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INTEGRATION OF MINE DEVELOPMENT PLANNING AND RECLAMATION AT A PLAINS COAL STRIP MINE - THE HIGHVALE MINE EXPERIENCE

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ABSTRACT

The Highvale Mine is located in CentraL Alberta, 65 km west of Edmonton. It is the largest of several coal strip mines operating in agricultural areas of Alberta. Government guidelines require that mined land be returned to a capability equivalent to or better than that which existed before mining.

Mine development planning, driven primarily by the economic extraction of coal, must also incorporate the goal of satisfactory reclamation. Satisfactory reclamation can only be achieved where land capability objectives are clearly stated along with the system by which it is measured.

Planning at the Highvale Mine incorporates an assessment of premine capability in order to establish targets for the reclaimed landscape. To achieve these capability targets significant efforts are made in preparing soil material handling plans which achieve the dual goals of economic extraction of coal, and return of mined land to an acceptable capability. Optimization of soil handling, especially through reduction of soil transport or storage, has been effectively integrated into mine development plans with the use of a geographic information system.

Current research into alternative methods of salvage combined with continued assessment of the suitability of overburden material points to success.

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Intégration de la planification du développement minier et de la réhabilitation dans une exploitation minière de charbon à ciel ouvert - l'expérience de la mine Highvale

par

D. K. McQueen, E. C. Wenzel, J. C. Bateman et E. Eartley

La mine Highvale est située dans le centre de l'Alberta, 65 km à l'ouest d'Edmonton. Il s'agit de la plus importante des exploitations de charbon à ciel ouvert des régions agricoles de l'Alberta. Une fois l'exploitation terminée, la réglementation gouvernementale exige que le site soit réhabilité vers ses caractéristiques initiales.

La planification du développement minier, motivée principalement par les critères économiques de l'extraction du charbon, doit également incorporer l'objectif d'une réhabilitation adéquate. Une réhabilitation adéquate ne peut se réaliser que lorsque les objectifs de caractérisation du site sont clairement définis de même que l'approche utilisée pour les mesurer.

A la mine Highvale, la planification englobe une évaluation des caractéristiques du site avant le début des opércitions minières. Pour réaliser les objectifs de réhabilitation du site, des efforts importants sont consacrés à la préparation des matériaux et au développement d'une planification visant à atteindre le double objectif de l'extraction rentable du charbon et de la réhabilitation ultérieure du site. L'optimisation des techniques de manipulation des matériaux, surtout en ce qui a trait à la réduction de leur transport et de leur entreposage, a pu être intégrée de façon efficace à un plan de développement minier grâce à l'aide d'un système d'information géographique.

La recherche actuelle en matière de méthodes alternatives de récupération, combinée à l'évaluation continue des charges de matériaux, semble promettre des bénéfices futurs, grâce à la réduction des coûts de manipulation des matériaux ainsi qu'aux succès d'une réhabilitation améliorée.

Mots-clés additionnels: caractérisation, sous-sol, réhabilitation, système d'information géographique, récupération.

ADDITIONAL KEY WORDS

Capability, suitability, subsoil, salvage, geographic information system.

OBJECTIVE

The primary objective of this paper is to illustrate the process by which an operating coal strip mine plans and implements reclamation activities in the context of sustainable development. It provides a summary of the process by way of example using one of the pits, Pit 04, in the Highvale Mine as a typical case.

BACKGROUND

The following section provides a brief summary of the longterm goals of the reclamation program and an overview of current mining operations at the Highvale Mine.

Longterm Goals

The coal mining activities carried out at the Highvale Mine are viewed by the owner, TrarisAlta Utilities Corporation, as being a temporary land use. The goal of this temporary use is to extract coal at an affordable cost for use as fuel at two mine-mouth thermal power plants. It is TransAlta's longterm goal, and a requirement of its mine Development and Reclamation Approval (C-2-81), that the land disturbed in the process of coal extraction be returned "… to a land capability that is equivalent to that which existed prior to disturbance". TransAlta ensures the sustainability of its mining development by achieving its stated land capability goals on its reclaimed lands, and through the eventual disposition of these lands back to the local agricultural community.

Mine Operations

TransAlta's Highvale Mine, currently comprising of four active pits, supplies about 12 million tonnes of coal per year to the Sundance and Keephills thermal power plants, located approximately 65 km west of Edmonton, Alberta.

Surface coal mining began in 1971 in the Highvale Mine permit area (Figure 1). The pits are located in a 16 km long, 6,560 ha band along the south side of Wabamun Lake. Mining commenced at the north end of each pit and hats extended southward disturbing approximately 115 ha of land annually.

For illustrative purposes this paper presents information on the development and planning of Pit 04 which is located at the northwest corner of the Permit Area. This pit, opened in the early 1980's, is expected to produce coal at an average annual rate of approximately 3.34 million tonnes per year until depletion in 2015 (TAU 1986). The entire pit development will result in the disturbance of nearly 810 ha. Presently, mine development activities in the pit annually disturb approximately 115 ha, an area roughly equivalent to that which is being reclaimed annually.

PRE-MINEPLANNING

The first step in mine reclamation planning involves understanding the environment in which the development is to occur. The first task is a multidisciplinary inventory of resources: soils, biological flora and fauna (terrestrial and aquatic), climate, surface water and groundwater and present land use. The impact that the mine development will have is assessed and specific mitigation measures are developed and incorporated in the Development and Reclamation Plan.

The following discussion presents the soil/land capability and material handling issues addressed in the integration of the mine development plan with the reclamation plan.

Specific Reclamation Objectives

The objective of reclamation, as stated previously, is to return the land to a level of capability equivalent to that which existed before mining. Capability is assessed for specific purposes, the choice of which must be determined locally. The Canada and Alberta Land Inventory programs include capability classifications for a number of purposes including, in part, such activities as agriculture, forestry, wildlife (ungulates and waterfowl, furbearers), fisheries and recreation. The choice of the most appropriate activity, hence capability system by which reclamation targets should be evaluated, was determined by reviewing recently prepared present land use maps (to determine the most common local activity or activities), and through discussion with local (county) and provincial agencies (Alberta Environment's Land Conservation and Reclamation Council).

In our particular case, the mine is in an area of extensive agricultural land use and therefore agriculture capability was chosen as the yardstick against which to assess the pro-mine situation and formulate post mine reclamation targets.

Capability Assessment Procedure

In Alberta there are two agricultural capability rating systems commonly used, the Canada Land Inventory (Brocke, 1977) and the more recently published Land Capability Classification (Alberta Soils Advisory Committee, 1987a). Both systems group mineral soils into 7 classes according to their potential (degree or intensity of limitation) for agricultural use. Classes 1 to 3 are capable of sustained production of common cultivated crops, class 4 is considered marginal, class 5 is capable of permanent pasture or hay, class 6 capable only for native grazing and class 7 has no potential for agricultural use.

Common subclass qualifiers include undesirable soil structure, topography and excess soil moisture. The effect of increasingly steep topography on the soil capability rating is presented in Table 1. The dominant soil slopes in Pit 04 are shown in Figure 2.

The systems differ in their approach to soil ratings (Monenco Limited, 1990). The CLI is more qualitative, allowing greater flexibility in interpretation, especially in situations of complex soil and landscape interactions. The LCC is a more quantitative system with an extensive list of parameters used in each evaluation.

The CLI system was selected for the pre-mine land capability assessment, because of its capacity to rate soil erodibility and slope interactions common to the mine area. There is, however, generally little difference in the class ratings obtained in both systems and the LCC system, because of its quantitative nature, may prove to be the system to use when assessing the reclaimed landscape.

Simply stated, the agricultural capability (Brocke 1977) of the land in Pit 04 was determined, based on climate, soil and topographic characteristics and summarized to establish land capability objectives for this particular pit (Figure 3, Table 2). In practise, however, the capability of lands throughout the entire area to be mined, including the other pits, are summed and the relative proportions of land occurring in each class (classes 3,4, 5, 6 and non-agricultural) becomes the target value for the mine as stated in the D&R Application (Table 2).

There is some operational flexibility built into the system using this approach as it allows for some swapping of areas of a particular capability between pits, where it may be beneficial to do so from a materials handling perspective, yet still achieves the overall capability targets.

Soil and Overburden Surveys and Integration

The quality of the baste field data is a critical element in planning a successful reclamation program. TransAlta has undertaken a number of related field investigation programs which together provide information adequate for long term planning and annual salvage operations.

The information from these investigation programs is used in determining the quality, quantity and location of soil materials required in the restoration of the disturbed lands. The soils information used for long term planning is verified in annual presalvage surveys and again at the time of actual salvage by qualified soils personnel. The field investigation programs involved:

Surveys for the 25 Year Plan: Standard pedlogic and surficial geologic survey techniques were employed in the field and laboratory programs undertaken in preparation for the 25 year development and reclamation planning period, 1986-2011 (Monenco Limited, 1986, 1987a). The programs are briefly summarized below and described in detail in a previous paper (Schori et al 1989).

The soil survey undertaken in 1985 was conducted, in part, on 425 ha of Pit 04 at survey intensity level 1 (i.e. one inspection per hectare [10Om grid]), with samples collected and analyzed from about 10% of these sites (50 sites)., Soils were classified according to the Canadian System of Soil Classification (Canadian Soil Survey Committee, 1978) and described as per the Canada Soil Information System Manual (Day, 1983). A summary version (grouped dominant soils only) of the Pit 04 soil map is presented in Figure 4.

A detailed overburden drilling program, (one drillhole per four hectares [20Om grid]), was conducted during the period 1984 to 1986 in areas currently under development. As part of this program a total of 141 drillholes were completed in Pit 04. Roughly 90% of the sites were drilled with an auger rig to refusal and the remainder with a reverse circulation drill rig to penetrate coal. Over 1,200 overburden samples were examined (stratigraphy, lithology, thickness, color, texture, plasticity and consistence) and approximately 550 of these were collected for laboratory analyses to describe the 10 major stratigraphie units in the mine area.

An extensive analytical program was conducted to characterize the soil and overburden, both chemically and physically. The parameters chosen reflect the information required to classify the relative suitability of these soil materials for reclamation purposes. The parameters and methods off analysis are presented in Table 3.

Surveys for Salvage Operations: As part of the routine mine operation an annual pre-salvage soil survey is conducted in the thin strip of land (typically less than 100m wide yet extending the full 4 km length of the mine cut, in Pit 04) to be salvaged ahead of mining in the following year. This survey confirms the boundaries of each soil unit and the thickness of suitable material in each unit. The results are used to develop a more detailed soil suitability map for use by both the mining contractor, for annual and quarterly salvage scheduling, and the supervisor of soy handling operations during the monitoring of salvage activity. Soil handling quality control procedures such as these reduce the costly rehandling of unsuitable soy materials and allows for the selection of good or fair rated materials in preference to poor rated, yet suitable subsoil.

Subsoil Suitability Assessment

The subsoil suitability criteria as shown in Table 4 are as per Alberta Soils Advisory Committee (1987b) with some modifications. It has been TransAlta's experience that modifications were necessary to reflect the combined effect of marginally adverse physical and chemical characteristics in their particular locale which is characterized by periods of excess moisture. Problems associated with poor soil tilth and slow soy drainage were common especially on these marginal soils.

The same subsoil suitability rating system used for soils was also used for overburden.

Subsequent to TransAlta's last D&R submission in 1986 (TAU_1 1986) permission has been given to use suitable rated sandstone units as a substitute for conventional subsoil sources on class 4, 5 and 6 lands. A fairly comprehensive initial review of the potential sandstone resource at the Highvale Mine and its pedogenic characteristics was completed and field studies are now being conducted to assess the behaviour of these sandstone derived reclaimed soils (Monenco Limited, 1990 Draft). The use of sandstone unit derived subsoil may have a potentially significant impact on the subsoil materials handling and reserve volumes.

Integration of Soil and Overburden Data

Subsequent to the completion of the overburden and soil surveys it became evident that a method of integrating subsoil information from the two programs was necessary for reclamation and material handling planning with this information.

In field and laboratory programs for it is soils general to map and describe the top 1.0 to 1.5 m of material from ground surface because overburden programs generally cover the material between 1.5 m and coal. However, throughout much of the Highvale Mine overburden studies actually sample and describe material situated between 0.8 and 1.5 m from ground surface as well as overburden below 1.5 m. The overlap of soils and overburden data for the 0.8 and 1.5 m interval in most of Highvale Mine has allowed for effective integration of data for this project. In addition, correlation of soil parent material types and overburden stratigraphie units was made possible by closely reviewing the information (field logs inspection sites) from both surveys in the zone of overlap from adjacent inspection sites.

Soil Suitability Map: A soy suitability thickness map was generated from the integrated soil and overburden data using soil boundaries to show the spatial extent of each suitable soil unit. An example of this type of map is Figure 5, which shows the dominant soil thickness and uses a simplified legend (reduced from 11 thickness categories to 5 general groupings).

Subsoil Handling Optimization

The objective of the subsoil handling optimization exercise is to meet or exceed the regulated reclamation requirements at the minimum cost, especially in terms of soil handling. Specific criteria included the following:

1. minimize subsoil haul distances;
2. minimize subsoil rehandling and stockpiling;
3. defer the block of deep replacement (currently 1.5m thick) associated with the replacement of Class 3 land as long as practical considering items 1 and 2;
4. confine the block of Class 3 land to one continuous area; and
5. preferentially salvage from (>1.0m thick) suitable subsoil area.

This is the point in mine development planning where a critical integration of mine development plans for salvage and replacement are merged with the suitable soil availability information. This integration was achieved using a geographic information system (GIS), specifically SPANS software produced by TYDAC Technologies Ltd. and a commonly available spreadsheet program, SYMPHONY (LOTUS Development Corp.).

A series of digitized maps were overlaid upon each other electronically. The maps included the annual subsoil salvage plan, both the dominant and subdominant subsoil thickness maps and the soil percentage composition map. The resulting "unique conditions report" from this multiple map overlay was used to generate available subsoil volumes on an annual basis (see Figure 6).

The minimum soil replacement requirement, of 0.35m, combined with the annual subsoil replacement plan, was used to determine the minimum volume of subsoil required annually for replacement. The optimal location of the deep block was determined where there were a number of years of consistent volume surpluses.

Numerous refinements maybe made within these exercises to determine the best "what-if scenario, for example, what if you are only permitted to use good or fair rated or thick material deposits for replaced Class 3 land. The combined use of a GIS and a spreadsheet is a potentially powerful planning tool for developing an integrated mine and soil handling plan.

Post-Mine Monitoring

To ensure that the land capability goals are being attained, detailed post-mine monitoring begins as the land is reclaimed and includes a detailed land inventory (landscape, soil morphology, sampling and analysis) and annual soil/crop productivity monitoring on sites representative of various CLI agricultural capability classes.

The information will be used to:

- support future land certification applications assist farm
- operations in crop planning/management assist farm
- operation in soy management
- correlate mine plot studies to field scale results

Land Inventory: The post mine (reclaimed) land inventory sampling is undertaken following spoil levelling until soil replacement is complete. Samples are obtained of the topsoil, subsoil and mine spoil on a density of one site per hectare (10Om grid). In areas of deep subsoil replacement, a minimum of one sample per 0.5m thickness of replaced subsoil is collected. Additional samples are taken if the subsoil is morphologically diverse.

The soil samples are analyzed for a similar suite of parameters as the pre-mine soils (Table 3) with the following exceptions:

Topsoil
- includes available N, P, K and S
- includes total nitrogen
- excludes CEC and exchangeable cations

Subsoil
- includes exchangeable cations

The reclaimed land inventory data provides information used in assessing the lands initial agricultural capability. The method of land assessment provided in the Land Capability Classification document (Alberta Soil Advisory 1987a) will serve as a guide to assessing reclaimed land at the Highvale Mine.

Reclamation Monitoring: The objective of the monitoring program is to document changes in reclaimed land soil characteristics over time, and to record annual crop (forage) productivity and species composition. There are currently 10 sites being monitored for cover, composition and biomass (oven dry). Ten 0.5m square quadrants are sampled at each site. In addition, crop quality is assessed for oven dry percentages of crude protein, acid-detergent fibre and digestible nutrients as well as digestible energy from composites at each site.

Monitoring is expected to continue until the reclaimed land receives certification. These results may also be related to those of the pre-mine productivity measurements made on a mix of crop types and a range of soils exhibiting different capability.

SUMMARY

It can be said that reclamation is the link between single use resource extraction and "sustainable" mining development where mining activity is simply a temporary use of the land resource.

Considerable effort must go into defining the pre-mine situation to enable planners to adequately determine reclamation objectives and properly assess the options which are available to achieve them.

The practical experience gained with reclamation at the Highvale Mine shows that there is a clear link between achieving the goals of reclamation and efficient integration in the mine development planning process. Suitable soil handling optimization exercises, aided with the use of a GIS and based on sound inventory data and mine plan layouts, point to significant cost efficiencies during salvage and replacement operations while maintaining reclamation goals (capability targets). Well defined post mine capability assessment criteria makes for more definitive subsoil salvage quality requirements which aids the planning process.

Adequate quality control procedures, from soil mapping to salvage monitoring, must be in place to ensure that the reclamation plan is implemented as intended. Feedback from field reclamation personnel responsible for implementation of the plan with the mining contractor provides a crucial communication link between the practical job of reclamation and the planning process. Results of the post mine inventory and monitoring programs are a further quality control check where assessments can be made routinely.

Table 1

Canada Land Inventory -Arable Agriculture Ratings of Highvale Mine Soil Map Units as Affected by Topography

Map Unit	C.L.I. Agriculture Rating (Level Land)	C.L.I. Rating for Various Slope Classes (%)				
		0-5	6-9 3T	10-15 4T	15-30 5T	a-30 6T
Kv_1	5D	-	-	-	6a	6T
Kv_2	4D	-	-	5a	5T	6T
Tb_1	3D	-	3DT	4T	5T	6T
Nm_1	4D	-	-	5a	5T	6T
Nk_1	4D	-	-	4DT	5T	6T
Un_1	3D	-	3DT	4T	5T	6T
Un_2	3D	-	3DT	4T	5T	6T
On_1	5W	-	-	-	5WT	6T
Rc	3FM	-	3FMT	4T	5T	6T
Pg_1	3D	-	3DT	4T	5T	6T
Md_1	3F	-	3FT	4T	5T	6T
Md_2	4M	-	-	5a	6a	6T
Fw_1	3D	-	3DT	4T	5T	6T
Fc_1	4D	-	-	5a	5T	6T
Rv_1	5DW	-	-	-	6a	6T
Rv_2	5W	-	-	-	6a	6T
Co_1	4M	-	-	5a	6a	6T
Le_1	3M	-	3MT	4T	5T	6T
Hv_1	3D	-	3DT	4T	5T	6T
Eb_1	4D	-	-	4DT	5T	6T
Kh_1	3D	-	3DT	4T	5T	6T
Wa_1	4D	-	-	5a	5T	6T
Eg_1	O	-	-	-	-	-
Eg_2	O	-	-	-	-	-
Kz_1	O	-	-	-	-	-
Kz_2	O	-	-	-	-	-

a Cumulative rating of combined subclass limitations such as structure "D" and slope T' is lower than either single limitation (i.e.) 4D and 4T is rated Class 5 (no subclass indicated).

\- Denotes capability rating is unaffected by slope class.

Table 2

Area Summary of CLI Capability for Agriculture
Pit 04 and Entire Highvale Mine Area 1986-2011

CLI Classification Class/Subclass	Area Within Mine Pit 04 (ha)	%	Entire Mine (ha)	%
3D	101		556	
3^{F}_{M}	4		9	
3^{T}_{F}	5		15	
3F	7		12	
Sub Total Class 3	117	15	592	22.2
4D	139		618	
4M	10		10	
4T	26		141	
4^{T}_{D}	131		198	
Sub Total Class 4	306	37	967	36.3
5D	63		270	
5W	14		72	
5^{W}_{D}	88		343	
5M	0		36	
5T	38		114	
5^{T}_{D}	25		31	
5^{T}_{M}	7		23	
Sub Total Class 5	235	29	889	33.4
6T	43		77	
6^{T}_{D}	44		47	
Sub Total Class 6	87	11	124	4.6
0[a]	62		87	3.3
Unclassed[b]	2		5	0.2
TOTALS	809		2664	100

a organic soils - not classified for capability

b unclassified = water bodies and other unclassified areas

Table 3

Laboratory Analysis

Parameter	Method Number
Physical	
grain size (sand, silt, clay)	2.12
saturation %	3.21
pH	3.21
electrical conductivity	3.21
organic carbon[(a)]	
Chemical	
soluble cations, (SAR)	3.26
cation exchange capacity (CEC)	3.321 B/3.34
exchangeable cations [0]^ (EC)	3.321 A

Notes:

Reference: McKeague, 1978.

(a) topsoil (Ap, Ah, Ahe) horizons of detailed pits only - by modified Walkley-B lack method.

(b) subsoil (B) horizons -where SAR is greatr than 8 and/or EC is greater than 2; or from select sites where soil morphology (columnar or prismatic structure) suggests possible cation problems.

Table 4

Highvale Mine
Soil Suitability Criteria for Reclamation *

Criterion	Unsuitable	Poor
pH	<4.5 or >8.5	8.0 - 8.5
SAR	>12	8 - 12
ESP	>15	10 - 15
EC mS/cm	>10	5 - 10
Saturation %	>120	80 - 120
Clay %	>60	40 - 60
Consistence * *	Extremely Hard When Dry or Very Firm When Moist or Very Sticky and Very Plastic When Wet	Very Hard When Dry or Firm When Moist or Sticky and Plastic When Wet

Notes

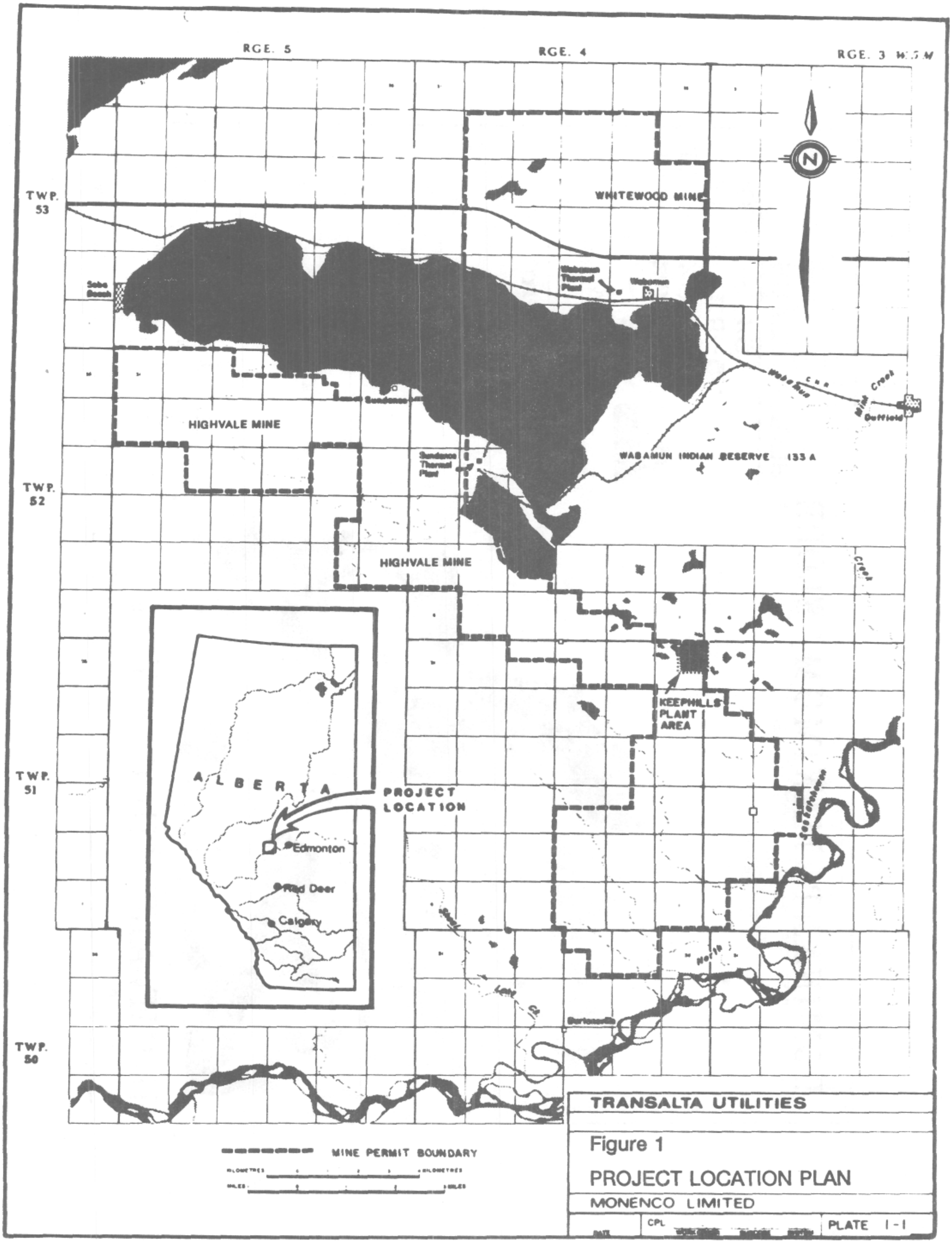
* If two suitability criteria in the following combinations are "poor" then a soil is also rated unsuitable.

Clay and Consistence
or Clay and SAR
or Clay and ESP
or Consistence and SAR
or Consistence and ESP

** Application of consistence terms used by CSSC, 1978.

Source

TransAlta Utilities Corporation. 1986. Highvale Mine - 1985 Development and Reclamation Plan


RGE. 5
RGE. 4
RGE. 3
TWP. 53
TWP. 52
TWP. 51
TWP. 50
WHITEWOOD MINE
HIGHVALE MINE
WABAMUN INDIAN RESERVE 133 A
HIGHVALE MINE
KEEPHILLS PLANT AREA
ALBERTA
PROJECT LOCATION
Edmonton
Red Deer
Calgary
MINE PERMIT BOUNDARY
TRANSALTA UTILITIES
Figure 1
PROJECT LOCATION PLAN
MONENCO LIMITED
PLATE 1-1

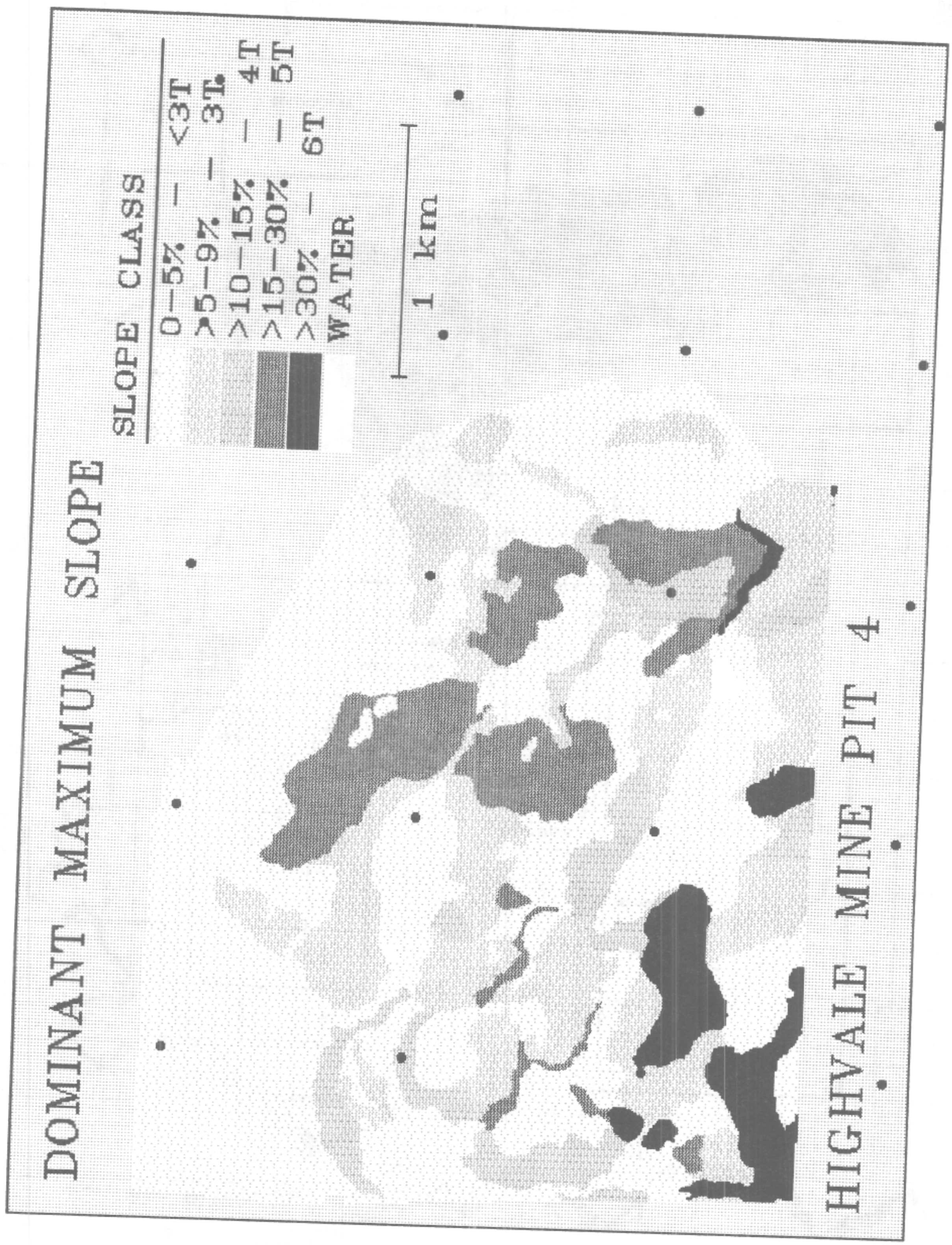

DOMINANT MAXIMUM SLOPE
SLOPE CLASS
0-5% — <3T
>5-9% — 3T
>10-15% — 4T
>15-30% — 5T
>30% — 6T
WATER
1 km
HIGHVALE MINE PIT 4

Figure 2

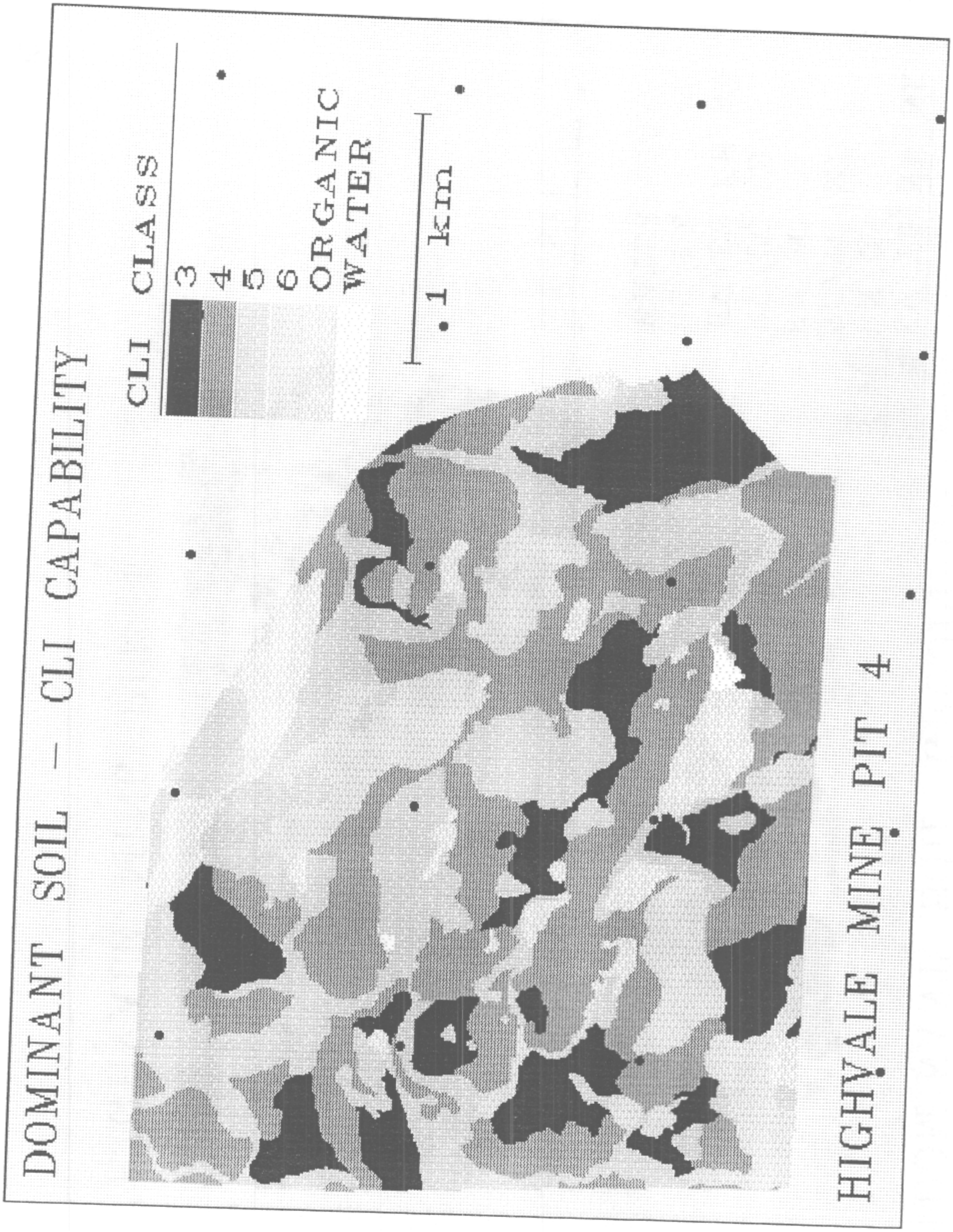

DOMINANT SOIL - CLI CAPABILITY
CLI CLASS
3
4
5
6
ORGANIC
WATER
1 km
HIGHVALE MINE PIT 4

Figure 3

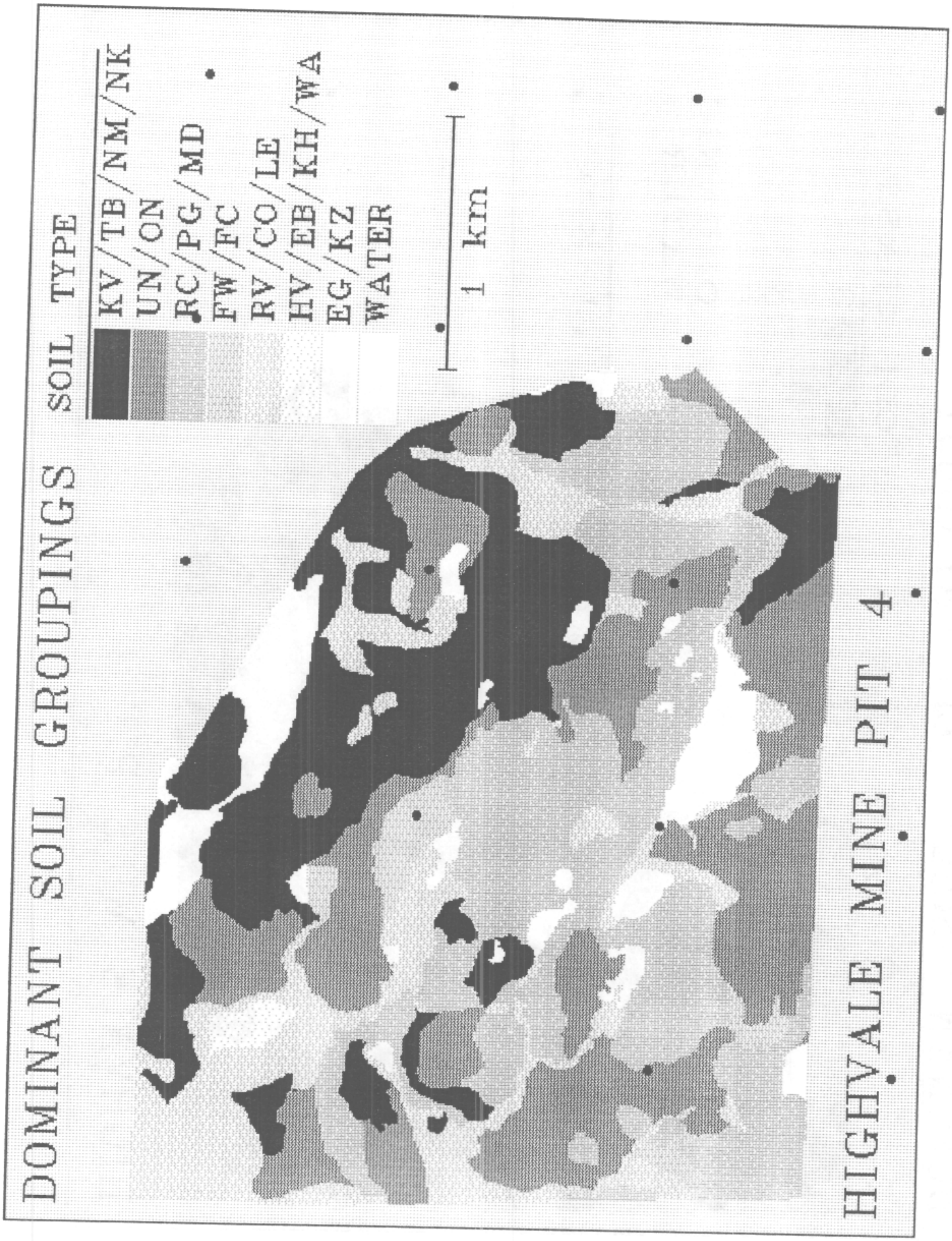

DOMINANT SOIL GROUPINGS
SOIL TYPE
KV/TB/NM/NK
UN/ON
RC/PG/MD
FW/FC
RV/CO/LE
HV/EB/KH/WA
EG/KZ
WATER
1 km
HIGHVALE MINE PIT 4

Figure 4

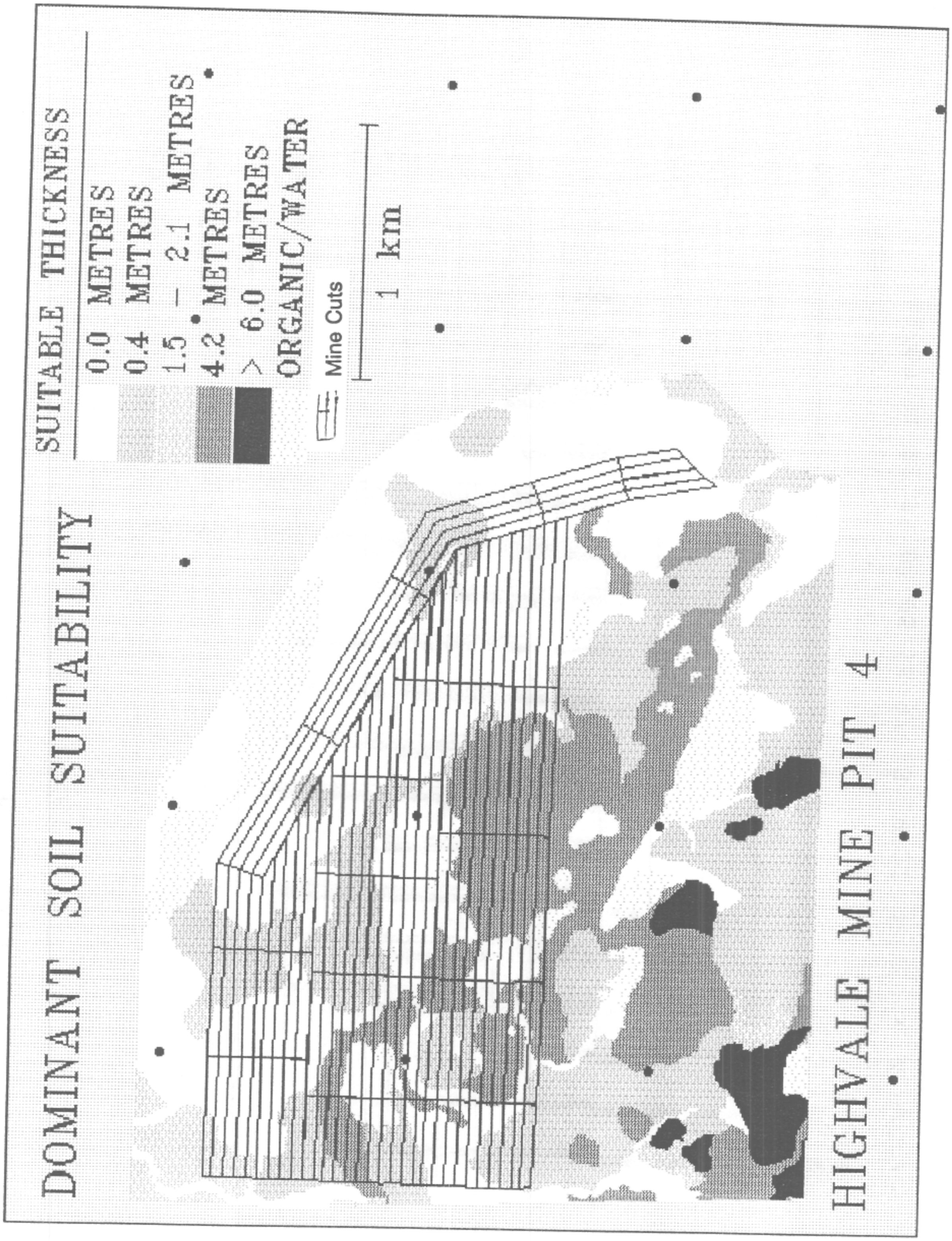

DOMINANT SOIL SUITABILITY
SUITABLE THICKNESS
0.0 METRES
0.4 METRES
1.5 – 2.1 METRES
4.2 METRES
> 6.0 METRES
ORGANIC/WATER
Mine Cuts
1 km
HIGHVALE MINE PIT 4

Figure 5

SUBSOIL VOLUME (Bern)
(Millions)

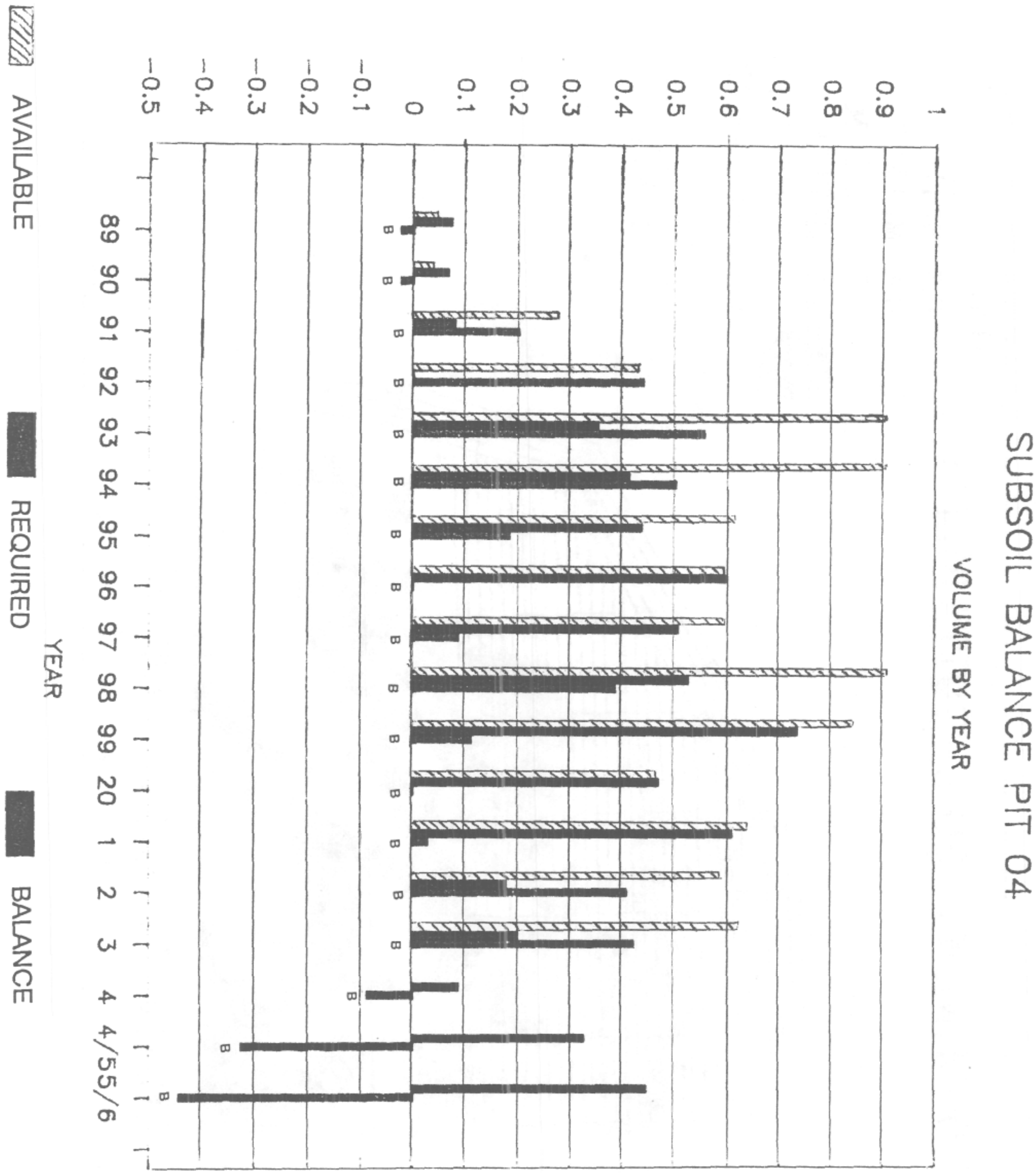


Figure 6