LECTURE #8

EROSION AND SEDIMENT CONTROL[1]

OBJECTIVES

After this lecture, you should be able to:

1. **Identify the principles and potential problems of erosion and sediment control during site development.**

2. **Identify erosion and sediment control practices.**

3. **Estimate erosion potential on urban construction sites.**

4. **Identify the steps for developing an effective erosion and sediment control sites on construction sites.**

5. **Apply the principles and concepts to develop an erosion and sediment control plan on a construction site.**

LECTURE OUTLINE

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[1]This lecture is developed from the “Erosion and Sediment Control on Construction Sites”, MOEE, 1996..

8.1 INTRODUCTION

In order to effectively control erosion and sediment during site development, careful planning should be the essential first step. Good planning requires answers to the fundamental question of “what, how, where, and when?”. This lecture provides a general overview of the basic terms and principles of erosion and sediment control, the potential problem areas, the procedures for developing an erosion and sediment control (ESC) plan, and a demonstration case study. It is anticipated that students will gain basic knowledge of how to develop and/or review a comprehensive ESC plan.

8.2 OVERVIEW

This lecture is organized into sections which describe the logical steps to develop an (ESC) plan. Section 8.3 discusses the purpose of an ESC plan while Section 8.4 outlines the ESC standards and specifications. The fundamental principles and potential problems of ESC during site development are then reviewed in Sections 8.5 and 8.6. Section 8.7 shows the techniques for estimating erosion potential and sediment yield at a construction site. Section 8.8 describes the procedure for developing an effective ESC plan. To demonstrate the principles and procedure for developing an ESC plan, a case study is discussed in Section 8.9. Section 8.10 summaries key concepts and points in this module.

Although a comprehensive ESC plan is a good starting point for erosion and sediment control at construction sites, proper field inspection and maintenance should be followed to effectively implement the solutions.

8.3 GENERAL GUIDELINES

What is an Erosion and Sediment Control Plan?

An ESC plan is a document which describes the potential for erosion and sedimentation problems on a construction site. It has both a written portion which is descriptive in nature, and a visual component of maps or site plans.

What is an "Adequate" Plan?

An adequate plan must contain enough information to satisfy the approval agencies that problems of erosion and sediment have been adequately addressed for the proposed project.

Why Comprehensive Site Planning?

Erosion and sediment control planning should be an integral part of the site planning process, not just an afterthought. The necessity for costly erosion control measures can be minimized if the site can be adapted to existing conditions and good conservation principles are applied.

Who is Responsible for Preparing a Plan?

The owner or lessee of the land being developed has the responsibility for plan preparation and submission. The owner may designate someone to prepare the plan, but he or she retains the ultimate responsibility.

8.4 EROSION AND SEDIMENT CONTROL STANDARDS AND SPECIFICATIONS

In order to select the appropriate devices to control erosion and sediment from construction sites, it is important to do everything possible to prevent erosion first. Sediment control should be considered only for the unavoidable erosion. The appendix describes standards and specifications for erosion and sediment control practices. Students are suggested to consult the specifications for:

1. Temporary Cover Practices
   - seeding
   - mulching

2. Permanent Cover Practices
   - sodding
   - vegetative buffer strips

3. Erosion Control Using Vegetative Practices
   - silt fencing
   - straw bales
   - sediment basins
   - sediment traps
   - sewer inlet traps

4. Sediment Control Practices
   - erosion control blankets

5. Temporary Runoff Controls
   - rock check dam
   - interception berm/swale

8.5 SEVEN BASIC PRINCIPLES FOR EROSION AND SEDIMENT CONTROL

1. Plan the development to fit the site.

   A) Plan the development to take advantage of existing topography, soils, drainage patterns, and natural vegetation.

   B) Determine where runoff will enter, cross, and exit the site.

   C) Determine whether subsurface water is a factor and avoid construction if possible in these areas.

   D) Locate large graded areas on the most level portion of the site.

   E) Keep development out of the floodplain.

   F) Avoid steep slopes, erodible soils and soils unsuitable for the intended purpose, where possible.

   G) Break up long steep slopes with benching, terracing, or through construction of diversion structures.

2. Minimize the extent of the disturbed area and the duration of exposure.

   A) Select source control practices as a first step.

   B) Limit and phase clearing of vegetation.

   C) Plan the development phases so that only areas being actively developed are exposed at one time; cover all other areas with a temporary or permanent cover.

   D) Complete grading as soon as possible; protect the area as soon as possible by implementing permanent vegetation cover when grading is complete, .

   E) Revegetate cut and fill slopes as work is progressing.

3. Stabilize and protect disturbed areas as soon as possible.

   A) Stabilize disturbed areas immediately after final grading, using mechanical or vegetative measures, or a combination of the two.

4. Keep runoff velocities low.

   A) It is important to understand that two factors will increase runoff velocities and volume during construction:

      i) removal of existing vegetation
      ii) increasing the amount of paved area on the site.

      Measures must be taken to counteract these anticipated increases in runoff volume and velocity.

   B) Minimize slope length and steepness.

5. Protect disturbed areas from runoff.

   A) Direct runoff away from bare soil areas.

6. Retain sediment within the corridor or site area.

7. Implement a thorough maintenance and follow-up program.

8.6 IDENTIFYING POTENTIAL PROBLEMS

Before the development of an ESC plan, it is important that potential problem areas be identified. This section reviews seven potential problem areas and the appropriate ESC devices.

1. Slopes

   Steep slopes are prone to erosion because flow velocity increases and infiltration decreases. If there is a need to create or modify a slope, greater care should be exercised for:

   - the clearing of existing vegetation cover
   - reestablishing vegetation cover
   - slopes of extensive slope length
   - slopes with high soil erodibility

The suitable ESC measures include:

- vegetative stabilization such as natural vegetative buffer or filter strip, standard or hydroseeding, sodding, etc.
- diversion measures such dikes, ditches, or combinations of dike/ditch which reduce slope length.
- slope drains which convey runoff over the slope face.
- slope stabilization measures such as retaining walls.

2. Streams and Waterways

Site development near streams and waterways must have effective erosion and sediment control in order to prevent sedimentation and erosion in the watercourses.

The suitable ESC measures include:

- prevent the sediment laden runoff from directly discharging to the streams by using vegetative filters and sediment traps or basins and check dams.
- protect stream banks from erosion due to increase runoff volume and velocity by
  - perserving existing cover
  - installing vegetative measures such as willows, grass, legumes, etc.
  - installing structural measures such as revetments, riprap, gabion, armour stone, deflectors, etc.

3. Surface Drainageways

Surface drainageways can become a major source of sediment unless they are designed, constructed, and maintain properly. In order to minimize erosion and sedimentation from surface runoff, the following measures can be used:

- Naturally stabilized grassed waterways should always be maintained (e.g., seeding or sodding) and utilized for runoff conveyance.
- Slow down runoff velocity and reduce runoff volume by using grassed waterways with check dams.

- Lined channels can be used where flow velocities are high.

4. Enclosed Drainage: Inlet and Outfall Control

   Sediment traps or filters can be installed at storm inlets to prevent sediment from entering the sewer system. At the storm outlet, sediment basins can be used during construction stages to prevent sediment from leaving the site.

5. Large, Flat Surface Areas

   Large, flat exposed areas can be major sediment sources if not protected. In order to reduce the extent of exposed area and the duration of exposure, clearing, grading, and vegetative restabilization should be timed. Additionally, sediment traps and diversions should be installed on the lower areas to intercept and collect sediment laden flows. For rights-of-way or parking construction, the exposed surface should be compacted and/or covered with crushed aggregate. Gravel or stone filter berms can also be placed at intervals along the rights-of-way to intercept runoff sediment.

6. Borrow and Stockpile Areas

   External borrow areas or on-site stockpiles must be protected from erosion. Runoff should be diverted from the face of the slopes where excavation exposes the soils. Temporary seeding or erosion control mats can be used to stabilize exposed surfaces if grading is delayed. If these areas are exposed for a longer period of time, they should be covered with topsoil and vegetation. For on-site stockpiles, they should be located away from any watercourses and separated by vegetative buffer strips if feasible.

7. Adjacent Properties

   Adjacent properties and waterways should be protected from sedimentation during site development. Generally, the ESC measures include sediment traps, diversions, grassed waterways, check dams, vegetative buffer strips, and silt fences.

8.7 QUANTIFYING RAINFALL EROSION AND SEDIMENT YIELD

Although ESC facilities are generally selected qualitatively (MNR et al. 1987), sizing and maintenance frequency of these facilities may require a quantitative estimation of the erosion and sediment yield. This section provides an overview of the estimation techniques for sheet and rill erosion potential and the delivery of sediment. Gully and channel erosion are not addressed because gully erosion is complex and not well understood while channel erosion requires an understanding of geomorphology and hydraulics which is beyond the context of this module.

The process of erosion and sedimentation can be divided into upland erosion, sediment transport, and sediment delivery at a watershed outlet. Upland sheet and rill erosion is typically estimated by the universal soil loss equation (USLE). It was developed from more than 40 years of experimental field observations collected by Agricultural Research Service of the U.S. Department of Agriculture. The USLE is given by (Wischmeier and Smith 1965; Dickinson and Rudra 1990)

$$A = (R)\ (K)\ (LS)\ (C)\ (P) \qquad \textbf{(1)}$$

where:

A = computed soil loss per unit area, in units selected for K and the period selected for R

R = the rainfall erosion factor, no. of rainfall erosion index units

K = the soil erodibility factor, the soil loss rate per erosion index unit for a specified soil

LS = the topographic factor, in terms of L, a slope-length factor, and S, a slope-steepness factor

C = the cropping management factor which can be related to land use

P = the erosion control support practice factor

The USLE is generally applied for the estimation of long-term average soil losses in runoff from specified field areas under specified vegetation and management systems. The time frame selected for analysis can be seasonal or annual time period. Selection of appropriate USLE's parameter values is the most important step in the estimation of upland erosion. Each of the parameters is discussed in the following paragraphs.

1. Rainfall erosion factor (R)

   R is a measure of the erosive force and the intensity of rain in a typical season or year. The two components of R are the total storm energy (E) and the maximum 30 minute intensity (I_{30}). Wall et al. (1983) developed values of the annual rainfall erosion factor (Table 3.1). Dickinson (1977) developed monthly distribution of annual R (Table 3.2)

2. Soil erodibility factor (K)

   K is a measure of the susceptibility of soil particles to rainfall erosion and runoff transport. It is a function of texture, structure, organic matter, and permeability. Wischmeier et al. (1971) developed a nomograph to calculate K (Fig. 8.1). The following five soil parameters which affect K can be determined from routine laboratory and standard soil profile:

- percent silt plus very fine sand
- percent sand greater than 0.10 mm
- organic matter content
- structure
- permeability

Tables 8.3 to 8.6 and Figs. 8.2 and 8.3 show the five soil parameters for Ontario soils.

3. Topographic factor (LS)

LS describes the combined effect of slope length and slope gradient and it can be estimated by (Dickinson and Rudra 1990)

$$LS = \left(\frac{L}{22.1}\right)^m \frac{(0.43+0.30S+0.043S^2)}{6.613} \qquad \textbf{(2)}$$

where L = length in metres from the point of origin of the overland flow to the point where the slope decreases to the extent that deposition begins or to the point at which runoff enters a defined channel.
S = the average slope (%) over the runoff length.
m = exponent dependent on the slope of flow path

4. Cropping Management Factor (C)

C estimates the effect of vegetative cover conditions, soil conditions, and the management practices on erosion rates. Tables 8.7 and 8.8 shows the general ranges of C for agricultural land, permanent pasture, woodland, idle rural land, and construction sites with protective practices.

5. Erosion Control Practice Factor (P)

P describes the effectiveness of erosion control practices such as contouring, compacting, sediment basins. Table 8.9 show typical values of P for construction sites.

Sediment yield is defined as the amount of sediment in the watercourses at the watershed outlet. It is not equal to the upland erosion because some of the eroded sediment will deposit along the travel path. Sediment delivery ratio (DR) is the ratio of sediment yield (Y) to gross erosion in the watershed (A). Since channel erosion is not included in the determination of DR, DR may be larger than one for some situations. Y can be estimated by

- streamflow sampling method;
- reservoir sedimentation survey method;
- mathematical bedload function methods;
- empirical equations linking Y with watershed hydrologic or morphologic characteristics; and
- watershed simulation models.

Detailed discussion of the DR determination is not intended for this lecture. Readers should consult some of the reference listed at the end of this module (e.g., Novotny and Chesters 1981).

8.8 PROCEDURE FOR PRODUCING AN EROSION AND SEDIMENT CONTROL PLAN

Step 1: Data Collection

1) Topography:
Prepare a small scale topographic map showing the existing contour elevations at intervals of from 0.5 to 1 metres.

2) Drainage:
Locate all existing drainage swales and patterns on the topographic map, including all existing underground storm drain pipes.

3) Soils:
Determine all major soil types and display on the topographic map either directly or else on an overlay.

4) Ground cover:
Mark features such as tree clusters, grassy areas, and rare or sensitive vegetation on the map. Existing large trees above a speckled diameter may be located at this point. Local requirements for tree preservation should be determined. Areas of exposed soils should be identified as well.

5) Adjacent areas:
Areas adjacent to the site should be investigated and features such as streams, roads, lakes, wetlands, and wooded areas marked. These areas should be identified because of the potential for off-site damage.

6) Existing development:
Mark any existing buildings or facilities on the site or adjacent to the site.

7) On and off-site utilities:
Identify all utility corridors, roadways, clearing limits, for all on-site and off-site utility construction.

Step two: Data Analysis

1) Topography:
The longer and steeper the slope, the greater the erosion potential.

0-7% - Low erosion hazard
7-15% - Moderate erosion hazard
> 15% - High erosion hazard

Excessively long slopes will be prone to erosion hazards:

0-7% - 300 feet
7-15% - 150 feet
> 15% - 75 feet

These distances may be shorter in areas with highly erodible soils.

2) Natural drainage:
Identify natural drainage such as overland flow, swales and depressions, and natural watercourses. It is these areas where water will tend to concentrate.

Where possible, natural drainage channels to drain water, rather than constructing man-made channels should be used. Man-made ditches and waterways can become part of the erosion problem if not properly stabilized.

Identify need for stormwater retention and/or detention areas. Establish sites for retention/detention areas.

Check the site for saturated soil or areas where groundwater may be encountered during construction. Avoid construction in these areas where possible.

3) Soils:
Determine the following site characteristics:

flood hazard
depth to bedrock
depth to seasonal water table
permeability
shrink-swell potential
texture
erodibility

4) Ground cover:
Ground cover is the MOST IMPORTANT factor in preventing erosion. Existing vegetation should be saved where possible. If it is necessary to remove vegetation, use measures such as staging construction, mulching, or temporary seeding to stabilize the area.

Staging construction means stabilizing one part of the site before disturbing another.

Buffers around water bodies should be delineated and the clearing limits flagged.

Step 3: Site Plan Development

After the analysis of site limitations, the planner develops the site plan. Buildings, roads, and parking lots should exploit strengths and overcome the limitations of the site.

1) Fit development to the existing terrain; avoid unnecessary land disturbance.

2) Confine construction activities to the least critical areas; protect highly erodible areas.

3) Cluster buildings together (the cluster concept lessens the erodible area, reduces runoff, and generally reduces development costs).

4) Minimize impervious areas and keep paved roads and parking lots to a minimum.

5) Use the natural drainage system and/or preserve the natural drainage system instead of replacing it with storm drains or concrete channels.

Step 4: Plan for Erosion and Sediment Control

Once the layout of the site has been decided upon, a plan to control erosion and sediment must be created.

1) Determine limits of clearing and grading:
Decide exactly which areas must be disturbed to accommodate the proposed construction. Show all limits of clearance for flagging in the field.

2) Divide the site into drainage areas by considering each area separately:
Determine how erosion and sedimentation can be controlled in each small drainage area before looking at the entire site.

3) Select erosion and sediment control practices, emphasizing source control and vegetative practices:
The first line of defence is to control erosion through cover practices. Structural measures should be considered only after cover practices are used to the maximum extent possible. Good management practices are also important, since they can reduce the need for structural controls. Management practices such as proper operations and maintenance are necessary for successful implementation of structural controls.

A) Cover Practices:
Keep in mind that the first line of defence is to prevent erosion. This is accomplished by protecting the soil surface from rainfall impact and using source controls. The best way to protect the soil is to preserve the existing ground cover.

Erosion and sediment control plans must contain provisions for permanent stabilization of disturbed areas. The selection of permanent vegetation should be based on:

- establishment requirements
- adaptability to site conditions
- aesthetics
- maintenance requirements

B) Structural Practices:
Structural practices are generally more expensive and less effective than source controls. They are often used in series with other vegetative or structural practices to capture sediment, as a second line of defence.

C) Management Measures:

I. Sequence construction.

II. Temporary seeding immediately after grading.

III. When possible, avoid grading activities from November through to March

IV. Stage construction in large projects.

V. Development and implementation of a regular maintenance schedule for erosion and sediment control practices.

VI. Physically marking off limits of land disturbance on sites with tape, signs or other methods so that workers can see areas to be protected.

VII. All workers should be educated on major provisions of the erosion and sediment control plan.

VIII. Designation of responsibility for implementing the erosion and sediment control plan to one individual, preferably the construction superintendent or foreman.

Step 5: Control of Pollutants Other than Sediment

These measures may be directed toward control of nutrient and pesticides to disposal of solid or hazardous wastes.

Step 6: Plan Preparation

The plan is prepared based on the information which has been gathered from Steps 1 through 5. The plan consists of two parts: a descriptive section and a site plan. The descriptive section describes the problems and solutions with justification. The site plan is a series of maps or drawings which illustrate the application of the solutions on the site.

Erosion and Sediment Control Checklist

Part I - Descriptive section

1. Project description
2. Existing site conditions
3. Adjacent areas
4. Soils
5. Critical areas
6. Erosion and Sediment Control Practices
7. Permanent stabilization
8. Stormwater Management considerations
9. Maintenance
10. Calculations
11. Controls Required for Pollutants other than Erosion and Sediment
12. Construction schedule

Part II - Site Plan

1. Vicinity maps
2. Existing contours
3. Existing vegetation
4. Soils
5. Indicate north
6. Critical erosion areas

7. Existing drainage patterns final contours
8. Limits of clearing and grading
9. Cut and fill Slopes

10. Conveyance
    A) Designate locations for grass-lined swales, interceptor trenches, or ditches;
    B) Show all drainage pipes, ditches, or cut-off trenches associated with erosion/sedimentation;
    C) Provide all temporary pipe inverts or minimum slopes and cover;
    D) Show grades, dimensions, location, and direction of flow in all ditches and swales;
    E) Provide details of bypassing off-sfte runoff around clearing limits/disturbed areas and sediment pond/trap; and
    F) Indicate locations and outlets of any possible dewatering systems.

11. Location of erosion and sediment control practices.

12. Sediment control facilities.
    A) Show all locations of sediment traps/ponds if required and all associated pipes and structures.
    B) Dimension pond berm widths and all inside and outside pond slopes.
    C) Indicate the trap/pond storage required and the depth, length, and width dimensions.
    D) Provide typical section views throughout the pond and outlet structure.
    E) Provide typical details of gravel cone and standpipe, and/or other filtering devices.
    F) Detail stabilization techniques for outlet/inlet.
    G) Show control/restrictor device location and details.
    H) Specify mulch and/or recommended cover for berms and slopes.
    I) Provide rock specifications and detail for rock check dams, if used
    J) Specify spacing for rock check dams as required for actual slopes on the site.
    K) Provide front and side sections of typical rock check dams.
    L) Indicate locations and provide details and specifications for silt fabric fences (include installation detail).

13. Detailed drawings

14. Control of Pollutants Other than Sediment

8.9 CASE STUDY

A development site as shown in Fig. 8.4 is located in the Central Ontario. It has a development area of approximately 19.0 hectares which consists of 65 single family, 140 semi-detached and 70 townhouse units, a 1.4 ha Park block, and a 0.4 ha stormwater quality facility.

Step 1: Background data collection

1) Topography
The topography of the site slopes gently from the southeast to the northwest direction.

2) Drainage
The existing drainage pattern is toward the northwest direction. Runoff from the development site and other external areas enters a ditch on the east side of the railway tracks and travels to the west side through an existing 600 mm diameter culvert. Eventually, the runoff discharges to the River "B".

3) Soils
The soils in the area are primarily a brown sandy silt till with some gravel, clay, boulders and cobbles (Soil structure - Silt loam). Some stratified reddish brown shale and bedrock were found at some test pits between 1.8 m to 3.5 m below ground.

4) Ground cover
Indigenous trees and shrubs are found to scatter around the development site with larger numbers at the southeast and southerly boundaries of the site.

5) Adjacent areas
A warm water River "B" is about 200 metres from the northwest corner of the development site. No wetland or woodlot is found at and adjacent to the development site.

6) Existing land use
Open space rural lands with some residential areas along the northeast boundary.

7) On and off-site utilities
The site is bounded by the CN railway track in the west. Drainage is along the ditch on the east and west side of the track.

Step 2: Data Analysis

1) Topography
Area slopes during construction stage are generally very gentle grades and long flow paths. As a result, it is estimated that the erosion potential of the development site will be moderate (MNR et. al 1987).

2) Natural and the proposed drainage
The ditch along the east side of the CN railway track will be used as the major conveyance system to receive the controlled flow from the development site. Within the site, runoff will be collected by the major and minor drainage system and treated at a stormwater quality pond. A grassed outfall channel will be constructed to convey the treated runoff to "B" River.

3) Soils
As the in-situ soil is primarily sandy-silt with some gravel and clay (Silt loam), it is estimated that the soil is of medium erosion potential (MNR et al. 1987).

4) Ground cover
Rough grading of the site is limited to designated areas.

Step 3: Site Plan Development

A thorough analysis of the site characteristics should be conducted in order to integrate an ESC plan with the associated site development plan. Grading or building in areas of high erosion potential should be avoided. The site plan shown in Fig. 8.5 was developed without any consideration for erosion and sediment control. Fortunately, the erosion potential of the site is generally moderate, As a result, the ESC plan described below may still be acceptable.

Steps 4 and 6: Plan for Erosion and Sediment Control (Figs 8.5 and 8.6)

1) All graded areas (e.g., areas of cut and fill, lot grading, roads) will be re-seeded and mulched as soon as possible.

2) All slopes created will be equal or less than 3 to 1.

3) Topsoil stockpiles will be stored in the Park Block which is located in the southern border of the site. If the stockpiles are not used for a long time, they will be seeded or cover with erosion control mats.

4) In order to trap the sediment from overland flow, silt fences will be erected along the perimeter of the site and around the topsoil stockpiles.

5) All storm sewer inlets will be protected from sediment by installing geotextile and aggregate stones.

6) The stormwater quality pond will be utilized as a temporary sediment pond during construction. A rock check dam will be constructed around the outlet control structure to back up flow inside the water quality pond.

   Based on the stormwater quality control criteria (MOEE 1994), the required volume of the quality pond will be about 3100 m^3 (or 165 m^3/ha) In order to estimate the maintenance frequency of the sediment control pond, the USLE is used as follows:

   R = 1140 (Toronto)
   K = 0.37 (Silt Loam)
   LS = 0.35 (L=625m; S=2%, m=0.5)
   C = 1 (assume no mulch or seeding)
   P = 0.4 (small sediment basin about 0.05 basins/ha)

   A = 59 tonnes/ha = 22 m^3/ha (assume sediment density equals 2650 kg/m^3)

   It may take about 7 years to fill up the temporary sediment pond.

7) Rock check dams will be constructed along the CNR ditch to slow down flow and trap sediments.

The construction schedule which minimizes the erosion and sedimentation from the development site is listed as follows:

1) Silt fences will be installed around the site.
2) The stormwater quality control facility (which also provides erosion and sediment control during construction) and the grassed outfall channel will be constructed at the northwest corner of the site.
3) Rock check dams will be installed along the CNR ditch.
4) General grading and removal of vegetation to the designated areas.
5) Topsoil will be stockpiled at the southern Park Block and be seeded if it is to remain for a long time.
6) Underground services (e.g., sewers) and roads will be constructed.
7) Sediment traps (e.g., filters cloth and granular stones) will be installed on all catchbasins.
8) House construction and sodding as soon as possible.
9) Periodic inspection and maintenance of erosion and sediment control measures.

10) Sediment control facilities will be removed after all construction activitiy and sediments will be removed and disposed of.

8.10 SUMMARY

A summary of the major topics covered by this module is provided below:

1. A comprehensive erosion and sediment plan is required to address the erosion and sedimentation potential of a development site. It consists of a written report and a series of location and facilities maps.

2. Erosion should be prevented first before sediment control is considered.

3. The seven basin principles for erosion and sediment control are:
   A. Plan the development to fit the site.
   B. Minimize the extent of the disturbed area and the duration of exposure.
   C. Stabilize and protect disturbed areas as soon as possible.
   D. Keep runoff velocities low.
   E. Protect disturbed areas from runoff.
   F. Retain sediment within the corridor or site area.
   G. Implement a thorough maintenance and follow-up program.

4. Erosion and sedimentation problem areas include:
   A. Steep slopes
   B. Close proximity to streams and waterways.
   C. Poorly designed surface drainageways.
   D. Inlet and outfall of enclosed drainage.
   E. Large, flat surface areas.
   F. Borrow and stockpile areas.
   G. Adjacent properties.

5. Upland sheet and rill erosion rates can be estimated by the universal soil loss equation in which erosion rate is a function of rainfall erosion power, soil erodibility, topography, ground cover, and erosion control practices.

6. An erosion and sediment plan should be prepared as follows:
   A. Collect data on topography, drainage, soils, ground cover, adjacent areas, existing development, and on- and off-site utilities.
   B. Develop a site plan to minimize erosion and sedimentation.
   C. Develop an erosion and sediment control plan which specifies grading and clearing limits, erosion and sediment control devices,

8.11 REFERENCES

Dickinson, W.T. 1977. Rainfall-intensity-frequency relationships from monthly extremes. Journal of Hydrology, 35: pp. 137-145.

Dickinson, W.T. and R.P. Rudra. 1990. The Guelph model for evaluating effects of agricultural management systems on erosion and sedimentation. University of Quelph School of Engineering Technical Report 126-86.

Goldman, S.J., K. Jackson, and T.A. Bursztynsky. 1986. Erosion and sediment control handbook. McGraw Hill Inc., U.S.A.

Ministries of Natural Resources, Environment, Municipal Affairs and transportation and Communications, Association of Conservation Authorities of Ontario, Municipal Engineers Association, Urban Development Institute. 1987. Guidelines on erosion and sediment control for urban construction sites.

Novotny, V. and G. Chesters. 1981. Handbook of nonpoint pollution. Van Nostrand Reinhold Co., New York, New York.

Washington State Department of Ecology. 1992. Stormwater management manual for the Puget Sound Basin. Volume II - Erosion and Sediment Control.

Wall, G.J., W.T. Dickinson, and J. Greuel. 1983. Rainfall erosion indices for Canada east of the Rock Mountains. Canadian Journal of Soil Science, 63: pp. 271-280.

Wischmeier, W.H. and D.D. Smith. 1965. Predicting rainfall-erosion losses from cropland east of the Rocky Mountains - Guide for the selection of practices for Soil and Water Conservation. Agricultural Handbook No. 282.

Wischmeier, W.H., C.B. Johnson, and B.V. Cross. 1971. A soil erodibility nomograph for farmland and construction sites. Journal of Soil and Water Conservation, 26: pp. 189-193.

Wischmeier, W.H. and D.D. Smith. 1978. Predicting rainfall erosion losses - A guide to conservation planning. Agriculture Handbook No. 537, U.S. Dept. Of Agriculture, Washington, D.C.

Table 8.1: Rainfall Erosion Indices (R) for Selected Climatic Locations in Canada (Dickinson and Rudra 1990)

Climatic Station	R Value		Climatic Station	R Value	
	Metric	English		Metric	English
Gander, Nfld.	870	51	Mt. Forest, Ont.	1160	68
St. Johns, Nfld.	1700	100	Niagara Falls, Ont.	1225	72
Summerside, P.E.I.	970	57	Ottawa, Ont.	1175	69
Moncton, N.B.	1225	72	Prospect Hill, Ont.	1585	93
St. John, N.B.	1960	115	Ridgetown, Ont.	1550	91
Halifax, N.S.	1790	105	St. Catharines, Ont.	1345	79
Shearwater, N.S.	2040	73	St. Thomas, Ont.	1190	70
Montreal, P.Q.	920	54	Sault Ste. Marie, Ont.	1380	81
Quebec City, P.Q.	1240	73	Simcoe, Ont.	1650	97
Abitibi Canyon, Ont.	1055	62	Sudbury, Ont.	1055	62
Brantford, Ont.	1295	76	Toronto, Ont.	1140	67
Delhi, Ont.	1415	83	Tweed, Ont.	920	54
Ear Falls, Ont.	835	49	White River, Ont.	1070	63
Fergus, Ont.	1600	94	Windsor, Ont.	1615	95
Geraldton, Ont.	750	44	Woodstock, Ont.	1735	102
Glen Allen, Ont.	1720	101	Dauphin, Man.	1090	64
Guelph, Ont.	1295	76	Winnipeg, Man.	1160	68
Hamilton, Ont.	1360	80	Regina, Sask.	850	50
Kingston, Ont.	1090	64	Saskatoon, Sask.	850	50
Kitchener, Ont.	1480	87	Calgary, Alta.	495	29
London, Ont.	1325	78	Edmonton, Alta.	630	37

Table 8.2: Monthly Distribution of Percent of Total R (Dickinson and Rudra 1990)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

Gander, Nfld.	0.5	3	3.5	5	4	10.5	11.5	17.5	17.5	13	11.5	2.5
St. John's, Nfld.	3	7	5.5	4.5	5.5	7.5	6	13	10.5	11	18	8.5
Summerside, PEI	3.5	4.5	2.5	3.5	10	10.5	9.5	17	11.5	14.5	7.5	5.5
Halifax, NS	0	0	0	7	9	11	14.5	14.5	11.5	18.5	14	0
Sydney, NS	3.5	12.5	7.5	3.5	4.5	5	7.5	11.5	10.5	10.5	12	11.5
Moncton, NB	3.5	4	3.5	5	6.5	10.5	15	15	9.5	12.5	10.5	4.5
Saint John, NB	0	0	0	8.5	8.5	8.5	10.5	15.5	13.5	17.5	17.5	0
Montreal, PQ	0	0	0	5.5	4.5	17.5	19.5	22.5	14	9	7.5	0
Quebec, PQ	0	0	0	3	9.5	14.5	20	18.5	17.5	10.5	6.5	0
Geraldton, Ont.	0	0	0	0	15.5	20	15.5	22	20.5	6.5	0	0
Kingston, Ont.	2.5	2	4	6	9.5	11.5	12.5	15.5	14.5	9.5	9	3.5
Lakehead, Ont.	0	0	0	4.5	12.5	11	14	25	19	5.5	8.5	0
London, Ont.	2	2.5	2.5	9	7.5	14.5	18	15	15.5	6.5	5	2
Ottawa, Ont.	0	0	0	4.5	6.5	16.5	21.5	20.5	16.5	6.5	7.5	0
Pinard, Ont.	0	0	0	2	11.5	16	19.5	24.5	18.5	7.5	0.5	0
Sault Ste. Marie, Ont.	1	2.5	4	5.5	18.5	12.5	11.5	20.5	10.5	5.5	6	2
Sudbury, Ont.	0.5	1.5	3.5	7.5	7	11	14.5	21	19.5	6	5.5	2.5
Toronto, Ont.	2.5	3.5	2.5	6.5	5.5	11.5	19.5	19.5	9.5	8	6.5	5
White River, Ont.	0	0	0	2	7.5	16	17	26.5	23.5	5.5	2	0
Windsor, Ont.	1.5	2.5	5.5	9.5	6.5	14.5	18.5	17	9.5	6.5	4	4.5
Winnipeg, Man.	0	0	0	7.5	10.5	17	27	26	8.5	3.5	0	0
Regina, Sask.	0	0	0	2	9	36.5	23.5	20.5	5.5	2	1	0
Calgary, Alta.	0	0	0	4	9.5	30.5	33.5	14	7	1.5	0	0
Edmonton, Alta.	0	0	0	2	9.5	22.5	34.5	21.5	7.5	1.5	1	0

Table 8.3: Soil Erodibility Factors for Soil Textures (Dickinson and Rudra 1990)

Textural Class	Average Organic Matter Content	Average K Value
Sand	2.29	0.01
Fine Sand	1.84	0.03
Loamy Sand	2.66	0.05
Loamy Coarse Sand	4.00	0.10
Loamy Fine Sand	2.96	0.12
Sandy Loam	3.47	0.14
Coarse Sandy Loam	3.84	0.12
Fine Sandy Loam	3.45	0.21
Very Fine Sandy Loam	3.79	0.34
Loam	3.70	0.31
Silt Loam	3.70	0.37
Sandy Clay Loam	3.78	0.22
Clay Loam	3.90	0.29
Silty Clay Loam	3.96	0.31
Silty Clay	3.98	0.24
Clay	3.96	0.20
Heavy Clay	4.00	0.15

Table 8.4: Structure Type - Nomograph Code Criteria (Dickinson and Rudra 1990)

Nomograph Class	U.S. Aggregate Size (mm)	Structure Type	Can. Aggregate Size (mm)
1	< 1	Very fine, granular, or structureless	--
2	1 - 2	Fine granular	< 2
3	2 - 10	Medium granular	2 - 5
	2 - 10	Coarse granular	5 - 10

4	> 10	Blocky, platy, massive, prismatic	> 10

Table 8.5: Drainage Classification and Hydraulic Conductivity Values for Soil Textural Classes (Dickinson and Rudra 1990)

Textural Class	Permeability Class	Hydraulic (cm/sec)	Conductivity (in/hr)
Gravels, coarse sands	rapid	$> 4.4 * 10^{-3}$	> 6.3
Loamy sands and sandy loams	moderately rapid	1.4 to $4.4 * 10^{-3}$	2.0 to 6.3
Fine sandy loams, loams	moderately rapid	0.4 to $1.4 * 10^{-3}$	0.63 to 2.0
Loams, silt loams, clay loams	moderately rapid	0.14 to $0.4 * 10^{-3}$	0.2 to 0.63
Clay loams, clays	slow	4 to $14 * 10^{-5}$	0.063 to 0.2
Dense, compacted clays	very slow	$< 4 * 10^{-5}$	< 0.063

Table 8.6: Texture Class vs. Seasonal Permeability Code (Dickinson and Rudra 1990)

Texture Class	Frosted Conditions	Late Spring Conditions	Summer Conditions
Sand	6	1	1
Fine Sand	6	1	2
Very Fine Sand	6	2	3
Loamy Sand	6	1	1
Loamy Fine Sand	6	1	2
Loamy Very Fine Sand	6	2	3
Sandy Loam	6	2	3
Fine Sandy Loam	6	2	3
Very Fine Sandy Loam	6	3	4
Loam	6	3	3
Silt Loam	6	3	3
Clay Loam	6	4	3
Silty Clay Loam	6	4	3
Silty Clay	6	5	4
Clay	6	5	4
Heavy Clay	6	5	4