ABSTRACT

Gulf Canada Resources Ltd. has been investigating the potential of developing a world class anthracite mine at the Mount Klappan property in northwestern B.C. Reclamation of disturbances associated with development of the proposed mine and planning for reclamation of mining activities were initiated early in the development process. Single species trials were established in 1984, while species mix trials were established in 1985. Operational reclamation work was started in 1985 with broadcast seeding of the tailings pond dyke. Hydroseeding was used initially in 1986 for vegetation establishment at a test pit site and around the pilot preparation plant. In 1988, a trial waste dump was constructed to test reclamation methods which would be appropriate for waste dump reclamation. In addition, aerial broadcast seeding was used to reclaim outlying exploration disturbance. Hydroseeding and aerial seeding were again used in 1993.

Methods and results from the Mount Klappan reclamation program are presented. Information gained is applicable to other high elevation sites in northwestern B.C.

1.0 INTRODUCTION

Gulf Canada Resources Limited has been exploring the possibilities of developing an open pit anthracite mine in the Mount Klappan area of northwestern British Columbia for the past decade. The coal deposits of this area have been known of since the turn of the century, although work over the past decade by Gulf has defined a reserve base and determined potentially suitable mine locations and designs. Exploration programs have been conducted with the aim of defining accurately recoverable reserves, determining coal quality and determining the location and thickness of the coal seams to allow accurate mine planning. Trial mining and trial cargoes have been produced from the Mount Klappan area to provide potential customers with coal for test burns and processing. These cargoes were prepared from the products of a pilot preparation plant located at the Mount Klappan site.

Environmental studies have been conducted at the Mount Klappan site in support of potential mine development. Biophysical resource studies have been conducted to determine the extent of potential impacts from mine development. These have included studies of aquatic systems, ground and surface water quality, wildlife and wildlife habitats, vegetation, including a detailed
study of rare and/or endangered species, soils, terrain and surficial materials. Studies of the local atmospheric conditions have been conducted at the mine site, as have studies of local lichen populations to act as a baseline from which any changes could be monitored.

Reclamation studies have been conducted as an integral part of mine development work. Single species trials were initiated early in the life of the project. Results from these were used to develop species mix trials. Operational reclamation trials were designed to test proposed reclamation methods in an operational setting while at the same time performing useful reclamation work. Reclamation of disturbed sites in the Mount Klappan area has utilized the results from the single species trials, the species mix trials and the operational reclamation trials to provide state of the art reclamation programs.

Innovative reclamation methods have been tested at the Mount Klappan site. Bioengineering techniques designed to establish vegetation on waste rock slopes at the angle of repose were tested in 1988 on a trial waste dump constructed for the purpose. The ability to establish a sustainable vegetation cover on steep slopes would reduce the need to reslope waste dumps and therefore limit the amount of area encompassed by the mine, thus reducing the impacts associated with mining.

2.0 EXPLORATION PROGRAM

No exploration work has been conducted at the Mount Klappan site in recent years. Previous exploration programs have included studies of the regional geology to define the context in which the coal was deposited. Drilling programs have provided details of the local stratigraphy and small samples (core) for detailed analysis. Hand and machine trenching programs have been conducted to map outcrops and structure, while geotechnical exploration programs have been conducted as an aid to mine planning.

Previously conducted exploration programs have provided sufficient information to allow mine planning to proceed with a high degree of confidence. Trial cargo programs, conducted at the Hobbit-Broatch test pit and on Lost Ridge, have provided additional information on coal quality and information required for the design of the coal preparation plant. There are no plans for further exploration programs in the immediate future. Any future exploration programs would be developed to address specific needs.

Exploration programs have been conducted in a manner which would allow protection of environmental values and reasonable reclamation of any disturbed sites. Much of the exploration work was conducted with helicopter support, thus minimizing the need for extensive road systems. Where possible, access for drills and trenching equipment was developed without roads, with equipment travelling across the tundra without breaking the surface. In many cases, exploration sites now have a cover of native vegetation established, thus further reducing the environmental impacts associated with exploration.
3.0 RECLAMATION PROGRAM

3.1 General

Reclamation of disturbances created during the exploration phase of the Mount Klappan Coal Project has been a major means of mitigating the impacts associated with exploration. Mine reclamation will similarly constitute the major means of mitigating the impacts of mining. Recognition of the importance of reclamation in both the exploration and mining phases of development has lead Gulf Canada Resources Ltd. to institute an extensive reclamation program at the mine site. The Mount Klappan reclamation program has developed along two lines; reclamation research and operational reclamation.

Reclamation research was initiated in the Mount Klappan area in 1984 with the establishment of single species trials. Prior to the establishment of the trials, little was known about species performance in the Mount Klappan area. There was, however, a wide body of information on species performance in both the Southeast and Northeast coal blocks of British Columbia, and it was from this knowledge that the species selected for testing at Mount Klappan were chosen. Information generated from the single species trials was used to formulate two species mixes, one for low and one for high elevations. These mixes were tested at the mine site in 1985. Results from the species mix trials were used to refine the mixes for use during operational reclamation.

The establishment of effective reclamation at the Mount Klappan site is hampered by the northern location and consequently the harsh climate. The native vegetation, which reflects this harsh climate, ranges from open sub-alpine spruce and fir forests at the lower elevations to open arcto-alpine tundra. This native vegetation cover has adapted to the harsh winters and the short, cool summers.

The native vegetation and the underlying parent materials have influenced the formation of soils. However, the cool, harsh climate has slowed soil genesis to the point where most of the soils of the area must be considered poorly developed. Soils are generally low in nutrients and have very limited structure. Local rock, primarily shales, mudstones, sandstones and conglomerates, weathers rapidly, forming soil-like materials. Investigations into the use of weathered rock as a growth medium have concluded that with appropriate fertilizers and seed mixes, establishment of a self-sustaining plant cover on the waste rock is possible.

Reclamation programs at the Mount Klappan site have been designed to provide immediate protection from erosion and to re-integrate the disturbed lands into the natural process of vegetation succession. In this way, the reclamation designs have been developed to restore productivity to the disturbed areas and to re-establish the pre-mining land and resource uses. Successional reclamation is the term applied to reclamation programs which utilize the natural successional processes to re-establish functioning ecosystems on the disturbed areas. Successional reclamation programs seek to allow native invasion of the disturbed sites while at the same time providing a temporary cover of vegetation which will provide immediate relief from erosion.
3.2 Reclamation Research  
3.2.1 Methods  

Single Species Trials - 1984  

Single species trials were established on July 12 and 13, 1984. The aim of the trials was to determine the ability of individual species to germinate and grow in the Mount Klappan area. High (1,825m ASL) and low (1,300m ASL) elevation sites were selected for the trials. Seed was applied at a rate of 100 kg/ha, while fertilizer applications were split, with grasses fertilized at rates of 330 and 660 kg/ha and the legumes fertilized at 100 and 200 kg/ha. A standard 13-16-10 blend of fertilizer was used. Table 3.2.1-1 presents the species which were tested. Unless otherwise noted, common varieties were used for the tests.

<table>
<thead>
<tr>
<th>Grasses</th>
<th>Legumes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard Fescue</td>
<td>Alsike Clover</td>
</tr>
<tr>
<td>Bromegrass</td>
<td>Rambler Alfalfa</td>
</tr>
<tr>
<td>Climax Timothy</td>
<td>White Clover</td>
</tr>
<tr>
<td>Meadow Foxtail</td>
<td></td>
</tr>
<tr>
<td>Boreal Creeping Red Fescue</td>
<td></td>
</tr>
<tr>
<td>Kentucky Bluegrass</td>
<td></td>
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<tr>
<td>Tracenta Bentgrass</td>
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</tr>
</tbody>
</table>

Species Mix Trials -1985  

Species mixes were developed on the basis of the information gained from the single species trials. Seed mixes were developed for both high and low elevations. Table 3.2.1-2 presents the mixes used for the 1985 species mix trials. The seed mixes were balanced for the weight of the seed of each species, so that the appropriate species composition would be achieved.

The seed mixes were balanced to provide both sod and bunch forming species. A high proportion of legumes were included in the mixes as it was determined during the single species trials that the established legumes developed root nodules, an indication of the presence of nitrogen fixing bacteria. All legume seed was double inoculated to ensure nitrogen fixation. Seed was applied at a rate of 100 kg/ha using a hand-held "Cyclone" seeder. Fertilizer (13-16-10) was applied to the test areas at the time of seeding at a rate of 300 kg/ha. The trials were established during the period from June 19th to 25th, 1985.
Three sites at low elevations and three sites at high elevations were selected for testing of the mixes. The sites were selected to represent a range of edaphic conditions which might be encountered. Sites were deemed to be dry, mesic or moist relative to the surrounding conditions.

**High Elevation Waste Rock Reclamation Trials - 1988**

Reclamation of the waste rock generated from mining operations at the higher elevations is expected to be challenging. The high elevation waste rock reclamation trials were designed to determine the extent of possible reclamation at a variety of slope angles using waste rock. A trial waste rock dump was constructed in the proposed mine area with three different slopes. Slopes of 2:1, 1.5:1 and 1.3:1 were constructed. Wattle fences, which are short retaining walls built of living willow cuttings, were built on a portion of the 1.3:1 slopes to determine if these would aid in the revegetation of these steeper slopes.

The entire trial waste rock dump was seeded with the high elevation seed mix (see Table 3.2.1-2) at a rate of 100 kg/ha of seed. A hydroseeder was used which allowed the seed to be mixed in a
slurry of water, fertilizer and mulch. Fertilizer (19-18-19) was applied at a rate of 400 kg/ha while mulch was applied at a rate of 300 kg/ha.

### 3.2.2 Results and Discussion

**Single Species Trials - 1984**

All of the seeded species in the single species trials established on July 13 and 14, 1984 showed signs of growth by the 15th of August 1984. However, access road construction during the winter of 1984/1985 resulted in the inadvertent destruction of all of the high elevation plots except the Timothy plot. By June 24, 1985, growth of all species at the low elevation plots was progressing well, and growth of the high elevation Timothy plot was also doing well. On June 24, 1985 at the low elevation site, grass covers ranged from 25 to 60 percent while legume covers ranged from 5 to 25 percent. The remaining plots were destroyed by snow clearing operations over the winter of 1985/1986.

**Species Mix Trials - 1985**

Results from the 1985 species mix trials were excellent. By the end of the 1985 growing season, all sites treated showed signs of plant growth, with the moist and low elevation sites having the best growth. Flowering and seed set was noted on at least some of the species in the mixes at all of the sites by the end of the 1986 growing season. The seeded cover continued to develop throughout the years, and by the end of the 1993 growing season was well established at all sites. Some high elevation sites, where the disturbance areas were small, have completely re-integrated with the surrounding tundra.

The one exception to the generally excellent performance of species seeded in the mixes has been the growth of Smooth Brome. This species has failed to form a significant part of the vegetation cover at any of the sites over the years since establishment. It was dropped from the low elevation species mix in 1988.

**High Elevation Waste Rock Reclamation Trials - 1988**

Results from the trial waste dump have been excellent, although the willows used for construction of the wattle fences have failed to survive. This is not unexpected since the willows used to construct the wattle fences were collected at lower elevations and are not adapted to life at the higher elevations. The wattle fences have, however, held the waste rock in place and allowed the seeded grasses and legumes to become established.

The grasses and legumes seeded onto the dump in 1988 continue to survive and grow. As the plants established in 1988 mature, the area covered by this vegetation increases. The cover on all slopes is essentially similar, although there appears to be more wind scour of the vegetation on
the windward side of the dump. Native tundra vegetation is encroaching on the trial dump slowly.

3.3 Operational Reclamation, 1985 -1993

3.3.1 Methods

Four programs of operational reclamation have been conducted at the Mount Klappan site. The first, conducted in 1985, entailed hand seeding of the outer face of the tailings pond dyke. In 1986, following recontouring of the Hobbit-Broatch test pit, a hydroseeder was brought in to seed the pit and the water pipeline route from the plantsite to the Little Klappan River. By the fall of 1988, the mine area had been fairly well defined, and a decision was taken to reclaim disturbed sites which would not be re-disturbed by development of the mine. The fourth operational reclamation program was conducted in 1993, and entailed the removal of all processing equipment, recontouring as appropriate, and seeding disturbed sites.

The outer face of the tailings pond dam was seeded in late August, 1985. A hand held "Cyclone" seeder was used to apply 100 kg/ha of the low elevation seed mix (Table 3.2.1-2) and 300 kg/ha of 13-16-10 fertilizer. The dam, which had been constructed earlier in the season, was seeded to prevent erosion of the face. The dam was built of local glacial till, and proved to be severely compacted. However, cleat marks from the bulldozer which had built the dam provided microsites for seeds to lodge in, germinate and grow.

The 1986 operational reclamation program entailed reclamation of the Hobbit-Broatch test pit area. The steep pit slopes were recontoured as much as possible, and a ephemeral stream channel was lined with rock to prevent excessive erosion. The entire pit area, except the stockpile pad, was seeded. The low elevation seed mix (see Table 3.2.1-2) was applied at a rate of 70 kg/ha in a slurry with fertilizer and mulch. Fertilizer (13-16-10) was applied at a rate of 300 kg/ha while mulch was applied at a rate of 1,200 kg/ha in an attempt to ameliorate the effects of the dark substrates. The materials were applied with a hydroseeder.

The water pipeline from the pilot plant to the Little Klappan River was recontoured and seeded during the 1986 program. The low elevation seed mix (Table 3.2.1-2) was applied at a rate of 70 kg/ha with fertilizer (13-16-10) applied at a rate of 300 kg/ha. Mulch was applied with the seed and fertilizer at a rate of 300 kg/ha. All materials were applied in a slurry with water by a hydroseeder.

The 1988 operational reclamation program was designed to revegetate all disturbed sites outside of the proposed mine area. This included many of the roads, trails, drill pads and trench locations, as well as areas around the plantsite and along the mine access road. At the higher elevations, the high elevation seed mix (Table 3.2.1-2) was applied at a rate of 100 kg/ha, while at low elevations, the low elevation seed mix, which was modified as shown in Table 3.3.1-1 was applied at a rate of 75 kg/ha. Fertilizer (19-18-19) was applied with the seed at the time of seeding. Mulch was applied with the seed and fertilizer at a rate of 300 kg/ha. Seed and
fertilizer were applied from a helicopter for sites which were inaccessible to the hydroseeder. Some hand broadcasting, using a "Cyclone" seeder was conducted during the 1988 program.

The 1993 operational reclamation program was developed to reclaim all outstanding reclamation liabilities, and return the disturbed areas to a "dormant" condition. A helicopter was used to apply the seed and fertilizer to upper elevation sites while a hydroseeder was used for low elevation sites. All seed was applied at a rate of 75 kg/ha while fertilizer (19-18-19) was applied at a rate of 300 kg/ha. Work was conducted in September, 1993.

| Table 3.3.1-1 |
| Operational Reclamation Low Elevation Seed Mix |
| Mount Klappan, 1988 |

<table>
<thead>
<tr>
<th>Species</th>
<th>Percent by Species Composition</th>
<th>Percent by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revised Low Elevation Mix</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boreal Creeping Red Fescue</td>
<td>20</td>
<td>24.8</td>
</tr>
<tr>
<td>Meadow Foxtail</td>
<td>15</td>
<td>15.5</td>
</tr>
<tr>
<td>Climax Timothy</td>
<td>15</td>
<td>8.9</td>
</tr>
<tr>
<td>Reubens Canada Bluegrass</td>
<td>15</td>
<td>5.3</td>
</tr>
<tr>
<td>Aurora Alsike Clover</td>
<td>25</td>
<td>25.3</td>
</tr>
<tr>
<td>White Clover</td>
<td>5</td>
<td>4.4</td>
</tr>
<tr>
<td>Rangelander Alfalfa</td>
<td>5</td>
<td>15.8</td>
</tr>
</tbody>
</table>

Two mulch rates were used with the hydroseeding. A heavy (1,200 kg/ha) mulch application was made on sites such as the plantsite area and the coal stockpile sites where substrates were dark. Results from the 1986 operational reclamation program had proved that the heavy mulch applications were effective in establishing a vegetation cover on these dark substrates. Light mulch rates (200 kg/ha) were used for all other hydrosseeded sites.

Prior to seeding, all non-natural materials, with the exception of the core storage boxes, were removed from the Mount Klappan project area or buried on site. This included removal of the entire camp establishment, the preparation plant, the core storage building, fuel tanks, and all other miscellaneous materials. Culverts which might become plugged were removed and drainage ways were left as open ditches. The adit site was collapsed and the timbers burned. Compacted areas were ripped and prepared for seeding, while foundations were buried. With the exception of the modified landforms and the agronomic species used in revegetation, very few traces of human activity remain on the site.
3.3.2 Results and Discussion

Results from all operational reclamation programs have been excellent. Good stands of grasses and legumes persist at all seeded sites, and there is evidence that native species are invading the sites which have been established for several years. Operational reclamation programs have built on the experience gained from the reclamation trials and from previous operational programs. This has lead to reclamation programs which have achieved the objectives of preventing erosion and providing a suitable vegetation cover on these sites.

Hand seeding of the outer face of the tailings pond dam in 1985 has resulted in the establishment of a good cover of grasses and legumes. There has been no erosion of this site over the past 8 years and there is no expectation that this situation will change. It is of interest to note the dominance of legumes on the north facing slope of the dam, while grasses dominate in other areas. This natural shift in species composition reflects the differences in site conditions between the north facing slopes and other exposures. The seed mixes have been designed to provide a diversity of species so that these differences in microclimate can be accommodated.

Seeding of the Hobbit-Broatch test pit and the water pipeline in 1986 showed that the use of a heavy mulch application could result in the establishment of vegetation on coal and coaly shales. The soils of the water pipeline area could have presented an erosion problem. However, seeding of this area in 1986 has resulted in the establishment of a dense stand of grasses and legumes.

The 1988 operational reclamation program established a cover of grasses and legumes over most of the disturbances which were outside of the proposed mine area. Enhancement of the invasion of disturbed sites by native species through the 1988 reclamation program has resulted in the revegetation of most sites outside of the proposed mine area.

Results from the revegetation work undertaken during the 1993 program will not be known until 1994. However, the removal of the buildings and mine facilities during the 1993 program has left the mine area in a neat and tidy state. There is every expectation that the seeding work conducted in 1993 will result in the establishment of a suitable vegetation cover over the treated sites. Progress of the reclamation of the Mount Klappan mine area will be monitored in the years ahead.

4.0 SUMMARY AND CONCLUSIONS

The reclamation trials and operational reclamation work which has been conducted at the Mount Klappan mine area over the past 10 years has generated a significant amount of information on reclamation in this part of British Columbia. Reports submitted to the B.C. Ministry of Energy, Mines and Petroleum Resources over the years provide documentation of the reclamation successes which have been achieved. Where problems have been encountered in previous programs, such as the failure of Smooth Brome in the seed mix trials, modifications have been made to subsequent programs to accommodate the new information. The refinement of
reclamation knowledge in the Mount Klappan area has lead to reclamation programs which provide consistent results and which achieve their aims.

Operational reclamation programs have been conducted on four different occasions in the Mount Klappan area. In addition, operational trials, such as the species mix trials conducted in 1985, have provided effective reclamation of disturbed sites. Vegetation was successfully established on angle of repose slopes at high elevations on the trial waste rock dump in 1988 and is expected on the upper elevation slopes as a result of the work conducted in 1993. With the exception of the 1993 reclamation work, vegetation has been established on all sites for at least 5 years, thus providing an indication of the long term success of the reclamation work at Mount Klappan.

Gulf Canada Resources Limited is committed to meet or exceed the reclamation expectations set out by government. To this end, Gulf has repeatedly demonstrated its commitment to a high standard of reclamation through programs of reclamation research and testing and through the timely conduct of operational reclamation programs which have maintained a minimal area of open disturbance.