

FACTORS INFLUENCING DENSITY AND COMPOSITION OF VEGETATIVE COVER ON WASTE ROCK SITES AT HIGHLAND VALLEY COPPER

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ABSTRACT

Highland Valley Copper is a large porphyry copper-molybdenum mine located in the southern interior of British Columbia. Field observations indicate that the vegetative cover supported on reclaimed sites is often variable, despite apparent similar growing conditions. A field program was undertaken at Highland Valley Copper to evaluate surface and subsurface factors that may influence the success of vegetation cover development on reclaimed sites. The program included sites where vegetation was established directly on waste rock material, and sites reclaimed on an overburden cap. The results of the program indicate that material characteristics are especially important for the upper 1 metre of the reclaimed site. The available water storage capacity, influenced by soil depth, coarse fragment content and soil texture is the most important factor that influences the reclamation potential of a site. These findings verify that site preparation activities are critical to the development of successful reclamation sites, and that monitoring to ensure placement of appropriate material on the dump surface will enhance the reclamation potential of sites.

INTRODUCTION

Field observations indicate that the vegetative cover supported by reclaimed sites is often variable. While some reclaimed sites may support a dense vegetative cover, other sites may be less successful, despite apparent similar growing conditions. A field program was initiated at Highland Valley Copper to investigate surface and subsurface factors that may influence the success of vegetation establishment and growth. The objectives were to identify and quantify where possible, factors that could be correlated with good vegetation cover.

The study involved the examination of reclaimed sites where vegetation was established directly on waste rock material at the Lornex mine area and sites reclaimed with an overburden cap at the Bethlehem mine area. Previous studies had determined that overburden capping was necessary for the establishment of vegetation on Bethlehem waste rock (Highland Valley Copper, 1991). Vegetative cover had been established on the sites for a period of time ranging from two to five

years. A similar approach and methodology was implemented in the examination of both types of reclaimed sites.

A primary goal of this investigation was to determine the available water storage capacity (AWSC) of these selected reclaimed sites, and to evaluate factors known to influence the AWSC. The AWSC provides a measure of the soil's ability to store water for plant use. It is dependant upon the soil texture, coarse fragment content and the depth of the soil. The soil texture is important because it determines the water retention characteristics of the soil. Depth of soil is also important, particularly where the soil is shallow and overlies a less suitable material (ie. waste rock or bedrock) because it limits the volume of soil available for water storage. Similarly coarse fragment content reduces the volume of soil available for water storage and is an important factor for sites reclaimed directly on waste rock.

The following discussion will first address the methods used in the study. This will be followed by a discussion of the observations and findings pertaining to sites reclaimed directly on waste rock material, and sites reclaimed on overburden capped waste rock. The paper will conclude with a discussion of the implications of this study to defining specific site preparation activities to optimize reclamation success on sites.

METHODS

Soil pits were excavated to assess subsurface features that might influence the establishment of vegetative cover on these sites. A total of 20 soil pits were excavated on reclaimed waste rock sites and eighteen soil pits were excavated on reclaimed overburden capped sites. In each area, soil pit sites were selected to compare the range of conditions present, including: good versus poor vegetation cover; time since establishment; type of vegetation present; and flat versus sloping sites.

Reclaimed Waste Rock Sites

Surface and subsurface features of selected sites were examined on the Lornex Northwest, Lornex Southeast and Lornex South waste rock dumps. A total of twenty soil pits were excavated using a backhoe; eight on the Lornex Northwest waste rock dump (seeded in 1992); ten on the Lornex Southeast waste rock dump (seeded in 1989 and 1991); and two on the Lornex South waste rock dump (seeded in 1987).

Surface Features. Assessments of surface features were conducted on the Lornex Northwest and Lornex Southeast sites. These included documentation of species composition and vegetative cover within discrete plots, detailed documentation and mapping of site conditions (plot elevation, slope length, and slope gradient). Additional site material characteristics (soil grading, material size, material type, and texture) were determined on the Lornex Northwest sites only. The surface material characteristics provided a qualitative assessment of the distribution of fresh versus altered waste rock, coarse versus fine material, and grading characteristics. Soil textures of the surface material were determined in the field. Weathering characteristics of the waste rock material were also noted. The species composition data were used to define vegetation groupings, and were cross-referenced to the site characteristics. This technique provided a method to identify possible correlations between the vegetation observed and the surface characteristics of the site.

Subsurface Features. Soil descriptions, by horizon included depth, coarse fragments, rooting features, soil texture (field and laboratory determinations), soil structure, moisture and colour. Soil horizons within each soil pit were differentiated by rooting characteristics. Because the soil profiles observed represent the earliest stages in soil development, classical soil nomenclature does not apply directly, but was utilized as an aid in the descriptive process. In each soil pit, an AC1 horizon was defined by the presence of moderate to abundant root development. Underlying this horizon, an AC2 horizon was identified, characterized by moderate to poor root development. Underlying these two horizons, a C horizon was defined by the absence of root development.

At each soil pit location, a soil sample was collected from each soil horizon identified. Soil samples were hand textured in the field and submitted to a laboratory for soil texture determinations. Coarse fragment content was visually determined for each soil horizon. The total coarse fragment content was determined as a percentage of the total volume of material within the horizon. The total coarse fragment content was reported as the sum of the percentage of stones, cobbles and gravels; observations regarding grading, and shape of the fragments were noted. Observations also included the mineralogy and weathering characteristics of the waste rock material.

Reclaimed Overburden Capped Sites

A total of eighteen soil pits were excavated on reclaimed overburden capped sites, and included: fourteen soil pits excavated on the Bethlehem North (seeded 1992) and Bethlehem Northeast (seeded 1991 and 1992) waste rock dumps, and four soil pits excavated on the Trojan dam (seeded 1991). The

evaluation of reclaimed overburden capped sites focused on identifying subsurface features that could be related to the success of vegetative growth on these sites. The same field methodology was used for the reclaimed overburden capped sites as the reclaimed waste rock sites, with exceptions as noted below.

Surface Features. Soil pits were located on sites representing a range of conditions and included flat and sloping sites, and sites characterized by dense versus poor vegetative cover. Detailed assessments of species composition were not performed on these sites. However, at each soil pit site, the vegetation present was described with reference to the species present, and the density of vegetation cover.

Subsurface Features. At each soil pit location, soil descriptions by horizon included depth, coarse fragments, rooting features, soil texture (field and laboratory determinations), soil structure, moisture and colour. Soil horizons within each soil pit were differentiated by rooting characteristics. These observations were recorded for each of the identified soil horizons and the material type (overburden or waste rock) was noted. A soil sample was collected from each soil horizon identified, hand textured in the field and submitted to a laboratory for soil texture determinations.

OBSERVATIONS AND FINDINGS

Field observations were carefully documented and provided a basis for comparing the soil and vegetation characteristics between sites. The following sections will present a summary of the field observations and a discussion of the findings of the field and laboratory data. The discussion will first present the observations and findings of sites reclaimed directly on waste rock material, including sites reclaimed on Lornex Northwest, Lornex Southeast and Lornex South waste rock dumps. This will be followed by a discussion of the observations and findings of sites reclaimed on overburden capped areas and include sites examined on Bethlehem North, Bethlehem Northeast and Trojan Dam.

Reclaimed Waste Rock Sites

The vegetation groupings identified plots with similar vegetation cover characteristics. For each vegetation grouping, site characteristics were compared to evaluate whether specific site characteristics could be related to vegetation cover. On reclaimed waste rock sites, no relationships were identified between vegetation cover and plot elevation, slope length, or aspect; interpretation of these data are limited by the number of plots with different aspects. On the Lornex Northwest

dump, no strong association was identified between slope gradient and vegetation grouping, however, this assessment did not include sites on angle of repose slopes. On the Lornex Southeast dump, a relationship was observed between vegetation cover and slope angle. The findings on the Lornex Southeast sites indicated that level areas had higher total vegetative cover than slopes, and that shallow slopes ($<30^{\circ}$) had higher total cover than steeper slopes ($>30^{\circ}$). A summary of the vegetation cover data for plots positioned on level areas, and shallow and steep slopes is presented on Table 1. These data confirm previous field observations that vegetation cover is related to slope angle.

Table 1
Effect of Slope Gradient on Vegetation Cover
at Lornex Southeast Waste Rock Dump

Slope Gradient	Percent of Plots with Low Cover ($<20\%$ total vegetative cover)
Level Areas	5%
Shallow slopes (<30 degrees)	34%
Steep slopes (>30 degrees)	55%

Additional site characteristics noted on the Lornex Northwest sites were compared to the vegetation data to identify possible relationships between surface conditions and vegetation type or cover. The surface material characteristics included: material size, material type, material grading and texture. No relationships were identified between these factors and the vegetation groupings or density of vegetation cover observed.

Soil samples submitted for soil texture determinations from the Lornex Northwest sites were primarily sandy loams with lesser loamy sand, silty loam and sandy clay loam textures. All soil samples submitted from the Lornex Southeast and Lornex South sites were classified as sandy loams.

Evaluation of the subsurface data collected from the soil pits suggests that AWSC is the principal factor influencing the development of vegetative cover on reclaimed sites. The AWSC represents a physical measure of the soil's ability to retain water, and is calculated using the soil volume (excluding coarse fragment content) of the upper 50 cm of the soil profile multiplied by an AWSC factor determined by the soil texture. Because of this relationship, coarse fragment content strongly influences the AWSC of the site. Figure 1 illustrates the relationship between vegetation cover and AWSC. Figure 2 illustrates the relationship between vegetation cover and coarse fragment content.

Lornex Northwest

Lornex South and Southeast

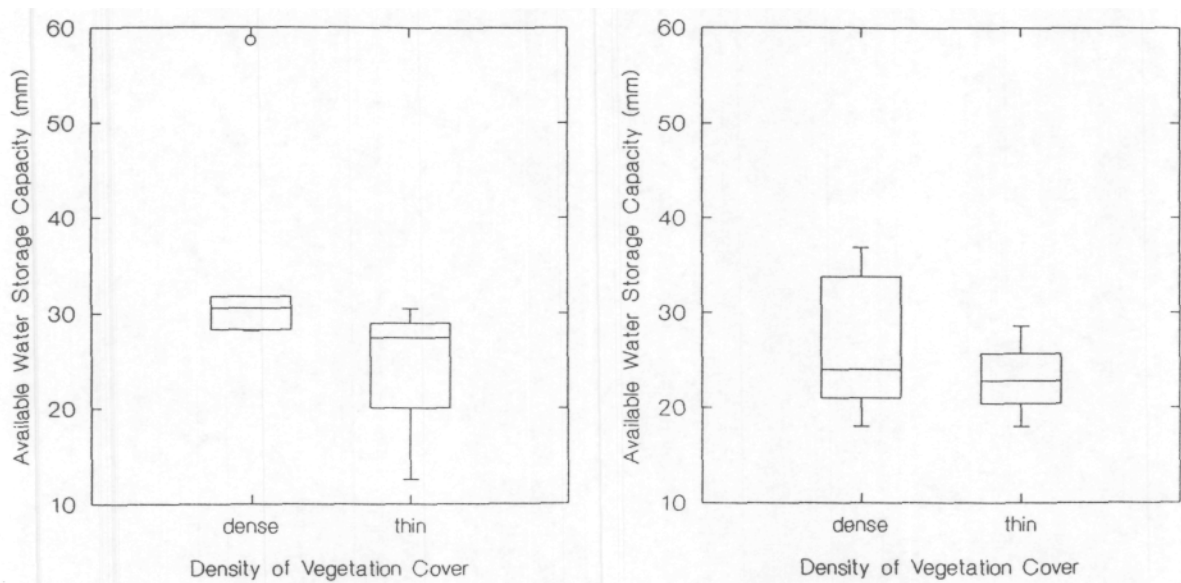


Figure 1 Comparison of vegetative cover and available water storage capacity of soil on reclaimed waste rock sites.

Lornex Northwest

Lornex South and Southeast

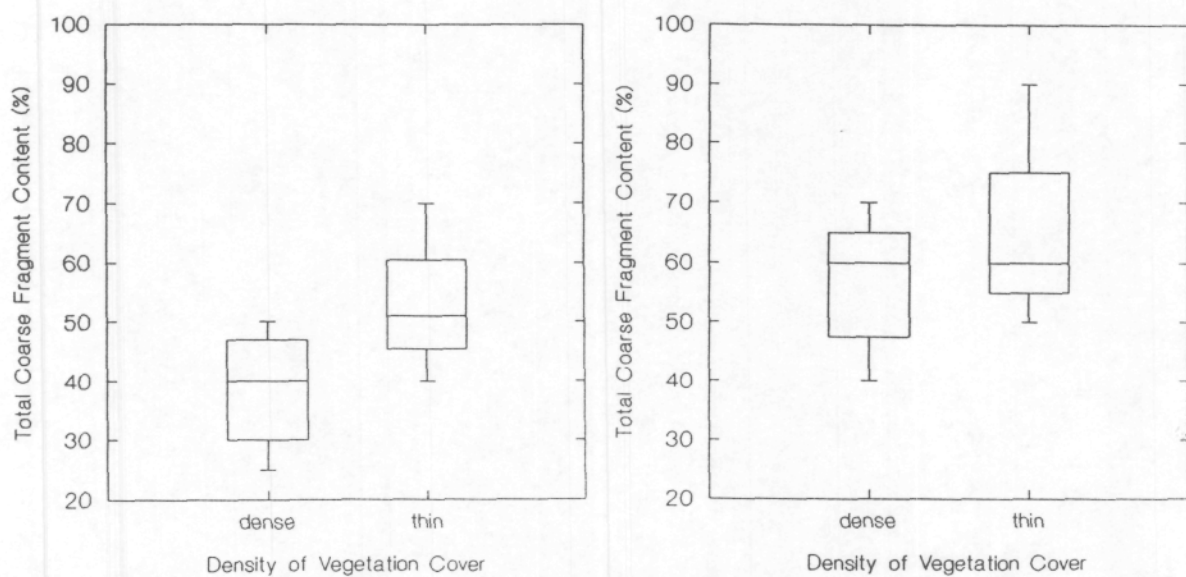


Figure 2 Comparison of vegetative cover and coarse fragment content of soil on reclaimed waste rock sites.

These data were evaluated using non-parametric statistics to generate box and whisker diagrams. The "box" on the diagram contains the middle 50% of the ranked data; the horizontal line within the box represents the median of the data set; and the vertical lines ("whiskers") extending from the box represent values within 1.5 times the range defined by the box. Data outliers are indicated by an asterisk or circle. Based upon these data, all of the Lornex sites display a clear relationship between vegetative cover and AWSC. Sites with dense vegetative cover are characterized by lower coarse fragment content, and higher AWSC. This relationship suggests that lower vegetation cover observed on the steeper slopes is a result of high coarse fragment content and lower AWSC.

In addition, field observations suggest that sites with higher coarse fragment contents may be characterized by greater void space than sites with a higher component of fine material. This further reduces the moisture holding capacity of the soil and results in a site that is less suitable for supporting vegetation. Observations of rooting characteristics relative to coarse fragment content also reveals some interesting relationships. Development of root mats around coarse fragments enables the plants to take up additional moisture through the absorption of water condensing on the fragments. However, the void between coarse fragment represents a dead area that is not capable of contributing essential moisture or nutrients to the root systems of the plants. The AWSC calculation does not consider the effect of large void spaces and perhaps is not directly applicable to these types of soils. A modification to the formula which would subtract the void volume from the total soil volume should be considered for mine soils. This modification was not used in the calculations presented here.

Field observations pertaining to rooting depth indicate that roots commonly extend to 80 cm or more on densely vegetated reclaimed waste rock sites. A maximum depth of rooting observed was 120 cm; and roots extending to 1 metre were not uncommon.

Soil analytical data for the soil profiles suggests there is some evidence of organic matter accumulation in the upper portion of the soil profiles. This is primarily attributable to root decomposition. These data indicate that the more densely vegetated sites are characterized by a higher percentage of organic matter, and the percentage of organic matter is higher on the Lornex Southeast sites, than the Lornex Northwest sites. This difference between sites is believed to be due to the duration of vegetation establishment, and the number of growing seasons that have elapsed allowing a build up of organic matter through the annual accumulation and decay of plant matter.

The Lornex Southeast sites were seeded in 1989 and 1991, compared to the Lornex Northwest site, seeded in 1992.

Reclaimed Overburden Capped Sites

Due to differences in the mineralogy and weathering characteristics of waste rock material between the Lornex and Bethlehem mine areas, the placement of overburden caps has been necessary on some waste rock dumps and rock fill dams of the Bethlehem mine area to improve growing conditions for reclamation of these sites. Despite the overburden capping on the Bethlehem North and Bethlehem Northeast waste rock dumps, and the Trojan dam, variation in the establishment of vegetation is apparent on these areas. Soil pits were excavated to assess subsurface features that might influence the establishment of vegetative cover on these sites.

Less textural variability was noted in the overburden material placed on the Bethlehem and Trojan sites compared to the Lornex waste rock material. Laboratory determinations of soil texture indicated that sandy loams were characteristic of all of the overburden capped sites.

Field observations indicate that AWSC is of primary importance to development of vegetation cover, because this is dependant upon the soil texture, thickness of the soil horizon, and coarse fragment content. The AWSC was determined for each pit to examine the potential relationship between the AWSC and the density of vegetation. These data, illustrated on Figure 3, indicate a strong relationship between these two variables. Soil pits with higher AWSC are characterized by a dense vegetation cover, and those soil pits with a smaller AWSC are characterized by thin vegetation cover.

Depth of overburden is a significant factor in the development of root systems and vigorous vegetation. Figure 4 compares the depth of overburden and density of vegetation cover noted at the

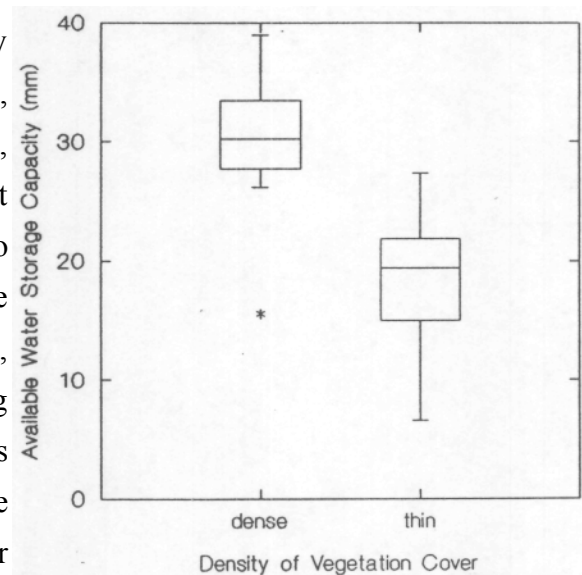
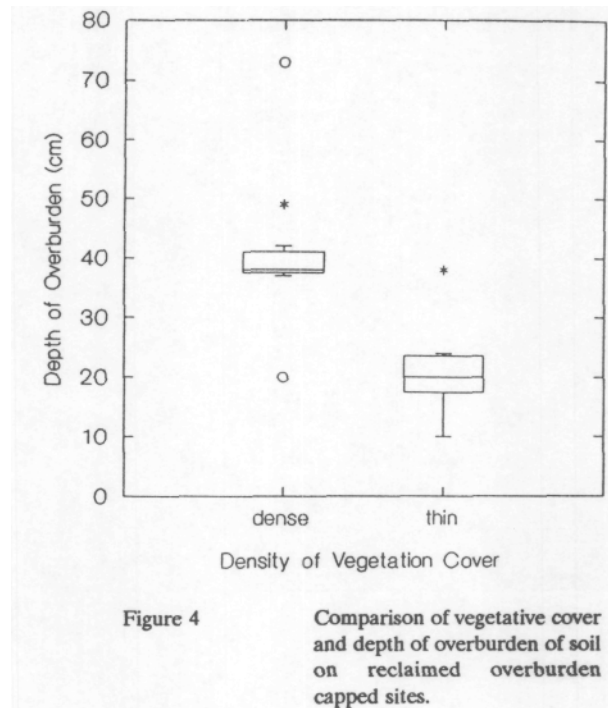


Figure 3 Comparison of vegetative cover and available water storage capacity of soil on reclaimed overburden capped sites.

Bethlehem and Trojan sites. This plot demonstrates a strong relationship between the depth of overburden placed on a site and the density of vegetation cover. On sites with overburden thickness of 20 cm or less, the vegetation cover is thin. In contrast, a dense vegetation cover was characteristic of sites with an overburden cap near to or exceeding a thickness of 37 cm. These data are consistent with field observations which suggest that the type of vegetation dominating a site varied with the overburden thickness. Legumes were abundant in areas of thicker overburden capping, and were the dominant vegetation on sites with depth of overburden exceeding 37 cm. Grass dominated vegetative covers were noted in areas with thinner capping of overburden material. Maximum depth of rooting observed was approximately 75 cm on the reclaimed overburden capped sites.



Examination of the coarse fragment content of the sites confirms the importance of overburden depth to vegetation establishment. On the Bethlehem North and Bethlehem Northeast waste rock dumps, poor growth was noted on sites with overburden capping of less than 25 cm even if the coarse fragment content of the overburden was 25% or less. This data strongly suggests that an adequate thickness of overburden material is essential to get the plants established on the sites. Comparison of the coarse fragment content of the overburden and waste rock material at the Bethlehem sites illustrates why overburden capping was essential to the establishment of vegetation on these sites. The coarse fragment content of waste rock material at the Bethlehem sites ranged from 70% to 95% with a mean of 82%. This is considerably greater than the coarse fragment content of the overburden material, which ranged from 15% to 45% with a mean of 32%. Overburden depth is a critical factor in the establishment of vegetation on these reclaimed sites. The data and observations indicate a minimum overburden depth of approximately 40 cm is required to produce a dense vegetation cover, and is essential to support legume growth. Lower coarse fragment content is also very important for

promoting vigorous vegetation. Both of these factors play a major role in determining the site's AWSC and ability to support vegetative growth.

SUMMARY

The findings of this program suggest that subsurface conditions greatly influence the ability of a site to support vegetation. The soil's moisture holding capacity, determined by the soil texture, soil depth and coarse fragment content, is the most important factor that influences the reclamation potential of the site. Characteristics common to sites with vigorous vegetative cover on both reclaimed waste rock and overburden capped sites include: coarse fragment of less than 50%, an AWSC of 30 or more, and soil textures ranging from sandy loam to silty loam, or sandy clay loam textures. For sites where overburden capping is required, the depth of overburden material is very important. A minimum depth of 40 cm overburden was recognized as important for the establishment of vegetation.

The Lornex Southeast data suggested that slope angle can influence the development of vegetative cover and indicated that level areas had higher total vegetative cover than slopes, and that shallow slopes ($<30^\circ$) had higher total cover than steeper slopes ($>30^\circ$). This relationship is attributed to the higher coarse fragment content typical of the steeper slope, resulting in reduced AWSC, and consequently, a lower potential to develop a vigorous vegetative cover on these areas.

The results of this study indicate that material characteristics are critical to the development of successful reclamation sites, and suggest that the final material placed on the surface of the dump should have an adequate fine particle component with a minimum coarse fragment content to optimize the AWSC of the soil. Typical depth of rooting suggests that these material characteristics are especially important for the upper 1 m of the reclaimed site. In addition, this study demonstrates that these characteristics can not be determined from surface observations only and that soil pits are necessary to provide observations and measurements of these subsurface features. Alternatively, careful monitoring of the materials placed on waste rock dump surfaces prior to reclamation is necessary to ensure placement of appropriate materials to promote productive vegetative growth. Such site preparation monitoring can be expected to achieve long term savings by improving vegetation establishment and sustainability on reclaimed sites.

REFERENCES

Highland Valley Copper, 1991. Annual Reclamation Report 1990.
Reclamation Permits No. M-II and M-55.