Reclamation and Environmental Protection Handbook for Sand, Gravel and Quarry Operations in British Columbia

Province of British Columbia

Ministry of Transportation and Highways

PROPERTIES BRANCH
GRAVEL MANAGEMENT PROGRAM
THIS HANDBOOK SHOULD BE CITED AS:

PREFACE

This handbook is based on "A User Guide to Pit and Quarry Reclamation in Alberta" which was developed for the Alberta Land Conservation and Reclamation Council. Where source material is not acknowledged in this handbook, it may be attributed to the Alberta guide. The use of substantial portions of text, graphics and photographs from this manual is gratefully acknowledged. Mr. Chris Powter of the Land Reclamation Division of Alberta Environment was instrumental in coordinating the Alberta Project and in securing permission for its use by the British Columbia Ministries of Energy, Mines and Petroleum Resources, and Transportation and Highways.

Although sand, gravel and quarry operations are found throughout British Columbia, they often are developed close to urban centres near markets for their products. These operations are a necessary part of society and must be developed in a fashion which is sensitive to local values, minimizes environmental and social impact during operations, and supports reclamation to a productive and useful state at completion.

This handbook addresses the broad range of issues which surround sand, gravel and quarry operations, and describes how sand, gravel and quarry operations should be developed, managed and reclaimed.
ACKNOWLEDGMENTS

The development and production of this handbook has been made possible through funding from the British Columbia Ministry of Energy, Mines, and Petroleum Resources, the British Columbia Ministry of Transportation and Highways, and the Canada/B.C. Mineral Development Agreement through the Department of Natural Resources Canada.

Dr. Bill Price of the Ministry of Energy, Mines and Petroleum Resources, developed the Terms of Reference and initial Table of Contents, acted as Contract Manager, and coordinated the project review by the Government Steering Committee. Bill Price also provided much of the technical and editorial direction.

Steve Lee and Ken Lukawesky of the Ministry of Transportation and Highways, Brian McBride of the Agricultural Land Commission, and Gordon Ford of the Ministry of Environment, Lands and Parks were responsible for ensuring review and coordinating input from their respective agencies. Thanks is also extended to the regional Ministry of Energy, Mines and Petroleum Resources mine inspectors and Ministry of Transportation and Highways gravel managers (Steve Likeness, Bryan James, Jason Jackson, Len Tony, Jim Place, and Ellis Bowes) for their contributions of information and materials and their reviews of earlier drafts of this guide.
Contents

PREFACE .......................................................................................................................................... 1
ACKNOWLEDGEMENTS .................................................................................................................. ii
ABOUT THE HANDBOOK .............................................................................................................. 1
HOW TO USE THE HANDBOOK .................................................................................................... 1

CHAPTER 1: INTRODUCTION ........................................................................................................ 3
PITS AND QUARRIES ....................................................................................................................... 3
THE IMPORTANCE OF RECLAMATION ......................................................................................... 3
WHICH GOVERNMENT AGENCY IS RESPONSIBLE? ..................................................................... 3
RECLAMATION AND REHABILITATION: DEFINING THE TERMS .................................................. 4
MINIMUM RECLAMATION REQUIREMENTS .................................................................................. 4
IMPORTANCE OF THE RESOURCE .................................................................................................. 5

CHAPTER 2: THE BASICS: IMPORTANT TERMINOLOGY, TYPES OF OPERATIONS
AND ENVIRONMENTAL AND COMMUNITY CONCERNS ............................................................ 7
COMMON TERMINOLOGY .............................................................................................................. 7
TYPES OF OPERATIONS, PROCESSING AND ASSOCIATED ACTIVITIES ...................................... 8
Types of Extraction .......................................................................................................................... 8
Processing Operations .................................................................................................................... 9
IMPORTANT ENVIRONMENTAL AND COMMUNITY CONCERNS ............................................... 11
Groundwater Quality and Availability ............................................................................................. 12
Adjacent Watercourses and Wetlands .............................................................................................. 12
On-site Runoff and Water Quality .................................................................................................. 13
Soil and Groundwater Contamination ............................................................................................ 14
Soil Erosion ..................................................................................................................................... 14
Water Erosion ................................................................................................................................. 14
Wind Erosion ................................................................................................................................. 15
Permafrost ....................................................................................................................................... 15
Sediment Loss and Silting ................................................................................................................. 15
Loss of High Quality Soil .................................................................................................................. 16
Loss of Plant Cover ......................................................................................................................... 16
Noise ............................................................................................................................................... 17
Dust ................................................................................................................................................ 17
Vibration ......................................................................................................................................... 18
Traffic Volumes and Safety ............................................................................................................ 18
Aesthetics ....................................................................................................................................... 18
Public Safety ................................................................................................................................... 18
Heritage Resources ......................................................................................................................... 19

CHAPTER 3: APPROVALS AND LEGISLATION .......................................................................... 20
APPROVALS ..................................................................................................................................... 20
Providing a Security .......................................................................................................................... 20
PROVINCIAL LEGISLATION ............................................................................................................. 20
Ministry of Energy, Mines and Petroleum Resources ........................................................................ 20
<table>
<thead>
<tr>
<th>Chapter 4: Considerations during the Planning, Active Use and Closure of an Operation</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>INFORMATION REQUIRED TO PLAN YOUR OPERATION</td>
<td>24</td>
</tr>
<tr>
<td>Determining the Characteristics of Your Deposit</td>
<td>24</td>
</tr>
<tr>
<td>Documenting Existing Landforms</td>
<td>24</td>
</tr>
<tr>
<td>Inventorying Soil and Overburden</td>
<td>25</td>
</tr>
<tr>
<td>Identifying Important Surface Water Features</td>
<td>26</td>
</tr>
<tr>
<td>Determining Groundwater Levels and Flow Patterns</td>
<td>26</td>
</tr>
<tr>
<td>Inventorying Existing Timber Resources and Plant Cover</td>
<td>28</td>
</tr>
<tr>
<td>Weed Control</td>
<td>29</td>
</tr>
<tr>
<td>Fish and Wildlife</td>
<td>29</td>
</tr>
<tr>
<td>Identifying Important Heritage Resources</td>
<td>29</td>
</tr>
<tr>
<td>Identifying Social and Community Issues</td>
<td>30</td>
</tr>
<tr>
<td>DESIGNING YOUR OPERATION</td>
<td>30</td>
</tr>
<tr>
<td>Permitting Restrictions</td>
<td>31</td>
</tr>
<tr>
<td>Determining the Preferred Access Routes</td>
<td>32</td>
</tr>
<tr>
<td>Selecting the Best Pit or Quarry Locations on your Site</td>
<td>32</td>
</tr>
<tr>
<td>Determining the Size, Shape and Depth of the Pit or Quarry</td>
<td>32</td>
</tr>
<tr>
<td>Determining Setback Requirements</td>
<td>33</td>
</tr>
<tr>
<td>Developing a Soil Management Plan</td>
<td>33</td>
</tr>
<tr>
<td>Dealing with Groundwater</td>
<td>33</td>
</tr>
<tr>
<td>Managing Natural Surface Runoff from Adjacent Areas</td>
<td>34</td>
</tr>
<tr>
<td>On-site Drainage and Water Management</td>
<td>34</td>
</tr>
<tr>
<td>Selecting Storage and Stockpile Sites</td>
<td>34</td>
</tr>
<tr>
<td>Scheduling Activities within Your Site</td>
<td>35</td>
</tr>
<tr>
<td>Working with the Mine Inspector</td>
<td>35</td>
</tr>
<tr>
<td>PREPARING YOUR PIT OR QUARRY</td>
<td>35</td>
</tr>
<tr>
<td>Laying Out Active Work Areas</td>
<td>35</td>
</tr>
<tr>
<td>Clearing and Grubbing</td>
<td>36</td>
</tr>
<tr>
<td>Initial Stripping and Management of Soil and Overburden</td>
<td>36</td>
</tr>
<tr>
<td>Minimizing Soil Erosion</td>
<td>37</td>
</tr>
<tr>
<td>Site Water Management</td>
<td>38</td>
</tr>
</tbody>
</table>
CHAPTER
CLOSING
DEWATERING
MANAGING SURFACE RUNOFF
TIMING CONSIDERATIONS
YOUR OPERATION

CHAPTER 5: IMPORTANT ENVIRONMENTAL PROTECTION AND REMEDIATION MEASURES

OPERATING YOUR PIT OR QUARRY

MINIMIZING EFFECTS ON GROUNDWATER FLOWS

PROTECTING SURFACE WATERCOURSES AND WETLANDS

MANAGING SURFACE RUNOFF

DEWATERING

DEWATERING

ESTABLISHING STABLE SLOPES

CONTROLLING SURFACE EROSION

SEDIMENT REMOVAL

SOIL HANDLING
CHAPTER 6: SELECTING AN END LAND USE FOR RECLAMATION .............................. 75
POTENTIAL LAND USES............................................................................................ 75
Agriculture: .............................................................................................................. 75
Forestry: .................................................................................................................. 76
Wildlife Habitat: ....................................................................................................... 76
Fish Habitat: ............................................................................................................ 76
Recreation: ............................................................................................................... 76
Residential Use: ...................................................................................................... 77
Industrial Use: ......................................................................................................... 77
Perpetual Extraction: .............................................................................................. 77
IMPORTANT CONSIDERATIONS ............................................................................ 77
Regional Environmental Limitations ........................................................................ 77
Site Specific Environmental Limitations ................................................................. 81
Surrounding Land Uses and Community Needs .................................................... 81
Local Zoning ........................................................................................................... 82
Configuration of the Site ........................................................................................ 82
Cost .......................................................................................................................... 82
Where to go From Here ........................................................................................... 82

CHAPTER 7: RECLAIMING FOR AGRICULTURE .............................................. 83
INTRODUCTION ...................................................................................................... 83
Pit and Quarry Operations within the Agricultural Land Reserve ......................... 83
Agricultural Uses outside the Agricultural Land Reserve ...................................... 84
IMPORTANT FACTORS ......................................................................................... 85
Land Use ................................................................................................................ 85
Soils and Land Capability ...................................................................................... 85
Soil Salvage ............................................................................................................. 85
Soils and Post-Reclamation Capability for Agriculture ........................................ 86
Site Drainage ........................................................................................................... 87
Soil Replacement, Compaction and Tithi ................................................................. 89
METHODS FOR RECLAMATION ....................................................................... 91
Grading and Contouring .......................................................................................... 91
Replacing Overburden and Subsoil ......................................................................... 91
CHAPTER 8: RECLAIMING FOR FORESTRY ...................................................... 98

IMPORTANT FACTORS IN DEVELOPING YOUR OPERATION ...................... 98
  Meeting Ministry of Forest Regulations ....................................................... 98
  Adjacent Land Uses .................................................................................... 98
  Soil Types and Availability ......................................................................... 99
  Soil Salvaging ............................................................................................. 99
  Site Drainage .............................................................................................. 99
  Topography ................................................................................................. 99
  Compaction ................................................................................................. 100
  Species Selection ......................................................................................... 100
  Progressive Development and Reclamation ................................................ 100

METHODS FOR RECLAMATION ................................................................ 100
  Grading ........................................................................................................ 100
  Ripping ........................................................................................................ 100
  Site Drainage .............................................................................................. 100
  Replacing Topsoil ....................................................................................... 101
  Selection of Tree Seedlings ........................................................................ 101
  Tree Planting ............................................................................................... 101
  Managing Reforestation Areas .................................................................... 101

OTHER SOURCES OF INFORMATION ......................................................... 103

CHAPTER 9: RECLAIMING FOR WILDLIFE HABITAT ............................. 104

IMPORTANT FACTORS TO CONSIDER IN PLANNING YOUR OPERATION .......... 104
  Adjacent Land Uses .................................................................................... 104
  Local Zoning ............................................................................................... 104
  Public Access ............................................................................................. 104
  Types of Wildlife: Using Key Wildlife as a Focus for Your Plan .................. 104
  Conserving Topsoil ..................................................................................... 105
  Shape, Size and Depth of Pit ....................................................................... 105
  Highwalls .................................................................................................... 106
  Selection of Plant Species for Wildlife Habitat ............................................ 106
  Choosing Plants ......................................................................................... 108
  Salvaging Shrubs and Small Trees ............................................................... 109
  Water Sources ............................................................................................ 109

RESTORING UPLAND HABITAT ............................................................... 110
  Grading and Contouring ............................................................................. 110
  Diversity of Habitat ..................................................................................... 110
  Constructing New Landforms for Wildlife ................................................ 110
  Ripping ........................................................................................................ 111
Site Drainage ................................................................. 111
Replacing Overburden and Topsoil ................................ 112
Planting and Establishing Upland Vegetation .......... 112
Special Habitat Features ............................................. 113
Management of Upland Habitat ........................... 114

WETLAND HABITAT .................................................... 114
Grading and Contouring ........................................ 114
Soil Placement and Water Retention ................... 115
Ensuring an Adequate Water Supply ....................... 116
Planting and Establishing Wetland Vegetation ........ 116
Special Wetland Features ........................................ 117
Management of Wetland Habitat .......................... 118

OTHER SOURCES OF INFORMATION ......................... 119
Books and Reports ................................................... 119

CHAPTER 10: RECLAIMING FOR FISH HABITAT .......... 120

IMPORTANT CONSIDERATIONS IN DEVELOPING YOUR OPERATION ..... 120
Regulations and Approvals .................................. 120
Type of Fish and Fish Habitat ............................... 120
Water Availability .................................................. 121
Water Quality .......................................................... 121
Shape, Size and Depth of Pit ................................. 121
Progressive Development and Reclamation ............. 122

METHODS FOR RECLAMATION ................................. 122
Grading and Contouring ....................................... 122
Creating Suitable Waterbodies for Fish ................ 122
Ensuring an Adequate Water Supply ....................... 124
Screens ................................................................. 124
Maintaining Water Quality .................................. 124
Providing Adequate Food ........................................ 125

OTHER SOURCES OF INFORMATION ..................... 126
Permitting for Freshwater Fish Culture and Fish Habitat Protection ........ 126
Books and Reports ................................................... 126

CHAPTER 11: RECLAIMING FOR RECREATIONAL USE ........ 127

IMPORTANT CONSIDERATIONS IN DEVELOPING YOUR OPERATION ..... 128
Adjacent Land Use .................................................. 128
Local Zoning .......................................................... 128
Type of Recreational Use ........................................ 128
Design Stages for Your Recreational Area .............. 129
Progressive Development and Reclamation .......... 130

METHODS FOR RECLAMATION ................................. 130
Grading and Contouring ....................................... 130
Site Drainage .......................................................... 130
Creation of Waterbodies ........................................ 131
Replanting Trees, Shrubs and Groundcovers ............ 131
Providing Public Facilities ....................................................................................... 132
OTHER SOURCES OF INFORMATION ........................................................................ 132
Non-Government Organizations ............................................................................. 132

CHAPTER 12: RECLAIMING FOR RESIDENTIAL AND INDUSTRIAL USES ........................................................................... 133
IMPORTANT CONSIDERATIONS IN DEVELOPING YOUR OPERATION .......................................................... 133
Municipal and Regional By-Laws ........................................................................ 133
Local Zoning ........................................................................................................... 133
Adjacent Land Use .................................................................................................. 133
Demand for Development Sites ........................................................................... 133
Access ...................................................................................................................... 133
Keeping Your Development Concepts Flexible ..................................................... 134
Progressive Development and Reclamation ........................................................ 134
SITUATIONS TO AVOID .......................................................................................... 134
Shallow Groundwater ............................................................................................ 134
Flooding Potential ................................................................................................ 134
Poor Foundation Conditions ................................................................................ 134
Undevelopable Areas ............................................................................................ 134
METHODS FOR RECLAMATION ............................................................................. 134
Backfilling .............................................................................................................. 135
Grading and Contouring ....................................................................................... 135
Development of Slopes ....................................................................................... 136
Site Drainage ......................................................................................................... 136
Replacing Overburden and Topsoil ...................................................................... 136
Re-establishing Plant Cover ................................................................................ 136

OTHER SOURCES OF INFORMATION ...................................................................... 137

CHAPTER 13: RECLAIMING OPERATIONS ESTABLISHED PRIOR TO THE PRESENT ENVIRONMENTAL RULES ........................................................................... 138
ARE YOU REQUIRED TO RECLAIM YOUR OPERATION? .......................................................................................... 138
THE NEED FOR RECLAMATION ............................................................................. 138
RECLAIMING OLD OPERATIONS ........................................................................ 138

CHAPTER 14: CASE HISTORIES ............................................................................ 140
VITTICK PIT, LANGLEY, BRITISH COLUMBIA .................................................................................. 140
Project Background ................................................................................................ 140
Planning and End Land Use ................................................................................ 140
Reclamation Techniques ...................................................................................... 140
Results .................................................................................................................... 142
PLATEAU PIT, CRANBROOK, BRITISH COLUMBIA ........................................................................ 143
Project Background ................................................................................................ 143
Planning and End Use ........................................................................................ 143
Reclamation Techniques ...................................................................................... 143
Results .................................................................................................................... 144
STEELHEAD “DUECK” PIT, MATSQUI, BRITISH COLUMBIA ......................................................... 144
CHAPTER 15: ASSISTANCE FROM GOVERNMENT AND NON-GOVERNMENT AGENCIES

PROVINCIAL GOVERNMENT SOURCES OF TECHNICAL ASSISTANCE

FEDERAL GOVERNMENT SOURCES OF TECHNICAL ASSISTANCE

NON-GOVERNMENT SOURCES OF TECHNICAL ASSISTANCE
1. ABOUT THE HANDBOOK

This handbook is intended for use by private and government operators and by regulators. The manual may also provide useful information for the general public and schools. Information in the manual can be used to assist in the development, operation and reclamation of small pits and quarries, medium-sized operations, and major long-term ventures, including government operations such as pits operated by the Ministry of Transportation and Highways, and the Ministry of Forests.

The manual has been designed to assist users with a broad range of experience. Some users may have little or no previous experience in the pit and quarry industry, while others may have professional training and many years of experience. As a result, the manual includes:

- an introduction to reclamation planning and methods,
- a summary of current regulations and requirements for operations on private and public lands,
- general guidelines for planning, operation and closure,
- important measures for environmental protection,
- descriptions of reclamation methods and specific considerations for a broad range of end land uses, and
- case histories of several gravel pit operations in British Columbia.

The manual provides information on both sand and gravel pits and rock quarries. However, much of the focus is on sand and gravel operations which are much more common and widespread in British Columbia and where the range of reclamation needs and potential environmental concerns are often greater. As a result, much of the information in this manual is more applicable to sand and gravel operations than rock quarries.

2. HOW TO USE THE HANDBOOK

If this is the first time that you have been involved in a sand or gravel pit or a quarry operation, you should read and become familiar with Chapters 1 through 6 before you begin planning your operation.

- Chapter 1 describes the current status and importance of the sand and gravel and non-mineral rock industry in British Columbia.
- Chapter 2 describes some terms that are commonly used in the industry, and provides an overview of the types of operations and processes required during extraction and reclamation, and important environmental and community concerns that may need to be considered.
- Chapter 3 describes the current legislation and regulations that will apply to various types of operations in British Columbia.
- Chapter 4 outlines the tasks that will need to be completed during the planning, design, preparation, operation and closure of a pit or quarry.
- Chapter 5 describes specific practices and measures that should be used to prevent or minimize environmental impacts during the operation and reclamation of a pit or quarry, as well as means to solve some common problems after they have occurred.
- Chapter 6 provides information to assist you in selecting the best end land use for your operation.

Experienced operators may also find useful information on project development and reclamation, and environmental protection planning in Chapters 4 and 5.

Once you have selected an end land use for your operation, Chapters 7 through 12 will provide you with more detailed information on your land use choice. Each chapter describes important considerations in the development and reclamation of your operation. Specific methods for reclamation are also described. If you require more information for your land use, suitable government contacts and information sources are listed at the end of each chapter.

<table>
<thead>
<tr>
<th>If Your Preferred Land Use Is:</th>
<th>Go To:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>Chapter 7</td>
</tr>
<tr>
<td>Forestry</td>
<td>Chapter 8</td>
</tr>
<tr>
<td>Wildlife Habitat</td>
<td>Chapter 9</td>
</tr>
<tr>
<td>Fish Habitat</td>
<td>Chapter 10</td>
</tr>
<tr>
<td>Recreation</td>
<td>Chapter 11</td>
</tr>
<tr>
<td>Residential or Industrial</td>
<td>Chapter 12</td>
</tr>
</tbody>
</table>

Chapter 13 examines what can be done at sites that were developed before the importance of and requirements for reclamation were understood, and environmental regulations were established.

Chapter 14 describes four different sand and gravel pit operations in the Langley, Cranbrook, Matsqui and Skeena River areas of British Columbia. The case histories were selected to put a face to the industry, to demonstrate different approaches and methods for planning, operation and reclamation, and to show some of the common problems and successes in reclamation.

Chapter 15 provides a listing of government and non-government organizations that may be able to assist you in planning and reclaiming your operation.
1. PITS AND QUARRIES

The primary objective of this manual is to provide pit and quarry operators with a concise description of approaches and methods to effectively develop and extract various sand, gravel and rock resources, and reclaim disturbed sites to a productive land use. The manual also describes how impacts to the environment and adjacent lands can be minimized or avoided.

Throughout this manual, the terms pits and quarries are used to refer to specific types of operations for the extraction of sand, gravel, or non-mineral rock. It is therefore important that you understand the differences between these types of operations.

Sand and Gravel Pits

A pit is any site where sand and/or gravel resources are extracted. Because sand and gravel are often deposited together, both can be extracted from the same pit. However, local market demand will determine if one or both of these materials will be extracted.

Quarries

Quarries are any sites that are used for the extraction of building products such as limestone, shale, sandstones, or granite. Mineral products such as feldspar, silica sand and pumice are regulated differently under the British Columbia Mines Act, and are not addressed in this manual. Quarries may also be used as sources of rock to be broken down into manufactured sand and gravel, otherwise known as aggregate.

2. THE IMPORTANCE OF RECLAMATION

The extraction of sand, gravel or quarried rock is a highly productive and usually temporary land use that can greatly affect the future productivity of land. Sand and gravel and quarry operations are common throughout many areas of British Columbia, and are an important source of construction materials for rural and urban projects. It is estimated that there are over 4,000 pit and quarries in British Columbia. Although the land disturbed by any one individual pit or quarry may not seem very important, the combined total of disturbed land from all of these operations is significant; locally, regionally, and provincially. So the reclamation of even a small pit or quarry is important, and it is in everyone's best interest.

Why is reclamation of a pit or quarry important?

Disturbed areas are not only unsightly, but numerous environmental problems can arise from poor land management or from not reclaiming excavated areas. In some cases, these problems can result in detrimental changes in surface water quality, reduced availability of groundwater, losses of fish and wildlife habitat, and fewer recreational opportunities. In other cases, the main impact is the withdrawal of a valuable site from a productive future use. All of these changes affect the quality of life for you, your neighbours, and other residents of the province. Reclamation is also in the land owner's best interest because with reclamation, the value of the property is likely to increase in terms of its dollar value and productivity.

Effective reclamation will allow you to re-establish viable land uses on disturbed sites and to reduce environmental and land use problems. In fact, regulations in British Columbia require that you reclaim disturbed lands so that their productivity will eventually be equal to or greater than the capability or productivity of the land before it was disturbed. Through reclamation the capability of your site for forestry, agriculture, fish and wildlife habitat, or other societal needs may be maintained or enhanced.

3. WHICH GOVERNMENT AGENCY IS RESPONSIBLE?

In British Columbia, the Ministry of Energy, Mines and Petroleum Resources is responsible for overseeing all sand and gravel and quarry operations. If you intend to develop a sand and gravel pit or a quarry, you must file a form called the “Notice of Work and Reclamation Program on a Sand and Gravel and/or Quarry Operation” with the local office of the Ministry of Energy, Mines and Petroleum Resources. This form is also known simply as a Notice of Work or by its initials N-O-W.

The Ministry of Energy, Mines and Petroleum Resources will then circulate your application to a number of other government agencies who may have interests or concerns with your application. This approach — called a one-window approach — ensures that other provincial and federal ministries with interests in areas such as environmental protection, agriculture, forestry, cultural and historic resources, and transportation have input to your application, without requiring you to contact each Ministry individually. Each of the Ministries may request that special conditions be met during the development and reclamation of your site.
Within certain Municipal and Regional Districts, bylaws
may have been enacted to further regulate the sand and
gravel pits and quarry operations that fall within their
boundaries. You should contact the local municipal
government to determine if any special requirements
will exist for your operation.

4. RECLAMATION AND
REHABILITATION: DEFINING
THE TERMS

Words such as restoration, rehabilitation, and
revegetation are often used interchangeably with the
term reclamation. These terms have quite different
meanings, however, and should not be confused. In this
manual, we define these terms as follows:

- **Reclamation** is any process or measures to promote
  soil conservation and the eventual re-establishment of
  land productivity on a disturbed site. Reclaimed land
  uses may be quite different from the original land
  use(s).

- **Restoration** is defined as the re-creation of the
  original landforms, land productivity and land uses
  on a disturbed site.

- **Rehabilitation** is defined as the creation of landforms,
  land productivity and land uses that are compatible
  with the existing landscape and land uses in the
  surrounding area.

- **Revegetation** is defined as the re-establishment of
  plant cover on a disturbed site. Vegetation and soils
  are often used as important indicators of land
  capability and productivity.

5. MINIMUM RECLAMATION
REQUIREMENTS

Under the *Mines Act*, reclamation of your site must
meet the following criteria:

**Land Use**

A sand and gravel pit or quarry site must be reclaimed
to a neat, clean, and safe condition. Reclamation must
consider the previous land use and the highest post-
excavation productivity. The end use of the reclaimed site,
which is best decided during the early planning stages,
should be based on factors such as the present land use,
productivity, location, topography, and surrounding land
uses.

**Structures and Equipment**

All machinery, equipment, and building structures
must be removed at the close of operations. You may be
able to maintain some buildings if they can serve a
useful purpose that is compatible with your end land
use. Otherwise, concrete foundations must be backfilled,
covered with overburden and revegetated. Floor slabs
may also have to be backfilled and revegetated. All scrap
material must be disposed of properly.

**Watercourses and Surface Drainage**

Watercourses must be reclaimed as closely as possible
to their original condition, or in such a state that they are able to maintain themselves naturally
(Photo 1-1). A permanent system of drainage controls
must be developed so that water quality is maintained
and reclaimed areas are not affected by water erosion.
Where necessary, this is accomplished by the construc-
tion of perimeter interception ditches, erosion bars, and
contour berms, in conjunction with site recontouring
and revegetation.

If a pit or quarry has been excavated below the water
table and fills with water, you will likely have to drain
and backfill the hole. You will only be able to maintain
the pit or quarry as a lake or pond if a waterbody is
compatible with your end land use and will be a produc-
tive element in the local landscape. You will have to
ensure that the lake meets pre-mining productivity and
water quality objectives, and will be self-sustaining.

**Surface Preparation**

In sand and gravel pits, it is recommended that all
side slopes and benches be recontoured to slopes that
are no steeper than 2 Horizontal (H): 1 Vertical
(V)(Figure 1-1). Flatter slopes may be required if there
are concerns about erosion and long-term stability.
Steeper slopes may be permitted in rock quarries
depending on the type of rock and its stability. In sand
and gravel operations, most disturbed areas should be
graded to a flat to gently-rolling surface using the
existing overburden materials and/or stored overburden
materials. Where possible, resloping should prevent the
collection and concentration of surface runoff. Once the
subsurface materials have been regraded, available topsoil
or other suitable soil materials should be used to provide
a rooting bed for plants.

Settling ponds must be backfilled if required in the
permit issued under the *Mines Act*. In some cases, the
sediments collected in the pond can be recovered to be
used as a soil amendment or for revegetation. If roads
are going to be abandoned, culverts must be removed
and the original drainage patterns restored. To ensure
that drainage channels remain stable, erosion bars may
have to be installed in the channel at frequent intervals. If the road bed is highly compacted, you will have to rip the road bed to allow for easier revegetation.

**Revegetation**

Re-establishment of self-sustaining plant cover is an important part of ensuring that land productivity is restored on your site. Most end land uses require that some form of temporary or permanent plant cover be re-established on the disturbed land. Temporary plant cover may be established to reduce soil and wind erosion during intermittent, short-term closures of an operation or when long-term operation is likely. A permanent plant cover must be established as part of the reclamation program for permanently closed sites.

Plants that are used for revegetation must be adapted to the local climate and, except for agricultural end land uses, be capable of surviving with little or no care. Local conditions and land uses will determine the best revegetation methods. For example, planting of seedlings may be required to meet a reforestation condition in the permit.

Additional reclamation guidelines may be applicable if the pit operation is in the Agricultural Land Reserve, along valley breaks, or near major water courses. Other special requirements may be added, such as the need to protect wildlife habitat.

**6. IMPORTANCE OF THE RESOURCE**

Sand, gravel and quarry operations are necessary for the development and maintenance of our society, as well as an essential component of the British Columbia economy. Sand, gravel and quarry materials are used for housing, buildings, roads, and a wide variety of other industrial and recreational projects. Over 50 million tonnes of sand and gravel are excavated annually in

---

*Photo 1-1: Watercourses must be reclaimed as closely as possible to their original condition.*

---

*Figure 1-1: Slopes are expressed as the ratio of the horizontal run (H) to the vertical rise (V).*
British Columbia, and additional amounts of quarry material are also extracted. These operations directly employ 4,000 to 5,000 people and produce annual revenues of approximately $130 million dollars per year. Haulage costs further add to the cost of production. Current haulage costs are approximately $4/tonne, thereby bringing the total value of the industry to $330 million dollars per year.

The Ministry of Transportation and Highways is the largest single user of sand and gravel in British Columbia, and maintains a large number of sand and gravel pits and some rock quarries. Other non-commercial users include the Ministry of Forests, local municipalities, railway companies, and forestry companies. These non-commercial users require sand and gravel primarily for road construction and maintenance. Commercial operations, which account for about 40% of total annual production, provide materials for housing and buildings, roads, and other construction projects. Due to the high cost of transporting sand, gravel and rock, approximately 40% of all sand and gravel extraction in British Columbia is conducted in the lower mainland.

Because sand, gravel and stone deposits are created over very long periods of time by geological and other natural forces, they are considered a non-renewable resource. Like other non-renewable resources, it is important that they be managed wisely. Careful planning of your operation will allow you to maximize the permissible extraction of the sand, gravel or rock resource(s), while also conserving the upper soil layers and minimizing environmental impacts. Good planning will also help to ensure that your land use is compatible with that of your neighbours and that productive land uses are re-established after mining has been completed.
This chapter provides an overview of the basic information that is required to operate a sand and gravel pit or rock quarry, and effectively address the important environmental or community concerns that may arise as a result of your operation. Information provided in this chapter includes:

- Definitions for some of the common terms that are used in this manual to describe pit and quarry operations;
- Descriptions of the different types of extraction operations and the activities that are common to these operations; and
- A brief discussion of the important environmental and community concerns that may affect your operation.

Each operation will have a unique combination of mining and environmental concerns. It is important that you understand all of the specific activities and processes for your operation, as well as the ways that your operation may affect the local environment and nearby residents. This will allow you to develop an effective approach to maximizing the recovery of sand and gravel or quarry products, while minimizing detrimental effects on the environment and your neighbours.

1. COMMON TERMINOLOGY

A number of terms are used in this manual to describe types of operations, products and activities that are associated with sand and gravel and quarry operations. (Note: United Soil Classification terms are also provided in Chapter 5).

- **sand.** Unconsolidated materials that are primarily made up of rock particles 0.06mm to 5.0mm in diameter.
- **gravel.** Unconsolidated materials that are made up of rock fragments 2mm to 7.5cm in diameter (Photo 2-1).
- **aggregate.** Sand, gravel, crushed stone and quarried rock.
- **site.** For the purpose of this manual, site refers to all of the disturbed and undisturbed land within the legal boundaries of your lease or property (Figure 2-1).
- **operation.** As used in this manual, an operation refers to all of the active work and processing areas within your site, including the pit or quarry area, stockpile and storage areas, haul roads, processing sites, weigh scales, etc. (Figure 2-1).
- **pit.** For the purpose of this manual, a pit is defined as a place designated by the Chief Inspector of Mines as a mine for the extraction and processing of sand and gravel (Figure 2-1).
- **quarry.** For the purpose of this manual, a quarry is defined as a place designated by the Chief Inspector of Mines as a mine for the extraction and processing of non-mineral rock.
- **soil.** The unconsolidated material on the immediate surface of the land that serves as a natural medium for the growth of plants (Figure 2-2).
- **topsoil.** The uppermost soil layer that is commonly characterized by dark-coloured, organically-enriched materials (Figure 2-2). Topsoil layers can be very thin, but are commonly 10 to 30cm deep. It normally includes the surface layer of plant litter. The majority of plant roots are located in the topsoil layer.
- **subsoil.** The soil layer between the topsoil and the overburden. Subsoil layers may show differences in colour (often reddish brown or mottled), clay content, structure and chemistry (e.g., salinity, sodicity) compared to the topsoil and overburden (Figure 2-2). Subsoils typically contain some plant roots and are the maximum depth of rooting.
- **overburden.** The unconsolidated material between the soil layer (rooting zone) and the bedrock, excluding the economically valuable sand and gravel layers. Overburden is typically comprised of glacial till, and/or freshwater or marine sediments (Figure 2-2). Sand and gravel deposits are often sandwiched between layers of overburden. If overburden overlays
Figure 2-1: The area of active extraction is referred to as the pit or quarry (1). All active areas including the pit or quarry access roads, and stockpiles are referred to as the operation (2). All of the disturbed areas and undisturbed lands within the legal property or lease boundaries are referred to as the site (3).

- Bedrock. The solid rock that underlies the soil and overburden, or that is exposed at the surface (Figure 2-2).
- Groundwater. Water that passes through or stands in the soil and underlying overburden or bedrock layers (Figure 2-3).
- Aquifer. A geological formation that is made up of porous, permeable materials that are saturated with sufficient water to result in adequate flows of water into wells, boreholes and springs (Figure 2-3).
- Watertable. The upper surface or elevation of the groundwater that is within the aquifer that is closest to the ground surface (Figure 2-3).

Construction materials, dimension stone, mineral, non-mineral, and mineral substance are defined in the Mineral Tenure Act.

2. TYPES OF OPERATIONS, PROCESSING AND ASSOCIATED ACTIVITIES

Sand, gravel and quarry operations can involve a number of different types of extraction and processing activities. Descriptions of these activities are provided below to assist you in better understanding the range of activities in resource extraction. General descriptions of sand and gravel pits and non-mineral rock quarries are provided in Chapter 1.

Types of Extraction

Sand and Gravel Pits

In general, extraction and processing activities are similar for sand and gravel operations. Pits depths are variable, but often do not exceed 5 to 7m. Pit sizes can range from 1 to 2ha to very large operations that are 40
Screening is used to separate sand from gravels and to remove waste materials such as till.

to 50ha in size or more. Sand and gravel are relatively cheap commodities relative to their bulk, and a major cost of their supply is transportation. As a result, most sand and gravel pits are located near the site where these materials will eventually be used, such as roads, industrial projects and residential developments. Most pits are also located close to cheap modes of transportation such as ocean barges, highways, or railways.

**Quarries**

The sizes and depths of rock quarries are highly variable, depending on the rock formation and the type of quarry operation. As with sand and gravel, transportation of quarried materials is expensive and, therefore, most quarries are located close to highways, railways, or water transport.

![Cross-section of a gravel deposit showing groundwater flows, the watertable and the aquifer.](image)

**Other Types of Operations**

Borrow pits, while occasionally containing resources of sand and gravel, are often excavated to provide low quality fill (e.g., overburden) for construction activities such as road building and landscaping. Fill of this type is usually removed and then compacted on site as a base for construction. Borrow material is commonly used to construct gentle slopes at roadsides and to landscape around residential developments. Topsoil is then placed on top of the borrow, and the area is seeded to provide a vegetation cover.

Clay and marl pits are usually opened for special situations requiring such material. As clay can help reduce seepage, it is often used to line dugouts, water reservoirs, or ditches. Marl or bog lime may be used to reduce the acidity of soils or waters.

**Processing Operations**

The following activities are used individually or in tandem to process the sand, gravel, or rock at pit or quarry operations.

**Crushing**

Crushing is a process whereby gravel or rock is broken down to improve its gradation, increase stability and/or maximize utilization of the resource.

**Screening**

As many deposits contain mixtures of both sands and gravels, they are often screened to sort the different sizes of aggregates required for different construction purposes (Photo 2-2). Screening also provides a means of separating sand from the gravels, and removing waste materials such as silt.

**Washing**

Washing of gravel typically takes place when there is a requirement for clean construction materials that do not contain large quantities of non-granular materials (e.g., till) or fine granular material (e.g., sand). Finer gravels are commonly washed to remove sands and other material that accumulate during extraction and processing, or that were originally present. The outwash from the washing operation is often piped into ponds to separate fine, solid materials, and to allow recycling of the wash water. Depending on its characteristics, some finer material may be collected for further processing.

**Dewatering**

Many gravel beds were originally deposited by glacial streams, and are now located below the present groundwater level. Extracting gravel from below the water table requires either lowering the groundwater level to allow conventional excavation or dredging (Figure 2-4). Excavation below the water table is usually very restricted in British Columbia. Conventional extraction can be achieved by ditching on a sloping site,
or by pumping from sumps or shallow wells on a level site. If dewatering is proposed, the potential impact on domestic wells and low flows in adjacent creeks must be assessed. If impacts are judged to be severe, gravel should not be excavated below the water table, or the pit must be operated in a manner that will not affect groundwater levels (i.e., dredging).

Stockpiling
As gravel or sand is excavated and processed, it is frequently stored in large piles called stockpiles (Photo 2-3). This generally occurs in long-term operations. When the demand for the resource is not particularly high or when more aggregate is extracted than can be used for a specific project, the excess material is stockpiled. These stockpiles may last from a few weeks to several years. Stockpiles should be placed in areas where they are easily accessible for loading onto gravel trucks and will not obstruct future access to extractable deposits or limit expansion for other pit operations such as the use of asphalt plants.

Drilling and Blasting
Drilling and blasting is used in some sand and gravel pits and most quarries to loosen a deposit or to break competent bedrock or large rock pieces into manageable sizes. Blasting is strictly regulated in British Columbia, and must be supervised by a certified and experienced blaster.

In a typical quarry operation, holes are drilled into the rock with an air trac drill and explosive charges are placed and detonated in the holes. Care must be taken with blasting to ensure that rock fragments are not cast outside of the mine site, rock that will comprise the final wall of the quarry does not sustain substantial blast damage, and the residual material or shotrock is of useful dimensions.

Other Site Uses
In addition to the extraction of sand and gravel or non-mineral rock, pits and quarries are sometimes used for other purposes during the operational phase or when operations are complete. Some of these uses can result in environmental problems such as groundwater contamination. If you are considering other site uses in your pit or quarry, you should contact the Ministry of Environment, Lands and Parks to determine if these other uses will be permitted, and if special precautions are required.

Common alternate uses of pits and quarries that may not be permitted or require special considerations include the following:

Asphalt Plants. Because asphalt plants require ready supplies of gravel, they are commonly located in or close to active pits. At any asphalt plant, there are many contaminants on site including liquid asphalt, asphalt storage tanks, solvents for cleaning equipment, and diesel fuel. If these contaminants are not contained or handled properly (See Chapter 5, Important Environmental Protection and Remediation Measures), spills may result in the contamination of soil or groundwater.
Stockpiling of sand and gravel.

Storage of Wood Waste. Wood waste from highway projects or forestry road projects is often stored in inactive pits due to the proximity of the pits to good road access. If wood waste is temporarily stored on a site, measures should be taken to control water contact with the waste, since water leaching through wood waste can introduce toxic substances to surface and ground water. This could involve placing all wood waste above the high water table, and possibly covering the waste in very wet climates. If the wood waste is left uncovered, groundwater monitoring wells should be established immediately upstream and downstream from the site.

Recycling Operations. Recycling operations are sometimes located in old or inactive pits or quarries. These sites can provide a ready area for storage of waste materials, as well as good access to low cost transportation systems. Prior to such use, however, you will have to obtain a permit from the Ministry of Environment, Lands and Parks. Some recycling activities can result in the release of accidental spill of toxic substances. For example, appliances may contain PCBs, freon, PCPs, and PAHs, paints may contain heavy metals or solvents, and gypsum board may produce leachates such as calcium sulphate.

Storage of Other Types of Waste. Due to low transportation costs, construction and land clearing, debris are sometimes stored in gravel pits. If significant quantities of waste are to be stored, a permit must be obtained from the Environmental Protection Division of the Ministry of Environment, Lands and Parks. The permit application must include an assessment of any leachate that would be generated from the waste, and its potential impact.

3. IMPORTANT ENVIRONMENTAL AND COMMUNITY CONCERNS

Pits and quarries typically require the removal of the topsoil, stripping of overburden and spoil material, and development of processing and loading facilities and service areas. These activities, along with access roads, usually result in disturbance or removal of soil, landforms and vegetation. Erosion of exposed surfaces by wind and water can result in further losses of soil and can cause significant impacts on downstream water quality. Dust, noise and vibration from your operation may also be a nuisance or concern to nearby residents.

During the preparation of the development and reclamation plan for your pit or quarry, as well as during site development and operation, there will be a number of issues related to environmental and community impacts that you will need to consider. These concerns may affect your ability to obtain a permit to develop your site, the way in which you operate your pit or quarry, your success in reclamation, and your ability to restore a productive end land use on your site. It is, therefore, important that you effectively manage or eliminate as many of these concerns as possible.

Good environmental practice is important, no matter what the location or size of your operation. In fact, stringent environmental legislation and guidelines require all operators to minimize environmental damage, effects on human health and nuisance problems for residences and communities.

Environmental and community issues that you are most likely to encounter are described below. All of these problems can often be avoided or minimized through the use of environmental protection planning and remediation measures. General recommendations are provided below. For issues that are marked with an asterisk (*), additional details on specific mitigation measures and processes are provided in detail in Chapter 5.

- Groundwater Quality and Availability*
- Adjacent Watercourses and Wetlands*
- On-site Runoff and Water Quality*
- Soil and Groundwater Contamination*
- Soil Erosion*
- Sediment Loss and Siltation*
- Loss of High Quality Soil*
- Loss of Plant Cover
- Noise*
- Dust*
- Vibration*
- Traffic Volumes and Safety
- Aesthetics
- Public Safety
Groundwater Quality and Availability

Groundwater flows commonly occur in saturated materials at some depth beneath most sand and gravel pits. Some quarries may also be affected by groundwater flows. Groundwater flow is recharged by precipitation on upland areas that infiltrates into the surface, and percolates down to the water table. Groundwater flow discharges in lowland areas as springs, or as direct discharge into creeks or rivers (Figure 2-5). Groundwater discharge can sustain stream flows during periods of drought. Wells are often drilled or dug into aquifers to obtain water for domestic, irrigation or industrial supply. If a site is dewatered to allow mining below the water table, groundwater levels and, ultimately, well yields and spring discharges to streams could be reduced (Figure 2-5).

To prevent impacts to wells and streams, it is important that pits are designed and operated in a manner that does not cause or require lowering of the water table. At most sand and gravel sites, the Ministry of Energy, Mines and Petroleum Resources will generally only permit mining to within 1 m of the annual high water table to prevent unacceptable impacts to groundwater quality and availability. If you need to excavate below the water table, an alternate method of excavation such as dredging may be acceptable. For quarries that are excavated in less permeable rock, the water table is less of a concern and may not limit excavation. However, if bedrock wells are located near the quarry, excavation below the water table may not be acceptable.

Adjacent Watercourses and Wetlands

The availability and quality of surface water in adjacent creeks or wetlands are important in maintaining downstream flows of high quality water for domestic and agricultural use, as well as sustaining aquatic habitats. Because of the high value of surface water resources, pits and quarries must be designed and operated in a manner that minimizes or prevents impacts on any adjacent surface water courses or wetland areas.

If a pit or quarry intersects a natural drainage course, it will be necessary to construct a diversion channel around the operation to prevent water flows into the work area and avoid detrimental effects on water quality (e.g., increased suspended sediment) (Figure 2-6). Prior to altering a watercourse in any way, however, you will need to obtain an approval from the Water Management Branch of the Ministry of Environment, Lands and Parks. Diversions can be permanent or temporary life-of-excavation structures. In general, diversion channels...
should be able to carry a 1:200 peak runoff flow (that is, the largest flows that are likely to occur within a 200-year period). The channel must also be constructed of non-erodible materials to prevent sediments from entering the stream flow. It is recommended that you consult with a professional engineer in designing any diversion channels.

Care must be taken to prevent any sediments from your operation from entering streams, rivers or wetland areas. To reduce the risk of sediment damage to aquatic habitat, the Ministry of Environment, Lands and Parks and the Federal Department of Fisheries and Oceans generally requires that a buffer of 15 to 30m of undisturbed vegetation be left between the limit of a surface disturbance and the high water mark in a fish-bearing creek. Additional control measures such as sedimentation ponds can be used to contain sediments that are entrained in the site runoff.

**On-site Runoff and Water Quality**

Pits and quarries have the potential to alter the quality and quantity of local groundwater and surface water. Runoff from disturbed areas will often be more variable than from undisturbed areas. Heavy equipment compacts surface soils and subsoils and, in turn, rainfall or meltwater that does not soak into the ground or collect in small depressions, moves over the ground surface as overland flow. In addition, because compacted soils hinder infiltration and plant establishment, surface runoff is rapid and erosion of soils may be increased. As a result of increased sediment in the surface runoff, water quality in nearby streams may decline (see below). In a worst case, increased surface runoff can create flash floods as smaller channels merge with larger channels.

Runoff from a pit or quarry site must be collected and treated as necessary to prevent degradation of the natural surface water courses that drain the site. As noted above, you may need to construct an interception ditch around your operation to direct clean runoff from the surrounding undisturbed areas, and reduce the volume of water that requires treatment (Figure 2-6). For large extraction sites (greater than 20ha) with high runoff potential, storm water retention structures may be required to minimize highly erosive, peak flows.

Following excavation, you will need to grade the disturbed areas within your site so that runoff is not concentrated, except in properly designed swales or drainage ditches. Site grading should also prevent surface ponding unless ponds are required as part of your end land use. For example, permanent ponds might be created to provide wetland habitat, recreational lakes or storm water detention ponds.

The steepness and length of slopes within your pit or quarry will have a direct influence on surface runoff and the potential for soil erosion. As slopes become steeper and/or longer, more stringent methods for erosion protection will have to be employed (see Chapter 5: Erosion Control).

The grading plan for most reclaimed areas should include swales along contours to prevent large runoff flows from accumulating at the base of long slopes, and an undulating base to create a number of small drainage courses instead of one large one (Figure 2-7). If the site is to be reclaimed for agriculture, forestry or any other use that requires a well drained root zone in the soil profile, a drainage layer or other means to ensure good subsurface drainage will be required below the topsoil/subsoil.

**Soil and Groundwater Contamination**

Groundwater quality and downstream groundwater use can be affected by a pit or quarry operation if contaminants are allowed to leach from the surface down.
into the water table (Figure 2-5). As the depth of unsaturated soil beneath a sand and gravel pit is reduced, so is the natural capacity of the sediments to cleanse contaminated infiltrating water. Removal of the topsoil and gravel will slightly increase the risk of groundwater contamination. Because surface runoff flows often increase across an exposed mined surface, the potential for surface migration of chemical contaminants also increases.

Chemical contamination of groundwater and surface water can only occur if liquids are spilled on the ground, or if solids that are disposed of on the property are leached by surface and groundwater flows. A variety of regulations in British Columbia govern the use and storage of potential contaminants such as fuels, lubricants, and fertilizers (if reclaimed for agriculture). Compliance with these regulations will prevent adverse impacts to groundwater and surface water quality from occurring.

**Soil Erosion**

Removal of plant cover and disturbance of soil layers and overburden during the development and operation of a pit or quarry increases the potential for erosion of soil and other unconsolidated materials through the actions of water and/or wind. Melting of permafrost, which occurs in some areas of British Columbia, can also cause significant soil erosion problems.

**Water Erosion**

Soil erosion by water can include sheet and rill erosion, as well as gully erosion in areas of concentrated flow. Soil erosion is a two-step process. First, soil particles are detached by raindrop splashes or running water, and second, the particles are transported by runoff water (Figure 2-8). The potential for water erosion of soil is related to:

- climatic factors (rainfall intensity and duration, snowmelt),
- soil erodibility (texture and permeability),
- topography (slope length and gradient),
- cover (vegetation or crop management factors), and
- conservation practices (contour tillage, mulching, terracing).

Soils in the Peace River area of British Columbia, like those in most of the interior, higher elevation areas of the province, are susceptible to erosion during snowmelt when water infiltration is limited by the frozen, impermeable, near-surface soils. The South Coast region is particularly susceptible to water erosion of soil due to the long, winter rainfalls (during November through March), and the resulting water-logged soils that result in higher runoff.

A variety of measures can be used to control water erosion, including perimeter ditching, management of on-site drainage, use of erosion control structures (e.g., silt fences) or materials (e.g., mulches, geotextile fabrics), and temporary or permanent plant covers.

**Wind Erosion**

Wind erosion occurs under dry, bare soil conditions, particularly in exposed areas such as large open fields.
In sand, gravel and quarry operations, uncovered soil stockpiles and recently topsoiled, reclaimed areas are particularly susceptible to wind erosion. Fine sand and silt-sized particles are most susceptible to wind transport. As noted above for water erosion, a variety of methods can be used to control wind erosion of surface materials.

**Permafrost**

Discontinuous permafrost (permanently frozen ground) occurs in some areas of northeastern British Columbia and at very high elevations throughout mountainous parts of the province. If your pit or quarry occurs in this type of terrain, care must be taken to prevent excessive disturbance that might destroy the insulating effectiveness of the "active" upper layers of soil. Destruction of the active layer's insulating properties can result in a number of severe problems, including collapsing of the land surface, slumping, rutting, and flooding.

Careful planning and scheduling of your excavations and land disturbances during winter are the best methods to avoid erosion problems from melting permafrost. Some methods such as wood chip mulches can be used to minimize melting of permafrost in disturbed sites.

**Sediment Loss and Siltation**

Soil erosion, materials handling and washing of gravels can produce large volumes of muds and silts. If these materials are washed into natural watercourses, water quality can be severely reduced. This can detrimentally affect water quality for domestic use, and degrade aquatic habitats.

The most serious direct effect of sedimentation is the smothering of spawning gravels for salmon, trout and other fish (Figure 2-9). If gravels become choked with silt, eggs may not be laid or, if laid, may be smothered. If the eggs develop into young fish (fry), silt can make it difficult for fry to emerge. A buildup of sediments can also eliminate hiding and overwintering places for small fish and aquatic animals, and reduce the growth of algae (single cell plants), resulting in the loss of food for some insects and fish.

When sediments are carried by surface waters, water becomes turbid (muddy), thereby reducing the value of the water for domestic or industrial use. Sediments also inhibit the penetration of sunlight and the growth of aquatic plants. The scouring action of suspended sediments can also harm mayflies, stoneflies and other aquatic insects, that are important foods for fish. Heavy sediments can make it difficult for some fish to feed and
breath. In extreme cases, fish may move away until conditions improve.

**Loss of High Quality Soil**

Soil materials on your site are an extremely valuable, non-renewable resource. Because good quality topsoil can take decades to develop, and improvement of poor quality soils is often impractical, all pit and quarry operations should include a soil handling plan. As discussed later in Chapter 4, you will likely have a soil specialist complete a detailed soil survey for your site to determine the types of soil, their distribution and their variability. Information on soils is critical to developing plans for soil salvaging, soil handling and their eventual use in reclamation.

Successful reclamation almost always requires the careful salvage and replacement of the uppermost soil layers. During the operation of your pit or quarry:

- Salvage your best soil materials (topsoil, subsoil, etc.). Remember to strip topsoil from vehicle access routes and the buffer zone around the edge of the pit (Photo 2-4);
- During soil salvage, keep the high quality soil materials (i.e., topsoil and subsoil) separate from less productive or potentially problematic materials such as overburden;
- Don’t bury topsoil or suitable subsoil under storage areas for overburden and aggregate stockpiles;
- Prevent erosion of topsoil by wind or water during salvage and stockpiling and after replacement; and
- Take precautions to control theft of topsoil from stockpiles.

**Loss of Plant Cover**

Vegetation is an integral part of all natural habitats. Plant cover can provide hiding cover and food for thousands of organisms from small insects to large animals such as moose. It is the first link in the food chain that provides energy for all life on earth (Photo 2-5).

Vegetation also builds and maintains the organic content, physical structure and water content of soils. This helps develop a more open soil structure which, in turn, improves the infiltration and storage of water within the root zone. Vegetation also helps to establish and maintain a layer of partly decomposed organic matter at or near the surface of the soil. This prevents surface water from removing fine soil particles and from clogging soil openings that are important for water infiltration. Plant covers also spread water over the surface of the land which, in turn, helps the soil soak up surface water and reduce overland flows. By reducing overland flows, vegetation results in less erosion of your soil. Vegetation is also important in shading the ground, minimizing wind erosion, and reducing snow melt and evaporation from the soil, thereby helping to keep your soil moist.

Losses of plant cover commonly occur during the initial layout of an operation, stripping and stockpiling of the surface soil layers, or through burial in storage areas. Vegetation that is not stripped or buried may be crushed by equipment travel and other processing operations. Because of the many important aspects of plant cover, you should try to minimize losses of natural vegetation as much as possible.

**Noise**

Nearby residences or facilities may be disturbed by noise that is generated by your operation. The permit issued under the *Mines Act* and municipal bylaws may stipulate the allowable levels of noise, and may also

Photo 2-4: Topsoil is a valuable resource that must be protected during the development of your operation. (Source: D. McQueen).
Losses of native vegetation should be minimized during the development of your pit.

Heavy trucks are a source of material transfer noise and vibration. (Source: D. Kennedy).

restrict the hours of operation. As an operator, you should be aware of these regulations. Such conditions may be included in your mining permit. Special attention should be paid to the nighttime and holiday restrictions. Excessive noise can also have an adverse effect on domestic livestock and wildlife. This may be an important consideration for your operation, particularly if it is located in a remote location.

Sources of noise in most pit and quarry operations can be grouped into four general categories:

- stationary equipment noise,
- portable equipment noise,
- material transfer noise, and
- blasting noise.

Stationary equipment noise is generated by equipment such as screens and crushers that generally remain in the same location during the life of an operation. Portable equipment noise is generated by mobile equipment such as rock drills, front end loaders, and heavy trucks. Material transfer noise is produced by trucks (Photo 2-6), conveyors and other equipment that move material from one location to another. Blasting noise is generated by the detonation of explosives. Noise reduction methods should be considered during the planning stages of your operation.

You should also be familiar with the existing “noise environment” and noise restrictions in the surrounding area. Sensitive community areas such as senior’s facilities, hospitals, and residences should receive extra attention. If your pit or quarry is located close to any of these areas, you should undertake a noise survey prior to beginning operations to pinpoint potential noise problems.

Some typical noise levels are provided in Table 2-1. However, a direct comparison of various noise sources cannot be made based on the noise levels alone. You must also consider the frequency of the noise (high or low) and its duration. For example, equipment that operates for a shorter period of time and has a high noise level may not be more annoying than equipment that operates for a longer period of time and has a lower noise level. In addition, although two noise sources may generate the same noise level, one type of equipment may be more annoying than another because of the frequency of the noise.

A “Community Information Noise Program” is an ideal method for keeping the community informed of noise improvements at the operation and for obtaining community feedback. Methods such as these are useful ways of reducing the amount of misinformation in the community.

Dust

Activities associated with pit and quarry operations can result in dust emissions that can have a negative effect on the local air quality. For example, heavy equipment and processing machinery can create fine materials that become airborne and are carried off site (Figure 2-10). The action of wind on exposed areas and stockpiles also have a similar effect. Dust emissions from pit and quarry activities will settle from the air rapidly and therefore, are, usually only a problem close to the site. Temporary or permanent plant covers, erosion blankets, dust suppressants, and plastic sheeting may be used to reduce dust emission problems.

Vibration

Some types of equipment that are used in pit and quarry operations can produce ground vibrations that are perceptible by nearby residents. For example, large trucks operating on rough roads may cause ground vibrations (Photo 2-6).
Vibrations from your site may disturb nearby residents, create a form of low-level stress to wildlife and livestock, and cause structural damage to nearby buildings. While the latter represents an area of greatest concern for most operators, the level of vibration required to cause structural damage can generally only be produced by blasting the ground. Depending on the design of the blast, the type of ground, and the distance between the blast and nearby buildings, it is possible for blast vibrations to crack gypsum wallboard and concrete foundations. The maximum vibration levels that can be produced by your operation may be stated in your mining permit. It is best to consider vibration reduction methods during the planning stages for your operation.

Traffic Volumes and Safety

Haulage is one of the major components of any pit or quarry operation. Depending on the number, frequency and timing of traffic to and from your site, trucks, equipment and staff vehicles can:

- increase wear on the road surface,
- increase noise,
- increase fumes and dust,
- cause traffic congestion, and
- heighten community concerns for safety.

By considering operational hours and alternative hauling methods (e.g., barging, rail), you may be able to reduce some of these traffic-related impacts. If you are responsible for a large operation with many employees, staff carpooling may be one means of reducing traffic to and from your site. It is recommended that you work with the Ministry of Transportation and Highways to address and resolve these concerns.

### Aesthetics

If your pit or quarry is located in an undisturbed area that is close to a residential area or clearly visible from a public highway, roadway or pathway, there may be community concerns about the visual impact of the development on the local landscape. You may be able to screen your operation from adjacent residences or roadways by maintaining a buffer area of trees and shrubs around your site, or by locating your operation in existing depressions or behind hills and outcrops.

### Public Safety

Pits and quarries must be operated in a manner that does not pose any risk to the public. This may require fencing around the site and a gated entry to restrict public access. Try to avoid the use of single bar or chain gates. These gates may not be visible to motorcyclists and snowmobiles travelling at high speeds and therefore, may create a safety hazard.

All equipment should be locked, and keys removed to prevent unauthorized use during non-operating periods. The driveway should be located at a position with good site lines along adjacent roadways to reduce the risk of traffic accidents. Signage should be in place to warn of steep or unstable slopes. If the pit or quarry is to be left dormant, all slopes should be graded to a stable configuration.

---

**Figure 2-10**: Loading and other activities can create fine materials which become airborne and are carried off-site (Source: M. Rawlings).

**Table 2-1. Examples of Typical Noise Levels (dBA).**

<table>
<thead>
<tr>
<th>Noise Source</th>
<th>Noise Level (dBA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Threshold of Hearing</td>
<td>0</td>
</tr>
<tr>
<td>Soft whisper at 5m</td>
<td>30</td>
</tr>
<tr>
<td>Public Library</td>
<td>40</td>
</tr>
<tr>
<td>Noisy Office</td>
<td>50</td>
</tr>
<tr>
<td>Light car traffic at 15m</td>
<td>55</td>
</tr>
<tr>
<td>Highway traffic at 15m</td>
<td>74</td>
</tr>
<tr>
<td>Excavator at 15m</td>
<td>81</td>
</tr>
<tr>
<td>Loader at 15m</td>
<td>87</td>
</tr>
<tr>
<td>Dozer at 15m</td>
<td>87</td>
</tr>
<tr>
<td>Heavy truck at 15m</td>
<td>90</td>
</tr>
<tr>
<td>Hydraulic drill at 15m</td>
<td>91</td>
</tr>
<tr>
<td>Freight train at 15m</td>
<td>95</td>
</tr>
<tr>
<td>Pneumatic drill at 15m</td>
<td>96</td>
</tr>
<tr>
<td>Jet takeoff at 500m</td>
<td>100</td>
</tr>
<tr>
<td>Jet takeoff at 50m</td>
<td>120</td>
</tr>
</tbody>
</table>
Heritage Resources

Heritage resources include sites, objects and structures that are of paleontological, prehistoric, historic, architectural, or scenic significance to the province.

- Paleontological sites are areas where fossils of plants or animals have been preserved.
- Prehistoric sites include stone structures, shell middens and bone or stone artifacts such as arrow heads. Most sites predate the arrival of Europeans.
- Historic sites include structures, features and objects of European influence. Buildings and building remains represent the most common type of historic sites.

Although heritage sites may be found anywhere in the province, they are frequently located next to waterbodies. Because sands and gravels are deposited by water, sand and gravel operations have a potential to be located on or near heritage sites. To protect these sites, operators must take care not to disturb or damage what may be a heritage resource.

If you find any heritage dwelling, object or artifact on your site, all operations must cease until the Heritage Conservation Branch has been notified, and they have given approval or a permit to proceed.
1. APPROVALS

As noted earlier in the Introduction, the Ministry of Energy, Mines and Petroleum Resources is responsible for issuing and enforcing operating permits for practically all sand and gravel and quarry operations in the province. When you intend to develop a pit or quarry, and you have the proper tenure in place, you must file a permit application called the “Notice of Work and Reclamation Program on a Sand and Gravel and/or Quarry Operation” with the local office of the Ministry. The Ministry then provides a “one-window approach” to obtaining approval for pits and quarries on behalf of most provincial and federal government agencies. This means that the Ministry will circulate the Notice of Work to the appropriate agencies and First Nations for review. The Ministry of Energy, Mines and Petroleum Resources will compile all responses in relation to the application.

If there are concerns regarding your operation, the Ministry of Energy, Mines and Petroleum Resources will usually make it a condition of the Mines Act Permit that you meet these concerns. However, in some cases, where significant concerns exist or where the concerns occur outside the Ministry’s jurisdiction, you may be required to obtain individual permits from other agencies before you can obtain your Mines Act Permit. For example, you may have to obtain permits under the Agricultural Land Commission or Forest Lands Commission, if your site falls within these jurisdictions. Similarly, the local government may have authority under a soil removal bylaw to require a Soil Removal Permit prior to extraction of sand and gravel.

Providing a Security

Reclamation securities are usually required as a condition of all Mines Act Permits granted by the Ministry of Energy, Mines and Petroleum Resources. Over the last several years as permits have been revised or renewed, reclamation security bonds have increased on many properties. This policy reflects the government’s desire to reduce the chance that public money might be required to reclaim a pit or quarry in the case of default. The policy also reflects the need to accurately show the actual outstanding reclamation obligations of each pit and quarry property. If you do not comply with the conditions of the Mines Act Permit, the Minister may order closure of your pit or quarry and confiscate the security.

For new operations, security levels are now being set to reflect the cost and risk to the province if default occurs. There is also a greater reliance on advice from technical and risk management professionals than was the case for older operations.

Acceptable reclamation securities include: cash, bonds guaranteed by the Government of Canada of no longer than 3 years duration, or an irrevocable letter of credit. Insurance Act bonds and performance bonds are not acceptable. Once the reclamation security has been posted, your Mines Act Permit will be issued by the Ministry.

2. PROVINCIAL LEGISLATION

Depending on the type and location of your operation, some government departments may or may not have an interest in your operation. The following sections describe the interests and legislation of some of the government departments that may review your Notice of Work.

Ministry of Energy, Mines and Petroleum Resources

Pits and quarries fall within the definition of a “mine” under the Mines Act. The Mines Act, administered by the Ministry of Energy, Mines and Petroleum Resources, requires that all mines file a permit application (Notice of Work) with the Ministry. This permit covers all aspects of the operation of the mine from exploration through extraction, reclamation and abandonment. The process for obtaining a permit is noted above.

It is very possible that a prior right to mine material from your site may have previously been issued under the Mineral Tenure Act for either placer minerals (placer claims) or hardrock minerals (mineral claims). Placer and mineral claims provide the right to extract the mineral that may be contained within the sand, gravel and rock, but do not provide the right to produce sand or gravel. You must contact the local Gold Commissioner of the Ministry of Energy, Mines and Petroleum Resources to determine if conflict exists. The Gold Commissioner is not contacted through your submission of the Notice of Work application. The tenure for sand, gravel and rock on Crown land is issued under the Land Act through BC Lands (see below).

Environmental Assessment Office

The Environmental Assessment Act, which is administered by the independent Environmental Assessment Office, requires new sand and gravel pits with production greater than 500,000 tonnes per year, or 1,000,000 tonnes over 4 years to be included in the environmental assessment process. For quarries the production limit
for inclusion is 250,000 tonnes per year. The Minister may request an Environmental Impact Assessment for a project that falls below threshold limits if the projects is judged to have significant impacts or if it is in the public interest to have an impact assessment conducted.

**Ministry of Environment, Lands and Parks**

**Environmental Protection Division**

The Environmental Protection Division regulates the Waste Management Act and is responsible for issuing air emissions, effluent discharge, and waste disposal permits. Its concerns include:

- waste disposal,
- atmospheric emissions (including particulate emissions or dust),
- water contamination from sediments and suspended solids in surface runoff and washplant settling pond discharge,
- groundwater contamination from inappropriate activities during operation and land use after closure/reclamation,
- fuel storage (Photo 3-1), and
- spill reporting (e.g., fuel or other hazardous materials).

**Water Management Branch**

Under the Water Act, the Water Management Branch has the authority to regulate and issue permits for work in and about a stream, including channel and bank modification such as:

- any use of or diversion of any watercourse, including all surface freshwater and groundwater,
- any stream crossing requiring a bridge or installation of culverts of a size specified by the Water Act, and
- surface water licenses or temporary licenses.

**Fish and Wildlife Branch**

The Fish and Wildlife Branch is responsible for the protection of fish and wildlife and their habitat. This includes freshwater fish such as steelhead, trout and char, most wildlife, and their habitat. This branch will provide information regarding fish and wildlife related requirements that will need to be met at your site, and will indicate whether the Federal Department of Fisheries and Oceans or the Canadian Wildlife Service will need to be contacted. The Department of Fisheries and Oceans (see below) is generally responsible for Pacific salmon populations, and the Canadian Wildlife Service has some responsibilities for migratory birds, such as waterfowl, under the Federal Migratory Birds Convention Act.

**Parks Department (BC Parks)**

Pits and quarries are generally not permitted in any park or recreation area unless they are in some way required to maintain the conservation or recreational value of the park. Proposals in the vicinity of an existing park or recreation area that may potentially cause visual, noise or traffic nuisance impacts on the park will be submitted to BC Parks for review. Access or hauling through a park or recreation area usually requires a permit from BC Parks.

**Lands and Water Management Department (BC Lands)**

The Lands and Water Management Department (BC Lands) administers the Land Act and is responsible for the sale, lease and license of crown lands. Tenure to sand, gravel and rock used for construction purposes is issued under the Land Act. Prior to removing any material, you must have a right issued under the Land Act. As noted above it is very possible that prior rights to the materials may exist under the Mineral Tenure Act for either placer minerals (placer claims) or hardrock minerals (mineral claims). The area you wish to use for your excavation may also be subject to First Nations' land claims. BC Lands will notify you if your operation is on or near any land subject to land claims of First Nations.
Agricultural Land Commission

The Agricultural Land Commission was developed in 1973 when the Agricultural Land Commission Act was proclaimed law. The goals of this act are to:

- preserve agricultural land,
- encourage the establishment and maintenance of farms, and
- assist local governments in preparation of land reserve boundaries.

The Commission received further power in 1977 when the Soil Conservation Act was introduced and proclaimed law. Any soil disturbance within the Agricultural Land Reserve requires a permit under the Act. Gravel is considered “soil” under this act and its removal is, therefore, regulated by the Agricultural Land Commission. The Commission will not allow any excavation in the Agricultural Land Reserve until you have met the demands of their permitting process. To obtain the permit, you will have to submit a detailed written report and site description. You may also have to submit an additional reclamation bond. Details on the permitting process and its requirement are outlined in Chapter 7.

Forest Land Commission

The Forest Land Commission was established in 1994 under the authority of the Forest Land Commission Act. The objective of the Commission is to minimize the impact of urban development and rural settlement on Forest Reserve Land and to work to this end with local governments, First Nations and other communities of interest. Forest Reserve Land includes private land that is assessed under the Assessment Act as managed forest land. Accepted uses of Forest Reserve Lands are quite restricted and approval may be required from the Forest Land Commission for the operation of gravel pits on these lands.

Ministry of Agriculture, Fisheries and Food

The Weed Control Act was developed to control the spread of noxious weeds and minimize their impacts on agriculture. As a result of this Act, you are required to control weeds such as Canada thistle, sow thistle and various knapweeds. Weeds must be controlled on all lands, not just agricultural lands, and cannot be transported. More information on weeds and their control is provided in Chapter 4: General Considerations for Operations, and Chapter 7: Reclaiming Land for Agriculture. You should also be aware that Regional Districts and municipalities (see below) may also have bylaws regarding the control of weeds.

Ministry of Forests

Under the Forest Act, Range Act and Forest Practices Code of B.C. Act the Ministry of Forests is responsible for the management of all forest and range resources within the provincial forest lands of British Columbia. The Forest Practices Code of B.C. Act provides the Ministries of Forests; Environment, Lands and Parks; and Energy; Mines and Petroleum Resources with enhanced authorities and obligations for the management of activities within provincial forests. Activities such as gravel extraction may be subject to enhanced requirements for planning, public consultation, operations and reclamation. Forestry permits that may be required for sand and gravel or quarry operations include:

- Special Use Permit,
- Road Permit,
- Road Use Permit,
- Free Use Permit,
- License to Cut,
- Timber Sale License, and
- Burning Permit.

Further information is provided in Chapter 8.

Ministry of Tourism and Ministry Responsible for Culture

Management of heritage resources within British Columbia is shared by the Archaeological Conservation Branch and Heritage Conservation Branch. The Archaeological Branch is responsible for managing archaeological resources. The Heritage Conservation Branch is responsible for managing historical buildings and sites. Archaeological sites are valuable provincial resources and are protected and managed under the Heritage Conservation Act (Photo 3-2). You are required to obtain a permit if a heritage site or artifact is uncovered during excavation. You are not allowed to excavate land that has been obtained from the Ministry of Tourism and Ministry Responsible for Culture.

Ministry of Transportation and Highways

Under the Highways Act, the Ministry of Transportation and Highways is responsible for regulating access to and traffic on any provincial highway. Pit and quarry operators should be aware that an access permit is required for access to any provincial highway, and new permits for any existing accesses are required where land ownership or designated land uses has changed.
You should also be aware that load restrictions may be placed on any provincial highway when and where the carrying capacity is inadequate.

3. FEDERAL LEGISLATION

Department of Fisheries and Oceans

The Department of Fisheries and Oceans receives its power from the federal Fisheries Act. It is responsible for all fish and fish habitat. However, for the most part, the Department has ceded freshwater management to the province, and its primary role in British Columbia is the management of Pacific salmon populations and all water bodies and courses that support these fish. As a result, the Department's interest extends to any activity that may cause an impact on these fish either directly or indirectly (e.g., a non-producing stream that feeds a producing stream). Because Pacific salmon populations sometimes share water with steelhead and trout, there is a significant overlap of interest with the Fish and Wildlife Branch of the Ministry of Environment, Lands and Parks. These organizations work closely together to protect fish and fish habitat.

Canadian Coast Guard and Transport Canada

Navigable waters are the responsibility of the Coast Guard and are protected under the Navigable Waters Protection Act. Navigable waterways must be kept clear and open for boats and barges. Any proposed operation involving the following situations may require a Navigable Water Protection Act Permit:

- excavating materials from any navigable waterway,
- placing a structure across a navigable waterway (e.g., floating crane or barge terminal),
- building a structure across a navigable waterway that may impede navigation in the waterway,
- using water from a navigable waterway that may impede navigation in the waterway, and
- discharging water, effluent or solid matter into a navigable waterway.

4. REGIONAL AND MUNICIPAL LEGISLATION

Local government consists of Regional Districts with regulatory power generally in rural areas, and municipalities with power principally in urban areas. Local governments have a wide range of interests and responsibilities surrounding sand, gravel and quarry operations. Some municipalities or Regional Districts may request that special conditions be included on the Mines Act Permit. In addition, the Municipal Act authorizes local governments to pass soil removal bylaws to regulate the extraction and deposition of soil materials, the definition of which may include sand, gravel and rock. These bylaws may empower local governments to require gravel pits and quarry operations to obtain a permit from the local government. These permits may include conditions such as:

- detailed plans for the removal, storage and re-application of topsoil,
- detailed groundwater mapping and drainage plans,
- special permitting for air emissions,
- adherence to noise and weed control bylaws,
- defined hours of operations,
- additional security deposits, and
- soil removal fees.

The 1995 Growth Strategies Act requires regional districts to develop growth strategies that include planning for future resource needs. Therefore, broad-based planning for future supplies of sand, gravel and rock will become more common.

5. FIRST NATIONS

Unlike many areas of Canada, most First Nations in British Columbia have yet to sign treaties with the federal or provincial governments. First Nations in British Columbia have been seeking resolution of this situation for many years. As a result, much of the land in the province is currently subject to Aboriginal land claims and the land tenure may be uncertain. On Crown lands, BC Lands will consult with First Nations on pit and quarry tenure applications where aboriginal rights might be affected by issuing land tenure.

Many provincial and federal Ministries have entered cooperative or joint management programs with First Nations to administer natural and social resources. The Sechelt Indian Band has legal status that is very similar to that of a municipality. As a result of these programs and legislation, First Nations have varying rights, responsibilities and interests in resources such as fish, wildlife, and heritage resources. First Nations will also have concerns relating to issues such as noise, dust, and traffic. The Ministry of Energy, Mines and Petroleum Resources may coordinate with BC Lands to refer your Notice of Work to the appropriate First Nation for review to ensure that their concerns are considered, or may refer the Notice of Work to First Nations separately.
Chapter 4 describes the basic steps in planning and operating a pit or quarry operation, from the collection of baseline information on your site and site design to closure of the operation. These basic approaches and activities are common to almost all operations, regardless of the end land use for the site. Some are required to meet or exceed the minimum standards for pit and quarry operation and reclamation. All are good management practices. Highlights in this chapter include:

- collection of baseline information for your site,
- designing and planning your operation,
- preparing your site for extraction,
- operating your pit or quarry, and
- closing your pit or quarry.

Methods to avoid environmental problems during site development and operation, or to minimize or resolve existing environmental problems are described in Chapter 5. Information on selecting an end land use for reclamation of your operation is provided in Chapter 6. Considerations and methods for specific end land uses are provided in Chapters 7 through 13.

1. INFORMATION REQUIRED TO PLAN YOUR OPERATION

You will have to develop a mining and reclamation plan for your pit or quarry. To develop these plans, you will need to collect and review information on the occurrence and quality of granular material, topsoil, subsoil and overburden, as well as the existing features of your site such as landforms, watercourses, vegetation, wildlife habitat, and adjacent land uses. This information will assist you in preparing a site development and reclamation plan that will maximize the amount of sand and gravel or quarry products that can be extracted, while minimizing detrimental effects on the environment, adjacent land uses and nearby residents. It will also assist you in preparing a reclamation plan that will meet the minimum reclamation requirements for the re-establishment of equal or greater land use capability.

Determining the Characteristics of Your Deposit

One of the most important types of background information you will require is information on the characteristics of the sand, gravel and/or non-mineral rock deposit that occurs within your site. In some areas of British Columbia, pits may also be opened up to extract other materials such as marl, peat and clay borrow. Depending on the size and complexity of the proposed development, you may want to retain a qualified engineer or geologist to help you identify the specific location and quality of your deposit.

Field investigations will be required for most types of operations. These generally involve excavation of test pits and/or drilling of test holes, preferably on a grid pattern. Test pits are usually dug with backhoe or excavator. Test holes may sometimes be completed with an auger, but usually require a drill rig. In all cases, the sequence of subsurface materials, the position of the groundwater table, and evidence of seepage should be noted. You may also want to retain samples for testing to determine material characteristics. For safety reasons, it is important to backfill all test excavations and to leave a clean site.

Deposit characteristics that will need to be considered for your operation include:

- The specific location and depth of deposits within your property that can be extracted economically. For example, are granular resources present throughout your site and, if not, where are they present? Do they extend into neighboring properties and is there a need for a comprehensive resource development plan?
- The thickness and variability of the deposits;
- The composition of the granular material in terms of the gravel, sand and fines content;
- The distribution and thickness of overburden relative to the available deposits (i.e., overburden stripping ratios); and
- The distribution of the deposit relative to the local groundwater table.

Based on this information, volumes of different materials to be extracted can be estimated. The information will also be useful in helping you determine the best sequencing for mining, and the preferred locations for soil and overburden stockpiles and other project facilities (see Designing and Planning Your Operation; Section 2 of this Chapter).
**Documenting Existing Landforms**

It is recommended that you prepare a detailed topographic map to document all of the major landform features within and adjacent to the proposed development. This information will be of value to you in recontouring your site to best achieve your end land use, while also complimenting the surrounding landscape. If your development is located within the Agricultural Land Reserve or certain municipalities, you will be required to prepare a detailed topographic map with 2m contour intervals to illustrate the potential impact of your operation on major landforms (Figure 4-1). Cross sections must be drafted for the development and reclamation plan, showing comparisons of what the area looked like before and after the proposed development.

**Inventorying Soil and Overburden**

It is important that you develop a soil management plan to guide the removal and storage of soil materials from active sites, and the replacement of soil in reclamation areas. Proper salvage and handling of soil materials is essential to the success of your reclamation program, as well as the re-establishment of productive land uses on your site. In particular, soil materials that are going to be replaced on the surface of a reclaimed area must provide a suitable rooting medium for plants.

To develop a soil management plan, you will need to obtain information on the availability, volume and location of the most suitable soil materials. Soil characteristics, quality criteria and methods for rating soil as a rooting material are described in detail in Chapter 7 (Table 7-1). Topsoil, subsoils and overburden should be rated using these criteria, and placed in one of four rating classes: good, fair, poor or unsuitable.

**Topsoil and Subsoil**

As part of the soil inventory for your site, you should document the distribution, thickness, quality and variations of organic-rich topsoil and the underlying subsoil within all of the proposed active work areas within your operation. Information on the quality and availability of topsoil and subsoil is required so that the amount of soil materials that are available for salvage can be estimated. Information on topsoil and subsoil volumes and quality is important in determining the need for separate stripping of topsoil and subsoil, and the best sequencing for stripping and salvage. It also can be used to estimate storage requirements and identify preferred stockpile locations. An estimate of topsoil and subsoil volumes is also useful in determining the average soil thickness that should be replaced during reclamation.

**Overburden**

Information on the distribution of overburden will be required during most stages of your development. During planning, information on overburden volumes is required to identify areas that are favourable for pit or

---

**Figure 4-1:** Drafting current and proposed cross-sections of your site assists in determining the types of impacts which your operation may have. *(Source: D. McQueen).*
Identifying Important Surface Water Features

All permanent and seasonal watercourses in the immediate vicinity of the proposed pit or quarry should be identified on a topographic plan for your site. This will help identify drainage courses that will be intersected by the proposed pit or quarry operations, and the need for temporary or permanent diversions of these watercourses. You should also identify all major creeks or rivers that are located close to your site that could stop or restrict operations during flood conditions. If flood conditions could affect your operation or if diversions of natural drainage courses will be necessary, flow characteristics of major creeks or rivers in the area will need to be assessed. Long-time residents of the area may be able to provide you with additional information on flood levels.

Flood mapping and flow information on local creeks may be available from the Water Management Branch of the Ministry of Environment, Lands and Parks, or the Water Resources Branch of the Inland Water Directorate, Environment Canada. If this information is not available, storm runoff flows can be estimated by:

- Determining the catchment area of the water course;
- Assessing the characteristics of the catchment basin that affect the movement and volumes of surface water (for example, the slope, soil types, vegetation types and the amount of surface disturbance); and
- Estimating the amount of rainfall. This is typically done using data such as IDF (intensity, duration and frequency) curves which are available from the Atmospheric Environment Service of Environment Canada.

Except for very small operations, it is recommended that you consult with a professional engineer if you have to estimate runoff flows.

Determining Groundwater Levels and Flow Patterns

The position of the groundwater table and its seasonal fluctuations have important implications for development of your operation. In most areas of British Columbia, the Ministry of Energy, Mines and Petroleum Resources will only allow extraction of sands, gravel and other materials to within one metre or more above the winter high water table. Prior to designing your pit or quarry, it is therefore important that you determine the elevation of the annual high water table, and estimate the direction and volumes of groundwater flows beneath your site. You should also document the location of springs, domestic wells and other groundwater uses in the area. The District Mines Inspector may be able to assist you in determining what groundwater studies will have to be completed.

For many sensitive sites, particularly those near residential areas that are dependent on a groundwater source for domestic water, a comprehensive groundwater study will likely be required as a condition of any permit issued by the Ministry of Energy, Mines and Petroleum Resources.

Documenting Domestic Wells

Information on domestic wells can be obtained from the Groundwater Section, Water Management Branch of the Ministry of Environment, Lands and Parks. You should identify all domestic wells within a reasonable distance of the proposed pit or quarry. Locations of these wells should be plotted on a 1:5,000 or 1:20,000 scale topographic plan of the pit area (Figure 4-2). If available, you should also record the following information for each well:

- well depth,
- depth to water,
- completed in confined or unconfined aquifer,
- date of construction,
- previous problems with quantity, and
- previous problems with quality.
Estimating Groundwater Flows and Water Table Elevations

You will likely need to determine the direction of groundwater flow beneath your operation so that potential impacts associated with extraction can be identified. On sites that slope towards a perennial creek or river, the groundwater can be assumed to flow directly or at an angle towards that creek or river. For level sites that are distant from any surface watercourses or sites that are adjacent to a seasonal creek, the groundwater flow direction can only be determined by measuring the surface elevations of the water table.

The water table elevation beneath a site can sometimes be estimated from the elevation of surface features such as springs or creeks that flow year round, or from information reported on the well records. However, it is generally necessary to install standpipes down into the water table within the pit or quarry area to measure depths to the water table and determine water table elevations. Standpipes can be installed in the holes drilled or excavated to delineate the sand and gravel or non-mineral rock reserves, but the holes must be deep enough to reach the water table, or at least 2m below the planned depth of excavation. Standpipes can be constructed of 25mm to 100mm diameter PVC, with hack saw slots and a solid bottom (Photo 4-1).

Water level data from the standpipes and reliable domestic well logs should be plotted on a plan of the development site (Figure 4-2) to estimate the surface contours of the water table. You should also note the locations of any springs or creeks at or near the site. The direction of groundwater flow can then be determined from the orientation of the water table contours and the location of springs (Figure 4-2).

The water table in aquifers will fluctuate on a seasonal basis, reaching a peak level at the end of the annual wet season and a low level at the end of the dry season. For southern coastal areas, the annual high and low groundwater levels typically occur in February - April and August - October, respectively (Figure 4-3). For interior and northern areas, the annual low levels generally occur in February/March when the ground is frozen, and the high levels typically occur in May/June following the snow melt. As the annual high level is most critical to the design of a pit or quarry, groundwater level measurements that are taken outside of the high water table period or during an exceptionally dry year should be corrected. The Water Management Branch in your Regional office of the Ministry of Environment, Lands and Parks may have local monitoring data that can be used to estimate the correction. Once a correction factor is determined, it can be added to the water table contours to produce a contour plan of the annual high water table.

As part of your mine plan, you may have to provide a cross section of the pit or quarry area showing the different layers of the sand and gravel deposit and overburden, as well as the groundwater flow. This drawing, referred to as a hydrogeological section, is useful in assessing the impacts of mining on groundwater flow. The cross-section is usually developed using test hole data from the site, well records, and the locations of springs and creeks. It should be
oriented in the direction of groundwater flow and show the proposed limits of your operation.

<table>
<thead>
<tr>
<th>First Sampling</th>
<th>Subsequent Sampling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Parameters</td>
<td>Physical Parameters</td>
</tr>
<tr>
<td>Electrical conductance</td>
<td>Electrical conductance</td>
</tr>
<tr>
<td>pH</td>
<td>pH</td>
</tr>
<tr>
<td>Hardness</td>
<td>Turbidity</td>
</tr>
<tr>
<td>Turbidity</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dissolved Anions</th>
<th>Dissolved Anions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkalinity</td>
<td>Alkalinity</td>
</tr>
<tr>
<td>Chloride</td>
<td>Chloride</td>
</tr>
<tr>
<td>Sulphate</td>
<td>Sulphate</td>
</tr>
<tr>
<td>Fluoride</td>
<td>Fluoride</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nutrients</th>
<th>Nutrients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrite/Nitrate</td>
<td>Nitrite/Nitrate</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total Metals</th>
<th>Total Metals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cadmium</td>
<td>Iron</td>
</tr>
<tr>
<td>Calcium</td>
<td>Manganese</td>
</tr>
<tr>
<td>Chromium</td>
<td>Any metals with anomalous concentrations in first sampling.</td>
</tr>
<tr>
<td>Copper</td>
<td>Potassium</td>
</tr>
<tr>
<td>Iron</td>
<td>Sodium</td>
</tr>
<tr>
<td>Lead</td>
<td>Zinc</td>
</tr>
<tr>
<td>Magnesium</td>
<td></td>
</tr>
<tr>
<td>Manganese</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dissolved Metals</th>
<th>Dissolved Metals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron</td>
<td></td>
</tr>
<tr>
<td>Manganese</td>
<td></td>
</tr>
</tbody>
</table>

Table 4-1: Recommended Parameters For Baseline Water Quality Monitoring.

High groundwater table conditions can also have an impact on your selection of an end land use. As discussed in Chapters 7 to 12, high groundwater table conditions favour some land uses, notably wetland wildlife, fish habitat and some types of recreational development. In contrast, high groundwater table conditions are typically not compatible with land uses such as residential and industrial land development.

**Assessing Groundwater Quality**

Prior to mining, baseline data should be collected for some of the wells and springs located downstream of the site, so that any current but undocumented water quality problems are not attributed to the mining operation. Ideally, the samples should be collected during the period of lowest water levels. The list of parameters for laboratory analysis should include those listed in Table 4-1. Monitoring should continue on an annual basis after the pit is started to check for any changes in the groundwater quality. All samples should be collected at the same time of the year, generally the middle of the dry season, to avoid any seasonal variations in the monitoring data.

If there is a possibility of hydrocarbon or toxic chemical contamination from previous land use in the area, some baseline analyses should also be performed. As these can be expensive, the suite should be selected by an environmental consultant with knowledge of the area.

**Inventorying Existing Timber Resources and Plant Cover**

Information on the existing forest cover, shrubs and ground covers within the proposed development area will be of value to you in determining the best approach for re-establishment and management of vegetation during reclamation. This information is also required to document the existing capability and productivity of your site for comparison to post-reclamation conditions.

It is recommended that you work with a professional forester, biologist or agrologist to document the various plant associations within and adjacent to your site. This is best done using the site classifications methods of the Ministry of Forests. The Ministry has classified the province into 14 biogeoclimatic zones, each of which represents a distinct combination of climate, physiography, vegetation and soil. Site associations, which are the basic unit of the site classification, should be deter-
mined for the proposed development area and adjacent lands. The Ministry of Forests may be able to assist you in determining the site associations within your property.

The Ministry of Forests has developed management guidelines for each site association in the province. These guidelines include recommendations for ground cover seed mixes, the preferred tree species for replanting, and the stocking standards for trees. Depending on your end land use, the guidelines can be useful in developing a reclamation plan for your site.

**Weed Control**

Pits and quarries are particularly susceptible to weed problems both on and off site, and through all phases of development, operation, and closure. Weed problems associated with pits and quarries include:

- large areas of disturbed soil that are susceptible to invasion,
- machinery used in operations may introduce weeds from other sites, and
- material excavated and moved from the pit can spread weeds from one site to another.

The control of weeds, including noxious weeds as defined in the provincial Weed Control Act, is of concern during all phases of the life of the pit. Weeds that are considered noxious under the act include:

- Annual sow thistle
- Canada thistle
- Common Cuprina
- Common toadflax
- Dodder
- Hound's-tongue
- Jointed goatgrass
- Leafy spurge
- Scentless chamomile
- Spotted knapweed
- Sow thistle
- Tansy ragwort
- Tansy
- Velvetleaf
- Dalmatian toadflax
- Perennial sow thistle
- Wild oats
- Rush skeletonweed
- Yellow starthistle

There are Local Weed Districts in British Columbia that may designate additional weeds as being noxious in their particular area. Local regional districts and municipal governments may also have bylaws regarding the control of weeds.

There are five general weed control methods: prevention, mechanical, cultural, biological and chemical. Common practices in gravel pit areas include cultural (reseeding with an appropriate vegetation seed mix to out compete weeds), mechanical (tilage, mowing, burning and mulching that may include covering with black plastic) and chemical applications (herbicides). Use of these various practices must be in accordance with accepted management procedures.

A common cultural practise is the early establishment of vegetation (prescribed grass-legume mix or cereal) using certified seed on disturbed areas and on soil stockpiles (especially topsoil piles). The progressive reseeding of newly reclaimed areas will also prevent or strongly curtail the establishment of weed species. Other weed control practices are discussed in greater detail in Chapter 7: Reclaiming Land for Agriculture.

**Fish and Wildlife**

As a result of the diversity of landforms, vegetation and climate in British Columbia, the province supports more species of fish and wildlife than most other regions in Canada. In areas where sand and gravel deposits are located at low elevation such as valley bottoms or in proximity to lakes, rivers and other watercourses, there is a potential for pits and some quarries to destroy important fish and wildlife habitat. Changes in drainage patterns and landforms can also affect fish and wildlife habitats outside of your site.

You should contact your regional office of the Fish and Wildlife Branch (Ministry of Environment, Lands and Parks) to determine if important habitat for fish and wildlife occurs within or close to your proposed development site. For large operations (more than 50-60ha in size), you will likely have to retain a professional biologist to conduct baseline surveys of fish and wildlife populations and habitats on or in the vicinity of your site.

If important habitat is present, you may be required to develop a mitigation plan to minimize or avoid impacts on fish and wildlife populations and their habitats. Fish and Wildlife staff or a professional wildlife consultant can assist you in the development of a plan.
Identifying Important Heritage Resources

Heritage resources include things that may be considered to be of historic, prehistoric, palaeontological, architectural, or scenic significance to the province. If these objects are on the surface of your site, they may or may not be readily recognizable. (Photo 4-3).

If you suspect that there are heritage resources on your site, you should contact the Heritage Conservation Branch immediately. They will assist you in determining proper mitigation efforts or recommend an appropriate archaeologist to recover the find at your site. If you are not sure if there are heritage sites on your property, you can contact the Heritage Conservation Board, who will determine if a Heritage Assessment needs to be conducted before you begin operations.

If heritage sites are present within your property or if you uncover an artifact during excavations, make every effort not to disturb it. Often the location of the artifact will tell an experienced archaeologist a great deal about the artifact's age and importance. As a temporary measure, you can prevent disturbance of heritage sites by erecting fencing around the site or by maintaining vegetated buffer zones. However, be sure that the temporary buffer zones you provide are fairly large; some artifacts may be so brittle that vibrations from earth moving equipment or blasting may damage them.

The Heritage Conservation Board will recommend permanent measures for protecting the sites or artifacts on your property. They may recommend something as simple as fencing off the site or leaving a buffer zone, or they may recommend complete removal of the artifacts or site by qualified archaeologists (Photo 4-4).

Identifying Social and Community Issues

There are a number of social and community factors to be aware of when you are planning your operation. Some issues may be of high concern to local residents, but in some locations or circumstances the broader public may also have special interests in your operation.

Community concerns generally relate to the real or perceived effects of your operation on people, property and/or the environment. For example, residents may be concerned that your operation will affect local groundwater supplies, a local population of deer, or a Native burial ground. Social and community concerns may also focus on issues such as:

- altered traffic patterns, including pedestrian traffic,
- increased dust levels,
- increased noise,
- loss or alteration of leisure or recreation areas,
- decreased property values, and
- potential for local employment.

Acknowledging and addressing social and community concerns early in the planning process may allow these concerns to be resolved. For example, if local residents suggest that haul trucks may pass too closely to a playground, try to determine an alternate access route or suggest reducing the speeds of haul trucks in this area.

Depending on the types and severity of issues that may be encountered, you may want to retain a public consultation specialist to assist you in identifying and managing community-based concerns.

2. DESIGNING YOUR OPERATION

The application for your proposed development has to include a development and reclamation plan that identifies the types of facilities that will be constructed or developed on your site, the preferred mining sequence and activities, off-site and on-site water management, soil salvaging and handling methods, and recontouring, reclamation and revegetation activities.
Your plan should include an operational sequence that complements progressive reclamation while maximizing extraction of the resource and minimizing environmental impacts. The development and reclamation plan must provide adequate information for the Government of British Columbia to:

- determine if the sand and gravel deposit or quarry product will be efficiently extracted,
- assess the risk of significant impacts to the environment and nearby residents,
- identify the preferred end land use, and
- determine if the post-reclamation land capability will be equal to or greater than the pre-disturbance capability.

The development and reclamation plan must indicate the location and types of all facilities and activity areas within your proposed development, including:

- the property boundaries,
- the edges of the undisturbed buffer zones and setbacks,
- access routes and internal roads,
- the initial pit or quarry area,
- soil storage area(s),
- overburden storage area(s),
- processing facilities such as the screens, crusher and washing plant (if part of the operation),
- product stockpile site(s), and
- surface drainage facilities (ditches, sump, settling pond, etc.) (Figure 4-4).

Effective planning of your operation prior to development is one of the most important tasks in successfully operating a pit or quarry, and reclaiming the disturbed lands to a productive end land use. Good planning can save time and money by ensuring that as much of the deposits within your site as possible are used, reducing the need for multiple handling of materials and conserving the upper soil layers for use in reclamation. Good planning also helps reduce or avoid impacts to the environment, nearby residents and adjacent property.

**Permitting Restrictions**

Your permit to develop your pit or quarry may have a number of restrictions placed on it by the Ministry of Energy, Mines and Petroleum Resources and its referral agencies (e.g., Ministry of Environment, Lands and Parks), the Agricultural Land Commission, the local municipal or regional government or, in the case of private land, the landowner. These restrictions may include time limits on the life of the pit or quarry, hours of operation, product haul routes, royalties and levies, setback requirements from neighbors, rights-of-ways and waterbodies, maximum allowable excavation depths, and the final reclamation slopes and elevations.
Determining the Preferred Access Routes

You should consult local authorities to determine the preferred site(s) for haul roads and access to and from public roads. Consideration must also be given to the potential impacts of noise, dust and safety that an access road may have on immediate neighbors.

Selecting the Best Pit or Quarry Locations on your Site

The preferred location for a pit or quarry will be determined to a great extent by the characteristics of the deposit and by site conditions. The location of the facilities such as a weigh scale, screens, storage piles, sumps and/or sedimentation ponds will depend on both the progressive staged development and the ultimate extent of the pit or quarry. The maximum potentially disturbed area should be known in the early planning phase so that an orderly soil handling plan for salvage and reclamation can be devised.

When a deposit is relatively uniform with respect to thickness, materials composition and quality, and when overburden and groundwater conditions are similar, the pit or quarry can be located in the most favourable site in terms of site development and access. This will permit materials extraction to be maximized and development to proceed in an orderly sequence and progressive fashion.

If the deposit, overburden and groundwater conditions are variable, it may only be feasible to extract material from the most favourable sections of the site. In this case, the pit or quarry might best be developed where the aggregate thickness and quality is greatest and/or the overburden is thin and the depth to the water table is greatest.

Determining the Size, Shape and Depth of the Pit or Quarry

The dimensions of the sand and gravel deposit or the rock formation will largely determine the size, shape and depth of your pit or quarry, respectively. The distribution of overburden will also influence the final configuration of the pit or quarry, particularly if the overburden layer is too thick to make extraction of some parts of your deposit economically feasible.

The depth of your pit or quarry will be controlled by one or more of three major factors:

- the depth of suitable sand and gravel or non-mineral rock,
- the depth to groundwater if the excavation must remain above the water table, and
- the slope geometry and the size of your property.

If dewatering is to be undertaken, the maximum depth of dewatering rather than the natural groundwater elevation will define the lower limit of excavation. Slope geometry will only limit the excavation on steep or very small sites.

Within the Agricultural Land Reserve, the highest groundwater level during the winter or spring must not encroach within 60cm of the root zone on lands that are reclaimed for agriculture. In some situations, the Agricultural Land Commission will permit the temporary excavation of the pit to or below the water table to more fully utilize the aggregate resource. However, the pit must be back filled to meet the 60cm minimum criteria once extraction is complete.

In deciding on the preferred shape, size and depth of your pit or quarry you may also want to consider the proposed end land use for your site. With a specific use in mind, it may be feasible to:

- Remove topographic irregularities that impede agricultural and forest land capability;
- Raise site grades following extraction (by importing suitable fill material) to favour well drained agricultural, industrial and residential uses;

Figure 4-5: Buffer zones and setbacks must be incorporated into your plan.
Develop irregular rather than regular side walls, so as to improve site conditions for recreational or wildlife uses; or

Excavate material from below the water table, so that productive wetland habitats and/or fish habitat can be developed.

Chapters 7 to 12 address such considerations for a variety of possible end land uses.

**Determining Setback Requirements**

Undisturbed buffer zones or setbacks must be incorporated into the development plan along the property boundaries, road allowances and other rights-of-way (RoW), and adjacent to permanent natural and man-made structures (Figure 4-5). The primary intention is to protect pre-existing site features from adverse impacts (such as slumping) due to the pit or quarry operation. In addition, you must be able to carry out slope grading at the closure of your operation without impacts on these adjacent natural features and man-made structures. Undisturbed buffer areas can also screen your operation from neighbors, help reduce noise impacts and prevent dust from affecting nearby residents.

You will be required to provide a minimum setback between the property lines and the slope crests as a safety factor for unstable pit slopes and effects on adjacent properties. The Health, Safety and Reclamation Code for Mines in British Columbia states:

The excavation of clay, earth, sand, gravel, or other unconsolidated material in a surface mine shall not be carried on within a distance from the property boundary that is equal to 1.5 times the ultimate depth of excavation in the unconsolidated material, and material that sloughs from within this distance shall not be removed.

Rock shall not be excavated within a distance of 5m from the property boundary.

The owners of adjoining properties may, by agreement in writing, waive the provisions of the above two conditions.

All pits should be located outside of the 1:200 year flood plain. If possible, a 50m setback should be maintained between the edge of the pit and the high water mark of a fish bearing stream or lake. If pits are located within levels areas on the 1:200 year flood plain, it is recommended that at least a 15m setback be provided with a low vegetated berm constructed at the edge of the setback to contain uncontrolled runoff from the site.

**Developing a Soil Management Plan**

During the design stage for your proposed development, you should prepare a soil management plan to serve as a guide for the site supervisor and the equipment operators in targeting the appropriate soil layers to be separately salvaged during each phase of your operation. The plan should also describe the suitability of individual soil horizons for use as topsoil, subsoil, overburden and drain layer material, along with their expected stripping depth and thickness. The soil management plan in combination with the development schedule for your pit or quarry will dictate when particular soil materials will become available for salvage, and whether or not they must be stockpiled or directly replaced on an adjacent reclamation area.

In non-agricultural areas with little mineral topsoil, there may be no need for separate salvage of the topsoil and subsoil layers. However, even in these areas, the objective of your soil management plan should be to retain an adequate volume of the most suitable soil materials for reconstruction of a suitable rooting zone on your reclaimed site.

**Dealing with Groundwater**

If the extractable deposits are entirely above the water table or if the site can be dewatered to an elevation below the base of the deposits, the pit or quarry can be developed "in the dry." In such cases, minor groundwater seepage that flows into the pit or quarry can be directed from the site in a small ditch, or pumped from a sump located at a low point on the site. If your excavations can be made in a dry site, materials handling will be easier and less water will have to be managed on the site.

There are situations where extraction may be permitted below the water table. If extraction is permitted below the water table, you can expect an number of constraints to be placed on your operation and the management of the groundwater inflow. Methods for dewatering pits and quarries are described later in Chapter 5 (Section 4). It is recommended that you contact the Ministry of Energy, Mines and Petroleum Resources for further information and assistance if you believe it is necessary to extract deposits below the water table.
Managing Natural Surface Runoff from Adjacent Areas

If significant surface water or near-surface water is likely to drain into the proposed pit or quarry area, you will have to construct perimeter interception ditches around your operation to prevent natural, clean flows of water from mixing with on-site runoff, and having to be handled and treated in your drainage system, sump or settling pond.

Prior to the diversion of any natural watercourses, however, you must obtain a permit from the Water Management Branch of the Ministry of Environment, Lands and Parks. The permit application must include the design flow calculations (normally the 1:200 year peak-flood flow), the design rationale, and the design details for the diversion structure. The design plan for a diversion channel must include information on its conveyance capacity (the cross section and grade of the channel), erosion protection measures and energy dissipation structures, particularly if the diversion has any steep grades.

Assessment and management of surface flows is complex. Except for small operations or operations with only minor needs for surface water management, it is advisable that you retain a qualified engineer to estimate runoff quantities and assist you in the design of structures to manage surface water within and adjacent to your development area. Details on management of surface water flows are provided in Chapter 5.

On-site Drainage and Water Management

Good on-site surface drainage will contribute to the effective extraction of your deposit. It is usually best achieved by directing runoff and any groundwater seepage to the low point of the pit or quarry. If necessary, drainage ditches may need to be constructed, draining to a sump. Water that collects in the sump can be allowed to seep away into the soil (i.e. exfiltration), or can be conveyed to a sedimentation pond for treatment and surface discharge.

Surface runoff from disturbed areas within your operation will generally be much greater than from undisturbed areas. As a result, it is important that you estimate surface runoff flows from your operation and ensure that adequate facilities and structures are in place to manage this. In particular, you will need to estimate retention times to design any exfiltration or sedimentation ponds and conveyance/discharge channels that are required. In most situations, the Environmental Protection Division of the Ministry of Environment, Lands and Parks will encourage exfiltration as a means of stormwater discharge. An exfiltration basin does not require an effluent discharge permit. If you must discharge sump water off your site, you will need to obtain an effluent discharge permit from the Environmental Protection Division of the Ministry of Environment, Lands and Parks. The application for a discharge permit has to provide design calculations for the runoff volume and treatment system.

If a wash plant is operated, wash water should be discharged into a sedimentation pond, and clarified water decanted or pumped from the surface of the pond for recycling. Flocculants may be added to speed sedimentation of the wash water. If surface discharge of wash water is necessary, you will have to obtain an effluent discharge permit from the Environmental Protection Division of the Ministry of the Environment, Lands and Parks.

If your pit or quarry is completely enclosed and lies above the water table, without any sides open to a natural slope, a large storage reservoir for surface runoff will be created (Figure 4-7). The impact of storm flows would probably not need to be assessed in this situation, as all accumulated water could be allowed to seep out slowly (this is referred to as exfiltration) after a storm. However, there may be concerns if your operation is located in easily erodible materials, or if piping is likely to occur in underlying sediments. For example, in the Kamloops area, gravel deposits are often located above the river on silty terraces that can be prone to piping, slumping and collapse if groundwater recharge is concentrated beneath the pit. In these circumstances, stormwater may have to be treated in a sedimentation pond and discharged as a surface flow.

Selecting Storage and Stockpile Sites

Before site clearing and extraction begins, you will need to identify sites for both short and long-term storage of the topsoil, subsoil and overburden that are to be stripped from your initial extraction area (Photo 4-5). These materials should be stored separately, to avoid mixing of the soil and overburden. You may also want to set aside areas for stockpiling pit-run and/or
Photo 4-5: Stockpiles will be required for both long-term and short-term storage. (Source: S. Likness)

processed sand and gravel, and oversize stones produced during the normal course of extraction.

Approximate areas required for long-term storage of soil and overburden can be determined based on the estimates of initial stripping volumes, and the progressive availability and use of these materials as indicated in your soil handling plan. If possible, you should locate storage sites in areas that will not be disturbed by extraction, to avoid “double handling” of materials. Stockpiles should not be located in areas where water will accumulate.

Stockpiling of sand and gravel or non-mineral rock is typically temporary. Stockpiles may be located in areas where all of the resources have been extracted and reclamation has not yet occurred, or in areas that have been stripped of soil but not yet mined. In either event, you will want to locate the stockpiles where they will not impede extraction or hinder the orderly progressive reclamation of your site.

Scheduling Activities within Your Site

The design of your pit or quarry must take into account the progressive nature of the operation (that is, the need to further develop the pit or quarry as your existing supply is exhausted). The demand for the product will determine the rate of production. By combining demand estimates with the deposit characteristics, a development plan can be prepared for your site. The timing of operations such as soil salvage, overburden removal, backfilling, recontouring and reclamation will depend on the development plan and configuration of your operation. It is generally preferable to progressively disturb and reclaim areas to minimize double handling of soil and overburden materials. If timing/scheduling permits, it is often preferable to directly replace the salvaged soil or overburden into the area to be reclaimed rather than to store it in stockpiles and replace it later.

Working with the Mine Inspector

Your local mine inspector can advise you if your application to the Ministry of Energy, Mines and Petroleum Resources will meet Ministry requirements. The mine inspector will also conduct inspections throughout the life of your operation from initial site preparation, through pit or quarry development and operation, to final site clean-up and reclamation. In particular, the inspector will check to ensure that progressive reclamation procedures are being implemented. By following inspection reports, you will help ensure that your reclamation activities are conducted in a safe and efficient manner, and that your planned end land use is achieved.

3. PREPARING YOUR PIT OR QUARRY

Laying Out Active Work Areas

The first task in preparing your site is to identify the specific locations of each project component on the ground, as identified in the development and reclamation plan. Facility layout prior to, rather than during extraction will promote an orderly and efficient operation. Double handling of topsoil and overburden can also be avoided or at least minimized. Development and reclamation of the site can then proceed in a progressive fashion, as described in your plan.
Clearing and Grubbing

Clearing of vegetation should be restricted to only those areas within your site that will be actively used during extraction and processing. Wherever possible, natural vegetation should be left undisturbed to provide erosion protection for soils. In particular, it is important that buffer zones of undisturbed natural vegetation be maintained along all watercourses.

It will be necessary to remove vegetation from some areas within your operation, such as the initial pit or quarry area, storage and stockpile sites, access roads and any proposed processing facility locations. Within a Provincial Forest, the Ministry of Forests may issue a Licence to Cut, or Free Use Permit. Merchantable timber, if present, should be salvaged. On public lands, timber salvage requirements will normally be specified in your license/lease agreement. If you are unsure, check with the Ministry of Forests.

Depending on your final land use, roots and stumps may need to be grubbed once clearing and timber salvage is completed. If this material is not a hazard, it can be left in place to conserve topsoil. If stumps and roots are removed, they can be stockpiled for use as erosion control on slopes or to create cover for small wildlife. Brush and tree waste can also be chipped for use as a landscape mulch or combined with a high nitrogen fertilizer for reclamation of the site.

Excess stumps and roots can be burned. On private lands, you should check with your local municipal government or the Ministry of Environment, Lands and Parks to determine if a burning permit is required for your operation. On public lands, you must contact the British Columbia Ministry of Forests to obtain a burning permit.

Initial Stripping and Management of Soil and Overburden

The removal of topsoil, subsoil and overburden is a common first step in getting to the resource deposit. During your initial site development, the primary goal of the soil management program should be to effectively remove topsoil from all of the areas that will be disturbed. You should also salvage sufficient volumes of the most suitable subsoils for storage and/or direct replacement in the areas being reclaimed. Depending on your end land use, there may be a need for stockpiles of drainage layer materials, direct placement of overburden as fill, or temporary storage of overburden.

The way you handle your soil layers will directly determine reclamation success. With few exceptions, you should be prepared to carefully remove the topsoil, subsoil and overburden in a sequential pattern that allows you transfer these materials from an area that is about to be opened to a site that is ready for reclamation. This is referred to as direct soil transfer. Direct soil transfer reduces the cost of material handling while conserving the upper soil layers. If you cannot directly transfer your soil materials, a storage area should be set aside outside of your active pit or quarry area.

Topsoil Stripping and Stockpiling

After clearing and grubbing, you should strip and stockpile organic-rich topsoil from all of the areas that will be disturbed. These include:

- the area to be opened for the pit or quarry,
- an area around the pit or quarry excavation that is at least as wide as the maximum depth of the side walls to allow for slumping and to provide access,
- the out-of-pit access roads, and
- the subsoil, overburden storage and stockpile areas (Figure 4-8).

It is important that you do not strip soil materials when they are wet, as wet soils are easily compacted (see Chapter 5 on avoiding soil compaction).
Unless leveling is required, there is no need to remove the existing topsoil from the topsoil storage site. If topsoil is removed from the storage area, a 150mm thick layer of wood shaving or chips can be placed below the stored topsoil to act as a marker for the equipment operator and as a buffer to prevent soil mixing.

You should stockpile the topsoil from the initial phase of site clearing in the storage area identified on your development and reclamation plan. Topsoil should be stored separately from the subsoil and overburden. You should try to not include any roots or stumps in the stockpile. The shape of the stockpile should provide for positive drainage (i.e. sufficiently sloped to prevent puddling or ponding), to minimize water infiltration into the pile. Keep in mind that thin topsoil salvage piles (e.g. 1 to 2m in depth) tend to maintain topsoil quality better than thick piles. However, thicker piles are permitted provided that the side slopes do not exceed a run:rise of 2 Horizontal (H):1 Vertical (V). Regardless of the pile depth, piling and spreading activities should be minimized to limit topsoil loss.

To minimize erosion and weed growth, you will want to seed the stockpile with fast growing annual grasses (cereals such as oats, barley or rye) and/or a locally adapted forage mix using certified seed. If stockpiles are developed too late in the fall for good plant cover establishment, plastic sheeting may be used to physically protect the pile from erosion (Photo 4-6).

The initial topsoil stockpile will typically remain undisturbed until the final stage of site reclamation. In the interim, topsoil material that is stripped from active areas should be directly transferred to reclamation areas to minimize “double handling” of materials.

The use of appropriate equipment for topsoil salvage is critical to the successful separation of the topsoil layer from the underlying horizons. This is particularly true in areas of wavy or relatively thin topsoil and unsuitable subsoil where soil mixing may result in very poor quality topsoil material. An excavator with a clean-out bucket has been found to be superior to the use of either a wide-blade equipped bulldozer or scraper buggies (Photo 4-7). In situations where topsoil thickness is relatively uniform and the subsoil is firm and easily trafficable, the use of scrapers and dozers may be suitable (Photo 4-8). Scrapers should not be used in soft soil conditions.

On tree or shrub covered steep slopes, land clearing activities usually result in a mixed topsoil/subsoil layer which is generally only suitable for use as subsoil or subgrade materials. Topsoil is rarely salvageable from these areas.

Subsoil and Overburden Stripping and Stockpiling

When topsoil salvage is complete, you can begin stripping subsoil and overburden from the same area. As discussed earlier, sufficient volumes of subsoil should be salvaged for replacement during reclamation. If the suitability of the subsoil is superior to the overburden, the subsoil should be separately stockpiled from both the topsoil and the waste overburden in the area(s) designated in the plan. There is no need to separately handle subsoil and overburden of the same suitability. As with topsoil, erosion potential and weed growth can be minimized by seeding or physically covering the subsoil and overburden stockpile(s).

Subsoil and overburden materials stripped during initial site preparation should be stockpiled until the final site reclamation stage. As part of the progressive and sequential development and reclamation plan, subsoils and overburden salvaged from new areas should be used to reclaim the previous extraction area and avoid double handling. If your end land use may require fill to provide adequate soil drainage or restore specific land surface elevations, you may want to store or direct transfer poor quality subsoils and overburden to use as fill.

Minimizing Soil Erosion

As discussed in Chapter 2, soil erosion may be caused by a number of factors including water, wind, and destruction of permafrost. The soils that are most susceptible to water and wind erosion are silts and very
fine sands, particularly those with small amounts of organic matter or clay. During the startup of your pit or quarry, and the active operation of your site, you should include special precautions to minimize the potential for soil erosion. Details on erosion control measures are provided in Chapter 5.

**Site Water Management**

All perimeter interception ditches, creek diversions and treatment facilities that are required for the pit or quarry should be constructed prior to, during or immediately following the stripping and grabbing of the site. This will minimize the window during which uncontrolled runoff from the site could potentially cause an impact on local creeks or adjacent properties. If site clearing and soil stripping is likely to occur during periods of high amounts of rainfall, you should be prepared to implement temporary measures to contain and treat surface runoff from the disturbed areas. Details on protection measures for site runoff, particularly where flow volumes may be excessive, are provided in Chapter 5.

**Timing**

Grubbing, topsoil salvage and overburden removal should generally be carried out in the early summer to early fall when the ground is not frozen or excessively wet. While it may be feasible or even desirable to clear during the winter, grubbing of roots and stumps is very difficult when the ground is frozen. In addition, it is usually not possible to salvage topsoil separately from the underlying subsoil/overburden when the near-surface soils are frozen.

If the initial site work is to be completed during the wet season, there is a higher risk that uncontrolled runoff will affect adjacent creeks and waterbodies. It is recommended that you check local weather records to determine the “driest windows” for the site work.

In northern and eastern areas of British Columbia, clearing and soil salvage in sites with permanently poor drainage may best be completed during the winter when frozen conditions provide greater soil strength. However, this practice requires special planning, particularly as it relates to the selection of appropriate equipment, stockpile design, and knowledge of the target stripping and frost depths on the site.

4. OPERATING YOUR PIT OR QUARRY

When site preparations are complete, you are ready to begin extracting granular material or non-mineral rock. This should be carried out sequentially so that progressive operation and reclamation of the site is achieved.

**Progressive Operation and Reclamation**

For very small deposits, it is sometimes possible to complete the site preparation - extraction - site restoration sequence within one year. However, most deposits are larger and cannot be developed within such a short period of time. The recommended approach in such cases is for the operator to subdivide the deposit into more or less equal segments (in terms of stripping requirements and extraction volume). These areas should be of such a size that site preparation, materials extraction and reclamation can be completed within one year.
The above procedures ensure that the operator has an efficient and orderly area to work in, and reclamation proceeds in a progressive and ongoing fashion. Terminal reclamation, in which site restoration activities are left until all material has been extracted, should be avoided.

Proper development and phasing of a gravel pit is important if the site is to be safely operated and easily reclaimed. Examples of three acceptable pit operations are shown in Figures 4-9 through 4-11. All three involve mining of the deposit by starting at the top and working down. If excavation starts at the toe area of the deposit, very high slopes that are unsafe and difficult to reclaim will be created (Figure 4-12).

**Materials Handling**

To maintain an efficient operation, double handling of topsoil, overburden and sand and gravel materials should be avoided. This can be best achieved by progressively developing and reclaiming the pit or quarry. With the exception of the materials that are salvaged from the initial extraction area, topsoil and overburden can be directly moved from each new extraction area to the adjacent reclamation site. In areas of high precipitation, both the stripping of new areas and the reapplication of soil should be scheduled for the driest months of the year to reduce problems associated with handling wet soils.

As discussed earlier, topsoil and overburden from the initial extraction area should be stockpiled for the duration of your operation, and then be used in reclaiming the last operating area (Figure 4-8). Materials handling can also be reduced by extracting and processing materials only as they are required and sold.

**Equipment**

The type of equipment that you use in your operation will depend on the size of your proposed operation, your need for processing, and the local availability of equipment.

Stripping, stockpiling and replacement of topsoil and overburden is generally carried out using excavators, scrapers (buggies), bulldozers or graders (Photos 4-7 and 4-8). Extraction of the exposed granular material is typically carried out using a loader and truck operation (Photo 4-9). If material from below the water table is to be mined, drag lines and clam shells may be used (Photo 4-10).

**Drainage and Dewatering**

The drainage system for your pit or quarry, including all gravity ditches and pumped wells or sumps, must be maintained for the life of your operation. Maintenance requirements will usually be minimal if extraction operations remain above the seasonally high groundwater table (as is usually required by the Ministry of Energy, Mines and Petroleum Resources). In dry sites, the small quantities of runoff can often be exfiltrated from a sump or basin sited at the low end of the pit or quarry. You may have to periodically scarify...

---

Figure 4-9: Loader operation of free running sand and gravel pit (phased development) (Source: A. Holmes).
Figure 4-10: Bench excavation of cemented sand and gravel - loader operation (Source: A. Holmes and S. Wuscke).

Figure 4-11: Single elevation loader/dozer operation (Source: A. Holmes and S. Wuscke).

Figure 4-12: Improper pit development (Source: A. Holmes and S. Wuscke).
and excavate the fine sediments from the sump to keep it operating efficiently.

Periodic inspections and maintenance will be required for operations that have drainage channels, pumps, and/or sedimentation ponds. You will likely be required to monitor the amounts of suspended sediments in the discharged water as a requirement of the discharge permit for the sedimentation pond. You should also be prepared to remove built-up sediments from the bottom of the sedimentation pond at regular intervals. These sediments should be disposed of in a trench or pit and covered with coarse granular soil to prevent erosion. In some cases, these sediments may be mixed with manure or compost to provide an additional source of "topsoil".

Perimeter interception ditches and diversions should be inspected on a regular basis and repaired, as required. For example, additional armouring, resloping or re-establishment of vegetation may be required to repair areas that are eroding along the ditch. Proper maintenance of the perimeter facilities will minimize water in the pit or quarry area, and prevent erosion of the ditches and subsequent siltation of the collected water. Sediment buildup in these ditches and channels should be removed on a regular basis and used as a soil material or disposed of as backfill.

Environmental Audits and Soil Contamination

Two to three months after the startup of your operation, an environmental audit should be performed to identify any possible sources of contamination. You may need to retain a qualified consultant to assist you with the audit. Possible contaminant sources include:

- fuel storage facilities,
- maintenance areas where lubricants and solvents are used and stored,
- wood wastes and construction debris stored on the site,
- salt or other road maintenance supplies, and
- paints, solvents, fertilizers, etc.

After all possible sources of contamination have been documented, proper storage and handling protocols for contaminants should be renewed and compared to those practiced on the site. If there are deficiencies in the handling or storage of these materials improvements to the site facilities and handling procedures should be made immediately. Failure to do so may result in charges under the Waste Management Act. If significant soil or water contamination is expected to have occurred as a result of deficient storage procedures, the extent of the contamination should be investigated, and appropriate remedial measures should be implemented.

5. CLOSING YOUR OPERATION

When the last extraction area is depleted, the final phase in the operations plan is to close the pit or quarry and complete reclamation of the site. As with the site preparation and operation phases, this should be carried out progressively if possible.

Temporary and Permanent Closure

A pit or quarry may be closed on either a temporary or permanent basis. Temporary closure occurs most frequently when a short-term decrease in demand develops before the resources of the pit or quarry are exhausted. In this case, you only need to clean up the active work
area and address drainage and erosion concerns.

At closure, the following will be undertaken: clean-up and implementation of drainage and erosion measures, site grading, subsoil and overburden replacement, topsoil replacement and site revegetation. As with all stages of your operation, closure operations must be carried out bearing in mind the end land use for your site. Once you have satisfied all of the reclamation conditions of your permit, it will be considered closed by the Ministry of Energy, Mines and Petroleum Resources. Site-specific recommendations for different land uses are described in Chapters 7 to 12.

**Site Clean-up**

A clean pit or quarry area should be maintained for the duration of the extraction operation. Prior to closure, all remaining debris and garbage must be removed from the site. Do not bury it on the site unless such disposal is authorized by the Ministry of Environment, Lands and Parks. If closure is permanent, equipment and buildings must also be removed. In very stony pits, disposal of large boulders may not be a concern unless a residential or industrial use is planned and the boulders are likely to create a problem for deep foundations. In most cases, boulders can be buried in the abandoned pit beneath a layer of backfill or overburden material. However, for landscaping purposes in urban areas or recreational sites you may want to try to sell these materials. At a minimum, you should note or mark the location of the boulder disposal site for future use. Ideally, a conceptual site plan should be developed for the reclaimed site to guide backfill operations.

Weed control is an important consideration in site maintenance and closure, particularly in relation to topsoil and overburden stockpiles. Weed growth can often become a problem and may need to be controlled (Photo 4-11). For advice on weed control, contact your local municipality or District Agrologist. Additional information on weed control is provided in Chapter 4.

If significant leaks/spills of fuels or other hydrocarbons occur, the affected areas must be cleaned up by excavating the obviously contaminated soil, and either treating it on site or shipping it to a permitted treatment facility. Following remediation of the site, soils left in the contaminated area should be sampled and analyzed for the contaminants of concern to ensure that residual contaminant levels meet the appropriate standards for the end land use.

**Establishing Final Elevations and Backfilling**

Final elevations and slopes for all disturbed areas within your operation should be identified in your development and reclamation plan. Final elevations should compliment adjacent landforms and provide a smooth transition between the land contours and drainage channels on adjacent lands and the reclaimed areas. If steep slopes or highwalls are maintained in the reclaimed landscape, precautions for public safety should be considered (e.g., signs, fencing), particularly if the pit or quarry borders a public road or a residential area.

Side slopes should be graded back and recontoured to blend in with the adjacent natural contours. The objectives of recontouring are two-fold: to minimize the potential for erosion and to maximize the land capability for the proposed end land use.

When the site is to be temporarily abandoned, it is satisfactory to "round" the slope crests and to grade the side slopes to a gradient not steeper than 2H:1V. This will limit surficial erosion and small-scale slumping.

For permanent closures, pit and quarry slopes cannot be steeper than the maximum reclamation slopes (see Chapter 5). In practice, gentle slopes are required for most end land uses (see Chapters 7 to 12). However, it may not be possible to achieve a flatter slope than 2H:1V in areas of naturally steep terrain.

**Drainage and Erosion Control**

When a pit or quarry is abandoned on a temporary basis, drainage and erosion control measures should aim to promote positive site drainage and ensure that access to remaining reserves is maintained. Once the deposit is depleted and the site is to be permanently closed, final slope grading will minimize erosion potential in most instances. Unless wetlands are to be developed as part of the reclaimed landscape, positive drainage off the site should be maintained for most potential land uses.

**Topsoil and Subsoil Replacement**

Once "rough grading" of the disturbed areas within your site has been completed, soil materials can be replaced as described in the soil management component of your development and reclamation plan. In areas where permanent revegetation is required to support the preferred end land use (e.g., agriculture, forestry, wildlife habitat, recreation), it is important that
only the best quality soil materials be placed in the rooting zone. Poor quality soil material should be placed at the base of the pit or quarry and later covered with better quality soil (suitable overburden, subsoil and/or topsoil).

For most end land uses, the available soil materials should be spread evenly across the disturbed sites. For some land uses, however, this may not be required. If wetlands are to be constructed as part of the reclaimed site, topsoil or high quality subsoil should only be placed in areas that will have a water depth less than 1 m. In steeply sloping areas where soil erosion may occur, uncapped suitable subsoil should be used instead of high quality topsoil replacement.

**Soil Compaction and Crusting**

When replacing any soil materials on your reclaimed areas, you should minimize use of rubber tired equipment that can compact soils and destroy the soil structure. It is also essential that you do not handle soils when they are wet and are most susceptible to severe soil compaction. Soil compaction greatly reduces the capability of soils to sustain plant growth and, as a result, can detrimentally affect the land capability for your end use.

Soil compaction occurs when the large, water and air conducting pores within the soil are reduced or destroyed. The repeated movement of rubber tired equipment across bare soil surfaces often results in severe soil compaction and the loss of soil structure particularly when soils are wet. Excess compaction results in:
- difficult penetration by tillage equipment,
- reduced root penetration by plants,
- restricted movements of air and water in the soil,
- reduced capacity of the soil for water storage, and
- poor trafficability.

Details on avoiding and mitigating soil compaction are provided in Chapter 5, Sections 8 and 9.

Heavy traffic or tillage of wet soils can also result in the breakdown of the soil structure. Once soils are broken down into a solid mass without any large pores, the puddled surface can dry to form a hard crust that resists water infiltration. The crust and poor soil structure also inhibits re-establishment of plant cover. If soils become compacted or crusted on your site, you may want to use a combination of soil ripping techniques and soil amendments to loosen the soil and restore soil structure (see Chapter 5, Section 9).

**Vegetation Establishment**

Re-establishment of vegetation cover on reclaimed areas is important in successfully restoring the capability of the land for most end land uses, as well as providing some form of erosion control (Photo 4-12). Additional benefits of a vegetation cover include:

- improved soil nutrients through nitrogen fixing plants such as clover or alfalfa,
- use as feed for domestic livestock and/or wildlife,
- use as green manure to improve soil quality, and
- improvements in soil structure through root system establishment.

The use of forage mixes, either alone or underseeded with a cereal, provides both an initial cover and a long-lived cover that may be useful as pasture land. Direct planting of shrub and tree seedlings will be required if forestry is your end land use. Tree and shrub plantings are also often required for end land uses such as wildlife habitat or recreation.

Your selection of seed type/mixes or root stock will depend largely on your intended land use: pasture, forage crop or short-term cover for annually cultivated land or an initial cover for productive forest land or wildlife habitat. Climate variation within the province and local site moisture will also affect your choice of seed mix. The Ministry of Forests may be able to assist you in selecting the best seed mix for your site. As a general rule, mixtures of grass species or grasses and legumes produce hardy long-lived stands, provide long grazing periods, and have a better chance of becoming established than single species stands.

You can apply seed and fertilizer using one of two basic methods: broadcast and drill seeding (Photos 4-13, and 4-14). Hydroseeding, aerial seeding and the use of hand-held cyclone seeders are variations of the broadcast method. Drill seeding is preferred where slopes and soil conditions (non-stony) permit this method (Photo 4-15). Grass drills work best for seeding grasses and legumes. Grain drills place grass seed too
deep but can be lifted to broadcast grass seed. With broadcast seeding, your “catch” will improve if you cover the seed with a thin layer of soil by harrowing or some other method (e.g., passage of a tracked vehicle).

Row spacing and seeding rates for groundcovers vary from region to region throughout the province, by biogeoclimatic zone and by forage crop. Target seeding rates (viable seeds/m²) by drill should be approximately half of those recommended for broadcast. In erosion-prone sites, you can double the normal seeding rates to provide extra protection for the surface soils. Use of high seeding rates should be avoided, however, as they result in overly-dense stagnant stands.

Annual cover crops such as the spring barley, oats, winter wheat or fall rye are commonly used as an initial ground cover because they are large seeded (easy to seed, broadcast or drill) and germinate and develop rapidly.

Time of seeding varies by site and type of seed or seed mix, but is usually best in early spring (mid-May). Late summer or early fall plantings may be appropriate in your area. Poor growth will result if a frost or drought occurs immediately following germination. In most cases, you should reseed your area as soon as possible to minimize surface erosion. Since late fall seeding usually results in little, if any, winter soil protection, these areas may require a mulch cover to provide temporary soil cover. Areas with poor catch should be reseeded.

Shrub selection and propagation from cuttings must follow a number of general guides (see also Chapter 7). Preferred species are those that are:

- climatically adapted to your site,
- adapted to local moisture conditions, and
- useful to wildlife as browse and/or cover,

Selection of appropriate tree seedlings, site preparation and timing of planting must be done in accordance with local silvicultural (forest management) practices. Tree planting, with or without an accompanying forage seeding for erosion protection, depends on local soil and site conditions such as soil erosion hazards, soil moisture, sunlight competition, and the potential for damage by mice and other small mammals.

Fertilizing helps to establish and maintain a stand for the first few years. You should usually use a mixed fertilizer containing nitrogen, phosphorous, potassium and possibly sulphur. Where a seed mix and subsequent vegetative cover includes a significant nitrogen-fixing legume component, the need for nitrogen fertilizer may be reduced. You should have the reclaimed soils tested to determine the need for fertilization, the most appropriate fertilizer mix and the rate of application. Slow release fertilizers are particularly useful in areas of high precipitation since they may prevent excessive leaching of soluble nutrients.

In the absence of soil test results, the Ministry of Energy, Mines and Petroleum Resources commonly recommends the use of a 13-16-10 fertilizer applied at a rate of 300 kilograms per hectare. Sulphur fertilizer additions are recommended for soils with low organic matter content.

**Maintenance and Monitoring**

As noted earlier, any ditches, french drains and detention ponds that are necessary to control runoff on the site will have to be cleaned out regularly and repaired, as required. It may also be necessary to
monitor the quality of site runoff where it discharges into a creek until it can be demonstrated that the site reclamation has achieved the necessary erosion control.

In development sites within the Agricultural Land Reserve, regular monitoring and reporting of site development and reclamation (i.e., twice per year) is usually a conditional requirement of the Agricultural Land Commission as indicated in their approval. Monitoring of site development and reclamation is also a good practice outside of the Agricultural Land Reserve.
In recent years, most of us have come to realize the importance of maintaining a healthy natural environment, while also encouraging ongoing opportunities for economic development. As discussed in Chapters 2 and 4, it is important that in developing and operating your pit or quarry you maintain groundwater and surface water quality, conserving productive soils, minimize losses of natural vegetation, and reduce nuisance problems such as dust or excessive equipment noise.

In this Chapter, we provide recommendations on how you can manage or eliminate some of the common environmental problems that may be encountered during the development and operation of your pit or quarry. Important environmental protection and preventative measures are discussed for:

- minimizing effects on groundwater flows,
- protecting surface watercourses,
- managing normal runoff and stormwater flows,
- dewatering,
- establishing stable slopes,
- controlling surface erosion,
- maximizing sediment removal,
- conserving topsoil,
- avoiding compaction of soils,
- restoring compacted soils,
- avoiding contamination of soil and groundwater,
- minimizing effects on wildlife and wildlife habitat,
- minimizing noise,
- controlling dust, and
- minimizing ground vibrations.

Some of the measures discussed in this chapter require professional assistance to ensure that the appropriate methods are selected and employed. Government agencies can assist you in determining the need for professional help. Professional associations for Agrologists, Biologists, Engineers, Foresters, and Planners can also help you in finding suitable individuals to assist you with your project.

1. MINIMIZING EFFECTS ON GROUNDWATER FLOWS

   Surface excavations can affect natural groundwater flows, and it is important that these effects be considered during the planning phase for your pit or quarry. Most sand and gravel deposits are sited in permeable sediments, whose high capability for storing water make them important sources of water for domestic, industrial or irrigation uses. In some cases, there may be a benefit to a lowering of the water table. For example, in an agricultural area with water-logged soils, pumping can lower the groundwater table and improve soil conditions. However, because of the serious effects to groundwater and surface water that can result, it is generally recommended that pits and quarries be designed so that they do not alter groundwater flows and quality.

   Lowering of the water table as a result of the development of a pit or quarry can:

   - Cause shallow wells to dry up or yield less water, thereby affecting existing or future uses of groundwater; and
   - Reduce flows in local watercourses during low-water periods, and damage aquatic habitat.

   If either of these impacts are likely, your pit should be designed and operated in a manner that will not require you to lower groundwater levels through pumping or other methods. This can be most easily achieved by determining the elevation of the high groundwater table, as discussed in Section 1 of Chapter 4, and designing the pit to remain a metre above this depth. If you find that it is necessary to extract sand and gravel from below the water table elevation, you can minimize impacts to groundwater by using one or more of the following measures.

   - Excavate the portion of the pit below the water table during the season when the water table is lowest, and backfilling with free draining granular backfill prior to the peak water table season. This method may not be attractive due to the value of the granular backfill material.
   - Construct impoundment berms across the completed pit at various locations, to act as small dams (Figure 5-1). The purpose of these berms is to create a
terraced series of ponds, with a surface elevation approximating that of the original water table. Although some maintenance of the berms will be required, this can be minimized if the crest and upper berm slopes are well vegetated, and the waterline is armoured with riprap. Berms that are intended to impound a significant head or volume of water should be designed by a geotechnical engineer.

- Lower the final depth of the pit to less than 1 m below the high winter water table. While this would limit the impact on the groundwater resource, it might not be compatible with the reclamation objectives.
- Use a clam shell or dragline for excavation below the water table. Because little or no drainage is required with this equipment, there would be minimal impact on groundwater levels (Figure 5-2).

The first two measures can also be used in old gravel pits where reclamation is an afterthought.

Quarries are much less likely to have a significant impact on groundwater than gravel pits. If a quarry excavation goes into the water table, the low permeability of the rock usually limits drainage of the groundwater and lowering of the groundwater table. As a result, it is generally not necessary to use methods to maintain natural groundwater levels around a quarry. However, if domestic wells are located close by, or permeable rock is exposed, even a quarry may detrimentally affect groundwater levels. In these situations, you will likely need to retain a professional groundwater specialist, engineer, or hydrologist to assist in the design and construction of measures to minimize these effects.

### 2. Protecting Surface Watercourses and Wetlands

Watercourses are the product of the water, substrate within a stream channel, and the surrounding upland areas in the local drainage basin. Upland areas immediately adjacent to a watercourse or wetland — referred to as riparian areas — are important for aquatic ecosystems in watercourses and wetlands because they provide:

- **Food sources.** Insects, leaves and other material that falls into the water are a major source of food for fish and other stream organisms.
- **Woody debris.** Rootwads, trees and other large woody debris add complexity to a stream and provide hiding and holding spaces for fish.
- **Temperature regulation.** Trees and overhanging vegetation shade the water surface and protect it from rapid warming that is harmful to fish.
- **Buffer zone and filter.** The vegetation of the riparian zone acts as a filter, slowing the movement of silt and pollutants that could harm fish and fish habitat.
- **Cover.** Riparian vegetation protects small fish from predation by birds and small mammals. It also provides security for fish and other aquatic animals.
- **Stream bank stability.** The interlocking roots of riparian vegetation provide natural bank protection by slowing erosion.

To protect the integrity of a watercourse, it is important to preserve the riparian zone, including its trees and other vegetation. This is best accomplished with...
leave strips. These are buffer zones of undisturbed natural vegetation that parallel a watercourse so that it is protected from changes occurring in the adjacent upland areas (Figure 5-3).

The width of the leave strip that is necessary to protect a stream or waterbody will vary with the terrain and vegetation type. The Department of Fisheries and Oceans suggests that 30m from the high water mark is a minimum width for fish-bearing streams and streams that flow to fish-bearing watercourses. Wider leave strips may be necessary in areas where:

- the high water mark is not clearly defined,
- the channel is unstable,
- the watercourse is in a ravine, or
- the surrounding land uses have the potential for severe impacts.

In most situations, it is recommended that you contact the Department of Fisheries and Oceans and the Ministry of Environment, Lands and Parks to determine the requirements for your site.

The leave strip can only be effective as long as it is protected. To do this, you should clearly identify the boundaries of the leave strip on the ground and in-site plans. In populated areas or in sites containing important fish habitat, you should construct fences to protect the leave strips.

3. MANAGING SURFACE RUNOFF

Proper drainage of a pit or quarry can improve operating conditions, and minimize the need for elaborate measures to control erosion and retain sediment. A drainage plan for a pit or quarry typically includes the following:

- diversion channels to convey natural watercourses around the site,
- perimeter interception ditches to divert diffuse offsite runoff around the site, and

In most situations, it is recommended that you contact the Department of Fisheries and Oceans and the Ministry of Environment, Lands and Parks to determine the requirements for your site.

The leave strip can only be effective as long as it is protected. To do this, you should clearly identify the boundaries of the leave strip on the ground and in-site plans. In populated areas or in sites containing important fish habitat, you should construct fences to protect the leave strips.
Figure 5-4: Series of 1m high drop structures in extremely competent foundation convey diverted water down steep slope and dissipate hydraulic head. (Source: A. Holmes).

- collection ditches within the pit or quarry area to collect and convey onsite runoff to a treatment/discharge facility.

For operations that require lowering of the water table, groundwater drainage measures will also be required (see Chapter 4, Section 3).

**Diversion Channels**

Diversion channels are often necessary to intercept runoff and prevent creeks from flowing across ground that is disturbed by gravel extraction. Diversion channels must be sized to convey the expected water flows, without any erosion of the ditch structures.

Before you construct a diversion channel, you must obtain approval from the Water Management Branch of the Ministry of Environment, Lands and Parks. It is recommended that you retain a qualified Professional Engineer for advice on design and construction of works or diversions in a permanent stream. You will be given good advice on:

- side slopes,
- gradient,
- riprap and erosion protection,
- ditch depth and bottom width sufficient to convey a 1:200 year storm runoff, with 30cm of freeboard, and
- vegetated side slopes (where possible).

Drop structures can be fabricated from gabions (rock filled wire baskets), broken rock (riprap), concrete or timber. (Figure 5-4). Typical examples of drop structures are shown in Photos 5-1 and 5-2. Drop structures and bedding should be designed by a qualified engineer as they are susceptible to piping.

**Culverts** are often used as part of a diversion channel. They can be aligned down the slope, but they must have an adequate inlet to contain the flow and direct it into the culvert. You must also construct a stilling basin at the downstream end of the culvert to slow the flow and direct it back into the drainage channel. A possible design for a stilling basin is shown in Figure 5-5.

Diversion channels should not be located near the crest of a high slope. Often they will need to be lined with a synthetic membrane or shotcrete to prevent seepage losses. Liners must be properly designed and installed, or they will not survive the erosive forces of flowing water. The use of a liner in your diversion channel is best recommended by a qualified Professional Engineer.

To intercept runoff from surrounding natural areas and convey it around your excavation, perimeter ditches should be set back about 10 to 30m back from the crest of the excavation slopes. Perimeter ditches should be aligned to follow a constant grade, and to maximize the interception of drainage from surrounding undisturbed...
areas. All ditches should be designed to resist erosion, so that sediments are not picked up and carried into the natural drainage course that receives the ditch flow.

The recommended depth and bottom width for your perimeter ditches will depend on the peak flows that are likely to occur in your area. Perimeter ditches should be designed to handle a 1:200 year flood (that is, the highest flows during a 200-year period). A site-specific study is normally required to estimate the 1:200 year flood flows. However, for small catchment areas of 50ha or less with natural vegetation cover, you can determine the minimum depth for a perimeter ditch with a 100cm wide bottom using Table 5-1:

- the pit has design life of more than 50 years (the ditch design should then be based on a 1:200 year event),
- the catchment area is larger than 50ha in size,
- the catchment area is substantially disturbed, or
- the ditches are excavated in erodible sand or silt.

**In-Pit Drainage Swales**

As a pit is developed, progressively longer slopes and larger drainage areas will be left above the working face. If left unprotected, these slopes can start to erode during periods of high runoff. To reduce the flow of water down the slopes, swales should be developed on benches created at regular intervals along the slope. In very wet areas or where significant portions of a slope are constructed in easily-erodible silt or sand, benches should be left every 15 to 20m (vertical measurement). In dry southern interior areas or areas underlain by well drained and graded granular soils, the spacing of benches could be increased to as much as 90m.

<table>
<thead>
<tr>
<th>Catchment Area</th>
<th>Less than 25ha</th>
<th>25-50 ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coastal and Southern Interior B.C.</td>
<td>80cm</td>
<td>100cm</td>
</tr>
<tr>
<td>North Central and North Eastern B.C.</td>
<td>90cm</td>
<td>110cm</td>
</tr>
</tbody>
</table>

Table 5-1 Depths of Perimeter Ditches (assuming 100cm wide bottom).
Benchs should have a constant grade across the slope of between 500H:1V (0.2%) and 200H:1V (0.5%). The swale should be sited at the toe of the slope, and the bench should be wide enough to provide at least a 5m-wide access track between the edge of the swale and the crest of the downhill slope. As the areas that drain into these swales will generally be small, a design similar to that shown in Figure 5-7 should be adequate.

On unreclaimed slopes, frequent sediment removal is required to maintain the swales. Maintenance requirements can be reduced, however, by progressive reclamation and revegetation of these slopes. Sediment traps can also be constructed in the swale to further reduce maintenance needs and improve the quality of discharged water (see Section 7 of this chapter).

**Site Grading and In-Pit Drainage Ditches**

The active work areas within your operation, particularly within the pit or quarry area, should be graded to prevent uncontrolled runoff from the site. Grading, in combination with in-pit drainage ditches, should be designed to convey storm water to a seepage (exfiltration) basin or sedimentation pond located at a low point in the site. Temporary drainage ditches that may be moved as the pit or quarry is developed, do not have to be constructed to the same standards as diversion or interception trenches.

However, they should be sized to convey a 1:100 year storm and be graded at less than 200H:1V (0.5%) if they are excavated in erodible silt or sand.

Where ditches collect runoff from disturbed areas, large volumes of sediment can accumulate, and frequent cleaning may be necessary.

**Culverts and Stream Crossings**

Access roads to your operation or haul roads within your site may have to cross natural watercourses. All road crossings and culverts should be carefully designed to ensure that they not only have sufficient capacity to handle all flows, but also permit fish to move upstream and downstream under varying flow conditions. Poor culvert installations are one of the primary causes of fish habitat losses. You should consult with the Ministry of Environment, Lands and Parks during the planning of any culverts and stream crossings for your operation.

**4.0 DEWATERING**

If dewatering of your pit or quarry is required and only in-pit drainage is involved, one or more of the following three methods are typically used:

- ditches,
- wells (perimeter and in-pit locations), and
- sumps.

**Ditches**

Ditches can only be used effectively on sloping sites that are located near a creek that is capable of carrying the dewatering flow. If a ditch is properly designed and constructed, the clean groundwater that seeps into the ditch will not mobilize sediments and can be discharged directly into a natural watercourse. The following design criteria are adequate for preventing erosion of the ditch for most excavations in granular soils.

- Side slopes at 2V:1H
- Bottom or invert grade less than 50H:1V
- Use of a 100mm layer of 50mm minus pit run, possibly with a filter cloth underlay, in areas of the ditch that are excavated in fine-grained soils.
The ditch must be sized to carry the groundwater discharge. If the water table is only to be drawn down a few metres over the life of the project, flows will be small and a 90cm deep ditch with a 30cm wide bottom at a minimum grade of 1.0% (1%) should be adequate. If the water table must be reduced more than a few metres, ditch flows could be very high. In these situations, it is recommended that you hire a Professional Engineer to advise you on the most suitable ditch design.

**Wells**

Wells can be installed by local well drilling contractors. The general procedure for developing a dewatering well system (or well field) is to install one or two dewatering wells, plus an unpumped observation well in the middle of the area to be dewatered. Pumps are installed in the first two wells, and the drawdown that is induced at the observation well is measured (Figure 5-8). The need for additional wells can be determined by comparing the amount of drawdown achieved with the first wells, against the drawdown that is required.

Due to the high cost of drilling wells, and the large cost differences between large- and small-diameter wells, it is generally cost effective to retain a hydrogeologist to provide some initial advice on the number and diameter of wells that will be required.

After the initial period of operation when fine sediments are sometimes flushed from the formation immediately surrounding a well, the discharge from properly constructed wells will be free of sediment. This water may be suitable for direct discharge to creeks if the water contains enough dissolved oxygen to support fish. If dissolved oxygen levels are too low, methods will have to be used to increase oxygen levels in the water (e.g., aeration). The regional biologist with the Fish and Wildlife Division of the Ministry of Environment, Lands and Parks, or the local Habitat Protection Officer for the Federal Department of Fisheries and Oceans can assist you in determining the need to increase dissolved oxygen levels and choosing a preferred method.

**Sumps**

Sumps can be considered as large-diameter shallow wells. If they are properly constructed with perforated casing, cribbing or concrete rings (Figure 5-9), the water pumped from a sump should be of adequate quality to discharge directly to a surface watercourse. However, as noted above, you will need to determine if the levels of dissolved oxygen in the water are adequate for release. Water from a poorly constructed sump may require clarification prior to discharge.

5. **ESTABLISHING STABLE SLOPES**

The stability of a slope is controlled by a wide range of factors that include:

- the physical/mechanical/engineering properties of the soil or rock in which the slope is excavated,
- the height and angle of the slope,
- the height of the water table within the slope,
- the quantity of seepage that discharges on the face of the slope,
- the quantity of runoff that flows down the slope face, and
- the extent and type of vegetative cover.
Due to the many factors that control the stability of a slope and the wide range of site conditions found in British Columbia, it is recommended that you consult with a Professional Engineer for operations with high, steep or highly erodible slopes, or with significant groundwater seepage on the slope face. Descriptive information on soils is given in Table 5.2.

**Characterizing Soil and Rock**

Unstable slopes or exposed easily-erodible soils can lead to serious erosion problems and public liability that could affect adjacent residents and land use. It is, therefore, important that the materials (either rock or soil) that comprise a slope be properly characterized before or as soon after excavation as possible. This may involve an engineering evaluation of the strength and mechanical properties of the soil or rock that will be exposed in the slope and slope stability. Slopes should then be excavated or graded to stable configurations.

Typical mechanical properties for selected soils and rocks are provided in Table 5.2. These materials derive their strength from either friction between granular soil particles or blocks of broken rock, cohesive forces between fine grained soil particles, or cohesive forces between the crystals or grains that comprise intact rock. Clays, which are very fine grained soil particles (less than 0.002mm in diameter), typically derive their strength from a combination of friction and cohesion. Granular (cohesionless) soils (sand, gravel and silt) and blasted rock have only frictional strength, unless they have some clay content or some cementation. Strength that results from cementation will generally be lost if the soils are disturbed.

The stability of slopes that are constructed in materials that derive their strength from friction (i.e. granular soils and broken rock) is usually easy to predict, as these materials will stand at their friction angle if they are dry. If they are saturated, frictional strength is reduced and slopes must be flatter. Surface erosion due...
to seepage and piping can severely reduce the stable angle for a slope that is constructed in fine granular and easily-eroded materials such as fine sand and silt.

Cohesive soils (those with a clay component) are generally more resistant to erosion and, if dry, will stand at steeper angles than granular soils over the short term. However, steep slopes in cohesive soils may fail suddenly or cracks may develop over time. Once initial movement occurs, disturbance reduces the cohesive strength of the soil, and the failure may progress for a long period of time. It is, therefore, important that slopes which are excavated in cohesive materials are conservatively designed to prevent long-term stability problems. If steep slopes are required, it is recommended they be visually monitored for indications of failure (e.g., cracks), within a program designed by a qualified professional engineer.

As discussed in the following section, the presence of beds of different soil types or structure in a rock mass (bedding planes, fractures, or faults) are also important factors in the design of slopes, as discussed in the following section.

### Preventing Rock and Soil Slope Failures

The normal procedure for slope design is to determine the most likely form of slope failure, and then base the slope design on a provision for a reasonable safety factor against this failure. Detailed methods for slope stability analyses are beyond the scope of this manual. However, the basic types of failure mechanisms that may occur on your site, and typical slope design parameters are described below (Figure 5-10).

Circular failures normally occur in soil or very fractured rock where the frictional strength of the material limits the angle to which the slope can be excavated. Stable slopes can normally be established in cohesionless soils at 1.5H:1V for dry conditions, and 2H:1V for partially-saturated conditions. For long-term stability, soil slopes should be graded to shallower angles to prevent small-scale slumping and to reduce the potential for erosion from surface runoff.

Plane failures can occur when a continuous plane with an orientation similar to that shown in Figure 5-10 is present (e.g., a dipping clay layer in a soil slope, or a fault plane in a rock slope). If the friction along the plane is less than the slope, the top block will slip when the plane is exposed in the slope face. This failure mechanism is generally only a limiting factor for rock slopes at angles in excess of 1.5H:1V. However, plane failure can occur in slopes at angles as shallow as 6H:1V, when soft, saturated clay is present.

Wedge failures can occur when two structures intersect, as shown in Figure 5-10. This type of failure occurs only in rock slopes that are generally steeper than 1H:1V, and is often evident as small failures on individual benches of a high slope.

Toppling failures can occur where steep structures dip between about 1H:2.7V into the slope to 1H:11.5V out of the slope (Figure 5-10).

Groundwater has a very significant effect on the stability of a slope. A slope composed of uniform sand that has a frictional strength of about 1.5H:1V, will stand at a similar slope if dry. However, if groundwater pressure is present in the slope, the frictional strength will be reduced and the slope may not stand at angles above 2H:1V. Seepage at the toe of slope can also continually undercut the slope, leading to a progressive failure.

To guard against significant environmental damage due to unstable slopes, it is important that you are aware of possible failure mechanisms and that you document any small-scale failures or local groundwater discharge that occur early in the life of the pit operation. If a dangerous occurrence has taken place it must be reported to the Inspector of Mines. The cause of these failures should be determined and design modifications undertaken to ensure a safe and stable slope (e.g., flattening, slope drainage, or rock bolting), and consultation with a qualified geotechnical engineer is recommended.

The following slope configurations for materials and groundwater conditions are given only to show the significant effect that water has on the stability of a slope.
### Soil Description (Unified Soil Classification System)

<table>
<thead>
<tr>
<th>Coarse Grained (more than 50% larger than #200 sieve size)</th>
<th>Gravels (more than 50% of coarse fraction of gravel size)</th>
<th>Group Symbols</th>
<th>Friction Angle *</th>
<th>Cohesion kPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Densities</td>
<td>Well-graded gravels, sandy gravels, with little or no fines.</td>
<td>GM</td>
<td>28 - 32</td>
<td>10 - 30</td>
</tr>
<tr>
<td>Poorly-graded gravels, sandy gravels, with little or no fines.</td>
<td>GP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silty gravels, silty sandy gravels</td>
<td>GM</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clayey gravels, Clayey sandy gravels</td>
<td>GC</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Sand Grains (more than 50% of coarse fraction of sand size) | Well-graded sands, gravelly sands, with little or no fines. | SW            | 30 - 37         | 10 - 20      |
| Poorly-graded sands, gravelly sands, with little or no fines. | SP            |               |                 |             |
| Silty sands                                                 | SM            |               |                 |             |
| Clayey sands,                                                | SC            |               |                 |             |

<table>
<thead>
<tr>
<th>Fine Grained (more than 50% finer than #200 sieve size)</th>
<th>Silts and clays (liquid limit less than 50)</th>
<th>Inorganic silts, silty or clayey fine sands, with slight plasticity</th>
<th>ML</th>
<th>20 - 35</th>
<th>10 - 20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silts and clays (liquid limit greater than 50)</td>
<td>Inorganic clays, silty clays, sandy clays of low plasticity</td>
<td>ML</td>
<td>20 - 35</td>
<td>10 - 20</td>
<td></td>
</tr>
<tr>
<td>Organic silts and organic silts of low plasticity.</td>
<td>ML</td>
<td>20 - 35</td>
<td>10 - 20</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Highly Organic Soils                                     | Peat and other highly organic soils.             | Pt |               |             |

### Blasted/Broken Rock

<table>
<thead>
<tr>
<th>Rocks</th>
<th>Cohesion kPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basalt</td>
<td>40 - 50</td>
</tr>
<tr>
<td>Chalk</td>
<td>30 - 40</td>
</tr>
<tr>
<td>Granite</td>
<td>45 - 50</td>
</tr>
<tr>
<td>Limestone</td>
<td>35 - 40</td>
</tr>
<tr>
<td>Sandstone</td>
<td>35 - 45</td>
</tr>
<tr>
<td>Shale</td>
<td>30 - 35</td>
</tr>
</tbody>
</table>

### Intact Rock

<table>
<thead>
<tr>
<th>Rocks</th>
<th>Cohesion kPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard igneous Rocks: granite, basalt</td>
<td>35 - 40</td>
</tr>
<tr>
<td>Metamorphic Rocks: quartzite, gneiss, slate</td>
<td>30 - 40</td>
</tr>
<tr>
<td>Hard sedimentary rocks: limestone, dolomite, sandstone</td>
<td>35 - 45</td>
</tr>
<tr>
<td>Soft sedimentary rocks: sandstone, coal, chalk, shale</td>
<td>25 - 35</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rocks</th>
<th>Cohesion kPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard igneous Rocks: granite, basalt</td>
<td>35000 - 35500</td>
</tr>
<tr>
<td>Metamorphic Rocks: quartzite, gneiss, slate</td>
<td>20000 - 40000</td>
</tr>
<tr>
<td>Hard sedimentary rocks: limestone, dolomite, sandstone</td>
<td>10000 - 30000</td>
</tr>
<tr>
<td>Soft sedimentary rocks: sandstone, coal, chalk, shale</td>
<td>1000 - 20000</td>
</tr>
</tbody>
</table>

Table 5-2: Typical soil and rock properties.
CIRCULAR FAILURE IN SOIL OR HIGHLY FACTURED ROCK

PLANE FAILURE ON WEAK PLANE IN ROCK, OR ALONG DIPPING SOIL FRICTION ALONG PLANE IS LESS THAN SLOPE, AND PLANE DAYLIGHTS IN SLOPE

WEDGE FAILURE ALONG INTERSECTION OF TWO STRUCTURES (FRICTION ALONG INTERSECTING STRUCTURES IS SIGNIFICANTLY LESS THAN DIP OF INTERSECTION)

TOPPLING FAILURE DUE TO STEEP STRUCTURES

---

For Dry Conditions (or Permanently Dewatered)

<table>
<thead>
<tr>
<th>Cohesionless (granular) soils</th>
<th>2H:1V slopes.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>vegetated at reclamation.</td>
</tr>
<tr>
<td></td>
<td>perimeter interception of water.</td>
</tr>
</tbody>
</table>

| Cohesive (clay) soils       | 2H:1V slopes, flatter if clay is soft (i.e. penetrated easily with your thumb). |
|------------------------------| vegetated at reclamation. |
|                              | perimeter interception of water. |

| Rock (competent)            | 1H:1V to 1H:1.5V overall slope. |
|------------------------------| 8m wide berms, 8 to 15m high benches (figure 5-11). |

| Rock (weak, highly fractured)| 1H:1V overall slope. |
|------------------------------| 8m wide berms, 8 to 15m high benches. |

For Groundwater Seepage Conditions (seepage surfaces on slope)

| Cohesionless (granular) soils | 3H:1V slopes, or buttressed 2H:1V slopes. |
|------------------------------| recommend flooding at completion (i.e. pit or quarry reclaimed as pond or lake). |

| Cohesive (clay) soils        | 3H:1V slopes, flatter if clay is soft. |
|------------------------------| recommend flooding at completion (i.e. pit or quarry reclaimed as pond or lake). |

| Rock (competent)             | 1.5H:1V to 1H:1.5V overall slope for competent rock. |
|------------------------------| 8m wide berms, 8 to 15m high benches. |

| Rock (weak, highly fractured)| 1.5H:1V to 1H:1V for weak, highly fractured rock. |
|------------------------------| 8m wide berms, 8 to 15m high benches. |

Temporary working slopes for rock quarries must be benched but can be excavated at any angle that will maintain stability.

6. CONTROLLING SURFACE EROSION

Since most extraction activities will result in soil disturbance and vegetation removal, surface erosion is likely to occur unless preventative measures are included in the mine plan and implemented progressively during your operation. For totally contained sites, preventative measures do not need to be implemented prior to reclamation provided that all site runoff is collected and treated prior to discharge. However, because it is often easier to control erosion than
remove sediments from runoff, you should implement erosion control measures progressively throughout the life of your operation.

Recommendations for Operating Slopes

| Cohesionless (granular) soils | ● excavate to angle of repose to maximum bench height of 30m. |
|                             | ● scarps to be pushed down with bulldozer. |
|                             | ● grade and reclaim each face to 2H:1V as it is completed. |
| Cohesive or cemented soils  | ● excavate near vertical faces between benches. |
|                             | ● bench heights compatible with loading equipment (no more than 2m higher than the reach of loading equipment). |
|                             | ● grade and reclaim each bench as it is completed. |

As a precaution against erosion caused by a catastrophic storm, you should install appropriate erosion control measures as you develop your operation. During normal rainfall events, a pit or quarry will only experience moderate erosion. However, the appearance and use of a site can be significantly altered by a 1:50 or 1:100 year storm event if erosion protection or surface water controls are inadequate. In extreme cases, erosion could seriously impair your ability to re-establish a productive end land use within your site.

Erosion control measures that are considered suitable for pit and quarry operations include:

- perimeter surface water control to minimize flow over slopes and other disturbed areas (addressed in Section 3),
- establishment of vegetation cover such as annual grasses on temporary slopes,
- use of mulches, geotextile cloths or plastic film to cover problem areas,
- progressive establishment of permanent vegetation cover on final slopes,
- site grading and ditching to collect and contain runoff, and
- construction of filters in seepage zones to prevent piping failures.

Preventing Surface Water Erosion

A number of conservation practices can be employed to reduce the potential for soil erosion caused by surface water runoff. The following erosion control measures are considered suitable for pit and quarry operations:

- surface cover such as seeding and mulching (discussed below), and
- retention structures such as the use of filter fences, sediment ponds, or surface contouring (see Section 7 of this chapter).

Some of the more common cover management techniques to prevent soil erosion are identified below. Depending on the expected duration of the soil exposure, temporary or permanent measures can be employed.

Temporary Cover to Control Water Erosion

Seeding can be used to temporarily stabilize soil surfaces in areas where the surface is to be re-disturbed within a short period of time (i.e., less than 6 months) or where permanent seeding will follow. Rapidly growing annual plants are commonly used to establish temporary cover. However, there must be sufficient time for the plants to become established if they are to be effective in preventing erosion. If they are seeded too early or too late in the growing season, mulching will be required to provide immediate protection (see Mulches and Matting).

In British Columbia, winter cover crops are commonly used to protect exposed soils. These include winter wheat and rye, fall rye, and annual rye grass which are usually sown in the fall. Spring oats and barley are generally sown in spring for establishment of a quick-growing cover. These cover crops are often ploughed into the soil or used with green manure. The preferred species for use varies throughout the province, and therefore, you should contact your local district agriculturist or soil conservation group for advice on seed type, rates and timing of application. A list of forage mixes that can be used as alternatives to cereal cover crops in various regions of the province is provided in Appendices 1 and 2.
Ground preparation is important for the successful establishment of your cover crop. Shallow burial of the seed and fertilizer is required to ensure germination and prevent the physical removal of the seed by wind or water. A roughened soil surface, created by tillage or other methods (depth of 5 to 10cm) increases infiltration, provides better tilth and a greater number of micro sites for seed catchment, and reduces the potential for sheet or rill erosion.

Hydroseeding with appropriate seed-mulch-fertilizer-tackifier is a form of broadcast seeding. For best results, a mixed fertilizer (nitrogen, phosphorus, potassium and often sulphur) is required. However, the type of fertilizer and rate of application depend on local site conditions. It is recommended that a soil fertility analysis be undertaken to help you determine the best fertilizer mix and soil requirements (e.g., lime). Seeding methods, (broadcast and drill), are briefly described in Section 7 of this chapter (See Cover Crops).

**Mulches and Matting to Control Water Erosion**

The application of plant mulches or mats provide immediate protection of the soil surface. They are commonly used in conjunction with seeding or following seeding of erosion-prone areas, and are particularly useful in providing temporary cover during the winter, and protecting sites where only minimal soil erosion can be tolerated.

Mulches provide physical protection to the soil surface by reducing rainfall “splash” and holding seed, fertilizer and topsoil in place. In addition, mulches also tend to moderate soil temperatures, conserve soil moisture, and increase infiltration. They do not need to be removed since plants will grow through them.

Common natural mulches include:

- straw,
- wood chips,
- bark (shredded and chipped),
- wood fibre (used in hydroseeding), and
- manure.

Of these materials, straw is generally preferred. Suggested application rates are provided in Table 5-3. To prevent removal by wind or flowing water, you should anchor straw mulches into the soil surface by discing, rolling, punching or crimping. On steeper slopes, netting can be placed over the mulch or a mixed tackifier/fiber mulch can be applied with a hydroseed sprayer.

<table>
<thead>
<tr>
<th>Mulch Type</th>
<th>Application Rate (per ha)</th>
<th>Thickness</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straw/Hay</td>
<td>3.2 to 5.5 tonnes</td>
<td>5cm</td>
<td>free of weed or other seeds</td>
</tr>
<tr>
<td>Wood Fibre</td>
<td>1.0 to 1.5 tonnes</td>
<td>-</td>
<td>Higher rates in critical areas; use tackifier as required</td>
</tr>
<tr>
<td>Coarse Gravel</td>
<td>-</td>
<td>7 to 8cm</td>
<td>only practical in small areas</td>
</tr>
</tbody>
</table>

Table 5-3. Mulch Material and Application Rates

For matting or blankets to be effective, firm and close contact must be made with the soil. This generally requires a relatively smooth soil surface (Figure 5-12). The following procedure should be followed:

- apply seed and fertilizer prior to laying the blanket,
- anchor the top of the blanket by burying it in a trench and stapling it,
- pin the blanket onto the slope in an intensive pattern (using pegs at least 15cm long),
- ensure good overlap between the sheets, and
- roll the sheets to improve contact, if possible.

These sites should be inspected regularly, particularly after heavy rainfalls or spring snowmelt, to determine if any erosion problems are occurring and to implement remedial measures if necessary.

**Washed gravel** (2 to 4cm diameter) is sometimes used in very small areas to minimize soil erosion.

**Plastic sheet covering** is used in situations where immediate protection is required. Plastic sheeting must be at least 6mm in thickness to be sufficiently durable. Although it is quickly and easily placed, it is essential that the sheeting remains in close contact with the soil surface and is weighted down with sandbags, tires roped together or stapled to wood planks. It should also be toed in at the top of slopes. The sheeting must be removed if revegetation is to follow.
Permanent Cover to Control Water Erosion

The establishment of a perennial plant cover (grasses, legumes, shrubs and trees) is one of the most commonly used techniques for providing permanent cover for protection or reclamation of pits and quarries. It is appropriate for areas that have been reclaimed and recontoured to their final grade, as well as areas that will remain exposed, yet inactive, for long periods of time (i.e., greater than one year). In general, commercially-available varieties of grasses and legumes (referred to as agronomic species) are most appropriate for areas that will be redisturbed as part of a continuing extraction process. Regardless of the species selected, they should be tolerant to a wide range of growing conditions and require low maintenance. Methods for establishing a permanent cover — site preparation, seeding, and fertilization — are similar to those already discussed for Temporary Cover.

The use of native grasses and herbs, shrubs and trees is often restricted to the final reclaimed areas. Shrub planting helps anchor the soil surface and may provide browse or cover for some wildlife if suitable species are chosen. Methods for establishing shrubs include:

- natural cuttings (i.e. willows),
- transplants of shrubs or small trees,
- container grown seedlings, and
- planting from seed.

A permanent cover technique that uses vegetation as a structural entity for the protection of sensitive sites is referred to as bioengineering. Sensitive areas typically include slopes with seepage, active gullies, streambanks and other unstable soil conditions. There are numerous bioengineering techniques that can be used in a variety of sites. However, they must be designed and installed

Figure 5-12: Orientation of netting and matting
correctly to be effective. Some commonly-used techniques include:

- **Wattling**: uses tied bundles of dormant cuttings of a sprouting type shrub (e.g., willow, red-osier dogwood) to control erosion on steep sideslopes. A trench is dug along a contour, and the bundles are laid in the trench in an overlapping pattern, staked and partially covered with soil (Figure 5-13A).

- **Brush Layering**: similar to wattling except that it uses cut branches rather than dormant cuttings. Branches are laid in the trench in a criss-cross pattern, with the growing tips protruding above the ground and the cut ends buried in soil.

- **Hedge Brush Layering**: similar to brush layering except that rooted plant material is interspersed with cuttings along the trench (Figure 5-13B).

Prior to the establishment of permanent vegetation on a reclaimed site, you may want to use conservation tillage to minimize soil erosion and improve soil quality. Conservation tillage can include practices such as green manuring or plow down of temporary cover crops. Fall tillage should be avoided so that a high quality stubble or plant cover is maintained over the winter.

**Preventing Groundwater Discharge**

Water that discharges from a slope can slowly erode fine sediments, leading to slope instability and a continuous stream of turbid water. To prevent instability and progressive slope failures, steps should be taken to control seepage erosion as soon as it is identified. Filter buttresses and toe drains can be used to control this type of erosion.

**Filter Buttresses**

Free draining sand and gravel, possibly with a coarse rock or crushed rock toe, can be placed against the toe of a slope. The gravel needs to be properly graded and carefully placed, to prevent migration of fine sediments with the groundwater flow and, at the same time, allow relatively free passage of the water. The gravel drain can be installed in advance of completing the slope excavation, as illustrated in Figure 5-14.

As an alternative to a properly graded sand and gravel buttress, commercially available geotextiles (filter cloths) can be placed over seepage areas located on the excavated slope. This cloth needs to be held in place (weighted down) with a cover of free draining crushed rock or coarse gravel. Suppliers of geotextiles can assist in the selection of the appropriate filter cloth for your application.

**Toe Drains**

If the permeable water-bearing zones extend below the base of the pit, a drain can be constructed along the toe of the slope to lower the water table below the slope. In severe cases, sub-horizontal drainholes can be drilled into the slope to intercept water in permeable zones that may be seeping out of the slope. Any water that passes through the buttress or into a toe drain should be collected by the pit drainage system and conveyed to the treatment/discharge facility.

**Wind Erosion**

Soil surfaces that are prone to wind erosion may be protected by a number of different methods:

- establishment of temporary cover crops or permanent plant cover,
- use of organic mulches,
- installation of mats or plastic film (especially on stockpiles),

![Figure 5-13a: Use of wattling as a control measure for soil erosion (Source: D. McQueen).](image-url)
- maintenance or planting of tree and shrub windbreaks that are at right angles to the predominant wind direction, or
- installation of "snow fences" at right angles to the predominant wind direction.

**Permafrost**

Disturbance of the insulating layer above the permafrost may result in exposure and melting if the air temperature is above freezing. Thawing of this sensitive terrain may cause a number of problems including thermokarst, rutting, flooding and slumping.

Permafrost in British Columbia is limited to discontinuous zones in the Fort Nelson area, and high elevations in some other areas of the province. In the Fort Nelson area, it occurs beneath well drained bogs that act as insulation. These sites can often be identified by the presence of stunted spruce (less than 6m in height) and leaning trees. Permafrost is unlikely to occur beneath well drained upland forests or beneath poorly drained bogs.

If your site is located in northeastern British Columbia and surface features indicate that it may be underlain by permafrost, care should be taken to identify and preserve the permafrost areas. If permafrost areas are disturbed and a proper reclamation strategy is not implemented, melting of the frost could lead to a progressive sequence of ground slumping, exposure of more permafrost, and further slumping.

A test pitting program should be conducted in the late summer or early fall, after seasonal frost has thawed. Areas of permafrost should be delineated and, if possible, be avoided. If the permafrost is also underlain by a high water table, the operation will be subject to severe operating problems and should probably not be developed. All test pits that encounter permafrost should be backfilled carefully (fill should be tamped), and the original subsoil, organic soil and vegetative cover should be restored.

If there are considerable reserves above the water table and it is necessary to develop the pit in permafrost, it should be developed and operated in the winter months when access and site work will cause the least damage to the upper insulating layer. Areas that are to be excavated can be stripped while frozen and the organic soil and subsoil stockpiled separately. The exposed borrow can then be left to dry and thaw over the next summer for excavation the following winter, or it can be excavated and stockpiled for thawing, drying and subsequent use. If an area is well drained (i.e. the water table is at a great depth), consideration could be
Given to excavating sand and gravel during the fall, before freeze up.

After borrow areas are depleted, the pit should be re-sloped to a stable configuration and subsoil and topsoil from subsequent borrow areas should be placed on the surface to re-establish the insulating layer. It is very important that reclamation is conducted in this progressive manner to minimize thawing that will occur behind the slopes of the excavation.

Access roads should avoid permafrost areas. If this is not possible, a Professional Engineer with experience in design and construction of northern roads should be consulted. Similarly, if any problems with thawing permafrost develop in reclaimed areas of the pit, a reclamation consultant with northern experience should be retained to advise on remedial methods.

7.0 SEDIMENT REMOVAL

Regardless of the erosion control measures that you adopt, runoff from operational and unreclaimed areas of your pit will contain suspended sediments. To meet government regulations for discharge of surface water, you will likely be required to implement some sediment removal measures to ensure that discharges meet clean water standards under all conditions up to and including the design flow. You will need to consult with the Department of Fisheries and Oceans and/or the Fish and Wildlife Branch of the Ministry of Environment, Lands and Parks to determine the discharge standards that will be enforced at your site. For most operations, the suspended sediment content of discharge water is to be between 25 and 75 mg/l. Design flows for sediment removal are normally that which would be generated during a 1:10 year storm. Methods that are commonly employed for sediment removal are discussed below, starting with the least complex methods.

Surface Roughening

Surface roughening provides for an irregular soil surface with horizontal depressions at right angles to the slopes. Surface roughening promotes the establishment of vegetation establishment by increasing infiltration, reducing runoff velocity, and providing “micro basins” to trap sediments. This method is best suited for bare slopes prior to temporary or permanent stabilization with vegetation. There are a number of different methods for roughening a surface:

- **Grooving** of the slope by running wheeled equipment parallel to the contour. The resulting tracks or ruts effectively create furrows and sediment traps that are at right angles to the slope (Figure 5-15A);
- **Contour tillage** by running tillage equipment along the slope contour to produce small furrows. This is a common conservation technique used in farming. It is particularly well suited for lower gradient slopes (3H: 1V or less, but best suited for slopes of 33H:1V to 12H:1V); and
- **Tracking** of the slopes by running a bulldozer up and down the slope to scarify the soil surface. To be effective, the cleat or tread marks must be at right angles to the slope. This technique can be used on steep slopes (2H:1V) (Figure 5-15B).

Gradient Terraces and Simple Terraces

Gradient terraces are ridged embankments with cross slope channels running at shallow gradients along intermittent contours (Figure 5-16). Their purpose is to intercept surface runoff and conduct it off the erodible slope to a stable outlet at a low velocity.

Gradient terraces are often used where erosion problems already exist, and other less intensive methods have not proved effective. It should not be used in loose sands or soils too steep, stony or shallow to permit practical installation and maintenance. These structures require detailed design.

Simple terraces with steep-faced slopes can be constructed during the reclamation of fields to maintain low gradients in the majority of the field and adjust for changes in local elevations (relief). In agricultural areas, it is important that some areas along the terrace faces be made passable for farm equipment to access and work in adjoining fields.

If you construct either of these types of terraces on your site, they will require ongoing monitoring and maintenance to ensure that they remain effective in preventing sedimentation.

Sediment Traps

Sediment traps are used to trap or remove sediment from the runoff water prior to discharge from the site. Sedimentation occurs in the small stilling basins that are created on the upstream side of the traps. As the size of
these basins is generally very small, the residence time is typically only sufficient for settling sand-size material.

You can construct sediment traps along any runoff flow path such as a ditch or swale, or along a slope contour. The purpose of the sediment traps is to remove suspended sediments from the flow to:

- allow direct discharge of the flow into a natural watercourse,
- reduce sediment loading to a central sedimentation pond, or
- reduce maintenance requirements for a ditch or swale.

A variety of sediment traps can be constructed, depending on:

- the size of the particles to be retained and the retention objective,
- the flow conditions under which the system must operate, and
- the availability of materials and the required size of the structure.

There are several different types of sediment traps that you may want to consider for your site.

**Silt Fences**

Silt fences are geotextiles (filter fabrics) with very small openings that can be installed across a flow path to retain sand and silt particles carried in the flow. The silt fences also create a small sedimentation basin that allows coarse sediments to settle from the flow prior to flowing though the filter (Figure 5-17). Silt fences are not very effective for removing clay and very fine silt-size particles.

Silt fences can be used along slopes and around stockpiles, as shown in Figure 5-15. They can also be constructed within ditches. When used on slopes, silt fences are generally located at or just above the toe of the slope.

You can construct silt fences using woven geotextile fabrics made from polypropylene, polyester or nylon. Silt fences can be designed to allow passage of flows ranging from as little as 0.1 l/s per metre of fence width, to in excess of 2 l/s per metre of fence width. Generally, the ability of the filter to retain silt-size particles will decrease as the flow capacity increases. A fabric with the appropriate flow capacity and silt retention properties should, therefore, be selected for each application in consultation with the supplier. For most applications, the geotextile should meet the following minimum specifications.

<table>
<thead>
<tr>
<th>Permeability</th>
<th>0.01 cm/sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equivalent opening size</td>
<td>0.5 mm</td>
</tr>
<tr>
<td>Filtering efficiency</td>
<td>90% of influent quality</td>
</tr>
<tr>
<td>Grab tensile strength</td>
<td>700 N or more if no mesh reinforcement used</td>
</tr>
</tbody>
</table>

Support stakes can be made of steel or wood, and can usually be purchased with the geotextile as a single unit. In soft ground, it is advantageous to use a wide wood post for additional passive support. Stakes should be a
minimum of 1m long plus the depth of burial, and should be buried or driven to a minimum depth of 70cm, if possible. Shallower depths of installation are acceptable, but may require some additional support for the top of the stake. The distance between support stakes should be 1m or less if high-strength geotextile is used without reinforcement, or 2m or less if wire mesh reinforcement is used.

The geotextile fabric and the support mesh must be well anchored. The bottom of the silt fence should be buried in a 20cm deep trench and backfilled with clean gravel, as shown in Figure 5-17.

If you install silt fences, you will need to inspect and maintain them on a regular basis. Maintenance activities include:

- regular inspection of the fence and repair of tears or broken fasteners,
- regular removal of sediment accumulations and cleaning of the geotextile fabric, and
- replacement of the geotextile fabric if it becomes weakened by sunlight, clogged by sediment, or damaged beyond repair.

Other Sedimentation Traps

A number of materials that may be more readily available than geotextile silt fences can be used to construct sedimentation traps. In many instances, these traps will provide sediment removal that is equivalent or even superior to silt fences, but due to the inconsistency of these materials and the difficulty in predicting their flow capacity, they may not be suited for some applications. It is, therefore, important that the performance of the following types of sedimentation traps is visually monitored after they are installed, and that improvements or replacement with silt fences be done as necessary.

As with silt fences, the following types of sedimentation traps need to be inspected and maintained on a regular basis. Maintenance should involve regular removal of any sediments that accumulate in the trap, particularly following large rain storms or spring melt off, and replacement of any damaged or ineffective barriers.

- **Hay Bales.** If hay or straw bales are readily available, you may want to construct sediment traps along a ditch or swale by building a low check dam. Only new bales should be used as weathered or rotting bales will not effectively trap sediment. It is also important that each bale is well anchored in a shallow trench (10cm deep), and that the backfill is compacted against the upstream side of the bale (Figure 5-18). This will help reduce the potential for piping or seepage erosion beneath the bale.

It is important that sufficient numbers of bales are used to build a low level check dam across the entire width of the channel (Figure 5-19). If too few bales are used, high flows are likely to cut around the end bales. Bales can also be used along a slope contour in a similar manner to silt fences.

- **Gravel Filter Berms.** You can also trap sediment in surface runoff by constructing gravel filter berms along a ditch or swale using coarse, clear crushed rock. The berm should form a level crested dam across a ditch or swale, as shown in Figure 5-20.

- **Brush Barriers.** An inexpensive check dam can be constructed using branches and filter fabric as shown in Figure 5-21. Brush barriers are most suitable for use on slopes, but they can also be used in a swale.

Seepage (Exfiltration) Basins

If storm water runoff is allowed to seep into the ground (i.e. exfiltration), any sediments contained in the water would be filtered out by the first few metres of material under the seepage basin. Seepage or exfiltration basins are only suitable for pits that have more than about 1m of unsaturated sand or sand and gravel beneath the lowest point in the pit. As storm runoff from these pits is usually not very large, an exfiltration pond can be quite small.
You should not construct exfiltration basins in pits with silty bases, as seepage into these sediments can be very slow and ponding will likely occur. Similarly, if your pit is located on a terrace or slope where layers of silt or fine sand are present beneath the floor of the excavation, seepage basins should be used with caution. Seepage of water out of the basin could result in piping erosion that could lead to failure of the slope and the basin.

Seepage basins should be about 0.6m deep to provide for storage of some storm runoff, and sediments. They are generally excavations as opposed to cut and fill structures, as runoff must gravity flow into the basin. Slopes should be cut at 2H:1V and, other than some riprap protection at the inlet, no erosion protection should be provided, since maintenance of the basin will involve frequent excavation of accumulated sediments. You can calculate the approximate size of the seepage pond that you will need using Table 5-4.

**Sedimentation Ponds**

Sedimentation ponds are simply storm water retention ponds designed to retain runoff from peak storm events for a minimum period of 5 to 10 hours. This period is usually sufficient for silt and sand-sized particles to settle a distance of 1m.

A typical design for a sedimentation pond includes an inlet and several outlet structures that must be capable of withstanding the 1:100 year or 1:200 year peak-storm event. Specifically it will require:
Figure 5-18: Installation of straw hay bales for use as dikes or perimeter filter barriers (Source: International Erosion Control Association).
• An inlet to carry water into the pond and distribute the flow across the full width of the pond;
• A decant outlet for clarified water. This can be a perforated riser, as shown on Figure 5-19, or a culvert or armoured spillway. A perforated riser allows you to slowly drain the pond during dry periods, whereas spillways do not;
• An emergency spillway for flows in excess of the design storm event must be provided. A typical emergency spillway structure is shown on Figure 5-22;
• An armoured or lined channel or pipe to carry water from the decant outlet to a natural watercourse.

Because sedimentation ponds must be sized to meet the expected water volumes during storm events, it is not possible to provide standard specifications for all situations. However, in general, sedimentation ponds should be about 2.1m deep and provide:
• a minimum of 0.6m of freeboard during peak events,
• a 1m settling zone, and
- 0.5m of sediment storage.

A typical design for a sedimentation pond is shown in Figure 5-22. It is important to note that these ponds are designed to handle a 1:10 year peak-storm event, whereas the design of all diversion channels, emergency spillways etc., should be based on a 1:100 year or 1:200 year peak flow. If you need to construct a sedimentation pond where any of the side embankments or the downhill embankment must be constructed or reinforced, you should consult with a Professional Engineer to ensure that the structure will remain stable during peak-storm events.

If the catchment area for a sedimentation pond is less than 50ha in size, you can determine the minimum size of a suitable pond using the following formula (assume 1m deep settling zone).

\[
Pond \text{ Area} = C \times I \times A
\]

where

- \( C \) = runoff coefficient (site specific parameter)
- \( I \) = precipitation during a 1:10 year storm of 6-hour duration
- \( A \) = catchment area draining into pond

The pond size calculated with this formula will provide for 6 hours of retention during a 1:10 storm. If your catchment area is larger than 50ha, you should work with a Professional Engineer to complete a site-specific analysis.

The dimensions of your pond should be between 5 Long (L):1 Wide (W) and 10L:1W, with the long dimension parallel to the direction of flow. This will ensure a uniform flow in the pond that will maximize retention time and prevent short-circuiting. Square ponds should be avoided. However, if a square design is necessary, baffles can be constructed to lengthen the flow path through the pond.

Most sedimentation ponds will require a discharge permit that will regulate the quality of discharge to an adjacent creek or river. You will need to consult with the Environmental Protection Division of the Ministry of Environment, Lands and Parks to determine the need for a permit. If a permit is required, discharge from the pond must be monitored to confirm compliance with the discharge criteria stipulated in the permit. If this criteria is not met, you may have to use additional measures, such as sediment flocculation.

Sediment must be excavated from the pond after every major storm or when 33% of the storage volume is filled. To reduce maintenance costs for a sedimentation
in conjunction with flocculants can often be used to achieve the required discharge quality.

Flocculants are mixed with the runoff at the pond inlet to cause the clay particles to bind together to form larger particles that will settle out. The addition of flocculant has to be automated, so that it is constantly adjusted to the pond inflow. This is very important, since flocculants can be a threat to aquatic life if they are present in concentrations above those approved for discharge. As flocculant systems involve a fairly complex design, a Professional Engineer, Agrologist or Biologist with experience in this field should be retained to assist with the design and initial adjustments to the flocculation system.

8. SOIL HANDLING

As discussed in detail in Chapter 4, the objective of your soil handling plan should be to preserve the best soil materials from your site prior to excavation so that these materials can be used during reclamation. A thorough knowledge of the types, volumes, and suitability of your soil materials is required in advance of extraction, to ensure that salvage and replacement operations are optimized. This may require the help of a qualified soil specialist. Details on soil quality criteria and suitability for reclamation are provided in Chapter 7 (Reclaiming for Agriculture).

Soil loss prevention requires commitment and planning. Sequential salvage and replacement of your best quality soil material as part of an extraction operation is vital in maintaining land capability. Sequential replacement of soil material (overburden, subsoil and finally topsoil) results in the best possible root zone for plant growth. Salvage and replacement of topsoil and the upper soil layer (organic litter and surface mineral soil) also promotes better growth of plant cover, and serves as a source of native seeds, root stocks and plants that can directly benefit land uses such as wildlife habitat and recreation.

Topsoil volumes are often inadequate for reclamation on sites that have been active for many years, often before soil salvage was a common practice, or where topsoil has been lost due to multiple handling (direct replacement is preferred to storage and replacement). For these sites topsoil may sometimes be obtained from suitable off-site sources. Potential off-site sources of topsoil include undisturbed natural areas or farmed lands that are being developed for residential or
industrial uses where excess topsoil is being removed during site preparation. However, the costs for obtaining this topsoil may be prohibitively expensive. An alternative method is to manufacture soil using suitably textured mineral soil amended with organic materials, such as well decomposed manure or peat, compost or sewage sludges. Manufacturing of high-quality topsoil requires careful assessment and mixing of the mineral and organic materials.

Wetland Soils

Wetland soils commonly include water-logged mineral soils and thin to thick organic deposits such as peat and bog soils. Wetland soils can pose several special problems during salvage, operations and reclamation. Soil salvage from wetland areas can be difficult due to soft soil conditions. When inappropriate equipment is used or timing of salvage is poor, soil mixing, excessive machine down-time and soil waste can occur.

The first principle for equipment operations in wetland soils is to avoid repeated movement in any area. Soil vibration and disruption causes significant weakening of the soil. Only low-bearing pressure (tracked) equipment should be used in areas with high-moisture conditions. “Swamp pads” or extra wide pads are most useful on dozers working in this environment. Excavators working off the undisturbed side of the salvage area can pile soil into windrows for later pickup.

Wetland soils are often best salvaged during winter. Because soil strength is increased by the presence of thick frost layers, a wider range of vehicles may be able to work the site. Timing of these operations is critical. You should restrict work to times when the frost is sufficiently thick to support the vehicles weight and day time temperatures remain low enough to prevent sloppy surface conditions. Ripping equipment with tines should be used first to break up the frost layer to the bottom depth of the soil layer to be salvaged. The loosened soil should then be picked up the same day with scrapers or windrowed using bulldozers.

In some areas, it may be feasible to drain wetland soils by locally lowering the groundwater table and/or diverting surface runoff prior to salvage. Once the area has had sufficient time to “dry out”, normal salvage operations can proceed.

Frozen Soils

Frozen soils are difficult to store since slumping can occur once the frost melts. This problem can be severe if the soil contains high amounts of water or if stockpile sideslopes are steep. Taking soil from wet piles and placing wet soil in the field is also difficult.

9. Preventing Compaction

Soil compaction is one of the most common problems that adversely affects crop production in many areas of British Columbia. It is especially common in areas subjected to disturbance and heavy equipment traffic, as found in pit and quarry operations. Soil compaction causes a reduction in the large pores, in the soil which hampers the movement of water and air and may restrict root development.

At the completion of your operation, good subsurface drainage is generally required for most end land uses. If subsurface drainage must be maintained, the following practices should be adopted by the mining operation to prevent compaction of the soil horizons beneath the reclaimed surface. Similar methods should be used to prevent compaction of topsoil once it is replaced.

- Prevent or minimize traffic on fine-grained materials during wet weather.
- Establish proper roads within your site, and restrict off-road traffic, particularly when the soil is wet. If roads are aligned over fine-grained soils, a free draining road base and lateral ditches should be constructed.
- Improve drainage with ditches and/or French drains.

10. Restoring Compacted Soils

The reclaimed subgrade and sometimes the replaced subsoil may become compacted, during soil replacement. When compaction does occur, subsoiling or ripping to a depth of 60cm or more (75cm in sands) with shanks spaced at 60cm, and then cross ripping at 90 degrees to the first direction, results in an intensive pattern of loosened subsoil.

You can also maintain good soil structure or improve poor soil structure by using one or more of the following practices throughout the life of your operation. Within the surface layer, this can be accomplished through:

- additions of organic matter (manure etc.),
- careful cropping sequences, including cover cropping, and
- reduced tillage operations.
Below the plow layer, soil structure can be maintained or improved through:

- deep tillage,
- subsoiling,
- drainage, and
- growth of deep rooted perennial crops.

Common soil tillage instruments are described in Chapter 7 of this manual.

11. AVOIDING CONTAMINATION OF SOIL AND GROUNDWATER

Possible sources of soil and groundwater contamination at a pit or quarry include:

- fuel, hydraulic fluid and lubricants,
- chemicals and products stored on site,
- contaminated backfill, and
- fertilizers.

Methods to contain spills and to store contaminated soils are described below. The best method for spill treatment is prevention. You should develop specific procedures for refueling of equipment, fuel storage, storage and use of fluids, lubricants, pesticides and fertilizers to ensure that spills and mishandling of these products are minimized throughout the life of your operation.

Fuel, Hydraulic Fluid and Lubricants

To prevent losses of fuel to the subsurface, fuel storage tanks should be designed to provide double containment. Problems associated with managing rain water that falls on the storage area can be avoided by using a double walled tank or constructing a tank in a box.

Active refueling areas should be lined with a hydrocarbon resistant PVC membrane to collect any spills or leaks that occur during the filling operation. The membrane should be properly bedded and covered with a drainage net, bedding sand and a layer of trafficable fill. Water or fuel that seeps to the drainage layer should be collected in a central sump with an oil/water separator to prevent discharge of hydrocarbons. For small refueling areas, fine-grained soils should be placed over the site, and removed to a lined storage area when they become contaminated.

Where possible, all hydraulic fluids and lubricants should be stored in covered structures with concrete slabs. If spills/leaks of fuels, hydraulic fluids or lubricants are noted, the soil should be excavated and removed to a storage area.

A membrane liner beneath a membrane cover can serve as a storage area for contaminated soil until it can be treated on site or shipped to an off-site treatment facility. It may be cost effective to stockpile all contaminated soils on site, and hire a specialist to initiate an on-site treatment program after a significant volume has accumulated.

Chemicals and Products Stored on Site

Chemicals and other products are sometimes stored in inactive portions of a pit or quarry. Salt for ice control and pesticides for weed control are two examples. Salt stockpiles should be covered with a roof or plastic film to prevent leaching. Toxic compounds should be stored in covered structures with concrete slabs. Under the new hazardous waste regulations for the province, you are responsible for ensuring that all hazardous products are properly identified, stored and handled on your site.

Contaminated Backfill

Contaminated backfill can inadvertently be backhauled from a contaminated site if strict control is not exercised over all backhaul activity. Backhaul loads should only be accepted if the source of the material is accurately known. If the backhaul soil comes from a site that is known to be contaminated, you must obtain documentation from the shipper that the soil complies with all of the contaminant criteria that are applicable to the planned end use.

Fertilizers and Pesticides

If fertilizer is applied to promote the establishment of a vegetative cover during and following reclamation, care should be taken to limit the application to the amount that can be utilized by the crop. Excess nitrate or pesticide left in the topsoil after the growing season will readily leach to the water table with the onset of wet autumn weather. In turn, these products can affect the quality of groundwater.

A Pesticide Use Permit must be obtained prior to applying any non-exempted pesticides on Crown Land. The permit will normally specify that a 10m pesticide
free zone (PFZ) be maintained adjacent to any surface water bodies, including lakes, watercourses or drainage ditches. An additional buffer, typically 5m wide, is often specified to minimize entry of pesticides into the PFZ. Similar pesticide free and buffer zones should be observed on private lands to prevent pesticide contamination of surface waters.

12. MINIMIZING EFFECTS ON WILDLIFE AND WILDLIFE HABITAT

All or some of the following methods may be useful in minimizing the effects of your operation on fish and wildlife.

• Minimize the area that will be disturbed by your operation at any one time. Maintain as much tree and shrub cover as possible in unworkable sites within the permitted area. Reclaim worked areas as soon as possible after extraction is finished.

• Maintain a buffer zone of undisturbed groundcovers, shrubs and/or trees between your operation and important habitats. It is likely that the Ministry of Environment, Lands and Parks or the Federal Department of Fisheries and Oceans will require that you maintain an undisturbed buffer zone a minimum of 30m wide between your active area and any waterbody or watercourse.

• If your development is close to important winter habitat for wildlife, try to complete most activities during the late-spring to early-winter period to avoid conflicts with wildlife.

• Use gates and other structures to restrict public access, particularly if your operation is in a remote area where increased access may make poaching easier.

• Request or require all employees not to fish or hunt in the vicinity of the pit or quarry.

13. NOISE

To reduce the level of noise produced by a quarry or gravel pit operation, you should first identify the various noise sources and the residences or facilities that will be most exposed to noise from your operation (these areas are referred to as receivers). Noise sources that are most predominant at the receiver locations must be treated first. Acoustical treatment of noise emitted by other less predominant noise sources will not reduce the total noise level unless the predominant noise sources have also been treated.

Stationary equipment noise is usually the easiest to control since the noise source is always in the same location. Effective noise reduction for stationary sources generally consists of barriers or enclosures. Portable equipment noise may be minimized by the selection of “quiet” equipment or by providing barriers. However, barriers are only effective if they are long and high enough to cover all possible equipment locations. Rock drills are generally the noisiest type of portable equipment used in quarries and pits. Although drilling noise can be reduced using barriers, selection of the quietest available equipment is often a more practical approach. For example, hydraulic drills are generally quieter than pneumatic drills. They are also usually faster, which would reduce the duration of the drilling noise. Barriers, enclosures, and impact absorbing linings are effective noise control measures for material transfer equipment. Blasting noise can be significantly reduced through proper design of the blasting process. For all types of noise, administrative controls can be another effective means of reducing noise impact on neighbours. Available noise control methods are discussed in greater detail below.

Barriers must be constructed of relatively heavy, non-porous materials such as 18 gauge steel, 25mm thick wood, earth, rock, or sand. For example, stockpiles of sand or gravel can sometimes be placed so that they act as barriers. To be effective, a barrier must be high enough to interrupt the line of sight between the top of the noise source and nearby neighbours. The barrier must also be long enough to prevent noise from “leaking” around the ends. Effective barriers can reduce noise levels by as much as 10 dBA, which would result in the noise sounding about one-half as loud.

Standard engine exhaust mufflers can be replaced with superior models to provide additional silencing. Engine enclosure kits are also available from some equipment manufacturers. In general, engine enclosures are made of heavy weight material and are lined with sound absorptive material placed behind perforated metal for protection. Silenced ventilation openings can be designed to reduce noise while ensuring that cooling airflow is not compromised. An enclosure can provide noise reductions of up to 15 dBA.
A considerable amount of noise is generated when rock is dumped into steel hoppers. Impact absorbing linings such as heavy rubber-type materials can be used to line hoppers and conveyors. The resilient material absorbs impact sound energy from rocks hitting the steel, and can reduce noise levels by 5 to 7 dBA.

Reduction of blasting noise requires careful design of the blasting process. The blast design should take into account the following factors:

- the charge weight and depth per delay,
- the spacing between blast holes,
- the cover over the blast holes,
- the blast delay intervals and firing sequence,
- the length of the stemming, and
- the cover for the detonating cord.

Noise levels can be significantly reduced by using sequential delay systems so that all of the energy is released at once. In general, the sequential delays should be in the range of 17ms to 58ms. Exposed Primacord (blasting cord) produces a sharp "cracking" sound. The Primacord and the exposed pigtail lengths should be covered with at least 8cm of cover. Ideally, blasting should be conducted under favourable atmospheric conditions. If possible, avoid blasting during temperature inversions or when the receivers are downwind of the blast location. To cause the least annoyance to nearby residences, blasting should be limited to weekdays during midday (i.e. Monday to Friday from 10 a.m. until 4 p.m.). In situations where only one or two blasts are required per day, it is desirable to carry out the blast(s) at the same time(s) each day.

Administrative controls such as prohibiting the use of engine "(Jake") brakes in the vicinity of noise-sensitive community areas. This may require inclusion of restrictive clauses in contracts with carriers.

14. CONTROLLING DUST EMISSIONS

Dust emissions from pit and quarry activities can often be controlled by adopting "good housekeeping" practices. Since much of the dust will be created on roadways at or near the site, efforts should be made to keep them free of loose material. Roads that have a paved surface should be washed or swept regularly.

On unpaved roadways, regular application of water is the most effective means of preventing dust releases. Approved chemical agents can also be effective in controlling dust. These chemicals, however, can have an adverse effect on the quality of surface waters and groundwaters and should be used sparingly.

Other than roadways, materials handling and processing activities usually cause the highest dust emissions. Materials handling includes activities such as loading of gravel trucks, and conveyor systems. The easiest technique to control dust emissions from these activities is to limit the height from which the material is dropped. Lower drop heights will reduce the dust and extend the life of the haul trucks. Material processing includes crushing and screening activities. For smaller operations, these activities do not represent a source of high emissions. For larger pits and quarries, however, processing activities can produce significant amounts of dust, and should be controlled by spraying the material with water as it is being processed. For some operations, it will be necessary to install control equipment such as filters to collect and remove the dust.

Erosion control measures at the pit or quarry will also help in controlling dust. Planting vegetation or the placing mulches on exposed slopes and topsoil stockpiles will greatly reduce windblown dust. Stockpiles of production material should be kept small to reduce the chance of wind erosion.

In summary, the dust controls required at a pit or quarry should be selected with consideration of the size of the operation and the proximity of neighbouring properties. A dust control strategy and control equipment would probably be required for large operations with processing machinery and smaller operations located near residences. For small operations in remote areas, "good housekeeping" practices may be all that is required.
15. VIBRATION

Vibrations that may be of concern to neighbours around your operation may be produced by a variety of heavy equipment, hauling trucks or blasting. It is important to remember that it is often the annoyance caused by vibrations, rather than actual structural damage, that prompts many complaints. Neighbours may be annoyed by some vibration, but these vibrational levels may be much lower than vibrations that can cause structural damage.

Heavy trucks travelling to or from your operation may cause enough vibration to be an annoyance to neighbours. Where roads approaching the quarry or pit pass close to buildings, they should be paved or regularly graded and vehicle speeds should be minimized.

Vibrations associated with blasting may also be a nuisance to neighbours or, in extreme cases, may cause damage to adjacent buildings. To reduce ground vibration produced by blasting, you will need to consider several factors:

- the charge weight per delay,
- the length of delay,
- the blast hole spacing, and
- the firing sequence.

There is no clear evidence that trenches or barriers can significantly reduce ground vibration due to blasting.

If you have neighbours close by who may be bothered by vibrations from blasting, it is important that you recognize that the maximum allowable charge per delay to minimize nuisance complaints will be significantly less than that which would actually cause damage. If the acceptability of your proposed blasting operations is in doubt, it is recommended that you consult with a Professional Engineer to determine the best methods to minimize problems with your neighbours. It is often best to consult with your neighbours and involve them in finding agreeable solutions to these problems, rather than ignoring their concerns.

If vibration problems are a concern, it is strongly recommended that you monitor vibrations at the nearest receptor location during blasting. This information will be helpful in developing solutions to potential problems. It also may be important in minimizing your risk of being blamed for apparent damage to adjacent properties.

16. THE NEXT STEP

Potential land uses for reclaimed areas in British Columbia are described in the following chapter. This chapter also provides information on considerations in selecting the best land use for your pit or quarry site.

If you are familiar with these land uses and have already selected a land use for your site, Chapters 7 through 12 provide specific details on reclamation for agriculture, forestry, wildlife habitat, fish habitat, recreation, residential and industrial uses.
Keeping environmental and reclamation concepts in mind, as well as design and operational parameters, you will be in a good position to select an end land use. Chapter 6 describes how you can select the most appropriate land use or uses for your operation. Information on specific land uses and reclamation methods is provided in Chapter 7 through Chapter 12. Chapter 13 describes how reclamation and environmental protection planning can be integrated with operations established prior to present environmental regulations.

In this chapter, information is provided on:

- The range of potential land uses:
  - agriculture,
  - forestry,
  - wildlife habitat,
  - fish habitat,
  - recreation, and
  - residential and industrial use.

- Important considerations in selecting a land use for reclamation include:
  - site capability and productivity,
  - regional limitations,
  - environmental limitations,
  - size and depth of the pit or quarry,
  - surrounding land uses,
  - local zoning, and
  - costs.

1. POTENTIAL LAND USES

Within British Columbia, six major land uses are typically considered for pit and quarry operations. The selection of an end land use or a combination of end land uses for your site should be based on:

- the existing suitability and capability of the site and the surrounding area,
- the probable suitability and capability of the site and the surrounding area following reclamation,
- the regulatory requirements for restoration of site productivity (i.e., as required by the permit issued under the Mines Act; and the requirement to restore land capability and productivity for agriculture on disturbed lands within the Agricultural Land Reserve), and
- the probable demand or need in the region surrounding your site.

For the purpose of this manual, there are several important terms that are used in discussing the applicability of land for existing or future uses:

- **Productivity** is defined as the capacity of a specific land unit to produce a specific crop or product. Depending on the land use, this may be measured as the annual growth or production of plant biomass (e.g., kg of forage produced per ha, cubic metres of wood fibre produced per ha), the number of animals produced per square kilometre, the average growth rate of a species, or the value of resulting residential properties.

- **Capability** is defined as the ability of a specific land unit to currently or eventually support a given land use based on physical, chemical and biological characteristics, including topography, drainage, surface and ground water, soils and vegetation. For example, the Ministry of Forests have developed methods to assess the capability of lands for forestry based on an assessment of the biophysical conditions of a site. Similar land capability classification schemes have been developed for agriculture, wildlife, fisheries, and recreation.

- **Suitability** is defined as the appropriateness and compatibility of an end use, including consideration of the site capability, regional and local needs, adjacent land use(s), and the requirement of the mining operation.

It is beyond the scope of this manual to fully describe the range of methods that can be used to quantify land productivity and capability. However, some methods and approaches are discussed in the specific chapters for agricultural, forestry, wildlife, fisheries, recreation, residential or industrial end land uses.

In general, pits and quarries that are located in good quality agricultural land are reclaimed for agricultural purposes, whereas extraction sites in productive forest are reclaimed for forestry. If you want to reclaim a pit or quarry within an agricultural or forested area for other land uses such as wildlife habitat, fish habitat, recreation, residential use or industrial use, it is likely that you will have to obtain approvals from the Agricultural Land Commission or the Ministry of Forests, respectively.

**Agriculture**

Depending on your location in the province, agriculture can include production of forage crops, livestock, cereal crops, orchards or market vegetables. Reclamation must focus on removing limitations to agricultural productivity such as irregular topography, poor soil
the proposal will either enhance or maintain the Agricultural Land Commission. Resource extraction in some as those
and methods of reclaiming land for agricultural use are the existed prior to extraction is one which
forage production or pasture lands. However, before you opportunities or potential of the property.
agricultural development program. Land capability criteria and methods of reclaiming land for agricultural use are the same as those within the Agricultural Land Reserve.

Forestry
A forestry land use requires that trees will be grown primarily for timber, either on a commercial or local woodlot scale. However, there is also the potential to reclaim lands as forests in the broader sense, that provide habitats for wildlife, recreational values and aesthetic values.

Reclamation for forestry normally must provide moderate to gently rolling landforms, and good drainage. It is best considered when your operation is located within a forestry area, or near existing tree farms.

Wildlife Habitat
A wildlife habitat end use assumes that combinations of landforms, waterbodies and/or water courses, and vegetation will be available to provide the basic needs of wildlife for food, water, cover and space, although not all needs must be provided within your proposed site.

As a mixture of landforms, waterbodies, and vegetation can provide habitat for a variety of wildlife, this land use is adaptable to many operations throughout the province. Wildlife end uses can frequently be integrated with other end uses such as forestry, recreation or even low-density residential use. Wildlife use of rapidly growing, early successional species may also be a suitable objective for perpetual extraction operations for sand and gravel that may be temporarily closed for long periods of time (i.e., 10 to 30 years or more) between periods of active use.

Wildlife habitat reclamation requires as much detailed planning and care in implementation as any other land use. Some reclamation programs have used the wildlife habitat end use as a means of minimizing reclamation requirements or using sloppy revegetation practices. The choice of a wildlife habitat end use is no excuse for poor planning, lack of topsoil salvage, limited recontouring of a site, or ineffective revegetation.

Fish Habitat
As fish habitat must include a year-round source of high quality water, it is a specialized use that is suitable only for operations in which permanent waterbodies or water courses will be formed through drainage from adjacent areas, by excavating into the groundwater table, or by excavation in flood plains. It is most often an appropriate use for a small area within your reclaimed sites, as opposed to a single end use for the entire site. It should only be considered when it will compliment an existing site use, or if it will be more productive than alternative terrestrial land uses for the site. Operators choosing this option are cautioned that this end land use will only be permitted when it matches or exceeds the premining site capability or productivity.

Like wildlife habitat, the fish habitat end use has been abused by some operators in the province. Some pit and quarry operations have used fish habitat creation as an excuse to excavate below the water table, and to leave the raw extraction areas to fill with water. In other cases, it has been used an after thought when excavations have resulted in the creation of water-filled pits. Fish habitat requires careful recontouring, re-establishment of cover, replacement of subsoils and topsoils in shallow water areas, and even replanting with aquatic plants.

Recreation
Recreation includes a wide variety of uses including casual, nature-oriented activities such as hiking and bird
watching, formalized activities such as field sports, tennis or dirt-bike racing, and passive uses such as campsites and highway rest areas. Due to the large number of possible activities, recreational land can be developed with a wide variety of environmental and excavation conditions. However, to be productive and thus acceptable, there must be regional demands for the types of recreational activities and facilities that would be offered. Public safety is of high importance with this land use.

**Residential Use**

Residential use can range from a country acreage or home, to a high-density housing development in cities and towns. Visual quality of the site is important, as are safety considerations. Residential development will usually require the construction of a costly infrastructure for water and sewer lines, electrical supply, and road access.

**Industrial Use**

Industrial uses can include a wide range of structures and activities, including buildings, storage sites, processing, and disposal. Like residential uses, safety considerations are very important, and may limit the use and value of the site. Infrastructure costs can also be high. Due to the porous nature of sand and gravel deposits, the use of pits and quarries as disposal sites is generally not permitted, since wastes can easily contaminate groundwater sources, surface water and soil.

**Perpetual Extraction**

Although extraction of sand and gravel deposits or rock products is usually a temporary land use, some pits and quarries may operate indefinitely due to the size of the deposit and the limited or infrequent demand for the products. One example of this type of operation is the intermittent use of some gravel pits for highway maintenance. Long term operations such as these are referred to as perpetual extraction. Within British Columbia, some of these sites were established prior to existing reclamation legislation, and present special challenges for reclamation due to the lack of topsoil salvage and longterm planning.

2. **IMPORTANT CONSIDERATIONS**

**Regional Environmental Limitations**

Biological, geological and climatic factors on and adjacent to your operation will play a large role in determining the types of land uses that are possible.

Regional factors such as climate, soil types, and landforms will strongly influence the types of plant cover that can be grown, and the types of waterbodies that might be developed. The combination of these physical factors and biological factors will limit the types of land uses that can be developed on your property.

British Columbia can be divided into 9 broad regions based on climate, soil types, landforms and vegetation cover (Figure 6-1):

- Taiga Plains
- Northern Boreal Mountains
- Boreal Plains
- Sub-Boreal Interior
- Southern Interior Mountains
- Central Interior
- Southern Interior
- Coast and Mountains
- Georgia Depression

**The Taiga Plains**

Winters in this region are long and cold. In some areas, permafrost may occur and, in other very cold years, additional pockets of soil may freeze year round as well. There is little precipitation and what does fall, falls as snow. The forests are not diverse. They are mostly comprised of white and black spruce with some aspen and poplar.

Because of the harsh climate and poorly drained soils there is very little agriculture. Some logging occurs. The demand for lumber from this area may increase as the demand for aspen and poplar for pulp and paper increases. Guiding and fur trapping remain the most important renewable resource industries in this region.

The area supports a large number of moose and furbearers, but other types of wildlife, such as birds, are not as common as in other parts of the province.

**Northern Boreal Mountains**

The area is characterized by mountains and plateaus. The mountains can be very rugged or rolling. The lowlands of this area are often occupied with wetlands, small lakes, and meandering streams. Permafrost may occur in some valleys. The St. Elias Mountains and Boundary Ranges provide a rain shadow and cause some parts of this region to be very dry. Precipitation is
evenly spread throughout the year. The far west of this region exhibits some coastal vegetation, but towards the interior, the vegetation is more typical of boreal forests. The forests are mostly white spruce with very little black spruce. Areas where fires have been common tend to be covered in aspen forests. Understories can be diverse and may contain green alder, soapbark, prickly rose, and mosses. Wetlands are usually rich, with white spruce, tall willows, and sedges. Unlike the other boreal sections of the province, alpine tundra is common.

Human activity in this region has been minimal, although some mineral exploration, open-pit mining, and placer mining have occurred. Guiding is the most important renewable resource industry.

**Boreal Plains**

Winters in this region are long and cold. The Rocky Mountains provide a rain shadow so that little precipitation occurs. Almost half of the precipitation that does occur falls in the form of snow. Most of the Boreal Plains is covered in lowland forests. When mature, these forests are mostly comprised of white and black spruce. However, forest fires are frequent and the burns allow aspen and poplar to invade. There are two small subalpine zones where the forests are comprised of Engelmann spruce and subalpine fir. There is very little alpine tundra in this region. Wetlands are scattered throughout the region and are covered with scrubby forests of black spruce and tamarack.

Despite the harsh climate, this region is surprisingly rich in wildlife. Because of the limited snowfall, animals such as moose and caribou use the area for winter range. Birds are more numerous than in the Taiga Plains and are often associated with the scattered wetlands and ponds.
Agriculture is limited to grazing in most areas of this region, although some important agricultural land occurs near Dawson Creek and Fort St. John. Like the Taiga Plains, logging is becoming more important as the demand for aspen and poplar grows. Natural gas production and mining occurs throughout the area.

**Sub-Boreal Interior**

Much of this region is in a rainshadow and is comparatively dry. Precipitation is distributed evenly throughout the year. There are several mountain ranges, plateaus, and river systems in this area. The low lying plateau area is comprised of the Nechako Lowlands, the northern portion of the Nechako Plateau, and the southern portion of the Northern Rocky Mountain Trench. The mountains include the Skeena and Omineca Mountains, and the Hart and Muskwa Ranges. The Fraser, Nechako, and other rivers carve the Interior Plateau. There are three primary vegetation zones. White spruce and subalpine fir forests cover the largest part of this region. In more southerly areas, Douglas-fir is the dominant conifer. In northerly areas, lodgepole pine becomes the dominant forest cover. Common plants of the understory include prickly rose, soapberry, willows, blackwinberry, devil's club, twinflower, fireweed, and a host of other plants. Extensive alpine tundra belts occur at higher elevations of the northern mountains.

Like other boreal forests the sub-boreal forest of British Columbia supports a variety of wildlife with animals such as moose, and black bear being common, as well as many kinds of birds. Logging is the most extensive renewable resource industry in this ecozone and there are many mines. Agriculture is restricted to the area near the Fraser Basin, and is often limited to grazing and some forage crops.

**Southern Interior Mountains**

There are two very different climates in this region— one in the mountains the other in the Rocky Mountain trench. In summer, the trench is warmer and drier than the mountains. In winter, the Trench serves as an access route for Arctic air and is therefore cooler and drier than the mountain areas. This ecoregion has a great variety of habitat types because of the very wet valleys and very dry rainshadow valleys that occur here. Most of the area is dominated by forests of western hemlock and western red cedar. These hemlock and cedar forests commonly have understories with plants and shrubs such as blueberries, Utah honeysuckle, false box, devil's club, oak fern, twinflower, queen's cup. Ferns and mosses are also very common in these understories. Low and dry vegetation zones are comprised of climax Douglas-fir forest with understories composed of saskatoon, rose, soapberry, and birch-leaved spirea. The subalpine vegetation is dominated by subalpine fir and Engelmann spruce. Understory plants at subalpine include white flowered rhododendren, black gooseberry, false althea, bunchberry and dense moss. The alpine tundra vegetation is rock and glacier with patches of heath and grass-sedge meadows.

This ecoregion supports a large numbers of wildlife. The Columbia River valley is a very important migratory bird route. The diverse landscape provides excellent habitat for mountain goats, bighorn sheep, mule and white-tailed deer, elk, and large carnivores such as grizzly bears and cougars.

Agriculture is restricted to the Rocky Mountain Trench and wider southerly valleys. Agriculture here is based largely on grazing and forage crops except in the extreme south where lowlands have been developed for cereal crops and fruit production. The area near Creston is particularly well known for its orchards and cereal crop production. Renewable resource industries include forestry, and a rapidly expanding tourism and recreation industry. Coal mining occurs in the Elk River valley and metal mining occurs in the lowlands and mountains. Many reservoirs have been built on the Columbia and Kootenay rivers.

**Central Interior**

The climate is characterized by cold winters and warm summers. The most precipitation falls in the late spring or early summer. The area lays in the rainshadow of the Coast Mountains, but the extreme western areas do receive large amounts of rainfall. This region contains the Chilcotin and Cariboo plateaus, most of the Nechako Plateau, and the Bulkley, Tahltta, and Chilcotin ranges. The plateaus are flat and gently rolling. Meandering streams and low depressions have created many wetlands and lakes. Vegetation ranges from grassland to alpine forests. At low elevations, forests are dominated by Douglas-fir. There are limited subalpine areas where Engelmann spruce and subalpine fir are common. Much of the region, especially to the north, is covered by sub-boreal forests of white spruce.

The regions supports many different kinds of birds including the only breeding colony of American white pelicans in British Columbia. The most common large animal is the moose but deer and large carnivores such as grizzly bear and cougar are also found in the area.
Agriculture is limited to grazing and forage crops. Logging is the most important renewable resource industry and is continuing to become more important in this region. Mining has also been very common.

**Southern Interior**

This area lays in the rainshadow of the Coast and Cascade mountains and subsequently has the warmest and driest climate in the province. However, the region is not protected from cold Arctic air that approaches from the north and cold spells do occur periodically. The area includes physical features such as the Thompson Plateau, the eastern portion of the Pavilion ranges, the southeast portion of the Cascades and the parts of the Shuswap and Okanagan highlands. The Thompson Plateau is characterized by gently rolling upland. The Thompson and Okanagan rivers have carved the area into large basins.

The vegetation in this area ranges from open grasslands to dense coniferous forests. The grasslands of the region have been damaged by overgrazing of livestock. Open parklands of ponderosa pine and Douglas-fir occur at low elevations while higher elevations have forests of white, Engelmann, and hybrid spruce. Like many regions of British Columbia alpine tundra is common at the highest elevations.

A large number of birds occur in the region while larger mammals are less common. Mule deer and bighorn sheep are the most common large animals.

Agriculture is comprised mainly of grazing and forage crops but the area is also well known for its orchards and vineyards. Tourism is an important industry. Logging is not as common as in other parts of the province because the warm, dry climate slows tree growth.

**Coast and Mountains**

The region is characterized by cool moist summers and mild moist winters. The region is characterized by the Coast mountains, small islands, and large islands such as the Queen Charlottes, and Vancouver Island. Low elevation forests are dominated by Western hemlock, while higher elevation forests are dominated by mountain hemlock and amabilis fir. Understories are dominated by woody shrubs such as blueberries, salal, and huckleberry. Mosses frequently cover the ground. Alpine tundra is very limited on Vancouver Island and the Queen Charlottes but is more common on the mainland. Wetlands and bogs are common along flat, poorly drained areas of the coast.

Wetlands and the marine environment provide important habitat for birds, particularly waterfowl and shorebirds. Large animals such as blacktailed deer and bears are common. It is important to note that some animals that appear on the mainland, such as the grizzly bear, may not appear on the islands. A variety of marine mammals including whales, seals, dolphins, and otters can be found in coastal waters. Some of the marine mammals have important habitat requirements on land. For example, seals commonly rest, and breed on sand and gravel beaches along the coast.

This is the most productive forest region in the province. Forest harvesting dominates the landscape. There is little significant agricultural activity in this region. The tourism and recreation industry is rapidly expanding and industries such as forestry are increasing in conflict with the wilderness requirements of this new industry.

**Georgia Depression**

The climate of this area is mild and relatively dry for a coastal location. The dryness of this area is created by the rainshadow of the Vancouver Island Range. Most of the shoreline is rocky and steep. Several large estuaries, including the Fraser River estuary, occur here. Vegetation is lush because of the warm, moist climate, and long growing season. At low elevations forests are dominated by Douglas-fir but a large variety of other trees are interspersed including: grand fir, western red cedar, bigleaf maple, red alder, and black cottonwood. Understories typically contain salal, oregon grape, red huckleberry, roses, salmon berry, and mosses. Subalpine vegetation is dominated by mountain hemlock and amabilis fir. Alpine tundra is limited to a few mountain peaks on Vancouver Island.

This part of the province supports a large number of birds. It is one of the most important migratory and wintering areas for waterbirds in the province. This area is the most densely populated region of the province and as a result many of the large animals have been excluded. However, black-tailed deer, bears, and cougars can be found in adjacent forest lands. Roosevelt elk can also be found on some portions of Vancouver island.

Large portions of the region have been converted to urban and industry use. Agriculture is intense and includes dairy production, food crops, and cereals. Logging remains important on the edge of the region but there is increasing pressure to maintain forests for recreational use for urban people.
Site Specific Environmental Limitations

Site specific environmental conditions within each region will further guide or limit the types of land uses that can be successful.

The local climate will play a large role in determining what kinds of vegetation and waterbodies can be established and maintained in your area. For example, dry conditions in some parts of the Okanagan region will limit uses dependent on the establishment of trees and shrubs, or the maintenance of permanent water. Site-specific factors such as landforms, slope and aspect can further modify the climate at a micro-scale. For example, within specific microsites in the Okanagan such as north facing slopes or poorly drained sites at the bottoms of slopes, it may be possible to establish productive tree and shrub habitats or to develop small self-sustaining wetlands.

Soil types will also strongly influence end uses such as agriculture, forestry, wildlife habitat and recreation. Local soil conditions such as salinity or acidity can prevent the growing of cereal and some forage crops, and the establishment of trees and shrubs.

The local quality and availability of water will determine if fish habitat, wetland habitats for wildlife, and water-based recreational uses are possible. Poor local drainage may impede farming, forestry, residential and industrial uses, or require costly drainage works to be installed.

Topography will also influence your decision (Figure 6-2). Moderately to steeply rolling land and steep slopes will prevent easy and safe use of farming machinery or mechanical tree harvesters. Steep or uneven terrain could hamper topsoil conservation and also limit construction of permanent buildings and other facilities. There is also higher potential for erosion on steep slopes. A site located on low-lying lands such as floodplains may be well suited for agriculture, but may also be suitable for wildlife habitat, fish habitat and/or low density recreation. Flood risks might prohibit residential, industrial or intensive recreational use. Unusual landforms and drainage channels are often desirable features for wildlife habitat, fish habitat and/or recreation.

Surrounding Land Uses and Community Needs

It is important that the land use you select for your operation is compatible with land uses on adjacent properties. A safe rule of thumb is to return the site to a use similar to what existed prior to disturbance, or to uses that are common in surrounding areas. However, some site conditions encourage innovative designs that will add diversity to the landscape, while still complementing adjacent land uses. For example, small areas of wildlife habitat, fish habitat or recreational sites can often be developed in areas dominated by agricultural or forestry uses to provide a different element in the landscape.

The location of your operation relative to city centres and towns is also important. In many cases, zoning regulations by the city, town or municipal district, or integrated resource planning will dictate the kinds of land uses that can be considered.

Sites within the fringes of towns and cities are often best developed for intensive uses such as residential developments, industry, or organized recreational uses such as parks or sports complexes. On the periphery of urban centres, less intensive uses such as agriculture, country residential, wildlife habitat, fish habitat and nature-oriented recreation are often more productive. Sites in developed rural areas might be better suited for farming, wildlife habitat and/or fish habitat. Within the Agricultural Land Reserve, you will be required to reclaim almost all disturbed areas for agriculture.

In the development of certain land uses, operators should recognize the potential for creating problems with public access and vandalism, noise, pollutants, and wildlife. For example, recreational areas require good access and regular maintenance. Depending on the type of recreational use, some supervision may be necessary to control problems such as vandalism. Creation of wildlife habitat in farming areas must consider the potential for disturbance or damage to crops. Creation of fish habitat near agricultural, residential or industrial areas must also consider the potential for contamination of water by fertilizers, effluents and air pollutants. Development of an industrial site next to a residential area or a natural area may result in problems with noise, dust and air emissions.
A general assessment of what land uses are compatible and incompatible is summarized below. Exceptions are possible depending on the specific conditions of your site.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Forestry</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Wildlife Habitat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fish Habitat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Recreation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Residential</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industrial</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Compatible
  ○ Compatible with some land uses
  X Not Compatible

**Local Zoning**

Before planning and developing your site, be sure to review local ordinances and current and proposed zoning regulations. These regulations, established by the Municipalities, Regional Districts, and the Provincial Government, may restrict the kinds of developments or land uses that will be permitted on your site.

**Configuration of the Site**

The estimated size and depth of your final pit or quarry will also influence your choice of a final land use.

In general, if a pit is less than 2ha in size, it is best to return the land to a similar use as adjacent lands. However, small operations can offer excellent opportunities for development of wildlife habitat, fish habitat or casual recreation. Larger reclamation areas provide increasing opportunity for re-establishment of any of the seven land uses described above. For large operations, it is also increasingly feasible to combine two or more land uses within the reclaimed area. In particular, forestry and agricultural uses require large land areas to make harvesting of trees and crops practical. Residential and industrial land uses may also require large land areas to justify costs for site development.

**Cost**

As the owner or operator, you are one of the best judges of what the reclaimed land from your operation will be worth. Within a city’s or town’s limits, land values may justify the expenditures for regrading of a pit and quarry, site drainage, and installation of sewer, water and electrical systems for residential and industrial development. In contrast, need for open spaces and recreational facilities may also make recreational uses (e.g., parks, golf courses) and wildlife habitat a viable land use.

In areas with good farming capability, land values may similarly justify the cost of regrading and careful replacement of topsoil to return the land to an agricultural use. Within the Agricultural Land Reserve, you likely will be required to do so. However, if soil problems are present, a wildlife habitat or recreational use may be more appropriate. In recent years, many rural landowners have developed “islands” of wildlife habitat or fish habitat on their land. Pits and quarries are often ideal locations for these uses.

In remote areas, forestry and wildlife habitat are often the only cost-effective uses. Within the forested areas of the province, you may be required to restore your operation to a productive forestry use.

**Where to go From Here**

If you have now decided on one or more land uses for your operation, Chapters 7 through 12 can provide you with detailed information on important considerations during design and operation, as well as information on reclamation techniques, equipment use, soil handling and revegetation.

<table>
<thead>
<tr>
<th>If You Selected:</th>
<th>Turn To:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>Chapter 7</td>
</tr>
<tr>
<td>Forestry</td>
<td>Chapter 8</td>
</tr>
<tr>
<td>Wildlife Habitat</td>
<td>Chapter 9</td>
</tr>
<tr>
<td>Fish Habitat</td>
<td>Chapter 10</td>
</tr>
<tr>
<td>Recreation</td>
<td>Chapter 11</td>
</tr>
<tr>
<td>Residential or Industrial</td>
<td>Chapter 12</td>
</tr>
<tr>
<td>Prelegislation Operations</td>
<td>Chapter 13</td>
</tr>
</tbody>
</table>

If you are still unsure of the best land use for your operation, a number of government agencies can assist you in your selection. Possible contacts include the Ministry of Energy, Mines and Petroleum Resources, the Ministry of Environment, Lands and Parks; the Ministry of Forests, the Ministry of Agriculture, Food, and Fisheries, the Agricultural Land Commission, and Municipal Affairs are listed in Chapter 15.
This chapter provides specific information on issues that may affect agricultural land uses on your property, including:

- Important considerations in reclaiming your site for agriculture:
  - adjacent land uses and zoning,
  - pre-disturbance soil types and land capability,
  - soil suitability for salvage,
  - materials handling methods,
  - limitations on land capability for agriculture after reclamation,
  - weed control, and
  - requirements on land within the Agricultural Land Reserve.

- Methods of reclamation:
  - site grading and contouring,
  - replacing subsoil,
  - replacing topsoil,
  - tillage,
  - drainage restoration and/or improvements,
  - planting cover crops, and
  - measures to alleviate other site limitations.

Reclamation planning may require the services of professionals, including reclamation agrologists, hydrogeologists and geotechnical engineers who are familiar with the proposed extraction operation from conception through to reclamation completion. Personnel from the Ministry of Energy, Mines and Petroleum Resources, the Agricultural Land Commission, and the Ministry of Agriculture, Fisheries and Food, as well as private consultants, may be useful contacts when assistance is required.

1. INTRODUCTION

Most of the best agricultural land in the province, approximately 4.7 million hectares, is within the Agricultural Land Reserve (Figure 7-1) that is administered by the Agricultural Land Commission. In some areas of the province, agricultural lands also occur outside the Agricultural Land Reserve.

There are a wide variety of agricultural uses within these lands including forage production, cereal crops, market gardens, fruit orchards, vineyards, berry farms, improved pasture land, and native rangelands. Sand and gravel extraction occurs in a number of locations within the Agricultural Land Reserve, under the combined authority of the Agricultural Land Commission, the Ministry of Energy, Mines and Petroleum Resources, and the local government.

Pit and Quarry Operations within the Agricultural Land Reserve

The Agricultural Land Commission Act was proclaimed law in 1973 and the British Columbia Agricultural Land Commission was established to administer the lands within the Agricultural Land Reserve. To further protect the soil resource within the Agricultural Land Reserve, the Soil Conservation Act (1977) was passed that put effective controls on soil removal and fill placement activities within these lands. Resource extraction is ordinarily a permitted temporary use within the Agricultural Land Reserve, provided that the extraction operation will not reduce the agricultural capability of the soils and/or the agricultural potential of the site. In principle, land capability for agriculture following reclamation must be better than that which existed prior to extraction.

To develop a commercial pit or quarry operation within the Agricultural Land Reserve, an application, by way of Schedule H under the Soil Conservation Act, must be made through the local authority. The application is then generally processed simultaneously by both the
Agricultural Land Commission and the local authority. The Commission will require varying levels of information to assess a proposal, depending on the sensitivity of a site, the type of agricultural production, or the size of operation. The Commission frequently will require the submission of an extraction/reclamation plan that describes all aspects of the operation. The extraction/reclamation plan is usually required in the form of a written report complete with site and operational plans. The plan must demonstrate that the proposal has a clear agricultural direction with a predetermined end capability for agriculture that is superior to that prior to extraction.

Generally, the preparation of this material will require the services of professional consultants, including Agrologists and Engineers. The following information requirements have been provided by B. McBride of the Agricultural Land Commission.

**Written Report**

As part of the Agricultural Land Commission application, you will need to complete a report that describes all aspects of your proposed operation, as well as how the proposed reclamation will enhance the site for agriculture. The report should describe:

- proven sand and gravel reserves (include drill logs with their locations identified on a map of the site),
- location of the water table,
- volumes and depths of gravel that will be removed,
- pre-extraction topography, landform and soil types, complete with soil profile descriptions,
- agricultural land capability ratings, before and after extraction,
- potential crop or agricultural options,
- size, location and extraction sequence, if the operation will be phased over two or more years,
- time table for extraction,
- types of drainage control that will be used during the operation and following reclamation,
- final elevations of the site following extraction and reclamation, and
- soil management methods that will be used, including:
  - stripping of soil horizons,
  - transport of soil to the storage areas,
  - soil storage, and
  - screening of topsoil prior to placement.

**Maps and Site Description Plans**

In addition to the application form and report, you will also need to prepare a series of maps and site plans, showing:

- current and projected agricultural capability,
- initial and final topographic contours (contour intervals must be 2m or less),
- a series of north/south and east/west cross-sectional profiles, showing initial and final elevations, and identifying volumes and the area of extraction,
- location and size of each extraction phase and, if applicable, the order in which each phase, is to be opened up and reclaimed,
- the location of permanent processing, product storage areas and other site facilities,
- identification of soil salvage areas including information on soil layer thickness,
- location of soil storage areas, and
- drainage control structures during operations and following reclamation.

The Agricultural Land Commission may ask you to modify your site plan, depending on the specific circumstances of your site. The Agricultural Land Commission approval commonly includes some conditions on the approval, based on the extraction - reclamation plan. For example, you may be required to maintain a buffer zone of trees and shrubs between your operation and an adjacent neighbour. It is also common for the Agricultural Land Commission to require ongoing monitoring of the site activities and reclamation progress. Prior to commencement of any works, the Agricultural Land Commission generally requires the posting of bonds as an incentive for good land reclamation.

**Agricultural Uses outside the Agricultural Land Reserve**

Agriculture is an acceptable end land use in areas outside of the Agricultural Land Reserve where local (municipal or regional district) zoning permits. If your land is not in the Agricultural Land Reserve and the decision is made to reclaim your site for agriculture, careful consideration must be given to its intended use (i.e., whether it is to be for soil based crops or a use that requires only a dry stable land surface, such as greenhouses). In the latter case, land capability for agriculture is not particularly relevant.
If the site is to be used for crop production, then the criteria and methods for reclaiming these lands should be the same as those employed within the Agricultural Land Reserve.

2. IMPORTANT FACTORS

A number of important factors will determine the way in which you can best reclaim your operation, as well as your choice of a specific agricultural end use for the site. These include how the landform may be modified to enhance the agricultural capability of a site, as well as present and surrounding land uses.

Land Use

Prior to making an application, the end land use and soil capability for agriculture must be determined. The extraction/reclamation plan must show how the project will improve a site from its initial state to the projected improved agricultural condition following completion of reclamation.

The current land use and zoning of your site, as well as neighbouring properties, will strongly influence the end land use for your reclaimed areas. In general, it is likely that the end land use will have to be similar to the types of farming that existed on or adjacent to your land prior to your operation. In some cases, however, improved drainage may allow different types of farming to take place on the reclaimed sites. The planning of your operation and your reclamation program must consider potential impacts on the surrounding lands, including changes in groundwater, surface drainage, road access and topography (slopes and elevations).

In most agricultural areas, you will need to recontour the site to maximize relatively flat areas. It is not acceptable to leave the isolated depressions/or irregular slopes that often result from the exhausted pit excavation.

Soils and Land Capability

A thorough understanding of the landforms and soils of your site is required for the preparation of a successful agricultural reclamation plan. Features such as texture, stoniness, horizon colours, horizon depths, drainage characteristics and soil chemistry are used in identifying and mapping soil types.

Background information on soils in your local area may be available from regional and broader scale soil surveys. The pamphlet “Index of Soil Surveys in British Columbia”, available through the Integrated Manage-

ment Branch of the Ministry of Environment, Lands and Parks, can tell you if soil maps are available for your area. Land capability maps for agriculture, available through Maps B.C., also provide important information on soil capability. These maps and reports provide background information from which more detailed assessments can be made.

The capability of your land for agriculture is determined by its soil (land) characteristics and climate. These factors dictate the types of crops that can be grown, and the management practices that will be required. The report, “Land Capability Classification for Agriculture in British Columbia”, available through the Ministry of Agriculture, Fisheries and Food, provides information on specific methods for determining land capability for agriculture.

In areas of current agricultural activity or areas with moderate to high capability for agriculture, you will have to complete a detailed soil survey as part of the development and reclamation plan. A detailed soil survey must be conducted by a soil specialist, and generally requires at least one soil inspection per ha, though the actual inspection intensity will be dependant on your site’s complexity.

Based on these surveys, you can then determine the suitability of the various soil types and horizons for use during reclamation. The suitability of soils as reclamation material is determined by their physical and chemical properties. Table 7-1 provides a summary of these soil properties and their respective suitability ratings.

Soil Salvage

In agricultural areas, you will be required to salvage topsoil, subsoil and possibly overburden, and stockpile them in separate storage areas, or directly replace them in reclaimed areas (see Chapter 4, Section 3). Your soil management plan will provide information on the location and suitability of the soil materials available for salvage.

In most cases you will need at least two long term stockpiles, one for topsoil and the other for suitable subsoil. You may also need temporary storage areas for drainage layer material. In some cases, it may be necessary to set aside permanent disposal areas for waste overburden.

Erosion control measures should be used on all stockpiles to minimize losses of soil (see Chapter 5, Section 6). Mixing and double handling of the different soil materials should also be avoided. As described earlier, your soil management
### Table 7-1: Criteria For Evaluating Suitability Of Soil For Use In The Root Zone
(Source: revised from Alberta Agriculture, 1987)

<table>
<thead>
<tr>
<th>Rating/Property</th>
<th>Good (G)</th>
<th>Fair (F)</th>
<th>Poor (P)</th>
<th>Unsuitable (U)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reaction (pH)</td>
<td>&gt;5.0 to 7.5</td>
<td>4.0 to 5.0 &amp; 7.6 to 8.4</td>
<td>3.5 to 4.0 &amp; 8.5 to 9.0</td>
<td>&lt;3.5 and &gt;9.0</td>
</tr>
<tr>
<td>Salinity (EC) (dS/m)</td>
<td>&lt;2</td>
<td>2 to 4</td>
<td>4 to 6</td>
<td>&gt;6</td>
</tr>
<tr>
<td>Sodicity (SAR)</td>
<td>&lt;4</td>
<td>4 to 8</td>
<td>8 to 12</td>
<td>&gt;12</td>
</tr>
<tr>
<td>Saturation (%)</td>
<td>30 to 60</td>
<td>20 to 30, 60 to 80</td>
<td>15 to 20, 80 to 120</td>
<td>&lt;15 and &gt;120</td>
</tr>
<tr>
<td>Stoniness</td>
<td>S0, S1</td>
<td>S2</td>
<td>S3, S4</td>
<td>S5</td>
</tr>
<tr>
<td>Topsoil (Stoniness Class) (total area)</td>
<td>&lt;0.1</td>
<td>0.1 to 2</td>
<td>3 to 50</td>
<td>&gt;50</td>
</tr>
<tr>
<td>Subsoil (% volume, &gt; 15 cm diameter)</td>
<td>&lt;3</td>
<td>3 to 25</td>
<td>25 to 50</td>
<td>&gt;50</td>
</tr>
<tr>
<td>Texture</td>
<td>ISL, VSL, L, SL, SIl</td>
<td>CL, SCH, SICL</td>
<td>S, LS, SC, SIC, C, HC</td>
<td></td>
</tr>
<tr>
<td>Moist Consistency</td>
<td>very friable, friable</td>
<td>loose</td>
<td>firm, very firm</td>
<td>extremely firm</td>
</tr>
<tr>
<td>Organic Carbon (%) (Topsoil only)</td>
<td>2 to 7</td>
<td>1 to 2</td>
<td>&lt;1</td>
<td>&gt;17 (use as soil amendment)</td>
</tr>
<tr>
<td>CaCO₃ Equivalent</td>
<td>&lt;2</td>
<td>2 to 20</td>
<td>20 to 70</td>
<td>&gt;70</td>
</tr>
<tr>
<td>Coarse Fragments (% volume, &gt; 2 mm diameter)</td>
<td>&lt;30</td>
<td>30 to 30</td>
<td>50 to 70</td>
<td>&gt;70</td>
</tr>
</tbody>
</table>
| Notes to table: | 1. Materials characterized by an SAR of 12 to 20 may be rated as poor if texture is sandy loam or coarser and saturation % is less than 100.
2. C - May be upgraded to fair or good in some arid areas.
3. HC - May be upgraded to fair or good in some areas.
4. Matrix texture (modal) finer than sandy loam.
5. Matrix texture (modal) sandy loam and coarser.

Plan should clearly describe when and where soil materials will need to be stored or directly transferred.

On some sites, there may not be sufficient soil materials to adequately reclaim the site and reconstruct suitable soils. In these circumstances, you may be able to obtain off-site soil materials for use in final reclamation. Temporary storage of these materials may be required if scheduling of availability does not coincide with the timing of replacement. Before using off-site materials, however, the suitability of these materials must be confirmed by a Professional Agrologist, and permission obtained from the Agricultural Land Commission and the local authority (municipality or regional district).

**Soils and Post-Reclamation Capability for Agriculture**

The Agricultural Land Commission views extraction proposals as potential opportunities for agricultural enhancement. Clear end land use objectives and land capability for agriculture targets are pre-determined in the extraction/reclamation plan.

The capability of your site for agriculture is determined by a combination of the reconstructed soil, the recontoured landforms, and site climate. Although the local climate is unlikely to be affected by your operation or reclamation, you should be aware that changes in the slope, aspect and shape of your site can result in important climatic effects such as increased cold air drainage.

In developing the major landscape objectives for your reclamation area, you will have to consider the type of landforms, site drainage and soils that will be re-created on your site, relative to land capability.

**Landforms**

Landform characteristics such as slope gradient, length and complexity affect both the mobility of farm and reclamation equipment and the potential for soil erosion. In general, as slopes become steeper and more complex (multidirectional), farming equipment becomes less efficient, and crop success becomes more variable.

Most of the cultivation/seeding and fertilization equipment that is used in farming or reclamation can work on slopes as steep as 3.5 Horizontal (H): 1
Vertical (V) or just under 30%. However, on slopes this steep, continuous intense soil tillage is impractical. With special soil conservation practices, arable crops can be grown on slopes as steep as 7H:1V (15%), but with increasing machinery limitations above grades of about 10H:1V (10%). Slopes in the range of 6H:1V (16%) to 3H:1V (30%) are usually only suitable for such uses as pasture or forage production that do not require regular cultivation. In some areas of British Columbia, such as the Okanagan Valley, these sites may also be suited for tree fruits or grapes.

The potential for erosion on sloping land is increased both with increases in slope length as well as increases in slope gradient. When planning for agricultural land uses, it is often best to terrace the fields (i.e., maximize the slope gradient over the shortest possible area in order to maximize the area of level or near level agricultural land) (Photo 7-1). However, these slopes must be geotechnically stable and allow establishment of some type of protective plant cover. Slope gradient limitations for agricultural land capability in British Columbia are summarized in Table 7-2.

The landform patterns and slope complexity of your site will affect soil drainage, since with increasing slope complexity there is usually an increase in the occurrence of isolated pockets or depressions that can collect runoff and snow. Lower slope and depressional areas also tend to have moister soils than do areas in mid and upper slope positions, because of increased seepage and accumulation of runoff. Drainage improvements for these isolated areas are generally difficult and expensive to install.

### Site Drainage

Areas reclaimed for agriculture must be provided with both adequate site and soil drainage. Site drainage refers to the removal of surface runoff water (including intercepted groundwater or seepage) from a site. Soil drainage refers to the removal of excess free water in the rooting zone.

Re-establishment of site drainage will help:

- Prevent erosion from uncontrolled overland flow that, in turn, may result in soil losses from the site and sedimentation in local surface water bodies;
- Control flooding and ponding on your site and adjacent areas; and
- Minimize obstacles for farm equipment such as gullies and wet depressions.

The British Columbia Agricultural Drainage Manual provides information on a number of methods to improve site drainage. These include:

- permanent interceptor drains,
- grassed and mixed stone-grass waterways,
- temporary drainage diversions to avoid bare soil or newly seeded areas,
- protection of bare or recently seeded areas to increase infiltration as with mulch covers,
- use of silt fencing on exposed slopes to intercept sediment, and
- construction of temporary sedimentation ponds to prevent sediment from entering and degrading the quality of surface waters.

Soil drainage is strongly influenced by both slope position and soil permeability (the rate at which water...
moves into and through a soil). Excess water may occur because of poor drainage associated with high water tables, or seepage and runoff from surrounding uplands into depressional areas with no or limited outlets.

Soil permeability is governed by the rate at which water seeps (infiltrates) into the soil, as well as the permeability of the various soil horizons. Both of these factors are strongly related to the texture and structure of the different soil horizons.

During the reconstruction of soils in your reclamation area, it may be necessary to install a layer of porous drainage material to reduce the amount of water in the soil, particularly if soil drainage was a problem prior to the start of your operation. You may also be able to modify the texture and structure of the overburden subsoil and topsoil to improve soil drainage.

Rockiness

The potential occurrence of bedrock outcrops and shallow soil cover over bedrock is of particular concern in reclamation planning for quarries. Root depth, soil drainage, tillage and other mechanized operations are all affected by the presence of shallow bedrock or outcrops. Class 1 agricultural land must have at least 1m of soil cover over bedrock and outcrops must be spaced a minimum of 75m apart. Thinner soil cover and increased frequency of outcrops will reduce the capability of the site for agriculture.

Soil Texture

The physical characteristics of the replaced soil materials will strongly influence its suitability as rooting material. Soil texture — the relative composition of sand, silt and/or clay particles smaller than 2.0mm in diameter (see Figure 7-2) — will strongly influence the ability of soils to hold and transmit water (Table 7-3). In turn, these characteristics are modified by other factors such as soil structure, the type of crop, and soil tillage practices.

The coarse fragment content of a soil is determined by the presence of soil particles that are coarser than sand (>2.0mm diameter); these include gravel (>2mm to 75mm), cobbles (75mm to 250mm) and stones (>250mm). As the coarse fragment content increases in size and frequency, it will reduce the amount of available water storage, while also negatively affecting soil tillage operations.

Stoniness

Stoniness refers to the coarse soil fragments with diameters of 25mm or larger, including coarse gravels (25mm to 75mm), cobbles and stones, that significantly hinder mechanized tillage, planting and/or harvesting operations.

Soil capability decreases with increasing stoniness (Table 7-4). The selection of non-stony soil material or the removal of coarse fragments from the soil prior to replacement in the upper 25cm of the reclaimed soil profile, is critical in maintaining high capability. The 25cm depth is a minimum thickness as frost action and deep ploughing may cause coarse material to be brought into the surface layer.

In areas of the province that are climatically suitable for growing tree fruits and grapes, stoniness may not be a significant limitation to these relatively low tillage operations.

Soil Consistence

Soil consistence describes a soil’s strength (relative hardness when dry, friability when moist) and stickiness or plasticity when wet. It can be described under varying moisture contents, but for the purposes of rating its suitability, it is commonly described under moist conditions in terms of friability and relative hardness. Soil consistence strongly impacts soil workability (tilth), seedbed quality and ease of vehicle movement (trafficability).

Soil Chemistry and Fertility

The chemical characteristics of the soil material in the root zone can affect both the physical nature of the soil and fertility. To identify potentially adverse plant growth conditions, the following soil characteristics should be measured:
Texture Infiltration Rate @ Saturation\(^1\) Hydraulic Conductivity AWSC\(^2\)

<table>
<thead>
<tr>
<th>Soil</th>
<th>Cultivated</th>
<th>Class(^1)</th>
<th>Rate</th>
<th>mm H(_2)O/m soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sod</td>
<td>mm/hr</td>
<td>mm/hr</td>
<td>Class(^1)</td>
<td>Rate m/day</td>
</tr>
<tr>
<td>Sand</td>
<td>7.5</td>
<td>4.2</td>
<td>rapid</td>
<td>80</td>
</tr>
<tr>
<td>Loamy Sand</td>
<td>6.7</td>
<td>3.3</td>
<td>slow</td>
<td>100</td>
</tr>
<tr>
<td>Sandy Loam</td>
<td>4.6</td>
<td>2.5</td>
<td>mod. rapid</td>
<td>1.5 - 3.0</td>
</tr>
<tr>
<td>Fine Sandy Loam</td>
<td>4.2</td>
<td>2.5</td>
<td>mod.</td>
<td>0.5 - 1.5</td>
</tr>
<tr>
<td>Loam</td>
<td>3.3</td>
<td>2.1</td>
<td>mod.</td>
<td>0.10 - 0.50</td>
</tr>
<tr>
<td>Silt Loam</td>
<td>3.3</td>
<td>2.1</td>
<td>slow</td>
<td>210</td>
</tr>
<tr>
<td>Clay Loam</td>
<td>2.9</td>
<td>1.7</td>
<td>slow</td>
<td>0.025 - 0.10</td>
</tr>
<tr>
<td>Clay</td>
<td>2.5</td>
<td>0.8</td>
<td>very slow</td>
<td>&lt;0.03</td>
</tr>
<tr>
<td>Organic (muck)</td>
<td>5.0</td>
<td>5.0</td>
<td>variable</td>
<td>0.10 - 6.0</td>
</tr>
</tbody>
</table>

Table 7-3: General Influence Of Soil Texture On Soil Water Relationships

\(^{1}\)Available Water Storage Capacity; adapted from "Irrigation Design Manual", rev. 1983

<table>
<thead>
<tr>
<th>Capability Class</th>
<th>Coarse Fragments(^1)</th>
<th>Cobble &amp; Stones(^2)</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&lt;5 %</td>
<td>&lt;0.01 %</td>
<td>Class 1 tree fruit</td>
</tr>
<tr>
<td>2 P (*1)</td>
<td>6 to 10 %</td>
<td>0.01 to 1 %</td>
<td>Class 2 tree fruit</td>
</tr>
<tr>
<td>3 P (*2P)</td>
<td>11 to 20 %</td>
<td>2 to 5 %</td>
<td>Class 3 tree fruit</td>
</tr>
<tr>
<td>4 P (*3P)</td>
<td>21 to 40 %</td>
<td>6 to 15 %(^3)</td>
<td>Class 3 tree fruit</td>
</tr>
<tr>
<td>5 P (*3P)</td>
<td>41 to 60 %</td>
<td>16 to 30 %</td>
<td>Class 3 tree fruit</td>
</tr>
<tr>
<td>6 P</td>
<td>61 to 90 %</td>
<td>31 to 80 %</td>
<td>Class 7 if presently not suitable for grazing</td>
</tr>
</tbody>
</table>

Table 7-4: Soil Stoniness and Land Capability Ratings

Soil Replacement, Compaction and Tilth

- soil reaction (pH),
- salinity (soluble salts),
- sodicity (excess sodium),
- lime content (CaCO\(_3\) equivalent) or lime requirement,
- nutrient content (N, P, K, S, Ca, Mg),
- ability to retain nutrients (the nutrient holding capacity of a soil is affected by the clay and organic matter content of the soil. In turn, this strongly influences the retention of and exchange of nutrients against leaching by percolating water).

Routine fertility testing is required on representative soil samples to determine the levels of nutrients and recommended additions. In humid, coastal areas of the province where strongly acidic (i.e., pH < 5.5) soils are common, a lime requirement test should be performed to determine the correct rate of lime application.

**Soil Replacement, Compaction and Tilth**

**Soil Layer Replacement**

The order, suitability and thickness of the individual replaced soil layers will strongly influence the capability of the reclaimed soil. A typical reclaimed soil profile for coastal areas or potentially irrigated lands is shown in
Figure 7-3. The combined thickness of the topsoil and subsoil layers, or root zone, is at least 50 cm. This zone may be thicker if additional volumes of suitable materials are present. To ensure that crops are not stressed by soil droughtiness, especially in areas where soil moisture deficits occur over the growing season, the available water storage capacity of the surface 50 cm should be greater than 75 mm in non-irrigable areas and greater than 60 mm in irrigable areas (see Table 7-3). The soil or root zone should be underlain by a drainage layer to an approximate depth of 1 m, made up of moderately rapid to rapidly draining soil materials.

The reclaimed area should be monitored following re-seeding to determine if sufficient drainage has been provided. If poorly drained areas persist, it may be necessary to install additional drainage structures.

**Compaction**

Although the post-reclamation soil capability is primarily determined by the suitability of the replaced soil layers, it is also influenced by the structure of the soil and the degree of compaction. Mitigative measures to reduce or prevent excessive compaction and improve soil tilth should be an integral part of the reclamation process.

Potential for soil compaction evolves around the soil strength at the time of replacement, a factor strongly related to soil moisture content and soil cohesiveness (related to clay content and type), grain size distribution, and passage of rubber tired equipment. To minimize the potential for compaction, you should avoid handling soil when it is wet (i.e., free drainage has practically ceased) as a rule of thumb, soils should not be handled for 2 days after a heavy rainstorm.

Compaction can also be minimized by selecting soil materials with low clay contents for replacement in the root zone. Soils in the coarse and medium textured groups should be used whenever possible, if they are available (see Figure 7-2).

Although recently reclaimed soils often exhibit poor structure, farming practices and natural processes can improve soils over time (see Chapter 5, Sections 9 and 10 for additional information). Farming practices that can help improve soil structure include plowing in surface organic mulches, planting of deep rooted crops to open up the subsoil, and use of rippers to break up the subsoil. Natural processes such as freezing-thawing of the soil and wet-dry cycles also tend to breakup soil clods and open up the soil structure.

**Tilth**

Tilth is the physical condition of the soil relative to its ease of tillage, its suitability as a seedbed, and its resistance to root penetration and seedling emergence. Soil structure, along with texture, soil consistence, permeability and depth to root restricting layers are important factors that influence soil tilth. Methods for assessing soil tilth are presented in the report "Land Capability Classification for Agriculture".

**Weeds**

Disturbed land is very susceptible to invasion by unwanted or undesirable species. The control of weeds, including noxious weeds, as defined in the provincial Weed Control Act (1973), is of concern during all phases of the life of the operation. It is the responsibility
of land occupiers to control noxious weeds on all land that they occupy or have control over. Under the Act (gazetted to 11 May 1993) the following weeds are deemed noxious throughout British Columbia:

<table>
<thead>
<tr>
<th>Weed Name</th>
<th>Weed Name</th>
<th>Weed Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual sow thistle</td>
<td>Dodder</td>
<td>Scentless chamomile</td>
</tr>
<tr>
<td>Canada thistle</td>
<td>Hound's-tongue</td>
<td>Spotted knapweed</td>
</tr>
<tr>
<td>Common Cuprina</td>
<td>Jointed goagrass</td>
<td>Tansy ragwort</td>
</tr>
<tr>
<td>Common toadflax</td>
<td>Leafy spurge</td>
<td>Velvetleaf</td>
</tr>
<tr>
<td>Dalmatian toadflax</td>
<td>Perennial sow thistle</td>
<td>Wild oats</td>
</tr>
<tr>
<td>Diffuse knapweed</td>
<td>Rush skeletonweed</td>
<td>Yellow starthistle</td>
</tr>
</tbody>
</table>

Local Weed Districts designate additional weeds as noxious, to those on the provincial list. Local regional districts and municipal governments may also have bylaws regarding the control of weeds.

There are five general categories of weed control methods: prevention, mechanical, cultural, biological and chemical. The most common practices in gravel pit areas include:

- cultural methods such as reseeding with an appropriate vegetation mix that can out-compete weeds,
- mechanical methods such as tillage, mowing, burning and mulching or use of black plastic sheeting, and,
- chemical methods such as the use of herbicides.

Regardless of the methods you choose, they must be in accordance with accepted management procedures and pesticide application regulations.

Weed establishment on disturbed areas and soil stockpiles can be reduced through the early establishment of grass-legume covers or cereal crops. Certified seed should be used to minimize the potential of introducing additional weed seeds. It is strongly recommended that you reseed all newly reclaimed areas as soon as possible after soil replacement and conditioning.

You are encouraged to contact your local District Agriculturist for current information on weed species and control procedures in your area. The Ministry of Agriculture, Fisheries and Food can provide you with a copy of “Field Crop Guide to Weed, Disease, Insect, Bird and Rodent Control for Commercial Growers”, 1994/95 edition. This guide includes a selection table for herbicides to control common weeds in forage grasses and legumes.

Storage, transportation and application of herbicides must follow current regulations as outlined in the Ministry of the Environment publication “Handbook for Pesticide Applicators and Dispensers, 5th Ed.” (1990 printing). Chapter 12 of that publication provides a good introduction to the topic of weeds and herbicides.

3. METHODS FOR RECLAMATION

Grading and Contouring

In areas that are being reclaimed for agricultural use, the final slopes and landforms for your site should be determined by the need to maximize the ease of operation of mechanized farm equipment, and minimize soil erosion risk. The reclaimed area should also “blend” into adjacent undisturbed terrain and provide adequate soil drainage and vehicular access.

Farm equipment for cultivating, seeding and fertilizing, as well as heavier machinery for reclamation, can work on slopes as steep as 3.5H:1V (nearly 30%) (equivalent to Agricultural Capability Class 5T, per Table 7-2), but work more efficiently on lower gradients. Excavation of pits and quarries often results in steep slopes along the highwall, on the sideslopes into the pit, or on the face of overburden waste storage areas. To maximize the amount of flat or gently sloping areas within your reclaimed site, it is best if you incorporate a single steep slope or series of steep faced terraces into the reclaimed landscape. However, it is essential that these be geotechnically stable and that the soil surface be protected with a permanent vegetation cover (see Chapter 5, Section 4). Drainage from upland areas must be diverted away from these slopes, or directed into properly designed water drop structure(s) down the face of the slope.

To avoid severe erosion of topsoil, land that is intended for the production of annual crops should have slopes no greater than 5% (Class 1). In moist areas of the province, such as the Lower Fraser Valley, the Agricultural Land Commission usually recommends that slopes be less than 1% on cropland to minimize sheet and rill erosion.

As slope length increases so does the soil erosion hazard. Where intervening slopes are flat enough to be reclaimable, terraces may be used for agriculture (Figure 7-4).

Replacing Overburden and Subsoil

During the replacement of overburden and subsoil materials, it is important to ensure that the highest
quality soil material is placed in the rooting zone. During the development of your pit or quarry, good planning and careful evaluation of the suitability of overburden and subsoil will help ensure the efficient placement or burial of poor quality soil materials (stony, saline, clayey, etc.). In particular, you should identify areas that will require fill to minimize the need for double handling of soil materials.

Compaction, as a result of soil placement by heavy equipment, can be reduced during placement by dumping material in thick (1m) lifts. For example, soil materials can be end dumped from trucks and levelled with low ground pressure equipment, such as tracked bulldozers (Photo 7-2). As noted earlier, it is important that you only handle soils when they are relatively dry. If you replace soils when they are frozen, care must be taken to avoid burial of excessive amounts of snow or ice that will later thaw and cause “sink holes” or irregular settlement. Vehicles and equipment should be restricted to designated “roads” or routes, so that ripping and subsoiling activities can be limited to these specific areas. Random, repeated running of equipment over levelled areas should be avoided wherever possible.

If compaction does occur, you should rip the affected areas to a depth of 60cm or more (75cm in sands) with shanks or ripper teeth spaced at 60cm, and then cross rip at 90° to the first direction. This method results in an intensive pattern of loosened subsoil. The positive soil benefits include:

- breaking up the surface crust,
- increased infiltration of water (reduced runoff and erosion),
- increased subsoil permeability to both air and water (better tilth), and
- bringing up stones for picking, that would otherwise surface later by frost action and deep tillage.

Where less than 60cm of non-stony subsoil is placed over stony overburden the subsoiling depth should be restricted to the thickness of suitable subsoil to avoid mixing of stones into the subsoil layer. To achieve maximum shatter of compacted layers, soil loosening should only be carried out under dry soil conditions.
Salvaging and reuse of topsoil materials is necessary.

Where topsoil volumes are limited, there is no need to mix for erosion control.

Specific end land use is not defined or in ditches unless they require your site that will be used for cultivation or pasture. The thickness should be equivalent to or greater than that of coarse fragments larger than coarse gravels.

As an alternative to screening, stone picking is another option. This method is not as effective as screening. Stone picking only removes a portion of the cobbles (>3.5cm) and larger fragments and not the coarse gravels (<3.5cm). In addition, several passes may be required that will add significantly to your reclamation costs.

Once the subsoil is in place, roughening the subsoil surface may help hold the topsoil in place following initial placement.

Replacing Topsoil

**Thickness**

Topsoil thickness should be maximized in all areas of your site that will be used for cultivation or pasture land. The thickness should be equivalent to or greater than that was present before disturbance. The placement of stakes, flagged to the desired replacement thickness, is good practice in assisting the machine operator.

Topsoil should not be replaced in areas such as roads, steep slopes or wet depressions, where the specific end land use is not defined as agriculture. Where topsoil volumes are limited, there is no need to place topsoil on steeply sloping (non-cultivable) lands or in ditches unless they require it for grass establishment for erosion control.

**Quality**

For the most part, topsoil quality is established during the salvage operations when it is easiest to prevent mixing of high quality soil with undesirable soil materials. Since one of the most important criteria for the salvaging and reuse of topsoil materials is the organic matter content and lack of stoniness, gravelly or stony topsoil (greater than 5% content by volume) should be passed through a 25mm screen prior to use.

If you do not have adequate topsoil materials on your site, you may be able to obtain suitable topsoil from offsite sources. For example, topsoil is often stripped from farm lands that are being converted to industrial or residential uses, and is available for purchase. You may also be able to “manufacture” topsoil using the mature (drained) washings from the sedimentation ponds on your site. With careful planning, these fines, typically very fine sandy loam or silt in texture, can be mixed with suitable organic matter such as manure, biosolids, or compost, and used as a substitute for topsoil.

**Placement**

To avoid compaction of topsoil, you should minimize machine traffic as much as possible, and not work it when it is wet. Heavy traffic also breaks down soil structure, making it less permeable and more erodible.

You should only till the seed bed just prior to seeding to minimize the time period in which the soil surface will be exposed to water and wind erosion. Soil tillage should be carried out across slopes to reduce the effective slope length, and slow runoff velocity and the potential for rill formation (see Tillage below). Soil ripping or subsoiling is sometimes done with the topsoil in place which results in some soil mixing (topsoil/subsoil). This practice is most successful when soils are dry, soil strength is at its highest, and problems of rutting, mixing and soil remoulding, rather than shattering, are minimized.

**Tillage**

Tillage is the mechanical manipulation of soil to produce favorable soil conditions for crop production, especially in the seedbed and upper root zone. Deep tillage, including subsoiling, refers to operations that affect the soil below the normal depth of ploughing (see Replacing Overburden and Subsoil). During reclamation, tillage is usually done to prepare a suitable seedbed, incorporate soil amendments (fertilizers, organic mulches and cover crop residue) and kill weeds.

Soil tillage is really only effective over a narrow range of soil moisture conditions. Soils should be moderately dry to slightly moist. Medium and fine textured soils have a narrower range of acceptable moisture contents as compared to coarse, sandy textured, soils.

There are two basic types of tillage implements: plows and discs that lift and invert the soil (Figures 7-5 and 7-
Figure 7-5: The effect of plowing on soil. (Soil Management Handbook for the Lower Fraser Valley).

Figure 7-6: The effect of discing on soil. (Soil Management Handbook for the Lower Fraser Valley).

Figure 7-7: Effects of shovel and chisel cultivators on soil. (Soil Management Handbook for the Lower Fraser Valley).
6), and cultivators and harrows that lift and stir, without inverting the soil (Figure 7-7), in situations where it is undesirable to mix thin topsoil with the underlying subsoil (i.e., strongly contrasting suitability, stony subsoil) it is better to use cultivators or harrows rather than plows or deep discs.

**Protection**

Once you have replaced topsoil on your site, it should be protected from erosion through proper runoff control and establishment of temporary or permanent plant cover (see Planting Cover Crops below). When finishing off the topsoil placement, you **should not** back-blade to make a "nice, smooth" surface, as this usually results in severe erosion losses. Instead, you should leave track cleat marks or ridges and troughs across the slope to slow runoff velocity (Figure 5-15). Surface roughness and plant cover reduce water and wind erosion. Erosion losses can also be minimized by keeping disturbed areas as small as possible. Use of a mulch application after seeding may provide the interim protection needed before the plant cover is sufficiently established.

**Site Drainage**

Control and re-establishment of site drainage is required in reclaiming for agriculture to:

- minimize erosion, soil loss and sedimentation that can result from overland flow and channel flow through reclaimed areas,
- control flooding or ponding,
- minimize obstacles to farming equipment,
- increase field trafficability,
- allow earlier access for planting, and
- increase soil temperature and aeration.

Because runoff water may flow to or from adjacent properties, and affect the entire drainage basin or sub-basin, it is important that you establish a good drainage system for your reclaimed area.

If you are using progressive reclamation, site drainage is also important in lowering water table levels in work areas and in re-cycling ponded water for site use. Progressive development and reclamation procedures also reduce the need for complex runoff control measures over large areas.

You can re-establish site drainage in agricultural areas by a number of methods, including:

- Interceptor drains and grassed water runs to slow the velocity of runoff water and prevent severe erosion,
- Placement of toe slope drains to collect and remove seepage from the subsoil,
- Use of temporary diversion drainage on newly topsoiled and seeded areas, and
- Sedimentation impoundments to protect water quality in downstream areas. The size and location of impoundments is determined by runoff volumes, erosion rates, and required retention times.

Drainage systems for operating pits are almost always enclosed, feeding back to a central pond in the bottom of the pit. If you must drain a pit across other land, you must obtain a license from the Ministry of Environment, Lands and Parks (Water Management Branch). The number of ponds should be limited on agricultural land to reduce obstacles, and to provide one stable water supply source for cattle or other on-farm uses (domestic supply, supplemental irrigation, fish farming).

You should leave buffer strips of undisturbed vegetation along streams, reservoirs, roads, and property lines to help slow runoff velocity, trap sediment and promote infiltration. The need for site drainage structures can also be reduced by ripping compacted overburden before you apply subsoil and topsoil. Such measures increase infiltration rates and reduce runoff. Ripping is most efficient if it follows the contours across the slope.

For ease of agricultural equipment mobility and maximization of field usage, subsurface (buried) soil drainage systems are favored as compared to open ditches. Subsurface drainage requires that soils be permeable enough for economic drain spacing. A good discussion of drainage planning requirements, ditch and waterway design (including grassed waterways), subsurface drain design, and related issues is contained in the "British Columbia Agricultural Drainage Design Manual". This guide is available through the Ministry of Agriculture, Fisheries and Food.

**Cover Crops**

As discussed in Chapter 4 (Section 5, Vegetation Establishment) the primary purpose for establishing a cover crop is usually to provide erosion control, However, side benefits such as nutrient capture, green
manure use and soil structure improvement may also be significant. Vigorous, deep rooting crops such as clover help to open the soil structure, while also increasing the amount of organic matter and the nitrogen content. The use of forage mixes, either alone or underseeded with a cereal, provides for both initial cover and a long-lived, useful cover for pasture or grazing land.

Your selection of seed type or mixes will depend largely on the local climate and your intended land use: pasture, forage crop or short-term cover for annually cultivated land. A general discussion of possible seed mixes is noted in Chapter 4, with a general guide to revegetation prescriptions contained in Appendix 1.

You can apply seed and fertilizer using one of two basic methods, broadcast and drill seeding (Figure 4-14, 4-15). Hydroseeding, aerial and the use of hand-held cyclone seeders are variations of the broadcast method. Drill seeding is preferred where slopes and soil conditions permit (i.e., shallow slopes with non-stony soils). Grass drills work best for seeding grasses and legumes. Grain drills place grass seed too deep, but can be lifted to broadcast grass seed. With broadcast seeding, your “catch” will improve if you cover the seed, with a thin layer of soil, by harrowing or some other method (such as passage of a tracked vehicle).

Row spacing and seeding rates vary by forage crop (Appendices 1 and 2). Target seeding rates (viable seeds/m²) by drill should be approximately half of those recommended for broadcast. Although twice as much seed could be used for erosion control on a difficult site, you should avoid excessive seeding rates, as they result in overly-dense, stagnant stands.

Cereal cover crops, such as spring barley, oats, winter wheat or fall rye, are used because they are large seeded (easy to seed using a broadcast seeder or drill) and germinate and develop rapidly. If seeded in mid to late summer, they provide cover by fall but do not generally set seed, and will not take over the stand the following year if turned under (green manured) before seed set. Seeding rates of these cereals is variable throughout the province, though rates of about 80 kg/ha (2 bu/ac) are common in the South Coast. The rate of application is highly dependent on purpose of the cover crop and the proposed use of the site in the following season. Cover crop residue management is an important consideration when planning for the establishment of the follow up crop. Check with your local District Agriculturist or Soil Conservation Unit for information on useful cover crops, seeding rates and planting dates in your area. Your choice of crops may be dependent on your proposed future use of the site.

Soil testing is required to identify the most appropriate fertilizer mix and rate of application. Fertilizing helps to establish and maintain a stand for a few years. You should usually use a mixed fertilizer, containing nitrogen, phosphorous, potassium and possibly sulphur. Where a seed mix and subsequent vegetative cover includes a significant, nitrogen-fixing, legume component, the need for nitrogen fertilizer may be reduced. Slow release fertilizers are particularly useful in areas of high precipitation since they may prevent excessive leaching of soluble nutrients.

4. OTHERS SOURCES OF INFORMATION

For additional information on reclaiming land for agriculture, write or phone:

- Reclamation Agrologist
  Agricultural Land Commission
  133 - 4940 Canada Way
  Burnaby B.C. V5G 4K6
  Telephone: (604) 660-7000

- Head, Soils and Engineering Branch,
  BC Ministry of Agriculture Fisheries and Food
  333832 S. Fraser Way
  Abbotsford, B.C. V2S 2C5
  Telephone: (604) 852-5363

- Provincial Soil Conservation/Management Specialist
  BC Ministry of Agriculture Fisheries and Food
  R.R. 8 RMD 7, Experimental Farm Site
  Prince George, B.C. V2N 4M6
  Telephone: (604) 565-6466

- District Agriculturist
  BC Ministry of Agriculture, Fisheries and Food
  (contact Enquiry B.C. for local branch office)

- Reclamation Engineer / Senior Reclamation Agrologist
  Resource Management Branch
  BC Ministry of Energy, Mines and Petroleum Resources
  Victoria, BC
  Telephone: (604) 356-2210 / 356-5275
Books and Reports


Soil Management Handbook for the Lower Fraser Valley. 1991. Published by the B.C. Ministry of Agriculture and Food, Agricultural Engineering Branch, Abbotsford, B.C.


CHAPTER 8
RECLAIMING FOR FORESTRY

If you have selected forestry as the end land use for your pit or quarry, this chapter provides specific information on issues that may affect forestry uses on your property, including:

Important considerations in reclaiming your site for forestry:
- meeting forest management regulations,
- adjacent land uses,
- soil types and availability,
- soil salvaging,
- drainage,
- topography,
- compaction,
- species selection, and
- progressive reclamation and development.

Methods for reclamation:
- grading,
- ripping,
- site drainage,
- replacing topsoil,
- selecting tree seedlings,
- tree planting, and
- managing reforestation areas.

1. IMPORTANT FACTORS IN DEVELOPING YOUR OPERATION

Meeting Ministry of Forest Regulations

If your pit or quarry operation is on Crown Land, the Ministry of Forests has jurisdiction over harvesting, land use and silviculture. A Special Use Permit must be issued by the Ministry of Forests to allow occupation of the Crown Land and extraction of the sand and gravel, or non-mineral rock resource. This permit does not allow for harvesting or selling of the timber from that site. Provisions can be made in the Special Use Permit for such things as building of access roads to the site, timing of work, and degree of reclamation to be done.

To harvest and sell the timber on the site, a harvesting permit will be required. The type of harvesting permit required depends on the size of the operation and the proposed land use after harvesting. A Licence to Cut agreement allows individuals to cut and/or remove timber from the land. A Licence to Cut is normally given for occupiers of smaller tracts of land. If the pit or quarry operation is to occupy a large area of Crown Land, then a timber sale may be conducted so that a forest company can carry out the harvest. You could then set up operations on the site, most likely with a Special Use Permit. A Timber Sale Licence is an agreement in which a specific volume of timber in a specific area is to be harvested. Once harvesting is completed, the pit or quarry operations can be covered under a Special Use Permit.

A Free Use Permit allows Crown timber to be cut and utilized for very specific purposes such as construction of buildings, telephone/hydro poles, fence posts, etc. and be free of stumpage assessment. The operator would not be allowed to sell timber cut under this permit.

Other permits that may be required include a Road Permit to allow for the construction or modification of forest roads for accessing timber that is planned for harvest. Road access construction may also be permitted with a Special Use Permit if specific provisions have been made. If the pit or quarry site is accessible only by forest roads, a Road Use Permit will be required in order to allow all traffic related to that operation to travel on the road(s).

A Burning Permit will be required for pit or quarry operators to burn wood waste material resulting from timber harvesting and land clearing operations, or for burning any other materials during the fire season.

The reclamation standards required for pits or quarries reclaimed for forestry end land use will be stated within the Pre-Harvest Silvicultural Prescription (PHSP) for the site. The Pre-Harvest Silvicultural Prescription is a process for collecting site-specific field data, establishing management objectives and standards for silviculture and prescribing a series of treatments that will be required to achieve the objectives and standards for silviculture. The pit or quarry operator will be required to submit a Pre-Harvest Silvicultural Prescription if a Timber Sale Licence or Licence to Cut has been issued. If they are working under a Special Use Permit, a Pre-Harvest Silvicultural Prescription is not required.

For pit or quarry operations on private land, the Ministry of Forests has no jurisdiction over harvesting, land use, or silviculture. However, timber harvested on private land cannot be sold until the land owner obtains a timber mark from the Ministry of Forests.

Adjacent Land Uses

Because of the long-term requirements of forest production, you should carefully consider the surround-
ing land uses. A forestry land use is most suitable where the adjacent land use is commercial forestry or natural forest growth. Zoning maps should be consulted, as agricultural crops cannot grow where the climate is limiting such maps may indicate that forestry is the best use for that area. These types of maps include the Canada Land Inventory Series available from Maps BC (Ministry of Environment, Lands and Parks) or the federal Department of Environment.

If your reclamation area is on the edge of a city, commercial revenue from timber production is generally not feasible. You may instead want to cultivate Christmas trees or nursery seedlings.

The size of your pit is an important factor in deciding whether or not you should consider forestry as a land use. Pits less than 2 hectares in size might not be considered for forest production, simply because it is often not economical to harvest on such a small area. However, if your pit is already part of a larger, adjacent cut block, it could be incorporated in this cut block following reclamation and replanting with suitable species of trees.

**Soil Types and Availability**

If you have selected forestry as your end land use, a soil survey is recommended. At minimum, you should know something about the soil horizons in the pit area. If you are required to prepare a Pre-Harvest Silvicultural Prescription, soil information will be required. Soil horizons can be easily viewed at exposed areas such as road cuts or by digging a small pit. Important characteristics of the soil include texture, coarse fragment content, depth to root restricting layer, and moisture.

- The soil replaced on the completed pit should provide similar growing conditions to those existed before excavation. At a minimum, surface soils should be salvaged to the depth of tree rooting.
- If soils are coarse textured (sandy) and/or have a large component of coarse fragments (stones), then the depth necessary to provide good moisture conditions will increase.
- Soils may become compacted during handling and spreading and will require some scarification (ripping) to allow adequate root development and water transport.

**Soil Salvaging**

Regardless of the end use, proper soil salvaging is a very important component of your reclamation operation. However, in many of the forested areas of British Columbia, there is little topsoil. It is important to salvage all of the weathered soil material and certainly necessary to salvage soils to the depth that trees are rooted. If the topsoil (the organic enriched surface material) is deep and continuous enough to be stripped separately, then this higher quality soil material should be stockpiled separately from subsoil. These organic enriched soil materials will provide the best growth conditions. Unweathered overburden should also be stockpiled separately. Because of the value of the topsoil, it is very important that the topsoil and the subsoil are not mixed with the overburden.

The soil materials should be stripped using an excavator and trucked to the stockpile locations. You should pile topsoil and subsoil in low mounds to prevent soil compaction and to maintain soil productivity. The stockpiles should be seeded with a grass cover to prevent erosion, and weed development. When you replace the soil after excavation, it should be loaded into trucks for hauling and spreading. Heavy equipment should not be run over the soil.

**Site Drainage**

The removal of the gravels beneath the existing forest may result in changes to the soil drainage when the soil materials are replaced. The drainage class of the soil before excavation and after replacement will be an important planning consideration. For example, if the tree roots will be closer to the water table and soil moisture conditions are expected to be wetter, this may influence the selection of tree species for planting.

Natural drainages that existed prior to the development of the pit may be reestablished through the site at the close of excavation. These drainage areas must be designed to carry the maximum possible flow and not cause flooding of the site. Depending upon the size of the drainage and its duration of flow, the soils in the vicinity of the drainage could receive additional moisture. Sites adjacent to these drainages may be planted with different tree species.

**Topography**

The slope angle of the final pit surface will be important in determining the success of forest establish-
ment. Steep slopes can result in dryer soil moisture regimes than low slope or level sites with the same soil depth and composition. The aspect of the slope can also be important in controlling the soil temperature and soil moisture conditions. South and south-east facing slopes are generally warmer and dryer than adjacent slopes that face in a north to north-westerly direction. These factors must be considered in the Pre-Harvest Silvicultural Prescription to ensure that the most suitable tree species are selected for planting. The final configuration of your pit or quarry should be designed to provide the best growing conditions for the selected tree species.

Compaction

As discussed previously, compaction of the soil material should be avoided through the use of rubber tired equipment versus track mounted equipment for stripping, loading or pushing. Some compaction may occur in the final spreading of the topsoil onto the reclaimed site. Ripping this soil will reduce compaction. The moisture condition of the soil at the time of spreading can also be very important in reducing compaction. If the soils are wet, much greater opportunity for compaction will occur. Therefore soil handling should only occur when the soils are moist to dry.

Species Selection

British Columbia is more variable physically and biologically than any comparable region in Canada. The Ministry of Forests has classified the province into 14 biogeoclimatic zones, each of which represents a distinctive combination of climate, physiography, vegetation and soil. Management interpretations have been developed for each of the site units within these zones. These interpretations include forage seed mixes, stocking standards, preferred and acceptable tree species, and prescribed fire sensitivity.

Progressive Development and Reclamation

Unless your reclaimed area is to be used for Christmas tree production, progressive tree planting in areas smaller than 4ha is impractical. If your area is large enough, however, different sections of the pit or quarry (larger than 4ha in size) can be developed as individual reforestation projects.

Regardless of the size of the reclamation area, you should progressively grade your site, replace and scarify (rip) the overburden, and replace the topsoil while equipment is available (see Chapter 4). In those regions of British Columbia that experience high amounts of rainfall you should also establish a temporary grass cover on these areas to control erosion. Some sites in the dryer portions of the province will not require grass seeding, or should be seeded at very low rates to ensure that the grasses do not compete with the tree seedlings.

2. METHODS FOR RECLAMATION

Grading

Once you have completed your extraction operation, you will need to grade the site, prior to replacing the overburden, subsoil and topsoil. Unless your pit is very small (less than 1 ha), you should progressively complete these tasks for each major section of the pit.

For a forestry end use, it is best if you reshape the pit to form a gentle land contour with slopes that are geotechnically stable and that you can operate machinery on. Reshaping should minimize slope angles and ridges that cause wind-scouring and erosion. Once overburden is placed back over the pit contours, it is often necessary to recontour the final slopes to enhance drainage and to provide access for scarification, topsoil placement and tree planting (Photos 8-1, 8-2).

Ripping

If the use of heavy equipment during the grading of soil materials has compacted the ground, you should loosen the soil surface by ripping. Soil compaction tends to break down the soil structure, reduces the pore space of the soil, and forms a tight barrier to the percolation of moisture and nutrients. The decreased pore space reduces the water holding capacity of the soil. It also hinders penetration and water and nutrient uptake by roots.

To reduce the effects of soil compaction, you can work your reclamation site with deep rippers or plows. You should work along the contours, preferably to a depth of at least 0.5 metres. In general, the deeper and more extensive the ripping and plowing, the greater the success of seedling establishment and tree growth.

Site Drainage

Site drainage is extremely important for preventing erosion, and should be part of the recontouring phase of the reclamation work. Where possible, you should
grade your site along the contours to enhance snow and rain collection and absorption.

In dryer regions of the province, surface roughness can provide areas where snow can build-up. These areas can provide an important source of moisture for trees. In coastal and other areas of high rainfall, it will be important to drain water from the site and avoid ponding of surface water, as too much soil moisture can limit tree growth.

On any slopes within your site, you should develop surface drainage features such as terraces to guard against erosion. Try not to create features such as gullies and down-slope grading that encourage erosion.

**Replacing Topsoil**

Once you have completed recontouring your site, you are required to replace the topsoil. If topsoil is scarce, it can be placed on the portion of the site where the best tree growth will occur. As discussed above, use of heavy equipment on replaced topsoil should be minimized to prevent soil compaction.

**Selection of Tree Seedlings**

You should select trees for your site based on site conditions. Stocking standards are available from the Ministry of Forests that will detail preferred and acceptable species, that are ecologically suited to the site. Preferred species are those that best meet the management objectives for a site. Acceptable species may occur as a component of mixed stands but are not considered to be the target species for the site.

Seedlings may be obtained commercially as container grown stock (roots and soil), or occasionally as bareroot stock. Containerized stock generally have better survival and growth. Each container seedling is sown and grown in a separate cavity. This ensures that all the sensitive and active root tips are shipped to you intact with your seedlings (Photos 8-3, 8-4).

**Tree Planting**

Tree planting can be done in the spring or fall, when soil moisture conditions are suitable. Seedlings for spring plantings are packed at the nursery in the fall and placed in cold storage until required in the spring. Before delivery the seedlings must be carefully and evenly thawed. Seedlings should be maintained in cool conditions until planted. Handle the boxes carefully to protect the seedlings from damage. Store the seedlings on the planting site in the shade, near streams or patches of snow to keep them cool until planted.

Plant the trees at the required spacing, choosing the best microsite. Plant the seedlings straight and to the correct depth. Tamp the root system firmly to prevent air pockets forming and drying out the roots (Photo 8-5).

**Managing Reforestation Areas**

Forests must be managed until they reach free-growing state. A free-growing crop is a crop of healthy trees, the growth of which is not reduced by competition from plants, shrubs or other trees (Photos 8-6, 8-7).

Free-growing trees must be:

- of the preferred or acceptable species for the site,
- meet stocking densities,
- include planted trees that have been in the ground for at least 5 years,
- have good form and are free of insects, disease and damage, and are free of competing vegetation within a 1 m radius of the crop tree.

Management requirements to meet this free-growing state are likely to include weeding, pest control, fertilizing, and thinning. As some management tech-
niques may not be permitted on public lands, you should contact your local forest service office for advice.

**Weed Control**

Weedy vegetation, as well as grasses and forbs, can out compete young seedlings, and need to be kept clear from the tree stem for at least 0.5 metres. While you may do this by cultivation, careful use of herbicides represents the most efficient method for weed control. Use of herbicides should be undertaken with extreme caution as damage can easily be done to the trees. Information on herbicides can be obtained from your local office of the Ministry of Forests, Ministry of Environment, Lands, and Parks, or the Ministry of Agriculture, Fisheries, and Food.

**Pest Control**

Insects and disease may pose problems for your tree plantation. There are many effective methods for control including biological control, pesticides, and different land management practices. Information on preferred control methods can be obtained from the district representatives of the Ministry of Forests, Ministry of Environment, Lands, and Parks or the Ministry of Agriculture, Fisheries, and Food.

**Thinning**

Thinning may be required to remove injured or sickly trees, or to meet the maximum density of trees per hectare.

**Fertilization**

Fertilization may be useful in improving the productivity of your plantation, particularly during the early growth stage (4-5 years) of the young seedlings.

**Firebreaks**

In large reclaimed areas, or where your reclaimed area abuts natural forest stands, you may want to develop and maintain firebreaks. Firebreaks can be provided by access roads through the plantation, and are best in place from the beginning of the operation. Firebreaks should run perpendicular to the prevailing winds.
3. OTHER SOURCES OF INFORMATION

For additional information on permits and reclaiming forest land, write or phone:

- Ministry of Forests Provincial Headquarters (Victoria):
  Timber Harvesting Branch,
  Forest Land Use & Timber Marks Section
  3rd Floor, 1450 Government St.
  Victoria, BC V8W 3E7
  Telephone: (604) 387-5291Fax: (604) 387-6445

- Silviculture Branch,
  Silviculture Programs Section
  3rd Floor, 31 Bastion Square
  Victoria, BC V8W 3E7
  Telephone: (604) 387-1191Fax: (604) 387-1467

Within British Columbia, you can contact any government agency toll free through the Enquiry BC system by calling 1-800-663-7867.
If you have selected wildlife habitat as the end land use for your pit or quarry, or as a secondary use to include with other land uses, this chapter provides specific information on issues that may affect your choice of wildlife habitat. These include:

- Important factors that you should consider in reclaiming your site for wildlife:
  - adjacent land uses,
  - local zoning,
  - public access,
  - types of wildlife that may use the site,
  - shape, size and depth of your pit or quarry,
  - potential to maintain highwalls,
  - the need to conserve topsoil,
  - salvaging shrubs and small trees,
  - water sources, and
  - progressive reclamation and development.

- A general approach you should follow to successfully reclaim wildlife habitat.

- Approaches to restore upland habitats.

- Approaches to restoring wetland habitats.

Wildlife habitat reclamation can be adapted to almost any site and almost any type of disturbance you might encounter in British Columbia. As habitat reclamation can often be implemented in sites where agriculture, forestry, or residential/commercial uses are impractical, it is often a more viable and economical objective. The adaptability and flexibility of wildlife habitat reclamation offers you the ability to develop valuable islands of habitat within otherwise simplistic landscapes. Even if other end uses are the principle objective of your reclamation project, the creation or enhancement of wildlife habitat may be included as a secondary objective.

Wildlife habitat reclamation requires as much detailed planning and care in implementation as any other land use. Some past reclamation programs have used a wildlife habitat end use as an excuse for minimizing reclamation activities or using sloppy revegetation practices. The choice of a wildlife habitat end use is no excuse for poor planning, lack of topsoil salvage, limited recontouring of a site, or ineffective revegetation.

1. IMPORTANT FACTORS TO CONSIDER IN PLANNING YOUR OPERATION

Adjacent Land Uses

While reclamation for wildlife habitat, particularly upland habitat, can take place in a remote wilderness area or on the periphery of a city, potential conflicts with adjacent land uses must be taken into consideration. Typical problems are nuisance related, such as damage to agricultural crops by waterfowl, or browsing of ornamental plants and shelterbelts by deer. Some adjacent land uses such as cattle grazing or residential development may also detrimentally affect wildlife habitat projects. In some of these cases, it may be necessary to install fencing around the habitat project to protect vegetation from overgrazing by livestock and to minimize harassment of wildlife by dogs (Photo 9-1). If habitat projects are located immediately adjacent to major roadways or railways, you should also consider the potential for roadkills. Fencing can sometimes be used to direct animals away from dangerous crossing areas along highways and railways.

Local Zoning

Before planning and developing your site, be sure to review local ordinances and current and proposed zoning regulations. Depending on the location of your site, you should contact the municipal government, the Agricultural Land Commission, and/or the Ministry of the Energy, Mines and Petroleum Resources to determine if development of wildlife habitat will be permitted on your site.

Public Access

Wildlife habitat projects that have been funded with public money (e.g., government grants) or with money from organizations such as Ducks Unlimited or Wildlife Habitat Canada may require that public access be provided for uses such as hiking, hunting or bird watching. If you are considering external funding, it is advisable to check on any binding requirements before obtaining monies from certain organizations.

Types of Wildlife: Using Key Wildlife as a Focus for Your Plan

Before you design your pit and reclamation plan, you should ask yourself “What wildlife is present now?”, and “What wildlife would I like to eventually have on my reclaimed areas?” (Table 9-1, Photo 9-2). In general, your habitat project should be aimed at benefiting those species that are common in your region and are most likely to use a reclaimed site. However, in some special cases, you may be able to develop habitat for uncommon, endangered or threatened wildlife species.
Certain wildlife species, such as black-tailed deer or bighorn sheep have quite specialized habitat requirements. Other wildlife such as house sparrows or raccoons are less selective, and will be at home, regardless of adjacent land uses, as long as their basic requirements of food and cover are available.

- To simplify the design of your reclamation plan, only a few wildlife species, known as key species, should be considered as a focus of the plan.
- Key wildlife species must be carefully chosen, and should be common in adjacent areas. By providing habitat for one or more key species, you will also be providing habitat for a host of other species. For example, if you develop habitat for waterfowl, the same area is also likely to support amphibians, reptiles, songbirds, and muskrat (Photo 9-3).

Suggested key wildlife species for the different regions of British Columbia (also see Chapter 6) are shown in Table 9-1.

Your local Fish and Wildlife representatives can assist you in the selection of key wildlife species for a site. Your reclamation program may even be able to add to existing or proposed wildlife management programs.

**Conserving Topsoil**

As described in Chapter 4, it is important that you carefully and separately salvage and stockpile topsoil and overburden for later use in progressive reclamation of your site.

**Shape, Size and Depth of Pit**

Virtually any shape, size or depth of pit can be used for wildlife habitat. The physical characteristics of the pit are limiting only to the type of wildlife habitat that might be developed in your pit.

If your pit is oddly shaped with variable depths and rough and irregular contours, it is probably already well on its way to becoming good habitat (Figure 9-1). In many cases, the more different landforms you can keep or develop on your site, the more useful it will be to wildlife.

The size of your reclamation area, however, may limit the types of wildlife that can or will use the site. Larger wildlife such as deer, moose and elk require large blocks (10ha or more) of trees and shrubs for food and cover, as well as safe escape routes. Smaller wildlife such as songbirds, upland gamebirds or rabbits will use almost any size or type of pit.
## Table 9-1. Suggested Key Wildlife Species

<table>
<thead>
<tr>
<th>Biogeographical Region</th>
<th>Upland Areas</th>
<th>Representative Species</th>
<th>Wetland</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taiga Plains</td>
<td>moose, mule deer, caribou</td>
<td></td>
<td>dabbling ducks, muskrat, beaver</td>
</tr>
<tr>
<td>Northern Boreal Mountains</td>
<td>moose, caribou</td>
<td></td>
<td>muskrat, beaver</td>
</tr>
<tr>
<td>Boreal Plains</td>
<td>moose, mule deer, white-tailed deer</td>
<td></td>
<td>dabbling ducks</td>
</tr>
<tr>
<td>Sub-boreal Interior</td>
<td>moose</td>
<td></td>
<td>dabbling ducks, muskrat</td>
</tr>
<tr>
<td>Southern Interior Mountains</td>
<td>moose, mule deer, white-tailed deer, bighorn sheep, elk</td>
<td></td>
<td>dabbling ducks</td>
</tr>
<tr>
<td>Central Interior</td>
<td>moose, mule deer</td>
<td></td>
<td>dabbling ducks, muskrat</td>
</tr>
<tr>
<td>Southern Interior</td>
<td>mule deer, bighorn sheep</td>
<td></td>
<td>song birds, dabbling ducks</td>
</tr>
<tr>
<td>Coast and Mountains</td>
<td>black-tailed deer, red squirrel</td>
<td></td>
<td>dabbling ducks, sea ducks (coast)</td>
</tr>
<tr>
<td>Georgia Depression</td>
<td>black-tailed deer, Roosevelt Elk</td>
<td></td>
<td>dabbling ducks, sea ducks (coast)</td>
</tr>
</tbody>
</table>

### Highwalls

If the highwalls within your pit or quarry are stable, they may provide important nesting habitat for some birds of prey or escape terrain for wildlife such as bighorn sheep. To be useful, highwalls must be composed of stable, rock faces. Soft and loose rock material will easily erode or slump. If you plan to retain a stable highwall as part of your reclamation plan, be sure to consider safety precautions such as signage or restriction of public access. You will have to obtain permission from the Ministry of Energy, Mines and Petroleum Resources to retain a highwall.

### Selection of Plant Species for Wildlife Habitat

Once you have finished recontouring your site, and have replaced the overburden and topsoil, the establishment of a self-sustaining plant cover should be your next
Photo 9-4: Indigenous and non-native plant species. (Source: J. Green and others).
objective. This is the known as revegetation, and is the last essential element of wildlife habitat reclamation.

Revegetation for wildlife must consider several factors, including the seasonal needs of your key wildlife species for food and cover, the size of the reclamation area, soil types and moisture, the arrangement of plant communities within your site, and the placement and spacing of plants within each community. The potential for soil erosion (see Chapters 4 and 5) should also be considered.

In designing your revegetation plan, there are two important issues you should consider:

• the best approach for revegetation, and
• the use of non-native and indigenous (wild) plants.

Your Best Approach to Revegetation. There are two basic approaches to re-establishing plant cover on your site:

• using indigenous plant species, you can establish a younger stage of the desired plant community; or
• using a mixture of indigenous and non-native plants you can establish a plant cover with good potential for developing into the desired plant community (Photo 9-4).

Natural invasion of indigenous trees, shrubs, grasses and forbs from adjacent areas is important in either of these approaches. The combinations of planted and naturally-invading species result in many different stages of plant development, that provide a good mixture and diversity of habitats with the least amount of effort and cost.

Other approaches for revegetation have been attempted such as the transplanting of large trees and shrubs to immediately provide habitat, or the development of exotic plant communities. In general, these approaches are costly, and are not very effective in providing good wildlife habitat over large areas.

Choosing Plants

Once you have chosen a key wildlife species for your reclamation project, you will want to select a variety of plants for use in your planting and seeding program. Obviously any of the plants you select should be hardy to your area. As a rule of thumb, the trees, shrubs and groundcovers that are present on and around your proposed site are likely to be the species best suited to your particular reclamation conditions.

You can use both indigenous and non-native species of plants for reclamation. Indigenous species are those that grow naturally in the local area. Non-native species are those that have been developed by selective breeding for special characteristics and growing conditions.

The use of indigenous species in reclamation is becoming common, as commercial sources of seed, rootstock and seedlings become available. Indigenous species of plants have several advantages, as they:

• are better adapted to grow and reproduce under local conditions;
• require little or no maintenance to establish and flourish on a site; and
• have better long-term survival than non-native species.

However, their initial growth often appears to be slower than non-native species, as they channel much of their first year energy into root growth.

Non-native species are useful in some growing conditions.

[Photo 9-5: Trees and shrubs can be salvaged from proposed pit or quarry areas and replanted in reclaimed sites.]
Many species have a faster initial growth of above-ground leaves and stalks than most indigenous species, while also producing deep or fibrous roots. They can therefore often provide plant cover and erosion control within a period of only 2-3 months.

- Non-native species are readily available through local suppliers, and at lower initial cost, than indigenous species. Often non-native species may be used to swiftly establish a plant cover, while indigenous species are included for long-term habitat re-establishment.

Although there is much controversy regarding the relative merits of indigenous vs. non-native species, there is little evidence to suggest that one is superior to the other for wildlife habitat reclamation. However, if you can obtain indigenous seed at reasonable cost, it is a good choice as little long-term maintenance is required.

**Salvaging Shrubs and Small Trees**

Time, money, and effort can be reduced by salvaging trees, shrubs and ground covers during the initial and progressive phases of your extraction project (Photo 9-5).

If you salvage shrubs and small trees during the preparation of your pit or the next phase of your pit operation, they should be replanted as soon as possible. Trees and shrubs from the immediate site will provide plants that are well adapted to the site conditions. Salvaging may also enhance the revegetation of your site, as well as reduce the total cost for planting.

**Water Sources**

Water is a very important consideration in developing and improving wildlife habitat. Most wildlife require open water sources as a component of, or close to their habitat. If your pit is excavated below the level of the permanent water table, water will pond in the bottom of the pit. This type of excavation is generally not permitted by the Ministry of Energy, Mines and Petroleum Resources. If you have river or stream front property, you may be able to pump water from a nearby channel, but you must apply for and obtain a water permit. Diversion of water from natural channels is more complicated. In general, you may not divert water or construct works that divert, impede or otherwise interfere with a natural watercourse unless authorized. Contact the Water Management Branch of the Ministry of Environment, Lands and Parks for more information on the types of alterations permitted in or about a watercourse.
2. RESTORING UPLAND HABITAT

Grading and Contouring

In many situations, the rolling, hummocky terrain of an unreclaimed pit or quarry is more suitable for wildlife than recontoured and smoothed out landforms with little relief. However, some recontouring is generally necessary to blend your site contours with the surrounding landforms, and to control erosion of the subsoil and topsoil. When grading and contouring, you should follow four basic steps.

1. Determine how landforms can be graded and contoured to improve habitat diversity and site drainage, while maintaining rough areas that already provide potentially good landforms,
2. Dump excess overburden in specific patterns to enhance habitat diversity,
3. Establish final site landforms with precautions to minimize soil erosion, and
4. Prepare a suitable seed bed for groundcovers, shrubs and trees by ripping compacted overburden and replacing topsoil.

Diversity of Habitat

Rough to rolling terrain provides a variety of landforms, increases snow accumulation, and helps retain rainfall and runoff, thus preventing surface erosion. It also provides a variety of sites for plants to establish, thus increasing plant diversity and the amount of habitat edge. Rolling landforms can also provide wildlife with visual protection from humans and predators (Figure 9-2) during the first 5-10 years after reclamation when plant cover is still developing.

Constructing New Landforms for Wildlife

Although some new landforms can be created for wildlife following the extraction phase, it is preferable to do so during the actual operation of your pit. There are a number of ways that you can create large landform features during the extraction of resources:

- Create an irregular, sinuous edge when opening and developing your pit (Figure 9-1);
- Use waste piles during the extraction of gravels and other resources to create a rolling “knob and kettle” terrain on the pit floor (Figure 9-3);
- Regrade pit walls to provide appropriate slopes into the pit bottom. Keep slopes and contours irregular (Figure 9-3);
- Recontour or design below-grade haul roads as valley-like approaches to the pit bottom (Figure 9-3). In some cases, you might even use these sites as inlets for small watercourses; and

Figure 9-3: Knob and kettle terrain and below-grade haul roads can be used to develop irregular terrain and coulees for wildlife.
• On flat areas or shallow slopes, existing depressions and irregularities should be maintained. These sites are particularly valuable in dry areas where collection of rainfall and snowmelt can promote the growth of trees and shrubs.

By developing these features during the pit operation, you can usually create much larger landforms than through later recontouring activities. You can also minimize costs, materials handling, manpower requirements and equipment needs.

You can also create rough and rolling terrain for wildlife by building-up or excavating new landforms during the recontouring and grading of your reclamation area.

Methods you can use to build-up new landforms include:

• Dumping of excess overburden in an irregular but planned fashion on flatland areas or along existing slopes to create irregularly shaped rises or "knobs", 2-3 metres in height (Figure 9-4). Ensure that any follow-up machine work will minimize the loss of surface irregularities on these areas.

• Regrading of existing site features, such as pit slopes or overburden waste piles, to create gradual ridges and terraces across the slope (Figure 9-3). New features should run across the hill at right angles or very shallow angles. Depressions between the ridges may be suitable for development of poorly drained shrublands and grasslands.

**Ripping**

As discussed in Chapter 4, ripping and loosening of the subsoil and overburden reduces soil compaction, and provides a good base for topsoil placement.

**Site Drainage**

As with any land use, it is important that drainage patterns be developed within your reclaimed areas to minimize erosion problems, and direct surface runoff to areas where it is desired (see Chapters 4 and 5).

Water sources are an important habitat feature for most wildlife. Development or maintenance of ponds, wetlands and watercourses on or in the vicinity of your reclamation project will usually ensure that wildlife will be attracted. Waterforms not only provide a ready source of open water, but they also create a variety of habitat types along their shorelines. (Methods to create large wetland areas and ponds are discussed in detail later in this chapter.)

Minor modifications in site drainage and recontouring can often provide small water holes for wildlife (Figure 9-5). If depressions do not already exist within the pit floor, small depressions can be excavated with backhoes. You should then recontour the adjacent pit floor and slopes to channel surface runoff into these depressions. If the bottom of these depressions are leaky, you may need to line the area with clay to hold water. The shorelines should be seeded with grass.
species to prevent erosion and slumping. You may want to plant a few willows near the highwater zone of the water hole, but they will likely establish themselves.

To maximize use of these water holes by wildlife, you should ensure that fences or other structures do not obstruct wildlife access to the water hole. Most of the area within 10-15 metres of the water hole should be kept in grass cover to provide wildlife with a good line of sight when using the water hole. Tree and shrub cover should be maintained or developed around the periphery of the grassed area to provide hiding cover for wildlife.

**Replacing Overburden and Topsoil**

To effectively develop upland habitat for wildlife, you will need to establish suitable, self-sustaining plant cover. To ensure good success in plant establishment, you must carefully replace overburden and topsoils, particularly in areas where dense tree and shrub cover is desired. Methods for overburden and topsoil replacement are discussed in Chapter 3.

**Planting and Establishing Upland Vegetation**

Grasses and forbs provide an important food source for many wildlife species. Such cover is also important as nesting cover for some birds and as habitat for small mammals. Grasses and forbs should not be seeded in areas where shrub and tree seedlings have been planted, as they will often compete for soil nutrients and water.

Trees and shrubs provide wildlife with food in the form of woody browse, berries, and leaves. They also provide wildlife with escape and hiding cover, shade from the sun, protection from winter winds and low temperatures. A number of birds and small mammals may also nest in larger trees and shrubs.

In upland areas, trees and shrubs are best planted in locations where natural growth of the seedlings would normally occur. These locations include features such as north to westerly-facing slopes and gullies that are protected from the prevailing winds (Figure 9-6). Seedlings or containerized stock are best planted by hand in areas of rough topography. You may also want to take cuttings from willows and poplars in adjacent wooded areas, for planting within your reclamation site.
Contact your local Ministry of Forests' office for information on successfully growing trees and shrubs from cuttings. In areas where elk, moose and deer are abundant, it may be necessary to fence off your reclaimed site to prevent browsing of the newly planted ground covers, shrubs and trees. Most herbivorous (plant eating) wildlife prefer young plants, and can severely damage or pull out entire young plants while foraging.

Once your trees and shrubs are established, natural invasion of indigenous shrubs and trees may also occur.

**Special Habitat Features**

There are a number of special habitat features that you can develop to improve habitat conditions for wildlife. Many abrupt landform features on a site such as cliffs and gullies can be lost during site preparation and operations. However, other landform features such as highwalls, steep slopes, rock piles, and snags (dead trees) are created during site operations. Features such as these can often be retained for wildlife with only minimal modifications. They also can improve the scenic qualities of your site.

**Highwalls**

Rock highwalls are commonly created in most quarry operations, as well as some gravel pits in British Columbia. These highwalls can provide excellent opportunities for wildlife habitat enhancement.

Isolated ledges and holes on the rock face can provide a variety of nesting sites for hawks, eagles, and other birds (Figure 9-7). Overhanging cliff faces often provide important denning sites for other mammals such as marmots, foxes and coyotes. If features such as these are lacking, they can often be created or enhanced by dislodging rock chunks with a prybar, or chiseling or blasting small holes. Loose rock along the foot of a rock face should be left in place, as it provides habitat for a number of small mammals and birds.

**Rockpiles**

Large boulders or rock chunks are common waste materials in most pit and quarry operations. By retaining or building small piles of large rocks, you can create important habitat for small mammals, while also providing screening and hiding cover for larger mammals (Figure 9-8). Rock piles are best located in flat areas or along the bottom of small draws in the reclaimed pit and adjacent areas. Rockpiles should be 1 to 4 metres in height, and loosely stacked to provide small nooks and crannies for small animals. Rock piles along ridges or hilltops may also be used for roosting by hawks and other birds of prey.

**Brushpiles, Deadfall, and Snags**

You can use brush piles and deadfall to create temporary protective cover and perching sites for small animals and birds (Figure 9-9). In dry areas, however, these structures may be a fire hazard, so check with the Ministry of Forests first to determine if there are any restrictions on retaining brush piles and deadfall. Snags can also be mounted upright in concrete, rocks or holes.
Figure 9-10: A variety of structures can be used to provide nesting sites for waterfowl and other birds.

to provide nesting cavities for songbirds, or nesting sites for hawks, owls, and eagles (Figure 9-10).

You may also want to construct artificial nest structures for birds of prey or cavity-nesting birds (Figure 9-10). Bird houses and platforms can be mounted on wood or steel posts or nearby trees to provide new nesting and perching sites.

Management of Upland Habitat

Once you have completed seeding and planting of your site, you should control access by livestock and people to prevent damage to the new ground covers, and the tree and shrub seedlings. As a rule of thumb, no heavy traffic or grazing pressure should be permitted on a newly-reclaimed site for at least five years.

Fertilization of grass and other ground covers will often speed the establishment of a self-sustaining ground cover. During the first 1 to 3 years after planting of tree and shrub seedlings, you may want to water the seedlings during extended dry periods in the spring to summer period to maintain seedling survival and growth.

3. WETLAND HABITAT

During the operation of some pits, you may unintentionally create wetlands by excavating below the level of the permanent water table, or by creating depressions in sites with poorly drained soils (e.g., clays). Wetlands and ponds can add tremendously to a wildlife habitat project by providing a variety of new habitats and food sources for water-associated wildlife. The wetland margins and shorelines also provide highly productive habitat for upland and wetland wildlife.

An ideal wetland for wildlife should consist of interspersed areas of water that are less than and more than 1.5 metres deep. The shallow water depths will promote the growth of aquatic plants, whereas the deeper water will remain as open water. The dispersion of plants and open water provides wetland wildlife with abundant food, nesting sites, and protective cover. To be of value to nesting waterfowl, wetlands should also be surrounded with a wide margin of dense wetland and upland grasses.

Grading and Contouring

During the operation and reclamation of your pit, recontouring and grading should attempt to:

- provide site drainage features that will eventually channel surface runoff from the site and its surrounding area into the wetland, and
- create new landforms, above and below the waterline, such as irregular pond bottoms, islands, peninsulas, contoured banks, and mounds (Photo 9-6).

In general the greater the diversity of landforms, the greater the potential for wildlife use. This is true for both wetland and upland wildlife habitat.

Grading and contouring of your site should enhance water capturing capabilities and channel runoff towards the wetland basins. In particular, areas surrounding the wetland basin should be gently sloped towards the wetland.

A large variety of landforms can be created within a wetland basin during site development and reclamation. During grading and contouring, try to include one of more of the following features (Figures 9-11, 9-12):
Figure 9-11: Wetlands for wildlife should have an irregular shoreline, with a mixture of open meadows and shrubs in the surrounding area.

- Ponds and wetlands should have irregular, rough bottoms. Irregular bottom contours can be created by dumping overburden in an irregular fashion.
- Bottom slopes within the wetland should be contoured like terraces with slopes and flat sections as the depth increases. This provides a wide variety of water depths for establishment of aquatic plants.
- Wetland shorelines should be convoluted, with small bays, and fingers of land protruding into the water. Irregular shorelines such as this provide much more usable habitat for ducks and other wildlife.
- Water depths should range from 0.3 to 1.5 metres within 60 to 80% of the wetland area. At least 20 to 40% of the wetland should be a minimum of 3 metres deep.
- Nesting islands for ducks and geese can be constructed by dumping overburden or waste rock in distinct piles within the wetland (see Special Habitat Features below).

**Soil Placement and Water Retention**

If water levels in your wetland are not maintained by groundwater levels, the substrate material must be impervious to water. As a result, substrates such as clay deserve special attention.
• Any subsoils that contain clays should be stockpiled separately.
• When soils are replaced, the clay subsoil should be compacted over the entire wetland bottom to ensure a water-tight seal. Overburden and topsoil should only be placed down to 1.5 metres below the high water mark for the wetland. The organic soil will provide a good substrate for establishment of aquatic plants and water tolerant grasses.

Ensuring an Adequate Water Supply
Wetlands generally do not require a continual supply of clean water. In most cases, the water supplies from groundwater and from surface runoff will fulfill the requirements of a wetland project. Adequate water supplies may be provided from:
• Groundwater (if the wetland basin is below the permanent water table); and
• Surface runoff (if the surrounding area is contoured to enhance collection of surface run-off).

Although these two methods are often used to supply a wetland with water, these water sources cannot always be depended on. There are two alternate, and more expensive, methods:
• In sites that are close to watercourses or waterbodies, it may be possible to pump water into the wetland. However, pumping costs can be high.
• Water may be diverted from adjacent watercourses or waterbodies to the wetland.

In either case, you must obtain a permit from the Ministry of Environment, Lands and Parks (Water Management Branch) before any water diversion or pumping occurs.

Planting and Establishing Wetland Vegetation
There are four recognizable zones of vegetation that are typically found around wetlands. When seeding and planting vegetation, you should try to locate specific types of plants within the appropriate zone (Figure 9-13).

The Upland zone extends upward from the high water mark of the wetland, and will rarely, if ever, experience flooding. Trees, shrubs and groundcovers are usually typical of surrounding natural areas. Where possible, containerized tree and shrub seedlings should be planted upwind of the wetland to provide a windbreak.

The Wet Meadow zone is typically flooded for three or four weeks in the spring. It may extend from slightly above to 0.5 metres below the highwater mark of the wetland. Under natural conditions, shrubs such as willows and alders are common. Shrub seedlings and/or stem cuttings of willow, alder and dwarf birch may be used to establish shrub communities in these wet meadow areas.

The Shallow Marsh zone commonly contains a variety of sedges and water tolerant grasses, intermixed with a wide variety of broad-leaved forbs. This zone is normally located in the range of 0.1-1.0 metres below the highwater mark of the wetland. Sod-forming grasses such as red fescue or flood tolerant grasses such as reed canarygrass may be broadcast seeded immediately adjacent to the shoreline and will reduce erosion and enhance shoreline features. They also provide excellent nesting cover for waterfowl.
The Emergent zone is typically composed of sedges, rushes and reeds. Water depths in the emergent zone usually range from 0.5 to 2.0 metres below the highwater mark of the wetland. Commercial availability of such plants is limited but these species often establish themselves naturally after a few growing seasons. To speed up the establishment of wetland plants, you can transfer bottom ooze and rootstocks of plants from nearby natural wetlands on your property. Plugs of young aquatic plants or mature root masses may also be transplanted. As these plugs can initially be dislodged by waves or changing water levels, they should be secured with rock weights or metal stakes.

**Special Wetland Features**

**Islands**

Islands can provide safe nesting sites for waterfowl, as well as loafing and feeding sites. Islands also increase the amount of productive shoreline habitat.

Islands are best developed as part of the initial reclamation plan, as they are easier to construct before a wetland is flooded. Front-end loaders and bulldozers may be effectively used to create islands prior to flooding. Islands may be constructed of overburden, rock, or any other relatively stable fill material. The top of the islands should be at least 1 metre above the highwater mark of the wetland. Because vegetation provides important cover for wildlife, the island should be covered with topsoil and revegetated with grasses and a few low shrubs.

Islands should be separated from the shore by permanent water at least 1 to 2 metres deep and 4-5 metres wide (Figures 9-14, 9-15, 9-16). While the size of islands can be variable, it is generally more productive to have numerous small islands, than only a few large ones. However, because many waterfowl species are territorial, islands should be spaced at least 20 to 50 metres apart.

**Artificial Nest Structures**

Nest platforms, bales, and old tires may be used to provide and enhance nesting sites for waterfowl (Figure 9-17). Nest structures should be placed in 0.5 to 1.0 metres of water and should be located far enough apart so that waterfowl are secluded from each other.

![Figure 9-13](image)

**Figure 9-13:** To establish successfully, seeds and transplants of wetland vegetation must be located in sites with the correct water depth.

![Figure 9-14](image)

**Figure 9-14:** Nesting islands for waterfowl must be separated from the shoreline by permanent water.
Nest platforms and boxes can be mounted on telephone poles or nearby trees to provide nesting and perch sites for tree nesting species such as blue herons and double-breasted cormorants, or cavity nesters such as wood ducks or buffleheads.

- Nesting platforms should be 0.5 to 1.0 sq metres in size and should be lined with wire mesh. Platforms should be mounted in old trees or on telephone poles, at least 3 to 8 metres above the water (Figure 9-10).
- Nesting platforms should be located close to the windward side of the pond to minimize wave erosion.
- Nesting platforms should be 4 to 5 metres wide, with the long axis parallel to the prevailing wind.
- Nesting platforms should be mounted in old trees or on telephone poles, at least 3 to 8 metres above the water (Figure 9-10).
- Nesting platforms should be placed in at least 0.3 metres of water and the level of the nest platform should be at least 1.0 metre above high water level (Figure 9-10).
- Nesting platforms should be mounted in old trees or on telephone poles, at least 3 to 8 metres above the water (Figure 9-10).
- Nesting platforms should be placed in at least 0.3 metres of water and the level of the nest platform should be at least 1.0 metre above high water level (Figure 9-10).
- Nesting platforms should be placed in at least 0.3 metres of water and the level of the nest platform should be at least 1.0 metre above high water level (Figure 9-10).

Round hay bales can be used to provide excellent nesting sites for Canada geese and ducks (Figure 9-11). Flax bales last longest, and should be wrapped with hog wire to keep the bale together. Bales should be placed 10 metres or more offshore in water no deeper than 1.0 metre. A minimum of 1ha of wetland is required for each nesting bale. Bales can be easily placed in a wetland by dropping the bale through a hole in the ice during winter.

Advice on nesting structures for waterfowl are available through your local office of the Wildlife Branch or the Canadian Wildlife Service. Ducks Unlimited also can provide valuable information.

Management of Wetland Habitat

Wetlands, like upland areas, may require fencing during the first several growing seasons to allow vegetation establishment. As wetland vegetation tends to die out when continuously flooded, the wetland should be partially drained every 5 to 7 years to allow re-establishment of aquatic plants. Natural cycles of drought and wet spells will sometimes provide adequate changes in water levels. However, you may want to install an outlet with a controllable weir on your wetland to permit easier management of water levels.
4. OTHER SOURCES OF INFORMATION

For additional information on reclaiming wildlife habitat, write or phone:

**Head Office - Wildlife Branch,**
Ministry of Environment, Lands and Parks,
780 Blanshard Street,
Victoria, B.C. V8V 1X4
Telephone: (604) 387-1161 Fax: (604) 356-9145

**Fish and Wildlife Regional Offices**

**Northern Interior Regional Headquarters**
Telephone: (604) 565-6145 Fax: (604) 565-6629

**Southern Interior Sub-Regional Office**
Telephone: (604) 490-8200 Fax: (604) 492-1314

**Kootenay Regional Headquarters**
Telephone: (604) 354-6344 Fax: (604) 354-6332

**Vancouver Island Regional Headquarters**
Telephone: (604) 721-3211 Fax: (604) 755-2473

**Southern Interior Regional Headquarters**
Telephone: (604) 371-6200 Fax: (604) 828-4000

**Skeena Regional Headquarters**
Telephone: (604) 847-7303 Fax: (604) 847-7728

**Lower Mainland Regional Headquarters**
Telephone: (604) 582-5200 Fax: (604) 660-8926

**Northern Sub-Regional Office**
Telephone: (604) 398-4562 Fax: (604) 398-4214

Within British Columbia, you can contact any government agency toll free through the Enquiry BC system by calling 1-800-663-7867.

Additional assistance on reclamation of wildlife habitat can be obtained from:

**Ducks Unlimited,**
Box 1170, Station “A”
14343-44th Ave.
Surrey, B.C. V3S 4P6
Telephone: (604) 591-1104

**Wildlife Habitat Canada,**
14343 - 44th Avenue,
Surrey, British Columbia
Telephone: (604) 591-1104

**Books and Reports**

Wildlife Handbooks for the Southern Interior Ecoprovince. 9 Volumes. Wildlife Branch, Ministry of Environment, Lands and Parks. Victoria, B.C.

Fish habitat may be a viable end use for your operation if adequate water supplies are present. Fish habitat projects are often compatible with other end uses, particularly in combination with the development of wetland habitat.

Like wildlife habitat, the fish habitat end use has been abused by some operators in the province. Some pit and quarry operations have used fish habitat creation as an excuse to excavate below the water table, and to leave the raw extraction areas to fill with water. Fish habitat requires careful re-contouring, re-establishment of cover, replacement of subsoils and topsoils in shallow water areas, and even replanting with aquatic plants.

If you have selected fish habitat as the end land use for your pit or quarry, or as a secondary use to include with other land uses, this chapter provides a summary of the issues you may encounter in planning your project. Some of the issues are complex. Before finalizing a project, you should examine the recommended literature at the end of this chapter and discuss your ideas with a biologist from the Ministry of Environment, Lands and Parks.

- Important considerations in reclaiming fish habitat on your site:
  - regulations and approvals,
  - type of fish and fish habitat,
  - water availability,
  - water quality,
  - shape, size and depth of your pit or quarry, and
  - progressive reclamation and development.

- Methods for reclamation:
  - grading and contouring,
  - creating suitable waterbodies for fish,
  - spawning,
  - ensuring an adequate water supply,
  - maintaining water quality, and
  - providing adequate food.

1. IMPORTANT CONSIDERATIONS IN DEVELOPING YOUR OPERATION

Regulations and Approvals

Before planning and reclaiming your site, be sure to contact the local office of the Ministry of Environment, Lands and Parks. Their permits are required both for modifications to wild fish habitat and for freshwater fish in ponds. If your project site contains salmon or salmon habitat, permission of the Department of Fisheries and Oceans will also be required. Biologists at these offices will not only ensure that your proposal meets current regulations, but will direct you to information sources that will help in your planning process.

Local ordinances as well as current and proposed zoning regulations should also be reviewed. These regulations, established by Regional Districts or Municipalities, will allow you to determine if development of fish habitat will be allowed on your site and what types of restrictions may apply.

Type of Fish and Fish Habitat

Fish habitats in reclaimed pits or quarries generally fall into one of two types: wild and cultured. Where there is a well defined surface flow, spawning or rearing habitats for nearby stocks of wild fish can be created (Photo 10-1). Alternately, flooded excavations can be used as fish ponds to culture fish for commercial or recreational use. Selection of the best fish habitat type is generally dictated by the nature of the site.

Wild trout and coho salmon can benefit from habitat works associated from rehabilitated pits and quarries - as long as there is a free flowing connection to natural stream systems. Where gravel pits or quarries are located in flood plain areas, it is often possible to divert a small watercourse or seepage through the excavation and develop one or more ponds that provide rearing and spawning habitats for the wild fish to colonize. Alternately, small water courses on pit sites can be rehabilitated to develop additional habitat.
In British Columbia, freshwater fish culture (both commercial and private) is regulated by Ministry of Environment, Lands and Parks who are very concerned about the potential impact of escaped farm fish and their diseases on wild stocks. As a result, fish culture is generally limited to native rainbow trout stock that are available from provincial hatcheries and commercial suppliers. Other salmon species, such as brook trout and kokanee, may also be approved as long as they are available from provincial hatcheries and commercial sources in British Columbia. There are some instances of carp production in the Fraser Valley, but this is very limited. Regardless of species, domestic fish must never be released to the wild.

**Water Availability**

Trout and salmon require continuous supplies of clean, fresh water. Fish habitat should not be contemplated unless the site has a reliable source of water. Ponds may sometimes form in pits or quarries if local runoff is sufficient and the pond bottom is well sealed. Ponds may also be created when pits are excavated below the groundwater table. In many cases, however, you will need to obtain additional water to maintain water quality, as well as water levels. In some cases, water can be pumped from adjacent watercourses or waterbodies or diverted from local streams, if authorized by the Ministry of Environment, Lands and Parks Water Management Branch.

Wild fish also prefer habitats with steady flows. This not only ensures water quality, but helps the fish find your habitat. Fish may also move back and forth between the reclaimed habitat and nearby streams or lakes.

Water flow limits the number of fish a habitat can support. In an earthen pond, with a water depth of 2m or more, and with little or no water flow, trout should not be stocked at more than about 6 kg/m³. Under good conditions, with a higher rate of flow, this can be increased to as much as 30 kg/m³.

**Water Quality**

Salmon and trout are sensitive to the temperature and dissolved oxygen content of water as well as other chemical characteristics. Temperatures of 10-18°C are best for trout growth. Higher temperatures encourage disease while those above 24°C generally result in death. Summer temperatures below 10°C slow growth.

Salmon and trout breath oxygen dissolved in the water. As water warms, its ability to hold oxygen decreases while the fish's metabolic consumption of oxygen increases. Where water is derived from a stream source, this may not be of concern. However, it severely limits the capacity of isolated ponds. As a rule of thumb, ponds should have an oxygen content of 5-6 mg/L at their outlet.

If you propose to use a natural surface water supply that already contains fish, the water quality is probably adequate. However, if you are planning to rear fish in high densities, or on using groundwater, or surface waters that do not have any wild fish, it is advisable to have the water quality examined. This will help to ensure the success of the project and is inexpensive, relative to the cost of reclamation. Samples can be analysed at laboratories throughout British Columbia. Water quality criteria for aquatic life are summarized below:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Recommended Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>6.7 - 9.0</td>
</tr>
<tr>
<td>Alkalinity</td>
<td>20 - 200 mg/L</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>maximum of 2 mg/L</td>
</tr>
<tr>
<td>Calcium</td>
<td>minimum of 52 mg/L</td>
</tr>
<tr>
<td>Zinc</td>
<td>maximum of 0.04 mg/L at pH 7.6</td>
</tr>
<tr>
<td>Copper</td>
<td>maximum of 0.006 mg/L in soft water</td>
</tr>
<tr>
<td>Iron</td>
<td>maximum of 1.0 mg/L</td>
</tr>
<tr>
<td>Ammonia-nitrogen</td>
<td>maximum of 0.012 mg/L as NH₃</td>
</tr>
<tr>
<td>Nitrite-nitrogen</td>
<td>maximum of 0.55 mg/L</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>maximum of 110% of total saturation</td>
</tr>
<tr>
<td>Suspended solids</td>
<td>maximum of 80 mg/L</td>
</tr>
<tr>
<td>Dissolved solids</td>
<td>maximum of 400 mg/L</td>
</tr>
<tr>
<td>Hydrogen sulfide</td>
<td>maximum of 0.002 mg/L</td>
</tr>
</tbody>
</table>

Fish can sometimes tolerate conditions outside these ranges, however growth and survivals may be reduced. An experienced fish culture biologist should be consulted.

**Shape, Size and Depth of Pit**

The shape of an excavation is of little concern for fish use. However, if your pit has an irregular shoreline, it will provide a greater variety of habitats for fish. As discussed in Chapter 9, irregular shorelines also benefit wetland wildlife. However, the size of your pit or quarry does determine its capacity. Where fish are reared for angling, size can commonly be summarized as:

- Ponds up to 2.0 hectares in size can serve one or two fishers, or provide a family trout pond.
• Ponds for public use must be much larger, or re-stocked regularly to accommodate a full season of fishing.

The depth of your pit is perhaps the most important, limiting characteristic. As shallow, surface pits are likely to fill in with aquatic weeds and will not support fish, they are best developed as wetland habitat. Pits less than 2 m in depth are also likely to become too warm in summer unless there is a substantial water flow. Good quality ponds for rearing and overwintering of fish can have varying depths but require either one or more deep water zones of at least 5 to 8 metres deep or steady flushing flows.

In static ponds, good wind exposure is important. Wind helps to circulate the water and replace oxygen. The movement of water also deters the formation of algal mats on the surface. Thorough, wind induced mixing prior to fall freeze-up and immediately after spring break-up can also reduce the fish losses that sometimes result from over winter oxygen depletion.

Progressive Development and Reclamation

Progressive development and reclamation can be put to use in preparing the bed of your pit. While equipment is available, numerous landforms can be created to enhance underwater habitat and fishing conditions. The requirement of water for a fisheries operation generally precludes the flooding of one section of the extraction facility while work is ongoing in other sections, unless the sections are separate excavations and the water from one does not drain into the other. If a vegetation cover is established, it will better prepare the bottom of the pit for eventual flooding.

2. METHODS FOR RECLAMATION

Grading and Contouring

During the operating period of your pit, overburden and waste materials can be re-deposited and graded into diverse landforms above and below the waterline.

Steep pit slopes can provide excellent offshore angling opportunities because of the depth and shade that they provide near the shoreline. Both juvenile and adult fish are often found close to cutbanks and steep slopes. However, steep pit slopes should be retained only if they are stable rock cliffs. Loose soil and gravel highwalls are likely to undercut or slump, and are a safety hazard.

Where recreational angling is desired, the banks should be graded to a slope of 3H:1V whenever possible. This will minimize weed growth along the shore, and provide better access for casting and landing fish. To provide adequate cover for fish, you can build artificial reefs and shoals offshore (see below) where they will not interfere with shoreline angling.

Fish habitats should also include areas with shallower slopes to encourage aquatic plant growth and nursery areas for fish. These shallow areas will also benefit waterfowl. Construction of terraced slopes with shallow slopes (Figure 10-1) create a variety of water depths. This diversity of water depths provides suitable areas for different types and heights of aquatic plants that provide shade and hiding cover for juvenile and adult fish.

Creating Suitable Waterbodies for Fish

Depth

Your fish habitat will be most productive when a variety of water depths are provided. As a general rule of thumb for ponds:

- Approximately one third of the water surface area should have minimum depths of 5 to 8 metres. This provides overwintering areas for fish;
- Approximately one quarter of the water area should be shallow with depths of 0.5 to 1.5 m; and
- The remaining areas should have variable depths between these two extremes.

Depth is less critical in stream situations as long as the water flow is continuous. However, at least a third of the stream should be pools that are deep enough to provide refuge during periods of flood, drought, or ice formation.

Gradient

Stream habitats for wild fish should be considered only in areas with a gradient of less than 3%. Although fish may be capable of passing through reaches of higher gradient, they are unlikely to colonize them. If a small waterfall or cascade separates your low gradient stream from downstream waters that contain fish, it may be possible to construct a fishway to guide colonizing fish past the barrier. However, these are difficult to design and expert help will be required.
Old tires can be used to create reefs and shoals for fish. If the bottom of your pit has already been smoothly graded, or if few opportunities exist to create irregular bottom contours, you should consider adding structures that will provide underwater cover for fish. These structures often provide good habitat for fish prey. Prior to flooding of the pit, you can construct a number of artificial “reefs” or shoals using materials such as:

- Brush piles,
- Anchored, submerged tree crowns,
- Bundles of old tires (Figure 10-2), or
- Loose piles of rock, concrete blocks and broken tiles (see Figure 10-3).

These artificial reefs can also be hauled onto the ice during winter, and allowed to sink the following spring.

In shallow bays and other nearshore areas (up to 2 metres in depth), rooted aquatic plants will provide protective cover for rainbow trout and smaller fish, as well as habitat for many other aquatic organisms. Although a variety of aquatic plants will eventually establish themselves, the process can be accelerated by transplanting plugs of aquatic plants or mats of floating plants from adjacent wetlands. Plugs of cattails, bulrush and sedges can be dug by hand or with a backhoe. Just prior to flooding, these plugs should be firmly planted in the bottom substrate, and anchored with a rock.

**Shoreline Vegetation**

Shade is important for some fish species, such as trout. By planting trees, brush, and other vegetation along side or overhanging the banks of your fish habitat, you can provide shade cover, and greatly improve fish production. This is particularly valuable if there are deep pools within the shaded area. Insects in the shoreline...
vegetation are a good source of food for fish, as they often drop on, or fly over, the surface of the water.

Shrub seedlings and stem cuttings of willow, alder, cottonwood, and dwarf birch are useful in establishing shrub communities along the shoreline of fish ponds.

One problem with planting trees along the shore is that the leaves will fall into the water in autumn. Leaves then use up oxygen during the water as they decay. If too much dissolved oxygen is taken from an isolated pond, winter kill can occur. If your fish habitat does not have a continuous fresh water supply, only a small number of deciduous (broadleaves) trees should be planted along the shoreline.

**Spawning**

Rainbow trout and salmon are stream spawners that require clean gravels and inflowing streams. These fish bury their eggs in select parts of the stream, usually in riffles at the lower boundary of pools where there are clean gravels, little sand, and no large rocks. These areas, which are low in sediments but high in gravels, provide good hiding places. Sites without these characteristics will not support natural reproduction and cultured stocks will need to be restocked periodically.

Spawning habitat for trout must have two basic characteristics:

- Clean gravels in which the fish can lay their eggs, and
- Moving water to carry oxygen to the eggs, and remove wastes and silt from around the eggs.

This type of habitat is not commonly available in reclaimed ponds. However, it may occur upstream or downstream along inlet and outlet channels to your fish habitat.

**Ensuring an Adequate Water Supply**

Your fish habitat should have a supply of fresh water throughout most of the open water period to maintain water quality, and to replace water that is lost through evaporation and seepage. The best situation is a continual flow of fresh water through an inlet and outlet channel.

Potential supplies of fresh water for wild fish habitat include:

- Water from adjacent rivers and streams can be pumped or diverted to your project. Steady flows of this type are particularly important in coho rearing habitats. As noted earlier, without a well-defined flow, the fish may not find or use your habitat.
- Exposed groundwater tables during excavation below the permanent water table often provide high quality water conditions, and can be developed as good fish habitat.
- Exposed groundwater tables during excavation below the permanent water table often provide high quality water conditions, and can be developed as good fish habitat.

Water for ponds can be obtained from:

- High quality groundwater reserves may be accessible from deep wells. However, the mineral content and dissolved oxygen of some groundwater may make it unsuitable for fish use (Photo 10-2).
- Use of irrigation water may be allowed in some irrigation districts. To use irrigation water, you will need to obtain a user permit. You will also need to build a pipeline or lateral ditch to your pond. As irrigation canals may contain undesirable fish such as suckers, the inlet should be screened. This type of development will require careful review and input from government agencies.

Regardless of the water source, pumping of water into a pond can be costly. All of these options require authorization and permitting by the Water Management Branch of the Ministry of Environment, Lands and Parks.

**Screens**

Where a trout pond drains into a natural watercourse, some form of screen or filter is required to prevent fish escaping into the wild. If surface water is used as a water source, the intake must be similarly screened to prevent wild fish from entering.

**Maintaining Water Quality**

Water quality in fish habitats can be affected by both the biological process in the water and by contamination from outside sources. The biological processes that cause problems usually fall into two groups: oxygen depletion, and build-up of waste.

Dissolved oxygen depression generally occurs under winter ice, or when large amounts of leaves, litter, grass, or other organic material decays in the water. Oxygen depletion under ice in winter is a function of both ice cover (that seals off the oxygen supply), fish metabolism (that uses oxygen) and decaying organic material (that uses up additional oxygen). Obviously the significance of this problem varies from location to location.

If oxygen levels become too low, fish kills will occur. Some possible solutions include:
Exposed water tables during excavation can provide high quality water for fish habitat.

Cattle manure can be a local source of water pollution.

Incorrect application of herbicides and pesticides can be a local source of water pollution.

Construction of one or more deep water zones (5 to 8 metres) to provide adequate supplies of oxygen for overwintering fish. Note, however, that under-ice conditions must allow mixing of water to maintain adequate oxygen for fish.

Increasing water flow through the pond.

Building fish habitat in exposed locations that permit wind to circulate and mix the water.

Controlling inputs of leaves, aquatic plants and other organic material.

Reducing the number of fish stocked in the pond.

Aeration of the water using wind or motor driven pumps. By injecting air bubbles into the deeper areas of the pond, oxygen levels can be increased through direct aeration, mixing of the water, and by creating open water areas in the ice (Figure 10-4).

Water quality is usually best when a fresh supply of clean, clear water is available to the fish habitat. There are a number of situations, however, where outside contaminants can seriously degrade water quality. These include:

- Fertilizer-rich runoff from farm fields,
- Leaching of nutrients from cattle yards and feedlots (Photo 10-3), and
- Over spraying of herbicides and insecticides (Photo 10-4).

Surface drainage from these types of areas should be directed away from the drainage basin for your fish habitat. You should also avoid use of fertilizers, insecticides and herbicides in the vicinity of fish habitat.

Providing Adequate Food

Adequate food for fish is generally provided if external surface water sources are used for water maintenance. However, if your fish habitat is maintained by cold groundwater sources, there may be inadequate foods for fish, particularly during the first 3 to 5 years after reclamation. In that case it may be necessary either to stock fish at very low densities, or to supplement the food supply with commercial fish feed.

Once a pond or stream channel is established, aquatic plants, bottom substrates and artificial "reefs" can provide habitats for small aquatic mammals and plants that are important fish foods. As noted above, trees and shrubs along the shoreline can provide a good supply of insects for fish.

In general both trout and coho feed on aquatic organisms that are typically present in British Columbia waters. These fish also feed on insects, leeches, clams, snails, and occasionally on small fish.
3. OTHER SOURCES OF INFORMATION

For additional information on reclaiming fish habitat, write or phone the agencies listed below. For the most part these are district offices: there may be smaller offices nearer your location.

**Permitting for Freshwater Fish Culture and Fish Habitat Protection**

Fisheries Branch
Ministry of Environment, Lands and Parks
3rd Floor, 780 Blanshard St., Victoria, B.C. V8V 1X4
Telephone: (604) 387-9591 Fax: (604) 387-9750

**REGIONAL OFFICES**

**Northern Interior Regional Headquarters**
Telephone: (604) 565-6145 Fax: (604) 565-6629

**Southern Interior Sub-Regional Office**
Telephone: (604) 490-8200 Fax: (604) 492-1314

**Kootenay Regional Headquarters**
Telephone: (604) 354-6344 Fax: (604) 354-6332

**Vancouver Island Regional Headquarters**
Telephone: (604) 731-3211 Fax: (604) 755-2473

**Southern Interior Regional Headquarters**
Telephone: (604) 371-6200 Fax: (604) 828-4000

**Skeena Regional Headquarters**
Telephone: (604) 847-7303 Fax: (604) 847-7728

**Lower Mainland Regional Headquarters**
Telephone: (604) 582-5200 Fax: (604) 660-8926

**Northern Sub-Regional Office**
Telephone: (604) 398-4562 Fax: (604) 398-4214

**Salmon Habitats**

**Habitat Management Division**
Department of Fisheries and Oceans
3rd floor, 555 West Hastings,
Vancouver, B.C. V6B 5G3
Telephone: (604) 666-6566 Fax (604) 666-7907

**Fish Farming and Pond Management**

Aquaculture Industry Development
Ministry of Agriculture, Fisheries and Food
1st Floor, 808 Douglas St.
Victoria, B.C. V8W 2Z7
Telephone: (604) 387-9580 Fax (604) 356-7280

Within British Columbia, you can contact any government agency toll free through the Enquiry BC system by calling 1-800-663-7867.

**Books and Reports**


Department of Fisheries and Oceans. 1986. The Department of Fisheries and Oceans Policy for the Management of Fish Habitat. Ottawa. 28 p.
If you have selected recreation as the end land use for your pit or quarry, or as a secondary use to include with other land uses, this chapter provides specific information on issues that may affect your choice of recreation developments:

- Important considerations in reclaiming your site for recreation:
  - adjacent land uses,
  - local zoning,
  - types of recreational use,
  - design stages for your recreation area, and
  - progressive reclamation and development.

- Methods for reclamation:
  - grading and contouring,
  - site drainage,
  - creation of waterbodies,
  - replanting trees, shrubs and groundcovers,
  - providing public facilities.

Recreation can mean many things to different people. It can include a wide range of different activities from physical challenges to solitude, social gatherings, and wilderness experiences (Photo 11-1). Recreation can generally be defined as any activity that takes place in the absence of other demands on our time, where there are no commitments or products to produce.

In British Columbia, there are many examples of pits and quarries that have been successfully reclaimed for recreational end uses. Probably the most beautiful example of a successfully reclaimed quarry is The Butchart Gardens, in Victoria (Photo 11-2). Other reclamation examples include sand and gravel pits that have been reclaimed by the Ministry of Transportation and Highways or BC Parks to provide campsites or highway pullouts.

To be successful, reclamation of a pit or quarry for recreation must address five objectives:

- **Uniqueness**: Recreational developments should be based on natural and cultural themes that are important in the local area.

- **Environmental responsibility**: Recreational opportunities should be compatible with the site conditions, surrounding landforms and adjacent land uses, while also meeting user demands.

- **Balanced Integration**: The level of site development must be compatible with the capacity of the reclaimed area to support recreation.

- **Economic Viability**: Recreational developments must be economic to construct, maintain and operate.

- **Flexibility**: The framework for development and final reclamation of the pit or quarry must be able to accommodate ongoing changes in adjacent land uses and the environment.

As with all land uses, effective planning for a recreational end use should be part of the design and operational phases for your pit.
1. IMPORTANT CONSIDERATIONS IN DEVELOPING YOUR OPERATION

Protecting resources and retaining natural scenic beauty are essential to providing quality natural recreation experiences. Because of this, you should identify the important landscape features within and adjacent to your proposed pit or quarry. The abundance and variety of landscape elements that exist on and adjacent to the site need to be recorded. Based on these features, you can then establish objectives for retaining and protecting visual qualities. Once you have identified the types of visual elements that will be kept or developed in and around your development, you can then select the recreational activities that best suit these conditions, or use natural elements to highlight desired recreational activities.

Adjacent Land Use

To determine if your pit has potential for recreation, it is first necessary to consider the types of land uses that occur around your site (see Chapter 6). Establishing current and proposed (if possible) land uses will assist you in determining the most suitable type of recreation facility for your reclamation area. For example, the development of a recreational put-and-take fishing pond could be a great attraction, if there are few local opportunities for lake or stream fishing.

In addition to adjacent land uses, you must also consider the proximity of your site to other recreation facilities, the services these other sites offer, and your potential to attract recreation area users. Other important considerations include:

- the location of your site relative to tourist travel routes,
- the numbers and origin of potential users (urban versus rural use),
- proximity to recreational water bodies,
- available utility services, and
- health and development regulations.

Local Zoning

Before planning and developing your site, be sure to review local ordinances and current and proposed zoning regulations. These regulations, established by the Regional Districts, Municipalities, and the Provincial Government, will allow you to determine if a recreation development will be allowed on your site and what types of recreation will be permitted.

Type of Recreational Use

The type of recreational use you provide will depend on two major factors: the size of your reclamation area, and market demands.

The amount of area available is important in determining the potential for different recreational activities. For example, campgrounds will require the greatest amount of area. Back-in spur campsites on loop roads are the most common arrangement. Sites are generally spaced 30 meters on centre and are 10 meters wide (Figure 11-1). Picnic and other types of day use areas vary in size depending on the type of facility. In all cases adequate parking and basic user comfort facilities must be provided.

![Figure 11-1: Typical layout for back-in spur campsites.](image)

Market demand will provide an indication as to what type of recreation facilities are required. These may vary from intensely developed commercial theme parks to convenient roadside rest areas. To determine the best type of recreational use for your site, first determine the overall area and the quality of your site's main features. Important features include the types and location of:

- landforms such as rolling hills, flat areas, and bluffs,
- waterforms such as ponds, wetlands and streams,
- forested and open vegetative communities, and
- historical and prehistoric cultural sites

If you are uncertain of your site's potential, government agencies such as the Ministry of Housing, Recreation, and Consumer Services can assist you in identifying potential recreational uses, as well as important local and regional needs. You should then assess your potential to service the desired market. For large reclamation areas, you may want to retain a consultant to assist with the determination of the most appropriate
recreational activities to provide. On public lands the British Columbia Ministry of Environment, Lands and Parks (Crown Lands) or Ministry of Forests will often stipulate the preferred end use.

**Design Stages for Your Recreational Area**

Once you have decided to reclaim your pit or quarry to provide recreational facilities, you should design an overall site plan. As noted above, you should develop your site plan along with the site extraction plans in order to maximize the advantages of both the site resources and the planned recreation activity. The design of your site plan should involve four stages:

- **programming**
- **planning**
- **concept design, and**
- **detailed design**

**Programming**

During the programming stage, you will need to consider regional and local markets for recreation. On the basis of your review of market demands, you can develop objectives that outline the facilities you want to provide, establish a development schedule, and set your overall budget. Seasonal considerations should be included in your objectives. Summer, for example, may include activities such as picnicking, hiking, all terrain vehicle usage, camping, swimming, fishing, archery, shooting, and wildlife observation. Winter activities may include cross country skiing, snowmobiling, skating, and camping.

**Planning**

During the planning stage, you will need to determine the specific areas and locational requirements for each of the recreational uses that you have proposed. You should also consider how each of these uses will relate to each other in terms of space, location, season of use and type of activities. These uses should then be illustrated on a site zoning plan (Figure 11-2). The zoning plan should also identify sensitive environmental areas such as erosion-prone soils and slopes, plant communities, waterbodies, and watercourses. Remember to consider the local development regulations and guidelines as part of this planning process.
Concept Design

The concept design is similar to a zoning plan, but provides more detail on the proposed types of facilities for each recreational use (Figure 11-3). The concept design illustrates the different types of uses, and sets out the general dimensions and relationships between each of the recreation facilities to be provided. Your concept plan should be of sufficient detail to allow development permit applications to be made. For larger recreational projects such as golf courses, engineering studies are usually required for site drainage and facility development. As the concept design and engineering studies are completed, the project schedule and budget should also be refined.

Detailed Design

The detailed design is the final step in the design process, and includes the preparation of working drawings and specifications that are suitable to permit construction (Figure 11-4). Your detailed design should set out the specific quality and quantity requirements for your recreational project, such as:

- final landforms,
- utility locations,
- roads and parking,
- site developments including buildings,
- landscaping, and
- maintenance and operations.

Progressive Development and Reclamation

As with most land uses, progressive development and reclamation of your pit or quarry is strongly recommended. For recreational land uses, progressive development and reclamation will permit you to sequentially develop different areas for specific recreational uses. By minimizing the actively disturbed area of the pit, progressive development and reclamation also limits the visual impacts of extraction on existing and proposed recreational uses.

2. METHODS FOR RECLAMATION

Grading and Contouring

For recreational end uses, grading and contouring of a pit or quarry is often necessary to create:
Site Drainage

As depressional areas are usually created during the development of pits and quarries, it is important that you develop adequate site drainage to provide well-drained areas for land-related recreational activities. In contrast, you may want to direct local surface runoff to provide water for tree and shrub plantings, or wetlands and ponds. Basic approaches to site drainage are discussed in Chapter 3.

Creation of Waterbodies

During the grading and contouring of your site, it is often possible to direct surface runoff towards specific depressions or low areas to create a pond or wetland. Where your pit or quarry has exposed the groundwater table, water levels in these areas will often be maintained by groundwater sources. However, if ponds and wetlands are to be valuable assets for your recreational use, the area surrounding the waterbody should be shaped to provide a natural-looking basin (Photo 11-3). Users shouldn't feel like they're in a hole. In addition, some ponds may become unsightly due to algal growth. You may wish to consult a limnologist regarding pond design and water flow requirements to prevent unwanted algal growth.

Replanting Trees, Shrubs and Groundcovers

If all or part of your pit operation has been cleared out of an existing forest, the trees along the forest edge are often prone to blowdown until they establish a more sturdy root system. Trees that have blown down should only be removed if they are unsightly or present a hazard to the recreational use of the area.

Groundcovers (grasses and forbs) should be established as early as possible in the reclamation process in order to reduce erosion, control dust, and improve the quality of the soil. In the short-term, you may want to plant forage crops to control erosion and reduce impacts on adjoining properties (a good neighbor policy). In the long-term, you will want to select groundcovers that best suit the proposed recreational use. For organized activities such as playing fields and picnic sites, you will want to select grasses that can withstand heavy foot traffic. In nature-oriented recreational areas, you may want to plant palatable groundcovers to entice wildlife (see Chapter 9).

For many recreational uses, you will want to plant trees and shrubs to:
• separate different recreational activities, such as playing fields and picnic sites, from one another,
• define specific areas such as individual campsites or picnic sites,
• screen natural areas from areas for organized activities, and
• improve the scenic quality of your site.

You should only plant trees and shrubs that are proven to be hardy for your region. As a rule of thumb, the most suitable types of trees and shrubs will be those that existed on your site prior to development, or that exist in adjacent areas.

Providing Public Facilities
Depending on the type of recreational activities that you select, and the number and type of users, you may need to provide basic facilities such as toilets (pit privies/flush toilets) drinking water, garbage disposal and parking. Additional facilities such as picnic tables and shelters, fire circles, trails and the development of site amenities may also be required, and can greatly improve the recreational values of your site (Photo 11-4). In some locations such as urban fringes, interpretive signs could be posted describing the development and reclamation process for your pit.

3. OTHER SOURCES OF INFORMATION
In order to determine the local needs for tourism and recreation in your area the following government and non-government agencies may be able to assist you:

Ministry of Small Business, Tourism and Culture
Tourism Division, Research and Economic Analysis Suite 300 -1803 Douglas St.
Victoria, B.C. V8T 5C3
Telephone: (604) 387-1566 Fax: (604) 387-5774

Within British Columbia, you can contact any government agency toll free through the Enquiry BC system by calling 1-800-663-7867.

Non-Government Organizations
Tourism Association of Vancouver Island
Victoria, B.C.
Telephone: (604) 382-3551 FAX: (604) 382-3523

Okanagan Similkameen Tourist Association
Kelowna, B.C.
Telephone: (604) 860-5999 Fax: (604) 861-7473

Kootenay Country Tourist Association
Nelson, B.C.
Telephone: (604) 352-6033 Fax: (604) 352-1656

High Country Tourist Association
Kamloops, B.C.
Telephone: (604) 372-7770 Fax: (604) 828-4656

Cariboo Tourist Association
Williams Lake, B.C.
Telephone: (604) 392-2226 Fax: (604) 392-2838

North by Northwest Tourism Association of B.C.
Smithers, B.C.
Telephone: (604) 847-5227 Fax: (604) 847-7585

Peace River Alaska Highway Tourist Association
Fort St. John, B.C.
Telephone: (604) 785-2544 Fax: (604) 785-4424

BC Rocky Mountain Visitors Association
Kimberley, B.C.
Telephone: (604) 427-4838 Fax: (604) 427-3344

Additional technical information on reclaiming land for recreation may be available from:

B.C. Society of Landscape Architects
P.O. Box 326 Stn A.
Vancouver, B.C. V6C 2M7
Telephone: (604) 732-5390
Chapter 12

Reclaiming for Residential and Industrial Uses

If you have selected residential and industrial land uses as the end use for your pit and quarry, this chapter provides specific information on issues that may affect your choice of residential or industrial development.

- Important considerations in reclaiming your site for residential and industrial uses:
  - municipal and regional bylaws,
  - adjacent land uses,
  - demand for development sites,
  - access,
  - keeping your development concepts flexible, and
  - progressive reclamation and development.

- Situations to avoid:
  - shallow groundwater,
  - flooding potential,
  - poor foundation conditions, and
  - undevelopable areas.

- Methods for reclamation:
  - backfilling,
  - grading and contouring,
  - development of slopes,
  - site drainage,
  - replacing overburden and topsoil, and
  - re-establishing plant cover.

Civil engineering firms who are qualified in the provision of municipal services will provide valuable advice on the above, and the general concept, as will the engineering department of local government.

1. Important Considerations in Developing Your Operation

Municipal and Regional By-Laws

Development of pits and quarries for residential or industrial use must conform to provincial, municipal and regional district zoning regulations. Under the British Columbia Municipal Act, municipalities and regional districts can:

- establish community plans and regulate the use of land,
- specify guidelines for land subdivision and land use regulation.

As a result, your municipality or regional district must approve development of plans for residential and industrial use (Chapter 3). They must also ensure the proposed end land use is compatible with land use and zoning regulations. If you have decided to develop your pit for residential or industrial uses, you should maintain close contact with municipal staff throughout the planning, development and reclamation phases of your operation.

Local Zoning

Zoning by-laws are enacted by the municipalities and regional districts to ensure that development proceeds in compliance with planning guidelines and regulations. Before planning and developing your site, be sure to review local ordinances and current and proposed zoning regulations. These regulations, established by the Regional District and Municipal offices, and the Provincial Government, will allow you to determine if residential and/or industrial land uses will be permitted on your site.

Adjacent Land Use

Zoning will normally ensure that your proposed residential or industrial land use is compatible with adjacent land uses. However, if your pit is close to a major urban area, land use may be in transition, tending to change over time from farming or range lands to residential and industrial uses. A high density residential or industrial land use may be appropriate in this case. On the other hand, only a low density residential development (such as acreages) might be compatible with other rural land uses. Industrial and high density residential developments would not likely be acceptable.

Demand for Development Sites

Assuming that you can obtain zoning approval for your residential or industrial land use, you should ensure there is or will be a demand for your proposed use. Demand will often depend on the location of the property relative to city centres and transportation routes. Your municipality should be able to assist you in determining the demand for your proposed residential or industrial use. On public lands, Ministry of Environment, Lands and Parks (Crown Lands) or Ministry of Forests will often stipulate the preferred land use.
Access
Road access to your site is a very important factor in assessing the suitability of your site for either residential or industrial development. If your operation is close to a population centre, a network of access roads and utilities may already be in place or available close by. Development of your site may therefore proceed without major costs for access improvements and infrastructure. In rural areas, however, development costs could be prohibitive if your site is well removed from adequate road access or utility connections.

Keeping Your Development Concepts Flexible
As discussed in Chapter 4, your development concept and plan should be established before site preparation begins. However, if your operation will involve a large area and/or continue for more than ten years, it is possible that municipal by-laws or zoning will change. Local and regional demand for a specific type of residential or industrial development site may also change.

To be able to respond to these uncertainties, your development concept should remain flexible. This will allow you to make allowances for changes and modifications in your development and reclamation plans as required.

Progressive Development and Reclamation
As with most end uses for pit and quarries, progressive development and reclamation will directly benefit residential and industrial uses by permitting you to develop some areas of your site operation well in advance of the final abandonment of your operation. Progressive development and reclamation can also save you money by minimizing multiple handling of topsoil, overburden, gravel, and non-mineral rock, and making best use of heavy equipment when it is easily available.

2. SITUATIONS TO AVOID
There are a number of situations to be avoided in developing a pit or quarry for residential and industrial uses, including:

Shallow Groundwater
Groundwater is a concern for residential and industrial developments in areas where the seasonal high groundwater table can rise to within 1 metre or less below the ground surface. You can generally avoid this problem by raising development site grades. Otherwise, you will need to consider measures to protect basements and other below grade structures from seepage.

Flooding Potential
Because gravel and sand pits are frequently located adjacent to river and stream channels, you should ensure that the final grade of your residential or industrial area will be above the level of major floods. Development in such areas may also be controlled by local zoning.

Poor Foundation Conditions
In many instances, the soils underlying sand and gravel deposits will provide good foundation conditions for residential and industrial structures. However, if you backfill all or part of your site with imported material or if major volumes of settled sediments or stockpiles fines exist, you may encounter ground settlement problems. If you are in doubt as to the adequacy of the foundation conditions in your proposed site, it is wise to consult a qualified professional engineer.

Undevelopable Areas
When you are preparing a development concept for residential or industrial use, one of your primary objectives should be to maximize the area available for development. Conditions that can limit your development potential include:

- very narrow areas, especially when bounded by steep slopes or water (both of which may require buffers or setbacks),
- areas to which access is restricted by steep terrain or water, and
- depressional areas that are deep in relation to their size and, thus, unattractive for development.

3. METHODS FOR RECLAMATION
Reclamation for a residential or industrial end use will likely involve:

- backfilling, if required, to achieve satisfactory grades for development,
- grading and contouring of the site,
- installation of drainage and erosion control measures,
- replacement of overburden and topsoil materials, and
- planting of trees, shrubs and ground covers.
These activities should be carried out in sequence, as part of the progressive development and reclamation plan for your site.

**Backfilling**

Backfilling involves raising the elevation of the depleted pit floor and other proposed development areas, using overburden from your site and/or fill material from an off-site source (Figure 12-1). It provides a means of raising site grades above the groundwater table, anticipated flood levels or other potential constraints to development. Depending on the overall development concept, grades may be raised across the entire property or merely in certain areas, such as individual development sites.

You should only use mineral soil as backfill. Ideally, this material should be placed and compacted in thin lifts.

If the fill is poorly compacted or consists of inhomogeneous material, differential settlement could occur. While deep pile foundations would address settlement concerns related to structures, it is difficult to address the problem of differential settlement of roads and underground services. Proper selection and compaction of backfill materials is therefore mandatory for a site that is to be intensively developed.

Under no circumstances should settled sediment, organic soil, landfill materials or domestic garbage be used as backfill material. Experience has shown that these materials break down very slowly over a long period of time, resulting in long-term settlement that will often make the site unsuitable for residential or industrial structures. Domestic garbage and other organic fill may also generate methane gas. Unless complex and costly collection and disposal systems are installed, methane can lead to long-term health and fire hazards.

The origin of all backfill materials should be known, and if the material is from a potentially contaminated site, it should not be accepted unless proper documentation of contaminant levels is provided.

**Grading and Contouring**

Once you have completed any necessary backfilling, you should grade and recontour your site to your design specifications. Graded contours for the pit area should blend into the adjacent terrain (Figure 12-2). Your grading plan should also provide for surface and storm water drainage of the site (see below). For deep pits below the watertable, it may be possible to create a feature lake with a gently graded shoreline for residential development (Photo 12-1).
Development of Slopes

Under the Health, Safety and Reclamation Code for Mines in British Columbia, slopes must be graded to a configuration that is stable, with an adequate factor of safety, and that can sustain vegetation. For slopes in granular soils, this is generally considered to be 2:1. While adequate for revegetation and erosion control, these slopes are too steep for any residential or industrial options; suitable slopes should be in the range of 10:1 to 20:1. These slopes can be constructed by:

- Creating gentle slopes as part of the actual mining operation,
- Backfilling and compacting steep slopes with excess overburden or off-site fill to construct gentle slopes, or
- Cutting down steep pit walls from above to create gentler slopes.

The recommended slopes are gentle enough to be developed, yet still provide positive surface drainage.

Site Drainage

Due to the nature of residential and industrial developments, less bare ground is available to absorb rainfall and runoff than in natural areas. Because surface runoff may be higher, you must consider requirements for storm water drainage and control during site grading and contouring. Depending on the features of your reclamation areas, and your proposed residential or industrial use, you may need to construct swales and drainageways between development sites. If runoff from the site will be significantly greater than for the predevelopment condition, the hydraulic capacity of the creeks that drain the site should be checked. If the capacity will be exceeded during the design storm event, storm water retention ponds may be necessary (Photo 12-2). In some areas, storm water infiltration systems, which introduce runoff into the ground from wells or basins, may be feasible, but oil water separators may be necessary to prevent groundwater contamination.

Replacing Overburden and Topsoil

Overburden and topsoil replacement is the final reclamation task, prior to re-establishment of a vegetation cover. Overburden and topsoil should be spread evenly across the site (see Chapter 2). To avoid wastage of good overburden and topsoil, these materials should not be replaced in areas that are likely to be excavated, paved, or flooded. Once the topsoil has been replaced and graded, a temporary or permanent groundcover should be established to minimize soil and wind erosion.

Re-establishing Plant Cover

Your needs for re-establishing plant cover will vary greatly depending on your preferred residential or industrial land use. In residential developments and in some industrial developments, landscaping with trees, shrubs and groundcovers is generally expected as part of the development. Due to the complexity of the task, you will probably need to hire a qualified landscape architect to assist you in designing and implementing appropriate landscaping.

Regardless of the final use, it is important that a permanent plant cover be established in all areas of your residential or industrial development that will not be occupied by buildings, parking areas, roadways, and other structural facilities.
4. OTHER SOURCES OF INFORMATION

For additional information on reclaiming land for residential and industrial use, you should write or phone your local Regional or Municipal District to inquire about local bylaws and zoning regulations. Your local Chamber of Commerce may also be able to assist you with determining the requirement for residential or industrial lands in your area.

Additional information on reclaiming land for residential and industrial use may be available from:

B.C. Society of Landscape Architects
P.O. Box 326 Stn A.
Vancouver, B.C. V6C 2M7
Telephone: (604) 732 5390
1. ARE YOU REQUIRED TO RECLAIM YOUR OPERATION?

The first reclamation legislation in British Columbia was enacted through the Ministry of Energy, Mines and Petroleum Resources in 1969 when existing mining legislation was amended to require reclamation for major coal mines and hardrock minerals. In 1973, this legislation was amended to include coal exploration, mineral exploration, sand and gravel pits and quarries. If your operation was established in 1973 or later you are likely to be required to reclaim your operation under conditions determined by Ministry of Energy, Mines and Petroleum Resources.

In 1973, the Agricultural Land Commission Act was also proclaimed law. The Agricultural Land Commission has very specific guidelines on reclaiming land within the boundaries of the Agricultural Land Reserve. If your operation is located within the Agricultural Land Reserve and was established in 1973 or later you will be required to reclaim the land to standards determined by the Commission. You may also be required to reclaim your land to the Commission's standards if your operation was established before 1973 but has expanded since that time.

Since the first reclamation legislation for pits and quarries was only established in 1973, there are many old sites that were not reclaimed when operations ceased. In other cases, especially for quarries, there are sites that may still be operating that were started prior to the enactment of this legislation. For some abandoned sites natural invasion of trees, shrubs and groundcover may have occurred and the sites may no longer be visible. In these cases, reclamation is probably not necessary. However, if your old site presents a safety or environmental hazard under the Mines Act the local Mine Inspector can remedy the safety or pollution problem and attach costs to the title.

2. THE NEED FOR RECLAMATION

Why is reclamation of a pit or quarry necessary? Disturbed areas are not only unsightly, but numerous environmental problems can arise from poor land management or from not reclaiming excavated areas. In some cases, these problems can result from detrimental changes in surface water quality, reduced availability of groundwater, losses of fish and wildlife habitat, and fewer recreational opportunities. In other cases, the main impact is the withdrawal of a valuable site from a productive future use. All of these changes affect the quality of life for you, your neighbours, and other provincial residents. In addition, unreclaimed sites often have a lower property value than reclaimed sites. It is generally to your advantage to reclaim your site.

3. RECLAIMING OLD OPERATIONS

Reclaiming old extraction sites can be more difficult than reclaiming new extraction sites since high quality soil materials are often lacking or in short supply, and the land surface may be scarred with erosion channels. In old sites, topsoil and subsoil was often not salvaged, or if salvaged, was sold or used for another purpose (such as binding the extracted gravel). Old sites are also notoriously prone to erosion surface grades are commonly left that concentrate surface runoff into gullies and channels that gouge the land surface and cause slumping of slopes. The lack of erosion control measures on slopes and sparse vegetation cover also allow sheet erosion to occur.

Since purchasing large volumes of soil can be very expensive, you may try to reduce the cost by purchasing low cost soil or using refuse (e.g., ditching waste, lawn and garden waste) that has accumulated at the site over time. If you wish to use this low cost “soil”, be very cautious that you do not purchase or use material that comes from a contaminated site. Use of this “soil” will end up costing you much more over time.

High quality soil can be developed by several methods. You can add organic (e.g., manure) or inorganic fertilizers to low quality soil. This will provide appropriate nutrients for plant life while also providing suitable rooting material. High quality soil may also be developed by encouraging natural vegetation regeneration. For example, if your planned end land use is forestry and you lack appropriate soil to plant more serally advanced seedlings, you may encourage forest growth by first planting a hardy, fast growing species such as red alder. The alder will grow rapidly and add nutrients to the soil through leaf loss. Eventually soil quality will increase and other species will naturally invade. You may wish to try a combination of methods. For example, adding fertilizer, stabilizing the surface with agronomic species and allowing natural regeneration.
Once you have developed a method for providing soil you can begin developing a reclamation plan. Use the other Chapters in this manual, as well as the documents they reference, to assist you in undertaking the following steps:

- Determine the capability and suitability of your land and reclamation materials to your support your desired end land use (See Chapter 6 for Selecting an End Land Use). Because the key reclamation materials (e.g., high quality soil) will likely be in short supply, your reclamation plans may be less ambitious than for new operations.
- Ensure that the excavation does not represent a contaminated site. If it does, take proper measures to remediate it.
- Properly dispose of any waste (e.g., old cars, tires, woodwaste) that has accumulated on site,
- Rip compacted areas and reslope the excavation,
- Develop and install erosion control measures,
- Develop a revegetation plan suitable for your resources and final land use,
- Reapply or develop a soil of sufficient capability to permit revegetation (see above),
- Revegetate your site, and
- Maintain and monitor the steps that you have undertaken to reclaim your site.

Although reclamation of old sites may be more difficult than sites that have been properly planned from the beginning, reclamation can be conducted using the guidelines provided in this and other manuals. Be sure to contact the appropriate government representatives such as the Ministry of Energy, Mines and Petroleum Resources and the Ministry of Environment, Lands and Parks for assistance in reclaiming your site.
1. VITTICK PIT, LANGLEY, BRITISH COLUMBIA

Project Coordinator: Neil Calver, Engineering Technologist
The Corporation of the Township of Langley.

**Project Background**

The Township of Langley has been excavating low quality sand and gravel from the Vittick Pit for approximately 30 years. The pit has been used as a source of construction materials for local municipal road construction projects, and as a disposal site for backhauled ditch cleaning material and unsuitable subgrade from road construction projects in the surrounding area (Figure 14-1 and Photo 14-1). Most of the excavation has been conducted using loaders and trucks. No secondary processing (e.g., screening/washing) has occurred on the site. At the present time, available reserves have been excavated from about 50% of the property. The remaining southern 50% is undisturbed agricultural land.

**Planning and End Land Use**

The Vittick Pit covers a 6ha property in a rural area east of central Langley. Surrounding land use is low density rural residential and agriculture on three sides, and higher density residential on the west side. The pit was established before current environmental legislation and practices came into effect, and reclamation planning was not initiated until 1993. The lack of pre-mine planning prior to 1993 had resulted in most of the topsoil being sold or otherwise disposed of, and excavation has occurred below the watertable (Photo 14-2).

As the first technical task in the reclamation planning process for the Vittick Pit, a detailed soil survey was conducted in 1993. Because most of the original topsoil and subsoil have been sold or disposed of, soil for reclamation will have to come from four sources:

- small stockpiles presently on the site,
- salvaged from the expansion areas to the south,
- imported from off site, and
- manufactured by mixing on site mineral soils (silty subsoil) with organic amendments such as manure, compost, or biosolids.

The suitability of these soil materials for reclamation will have to be certified by a professional agrologist.

Reclamation planning is necessary, because the property was incorporated into the Agricultural Land Reserve in the mid 1970’s, and it must be reclaimed to permit agricultural use. The primary objectives for reclamation will be to maximize the creation of high capability (Class 1) agricultural land, and prevent any adverse impacts on groundwater. Groundwater is used as a source of domestic water by residences that are adjacent to three sides of the pit.

**Reclamation Techniques**

A plan was developed to guide excavation of the remaining sand and gravel reserves in the pit, and to redistribute much of this material in areas that were excavated below the watertable (Figure 14-2). Additional sand and gravel must be stockpiled for use as the drainage layer in the reclamation profile (Figure 14-3).

Reclamation of the remainder of the pit is dictated by the rate at which the pit will be filled by ditching waste and subgrade material. The filling life of the pit is expected to be about 25 years. Sand and gravel will be used to fill areas below the natural water table elevation, in advance of pit backfilling. The pit will then be progressively filled with backhaul materials to an elevation 1m below the final grade. Once the pit has been filled, a drainage layer will be constructed, prior to placement of the subsoil and topsoil layers (Figure 14-3).
Figure 14-1: Plan of Vittick Pit area showing well locations (Source: A. Holmes).
Topsoil and subsoil from the pit expansion areas will be excavated and placed on completely backfilled portions of the pit, or stockpiled for subsequent use.

The existing drainage channel will be routed around the northwest perimeter of the site. Four hydraulic drop structures will be constructed to convey the stormwater down the steep grade along the north boundary of the site, to a discharge channel, and then into a local creek. A sedimentation pond will also be constructed and maintained to treat runoff from the site until reclamation is complete.

**Results**

The operating and reclamation plan for this site has only just been begun, and will be ongoing for approxi-
1. PLATEAU PIT, CRANBROOK, BRITISH COLUMBIA

Project Manager: Jason Jackson, Regional Gravel Manager
Ministry of Transportation and Highways.

Planning and End Use

The immediate area around the pit is forested. Local land uses include cattle grazing, Christmas tree farming, and rural residential housing. Deciding on a final land use was difficult because some portions of the pit will remain active for the next 20 years, and there are many different land uses in the area. It was decided to not reforest the site for logging since the land may be used for either rural residential housing or Christmas tree farming in the near future. Instead, the site will be reclaimed for cattle grazing as an interim land use while the remainder of the pit is being excavated.

Much of the original topsoil from the pit had been discarded but some substantial topsoil piles were still located around the perimeter of the pit. The ditching and organic waste also provided additional material to be used in reclamation.

Reclamation Techniques

The inorganic waste which had accumulated in the pit was removed. Approximately 1000m³ of remaining topsoil was moved into a stockpile adjacent to the working pit face. This topsoil will be used for future progressive reclamation techniques. A D-8 bulldozer was used to rip the compacted floor and to reshape it to a gently rolling landscape. Ditching and organic waste were then spread over the pit floor and covered with overburden. A loader and a tandem dump truck distributed soil from the perimeter piles throughout the pit floor (Photo 14-3). The soil was then spread evenly using the D-8 (Photo 14-4).

The earth moving operations were planned for fall to simplify soil handling (to avoid wet soils) but this prevented seeding the reshaped areas. The reclaimed area was scheduled to be harrowed, and then seeded and fertilized the following spring. The seeding and
fertilizing operations were to be completed using a broadcast seeder mounted on a farm tractor.

**Results**

To date, the old pit floor has been blended into the surrounding area. Adequate space was left in the pit for future production and stockpiling of sand and gravel from the current working space. Once the grass groundcover is re-established, the original area of the pit should be stable and self-sustaining until the remaining sand and gravel is depleted. The area will then be available for a variety of local end land uses including grazing, residential, or Christmas tree farming.

**3. STEELHEAD "DUECK" PIT, MATSQUI, BRITISH COLUMBIA**

Project Manager: Dennis Baker, Pit Manager Steelhead Aggregates Ltd.

**Project Background**

The Dueck Pit will be used as a new site by Steelhead Aggregates Ltd. of Abbotsford to expand their commercial sand and gravel production. The site is being excavated using loaders. Secondary processing includes the use of a potable screen and cone crusher for oversized material. A number of "value added" screened products are available from this pit in addition to pit-run sales.

**Planning and End Land Use**

The Dueck Pit is situated in the Corporation of the District of Matsqui and its entire area, approximately 6ha, is within the provincial Agricultural Land Reserve. The sand and gravel reserve is estimated at approximately 1,000,000 tonnes. High capability (Class 1) and low capability (Classes 6 and 7) agricultural land each make up approximately half of the total area of the site. A secondary highway, "Ross Road", runs adjacent to the site.

Because the operation is located in the Agricultural Land Reserve, it must be reclaimed for an agricultural land use of a similar or greater capability than existed before the operation began. It is estimated that the amount of high capability agricultural land will be increased by 23% to a total of 73% of the site, while low capability land will be reduced to 27%.

In addition to improving the capability of the land for agriculture, the excavation and backfilling of portions of the property will allow for improvements to the adjacent road. Current reclamation plans include both road grade reduction and straightening.

**Reclamation and Environmental Protection Techniques**

Ground disturbance was minimized during the opening phase of the operation. A vegetation buffer was retained on the steeply sloping border of the site to provide an effective visual and sediment retention buffer (Photo 14-5). Land clearing activities were carried out using equipment adapted to the site conditions. Timber was salvaged and piled for transport offsite, the dozer was equipped with a wide-toothed brush rake which effectively allowed separation of tree and shrub stems and roots from most of the surface soil during the knock down and debris pile phase. Further soil separation was achieved at the burning piles. Using a hoe mounted grapple, debris were picked up and shaken before being placed into the fire. By using a portable fan to provide oxygen to the slash fire, the reclamation crew was able to keep the fire burning hot and smoke free (Photo 14-6).

In areas where trees had been cleared but soil salvage was not yet undertaken, the soil surface was left in a roughened condition. This roughened surface retarded runoff, improved filtration and trapped sediment better than a smoothly graded surface.

Prior to the extraction of sand and gravel, all topsoil, subsoil and a thin layer of low quality sand and gravel was stripped from the site and stockpiled in separate piles. These stockpiles will be used in reclamation of the pit. The low quality sand and gravel will be used as a drainage layer, while the subsoil and topsoil will be replaced in their respective layers.

Soil stripping was conducted using a hydraulic excavator with a 1.7m wide bucket, which allowed for careful separation of topsoil, subsoil, and low quality sand and gravel. To ensure maximum recovery of topsoil and subsoil, these layers were first stripped from areas to be disturbed by development activities such as debris piles, site access roads and soil piles (except topsoil). Salvage activities were suspended when the soil moisture was too high to allow proper soil handling and separation. In some treed areas, the thin topsoil layers were accidentally mixed with excessive amounts of subsoil during clearing of the tree cover. This mixed soil material was placed in subsoil piles to maintain the quality of the topsoil pile.

Since it was too late in the year to establish good vegetative cover on the topsoil piles, they were covered with plastic sheeting. The soil piles will be seeded and fertilized during the first available planting period.
Results

Initial reclamation and environmental protection techniques were successfully completed. The successful completion of this phase will allow for subsequent phases to be undertaken with greater ease. However, the final success of the reclamation program will be determined by the amount of land which is eventually reclaimed to high agricultural capability.

4. ESKER CREEK OVERPASS

Project Manager: Kevin Higgins
Ministry of Transportation and Highways

Project Background

Sand and gravel were needed for the Ministry of Transportation and Highways’ road improvement projects on the Yellowhead Highway near the Skeena River. Sand and gravel resources are typically difficult to obtain in this area so they are frequently manufactured through crushing. However, one readily available source of gravel was located in the middle of the Skeena River near part of a planned road improvement project. The sand and gravel resource was obtained by dredging up to 3m below normal water levels, using a backhoe and D-7 bulldozer. The use of river gravels meant that screening was the only secondary processing activity required. All of the gravel excavated was used in the highway improvement project.

Planning and End Use

The gravel was located on an island in the middle of one of the most productive salmon rivers in British Columbia, the Skeena River. Any work conducted in the river had to be conducted so that the Department of Fisheries and Oceans policy of “no net loss” of fish habitat would be met. Dredging the gravel below the water table presented an excellent opportunity to obtain the required material while also meeting the requirement of “no net loss” of habitat. Any habitat lost through the project was replaced with coho rearing ponds created by the deep dredging. Reclamation activities such as grading and contouring were conducted while the excavation machinery was on site and readily available.

Reclamation Techniques

The pit surface was contoured to eliminate any shallow pools which could strand fish (Photo 14-7). North facing slopes were made quite steep (2 Horizontal [H]:1 Vertical [V]) to keep trees and shrubs close to the water. This provides shade for the fish. South facing slopes were given a gentle slope (5 to 10H:1V) so that there would almost always be shallow water in the ponds, even during dry years. This provides important juvenile fish habitat. These gentle slopes also allow for wetland vegetation to establish in a number of areas. A series of channels were constructed to interconnect the ponds and the Skeena River (Figure 14-4). Fallen trees were added to one section of the ponds to provide cover.
Figure 14-4: Water channels were used in the Esker Creek Pit to interconnect ponds and to allow fresh water flow (Source: Ministry of Transportation and Highways).
for rearing fish. The pit area was revegetated by seeding the overburden and planting limited amounts of cottonwood trees to control summer water temperature and to supply food and shelter for rearing salmon.

**Results**

To review and analyze the performance of the newly developed fish habitat, a multiyear monitoring program was undertaken. Substantial numbers of juvenile coho moved into the ponds in the first summer and 60% of them successfully overwintered there. This survival rate was lower than desired but may have been the result of an unusually cold winter. By the end of the third year, the studies showed that the fish population had grown by 250%. In addition, other fish species have begun to use the site for spawning and rearing and some swans also use the wetland habitat. This reclamation program has clearly been successful, and it shows that reclamation cannot only restore pre-extraction productivity but may also enhance it.
CHAPTER 15
ASSISTANCE FROM GOVERNMENT AND NON-GOVERNMENT AGENCIES

1. PROVINCIAL GOVERNMENT SOURCES OF TECHNICAL ASSISTANCE

MINISTRY OF ENERGY, MINES AND PETROLEUM RESOURCES, DISTRICT OFFICES

East Kootenay Regional Office
Suite 200, 1113 Baker Street
Cranbrook, B.C. V1C 1A7
Telephone: (604) 426-1557 Fax: (604) 426-1652

South Central Regional Office
Suite 200, 2985 Airport Dr.
Kelowna, B.C. V1Y 9V9
Telephone: (604) 828-4566 Fax: (604) 828-4726

Southwestern Regional Office
IA - 341 1 Shenton Rd.
Nanaimo, B.C. V9T 2H1
Telephone: (604) 751-7240 Fax: (604) 751-2718

North East Regional Office
3390 - 22nd Avenue
Prince George, B.C. V2N 3A1
Telephone: (604) 565-6125 Fax: (604) 565-6015

North West Regional Office
Bag 5000
3792 Allred Avenue
Smithers, B.C. V0J 2N0
Telephone: (604) 847-7385 Fax: (604) 847-7603

Lower Mainland Regional Office
301 - 865 Hornby St.
Vancouver, B.C. V6Z 2G3
Telephone: (604) 660-0223 Fax: (604) 775-0313

GOLD COMMISSIONER OFFICES

MINING REGION - CARIBOO
102 - 350 Barlow St.
Quesnel, B.C. V2J 2C1
Telephone: (604) 992-4301 Fax: (604) 992-4314

MINING REGION - COAST/LIARD
Atlin, Clinton, Liard, Skeena Lillooet
New Westminster, and Vancouver Mining Divisions
302 - 885 Hornby St.
Vancouver, B.C. V6Z 2C5
Telephone: (604) 660-2669 Fax: (604) 660-2653

MINING REGION - KAMLOOPS/OKANAGAN
Kamloops, Nicola, Osoyoos, Revelstoke, Slocan and Vernon Mining Divisions
250 - 455 Columbia St.
Kamloops, B.C. V2C 6K4
Telephone: (604) 828-4545 Fax: (604) 828-4542

MINING REGION - KOOTENAY
Fort Steele, Golden, Greenwood, Nelson, Slocan and Trail Creek Mining Divisions
310 Ward St.
Nelson, B.C. V1L 5S4
Telephone: (604) 354-6104 Fax: (604) 354-6102

MINING REGION - OMINECA
Omineca Mining Division
1020 Murray St.
Bag 5000
Smithers, B.C. V0J 2N0
Telephone: (604) 847-7207 Fax: (604) 847-7232

MINING REGION - VANCOUVER ISLAND
Alberni, Nanaimo and Victoria Mining Divisions
525 Superior St.
Victoria, B.C. V8V 1X4
Telephone: (604) 356-2248 Fax: (604) 387-3594

MINISTRY OF ENVIRONMENT LANDS, AND PARKS

Wildlife Branch Head Office
Wildlife Branch,
Ministry of Environment, Lands and Parks,
780 Blanshard Street,
Victoria, B.C. V8V 1X4
Telephone: (604) 356-1161 Fax: (604) 356-9145

Fisheries Branch Head Office
Fisheries Branch
Ministry of Environment, Lands and Parks
3rd Floor, 780 Blanshard St.,
Victoria, B.C. V8V 1X4
Telephone: (604) 387-9591 Fax: (604) 387-9750
FISH AND WILDLIFE REGIONAL OFFICES

Northern Interior Regional Headquarters
Prince George, B.C.
Telephone: (604) 565-6145 Fax: (604) 565-6629

Southern Interior Sub-Regional Office
Penticton, B.C.
Telephone: (604) 490-8200 Fax: (604) 492-1314

Kootenay Regional Headquarters
Nelson, B.C.
Telephone: (604) 354-6344 Fax: (604) 354-6332

Vancouver Island Regional Headquarters
Nanaimo, B.C.
Telephone: (604) 731-3211 Fax: (604) 755-2473

Northern Sub-Regional Office
Williams Lake, B.C.
Telephone: (604) 398-4562 Fax: (604) 398-4214

MINISTRY OF TRANSPORTATION AND HIGHWAYS

Properties Branch
Manager, Gravel Program
3B - 940 Blanshard Street
Victoria, B.C. V8W 3E6
Telephone: (604) 387-1838

AGRICULTURAL LAND COMMISSION

Reclamation Agrologist
Agricultural Land Commission
135 - 4940 Canada Way
Burnaby B.C. V5G 4K6
Telephone: (604) 660-7000

MINISTRY OF AGRICULTURE, FISHERIES AND FOOD

Soil and Engineering Branch
Head, Soils and Engineering Branch,
Ministry of Agriculture Fisheries and Food
333832 S. Fraser Way
Abbotsford, B.C. V2S 2G5
Telephone: (604) 852-5363

Provincial Soil Conservation/Management Specialist
Ministry of Agriculture Fisheries and Food
R.R. 8 RMD 7, Experimental Farm Site
Prince George, B.C. V2N 4M6
Telephone: (604) 565-6466

District Agriculturist
(contact Enquiry B.C. for local branch office)

Aquaculture Industry Development
Ministry of Agriculture, Fisheries and Food
1st Floor, 808 Douglas St.
Victoria, B.C. V8W 2Z7
Telephone: (604) 387-9580 Fax: (604) 356-7280

2. FEDERAL GOVERNMENT SOURCES OF TECHNICAL ASSISTANCE

Department of Fisheries and Oceans
3rd Floor, 555 West Hastings
Vancouver, B.C. V6B 5G3
Telephone: (604) 666-3545

Canadian Wildlife Service
P.O. Box 340
Delta, B.C. V4K 3X3
Telephone: (604) 946-7022

3. NON-GOVERNMENT SOURCES OF TECHNICAL ASSISTANCE

Ducks Unlimited,
Box 1170, Station “A”
14343-44th Ave.
Surrey, B.C. V3S 4P6
Telephone: (604) 591-1104

Wildlife Habitat Canada,
14343 - 44th Avenue,
Surrey, B.C.
Telephone: (604) 591-1104