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CRITERIA FOR SELECTION OF SITES
FOR SOLID WASTE DISPOSAL

compiled by

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CRITERIA FOR SELECTION OF SITES FOR SOLID WASTE DISPOSAL

General statement

Any form of garbage dump, nuisance ground, refuse disposal site or sanitary landfill operation will cause three basic kinds of pollution. These are:

(i) aesthetic pollution - offensive visually and conceptually

(ii) air pollution - offensive nasally, detrimental to health

(iii) water pollution - detrimental to health.

In our opinion the basic problems and the basic principles relating to garbage disposal are relatively well defined, and in terms of immediate application to Alberta situations no need exists for an interdisciplinary research project.

The ramifications of aesthetic pollution are self-evident, as are the various degrees of problem solution. People dislike the sight and smell of a garbage dump and prefer not to live near one. One can most desirably have no garbage dumps, for example, complete reuse or complete incineration as proposed by Lilge, 1969:

> "The traditional means of disposing of rubbish, i.e. by burying it in out of the way places, are no longer satisfactory. The danger of contaminating ground waters, rivers and lakes is far too serious to continue this practice. Apart from this, refuse dump locations which are situated at economical distances from the gathering sources are now practically nonexistent in most cities. Obviously a new approach to disposal of city refuses must be found.
>
> The conversion of city refuse to useful products would be a solution to all aspects of the disposal problem and in addition would provide a new source of materials and energy."

On the second level of desirability one can locate dumps in little-travelled and lightly inhabited areas, screened from public view by trees, which also helps prevent widespread wind distribution of garbage over the surrounding countryside. Other methods of alleviating aesthetic pollution problems include incineration and sanitary landfill operations. The former causes air pollution, the latter may lead to pollution of both groundwater and surface water.

Although not within our sphere of competence, it seems fairly evident to us that air pollution is measurable, and is controllable to the extent that specific limits are definable (and are defined) for emission of particulate matter and gases to the atmosphere.

The remaining area of concern is that of water pollution, which takes place by the flow of leachates from garbage piles into groundwater aquifers and surface water systems. This appears to be an area of uncertainty in Alberta, and yet as mentioned previously the basic problems of water pollution by garbage leachates and the basic principles involved have been relatively well defined by recent work in the United States, particularly in Illinois (see reference listings). These principles are clearly applicable to Alberta situations, although quantitative factors may differ (e.g. climate, rainfall, volumes of water movement through garbage, chemical and biochemical reaction rates in garbage piles). Three significant differences between Illinois and Alberta situations are:

(i) rainfall, which in Alberta is roughly half that of Illinois

(ii) frost-free period, which in much of Alberta is roughly half that of Illinois

(iii) bedrock aquifers, which are much more permeable in Illinois than in Alberta.

All three factors suggest that water pollution problems originating from refuse dumps in Alberta will be smaller than in Illinois.

Significant elements affecting the relationship of water and refusal disposal sites

The main elements of significance to the interactions between refuse disposal sites and the hydrologic environment are outlined below.

1. Climate.

Climatic effects are of significance in that essentially no percolation of water into the ground takes place in Alberta from November to March, due to the ground being frozen. Major recharge takes place in the spring when the ground is generally saturated, and additional groundwater recharge may also take place in summer and fall in periods of heavy and/or prolonged rainfall.

Rainfall in the Edmonton region is roughly 16 inches annually, about half that of Illinois areas. Of this amount roughly 10 to 20 per cent (1 1/2 to 3 inches) may penetrate into the ground to reach the water table.

2. Groundwater Movement.

Of precipitation that falls on the ground, part runs off on the surface, part penetrates into the soil and is used by plants or is evaporated back to the atmosphere, and a smaller portion penetrates more deeply into the ground to form part of the groundwater system. Groundwater moves through the earth from topographically high areas (called recharge areas) to topographically low areas (called discharge areas), along generally predictable flow paths. The actual path that water travels through the ground is influenced by various factors, particularly variations in the characteristics of the earth materials, and also the topography of the land surface, to which the water table is closely related. Man-induced modifications may also produce changes in direction and rate of flow, brought about by the effects of pumping water from particular aquifers.

The flow of water from high to low ground is a dynamic system, regularly recharged by precipitation; these groundwater flow systems vary immensely in size, from a few tens or hundreds of feet to tens or hundreds of miles depending on the driving force and the ability of the aquifers to transmit water.

Groundwater can move rapidly and in quantity through earth materials with large intergranular spaces (such as gravels and coarse sands) or with extensive fractures or fissures (such as some shales and coal seams). Water moves more slowly through fine-grained sands, clayey sands and silts, and extremely slowly through clays, shales and glacial till (which generally has a high clay content). The rate and volume of movement also depend on the hydraulic head (i.e. the pressure or weight of water that serves as the driving force); the greater the hydraulic head difference between the top and bottom of a flow system, the faster the rate of flow.

3. Lithologic and topographic effects.

As indicated above, composition of subsurface materials and topography influence the rate and volume of water moving through the earth. With the same topographic situation, such as a 100-foot high slope from a plain to a valley floor, more groundwater can move more quickly through sand from the plain to the valley floor than through silt or through a clay. With the same lithologic situation, such as a sand hill, more water will move more quickly from crest to foot of a 200-foot high hill than a 100-foot high hill. The topography in effect constitutes the driving force in a groundwater system. On an extensive flat plain there is no significant groundwater movement because no driving force exists.

4. Chemical changes in groundwater.

Precipitation falling on the ground contains small amounts of various materials such as carbonate and sulphate ions. As the water moves through the ground it picks up more, mainly inorganic, chemical materials both by direct solution and also as a result of chemical interaction between the earth materials and the ions already in the water. Much of this takes place by exchange of ions that are held on clay minerals in the ground. Usually, therefore, the longer the water stays beneath the ground, the greater becomes its content of dissolved solid materials. Thus groundwaters that move slowly (through fine-grained materials) or for long distances tend to have higher dissolved solids contents than fast-moving or short flow-path groundwaters. The best quality groundwater supplies are therefore generally to be found in the coarser-grained and more permeable deposits.

Interactions among the elements and refuse disposal situations

The interaction of prime significance is that precipitation percolating from the surface downward through a refuse dump or sanitary landfill will dissolve a variety of materials from the garbage. For a number of years, therefore, soluble materials are leached from the refuse, and the resulting leachate is the cause of contamination. The typical leachate contains large amounts of inorganic chemical materials (e.g. sodium, calcium, carbonates, chlorides, nitrates, sulphates), various organic materials and organic degradation products, such as hexanes, ammonia, nitrates and various compounds with a significant chemical oxygen demand; a significant bacterial content is also common. The amount of leachate formation and the extent of contamination depend on a number of parameters as illustrated below.

However, it should be noted that in all of the situations to be outlined a natural purification of leachates does take place in the ground, as clay minerals may hold onto contaminants by an ion exchange process. Also, some self purification will take place within the garbage dump itself. Consequently, organic contaminants tend to travel less far than inorganic dissolved solid materials, due to the purification processes. The length of time of residence of leachates in the ground and the amount of clay mineral materials are the significant limitations on the natural purification processes.

A. In a dry, desert or semi-desert type of environment, little leaching takes place (figure A) by precipitation, and as the groundwater table is deep little leaching is effected by groundwater.

B. In a moist environment much of the precipitation penetrates into the ground, and leaching of garbage is extensive (figure B). If the garbage is mounded in an attempt to keep the material above the water table, the water table will also become mounded and leachate is still formed. The extent and rate of leachate migration depend on the rainfall, permeabilities of the surrounding materials, and rate of local groundwater flow.

C. In a low-permeability situation (figure C) the water table usually is close to the land surface, due to slow percolation, and groundwater movement is also slow. Thus the extent of leachate contamination in this type of situation is small.

D. In a high-permeability situation (figure D), the water table may be shallow or deep, depending on rainfall and position of the site in the groundwater system. Rapid and extensive movement of groundwater and of leachate is possible, constituting a high-risk situation for contamination.

The position of the site in the groundwater flow system, therefore, becomes most significant in the high-permeability situations, and several possible situations are outlined in diagrams E, F and G.

E. A high-ground, hill top or slope crest location for a refuse dump will be in a groundwater recharge area, meaning that recharge water percolates downward from the surface to replenish the groundwater. Leachate formed by downward-moving water will contaminate the groundwater system and produce extensive and long-lasting contamination.

F. A low-ground location is, by contrast, in a groundwater discharge area where under normal earth conditions groundwater moves upward towards the surface and discharges by springs or by seepage to the surface. The possibility of contamination of groundwater by leachates is thus small, but on the other hand the upward-moving groundwater may produce a leachate which discharges at the surface and pollutes the surface water drainage system. A slower discharge of groundwater will evaporate at the land surface, and thus any leachate will also evaporate leaving a precipitate at the land surface. Such precipitates will be washed away by heavy rainfall, causing limited contamination of surface-water systems.

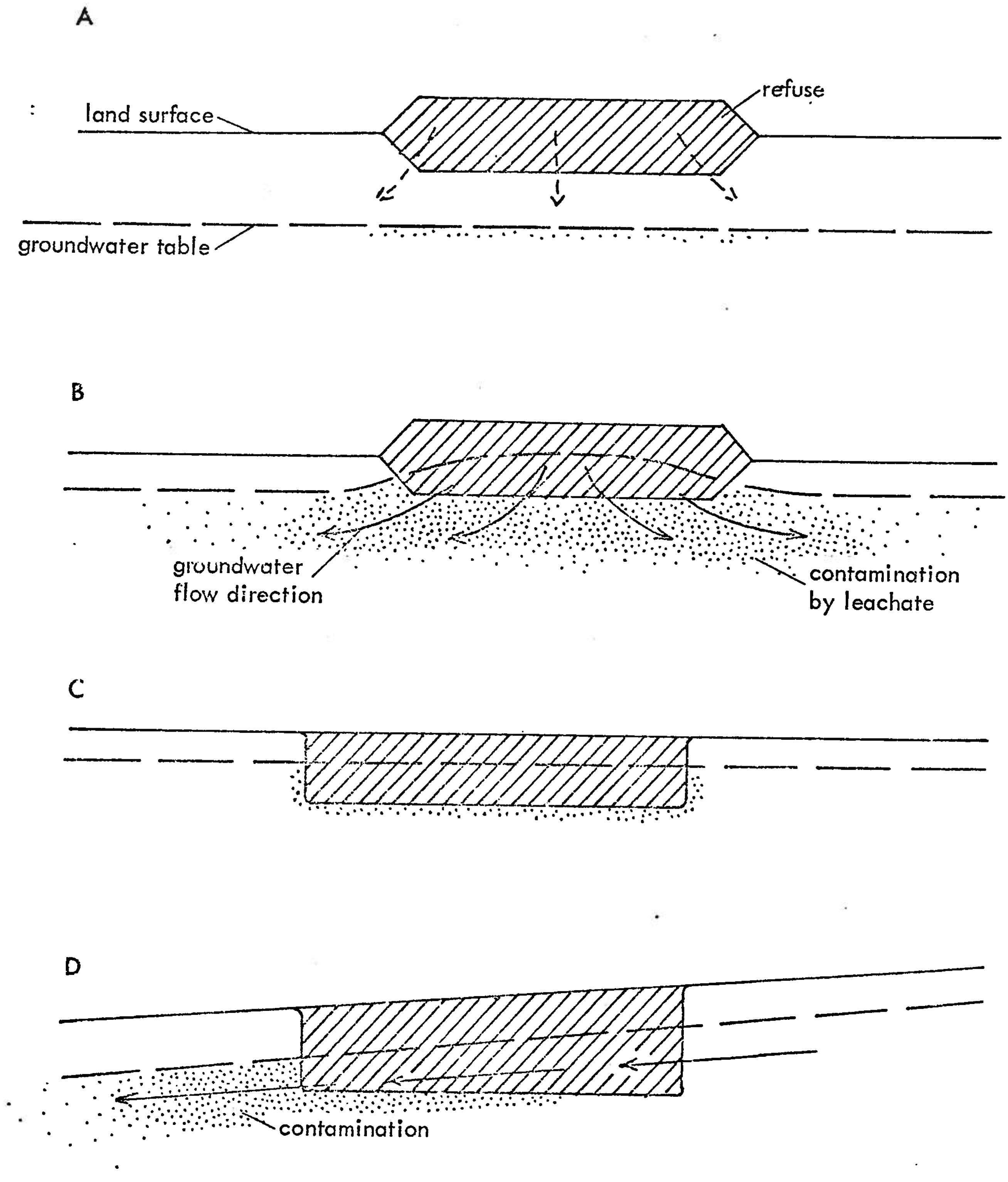
G. Many groundwater discharge areas are in river valleys where the local flow system situation can be complicated by the presence of terrace deposits of highly

Figure A. Dry, desert environment; gives deep water table, little leaching

Figure B. Moist environment; gives shallow water table, extensive leachate formation

Figure C. Low permeability; shallow water table, slow and localized groundwater and leachate movement

Figure D. High permeability; rapid and extensive movement of groundwater and leachate


A
land surface
refuse
groundwater table
B
groundwater
flow direction
contamination
by leachate
C
D
contamination

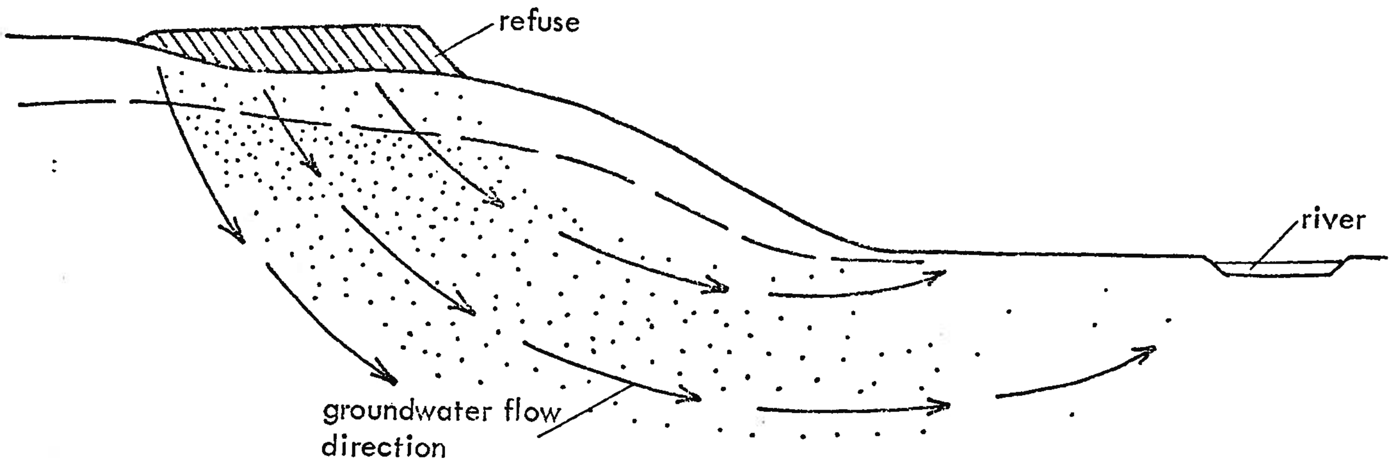
:

Figure E. High ground location (groundwater recharge area); leachate moves into the groundwater, causing extensive contamination

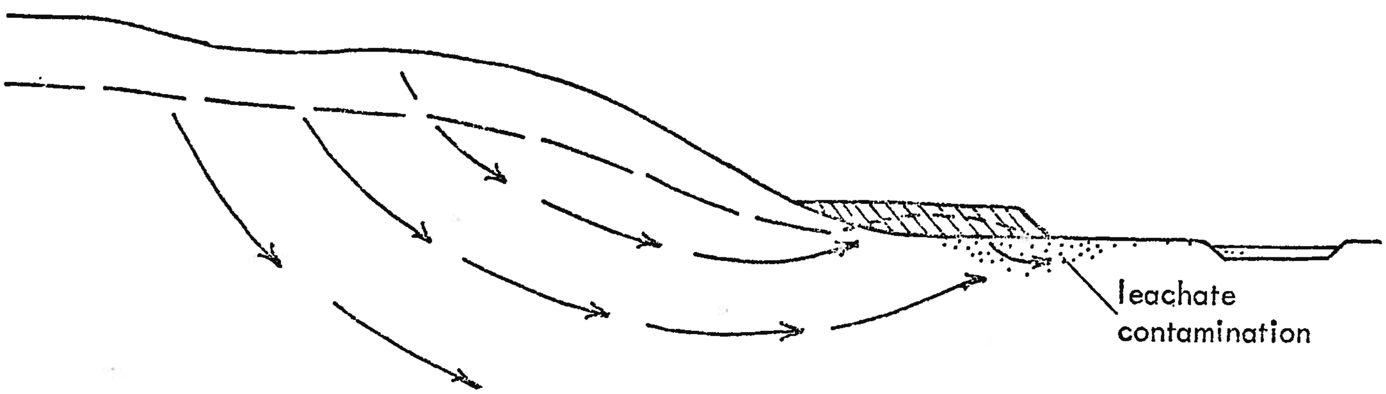
Figure F. Low ground location (groundwater discharge area); upward groundwater movement prevents significant leachate contamination

Figure G. Low ground location (groundwater discharge area); buried highly permeable gravel bed intercepts upward-moving groundwater, and induces downward movement of refuse leachate

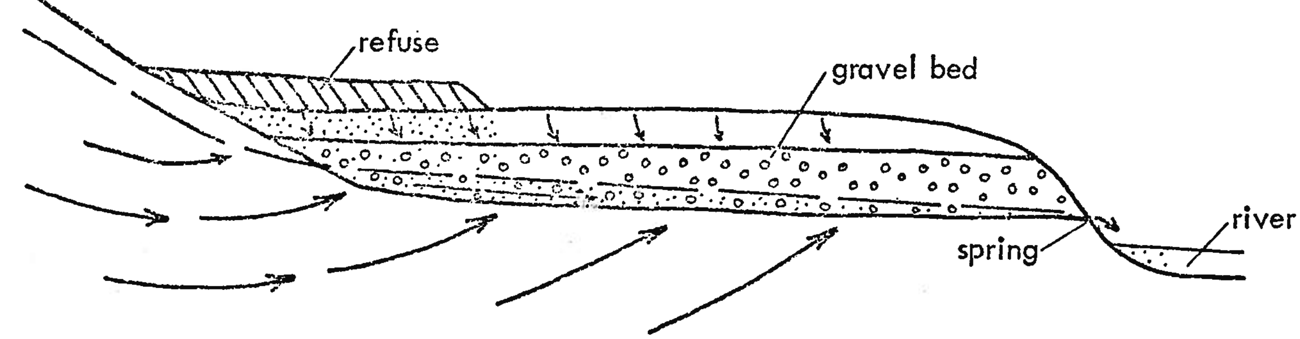
E


refuse
river
groundwater flow direction

F


leachate contamination

G


refuse
gravel bed
river
spring

permeable sand and gravel bodies. Figure G represents such a situation, similar to that in the North Saskatchewan River valley between Edmonton and Fort Saskatchewan. The buried highly permeable gravel beds intercept the upward-moving groundwater, preventing it from reaching the surface and draining it towards the river. A garbage dump located in the same situation as in figure F will in this instance result in more groundwater contamination, as downward movement of groundwater is induced by the "drain" effect of the gravel bed.

Because of complexities of this type that may cause the converse of an anticipated situation, all potential river-valley refuse disposal sites should have a thorough evaluation, including test-hole drilling of the underlying deposits.

Garbage disposal site selection in the Edmonton area

The most desirable garbage disposal sites are those from which minimal pollution will take place. Based on the work of Cartwright and Sherman (1969) in Illinois, and on the discussion above, a set of criteria have been compiled that relate to garbage disposal site selection in the Edmonton area. These are set out below, and are then applied to the geological situation in the Edmonton region to indicate the more favorable areas.

Criteria

I Type of unconsolidated material:

- Favorable: glacial lake silts and clays, till, windblown silts.
- Unfavorable: sand, gravel.
- Questionable: fissured till.

II Thickness of unconsolidated material:

- Favorable: 50 feet or more.
- Unfavorable: less than 50 feet.

III Type of bedrock:

- Favorable: shale, siltstone.
- Unfavorable: sandstones, coal seams.

IV Site topography:

Favorable: flat plains (prairie) areas.

Unfavorable: depressions where water accumulates; ravines and gullies; stream/river terraces and flood plains; other sites where leachate might discharge into surface water bodies.

Questionable: dry valley bottom sites (require specific evaluation).

V Groundwater situation:

Favorable: limited groundwater discharge (areas of saline soils, phreatophytic plant growth).

Unfavorable: groundwater recharge areas; active groundwater discharge areas (springs, seepages, bogs - water on the ground).

Questionable: groundwater situation undefined (specific evaluation required).

VI Relations to nearby water wells and/or aquifers:

Favorable: all nearby wells are deep; all aquifers covered by 50 feet or more favorable materials; no domestic wells within 1000 feet; no municipal or industrial wells in the area.

Unfavorable: shallow wells within 1000 feet; aquifer cover less than 50 feet of favorable materials; municipal and/or industrial wells exist in the area (wells as distant as several miles may induce groundwater pollution because of pumping effects).

If all favorable conditions are met there is little chance of groundwater contamination.

Application to the Edmonton region

Based on the above criteria the suitability of various sections of the Edmonton region as outlined on the geological map (in pocket) are evaluated below, in increasing order of preference:

7. Sand and gravel areas - mainly west and southwest of Edmonton are unsuitable because:

a) thick sand and gravel deposits which, in conjunction with the generally rolling topography have high potential for local groundwater contamination

b) high permeability.

6. Dune sand areas - mainly northeast and southwest of Edmonton are unsuitable because of:

a) sands of variable thickness

b) high permeability, which in conjunction with the rolling topography have high potential for local groundwater contamination (which is a recurring problem in northeast area farmyards).

5. Alluvium - river valley sites are unsuitable because of:

a) gravel, sands and silts

b) high permeability

c) regional groundwater discharge conditions

d) potential for garbage leachate to pollute surface waters.

4. Gwynne outlet area - suitable sites may exist.

Assessment:

a) thin surficial deposits on bedrock

b) bedrock is shale, siltstone and sandstone, generally flat lying, with local bedrock channels

c) groundwater situation is partly undefined

d) domestic wells 50-350 feet deep.

Recommendation:

Individual sites require evaluation to determine suitability especially concerning aquifer locations and depths.

3. Ground moraine area - suitable sites may exist.

Assessment:

a) generally thin till but ranging up to 100 feet thick locally

b) the till generally overlies bedrock of shale, siltstone and sandstone but can locally overlie unconsolidated sands and gravels in buried valleys.

c) generally low relief ranging to rolling in local areas

d) groundwater situation undefined in flat areas

e) poor aquifer.

Recommendation:

Individual sites require detailed investigation to determine suitability, especially concerning till thickness, nature of underlying materials, and aquifer distribution.

2. Hummocky dead ice moraine - suitable sites may exist.

Assessment:

a) mainly thick till, with local gravel sand and silt lenses

b) regional topographic high, hilly local relief

c) many short groundwater flow systems feeding potholes and sloughs

d) domestic wells often use sand and gravel lenses in the till.

Recommendation:

Suitable sites may exist in areas of low local relief; individual sites require investigation especially concerning till thickness and nature of underlying materials.

1. Lake Edmonton deposits - suitable sites may exist.

Assessment:

a) bedded fine sands, silts and clays, ranging from 1 to 100 feet thick and usually overlying till

b) generally flat to gently rolling topography

c) groundwater situation largely undefined

d) poor aquifer.

Recommendations:

Individual sites require investigation, especially concerning thickness and sand content of lake sediments and thickness of underlying till. Local depressions where water accumulates should be avoided.

The application of these criteria indicates that areas of thick fine grained lake sediments underlain by thick till have the greatest suitability for solid waste disposal in the Edmonton region.

However, the preglacial drainage system in the Edmonton region has a number of valleys, now buried, that contain extensive sand and gravel deposits. In the larger valleys these deposits have substantial value as aquifers, and are highly permeable. Northeast of Edmonton, gravel operators have long worked pits containing these materials.

These valley locations are mostly unsuitable for solid waste disposal sites because of the considerable potential for groundwater and surface water pollution. Any potentially suitable sites in these areas should be thoroughly evaluated to determine the local groundwater situation.

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