

## BIOREMEDIATION OF CONTAMINATED SITES

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Hydrocarbon contamination is commonly associated with abandoned wellsites. The cause of this contamination can be related to drilling waste material and/or the result from operations which took place on the site. Prior to the commencement of land reclamation, these sites often require an appropriate treatment to enhance remediation and degrade the hydrocarbon which is present in the soil. Landfarming is a recognized approach in the bioremediation of hydrocarbon contaminated soil. This land treatment method involves cultivating the soil surface and is normally aided with fertilizer amendment to provide a nutrient source for the microbial population involved in the degradation of hydrocarbon.

### LANDSCAPE

The effectiveness of bioremediation will depend upon the prevailing environmental conditions in association with the landscape features. The site topography will influence the drainage capacity of an area including the degree of surface water runoff and any pooling or ponding condition. The site topography and parent material directly control the type of soil which will develop on-site. It is known that the bioremediation is inhibited by anaerobic conditions which may occur on poorly drained sites. Sites that are sloped in addition to having pits or trenches to collect surface runoff water are preferable in maintaining adequate drainage.

### SOIL PROPERTIES

The physical properties of a soil are an important aspect of bioremediation. The soil texture is an essential characteristic as it will determine the effectiveness of containment. There will be a tendency for hydrocarbon to leach or migrate downward into the soil if the percentage of sand is high. As the hydrocarbon components leach deeper into the soil profile, the soil environment becomes increasingly anaerobic. This will reduce microbial activity as well as pose mechanical difficulty in the landfarming operation. The macrostructure of the soil will also have a bearing as fissures may allow for the "escape" of oily material.

The introduction of hydrocarbon into a soil may affect the soil's wettability. For example, the infiltration of surface water into the soil profile is inhibited by the introduced hydrocarbon (i.e. the soil has poor wettability). This is often evidenced by a pooling condition that takes place on these sites. The reason for the development of this is that a thin layer of heavier oil film (being hydrophobic molecules) coats the individual soil aggregates preventing access of water and oxygen to the center of the aggregates (Rowell, 1977). This creates an anaerobic condition deleterious to microbial activity. In order for microbial activity to proceed under optimal conditions, there needs to be adequate aeration in combination with ideal moisture content. This displacement of air and water by hydrocarbon from the soil pores greatly influences degradation. In one experiment, the production of CO<sub>2</sub> from microbial respiration rose steadily as the oil content was increased to about 5.5% by weight; it dropped at about 8.5% (Schwendinger, 1968). These results suggest the problems associated with anaerobic conditions. In a landfarming operation, the incorporation of straw amendment is used to improve aeration.

Fertilizer amendment is used as a nutrient source for the microbes to "accelerate" the process of biodegradation. In particular, there is a requirement for nitrogen and, to a lesser extent, phosphorous and potassium in degrading hydrocarbon. The amount of amendment required and the appropriate ratio of N:P:K can be determined through soil testing. Under optimal nutrient conditions, the time frame for degradation will depend upon the percent hydrocarbon in addition to the soil properties.

Other soil properties that influence microbial activity include temperature, pH, and salt content. The additional of nitrogenous fertilizer is expected to have an acidifying effect on the soil. The pH level needs to be monitored as part of a land treatment program and, if necessary, lime incorporated to maintain the soil near an optimal pH of 6.5 (Toogood et al, 1997).

## CHEMISTRY

The hydrocarbon compounds identified in oilfield waste are degraded by a wide variety of microorganisms including bacteria, yeast, filamentous fungi, and actinomycetes. Bacteria appear to play a major role in degradation. There is substrate specificity and oxidation is found to be an inducible system (i.e. the enzymes involved in the initial breakdown are produced by the organism in the presence of the substrate) (Rowell, 1977). This is confirmed by the lag in microbial activity following introduction of a hydrocarbon source.

Once the initial reaction unique to the microorganism is initiated, the pathway to degradation follows a well characterized pathway such as B oxidation in the metabolism of alkane (this fraction accounts for a large proportion of the hydrocarbon present in most petroleum oils) (Rowell, 1977). The final products are normally carbon incorporated into the microbial cellular tissue or respired carbon dioxide. However, intermediate compounds may build-up if the environmental conditions are unsuitable or there are limiting nutrients. These intermediate compounds may leach into the soil profile allowing for selectivity of various components. The result is that the soil can act as a chromatography column (Plice, 1948).

The lighter chain hydrocarbon and aromatics cause varying degrees of toxicity to microorganisms. However, due to the properties of these molecules, there is a significant proportion lost to volatilization. The process of landfarming enhances the volatilization of these compounds through aeration.

It has been generally found that landfarming is a viable approach to the bioremediation of contaminated sites. However, several factors including landscape, soil properties, and chemistry need to be taken into consideration to ensure the success of this form of land treatment.

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- c. Plice, M.J. 1948. Some Effects of Crude Oil Petroleum on Soil Fertility. *Proc. Soil Sci. Soc. Am.* 13:413-416.



CANADIAN LAND RECLAMATION ASSOCIATION

ASSOCIATION CANADIENNE DE RÉHABILITATION DES SITES DÉGRADÉS

*Conservation and Reclamation:  
An Ecosystem Perspective*

Canadian Land Reclamation Association's  
21st Annual Meeting

Calgary, Alberta  
September 18-20, 1996

# **Conservation and Reclamation:**

## **An Ecosystem Perspective**

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21st Annual Meeting

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This report may be cited as:

Powter, C.B., M.A. Naeth and D.A. Lloyd (compilers), 1996. Conservation and Reclamation: An Ecosystem Perspective. 21st Annual Meeting, Canadian Land Reclamation Association, Calgary, Alberta. 153 pp.

## ACKNOWLEDGEMENTS

The compilers acknowledge the assistance of Jamie Legarie, Alberta Environmental Protection, Land Reclamation Division in preparing the manuscript. We also thank the authors for providing their papers on short notice.

The compilers edited some of the papers for format and length. We apologize for any errors that may have resulted.

## TABLE OF CONTENTS

<b>LIST OF SPONSORS</b> .....	vi
<b>INDUSTRIAL FACILITIES</b>	
Industrial Site Decommissioning in Alberta .....	1
<b>Walter J. Ceroici</b>	
Changing Knowledge Needs for Wellsite Reclamation .....	3
<b>Jim Smith</b>	
The Orphan Facilities and Pipeline Program: An Industry/Government Responsibility .....	7
<b>David Lloyd and David Sandmeyer</b>	
In-Situ Amelioration of Sodic Mine Spoil Using Sulfur, Gypsum and Crop Management ...	11
<b>Jeff J. Sansom, M. Anne Naeth, and David S. Chanasyk</b>	
Bioremediation of Contaminated Sites .....	13
<b>Christopher Schneider</b>	
Contaminant Metal Concentration in Alberta Soils Under Different Land Uses .....	17
<b>Gerry Lutwick, Gordon D. Dinwoodie, David Gower and G. E. Nason</b>	
Waste Disposal Guidelines from a Testing Lab's Perspective .....	19
<b>John Ashworth</b>	
Reclamation of a Former Heavy Oil Plant in Northeastern Alberta .....	23
<b>Tim R. Bossenberry, J. Jeffrey Wilson, David Evans, Darrell Chollak and George Walker</b>	
Nutrient and Metal Levels and Dynamics on a 30-year Revegetated Copper-Nickel Tailings Site at Copper Cliff, Ontario .....	27
<b>Jeremy Niemi, John Giffen and Keith Winterhalder</b>	
<b>FORESTS</b>	
Land Application of BCTMP Mill Waste Research in Alberta .....	31
<b>Terry M. Macyk</b>	
Reclamation to Native Forest Ecosystems in the Oil Sand Region .....	33
<b>Steve Tuttle</b>	
Land Capability Classification for Forest Ecosystems .....	37
<b>Leonard A. Leskiw, Steve Tuttle and Earle Anderson</b>	
Forest Land Restoration on Vancouver Island .....	39
<b>David Polster</b>	

Lichen Diversity in the Reclaimed Areas of Sudbury, Ontario .....	43
<b>S. Wainio and Peter Beckett</b>	

## **MOUNTAINS**

Application of Population Biology, Conservation Biology and Succession Theory to the Reclamation of a High Elevation Coal Mine .....	47
<b>Clint R. Smyth</b>	

Plant Community Changes in Response to Anchor Chaining and Seeding on Pinyon/Juniper Sites in Central Utah .....	51
<b>J. Gregory Sutor</b>	

Tailings Disposal and Reclamation at the Coal Valley Mine .....	53
<b>Dane McCoy</b>	

In-Pit Disposal Program for Acid Generating Waste Rock .....	57
<b>Jamie Quesnel and S. W. Stogran</b>	

Reclamation, Trans Canada Highway Twinning, Banff National Park .....	63
<b>Otto Hammer</b>	

## **GENERAL ISSUES**

Railway Reclamation: Issues and Opportunities .....	67
<b>Chris B. Powter and David A. Lloyd</b>	

Experiences in Reclaiming Railways Under Alberta's new Reclamation Guidelines .....	71
<b>Mark Polet</b>	

Pipeline Abandonment: A Discussion Paper .....	73
<b>Karen Etherington</b>	

Legal Perspectives on Land Reclamation .....	75
<b>Gilbert Van Nes</b>	

Liability for Reclamation: Enforcement at Common Law .....	77
<b>Adrian Currie</b>	

## **WATER AND WETLANDS**

Coursier Reservoir: The Planning and Costs Associated with the Reconstruction and Revegetation of a Subalpine Lake .....	81
<b>J. Leah Jackson</b>	

Spray Lakes Reclamation Project .....	85
<b>Margwyn R. Zaccaruk</b>	

The Pine Coulee Project: Linking Reclamation Planning to Impact Assessment .....	89
<b>Ron Middleton</b>	

Design and Construction Management Aspects of Constructed Wetlands .....	93
<b>Bernard Amell and Kim Eastlick</b>	

Natural Revegetation of an Alberta Peatland after Horticultural Peat Extraction .....	97
<b>Wayne S. Tedder and Larry W. Turchenek</b>	

## **RUNOFF/EROSION**

Computer Modelling of Soil Erosion from Reclaimed Land .....	101
<b>Les Sawatsky, Wes Dick and Senarath Ekanayake</b>	

Runoff and Sediment Yield under Grazing in Foothills Fescue Grassland of Alberta .....	103
<b>M. Anne Naeth and David S. Chanasyk</b>	

Runoff Curve Numbers for Two Reclaimed Watersheds in Central Alberta .....	107
<b>Ted E. Harms and David S. Chanasyk</b>	

Vegetation Characteristics, Grazing Disturbance and Soil Erosion .....	111
<b>Suzanne I. Gill, M. Anne Naeth, David S. Chanasyk and V. S. Baron</b>	

## **PRAIRIE**

Renewing the Ecological Integrity of Disturbed Native Prairie .....	113
<b>Heather S. Gerling</b>	

Mixed Grass Prairie habitat Restoration Project: Landscape Restoration in the Moist Mixed Grass Prairie .....	117
<b>Dean Nerberg</b>	

Native Prairie Regeneration After Pipeline Construction: A Comparison Between Topsoil Stripping versus No Topsoil Stripping During Construction .....	119
<b>Gordon Dunn and Gina Fryer</b>	

Restoration of Native Sandhills Vegetation after Pipeline Construction in the Great Sand Hills Region of Saskatchewan .....	123
<b>David G. Walker, Laurier Kremer and Wayne Marshall</b>	

The Effects of Grazing, Mowing, Glyphosate and Burning on Smooth Brome in Fescue Grassland .....	125
<b>D. J. Brown and M. Anne Naeth</b>	

## **VEGETATION**

Avoiding Downy Brome When Buying Seed .....	127
<b>Kerby Lowen and Sarah Foster-Stubbs</b>	

Biodiversity and Reclamation: How Many Species do we Need in a Seed Mix? . . . . .	131
<b>Dana Bush and M. Anne Naeth</b>	
Germination and Survivability of Selected Native and Introduced Grasses and Legumes . . . . .	133
<b>William E. Pelech and M. Anne Naeth</b>	
Road Maps for Repairing Ecological Damage . . . . .	135
<b>Andy Hammermeister</b>	
Ecovar Developments in Western Canada . . . . .	137
<b>Les Wetter and Brent Wark</b>	
Plant Growth on Aggregated Oil Sands Processing Wastes . . . . .	139
<b>Xiaomei Li, Jim Storey, Paul Y. P. Yeung and Martin Y. P. Fung</b>	
The Clover Bar Landfill: A State of the Art Landfill Reclamation Process . . . . .	141
<b>Ann Smreciu, Nolan Turner and Don Barron</b>	
<b>BULK DENSITY</b>	
A Method of Characterizing the Bulk Density of Compressible Particulate Material . . . . .	145
<b>D. Guenther, Stacy Schaub and J. Leonard</b>	
Near-Surface Compaction Under Grazing of Annual and Perennial Forages . . . . .	149
<b>Dennis Twerdoff, David S. Chanasyk, M. Anne Naeth and V. S. Baron</b>	
Grazing Impacts on Bulk Density and Soil Strength in the Foothills Fescue Grasslands of Alberta, Canada . . . . .	151
<b>David S. Chanasyk and M. Anne Naeth</b>	
Computer Modelling of Soil Erosion from Reclaimed Land . . . . .	155
<b>Les Sawatsky, Wes Dick and Senarath Ekanayake</b>	

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