POST-EA INFORMATION PACKAGE INCLUDING
AN UPDATED PROJECT DESCRIPTION
ALL SEASON ROAD TO PRAIRIE CREEK MINE

APPENDIX 14-1

SUBMITTED IN SUPPORT OF:
Water Licences MV/PC2014L8-0006, and
Land Use Permits MV/PC2014F0013

SUBMITTED TO:
Mackenzie Valley Land and Water Board
Yellowknife, NT X1A 2N7

SUBMITTED BY:
Canadian Zinc Corporation
Vancouver, BC, V6B 4N9

February 2019
Revision History

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<th>Description</th>
<th>Revised By (Initials)</th>
<th>Revision Date</th>
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<td>Draft Version by Allnorth</td>
<td>Allnorth (WBM)</td>
<td>2015-08-24</td>
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<td>Revised Version by Tetra Tech</td>
<td>Tetra Tech (JL, TB, RH)</td>
<td>2018-12-04</td>
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Review and Approval

The following signatures indicate that the undersigned have read and agreed to the contents of this document, and that they approve and accept its distribution and use.

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<tr>
<td>Document Owner</td>
<td>David Harpley</td>
<td></td>
<td>2018-12-04</td>
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<td>Reviewed by:</td>
<td>Full Name, Job Title</td>
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Distribution List

This Plan and the most recent revisions have been distributed to:

Copy #1 – Canadian Zinc Corporation

Copy #2 –
This Sediment and Erosion Control Plan (SECP) describes the methods to be used to mitigate and manage erosion and sedimentation during the relatively short-term construction and long-term operations phases of the Prairie Creek All-Season Road (ASR) leading to the Prairie Creek Mine. The plan outlines the approaches and concepts that will be used to ensure that potentially harmful environmental effects, due to the potential mobilization of sediments to surface waters during construction activities, do not occur. The primary goal of this SECP is to prevent erosion and proactively control it at the source before having to manage the mobilized sediment. To achieve this, the plan identifies the following:

- Potential erosion and sediment sources;
- Best management practices and procedures;
- Mitigation measures and methods for preventing erosion; and
- Monitoring and adaptive management.

Canadian Zinc Corporation (CZN) will identify areas that are susceptible to erosion and sedimentation and will implement industry-standard Best Management Practices (BMPs) to mitigate the potential hazards. Numerous sediment management and mitigation strategies are provided in documents from the Government of Northwest Territories (GNWT 2013), Alberta Transportation (AT 2011), and the Transportation Association of Canada (TAC 2005). Each strategy outlines measures to avoid erosion or minimize potential adverse effects of sedimentation on water quality and aquatic resources due to road construction activities. The BMPs presented in this SECP are adopted from the GNWT’s *Erosion and Sediment Manual*.

Sediment and erosion control will be minimized by conducting ASR construction activities outside of more difficult or sensitive seasons, where possible, and by employing proactive control strategies for ground clearing, work in riparian areas, borrow pit development, and the installation of water crossings. Watercourse crossing structures will be inspected at least monthly to check on their performance and address any developing issues before impacts occur.

Water quality monitoring immediately prior to, during, and after ASR construction will focus on upstream and downstream differences, with TSS and turbidity being the prime parameters. A significant increase in either parameter downstream will trigger a response. A Canadian Council of Ministers of the Environment (CCME) guideline applies to both parameters and will be used for compliance. A sub-set of watercourse crossings will be monitored during road operations.

This SECP is a living management plan that will be updated throughout the life of the access road. It will be adapted to include any useful lessons learned (in terms of both the project, traditional knowledge, and recent technologies) that will be gained in the coming years. CZN looks forward to using this SECP for engaging with representatives of the Nahanni Butte Dene Band, Liidlii Kué First Nation, and Dehcho First Nations to discuss, clarify, and add to the current principles and objectives of this management plan.
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LIMITATIONS OF REPORT
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# GLOSSARY OF TERMS

<table>
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<tr>
<th>Glossary of Terms</th>
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<tr>
<td>Berm</td>
<td>Low earth mound constructed in the path of flowing water to divert its direction.</td>
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<tr>
<td>Cross Ditch</td>
<td>Shallow trench excavated across a road to drain water in the downslope direction.</td>
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<tr>
<td>Cross Drain</td>
<td>Pipe that extends through the roadbed to drain water from the uphill side of the road.</td>
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<tr>
<td>Erosion</td>
<td>The wearing away of soil or rock by water, wind, ice, or other geological agents, including such processes as gravity.</td>
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<tr>
<td>Footprint</td>
<td>The proposed development area that directly affects the soil and vegetation components of the landscape.</td>
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<tr>
<td>Freshet</td>
<td>Rapid rise in stream flow due to runoff from snowmelt during spring.</td>
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<tr>
<td>Peatland</td>
<td>Poorly drained organic terrain characterized by a high-water table and the presence of permafrost.</td>
</tr>
<tr>
<td>Reclamation</td>
<td>The process of reconverting disturbed land to its former or other productive uses.</td>
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<td>Riprap</td>
<td>An erosion-resistant ground cover of large, loose, angular stones used to stabilize slopes and protect soil from the erosive forces of runoff.</td>
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<tr>
<td>Riparian</td>
<td>An area of land adjacent to a stream, river, lake, or wetland containing vegetation that, due to the presence of water, is distinctly different from the vegetation of adjacent upland areas.</td>
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<tr>
<td>Sedimentation</td>
<td>The process by which suspended particles in water settle to the bottom of a waterbody.</td>
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<tr>
<td>Turbidity</td>
<td>The cloudiness or haziness of a fluid caused by large numbers of individually suspended particles that are generally invisible to the naked eye.</td>
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<tr>
<td>Watershed</td>
<td>The area of land that drains water into a stream, river, or lake.</td>
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## ACRONYMS & ABBREVIATIONS

<table>
<thead>
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<th>Acronym/Abbreviation</th>
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<td>Allnorth Consultants Ltd.</td>
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<td>All-Season Road</td>
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<td>AT</td>
<td>Alberta Transportation</td>
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<td>BPMRP</td>
<td>Borrow Pit Management and Reclamation Plan</td>
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<td>BMPs</td>
<td>Best Management Practices</td>
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<td>CCME</td>
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<td>GNWT</td>
<td>Government of Northwest Territories</td>
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<td>Hatfield</td>
<td>Hatfield Consultants</td>
</tr>
<tr>
<td>km</td>
<td>Kilometres</td>
</tr>
<tr>
<td>KP</td>
<td>Kilometre Post</td>
</tr>
<tr>
<td>L</td>
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<tr>
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<td>Metres</td>
</tr>
<tr>
<td>mg</td>
<td>Milligrams</td>
</tr>
<tr>
<td>mm</td>
<td>Millimetres</td>
</tr>
<tr>
<td>Mine</td>
<td>Prairie Creek Mine</td>
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<tr>
<td>MTO</td>
<td>Ministry of Transportation Ontario</td>
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<td>NNPR</td>
<td>Nahanni National Park Reserve</td>
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<tr>
<td>NTU</td>
<td>Nephelometric Turbidity Unit</td>
</tr>
<tr>
<td>Project</td>
<td>Prairie Creek Access Road</td>
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<td>RCP</td>
<td>Road Construction Plan</td>
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<td>SECP</td>
<td>Sediment and Erosion Control Plan</td>
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<tr>
<td>TAC</td>
<td>Transportation Association of Canada</td>
</tr>
<tr>
<td>Tetra Tech</td>
<td>Tetra Tech Canada Inc.</td>
</tr>
<tr>
<td>TSS</td>
<td>Total Suspended Solids</td>
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1.0 INTRODUCTION

This Sediment and Erosion Control Plan (SECP) was prepared for Canadian Zinc Corporation (CZN) by Tetra Tech Canada Inc. (Tetra Tech) with input from Hatfield Consultants (Hatfield) related to water quality monitoring (see Section 6.0). This management plan serves to outline the sediment and erosion control practices to be employed during the construction and operation of the Prairie Creek All-Season Road (ASR).

This SECP builds on a previous draft plan developed by Allnorth Consultants Ltd. (Allnorth) in 2015. Currently, this management plan is at a conceptual stage as the road is undergoing preliminary design.

1.1 Company Name, Location, and Mailing Address

Company Name:
Canadian Zinc Corporation

Head Office:
Address: Suite 1710 – 650 West Georgia Street, Vancouver, BC, V6B 4N9
Phone: +1.604.688.2001
Fax: +1.604.688.2043
Email: david@canadianzinc.com

Prairie Creek Mine:
Iridium 9555 Satellite Phone 1 (yellow) 011.8816.315.30998
Iridium 9505A Satellite Phone 2 (black) 011.8816.315.30997
Iridium 9505A Satellite Phone 3 (orange) 011.8816.315.30996
Ground-To-Air Radio Handheld FREQ 122.800

1.2 Purpose and Scope

The purpose of the SECP is to identify environmentally-sound practices for managing sediment and controlling erosion during the construction and operation of the ASR. It provides guidelines to ensure that mitigation and control measures are implemented in a responsible manner that comply with applicable legislation, regulations, and authorizations.

To achieve this, the SECP identifies the following:

- Potential erosion and sediment sources;
- Best management practices and procedures;
- Methods for preventing erosion; and
- Monitoring and adaptive management.

The SECP is a living document that will be updated throughout the life of the road to adapt and incorporate any changes that may arise (e.g. site conditions, design modifications). Updates to this plan will also include results from ongoing engagement with the potentially-affected Indigenous groups, including Nahanni Butte Dene Band, Liidlii Kué First Nation, and Dehcho First Nations, as well as all applicable regulators and land managers. A final SECP will be completed after detailed design of the road and will be implemented prior to construction.
1.3 Related Documents

This SECP is linked to several other CZN management plans, including:

- Health, Safety, and Emergency Response Plan;
- Engagement Plan;
- Borrow Pit Management and Reclamation Plans;
- Explosives Management Plan;
- Invasive Species Management Plan;
- Permafrost Management Plan;
- Rare Plant Management Plan;
- Road Closure and Reclamation Plan;
- Road Construction Plan;
- Road Operations and Maintenance Plan;
- Spill Contingency Plan;
- Sundog Creek Diversion Plan;
- Traffic Control Mitigation and Management Plan;
- Waste Management Plan; and

Details of the road, together with the schedule of road construction and operations, are provided in the Road Construction Plan (RCP). A map book of the road is provided in Appendix A.

1.4 Regulatory Requirements

The SECP was prepared in accordance with guidance provided in the following best management practices (BMP) publications:

- Government of Northwest Territories, Department of Transportation’s Erosion and Sediment Control Manual (GNWT 2013);
- Alberta Transportation’s Erosion and Sediment Control Best Management Practices (AT 2011);
- Government of Northwest Territories, Department of Lands’ Northern Land Use Guidelines – Access: Roads and Trails (GNWT 2015a);
- Government of Northwest Territories, Department of Lands’ Northern Land Use Guidelines – Pits and Quarries (GNWT 2015b);
- Transportation Association of Canada’s National Guide to Erosion and Sediment Control on Roadway Projects (TAC 2005); and
2.0 PROJECT DESCRIPTION

CZN is planning to operate the Prairie Creek Mine (Mine). The Mine is located at approximately 61° 33’ north latitude and 124° 48’ west longitude adjacent to Prairie Creek, a tributary of the South Nahanni River in the south-west corner of the Northwest Territories (Figure 1).

A 170 km all-season road connecting the Mine, at Kilometre Post (KP) 0, to the Liard Highway via the Nahanni Butte access road (Figure 2) will generally follow the alignment of a previously permitted winter road, while reflecting the terrain, site characteristics, and road specifications suitable and preferred for the ASR. Approximately half of the proposed ASR (85 km between KP 17 to KP 102) is located within the Nahanni National Park Reserve (NNPR). The NNPR, a world heritage site, is known for its globally-significant karst terrain, as well as the South Nahanni River, a Canadian Heritage River. Approximately half of the ASR alignment will directly overlap with the alignment of the permitted winter road.

Construction of the ASR will take approximately three years to complete. Initial winter roads will be built to gain access to the Mine, allow further investigation of the ASR alignment to complete detailed design, and to provide access for road construction. CZN’s intent is to build the initial winter roads on the ASR alignment as much as possible to minimize the total extent of disturbance.

The ASR will cross approximately 18 major streams with clear span bridges or large diameter culverts, and 85 minor streams with culvert diameters ranging from 800 mm to 2,000 mm based on the size of the stream. Construction of the ASR will be supported by temporary camps at KP 23 (Sundog), KP 39 (Cat Camp), KP 65, KP 87, KP 121 (Grainger Gap), KP 151 or 158, and KP 177.5. The camps at KP 39, KP 87, and KP 121 will likely be retained in a reduced form to support on-going road maintenance.

3.0 POTENTIAL SEDIMENT AND EROSION SOURCES

While there is always a potential for natural erosion (especially on steep slopes, near waterways etc.), construction activities greatly influence the risk and can increase the rate of erosion. Identifying and assessing the areas at risk for erosion are the first steps in developing an effective plan for prevention or mitigation.

The potential sources of sediment generation during construction of the ASR include the following:

- Embankment Cuts (e.g. earthworks requiring stabilization and runoff control of uphill areas, like the bridge crossings of Sundog Creek);
- In-Stream Works (e.g. work within a floodplain or active channel area, such as placement of fill and/or riprap along road embankments or bridge abutments);
- Surface Water Diversion (e.g. diverting runoff from disturbed areas into existing creeks and rivers); and
- Water Level Changes (e.g. shoreline and water flow channels of affected waterbodies due to the water level change during season changes).
4.0 DESIGN AND SELECTION OF BEST MANAGEMENT PRACTICES

Design and construction of the ASR will be informed by industry-standard BMPs for preventing sedimentation and controlling erosion. Numerous sediment management and mitigation strategies are provided in documents from the Government of Northwest Territories (GNWT 2013), Alberta Transportation (AT 2011), and the Transportation Association of Canada (TAC 2005). Each strategy outlines measures to avoid erosion or minimize potential adverse effects of sedimentation on water quality and aquatic resources due to road construction activities.

Following detailed assessment of areas sensitive to erosion and sedimentation, specific measures for mitigation and management of erosion and sedimentation will be designed and implemented. Failure to properly implement appropriate erosion and sediment control measures can result in three types of potential consequences:

- Ecological (e.g. the introduction of sediments to the aquatic environment);
- Project (e.g. the need to repair erosion damage and the implications for project schedule and cost); and
- Legal (e.g. penalties associated with the deposition of sediment in receiving water bodies or other environmentally sensitive sites).

Selecting the appropriate measures for erosion and sediment control will aid in making the construction process and operations more efficient while minimizing potential impacts on water quality and the aquatic resources of streams along the ASR alignment. CZN’s primary goal for this management plan is to prevent erosion and associated sedimentation.

The BMPs presented in the GNWT’s *Erosion and Sediment Manual* (GNWT 2013) will serve as the main reference for this SECP. Applicable BMPs are included in Appendix B.

4.1 Procedural BMPs

Procedural BMPs are non-structural methods that can reduce the potential for erosion and sediment transport at a construction site. They are often referred to as *minimum measures* and include site management (e.g. minimizing exposed soils, perimeter control, stockpile management, and site access management) and scheduling procedures (e.g. maximizing favourable weather, optimizing construction sequencing, and early reclamation of disturbed terrain).

Procedural BMPs consider sediments that may not originate from water erosion on exposed soil or constructed surfaces, including wind-blown dust from work areas and material stockpiles, soil or debris deposited by truck tires, and material spilled from truck boxes. CZN will develop procedural BMPs as the ASR advances closer to detailed design.

4.2 Water Management BMPs

Water management BMPs are methods or procedures that are intended to control water and reduce erosion potential using on-site and off-site measures. The general principles that CZN will follow, when implementing water management BMPs, will be to:

- **Keep Clean Water Clean.** Divert clean water around the site and convey clean water from undisturbed areas within the site to natural receiving streams;
- **Minimize Watercourse Disturbance.** Use existing drainage, where possible, and integrate on-site drainage into the project design;

- **Proper Channel Design.** Follow natural channel profiles for watercourse diversions, where possible, and design new drainage channels to accommodate design discharges; and

- **Manage Groundwater.** Anticipate, investigate, and manage groundwater where applicable.

### 4.3 Sediment and Erosion Control BMPs

A range of factors influence erosion potential over time, including soil characteristics, topography, and climate. Sediment and erosion control BMPs aim to reduce the erosion potential of the soil by reducing the exposure of disturbed soils as well as controlling runoff. Popular methods for protecting exposed surfaces include: top-soiling, mulching, aggregate cover, and plastic sheeting. Methods for runoff control include: slope grading, implementing slope drains, plastic sheeting, fibre rolls, and wattles.

Sediment and erosion control BMPs are intended for application to flowing water where there is a need to retain mobilized sediment. Sediment control can be accomplished using methods of filtering or settling sediment-laden runoff water. Common methods include the use of sediment fences, berm interceptors, rock check dams, and turbidity curtains. Factors to consider when selecting appropriate sediment control methods include flow quantity and velocity, soil characteristics, topography, climate and season, and accessibility.

Numerous BMPs for sediment and erosion control are outlined in the GNWT’s *Erosion and Sediment Control Manual* (GNWT 2013). BMPs applicable to construction of the ASR are included in Appendix B and are listed in the table below:

**Table 1: Selection of Sediment and Erosion Control BMPs for ASR Construction**

<table>
<thead>
<tr>
<th>BMP Name (BMP #)</th>
<th>Clearing / Grubbing</th>
<th>Borrow Pits</th>
<th>Cut Slopes</th>
<th>Fill Slopes</th>
<th>Ditches / Channels</th>
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Table 1: Selection of Sediment and Erosion Control BMPs for ASR Construction

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<th>BMP Name (BMP #)</th>
<th>Clearing / Grubbing</th>
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</table>

5.0 SEDIMENT AND EROSION CONTROL

CZN will ensure that sediment and erosion control measures are implemented for any disturbed soils where there is a risk of sediment transfer to surface water. Since it is typically easier to stop erosion at the source rather than try to control sediment once it has become mobilized in water, CZN’s primary focus will be to reduce the potential for erosion.

The following sections highlight the proposed mitigation measures and methods that will be used for sediment and erosion control during construction and operation of the ASR.

5.1 Mitigation Measures

5.1.1 Strategic Scheduling of Work

Construction activities in sensitive areas will be avoided during the spring and early summer months, as much as possible. Fall or winter construction is preferred as watercourses will either be at low levels or frozen. Work may be suspended during periods of heavy or persistent rainfall if sediment mobilization and discharge to receiving waters could occur.

5.1.2 Pre-Construction/Construction Phases

Minimizing areas of terrain disturbance will minimize the amount of erosion and sedimentation that may occur. CZN will ensure that only areas that must be graded in the current phase of development will be cleared. Existing vegetation will be left in place as long as possible to maintain the stability of the soil. CZN will also execute proper management of site access, perimeter control, and stockpiling to control potential wind-blown sediments.

Pre-work meetings with all individuals involved with the construction will be held on-site prior to the construction phase of the project. These meetings will include review of all environmental requirements, which mitigation and erosion control measures are to be used, and where, during each phase of construction.

Sediment control measures will be installed as closely as possible to the sediment source to minimize the quantity of water that must be managed, and therefore reduce the potential for environmental impacts.

5.1.3 Post-Construction Phase

Following the construction of road subgrade or installation of stream crossing structures, exposed soils will be stabilized for long term erosion protection and sediment controls will be implemented until re-vegetation occurs.
This will be especially important in riparian areas, sites containing fine soil types, and/or wet/saturated unstable soils.

5.2 Methods

5.2.1 Clearing and Grubbing

Clearing, grubbing, and site preparations leading to the storage and disposal of construction wastes, overburden, soil, or other substances will be managed to minimize the potential for entry into any streams or watercourses, using the following approaches:

- No materials will be stockpiled within 15 m of the top of bank of any defined watercourse or wetland; and
- Soil stockpiles will be sloped to minimize erosion, wherever possible. In difficult locations where an unstable stockpile is close to a watercourse, a berm will be installed around the perimeter of the stockpile to prevent release of sediments to the watercourse.

5.2.2 Riparian Areas

CZN will follow standard best management practices when operating within riparian areas, where practical and feasible, beginning with minimizing the removal of riparian vegetation as much as possible. CZN recognizes that preserving riparian zones is the most effective natural sediment control measure and that natural vegetation promotes infiltration, which may reduce the volume of runoff. Riparian zones within the footprint of construction will be delineated and fenced off prior to commencement of construction to minimize trespassing. CZN commits to not placing road stripping in riparian zones.

When necessary, construction within riparian areas will be conducted in favourable weather and low-water conditions, and according to project regulatory approvals. Machinery on land will be operated above the high-water mark in a manner that minimizes the disturbance to the banks of the watercourses, unless work in braided alluvial floodplains is required, in which case machinery will avoid normally active channels. Equipment used for installation of culverts will operate outside the wetted channel from the top of the bank or in a dry stream channel.

Riparian vegetation alone; however, is not intended for heavy sediment load filtration, high volume discharge, or as a sole source for construction runoff control. Silt fences will be installed on the lower perimeter of slopes (i.e. lower 1/3 to 1/2) to supplement sediment control in riparian areas during construction.

Re-vegetation of riparian areas will be promoted and performed as quickly as possible for bank stabilizations and to further minimize potential sedimentation.

5.2.3 Borrow Pits

Significant release of sediments to drainage systems and receiving waters can be caused by the development of borrow pits and the temporary roads leading to them. To minimize potential environmental impacts, construction activities at or near borrow pits will incorporate the following practices:

- **Access Roads.** Most borrow pits will be accessed in winter by temporary ice roads. Borrow pit access roads made from granular materials will be restricted only to locations that will require access after road construction. Roads will be constructed prior to site area development in a manner that will prevent the loosening of native subsoil. Non-winter access roads will be constructed of suitable coarse, granular material with minimal fines.
Wood wastes, such as sawdust, and wood chips, are not acceptable for the construction of access roads due to the potential release of leachate;

- **Diversion of Surface Water.** Before materials are removed from the borrow pits, surface water will be suitably diverted around the operating area. Drainage will be controlled throughout the borrow operations to prevent natural drainage and surface runoff from carrying sediment into the surrounding watercourses;

- **Floodplains.** All borrow pits located in floodplains will not be excavated below the water table and extracting or excavating ditch depths below normal flood plain level will be avoided;

- **Runoff.** Borrow runoff will be collected via interceptor ditches or swales, as necessary. Flows will be routed to settling areas or ponds, if necessary, to allow the settlement of sediments before release to the receiving environment; and

- **Stand-off Distances.** Borrow stockpiles of rock and coarse material will be located a minimum of 50 m from flowing watercourses, and soil or fine material at least 100 m from flowing watercourses. Where this is not possible (e.g. in tight canyons or valleys), CZN will implement enhanced erosion and sediment control measures to avoid potential impacts.

Borrow source investigations will be completed during detailed design of the ASR which will determine material characteristics and water table levels. Borrow Pit Management and Reclamation Plans (BPMRP) will be prepared for each individual borrow source and will include detailed, site-specific extraction and reclamation plans, including borrow extraction within floodplains subject to water table influence.

All borrow pits will maintain a minimum 50 m buffer between the active portion of a floodplain and the borrow source. Borrow pits which may be impacted by high water flows (Q100) will be guarded, if deemed necessary, by a berm elevated 1 m above the determined Q100 elevation. During detailed design, borrow pit stability, potential risk from active stream channel, and potential risk from high water flows will be reviewed and appropriate protection measures such as berms will be included in the BPMRP.

The development, working, and restoration of borrow sources will be carefully planned and carried out to reduce or avoid negative effects including permafrost thaw and soil erosion.

### 5.2.4 Watercourse Crossings

Watercourse crossings and in-stream work will be avoided where possible; however, to date, approximately 102 major and minor stream crossings have been identified along the preliminary route of the ASR. Consequently, several bridges (clear-span and multi-span) and large diameter culverts will need to be installed along the alignment. The following sediment and erosion mitigations will be applied for all watercourse crossings:

- **Bridges and approach roads** will be designed to achieve minimal back-water effects which increase the head in the stream and will address any such backwater effects in the project design;

- **Equipment crossings** through open surface water will be avoided. If a crossing is unavoidable, it will be limited to a one-time crossing (over and back) to gain equipment access to the opposite side. This will only be considered if the stream depth and bedding material is suitable to support such equipment and will not create significant streambed damage;

- **Equipment used for construction,** including site preparation and maintenance of bridges, will be positioned either in a dry stream channel or on top of the bank;

- **Isolation of the stream area** is required for keying in riprap or other in-stream works if the area is not frozen. In-stream isolation is needed to prevent disturbed, turbid water from being released. Water pumps will be used to
draw turbid water from the work area and discharge it to a well-vegetated area or settling basin away from the stream. Alternatively, the turbid water can be allowed to clear after the work is complete before removing the isolation. Inspections for fish inside the isolated area and possible salvage may need to be completed prior to commencement of work;

- Unconsolidated materials from clearing or brought in as fill material will be stockpiled in areas where surface runoff from such material cannot lead to sedimentation of the watercourse;

- Sediment fences or other measures will be deployed as necessary, before starting work, in areas where there is potential for surface run-off to entrain and transport sediments to the channel (e.g. road fill slopes); and

- New watercourse crossings will be regularly inspected to ensure any exposed mineral soils are stable and beginning to re-vegetate. Temporary crossing structures will be removed after usage to avoid blockage and erosion.

### 5.2.5 Runoff Control

During ASR construction, sediment and erosion control will focus on managing surface drainage patterns and minimizing the potential to adversely affect water quality in streams and drainages. Runoff controls reduce the erosive energy of runoff and conveys it using non-erodible surfaces.

Where fish spawning areas are situated in the receiving waters, the runoff water will not, at any time, increase the level of total suspended solids (TSS) significantly above the baseline level in the receiving waters. Sediment-bearing water will be conveyed away from streams and drainages during construction.

Runoff control will be achieved by establishing temporary or permanent structures such as berm interceptors, rock check dams, and several types of swales and bars. Generally, runoff control will incorporate the following measures:

- A stable road bed will be constructed adjacent to creeks and runoff control will be provided to minimize potential dispersal of sediments during precipitation events;

- Catchment areas will be controlled by planning construction activities according to the topography surrounding the drainage;

- A clean water diversion swale may be employed to keep clean water out of a disturbed area together with a perimeter ditch/dike system to channel silt-laden water to an on-site sediment control area;

- For larger disturbed areas, sites will be divided internally into smaller catchment areas to avoid concentrating large volumes of runoff water;

- Water in each catchment area will be isolated from other catchments;

- Each catchment area will be graded to encourage runoff to be dispersed and prevent gullying; and

- Water bars or cross ditches will be installed to direct road surface runoff away from the access road in a safe manner and, where required, appropriately-sized culverts will be installed to reduce road failure through erosion.

Slope breaks may be used to reduce the effective length of slopes. Slope breaks are terraces with diversion swales or dikes, which collect sheet runoff from a catchment area and direct it to a slope drain or other drop structure. The diversion swales will be gently sloping, and may include check dams, rock lining, or grass linking depending on the soil types and slope.
Check dams are small barriers placed across a swale or ditch. They reduce the effective slope of the channel, decreasing water velocity and allowing for sediment to settle. Some general recommendations for check dams that will be implemented include the following:

- Steeper swales (>5% in stable soils) require check dams to slow velocity and reduce channel erosion (sediment capture is a secondary function);
- Check dams made from drain rock with a finer material core and coarse drain rock surfacing; and
- Settling ponds between dams will be created. The base elevation of a check dam should preferably be the same level as the top of the check dam below.

Rock channel lining is an armouring technique to prevent channel bed erosion. When implementing a rock channel lining system, the following recommendations will be followed:

- Channels with runoff velocities >2 m per second will be considered for rock-lining;
- The channel base will be armoured with rock graded from small to large sizes that is free of silt, overburden, or other substances deleterious to fish;
- Where riprap is not available, fabric linings/geotextile can be used;
- A mix of sizes of rock will be determined according to the volume and design velocity of the channel; and
- The toe of rock riprap at channel drops will be trenched-in (keyed).

Groundwater control will prevent water ponding and flooding. The following recommendations made for groundwater control will be applied:

- Areas of sand or silt soils with groundwater seepage are highly susceptible to erosion and shallow sloughing, therefore, perforated drains can be installed to intercept the groundwater before it surfaces; and
- Alternatively, a surface applied drainage blanket of riprap can stabilize the slope. Engineering advice will be obtained for proper design.

Energy dissipaters are precast concrete structures or riprap/geotextile solutions (rock aprons). Energy dissipaters can be installed at the outfall of culverts or high-velocity channels. Energy dissipaters will reduce runoff velocities to less than 2 m per second and will disperse the runoff.

### 6.0 MONITORING

To ensure the successful performance of erosion and sediment control measures, it is essential to monitor the control measures and other construction activities, and to adjust, modify, and install additional controls as required to address evolving conditions. Monitoring will be completed during construction periods, prior to spring freshet, and in response to any significant rainfall or high-water events to ensure sediment and erosion control mitigation measures are effective. Along with inspections of the control structures themselves, monitoring water quality will serve to evaluate the success of the control measures.
6.1 Performance Monitoring

Performance monitoring of the ASR should be carried out regularly to help identify potential erosion areas that need additional mitigation or response. Visual inspections should be carried out at the below intervals to identify deficiencies and promote early detection.

6.1.1 Monthly (Maintenance)

Monthly inspections of the ASR will be performed by a designated Road Maintenance Superintendent. Inspections will be documented with field notes and photographs of the road and borrow sources and will be maintained onsite at all times.

Inspections and visual monitoring will be of importance at the following features:

- Major Watercourse Crossings (bridges);
- Minor Watercourse Crossings (culverts);
- Road Embankments Cuts;
- Runoff Controls;
- Surface Water Diversions; and
- Borrow Pits.

6.1.2 Annually (Hydrotechnical)

Annual inspections should be performed by a qualified Hydrotechnical Engineer experienced in sediment and erosion control. Inspections will identify any adverse impacts at watercourse crossings and drainage structures from the construction and operation of the road. Documented records of all road maintenance, as required by the Road Operations and Maintenance Plan, will be reviewed as part of this inspection.

6.2 Baseline Water Quality

ASR construction, occurring subsequent to initial winter roads, has the potential to cause erosion and sedimentation of streams. The main parameters of concern are TSS and turbidity. In terms of baseline conditions in streams, TSS and turbidity levels naturally vary according to weather and flow conditions. This makes it a challenge to establish representative baseline conditions. Moreover, the collection of baseline data is of questionable value, given that changes due to construction can be easily identified, and mitigation applied if necessary.

Where baseline may be useful is for the prior determination of a linear regression between TSS and turbidity. The former normally requires laboratory analysis, whereas the latter can be determined in the field quickly using a portable meter. However, such a relationship also requires sampling during a range of natural flow conditions, furthermore there is no assurance that such a relationship will be accurate during and after construction.

Therefore, we propose to rely on TSS and turbidity readings taken upstream and downstream of crossings immediately before, during, and after construction. The Canadian Council of Ministers of the Environment (CCME)

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1 The water quality concern related to crossings is the erosion of terrestrial soils and the addition of suspended soils to natural stream water. These soils will likely have different properties compared to the natural sediments in each stream.
has produced guidelines for both TSS and turbidity which will be used to detect differences between upstream and downstream water quality. Both guidelines are summarized in Appendix C.

Should linear regression be considered a viable approach, the approach could be tested with visits to stream crossing locations at KP 6.2 (Casket Creek), KP 13.1 (Funeral Tributary), and KP 23 (Sundog Creek) during different flow conditions. These crossings are accessible from the Mine by the existing access road.

At most locations, initial ASR construction will occur in winter. Therefore, the following spring would be the first opportunity to evaluate sedimentation associated with construction. Mitigation in the form of silt fencing and other sediment-limiting approaches will be put in place in advance of spring thaw; however, regular inspections at the onset of thaw and thereafter will be required to verify effectiveness.

Much less issues, and therefore monitoring, are expected to occur associated with the initial winter roads. Natural ground cover will largely be undisturbed. The exception will be small road sections where non-typical winter road construction will be employed, involving some cut and fill.

### 6.3 Short-Term (Construction) Monitoring

Short-term water quality monitoring will be undertaken during ASR construction periods in the open water season. If ASR construction occurs in winter, as much of it is anticipated to do, monitoring will be initiated in the subsequent spring. The following program is recommended for new construction and disturbed areas identified as follows:

- At all identifiable stream crossings with a defined channel:
  - Two sampling sites located upstream beyond the potential influence of the construction; and
  - Three sampling sites located downstream of the construction representing near-field, intermediate-field, and far field.

- At the Mosquito Lake crossing, one sampling site upstream and two sampling sites downstream;

- The specific locations of all monitoring sites will be determined and marked by a suitably qualified person. The monitoring will be undertaken by CZN’s Environmental Monitors;

- Monitoring will occur during construction and/or during the spring and summer period thereafter at each location. Monitoring will occur immediately after significant runoff events, and weekly during periods of rainfall, declining to monthly if successive weeks indicate no effects. Daily monitoring will occur on streams potentially affected by active construction activities, declining to weekly if successive days indicate no effects;

- Measurements of turbidity, dissolved oxygen, conductivity, and pH will be collected using portable meters. If initial measurements of dissolved oxygen, conductivity, and pH indicate that levels are only minimally influenced by construction activities (based on comparisons with data collected at the two upstream sites) then measurement of these variable will cease. Turbidity readings will be used as an indication of elevated sediment content. A 10% increase between upstream and downstream near-field will trigger an upstream and downstream TSS sample, downstream for regulatory significance and upstream to confirm that the TSS elevation is not from natural causes.

- Results will be compared against the CCME Canadian Water Quality Guidelines for the Protection of Aquatic Life. If these thresholds are exceeded in the re-alignment or downstream, but not the reference sites, adaptive management efforts to reduce impacts will be identified.
6.4 Long-Term (Operational) Monitoring

Long-term (i.e., multi-year) monitoring of water quality will occur at a subset of stream crossing sites (both upstream and downstream) and at the Mosquito Lake crossing. This program will include:

- Monitoring will occur during the spring freshet (June) and after significant summer storms; and
- Measurements and the comparison of results will be the same as for the short-term program above.

7.0 ADAPTIVE MANAGEMENT

If water monitoring detects a water quality compliance or sedimentation issue, adaptive management will be applied to remedy the situation. The remedy is likely to be highly site-specific depending on the issue, and for example could consist of silt fence deployment, additional armour, active revegetation, ground recontouring, or installation of additional drainage structures. It will be difficult to predict which remedy is appropriate before the issue occurs. Follow-up monitoring will be needed to verify the success of the remedy.

7.1 Water Quality

Comprehensive monitoring of TSS and turbidity will be completed, and sampling frequency will be increased if there is an exceedance of either the CCME TSS or turbidity water quality guideline protective of aquatic life. This increased frequency will cease once the guideline is no longer exceeded. Allowances will be made for safety concerns or technical challenges due to weather.

7.2 Rapid Response Plan

Inspections of watercourse structures will take place on a regular basis to ensure that, to the extent feasible, recommended measures are installed in advance of significant rainfall or high flow events which may occur with little warning. In the event of an intense precipitation event and an erosion and sediment control-related failure, CZN will ensure the safety of all persons, including workers and anyone off-site that could be affected. Measures to control runoff and prevent the off-site discharge of sediment-laden water will be implemented and any damaged erosion and sediment control measures will be repaired in order of importance. If necessary, construction activities will be shut down until repairs are completed and favourable conditions return.
REFERENCES


FIGURES

Figure 1  Prairie Creek Mine Overview
Figure 2  Proposed Access Road Alignment
Figure 1

Prairie Creek Mine Overview

LEGEND

- Proposed Prairie Creek Access Road

NOTES
Base data source: Imagery from ESRI; DigitalGlobe (2016).

FILE NO.
EARC03145-01_Figure1.mxd

PROJECT NO.
EARC03145-01

CLIENT
TETRA TECH

PROJECTION
NWT Lambert

DATUM
NAD83

Scale: 1:15,000

0 100 200
Metres

OFFICE
TI-VANC

DWN
SL

CKD
BB

APVD
RH

REV
0

DATE
November 21, 2018

ENG.EARC03145-01
**LEGEND**

- **Access Road Kilometre Marker**
- **Proposed Prairie Creek Access Road**
- **Proposed Winter Road Alignment**
- **Existing Road**
- **Nahanni National Park Reserve Boundary**
- **Watercourse**
- **Waterbody**

**NOTES**

- Base data source:
  - Road alignment provided by AllNorth (July 2018)
  - Existing roads from CanVec (1:50,000)
  - Watercourses from CanVec (1:250,000)

**SCALE**

- 1:350,000

**PROJECTION**

- NAD83
- UTM Zone 10

**STATUS**

- BL: BASE LINE
- CO: CHECKED
- APVD: APPROVED

**CLIENT**

- ENG.EARC03145-01

**PROJECT NO.**

- ENG.EARC03145-01

**DATE**

- December 3, 2018

**Figure 2**
APPENDIX A

ACCESS ROAD MAP BOOK
Useable life of approximately one year dependent on regular maintenance

**Construction**

- Two methods of installation are commonly used
  - Trench method (common method)
  - Mechanical (slicing) installation method (e.g. Tommy Silt Fence Machine or equivalent) (used in areas where soil depth is not a concern, therefore has not been included in this manual)

- Trench Method
  - Select location of sediment fence (fence must be level - along contours)
  - Excavate a trench approximately 0.15 m deep by 0.15 m wide for entire length of fence along upstream side of posts;
  - With fabric on the upstream or upslope side toward the flow, drive support posts a minimum of 0.3 m into ground, spaced a maximum of 2 m apart;
  - Extend the loose flap of filter fabric the bottom to cover the base of trench (see figure);
  - Backfill and compact soil in trench, being careful not to damage fence or dislodge posts;
  - Where extra support is required, attach the wire mesh or snow fencing, as reinforcement, to upstream side of posts with staples or other type of ties. If using fencing material which is not stapled to the posts, place the wire mesh or snow fencing first and then line the upslope side with the fabric. Secure all tightly to the posts.

**Construction Considerations**

- Site Selection
  - Size of drainage area upslope of the sediment fence should be no greater than 0.1 ha for each 30 m length of sediment fence;
  - Maximum slope length above sediment fence should be no greater than 30 m;
  - Maximum slope gradient above the sediment fence should be no greater than 2H:1V;
- Fence should be placed on contour (level) to produce proper water detention;
Sediment Fence

Sediment Control

- Fence should be placed far enough away from toe of slope to provide adequate retention area (minimum of 1.8 m away from toe of slope is recommended) which will also permit access by equipment to conduct maintenance;

- Fence should not be installed immediately adjacent to a stream. The fence should be as far from the stream edge as possible and at a minimum far enough (>1.0 m is recommended) from the stream bank to allow room for a second fence to be installed, should the first one fail or become damaged; Ends of fence should be angled upslope (smile) to collect runoff;

- Fence fabric should not extend more than 0.7 m above grade when installed correctly;

- Fence fabric (and wire mesh or snow fence, if used) should be dug into a trench at least 0.15 m deep (six inches) and lay across the bottom of the trench 0.15 m to prevent undercutting of fence by runoff; Fence stakes can be wood or metal material dependent on design and ground conditions;

- Stakes are to be placed on downstream side of fence, fabric on the same side as the material to be contained;

- Posts should not be spaced greater than 2 m apart;

- Wire mesh or standard snow fencing may be placed on the upslope side of the fencing to provide additional strength and support reinforcement;

- Fence material should be cut from a continuous roll to avoid joints. If joints are necessary, the wrapping of fabric around the fence post with a minimum overlap of 0.2 m and staples should be used to attach the fabric to the post);

- Fence material (and wire mesh or snow fence, if used) should be attached to posts with heavy duty staples, tie wires, or hog rings;

- Trench backfill should be compacted.

- Long sections of silt fence are more prone to failure than short sections.
  - Maximum length of each section of silt fence should be 40 m.
  - Sediment fence should be installed in 'J' hook or 'smile' configuration, with maximum length of 40 m, along contours (level). The J pattern allows for an escape path for detained water (minimizes pushing over or overtopping of the fence structure).

**Inspection and Maintenance**

- Inspection frequency should be in accordance with the PESC and TESC Plans. Sediment fences should be inspected daily but at a minimum of once every 7 days, as well as after significant storm events and spring melt.
Sediment Fence

Sediment Control

B.M.P. #1

- Repair undercut fences. This is a sign that the fence was incorrectly installed or overloaded. Repair or replace damaged fencing (split, torn, loose or weathered) fabric immediately.
- Sediment build up should be removed once it accumulates to a depth of 0.3 m (one foot).
- Sediment should be removed and stored at a suitable stockpile location with no surface flow;
- Remove fence after vegetation is established;
- Deactivate fabric by cutting the fencing material between the stakes and pulling to remove; bottom trenched-in portion of fence fabric should be removed from the ground to avoid groundwater interception and potential for wildlife entanglement.

Similar Measures

- Straw Bales
- Rock Barrier
- Permeable/Synthetic Barriers

Design Considerations

- For sediment fence to work as a system, the following factors should be considered:
  a) quantity – adequate number, location, and spacing of fences for efficient detention and sedimentation
  b) installation – must be done correctly and on contour
  c) compaction – backfill and trenching of fabric
  d) support – posts adequately embedded, appropriate selection of post material and spacing
  e) attachment – secure fabric to post
- Install sediment fence in a 'J' hook or 'smile' configuration, so that the ends are higher than the fenceline to contain the water and sediment
Sediment Fence
(Trench Method)

Government of the Northwest Territories – Transportation
Sediment Fence (Mechanical Method)

Government of the Northwest Territories - Transportation
Sediment Fence
(Configuration Plan)

Government of the Northwest Territories – Transportation
Description and Purpose

- Consists of rock placed inside wire baskets to protect steep or erodible slopes from sheet flow erosion
- Protects erodible stream channel banks from potentially highly erosive concentrated flow velocities or high friction forces
- Use:
  a) Slope and Banks (mats and baskets)
  b) Single Gabion Drop (Check Dam) Structure for Ditch Channel
  c) Double Gabion "Energy Dissipater" Drop (Check Dam) Structure for Ditch Channel

Applications

- Primarily used as an erosion control.
- Permanent measure
- May be used on stream banks where low flow velocities exist (do not exceed 6 m/s) and are designed by a Qualified Professional.
- May be constructed to 0.5H:1V as a low height slope toe protection structure
- May be used on slopes up to 1.5H:1V as slope protection, a grade break and flow check
- Gabion matting is an alternative to riprap armouring of channels
- May be used to construct dikes or weirs
- Used as a check dam structure to reduce grade between structures and as velocity dissipator in channels
- Used as a splash pad to reduce flow velocity, dissipate flow energy and protect channel or ditchline bed

Advantages

- Relatively maintenance free
- Long lasting and sturdy structure.
- Will conform to shape of base and shift with settlement of the bed material. Lower thickness requirement for gabion (can be 1/2 to 1/3 riprap thickness) compared with riprap thickness for identical severe hydraulic conditions.
- Allows smaller diameter rock material to be used where it would normally be erodible with riprap placement
Gabions (a - c)

Erosion Control

- Gabions are porous, free-draining and flexible so they may be less affected by frost heaving and hydrostatic pressures
- Gabion check structures trap sediment and support plant growth to effect higher channel resistance to flow; however, cumulative build-up of silt may render gabions less effective with diminished height

Limitations
- Construction is labour intensive
- Expensive where rock is not readily available
- Extra costs associated with wire mesh cages and rock

Construction of Gabion Baskets and Mats
- Prepare subgrade at designated gabion location on mineral soil
- Excavate trench a minimum of 0.15 m deep to 'key-in' gabion structure. Construct gabion basket, as per design recommendations
- Line interior of basket with non-woven geotextile OR a gravely sand filter layer (if required by design) along areas where the basket is in contact with soil
  - Geotextile must be non-woven fabric to act as a separator (filter) between rock- and subgrade soils
  - Geotextile is not recommended within stream beds
- Backfill basket with rock with wire bracing at 1/3 points (or 0.3 m spacings)
- Install gabion basket top
- Construct a splash pad of rock or gabion mat underlain with geotextile fabric to reduce erosion on the downslope side of the installed structure.
- Backfill trench and compact soil around edges of completed basket
- Gabion mats are constructed by placing a layer of wire mesh, rock fill on mesh and place top layer of mesh. Attach the top and bottom layer with hooks, wire, or other connector to form a 'blanket'. Blanket mesh may be partially joined and then filled with rock and then closing the opening to secure.

Construction Considerations
- Gabions should be placed on a properly graded surface
- Non-woven geotextile, where included in design, should be used to prevent loss of underlying material and infiltration of fine-grained particles into the gabion structure
Gabions (a - c)
Erosion Control

- Rock in the baskets may be placed by hand to enhance dense packing of stones and decrease void spaces
- Construct gabion baskets with internal wire diaphragms to maintain structural stability and shape and restrict movement of internal rock pieces

**Inspection and Maintenance**
- Inspection frequency should be in accordance with the PESC and TESC Plans and should be inspected after major storm events, especially where undermining at the toe of the gabion is a concern
  - Repair as necessary; including hand grading and/or infilling of undermined areas with lined rocky material
- Timing for the removal of sediment should be determined based on depth of sediment collected, upslope channel erosion and the establishment of vegetation.

**Similar Measures**
- Berms/Barriers
- Check Dams
- Permeable/Synthetic Barriers
- Rock/Brush barriers
- Sand/Gravel Bag Barriers

**Design Considerations**
- The gabion design should include an energy dissipater (i.e. a gabion mat as a splash pad) on the downstream side of gabion drop structure if overtopping of the gabion is anticipated
Government of the Northwest Territories – Transportation

**Typical Ditch Cross-Section**

Front View from Downstream

Typical Ditch Cross-Section
Gabion Basket Ditch Barrier
N.T.S.

**Typical Barrier Spacing**

N.T.S.

<table>
<thead>
<tr>
<th>S (%)</th>
<th>Spacing (d) (m)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>5–7</td>
<td>30</td>
<td>Option to install a grade break (e.g., weave barrier) between structures.</td>
</tr>
<tr>
<td>7–8</td>
<td>25</td>
<td>A double gabion follows every 2 single gabions.</td>
</tr>
<tr>
<td>&gt;8%</td>
<td>≤15</td>
<td>Design by engineer required.</td>
</tr>
</tbody>
</table>

**Table 1**

Notes:
1. Suitable for medium to steep grades and channels leading to water course 4% < S < 10%.
2. i) Spacing to be determined by engineer based on hydraulic conditions.
   ii) Use in conjunction with double gabions or other barrier structures.
3. Soil covering between structures suggested for steep grade soil ditch.
4. This figure is provided for guidance only and does not constitute a design. A site-specific design is required from designer/engineer.

**Gabions**

Single Gabion Drop Structure for Ditch Channel
Berm Interceptor

Description and Purpose

- Earth dike barrier constructed of compacted soil to intercept and divert flow of runoff water away from erodible slopes, sensitive areas or water bodies.
- A spillway outlet of erosion-resistant granular material constructed to allow exit of diverted water to less sensitive areas.

Applications

- Primarily used as an erosion control by diverting water away from the work site. May be used in sediment control by being used for sediment pond construction or directing sediment laden water to sediment ponds.
- Temporary or permanent measure.
- Used instead of, or in conjunction with, diversion ditches.
- Perimeter control.
- Placed along contours and/or at toe of slope to divert run-off from sensitive areas.
- Used to divert water to sediment control structures.

Advantages

- Easy to construct.
- Can utilize on site soil material with a protective lining (e.g., poly sheeting or geotextile fabric).
- Can be converted to sedimentation/impoundment pond with the design of a permeable filter berm at the exit spillway area (see BMP #13).

Limitations

- Earth dike barriers may require design by a qualified person and may be required for earthen barriers in accordance with dam design guidelines and regulatory requirements. The consequences of failure will influence the level of design and construction requirements.

Construction

- Construct barrier from bottom up by placing and compacting subsequent lifts of soil.
- Degree of compaction of each lift to be specified by the design engineer based on consequences of failure.
Berm Interceptor

Erosion Control

B.M.P. #3

Construction Considerations

- The barrier should be trapezoidal in cross-section
- When using soils a protective liner should be used
- Low barriers should have the slopes suited to the construction material used
  - 1.5H:1V for granular soils
  - 2H:1V or flatter for compacted mixed or fine-grained soils

Inspection and Maintenance

- The degree and extent of inspection and maintenance performed on an earth dike barrier is directly related to the consequences of failure. An engineer experienced in embankment design and inspection may be required for design, inspection, design of remedial measures, and supervision of their implementation
- Inspection frequency should be in accordance with the PESC and TESC Plans
- Piping failures may be remedied, under the guidance of the qualified person, by replacing saturated soils with drier compacted soil and/or by placement of geotextile over the failed area and placing a stabilizing toe berm constructed of granular materials
- Inspect a minimum of once per week and remove sediment when depths reach approximately one-half the barrier height, unless instructed otherwise by the designer.
- Deactivate and remove barrier once slope soils have been stabilized and return berm to an acceptable free-draining and stable condition

Similar Measures

- Berms
- Sand/Gravel Bag Barriers

Design Considerations

- Qualified person design may be required for barriers constructed to hold back water (dike).
BERM INTERCEPTOR

TYPICAL LOCATION

NOTES:
1. SILT ACCUMULATION TO BE REMOVED WHEN HALF BERM INTERCEPTOR HEIGHT COVERED.
2. THIS FIGURE IS PROVIDED FOR GUIDANCE ONLY AND DOES NOT CONSTITUTE A DESIGN. A SITE SPECIFIC DESIGN IS REQUIRED FROM DESIGNER/ENGINEER.

Typical Section
BERM INTERCEPTOR

Government of the Northwest Territories – Transportation
Rock Check Dam
Erosion Control

Description and Purpose
- Small check dam constructed of rock pieces placed across steep (3-8% grade) channel
- Decrease flow velocities to reduce erosion caused by storm runoff
- Detain sediment laden runoff to slow water and allow sediment to settle out

Applications
- Primarily used as an erosion control method.
- Temporary or permanent measure
- Suitable in areas where rock is readily available
- Reduces long steep grade to intervals of gentle grades between successive structures
- Reduces flow velocities to decrease erosion potential caused by runoff
- Sediment laden runoff is detained behind structure allowing sediment to settle out
- May be used in channels that drain 4 hectares (ha) (10 acres (ac)) or less
- May be used in steep (3-8% grade) channels where storm water runoff velocity is less than 1.5 m/s (5 fps)

Advantages
- Cheaper than using riprap armouring or gabion structures in a ditch
- Easy to construct

Limitations
- Not appropriate for high flow velocity >1.5 m/sec; (use gabion structures for flow velocity >1.5 m/sec)
- Not appropriate for channels draining areas larger than 4 ha (10 ac)
- Expensive if rock has to be end-hauled to site
- Susceptible to failure if water undermines or outflanks structure

Construction
- Excavate a trench key-in a minimum of 0.15 m in depth at the rock check dam location
- Place non-woven geotextile fabric over footprint area of rock check dam
Rock Check Dam
Erosion Control

- Construct structure by machine or hand
- Structure should extend from one side of the ditch or channel to the other and the outer ends are not higher than the adjacent ground surface
- Structure should be constructed so that centre of the check dam is depressed to form an outlet at the centre which is a minimum of 0.30 m lower than the outer edges
- Height of structures should be less than 0.8 m in height to avoid impounding large volumes of runoff
- Downstream slope of the check dam should be 5H:1V (minimum)
- Upstream slope of the check dam should be 4H:1V (minimum)

Construction Considerations
- Should be designed with roadside design clear zone requirements in mind.
- Height and spacing between structures should be designed to reduce steep channel slope to intervals of gentler gradient
- Rock check structures should be constructed of free draining aggregate or broken rock
- Aggregate used should have a mean diameter ($D_{50}$) of between 75 mm and 150 mm and must be large enough to remain in place during high velocity flow situations. Maximum rock diameter should not exceed 150 mm if the structure is to be used as a sediment trap.
- If rock check structures are to be placed in channels with significant high flows, they must be properly designed for stone size and structure spacings

Inspection and Maintenance
- Inspection frequency should be in accordance with the PESC and TESC Plans
- Remove sediment build up before it reaches one half the check structure height. Store sediment in a stable location with drainage
- Erosion repairs should be made immediately to prevent failure of the structure
- Replace dislodged aggregate immediately with heavier aggregate or gabion structures

Similar Measures
- Synthetic Permeable (Ditch) Barriers
NOT TO SCALE

**NOTES:**
1. Suitable for flow velocity \( \leq 1.5 \text{ m/s} \).
2. Suitable for drainage area \( \leq 4 \text{ ha} \).
3. Suitable for grades from 5% to 8%.
4. Spacing \( d \) and rock size \( (D_{90}) \) to be determined by engineer based on hydraulic conditions.
5. This figure is provided for guidance only and does not constitute a design. A site specific design is required from designer/engineer.

**TABLE:**

<table>
<thead>
<tr>
<th>( D_{90} \text{ of Rock} ) (mm)</th>
<th>Maximum Flow Depth Over Rock (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>75</td>
<td>50</td>
</tr>
<tr>
<td>150</td>
<td>100</td>
</tr>
</tbody>
</table>

**ROCK CHECK DAM**

Government of the Northwest Territories – Transportation
Synthetic Permeable Barrier

Erosion Control

Description and Purpose

- Double panel, low profile, uni-body porous synthetic barriers used to dissipate flow energy and reduce velocity
- Barriers of patented design constructed of lightweight and durable synthetic materials
- May be used to create a grade break to reduce flow energy and velocities allowing some sediment to settle out at the upstream barrier panel of the barrier structure
- Can be used to dissipate flow energy and trap sediment during the period of revegetation; should be removed after successful re-establishment of vegetation

Applications

- Primarily used as an erosion control measure. Trapping of sediment is a secondary effect of slowing the water velocity.
- Temporary structure
- May be placed across trapezoidal (flat bottom) ditch to dissipate flow energy and reduce flow velocities
- Can be used to supplement as grade breaks along ditch section between permanent drop structures along steep ditch grades
- May be used as midslope grade breaks along contours of midslope or at toe of disturbed slopes
- Usually used as grade breaks along ditch (3 to 7% grade) in conjunction with erosion control matting or non-woven geotextile as soil covering mattings; may be used in conjunction with permanent gabion structure (i.e., gabion) at steep grade (+6%) areas

Advantages

- Prefabricated
- Reusable/moveable
- More appropriate for installing at transition areas where there is changing channel gradients to dissipate flow energy, thus minimizing erosion potential
- Provide portable flow control for construction sites, ditches, channels, roads, slopes
- The double panel porous barrier may allow significant energy loss as the flow of water undergoes change from moderate flow to low flow from the upstream panel to the downstream panel with sheet flow resulting downstream and roughly parallel
to the stream bed. Less turbulence and erosion energy may be created in comparison to cascading, over-topping flow from drop structures (i.e., gabions, check structures, straw bales)

- Barriers constructed of UV resistant material may be left in place for final channel stabilization as UV degradation is low
- Biodegradable synthetic option available
- Observed to enhance settling of silt material and may function as a sediment barrier with the formation of an earth berm behind the upstream barrier panel area

**Limitations**

- Not suitable for high flow velocities
- More appropriate for use as a grade break and may be installed between permanent drop structures
- Partially effective in retaining some sediment and reducing flow velocities
- Less sturdy as drop structures in resisting high flow impact
- Not to be designed as drop structures
- Must be hand installed
- Become brittle in cold weather and may be easily damaged by maintenance activities (snow plowing) or by the public
- At the time of deactivation of the structure, metallic anchor pins, if not biodegradable, will require removal Exposure of metallic anchor pin above ground may be a nuisance, may be a human hazard or cause damage to maintenance equipment
- The use of biodegradable (wood) anchor pins is advisable

**Construction**

- Install as per manufacturers recommended installation instructions when available
- Normally installed in conjunction with erosion control matting in ditches and channels
- Prepare soil surface
- Install basal layer of erosion mat or geotextile fabric; key-in basal mat/fabric at upslope end
- Place and anchor barrier panels to basal soils with adequate pin anchors
Synthetic Permeable Barrier
Erosion Control

B.M.P. #6

Construction Considerations

- Maintain direct contact between base of barrier and soil with placement of bottom matting/fabric in direct contact with ground surface
- Ensure the ends of barrier extend to outer edges of channel and to a sufficient height to provide freeboard for channel flow

Inspection and Maintenance

- Inspection frequency should be in accordance with the PESC and TESC Plans
- Remove sediment build-up before it reaches one-half the check structure height
- Do not damage barrier panel during maintenance and removal of sediment
- Partial or non-removal of sediment build-up will create a non-permeable barrier and a low elevation drop structure which will force water flow over top of the barrier. The option of non-removal of sediment may be open to converting the sediment build-up into a "vegetated earth mini-drop structure" along the ditch with the non-removal of the synthetic permeable barrier in-place. This will require topsoil and seeding (or intensive mulch seeding) to promote vegetation growth
- If erosion is noted at the toe or up slope edges of the structure, hand regrading or suitable repairs should be made immediately to prevent failure of the structure
- Remove and deactivate 1 year after vegetation is established

Similar Measures

- Sediment fences or straw bales partially equivalent in retaining sediment

Design Considerations

- Install synthetic permeable barrier along ditch interval between permanent drop structures (i.e., gabions)
- Can be economical alternative and supplemental to (i) total hard armouring of complete channel length, or (ii) high frequency of gabion installation required for high flow applications in steep ditch grade
SYNTHETIC PERMEABLE DITCH BARRIER
N.T.S.

NOTES:
1. FOR USE MAINLY AS A GRADE BREAK STRUCTURE FUNCTIONING AS A FLOW ENERGY DISSIPATOR AND VELOCITY RETARDER.
2. FOR SECONDARY USE AS SEDIMENT BARRIER.
3. REQUIRES NON-WOVEN GEOTEXTILE FABRIC OR BIODEGRADABLE (COCONUT FIBRE PREFERABLE) EROSION BLANKET MAT AT BASE AND KEY-IN TO SOIL AT UPSTREAM END.
4. MAY BE INSTALLED AS GRADE BREAK AT GRADE TRANSITION AREAS TO CREATE DISSIPATION OF FLOW ENERGY AND A MORE LAMINAR FLOW REGIME DOWNSTREAM OF STRUCTURE.
5. THIS FIGURE IS PROVIDED FOR GUIDANCE ONLY AND DOES NOT CONSTITUTE A DESIGN. A SITE SPECIFIC DESIGN IS REQUIRED FROM DESIGNER/ENGINEER.

SYNTHETIC PERMEABLE BARRIERS
**Description and Purpose**

- A barrier of clean straw bales primarily used as a perimeter sediment control measure
- May be used to intercept and detain sediment laden runoff allowing a portion of the sediment load to settle out

**Applications**

- Temporary measure
- Suitable for flow velocities of 0.3 m/s or less
- Usually placed 1 m to 2 m out from the toe of disturbed slopes
- Size of drainage area should be no greater than 0.1 ha per 30 m length of straw bale sediment barrier
- Maximum flow path length upstream of barrier should be less than 30 m
- Maximum slope gradient above the barrier should be no greater than 2H:1V
- May be used in conjunction with filter fabric as external wrap to encapsulate the bales

**Advantages**

- Straw bales are biodegradable. Clean straw minimizes the amount of weed/invasive plant seed and minimizes attraction to livestock and wildlife.
- Only requires one row of straw bales
- Easier to install than other barriers and economical if straw bales are readily available

**Limitations**

- Not appropriate for flow velocities greater than 0.3 m/s
- Susceptible to undermining and erosion damage if not properly keyed into substrate soil or if joints are not completely filled with straw
- Require extensive maintenance following high velocity flows associated with storm events
- Not as robust as some continuous perimeter control structures
- Availability of clean weed-free straw will be limited in most parts of the Territory. Clean straw minimizes the amount of weed/invasive plant seed and attraction to
wildlife and livestock. Do not use hay, as it may contain unwanted seed material and may attract wildlife and livestock.

- Short service life
- Must be installed by hand and must be keyed in (embedded) and staked securely into substrate
- Not to be used on asphalt or concrete covered surfaces
- Maximum straw bale barrier height of one bale or 0.5 m maximum height

Construction

- Straw bale barrier should be located a minimum distance 1.8 m away from the toe of the slope to provide adequate detention and sedimentation area as well as room for maintenance equipment
- Excavate a trench approximately 0.10 m deep with a width of one straw bale at the straw bale barrier location
- Place straw bales in excavated trench along contour, perpendicular to flow direction
  - Ensure twine or wire is not in contact with the soil
  - Ensure straw bale is in continuous contact with base of trench
  - Ends of barrier should be angled upslope to form enclosure to contain runoff
- Fill all joints with loose straw
- Drive two 50 mm by 50 mm wooden stakes 1.2 m long through each straw bale, ensuring each stake is embedded a minimum of 0.15 m into soil
- Backfill and compact the upstream and downstream edges of the structure to secure the straw bales into the subgrade
- Construct a splash pad using non-woven geotextile and angular rock on the downslope side of the check structure to protect the bed from erosion

Construction Considerations

- Maximum lengths of barriers should be 40 m, including ‘J-hook’ or ‘smile’ (similar to sediment fence in BMP #1) configuration to minimize risk of failure
- Barrier should be placed far enough away from toe of slope to provide adequate detention and sedimentation area (minimum of 1.8 m away from toe of slope is recommended) and room for maintenance equipment
- Ends of barriers should be angled upslope (in a ‘J-hook’ or ‘smile’ configuration) to form a pocket to collect runoff
Straw bales should be:
- Machine-made, firm/tight bales
- Weed-free cereal crop straw such as wheat, oats, rye, or barley
- Tightly compacted and bound with two rows of wire or synthetic string and shall show no signs of weathering
- No more than one year old

**Inspection and Maintenance**
- Inspection frequency should be in accordance with the PESC and TESC Plans
- Remove sediment build up before it reaches one half the check barrier height
- Immediately repair visible erosion damage and modify the barrier to prevent failure of the structure
- Watch for undermining, flanking of the structure (water going around) or erosion at overflow point of structure
- Replace damaged, decayed or dislodged straw bales immediately

**Similar Measures**
- Sediment fences
- Continuous Perimeter Control Structures
- Berm Interceptors
SECTION A – A

SECTION B – B

PLAN

NOTES:
1. THE STRAW BALES SHALL BE PLACED ON SLOPE CONTOUR.
2. BALES TO BE PLACED IN A ROW WITH THE ENDS TIGHTLY ABUTTING.
3. KEY IN BALES TO PREVENT EROSION OR FLOW UNDER BALES.
4. THIS FIGURE IS PROVIDED FOR GUIDANCE ONLY AND DOES NOT CONSTITUTE A DESIGN. A SITE SPECIFIC DESIGN IS REQUIRED FROM DESIGNER/ENGINEER.
Rolled Erosion Control Products (RECP)

- Channel Installation
- Slope Installation
- Straw or Coconut Fiber Rolls

Erosion Control

Description and Purpose

- Biodegradable or synthetic fabricated soil coverings used for temporary protection of disturbed soils on slopes and drainages until vegetation can be established
- Natural fibrous organic material (sod) stripped from the site may be utilized to protect soils from erosion if carefully removed and stored. This material may require staking or staked netting to hold it in place
- Categories of rolled erosion control products (RECP) can be:
  - Erosion control blankets (ECB) (generally biodegradable and temporary)
  - Turf reinforcement mats (TRM)
  - Composite turf reinforcement mats (C-TRM)
- RECP may be manufactured of organic material, synthetic material, or as a composite of organic and synthetic materials. There are many different products available with varying qualities, durability and lifespan (e.g. Curlex – wood product; expands to conform to the surface; filters; and is lighter in color to reduce heat).
- RECPs protect disturbed soils from raindrop impact and surface runoff erosion, increase water infiltration into soil, retain soil moisture and decrease evaporation loss
- Protect seeds from raindrop impact, runoff, and birds/animals
- Stabilize soil temperature and increase soil moisture to promote seed germination and enhance vegetation growth

Applications

- Temporary or permanent erosion control measure
- May be used to protect disturbed, exposed soils for cut or fill slopes at gradients of 2.5H:1V or steeper
- May be used on slopes where erosion potential is high
- May be used on slopes where vegetation is likely to be slow to develop
- May be used to protect disturbed exposed soils in ditches and channels (with high flow velocities) by providing additional protective cover while allowing successful high density vegetative growth to become established
Rolled Erosion Control Products (RECP)

a) Channel Installation
b) Slope Installation
c) Straw Rolls

Erosion Control

Advantages

- Erosion protection is higher, more uniform, and longer lasting than sprayed-on products (e.g., mulches)
- Wide range of commercially available temporary (biodegradable) or permanent products

Limitations

- Poor performance of RECP may result from the following:
  - Low density vegetation growth (beneath RECP) due to non-favourable weather and growth conditions (i.e., soil type, moisture, storm events at critical times). The effectiveness of RECP, especially along channels, is very dependent on success of vegetation growth on site. It is important that the designer assess the effectiveness of RECP in accordance with site, soil, terrain and vegetation growth conditions
  - Heaving (lifting) of RECP and the erosion of underlying soils (undermining) can occur under rapid snow melt conditions when melt water gets underneath the RECP or when high flow velocity is created in a narrow channel. This situation can occur along steep channels interlaced with drop structures where the RECP is installed between the check structures. Undermining can occur along un-anchored edges of RECP at upper edges of ditch when snow melt or overland flow occurs at tops of ditch and gets beneath the RECP. This is especially critical when underlying soil is easily erodible (e.g., fine-grained non-cohesive silty soils). It is important to trench-in and anchor the edges of the RECP installations and install anchor pins (staples) at sufficient density intervals (refer to BMP #8 Figures)
  - Ice build-up from groundwater seepage sources can uplift and dislocate the RECP which may cause flow to pass beneath the RECP to erode the substrate soils. Winter ice accumulation may be related to the groundwater regime frozen soils (permafrost or ground ice). Investigative design on subsurface drainage by a geotechnical engineer may be required in these areas.

- Can be labour intensive to install
- Must be installed on unfrozen flat ground
- Temporary blankets may be used for erosion control and require removal before implementation of the permanent measures
- Rolled erosion control products (RECP) are not suitable for rocky sites
### Rolled Erosion Control Products (RECP)
- a) Channel Installation
- b) Slope Installation
- c) Straw or Coconut Fiber Rolls

#### Erosion Control

- Proper surface preparation is required to ensure direct contact between blanket and soil
- Polyethylene sheeting (poly) can be used on sensitive slopes with precautions:
  - Poly sheeting RECP product can be easily damaged, ripped or cut, is non-biodegradable, and proper disposal is required
  - Poly sheeting product results in 100% runoff, thus increasing erosion potential in downslope areas receiving the increased flow volumes
  - Poly sheeting may increase flow velocity and should be used in conjunction with check dam structures on long slopes
  - Poly sheeting should be limited to a temporary covering for sensitive soil stockpiles or small critical unstable slope areas

#### Construction (Slopes)

The following is a general installation method for RECP on slopes:

- Prepare soil surface to make smooth and place topsoil and seed
- Surface must be smooth and free of large rocks, debris, or other deleterious materials. This is a critical step to get the RECP to stay in contact with the soils at all times
- RECP is to be securely anchored at top of slope in a minimum 0.15 m by 0.15 m trench for the entire width of the blanket

The blanket should be rolled out downslope and anchors (pegs) should be placed along central portion of blanket spaced at 4 anchors per m² minimum (0.5 m spacing) for slopes steeper than 2H:1V and 1/m² (1 m spacing) for slopes flatter than 2H:1V

- (1) Where the blanket roll is not long enough to cover the entire length of the slope, a minimum 0.15 m by 0.15 m anchor trench should be excavated at the location of the lap, and the downslope segment of the blanket anchored in the trench, similar to the method used for the top of the slope, or
- (2) When blankets must be spliced down the slope, place blanket end over end (shingle style with approximately 0.10 m overlap). Staple through overlapped area at 0.3 m intervals.

- The upslope portion of blanket should overlap the downslope portion of blanket, shingle style, at least 0.15 m with staple anchors placed a maximum 0.3 m apart
- Adjacent rolls of blanket should overlap a minimum 0.1 m
– Anchors along overlap between adjacent rolls should be placed 0.5 m apart

**Construction (Channels)**

- A RECP should be installed in accordance with the manufacturer’s directions where available

The following is a general installation method for channels:

- Prepare the surface and place topsoil and seed
  - Surface must be smooth and free of large rocks, debris, or other deleterious materials

- Begin by excavating a minimum 0.15 m deep and 0.15 m wide trench at the upstream end of channel and place end of RECP into the trench
  - Use a double row of staggered anchors (‘U’ shaped pegs) approximately 0.1 m apart (i.e., 0.2 m linear spacing) to secure RECP to soil in the base of trench
  - Backfill and compact soil over RECP in trench

- Roll the centre RECP in direction of water flow on base of channel

- Place further rolls of RECP, starting with the upstream RECP over top of the downslope section (shingle style). A minimum 0.15 m overlap of the upper roll over the top of the downslope section is required.
  - Use a double row of staggered anchors approximately 0.1 m apart to secure the RECP to soil
  - Use an anchor channel (excavated trench as above) for the second row of RECP where high flows may be anticipated, ensuring good overlap with upslope RECP section

- Full length (side) edge of RECP at top of sideslopes must be anchored in a minimum 0.15 m deep and 0.15 m wide trench
  - Use a double row of staggered staple anchors a maximum of 0.1 m apart (i.e., 0.2 m linear spacing) to secure RECP to soil in base of trench
  - Backfill and compact soil over RECP in anchor trench

- Overlap RECP on sideslopes (shingle style down channel) and a minimum of 0.1 m over the centre RECP and secure the RECP to soil with anchors spaced a maximum of 0.2 m apart
Rolled Erosion Control Products (RECP)

a) Channel Installation
b) Slope Installation
c) Straw or Coconut Fiber Rolls

Erosion Control

- In high flow channels, an anchor trench across the width of the channel is recommended at a maximum spacing of 10 m to anchor the ends of the RECP to the underlying soil
  - Use a double row of staggered anchors ('U'-shaped pegs) a maximum of 0.1 m apart (0.2 m linear spacing) to secure the RECP to the soil in the base of the trench
  - Backfill and compact soil over the RECP in the anchor trench
- Anchor terminal ends of the RECP in a minimum 0.15 m deep and 0.15 m wide anchor trench
  - Use a double row of staggered anchors a maximum of 0.1 m apart (i.e., 0.2 m linear spacing) to secure the RECP to the soil in the base of anchor trench
  - Backfill and compact soil over the RECP in anchor trench

Construction Considerations

- Slopes should be topsoiled and seeded prior to placing RECP
- Ensure blanket is in direct contact with the soil by properly grading soil, removing rocks or deleterious materials, prior to placing blanket. This is critical to the success of the installation.
- In channels, RECPs should extend above the anticipated high flow height, with a minimum 0.5 m of free board (extra room)
- For turf reinforcement mat (TRM), RECP should be placed immediately after topsoiling
- RECP should be anchored by using wire staples, metal geotextile stake pins, or triangular wooden stakes
  - All anchors should be a minimum of 0.15 to 0.2 m in length
  - For loose or saturated soils, use longer anchors
- RECPs must be placed to run with the direction of flow, without stretching the fabric and maintaining direct contact with underlying soil
- It is essential to understand product specifications and follow manufacturer's instructions on installation methods. These are available from suppliers, and on the Internet. The BMP #8 Figures offer guidance.
Rolled Erosion Control Products (RECP)

a) Channel Installation
b) Slope Installation
c) Straw Rolls

Erosion Control

Product Quality Assurance/Quality Control (QA/QC) Certification

RECPs should be certified by the supplier/manufacturer to ensure product performance and compliance with specified property requirements. A certificate for QA/QC testing of manufactured products is required. The performance and QA/QC testing should be carried out by reputable laboratories to ensure a commonly acceptable QA/QC standard. Dependent on product type and intended performance, the product information certificate should be provided by the product supplier/manufacturer to include the following: Manufacturer's Certificate on:

- Performance specification
  - Permissible Tractive Resistance (include testing methods and vegetative growth conditions)
  - Permissible Flow Velocity (if available)
  - Longevity (for biodegradable or non-biodegradable products)
- Minimum Average Roll Values (MARVs) along with specified testing methods for
  - Physical properties
    - Mass per unit area
    - Thickness
    - Tensile strength
    - UV Resistance
  - Other physical properties (for non-woven below Erosion Mat (if specified))
    - Grab tensile strength
    - Grab elongation
    - Puncture strength
    - Trapezoidal tear
    - UV Resistance

Inspection and Maintenance

- Areas covered with RECPs should be inspected regularly and repaired as required and in accordance with the PESC and TESC Plans. After periods of heavy rainfall or storm events check for RECP for separation or damage
- Any damaged or poorly performing areas should be repaired immediately. Regrading of the slope by hand methods may be required in the event of erosion.
Rolled Erosion Control Products (RECP)

a) Channel Installation
b) Slope Installation
c) Straw or Coconut Fiber Rolls

Erosion Control

- Inspection and maintenance should continue until dense vegetation is established
- Seeded areas should be monitored and areas with low vegetation density should be reseeded
- After approximately one year, a top dressing of fertilizer may be applied to improve vegetation cover and assist degradation of temporary blankets
- Some RECPs contain and embedded seed mix which may be suitable for use. Discuss the seed contained in the product to ensure compliance with GNWT requirements for seeding and invasive species.

Similar Measures

- Re-spreading of natural fibrous organic material (Sodding)
- Mulching (for slopes only)
- Riprap (primarily in channels)
- Gabion mattresses (primarily in channels)

Design Considerations

- Assess hydraulic (water) flow conditions and tractive stress on channel
- In areas which are anticipated to have slow vegetation return (northern areas with short growing seasons and permafrost zones), consideration should be given to covering the site with a layer of dense fibrous organic material, where available
- Assess local soil, weather and growth conditions for revegetation (within 3 to 12 months of the project) to determine if the use of RECP as a protective measure is suitable. If the revegetation conditions are assessed as favourable, the use of RECP can be considered

Discuss the suitability of the RECP product for use on the site with your supplier. Suppliers are key information sources and can provide detailed recommendations suitable to the specific location or site conditions.
ISOMETRIC VIEW

TYPICAL SLOPE SOIL STABILIZATION

NOTES:
1. SLOPE SURFACE SHALL BE FREE OF ROCKS, CLODS, STICKS AND GRASS. MATS/BLANKETS SHALL HAVE GOOD SOIL CONTACT.
2. APPLY PERMANENT SEEDING BEFORE PLACING BLANKETS.
3. LAY BLANKETS LOOSELY AND STAKE OR STAPLE TO MAINTAIN DIRECT CONTACT WITH THE SOIL. DO NOT STRETCH.
4. CHECK SLOTS, STAKING, STAPLING AND OTHER CONSTRUCTION DETAILS PER MANUFACTURER SPECIFICATIONS.
5. THIS FIGURE IS PROVIDED FOR GUIDANCE ONLY AND DOES NOT CONSTITUTE A DESIGN. A SITE SPECIFIC DESIGN IS REQUIRED FROM DESIGNER/ENGINEER.

ROLLED EROSION CONTROL PRODUCTS (RECP) SLOPE INSTALLATION

MATS/BLANKETS SHOULD BE INSTALLED VERTICALLY DOWNSLOPE.
TAMP SOIL OVER MAT/BLANKET
MINIMUM 100 mm OVERLAP
2:1 SLOPE
1 m
1 m
300 mm
150 mm
40 mm
40 mm
1.2 m
300 mm

BERM

STAPLES

NOT TO SCALE

Government of the Northwest Territories – Transportation
Description and Purpose

- Large, machine or hand-placed angular rock or boulders placed along ditchlines, stream channel and banks (e.g. bridge abutments) or on slopes to protect underlying soils from erosion due to flowing water.

- The rock for riprap should be pieces with angular edges of a rock-type and size which will not erode or weather in air or water. The rock should not generate acidic drainage or metal contamination which may need to be confirmed by lab testing.

- Can be used for lined downdrains which pass ditchline or stormwater flows to the base of a slope to prevent erosion of the slope.

- Used as a velocity diffuser for outlets of culverts, sediment pond inlets/outlets and protective barrier for splash pad on permanent check dam structures in ditchlines.

Applications

- Permanent measure.

- May be used on channel banks and slopes with flow velocities ranging from 2 m/s to 5 m/s (dependent on rock size and thickness); appropriate for slopes that do not exceed 2H:1V.

- Riprap may be applied as a lining on the drainage channel from the base to the anticipated flow height (mean annual peak flow) plus freeboard.
  - Other forms of soft armouring (RECP blankets with seeding) can be used to promote vegetation and to protect soils within the channel or on the portion of channel slopes above the riprap.

- Rip Rap should be used in conjunction with a non-woven geotextile underlay or a graded rock which prevents intrusion of fines from the basal soil or erosion beneath the rock structure. Fabric underlay is not recommended for use within the stream channel as it does not permit vegetative growth and can become a hazard if it becomes dislodged.

- For fluctuating high flow channels, the riprap should be underlain by a layer of granular filter material for long-term performance under cyclic drawdown conditions with/without an extra layer of non-woven geotextile as underlay.

Advantages

- Easy to install and repair.

- Very durable, long lasting, and virtually maintenance free.

- Flexible.
Riprap Armouring

a) Slope Protection
b) Channel Protection

Erosion Control

B.M.P. #9
(a & b)

Limitations

- Expensive form of channel lining and stabilization
- Requires heavy equipment and transport of broken rock or coarse aggregate to site
- May not be feasible in areas where suitable rock is not available
- Riprap may have to be placed by hand
- Normally 2 to 3 times riprap thickness is required in comparison with gabion mattress thickness for equivalent protection performance under identical hydraulic conditions
- Use of gabion materials are preferred at flow rates greater than 3 m/s due to larger nominal size of riprap and thickness required for erosion protection during flow velocities of this magnitude
- Can be classified as uniform or graded. Uniform riprap would contain stones which are of a single size range. Graded riprap would contain a mixture of stones ranging from small to large. Graded riprap forms a flexible self-healing cover and may be best for stream channels

Construction

- Grade the slope or channel to final design grade
- Place filter (underlay) layer on prepared slope
  - Filter layer can consist of non-woven geotextile underlay and/or well graded granular material dependent on hydraulic conditions
  - Filter fabric must stay in direct contact with underlying soils to prevent undermining of the structure
- Place riprap layer
- Riprap should consist of a graded mixture of sound, durable, angular stone with at least 50% of the riprap material being larger than 200 mm in diameter. The size range for rock material depends on the flow conditions and may require design by a qualified professional
Riprap Armouring
a) Slope Protection
b) Channel Protection
Erosion Control

- Riprap should be sized according to the following gradation and mass:

<table>
<thead>
<tr>
<th>Nominal Mass</th>
<th>1M</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal Diameter</td>
<td>kg</td>
<td>mm</td>
<td>kg</td>
<td>mm</td>
</tr>
<tr>
<td>Riprap Class</td>
<td>7</td>
<td>40</td>
<td>200</td>
<td>700</td>
</tr>
<tr>
<td>None heavier than:</td>
<td>kg</td>
<td>mm</td>
<td>40</td>
<td>130</td>
</tr>
<tr>
<td></td>
<td>300</td>
<td>450</td>
<td>800</td>
<td>1100</td>
</tr>
<tr>
<td>No less than 20% or more than 50% heavier than:</td>
<td>kg</td>
<td>mm</td>
<td>10</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>200</td>
<td>350</td>
<td>300</td>
<td>1100</td>
</tr>
<tr>
<td>No less than 50% or more than 80% heavier than:</td>
<td>kg</td>
<td>mm</td>
<td>7</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>175</td>
<td>300</td>
<td>200</td>
<td>800</td>
</tr>
<tr>
<td>100% heavier than:</td>
<td>kg</td>
<td>mm</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>125</td>
<td>200</td>
<td>40</td>
<td>200</td>
</tr>
</tbody>
</table>

Percentages quoted are by mass.
Sizes quoted are equivalent spherical diameters, and are for guidance only.

Source: AT Bridge Spec. 2010

- Non-woven geotextile fabric underlay below riprap should meet the following specifications and physical properties or as specified by the designing qualified professional:

| Non-Woven Geotextile Filter Fabric Specifications and Physical Properties |
|-----------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                            | Class 1M, 1 and 2 | Class 3         |
| Grab Strength               | 650 N            | 875 N           |
| Elongation (Failure)        | 50%              | 50%             |
| Puncture Strength           | 275 N            | 550 N           |
| Burst Strength              | 2.1 MPa          | 2.7 MPa         |
| Trapezoidal Tear            | 250 N            | 350 N           |
| Minimum Fabric Overlap      | to be 300 mm     |                 |

Source: AT Bridge Spec. 2010

Construction Considerations

- Riprap should be placed in a uniform thickness across the channel so as not to constrict channel width
- Blasted rock is preferred (if available)
- Riprap layer should be 1.5 to 2 times the thickness of the largest rocks used, 1.5 to 3 times the thickness of the $D_{50}$ material, and not less than 300 mm in thickness
## Riprap Armouring

<table>
<thead>
<tr>
<th>a) Slope Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>b) Channel Protection</td>
</tr>
</tbody>
</table>

### Erosion Control

#### B.M.P. #9

(a & b)

### Inspection and Maintenance

- Inspection frequency should be in accordance with the PESC and TESC Plans
- Periodic inspections to check for erosion of protective material (undermining) or movement of riprap should be conducted at a minimum of once per year following freshet

### Similar Measures

- Rolled erosion control products (RECP) which are well vegetated (not for use at very high flow and high velocity areas)
- Gabion mats/mattresses
TYPICAL SECTION

NOTE:
1. ‘T’ = THICKNESS: THICKNESS SHALL BE DETERMINED BY THE ENGINEER. MINIMUM THICKNESS = 300 mm. (i.e. 1.5x Dso) FOR Dso = 200 mm.

2. THIS FIGURE IS PROVIDED FOR GUIDANCE ONLY AND DOES NOT CONSTITUTE A DESIGN. A SITE SPECIFIC DESIGN IS REQUIRED FROM DESIGNER/ENGINEER.

RIPRAP ARMOURING FOR SLOPE
DESIGN HEIGHT (H), WIDTH AND STONE SIZE SHALL BE DETERMINED BY THE ENGINEER

DESIGN HIGH WATER (DEPTH DEPENDENT UPON FLOW)

MINIMUM 300 mm THICK LAYER OF 50 mm MINIMUM DIAMETER DRAIN ROCK. \( D_{50} = 200 \) mm. LARGER STONE SHALL BE USED DEPENDENT UPON GRADIENT, SOIL TYPE, AND DESIGN FLOW.

TYPICAL SECTION

NOTES:
1. RIPRAP GRADATION AND THICKNESS SHALL BE DETERMINED BY THE ENGINEER IN ACCORDANCE WITH HYDRAULIC CONDITIONS.
2. THIS FIGURE IS PROVIDED FOR GUIDANCE ONLY AND DOES NOT CONSTITUTE A DESIGN. A SITE SPECIFIC DESIGN IS REQUIRED FROM DESIGNER/ENGINEER.

RIPRAP ARMOURING FOR CHANNEL

Government of the Northwest Territories – Transportation
Description and Purpose

- Manufactured 3-dimensional, plastic matting with open cells which may be filled with topsoil or aggregate
- 3-dimensional structure stabilizes cut or fill slopes
- Cells confine topsoil or aggregate and protect the rooting zone while permitting surface drainage

Applications

- Permanent measure
- May be used with granular fill on cut or fill slopes up to a 1H:1V slope
- May be used with granular fill on slopes and in ditches where flow velocities are 3 m/s or less
- May be used as a flexible channel lining with aggregate fill used in cells
- May be used in temporary low-water stream crossing as granular pad for stream fording
- Matting is light, expandable, and easy to transport and place
- May be used in locations where rock is not available for rip rap armouring for some applications
- Use of native rock or granular fill materials reduces costs; local granular fill is preferred

Limitations

- Expensive
- May become brittle and easily damaged in freezing conditions
- Installation can be labour intensive
- Not to be used on slopes steeper than 1H:1V
- Slopes of 1H:1V can be difficult or hazardous to work on

Construction

- Cellular Confinement System mats should be installed in accordance with the manufacturer's directions when available
- The following is a general installation method
  - Slope should be graded to design elevations and final grade
– Rocks or other deleterious debris should be removed from mat location to provide a smooth surface

– Cellular confinement mats (mats) should be installed so that the top of the mat is flush with surrounding soil, extending 0.6 to 1.2 m beyond crest of slope.

– Every second cell along crest of slope should be anchored securely into the soil using ‘J’ pins or other suitable anchoring device

– The mat should be rolled out downslope

– Where the roll is not long enough to cover the entire length of the slope, the downslope section of mat should be butt-jointed to the upslope section and secured using staples, hog rings, or other suitable fasteners

– Adjacent rolls of mat should be butt-jointed and secured using staples, hog rings, or other suitable fasteners

– Anchors are placed at 1 m intervals down the slope
  • Additional anchors may be required to ensure the mat is in direct contact with soil
  • Additional anchors may be required along edges of mat

– Backfilling should start at the crest of the slope and proceed downslope
  • For topsoil, over-fill cells approximately 25 to 50 mm and lightly compact so that top of topsoil is flush with matting
  • For granular fill, overfill cells approximately 25 mm and tamp compact so that top of fill is flush with matting

– Seeding and/or an organic layer should be applied after fill placement

Construction Considerations

- Properly grading the soil surface by removing rocks or deleterious materials and grading to provide a smooth surface prior to installing the matting is required to ensure the mat stays in direct contact with the soil. This is critical to the stability and effectiveness of the structure.

- Mats should be placed running with the direction of flow or from upslope to downslope

- Use only a single layer of mats

- Prepare the site so that the top of the matting ends up flush with the adjacent terrain

- Infill from top of slope ensuring no large piles (<1m height) of fill are placed on the mat which may cause downward movement of the mat.
Inspection and Maintenance

- The area covered with mats should be inspected regularly in accordance with the PESC and TESC Plans. Inspections should be conducted after heavy rain or snow melt events to check for damage or loss of material
  - Any damaged areas should be repaired immediately
  - Areas with material loss should have material replaced and seed reapplied where vegetation is required
- Inspections should continue until soils have stabilized or vegetation is established
  - Areas where vegetation fails to grow should be reseeded immediately
- If matting is broken or damaged, washout of the mat and underlying soils may occur. Should the mat be undermined (material washed out from under the mat) the area should be re-graded and the mat repaired or replaced

Similar Measures

- Rolled erosion control products (RECP)
- Riprap armouring
Energy Dissipators
a) for Culvert Outlets
b) for Troughs at Bridge Headslopes

Erosion Control

B.M.P. #11

Description

a) Hard armour (riprap, gravel, concrete) placed at pipe outlets, in channels, and downstream of check structures to reduce velocity and dissipate energy of concentrated flows (BMP 17a)

b) Standard Drain Trough Terminal Protection Structure\(^1\) generally used at bridge headslopes (BMP 17b)
   - Minimizes erosion at outlet location by dissipating flow energy

Applications

- Permanent measure
- May be used at outlets of pipes, drains, culverts, conduits, or channels with substantial flows
- May be used at slope drain outlets located at the bottom of gentle to steep slopes
- May be used where lined channels discharge into unlined channels
- May be used as splash pad on downstream side of gabions, check structures, berms, or other barriers to prevent erosion caused by overtopping of structure
- May be used at the inlet/outlet of a sediment pond or outlet of a pumping station hose.

Advantages

- Reduces flow energy to protect soils from erosion within a relatively small area

Limitations

- May be expensive if construction materials (riprap, gravel, or concrete) are not readily available
- Small rocks or stones can be dislodged during high flows. Suitably sized rock must be used.
- Grouted (cement) riprap may breakup due to hydrostatic pressure, frost heave, or settlement
- May be labour intensive to prepare and construct
- High flow velocities may require paved outlet structures, stilling basins, plunge pools, drop structures, baffles, or concrete splash pads. High flow velocities will

\(^1\) Alberta Transportation: Specifications for Bridge Construction 2010: Section 9 for details.
require structures designed by qualified professional (QP). Energy dissipators constructed of riprap alone may not be adequate for high flow velocities

Construction

- Construct QP designed structures as per the designer’s instruction.
- For non-QP installations:
  - Grade the area to final design grades and elevations
  - Sub-excavate the energy dissipator location to thickness of energy dissipator
  - Place filtration bedding material on base of excavation
    - Bedding material can be comprised of non-woven geotextile, or well graded sand and gravel, depending on flow velocity or engineering design. Bedding material acts as separating filter between the subgrade and the riprap energy dissipator material
  - Place energy dissipator material (riprap, gravel, concrete) over bedding material
    - Top of energy dissipator should be flush with surrounding grade

Construction Considerations

- Length of energy dissipator ($L_a$) at outlets shall be of sufficient length to dissipate energy. The following rule should be followed for sizing:
  - $L_a = 4.5 \times D$ (where D is the diameter of the pipe or channel at the outlet)
- Width of energy dissipator ($W_a$) at outlets shall be of sufficient width to contain flow and initial splash
  - $W_a = 4 \times D$
- Thickness of energy dissipator ($d_a$) material at outlets shall be of sufficient size and thickness to reduce flow velocity
  - $d_a = 1.5 \times$ maximum rock diameter (with a minimum thickness of 0.30 m)
- Energy dissipator (splash pad, apron) shall be set at a zero (0%) grade and be in alignment with the direction of flow from the outlet
- Bedding (filtration) layer can comprise of either non-woven geotextile (refer to suppliers or engineers for information on suitable thickness) or a minimum of 0.15 m well graded sand and gravel layer
- Energy dissipator should be constructed of well-graded riprap
  - Minimum $D_{50} = 150$ mm. Preferable $D_{50} = 300$ mm
### Energy Dissipators

- **a) for Culvert Outlets**
- **b) for Troughs at Bridge Headslopes**

#### Erosion Control

- Minimum thickness = a) $1.5 \times D_{50}$ or b) 0.30 m to 0.45 m thickness (a or b whichever is greater)

- Energy dissipator shall be designed to accommodate a 10-year peak runoff or the design discharge of the upstream channel, pipe, drain, or culvert, whichever is greater

#### Inspection and Maintenance

- Inspection frequency should be in accordance with the PESC and TESC Plans

- Inspections should be conducted once weekly, following heavy rain or snowmelt events during construction and following heavy rainfall or snowmelt events post-construction at a minimum. Any damage to the structure (undermining or washout) should be repaired immediately

#### Similar Measures

- Gabion mattresses
B) MINIMUM THICKNESS = 300 mm. (i.e. 1.5 x D₅₀) FOR D₅₀ = 200 mm.

SECTION

0.5 x 'D' MIN.

La = 4.5 x 'D' MIN.
'D' = PIPE DIAMETER

PLAN

'D'

50% SHALL BE LARGER THAN 200 mm MIN. DIA.

4.0 x 'D' MIN.

NOTES:
1. 'La' = LENGTH OF APRON. DISTANCE 'La' SHALL BE OF SUFFICIENT LENGTH TO DISSIPATE ENERGY.
2. APRON SHALL BE SET AT A ZERO GRADE AND ALIGNED STRAIGHT.
3. FILTER MATERIAL SHALL BE FILTER FABRIC OR 150 mm THICK MINIMUM GRANED GRAVEL LAYER.
4. FOR PIPE DIAMETER > 600 mm, DESIGN BY ENGINEER IS REQUIRED.
5. THIS FIGURE IS PROVIDED FOR GUIDANCE ONLY AND DOES NOT CONSTITUTE A DESIGN. A SITE SPECIFIC DESIGN IS REQUIRED FROM DESIGNER/ENGINEER.

ENERGY DISSIPATOR FOR CULVERT OUTLET

Government of the Northwest Territories – Transportation
ENERGY DISSIPATOR
FOR SEMI-CIRCULAR TROUGH
DRAIN TERMINAL PROTECTION
FOR BRIDGE HEADSLOPE

GENERAL NOTES
- DIMENSIONS ARE GIVEN IN m. DETAILS ARE NOT TO SCALE.
- PLACING OF BAGGED CONCRETE RIPRAP SHALL START AT THE BOTTOM CENTRE OF THE DISHED AREA AND SHALL PROCEED IN A CONTINUOUS SPIRAL FASHION OUTWARD UNTIL THE ENTIRE DISH IS COVERED. EACH CONCRETE FILLED BAG SHALL LAP OVER THE EDGES OF THE PREVIOUSLY PLACED BAGS.

SOURCE: ALBERTA TRANSPORTATION SPECIFICATIONS FOR BRIDGE CONSTRUCTION DRAWING S-1410-91
- THIS FIGURE IS PROVIDED FOR GUIDANCE ONLY AND DOES NOT CONSTITUTE A DESIGN. A SITE SPECIFIC DESIGN IS REQUIRED FROM DESIGNER/ENGINEER.
# Sediment Traps and Basins

<table>
<thead>
<tr>
<th>a) Riser Outlet Option</th>
<th>b) Permeable Rock Berm Outlet Option</th>
<th>B.M.P. #12</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sediment Control</strong></td>
<td></td>
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</tr>
</tbody>
</table>

## Description and Purpose

- A low height dam or enclosure for impoundment of sediment-laden storm water to promote settling of smaller (silt) size particles
- Used to trap sediment-laden run off and promote settling of sediment prior releasing to enter downslope watercourses
- Constructed by excavating a pond or constructing berms above the original ground surface
- Sediment traps and basins can be divided on size of pond impoundment enclosure
  - Basin (Type I) for pond area ≥500 m²
  - Trap (Type II) for pond area ≤500 m²

## Applications

- Temporary or Permanent measure
- Used at terminal (end) or selected points for containing sediment laden water to promote the sedimentation of silts and larger sized soil particles prior to release downstream or downslope
- Used as a final (last chance) sediment control measure at the perimeter of a construction sites where sediment-laden runoff may enter watercourses, storm drains, or other sensitive areas
- Used where there is a need to control and contain a significant amount of sediment from stormwater due to site disturbance
- Sediment basins (Type I) used for disturbed drainage areas greater than 2.0 ha
- Sediment traps (Type II) used for disturbed drainage areas of 2.0 ha or less
- Where practical, contributing drainage areas should be subdivided into smaller areas and multiple sediment impoundment controls installed. Too much flow into the sediment pond will result in ineffective settling due to overloading of the structure.

## Advantages

- High capacity of runoff containment where an efficient and effective means of promoting sedimentation is necessary along perimeters of construction sites where high risk sensitive environmental areas and watercourses may be impacted
- Accumulated sediment deposits can be cleaned out easily
Sediment Traps and Basins

a) Riser Outlet Option
b) Permeable Rock Berm Outlet Option

Sediment Control

- Can be deactivated easily by breaching the enclosure dike when empty to grade for project completion

Limitations

- Require design by a qualified person (QP)
- Permanent traps and basins should be avoided in areas of permafrost as ponding water increases permafrost melt. Temporary traps and basins should be removed as soon as they are no longer required (in-place no more than one summer season)
- Sediment traps and basins do not remove 100% of the sediment; net efficiency for removal of sediment may be around 50%, dependent on the trap or basin design and nature of surface soil
- Anticipated service life of 3 years or less due to possible clogging of outlets in the long-term
- Sedimentation traps and basins with a riser outlet should have a spillway with adequate erosion protection to permit overflow in the event that the riser pipe outlet clogs during a storm event
- For drainage areas greater than 40 ha, multiple basins may be required
- Efficiency of the sediment pond is very dependent on surface area, duration of water detention, and the suspended particulate size. Sediment ponds require large surface areas and long detention periods to permit settling of fine materials. Erosion protection measures are necessary and sediment controls will be needed to reduce the sediment load in the water entering the pond
- Fences and signage may be required to reduce danger to the public and wildlife
- Ponds must be monitored and the removal of sediment build up (maintenance) is required. The removed material must be placed in a stable suitable area where it is not subjected to water erosion.

Construction

- The consequences of failure for any water retaining structure (pond) will determine the level of effort in the design and construction phases. A qualified professional (e.g. engineer) should be consulted to design water-retaining structures
  - The construction guidelines presented herein are minimum requirements and does not override the QP design criteria. All footprint area for a pond berm should be stripped of vegetation, topsoil, and roots to expose mineral subgrade soils
## Sediment Traps and Basins

**a) Riser Outlet Option**

**b) Permeable Rock Berm Outlet Option**

### Sediment Control

| o Fill material used for the berm should be clean mineral soil with sufficient moisture to allow proper compaction |
| o Fill material should be placed in lifts not exceeding 150 mm in compacted thickness and should be compacted to a minimum of 95% Standard Proctor maximum dry Density (SPD) |
| o The main outlet structure should be installed at farthest possible point from inlet |
| - Outlet should be placed on firm, smooth ground and should be backfilled and compacted to 95% SPD |
| - Proper inlet and outlet protection should be installed to protect from erosion |
| - Outlet pipe should consist of corrugated steel pipe to protect against pinching and blockage unless otherwise recommended by the QP |
| o The embankment should be topsoiled & seeded or protected with rolled erosion control product (RECP), gravel or riprap immediately after construction |
| o Construct an emergency spillway to accommodate flows not carried by the principle outlet |
| - Emergency spillway should consist of an open channel (earth or vegetated) over native undisturbed soil (not fill) where possible |
| - If spillway is elevated, the spillway and the outlet location should be protected with riprap |
| - Spillway crest should be at least 0.15 m below the berm level |

### Construction Considerations

- Preferable to strip to mineral soil only along the footprint area required for dike construction; within the pond floor (centre) area it may be preferred to clear by cutting stumps low but leaving the organic layers intact to minimize erosion and promote sedimentation. For maintenance purposes, a non-woven geotextile fabric should be placed over the organics and used as a liner for the pond area if the pond area is to be returned to pre-disturbance conditions. This should be outlined in the PESC Plan designs.
- Can be constructed by excavating, constructing berms (embankments), or a combination of the two methods.
- Baffles or deflection berms should be provided to increase retention time of flow from inlet to outlet.
Sediment Traps and Basins

a) Riser Outlet Option
b) Permeable Rock Berm Outlet Option

Sediment Control

- Construct sediment ponds and basins where necessary to prevent sediment from leaving the site perimeter or entering environmentally sensitive areas. Ponds should be constructed prior to the wet season and main construction activities
  - Sediment pond bottom should be flat or gently sloping towards outlet
  - Berm slopes should not be steeper than 2H:1V and should be compacted
  - Ponds should be located where:
    - Low berms can be constructed across a swale or low natural terrain
    - Ponds must be accessible to conduct maintenance work, including sediment removal
    - Ponds should be away from permafrost soil areas, where feasible

Inspection and Maintenance

- Regular inspection is required to identify seepage, structural soundness of berm, damage to the outlet or obstruction and the amount of sediment accumulation
- Inspection frequency should be in accordance with the PESC and TESC Plans
- Sediment should be removed upon reaching 1/2 height of the containment berm or within 0.4 m of crest of embankment
- Sediment traps may be deactivated or removed after vegetation has been established in previously disturbed upstream areas

Design Considerations

- The design can consist of (a) a riser outlet option or (b) a permeable rock berm outlet option. (The permeable rock berm outlet option is preferable for highway construction)
- Minimum particle size for riprap rock shall be 200 mm
- If the design of a riser outlet is utilized
  - Main outlet pipe shall be fabricated from corrugated steel pipe conforming to CSA Standard CAN 5-G401-M81 or the latest revision thereof
  - Outlet pipe shall consist of a horizontal pipe welded to a similar vertical riser at a 45 degree mitre joint
  - Close to the base of the riser pipe, a 100 mm diameter hole shall be fabricated and a mesh with 12 mm square openings tack welded over the hole as a screen
  - A similar hole shall be provided along the riser pipe immediately above the elevation of the maximum sediment build-up (usually 0.4 m below crest of berm)
Government of the Northwest Territories – Transportation
Diversion Ditch (Intercept Ditch)

Description and Purpose

- Channels or swales constructed along the crest of slopes to intercept and prevent overland flows from entering areas with bare soil slopes. This diversion will convey runoff away from the slope or construction area and minimize erosion and downslope sediment delivery from overland sheet flow.

- Can be used to direct runoff to slope drains (or downdrains) which carry water from higher to lower slope elevations.

Applications

- Permanent or temporary measure.

- Effective method of intercepting overland flows to avoid flow over exposed slopes and resulting erosion, especially on cut slopes in highly erodible soils (sand and silt).

- Can be used in conjunction with an existing slope drain which was installed down a steep slope.

- May be lined with vegetation, riprap, erosion control blankets, or some other erosion protection measure in order to divert clean water, protect the ditchline base from erosion, and to protect highly sensitive and high risk environmental areas downslope.

- Can be used in conjunction with erosion or sediment control measures, such as check dam structures, diversion into vegetated areas, or permeable synthetic barriers as part of permanent channel design to protect highly sensitive and high risk environmental areas.

Limitations

- Ditch may require design by qualified personnel if flow velocities and/or volumes are large, or if the ditch crosses areas with soil stability conditions.

- Ditch may require lining with riprap, RECP or non-woven geotextile fabric to minimize soil erosion from the concentrated flow.

- Ditch must be graded to maintain adequate depth, and positive drainage to avoid ponding and breaching of channel sides, which may lead to overtopping of the channel and result in downslope erosion.

- Removal of sediment build-up and other ditch maintenance works may be difficult due to limited access in some areas (crest of slopes).

- Ditch may require removal or infilling for reclamation activities on the work site.
Diversion Ditch ( Intercept Ditch)  
Erosion Control  

Construction

- Excavate the diversion ditch a minimum setback distance of 2 m from the crest of the slope. The ditch excavation material can be used to prepare a berm on the downslope side but this must not load the top of slope or add soil to the slope. This may require design by a geotechnical engineer
  - Place and compact excavated soil to form a berm between the crest of slope and the diversion ditch to provide adequate depth (up to 1 m) for the ditch
  - The potential for failure and the consequence of a failure of this berm will determine the level of compaction effort required
  - Sideslopes of the ditch should not be steeper than 2H:1V (depending upon material type)
  - Depth of ditch (from base of ditch to top of berm) should be a maximum of 1 m in depth; width of ditch should be 1 m maximum. If a larger ditch is required, then alternate drainage control measures should be explored
  - Ditch grade should be a minimum of 1% to promote positive drainage and prevent ponding and saturation of soils

Construction Considerations

- Channel should be graded towards nearest natural draw or drainage pipe

Inspection and Maintenance

- Inspection frequency should be in accordance with the PESC and TESC Plans
- Repair any damage or erosion to the ditch base or berm immediately

Similar Measures

- Berms
- Barriers
TYPICAL DIVERSION DITCH

NOTES:
1. THE DITCH BEHIND THE DYKE SHALL HAVE POSITIVE GRADE TO A STABILIZED OUTLET.
2. THE DYKE SHALL BE ADEQUATELY COMPACTED TO PREVENT FAILURE.
3. FOR SENSITIVE HIGH RISK AREAS, THE DITCH SHALL BE STABILIZED WITH TEMPORARY OR PERMANENT SEEDING OR RIPRAP.
4. THIS FIGURE IS PROVIDED FOR GUIDANCE ONLY AND DOES NOT CONSTITUTE A DESIGN. A SITE SPECIFIC DESIGN IS REQUIRED FROM DESIGNER/ENGINEER.

DIVERSION (INTERCEPT) DITCH

Government of the Northwest Territories – Transportation
Riparian Zone Preservation
Sediment Control and Erosion Control

B.M.P. #21

Description and Purpose

- Protection of existing plants and trees adjacent to all natural water bodies (riparian zones) adjacent to and downslope of construction areas
- Existing vegetation acts as an effective vegetative buffer strip as an erosion and sediment control measure

Applications

- Permanent measure
- Existing established vegetation acts as an effective sediment control and erosion control buffer strip to slow runoff flows and allow sediment deposition and the organic matter provides filtration
- May be used along site boundaries to minimize sediment transport off of construction sites despite lack of adjacent watercourses

Advantages

- Existing dense vegetation is more effective than any man-made structures or other methods for erosion or sediment control, however, other forms of sediment and erosion control may be required on construction sites in addition to preserved vegetation zones
- Any vegetation removal along steep valley slopes with highly erodible soil will be detrimental and will contribute to long-term sediment yield; it is important to minimize stripping and strip only the necessary areas within the construction footprint. Preservation of the riparian zone is important to stability (erosion) and sediment control along river valley slopes and along the edges of waterbodies

Limitations

- Preservation of riparian zones may interfere with construction efficiency and access
- Careful planning is required to work around preserved riparian zones
- Too much sediment laden water introduced into one area may cause damage to the vegetation through erosion or through deposits of sediment causing smothering

Construction

- It is highly important to preserve an established vegetative buffer as freshly planted vegetation generally requires substantial growth periods before they are as effective as established riparian vegetation
Wherever possible, retain as much existing vegetation as possible between construction areas and sensitive zones (wetlands, marshes, streams, floodplains, permafrost areas, etc.) to entrap sediment and to minimize sediment transport off of the construction site into the sensitive zones.

Define and delineate those riparian zones to be preserved in the Environmental Management Plan (EM Plan) prior to commencement of construction.

Clearly mark (e.g., easily seen by equipment operators) those riparian zones to be preserved in the field (with construction fencing, survey flagging, spray paint or other highly visible measures) so all construction personnel can immediately identify those areas to be preserved.

Construction Considerations

- Riparian zone reserves must be clearly marked prior to start of construction work to minimize trespassing and to ensure the integrity of the reserved riparian zone is maintained.
- Do not allow equipment to enter areas not necessary for construction purposes.
- Based on site-specific situations, established buffer zones of adequate width may be used to protect these areas.

Inspection and Maintenance

- Inspection frequency should be in accordance with the PESC and TESC Plans.
- Maintain fences or other marking for protecting reserved riparian zones from trespass by equipment or other operations (e.g., hand falling operations).
Crushed Rock Buttress on Cut Slope in Permafrost

Description and Purpose
- This BMP utilizes concepts, suggested designs and construction recommendations from Vinson and McHattie (2009) which should be consulted.

Applications
- In ground ice-rich soil conditions, highway cut slopes should be minimized through road alignment design and grade adaptations.
- Where cuts in ground ice-rich soil will not naturally stabilize through build-up of toe debris, a buttress of crushed rock or coarse aggregate may be placed against the cut slope.
- A buttress may be considered for road cut slopes exceeding 3 m high if engineering, drainage, slope stability, thermal protection and other requirements are met.
- The buttress may be 2.5 m or greater in thickness to facilitate construction by machinery and provide the necessary thermal protection.

Advantages
- 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.

Limitations
- 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.

Construction
- The design of a crushed rock buttress for cut slopes in ground ice-rich permafrost should be completed by a geotechnical engineer familiar with permafrost conditions.
- As continued thermal protection of the ground ice-rich permafrost is required during summer construction season, all personnel, machinery, geotextile, crushed rock...
and other items must be available at site, to allow rapid construction and reinstatement of thermal protection. All construction procedures should be determined and discussed in advance with construction personnel.

- The crushed rock should be of light colour to minimize sunlight adsorption and heating which would be detrimental to permafrost preservation.
- The cut slope should be prepared with the strategy of minimizing the volume and extent of disturbance.
- Any stripped organic or topsoil material should be retained and stockpiled for use in covering exposed sub soil in the cut slope area.
- The cut slope should not be greater than 1H:2V slope and must be designed according to global slope stability requirements and thermal preservation considerations.
- Geotextile sheeting should be placed tight over the cut slope and staked or pinned, to allow installation of the crushed rock buttress and prevent intrusion of fines into the free draining crushed rock material.
- If the natural angle of repose is greater than the buttress angle, then the crushed rock material may not require mechanical compaction and will naturally consolidate in place.

Construction Considerations

- If cold air transfer is required into the rock buttress, the crushed rock material gradation and pore space characteristics should be designed and specified for construction.
- Ramps may be required for construction machinery access at the buttress site.
- Site conditions and availability of equipment will determine if standard design features and construction techniques can be used for the buttress.

Inspection and Maintenance

- The buttress and cut slope will require periodic inspection after snow melt and major rain storms.
- Where crushed rock has been lost from the buttress due to ground ice melting, it should be replaced with similar material.
Gravel Buttress

Blanket of Crushed Rock or Coarse Granular Material

Ice-Rich Permafrost

Geotextile

Cutslope angle will depend on global slope stability analysis

Cutslopes in Ice-Rich Permafrost

Coarse Granular Material

Vinson and McHattie (2009)

Government of the Northwest Territories – Transportation
Controlled Ablation (Melt) of Cut Slope, Containment Ditch and Separation Berm Erosion Control

B.M.P. #23

Description and Purpose

- This BMP utilizes concepts and suggested designs from Vinson and McHattie (2009) which should be consulted.
- It is preferable to design highway alignments in permafrost terrain to minimize extensive cut slopes which disturb dispersed or massive ground ice in surface soils.
- If extensive cuts into soils with ground ice will be required, and the environmental impacts from melt, slope regression and creation of fluidized soils are too large, then changing the highway location and alignment should be considered.
- Where minimal cuts into soils with ground ice are required, consideration should be given to minor relocation of the highway alignment to eliminate cuts completely.

Applications

- The controlled ablation of cut slope BMP is recommended if the cut slope height exceeds 3 m and significant ground ice in fine-grained sediment is present behind the cut slope.

Advantages

- Where no other highway configuration is possible to avoid permafrost with high ground ice, this BMP allows controlled ablation 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.

Limitations

- 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 retrogressive soil failure at the cut slope will require time to come to a slope gradient in equilibrium with water, soil and thermal conditions.
Controlled Ablation (Melt) of Cut Slope, Containment Ditch and Separation Berm Erosion Control

Construction

- The design of a controlled ablation (melt) of cut slope with containment ditch and separation berm in ice-rich permafrost should be completed by a geotechnical engineer familiar with permafrost conditions.

- As thermal protection of the ice-rich permafrost is required during the summer construction season, all personnel, machinery, geotextile, crushed rock, coarse aggregate and other items must be available at site, to allow rapid construction and re-instatement of thermal protection. All construction procedures should be determined and discussed in advance with construction personnel.

- Hand clear the brush and trees in the area beyond the cut slope stake limit to allow controlled ablation of the ground ice in the slope. No machinery must be allowed on the area to be cleared. The cleared area width should be about 1.5 times the cut slope height. If a 3 m cut slope is planned, the hand clearing should extend about 4.5 m back from the cut slope edge. Trees over 0.1 m diameter and brush taller than 1.5 m should be cleared off, and the organic mat and topsoil are preserved intact. Cut tree stumps close to the ground. If the organic mat is thin or expected to break apart when the cut slope retreats back, light-coloured geotextile netting should be installed on the surface and pinned or staked to keep the organic mat together as a sheet and not broken apart.

- Prepare a cut slope as steep as possible to reduce the area of soil disturbance and impact to the natural insulation from surface organic deposits. The slope may be cut up to 1H:4V (nearly vertical) if the geotechnical engineer has determined this.

- Any stripped organic or topsoil material should be retained and stockpiled for use in covering exposed sub-soil in the cut slope area.

- The crushed rock for the separation berm should be of light colour to minimize sunlight adsorption and heating which would be detrimental to permafrost preservation.

- Construct a wide ditch at the cut slope base to capture and drain sloughed soil material. The ditch should be built to allow cleanout of accumulated material, if necessary. If no separation berm is constructed, the ditch should be a minimum of 2.5 m wide. If a separation berm is included, the ditch should be a minimum of 4.5 m wide.
Controlled Ablation (Melt) of Cut Slope, Containment Ditch and Separation Berm Erosion Control

- Construct a separation berm of crushed rock or coarse aggregate to act as a lateral containment feature which will allow drainage of wet, failed soils. The berm should be about 1 m high and about 2 to 3 m wide at the base.

- Sloughed and flowed soil will build up against the berm, to prevent highway ditch blockage and begin to stabilize the slope toe.

- In order that the separation berm has no intrusion of fines from the failed soils, a layer of geotextile should be placed below the berm and wrapped up the top of the berm on the cut slope side, and later covered with further crushed rock or coarse aggregate to protect the geotextile.

- Construct a ditch outside the separation berm and beside the highway for road surface runoff.

- As the ground ice ablates and the wet soil accumulates behind the berm, the organic mat will subside and drape over and shade the cut slope and provide some thermal insulation.

- The sloughed and flowed soil from melt should be retained by the berm and not removed as it serves to buttress the subsiding cut slope.

- The separation berm should be maintained as required, to hold back the soil and allow drainage. No soil should overtop the berm and drainage should be maintained through the berm.

- Additional site drainage requirements may arise which should be referred to the geotechnical engineer. No ponded water should be allowed to accumulate in the ditch which will cause permafrost degradation below.

- Dry seeding of the cut slope and accumulated sloughed sediment using native species may be attempted when the surface is stable.

- The cut slope, separation berm and ditch should be designed so that only minimal maintenance is required. The cut slope and accumulated sediment should be inspected after large rain events.

Construction Considerations

- The gravel buttress technique can be used instead of the controlled ablation technique for cut slopes up to 3 m high.

- Where cut slopes in fine-grained soils with high ground ice content will not self-stabilize through build-up of toe deposits, the insulated thermal blanket technique may be considered.
Where slope height and crushed rock availability make the gravel buttress technique too impractical, the insulated thermal blanket technique may be considered.

Inspection and Maintenance

- The cut slope, the accumulated sediment and the organic mat cover should be inspected after large rain events.
- The organic mat cover should be preserved as a complete layer over the cut slope for thermal protection. If the cover becomes fragmented, additional organic material can be added to complete the organic mat cover.

Design Considerations

- The controlled ablation technique should be designed by a geotechnical engineer familiar with permafrost conditions.
The diagram illustrates a construction technique for areas with ice-rich permafrost. The material includes:

- **Trees Removed**
- **Containment Ditch**
- **Granular Berm**
- **Bypass Ditch**
- **Ground Ice in Mineral Soil**
- **Ice Wedge**
- **Granular Road Prism**
- **Replanted Shrubs**
- **Replanted Grasses, Birch and Willow Trees**
- **Original Profile**
- **Reclaimed and Replaced Organic Material**
- **Redeposited Mineral Soil**
- **Granular Material**
- **Coarse Granular Material**
- **Organic Material**
- **Reclaimed and Replaced Organic Material**

The bypass ditch requires maintenance to allow meltwater and road drainage. The section highlights the process of cutting and replacing organic materials in ice-rich permafrost conditions.
Description and Purpose

- This BMP utilizes concepts, suggested designs and construction recommendations from Vinson and McHattie (2009), which should be consulted.

- Where cut slopes must be prepared for highway construction where the sub-soil has extensive ground ice, an insulated thermal blanket can be installed to assist with preservation of the ground ice through thermal insulation, support of the cut slope, and water drainage.

Applications

- Insulated thermal blanket technique may be used on cut slopes in fine-grained soils with ground ice that will not self-stabilize when disturbed.

- The method can be implemented where gravel buttresses are impractical.

Advantages

- 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 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 slope to reduce ground ice melting and allow water drainage out.

Limitations

- Melting of ground ice is usually progressive, resulting in loss of soil strength and volume, and may cause retrogressive slope failure behind the blanket.

- Climate change with slow increase in average air temperatures 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.
The design of an insulated thermal blanket on cut slopes in ice-rich permafrost should be completed by a geotechnical engineer familiar with permafrost conditions.

As thermal protection of the ice-rich permafrost is required during the summer construction season, all personnel, machinery, geotextile, crushed rock, insulating material, reserved organic materials, and other items must be available at site, to allow rapid construction and re-instatement of thermal protection. All construction procedures should be determined and discussed in advance with construction staff.

Prepare the cut slope with the steepest gradient possible for stability, so that a minimum amount of subsoil with ground ice is exposed.

Remove and retain all surface topsoil and organic material for later use as the top insulating layer.

Install a layer of non-woven geotextile against the cut surface, to prevent intrusion of fines into the thermal blanket material. This geotextile may be pinned or staked down or secured above and draped over the cut surface and the blanket material placed.

Have the insulated thermal blanket material on hand and place this against the slope, creating a layer about 1 m thick perpendicular to the face and thinning slightly upwards.

The thermal blanket material should be crushed rock or large size aggregate obtained locally.

The crushed rock or aggregate may be placed with minimum compaction only if the natural friction angle is larger than the finished slope, (i.e. the material will self-support).

For a finished slope angle of 1.5H:1V, the angle of repose for the material must be greater than 35 degrees (coarse durable angular rock pieces will often maintain a natural slope angle of 45 degrees).

A non-rigid, permeable synthetic insulating layer may be placed over the lower layer at this stage (the choice of insulating layer material will depend on cost, availability and degree of thermal insulation required). The manufacturer's instructions and recommendations on installation and maintenance should be followed.

The reserved organic material should be placed on the slope in a layer at least 0.6 m thick, with a geogrid or natural erosion control net placed over top with pins or stakes to ensure it covers and retains the organic material.
Vegetation should be established on the topsoil or organics by dry broadcast seeding or planting of rooted native plant stock. A vegetation cover will help ensure sunlight is absorbed or reflected before it warms the soil.

**Construction Considerations**

- The thermal blanket material should be light coloured rock to avoid absorbing sunlight and heating and so causing ground ice melt.

**Inspection and Maintenance**

- The insulated blankets should be inspected after snowmelt and after major rain storm events.
- These insulated cut slopes should be inspected at regular intervals and areas with sunken thermal blanket from ground ice loss should be in-filled with further blanket material.

**Design Considerations**

- The insulated thermal blanket technique should be designed by a geotechnical engineer with experience in permafrost terrain.
Cutslopes in Ice-Rich Permafrost

Vinson and McHattie (2009)
Description and Purpose

- Schedule the sequence and timing of construction activities in order to:
  - Efficiently maximize the amount of erosion protection installed (such as topsoiling and seeding) as soon as a portion of grade construction is completed, and
  - Limit the portion of land disturbance from construction compatible with the efficient and achievable rate of erosion control measures constructed.

Incorporate erosion and sedimentation control concerns during the scheduling phase which will minimize the amount and duration of bare soil exposure to erosion elements and ensure erosion and sedimentation control measures are implemented at an appropriate time.

- An operational schedule may be designed during planning stages by the contractor and altered during actual construction to suit variable conditions as these are encountered.

Applications

- Temporary measure

Advantages

- Ensures erosion and sedimentation control issues are identified during the planning stage by the contractor.
- Promotes timely implementation of erosion and sediment control practices.
- Planning for activities to be completed during dry seasons to reduce erosion due to rainfall and sediment transport due to excessive overland flows (avoid flooding periods).
- Planning may avoid fish and wildlife sensitive periods (spawning and nesting).
- Planning to ensure timely mobilization of equipment and labour.
- Plan to have all needed ESC materials on hand when required.
- May be used to minimize bare soil exposure and erosion hazards.
- Promotes efficient utilization of equipment where needed for erosion and sedimentation control on construction projects.
- Promotes the installation of permanent erosion control measures (such as topsoiling and seeding) immediately after completion of each phase to get vegetation establishment underway.
### Scheduling

#### Sediment Control and Erosion Control

- Avoids the cost of costly remobilization if equipment is moved off site and is then required for implementing an erosion control measure.
- Finishes the project as it progresses rather than leaving all of the finish work until the end. Promotes good will, allows erosion and sediment controls to be removed and reduces liability while the labour is on site to do the work. No re-deployment required.
- Promotes good housekeeping

### Limitations

- May not have been accounted for in the bidding and contract finalization or planning stages

### Implementation

- Incorporate a schedule for erosion control and protection structures as part of the overall construction plan
- Determine sequencing and timetable for the start and end of each item, such as clearing, grubbing, stripping, etc., as part of the construction schedule
- Incorporate installation of appropriate erosion and/or sediment control measures in the construction schedule
- Allow sufficient time before construction operations and seasonal rainfall periods to install erosion and/or sediment control measures
- Whenever possible, schedule work to minimize the extent of site disturbance (soil exposure) at any one time
- Incorporate staged topsoiling and revegetation of graded slopes as work progresses
  - Don’t leave all topsoiling and revegetation until the very end of the project
  - Remove un-necessary ESC controls as and when they are no longer needed

### Inspection and Maintenance

- Routinely verify that construction activities and the installation of erosion and sediment control measures are progressing in accordance with the approved schedule
  - If progress deviates from schedule, take corrective action
  - An ESC Plan is a living document and is expected to be updated as required.
- When changes to the project schedule are unavoidable, alter the schedule as soon as practical to maintain control of erosion
Scheduling

Sediment Control and Erosion Control

- If previously unidentified erosion issues occur, install control measures to correct the problem and, if significant, add to the inspection plan and amend the Erosion and Sediment Control Plan.
Stabilized Worksite Entrances

Sediment Control

B.M.P. #26

Description and Purpose

▪ Comprised of a gravel pad located at site access points (entrances and exits) that are used to reduce the amount of sediment carried off construction sites by vehicles

▪ Used within communities to protect stormwater infrastructure, protect city streets and paved highway or linear sections

▪ Collects sediment from vehicle washing and retains sediment on construction site

▪ Should include a water supply to wash off excess soil from vehicles prior to exiting the construction site

Applications

▪ Temporary measure

▪ For use anywhere vehicles enter or exit a construction site and control of sediment is required (paved surfaces, near storm drains)

Advantages

▪ Retains sediment on construction site

▪ Reduces deposition of sediments on public roads which may be carried by runoff into natural watercourses or lakes or stormwater infrastructure

▪ Reduces tracking of sediment down roadways and deposit into stormdrain infrastructure

▪ Reduces creation of dust

Limitations

▪ Measures should be installed to collect the sediment-laden runoff from the gravel pads and keep it on site

▪ Installation of gravel pads may be limited by space constraints

Tire wash facilities may be restricted by lack of suitable water source

Implementation

▪ Install gravel pad at planned entrances and exits to worksite
  – Gravel pad (minimum of 15 m in length) should be of sufficient length to accommodate longest anticipated vehicle entering or exiting the site
  – Width of pad should be sufficient to accommodate the widest anticipated vehicle entering or exiting the site (minimum of 3.6 m in width)
Thick of gravel pad should be a minimum of 0.3 m thick (0.3 m thickness is preferred for linear projects) and should comprise 50 to 150 mm diameter coarse aggregate placed on top of woven geotextile filter fabric

- Install temporary sediment control measures (such as straw bale barriers) to collect the washed off sediment from the gravel pad

**Construction Considerations**

- Should be constructed at all access points to construction sites
  - If impractical to construct at all access points, limit vehicle access to stabilized worksite entrances only
- Entrances located with steep grades or at curves on public roads should be avoided
- Woven geotextile filter fabric should be used as underlay be low gravel pad as a strength requirement and to stop gravel from being impacted into fine soils below
- Install an elevated ridge adjacent to roadway if gradient of the gravel pad is steeper than 2%, sloped towards the roadway

**Inspection and Maintenance**

- Inspection frequency should be in accordance with the PESC and TESC Plans
- Granular material should be regraded when required
  - Material may need to be added to fill large voids to maintain a minimum pad thickness of 0.3 m
- Inspect and clean out downslope sediment control measures as required, (at least once per week) and after periods of significant rainfall
- Material incidentally deposited onto public roads should be removed as soon as the problem is identified
SECTION A - A

NOTE:
USE SANDBAGS, STRAW BALES OR OTHER APPROVED METHODS TO CHANNELIZE RUNOFF TO BASIN AS REQUIRED.

SUPPLY WATER TO WASH WHEELS IF NECESSARY

FLOW

FLOW

FLOW

FLOW

50–75 mm COURSE AGGREGATE MIN. 150 mm THICK

DIVERSION RIDGE

3.5 m MIN.

15 m MIN.

1. THE ENTRANCE SHALL BE MAINTAINED IN A CONDITION THAT WILL PREVENT TRACKING OR FLOWING OF SEDIMENT ONTO PUBLIC RIGHT-OF-WAY. THIS MAY REQUIRE TOP DRESSING, REPAIR AND/OR CLEANOUT OF ANY MEASURES USED TO TRAP SEDIMENT.

2. WHEN NECESSARY, WHEELS SHALL BE CLEANED PRIOR TO ENTRANCE ONTO PUBLIC RIGHT-OF-WAY.

3. WHEN WASHING IS REQUIRED, IT SHALL BE DONE ON AN AREA STABILIZED WITH CRUSHED STONE THAT DRAINS INTO AN APPROVED SEDIMENT TRAP OR SEDIMENT BASIN.

4. FOR HIGHWAY CONSTRUCTION, 300mm THICKNESS OF GRAVEL IS PREFERRED.

5. THIS FIGURE IS PROVIDED FOR GUIDANCE ONLY AND DOES NOT CONSTITUTE A DESIGN. A SITE SPECIFIC DESIGN IS REQUIRED FROM DESIGNER/ENGINEER.
Description and Purpose

- Texturing of slopes, either by roughening the surface, tracking the surface, or installing grooves or benches
- Texturing reduces the runoff velocity, traps sediment and seed, and increases the infiltration of water into the soil

a) Surface Roughening
b) Grooved or Serrated Slope
c) Benched Slope

Applications

- Temporary and Permanent measure
- May be used to roughen the exposed soils on the slope surface, opposite to the direction of water flow, to minimize erosion. May trap a small amount of sediment as a secondary benefit
- May be used on fresh cut or fill slopes (8 m length or longer; practical travel reach of a bulldozer) with gradients of generally 3H:1V or steeper (2H:1V as general steepness limit) constructed in cohesive soils
- May be used on slope subgrade that will not be immediately topsoiled, vegetated or otherwise stabilized
- May be applied to topsoiled slope to provide track serration to further reduce erosion potential and promote water infiltration. May also capture seed which is moved by wind or water
- May be used in graded areas with smooth and hard surfaces to avoid and intercept sheet flow
- As part of slope design, benching (terracing) may be used to effect a reduction in erosion hazard where a long slope length needs to be shortened into smaller section lengths with mid-benches; normally a 3 m wide bench can be appropriate
  - Benching is usually a permanent slope design feature and should only be designed by a qualified geotechnical engineer
  - Benching of a long slope section to divide it into short sections can reduce erosion hazard in the range of 30 to 50% (e.g., sediment yield for 15 m high 3H:1V slope with mid-bench)
Advantages

- Reduces erosion potential of a slope by breaking up steep slope sections
- Texturing will create small ridges to increase surface roughness to reduce overland flow velocities and erosion energy
- Texturing will create minor spaces to entrap a portion of the coarse sediment and reduce amount of sediment transported downslope
- Texturing of slopes will benefit development of vegetation through retaining of water, fines and seeds
- Texturing of slopes aids in performance of topsoiling, addition of mulches and hydrotechnical seeding by reducing soil creep and losses due to overland flows
- Texturing with track-walking up/downslope may effect a 50% reduction of sediment yield compared with an untracked slope

Limitations

- Surface roughening and tracking may increase slope grading costs
- Surface roughening and tracking may cause sloughing in certain soil types (i.e., sandy silt) and in seepage areas. Geotechnical advice is recommended
- Texturing by tracking provides limited sediment and erosion control and should be used in conjunction with other measures and prior to topsoiling to reduce creep on steeper slopes
  - Should be used in conjunction with other erosion and sediment control measures (i.e., offtake ditches, topsoiling and seeding) to limit the sheet flow downslope

Construction

- Surface Roughening
  - Leave soil in rough grade condition, do not smooth graded slopes
  - Uneven surface of the soil will aid in decreasing runoff velocities, will trap sediment, and will increase infiltration of water
- Surface Tracking
  - Use tracked construction equipment to move up and down the slope, leaving depressions opposite (horizontal) to the slope direction; limit passes to prevent over compaction of the surface soils
  - Depressions in the soil will aid in decreasing runoff velocities, trap sediment, and increase infiltration of water
• Grooving
  – Excavate shallow furrows across the width of the slope, opposite to the direction of the slope
  – If used, contour grooves should be approximately 0.1 to 0.2 m in depth
  – Grooves can be made by using equipment or by hand

• Benching
  – Construct narrow, flatter sections of soil on the slope, perpendicular to the direction of the slope
  – Benches should be designed by a qualified geotechnical engineer

Construction Considerations

• During tracking operations, care must be taken to minimize disturbance to the soil where the equipment turns or changes direction

• Minimize the number of tracking passes to 1 or 2 times to avoid overcompaction, which can negatively impact the vegetation growth

• It is practical to track roughen a slope length of greater than 8 m for efficient up/down slope operation of a small bulldozer. It is important to minimize the loosening of soil caused by turning movement of the bulldozer at the end of each pass. As the erosion potential is lower for slopes of low vertical height (<3 m height and 3H:1V slope), the tracking of low slopes is not required and not practical for a bulldozer tracking operation.
"Tracking" with machinery up and down the slope provides grooves that will catch seed, rainfall and reduce runoff.

Tracking

Contour Furrows

Surface Roughening

Grooves will catch seed, fertilizer, mulch, rainfall and decrease runoff.

15 m

150 mm

3

Maximum 1

Government of the Northwest Territories – Transportation
NOTE:
GROOVE BY CUTTING SERRATIONS ALONG THE CONTOUR. IRREGULARITIES IN THE SOIL SURFACE CATCH RAINWATER, SEED, MULCH AND FERTILIZER.

GROOVED OR SERRATED SLOPE

Government of the Northwest Territories – Transportation
**Rolls**

a) Coir Roll  
b) Fibre Roll

### Streambank Stabilization Techniques and Erosion Control

#### Description and Purpose

- Coir rolls are long cylindrical tubes that are composed of interwoven coconut fibres which are bound together with durable coir netting. Coir rolls are particularly applicable for wetland, streambank, and shoreline projects. Coir rolls are most commonly available in 0.3 m diameters and 6 m lengths. These rolls can be linked together to form longer tubes, and are often used in combination with other biotechnical techniques, such as brush layering or live siltation methods or branch staking. Coir logs encourage siltation and wetland/floodplain maintenance.

- Fibre rolls are installed along slope contours as a grade break to reduce erosion potential by reducing overland flow velocities.

- Straw rolls consist of bundled straw (or natural fibre) wrapped in photo-degradable open-weave plastic or natural fiber netting staked into the soil along slope contours as a grade break to reduce erosion potential.

- Live stakes or branches can be installed to anchor the fibre rolls to provide deep rooted vegetation with potential favourable moisture retention provided by fibre roll.

- Fibre rolls may capture sediment, organic matter, and seeds carried by runoff.

#### Applications

- The tough, long-lasting coconut fibres make coir rolls appropriate for wetland, streambank, and shoreline applications. Coir rolls work well when immediate erosion control is needed. Brush layers work well with coir roll applications, adding further stabilization with a live root system, while also providing excellent habitat features. The coir roll provides a base for the brush layer cuttings to be laid upon at an appropriate angle which benefits the growth of cuttings. The cuttings provide further protection from breaking waves and high flows.

- Fibre rolls may be used on slopes stable enough to support vegetation (steep, confined slopes and channel banks with gradients greater than 1H:1V may have low success potential).

- Fibre rolls may be used on long slopes as a grade break to shorten the length of slope between other slope retention features.

- Fibre rolls may be used as grade breaks, where slopes transition from flatter to steeper gradients.

#### Advantages

- The coir material is natural and long lasting (5 to 7 years), and has high tensile strength.
Rolls

a) Coir Roll
b) Fibre Roll

Streambank Stabilization Techniques and Erosion Control

- The coir rolls and fibre rolls accumulate sediment while the plant roots develop. Eventually the coir material biodegrades and the cohesive strength of the root systems and flexible nature of the roots become the primary stabilizing element.

- The coir roll/brush layering combination provides immediate shoreline and streambank protection, with additional benefits of riparian enhancement when the cuttings become established.

- Coir rolls address ecological concerns by encouraging vegetation and small wildlife habitat, and are an alternative to stone revetments or other structural measures.

- The high tensile strength coconut fibres, the fibre netting and the wooden stakes used to anchor the material make up the initial structural components of the system, while plant root and top growth increase the strength and water velocity reduction and sediment capture effects of the structure.

- Fibre rolls can be used on slopes too steep for sediment fences or straw bale sediment barriers.

- In time, the plastic netting will degrade due to the sunlight and straw will degrade and be incorporated into the soil. Natural fiber netting (Bionet™) is also available.

- The primary purpose of fibre rolls is erosion control, however fibre rolls do provide a small amount of sediment control as a secondary benefit.

Limitations

- This technique should be implemented during the dormancy period of the cuttings used for brush layering and staking.

- Coir rolls are relatively expensive.

- Fibre rolls are designed for low sheet flow velocities.

- Fibre rolls are designed for short slopes with a maximum gradient of 1H:1V.

- Fibre rolls may be labour intensive to install.

- Straw rolls have a shorter life span due to natural degradation.
  - Usually only functional for two seasons
  - Susceptible to undermining and failure if not properly keyed into the soil.

- Labour intensive maintenance may be required to ensure rolls are in continuous contact with the soil, especially when used on steep slopes or sandy soils.
Rolls

a) Coir Roll
b) Fibre Roll

Streambank Stabilization Techniques and Erosion Control

Construction

- Determine the annual maximum water elevation
- Mark the water level on a stake driven into the substrate, 0.3 or 0.6 m offshore. Installing the materials and plants at the correct elevation is the most important aspect to assure success of the installation. Determine, on site, where the installation will begin and end.
- Determine soil level by laying a straight cutting on the coir roll with approximately 20% of the cutting sticking out past the roll, and with the basal ends dipping down into the soil.
- Begin installation at the downstream end (if using in a streambank project).
- Prepare the site for installation of coir rolls by removing any large rocks, obstructions or material that may prevent the coir from making direct and firm contact with the soil. Coir rolls must be level, installed along a horizontal contour. Place coir rolls parallel to the stream bank or shoreline. It is very important to key the ends of the coir rolls firmly into the shoreline or stream bank, so waves and flows will not scour behind the rolls and compromise the integrity of the structure.
- Install the coir roll such that 0.05 m of the roll extends above the annual water elevation.
- Adjacent rolls shall be laced together, end-to-end, tightly and securely.
- If using brush layer cuttings, prepare the soil bed behind the installed coir rolls for brush laying. It is important that the bud ends of the live cuttings angle up to some degree from the basal ends. Lay cuttings in this fashion, slightly crisscrossed for additional strength.
- Next, backfill over the cuttings with soil, covering the lower 80% of the branches. At this time, the soil can be leveled and prepared for a soil wrap for additional height and soil stability.
- If simply covering the cuttings with soil, compact slightly and grade slope to appropriate angle. Use water to wash soil in between branch layers.
- If using plant materials, such as container-grown, pre-rooted plant plugs or willow stakes, they should be planted into the coir rolls and through the coir mats and netting.
- To install plant plugs and willow stakes into the coir roll, use a planting iron or pilot bar into the roll and wedge it back and forth to create a hole for the plant. It is extremely important that the root system of the plant be placed below the water.
Rolls
a) Coir Roll
b) Fibre Roll
Streambank Stabilization Techniques and Erosion Control

- Mulch and seed exposed areas with native species
- Prepare the slope face and remove large rocks or other deleterious materials
- Excavate small trenches a minimum of 0.15 m deep and 0.15 m wide across the width of the slope, perpendicular to the slope direction, starting at the toe of the slope and working upwards towards the crest of slope
- Space trenches a maximum of 3 to 8 m apart along the slope incline, with steeper slopes having trenches spaced closer together
- Place fibre rolls into the trenches, ensuring continuous contact between the fibre roll and the soil surface
- Butt-joint adjacent fibre roll segments tightly against one another and lace together
- Use a metal bar to make a pilot hole through middle of the fibre roll a minimum depth of 0.3 m into underlying soil
- Pilot holes should be spaced a maximum of 1 m apart
- Secure fibre roll to soil using wooden stake or other appropriate anchor. Live stakes may be used as alternate anchors
- Place soil excavated from the trench on the upslope side of fibre roll. Seed the soil along the upslope and downslope sides of the fibre roll to promote vegetation growth
- Compact the soil upslope of the fibre roll to minimize undermining by runoff

Construction Considerations

- All work site disturbance should be minimized. Protect any existing plants, when possible, and avoid additional disturbance that can lead to erosion and sedimentation
- Install additional erosion and sediment control measures such as temporary diversion dikes, sediment fences and continuous berms, as needed, before beginning work
- Coir rolls can be used in the stream as a sediment barrier, silt curtain, and/or coffer dam to control sediment while work is being done in the water
- Topsoil should be saved, if possible, and replaced once the subsoil has been removed or regraded. Soil shall be stored away from the water’s edge and it shall be moved to its final location and stabilized as quickly as possible
Rolls
a) Coir Roll  
b) Fibre Roll
Streambank Stabilization Techniques and Erosion Control

- For typical applications at the water’s edge, coir rolls are held in place with a single row of stakes, spaced 0.3 m apart. Stakes may be driven through the netting on the outer edge of the roll. It is very difficult to drive stakes through the high-density rolls, however, a stake can be driven with the help of a pilot hole through the low density part of the coir rolls
- Lacing among the stakes is recommended for coir mats exposed to extreme conditions such as ice, waves, or flooding
- Coir rolls shall be placed along streambanks or shorelines at a height sufficient to protect the bank from flows or waves. Additional coir rolls may be placed above the lower rolls, in a tile-like fashion, to protect the upper shore or stream bank
- Use live stakes in place of wooden stakes for streambank coil rolls
- If the slope soil is loose and uncompacted, excavate a trench to a minimum depth of 2/3 of the diameter of the coir roll
- For steep slopes, additional anchors placed on the downslope side of the coir roll may be required

Inspection and Maintenance
- Inspection frequency should be in accordance with the PESC and TESC Plans
- Check plants to ensure that they have been firmly installed into the soil below the fibre material
- Water plants, if necessary, during the establishment phase
- Check all materials periodically or after major storms to ensure they remain properly secured. Make necessary repairs promptly
- All temporary and permanent erosion control measures shall be maintained and repaired as needed to ensure continued performance of their intended use
- Areas damaged by washout (rilling or gulleying) should be repaired immediately
- Additional stormwater control measures should be considered for erosion (rilling or gulleying) areas damaged by runoff
Government of the Northwest Territories – Transportation
APPENDIX C

CCME WATER QUALITY GUIDELINES

TSS

Clear Flow:

*Maximum increase of 25 mg/L from background levels for any short-term exposure (e.g. 24-hour period). Maximum average increase of 5 mg/L from background levels for longer term exposures (e.g. inputs lasting between 24 hours and 30 days).*

High Flow:

*Maximum increase of 25 mg/L from background levels at any time when background levels are between 25 mg/L and 250 mg/L. Should not increase more than 10% of background levels when background is ≥ 250 mg/L.*

Turbidity

Clear Flow:

*Maximum increase of 8 NTUs from background levels for a short-term exposure (e.g. 24-hour period). Maximum average increase of 2 NTUs from background levels for a longer-term exposure (e.g. 30-day period).*

High Flow or Turbid Waters:

*Maximum increase of 8 NTUs from background levels at any one time when background levels are between 8 NTUs and 80 NTUs. Should not increase more than 10% of background levels when background is > 80 NTUs.*
APPENDIX D

TETRA TECH’S LIMITATIONS ON USE OF THIS DOCUMENT
LIMITATIONS ON USE OF THIS DOCUMENT

1.1 USE OF DOCUMENT AND OWNERSHIP

This document pertains to a specific site, a specific development, and a specific scope of work. The document may include plans, drawings, profiles and other supporting documents that collectively constitute the document (the “Professional Document”).

The Professional Document is intended for the sole use of TETRA TECH’s Client (the “Client”) as specifically identified in the TETRA TECH Services Agreement or other Contractual Agreement entered into with the Client (either of which is termed the “Contract” herein). TETRA TECH does not accept any responsibility for the accuracy of any of the data, analyses, recommendations or other contents of the Professional Document when it is used or relied upon by any party other than the Client, unless authorized in writing by TETRA TECH.

Any unauthorized use of the Professional Document is at the sole risk of the user. TETRA TECH accepts no responsibility whatsoever for any loss or damage where such loss or damage is alleged to be or, is in fact, caused by the unauthorized use of the Professional Document.

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The Professional Document and any other form or type of data or documents generated by TETRA TECH during the performance of the work are TETRA TECH’s professional work product and shall remain the copyright property of TETRA TECH.

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1.2 ALTERNATIVE DOCUMENT FORMAT

Where TETRA TECH submits electronic file and/or hard copy versions of the Professional Document or any drawings or other project-related documents and deliverables (collectively termed TETRA TECH’s “Instruments of Professional Service”), only the signed and/or sealed versions shall be considered final. The original signed and/or sealed electronic file and/or hard copy version archived by TETRA TECH shall be deemed to be the original. TETRA TECH will archive a protected digital copy of the original signed and/or sealed version for a period of 10 years.

Both electronic file and/or hard copy versions of TETRA TECH’s Instruments of Professional Service shall not, under any circumstances, be altered by any party except TETRA TECH. TETRA TECH’s Instruments of Professional Service will be used only and exactly as submitted by TETRA TECH.

Electronic files submitted by TETRA TECH have been prepared and submitted using specific software and hardware systems. TETRA TECH makes no representation about the compatibility of these files with the Client’s current or future software and hardware systems.

1.3 STANDARD OF CARE

Services performed by TETRA TECH for the Professional Document have been conducted in accordance with the Contract, in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions in the jurisdiction in which the services are provided. Professional judgment has been applied in developing the conclusions and/or recommendations provided in this Professional Document. No warranty or guarantee, express or implied, is made concerning the test results, comments, recommendations, or any other portion of the Professional Document.

If any error or omission is detected by the Client or an Authorized Party, the error or omission must be immediately brought to the attention of TETRA TECH.

1.4 DISCLOSURE OF INFORMATION BY CLIENT

The Client acknowledges that it has fully cooperated with TETRA TECH with respect to the provision of all available information on the present, past, and proposed conditions on the site, including historical information respecting the use of the site. The Client further acknowledges that in order for TETRA TECH to properly provide the services contracted for in the Contract, TETRA TECH has relied upon the Client with respect to both the full disclosure and accuracy of any such information.

1.5 INFORMATION PROVIDED TO TETRA TECH BY OTHERS

During the performance of the work and the preparation of this Professional Document, TETRA TECH may have relied on information provided by persons other than the Client.

While TETRA TECH endeavours to verify the accuracy of such information, TETRA TECH accepts no responsibility for the accuracy or the reliability of such information even where inaccurate or unreliable information impacts any recommendations, design or other deliverables and causes the Client or an Authorized Party loss or damage.

1.6 GENERAL LIMITATIONS OF DOCUMENT

This Professional Document is based solely on the conditions presented and the data available to TETRA TECH at the time the data were collected in the field or gathered from available databases.

The Client, and any Authorized Party, acknowledges that the Professional Document is based on limited data and that the conclusions, opinions, and recommendations contained in the Professional Document are the result of the application of professional judgment to such limited data.

The Professional Document is not applicable to any other sites, nor should it be relied upon for types of development other than those to which it refers. Any variation from the site conditions present, or variation in assumed conditions which might form the basis of design or recommendations as outlined in this report, at or on the development proposed as of the date of the Professional Document requires a supplementary investigation and assessment.

TETRA TECH is neither qualified to, nor is it making, any recommendations with respect to the purchase, sale, investment or development of the property, the decisions on which are the sole responsibility of the Client.
1.7 ENVIRONMENTAL AND REGULATORY ISSUES

Unless stipulated in the report, TETRA TECH has not been retained to investigate, address or consider and has not investigated, addressed or considered any environmental or regulatory issues associated with development on the subject site.

1.8 NATURE AND EXACTNESS OF SOIL AND ROCK DESCRIPTIONS

Classification and identification of soils and rocks are based upon commonly accepted systems and methods employed in professional geotechnical practice. This report contains descriptions of the systems and methods used. Where deviations from the system or method prevail, they are specifically mentioned.

Classification and identification of geological units are judgmental in nature as to both type and condition. TETRA TECH does not warrant conditions represented herein as exact, but infers accuracy only to the extent that is common in practice.

Where subsurface conditions encountered during development are different from those described in this report, qualified geotechnical personnel should revisit the site and review recommendations in light of the actual conditions encountered.

1.9 LOGS OF TESTHOLES

The testhole logs are a compilation of conditions and classification of soils and rocks as obtained from field observations and laboratory testing of selected samples. Soil and rock zones have been interpreted. Change from one geological zone to the other, indicated on the logs as a distinct line, can be, in fact, transitional. The extent of transition is interpretive. Any circumstance which requires precise definition of soil or rock zone transition elevations may require further investigation and review.

1.10 STRATIGRAPHIC AND GEOLOGICAL INFORMATION

The stratigraphic and geological information indicated on drawings contained in this report are inferred from logs of test holes and/or soil/rock exposures. Stratigraphy is known only at the locations of the test hole or exposure. Actual geology and stratigraphy between test holes and/or exposures may vary from that shown on these drawings. Natural variations in geological conditions are inherent and are a function of the historic environment. TETRA TECH does not represent the conditions illustrated as exact but recognizes that variations will exist. Where knowledge of more precise locations of geological units is necessary, additional investigation and review may be necessary.

1.11 PROTECTION OF EXPOSED GROUND

Excavation and construction operations expose geological materials to climatic elements (freeze/thaw, wet/dry) and/or mechanical disturbance which can cause severe deterioration. Unless otherwise specifically indicated in this report, the walls and floors of excavations must be protected from the elements, particularly moisture, desiccation, frost action and construction traffic.

1.12 SUPPORT OF ADJACENT GROUND AND STRUCTURES

Unless otherwise specifically advised, support of ground and structures adjacent to the anticipated construction and preservation of adjacent ground and structures from the adverse impact of construction activity is required.

1.13 INFLUENCE OF CONSTRUCTION ACTIVITY

There is a direct correlation between construction activity and structural performance of adjacent buildings and other installations. The influence of all anticipated construction activities should be considered by the contractor, owner, architect and prime engineer in consultation with a geotechnical engineer when the final design and construction techniques are known.

1.14 OBSERVATIONS DURING CONSTRUCTION

Because of the nature of geological deposits, the judgmental nature of geotechnical engineering, as well as the potential of adverse circumstances arising from construction activity, observations during site preparation, excavation and construction should be carried out by a geotechnical engineer. These observations may then serve as the basis for confirmation and/or alteration of geotechnical recommendations or design guidelines presented herein.

1.15 DRAINAGE SYSTEMS

Where temporary or permanent drainage systems are installed within or around a structure, the systems which will be installed must protect the structure from loss of ground due to internal erosion and must be designed so as to assure continued performance of the drains. Specific design detail of such systems should be developed or reviewed by the geotechnical engineer. Unless otherwise specified, it is a condition of this report that effective temporary and permanent drainage systems are required and that they must be considered in relation to project purpose and function.

1.16 BEARING CAPACITY

Design bearing capacities, loads and allowable stresses quoted in this report relate to a specific soil or rock type and condition. Construction activity and environmental circumstances can materially change the condition of soil or rock. The elevation at which a soil or rock type occurs is variable. It is a requirement of this report that structural elements be founded in and/or upon geological materials of the type and in the condition assumed. Sufficient observations should be made by qualified geotechnical personnel during construction to assure that the soil and/or rock conditions assumed in this report in fact exist at the site.

1.17 SAMPLES

TETRA TECH will retain all soil and rock samples for 30 days after this report is issued. Further storage or transfer of samples can be made at the Client’s expense upon written request, otherwise samples will be discarded.