GEOTEAM

Amulsar Gold Project
Surface Water Management Plan

Version 2
June 2016

Revision History

Revision	Date	Details	Prepared	Checked	Approved
V1	February 2016	Draft	Golder Associates UK		
V2	February 2016	Edited to v10	AB		

Plan approved by ____ Date ______________________

Health, Environmental, Safety and Security Manager

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Glossary

ARD	Acid Rock Drainage
BMP	Best Management Practice
BRSF	Barren Rock Storage Facility
CR	Commitments Register
CWP	Construction Work Package
EBRD	European Bank for Reconstruction and Development
EHS	Environment(al), Health and Safety
EIA	Environmental Impact Assessment
ESIA	Environmental and Social Impact Assessment
ESMP	Environmental and Social Management Plan
ESMS	Environmental and Social Management System
Geoteam	Geoteam CJSC
GIIP	Good International Industry Practice
HESS	Health, Environmental, Safety and Security
HLF	Heap Leach Facility
HSEC	Health, Safety, Environment and Community/Social
IFC	International Finance Corporation
Lydian	Lydian International Ltd
MAC	Maximum Acceptable Concentration
MP	Management Plan
MR	Mining Right
NAG	Non-Acid Generating
O&M	Operations and Maintenance
PAG	Potentially Acid Generating
PMT	Project Management Team
PR	Performance Requirement (of EBRD)
PS	Performance Standard (of IFC)
PTS	Passive Treatment System
RA	Republic of Armenia
SAP	Sampling and Analysis Plan
SWMP	Surface Water Management Plan
TSS	Total Suspended Solids
VE	Value Engineering

1 INTRODUCTION

Lydian International Ltd (Lydian) and its wholly-owned Armenian subsidiary, Geoteam CJSC (Geoteam), are developing the Amulsar Gold Project (the Project) in the central part of the Republic of Armenia (RA). The proposed Project will develop the gold deposit via open-pit mining and heap-leach processing using dilute cyanide solution.

A Mining Right (MR) for the Project was granted by the RA government in November 2014. This was based, in part, on the approval of the regulatory Environmental Impact Assessment (EIA) for the Project in October 2014. Some permits also exist for ongoing exploration and development activities with additional permits required for the construction and operation phase. The Project is currently in the early stages of development, with construction activities planned to start during the second quarter 2016 subject to financing.

In parallel with the EIA, an Environmental and Social Impact Assessment (ESIA) was undertaken in compliance with, amongst others, the Performance Standards (PS) of the International Finance Corporation (IFC) and the Performance Requirements (PR) of the European Bank for Reconstruction and Development (EBRD).

In mid-2015, a Value Engineering (VE) and Optimization process was initiated, with Lydian commissioning Samuel Engineering Inc. (Samuel) and other consultants to perform engineering design on several identified VE and Optimization concepts. The objective was to reduce capital expenditure without increasing operating costs or environmental and social impacts. The results from this work done in 2015, which were published in the NI “43-101 Technical Report: Amulsar Value Engineering and Optimization” in November 2015, included reduced capital and operational costs, making the Project more viable in a challenging economic environment.

Changes to the Project design as a result of the VE and Optimisation work have resulted in the need to prepare a revision to the new EIA approved in October 2014 and amend the ESIA completed and disclosed in April 2015. Lydian is in the process of preparing a new EIA and to apply to government for a new MR, both expected for approval in the second quarter of 2016.

The Project is subject to various health, safety, environmental and community/social (HSEC) commitments arising from the ESIA undertaken in compliance with the IFC PS and EBRD PR. The draft final version of the ESIA, denoted v10, was published for public review and comment in February 2016 with a series of public consultation and disclosure meetings planned for March to May 2016. Disclosure of the ESIA is programmed to take place in May & June 2016.

Both the EIA and ESIA make a number of commitments pertaining to the mitigation and management of E&S impacts. These commitments and requirements must be fulfilled as the Project moves forward. To facilitate implementation, all commitments made in the ESIA have been compiled into a full Commitments Register (CR) which will be used by Lydian for tracking purposes throughout the Project. Although many of the commitments apply to E&S management during Project implementation (construction, operation and closure), some apply to the Project design and engineering phase and must be addressed before construction works starts on site. The implementation of many of the commitments depends not only on the actions of full Project team.

E&S commitments are being managed by Lydian and Geoteam using the Environmental and Social Management System (ESMS). The ESMS includes the Management Plans (MPs), such as this one, that detail requirements that Geoteam and its contractors will follow in order to fulfil the Project’s environmental and social commitments. For the purpose of this MP, "Contractor" means any all project participants, such as contractors working in the field on the project including but not limited to drilling contractors, construction contractors, camp service contractors, engineers, fabricators, suppliers, etc. Contractors should implement parts of the plans relevant to their activities, issuing their own management plans in line with the Geoteam ESMS, smaller contractors may fall directly under Lydian's OHSMS and ESMS and subject to specific training in the procedures relevant to the contract.

2 COMMITMENTS

ID	Condition/actions	CR.ID	Monitoring and compliance	Cross references to other MPA	Responsibility
SWMP1	Operational Management Plans for the BRSF, BRSF toe pond, contact water pond and HLF process and storm water ponds will be developed to confirm that there are no discharges to the groundwater environment.	GW13	The plans will be made available for inspection either on site or remotely	N/A	Site Environmental Manager
SWMP2	An Operations and Management Plan (OMP) will be produced that outlines the staff responsibilities, maintenance and inspection schedules and recording of all surface water related infrastructure.		A copy of the Operations and Management Plan and its associated records will be available for inspection on site or remotely.	EMP	Site Environmental Manager
SWMP3	A Sampling and Analysis Plan (SAP) will be produced that outlines the frequency of all water quality inspections and monitoring activities on site.	SW10 ES4	A copy of the Sampling and Analysis Plan will be available for inspection on site or remotely	EMP	Site Environmental Manager
SWMP4	All surface water run-off across exposed soils, where practicable, will be directed towards settlement facilities to remove any unacceptable levels of sediment load prior to being discharged.	BIO30, SL15,SW1	The results from the monitoring procedures required under SWMP 3 will be used to check this requirement. On site visual inspections could also be used.	BMP	Site Environmental Manager
SWMP5	All water discharged from the site will meet the maximum acceptable concentrations (MAC)	SW10, SW7, SW9	The monitoring results produced by the actions contained in SWMP3 will be available for		Site Environmental Manager

	II water quality standards		inspection to check conformance.		
SWMP6	All employees and contractors will be briefed on the requirements of the SWMP		All contractors and staff members to sign a register to confirm that they have received a briefing on controlling water quality. A record of this register will be maintained on site and will be made available for remote inspection.		Site Environmental Manager
SWMP7	Erosion Control measures will be incorporated in to the site design to ensure that no unacceptable levels of erosion or sediment loading occurs.	SW1, BIO32, SL11, SL16	Site working plans will be regularly updated to include details of where measure to control erosion have been incorporated into the site layout. The plan will be available for inspection on site or remotely. On site visual inspections can confirm that the work has been undertaken.	BMP	Site Environmental Manager
SWMP8	All water course crossings will be culverted to avoid sediment loading.	BIO31	Site working plans will be regularly updated, and where applicable will indicate where water crossings have been incorporated noting the size of the culvert used. The plan will be available for inspection on site or remotely. On site visual inspections can confirm that this has been undertaken.	BMP	Site Environmental Manager
SWMP9	All diversion drains and sediments ponds will be designed to manage the 100 year storm event plus a minimum 20% freeboard allowance.	SW13	Site working plans will be regularly produced showing the accurate details of the diversion drains and sediment ponds. The plan will confirm that the		Site Environmental Manager

			capacity of each piece of infrastructure meets the require volume. This plan will be available for remote inspection.		

3 PURPOSE

This Surface Water Management Plan (SWMP) has been prepared for Lydian by Golder Associates (UK) Ltd (Golder) to define how surface water within the Project area will be managed, where required, during the construction and operation of the mine. The SWMP addresses surface water management procedures and application of relevant mitigation measures identified in the ESIA recently undertaken.

The SWMP will apply to all activities being undertaken during the construction and operation of the Project. This current version of the SWMP is focused mainly on the construction phase of the Project based on the description in the NI 43-101 and impact assessment and the mitigation measures identified in the ESIA.

The intended use of the SWMP presented is to develop the concepts for water management at the Project and to aid in project permitting. This report is not to be construed as a project construction plan for bidding purposes, for economic evaluations, or for any other purpose other than those which have been described. In the event that this document is translated into Armenian, the English language version of the document shall be considered the prevailing master control document, and any discrepancy in meaning between English and Armenian versions shall defer to the English language version.

4 SCOPE, BACKGROUND AND CONTEXT

The effective management of surface water runoff during the development of mineral resources at the Amulsar Project is critical to the protection of downstream water resources. The use of hydraulic and sediment control structures as part of the Project's surface water management is intended to achieve the following primary objectives:

- To route runoff to ponds and collection sumps in order to minimise the release of mobilised sediment;
- To minimise natural ground runoff and non-contact water from entering disturbed areas and mixing with contact water;
- To capture contact water runoff from mine facilities, for re-use in the process;
- To treat excess contact water in a passive treatment system (PTS) to Armenian Maximum Acceptable Concentration (MAC) II water quality standards prior to discharge; and
- To minimise erosion of disturbed areas; and, when erosion does occur, to minimise suspended sediment flow to streams.

The project lifecycle includes the following phases:

- A construction phase, where necessary facilities and infrastructure are constructed;
- An operations phase, where mineral resources will be mined and processed; and
- A closure phase, where facilities and infrastructure will be demolished, as appropriate, and project-impacted areas will be stabilised and reclaimed.

This document addresses surface water management requirements through the construction and operations phases. The surface water management requirements and conceptual designs planned to support the closure phase are presented in the Preliminary Mine Reclamation, Closure, and Rehabilitation Plan (Golder, 2015).

During project construction and operations, it is expected that there may be a requirement to revise and optimise the SWMP surface water management concepts and designs to accommodate changing site conditions. As such, the SWMP and any associated implementation or operational plans should be considered "living documents".

This SWMP is structured as follows:

- Section 4: Responsibilities;
- Section 5: Surface Water Management Design Concept;
- Section 6: Construction Phase Surface Water Management;
- Section 7: Operational Phase Surface Water Management; and
- Section 8: Maintenance and Monitoring.

4.1 DEFINITIONS

The following definitions describe concepts referred to in this SWMP.

ARD: Acid Rock Drainage; refers to water flows coming from areas where the natural rock has reacted with air, water and the sulphide minerals occurring naturally in the rock to form acid drainage.

Coir Logs: A large-sized straw wattle (see straw wattle definition).

Contact Water Runoff: Surface water runoff derived from the mining, pit dewatering, potentially acid generating (PAG) waste rock, truck shop facility and heap leach areas.

Dewatering Sump: An excavated depression within a larger depression (such as a mine pit) for the purpose of collecting all surface water within the larger depression so that the collected water can be pumped from the depression and managed appropriately.

Diversion Ditch: An engineered linear excavation designed/constructed to divert surface water runoff from non-impacted areas around or away from potentially impacted areas.

Erosion Mat/ Blanket: Blanket of woven synthetic or natural materials used on slopes to slow surface water flow and minimise erosion.

Fresh Water: Non-contact surface water (see non-contact water runoff definition).

Grouted Riprap: Riprap material (see riprap definition) stabilised/bonded with Portland cement grout.

Impacted Water Runoff: Surface water runoff derived from the haul roads, crushing, conveyor, non-acid generating (NAG) waste rock, and top soil stockpiles that is potentially sediment-laden.

NAG: Non Acid Generating; refers to soil or rock materials that do not have the potential to create acidic surface water runoff due to low levels of sulphide mineralisation.

Natural Ground: Surface area devoid of mineral development or construction activities.

Non-contact Water Runoff: Surface water runoff derived from natural ground, (i.e. areas outside of the disturbed areas of the mine, waste rock, heap leach, and mineral process plant development areas).

PAG: Potentially Acid Generating: refers to soil or rock materials that have concentrations of sulphide minerals that have the potential to weather and create ARD conditions.

Riprap: Rock material with an engineered material size, used to armour water conveyance features (such as ditches) to minimise erosion.

Silt Fence: A temporary barrier to impede sediment transport from small, disturbed areas. The fence consists of filter fabric anchored across the direction of flow and is supported by posts.

Soil: Unconsolidated rock material, containing varying percentages of sand, silt, and clay, as well as generally containing adequate moisture and organic matter to promote plant growth.

Straw Wattles: Manufactured cylinders of compressed straw, typically 200mm to 300mm in diameter and 6.5m to 8m long, encased in nylon or other photo-degradable materials. Typically installed across the base of ditches or along slopes to serve as a filter to catch sediment in surface water runoff.

TSS: Total suspended solids, in surface water, sediment that is suspended within the water and can be transported by water flows. The maximum TSS capacity varies with surface water flow velocity.

Watershed: Drainage catchment area that contributes runoff to a specific surface water catchment feature, such as a natural stream or constructed ditch.

5 RESPONSIBILITIES

Geoteam is responsible for the implementation of this SWMP and for:

- Communicating the requirements of the SWMP to all employees and contractors;
- Ensuring that adequate resources (staff, equipment and budget) are available for the effective implementation of the SWMP;
- Documenting the implementation of the SWMP and particularly the included ESIA commitments; and
- Monitoring, inspecting and auditing the SWMP's implementation, including by contractors.

Specific Responsibilities for Geoteam personnel relating to this plan are as follows:

Project Director	Responsible for ensuring that the Amulsar Project complies with the requirements of this plan. Ensures that designated managers understand their responsibilities and that they have sufficient resources to carry out their functions effectively. Reviews all risk assessments with regard to site works and ensures that any resulting recommendations are duly implemented.
Health, Environmental, Safety and Security Manager	Responsible for monitoring compliance with procedure and developing training and auditing tools that will raise awareness. Ensures that all employees and contractors undergo environmental and health and safety inductions. Ensures that appropriate records and documentation are maintained for all areas of work. Responsible for the preparation, review and update of this management plan in order to ensure its on-going compliance with the requirements of the mine’s license to operate and other applicable RA legislation. Participates in risk assessments. Coordinates audits of site activities. Responsible for liaison with the competent authorities, including periodic/routine reporting and incident notifications. Responsible for dissemination of information and instructions to all staff and contractors regarding activities in compliance with this management plan. Provides suitable training – including emergency response training - on the intent and requirements of this management plan. Training records will be maintained and monitored to ensure that training is updated at regular intervals (e.g. refresher training at least every 6 months). Reports outcomes to the Project Director.
Environmental Manager	Implements this plan and related procedures. Ensures that staff and contractors follow this plan and related procedures, and maintain safe working practices. Monitors and audits the implementation of the plan. Reports on plan implementation to the Health, Environmental, Safety and Security Manager

Heads of Department	Train personnel in this plan and related procedures. Participate in risk assessments. Reporting any unsafe or unsatisfactory conditions to the HESS Manager Initiating incident response actions in accordance with this plan
Contractors	Responsible for reading, understanding, and implementing this management plan within their areas of work and responsibility. Communicate the contents of this management plan to their workforce and provide the necessary training. Ensure that the procedures established in this management plan are complied with by their workers and any subcontractors. Ensure that any environmental incidents are reported and dealt with effectively in accordance with the Incident Reporting and Investigation Procedure. Keep Geoteam fully informed of any site issues related to the management plan or its implementation. Ensure that staff attend compulsory environmental and health and safety inductions or training sessions as required by Geoteam. Report any unsafe or unsatisfactory conditions to the Environmental, Health, Safety and Security Manager.

6 SURFACE WATER MANAGEMENT DESIGN CONCEPT

This section of the SWMP presents the design concepts for surface water management during the construction and operational phases of the Project.

As outlined in Section 3, the primary objectives for surface water management at the Project are:

- To route runoff to ponds and collection sumps in order to minimise the release of mobilised sediment;
- To minimise natural ground runoff and non-contact water from entering disturbed areas and mixing with contact water;
- To capture contact water runoff from mine facilities, for re-use in the process;
- To treat excess contact water in a passive treatment system (PTS) to MAC II water quality standards prior to discharge; and
- To minimise erosion of disturbed areas; and, when erosion does occur, to minimise suspended sediment flow to streams.

The general surface water management design concept to meet these objectives can be considered to comprise four main components, as described in the following sections:

- Segregated capture and routing of non-contact and contact runoff (surface water conveyance);
- Erosion control;
- Sediment trapping in receiving surface water courses; and
- Contact water treatment.

Appendix 1 provides guidance on best management practices (BMP) that will used as a manual to develop appropriate techniques during the detailed Project design, to implement best practice during the construction and operational phases.

6.1 SEGREGATED CAPTURE AND ROUTING OF NON-CONTACT AND CONTACT RUNOFF (SURFACE WATER CONVEYANCE)

The volume of contact water generated will be minimised by diverting surface water runoff from natural areas (non-contact runoff) around Project-impacted areas back to natural drainages downstream of the Project areas. Impacted water (potentially sediment-laden water) from haul roads, crushers, the conveyor, and truck shop will be routed to sediment ponds. The ponds will allow the settlement of suspended sediment in the captured water (i.e. to clarify the water) and will serve as potential water treatment basins, if additional treatment such as flocculation or pH adjustment is required.

Options for surface water conveyance structures include, but are not limited to:

- Upstream diversions to route runoff around disturbed areas and Project infrastructure;
- Engineered culvert crossings to route stream flows below roads;
- Riprap, grouted riprap, or other engineered channel reinforcement to prevent channel scour over erodible subgrade;
- Collection sumps and check dams to reduce sediment concentration in runoff; and
- Sediment ponds to reduce sediment load in runoff downstream of disturbed areas prior to use, treatment (where required) and/or onward discharge.

6.2 EROSION CONTROL

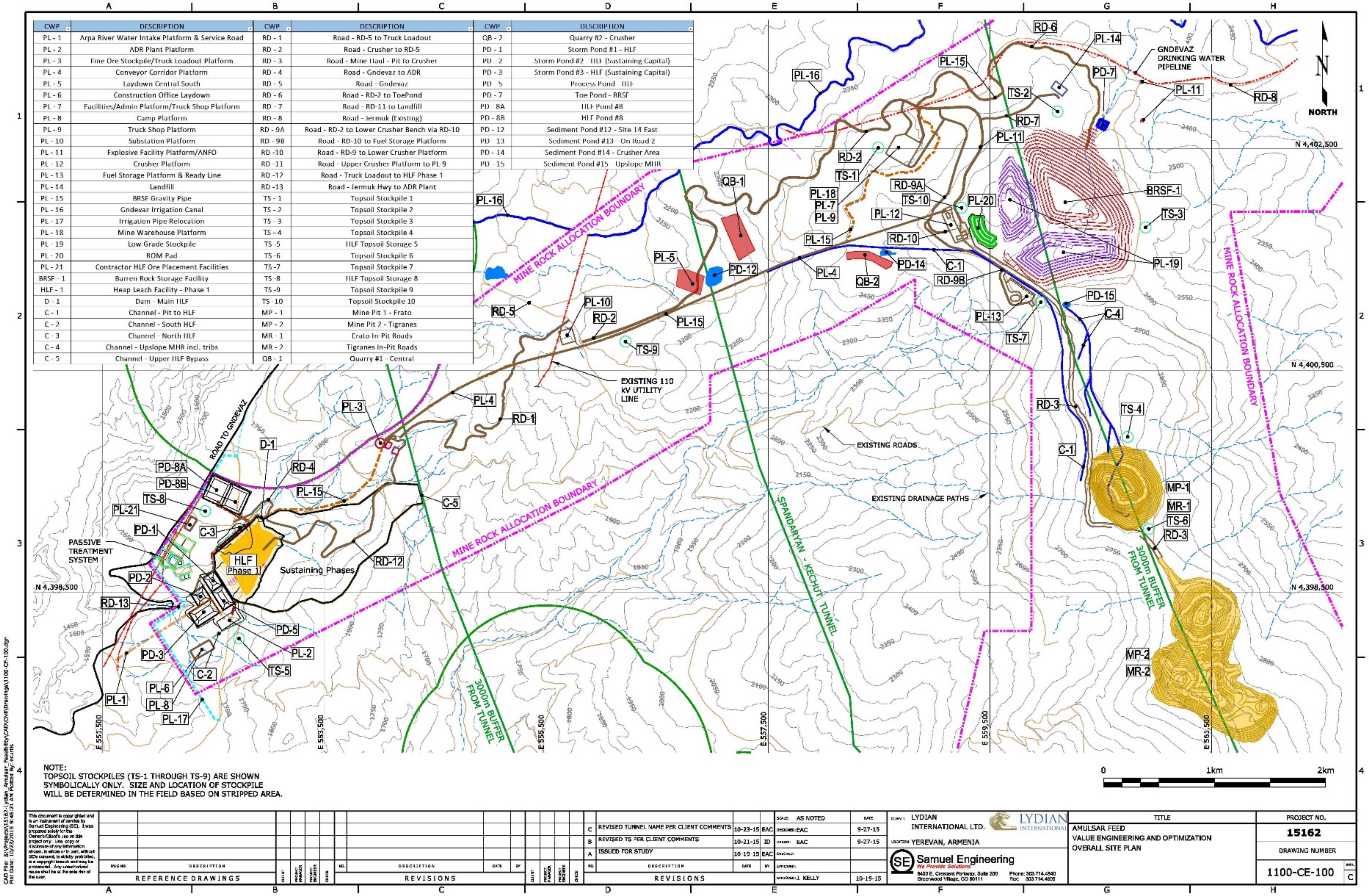
Erosion control measures will seek to reduce erosion and/or to detain the potential sources of sediment at the source areas, minimizing sediment from entering surface water features. Passive storm-water controls will reduce or eliminate suspended fines before they are incorporated into the site surface water runoff, generating sediment-laden water which may subsequently require water treatment effort. Options for erosion control include, but are not limited to the use of silt fences, straw wattles and erosion control mats.

6.3 SEDIMENT TRAPPING

Sediment trapping structures in channels and streambeds will serve to reduce the sediment load that reaches streams and which may be subsequently transported downstream.

The design of Project-specific surface water management structures should be performed and agreed at the detailed design stage of the Project. Structures and measures will be optimised as necessary throughout the life of mine and relocated or replaced as facilities expand throughout operations. This process should be informed by the final mine design and ongoing monitoring and performance inspections outlined in this Plan.

For reference, Lydian has prepared a Construction Work Package (CWP) Map, included as Figure 1 in this SWMP, that provides a description of each planned site facility and corresponding alpha-numeric code that is used throughout this document.



CWP	DESCRIPTION	CWP	DESCRIPTION	CWP	DESCRIPTION
PL - 1	Arpa River Water Intake Platform & Service Road	RD - 1	Road - RD-5 to Truck Loadout	QB - 2	Quarry #2 - Crusher
PL - 2	ADR Plant Platform	RD - 2	Road - Crusher to RD-5	PD - 1	Storm Pond #1 - HLF
PL - 3	Fine Ore Stockpile/Truck Loadout Platform	RD - 3	Road - Mine Haul - Pit to Crusher	PD - 2	Storm Pond #2 - HLF (Sustaining Capital)
PL - 4	Conveyor Corridor Platform	RD - 4	Road - Gndevaz to ADR	PD - 3	Storm Pond #3 - HLF (Sustaining Capital)
PL - 5	Laydown Central South	RD - 5	Road - Gndevaz	PD - 5	Process Pond - HLF
PL - 6	Construction Office Laydown	RD - 6	Road - RD-2 to ToePond	PD - 7	Toe Pond - BRSF
PL - 7	Facilities/Admin Platform/Truck Shop Platform	RD - 7	Road - RD-11 to Landfill	PD - 8A	HLF Pond #8
PL - 8	Camp Platform	RD - 8	Road - Jermuk (Existing)	PD - 8B	HLF Pond #8
PL - 9	Truck Shop Platform	RD - 9A	Road - RD-2 to Lower Crusher Bench via RD-10	PD - 12	Sediment Pond #12 - Site 14 East
PL - 10	Substation Platform	RD - 9B	Road - RD-10 to Fuel Storage Platform	PD - 13	Sediment Pond #13 - On Road 2
PL - 11	Explosive Facility Platform/ANFO	RD -10	Road - RD-9 to Lower Crusher Platform	PD - 14	Sediment Pond #14 - Crusher Area
PL - 12	Crusher Platform	RD -11	Road - Upper Crusher Platform to PL-9	PD - 15	Sediment Pond #15 - Upslope MHR
PL - 13	Fuel Storage Platform & Ready Line	RD -12	Road - Truck Loadout to HLF Phase 1		
PL - 14	Landfill	RD -13	Road - Jermuk Hwy to ADR Plant		
PL - 15	BRSF Gravity Pipe	TS - 1	Topsoil Stockpile 1		
PL - 16	Gndevaz Irrigation Canal	TS - 2	Topsoil Stockpile 2		
PL - 17	Irrigation Pipe Relocation	TS - 3	Topsoil Stockpile 3		
PL - 18	Mine Warehouse Platform	TS - 4	Topsoil Stockpile 4		
PL - 19	Low Grade Stockpile	TS -5	HLF Topsoil Storage 5		
PL - 20	ROM Pad	TS -6	Topsoil Stockpile 6		
PL - 21	Contractor HLF Ore Placement Facilities	TS -7	Topsoil Stockpile 7		
BRSF - 1	Barren Rock Storage Facility	TS -8	HLF Topsoil Storage 8		
HLF - 1	Heap Leach Facility - Phase 1	TS -9	Topsoil Stockpile 9		
D - 1	Dam - Main HLF	TS -10	Topsoil Stockpile 10		
C - 1	Channel - Pit to HLF	MP - 1	Mine Pit 1 - Erato		
C - 2	Channel - South HLF	MP - 2	Mine Pit 2 - Tigranes		
C - 3	Channel - North HLF	MR - 1	Erato In-Pit Roads		
C - 4	Channel - Upslope MHR incl. tribs	MR - 2	Tigranes In-Pit Roads		
C - 5	Channel - Upper HLF Bypass	QB - 1	Quarry #1 - Central		

Figure 1 Project Construction Work Package Map

7 CONSTRUCTION PHASE SURFACE WATER MANAGEMENT THROUGH YEAR 1 OF MINING

7.1 INTRODUCTION

During the construction phase and Year 1 of operations, access and haul roads will be constructed to provide access to mine facilities. In addition, the conveyor and crusher infrastructure will be developed.

Drainage ditches will be constructed and culverts placed, as required, to convey surface water along and under access roads. Diversion channels will be constructed to convey non-contact storm runoff around disturbed areas to the extent practical. Diversion channels will be constructed along haul roads to route impacted runoff to sediment ponds.

Selected surface water management features (such as those listed in Section 5) will be constructed/ installed to minimise erosion in disturbed areas and to minimise the transport of sediment in surface water flows. Specific best practice measures that could be used in the construction phase are discussed further in the following sections.

7.2 ROADS

A main access road, RD-2, entering the Project area from the west, from the existing road from Gndevaz (RD-5) will be constructed to provide off-site access to the mine and plant site area. Also as part of project construction activities, haul roads (RD-3/RD-11) will be constructed from the pit area (MP-1 and MP-2) to the BRSF, truck shop (PL-9), and crushers (PL-12). In addition, a haul road (RD-1) will be constructed from RD-5 to provide access to the truck loadout/fine ore stockpile (PL-3) and the heap leach facility (HLF).

Several other light-duty vehicle roads will be constructed to access project facilities as shown on Figure 1. The locations of temporary construction roads are not defined at this time. Design of water management structures for any additional roads or temporary facilities must be performed as part of the detailed design or included in construction execution plans.

Erosion control measures will be used to minimise erosion and sediment load to surface water derived from areas disturbed by road construction. Silt fencing and/or straw wattles will be used on the up-hill side of road cuts and on the down-hill side of roads. Rock check dams will be used, as needed, in drainage ditches along the road cuts (see Appendix A).

Roadside ditches will be regularly maintained with the road.

7.2.1 Main Access Road

The main access road, RD-2, runs north of the conveyor, roughly east-west, within the Arpa River watershed. The majority of water from the undisturbed drainage area that flows toward RD-2, as well as RD-6 that will be constructed to access the BRSF toe pond, will be conveyed under the roads in a series of culverts. The culverts will be placed at topographic low points along the road and will include best management practices (BMP) at the outlets to dissipate energy, minimize erosion, and allow for water to spread out into overland flow in the natural topography. The BMPs may include rock energy dissipaters at the culvert outlets and straw wattles (see Appendix A).

7.2.2 Light-duty Vehicle Roads

Several light-duty vehicle roads will be constructed for the Project. These roads will be designed to convey runoff to adjacent surface water ditches that are routed to the nearest sediment pond or a combination of BMPs and monitoring to ensure water released to the environment meets regulatory standards. Runoff from the upstream catchment areas, where practical will be diverted and culverts installed under the roads to allow drainage to flow to existing natural drainages. The portion of the runoff along roads RD-2 and RD-1 below Sediment Pond PD-12, though considered non-contact and unlikely to require sediment treatment, will be routed to Pond D-1 located north of the HLF using constructed ditches and natural drainage paths.

Some low-gradient ditches with small contributing watersheds may be soil or grass lined. Many of the roadside ditches will be constructed in rock and will not require additional revetment. Ditches of higher gradient may require rip-rap to prevent erosion where they cross erodible subgrade. Culverts will be required to convey water across switchbacks in the roads so that ditches remain on the 'cut' side of the roads.

7.2.3 Pit Haul Road RD-3 to the Crusher Area

A diversion ditch system (C-4) will be constructed to manage surface water derived from watersheds up-gradient of haul road RD-3 between the Tigranes/Artavazdes (MP-2) and Erato pit (MP-1) areas. Culverts and ditches should be sized to include the entire undisturbed watersheds on the western side of the ridgeline. Impacted runoff will be routed to sediment pond PD-15 to the north of MP-1 and then to PD-14. As the pits develop, the watersheds will decrease in size as runoff from the pit footprint will be internally drained to dewatering sumps and pumped via pipeline for treatment (if required) or consumption in the process circuit.

Runoff from RD-3 to the crusher area (PL-12) will be routed via roadside Channel C1 where it converges with channel C-4 after sediment Pond PD-15. The combined channel, C-1, conveys non-contact water to a sediment pond located southwest of the crusher, PD-14. PD-14 sediment pond allows for solids to settle out of suspension as well `as to provide a primary water source for construction water and dust suppression supply for the roads and crusher. The overflow from PD-14 is primarily conveyed via a pipeline located along the conveyor corridor to sediment pond, PD-12. The 300 mm pipeline is sized to convey the approximated 10 year peak event, with flows in excess of the 10-year peak event conveyed as overland flow along the conveyor corridor. PD-12 serves a dual function as an energy dissipator and water source. PD-12 will be used as a secondary dust suppression water source, or will discharge to a conveyance to the raw water pond (D-1) or discharge to the Gndevaz Reservoir after meeting irrigation water quality standards, depending on the water balance needs of the mine and the water needs of the community.

Water from Benik's Pond will be used for construction water, dust control on haul roads and access roads. The remaining demand not met by the storage in the non-contact water ponds and dams (PD-14, PD12, and D-1) will be supplied by the Arpa River. The Arpa River will provide the early demands of the construction water until the non-contact water ponds are constructed and provide capacity to store water.

It is important to note that water from the Gndevaz Reservoir and associated Gndevaz Channel is viewed as priority water for the Gndevaz community and as such will not be utilized by the Amulsar mine. Should the need arise to utilize some of this water it would only be done once full approval and authorization has been granted to the project.

7.2.4 Crusher Area and Haul Road RD-11 to the Truckshop Area

The portion of haul road RD-11 that connects from the crusher area to the truck shop will have a small ditch that conveys water to the system of ditches that manages water around the truck shop area.

7.2.5 Truck Shop Area to HLF (RD-2 and RD-1)

Access road RD-2 from the Truck Shop area to RD-1 is managed by small roadside ditch that flows to sediment pond PD-12. Beyond PD-12 the flows upslope of the road are conveyed by culverts under RD-2 or RD-1 into natural drainages. Flows considered to be non-contact that flow along the road or in surface water ditches below the road eventually are routed to pond D-1 near the HLF.

7.3 TRUCK SHOP

A truck shop will be constructed on the north-western side of the barren rock storage facility (BRSF). A system of ditches will be constructed around the perimeter of this facility to divert surface runoff away from entering the facility area and back to natural drainage downgradient of the facility. Surface flows in the immediate vicinity of the working area at the truck shop will be routed towards a sump at the wash bay installed at the truck shop to collect contact water. It will be collected in a separate pond and treated if necessary (i.e., oil skimmers). The contact water from the truck shop will be included in the contact water system and used in dust suppression at the crusher facility or conveyed to the contact water pond (PD-8) located near the HLF. Details of the conveyance system will be determined in the detailed design for the truck shop contact water.

7.4 CRUSHERS

7.4.1 Primary Crusher

The primary crusher areas will be drained by ditches that run along berms that enclose the facility. Culverts will be required to convey this water to ditches along the upstream side of the light-duty vehicle road that connects the primary and secondary crusher.

7.4.2 Secondary Crusher and Surge Pile

Light-duty vehicle roads that run around the surge pile will collect runoff from the surge pile and roads. A culvert will allow water from the light-duty vehicle roads to enter the diversion ditch that runs along the perimeter berm of the secondary crusher. The ditch will convey this water along with runoff from the secondary crusher to a concrete/grouted rip-rap ditch that runs down the hillside to a sediment pond (PD-14).

7.5 CONVEYOR AND STOCKPILES

A ditch will run the entire length of the conveyor corridor. As this collection occurs upstream of the Gndevaz Reservoir, it is assumed that this water will require sediment treatment and therefore is routed to PD-12 and D-1. If it is determined that this water is suitable for offsite release for use as irrigation water, water can be released at natural drainage intersections along the conveyor corridor. Where the alignment of the conveyor drainage ditch passes over steep topographic gradients, concrete lining should be installed to limit bed scour.

7.6 OTHER MINE FACILITIES

Additional infrastructure at the site includes the transfer station at the approximate mid-point of the conveyor and the stockpile at the end of the conveyor. A small diversion will be built upstream of the transfer station to divert non-contact water around the facility and to a natural drainage. Another small diversion will be built along the downstream perimeter of the stockpile area and convey water to a natural drainage that leads to D-1.

8 OPERATIONAL PHASE SURFACE WATER MANAGEMENT

8.1 INTRODUCTION

Key changes to the Project infrastructure and associated surface water management features as the Project moves into its operational phase are limited to the area around the pits, as outlined in the following sections. However, existing features and measures should be reviewed and optimised and additional features and measures implemented across the Project area where necessary during the operational phase, based on performance and conditions encountered.

8.2 YEAR 1 - YEAR 3 PERIOD

Following Year 1, the haul roads internal to the Tigranes/Artavazdes pits (MR-2) will migrate to accommodate the expanding pit footprint. As this occurs, drainage ditches upgradient of those haul roads will be abandoned, and new ditches will be required along the new haul road alignment. These ditches will route surface water to the main Haul Road channel, C-1, where flows will be routed along roadside ditches uphill of RD-3. Culverts will be required to convey water along switchbacks where the haul road is expanded at the southern end of the pit.

8.3 YEAR 3 - YEAR 5 PERIOD

During this period, mining of MP-1 will commence. RD-3 will have been constructed as part of the initial mine development and only those flows for surface water upslope of internal Erato pit haul roads will require diversion back to C-1. The flows will be diverted in the roadside ditches along RD-3 towards the PD-15.

8.4 YEAR 5 - END OF MINE LIFE

After Year 5, there are no major changes to the haul road and infrastructure layout and therefore, the existing system of culverts, ditches, and sediment ponds will not require further significant alteration associated with the evolving Project layout. Some existing culverts and ditches will become obsolete as the pit footprint expands and more water is handled by the pit dewatering system.

9 MAINTENANCE AND MONITORING

9.1 INTRODUCTION

During the life of the Amulsar Project, it will be necessary to perform maintenance of surface water management features and conduct monitoring to ensure the effectiveness of the surface water management measures employed.

This section frames the maintenance and monitoring requirements under the SWMP.

9.2 MAINTENANCE

Integral to the Project's operational phase will be the ongoing maintenance of surface water management features to meet the needs of expanding facilities and the conditions experienced on site; and to ensure as far as possible the safe operation of the Project with minimal environmental and social impacts.

Maintenance activities include but are not limited to:

- Visual condition assessment of all surface water management structures,
- Regular inspection of the integrity gravity pipe (PL-15 in Figure 1) which connects between the BRSF and the HLF.
- Dredging of sediment ponds;
- Maintaining erosion and sediment control BMPs
- Removal of sediment, detritus and other blockages from drainage ditches, channels and culverts; and
- Repair or replacement of damaged structures.

An Operations and Maintenance (O&M) Plan will be prepared to include the following:

- Staff responsibilities;
- Inspection and maintenance schedules for all surface water management features (including inspection frequencies);
- Maps, plans and/or diagrams of maintenance locations;
- Records of all inspections and maintenance work carried out;
- Logistics pertaining to supplies required by the SWMP;
- Staff training requirements and records;
- Method Statements for maintenance activities; and
- Health, Safety and Environment protocols for inspection and maintenance activities.

9.3 MONITORING

Environmental (surface water) monitoring related to the SWMP will contribute to the Project's Environmental Monitoring Plan (EMP) which is a wider programme that will be undertaken to monitor the Project's environmental impact. For the purpose of this SWMP, a 'SWMP Monitoring Programme' is referred to in order to identify priority monitoring activities pertinent to the effectiveness of the Project's surface water management. However, it is recognised that as project planning and development proceed, monitoring elements necessary for the range of Project monitoring goals can be consolidated where redundancies exist, and the SWMP-targeted monitoring will be integrated within the EMP. The

Sampling and Analysis Plan (SAP) will form part of the EMP but, by necessity will be prepared as part of the detailed design, to take account of sampling and gauging points.

Monitoring activities in relation to the SWMP will begin during the construction phase and will continue through the operational period. Monitoring requirements during the Project's closure phase will be addressed in future revisions of the Mine Reclamation, Closure and Rehabilitation Plan as the facility closure designs are advanced beyond the preliminary stage.

9.3.1 SWMP Monitoring Network

There are four main categories of SWMP monitoring points, as described in the following sections:

- Surface water diversion and culvert monitoring;
- Surface water flow monitoring;
- Sediment pond monitoring; and
- Discharge water quality monitoring.

9.3.1.1 Surface Water Diversion and Culvert Monitoring

Surface water diversions require monitoring if they are to be properly maintained and if they are to perform correctly. The surface water diversions, pipelines, outlet structures, and culverts must be observed and monitored particularly during spring runoff and following extreme precipitation events. Although many channels are designed to be self-cleaning, sediment accumulation can occur and must be removed. Channel lining materials must be maintained, and repaired following erosion or storm damage. Well-designed culverts can fail when clogged with grass, branches, or trash.

9.3.1.2 Surface Water Flow Monitoring

Flow rates in receiving surface water features must be monitored to detect changes in baseflow resulting from modifications to catchment runoff. Instrumented flow measurement structures (such as weirs) are recommended and preferred, but the mine may also utilise manual readings of surface water flow to determine how the mine and the climate are impacting surface water flow across the Project area.

9.3.1.3 Sediment Pond Monitoring

The sediment ponds must be monitored to determine when sufficient sedimentation has occurred to permit discharge and, if necessary, to determine flocculation requirements. The ponds must be operated in a manner that allows for sufficient residence time for sedimentation, and they must have sufficient operational storage to capture extreme storm events. If flocculants are necessary monitoring will be required to ensure that the sediment control system functions as designed. Finally, the ponds must be inspected for geotechnical issues, particularly after extreme weather or earthquake events.

9.3.1.4 Water Quality Monitoring

The water quality discharging from the sediment ponds must be frequently monitored for total suspended solids, and occasionally for other potential contaminants. The mine will work with local regulators to determine the agreed sampling methods and frequency prior to finalisation of the SAP.

9.3.2 Supplementary Monitoring

A meteorological station will be installed at a point near both the BRSF and the pits. Data produced by the meteorological station will be supplemented by measurements of snowpack depth and density at widely distributed points on and near the BRSF and around the pits. This information will be an important element in assessing the surface water management requirements of the Project because snowmelt is the primary source of spring runoff.

9.3.3 Monitoring Schedule

A monitoring schedule will be developed that will specify the sampling and measurement frequencies applicable at each monitoring point. Some points may be monitored on a quarterly basis, some on a monthly basis. In some cases, continuous monitoring may be done using continuous measurement devices. In those cases, a schedule will be developed to specify the frequency of downloading the continuously collected data and calibrating the equipment.

For some parameters (such as runoff volumes measured manually from facility surfaces), some form of event-based monitoring may be adopted. In such cases, high-frequency monitoring may be triggered at a particular set of monitoring points when high rainfall or other occurrences makes this appropriate. The final version of the plan will define when such monitoring should be undertaken, and when each high-frequency monitoring event may cease. The SAP will discuss the monitoring schedule in detail.

9.3.4 Sampling Procedures

Industry-practice best operating procedures will be adopted for sampling and analysis. Sampling and analysis will be guided by a compendium of standard operating procedures, which will be developed as the Project proceeds. These procedures will be based on industry-standard procedures, but will be adapted as appropriate for the project site. The SAP will provide detailed sampling procedures.

9.3.5 Data Storage

A system will be devised for the systematic and methodical capture and storage of all data generated by the SWMP monitoring programme, to include quality control and assessment of data input. This will include a standard filing system for storage of paper records, and a well-designed database to store all electronic data. The filing system and database will be designed to meet the needs of the larger environmental monitoring program, but will still accommodate querying of water-specific data on demand.

9.3.6 Reporting

Results of SWMP-related monitoring will be reported on a regular basis (suggested quarterly). The report will document the sampling rounds conducted during the monitoring period. The report will confirm that the sampling and analysis was carried out according to specified procedures and will include an explanation of any deviations from established protocols. It will present data collected during the monitoring period, including graphs of trends and basic analyses. If trends are identified that would violate an action level if the trend continued, the report will highlight the trend and include recommendations on how to proceed.

An annual report will be prepared, which will include more extensive analysis of the data collected over the entire period. In addition to considering trends and their meaning, the report will include recommendations on any modifications that should be made to any aspect of surface water management. This could include changes to operations, modifications of cover design, or changes in the monitoring network, sampling schedule, or parameter list. The report will include summary documentation of instances where action levels were surpassed during the prior year, with description and justification of the resulting actions.

9.3.7 Action Levels

Action levels will be defined by the SAP, but in general, they will define mitigation measures at various points or triggers. Example action levels include:

- When to discharge water from sediment ponds;
- When to change SWMP infrastructure to respond to changes in the mine layout; and
- When to discontinue monitoring of a stream or runoff from a reclaimed area post-closure.

Action levels will be defined by operations personnel based on the performance of the facilities over time.

9.3.8 Responsibility

Management of the 'SWMP Monitoring Programme' will be the responsibility of the Health Environmental Health and Safety and Security (HESS) Manager. Specifically, the manager will be responsible for:

- Assigning personnel to conduct field, office, and lab tasks;
- Ensuring that personnel are adequately trained to carry out monitoring programme functions;
- Ensuring that documentation of field activities is maintained;
- Ensuring that data generated by the monitoring are consistently and accurately captured in a database;
- Ensuring timely analysis of results and identification of relevant trends; and
- Ensuring that responsible action is taken in a timely manner when trends of concern are identified.

Appendix A
Best Management Practices for Surface Water Management

(Prepared for Lydian by Global Resources Engineering Ltd)

1.0 REPORT PURPOSE AND BASIS

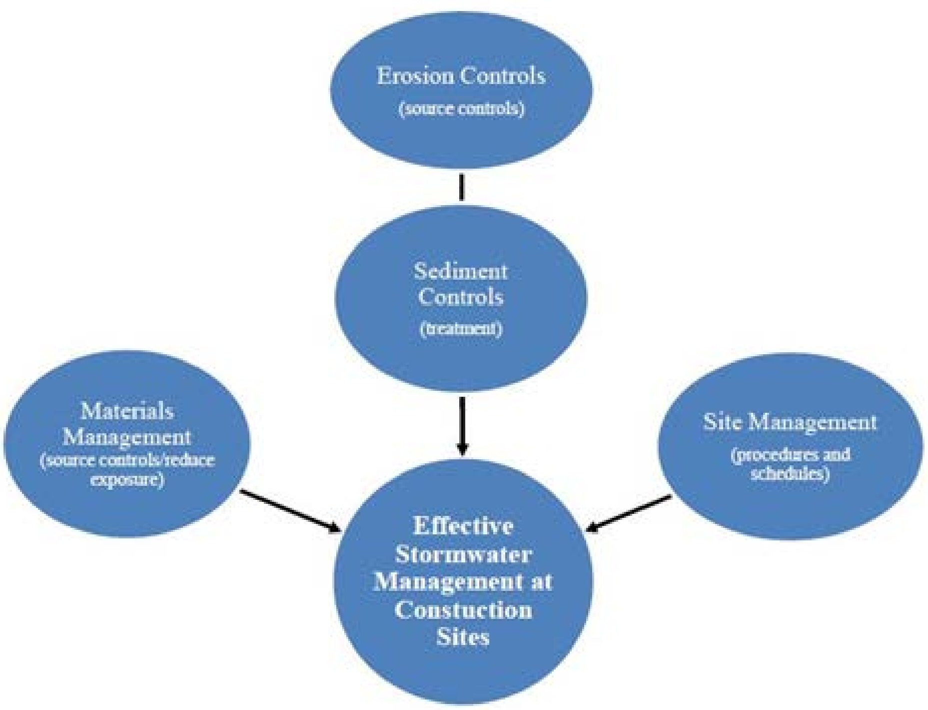
This Best Management Practices (BMP) report has been formulated to provide guidance related to surface water management at the Amulsar Project. The report serves as an addendum to the project overall Surface Water Management Plan (SWMP), which provides design details for the major surface water conveyance/handling features to be implemented at the project site. The BMP report provides general guidance to be used in managing surface water, especially in areas not specifically addressed in the project SWMP. The BMP report is not intended to provide specific storm water management details for every location on site, but rather, to provide management options for the various water management and sediment control challenges posed by development of the project.

The BMP report includes data, standard operating procedures, and guidelines that have been reproduced from Best Management Practices for Reclaiming Surface Mines in Washington and Oregon (Norman, Wampler, Throop, Schnitzer, & Roloff, 1997), Colorado Urban Storm Drainage Criteria Manual Volume 3 (Urban Drainage and Flood Control District, 2010), and Development Document for Final Effluent Guidelines and Standards for the Construction & Development Category (EPA, 2009) in addition to other sources as noted. The intent of the material presented is to be a compilation of guidance documents made up of pertinent published literature regarding storm water management in a format that pertains to the Amulsar Project.

2.0 DESIGN APPROACH

Effective management of storm water runoff during mining and related construction activities is critical to the protection of water resources. Both erosion and sediment controls are necessary for effective mine site management as well as effective material management and site management practices (Figure 2-1). Protection of waterways from mining/construction-related activities is the ultimate objective of these practices.

Figure 2-1 Effective Storm Water Management



3.0 STORM WATER MANAGEMENT

The following general guidelines describe the steps to create an effective storm water and erosion control system.

- Carefully plan the areas to be cleared in order to minimize disturbance
- Retain sediment by using erosion control BMP's
- Interrupt the flow of surface water to reduce runoff velocity
- Use geosynthetics and revegetation to stabilize cleared areas as soon as practical
- Isolate fines produced during mining and processing
- Develop a plan for maintaining storm water and erosion control structures
- Follow the plan and modify it as necessary to address changing conditions

[redacted] Project Construction Activity

The activities that will take place at the Amulsar Project include the construction of mine related infrastructure, including roads, power lines, and a conveyor. In addition, development of a heap leach facility and barren rock storage facility will be carried out. Prior to mining and during mine operations, construction borrow materials will be excavated/mined for project uses. Also, soil stockpiles will be constructed for storage of materials to be used in closure reclamation. During mine development, the Erato and Tigranes/Artavasdes pits will be mined and the barren rock storage facility and heap leach facility will be expanded. During mine closure, pits will be backfilled and other disturbed areas re-graded and reclaimed, as appropriate.

Drawing 01 presents major site features. Additional drawings related to surface water management are described in the site Surface Water Management Plan.

[redacted] Project Disturbance Areas

The project site contains a number of disturbance areas, each of which have a varying potential to provide sediment to site surface water runoff. As indicated previously, disturbance activity in the consolidated materials at the site will have less potential to cause erosion control issues than disturbance activities taking place in areas characterized by unconsolidated materials. In addition, many site construction activities, such as road construction, will use unconsolidated materials which must be protected from erosional processes until they can be stabilized. The following is a list of the main disturbance areas at the project site:

- Access and Haul Roads
  - Main access road
  - Pit and waste area haul Road
  - Primary and secondary crusher access road
  - Conveyor access road
  - Conveyor/stockpile haul road
- Primary and Secondary Crusher
  - Truck maintenance facilities
  - Fuel storage and dispensing facilities
  - Primary ore crusher
  - Ore processing facilities
  - Wastewater treatment facilities
  - Sediment Ponds
- Truck Shop
- Mine Pits

- Heap Leach Facility
- Conveyor Corridor and Ore Stockpiles
- Soil and Borrow Material Excavations and Stockpiles

4.0 EROSION

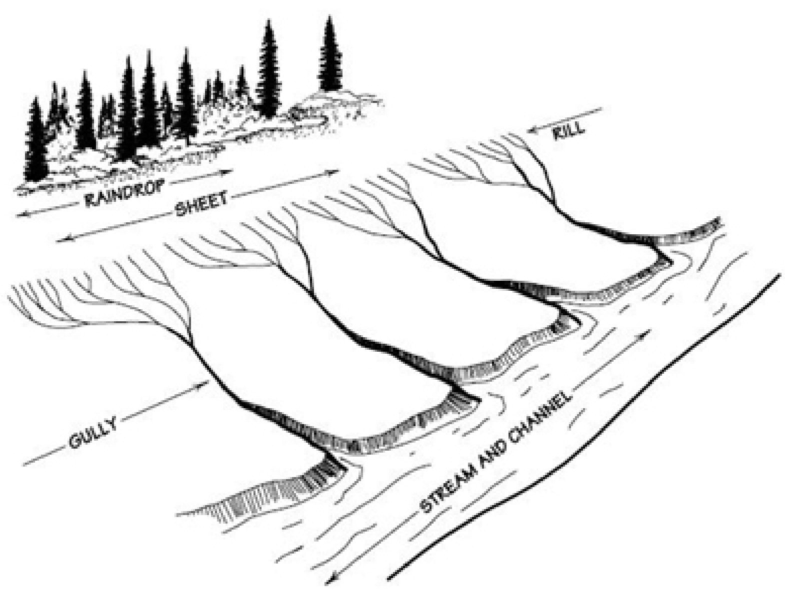
Soil erosion can generally be defined as the removal of soil by wind and water. Although soil erosion is a natural process, accelerated soil erosion occurs at construction and mine sites due to activities that disturb the natural soil and vegetation.

[redacted] Water Erosion

Water erosion has five primary mechanisms: raindrop erosion, sheet erosion, rill erosion, gully erosion, and channel erosion. Raindrops dislodge soil particles, making them more susceptible to movement by overland water flow. A single raindrop may move a splashed particle 2 feet vertically and 5 feet horizontally. The velocity of a raindrop is more than ten times higher than typical surface runoff velocities, which means that soil particles are more likely to be dislodged by raindrop impact than by surface runoff. Once the particles are mobilized, however, much less energy is required to keep them suspended or moving. Shallow surface flows on soil rarely move as a uniform sheet for more than several feet before concentrating in surface irregularities, known as rills. As the flow changes from a shallow sheet to a deeper rill flow, the flow velocity and shear stresses increase, which detach and transport soil particles. This action begins to cut into the soil mantle and form small channels. Rills are small, well-defined channels that are only a few inches deep. Gullies occur as the flows in rills come together into larger channels. The major difference between rill and gully erosion is size. Rills caused by erosion can be smoothed out by standard surface treatments such as harrowing. Gully erosion, however, typically requires heavy equipment to re-grade and stabilize the land surface.

Figure 4-1 Stormwater Erosion

Figure 4.1 Topography created by different types of erosion. Raindrop erosion affects any bare surface. If the water does not infiltrate, raindrops combine into sheets of water (overland flow) to cause sheet erosion, and sheets further concentrate to produce rill and gully erosion. Water from rills and gullies then combines to form streams and channels. (Redrawn from Beckett, Jackson, Raedere, Inc., 1975.)



[redacted] Wind Erosion

Wind erosion occurs when winds of sufficient velocity create movement of soil particles. The potential for wind erosion is dependent upon soil cover, soil particle size, wind velocity, duration of wind and unsheltered distance. Erodibility of soils is affected by multiple factors including physical soil characteristics, slope steepness, slope lengths, vegetative cover, and rainfall characteristics. Physical properties of soils such as particle size, cohesiveness, and density affect erodibility. Loose silt and sand-sized particles typically are more susceptible to erosion than "sticky" clay soils. Rocky soils are less susceptible to wind erosion, but are often found on steep slopes that are subject to water erosion.

[redacted] Factors Contributing to Erosion

Most of the soils at Amulsar are susceptible to wind or water erosion, or both. When surface vegetative cover and soil structure are disturbed during construction or there is little or no natural vegetative cover, the soil is more susceptible to erosion. Vegetation plays a critical role in controlling erosion. Roots bind soil together and the leaves or blades of grass reduce raindrop impact forces on the soil. Grass, tree litter and other ground cover not only intercept precipitation and allow infiltration, but also reduce runoff velocity and shear stress at the surface. Vegetation reduces wind velocity at the ground surface, and provides a rougher surface that can trap particles moving along the ground. In the absence of vegetation, soils become more susceptible to erosion. The rate of erosion is affected by four main factors:

- climate, which determines how much rain and snow will fall on a site and wind velocities,
- soil characteristics, which determine erodibility and infiltration rates,
- topography, which determines the velocity of runoff and the energy water will have to cause erosion,
- slope aspect, which determines amount of sunlight and thus determines snowmelt and vegetative growth, and
- vegetation, which slows runoff and prevents erosion by holding soils in place.

Each of these factors plays a role in determining which BMPs should be used to control erosion at a given site location.

5.0 SEDIMENTATION

Sedimentation occurs when eroded soil transported in wind or water is deposited from its suspended state. During a typical rainstorm, runoff normally builds up rapidly to a peak and then diminishes. Because the amount of sediment a watercourse can carry is dependent upon the velocity and volume of runoff, sediment is eventually deposited as runoff decreases. The deposited sediments may be re-suspended when future runoff events occur. In this way, sediments are moved progressively downstream in the waterway system.

[redacted] Suspended Sediment

Surface runoff and raindrops detach soil from the land surface, resulting in sediment transport into streams and rivers. Suspended sediment is composed of settleable and non-settleable solids. Settleable solids (sand and silt sized particles) are heavier than water and will settle in calm water. Non-settleable solids (clay and silt size particles) take a long time to settle – in some cases, years – and are the chief cause of turbidity. Sediment and turbidity can affect habitat, water quality, temperature, pollutant transport, and can cause sedimentation in downstream receiving waters. The effects of excess sediment in the water include direct physical effects such as reducing visibility and light in the water column, and physical abrasion of plant surfaces. Effects can also be indirect, as in changes to the chemical composition (e.g., pH, hardness) of the water, light penetration or turbidity, and temperature profile.

Sediment level measurement can be divided into several distinct subgroups:

- Total Suspended Solids (TSS) is a dry-weight measure of the suspended particulate material in water. Measuring TSS in storm water allows for estimation of sediment transport, which can have significant effects locally and in downstream receiving waters. TSS is typically measured in milligrams per liter (mg/L).

- Total Dissolved Solids (TDS) are a measure of the dissolved constituents in water and are a primary indication of the purity of drinking water. TDS is typically measured in milligrams per liter (mg/L).
- Settleable Solids, expressed as milliliters per liter (mL/L), are a measure of the solids that will settle to the bottom of a cone-shaped container (called an Imhoff cone) in a 60-minute period. Settleable solids are primarily a measure of particles that can be removed by reducing flow velocities or creating ponded areas.

[redacted] Turbidity

Turbidity is reported as Nephelometric Turbidity Units (NTU). A high NTU measurement indicates that little light is passing through because it is being absorbed or deflected by particles of sediment. According to ____( ) the effluent water quality limits for turbidity for category A2 water destined for potable use is 100 NTU.

6.0 SURFACE WATER DIVERSION AND COLLECTION

Surface water conveyance structures are engineered/implemented to manage site surface water in a manner that minimizes potential impacts to surface water quality. Diversion ditches are used to convey non-impacted surface water around or through disturbance areas to downstream natural drainages. Road ditches and culverts are used to convey potentially impacted surface water to points of use or re-cycle.

Sediment ponds are generally constructed downstream of disturbance activities to collect potentially impacted surface water runoff from disturbance areas. Sediment ponds can be used as settling ponds to reduce total suspended solids concentrations in contained water. Also, the sediment ponds can be used as potential water treatment basins, if additional water treatment is required prior to discharge or re-use.

7.0 EFFECTIVE EROSION AND SEDIMENT CONTROL

It is better to minimize erosion than to rely solely on sedimentation removal from construction site runoff. Erosion control BMPs limit the amount and rate of erosion occurring on disturbed areas. Sediment control BMPs attempt to capture the soil that has been eroded before it leaves the disturbed area. Despite the use of both erosion control and sediment control BMPs, some amount of sediment will remain in runoff leaving mining or construction site disturbed areas, but the use of upstream and downstream BMP’s can help to minimize offsite transport of sediment. The last line of treatment such as inlet protection and sediment basins should be viewed as "polishing" BMPs, as opposed to the only treatment on the site. An overview of erosion control methods is provided below. Following sections of this BMP report provide design details and guidance for effective use of various erosion and sediment control practices. BMPs should be combined and selected to meet the following objectives:

- Conduct land-disturbing activities in a manner that effectively reduces accelerated soil erosion and reduces sediment movement and deposition off-site.
- Schedule land disturbance activities to minimize the total amount of soil exposed at any given time.
- Establish temporary or permanent cover on areas that have been disturbed as soon as practical after grading is completed.
- Design and construct temporary or permanent facilities to limit the flow of water to non-erosive velocities for the conveyance of water around, through, or from the disturbed area.
- Remove sediment caused by accelerated soil erosion from surface runoff water before it leaves the project site.
- Stabilize disturbed areas with permanent cover and provide permanent storm water quality control measures for the post-mine condition.

The two most important things that can be done to minimize erosion, sedimentation, and turbidity are preventing raindrop erosion and slowing surface-water runoff velocities in the bare areas. Practices that reduce erosion can generally be classified as short- or long-term, although considerable overlap exists between erosion control practices. Some practices may be mid-term in one circumstance and serve as long-term practices or permanent solutions in other circumstances. Each circumstance must be evaluated on an individual basis to determine the appropriate erosion control practice. All erosion control practices require maintenance to be effective and are described in detail later in this report.

Generally, short-term erosion-control methods include:

- Erosion Blankets,
- Drain Rock Bags,
- Straw bales,
- Silt fences,
- Jute netting and/or mulch fabrics,
- Brush sediment barriers, and
- Plastic coverings.

Generally, mid-term to long-term erosion-control methods include:

- Geosynthetic Erosion Mats,
- Diversion ditches,
- Check dams,
- Filer Berms, and
- Gravel Covers

Generally, long-term to permanent erosion–control methods include:

- Rock-lined ditches,
- Grouted riprap ditches,
- Contours, berms, swales, and ditches, and
- Vegetative covers.

[redacted] Controlling Raindrop Erosion

On flat ground, raindrop erosion is typically not a problem, but on slopes, more soil is splashed downhill than uphill. Covering steep slopes with plastic sheeting, geosynthetics, mulch and/or re-vegetating bare areas reduces the erosion caused by raindrop impact. Gravel placed on berms or other bare areas at the project site can also significantly reduce sediment movement during heavy rains.

[redacted] Controlling Surface Runoff

Runoff velocities can be controlled by retarding flow and/or breaking up or minimizing slope length. Retarding flow on a slope can be accomplished with organic debris or geotextiles. Small, discontinuous terraces, berms, and furrows on the overburden cut above the mine pit(s) or on reclaimed slopes can effectively slow runoff and decrease sediment transport (Figure 7-1).

Figure 7-1 Grading Controls to Reduce Run-Off Velocities

Figure 7.1 Small, discontinuous terraces, berms, and furrows can effectively slow runoff and decrease sedimen transport. The relief is exaggerated for illustrative purposes. (From Banks, 1981.)

Figure 7-2 Back Cutting Benches for Improved Drainage

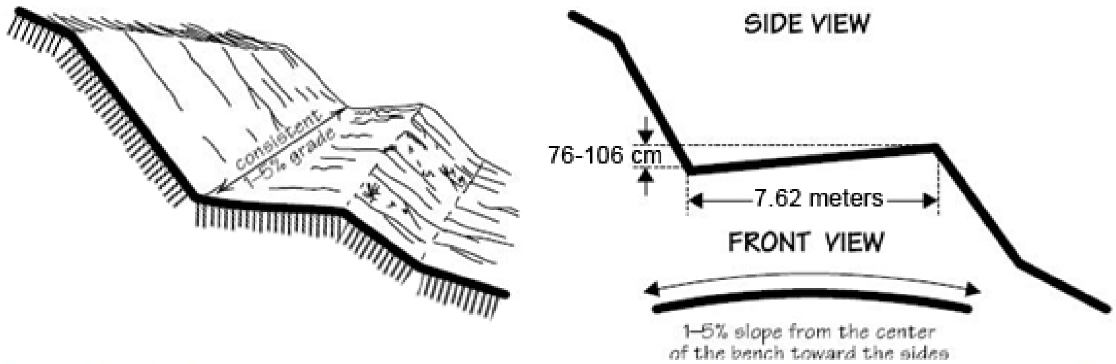


Figure 7.2 Benching and terracing of unconsolidated material to control runoff. Benches cut in overburden or other material likely to erode should be sloped into the hillside (side view) and away from the center of the bench (1–5% slope or grade) to allow drainage to either side (front view).

Other methods for reducing runoff velocities involve long-term structures incorporated into the drainage-ditch system. These structures should be used in the mine pit in conjunction with downstream settling ponds. Using only one method is generally not successful. Attempting to trap or control sediment in settling ponds may not work unless some sediment has been dispersed and trapped upslope of the final pond or discharge point.

Long-term erosion-control methods are more cost-effective if properly planned and coordinated with mining activities. In many areas, short-term erosion control will be needed until long-term controls are established. Some methods, such as re-vegetation, can be effective in both the short and long terms.

8.0 CONTROL TECHNIQUES

General erosion/sedimentation control methods are discussed above and the more specific control measures are described in more detail in the following sections of this report. The erosion/sedimentation controls at the project site will change over time as the configuration of the site changes. The location and choice of the various structures and techniques should be site specific. If abundant sediment is incorporated into project site surface water, it will essentially become an environmental contaminant, requiring treatment. The removal of sediment from surface water can be a difficult and costly process. Therefore, the best approach is to isolate the source of the sediment and to employ erosion control measures to reduce the sources of erosion and sediment. Sediment trapping methods will serve to remove settleable solid concentrations from mobilized sediment in surface water runoff. In addition, storm-water controls can reduce or eliminate suspended fines before they reach the settling pond system. Specific control techniques are described in more detail in the following sections of this report. The following is a list of those practices/controls and symbol key to be used as a descriptive tool.

Control Techniques Symbol Key
Water Handling Practices

WH-1 Contour and Diversion Ditches (DD)
WH-2 Rip-Rap (RR)
WH-3 Wire Enclosed Rock
WH-4 Stone Outlet Structure (SOS)
WH-5 Stone Outlet Protection (SOP)
WH-6 Stream Buffers (SB)

Erosion Controls

EC-1 Crushed Rock Cover (CRC)
EC-2 Geotextile (GT)
EC-3 Erosion Control Matting (ECM)
EC-4 Topsoiling (TS)
EC-4 Vegetation (V)
EC-5 Dust Control (DC)

Sediment Trapping Devices

ST-1 Fiber Rolls (FR)
ST-2 Rock Sock (RS)
ST-3 Silt Fences (SF)
ST-4 Check Dam (CD)
ST-5 Sediment Pond (SP)

9.0 WATER HANDING PRACTICES

[redacted] WH-1: Contour and Diversion ditches (DD)

9.1.1 General Description

Contour ditches are constructed along a line of approximately equal elevation across the slope (Figure 9-1). Diversion ditches guide water around unstable areas to prevent both erosion and saturation with water, reducing the likelihood of slope failure.

Figure 9-1 Contour Ditches

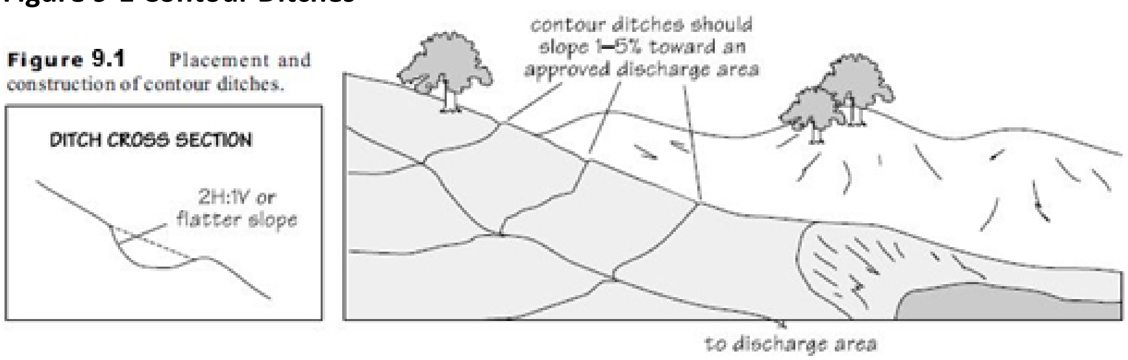
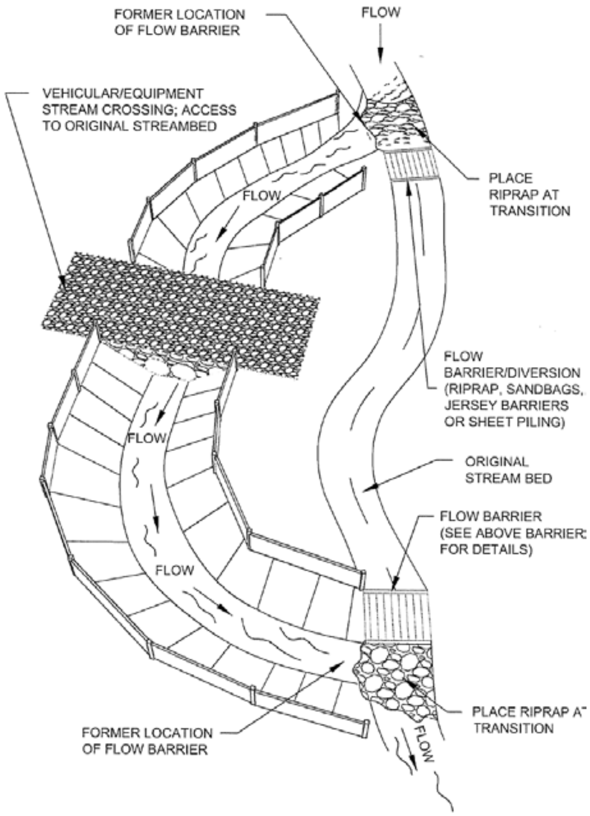


Figure 9-2 Diversion Ditch



9.1.2 Applicability

Channels and ditches are permanent, designed waterways shaped and lined with appropriate vegetation or structural material (grout or erosion control matting) to safely convey runoff to a sediment pond, vegetated area, or drainage. Contour and diversion ditches should be used to direct surface runoff away from disturbed areas and prevent rills and gullies from forming. The advantages of open channels are that they are generally inexpensive to construct, can be lined, and make it easy to trace the water. One disadvantage of un-lined channels is that they may, if improperly designed, erode during high flows and become a source of sediment themselves.

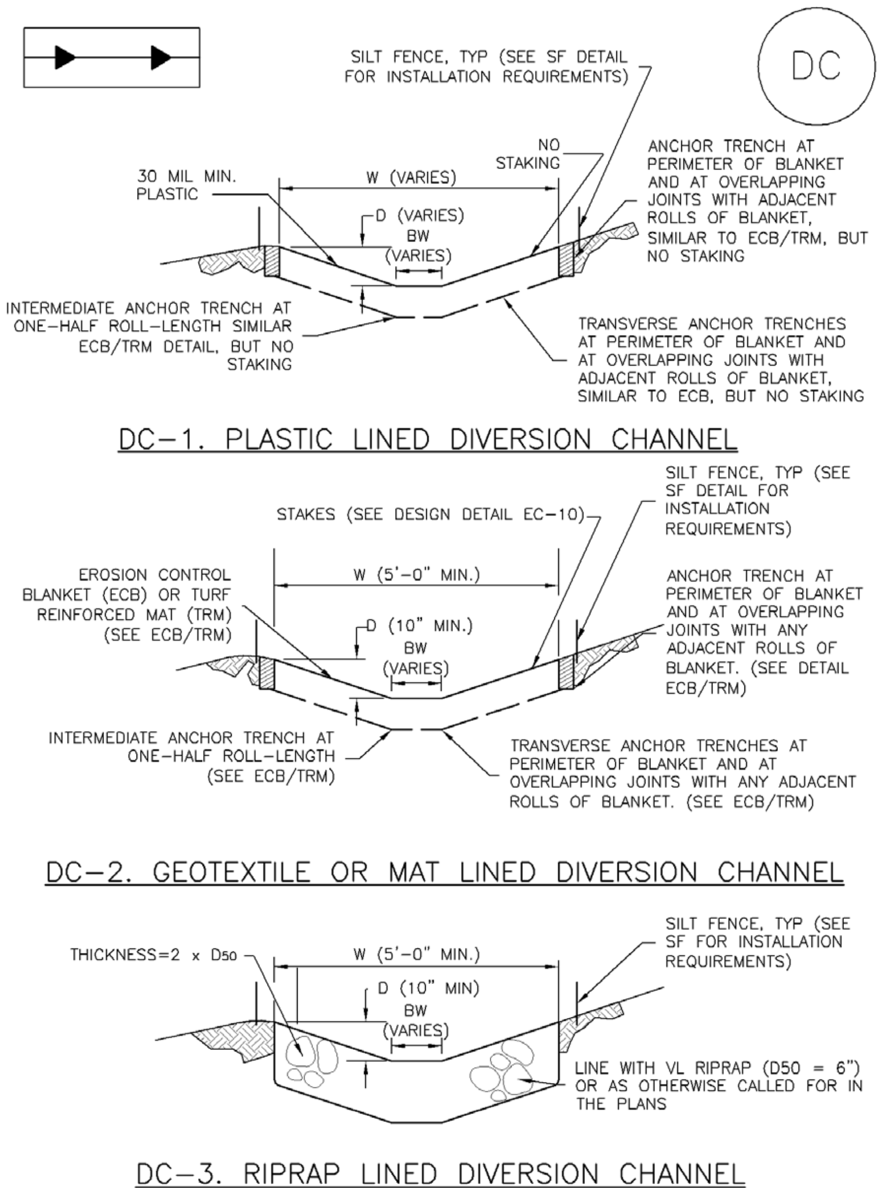
9.1.3 Design and Installation Criteria

Ditches should have a 1 to 5 percent grade directed away from steep slopes to the appropriate drainage or vegetated areas. Ditch channels may need to be lined to prevent scouring and minimize sediment transport. When their slope is greater than 5 percent, ditches are typically lined with rock. Where slope stability is of concern, impermeable liners may be used. Rock check dams, described below, should be placed in diversion and contour ditches at decreasing intervals as the slope increases.

The design of a channel or ditch cross section and lining is based primarily on the volume and velocity of flow expected in the channel. If flow is low and slow, grass channels are preferred to riprap or concrete lining, however in some locations vegetative linings are not an option and concrete or geosynthetic materials must be used. Although concrete channels are efficient and easy to maintain, they allow runoff to move so quickly that channel erosion and flooding can result downstream. Grass-lined or riprap channels more closely duplicate a natural system. Riprap and grass-lined channels, if designed properly, also remove pollutants via biofiltration (removal of pollution by plants). Engineered channels are recommended when the discharge will be greater than 1.5 cubic meters per second.

In addition to the primary design considerations of capacity and velocity, other important factors to consider when selecting a cross section and lining are land availability, compatibility with surrounding environment, safety, maintenance requirements, and outlet conditions.

Figure 9-3 Diversion Channel Design Detail



Channel Diversion Installation Notes

1. See Plan View For:
   - Location of diversion channel
   - Type of channel (Unlined, geotextile or mat lined, plastic line or riprap lined)
   - Length of each type of channel
   - Depth and width

- For rirprap lined channel, size of riprap, d50, shall be shown on plans

2. See drainage plans for details of permanent conveyance facilities.
3. Diversion channels indicated on the SWMP plan should be installed prior to work in down-gradient areas or natural channels.

Diversion Channel Maintenance Notes

1. Inspect BMPs each workday and maintain them in effective operating condition. Maintenance of BMPs should be proactive, not reactive. Inspect BMPs as soon as possible (and always within 24 hours) following a storm that causes surface erosion and perform necessary maintenance in a timely manner.
2. Frequent observations and maintenance are necessary to maintain BMPs in effective operating condition. Inspections and corrective measures should be documented thoroughly.
3. Where BMPs have failed, repair or replacement should be initiated upon discovery of the failure.
4. Diversion channels are to remain in place until work in the down-gradient area or natural channel is no longer required. If approved by local jurisdiction diversion channel may be left in place.

If diversion channels are removed, the disturbed area shall be covered with topsoil, seeded and mulched or otherwise stabilized according details given in the Closure Plan.

9.1.4 Limitations

Diversion ditches must be adequately sized to accommodate storm events without overtopping or blowing out in corners. Temporary ditches may be susceptible to erosion during large storm events if not properly protected with some sort or reinforcement such as an erosion control mat or geotextile.

9.1.5 Maintenance

Ditches should be checked on a regular interval and after storm events to make sure they are free of debris and sediment and structurally sound.

[redacted]WH-3: Riprap (RR)

The following section is adapted from Design of Riprap Revetment (Brown & Clyde, 1989) published by the Federal Highway Administration.

9.2.1 General Description

Riprap is a layer of large stones used to protect soil from erosion in areas of concentrated runoff. Riprap can also be used on slopes that are unstable because of seepage problems. Riprap consists of crushed rock placed on filter fabric on a prepared surface. The individual stones are typically angular in shape and well graded so that they will interlock. This interlocking property combines with the weight of the stone to form a solid mass that will resist erosion. Use riprap to stabilize slopes from construction (cut-and-fill), channel side slopes and bottoms, BMP inlets and outlets, check dams, slope drains, and storm drains.

Dumped riprap

Dumped riprap is graded stone dumped on a prepared slope in such a manner that segregation will not take place. Dumped riprap forms a layer of loose stone; individual stones can independently adjust to shifts in or movement of the base material. The placement of dumped riprap should be done by mechanized means, such as crane and skip, dragline, or some form of bucket. End dumping from trucks down the riprap slope causes segregation of the rock by size, reducing its stability, and therefore, should not be used as a means of placement. The effectiveness of dumped riprap has been well established where it is properly installed, of adequate size, and suitable size gradation. Advantages associated with the use of dumped rock riprap include:

- The riprap blanket is flexible and is not impaired or weakened by minor movement of the bank caused by settlement or other minor adjustments.
- Local damage or loss can be repaired by placement of more rock.
- Construction is not complicated.
- When exposed to fresh water, vegetation will often grow through the rocks, adding esthetic and structural value to the bank material and restoring natural roughness.

Riprap is recoverable and may be stockpiled for future use. One drawback to the use of rock riprap revetments is that they are more sensitive than some other bank-protection schemes to local economic factors. For example, freight/haul costs can significantly affect the cost of these revetments.

Hand-placed riprap

Hand Placed riprap is stone laid carefully by hand or by derrick following a definite pattern, with the voids between the larger stones filled with smaller stones and the surface kept relatively even. The need for interlocking stone in a hand-placed revetment requires that the stone be relatively uniform in size and shape (square or rectangular). Advantages associated with the use of hand-placed riprap include:

- The even interlocking surface produces a neat appearance and reduces flow turbulence at the water revetment interface.
- The support provided by the interlocking of individual stones permits the use of hand-placed riprap revetments on steeper bank slopes than is possible with the same size loose stone riprap.
- With hand-placed riprap, the blanket thickness can usually be reduced to 150 to 300 mm less than a loose riprap blanket, resulting in the use of less stone.

Disadvantages associated with hand-placed riprap include:

- Installation is very labor-intensive, resulting in high costs.
- The interlocking of individual rocks in hand-placed revetments results in a less flexible revetment; as mentioned above. A small shift in the base material of the bank can cause failure of large segments of the revetment.
- By their nature, hand-placed rock riprap revetments are more expensive to repair than are loose rock revetments.

Plated or keyed riprap

Plated or keyed riprap is similar to hand-placed riprap in appearance and behavior, but different in placement method. Plated riprap is placed on the bank with a skip and then tamped into place using a steel plate, thus forming a regular, well organized surface. Experience indicates that during the plating operation, the larger stones are fractured, producing smaller rock sizes to fill voids in the riprap blanket. Advantages and disadvantages associated with the use of plated riprap are similar to those listed above for hand-placed riprap. As with hand-placed riprap, riprap plating permits the use of steeper bank angles, and a reduction in riprap layer thickness (usually 150-300 mm less than loose riprap). Experience also indicates that riprap plating also permits the use of smaller stone sizes when compared with loose riprap. Like hand-placed riprap, riprap plating results in a more rigid riprap lining than loose riprap. This makes it susceptible to failure as a result of minor bank settlement. However, plated riprap installation is not as labor-intensive as that of hand-placed riprap.

9.2.2 Design and Installation Criteria

Riprap lined channels can be installed on somewhat steeper slopes than grass-lined channels. They require a foundation of filter fabric or gravel under the riprap. Generally, side slopes should not exceed

2:1, and riprap thickness should be 1.5 times the maximum stone diameter. Riprap should form a dense, uniform, well-graded mass (UNEP 1994). Lined channels should be sited in accordance with the natural drainage system and should not cross ridges. The channel design should accommodate for sharp curves or significant changes in slope by including additional design features such as increased cross sectional area and plunge pools. Channels should not receive direct sedimentation from disturbed areas and should be established only on the perimeter of a construction site to convey relatively clean storm water runoff. They should also be separated from disturbed areas by a vegetated buffer or other BMP to reduce sediment loads. Basic design recommendations for lined channels include the following:

- Construction of the channel should occur before grading and paving activities begin.
- Covering the bare soil with geotextiles can provide reinforced storm water conveyance immediately.
- Triangular-shaped channels should be used with low velocities and small quantities of runoff; trapezoidal channels are used with large flows of low velocity (low slope).
- Outlet stabilization structures might be needed if the runoff volume or velocity has the potential to exceed the capacity of the receiving area.

Standardized Riprap Size Definitions

The classes of machined riprap which are generally used for channel linings are described below. It should be noted that the D50 values listed below are approximate and intended only to aid the designer in evaluating the hydraulic performance of the various classes of machined riprap.

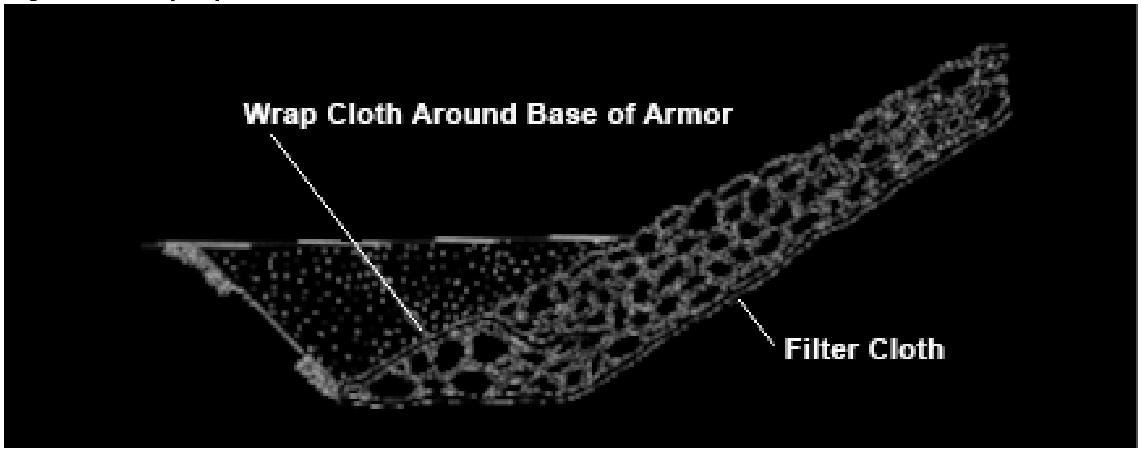
Machined Riprap (Class A-1) may be used for flow velocities up to 5 feet per second. The median stone size (D50) for this class of riprap is approximately 9 inches and it is placed to a minimum depth of 18 inches. Machined Riprap Class A-2 consists of the same basic material as Class A-1 Riprap; however, it is hand-placed to a depth of 12 inches. Because of the difficulty in ensuring the integrity of hand placement, machined Riprap Class A-2 is not recommended for ditch linings. Class A-3 is also not recommended due to the small size of the stone.

Machined Riprap (Class B) may be used for flow velocities greater than 5 feet per second, up to 10 feet per second. The D50 of this material is approximately 15 inches.

Machined Riprap (Class C) may be used for flow velocities greater than 10 feet per second, up to12 feet per second. The D50 of this material is approximately 20 inches.

If Riprap is to be placed on a ditch side slope steeper than 3H:1V, more attention to design is needed.

Figure 9-4 Riprap Filter Fabric Placement



Adapted from Brown & Clyde, 1989
http://www.fhwa.dot.gov/engineering/hydraulics/pubs/hec11si.pdf

9.2.3 Effectiveness

Lined channels can effectively transport storm water from construction areas if they are designed for expected flow volumes and velocities.

9.2.4 Limitations

Lined channels, if improperly installed, can alter the natural flow of surface water and have adverse effects on downstream waters. Additionally, if the design capacity is exceeded by a large storm event the channel might be destroyed and clogging with sediment and debris reduces the effectiveness of channels for storm water conveyance.

Common problems in lined channels include channel erosion before vegetation is fully established and gullying or head cutting in the channel if the grade is too steep. In addition, trees and brush tend to invade lined channels, causing maintenance problems.

Riprap-lined channels can be designed to safely convey greater runoff volumes on steeper slopes. However, they should generally be avoided on slopes exceeding 10 percent because stone displacement, erosion of the foundation, or channel overflow and erosion resulting from a channel that is too small can occur. Thus, channels established on slopes greater than 10 percent will usually require protection with rock gabions, concrete, or other highly stable and protective surfaces (UNEP 1994).

9.2.5 Maintenance

Maintenance requirements for lined channels are relatively minimal. During the vegetation establishment period, the channels should be inspected after every rainfall. The most important objective in the maintenance of lined channels is maintaining the stone layering and repairing areas of damaged rip-rap after storm events before erosion occurs. Periodic cleaning of silt and sand buildup in depositional areas is required so that water flow into the channel is unobstructed.

[redacted] WH-3: Wire Enclosed Rock (WER)

9.3.1 General Description

Wire-enclosed rock, or gabion, revetments consist of rectangular wire mesh baskets filled with rock. These revetments are formed by filling pre-assembled wire baskets with rock, and anchoring to the channel bottom or bank. Wire-enclosed rock revetments are generally of two types distinguished by shape:

- **Rock and Wire-Mattresses**: In mattress designs, the individual wire mesh units are laid end to end and side to side to form a mattress layer on the channel bed or bank. The gabion baskets comprising the mattress generally have a depth dimension which is much smaller than their width or length.
- **Block Gabions**: On the other hand, are more equi-dimensional, having depths that are approximately the same as their widths, and of the same order of magnitude as their lengths. They are typically rectangular or trapezoidal in shape. Block gabion revetments are formed by stacking the individual gabion blocks in a stepped fashion.

As revetments, wire-enclosed rock has limited flexibility. They will flex with bank surface subsidence; however, if excessive subsidence occurs, the baskets will span the void until the stresses in rock-filled baskets exceed the tensile strength of the wire strands. At this point the baskets will fail.

9.3.2 Applicability

Gabions can be used as retaining walls to mechanically stabilize steep slopes or for revetments, weirs, channel linings, culvert headwalls, and culvert outlet aprons. They are particularly useful where seepage is anticipated.

[redacted] WH-4: Stone Outlet Structure (SOS)

9.4.1 General Description

A stone outlet structure is a temporary stone dike installed in conjunction with and as a part of an earth dike. The purpose of the stone outlet structure is to impound sediment-laden runoff, provide a protected outlet for an earth dike, provide for diffusion of concentrated flow, and allow the area behind the dike to dewater slowly. The stone outlet structure can extend across the end of the channel behind the dike or be placed in the dike itself. In some cases, more than one stone outlet structure can be placed in a dike.

9.4.2 Applicability

Stone outlet structures apply to any point of discharge where there is a need to discharge runoff at a protected outlet or to diffuse concentrated flow for the duration of construction. The drainage area to this practice is typically limited to one-half acre or less to prevent excessive flow rates. The stone outlet structure should be located so as to discharge onto an already stabilized area or into a stable watercourse. Stabilization should consist of complete vegetative cover and/or paving that are sufficiently established to be erosion resistant.

9.4.3 Design and Installation Criteria

Design criteria are of two types: hydrologic design for a required trapping of sediment or flow rate to pass the design storm; and selecting appropriate installation criteria such that the stone outlet performs as designed.

Hydrologic Design

The hydrologic design should be based on the design storm and standard hydraulic calculations.
It should include the following considerations:

- Design rainfall and design storm - Typically a return period of 2 to 5 years is used. Runoff rates should be calculated with standard hydrologic procedures.
- Drainage area - The drainage area to this structure is typically limited to less than half an acre to ensure that the flow rates are not excessive.
- Length of crest and height of stone fill - The crest length and height of stone fill should be of sufficient size to transmit the design storm without overtopping. The volume of water stored behind the dike

can be estimated but would require routing the storm flow in the design storm. Flow through the stone outlet can be calculated using the relationships of Herrera and Felton (1991) as modified by Haan et al. (1994). The height of the fill should be small enough to prevent excessive flow velocities through the stone fill and prevent undercutting.

- Outlet stabilization - The discharge from the stone outlet should be stabilized with vegetated waterways or riprap until the flow reaches a stable channel. Design of the stabilized outlet should follow procedures presented earlier.

Installation Criteria Specifications

A stone outlet structure should conform to the following specifications:

- The outlet should be composed of 5 to 8-cm stone or recycled concrete, but clean gravel can be used if stone is not available.
- The crest of the stone dike should be at least 15 cm lower than the lowest elevation of the top of the earth dike and should be level.
- The stone outlet structure should be embedded into the soil a minimum of 10 cm.
- The minimum length of the crest of the stone outlet structure should be 2 m.
- The baffle board should extend 30 cm into the dike and 10 cm into the ground and be staked in place.
- The drainage area to this structure should be less than one-half acre.

[redacted]WH-5: Stone Outlet Protection (SOP)

9.5.1 Description

Rock outlet structures are rocks that are placed at the outfall of channels or culverts to reduce the velocity of flow in the receiving channel to non-erosive rates.

9.5.2 Applicability

This practice applies where discharge velocities and energies at the outlets of culverts are sufficient to erode the next downstream reach and is applicable to outlets of all types such as sediment basins, storm water management ponds, and road culverts.

9.5.3 Design and Installation Criteria

Hydrologic Design

Hydrologic design consists primarily of selecting the design runoff rate and sizing outlet protection. Standard hydrologic calculations should be used with an appropriate return period storm for the outlet being protected (typical return periods range from 2 to 10 years).

The process for sizing outlet protection involves selecting the type and geometry of the outlet protection and the size of the rock lining. The outlet protection could consist of a plunge pool (scour hole), an apron-type arrangement, or an energy dissipation basin (Haan et al. 1994). The design of each differs. Plunge pools are typically used for outlet pipes that are elevated above the water surface. Aprons are used for other types of outlets. Plunge pool geometry is based on the flow rate, pipe size and slope, tailwater depth, and size of the riprap lining (Haan et al. 1994). Apron dimensions are determined by the ratio of the tailwater depth to pipe diameter (Haan et al. 1994). Energy dissipation basins are used as an alternative to the plunge pool. Dimensions are a function of the brink depth in the pipe at the design flow, pipe diameter, and size of riprap (Haan et al. 1994). The size of the rock lining is a function of the discharge, pipe size, tailwater depth, and geometry selected. Details on sizing the rock are given in Haan et al. (1994).

The design method presented here applies to the sizing of rock riprap and gabions to protect a downstream area. It does not apply to rock lining of channels or streams. The design of rock outlet protection depends entirely on the location. Pipe outlets at the top of cuts or on slopes steeper than 10 percent cannot be protected by rock aprons or riprap sections because of re-concentration of flows and high velocities encountered after the flow leaves the apron.

Installation Criteria

The following criteria should be considered:

- Bottom grade - The outlet protection apron should be constructed with zero slope along its length. There should be no obstruction at the end of the apron. The elevation of the downstream end of the apron should be equal to the elevation of the receiving channel or adjacent ground.
- Alignment - The outer protection apron should be located so that there are no beds in the horizontal alignment.
- Materials - The outlet protection can be accomplished using rock riprap or gabions. Riprap should be composed of a well-graded mixture of stone sized so that 50 percent of the pieces, by weight, should be larger than the size determined using charts. The minimum d50 size to be used should be 9 inches. A well-graded mixture is defined as a mixture composed primarily of larger stone sizes but with a sufficient mixture of other sizes to fill the smaller voids between the stones. The diameter of the largest stone in such a mixture should be two times the size selected in Table 7-21 (MDE 1994).
- Thickness - Riprap specification values are summarized in Table 9-1.

Table 9-1 Riprap Sizes and Thickness

	D_{50} (inches)	D_{100} (inches)	Thickness (inches)
Class I	9.5	15	19
Class II	16	24	32
Class III	23	34	46

Source: USDOT 1995

- Stone Quality - Stone for riprap should consist of field stone or rough-hewn quarry stone. The stone should be hard and angular and of a quality that will not disintegrate on exposure to water or weathering. The specific gravity of the individual stones should be at least 2.5. Recycled concrete equivalent can be used, provided it has a density of at least 150 pounds per cubic foot and does not have any exposed steel or reinforcing bars.
- Filters - A layer of material placed between the riprap and the underlying soil surface can prevent soil movement into and through the riprap to prevent piping, reduce uplift pressure, and collect water. Riprap should have a filter placed under it in all cases. A filter can be of two general forms: a gravel layer or a geotextile.
- Gabions - Gabion baskets can be used as rock outlet protection provided they are made of hexagonal, triple-twist mesh with heavily galvanized steel wire. The maximum lined dimension of the mesh opening should not exceed 4.5 inches. The area of the mesh opening should not exceed 10 square inches. Gabions should be fabricated in such a manner that the sides, ends, and lid can be assembled at the construction site into a rectangular basket of the specified sizes. Gabions should be of a single-unit construction and installed according to the manufacturer’s specifications. Foundation conditions should be the same as for placing rock riprap. Geotextiles should be placed under all gabions, and gabions must be keyed in to prevent undermining of the main gabion structure.
- The subgrade for the filter, riprap, or gabion should be prepared to the required lines and grades. Any fill required in the subgrade should be compacted to a density of approximately that of the

surrounding undisturbed material.

- The rock or gravel should conform to the specified grading limits when installed in the riprap or filter, respectively.
- Geotextiles should be protected from punching, cutting, or tearing. Any damage other than occasional small holes should be repaired by placing another piece of geotextile fabric over the damaged part or by completely replacing the geotextile fabric. All overlaps, whether for repairs or for joining two pieces of geotextile fabric, should be a minimum of 1 foot in length.
- Stone for the riprap or gabion outlets can be placed by equipment. They should be constructed to the full course thickness in one operation and in such a manner as to avoid displacement of underlying materials. Care should be taken to ensure that the stone is not placed so that rolling would cause segregation of stone by size, i.e., the stone for riprap or gabion outlets should be delivered and placed in a manner that will ensure that it is reasonably homogeneous, with smaller stones filling the voids between larger stones. Riprap must be placed so as to prevent damage to the filter blanket or geotextile fabric. Hand placement will be required to the extent necessary to prevent damage to the permanent works.
- Stone should be placed so that it blends in with the existing ground and the depth to the stone surface is sufficient to transmit the flow without spilling over onto the unprotected surface.

Figure 9-5 Stone Outlet Protection Detail

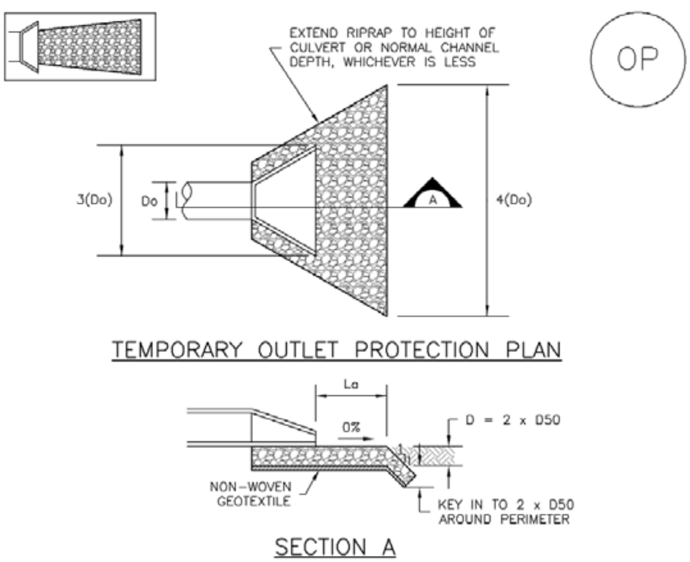


TABLE OP-1. TEMPORARY OUTLET PROTECTION SIZING TABLE

PIPE DIAMETER, Do (INCHES)	DISCHARGE, Q (CFS)	APRON LENGTH, La (FT)	RIPRAP D50 DIAMETER MIN (INCHES)
8	2.5 5	5 10	4 6
12	5 10	10 13	4 6
18	10 20 30 40	10 16 23 26	6 9 12 16
24	30 40 50 60	16 26 26 30	9 9 12 16

OP-1. TEMPORARY OUTLET PROTECTION

Source: UDFC, 2010

Temporary Outlet Protection Inspection and Maintenance Notes

1. Inspect BMPs each workday and maintain them in effective operating condition. Maintenance of BMPs should be proactive, not reactive. Inspect BMPs as soon as possible (and always within 24 hours) following a storm that causes surface erosion and perform necessary maintenance.
2. Frequent observations and maintenance are necessary to maintain BMPs in effective operating condition. Inspections and corrective measures should be documented thoroughly.
3. Where BMPs have failed, repair or replacement should be initiated upon discovery of the failure.

9.5.4 Limitations

Common problems with rock outlet structures include the following:

- If the foundation is not excavated deeply or wide enough, the flow cross-section could be restricted, resulting in erosion around the apron and scour holes at the outlet. Also, the riprap apron should be placed on a suitable foundation to prevent downstream erosion.
- If the riprap that is installed is smaller than specified, rock displacement might result; selectively grouting over the rock materials could stabilize the installation.
- If the riprap is not extended enough to reach a stable section of the channel, downstream erosion could result.
- If a filter is not installed under the riprap, stone displacement and erosion of the foundation might result.

9.5.5 Maintenance

Once a riprap outlet has been installed, the maintenance needs are very low. It should be inspected after high flows to see if scour has occurred beneath the riprap, if flows have occurred outside the boundaries of the riprap and caused scour, or if any stones have been dislodged. Repairs should be made immediately.

10.0 EROSION CONTROL MEASURES

Due to the Project location and climate, establishing vegetation may not be a short term solution for soil stabilization and erosion prevention. The project will need alternative control measures during the autumn, winter, and early spring months. Non-vegetative practices can be used during construction to stabilize and protect soil exposed to the erosive forces of water, as well as post-construction to provide a filtration mechanism for storm water pollutants. Non-vegetative stabilization techniques operate on the same principles as vegetative stabilization; however, these practices use a variety of synthetic or natural materials (such as coconut fiber) to stabilize exposed soils. Non-vegetative practices are particularly useful as temporary stabilization measures until vegetative practices have had a chance to become established. The following discussion refers to non-vegetative stabilization as a construction BMP that stabilizes and protects soil from erosion. A variety of proprietary and vendor-supplied materials are in this category, which are not discussed in detail.

[redacted]EC-1: Crushed Rock Cover (CRC)

10.1.1 General Description

Crushed or run-of-mine rock can be used as a protective layer in areas of exposed soil stockpiles or areas of concentrated runoff. This rock must be inert and can serve as a long term cover for soil material that is stored for reclamation.

10.1.2 Applicability

Use crushed rock cover to stabilize long term soil stockpiles and other areas sensitive to erosion in place of erosion blankets or geosynthetics. At remote projects with large areas subject to erosion, rock covers may be a suitable and cost effective alternative to traditional BMP’s, especially at projects with an excess of inert waste rock material. Also, rock covers may serve as a robust long-term or permanent BMP compared with commercial products which generally have a finite life span. The use of rock covers in large scale applications such as stockpile stabilization face materials handling difficulties, especially over unconsolidated loamy material with high moisture content.

10.1.3 Design and Installation

Cover long term soil stockpiles and disturbed areas with a layer of crushed rock at least twice the thickness of the largest rock size. With large areas, the cover may require a drainage network to be established to prevent erosion of the rock cover. Drainage networks may be constructed of geotextile or geogrid to provide stability and improved performance.

Installation can be completed with dump trucks and dozers. Over stockpile areas of unconsolidated and/or high moisture content, it may be necessary to place a structural geogrid or geotextile in order gain access to the material and begin placing cover rock.

10.1.4 Effectiveness

Rock covers serve to intercept rainfall and reduce run-off velocities. A rock cover is more durable than geosynthetic commercial erosion mats for long term, high UV exposure conditions.

10.1.5 Limitations

This solution may only be cost effective at project locations where a permanent (as opposed to long-term) solution is required. In difficult to access areas, the delivery of large quantities of temporary geosynthetic materials is cost prohibitive. Rock covers without a separation layer, such as geotextile, reduce erosion but may have limited capacity as erosion underneath the rock layer is possible without a separator.

[redacted]EC-2: Geotextiles (GT)

10.2.1 General Description

Geotextiles are porous fabrics also known as filter fabrics, road rugs, synthetic fabrics, construction fabrics, or simply fabrics. Geotextiles are manufactured by weaving or bonding fibers made from synthetic materials such as polypropylene, polyester, polyethylene, nylon, polyvinyl chloride, glass, and various mixtures of such materials. As a synthetic construction material, geotextiles are used for a variety of purposes such as separators, reinforcement, filtration and drainage, and erosion control (USEPA 1992). Some geotextiles are made of biodegradable materials such as mulch matting and netting. Mulch mattings are jute or other wood fibers that have been formed into sheets and are more stable than normal mulch. Netting is typically made from jute, wood fiber, plastic, paper, or cotton and can be used to hold the mulching and matting to the ground. Netting can also be used alone to stabilize soils while the plants are growing; however, it does not retain moisture or temperature well. Geotextiles can aid in plant growth by holding seeds, fertilizers, and topsoil in place. Fabrics are relatively inexpensive for certain applications—a wide variety of geotextiles exist to match the specific needs of various site areas.

10.2.2 Applicability

Geotextiles can be used for erosion control by using it alone. Geotextiles can be used as matting, which is used to stabilize the flow of channels or swales or to protect seedlings on recently planted slopes until they become established. Matting can be used on stream banks where moving water is likely to wash out new plantings. They can also be used to protect exposed soils immediately and temporarily, such as when active piles of soil are left overnight. Geotextiles are also used as separators. An example of such a use is geotextile as a separator between riprap and soil. This sandwiching prevents the soil from being eroded from beneath the riprap and maintaining the riprap's base.

10.2.3 Design and Installation Criteria

Many types of geotextiles are available. Therefore, the selected fabric should match its purpose. In the field, important concerns include regular inspections to determine whether cracks, tears, or breaches are present in the fabric and to identify when repairs should be made. Effective netting and matting require firm, continuous contact between the materials and the soil. If there is no contact, the material will not hold the soil, and erosion will occur underneath the material. Wind loading must also be considered, especially when placing geotextile over large areas, and care must be taken to temporarily secure fabric sheets with an adequate amount of sand bags until the textiles can be permanently anchored.

10.2.4 Effectiveness

A geotextile's effectiveness depends on the strength of the fabric and proper installation. For example, when protecting a cut slope with a geotextile, it is important to properly anchor the fabric using appropriate length and spacing of wire staples. This will ensure that it will not be undermined by a storm event. Large rocks may also be used as ballast to hold down the geotextile at seams and slope transitions.

10.2.5 Limitations

Geotextiles (primarily synthetic types) have the potential disadvantage of being sensitive to light and must be protected before installation. Some geotextiles might promote increased runoff and can blow away if not firmly anchored. Depending on the type of material used, geotextiles might need to be disposed of in a landfill, making them less desirable than vegetative stabilization. If the fabric is not properly selected, designed, or installed, the effectiveness can be reduced drastically.

10.2.6 Maintenance

Regular inspections should be made to determine whether cracks, tears, or breaches have formed in the fabric. If compromised, it should be repaired or replaced immediately. It is necessary to maintain contact between the ground and the geotextile at all times.

[redacted] EC-3: Rolled Erosion Control Products (RECP)

10.3.1 General Description

Rolled erosion control products is a category of a variety of products that can be either organic or made from a synthetic material. A wide variety of products exist to match the specific needs of the site. Organic mats are made from such materials as wood fiber, jute net, and coconut coir fiber. Unlike organic mats, synthetic mats are constructed from non-biodegradable materials and remain in place for many years. The Erosion Control Technology Council (ECTC 2005) characterizes rolled erosion control products according to these categories:

1. Mulch control netting - A planar woven natural fiber or extruded geosynthetic mesh used as a temporary degradable rolled erosion control product to anchor loose fiber mulches. Lifespan: 12 – 24 months
2. Open weave textile - A temporary degradable rolled erosion control product composed of processed natural or polymer yarns woven into a matrix, used to provide erosion control and facilitate vegetation establishment. Lifespan: 12-36 months
3. Erosion control blanket (ECB) - A temporary degradable rolled erosion control product composed of processed natural or polymer fibers which are mechanically, structurally or chemically bound together to form a continuous matrix to provide erosion control and facilitate vegetation establishment. ECBs can be further differentiated into rapidly degrading single-net and double-net types or slowly degrading types. Lifespan: 2-10(?) yrs
4. Turf Reinforcement Mat (TRM) - A rolled erosion control product composed of non-degradable synthetic fibers, filaments, nets, wire mesh, and/or other elements, processed into a permanent,

three-dimensional matrix of sufficient thickness. TRMs, which may be supplemented with degradable components, are designed to impart immediate erosion protection, enhance vegetation establishment and provide long-term functionality by permanently reinforcing vegetation during and after maturation. Note: TRMs are typically used in hydraulic applications, such as high flow ditches and channels, steep slopes, stream banks, and shorelines, where erosive forces may exceed the limits of natural, unreinforced vegetation or in areas where limited vegetation establishment is anticipated.

Rolled erosion control products aids in plant growth by holding seeds, fertilizers, and topsoil in place. Matting can be used to stabilize the flow of channels or swales or to protect seedlings on recently planted slopes until they become established and can also be used on stream banks where moving water is likely to wash out new plantings. It can also be used to protect exposed soils immediately and temporarily, such as when active stockpile areas are left for short periods of time.

10.3.2 Applicability

Mulch mattings, netting, and filter fabrics are particularly useful in steep areas and drainage swales where loose seed is vulnerable to being washed away or failing to survive dry soil (UNEP, 1994). ECM's can also be used to cover stockpiles and disturbed areas that are long-term temporary. ECM's can be furnished as short-term decomposable fiber mats, as permanent synthetic mats or as hybrid mats with polypropylene grid around an organic fiber matrix and last from 36 months to "permanent". All ECM's are designed to support vegetation and root mass and if left exposed to UV radiation they will eventually break down. As such, they are only considered permanent if applied in conjunction with vegetation.

10.3.3 Design and Installation Criteria

Matting is especially recommended for steep slopes and channels (UNEP, 1994). Many types of erosion control mats are available. Therefore, the selected product should match its purpose.

Design

Effective netting and matting require firm, continuous contact between the materials and the soil. If there is no contact, the material will not hold the soil, and erosion will occur underneath the material.

Table 10-1 Specifications for Rolled Erosion Control Products

Table 10.1 ECTC Standard Specification for Temporary Rolled Erosion Control Products (Adapted from Erosion Control Technology Council 2005)

Product Description	Slope Applications*		Channel Applications*	Minimum Tensile Strength[1]	Expected Longevity
	Maximum Gradient	C Factor[2,5]	Max. Shear Stress[3,4,6]		
Mulch Control Nets	5:1 (H:V)	≤0.10 @ 5:1	0.25 lbs/ft² (12 Pa)	5 lbs/ft (0.073 kN/m)	Up to 12 months
Netless Rolled Erosion Control Blankets	4:1 (H:V)	≤0.10 @ 4:1	0.5 lbs/ft² (24 Pa)	5 lbs/ft (0.073 kN/m)	
Single-net Erosion Control Blankets & Open Weave Textiles	3:1 (H:V)	≤0.15 @ 3:1	1.5 lbs/ft² (72 Pa)	50 lbs/ft (0.73 kN/m)	
Double-net Erosion Control Blankets	2:1 (H:V)	≤0.20 @ 2:1	1.75 lbs/ft² (84 Pa)	75 lbs/ft (1.09 kN/m)	
Mulch Control Nets	5:1 (H:V)	≤0.10 @ 5:1	0.25 lbs/ft² (12 Pa)	25 lbs/ft (0.36 kN/m)	24 months
Erosion Control Blankets & Open Weave Textiles (slowly degrading)	1.5:1 (H:V)	≤0.25 @ 1.5:1	2.00 lbs/ft² (96 Pa)	100 lbs/ft (1.45 kN/m)	24 months
Erosion Control Blankets & Open Weave Textiles	1:1 (H:V)	≤0.25 @ 1:1	2.25 lbs/ft² (108 Pa)	125 lbs/ft (1.82 kN/m)	36 months

* C Factor and shear stress for mulch control nettings must be obtained with netting used in conjunction with pre-applied mulch material. (*See Section 5.3 of Chapter 7 Construction BMPs for more information on the C Factor.*)

[1] Minimum Average Roll Values, Machine direction using ECTC Mod. ASTM D 5035.

[2] C Factor calculated as ratio of soil loss from RECP protected slope (tested at specified or greater gradient, H:V) to ratio of soil loss from unprotected (control) plot in large-scale testing.

[3] Required minimum shear stress RECP (unvegetated) can sustain without physical damage or excess erosion (> 12.7 mm (0.5 in) soil loss) during a 30-minute flow event in large-scale testing.

[4] The permissible shear stress levels established for each performance category are based on historical experience with products characterized by Manning's roughness coefficients in the range of 0.01 - 0.05.

[5] Acceptable large-scale test methods may include ASTM D 6459, or other independent testing deemed acceptable by the engineer.

[6] Per the engineer's discretion. Recommended acceptable large-scale testing protocol may include ASTM D 6460, or other independent testing deemed acceptable by the engineer.

Table 10-2 Specifications for Rolled Erosion Control Products

Table 10.2 ECTC Standard Specification for Permanent[1] Rolled Erosion Control Products
(Adapted from: Erosion Control Technology Council 2005)

Product Type	Slope Applications	Channel Applications	
	Maximum Gradient	Maximum Shear Stress[4,5]	Minimum Tensile Strength[2,3]
TRMs with a minimum thickness of 0.25 inches (6.35 mm) per ASTM D 6525 and UV stability of 80% per ASTM D 4355 (500 hours exposure).	0.5:1 (H:V)	6.0 lbs/ft^2 (288 Pa)	125 lbs/ft (1.82 kN/m)
	0.5:1 (H:V)	8.0 lbs/ft^2 (384 Pa)	150 lbs/ft (2.19 kN/m)
	0.5:1 (H:V)	10.0 lbs/ft^2 (480 Pa)	175 lbs/ft (2.55 kN/m)

[1] For TRMs containing degradable components, all property values must be obtained on the non-degradable portion of the matting alone.

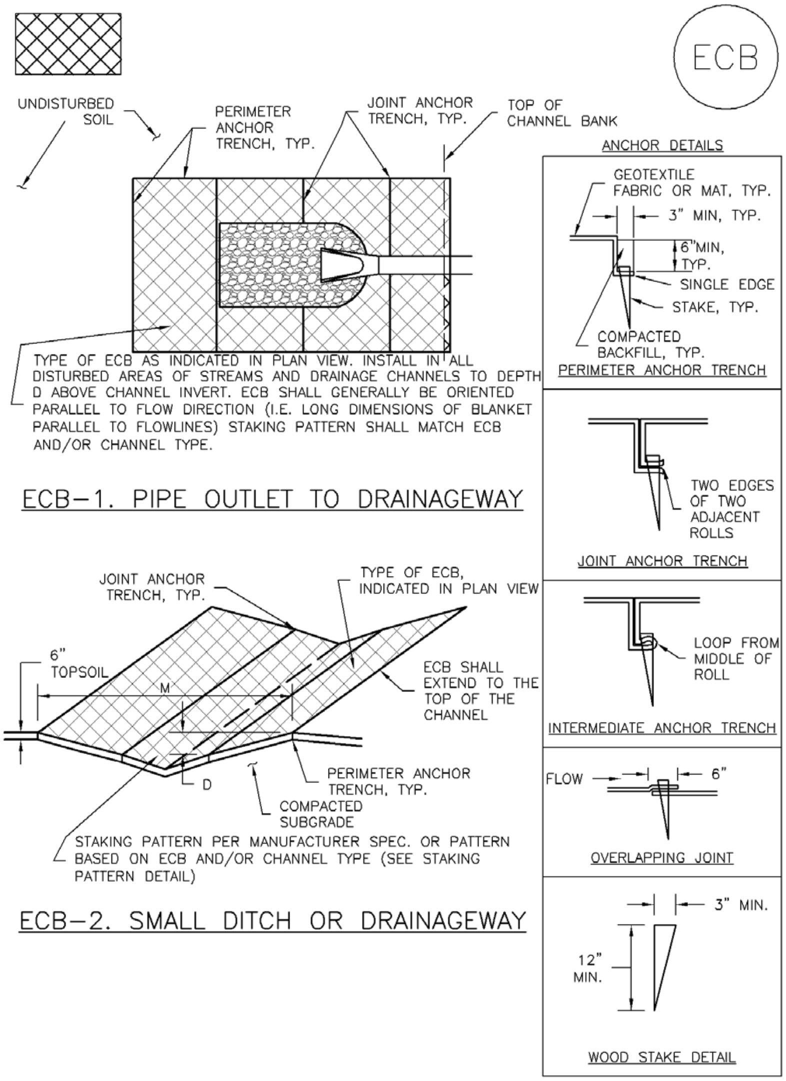
[2] Minimum Average Roll Values, machine direction only for tensile strength determination using ASTM D 6818 (Supersedes Mod. ASTM D 5035 for RECPs)

[3] Field conditions with high loading and/or high survivability requirements may warrant the use of a TRM with a tensile strength of 44 kN/m (3,000 lb/ft) or greater.

[4] Required minimum shear stress TRM (fully vegetated) can sustain without physical damage or excess erosion (> 12.7 mm (0.5 in.) soil loss) during a 30-minute flow event in large scale testing.

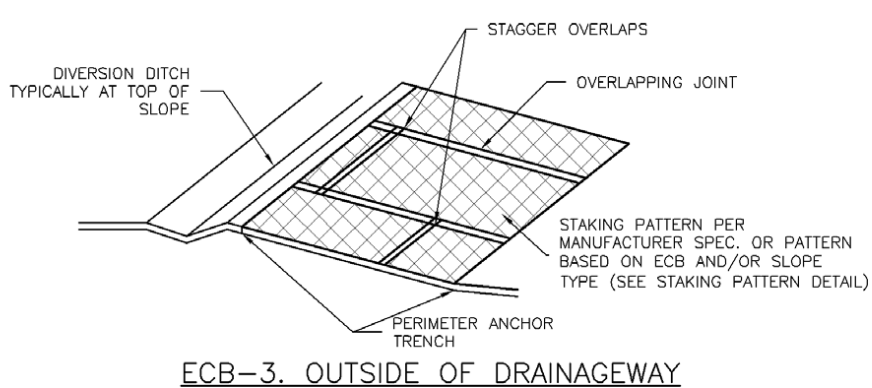
[5] Acceptable large-scale testing protocols may include ASTM D 6460, or other independent testing deemed acceptable by the engineer.

Figure 10-1 Rolled Erosion Control Product Details



Source: UDFC, 2010

Figure 10-2 Rolled Erosion Control Product Details



Source: UDFC, 2010

Installation

RECPs should be installed according to manufacturer's specifications and guidelines. Regardless of the type of product used, it is important to ensure no gaps or voids exist under the material and that all corners of the material are secured using stakes and trenching. Continuous contact between the product and the soil is necessary to avoid failure. Never use metal stakes to secure temporary erosion control products. Often wooden stakes are used to anchor RECPs; however, wood stakes may present installation and maintenance challenges and generally take a long time to biodegrade.

Figure 10-3 Erosion Blanket Installation

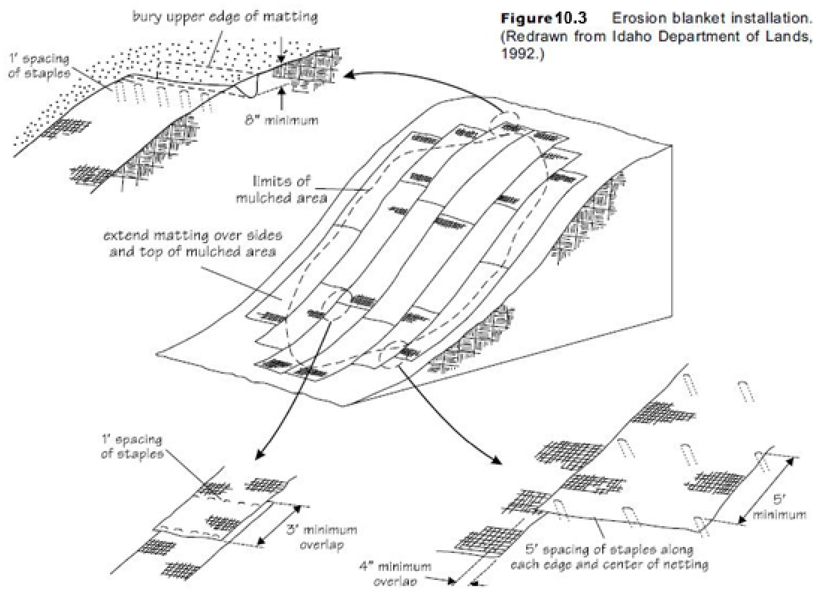
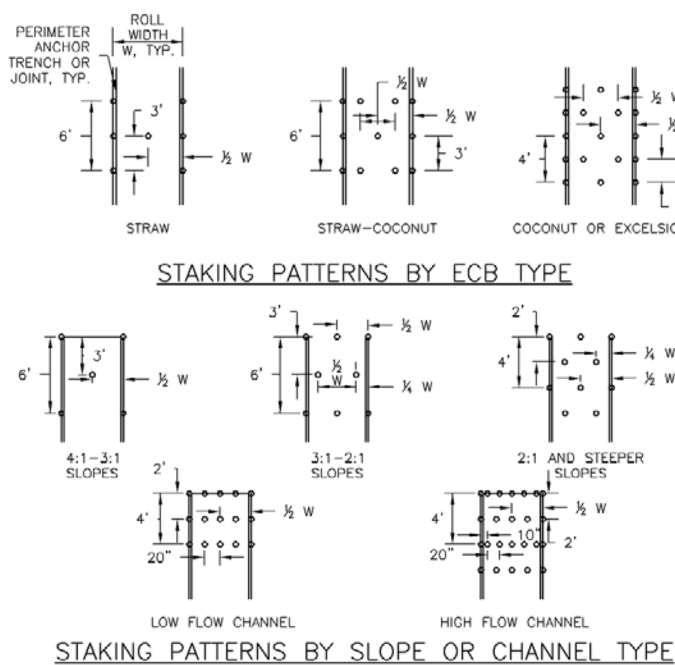


Figure 10-4 Erosion Blanket Installation



Source: UDFC, 2010

10.3.4 Effectiveness
The effectiveness of erosion control matting depends on the strength of the material and proper installation. For example, when protecting a cut slope with an erosion control mat, it is important to anchor the mat properly. Proper anchoring ensures that it will not be undermined by a storm event. While erosion control blankets can be effective, their performance varies. Some general trends are that organic materials tend to be the most effective (Harding 1990) and that thicker material are typically superior (Fifield 1999), but there are exceptions to both of these trends. Information about product testing of blankets is generally lacking. Reference the ASTM guide on erosion control that has performance standards.

10.3.5 Limitations
Erosion control mats (primarily synthetic types) are sensitive to light and for that reason must be protected before installation. Some erosion control mats might cause an increase in runoff or blow away if not firmly anchored. Erosion control mats might need to be properly disposed of in a landfill, depending on the type of material. Effectiveness could be reduced if the matting is not properly selected, designed, or installed.

10.3.6 Maintenance
Regular inspections are necessary to determine whether cracks, tears or breaches have formed in the matting. Contact between the ground and erosion control mat should be maintained at all times and trapped sediment removed after each storm event.

[redacted]EC-4: Topsoiling (TS)
10.4.1 General Description
Topsoiling is the placement of a surface layer of soil enriched in organic matter over a prepared subsoil to provide a suitable soil medium for vegetative growth on areas with poor moisture, low nutrient levels, undesirable pH, or the presence of other materials that would inhibit the establishment of vegetation. Advantages of topsoil include its high organic matter content and friable consistency and its water-holding capacity and nutrient content. The texture and friability of topsoil are usually more conducive to seedling emergence and root growth. In addition to being a better growth medium, topsoil is often less erodible than subsoils, and the coarser texture of topsoil increases infiltration capacity and reduces runoff. During construction, topsoil is often removed from the project area and stockpiled. It is replaced on areas to be grassed or landscaped during the final stages of the project.

10.4.2 Applicability
Conditions where topsoiling applies include the following:
- Where a sufficient supply of quality topsoil is available
- Where the subsoil or areas of existing surface soil present the following problems:
    - The structure, pH, or nutrient balance of the available soil cannot be amended by reasonable means to provide an adequate growth medium for the desired vegetation
    - The soil is too shallow to provide adequate rooting depth or will not supply necessary moisture and nutrients for growth of desired vegetation
    - The soil contains substances toxic to the desired vegetation
- Where slopes are 2:1 or flatter

10.4.3 Design and Installation Criteria
The topsoil should be uniformly distributed over the subsoil to a minimum compacted depth of 50 mm (2 inches) on slopes steeper than 3:1 and 100 mm (4 inches) on flatter slopes. Thicknesses of 100 to 150 mm

are preferred for vegetation establishment via seeding. The topsoil should not be placed while in a frozen or muddy condition or when the subsoil is excessively wet, frozen, or in a condition that is detrimental to proper grading or seedbed preparation. The final surface should be prepared so that any irregularities are corrected and depressions and water pockets do not form. On slopes and areas that will not be mowed, the surface could be left rough after spreading topsoil. A disk can be used to promote bonding at the interface between the topsoil and subsoil (Smolen et al. 1988).

10.4.4 Limitations

Limitations of applying topsoil can include the following:

- Topsoil spread when conditions are too wet, resulting in severe compaction
- Topsoil mixed with too much unsuitable subsoil material, resulting in poor vegetation establishment
- Topsoil not adequately incorporated or bonded with the subsoil, resulting in poor vegetation establishment and soil slippage on sloping areas
- Topsoiled areas not protected, resulting in excessive erosion
-

10.4.5 Maintenance

Newly topsoiled areas should be inspected frequently until the vegetation is established. Eroded or damaged areas should be repaired and re-vegetated.

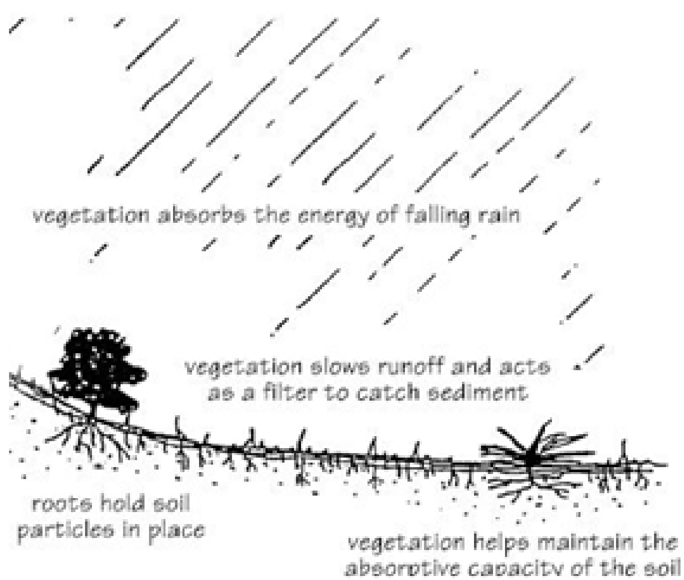
[redacted]EC-5: Vegetation (V)

Vegetation absorbs some of the energy of falling rain, holds soils in place, maintains the moisture-holding capacity of the soil, and reduces surface flow velocities (Figure 10-5).
The most effective way to use vegetation is to leave it undisturbed to prevent erosion and reduce the speed of surface water flows.

- If a new area must be cleared for mining, clear only the amount needed for expansion within one year.
- As an area is cleared of vegetation, save the sod or slash and stake it down across the cleared slopes to temporarily reduce storm-water runoff until the area is mined.
- Replace topsoil and replant mined areas as soon as possible.

Figure 10-5 Effect of Vegetation on Strom-Water Runoff

Figure 10.5 Effect of vegetation on storm-water runoff. (Modified from Washington State Department of Ecology, 1992.)



[redacted]EC-6: Dust Control (DC)

10.6.1 General Description

Dust control measures are practices that help reduce ground surface and air movement of dust from disturbed soil surfaces. Construction sites are good candidates for dust control measures because land disturbance from clearing and excavation generates a large amount of soil disturbance and open space for wind to pick up dust particles. These airborne particles pose a dual threat to the environment and human health. First, dust can be carried off-site, thereby increasing soil loss from the construction area and increasing the likelihood of sedimentation and water pollution. Second, blowing dust particles can contribute to respiratory health problems and create an inhospitable work environment.

10.6.2 Applicability

Dust control measures are applicable to any construction site where dust is created and there is the potential for air and water pollution from dust traveling across the landscape or through the air. Dust control measures are particularly important in arid or semiarid regions where soil can become extremely dry and vulnerable to transport by high winds.

Also, dust control measures should be implemented on all construction sites where there will be major soil disturbances or heavy construction activity, such as clearing, excavation, demolition, or excessive vehicle traffic. Earthmoving activities are the major source of dust from construction sites, but traffic and general disturbances can also be major contributors (WDEC 1992). Example locations for dust control are borrow areas, stockpiles, haul roads, access roads and the pit. The specific dust control measures implemented at a site will depend on the topography, land cover, soil characteristics, and amount of rainfall at the site.

10.6.3 Design and Installation Criteria

When designing a dust control plan for a site, the amount of soil exposed will dictate the quantity of dust generation and transport. Therefore, construction sequencing and disturbing small areas at one time can greatly reduce problematic dust from a site. If land must be disturbed, additional temporary stabilization measures should be considered before disturbance.

A number of methods can be used to control dust from a site. The following is a brief list of control measures and their design criteria. Not all control measures will be applicable to a site. The owner, operator, and contractors responsible for dust control should determine which practices accommodate their needs on the basis of specific site and weather conditions.

Sprinkling/Irrigation: Sprinkling the ground surface with water until it is moist is an effective dust control method for haul roads and other traffic routes (Smolen et al. 1988). This practice can be applied to almost any site and roads in particular. Roads should be watered within 12 hours of a wetting event (rain or truck) during the dry season and within 48 hours on more humid days or as visually necessary

Vegetative Cover: In areas not expected to handle vehicle traffic, vegetative stabilization of disturbed soil is often desirable. Vegetative cover provides protection to surface soils and slows wind velocity at the ground surface, thus reducing the potential for dust to become airborne. Vegetative cover is a practical application for long term stockpile areas and wherever possible,

Mulch: Mulching can be a quick and effective means of dust control for a recently disturbed area (Smolen et al. 1988). In the absence of organic mulch material, rubber tire mulch can be substituted.

Wind Breaks: Wind breaks are barriers (either natural or constructed) that reduce wind velocity and therefore reduce the possibility of carrying suspended particles. Wind breaks can be trees or shrubs left in place during site clearing or constructed barriers such as a wind fence, snow fence, tarp curtain, hay bale, crate wall, or sediment wall (USEPA 1992).

Stone: Stone can be an effective dust deterrent for construction roads and entrances.

10.6.4 Effectiveness

Sprinkling/Irrigation: Not available.

Vegetative Cover: Not available.

Wind Breaks/Barriers: For each foot of vertical height, an 8- to 10-foot deposition zone develops on the leeward side of the barrier. The barrier density and spacing will change its effectiveness at capturing windborne sediment.

Stone: The sizes of the stone can affect the amount of erosion that will take place. In areas of high wind, small stones are not as effective as 20-cm stones.

10.6.5 Limitations

In areas where evaporation rates are high, water application to exposed soils could require near constant attention. If water is applied in excess, runoff can result from the site and possibly create conditions where vehicles can track mud onto public roads.

10.6.6 Maintenance

Because dust controls are dependent on specific site conditions including the weather, inspection and maintenance are unique for each site. Generally, however, dust control measures involving application water requires more monitoring than structural or vegetative controls to remain effective. If structural controls are used, they should be inspected for deterioration regularly to ensure that they are still achieving their intended purpose.

11.0 SEDIMENT-TRAPPING DEVICES

The devices listed under this group of BMPs trap sediment primarily through impounding water and allowing for settling to occur (Haan, et al., 1994). Silt fence, super silt fence, straw bale dikes, sediment traps, and sediment basins all control flow through a porous flow control system such as filter fabric or straw bales, or they use a dam to impound water with a pipe, open channel, or rock fill outlet. For example, the filtering capacity of a silt fence (filter fabric) contributes only a small amount of trapping, but it serves to make the fence less porous and hence increases ponding. For steady-state flows, the trapping that occurs behind the flow-control device can be shown to be directly proportional to the surface area and indirectly proportional to flow through the system (Haan, et al., 1994). The ratio of the surface area to flow is known as the overflow rate, and trapping in such systems is predicted by the ratio of overflow rate to particle settling velocity. Although flows in nature are inherently non-steady-state and more complex than steady-state systems, studies have shown that the best predictor of trapping in such systems is still the ratio of settling velocity to overflow rate (Hayes, et al., 1984). In the case of non-steady-state, the overflow rate is best defined by the ratio of peak discharge to surface area (Hayes et al. 1984; McBurnie. et al., 1990).

The amount of trapping in these structures depends on the size of the structure, flow rates into the system, hydraulics of the flow control system, the size distribution of the sediment flowing into the structure, and the chemistry of the sediment-water system (Haan et al. 1994). Soils dominated by the clay fraction may require several large settling ponds in series. Trapping can be enhanced by chemical treatment of flows into the structure, but the effects have not been widely defined for varying mineralogy and chemistry of the sediment-water system (Haan et al. 1994; Tapp and Barfield 1986). Recent studies have been conducted on applying polyacrylamides (PAMs) to disturbed areas for enhancing settling (Benik et al. 1998; Masters et al. 2000; Roa-Espinosa et al. 2000), but results have not been definitive. No known studies have evaluated the effects of PAM application to disturbed areas on settling in sediment trapping devices.

Soils with sand as the dominant particle size are coarse-textured, light, and easily erodible. Water soaks into these soils rapidly. Silts and clays make fine-textured, heavy soils that are slow to erode and slow to drain. Clay-rich soils commonly cause the greatest impacts on water quality because they contain fine particles that settle slowly, travel far, and remain in suspension for a long time in settling ponds. Sediment flowing into sediment trapping devices is composed of primary particles and aggregated particles. Aggregates are formed when clays, silts, and sands are cemented together to form larger particles that have settling velocities far greater than those of any individual particles alone, although the degree of aggregation depends on the amount of cementing material present (typically clays and organic matter). Because the aggregates have higher settling velocities than primary particles, the degree of aggregation that is present has a large effect on the trapping that occurs. Procedures are available to measure the combined size distribution of aggregate and primary particle size distribution (Barfield, et al., 1979; Haan, et al., 1994). Procedures are also available to predict particle size distributions of aggregates and primary particles (Foster et al. 1985).

In the absence of chemical treatment, the sediment that can be captured in sediment trapping devices is typically the larger settleable solids. In many cases, to trap the smaller-sized clay particles, structures with surface areas larger than the construction site itself would have to be built (Barfield, 2000). Chemical treatment can be used to reduce the size captured, but it has not been widely adopted because of the cost and complexity of the operation (Tapp et al. 1981).

[redacted]ST-1: Sediment Control Log (SCL)

11.1.1 Description

Sediment control logs (also called fiber rolls or straw wattles) are tube-shaped erosion-control devices filled with straw, flax, rice, coconut fiber material, or composted material. Each log is wrapped with UV-degradable polypropylene netting for longevity or with 100 percent biodegradable materials like burlap, jute, or coir. SCL's complement permanent best management practices used for source control and revegetation. When installed in combination with straw mulch, erosion control blankets, hydraulic mulches, or bounded fiber matrices for slope stabilization, these devices reduce the effects of long or steep slopes (Earth Saver Erosion Control Products, 2005). SCL's also help to slow, filter, and spread overland flows. This helps to prevent erosion and minimizes rill and gully development. SCL's also help reduce sediment loads to receiving waters by filtering runoff and capturing sediments.

11.1.2 Applicability

SCL's can be used in areas of low shear stress. Avoid using them in channels that are actively incising or in reaches with large debris loads or potential for significant ice buildup (Maryland Department of the Environment, 2000). Logs have been used to control erosion in a variety of areas--along highways and at construction sites, golf courses, ski areas, vineyards, and reclaimed mines. According to the California Stormwater Quality Association (CASQA, 2003), fiber rolls can be suitable in the following settings:

- Along the toe, top, face, and at-grade breaks of exposed and erodible slopes to shorten slope length and spread runoff as sheet flow
- At the end of a downward slope where it transitions to a steeper slope
- Along the perimeter of a project
- As check dams in unlined ditches
- Downslope of exposed soil areas
- Around temporary stockpiles

11.1.3 Design and Installation

Fiber rolls should be prefabricated rolls or rolled tubes of geotextile fabric. When rolling the tubes, make sure each tube is at least 20 cm in diameter. Bind the rolls at each end and every 1.2 m along the length of the roll with jute-type twine (California Stormwater Quality Association, 2003).

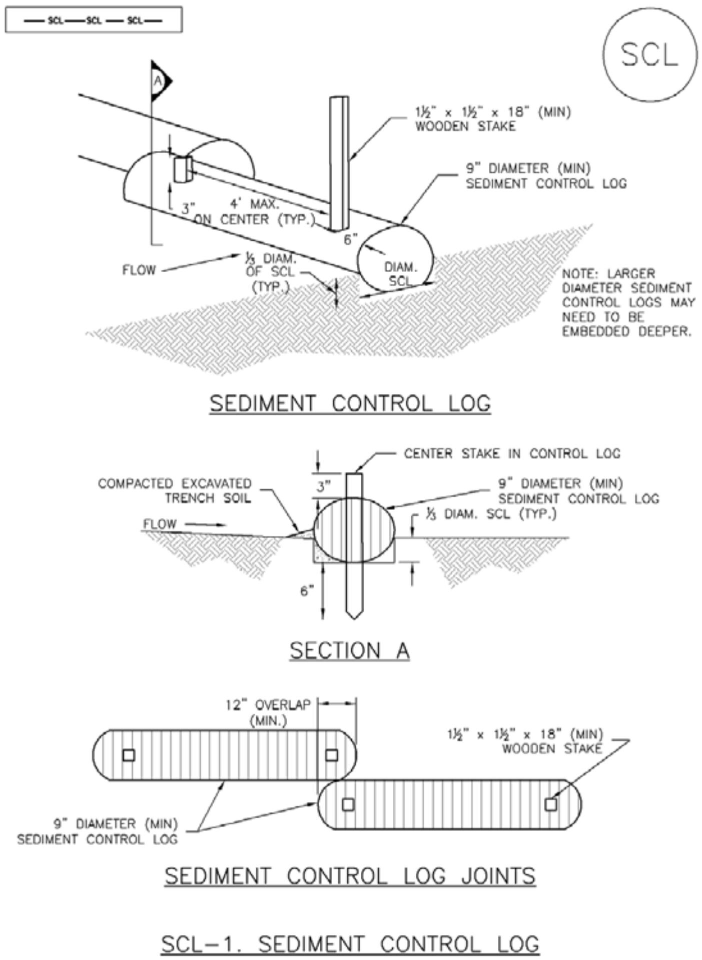
Slope ground projects

On slopes, install fiber rolls along the contour with a slight downward angle at the end of each row to prevent ponding at the midsection (California Straw Works, 2005). Turn the ends of each fiber roll upslope to prevent runoff from flowing around the roll. Install fiber rolls in shallow trenches dug 8 to 13 cm deep for soft, loamy soils and 5 to 8 cm deep for hard, rocky soils. Determine the vertical spacing for slope installations on the basis of the slope gradient and soil type. According to California Straw Works (2005), a good rule of thumb is:

1:1 slopes = 3 m apart
2:1 slopes = 6 m feet apart
3:1 slopes = 9 m feet apart
4:1 slopes = 12 m feet apart

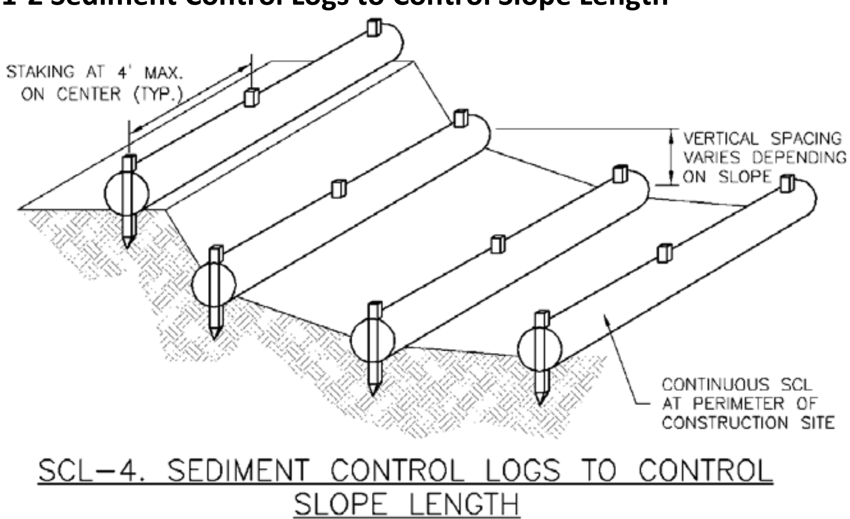
For soft, loamy soils, place the rows closer together. For hard, rocky soils, place the rows farther apart. Stake fiber rolls securely into the ground and orient them perpendicular to the slope. Biodegradable wood stakes or willow cuttings are recommended. Drive the stakes through the middle of the fiber roll and deep enough into the ground to anchor the roll in place. About 8 to 13 cm of the stake should stick out above the roll, and the stakes should be spaced 1 to 1.5 m apart. A 60 cm stake is recommended for use on soft, loamy soils. A 45 cm stake is recommended for use on hard, rocky soils.

Figure 11-1 Sediment Control Log



Source: UDFC, 2010

Figure 11-2 Sediment Control Logs to Control Slope Length



Source: UDFC, 2010

Sediment Control Log Installation Notes

1. Sediment control logs that act as a perimeter control shall be installed prior to any upgradient land-disturbing activities.
2. Sediment control logs shall consist of straw, compost, excelsior or coconut fiber, and shall be free of any noxious weed seeds or defects including rips, holes and obvious wear.
3. Sediment control logs may be used as small check dams in ditches and swales. However, they should not be used in perennial streams or high velocity drainage ways.
4. It is recommended that sediment control logs be trenched into the ground to a depth of approximately 1/3 of the diameter of the log. If trenching to this depth is not feasible and/or desirable (short term installation with desire not to damage landscape) a lesser trenching depth may be acceptable with more robust staking.
5. The uphill side of the sediment control log should be backfilled with soil that is free of rocks and debris. The soil should be tightly compacted into the shape of a right triangle using a shovel or weighted lawn roller.
6. Follow manufacturers' guidance for staking. If manufacturers' instructions do not specify spacing, stakes shall be placed on 4' centers and embedded a minimum of 6" into the ground, with 3" of the stake protruding from the top of the log. Stakes that are broken prior to installation should be replaced.

Sediment Control Log Maintenance Notes

1. Inspect BMPs each workday, and maintain them in effective operating condition. Maintenance of BMPs should be proactive, not reactive. Inspect BMPs as soon as possible (and always within 24 hours) following a storm that causes surface erosion and perform necessary maintenance.
2. Frequent observations and maintenance are necessary to maintain BMPs in effective operating condition. Inspections and corrective measures should be documented thoroughly.
3. Where BMPs have failed, repair or replacement should be initiated upon discovery of the failure.
4. Sediment accumulated upstream of sediment control log should be removed as needed to maintain functionality of the BMP, typically when depth of accumulated sediments is approximately ½ of the height of the sediment control log.
5. Sediment control log should be removed at the end of construction. If disturbed areas exist after removal, they should be covered with top soil, seeded and mulched or otherwise stabilized in a manner approved by the local jurisdiction.

11.1.4 Limitations

The installation and overall performance of fiber rolls have several limitations, including the following (California Stormwater Quality Association, 2003):

- Fiber rolls are not effective unless trenched.
- Fiber rolls can be difficult to move once saturated.
- To be effective, fiber rolls at the toe of slopes greater than 5:1 must be at least 50 cm in diameter. An equivalent installation, such as stacked smaller-diameter fiber rolls, can be used to achieve a similar level of protection.
- If not properly staked and entrenched, fiber rolls can be transported by high flows.
- Fiber rolls have a very limited sediment capture zone.
- Fiber rolls should not be used on slopes subject to creep, slumping, or landslide.

11.1.5 Maintenance Considerations

The maintenance requirements of fiber rolls are minimal, but short-term inspection is recommended to ensure that the rolls remain firmly anchored in place and are not crushed or damaged by equipment traffic

(Murphy and Dreher, 1996). Monitor fiber rolls daily during prolonged rain events. Repair or replace split, torn, unraveled, or slumping fiber rolls. Fiber rolls are typically left in place on slopes. If they are removed, collect and dispose of the accumulated sediment. Fill and compact holes, trenches, depressions, or any other ground disturbance to blend with the surrounding landscape.

11.1.6 Effectiveness

Unlike other BMPs that could cause water to back up and flow around the edges, fiber rolls allow water to flow through while capturing runoff sediments. Fiber rolls placed along the shorelines of lakes and ponds provide immediate protection by dissipating the erosive force of small waves. As an alternative to silt fences, fiber rolls have some distinct advantages, including the following (Earth Saver, 2005):

- They install more easily, particularly in shallow soils and rocky material.
- They are more adaptable to slope applications and contour installations than other erosion and sediment control practices.
- They are readily molded to fit the bank line.
- They blend in with the landscape and are less obtrusive than other erosion and sediment controls such as silt fence.
- They do not obstruct hydraulic mulch and seed applications.
- They can be removed or left in place after vegetation is established.

Fiber rolls can provide slope protection for 3 to 5 years (California Straw Works, 2005). They slowly decompose into mulch, and the netting breaks down into small pieces. The San Diego State University Soil Erosion Research Laboratory reported that the use of fiber roll products reduced offsite sediment delivery by 58 percent (International Erosion Control Association, 2005).

[redacted]ST-2: Rock Sock (RS)

11.2.1 Description

A rock sock is constructed of gravel that has been wrapped by wire mesh or a geotextile to form an elongated cylindrical filter. Rock socks are typically used either as a perimeter control or as part of inlet protection. When placed at angles in the curb line, rock socks are typically referred to as curb socks. Rock socks are intended to trap sediment from stormwater runoff that flows onto roadways as a result of construction activities.

11.2.2 Appropriate Uses

Rock socks can be used at the perimeter of a disturbed area to control localized sediment loading. A benefit of rock socks as opposed to other perimeter controls is that they do not have to be trenched or staked into the ground; therefore, they are often used on roadway construction projects where paved surfaces are present. Use rock socks in inlet protection applications when the construction of a roadway is substantially complete and the roadway has been directly connected to a receiving storm system.

11.2.3 Design and Installation

When rock socks are used as perimeter controls, the maximum recommended tributary drainage area per 100 linear feet of rock socks is approximately 0.25 acres with disturbed slope length of up to 150 feet and a tributary slope gradient no steeper than 3:1. A rock sock design detail and notes are provided in Detail RS-1.

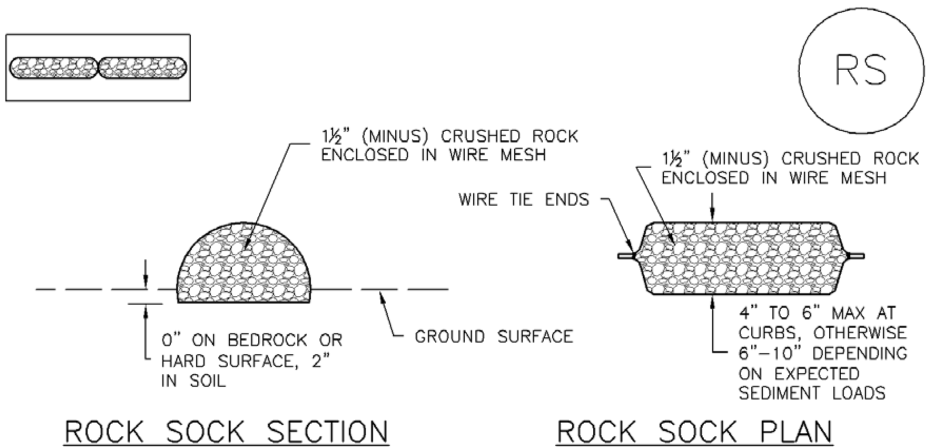
When placed in the gutter adjacent to a curb, rock socks should protrude no more than two feet from the curb in order for traffic to pass safely. If located in a high traffic area, place construction markers to alert drivers and street maintenance workers of their presence.

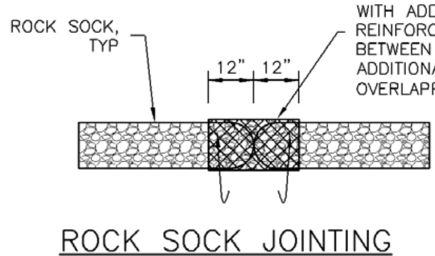
11.2.4 Maintenance

Rock socks are susceptible to displacement and breaking due to vehicle traffic. Inspect rock socks for damage and repair or replace as necessary. Remove sediment by sweeping or vacuuming as needed to maintain the functionality of the BMP, typically when sediment has accumulated behind the rock sock to one-half of the sock's height.

Once upstream stabilization is complete, rock socks and accumulated sediment should be removed and properly disposed.

Figure 11-3 Rock Sock Perimeter Control





GRADATION TABLE	
SIEVE SIZE	MASS PERCENT PASSING SQUARE MESH SIEVES
	NO. 4
2"	100
1½"	90 – 100
1"	20 – 55
¾"	0 – 15
⅜"	0 – 5
MATCHES SPECIFICATIONS FOR NO. 4 COARSE AGGREGATE FOR CONCRETE PER AASHTO M43. ALL ROCK SHALL BE FRACTURED FACE, ALL SIDES.	

ROCK SOCK INSTALLATION NOTES

1. SEE PLAN VIEW FOR:
   –LOCATION(S) OF ROCK SOCKS.
2. CRUSHED ROCK SHALL BE 1½" (MINUS) IN SIZE WITH A FRACTURED FACE (ALL SIDES) AND SHALL COMPLY WITH GRADATION SHOWN ON THIS SHEET (1½" MINUS).
3. WIRE MESH SHALL BE FABRICATED OF 10 GAGE POULTRY MESH, OR EQUIVALENT, WITH A MAXIMUM OPENING OF ½", RECOMMENDED MINIMUM ROLL WIDTH OF 48"
4. WIRE MESH SHALL BE SECURED USING "HOG RINGS" OR WIRE TIES AT 6" CENTERS ALONG ALL JOINTS AND AT 2" CENTERS ON ENDS OF SOCKS.
5. SOME MUNICIPALITIES MAY ALLOW THE USE OF FILTER FABRIC AS AN ALTERNATIVE TO WIRE MESH FOR THE ROCK ENCLOSURE.

RS–1. ROCK SOCK PERIMETER CONTROL

Source: UDFC, 2010

Rock Sock Maintenance Notes

1. Inspect BMPs each workday and maintain them in effective operating condition. Maintenance of BMPs should be proactive, not reactive. Inspect BMPs as soon as possible (and always within 24 hours) following a storm that causes surface erosion and perform necessary maintenance.
2. Frequent observations and maintenance are necessary to maintain BMPs in effective operating condition. Inspections and corrective measures should be documented thoroughly.
3. Where BMPs have failed, repair or replacement should be initiated upon discovery of the failure.
4. Rock socks shall be replaced if they become heavily soiled or damaged beyond repair.
5. Sediment accumulated upstream of rock socks shall be removed as needed to maintain functionality of the BMP. Typically when depth of accumulated sediments is approximately ½ of the height of the rock sock.
6. Rock socks are to remain in place until the upstream disturbed area is stabilized and approved by the local jurisdiction.
7. When rock socks are removed, all disturbed areas shall be covered with topsoil, seeded and mulched or otherwise stabilized.

[redacted]ST-3: Silt Fences (SF)

11.3.1 General Description

Silt fences are used as temporary sediment barriers consisting of filter fabric anchored across and supported by posts. Their purpose is to retain sediment from small, disturbed areas by reducing the velocity of sediment-laden runoff and promoting sediment deposition (Smolen et al. 1988). Silt fences capture sediment by ponding water and allowing for deposition, not by filtration. Silt fence fabric first screens silt and sand from runoff, resulting in clogging of the lower part of the fence. The pooling water allows sediments to settle out of the runoff. Silt fences work best in conjunction with temporary basins, traps, or diversions.

11.3.2 Applicability

Silt fences are generally placed at the toe of fills, along the edge of waterways, and along the site perimeter. Silt fences should be used below disturbed areas where runoff may occur in the form of sheet and rill erosion. The fences should not be used in drainage areas with concentrated and high flows, in large drainage areas, or in ditches and swales where concentrated flow is present. The drainage area for the fence should be selected on the basis of design storms and local hydrologic conditions so that the silt fence is not expected to overtop. A typical design calls for no greater than one-quarter acre of drainage area per 100 feet of fence, but that is highly variable, depending on climate. The fence should be stable enough to withstand runoff from a 10-year peak storm. Table 11-1 lists the maximum slope length specified by the U.S. Department of Transportation (USDOT). The slope lengths should be based on sediment load and flow rates. That would mean that the values given below should be adjusted for climatic conditions instead of one size fits all to ensure maximum effectiveness.

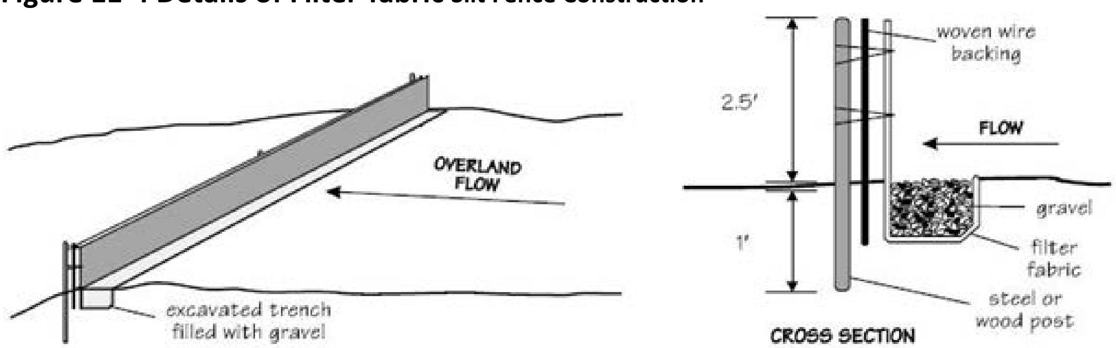
Table 11-1 Maximum Slope Lengths for Silt Fences

Slope (%)	18-inch (460 mm) fence	30-inch (760 mm) fence
≤ 2	250 ft (75 m)	500 ft (150 m)
5	100 ft (30 m)	250 ft (75 m)
10	50 ft (15 m)	150 ft (45 m)
20	25 ft (8 m)	70 ft (21 m)
25	20 m (6 ft)	55 ft (17 m)
30	15 ft (5 m)	45 ft (14 m)
35	15 ft (5 m)	40 ft (12 m)
40	15 ft (5 m)	35 ft (10 m)
45	10 ft (3 m)	30 ft (9 m)
50	10 ft (3 m)	25 ft (8 m)

Source: USDOT 1995.

A silt fence is made of filter fabric that allows water to pass through. Woven fabric is generally best. Depending on its pore size, filter fabric will trap different particle sizes. The fence is placed perpendicular to the flow direction and is held upright by stakes (Figure 11-4). A more durable construction uses chicken wire and T-posts to support the fabric vertically. It is essential to bury the bottom of the filter fabric to prevent flow under or around the fence. Maintenance is required to keep the fence functioning properly. Rock check dams or other methods may be needed to slow water enough to allow it to pass through the fence.

Figure 11-4 Details of Filter-fabric Silt Fence Construction



11.3.3 Design and Installation Criteria

Design criteria are of two types:

- Hydrologic design for a required trapping of sediment and flow rate to pass the design storm
- Selecting appropriate installation criteria such that the silt fence performs as designed

Hydrologic Design

A silt fence must provide sufficient storage capacity or be stabilized with over flow outlets such that the storage volume of water will not overtop the fence. For temporary fences, a 2-year storm event is typically used as a design standard. Fences that will be in place for 6 months or longer are commonly designed for a 10-year storm event (Sprague 1999). The space behind the fence used for impoundment volume must be sufficient to adequately contain the sediment that will be deposited. Each storm will deposit sediment behind the fence, and after a time, the amount of sediment accumulated will render the fence useless. Frequency of fence management is a function of its sizing (i.e., whether the fence was installed for a 2-year or a 10-year storm event) (Sprague 1999) and the amount of erosion that occurs in the area draining to the fence.

The fence should be designed to pass the design storm without causing damage, while trapping the required amount of sediment. It is necessary to use either a database or some type of model to develop the appropriate hydrologic design. Efforts to model the sediment trapping that occurs with a silt fence have resulted in models that predict the settling in the ponded area upstream from the fence (Barfield et al. 1996; Lindley et al. 1998). The results from model simulations show that trapping depends primarily on the surface area of the impounded water and the flow rate through the filter. The models use a clear water flow rate, typically specified by the manufacturer, to predict discharge. However, numerous studies have shown that sediment laden flows cause clogging of the geotextiles used to construct the fence, depending on the opening size and size of the sediment (Britton et al. 2001; Wyant 1980; Barrett et al. 1995; Fisher and Jarrett 1984). Thus, results from model studies to date are suspect and need to be modified to account for the effects of clogging on flow rate. Barfield et al. (2001) developed a model of flow rate using conditional probability concepts, but the results have not been experimentally verified.

Design aids have been developed for silt fence, using simulations from the SEDIMOT III model (Hayes and Barfield 1995). In the model, predictions are made about trapping efficiency using the ratio of settling velocity for the d15 of the eroded sediment, divided by the ratio of discharge to ponded surface area. The design aids yield conservative estimates as compared to the SEDIMOT III model, but the database used for generating the design aid is based on the assumption that clogging does not affect flow rates. The discussion above shows that assumption to be erroneous.

SEDCAD takes the approach of using a slurry flow rate, not a clean water flow rate, when it simulates fence effectiveness, reporting slurry rates ranging between 0.1 and 15 gallons per minute (gpm) per square foot. On the basis of this discussion, one can conclude that it is difficult to predict with accuracy the trapping efficiency of silt fence under a given set of conditions. In addition, the quality of installation and maintenance are important to the long-term performance of the fence. The best available estimate of sediment trapping obtained from modeling of hydrologic events should be applied with care in any site design problem.

Installation Criteria

Although this document does not endorse specific commercial products or brands, general installation criteria for the silt fence should incorporate the following factors:

- The fabric must have sufficient strength to counter forces created by contained water and sediment (Sprague 1999).
- The posts must have sufficient strength to counter the forces transferred to them by the fabric (Sprague 1999).
- The fence must be installed (anchored) with a buried toe of sufficient depth so that it does not become detached from the soil surface.
- The fence must be designed according to site-specific hydrologic and soil conditions such that it will not overtop during design events.
- In general, the fence requires a metal wire backing to provide sufficient strength to prevent failure from the weight of trapped sediment and to prevent the toe of the fabric from being removed from the ground.
- Maximum drainage area behind the fence should be determined on the basis of the local rainfall and the infiltration characteristics of the soil and cover.

Silt fence material is typically synthetic filter fabric. The fabric should have ultraviolet ray inhibitors and stabilizers to provide for a minimum useful construction life of 6 months or the duration of construction, whichever is greater. The height of the fence fabric should not exceed 1 meter, if standard strength filter fabric is used. It should be reinforced with a wire fence, extending down into the trench that buries the toe. The wire should be of sufficient strength to support the weight of the deposited sediment and water. In general, a minimum 14 gauge and a maximum mesh spacing of 6 inches is called for (Smolen et al. 1988). Typical requirements for the silt fence physical properties, as specified in selected local BMP standards and specifications, are presented in Table 11-2**.**

Table 11-2 Typical Requirements for Silt Fence Fabric

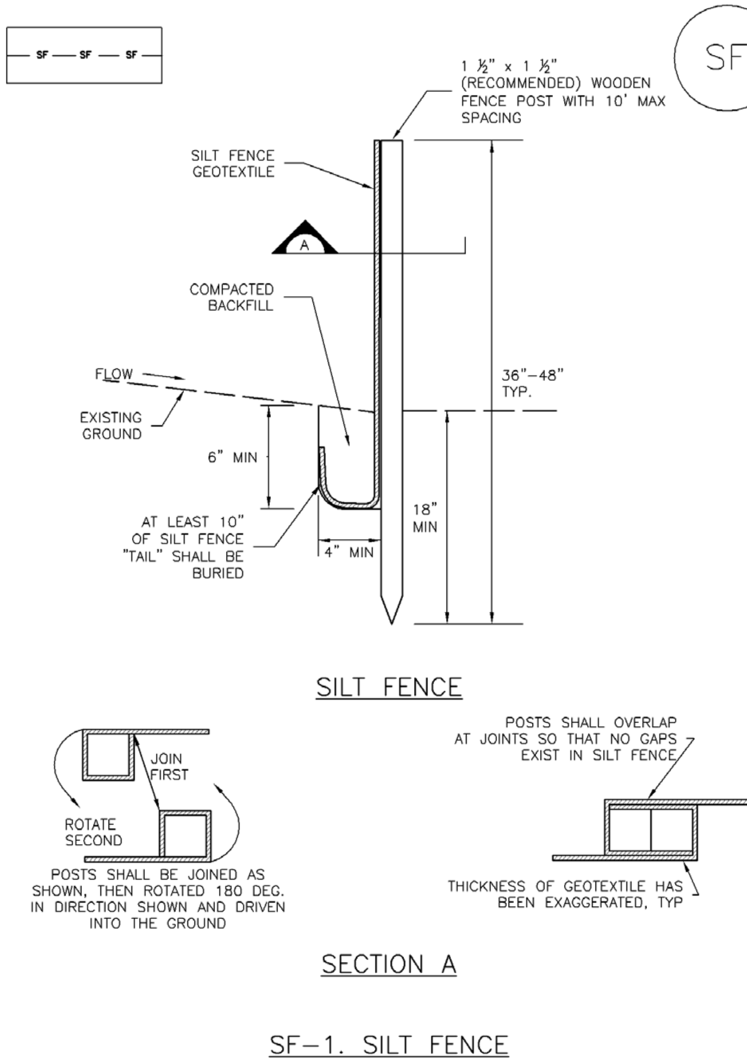
Physical property	Requirements	
	Woven fabric	Non-woven fabric
Filtering Efficiency	85%	85%
Tensile Strength at 20% (maximum) Elongation	Standard Strength—30 pound/linear inch Extra Strength—50 pound/linear inch	Standard Strength—50 pound/linear inch Extra Strength—70 pound/linear inch
Slurry Flow Rate	0.3 gallon/square feet/minute	4.5 gallons/square feet/minute
Water Flow Rate	15 gallons/square feet/minute	220 gallon/square feet/minute
UV Resistance	70%	85%

Source: NCDNR 1988; IDNR 1992.

Note that those numbers, particularly the flow rates, can vary widely depending on the local soil condition because of possible clogging of the filter material.

Material for the posts used to anchor the filter fabric can be constructed of either wood or steel. Wooden stakes should be buried at a depth sufficient to keep the fence, when loaded with sediment and water, from falling over. The depth of burial should depend on post diameter and soil strength characteristics when saturated. Many standards and specifications set a minimum post length of 5 feet with 4-inch diameter for posts composed of softwood (e.g., pine) and 2-inch diameter for posts composed of hardwood (e.g., oak) (Smolen et al. 1988). Steel posts should also be designed according to local wet soil strength characteristics. Some standards and specifications for the posts set a minimum weight of 1.33 pounds per linear feet with a minimum length of 4 feet. Steel posts should also have projections to adhere filter fabric to the post (Smolen et al. 1988). A silt fence should be erected continuously from a single roll of fabric to eliminate unwanted gaps in the fence. If a continuous roll of fabric is not available, the fabric should overlap from both directions only at posts with a minimum overlap of 6 inches and be rolled together with a special flexible rod to keep the ends from separating. Fence posts should be spaced at a distance on the basis of wet soil strength characteristics and post size and strength; generally, the posts are spaced approximately 4 to 6 feet apart. If standard strength fabric is used in combination with wire mesh, the spacing can be larger. Typically, standards and specifications call for the posts to be no more than 10 feet apart. If extra-strength fabric is used without wire mesh reinforcement, some standards call for the support posts to be spaced no more than 6 feet apart (VDCR 1995). Again, the spacing depends on wet soil strength characteristics and post size.

Figure 11-5 Typical Silt Fence Construction Detail



Source: UDFC, 2010

Silt Fence Installation Notes

1. Silt fence must be placed away from the toe of the slope to allow for water ponding. Silt fence at the toe of a slope should be installed in a flat location at least several feet (2-5 FT) from the toe of the slope to allow room for ponding and deposition.
2. A uniform 6” X 4” anchor trench shall be excavated using a trencher or silt fence installation device. No road graders, backhoes or similar equipment should be used.
3. Compact anchor trench by hand with a “jumping jack” or by wheel rolling. Compaction should be such that silt fence resists being pulled out of anchor trench by hand.
4. Silt fence should be pulled tight as it is anchored to the stakes. There should be no noticeable sag between stakes after it has been anchored to the stakes.
5. Silt fence fabric should be anchored to the stakes using 1” heavy duty staples or nails with 1” heads. Staples and nails should be placed 3” along the fabric down the stake.
6. At the end of a run of silt fence along a contour, the silt fence should be turned perpendicular to the contour to create a “J-hook.” The “J-hook” extending perpendicular to the contour should be of

sufficient length to keep runoff from flowing around the end of the silt fence (Typically 10'-20').

7. Silt fence shall be installed prior to any land disturbing activities.

Silt Fence Maintenance Notes

1. Inspect BMPs each workday and maintain them in effective operating condition. Maintenance of BMPs should be proactive, not reactive. Inspect BMPs as soon as possible (and always within 24 hours) following a storm that causes surface erosion and perform necessary maintenance.
2. Frequent observations and maintenance are necessary to maintain BMPs in effective operating condition. Inspections and corrective measures should be documented thoroughly.
3. Where BMPs have failed, repair or replacement should be initiated upon discovery of the failure.
4. Sediment accumulated upstream of the silt fence should be removed as needed to maintain the functionality of the BMP, typically when depth of accumulated sediments is approximately 6".
5. Repair or replace silt fence when there are signs of wear, such as sagging, tearing or collapse.
6. Silt fence is to remain in place until the upstream disturbed area is stabilized and approved by site personnel or is replaced by an equivalent perimeter sediment control BMP.
7. When silt fence is removed, all disturbed areas should be covered with topsoil, seeded and mulched or otherwise stabilized.

11.3.4 Effectiveness

The performance of silt fences has not been well defined. Laboratory studies using carefully controlled conditions have shown trapping efficiencies in the range of 40 to 100 percent, depending on the type of fabric, overflow rate, and detention time (Barrett et al. 1995; Wyant 1980; Wishowski et al. 1998). Field studies have been limited and quite inadequate; however, the results show that field-trapping efficiencies are very low. In fact, Barrett et al. (1995) obtained a value of zero percent trapping averaged over several samples with a standard error of 26 percent. Barrett et al. (1995) cite the following reasons for the field tests not showing the expected results:

- Inadequate fabric splices
- Sustained failure to correct fence damage resulting from overtopping
- Large holes in the fabric
- Under-runs because of inadequate toe-ins
- Silt fence damaged and partially covered by the temporary placement of stockpiles of materials

Silt fences are effective at removing large particle sediment, primarily aggregates, sands, and larger silts. Sediment is removed through impounding of water to slow velocity. It is argued that the silt fence will not contribute to a reduction in small particle sediment and is not effective against other pollutants (WYDEQ 1999). EPA (1993) reports the following effectiveness ranges for silt fences constructed of filter fabric: average TSS removal of 70 percent, sand removal of 80 to 90 percent, silt-loam removal of 50 to 80 percent, and silt-clay-loam removal of 0 to 20 percent. The actual trapping will vary widely for a given design because of differences in hydrologic regimes and soil types.

The advantages of using silt fences include minimal labor requirement for installation, low cost, high efficiency in removing sediment, durability, and sometimes reuse (Sprague 1999). Silt fences are the most readily available and cost-effective control options where options such as a diversion are not possible. The visibility of a silt fence is also an advantage (i.e., the fence is advertising the use of ESC practices). In addition, the silt fence visibility makes site inspection easier for contractors and government inspectors (CWP 1996).

11.3.5 Limitations

Silt fences should not be installed along areas where rocks or other hard surfaces prevent uniform anchoring of fence posts and entrenching of the filter fabric. An insufficient anchor greatly reduces their effectiveness and might create runoff channels. When the pores of the silt fence fabric become clogged with sediment, pools of water are likely to form uphill of the fence. Siting and design of the silt fence should account for this problem, and care should be taken to avoid unnecessary diversion of storm water from the pools that might cause further erosion damage. Silt fences can act as a diversion if placed slightly off-contour and can control shallow, uniform flows from small, disturbed areas and deliver sediment-laden water to deposition areas.

Silt fences will sag or collapse if a site is too large, if too much sediment accumulates, if the approach slope is too steep, or if the fence was not adequately supported. If the fence bottom is not properly installed or the flow velocity is too fast, fence undercuts or blowouts can occur because of excess runoff. Erosion around the end of the fence can occur if the fence ends do not extend upslope to prevent flow around the fence (IDNR 1992).

11.3.6 Maintenance

Site operators should inspect silt fences after each rainfall event to ensure that they are intact and that there are no gaps at the fence-ground interface or tears along the length of the fence. If gaps or tears are found, they should be repaired or the fabric should be replaced immediately. Accumulated sediments should be removed from the fence base when the sediment reaches one third to halfway up the height of the fence. Sediment removal should occur more frequently if accumulated sediment is creating a noticeable strain on the fabric, and there is the possibility that the fence could fail from a sudden storm event.

[redacted] ST-4: Earthen and Rock Check Dams (CD)

11.4.1 General Description

A check dam is a small, temporary barrier constructed across a drainage channel or swale to reduce the velocity of the flow. Check dams are typically constructed from coarse crushed rock ranging from about 2 to 4 inches in diameter, depending on the water velocities anticipated. A check dam can generally withstand higher velocity flows than a silt fence, and the integrity of the structure will not be affected if it is overtopped in a large storm event. The tops of check dams are lower than the channel margins so that water can spill over (instead of around the sides) during heavy storms. By reducing the flow velocity, the erosion potential is reduced, detention times are lengthened, and more sediment is able to settle out of the water column. Check dams can be constructed of stone, gabions, treated lumber, or logs (NAHB, No Date). Check dams are inexpensive and easy to install. They can be used permanently to settle sediment, reduce the velocity of runoff, and provide aeration. Check dams are often used in combination with other practices, such as sediment traps or basins.

11.4.2 Applicability

Check dams are commonly used (1) in channels that are degrading but where permanent stabilization is impractical because of their short period of usefulness and (2) in eroding channels where construction delays or weather conditions prevent timely installation of erosion-resistant linings (IDNR 1992).

Check dams are also useful in steeply sloped swales, in small channels, in swales where adequate vegetative protection cannot be established, or in swales or channels that will be used for a short time and it is not practical to line the channel or implement other flow control practices (USEPA 1993). In addition, check dams are appropriate where temporary seeding has been recently implemented but has not had time to fully develop and take root. The contributing drainage area should range from 2 to 10 acres. They should not be built in stream channels, either intermittent or perennial (UNEP 1994). Check dams can be effective sediment trapping devices when designed appropriately.

11.4.3 Design and Installation Criteria

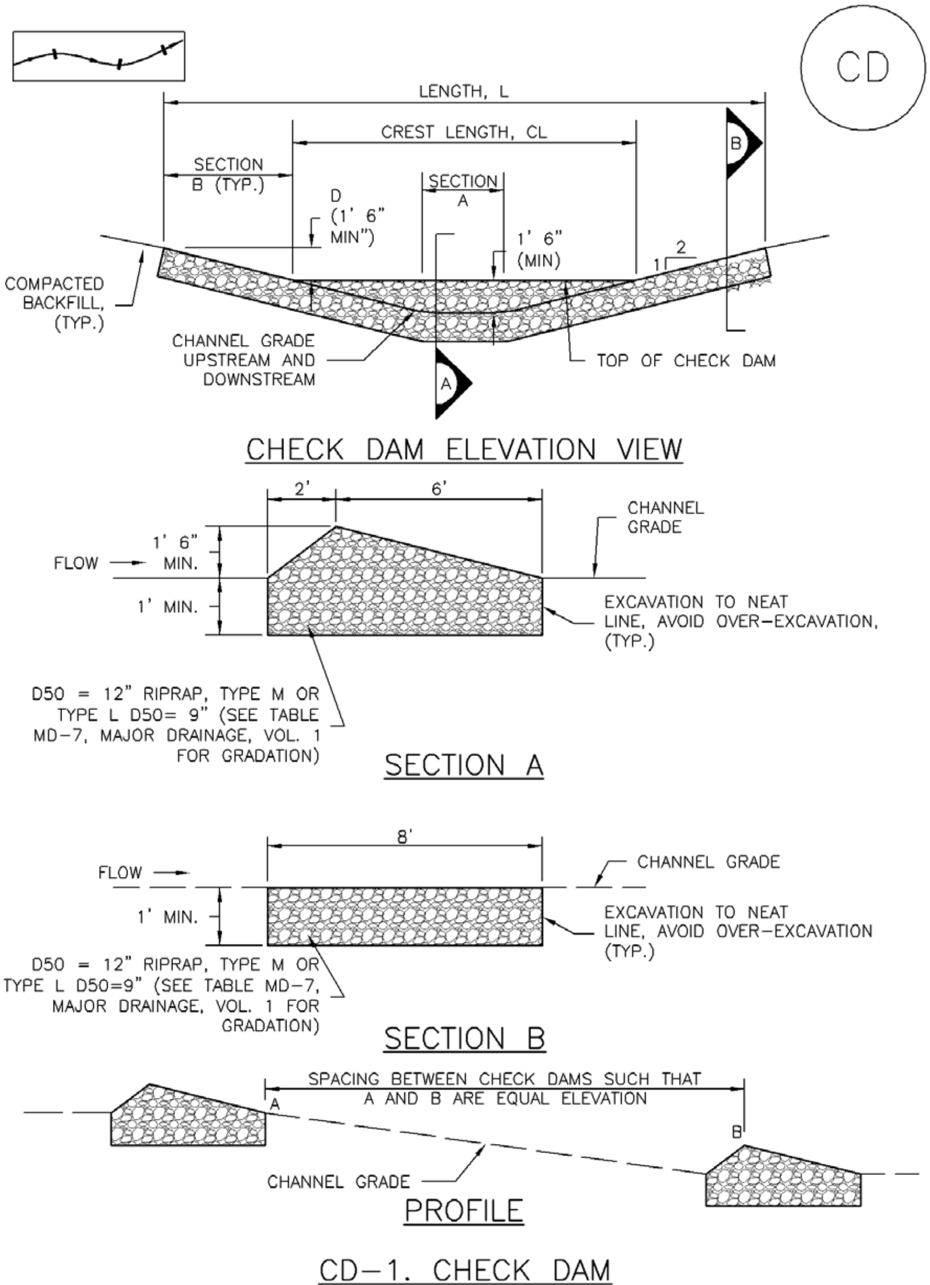
Check dams can be constructed from a number of different materials. Most commonly, they are made of rock, sandbags, or gabions. Rock or stone is often preferred because of its cost effectiveness and longevity. When using rock or stone, the material diameter should be 5 to 40 cm. The stones should be extended 45 cm beyond the banks, and the side slopes should be 2:1 or flatter. Lining the upstream side of the dam with a meter of 2.5 cm to 5 cm gravel can improve the efficiency of the dam (NAHB, No Date). Regardless of the material used, careful construction of a check dam is necessary to ensure its effectiveness.

The distance between rock check dams will vary depending on the slope of the ditch, with closer spacing when the slope is steeper. The size of stone used in the check dam should also vary with the expected design velocity and discharge. As velocity and discharge increase, the rock size should also increase. For most rock check dams, 8 cm to 30 cm is a suitable stone size. To improve the sediment-trapping efficiency of check dams, a filter zone can be applied to the upstream face. A well-graded, coarse aggregate that is less than 2.5 cm in size can be used as a filter zone.

All check dams should have a maximum height of 1 m. The center of the dam should be at least 6 inches lower than the edges. Such a design creates a weir effect that helps to channel flows away from the banks and prevent further erosion. Additional stability can be achieved by implanting the dam material approximately 15 cm into the sides and bottom of the channel (VDCR 1995).

When installing more than one check dam in a channel, outlet stabilization measures should be installed below the final dam in the series. Because that area is likely to be vulnerable to further erosion, riprap or some other stabilization measure is highly recommended.

Figure 11-6 Typical Rock Check Dam Construction Details



Source: UDFC, 2010

Check Dam Installation Notes

1. See plan view for:
    - Location of check dams
    - Check dam type (Check dam or reinforced check dam)
    - Length (L), crest length (CL) and depth (D)
2. Check dams indicated on initial SWMP should be installed after construction fence, but prior to any upstream land disturbing activities.
3. Riprap utilized for check dams should be of appropriate size for the application. Typical types of riprap

used for check dams are type M (D50 12") or type L (D50 9").

4. Riprap pad should be trenched into the ground a minimum of 1'.
5. The ends of the check dam should be a minimum of 1' 6" higher than the center of the check dam.

Check Dam Maintenance Notes

1. Inspect BMPs each workday and maintain them in effective operating condition. Maintenance of BMPs should be proactive, not reactive. Inspect BMPs as soon as possible (and always within 24 hours) following a storm that causes surface erosion and perform necessary maintenance.
2. Frequent observations and maintenance are necessary to maintain BMPs in effective operating condition. Inspections and corrective measures should be documented thoroughly.
3. Where BMPs have failed, repair or replacement should be initiated upon discovery of the failure.
4. Sediment accumulated upstream of the check dams should be removed when the sediment depth is within ½ of the height of the crest.
5. Check dams are to remain in place until the upstream disturbed area is stabilized and approved by the local jurisdiction.
6. When check dams are removed, excavations should be filled with suitable compacted backfill disturbed area shall be seeded and mulched and covered with geotextile or otherwise stabilized in a manner approved by the local jurisdiction.

11.4.4 Effectiveness

Field experience has shown that rock check dams are more effective than silt fences or straw bales to stabilize wet-weather ditches (VDCR 1995). Straw bales have been shown to have very low trapping efficiencies and should not be used for check dams. For long channels, check dams are most effective when used in a series, creating multiple barriers to sediment-laden runoff.

11.4.5 Limitations

Because the primary function of check dams is to slow runoff in a channel, they should not be used as a standalone substitute for other sediment trapping devices. Common problems with check dams include channel bypass and severe erosion when overtopped and ineffectiveness from accumulated sediment and debris. When designing check dams, because they reduce the capacity of a channel to transmit stormwater runoff, thus, the channel size must be taken into account (UNEP 1994). In addition, a check dam might reduce the hydraulic capacity of the channel and create turbulence, which erodes the channel banks (NAHB, No Date).

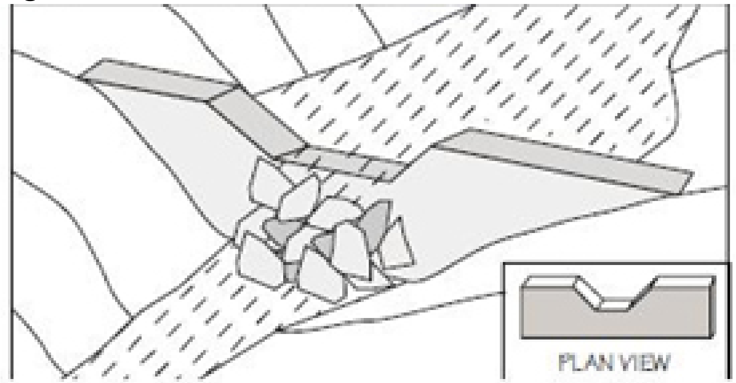
11.4.6 Maintenance

Check dams should be inspected periodically to ensure that they have not been repositioned as a result of storm water flow. In addition, the center of a check dam should always be lower than its edges. Additional stone might have to be added to maintain the correct height. Sediment should not be allowed to accumulate to more than half the original dam height. Any required maintenance should be performed immediately. When check dams are removed, take care to remove all dam materials to ensure proper flow within the channel. The channel should subsequently be stabilized as necessary to prevent local erosion.

[redacted]Concrete check dams

Concrete check dams (Figure 11-7) can be an effective long-term alternative to straw bales, bio bags, and rock-filled burlap bags. They can often be constructed from waste concrete that is cleaned out of mixer trucks, but time constraints may prevent this. Concrete check dams are most appropriate along ditches that are relatively permanent.

Figure 11-7 Concrete Check Dam Detail



Waste concrete check dam. It should be a minimum of 4 inches thick; length and width vary to fit application.

[redacted]ST-5: Sediment Basin (SP)

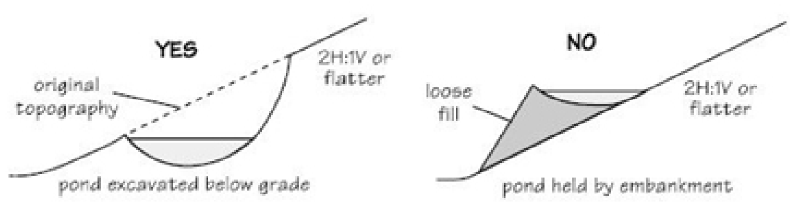
Most mine operations cannot rely solely on passive storm-water control methods and must employ settling ponds as an integral part of their storm-water system. These flat-bottomed excavations can range from small hand-dug sumps to ponds covering several acres. They slow water velocities enough to allow sediment to settle out of suspension. The number and size of ponds needed will depend on the site conditions. Construction of numerous ponds in the upper part of the drainage systems enhances effective trapping of sediments. For example, upper quarry benches and floors can be bermed so that they function as sediment basins during the rainy season.

11.6.1 General Description

Two types of ponds are commonly used—detention and retention. Detention ponds reduce the velocity of storm water, allowing sediment to settle before it moves off-site. Retention ponds are large enough to accept all storm water without surface discharge. Ponds can be developed by building embankments or by excavating below grade. Excavated ponds are preferable because they are less likely to fail than embankments (Figure 11-8). Embankments have to be carefully constructed using the same techniques that would be used for constructing waste and overburden dumps and stockpiles. Ideally, ponds should be situated at the bottom of a slope. Soil or geotextile liners may be required where stability is a concern. Many ponds are designed for the life of the operation, whereas others are used for only a short time.

Figure 11-8 Settling Pond Construction

Details of settling-pond construction. The excavation method on the left is preferred because it is less likely to fail and cause flooding than an constructed embankment (right).



Settling ponds are the best method of gathering turbid water to allow sediment to settle out. Gravity separation requires that water velocity be reduced to facilitate settling. In still water, a sand particle (0.05–2 mm) will settle at rates of 30 cm/second to 30 cm/several minutes. A silt particle (0.05–0.002 mm) may take several minutes to 6 hours to settle 30 cm. Clay particles (<0.002 mm) can take from 1 day to several months to settle. Pond surface area, retention time, and the particles' settling velocity determine the effectiveness of a settling pond system.

When sediment basins are designed properly, they can control sediment pollution through the following functions (Faircloth 1999):

- Sediment-laden runoff is caught to form an impoundment of water and create conditions where sediment will settle to the bottom of the basin.
- Treated runoff is released with less sediment concentration than when it entered the basin.
- Storage is provided for accumulated sediment, and re-suspension by subsequent storms is limited.

11.6.2 Applicability

Sediment basins should be located at a convenient concentration point for sediment-laden flows (NCDNR 1988). Ideal sites are areas where natural topography allows a pond to be formed by constructing a dam across a natural swale; such sites are preferred to those that require excavation (Smolen et al. 1988).

Sediment basins are also applicable in drainage areas where it is anticipated that other erosion controls, such as sediment traps, will not be sufficient to prevent off-site transport of sediment. Choosing to construct a sediment basin with either an earthen embankment or a stone/rock dam will depend on the materials available, location of the basin, and desired capacity for storm water runoff and settling of sediments.

Rock dams are suitable where earthen embankments would be difficult to construct or where riprap is readily available. Rock structures are also desirable where the top of the dam structure is to be used as an emergency overflow outlet. Such riprap dams are best for drainage areas of less than 50 acres. Earthen damming structures are appropriate where failure of the dam will not result in substantial damage or loss of property or life. If properly constructed, sediment basins with earthen dams can handle storm water runoff from drainage basins as large as 100 acres.

11.6.3 Configuration, location and size

Storm-water detention ponds should be designed to maximize both velocity reduction and storage time. That is, storm water entering a pond should spread out and migrate as slowly as possible toward the discharge point. Baffles constructed across the pond can reduce flow rates. A good rule of thumb is that the flow path of the pond should be at least five times the length of the pond. The inlet and outlet should be located so as to minimize the velocity and maximize the residence time.

If ponds are to be placed in the lowest area of the watershed, several should be constructed in a series. This will enable the first pond to slow the high-velocity waters coming into it and allow subsequent ponds to settle out sediments more effectively. For maximum treatment effectiveness, ponds should be placed as close as possible to those areas most likely to contribute sediment, such as the pit floor, the processing plant, and other areas of heavy equipment activity.

There are several widely used methods for determining the appropriate size of storm-water ponds for a given site. Most methods begin with estimating the size of the watershed and estimating runoff using infiltration rates. This information is then used to calculate the amount of runoff on the basis of annual precipitation or a storm event of a certain size. Observations of flow characteristics and locations made near the mine during storm events can be invaluable in developing a good storm-water pond system.

However, choosing an appropriate size for storm-water ponds can be difficult without site-specific information such as a storm hydrograph— a graph of the volume of water flowing past a certain point during a storm event. When hydrographic information is not available, theoretical calculations are used to estimate the flow volume for a given storm event. The calculations quickly become complicated because storm intensity and duration can have a significant effect on the amount of runoff. Also important, but even more complicated, is determining the influence of road systems, vegetative cover, and amount of compaction on runoff volumes.

The Natural Resources Conservation Service (formerly Soil Conservation Service) has developed a simplified method for estimating storm-water runoff. This method can work well if the limitations are understood, and it yields a good starting point for determining pond size.

There are many resources for information on designing stormwater ponds. For determining spillway designs and diversion ditch liner specifications, Urban Hydrology for Small Watersheds (Soil Conservation Service, 1986) is a good resource. Components of a sediment basin that must be considered in the hydrologic design include the following (Haan et al. 1994):

- A sediment storage volume sized to contain the sediment trapped during the life of the structure or between cleanouts
- A permanent pool volume (if included) above the sediment storage to protect trapped sediment and prevent re-suspension as well as providing a first flush of discharge that has been subjected to an extended detention period
- A detention volume that contains storm runoff for a period sufficient to trap the necessary quantity of suspended solids
- A principal spillway that can be a drop-inlet pipe and barrel, a trickle tube, or other type of controlled release structure
- An emergency spillway that is designed to handle excessive runoff from the rarer events and prevent overtopping
- For most mining situations, storm-water ponds should be designed to handle at least a 25-year/24-hour event or larger.

The following sections recommend procedures for conducting the hydrologic design and are summarized from Haan et al. (1994).

11.6.4 Sediment Storage Volume.

This volume should be sufficient to store the sediment trapped during the life of the structure or between cleanouts. Sediment storage volume can be calculated on the basis of sediment yield using relationships such as the RUSLE with an appropriate delivery ratio (Renard et al. 1994) or a computer model such as SEDIMOT III (Barfield et al. 1996) or SEDCAD (Warner et al. 1999). Many design specifications, however, base the sediment storage volume on a volume per acre disturbed. For example, Pennsylvania specifies a sediment storage volume of 1,000 cubic feet per acre drained (see DCN 43050, Pennsylvania Erosion and Sediment Pollution Control Program Manual). This volume is highly site-specific, depending on rainfall distributions, soil types, and construction techniques.

11.6.5 Permanent Pool Volume.

Providing a first flush of discharge that has been subjected to an extended detention period can help to minimize degradation of water quality and justify some permanent pool. The recommended capacity of the permanent pool varies with the regulatory agency. USDOT, for example, recommends 67 cubic yards per acre (126 m3/ha) (USDOT 1995). That standard has been adopted by many states as well. If an effluent criterion such as allowable peak TSS or peak settleable solids is used, the final design of both permanent pool and detention volume should be selected only after using a computer model to predict the expected peak effluent concentrations.

11.6.6 Detention Volume.

Storm runoff must be contained for a period of time sufficient to trap the necessary quantity of suspended solids. Because inflow is occurring simultaneously with outflow, the detention time for each slug of flow is different and should be considered individually. The size of the detention volume, as stated above, should also be developed in concert with determining the size of the permanent pool volume and the size of the principal spillway. When effluent TSS and settleable solids criteria are used, the size of the detention volume and permanent pool volume should be determined through a computer model calculation of expected effluent concentrations for a given design. The return period used to size the detention volume depends on the regulatory agency, but a return period of 10 years is typical for sediment basins that eventually become storm water detention ponds (i.e., are used to limit future flooding due to stormwater). EPA’s review of state construction site regulations found that the majority of states specify detention volume in terms of cubic feet per acre that drains to the sediment basin. State design values range between 1,800 and 5,400 cubic feet per acre, with 3,600 cubic feet per acre or expected runoff from the local 2-year, 24-hour storm event as the typical value.

11.6.7 Drainage

The method of releasing water from storm-water ponds can be critical in determining their efficiency. Standpipes, spillways, and infiltration are the most common release methods.

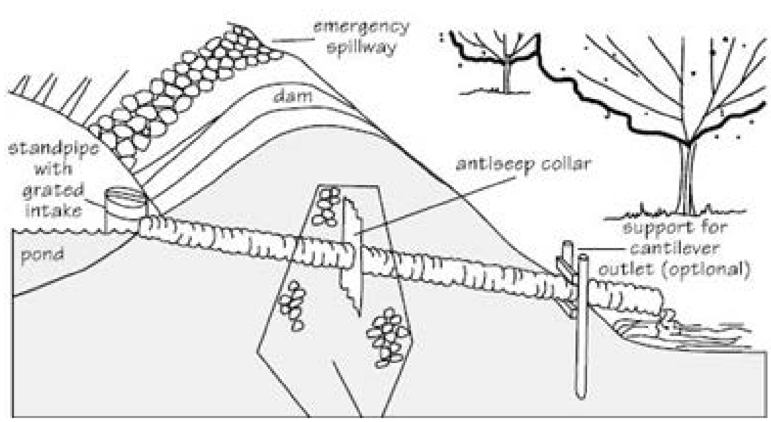
Standpipes are vertical pipes rising from the bottom of the pond and connected to a gently sloping pipe that passes through the side of the pond to the discharge point (Fig. 2.31). Antiseep collars must be attached to the pipe where it passes through the dam or settling pond wall to prevent water from flowing along the outside of the pipe. A grate or screen should be placed over the standpipe intake to prevent debris from clogging it.

Spillways are overflow channels that are part of the construction of all water impoundments. For small settling ponds used intermittently and designed for low maintenance, spillways may handle all water discharged from the pond. Where water is recirculated to the processing plant or where discharge is through a standpipe or subdrain, a spillway allows overflow during extremely wet weather or when the primary drain system becomes clogged.

Spillways should be located in undisturbed material and not over the face of a constructed dam. If the spillway is placed on erodible material, it must be rock lined to limit erosion that would compromise the safety of the dam.

Figure 11-9 Settling Pond Stand Pipe Cross Section

. Section through a berm showing standpipe with antiseep collar. (Modified from U.S. Soil Conservation Service, 1982.)



11.6.8 Principal Spillway

The principal spillway is a hydraulic outlet structure sized to provide the appropriate outflow rate to meet the effluent or trapping efficiency criteria. The principal spillway should have a dewatering device that slowly releases water contained in the detention storage over an extended period and at a rate determined to trap the required amount of sediment or provide for the appropriate effluent concentration in the design storm. The more common outlet structures are the drop-inlet structure and the trickle tube. Sizing of the principal spillway should follow standard design procedures with respect to hydrology and sediment considerations, but sizing the structure to simply pass the design storm is inappropriate and will not result in meeting an effluent or trapping efficiency standard. The size to be used in a given structure should be determined on the basis of the effluent or trapping efficiency standard being targeted and site-specific hydrologic and soil conditions. Appropriate design will require the use of a computer model such as SEDIMOT III (Barfield et al. 1996) or design aids such as those developed for South Carolina (Hayes and Barfield 1995). In general, the design is developed to maximize surface area, which will minimize peak discharge. Because failure of the dam could result in downstream damage, the design should be completed and certified by a licensed engineer with expertise in hydrologic computation.

11.6.9 Emergency Spillway.

Because overtopping of the dam can cause failure and downstream damage, an emergency spillway is necessary to handle excessive runoff from the larger, less frequent events and prevent overtopping. The design storm for the emergency spillway will depend on the hazard classification of the sediment basin. Typical return periods vary between 25 and 100 years, with 25 years recommended by USDOT. Sizing of the emergency spillway is typically accomplished to simply transmit the rare event without eroding the base of the spillway. Procedures for making the hydrologic and hydraulic computations are summarized in Haan et al. (1994). Again, because failure of the dam could result in downstream damage, the design should be completed and certified by a licensed engineer with expertise in hydrologic computation.

11.6.10 Installation Criteria

The embankment for permanent sediment basins should be designed using standard geotechnical construction techniques. The fill is typically constructed of earthen fill material placed and compacted in continuous layers over the entire length of the fill. USDOT recommends 15- to 20-cm layers (USDOT 1995). The embankment should be stabilized with vegetation after construction of the basin. A cutoff trench should be excavated along the centerline of the dam to prevent excessive seepage beneath the dam and be sized using standard geotechnical computations. USDOT recommends that a minimum depth of the cutoff trench be approximately 60 cm, the height should be to the riser crest elevation, the minimum bottom width should be 1.2 m or wide enough for compaction equipment, and slopes should be no steeper than 1:1.

Sediment basins can also be constructed with rock dams in a design that is similar to a sediment basin with an earthen embankment. It is important to remember that rock fill is highly heterogeneous and that flow rates calculated with any available procedure are not likely to match those that will actually occur. Because sediment trapping is inversely proportional to flow rate, the trapping efficiency will be affected significantly. No data are available to determine the variability of rock fill in actual installations so that confidence intervals can be placed on predicted flow rates. Such data should be collected and the confidence intervals calculated before recommending the use of rock dams as outlets on any structures other than sediment traps.

11.6.11 Effectiveness

The effectiveness of a sediment basin depends primarily on the sediment particle size and the ratio of basin surface area to inflow rate (Smolen et al. 1988; Haan et al. 1994). Basins with a large surface area-to-volume ratio will be most effective. Studies by Barfield and Clar (1985) show that a surface area-to-peak discharge ratio of 0.01 acre per cubic foot would trap more than 75 percent of the sediment coming from the Coastal Plain and Piedmont regions in Maryland. That efficiency might vary for other regions of the country and should not be used as a national standard. Studies by Hayes et al. (1984) and Stevens et al. (2001), however, show that similar relationships can be developed for other locations.

Laboratory data collected on pilot-scale facilities are available on the trapping efficiency of sediment basins, effluent concentrations, dead storage and flow patterns, and the effects of chemical flocculants on sediment trapping (Tapp et al. 1981; Wilson and Barfield 1984; Griffin et al. 1985; Jarrett 1999; Ward et al. 1977, 1979). In general, the laboratory studies show that pilot-scale ponds can be expected to trap 70 to 90 percent of sediment, depending on the sediment characteristics, pond volume, and flow rate. The trapping efficiency and effluent concentration are, in general, related to the overflow rate and can be reasonably well predicted using a plug flow model (Ward et al. 1977, 1979) and a Continuously Stirred Tank Reactor (CSTR) model (Wilson et al. 1982; Wilson et al. 1984). Extensive field-scale data is available on long-term trapping efficiency in storm water detention basins in which the annual trapping efficiency is related to the annual capacity inflow ratio of the basin. These structures are not representative of those used for sediment ponds but would be representative of those used for regional detention. A more limited database is available on single storm sediment trapping in the larger structures (Ward, et al. 1979) and on a field laboratory structure at Pennsylvania State University (Jarrett et al. 1999).
For maximum trap efficiency, Smolen et al. (1988) recommend the following:

- Allow the largest surface area possible, maximize the length-to-width ratio of the basin to prevent short circuiting, and ensure use of the entire design settling area.
- Locate inlets for the basin at the maximum distance from the principal spillway outlet.
- Allow the maximum reasonable time to detain water before dewatering the basin.
- Reduce the inflow rate into the basin and divert all sediment-free runoff.

Jarett (1999) has shown that the smaller the depth of the basin, the more sediment is discharged. A 0.15-meter-deep basin lost twice as much sediment as a 0.46-meter-deep basin. Jarrett also found that the performance of a sediment basin will increase with the use of a skimmer in the principal spillway. The sediment discharged was 1.8 times greater with only a perforated riser than with a skimmer in the principal spillway. In addition, increasing the dewatering time, which allows for more sediment deposition, decreases the sediment loss from the basin (Jarrett 1999).

11.6.12 Maintenance

Settling ponds must be cleaned out regularly to remain effective. Spillways should be kept open and ready to receive overflow during large storms. Settling ponds should be constructed and placed so that onsite equipment can be used to maintain them. In some situations, sediment can be pumped out of settling ponds as a slurry instead of being removed with heavy equipment. Regardless of the method of sediment removal, all sediment removed should be placed in a stable location so that it will not enter waterways.

12.0 BMP CONSTRUCTION PLAN

Construction BMPs include not only erosion and sediment control BMPs, but also material management and site management BMPs. Related practices include dewatering and construction in waterways, which are discussed in Sections 6 and 7. The design details and notes for the BMPs identified in this section are provided in stand-alone Fact Sheets that also include guidance on applicability, design, maintenance, and final disposition. A key to effective storm water management at construction sites is to understand how construction storm water management requirements change over the course of a construction project. Additionally, BMPs vary with regard to the functions they provide.

13.0 OPERATIONS AND MAINTENANCE

Although water quality is ultimately the operator's responsibility, maintenance of storm-water and erosion-control systems must be a priority for management and involve all mine employees. Managers should explain to staff why controlling storm water and erosion is so important. An effective program requires that everyone be on the lookout for seemingly insignificant situations that can snowball into major problems if not addressed in time.

Operators and their employees should be encouraged to experiment with improving their storm-water systems. Operators should not feel limited to the information provided in this document. Common sense and innovation, with an emphasis on early recognition and response to erosion and sediment-transport problems, is the key to effective storm-water control.

[redacted]Maintenance

Proactive maintenance is fundamental to effective BMP performance. Rather than maintaining the BMP in a reactive manner following failure, provide proactive maintenance that may help to reduce the likelihood of failure. The types and frequencies of maintenance are BMP-specific.

14.0 INSPECTIONS AND RECORDS

Routine and post-storm inspections of BMPs are essential to identify maintenance necessary for the BMPs to remain in effective operating conditions. The frequency of inspections is typically influenced by multiple factors including the weather, the phase of construction, activities on site, and the types of BMPs. Checklists and other forms of documentation are also important to meet the requirements of a construction storm water permit.

[redacted]Inspection Frequency

It is recommended to inspect all BMP's after a storm event and spot-checking BMPs every workday. This is typically reasonable to achieve and can help to ensure that the BMPs remain in good working condition. For example, vehicle tracking of sediment onto the roadway is a common problem that often requires maintenance more frequently than weekly. Fiber rolls, inlet protection and silt fences are other BMPs that are prone to damage and displacement, also benefiting from more frequent inspections. When the site or portions of the site are awaiting final stabilization (e.g., vegetative cover), where construction is essentially complete, the recommended frequency of inspection is at least once every month. Be sure that this change is documented and in accordance with relevant permit requirements prior to reducing the inspection schedule. When snow cover exists over the entire site for an extended period, inspections are not always feasible. Document this condition, including date of snowfall and date of melting conditions, and be aware of and prepare for areas where melting conditions may pose a risk of surface erosion.

[redacted]Inspection Records

Always check the requirements of the permit for required documentation of specific inspection items. Typically, these items can be incorporated into a checklist. Standard checklists may be developed and used for various types of construction projects (e.g., channel work, large-scale phased construction projects, or small urban sites). This kind of tool can help ensure the proper function of BMPs and provide a consistent approach to required documentation.

The checklist should always include the date and name/title of personnel making the inspection. It should include an area to note BMP failures, observed deviations from the SWMP, necessary repairs or corrective measures, corrective actions taken, and general observations.

Consider monitoring an online weather forecast site on a daily basis to keep aware of inclement weather and plan ahead for staff to inspect and maintain BMPs. Site wide sediment control depends on maintenance of BMPs so that they function as intended. This includes removing accumulated sediment before it limits the effectiveness of the BMP and identifying needed maintenance activities during site inspections or during general observations of site conditions. Where BMPs have failed, repairs or changes should be initiated as soon as practical, to minimize the discharge of pollutants. Where the BMPs specified in the SWMP are not functioning effectively at the site, modifications should be made that may include different or additional layers of BMPs. When new BMPs are installed or BMPs are replaced, check the permit for documentation requirements. This may require communication with the owner and/or engineer and, at a minimum, should be documented in the inspection and maintenance logbooks.

15.0 WORKS CITED

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