sediment laden runoff; • Aesthetically pleasing once established; • Grows stronger with time and root structure development; • Usually has deeper root structure than grass; • Rooting promotes water infiltration; • Planting conducted without large equipment; • Available local native species may be used; • May be used in conjunction with other practices for riparian remediation and stream bank stabilization on water crossings.	• Expensive to install if stock not readily available; • May be labour intensive to install; • Not commonly used in linear construction projects; • Revegetated areas are subject to erosion until plants are established; • Plants may be damaged by wildlife; • Watering may be required during dry season until plants are established. • May interfere with sight lines for linear projects. • Matured staked species may be considered a liability on some sites (airport lands) • May become protected habitat under Migratory Birds Convention Act. • May provide habitat for wildlife close to areas used by traffic.

Table 7.3: Erosion Control Measures – Source Control

BMP #	BMP Name	Applications				Comments	
		Slopes	Ditches and Channels	Large Flat Surface Areas	Borrow and Stockpile Area	Advantages	Limitations
21	Riparian Zone Preservation (Retention of natural vegetation within a riparian area to provide natural filtration of sediments and reduce runoff velocity)	✓	✓	✓	✓	• Natural vegetation buffer to filter and reduce runoff velocity by dissipating flow; • Most effective natural sediment control measure; • Promotes infiltration which may reduce volume of runoff.	• Planted vegetation requires substantial periods of time before they are as effective as established vegetation at controlling sediment; • Not intended for heavy sediment load filtration, high volume discharge or as a sole source for construction runoff control. • May not be deemed to be an acceptable addition to the highway right of way (line of sight obstruction at maturity of staked species). • May become protected habitat when vegetation matures and provides habitat for wildlife and/or migratory birds.
25	Scheduling (Used to promote the scheduling of events to minimize the exposure of soils to unfavourable weather conditions, plan site activities including the installation of BMPs)	✓	✓	✓	✓	• Promotes efficient, orderly construction of BMPs; • Identifies potential protection issues related to construction timing and seasonal climatic conditions; • Identifies fish sensitive periods which may be avoided; • May minimize the amount of soil exposure thereby reducing erosion potential; • Identifies need for early installation of perimeter control for sediment	• Needs to be flexible and revisited as construction progresses; • May require amendment in the event of delays in construction.

Table 7.3: Erosion Control Measures – Source Control

BMP #	BMP Name	Applications: Slopes	Applications: Ditches and Channels	Applications: Large Flat Surface Areas	Applications: Borrow and Stockpile Area	Comments: Advantages	Comments: Limitations
						entrapment and runoff control measures; • Provides timelines for permitting, in-stream works, and early vegetation establishment; • Allows for scheduling of equipment, delivery of supplies, and subcontractor deployment	
28	Compost Blanket (application of composted materials as a blanket to cover exposed soils to protect form erosion)	✓		✓	✓	• Economical if readily available; • Appropriate on slopes 2H:1V to level surface; • Provides nutrient base as soil amendment.	• Application on steep slopes (>2H:1V) may be difficult; • Treatment area should be accessible to blower trucks. • May not be readily available; • May not be authorized for use near or upslope of watercourses
2	Gabions (Manufactured metal basket or blanket which can be filled with cobbles for the construction of slope structures, velocity reduction structure and channel or ditch bed stabilization)	✓	✓			• Provides stabilization for steep slopes or reinforced channels in streams, rivers or creeks; • Can be used as mats for run out below ditch blocks or culvert inlets/outlets; • Can be designed to be used with compacted soil fill for areas requiring vegetation walls	• Should be used with caution within stream beds. Not a preferred treatment for fisheries sensitive areas. • May require design by Qualified Professional; • May be expensive and labour intensive • May have limited lifespan dependent on the quality and coating applied to the materials used.

Table 7.3: Erosion Control Measures – Source Control

BMP #	BMP Name	Applications				Comments	
		Slopes	Ditches and Channels	Large Flat Surface Areas	Borrow and Stockpile Area	Advantages	Limitations
38	Stream Diversion Channel (Man-made channel constructed to divert a stream around or through a construction site to protect water quality and provide a dry work area)		✓			• Protects environmentally sensitive areas; • Conveys flow consistency better than a dam, impoundment and pumping; • Not at risk of power failure or malfunction (e.g. pumps); • Maintains fish passage; • Diverts surface flows from entering the site or limits flow to specific area of the site	• Requires erosion protection; • Risk of export of sediment downstream if not properly staged; • Requires fish exclusion and fish salvage if working on a known or suspected fish-bearing stream. Permits may be required; • In-stream work windows are regulated by agencies and must be adhered to.
39	Coffer Dam (Man-made dam structure used to direct water around or out of a work area [e.g. metal sheet piling, sand bags, straw bales, aqua dam, etc.) to provide a dry work area and protect water quality.		✓			• Protects environmentally sensitive areas by limiting the work site area; • Diverts all or a portion of a stream or surface water flows around a site to maintain downstream flows; • Permits work to be conducted “in the dry” to minimize downstream sedimentation • May divert up to 2/3 of watercourse without significant impact to fish passage • Used to control erosion by keeping water out of the work site	• Used only to divert water- not used as a barricade which causes ponding; • Requires monitoring and maintenance; • Risk of export of sediment downstream • Used in areas of shallow flow depth (usually less than 1.2 m unless designed by an engineer); • Height of the dam should provide protection for a 1 in 10 year event, if possible (height of dam to be less than 1.2 m unless designed by an engineer); • All debris and accumulated sediment inside the work area must be cleared away before removal of the coffer dam; • Operations within the work area must be capable of withstanding flooding without risk

Table 7.3: Erosion Control Measures – Source Control

BMP #	BMP Name	Applications: Slopes	Applications: Ditches and Channels	Applications: Large Flat Surface Areas	Applications: Borrow and Stockpile Area	Comments: Advantages	Comments: Limitations
							to life and equipment damage; • May require authorization for in-stream works, fish exclusion and fish salvage on fish-bearing streams. Permits may be required; • In-stream work windows are regulated by agencies and must be adhered to. • Requires contingency planning for flooding or groundwater infiltration.

2 Adapted from Alberta Transportation (2011).

Table 7.4: Erosion Control Measures – Runoff Control

BMP #	BMP Name	Applications				Comments	
		Slopes	Ditches and Channels	Large Flat Surface Areas	Borrow and Stockpile Area	Advantages	Limitations
27	Slope Texturing (the roughening of surface soils to promote infiltration of water, trap seed, and reduce velocity and rill development on slopes through contouring or the use of horizontal machine track patterns)	✓		✓	✓	• Roughens slope surface to reduce potential erosion and sediment yield and promotes infiltration; • Suitable for clayey soils; • Contouring and roughening (tracking) of slope face reduces runoff velocity and increases infiltration rates; • Reduces erosion and collects sediment better than smooth surfaces; • Captures and holds water, seed and mulch, which promotes vegetation growth.	• Must be planned cost included in grading; • May cause sloughing in sensitive (wet) soils, • Tracking may compact soil, • Provides limited erosion control and should not be used as primary control measure; • Not suitable for silty and sandy soils; • Not practical for slope length <8 m for bulldozer operation up/down slope; • Not suitable for permafrost areas.
14	Diversion Ditch (Used to divert water from entering a construction site or through a site, may be used to divert water out of a ditch line)	✓	✓	✓	✓	• Intercepts and diverts water from the top of a slope away from disturbed soil areas to reduce downslope erosion; • May be incorporated into permanent project drainage systems using natural channel design. • May be used to temporarily divert a stream to permit culvert installation	• Channel must be sized appropriately to accommodate anticipated flow volumes and velocities; • Lining may be required; • May require design by qualified personnel; • Must be graded to minimize ponding.

Table 7.4: Erosion Control Measures – Runoff Control

BMP #	BMP Name	Applications				Comments	
		Slopes	Ditches and Channels	Large Flat Surface Areas	Borrow and Stockpile Area	Advantages	Limitations
11	Energy Dissipater (structure used to reduce the speed at which the water flows to reduce erosion and/or promote sediment deposit)	✓	✓			• Slows runoff velocity and dissipates flow energy to minimize erosion potential in relatively short distances; • May collect sediment due to reduced runoff velocities;	• Small diameter rocks can be dislodged; • May be expensive if rock has to be hauled in; • Grouted riprap armouring may breakup due to hydrostatic pressures, frost heaves, or settlement; • May be labour intensive to install; • May require design by qualified professional.
13	Slope (Down) Drains (Pipe structure which directs water from the top to the base of a slope)	✓				• Directs surface water runoff into drain pipe or lined channel and delivers to base of slope; • Protects exposed soils on the slope face from erosion causing rilling or gullying.	• Must be sized appropriately to accommodate anticipated flows; • Erosion can occur at inlet/outlet if protection is not installed; • Requires incorporation into permanent design; • Slope drain pipe must be anchored to slope.

Table 7.4: Erosion Control Measures – Runoff Control

BMP #	BMP Name	Applications: Slopes	Applications: Ditches and Channels	Applications: Large Flat Surface Areas	Applications: Borrow and Stockpile Area	Comments: Advantages	Comments: Limitations
2	Gabions (Gabion Baskets may be used beneath a perched culvert or steep drop to protect the soils from erosion as it drops from a height above, Gabion blankets may also be required to protect the run-out area beneath the structure)		✓			• Relatively maintenance free, permanent drop structure; • Long lasting; • May be less expensive than riprap; • Allows smaller diameter rock/stones to be used; • Relatively flexible; • Commercially available products; • Suitable for resisting high flow velocity.	• Construction may be labour intensive (hand installation); • Extra costs associated with gabion basket materials; • May be expensive if rock is not available in local area.
3	Berm Interceptor (Soil berm constructed of local material to intercept and redirect water flows, or build containment ponds)	✓		✓	✓	• Easy to construct; • Relatively inexpensive as local soil and material is used.	• Qualified Professional design required for fill heights in excess of 3 m; • May not be suitable for all soil types or sites; • Riprap spillway and/or permeable outlet may be required.

Table 7.4: Erosion Control Measures – Runoff Control

BMP #	BMP Name	Applications				Comments	
		Slopes	Ditches and Channels	Large Flat Surface Areas	Borrow and Stockpile Area	Advantages	Limitations
5	Rock Check Dam (Structure constructed of rock to slow water usually within a ditch line. May be used on slopes <9% with angular rock large enough to withstand velocity of the water flow)		✓		✓	• Permanent or temporary small, velocity control structure for steep (<9%) drainage channels; • Reduces grade length between structures; • Cheaper than gabions or armouring entire channel; • Easily constructed;	• Can be expensive in areas of limited rock source; • Not appropriate for channels >8% slope or draining areas larger than 10 ha; • Requires ongoing maintenance (particularly after high flow storm events); • Can fail if water undermines or outflanks structure or rock is not sized correctly for water velocity and volume; • May cause flooding during spring melt or when combined with icing conditions; • Maintenance costs increase for ditches when permanent
6	Synthetic Permeable Barriers (Manufactured product used to reduce flow velocity in small areas and for low flow situations, Re-usable and/or moveable)		✓			• Reusable/moveable; • Reduces flow velocities and dissipates flow energy which reduces some sediment; • Used as grade breaks in conjunction with sturdy permanent drop structures along steep grades.	• Not to be used as check structures; • Only suitable for small drainage areas (< 0.8 ha) and low-flow velocity; • Must be installed by hand in conjunction with RECP; • May become brittle in winter and are easily damaged by construction equipment or recreational vehicles; • Only partially effective in

Table 7.4: Erosion Control Measures – Runoff Control

BMP #	**BMP Name**	**Applications: Slopes**	**Ditches and Channels**	**Large Flat Surface Areas**	**Borrow and Stockpile Area**	**Comments: Advantages**	**Limitations**
							retaining sediment. • Must be maintained and, eventually, removed, so may require an extra mobilization to site. •
29 30	Rolls (Coir) Wattles (Manufactured materials or natural) (Used on fill or cut slopes to reduce runoff velocity, provide small slope breaks to permit infiltration and promote vegetation establishment.)	✓				• Function well in freeze-thaw conditions; • Low-cost solution to sheet flow and rill erosion on slopes; • Low to medium cost flow velocity control and silt trap; • Can be used on slopes too steep for silt fences or straw bale barriers; • Biodegradable manufactured types available. • Wattles can be made of willow or other local vegetation	• Labour intensive to install (hand installation); • Designed for slope surfaces with low flow velocities; • Designed for short slope lengths with a maximum slope of 2H:1V;

7.5 Sediment Control Best Management Practices (BMPs)

BMPs for sediment control are measures that are included have been used under various conditions throughout North America and are proven measures which minimize impact to the environment from construction sites, when the measures were properly planned and constructed. These measures reduce off-site sediment delivery by promoting the reduction of sediment before surface water is allowed to leave the construction site. There are generally two types of sediment control methods that can be used:

- Filtering and entrapment; and
- Impoundment.

An overview of appropriate sediment control BMPs is presented in Table 7.5 with their respective advantages and limitations. As with erosion control BMPs, experience plays an important role in the selection of appropriate BMPs, and the design and implementation of an erosion and sediment control plan. It is the designer's responsibility to select the sediment control BMPs that match site conditions.

7.5.1 Filtering and Entrapment

Soil particles suspended in surface water can be filtered through porous media consisting of natural and artificial materials (i.e., vegetative strips, stone filters, man-made fibre filters). Filtering can be effectively applied to concentrated small volumes of flow at inlets of permanent or temporary drainage systems and outlets of sedimentation ponds. This application requires careful maintenance to ensure continued effectiveness as sediment can clog these filters during storm events and/or during prolonged use.

Filtering is most effective when applied to non-concentrated (dispersed) sheet flow as a linear measure placed perpendicular to the direction of flow. Stream banks and the perimeter of regions of high-erosion potential are typical sites where filtering BMPs are employed for sediment control.

The most commonly used entrapment method is a silt fence. Sediment fencing is more effective for trapping particle sizes of fine and medium sand to coarse silt, depending on the mesh size used, and for low flow velocity (<1.0 m/sec) and gentle grades (<3%). Sediment fencing does not capture silt or clay sized particles as they are too small and will pass through the weave of the fabric. This method should only be used when there are **low runoff flow rates and volumes**; otherwise, its effectiveness will decrease and the system can be undermined, overtopped, or breached on the sides. Too much flow volume or velocity or too much sediment buildup may cause the fence to fail and fall over under the pressure.

Check dams constructed from coarse granular material may be used on a steeper gradient (3% to 8%) where high flow velocity or volumes are anticipated. These larger structures should be designed by a qualified person.

A sediment control plan may involve the use of bio-technical erosion control methods (bioengineering) for filtering. Bio-technical erosion control methods are considered permanent sediment control measures that involve using vegetation to reduce flow velocities. This strategy promotes controlled sedimentation by slowing the flow velocity which allows the sediment to settle out and allow it to be retained within the construction site. The denser the vegetation cover and the larger the stems or leaf size (obstructions) within the flow path, the greater the reduction in the flow velocity will be.

7.5.2 Impoundment BMPs

The temporary impoundment of sediment-laden surface water reduces flow velocity which allows sedimentation. However, sedimentation may take a long time if the suspended sediments contain a significant portion of clay/colloidal or organic particles. This technique is normally applied to **concentrated flow** within the permanent or temporary drainage system of a construction or maintenance site.

Permanent basins and traps should be avoided in areas of permafrost as ponding of water will contribute to increased rates of permafrost melt or degradation.

Common types of impoundment structures are:

- Sediment basins are designed for a large (>2.0 ha) runoff area;
- Sediment trap is designed for a small (<2.0 ha) runoff area; and
- Temporary barriers (synthetic weave barrier, rock check) along ditches or the toe of a slope.

The design of sediment containment is discussed in Section 12. A number of variations to the basic design can be used ranging from relatively small single basins to multiple interconnected basins. Containment basins and traps are to be designed by a Professional Engineer if the consequences of failure warrant (e.g., if there are risks to ecological values, property, or human health).

Ideally, impoundment basins should be located within the site near the sediment source. Roadside ditches and old drainage channels can also be used as sediment impoundment areas upon installation of permeable or impermeable berms. Sediment traps/basins should be installed near the perimeter of the site to prevent off-site sediment delivery. Sedimentation traps/basins may be constructed by excavation and/or earth dyke construction, together with installation of a granular berm as an outlet flow structure.

Where at all possible, the height of dykes or dams constructed to form impoundments should be kept as low as possible to assist in mitigating potential hazards due to a failure. If correctly constructed and well maintained, sediment basins and traps can be an effective means of minimizing the quantity of sediment that is transported off-site. Regular maintenance and sediment removal will be required to ensure that adequate capacity and drainage is maintained.

Extended detention ponds allow runoff to be detained through slow release rates. Detention allows the finer sediment to settle out. Due to the slow release, these ponds are generally designed to be dry between runoff events. Clogging of the outlet is a real potential due to the slow release rate and should be designed with a protective device, regularly monitored and maintained.

Table 7.5: Sediment Control Measures

	BMP Name	BMP #	Applications: Slopes	Applications: Ditches and Channels	Applications: Large Flat Surface Areas	Applications: Borrow and Stockpile Area	Comments: Advantages	Comments: Limitations
Filtering and Entrapment	Riparian Zone Preservation	21	✓	✓	✓	✓	• Well established vegetation buffer will filter and slow runoff; • Most effective natural sediment control measure.	• May not be feasible to retain; • Not practical for large flow volumes, high velocities, or too much sediment • Damage to riparian vegetation may occur if too much sediment is deposited; • Not able to be cleaned or maintained; • Newly planted riparian zones require substantial periods of time before they are effective at controlling sediment. • Within a right of way, riparian areas can become areas where wildlife will stage before crossing the highway.
Filtering and Entrapment	Straw Bale Barrier	7		✓	✓	✓	• Biodegradable; • Less expensive; and • Easier to install than other barriers.	• Labour intensive to install; • Short service life due to biodegradation; • Straw bales are not readily available across most of the NWT; • Maximum barrier height of one straw bale; • May require extensive maintenance after high flow storm events; • Require proper keying and staking.

Table 7.5: Sediment Control Measures

BMP Name	BMP #	Applications: Slopes	Applications: Ditches and Channels	Applications: Large Flat Surface Areas	Applications: Borrow and Stockpile Area	Comments: Advantages	Comments: Limitations
Rolls (Fibre) Coir or Wattles (Manufactured materials)	29	✓				• Function well in freeze-thaw conditions; • Low cost solution to sheet flow and rill erosion on slopes; • Low to medium cost flow control and silt trap; • Can be used on slopes too steep for sediment fences; • Biodegradable.	• Labour intensive to install (hand installation); • Designed for slope surfaces with low flow velocities; • Designed for short slope lengths with a maximum slope of 2H:1V;
Wattles (Live) (Usually collected live local material is used and bundled to make rolls or wattles)	30	✓				• Function well in freeze thaw conditions; • Solution for sheet flow and rill erosion near water bodies; • Can be used on slopes too steep for sediment fences; • Materials for construction may be immediately available; • Biodegradable – Live; • Improved strength over time; • Flow control and sediment trap; • Aesthetically pleasing once established.	• Labour intensive to install; • Designed for low flow velocities; • Designed for short slope lengths; • May cause visual obstruction.

Table 7.5: Sediment Control Measures

BMP Name	BMP #	Applications: Slopes	Applications: Ditches and Channels	Applications: Large Flat Surface Areas	Applications: Borrow and Stockpile Area	Comments: Advantages	Comments: Limitations
Sediment Fence (manufactured fencing used to slow flow velocity, promote settling and sediment detention)	1	✓		✓	✓	• Economical; • Readily available from suppliers; • Easy to install; • Slows water to settle out coarse grained sediment; • More effective than straw bale barriers.	• May fail during high runoff events; • Applicable for sheet flow erosion only; • Limited to locations where adequate space is available; • Maintenance to remove sediment build up is required on a regular basis; • Damage to sediment fence may occur during sediment removal; • Usable life of approximately one year, after which removal and disposal is required.
Storm Drain Inlet/Sediment Barrier	4			✓		• Temporary measure; • Easy to install and remove.	• Limits drain inlet capacity; • Very limited sediment entrapment capacity; • Requires regular clean-out and maintenance; • May increase intake flows downslope or at next storm drain or cause flooding.

Table 7.5: Sediment Control Measures

BMP Name		BMP #	Applications				Comments	
			Slopes	**Ditches and Channels**	**Large Flat Surface Areas**	**Borrow and Stockpile Area**	**Advantages**	**Limitations**
	Compost Blanket (compost spread in a layer over exposed soils to protect the site from raindrop erosion)	28	✓		✓	✓	• Economical if product readily available; • Appropriate on slopes 2H:1V slope or flatter • Natural fibers used to protect the site from raindrop erosion and protect seed during germination. • Provides nutrients for vegetation establishment • May be made from vegetation on site	• Application on steep slopes may be difficult; • Treatment area should be accessible to blower trucks. • May not be readily available if accessible material (vegetation) is not present • Trucking in material may make it too expensive
All BMPs	Scheduling (Planning of construction site activities including installation and maintenance of ESC measures)	25	✓	✓	✓	✓	• Identifies anticipated product requirements prior to start of construction (facilitates ordering and early delivery of necessary ESC products); • Identifies protection issues such as seasonal weather impacts (avoidance of heavy precipitation periods); • Identifies fish and wildlife restrictions (e.g. spawning periods and nesting) • Permits planning for efficient, early and orderly construction of BMPs; • Promotes early installation of perimeter control for sediment entrapment such as sediment ponds and sediment fencing.	

Table 7.5: Sediment Control Measures

	BMP Name	BMP #	Applications: Slopes	Applications: Ditches and Channels	Applications: Large Flat Surface Areas	Applications: Borrow and Stockpile Area	Comments: Advantages	Comments: Limitations
	Stream Diversion Channel (Diverts stream flow around a work site to re-enter the channel below the site)	38		✓			• Protects environmentally sensitive areas; • Conveys flow consistency better than a dam, impoundment and pumping; • Not at risk of power failure or malfunction (e.g. pumps); • Maintains fish passage. • Keeps clean water clean • May use plastic culvert for temporary water passage • Used to provide dry work area within a channel temporarily (e.g. culvert installation)	• Requires erosion protection; • Risk of export of sediment downstream if not properly staged; • Requires fish exclusion and fish salvage if working on a known or suspected fish-bearing stream. Permits may be required; • In-stream work windows are regulated by agencies and must be adhered to.
Impoundment	Sediment Traps/Basins (Constructed ponds which may be temporary or permanent in design. May require design by a qualified person)	12		✓			• May be constructed of a variety of materials; • Collects sediment laden runoff and reduces velocity of flow to allow deposition of sediment; • Can be cleaned and may be expanded if required; • Capable of being designed to handle large volumes of sediment laden runoff.	• “Last resort” measure; • Normally requires 250 m³ storage volume per ha of contributing area; • Can require large amount of area; • Requires monitoring of sediment in outflowing water and in sediment level; • Requires maintenance to remove sediment build up; • Requires design by qualified person; • Usually requires 'back-up' control measures in case trap/basin overflows or system becomes overloaded • May require back-up measures to address fine clays and silt sediment

7.6 Selection Considerations for Bio-technical Erosion Control Methods

The following should be evaluated when bio-technical erosion control methods are considered for use in an ESC Plan:

- Availability of Suitable Plants Suitable plants for use in bio-technical erosion control methods must be local and biologically appropriate for the proposed construction site.
- Mechanical and Hydrological Benefits of Plant Root Systems The root systems increase in depth and density with time and promote infiltration of surface moisture; however, when initially installed the plants used in bio-technical erosion control are usually in seed form or dormant and provide no immediate mechanical or hydrological benefit. The process of benching during installation may help reduce erosion and promotes plant growth by capturing moisture and nutrients.
- Use of Indigenous Materials The plants used must be biologically appropriate to the site climate, soil and moisture conditions. Harvest sites should have similar characteristics to the planting site. Large differences in growth conditions such as precipitation, temperature, elevation, slope aspect, drainage and soil type may decrease the effectiveness of the bio-technical erosion control system through plant mortality or poor growth.
- Transport of Weeds The qualified person and contractor responsible for design and implementation of bio-technical erosion control methods must minimize the risk of damaging existing vegetation and introducing invasive or foreign species into a new area. A qualified person should be consulted to confirm the suitability of plant species for use in bio-technical erosion control methods.
- Labour / Skill Requirements Crews can be easily trained to install bio-technical erosion control systems and the capital requirements are typically low. Bio-technical erosion control can be installed using heavy equipment, however the harvesting and installation of the living plant material is conducive to hand planting on sensitive sites that limit heavy equipment use.
- Costs The majority of bio-technical erosion control costs are associated with labour. Labour costs can be substantial because plant material must be harvested, prepared, installed and tended, and this is usually done by hand. Transportation and storage, if required, of living plants is also a cost consideration. In some cases, large refrigerated facilities are required to properly store living plant material for extended periods between harvesting and planting.
- Environmental Compatibility Selected properly, the plants provide non-intrusive systems that enhance fish and wildlife habitat as well as aesthetics. It is important to recognize the site sensitivities before selecting plants to be used in bio-technical erosion control. Harvesting plant species that are well acclimatized and appropriate to the installation site will provide the most effective bio-technical erosion control results.

- Access Bio-technical erosion control methods can be the most appropriate choice for sites with poor access such as riparian zones or sensitive stream banks. Difficult sites can be accessed on foot with minimal impact, however poor site access will increase costs associated with transportation and handling since machinery may not be able to support the labour force. For sites where access is good, heavy equipment can support bio-technical erosion control installation by transportation of supplies and equipment and preparation of earthworks.
- Timing Bio-technical erosion control methods are most effective when the plant stock is harvested during the dormant seasons (late fall or early spring). Nutrients and water stored within the plant during dormancy provides the best opportunity for the plant to establish roots when it is placed in soil. Plants that are harvested while in a growth period suffer higher mortality since the plant has already gone into leaf production and harvesting shocks the plant system. Plants can be harvested during a dormant period, cold stored and then planted when the soil has warmed.
- Maintenance Requirements Depending on the site, certain levels of maintenance are required. Supplemental plant stock may be required if minimum coverage of plant growth is not achieved by a certain time in the project schedule. Conversely, bio-technical erosion control systems that experience heavy growth may require trimming or mowing maintenance particularly on projects where sight lines are important.

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8.0 SELECTION OF BMP FOR EROSION AND SEDIMENT CONTROL

8.1 Preliminary Tasks

The following tasks should be completed before erosion and sediment control measures are selected for a given site:

- Conduct the Site Assessment (Section 5.0);
- Conduct the Site Evaluation (Section 6.6);
- Site Hazard Classification (Section 6.6.3); and
- Connectivity to Downstream Resources (Section 6.6.4).

The order in which these tasks should be completed is presented as a flow chart in Figure 8.1.

Conduct Site Assessment
(Section 5.0)

- Gather background information

⇩

Conduct Site Evaluation
(Section 6.6)

- Prepare slope analysis summary (Section 6.6.1)
- Prepare drainage analysis summary (Section 6.6.2) Determine the presence/absence and extent of permafrost or icing areas.
- Estimate soil loss for each drainage catchment on the construction site (Section 6.3)
- Prepare site hazard classification for each drainage catchment on the construction site (Section 6.6.3)
- Prepare connectivity rating to aquatic resources (Section 6.4.4)

⇩

Select Appropriate Erosion and Sediment Control Measures
(Section 8.2)

- Based on results of Site Evaluation

Figure 8.1: Steps in Preparing the Erosion and Sediment Control Pan

8.2 Guidelines for Selecting Appropriate Erosion and Sediment Control Measures

Failure of erosion and sediment control measures can result in three types of potential consequences:

- Ecological consequences related to the introduction of sediment to the aquatic environment. This is related to the connectivity to aquatic resources (see Table 6.3).
- Project consequences related to the need to repair erosion damage and the implications for project schedule and cost; and
- Legal consequences associated with the deposition of sediment in receiving water bodies or other environmentally sensitive sites.

The aim in selecting, designing, and constructing the appropriate erosion and sediment control measures is to reduce the risk of these negative consequences.

Following the site assessment and evaluation, the information required to adequately select the ESC measures for preparing an ESC Plan will be available. Selection of BMPs and other measures should be guided by a combination of the site erosion potential, the consequences of erosion and sediment control, and the experience and judgement of the designer.

A summary of the BMPs and other measures required based on site erosion potential and consequences of erosion and sedimentation is presented in Table 8.2.

Erosion Potential	Consequences of Erosion and Sedimentation	Level of Erosion and Sediment Control (BMPs and Other Measures)					
		Planning Strategies and Procedures	ESC Plans and Structural BMPs	Water Management	Staged Construction and Progressive Rehabilitation	More Intensive Sediment Control BMPs	Water Quality Monitoring
Low	Low	Recommended[b]	-	-	-	-	-
	High	Required	Required	-	-	-	-
Moderate	Low[a]	Required	-	-	-	-	-
	High	Required	Required	Recommended[b]	Recommended[b]	Recommended[b]	Recommended[b]
High	Low[a]	Required	Required	Required	Required	Required	Recommended[b]
	High	Required	Required	Required	Required	Required	Required[c]
Reference in Manual		7.2	7.3, 7.4, 8.0	7.3	7.2, 7.2.1	7.5	9.9

Source: Transportation Association of Canada, 2005

Table 8.1: Required Levels of Erosion and Sediment Control

Notes:
(a) If economically justified, it may be acceptable to limit ESC measures for low-consequence projects, including those distant from sensitive areas, to procedural BMPs only.
(b) This level of ESC should be implemented where practical. For example, a small, short-duration project may not require staged construction and progressive rehabilitation. Recommended actions may be necessary to demonstrate due diligence in the event of the release of sediment due to an extreme runoff event.
(c) Water quality monitoring provides a quantitative measurement of the effectiveness of ESC measures. Monitoring may be required by regulatory agencies.

The information presented in Table 8.2 must be supplemented with the designer's experience and judgement during the preparation of the ESC strategy. Those responsible for the design and implementation of BMPs and other measures should continue to utilize innovative approaches which best address specific situations. Advances in technology will also continue to improve the methods and materials that are currently employed. Reference should be made to the suppliers for the most up-to-date approved products.

Specific measures and BMPs are published in many manuals and standards, which describe criteria and specifications in detail. Many of the BMPs most commonly used in the Northwest Territories are presented in Appendix C. The BMPs are listed in terms of erosion control and sediment control, and the description, typical applications, advantages and limitations for each are provided. For each BMP, installation information and construction, maintenance and inspection considerations are provided, and where applicable, similar measures are noted to provide the designer with options and flexibility in choice.

Other factors affecting the selection of erosion and sediment control BMPs include:

- Site Specific Design Requirements;
- Specific Construction Requirements including available space and requirements to address the presence of permafrost;
- Regulatory laws and guidelines; and
- Cost.

8.3 Construction Phase Activities

Erosion control considerations for various construction phase activities are presented as follows. These construction-related activities must be addressed in the contractor's ESC Plan. Other aspects of environmental protection for these activities are to be addressed in the Environmental Management Plan (EMP).

Clearing and Grubbing

Clearing operations include slashing, cutting, stockpiling, and removal (or burning) of trees and brush. Clearing operations leave the stump and root mass intact, as well as the organic mat in the soil. Grubbing operations include the removal of the tree stumps and root masses left behind during clearing operations, however, the topsoil and the majority of the organic mat remains in place. Grubbing operations may cause localized soil exposure in areas where roots and stumps were removed. Clearing and grubbing may have an impact (melting) on permafrost areas, thus in the permafrost zones these activities should be carefully managed.

Stripping

Stripping is the removal of the organic mat from the construction site to expose the underlying mineral soil. The exposed soil will be disturbed during the stripping operation, thereby increasing the erosion potential.

In permafrost areas, the stripping of the organic mat and topsoil likely result in the melting of the permafrost layer, further increasing the erosion potential and the potential structural failure of the sub-soils. If it is necessary to strip this material, the area of stripping should be minimized and the material should be removed and stockpiled in a manner that makes it suitable for retrieval and reapplication.

Borrow Excavations

Borrow excavations may be located outside of the construction site boundaries and used for the purposes of removing borrow material for:

- Roadway subgrade construction, or
- The other site construction activities including dams, channels, berm structures or other erosion protection works associated with the transportation infrastructure project, or
- Purposes other than transportation infrastructure as outlined in the Quarry Permit.

Borrow excavations can be topographical highs such as hills or ridges, or on relatively flat terrain, or are large excavations utilized for the extraction of construction material. The borrow pit (quarry) area is to be restored as required by the GNWT-MACA Quarry Permit (Pursuant to subsection 3 (4) of the Commissioner's Land Act) or the relevant Land Use Permit. This may include restoring or remediating holding water areas. In northern areas where permafrost is present or may develop (temporary zones), borrow pits should be designed in a manner that does not permit the holding (ponding) of water as this increases the melt within the permafrost layer. Melting of the permafrost layer is known to contribute to subsequent infrastructure damage and may continue for an extended period of time.

Development of borrow excavations may include clearing, grubbing, stripping and excavation. The development of borrow excavations and haul roads may cause soil disturbance, create exposed slopes and/or alter the natural drainage courses in the vicinity of the borrow excavation. Borrow excavations and infrastructure construction within a permafrost zone should be designed by a qualified person.

Stockpiles

Stockpiles may include material removed from excavations, stripping, clearing, and from borrow pits. The creation of stockpiles may disturb the vegetated soil surface, create exposed slopes, and/or temporarily alter the natural drainage courses. Avoid ponding water in stockpile areas and provide sufficient drainage as required.

Cut Slope Construction

Cut slopes are slopes created through the excavation and removal of native soil. Cut slopes may increase the slope angle, disturb the soil surface, create exposed slopes, and/or alter the natural drainage courses. Cut slopes may expose soil with ground ice with resultant melting and drainage of water and soil slurries.

Fill Slope Construction

Fill (embankment) slopes are constructed by placing and compacting fill material. Fill slope embankments create large areas of disturbed exposed soils, may require steep slope angles and/or they may alter the natural drainage courses which impacts the overall erosion risk.

Ditch Construction

Where channels or ditches are constructed to direct and transport water along or transverse (crosswise) to the linear alignment, the original drainage pattern may be altered and concentration of flows created, thereby increasing flow velocity and erosion potential. Ditch construction creates exposed slopes which can be eroded.

In areas of permafrost and ground ice, melting can be expected. Ditches within the permafrost zone will require a wider base as the melting of the upper slope will allow fluid movement of soils into the ditch line. In permafrost zones, the ditch line should be wider than in non-permafrost areas, the slope cuts should be made near vertical, the vegetation and fibrous organic matter retained on the upslope side and the bank allowed to self-stabilize. The vegetative mat will relax over the slope as the soil flows to stabilize the slope, providing an insulating layer which will minimize further melting. During the self-stabilization period, the soil in the ditch needs to be monitored and removed only enough to allow water passage to resume as per the remainder of the ditch line. The material immediately at the base of the slope should not be removed as it provides stabilization for the area upslope.

Culvert Installation

Culverts are installed to provide surface drainage from the road prism and upslope ditches, and to connect natural drainage courses. Installation of culverts may cause flow concentrations, create cut slopes, disturb the soil surface on slope faces, and create scour zones at the culvert inlet or outlet. Areas known to have “icings” may require multiple drainage structures at differing levels (stacking). These should be designed by a qualified person. Ponding of water should be avoided and extra structures installed as necessary to provide adequate drainage, especially in areas where melting of permafrost is a concern.

Temporary Access Road Construction

Temporary access roads are constructed to accommodate construction equipment on the project site. Construction of temporary haul roads may alter drainage courses and may include the construction of cut slopes, fill slopes, ditches or culvert installation.

8.4 Selection of Best Management Practice (BMP) According to Construction Activity

A large number of ESC BMPs are available for use in an ESC Plan. The BMPs presented in this section are proven to be effective when properly implemented. Since the effective implementation of control measures is a site-specific operation, the BMPs have been grouped by typical construction activities that occur on transportation construction sites in Table 8.2. BMPs (Appendix C) typically used for stream bank stabilization applications are summarized in Tables 8.3 and 8.4.

When selecting BMPs, consideration must be given to site specific conditions. For example, a site with rocky sites and embankments where rock is solid will enable sediment fencing to be used as an ESC measure. An alternative method of controlling water or run-off from the site such as berms or diversion ditches may be required. As such, customized methods and techniques may be required to meet the specific requirements of any given construction site. Innovative ideas or variations of the ESC control measures may be developed and implemented on site, which may work as well as or better than the “standard method”. In such cases, the erosion and sediment controls should still be designed to be straightforward to implement, maintain, and inspect for effectiveness. If the intended result is achieved and can be maintained, the control measure should be acceptable for that specific site condition.

	BMP Name	Construction Activity								
		Clearing and Grubbing	Stripping	Borrow Pits	Stockpiles	Cut Slopes	Fill Slopes	Ditches/Channels	Culverts	Temporary Haul Roads
1.	Sediment Fence	✓	✓	✓	✓	✓	✓		✓	✓
2.	Gabions					✓	✓	✓	✓	
3.	Berm Interceptor	✓	✓	✓	✓	✓	✓			✓
4.	Storm Drain Inlet							✓	✓	
5	Rock Check							✓		
6.	Synthetic Permeable Barrier							✓		
7.	Straw Bale Barrier			✓	✓	✓	✓			✓
8.	Rolled Erosion Control Products (RECP)				✓	✓	✓	✓		
9.	Riprap Armouring					✓	✓	✓	✓	
10.	Cellular Confinement System					✓	✓	✓		
11.	Energy Dissipaters							✓	✓	
12.	Sediment Traps and Basins		✓					✓		
13.	Slope Drains					✓	✓			
14.	Diversion Ditches		✓	✓	✓	✓	✓			
15.	Seeding			✓	✓	✓	✓	✓		
16.	Mulching			✓	✓	✓	✓	✓		
17a	Hydroseeding			✓	✓	✓	✓	✓		
17b	Hydromulching			✓	✓	✓	✓	✓		
18.	Topsoiling		✓	✓	✓	✓	✓	✓		
19.	Soil and Root Mat Replacement (Sodding)	✓	✓	✓	✓	✓	✓	✓		
20a	Live Staking					✓	✓	✓		
21.	Riparian Zone Preservation	✓	✓	✓	✓	✓	✓	✓	✓	✓
22.	Crushed Rock Buttress for Slopes (Permafrost)					✓	✓			
23.	Controlled Ablation (Melt) of Cut Slope (Permafrost)					✓				
24.	Insulated Thermal Blanket on Cut Slope (Permafrost)					✓				
25.	Scheduling	✓	✓	✓	✓	✓	✓	✓	✓	✓
26.	Stabilized Worksite Entrances	✓	✓	✓	✓	✓	✓	✓	✓	✓
27.	Slope Texturing			✓	✓	✓	✓			✓
28.	Compost Blanket				✓	✓	✓			✓
29.	Rolls (Fibre- Coir, Wattles)			✓	✓	✓	✓			
30	Wattles (Live Facine)					✓				

Table 8.2: Application for BMPs Based on Construction Activities

BMP #	BMP Name	Category	Also Known As
29	Rolls (Fibre)	Bank Armour and Protection	• Coir Rolls • Coir Mats • Wattles
30	Wattles (Live)	Bank Armour and Protection	• (Live Facine)
20a	Live Staking	Bank Armour and Protection	• Live Staking
20b	Brush layering	Bank Armour and Protection	• Live Brush Layering
31	Brush Mattress	Bank Armour and Protection	• Live Brush Mattress • Brush Mat
32	Live Siltation	Bank Armour and Protection	• Vertical Brush layering
33	Willow Posts & Poles	Bank Armour and Protection	• Pole Planting • Dormant Live Posts
34	Rock Vanes	Bank Armour and Protection	• Rock Vanes • Upstream Angled Spurs
35	Longitudinal Stone Toe	Bank Armour and Protection	• Longitudinal Peaked Stone Toe Protection (LPSTP) • Stone Toe • Rock Toe • Stone Toe Buttress • Weighted Riprap Toe • Longitudinal Fill Stone Toe Protection (LFSTP)
36	Vegetated Mechanically Stabilized Earth (VMSE)	Bank Armour and Protection	• Vegetated Geogrids • Brush layering with Soil Wraps • Vegetated Geotextile Fabric Wrapped Soil
37	Vegetated Riprap	Bank Armour and Protection	• Vegetated Rock Revetment • Vegetated Rock Slope Protection (VRSP) • Face Planting • Joint Planting
38	Stream Diversion Channel	Diversion of Stream	• Diversion Ditching • Stream Diversion
39	Coffer Dam (Small Streams)	Diversion of Stream	• Coffer Dam • Dam • Stream Barrier

Note: Adapted from E-SenSS Software, 2005, Salix Applied Earthcare

Table 8.3: BMPs for Stream bank Applications

	BMP 29 Roll (Fibre)	BMP 20a Live Staking	BMP 20b Brush layering	BMP 31 Brush Mattress	BMP 32 Live Siltation	BMP 33 Willow Posts & Poles	BMP 34 Rock Vanes	BMP 35 Longitudinal Stone Toe	BMP 36 VMSE	BMP 37 Vegetated Riprap	BMP 38 Stream Diversion Channel	BMP 39 Coffer Dam
Erosion Process												
Toe erosion with upper bank failure	✓				✓		✓	✓		✓		
Scour of middle and upper banks by currents		✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
Local scour	✓	✓	✓	✓	✓	✓	✓			✓		
Erosion of local lenses or layers of non-cohesive sediment	✓	✓	✓	✓	✓	✓			✓	✓		
Erosion by overbank runoff			✓									
General Bed Degradation												
Erosion by navigation waves	✓	✓			✓	✓				✓	✓	✓
Erosion by wind waves	✓	✓			✓	✓				✓		
Erosion by ice and debris gouging	✓							✓		✓		
General bank instability or susceptibility to mass slope failure		✓	✓					✓	✓			
Spatial Application												
In-stream							✓				✓	✓
Toe	✓			✓	✓		✓	✓		✓		
Mid-bank		✓	✓	✓		✓			✓	✓		
Top of bank				✓						✓		
Hydrologic / Geomorphic Setting												
Resistive	✓			✓				✓	✓	✓		
Redirective							✓				✓	✓
Continuous				✓	✓			✓	✓	✓	✓	✓
Discontinuous							✓		✓			
Outer Bend	✓			✓	✓		✓	✓	✓	✓		
Inner Bend				✓					✓			
Incision								✓				
Lateral Migration	✓						✓			✓		
Aggradation					✓		✓					
Complexity												
Low					✓	✓		✓				
Moderate	✓	✓	✓	✓			✓			✓	✓	✓
High									✓		✓	✓

Note: Adapted from E-SenSS Software, 2005, Salix Applied Earthcare

Table 8.4: BMPs for Stream bank Applications Based on Erosion Process

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9.0 PERMANENT EROSION AND SEDIMENT CONTROL PLAN (PESC PLAN)

9.1 General

The Permanent Erosion and Sediment Control (PESC) Plan constitutes the measures designed by a qualified person to be constructed to address long term post-construction erosion and sedimentation hazards. In many cases it builds on the ESC Plan that guides the construction period. For example, a temporary pond during construction could be modified to become a permanent storm water retention pond. The PESC Plan should be designed using acceptable engineering and vegetation management approaches, and forms part of a project detailed design. The PESC Plan will also be referenced by the construction contractor in the development of the Environmental Management Plan (EMP).

A PESC Plan should be prepared as part of the design for all construction projects. For sites smaller than two ha (and not connected to an environmentally sensitive area), this consists of identifying minimum requirements for an erosion and sediment control strategy, and where practical, incorporating erosion and sediment controls into the detailed design to reduce on-site runoff and erosion. Sites larger than two ha require the development of a comprehensive PESC Plan and associated documents. During construction, the PESC Plan should be reviewed by a qualified person and modified as required as field conditions change.

A checklist for the development of the ESC Plans is included in Appendix D.

9.2 7Qualified Persons Responsibility

The qualified person is required to prepare and submit:

- A PESC Plan Report;
- Design and Construction Drawings showing PESC measures where appropriate;
- Contract special provisions which may be necessary to identify and address special areas of concern or types of work; and
- As-Built drawings showing the type, quantity and location of PESC measures installed.

A qualified person is responsible to monitor construction and confirm that the permanent erosion control works are installed according to the requirements of the PESC Plan.

The required qualifications of the Qualified Person are provided in Section 3.1.3.

9.3 PESC Plan Documentation

The PESC Plan must include a report and drawings. Reference should be made to GNWT DOT's guidelines for transportation projects. As a minimum the following should be addressed in the PESC Plan:

- Site Assessment;
- Design of the PESC Plan including highlighting procedural or minimum requirements, required BMPs and site specific designs;

- Shut Down considerations;
- Inspection, Monitoring and Maintenance Requirements; and
- Emergency Response Plan and incident reporting requirements.

9.4 Design and Construction Drawings

The Design and Construction Drawings must show the PESC measures (where appropriate) and reference the PESC Plan report.

9.5 Contract Special Provisions

Contract Special Provisions shall discuss other special or site specific items not included in the standard specifications for transportation construction. Information which may be included in the Special Provisions are design location of the devices, quantities and special regulatory requirements, or reference to special instructions on installing the erosion and sediment control devices.

9.6 Site Inspection during Construction

Once the PESC measures have been installed, it is important that their effectiveness is monitored and necessary maintenance be carried out through the remainder of the construction phase. The success of the entire erosion and sediment control strategy will depend upon this, and its importance cannot be overemphasized.

All temporary and permanent ESC measures must be inspected by the contractor daily and following heavy rainstorms or snowmelt events during the construction phase. Immediate action must be taken by the contractor when the need for maintenance or repair of PESC measures is identified for the ongoing performance of the measures.

A qualified person should inspect the PESC measures every seven days and following heavy rainstorms or snowmelt and advise the contractor immediately of any areas of concern. As site work progresses, the PESC Plan should be modified when necessary by the Qualified Person to reflect changing site conditions or new information which has been identified during construction.

A copy of the PESC Plan, along with a copy of the Construction Drawings, must be kept by the Contractor at the construction site for use by construction workers and inspection personnel.

9.7 Inspection and Incident Records

The Contractor and Qualified Person must both maintain separate records of their inspection of all ESC measures at the frequencies noted above, including notes regarding damage and deficiencies observed. The same document can be used to record maintenance and repairs undertaken after the inspection.

The Qualified Person must submit their inspection report of ESC measures to the GNWT - DOT on a weekly basis. The contractor must maintain records of their daily inspection and provide copies to the qualified person, if and when requested.

A sample inspection report form is presented in Appendix D. Inspection Report Forms may be developed or modified for the specific site.

9.8 As-Built Drawings and Project Records

A complete summary of the PESC measures installed must be documented by the Qualified Person during construction and updated as various measures modified. As-built drawings and supporting records must include a plan view drawing showing the type, quantity and location of PESC measures installed.

Supplemental information which should be included in the Final Details includes:

- Inspection and Maintenance Reports;
- Modifications to the PESC Plan;
- Photos of the installed PESC measures; and
- Incident Reports.

9.9 Post Construction

After final acceptance, the inspection and maintenance responsibilities of the PESC measures will be transferred from the construction contractor to the Maintenance Contract Inspector (MCI) and the GNWT-DOT's Maintenance Contractor.

The respective maintenance responsibilities at the Construction Phase and Post Construction Phase are described in the GNWT-DOT maintenance contract. Inspection and maintenance of PESC measures must continue regularly so that the measures remain effective in the long term. The following circumstances and conditions will permit BMPs to be removed:

- Revegetation of bare soil is successful;
- No obvious erosion scour is observed;
- No obvious bed load of silt and sediment laden runoff is observed;
- Inspection and maintenance report indicates satisfactory performance; and
- GNWT-DOT maintenance staff will assess and decide on performance of the structures and the requirement for necessary removal.

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10.0 TEMPORARY EROSION AND SEDIMENT CONTROL PLAN (TESC PLAN)

10.1 General

The temporary erosion and sediment control plan (TESC Plan) constitutes the measures designed and installed by the qualified person to address matters of erosion and sediment control which the contractor anticipates during the construction contract and includes activities up to the point of final acceptance of the construction work. The TESC Plan is prepared by the contractor and forms one component of the EMP which is also prepared by the contractor.

Sample checklists for the development of the TESC and PESC Plans are included in Appendix D. These forms may be modified to reflect changing requirements.

10.2 Contractor's Responsibility

The contractor is required to prepare and submit an Environmental Management Plan (EMP) to the Qualified Person prior to construction. In order to develop a TESC Plan, the contractor should incorporate recommendations of the Qualified Person's PESC Plan and Environmental Risk Assessment.

Responsibilities of the Qualified Person and Contractor as well as the guidelines provided by the GNWT-DOT for preparing an EMP are used in preparing the TESC Plan Documentation.As a minimum, the following should be addressed in the TESC Plan:

- Design of the TESC Plan including addressing procedural or minimum requirements, required BMPs and site specific designs;
- Shut Down considerations;
- Inspection, Monitoring and Maintenance requirements; and
- Emergency Response Plan and incident reporting requirements.

10.3 Site Inspection during Construction

During construction, before final acceptance of the construction contract works, the responsibility for the inspection, maintenance and repair of all TESC measures lies with the contractor. A schedule of planned maintenance activities is required with the submission of the EMP. When implemented controls are insufficient or not working as intended, changes to the TESC Plan component must be made by the contractor to ensure continued compliance.

All erosion and sediment control measures must be inspected daily by the contractor and following heavy rainstorms or snowmelt events. Some measures will require periodic replacement and/or removal of accumulated sediment.

Damage or deficiencies to control measures should be corrected immediately.

Details on inspection, maintenance and repair activities shall be recorded on the "Inspection and Maintenance Form". A sample form is presented in Appendix D.

10.4 Shutdown Considerations

The TESC Plan must include provisions for erosion and sediment control during shutdown periods. Shutdowns are considered any extended period of time during which the contractor is not actively developing the project site and may no longer have personnel or equipment on-site. Shutdowns may or may not be planned and may result from seasonal work stoppages, adverse weather events, or contractual disagreements. During a shutdown, erosion and sediment control measures must still be inspected and maintained. This will include during winter shutdown and more importantly, during spring snow melt prior to construction re-start when the contractor must provide timely, regular monitoring and maintenance as well as install additional measures as necessary.

10.5 Emergency Response Plan

The TESC Plan must show preparedness for an emergency response to erosion and sediment related problems. The contractor should reference the most current versions of the Environmental Management Plan (EMP), GNWT-DOT ESC Manual and should also reference the Qualified Person's PESC Plan for information on requirements and procedures.

10.6 Inspection and Incident Reports

All inspection, maintenance and repairs performed on erosion and sediment control measures should be recorded on the "Inspection and Maintenance Form". A sample form is presented in Appendix D. Inspection and maintenance report and repair records must be kept at the construction site for review by construction personnel, inspectors, Qualified Person and GNWT-DOT personnel.

10.7 Post Construction

After final acceptance, the inspection and maintenance responsibilities of any installations that must remain in operation may be transferred from the construction contractor to the Maintenance Contract Inspector (MCI) and the GNWT-DOT's Maintenance Contractor in the post construction phase as outlined in the contract agreement. The respective maintenance responsibilities at the Construction Phase and the Post Construction Phase are described in the GNWT-DOT maintenance contract. Inspection and maintenance must continue until the BMP is no longer required, at which time the BMP will have to be removed. The contractor may be responsible for the inspection and maintenance of the BMPs for a period following the end of construction. The following circumstances and conditions will permit BMPs to be removed:

- Revegetation of bare soil is successful;
- No obvious erosion scour is observed;
- No obvious bed load of silt and sediment laden runoff is observed; and
- GNWT-DOT maintenance staff will assess and decide on performance of the structures and requirement for necessary removal.

11.0 GUIDELINES FOR ESTIMATING RUNOFF FROM SMALL WATERSHEDS AND DESIGN OF OPEN CHANNELS

11.1 General

The design of erosion and sediment control measures should consider the peak flow rate of surface runoff to ensure channels and sedimentation containment systems are adequately sized. Furthermore, these structures must be protected from erosion due to concentrated water flow.

Channelized flow requires provision of erosion control measures to prevent concentrated water flow from causing erosion. The amount of runoff laden with sediment will influence the design requirements for sediment control. The estimate of runoff from small watersheds and the design of channel lining are presented below.

11.2 Estimating Runoff from Small Watersheds

The amount of runoff from each catchment on a transportation construction project site is related to the design rainfall storm and the catchment area affected by construction. A linear drainage design generally includes ditches and cross-drainage culverts as well as storm water storage/treatment areas and floodplain considerations.

For the design of erosion and sedimentation protection measures, runoff estimation is an important design consideration. The runoff assessment should be provided by a qualified hydrology professional or engineer. For small catchment areas, the guidelines for the estimate of runoff are presented in Appendix E. These guidelines should only be used in conjunction with professional judgement and experience. For major watercourse crossings, the drainage assessment is generally provided by a qualified engineer.

11.3 Design of Open Channels

Open channels are the system of ditches and swales that convey concentrated drainage on a transportation construction site. Culverts are pipes, either completely closed or arched, which also convey ditch or channel water. These channels and culverts must be designed to contain design runoff flow without overtopping. Furthermore, open channels must be able to convey the concentrated flows without promoting additional erosion within the channel. Open channel design should be provided by a qualified hydrology professional or engineer.

The use of permissible tractive resistance[7] has been adopted for the design of channel lining instead of the permissible velocity concept[8] which was historically used by some designers. For linear ditch/channel and a simplified flow regime, the channel design is a function of runoff, geometric channel properties and channel roughness (n).

[7] Tractive resistance: The resistance to motion due to friction per unit weight hauled.(Webster's Online Dictionary)
[8] Permissible velocity: The highest velocity at which water is permitted to pass through a structure or conduit without excessive damage (McGraw-Hill Science & Technology Dictionary)

The channel roughness (n) is dependent on the degree of irregularity of the **wetted** perimeter of open channel flow which may be influenced by erosion control BMPs in the channel. The protective linings for channels can include soft armour linings of different materials (e.g. vegetation, soil coverings or erosion protection matting, etc.) and hard armour linings (e.g. gabions, riprap, concrete linings, pipes, etc.), all of which will affect "n".

Simplified guidelines for design of linear channels and channel roughness (n) values for various protective channel lining materials are presented in Appendix F. These guidelines should only be used in conjunction with professional judgement and experience.

12.0 GUIDELINES FOR THE DESIGN OF SEDIMENT CONTAINMENT

12.1 General

The function of a sediment containment system is to provide storage capacity to runoff volume and to slow the flow velocity of runoff to allow the sedimentation of suspended soil particles (silt, clay) to occur. When designed correctly, most sediment containment systems do one or more of the following:

- Provide containment storage volume for incoming runoff waters;
- Create uniform flow zones, increased flow path length and width and increased sedimentation times to facilitate sedimentation of suspended particles; and
- Discharge water at a controlled rate that permits adequate detention time for sedimentation of suspended particles.

It is important to note that removal of all incoming suspended particles is not feasible due to the practical limits of water storage volume and available settling time. Therefore, the efficiency of a containment system is based on the efficiency of sedimentation of a target grain size.

The sediment containment system should be designed so that the outflow rate during the design rainfall event is equal to or smaller than the inflow rate of sediment-laden runoff. Coarse to medium size silt particles (particle size range 75 μm to 20 μm) can be realistically targeted for sedimentation. Finer size particles (i.e., clay and fine silt) will require a long time to settle and therefore may not be deposited in the sediment containment facility during the time of retention. As such, targeting clay, fine silt particles and organic silts for sedimentation is generally not practical.

The design capacity of a sediment containment system should be sufficient to impound the runoff volume collected from an area of disturbed land (bare soil) for a 1:2 year storm event of 24 hour rainfall intensity or a recommended runoff volume of 250 m^3 per hectare of disturbed land. Under conditions of land constraints, a minimum runoff volume of 150 m^3 per hectare can be considered. The designer of a sediment containment system should consider the flow rate at which sediment laden runoff enters the system and ensure that sufficient time exists to permit adequate sedimentation to occur before the water exits the system.

12.2 Containment Systems (Type I, II and III)

The type of containment system should be selected based on site specific conditions. The selection should generally be based on the following:

- Site erosion potential classification;
- Area of upstream soil exposure;
- Terrain conditions in the contributing area;
- Area and soil depth constraints in the planned containment system site; and
- Method of construction.

Construction of the containment system should be completed at high risk areas prior to any land disturbance and construction.

The selection of the location and type of sediment containment system should be based on the experience and judgement of the designer. The criteria for selection of the type of sediment containment systems are presented in Table 12.1.

Containment System *	Site Erosion Potential Classification	Design Particle Size *	Affected Land Area *
Type I (Sediment Basin)	High to Very High	Particle size ≤ 0.045 mm (medium silt and finer)	>2.0 ha
Type II (Sediment Trap)	Moderate	Particle size between 0.045 mm and 0.014 mm (fine sand, coarse to medium silt)	≤2.0 ha
Type III (Sediment Barrier)	Low to Very Low	Particle size >0.14 mm (medium to fine sand, coarse silt)	Grade break and velocity retarder for construction and intermediate areas

*Source: Fifield, 2001

Table 12.1: Containment System Types

The three types of sediment containment systems are discussed in the following sections. Ponding of water should be avoided in areas of underlying frozen soil condition where possible. Sediment ponds should be designed by a qualified person.

Type I (Sediment Basin)

Type I sediment containment system requires development of a structure to capture coarse to medium silt and a portion of smaller suspended particles. Since particles of this size have low settling velocities, large storage volumes, long flow-path lengths, and controlled discharges are required. As such, the containment basin will be configured accordingly to provide sufficient retention time and flow velocity reduction to permit sedimentation. Type I systems are designed to have the highest possible net efficiency and are best represented by the traditional sediment basin.

In general, sediment basins should be sized for a minimum recommended storage volume of 250 m^3/ha where possible over the contributing disturbed bare soil area. Length (L) to width (W_e) ratio should be between 4:1 and 8:1. A practical width (W_e) can be 6 to 8 m. Generally, a practical pond depth is 1.2 m. The maximum pond depth should not exceed 1.5 m. An illustration of the Type I structure is presented in Figure 12.1.

Type II (Sediment Trap)

The Type II sediment containment system will capture suspended particles (fine sand to coarse silt) having higher settling velocities than particles requiring Type I structure.

Consequently, small storage volumes and shorter flow-path lengths in comparison to widths can be used. As with a Type I structure, these sediment control systems will also have controlled discharges. Whereas their net effectiveness for the inflow and sedimentation of all suspended particles may be low, Type II systems will still have an effective sediment control measure.

In general, sediment traps should be sized for a recommended storage volume of 250 m^3/ha over the contributing area where possible or a minimum storage volume of 150 m^3/ha under conditions of land constraints. Length (L) to width (W_e) ratio should be between 2:1 and 3:1. A practical pond depth can be 1 m and the maximum pond depth should not exceed 1.5 m. Illustrations of Type II structures are presented in Figure 12.1 and Figure 12.2.

Type III (Sediment Barrier)

The least effective method to control suspended particles in runoff waters is represented by the Type III sediment containment systems. These are not necessarily design structures, as found with Type I and Type II systems, but are often BMPs (such as drainage ditch check structures). Whenever significant runoff occurs, all Type III systems have very low net and apparent effectiveness to control suspended particles. However, when runoff is low, the Type III sediment control systems can be effective in reducing flow velocity and suspended particles (coarse silt to fine sand) along gentle grade areas as long as they are regularly maintained.

12.3 Design Considerations

The design of a sedimentation pond can be a challenge as design parameters are difficult to define (e.g., storm events, runoff, soil erodibility and distribution of erodible soil). Thus, the evaluation of the effectiveness of pond performance is difficult to quantify. Therefore, the design of a sediment pond or the review of its performance should be undertaken by a qualified engineer with practical experience and professional judgement. A suggested design rationale for the design of sediment containment systems is presented in Appendix G.

The focus of sediment control is capturing silt and larger sized soil particles. It is not practical to design for clay particles or colloidal organic particles due to the significant amount of time required for these to settle. Therefore, erosion control should be emphasized for preventing release of water containing clay particles or colloidal organic particles from a construction site.

Methods that estimate the efficiency of a given sediment containment system should be used with caution as there are several variables that affect the effectiveness of these systems. Estimating the efficiency of a sediment containment system should be used as a preliminary means of evaluating various options. However, the final selection should be based on the site conditions and the experience and judgement of the designer.

Care should be taken when designing embankments, since these may have to be designed according to dam design guidelines and regulatory requirements. Regardless of the height of an embankment, the consequences of failure will determine the level of effort during design and construction. A qualified engineer should design the foundation and embankment, and provide inspection during and after construction. Similarly, the optimization of pond areas and depth to obtain maximum efficiency should be undertaken by a qualified engineer.

12.4 Design Examples

A design example for a sediment pond is presented in Appendix H as Example H.16.

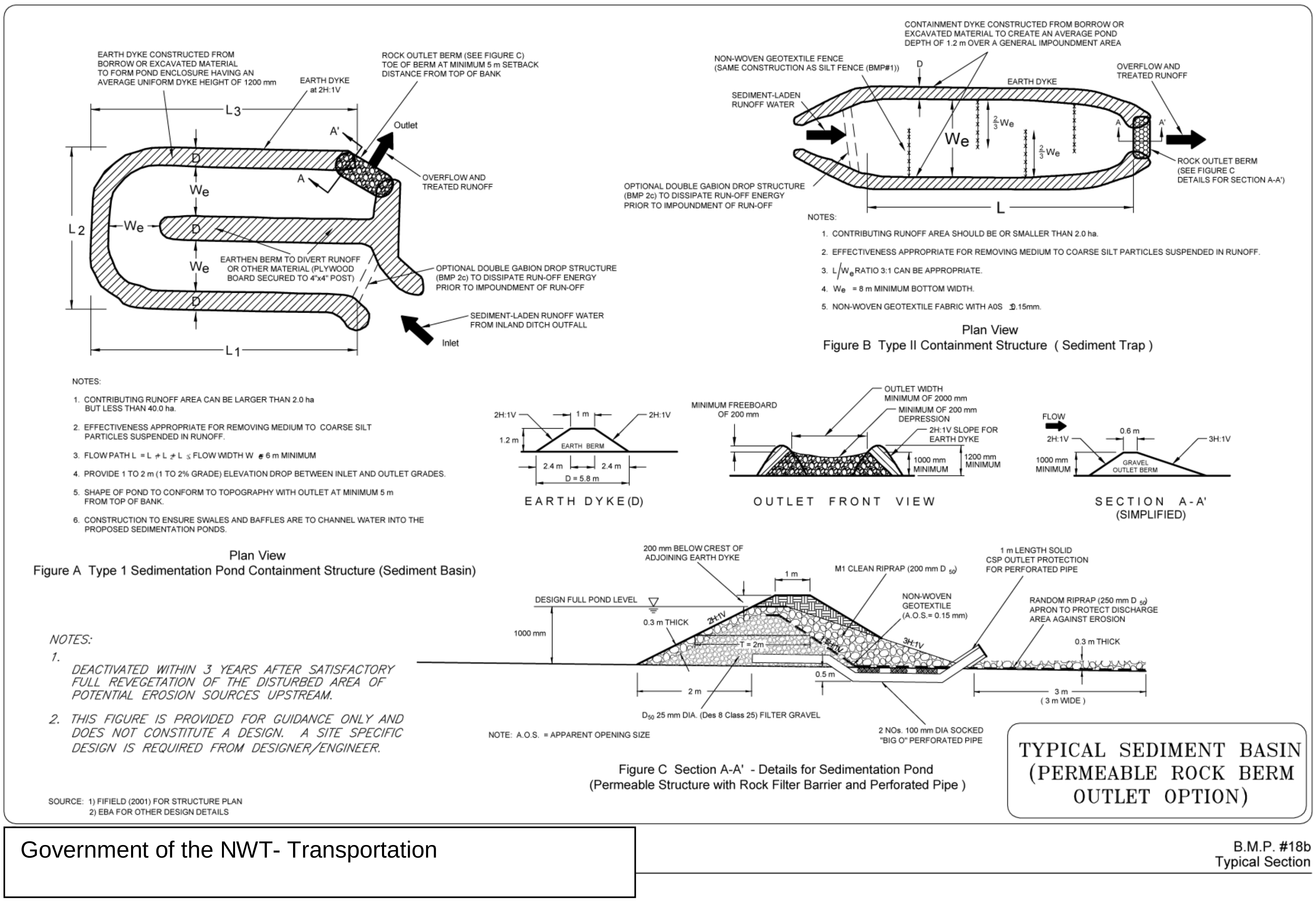

Figure 12.1: Type I and II Typical Sediment Containment Systems (Source: Fifield 2001)

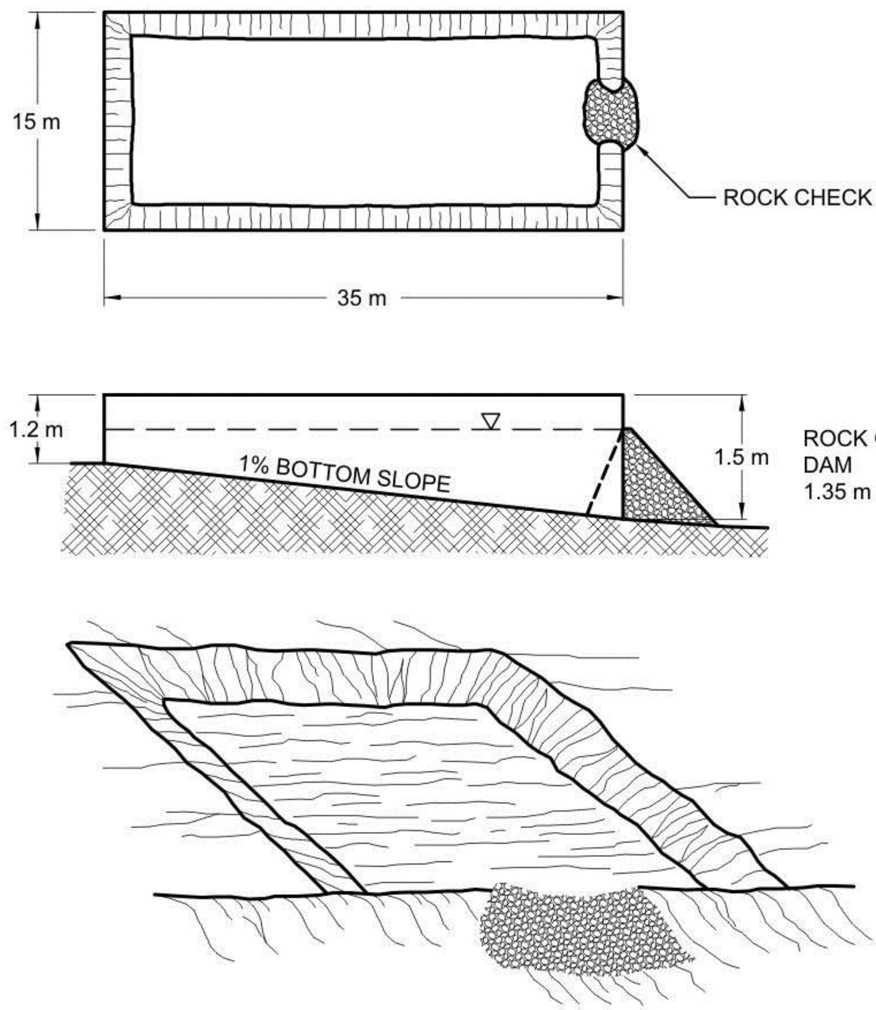

Figure 12.2: Type II Sediment Containment System (Sediment Trap) – Excavation Option

Source: City of Calgary, 2001

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