DESIGN OF AN OIL WASTE LAND TREATMENT FACILITY FOR THE COLD LAKE PRODUCTION PROJECT[1]

B. Runge[2] . Operations Manager. Western Oilfield Environmental Services. 100 - 622, 5th Avenue S.W. Calgary Alberta. T2P OM6
A. Kennedy. Manager, Environmental Affairs. Esso Resources Canada Ltd. Cold Lake District Operations. Service 15. Grande Centre, Alberta. TOA 1VO
M. Mears. Operations Advisor. Western Oilfield Environmental Services. 100 - 622, 5th Avenue S.W. Calgary, Alberta T2P 0M6

INTRODUCTION

Esso Resources Canada Ltd (Esso) operates an oil sands production project at Cold Lake, Alberta that produces approximately 14,000 m^3/day of bitumen for the world market. On December 8, 1988 a failure on observation well C7-13 created an oil spill of about 1000 m^3 of bitumen and 2600m3 of produced water. The bitumen spill and resultant seepage contaminated an area of muskeg of about 1 ha in area. The contaminated material was removed from the site during the winter and stockpiled pending a decision on the disposal option.

Esso later developed and began the operation of a Land Treatment Facility (LTF) on this site to dispose of the 3600 m^3 of bitumen and produced water contaminated muskeg. Several disposal options were evaluated on the basis of environmental, operational, and cost factors, and it was concluded that land treatment offered the most environmentally sound and cost effective disposal option.

Land treatment is a disposal process applied to waste oily sludges from petroleum refining (Huddleston, 1979). The activity of soil microorganisms along with physical and chemical processes, is utilized in degrading, transforming, and immobilizing the hydrocarbon components of the sludges. Principles advantages of land treatment of oil wastes are:

a) it utilizes naturally occurring processes and microorganisms in a temporary environment;

b) it can be operated and monitored as an integral part of an oil production facility;

c) it has the capability of disposing of significant volumes of production wastes; and

d) it disposes the wastes in a manner that the treatment site can be oper-

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[2] Deceased.

d) it disposes the wastes in a manner that the treatment site can be operated and abandoned without detrimental impacts to the environment.

Western Oilfield Environmental Services Ltd. was engaged by Esso to evaluate prospective site, provide a conceptual design for the LTF and prepare the relevant applications for approval of the LTF from the regulatory agencies.

The purpose of this paper is to describe the site evaluation process, the facility design, and operational aspects of the LTF.

SITE DESCRIPTION

The Esso Resources Cold Lake Project is located near Cold Lake, Alberta at approximately 54 degrees 25 minutes north latitude. The project is located within a stagnant ice moraine, or doughnut moraine, consisting of circular hummocks with central depressions. Regional vegetation is classified as the Dry Mixedwood Subregion of the Boreal Mixedwood Forest (Strong and Leggat, 1981). Upland sites are vegetated by an aspen/*Viburnum* association while low lying sites are vegetated with a bog birch/*Sphagnum* association.

Soils

A 2.1 ha cleared site which lay near the stockpiled oil waste material and which appeared to have suitable drainage conditions was selected as a prospective site for the LTF. Calculations indicated that 6.4 hectares would be required to meet LTF design criteria. Therefore another 4.3 hectares adjacent to the site was cleared. This consisted of 3.9 ha of aspen forest and 0.4 ha of birch/*Sphagnum* bog.

The site lies within a land unit described by Fenton and Andriashek (1983) as 50 percent organic and 50 percent doughnut moraine with hummocky terrain and low to moderate relief. Alberta Energy and Natural Resources (1977) classifies the area as knob and kettle ablation moraine. Orthic Grey Luvisols dominate the upland sites. They typically have developed on fine loamy calcareous glacial till. Often a thin layer of sandy outwash is found on top of the till. Low lying areas are characterized by organic soils and Gleysols (Alberta Energy and Natural Resources, 1977). A soil survey of the Sand River area mapped at the scale of 1:126,720 identifies the soils of the proposed site to be 50 percent Tomson, 30 percent La Corey, and 20 percent St. Lina soils (Kocaoglu, 1975). Tomson and La Corey soils are classified as Orthic Gray Luvisols, and St. Lina as a Terric Humic Mesisol. Detailed analytical data from representative soils as described by Kocaoglu (1975) are presented in Tables 1 and 2.

The site selected for evaluation has low relief and is level to nearly level. Two areas were sampled: the cleared and the adjacent uncleared areas. Following Alberta Environment's(1988) *Guidelines for Land Treatment of Industrial Wastes*, forty topsoil samples from within the cleared area were composited into two samples, and twenty-four subsoil samples were composited into two samples for each of depths, 15-30, 30-60, and 60-90 cm for the purposes of analysis. Samples were collected by hand auger at the bottom of these depth intervals.

Samples of native soils in the uncleared portion were collected with a hand auger, and at the edges of the forest cover, a backhoe. Three different areas of upland sites (Luvisols) were sampled and composited according to four depth intervals. These are designated 2-, 3- and 4-. Seven additional backhoe pits were dug to 4 m depths. Samples were collected at 1 m, 2 m, and 3 m depths and analyzed for texture and moisture. Samples at one meter were also analyzed for a range of other parameters as well . Two pits were dug in organic soil sites. Because of wetness, only one sample of the till material from each was collected and analyzed for texture.

Within all the backhoe pits sandy clay loam till material was present to a depth of four meters. In upland sites the till is a dark brown sandy clay loam, massive with few or no fractures, infrequent thin (2-4 cm) sand lenses, slightly calcareous, stiff to very stiff consistency, slightly moist, and with red mottles throughout the profile. Coarse fragments (> 2 cm) are two to 10 meters apart. Samples were collected at one meter depth intervals and analyzed for texture and moisture. Textures consistently fell within the sandy clay loam range.

Soils are acidic to moderately acidic in the upper layers with pH values ranging from 5.5 to 6.5 above 60 cm (Tables 1 and 2). Values at the 90 cm depth are in the neutral range, 6.8 to 7.5. The soils are generally low in fertility with low available nitrogen and phorphorus values and low CEC values. Chlorides, sulphates, conductivity, and sodium adsorption ratio values are all low, indicating favorable conditions for these parameters.

Field tests were conducted to obtain estimates of soil permeability within the study area. A total of 7 auger holes dug to a depth of 1 m were used to determine field estimates of soil permeability. Each hole was filled with water, and static levels were recorded at set time intervals over a 24 hour period.

Estimated soil permeabilities from the sample points were within the "ideal" range (10^{-3} - 10^{-6} cm/sec) specified by the Alberta Government guidelines (Alberta Environment,1988). Soil permeabilities were estimated at an average of 4×10^{-5} cm/sec.

Hydrology

Glacial drift within the study area is composed of unconsolidated sand and gravel Quaternary deposits. These deposits are 120 to150 m thick. Gamma ray logs from nearby oil wells (4-9 and 4-16-65-4-W4M) indicate sand and/or gravel deposits at approximately 27.0 and 33.0 m, respectively, below ground level (Stanley Associates Engineering Ltd., 1978).

Nine four meter holes were excavated with a backhoe, in an effort to determine the approximate static level within the study area. Of the nine holes excavated, only two within the low lying organic area contained any water after three hours. The average static level for shallow groundwater, calculated from available data, is 22.5 m. The range of static levels from available data is 12.2 - 45.7 m (Faculty of Environmental Design, 1985). In general, flow is in an east - southeasterly direction. More information on shallow groundwater in the project area is being collected to determine flow rates and direction.

LAND TREATMENT FACILITY DESIGN

General Design Features

The waste material to be land treated consists of 3600 m^3 bitumen and produced water contaminated muskeg. It is a thick semi-solid material consisting of oil, sand, peat, water, and woody fragments. Samples of the material were collected from six sub-surface locations on the waste pile and composited for analysis. Content by weight is 24.6 % oil, 30.6 % solids, and 44.6 % water.Results of the chemical analyses are presented in Table 3. Notable chemical characteristics are high levels of chlorides, and sodium, with resultant high EC and SAR values. However, application of the oily waste to the soil is planed to dilute chloride and sodium concentrations by a ratio of 1: 5830, waste to soil. Sodium and chlorides, therefore, will not be detrimental to microbial populations or plant growth.

The LTF has been designed to achieve cost effectiveness and minimal alteration of the existing landscape to facilitate ultimate reclamation objectives. The LTF will allow a two time application at a 5 percent loading rate in combination with interim waste storage. It may also be used by Esso Resource's Cold Lake project for future oily waste treatment if required during the term of the project.

About six and one half hectares of trees have been cleared, topsoil separated and stockpiled during grading, and the site graded and levelled to a 2.5 to 3 percent grade with a southerly aspect, topsoil has been reapplied, and the area bermed. In addition, organic material within the effected site has been excavated and stockpiled for for later use as a land surface amendment.

Surface runoff is controlled by draining water into an interception ditch at the bottom of the grade and liquids are then compared with Clean Water Licence to Operate lease discharge criteria. Should these criteria not be met, the liquids are returned to the central plant for recycle.

The facility would operate for the period of time required to treat the 3600 m^3 of contaminated material currently stored on site. At the completion of this treatment, the continued need for all or part of the site will be evaluated.

Regardless of the lifespan of the LTF, upon decommissioning the site will be properly restored to support vegetative cover similar to that originally present.

SITE PREPARATION

Near neutral soil conditions are required to facilitate microbial action. Acidic soil conditions (pH 5.5 to 6.5) were therefore corrected with the application of lime. Woody material from the site, primarily aspen stems, were chipped and applied as an organic amendment. Nitrogen, phosphorus and sulphur deficiences were corrected with applications of NPKS fertilizer. Lime is applied whenever necessary to maintain pH levels near 7.0.

The site was cleared with bulldozers and chainsaws; merchantable timber was salvaged, and stumps were rolled and raked and the timber bucked. A breaking disc was run over the cleared site to cut up roots below the surface. Remaining woody fragments were removed from the soil with a brush or root rake.

Under supervision, topsoil was separated, and stockpiled. Peat material from low lying areas was then stockpiled for subsequent spreading. The site was then graded to a 2.5 to 3 percent slope with a south-facing aspect; low lying areas were filled with till material. Compacted subsoils were cross-cultivated where necessary.

A mixture of 11-51-0 fetilizer at a rate of 20 lbs/acre and a seed mixture (streambank, crested wheatgrass, reed canary, creeping red fescue, timothy and white clover) at a rate of 25 lbs/acre was hydroseeded onto the ditch and berm areas.

Stockpiled topsoil and peat was spread over graded areas with loaders and rubber tired buggies. Topsoil was sampled to establish a data base line. Twelve groundwater observation wells were installed.

Lime, and 34-0-0, 11-51-0, and 0-0-60, fertilizers, calcium nitrate, and straw were then applied and tilled into the soil.

Oily wastes were then spread with a truck-mounted manure spreader, however as the spreader was not able to function adequately with the number of large rocks encountered heavy equipmtn was used to place the oil waste. The entire area has been aerated each month since application. Year Two of operations will see a continued program of aeration and fertilizer application. Soil samples will be collected to assess oil degradation and nutrient status.

Surface Run-on and Run-off Control Systems

On-site and off-site surface drainage is controlled by a perimeter berm and ditch system. The ditch is 0.5 m deep and 2 m wide. It was graded as required to allow flow to access areas where runoff is collected by a suction truck. Both the ditch and the berm was seeded with grass species. A 3.5 m wide buffer zone was provided around the facility and was seeded to control erosion.

Oily waste not being treated is being stored in the present storage area. This area is bermed and fenced and is suitable for material storage until subsequent material applications can be made.

MONITORING

A total of 12 groundwater observation wells were installed 1 m outside the LTF perimeter to accommodate sampling of shallow groundwater hydraulically up and down gradient.

Based on the size (6.4 ha) of the LTF, it is felt that water samples from 12 observation wells will yield representative shallow groundwater information. Two observation wells were installed along each side of the LTF and four were installed within the treatment plot near the perimeter. Observation wells are spaced equidistant from each other and were completed to the depth of the first aquifer to obtain water samples up and down gradient of the aquifer, taking into consideration micro-relief which may influence groundwater flow.

Standpipes have been set into the first aquifer to determine static levels and to obtain periodic water samples (Spring and Fall) from each standpipe. The perforated section of the standpipe extends from -0.5 m to below water table depth. Pea size gravel or sand was used to pack the annular space between the auger hole and the standpipe. A bentonitic clay product (Peltonite) was used to provide the annular seal.

Water samples will be obtained twice a year (Spring and Fall) and analyzed for the following parameters: pH; Ca; Mg; Na; K; Cl; NO3; SO4; chemical oxygen demand; TOC; TDS; oil and grease; EC; heavy metals. Analyses of all groundwater samples shall be conducted in accordance to standards specified by the Alberta Environment (1988).

Soil sampling and analysis will be proceed in accordance to specifications set out in the Alberta Environment (1988). Immediately after final grading and topsoil replacement, topsoil and subsoil sampling will be conducted within a grid system of 20 cells per hectare to establish a data baseline.

ABANDONMENT

The LTF will be closed upon the termination of Esso Resource's Cold Lake operations or at any time the facility is deemed unnecessary.

The ultimate objective of a reclamation program will be to restore the soil to a level of productivity similar to that of the native soil. Microbial decomposition of the oily material should result in a higher organic matter content. Revegetation objectives will emphasize restoring the original aspen parkland forest.

Soil monitoring will help determine the oily content of the soil and whether the soil is suitable for revegetation. As the oily content decreases to one to two percent or less, various species will be planted on an experimental basis. Species with medium tolerance to oil, such as white spruce, white clover, barley, creeping red fescue, and Timothy, or species with a high tolerance, such as oats, alsike clover, brome, willow, dogwood will be considered. Species that respond best will be emphasized in the planting program.

Ultimate reclamation will entail levelling the berm and filling the interception ditch. Since the land treatment process requires a soil maintenance program including cultivation and amendments, the soil should be in a condition conducive to final revegetation when closure is implemented.

CONCLUSION

The evaluation process and facility design have followed the Alberta Environment (1988) *Guidelines for Land Treatment of Industrial Wastes.* Sampling procedures following a grid configuration in the *Guidelines* were modified to suit local forested conditions.

Soil and drainage conditions meet criteria in the *Guidelines.* The facility has been designed to accomodate a two-time application combined with interim storage.

The land treatment facility will provide a cost effective and environmentally sound alternative for the disposal of a large amount of oily waste material. The monitoring program, which will gauge oil content reduction and groundwater quality, will provide an interesting perspective on land treatment as an effective disposal option for oily wastes.

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Table 1. **Analytical Data for a La Corey Soil Profile (SE36-58-9-W4M)**

Horizon	Depth (cm)	pH (H2O)	N %	Org. Cont. %	C:N	CaCO3 equiv. %	Exchangeable Cations (meq/100g) H	Na	K	Ca	Mg	Total Exchange Cap. (meg/100 g)	Sand (%)	Silt (%)	Clay (%)
L-H	8-0	6.2	0.71	10.25	14.40	-	6.6	0.1	1.2	24.1	2.8	36.4	-	-	-
Ae	0-9	6	0.09	0.9	10.00	-	1.9	0.1	0.2	4.6	0.9	7.3	38	48	14
Ba	9 - 14	5.6	0.05	0.54	10.80	-	2.2	0.1	0.3	6.9	1.9	11.2	35	39	26
Bt1	14-44	5	0.05	0.41	8.20	-	2.4	0.2	0.4	8.6	3.8	16.7	36	34	30
Bt2	44-81	5	0.03	0.36	12.00	-	2.4	0.8	0.4	9.3	4.2	16.6	34	37	29
BC	81-97	6.9	0.04	0.46	11.50	-	0.3	0.2	0.4	9.3	10.4	20.6	26	28	45
Ck1	97-130	7.7	-	-	-	5.46	-	-	-	-	-	-	37	37	26
Ck2	130+	7.6	-	-	-	9.72	-	-	-	-	-	-	44	35	21

Table 2. **Analytical Data for a Tomson Soil Profile (SW28-60-1-W4M)**

Horizon	Depth (cm)	pH (H2O)	N %	Org. Cont. %	C:N	CaCO3 equiv. %	Exchangeable Cations (meq/100g) H	Na	K	Ca	Mg	Total Exchange Cap. (meg/100 g)	Sand (%)	Silt (%)	Clay (%)
L-H	2.5-0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ae1	0-5	7.9	-	-	-	0.48	-	-	-	-	-	-	76	20	4
Ae2	5 - 13	7.2	0.02	0.18	9.00	-	-	0.02	0.12	1.1	0.46	2.5	62	31	7
IIBt1	13-28	6.8	0.04	0.38	10.00	-	1.2	0.05	0.34	8	5.5	15.5	47	23	30
IIBt2	28-61	5.5	0.03	0.27	9.00	-	1.5	0.07	0.27	6.7	4.7	13.8	47	25	28
IIBC	61-86	6.9	-	-	-	-	0.5	0.06	0.24	7	4.5	12.3	49	25	26
IICk	86+	7.5	-	-	-	7.15	-	-	-	-	-	11.7	46	26	28

TABLE 3. **Oily Waste Material - Chemical Characteristics**

PARAMETER	VALUE
pH	7.7
EC	6.62
Soluble Na (mg/L)	1306.4
Soluble Ca (mg/L)	156
Soluble Mg (mg/L)	71.98
Soluble K (mg/L)	28.93
Soluble NH3 (µg/g)	13
SAR	21.7
Soluble NO3 (µg/g)	0.166
Soluble SO4 (mg/L)	13.44
Soluble Cl (mg/L)	1881.5
Extractable N (µg/g)	0.5
Extractable P (µg/g)	2
Extractable K (µg/g)	33
B. Density (dry)(gm/cc)	0.32
TOC(%)	37.2
Total Oil (%)	24.6
Total Cadmium (µg/g)	<0.1
Total Chromium (µg/g)	5.2
Total Nickel (µg/g)	35.5
Total Lead (µg/g)	<1.0
Total Zinc (µg/g)	46.5
Total Mercury (µg/kg)	64.6
Total Copper (µg/g)	2.3
Solids (%)	30.6
Moisture (%)	44.6
Cation/EC Ratio	10.7
Anion/EC Ratio	8
Cation/Anion Ratio	1.3

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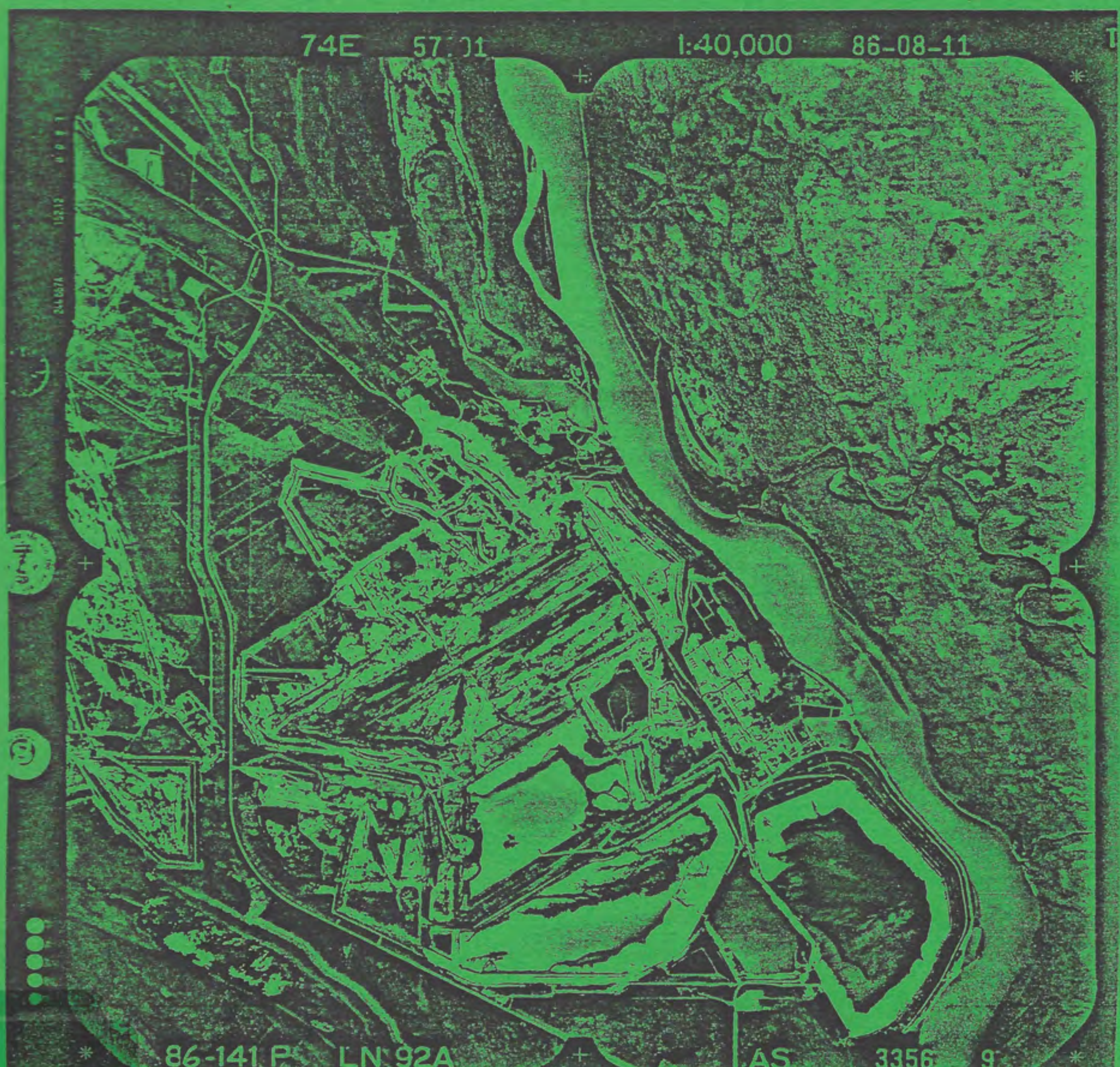

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Front Cover: 1986 airphoto of the Suncor facility, north of Fort McMurray, Alberta.

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DEDICATION

These proceedings are dedicated to the memory of Bruce Runge and Michael Mensforth. These two reclamationists passed away in the fall of 1990 while on the job.

Bruce Runge worked for Western Oilfield Environmental Services Ltd. as Operations Manager and was on his way to conduct a pipeline inspection in the Primrose Lake area when the helicopter he was in crashed on the outskirts of Edmonton. Bruce was 45 years old.

Michael Mensforth worked as a reclamation technologist for Alberta Environment, Land Reclamation Division and was on his way to a site in northern Alberta when he was killed in a freak vehicle accident. Micheal was 35 years old.

The loss of these two specialists is a blow to the small reclamation community of our province. It also points out to the rest of us that ours can be a dangerous profession and that safety is critical in our business.

SPONSORS

The Alberta Chapter of the Canadian Land Reclamation Association would like to thank the following sponsors for making the conference and tour a success:

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