THE INTERACTION OF GROUND WATER AND SURFACE MATERIALS IN MINE RECLAMATION [1]

- by -

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ABSTRACT

Ground water conditions are frequently overlooked when placing surface materials in a mine reclamation scheme. The purpose of this paper is to outline the interaction between the surface materials and ground water conditions at a mine site. By careful selection and placement of surface materials, it may be possible to minimize adverse impacts on the ground-water regime. Similarly the chances of successful replacement of surface materials may be enhanced by consideration of ground water conditions.

Effects on the ground-water regime will depend upon the placement of surface materials within the ground-water flow system.

Surface materials placed over recharge zones may alter the rate and quality of water infiltrating to the water table. In turn these effects may be reflected in changes in flow and water quality in springs and streams.

The effects of placing surface materials over ground water discharge areas are generally not so widespread. Medium and high permeability surface materials will generally allow ground water discharge to reach the ground surface. Soluble salts may be precipitated if the concentration in the ground water is high enough. These conditions may restrict the type of vegetation which could grow on the surface materials.

Placing low-permeability materials over a discharge area could result in quicking conditions or unstable slopes if the discharge zone occurs on a hillside.

By evaluating ground-water conditions before placing surface materials, it is possible to avoid may of the problems outlined above.

1. Presented at the Canadian Land Reclamation Meeting Edmonton, Alberta, August 18, 1977.

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1.0 INTRODUCTION

The ground water regime forms an integral part of the hydrologic cycle (Figure 1). Precipitation falling on the ground may seep into the ground and become part of the ground water system, alternatively the water may flow over the ground as surface runoff or it may return back to the atmosphere by evaporation. Surface materials replaced during mine reclamation are placed at a critical interface in the hydrologic system (Figure 2). The method of placement and type of surface materials used in mine reclamation can drastically change the volume of surface runoff and the amount of water seeping into the ground.

The effects of surface materials on the ground water regime may best be understood after briefly considering some of the factors controlling ground water movement.

The water table beneath the ground surface is generally a subdued reflection of the topography. Water tends to move from areas of higher potential (i.e. elevation) to ones of lower potential. The relationship of ground water flow lines to topography is shown schematically in Figure 3. Changes in the subsurface geology can

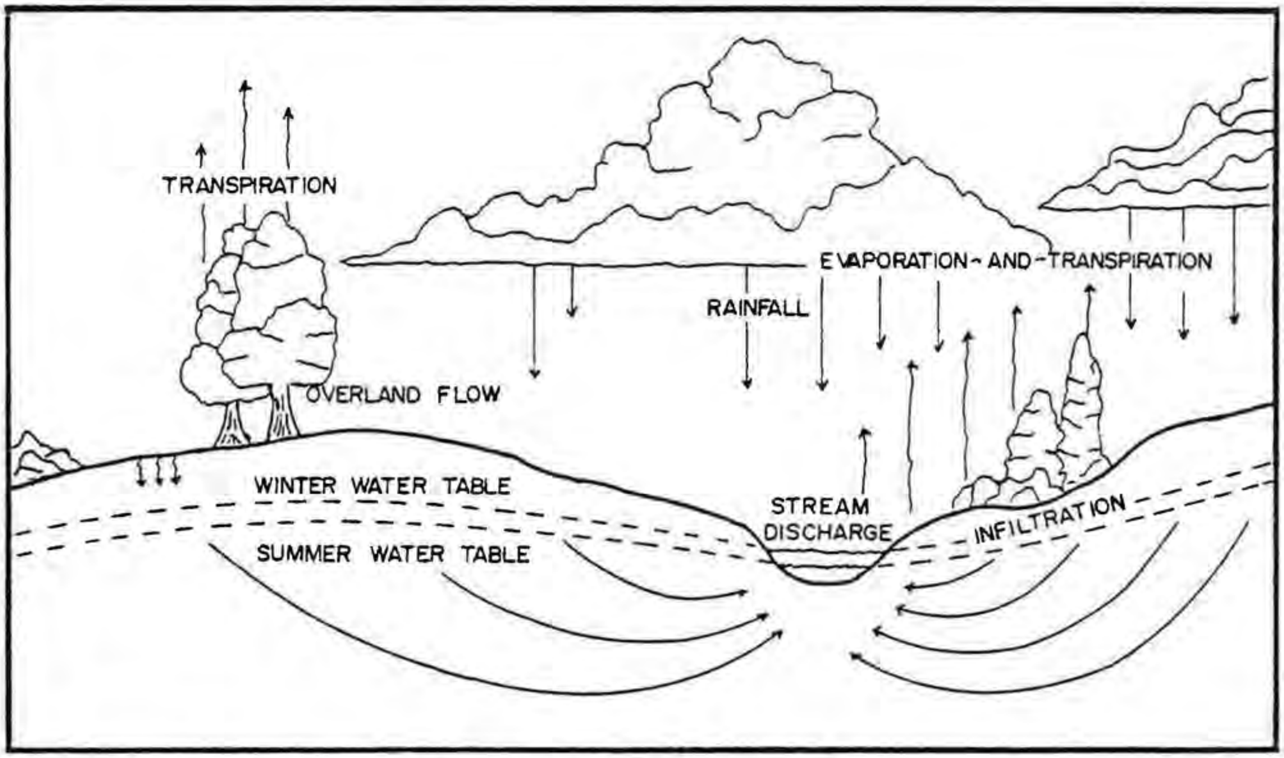

Figure 1 THE HYDROLOGIC CYCLE

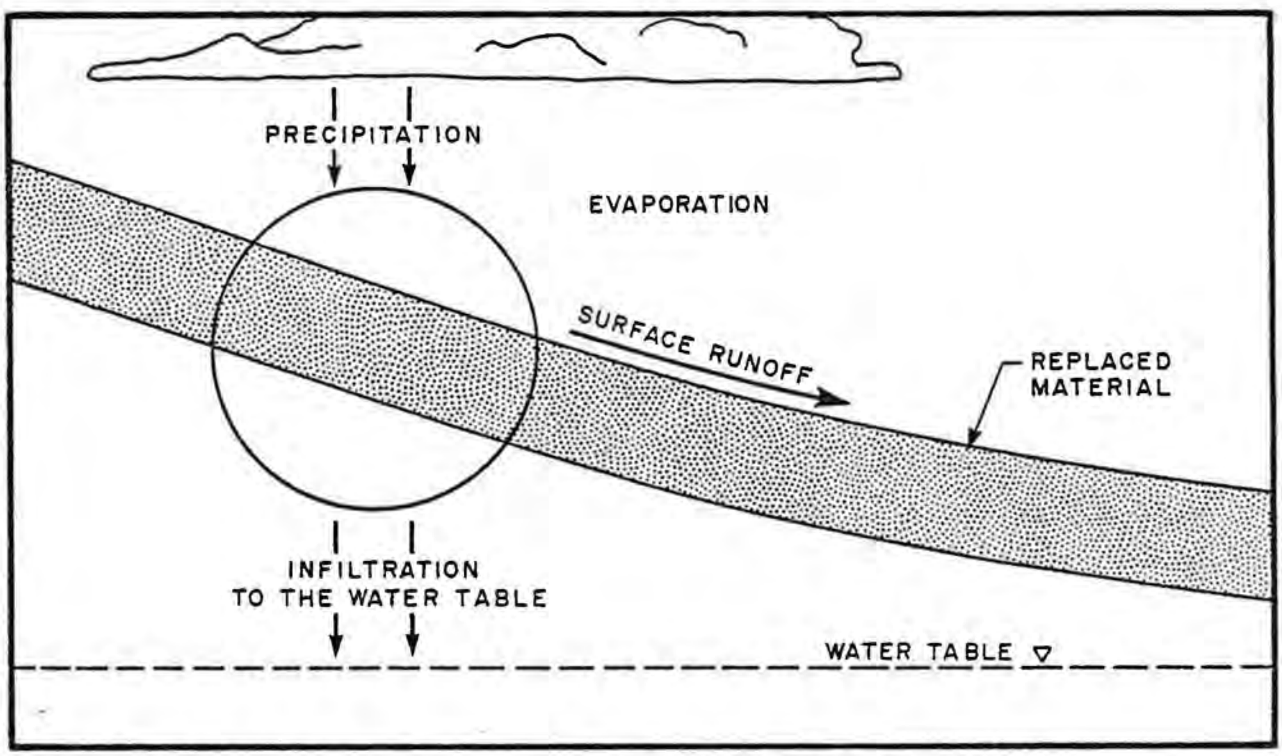

Figure 2 SCHEMATIC DIAGRAM SHOWING THE PLACEMENT OF RECLAIMED MATERIAL AT THE LAND/AIR INTERFACE OF THE HYDROLOGIC CYCLE.

modify these flow patterns considerably. There are two important areas which should be considered separately. The first is a recharge area where water infiltrating down from the ground surface replenishes the ground water system. Such an area has decreasing hydraulic heads with depth, i.e. deeper wells tend to have lower water levels. Ground water discharge areas occur at the other end of the ground water flow system where ground water discharges naturally at the ground surface. They are frequently characterized by springs, marshes or salt residue remaining after the evaporation of ground water.

Recharge and discharge areas are two extremes when considering the impact on the ground water system of placing surface materials. Because of this they will be considered separately.

1.1 Recharge Areas

Land reclamation over recharge zones may modify both the quality and quantity of water infiltrating through the soil to the water table.

Changes in water quality may be brought about by the type of surface material used for reclamation. Even if the material used is the same

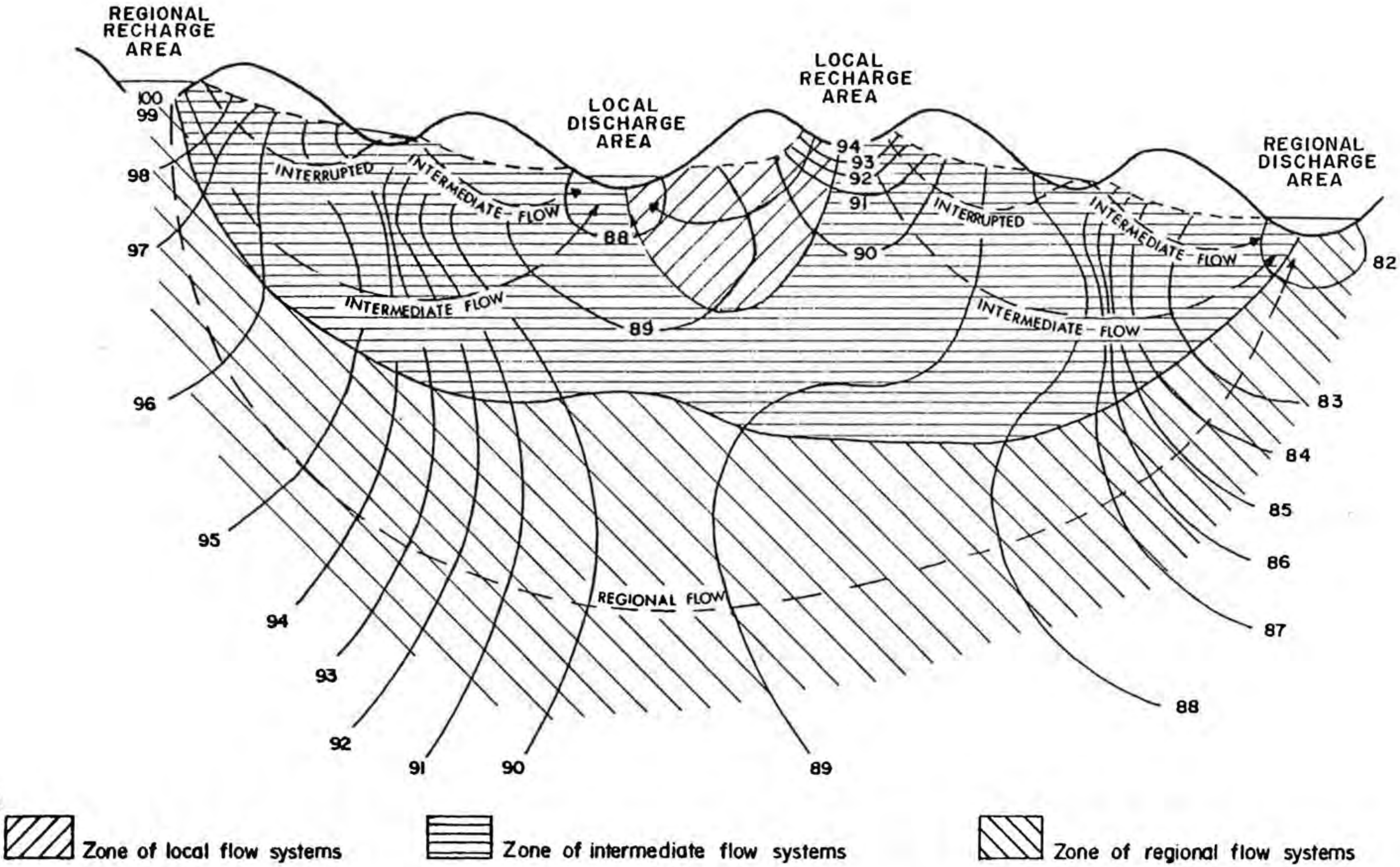

Figure 3 TYPES OF NATURAL FLOW SYSTEMS
(after Lissey, 1972)

as the natural soil cover there may be changes in the amount of soluble material absorbed by the infiltrating water. This can be brought about by the increase in the contact area brought about by decreased compaction or by the alteration of minerals by the oxidation-reduction processes. These changes in sub-surface-water chemistry are discussed in detail in the next paper, presented by Moran and Cherry.

Changes in ground water quality can have both direct and indirect changes on other environmental parameters, as shown in Figure 4. While the changes in ground water chemistry are implemented at a recharge area, many of the impacts may not be noticed until they move through the ground-water flow system.

Changes in ground water quality would readily be noticed in nearby springs, while changes in the water quality of streams and lakes will depend unpon the percentage of the surface water derived from ground water sources and the concentration of the chemical constituents in question. If the total dissolved solids are significantly increased at the recharge area then there may be increased precipitation of salts in

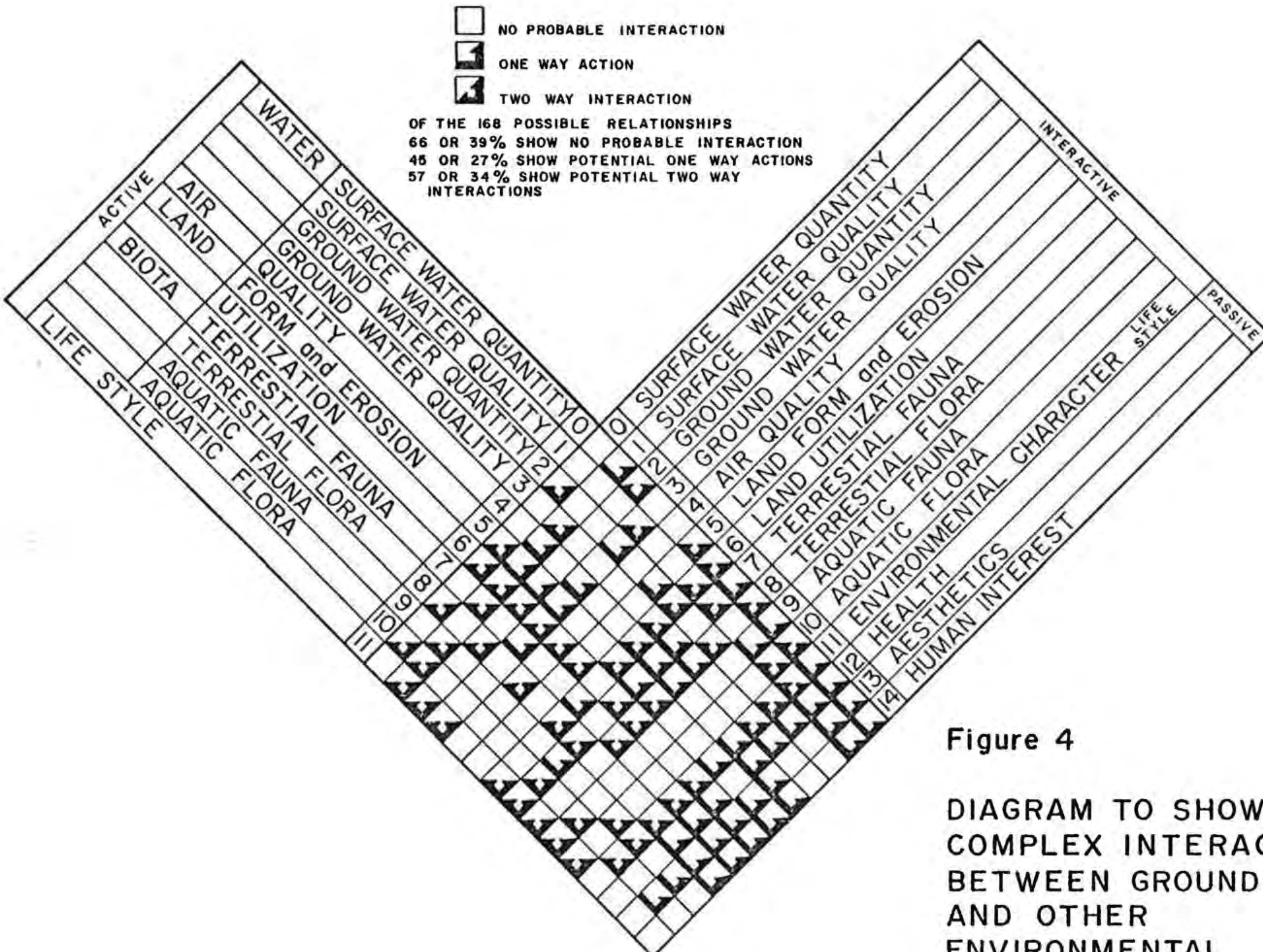

Figure 4

DIAGRAM TO SHOW THE COMPLEX INTERACTIONS BETWEEN GROUND-WATER AND OTHER ENVIRONMENTAL PARAMETERS discharge areas, possibly making land unsuitable for certain crops. Where ground waters are used for irrigation or stock watering, adverse changes in chemistry may require water treatment before use, as might ground water used for human consumption. In general these effects are likely to be more significant where the ground water quality is already marginal or where there is a possibility introducing minor chemical constituents which are toxic at low levels. For example drinking waters with arsenic levels exceeding 0.05 mg/l are unsuitable (Canadian Drinking Water Standards and Objectives, Anon., 1968). Examples of some of these levels are shown in Table I. The impact of chemical changes is likely to decrease away from the reclamation area due to dilution resulting from dispension and diffusion.

Changes in water quantity are generally a result of changes in the infiltration rate. Any increase or decrease from the natural recharge rate will result in changes in the ground water flow system which, in turn,will cause changes in other environmental parameters (Figure 4). When placing

TABLE I CANADIAN DRINKING WATER STANDARDS

TABLE VI

DRINKING WATER STANDARDS FOR TOXIC CHEMICALS*

Toxicant	*Objective* mg/1	*Acceptable Limit*—mg/1	*Maximum Permissible Limit*—mg/1
Arsenic as As	Not Detectable[1]	0.01	0.05
Barium as Ba	Not Detectable	<1.0	1.0
Boron as B	—	<5.0	5.0
Cadmium as Cd	Not Detectable	<0.01	0.01
Chromium as Cr^{VI}	Not Detectable	<0.05	0.05
Cyanide as CN	Not Detectable	0.01	0.20
Lead as Pb	Not Detectable	<0.05	0.05
Nitrate+Nitrite as N	<10.0	<10.0	10.0
Selenium as Se	Not Detectable	<0.01	0.01
Silver as Ag	—	—	0.05

*See Table VII and Table VIII for limits on biocides and other chemicals.

1 Not detachable by the method described in the latest edition of "Standard Methods" (APHA, AWWA, & WPCF), or by any other acceptable method approved by the control agency.

TABLE VIII

RECOMMENDED LIMITS FOR OTHER CHEMICALS IN DRINKING WATER

Chemical	Limit — mg/l	
	Objective	*Acceptable*
Alkalinity	(See Section 8.3.2(1))	
Ammonia as N	0.01	0.5
Calcium as Ca	<75	200
Chloride as Cl	<250	250
Copper as Cu	<0.01	1.0
Corrosion and Incrustation	(See Section 8.3.2(3))	
Iron (dissolved) as Fe	<0.05	0.3
Magnesium as Mg	<50	150
Manganese as Mn	<0.01	0.05
Methylene Blue Active Substances	<0.2	0.5
Phenolic Substances as Phenol	Not Detectable[1]	0.002
Phosphates as PO_4 (inorganic)	<0.2	0.2
Total Dissolved Solids	<500	1,000
Total Hardness as $CaCO_3$	<120	See Section 8.3.2(2)
Organics as CCE + CAE[2]	<0.05	0.2
Sulphate as SO_4^{--}	<250	500
Sulphide as H_2S	Not Detectable	0.3
Uranyl Ion as UO_2^{++}	<1.0	5.0
Zinc as Zn	<1.0	5.0

1 "Not detectable" by the method described in the latest edition of "Standard Methods" (AWWA, APHA, WPCF) or by any other acceptable method approved by the control agency.

2 Total of carbon chloroform and carbon alcohol extractibles.

3 Based on taste and odour considerations. Concentration greater than 0.05 mg/l may be objected to by the majority.

surface materials in a reclamation scheme any change in the infiltration rate will result in the opposite reaction from surface runoff. Table II illustrates how various factors related to the placement of surface materials may vary the rates of infiltration and surface runoff.

If the rate of infiltration is decreased and there results in a corresponding increase in surface runoff then the following effects may occur in the surface water system:

(a) Higher peak flows due to the more rapid runoff and loss of temporary storage in the ground water system.

(b) Lower "low flows" due to decreased storage from the ground water system.

(c) Increased erosion and sediment loads.

All three of these factors tend to decrease water resources potential.

The effects of decreased infiltration on the ground water system revolve around the lowering of the water table as evidenced by falling water levels in surrounding wells. Spring flows may decrease and stream flows become significantly

TABLE II

SUMMARY OF

SURFACE MATERIAL PARAMETERS

INFLUENCING GROUND WATER RECHARGE

Parameter	Ground Water Recharge	Surface Run Off
Slope - increase	decrease	increase
- decrease	increase	decrease
Compaction		
- increase	decrease (may reduce soluble material reaching water table)	increase
- decrease	increase (may increase soluble material reaching water table)	decrease
Material		
- increase permeability	increase	decrease
- decrease permeability	decrease	increase
Vegetation Cover	(may increase recharge by reducing run off or decrease recharge by increasing evapo-transpiration)	decrease

smaller during periods of low flow because ground water baseflow frequently makes up a large percentage of stream flow during these periods. Phreatophytic plants drawing their water supply from the water table may die if the water table falls significantly. A chain reaction could be started from the destruction of the vegetation cover which may start with increased erosion causing higher silt loads.

On the positive side, the lowering of the water table may result in the drainage of marsh or swamp land.

When the rate of infiltration is increased the volume and rate of surface runoff is generally decreased. This results in lower peak flows and increased ground water storage raises the low flow levels. Erosion will probably be decreased and the water resources potential will be enhanced.

Raising the water table could pose problems for areas where it is close to ground level. In such areas plant roots may be damaged and low-lying areas may become submerged. Because ground water movement is very slow these phenomena are more likely to occur within or adjacent to the reclamation area.

1.2 Ground Water Discharge Areas

Placement of materials over ground water discharge areas will have less widespread environmental effects than the placement of materials over recharge areas.

If the surface materials are to be successfully revegetated then ground water must be allowed to discharge freely from the underlying materials. If the discharging waters are high in total dissolved solids then there may be excessive precipitation of salts in the replaced material, brought about by evaportation. If this is likely to be a problem then the reclaimed materials should be thick enough to allow drainage of the ground water before it can evaporate. Drainage can be enhanced by placing a more permeable material first which would then act as a natural drain.

Engineering problems may result when the reclaimed surface materials become saturated and slopes become unstable. This may occur in materials of low permeability as they do not allow adequate drainage, more permeable materials may become saturate as well if their placement is such that ground water is impounded within the material because of inadequate drainage.

These problems can be solved by careful selection and placement of materials. Contouring can also enhance drainage and prevent accumulation of ground water in depressions. Vegetation should be selected to be compatible both with the proximatey of the water table and the quality of the ground water.

2.0 SUMMARY

The ground water system can be modified by the placement of surface materials in reclamation schemes. Both the quality and quantity of ground water may be altered and these changes may be noticed well outside the area being reclaimed. Within the area being rehabilitated ground water conditions may influence revegetation plans, create areas of poor drainage and possibly result in slope stability problems.

The first stage in developing solutions to these problems is to identify baseline ground water conditions and to place the area in the correct regional hydrogeological perspective.

Ground water baseline studies are now an integral part of the license application procedure in Alberta and involve the collection and evaluation of existing data. Additional ground water information is frequently obtained from core holes and other test holes. From this information ground water flow patterns may be determined and flow rates calculated.

Recharge and discharge areas can be identified and guidelines can be developed for the type of material and method of placement in the reclamation scheme.

The importance of ground water in the reclamation scheme will be site specific as will be the solution to any problems arising from the interaction of surface materials and the ground water system.

PROCEEDINGS

OF

THE SECOND ANNUAL GENERAL MEETING

OF THE

CANADIAN LAND RECLAMATION ASSOCIATION

August 17, 18, 19 & 20 — 1977 Edmonton, Alberta

(Sponsored by the Faculty of Extension, University of Alberta)

P R O G R A M

Canadian Land Reclamation Association

Second Annual General Meeting

August 17, 18, 19, 20, 1977

Edmonton, Alberta

Wednesday, August 17 (Optional Field Trips)

Field Trip No. 1 (Athabasca Tar Sands)

Leader: Philip Lulman (Syncrude Canada Ltd.)

Fee: $100.00 (covers bus and air transportation, lunch, and field trip information pamphlets)

Schedule: 7:30 am.- delegates board bus at Parking Lot T, located immediately south of the Lister Hall Student Residence complex. Air transportation from Edmonton Industrial Airport to Fort McMurray and return. Guided bus tour of surface mining and reclamation operations on Syncrude Canada Ltd. and Great Canadian Oil Sands Ltd. leases.
6:30 p.m.- delegates arrive back at Parking Lot T, University of Alberta campus.

Field Trip No. 2 (Aspen Parkland; Forestburg Coal Mine Reclamation)

Leader: George Robbins (Luscar Ltd.)

Fee: $25.00 (covers bus transportation, lunch, and field trip information pamphlets)

Schedule: 8:00 a.m. - delegates board bus at Parking Lot T, located immediately south of the Lister Hall student residence complex. Guided bus tour southeast of Edmonton, stopping at various points of interest (oil spill reclamation field plots; Black Nugget Park [abandoned minesite]; trench plots on Dodds-Roundhill Coal Field; solonetzic soil deep ploughing site) on the way to the Luscar Ltd. Coal Mine at Forestburg.
6:30 p.m. - delegates arrive back at Parking Lot T, University of Alberta campus.

Thursday, August 18

Events: Opening of Formal Meeting; Presentation of Papers

Location: Multi-Media Room, located on second floor of Education Building, University of Alberta.

8:00 a.m. Authors of papers being presented on August 18 meet with paper presentation chairmen and audio-visual co-ordinator (Douglas Patching)

9:00 a.m. Meeting Opened by Dr. Jack Winch (President of the C.L.R.A.; Head of the Department of Crop Science, University of Guelph). Comments by Dr. Winch.

9:15 a.m. Welcome to delegates on behalf of the Government of Alberta by the Hon. Mr. Dallas Schmidt, (Associate Minister Responsible for Lands, Alberta Department of Energy and Natural Resources)

9:25 a.m. Commencement of Paper Presentations. Morning session chaired by Mr. Henry Thiessen (Chairman of the Land Surface Conservation and Reclamation Council and Assistant Deputy Minister, Alberta Department of Environment).

9:30 a.m. Paper 1. Combined Overburden Revegetation and Wastewater Disposal in the Southern Alberta Foothills by H.F. Thimm, G.J. Clark and G. Baker (presented by Harald Thimm of Chemex Reclamation and Sump Disposal Services Ltd., Calgary, Alberta).

10:00 a.m. Paper 2. Brine Spillage in the Oil Industry; The Natural Recovery of an Area Affected by a Salt Water Spill near Swan Hills, Alberta by M.J. Rowell and J.M. Crepin (presented by Michael Rowell of Norwest Soils Research Ltd., Edmonton, Alberta)

10:30 a.m. Coffee Recess

11:00 a.m. Paper 3. The Interaction of Groundwater and Surface Materials in Mine Reclamation by Philip L. Hall of Groundwater Consultants Group Ltd., Edmonton, Alberta.

11:30 a.m. Paper 4. Subsurface Water Chemistry in Mined Land Reclamation; Key to Development of a Productive Post-Mining Landscape by S.R. Moran and J.A. Cherry (presented by Stephen Moran of the Research Council of Alberta, Edmonton, Alberta).

12:00 noon Lunch Recess

1:25 p.m.	Continuation of Paper Presentations. Afternoon session chaired by Mr. Philip Lulman (member of C.L.R.A. executive; reclamation research ecologist with Syncrude Canada Ltd.).
1:30 p.m.	Paper 5. Coal Mine Spoils and Their Revegetation Patterns in Central Alberta by A.E.A. Schumacher, R. Hermesh and A.L. Bedwany (presented by Alex Schumacher of Montreal Engineering Company Ltd., Calgary, Alberta).
2:00 p.m.	Paper 6. Surface Reclamation Situations and Practices on Coal Exploration and Surface Mine Sites at Sparwood, B.C. by R.J. Berdusco and A.W. Milligan (presented by Roger Berdusco of Kaiser Resources Ltd., Sparwood, B.C.).
2:30 p.m.	Paper 7. Agronomic Properties and Reclamation Possibilities for Surface Materials on Syncrude Lease #17 by H.M. Etter and G.L. Lesko (presented by Harold Etter of Thurber Consultants Ltd., Victoria, B.C.).
3:00 p.m.	Paper 8. The Use of Peat, Fertilizers and Mine Overburden to Stabilize Steep Tailings Sand Slopes by Michael J. Rowell of Norwest Soils Research Ltd., Edmonton, Alberta.
3:30 p.m.	Coffee Recess
4:00 p.m.	Paper 9. Oil Sands Tailings; Integrated Planning to Provide Long-Term Stabilization by David W. Devenny of E.B.A. Engineering Consultants Ltd., Edmonton, Alberta.
4:30 p.m.	Paper 10. Bioengineering. The Use of Plant Biomass to Stabilize and Reclaim Highly Disturbed Sites by H. Schiechtel and K. (Nick) Horstmann (presented by Margit Kuttler).
5:00 p.m.	End of August 18 Sessions.

Friday, August 19

Events: Presentation of Papers; C.L.R.A. Annual General Business Meeting; C.L.R.A. Annual Dinner.

Locations: Paper presentations and C.L.R.A. Annual General Business Meeting in Multi-Media Room, located on second floor of Education Building, University of Alberta.
- Annual Dinner held in Banquet Room located on second floor of Lister Hall.

8:00 a.m. Authors of Papers being presented on August 19 meet with paper presentation chairmen and audio-visual co-ordinator (Douglas Patching).

8:30 a.m. Showing of Film Rye on the Rocks. This film depicts reclamation situations at Copper Cliff, Ontario and is being shown for the purpose of introducing delegates to the site of the 1978 C.L.R.A. meeting (Sudbury, Ontario).

8:55 a.m. Continuation of Paper Presentations. Morning session chaired by Dr. J.V. Thirgood (Vice-President of C.L.R.A.; member of Forestry Faculty, University of British Columbia).

9:00 a.m. Paper 11. Reclamation of Coal Refuse Material on an Abandoned Mine Site at Staunton, Illinois by M.L. Wilkey and S.D. Zellmer (presented by Michael Wilkey of the Argonne National Laboratory, Argonne, Illinois).

9:30 a.m. Paper 12. A Case Study of Materials and Techniques Used in the Rehabilitation of a Pit and a Quarry in Southern Ontario by Sherry E. Yundt of the Ontario Ministry of Natural Resources, Toronto, Ontario).

10:00 a.m. Coffee Recess.

10:30 a.m. Paper 13. Amelioration and Revegetation of Smelter-Contaminated Soils in the Coeur D'Alene Mining District of Northern Idaho by D.B. Carter, H. Loewenstein and F.H. Pitkin (presented by Daniel Carter of Technicolor Graphic Services Inc., Sioux Falls, South Dakota).

11:00 a.m. Paper 14. The Influence of Uranium Mine Tailings on Tree Growth at Elliot Lake, Ontario by David R. Murray of the Elliot Lake Laboratory, Elliot Lake, Ontario.

11:30 a.m.	Paper 15. Weathering Coal Mine Waste. Assessing Potential Side Effects at Luscar, Alberta by D.W. Devenny and D.E. Ryder (presented by David Devenny of E.B.A. Engineering Consultants Ltd., Edmonton, Alberta).
12:00 noon	Lunch Recess.
1:25 p.m.	Continuation of Paper Presentations. Afternoon session chaired by Dr. John Railton, (Manager, Environmental Planning, Calgary Power Ltd., Calgary, Alberta).
1:30 p.m.	Paper 16. The Distribution of Nutrients and Organic Matter in Native Mountain Grasslands and Reclaimed Coalmined Areas in Southeastern B.C. by Paul F. Ziemkiewicz of the Faculty of Forestry, University of B.C., Vancouver, British Columbia.
2:00 p.m.	Paper 17. Systems Inventory of Surficial Disturbance, Peace River Coal Block, B.C. by D.M. (Murray) Galbraith of the British Columbia Ministry of Mines and Petroleum Resources, Victoria, British Columbia.
2:30 p.m.	Paper 18. The Selection and Utilization of Native Grasses for Reclamation in the Rocky Mountains of Alberta by D. Walker, R.S. Sadasivaiah and J. Weijer (presented by David Walker of the Department of Genetics, University of Alberta, Edmonton, Alberta).
3:00 p.m.	Coffee Recess; Distribution of Proceedings.
3:30 p.m.	Commencement of 1977 General Business Meeting of the Canadian Land Reclamation Association. Meeting chaired by Dr. J.V. Winch, C.L.R.A. President.
7:30 p.m.	Commencement of C.L.R.A. Annual Dinner in Banquet Room, second floor of Lister Hall.

Guest Speaker: William T. Plass, Principal Plant Ecologist, U.S.D.A. Forest Service, Northeastern Forest Experiment Station, Princeton, West Virginia.

Topic of Speech: Challenges in Co-operative Reclamation Research.

Note: Following the Annual Dinner and Mr. Plass's speech, delegates may retire to the adjacent Gold Room. A bartender will be on service until midnight.