Proceedings of the 6th Annual British Columbia Mine Reclamation Symposium in Vernon, BC, 1982.
The Technical and Research Committee on Reclamation

AN INTEGRATED RECLAMATION MANAGEMENT PLAN FOR THE HIGHLAND VALLEY MINING COMPLEX

Paper Presented
by

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ABSTRACT

In the Highland Valley, reclamation of large areas of mining disturbance is being undertaken by several mining companies. Methods and objectives for this reclamation are being studied.

Soil and vegetation surveys are used to classify disturbed materials into site types which have characteristic reclamation requirements. By integrating site type information, land-use options and reclamation research, reclamation techniques and objectives are proposed for each site type.

This approach is suitable for the design of reclamation programs for extensive areas when physical conditions are diverse and mining operations complex.

INTRODUCTION

The Highland Valley, in the Southern Interior Region of British Columbia, has the greatest concentration of open-pit hardrock mines in western Canada. The area was selected by the Reclamation Section of the Ministry of Energy, Mines and Petroleum Resources (MEMPR), to be the subject of a study which was undertaken by the author during the summer of 1981. The purpose of the study was to evaluate methods and objectives for the reclamation of land disturbed by mining activity in the Highland Valley.

This paper describes the study method and presents a summary of its results.

RATIONALE OF STUDY METHOD

At present, there are three mines operating in the Highland Valley and a fourth is expected to come into production soon (Table 1). Changes in mining technology and fluctuations in the price for copper make it hard to make accurate, long-term predictions of the output of ore, waste-rock and tailings. As a result, it is difficult to predict what the extent of reclamation will eventually be. The objective of this study was to

TABLE 1

CURRENT STATUS OF MINES IN THE HIGHLAND VALLEY

NAME AND OWNERSHIP	OPERATION PERIOD BEGIN	OPERATION PERIOD END	PRODUCT	VOLUME OF ORE (T/day)	AREA DISTURBED TO DATE (ha)	AREA RECLAIMED TO DATE (ha)	TOTAL ANTICIPATED DISTURBANCE (ha)	ELEVATION OF DISTURBED AREAS (m a.s.l.)
Bethlehem - Cominco	1962	198-	Cu & Mo	20,500	878.9	22	932	1200 - 1550
Highmont - Teck Corporation	1981	?	Cu & Mo	25,000	976	14	1160	1450 - 1900
Lornex - member of Rio Algom/ Rio Tinto Corporation	1972	1993?	Cu & Mo	85,000	1341	221	3280	1200 - 1550
Valley Copper - Cominco	?	?+20?	Cu & Mo	100,000	384[1]	-	+ 1820 + 750	1300 - 1400[2] 1160 - 1370

[1]Logged during exploration.
[2]Tailings disposal area jointly operated.

assess areas to be reclaimed, as shown by present conditions, so that prescriptions might be made for the future. Disturbed areas were to be classified into reclamation site types. Each reclamation site type would describe areas of disturbed materials that presented similar conditions for plant establishment and growth and had characteristic reclamation requirements (Figure 1). This classification scheme would be used:

1. to acquire more information about the problems associated with each reclamation site type;

2. to select reclamation techniques for each reclamation site type, based on results of reclamation trials carried out by mining companies in the Highland Valley and other reclamation research;

3. to identify "problem site types" where further reclamation research should be directed;

4. to propose land-use objectives for each reclamation site type using the distribution of natural vegetation in the area as an indication of "what grows where."

It could also be used to facilitate prediction of the results of reclamation of the Highland Valley, whatever the size of the area that will eventually be reclaimed.

PROPOSED CLASSIFICATION SCHEME

Numerous methods of classifying land are described in the literature (Hills, 1961; Krajina, 1965; Environment Canada, 1970). To fulfill the objectives of this study, the classification scheme had to fulfill three requirements:

1. it had to be at a scale suitable for management purposes;

2. it had to be based on information that could be acquired from the available maps and aerial photographs of the area;

3. it could not incorporate natural vegetation as a factor since it was to be applied to areas denuded of natural vegetation.

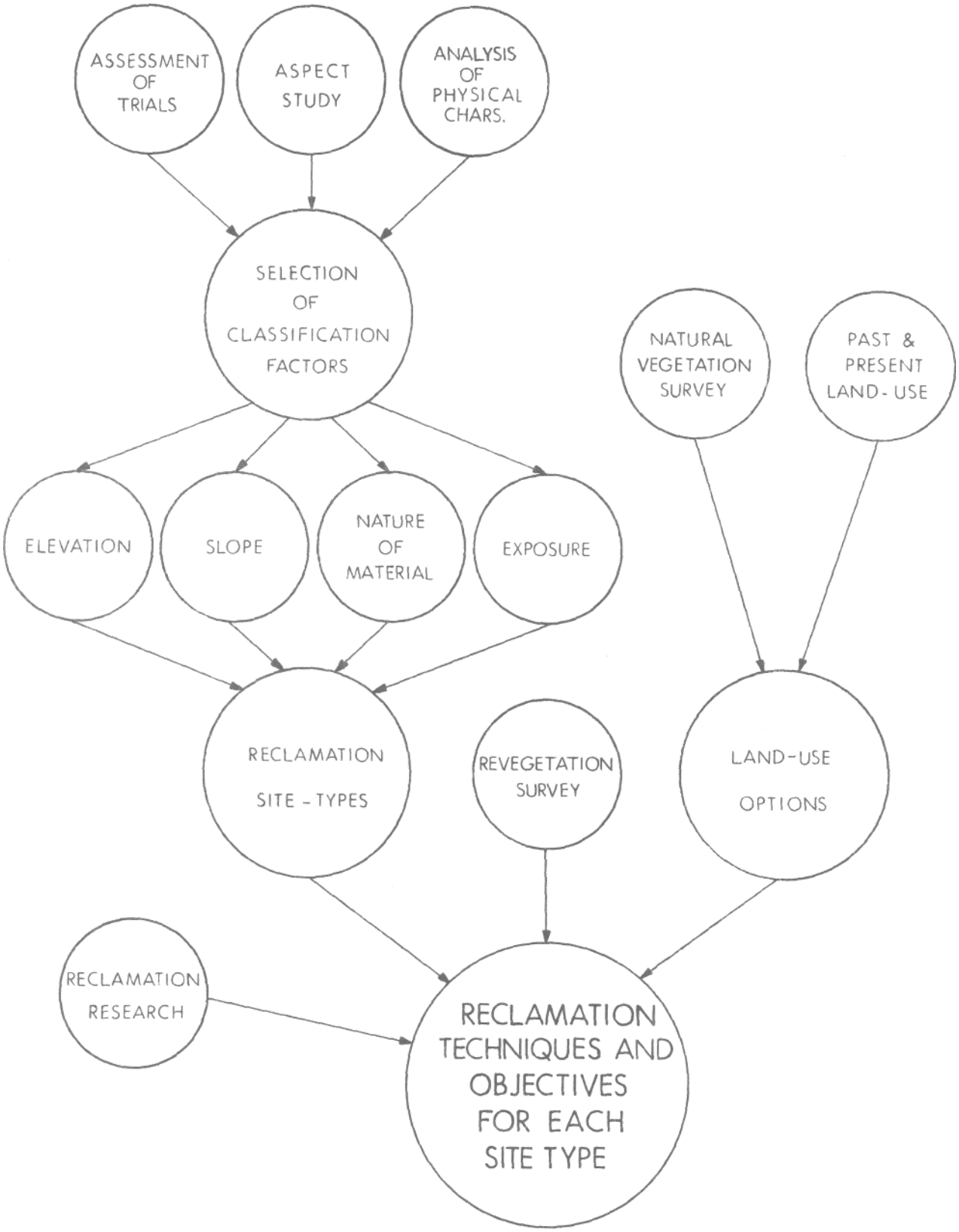

Figure 1. Reclamation techniques and objectives for each site type.

Review of Hills' method of classification indicated that disturbed areas in the Highland Valley might be classified according to the following factors:

- elevation
- aspect
- physical properties of material
- slope

These factors were selected on the assumption that local climate and the retention of moisture in the soil would be the most important factors affecting plant establishment and growth. Slope and physical properties also affect the stability of disturbed areas; reclamation techniques may therefore be modified by the need to control erosion and by constraints on the operation of machinery.

Aspect was selected as a factor in the proposed classification scheme because it is commonly assumed to affect local climate and soil moisture content. However, in semi-arid areas differences due to aspect may not be significant (Clark, 1969). At the Bethlehem mine, shelter from prevailing winds affects the success of reclamation (Walmsley, 1977). In the Highland Valley, prevailing winds are from the southwest.

Chemical properties of materials (pH, available nutrients, etc.) were not included because:

1. research by Lornex Mining Corporation (1973; undated), Dept. of Soil Science (1975; 1976/77) and Valley Copper Mines Ltd. (1980) on disturbed materials in the Highland Valley has shown that levels of available nutrients are generally limiting to plant growth;

2. fertilization has been required wherever seeding has taken place. Slope and physical characteristics have an effect on the retention of fertilizer in disturbed materials and there fore on their artificially-created chemical characteristics;

3. chemical characteristics are not readily identified from maps or aerial photographs.

An additional factor, "visibility from public areas," may be incorporated into the classification scheme. This factor is the subject of another study, the results of which will be published at a later date.

PRE-FIELD WORK

Information on elevation and slope of disturbed materials was obtained from maps and aerial photographs.

Disturbed materials could not be classified immediately according to their physical characteristics since this information could not be obtained from maps or aerial photographs. They were initially grouped according to differences in appearance on aerial photographs. Seven kinds of disturbed material could be distinguished:

1. areas of glacial till whose natural soil covering had been removed,
2. free-dumped waste-rock piles,
3. compacted waste-rock dumps,
4. areas of end-dumped waste-rock,
5. tailings areas,
6. access roads,
7. plant sites and machinery dumps,
8. stockpiled overburden,

End-dumped waste-rock will probably not remain after mining operations end (Munroe, 1981). Access roads will not be reclaimed (Highmont Operating Corporation, 1980) or will be ripped (Valley Copper Corporation, 1980). They and the plant sites, once cleared, will probably revert to a condition similar to the compacted waste-rock dumps or areas of glacial till. Free-dumped waste-rock piles may be covered with a thin layer of overburden as part of the reclamation operation.

Therefore, four kinds of disturbed materials were selected for field investigation:

1. glacial till lacking a natural soil covering (referred to hereafter as "raw till"),

2. waste-rock piles covered with overburden ("overburden/rock"),

3. compacted waste-rock ("compacted rock"),

4. tailings.

The distribution of natural vegetation communities was interpreted from aerial photographs and marked on transparencies. Results of a previous vegetation survey of the area (B.C. Research, 1971) assisted in the preliminary identification of communities.

FIELD WORK

1. Identification of each kind of disturbed material was checked in the field and samples were taken for the determination of physical properties in the laboratory.

2. Differences in the temperature and moisture content of disturbed materials associated with differences in aspect were investigated. However, a detailed account of this investigation is outside the scope of this paper.

3. All accessible reclaimed sites were assessed using the reclamation inventory method (MEMPR, undated). These sites included roadways, pipelines, test plots and "final configuration" dumps.

4. A selection of naturally revegetated areas was surveyed.

5. Interpreted boundaries of natural vegetation communities were field checked and representative areas were described in detail from the vegetation communities found in these areas.

LABORATORY WORK

Textural composition of the disturbed materials and soils was determined using the hydrometer method of particle size analysis described by the Department of Soil Science (1978).

RESULTS

PHYSICAL CHARACTERISTICS OF DISTURBED MATERIALS

The physical characteristics of disturbed materials and natural soils sampled are summarized as follows:

1. Raw till and tailings differed significantly in textural composition from each other and from overburden/rock and compacted rock. Raw till contained more sand-sized and less silt-sized particles. Tailings contained no particles greater than 2 mm in diameter but were highly variable in composition of particles less than 2 mm diameter.

2. No significant differences in textural composition were found between overburden/rock samples and compacted rock samples. (However, since it was not possible to sample more than one area of compacted rock and since rock type varies throughout the Highland Valley, this result should be interpreted with care.)

3. Overburden/rock and compacted rock were classed as sandy loam according to the USDA classification system (Brady, 1974). Raw till was classed as sand or loamy sand. Tailings were classed as sandy loam or loamy sand.

4. Natural soils sampled were classed as sandy loam and did not differ significantly in textural composition from overburden/ rock or compacted rock samples.

Differences in bulk density between types of disturbed material were not significant.

EFFECT OF ASPECT

The investigation into the effect of aspect on moisture content and temperature of disturbed materials showed that south-facing slopes were only significantly hotter and drier than north-facing slopes when they were exposed to prevailing winds.

Areas of raw till were significantly drier than overburden/rock areas and compacted rock areas.

ASSESSMENT OF RECLAIMED AREAS

Results of the assessment of reclaimed sites are summarized in Table 2. All sites were seeded with grass or grass/legume mixes. All sites were within the elevation range 1300 m to 1400 m. Details of treatment were very variable but records indicated that all sites had been adequately seeded and maintained with fertilizer. Although differences in length of establishment period, seeding rate and fertilizer treatment must be taken into account, it appears that establishment of grass/legume cover has been least successful on exposed, steeply-sloping sites and on a non-irrigated raw till site.

THE NATURAL REVEGETATION SURVEY

The natural revegetation survey indicated that invasion of disturbed sites does occur when there are sources of propagules nearby and when more sheltered micro-sites exist.

NATURAL VEGETATION SURVEY AND LAND-USE INFORMATION

During the natural vegetation survey of the Highland Valley, ten natural vegetation communities were distinguished. Community type varies according to elevation, topography, local drainage pattern and soil texture. The distribution of natural vegetation is illustrated in a generalized cross-section of the Highland Valley (Figure 2).

The middle slopes of the valley support either Douglas fir communities or, where fire has occurred, lodgepole pine communities. As elevation increases there is a gradual transition to lodgepole pine/spruce communities with spruce becoming increasingly abundant at higher elevations. With decreasing elevation, the forest becomes more open and the

TABLE 2

SUMMARY OF RESULTS OF ASSESSMENT OF RECLAIMED AREAS

Site Type	Date of Establishment	Percent Ground Cover			
		Min.	Max.	Mean	S.D.
Exposed south-facing slope; overburden/rock	1970	7	30	21	10.1
Exposed west-facing slope; overburden/rock	1972 - 1977?	6	35	19	11.7
Sheltered west-facing slope; overburden/rock	1977	30	50	38	7.5
Flat; overburden/rock	1977	25	65	38	16.4
Sheltered north-facing slope; overburden/rock (1)	1972	7	60	34	27.1
Sheltered north-facing slope; overburden/rock (2)	1972	20	40	32	8.3
Flat; overburden/rock	1979	25	40	31	5.4
Sheltered north-facing slope; raw till	?	35	40	24	11.5
Flat; raw till (irrigated)	?	8	80	59	17.4

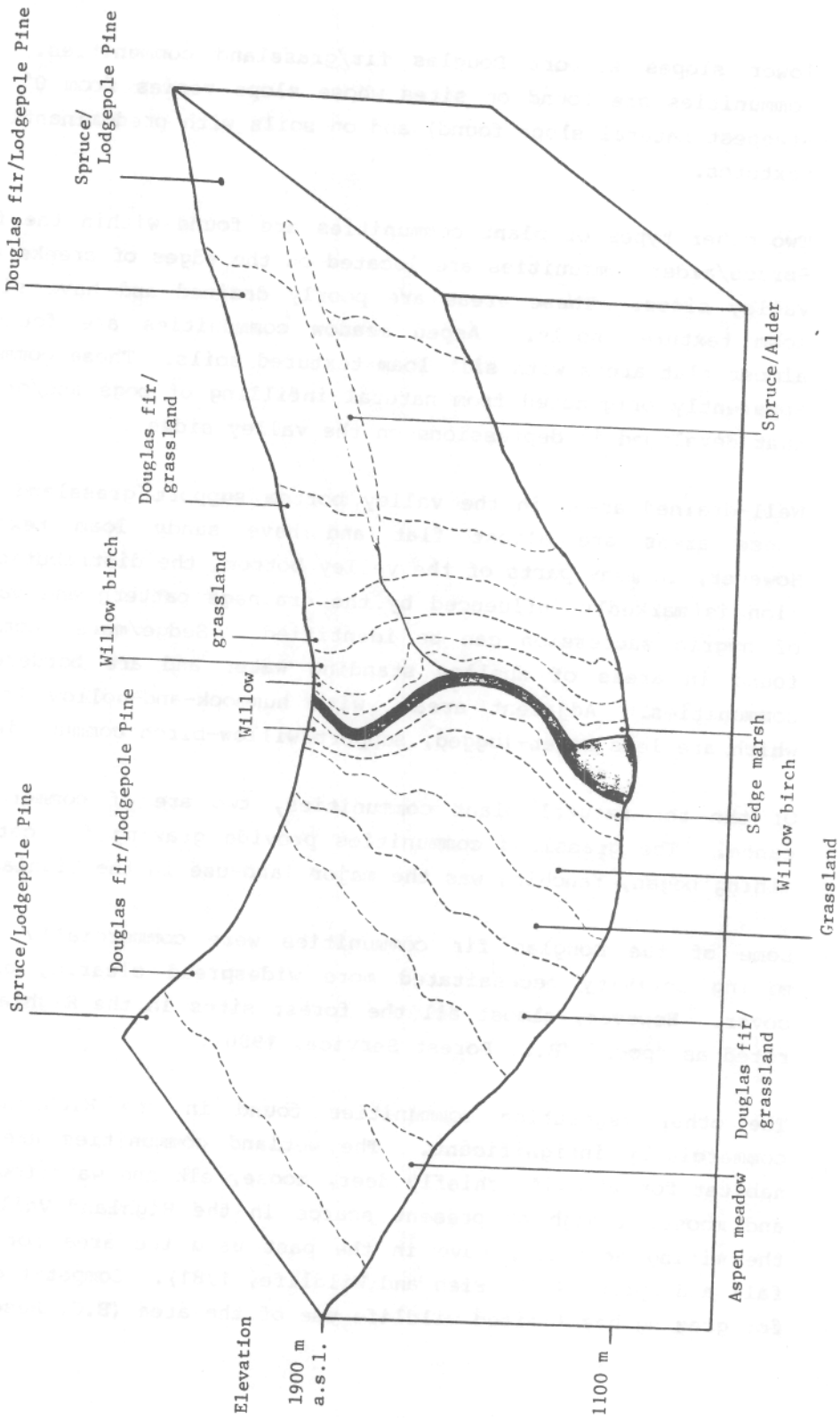

Figure 1. Generalized cross-sectional diagram of Highland Valley and its natural vegetation

lower slopes support Douglas fir/grassland communities. The forest communities are found on sites whose slope varies from 0° to 38° (the steepest natural slope found) and on soils with predominantly sandy loam textures.

Two other types of plant communities are found within the forest area. Spruce/alder communities are located on the edges of creeks draining the valley sides. These areas are poorly drained and have silt and silt loam textured soils. Aspen meadow communities are found on small, almost flat areas with silt loam textured soils. These communities have apparently originated from natural infilling of bogs and/or small ponds that developed in depressions on the valley sides.

Well-drained areas in the valley bottom support grassland communities. These areas are almost flat and have sandy loam textured soils. However, in many parts of the valley bottom, the distribution of vegetation is markedly influenced by the drainage pattern and various stages of hygric succession can be identified. Sedge/marsh communities are found in areas of shallow standing water and are bordered by willow communities. Adjacent areas, with hummock-and-hollow topography and which are less water-logged, support willow-birch communities.

Of the ten natural plant communities, two are of commercial significance. The grassland communities provide grazing for cattle. Before mining began, ranching was the major land-use in the Highland Valley.

Some of the Douglas fir communities were commercially logged before mining activity necessitated more widespread clearing of the forest cover. However, almost all the forest sites in the Highland Valley are rated as "poor" (B.C. Forest Service, 1980).

The other vegetation communities found in the Highland Valley are commercially insignificant. The wetland communities are important as habitat for wildlife chiefly deer, moose, elk and waterfowl. Deer, elk and moose, though at present scarce in the Highland Valley because of the mining activity, have in the past used the area for range in the fall and spring (B.C. Fish and Wildlife, 1981). Competition with cattle for grazing has limited wildlife use of the area (B.C. Research, 1971).

No crops are grown in the Highland Valley; this is probably due to the dry climate and the lack of suitable sites, sources of irrigation water and economic incentive.

Fishing is the only important recreational activity, although some hunting is done in the high elevation areas furthest from the centres of mining activity.

DISCUSSION

CLASSIFICATION OF DISTURBED AREAS

The analysis of physical characteristics of disturbed materials, the investigation into the effect of aspect, and the assessment of reclaimed sites indicate that disturbed areas in the Highland Valley should be classified according to the following factors; slope, nature of material, exposure to prevailing winds and elevation.

Using these factors eleven reclamation site types were identified:

I	low elevation tailings
II	high elevation tailings
III	low elevation flat overburden/rock (and compacted rock?)
IV	high elevation flat overburden/rock (and compacted rock?)
V	low elevation sheltered steeply-sloping overburden/rock
VI	high elevation sheltered steeply-sloping overburden/rock
VII	low elevation exposed steeply-sloping overburden/rock
VIII	high elevation exposed steeply-sloping overburden/rock
IX	low elevation gently-sloping raw till
X	high elevation gently-sloping raw till
XI	low elevation flat raw till

OPTIONS FOR POST-MINING LAND-USE

When mining has ceased, land-use in the Highland Valley will be determined by the economic climate and the degree of industrial development in the area. There are, however, a number of land-uses that should be considered now, since choice of an appropriate land-use objective for each reclamation site type has an important bearing on the choice of technique.

Past and present land-uses and the distribution of natural vegetation indicate that the following land-uses should be considered for the Highland Valley.

1. Range: This would require the establishment of grass and/or legume swards in areas where cattle is not restricted. Slopes of 30° or more would be little used by cattle for *grazing* unless forage was in very short supply (Pitt, 1982). Above 1400 m productivity would probably be low.

2. Agriculture: Flat or gently-sloping low elevation areas, near to sources of water and where the surrounding topography would maximize water retention, could be irrigated and used to grow crops.

3. Forestry: Flat to steeply-sloping areas from 1200 m to 1700 m could be used for forestry. Productivity would probably be low but the eventual value of the crop as well as the aesthetic effect should be taken into account. Natural invasion of areas close to sources of seed would probably occur. More extensive areas would require planting.

4. Wildlife: Areas supporting grasses and shrubs, particularly those in early serai stages, not used by cattle, would be of particular value to wildlife. Close proximity to forest cover would be an advantage.

5. Recreation: Well-stocked artificial lakes and ponds would increase the recreational use of this area which is already popular for fishing. The existence of a few roads providing access to both fishing and hunting areas would be advantageous.

PROPOSED RECLAMATION TECHNIQUES

The combination of information about reclamation site types, natural vegetation, natural revegetation and possible land-use options suggests particular reclamation techniques for each site type. Outlines of these techniques are given here; more details are available.

Low Elevation Tailings

These could *be* used for range or agriculture. Research on the potential of tailings for plant growth has been undertaken in the laboratory (Department of Soil Science, 1976/77). A large test plot was established on tailings in the Highland Valley in 1981. Creation of wetland communities might be attempted also, although more research into this kind of reclamation is required (Olson, 1981).

High Elevation Tailings

It is unlikely that these would be valuable for range or agriculture but they could provide grazing for wildlife. These sites could be reclaimed to a condition similar to the aspen meadow communities. Testing of grass, legume or shrub species suitable for high elevation sites is required. Information acquired in other parts of western Canada could be applied to this site type.

Low Elevation Flat Overburden/Rock (and compacted rock)

The feasibility of establishing grass/legume mixtures on these sites has been well proven by the mining companies in the area. These sites may be used for range.

High Elevation Flat Overburden/Rock (and compacted rock)

These sites would have less value for range than the preceding type but could provide for wildlife use. Establishment of commercially available legumes at this elevation might be difficult. Trials with "native" species would be informative.

Alternatively, these sites could be managed with a view to establishing tree and shrub cover. Local lodgepole pine stock and shrubs could be planted with, following or in place of grass/legume cover.

Low Elevation Sheltered Steeply-Sloping Overburden/Rock

Establishment of grass/legume cover on this site type is evidently possible. Though this site type has little potential range value, establishment of cover will increase slope stability and reduce erosion. The appearance of these sites, which are highly visible to the

public, would also be improved. If operation of machinery is a problem on these sites they may benefit from treatment similar to site types VII and VIII.

High Elevation Sheltered Steeply-Sloping Overburden/Rock

These sites are similar to high elevation flat overburden/rock but modification of the species mix will probably be necessary to ensure successful reclamation.

Low and High Elevation Exposed Steeply-Sloping Overburden/Rock

Both low and high elevation types pose problems for reclamation. There are two ways of avoiding the problems of applying seed to these exposed sites:

1. create mini-terraces to provide microsites. This may not be operationally feasible.

2. hand-plant dry-land shrubs. Much research on the use of shrubs for reclamation is being undertaken at present. With emphasis on the selection of species suitable for the climate of the Highland Valley a more intensive approach such as this would probably be justifiable for these particular site types.

Low Elevation Gently Sloping Raw Till

This site type poses slight problems due to the dry conditions which develop. However, many raw till areas are narrow strips resulting from pipeline construction. If a sparse grass and/or legume cover can be established, sufficient to reduce the extreme temperature and moisture conditions, natural invasion by trees and shrubs will occur. These sites would then provide wildlife habitat and eventually become re-forested. Complete restocking of these areas may not be desirable if they are to provide access. Extensive raw till areas may require artificial shrub establishment similar to steeply sloping exposed site types.

High Elevation Gently Sloping Raw Till

The choice of species for this site type is important. On small areas of this site type establishment of grasses and legumes may not be necessary before natural invasion occurs.

Low Elevation Flat Raw Till

Areas of this site type have potential for use as range and, if irrigated, agriculture. Grass and legume establishment is evidently the most appropriate treatment.

CONCLUSIONS

Developing a reclamation plan in this manner accomplishes the following:

1. makes best use of the knowledge and on-site information acquired by the mining companies in their reclamation activities to date.

2. provides a tool to assist in future reclamation work. Now that the factors that should be included in the classification scheme have been selected, the scheme can be applied to other areas of disturbance as they are created. It can be used as a means of extrapolating results of trials to other parts of the Highland Valley.

3. enables assessment of the outcome of reclamation to be made, whatever the extent of the disturbance that eventually occurs.

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