KEMESS SOUTH MINE RECLAMATION AND CLOSURE

Georgia Lysay, P.Eng
Jennifer McConnachie, P.Ag
Carolyn Johns
Jordan Evans

Northgate Minerals – Kemess Mine
Box 3519, Smithers BC, V0J 2N0

ABSTRACT

The general reclamation strategy for the Kemess South Mine site marries long-term erosion control with successional reclamation principles. For disturbed areas, this requires proper preparation of surfaces, application of growth media, and reintroduction of native pioneer species to initiate successional processes of recovery. The focus of reclamation during mine operations has been on the inactive areas of the tailings dam, waste rock dumps, and expended construction borrow areas.

The tailings are retained behind an earthfill dam. Reclamation activities were initiated at the dam in 2008 upon completion of the downstream buttresses. A series of diversion ditches to route water around and away from the dam structure were completed in 2009, and the final closure spillway is currently being constructed with completion scheduled for 2011.

The two waste rock dumps contain non-acid generating (NAG) waste rock and potentially acid generating (PAG) waste rock. Resloping of the NAG dump commenced in 2009, followed by placement of overburden and ground preparation. The PAG waste dump will be relocated into the open pit by the end of mine life for subaqueous disposal

Various techniques were applied to the borrow areas, including resloping, drainage control, surface preparation, bioengineering, pocket planting and introduction of native species.

Key Words: native seed, tailings dam, waste dump, reclamation

INTRODUCTION

The Kemess South Mine is an open pit gold-copper mine owned and operated by Northgate Minerals Corporation. The Kemess South mining and milling operation is located in the Omineca mountain range of north-central British Columbia, approximately 300 km northwest of Mackenzie, British Columbia. An all-weather main line industrial road from Mackenzie (Omineca Resource Access Road) provides for transportation of mine supplies and Cu-Au concentrate, while personnel are flown to site from select locations in the BC interior. The Kemess South Mine site consists of an open pit mine, waste rock dump (WRD), tailings storage and mill with a capacity to process over 52,000 tonnes per day of ore (Figure 1). Construction of the project started in 1996, and commercial production was achieved in the second quarter of 1998. The end of mine production is currently scheduled for early first quarter 2011.

The total disturbed area due to construction and operational activities is approximately 675 ha. Progressive reclamation of exhausted borrow areas and access corridors that are no longer required has been ongoing since 2000, while large-scale closure activities began in 2008 with reclamation of the downstream buttresses of the tailings dam. The reclamation work continued through 2009 and 2010 including re-sloping and overburden placement on the Main NAG Waste dump; removal of temporarily stockpiled PAG rock to final disposal in the open pit; final work in borrow areas; application of bioengineering techniques; and collection and planting of native seed. To date, approximately 180 ha are in the final stages of reclamation.

The overall end land use objective of the reclamation program at Kemess is to achieve adequate capability for wildlife habitat. This will generally be achieved via slope stabilization, surface erosion control, and successional revegetation, specifically:

- decommissioning of mine infrastructure
- regrading and resloping surfaces to control drainage and reflect adjacent landforms
- application of growth medium where required
- "rough and loose" surface preparation (Polster, 2009)
- planting of native species as pioneers and seed sources

Methodology and Philosophy

The general philosophy applied for reclamation at Kemess is to appropriately prepare the landscape to facilitate natural processes, which will lead to self-sustaining ecosystems. The most significant approach that stems from this philosophy is that of the rough and loose surface preparation. Although smooth, compacted slopes are efficient operationally, establishing self-sustaining revegetation on these types of surfaces is notoriously difficult. Rather, preparing the surface in a rough and loose manner not only promotes infiltration by minimizing the development of rills and channels; it also creates seed safe zones, where aerially-dispersed native seeds are more likely to be captured. These "microsites" are better able to support vegetation by protecting the seed from being transported (either via water or wind) away from the intended revegation locations and by providing favourable microclimates for seed germination (i.e., retaining moisture and warmth). Once the surface is properly prepared, native revegetation will take hold (Polster, 2009).

With this in mind, Kemess has also implemented revegetation programs with the intent of treating areas where the surfaces cannot be mechanically prepared, slope stability is a potential concern, and/or faster (than natural) establishment of groundcover is desired. The sections below detail some of the programs applying the principles noted above.

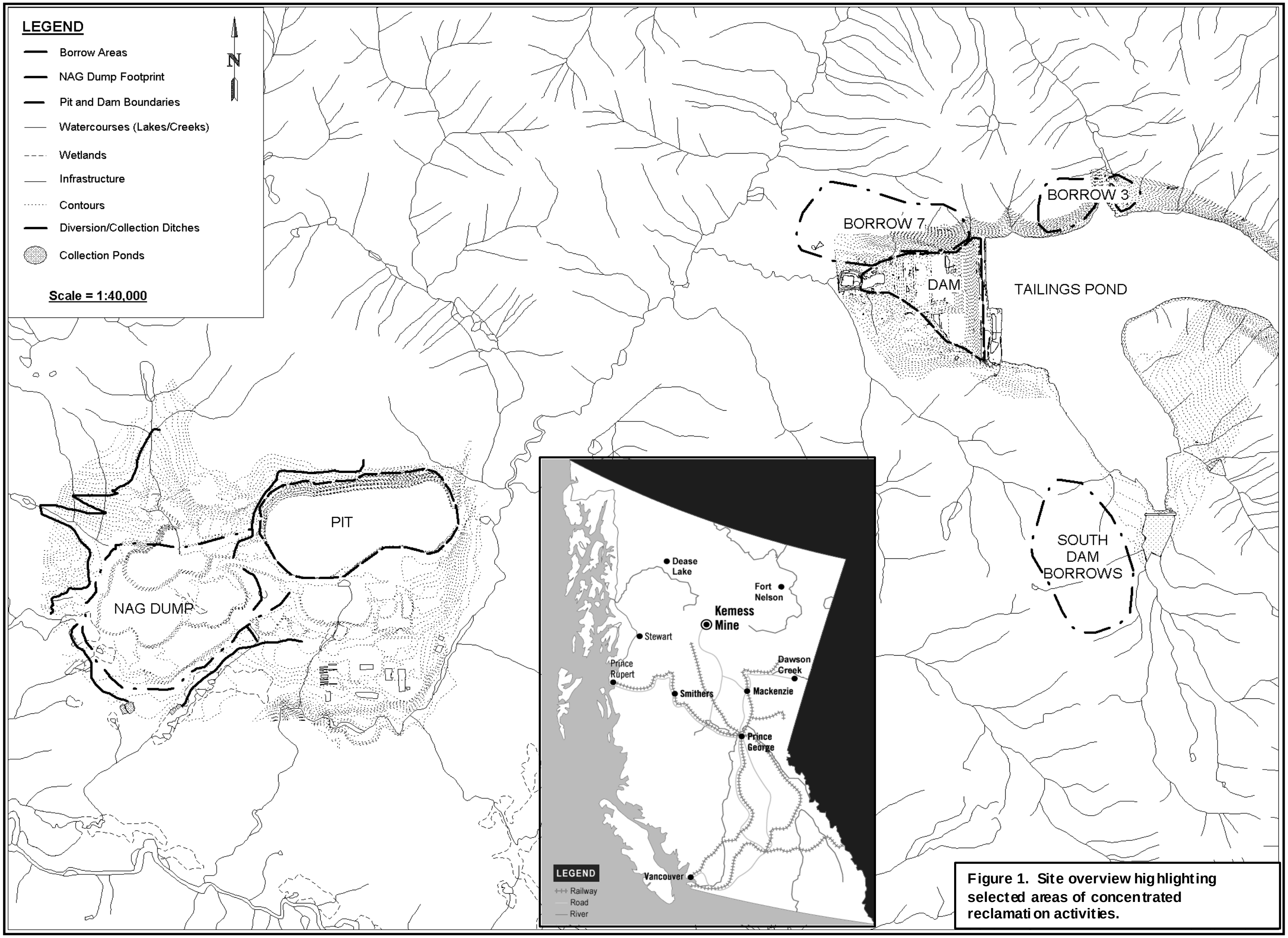

Figure 1. Site overview highlighting selected areas of concentrated reclamation activities.

Native Seed and Willow Collection

Due to low availability and high cost of commercially available native seed mixtures, in 2008 Kemess initiated a native seed collection program. Training was provided for the Environment Department and a small crew of local First Nations in the identification, collection, and storage of key plant species. The seed collection program continued in 2009, with the Kemess Environment Department increasing the number of species collected. Species and approximate numbers collected in the 2008 and 2009 seasons are listed in Table 1.

Table 1. Kemess Native Seed Collection (2008 and 2009)

Species Collected	2008 program	2009 program
lodgepole pine (*Pinus contorta*)	60,000 seeds	53,500 seeds
arctic lupine (*Lupinus arcticus*)	40,000 seeds	64,000 seeds
altai fescue (*Festuca altaica*)	750 g	200 g
fireweed (*Epilobium angustifolium*)	97 g	76 g
Willowherb (*Epilobium latifolium*)	-	45 g
Bluejoint (*Calamagrostis canadensis*)	-	205 g
Mountain Sorrel (*Oxyria digyna*)	-	111 g
Arnica (*Arnica cordifolia*)	-	50,000 seeds
Coltsfoot (*Petasites palmatus*)	-	8 g
smallflowered woodrush (*Luzula parviflora*)	-	7 g
arrow-leaved groundsel (*Senecio triangularis*)	-	20,000 seeds
Merten's sedge (*Carex mertensii*)	-	63 g
bunchberry (*Cornus canadensis*)	-	91 g
Thick-headed sedge (*Carex macloviana*)	-	30 g
Alpine milkvetch (*Astragalus alpinus*)	-	259 g
Sitka burnet (*Sanguisorba canadensis*)	-	50,000 seeds
Alpine Bluegrass (*Poa alpina*)	-	24 g
Subalpine Daisy (*Erigeron peregrinus*)	-	32 g

Arctic lupine and lodgepole pine seeds were sent to Woodmere nursery in Telkwa, BC for plug development with total plug numbers dependent on yearly planting requirements. The remaining seeds (including a portion of arctic lupine) were retained at Kemess for propagation trials in the on-site greenhouse to determine which of these species are most suitable for use in larger-scale planting programs. This program is currently ongoing, and results will be applied to planning for future planting programs.

A local willow collection program was conducted in April 2009. Approximately 50,000 willow stakes and 10,000 willow whips were collected. The whips were sent to a local nursery for propagation, and the stakes were stored in cold storage onsite (snow and/or refrigerated trailer) in advance of bioengineering applications in the summer of 2009. The collection program was repeated in November 2009 on a smaller scale with ~10,000 stakes and ~12,000 whips collected for use in summer 2010 reclamation works.

Application of Bioengineering Techniques

Willow staking has been conducted on site in various areas since 2000. Due to the large willow collection programs conducted in 2009, application of a greater number of bioengineering techniques (Polster, 2005) was possible in summer 2009 and 2010. Willow wattle fences (Photo 1a) were applied on hillsides with known seepages, in combination with live pole drains and willow staking. Brush layers (Photo 1b) were applied to slopes with surficial instability, and live pole drains were installed in talus areas to reduce rilling and to direct surface water to diversion structures.

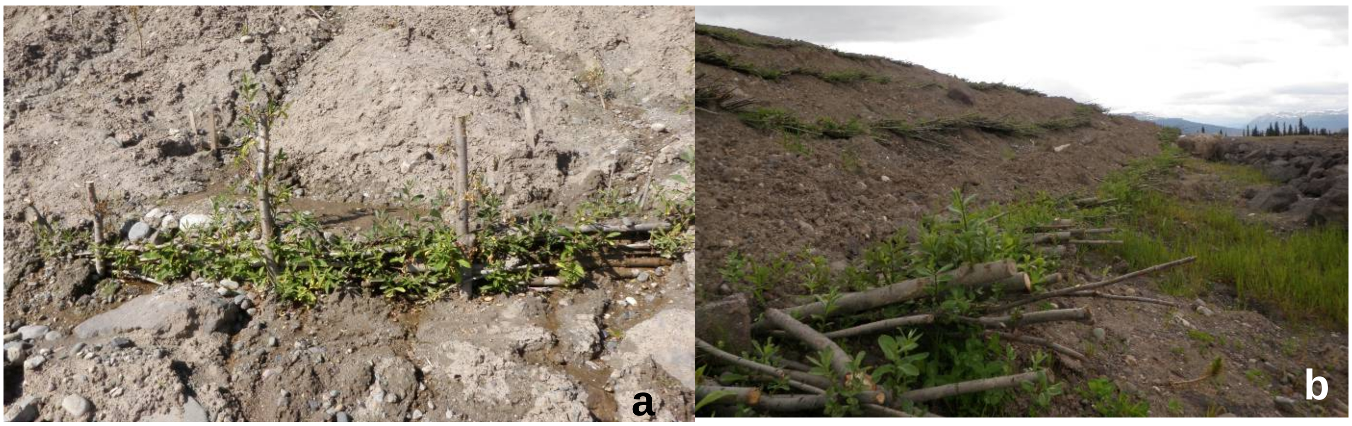

Photo 1. Willow wattle fences on Borrow 7 seepage areas (a), and willow brush layers for improvement of surficial soil stability (b).

Tailings Dam

The final dam raise, to an elevation of 1510m, and placement of NAG cycloned sand on the downstream buttress zone of the Tailings Dam were completed by spring 2008. Based on melt and precipitation events in previous years, it was observed that additional work would be required to control runoff and prevent erosion of the sand buttresses. This has been achieved through intensive surface preparation and construction of water diversion structures.

The closure work on the downstream side of the dam commenced in summer 2008 with resloping and contouring of the sand buttresses, such that they drain back and away from the crests. Overburden was then placed on top of the contoured sand to a thickness of 0.3 m on slopes and 0.2 m on buttress surfaces. The surface was then roughened using an excavator and/or ripped using a dozer as appropriate to obtain a “rough and loose” final surface. This rough surface extends to the sand layer in some locations, which also improves drainage of surface water into the underlying sand layer. Coarse woody debris was spread over the slopes to provide wildlife habitat and to further encourage establishment of micro-sites for ingress of native vegetation. The rough and loose surface preparation has proven to be effective in controlling surface snow melt, as witnessed in both the 2009 and 2010 spring melt seasons. Little to no erosion was observed on dam slopes (Photo 2).

In 2008, approximately 70,000 lodgepole pine and white spruce were planted on the face of the dam (approximately 40 ha). Approximately 5,500 and 1,000 plugs of willow (grown from local cuttings) and arctic lupine (grown from purchased seed stock), respectively, were also planted on the dam as the first wave of native plants. In 2009, this was augmented with plugs of willow, arctic lupine, and altai fescue developed from the 2008 local seed collection program. Three one acre plots of a purchased native seed mix were also planted on the dam face in early August 2009. The seed mix included a selection of mid to high elevation (1350 m to 1550 m) species, including: Slender Wheatgrass (*Elymus trachycaulus),* Rocky Mountain Fescue (*Festuca saximontana),* Alpine Bluegrass (*Poa alpina),* Alpine Timothy (*Phleum alpinum),* Spike Trisetum (*Trisetum spicatum),* Canada Milkvetch (*Astragalus canadensis), and* Fireweed (*Epilobium angustifolium).* In addition, selected seeds collected in the 2009 program were hand broadcast over the surface of the dam. These included Arnica, Coltsfoot, Fireweed, and Sitka burnet.

Observations made in early August 2009 indicated that the seedlings and plugs were doing well and that native vegetation had started to appear on the prepared dam surface, and this has been confirmed by observations made in June 2010 (Photo 2). This suggests that the rough and loose surface preparation technique does create favourable conditions for capturing the seeds of wind-borne species. Some supplementary planting of native species is planned for future years, however it is expected that the density of native species will increase with gradual ingress over time. Additional observations will be conducted in the summer of 2010 to assess the success rates of planted native species and to monitor ingress and infilling of plant cover over the reclaimed surface.

Photo 2. Dam face rough and loose preparation, coarse woody debris, and vegetation (white spruce, arctic lupine and willow)

Construction of the dam diversion ditches also commenced in 2008, after preparatory work in 2007. Two ditches were constructed along the northern boundary of the dam, at the base of the avalanche chute and talus areas. The upper ditch serves both purposes of diversion of runoff around the dam (away from the sand slope) and protection of the dam surface against avalanche runout. The ditches were completed in summer 2009, with the placement of large riprap.

Drainage swales were constructed on the surface of the buttresses to direct water away from the crests toward the closure diversion ditches. An added benefit to the surface preparation was a corresponding downgrade in the design of these on-buttress drainage swales. The swales were initially designed as geomembrane lined, rock armoured ditches. Due to the reduction in surface flow volume with the rough and loose preparation, the swales in low-grade areas (approximately 90% of total swale length) were modified to an overburden-lined swale. Although, liner and rock was installed as per the initial design where the swales extend over the buttress crests. This modification resulted in significant cost savings due to the reduced quantities of processed rock and liner. Construction of the closure spillway commenced in late 2009 and is scheduled for completion in 2011. The final reclamation of the upstream beach will coincide with this work, as spoil from the spillway excavation will be used for closure of the above-water upstream beach.

<u>Borrow Areas</u>

Borrow 3 is located on the north side of the Tailings Storage Facility (TSF). This borrow was one of the rock and overburden sources used during early construction of the TSF. Later borrow development consisted of mining talus for filter materials. Machine reclamation work was carried out in this area in 2005, including recontouring of old borrow benches and development trails. The steep rocky slope section of Borrow 3 was addressed during the 2009 reclamation activities. The objective of the 2009 program was to create micro-sites or “pockets” for establishment of vegetation on the exposed rock slope. Some pockets of vegetation have already established naturally in this area, and the intent was to augment these with additional sites. A lack of a suitable growth medium at the borrow area meant soil had to be moved to the site. Overburden from the mine site was mixed with water to form a slurry in preparation for relocation. Due to difficult access, a helicopter was used to sling the slurry to the borrow. Approximately 7 m^3 of soil was moved to create roughly 150 planting sites (Photo 3).

Photo 3. Soil delivery to Borrow 3 via helicopter and soil pocket planting with native species

Around 100 subalpine fir seedlings were transplanted to Borrow 3 from Borrow 10. Arctic lupine and altai fescue plugs (150 of each) were planted in the prepared soil pockets (Photo 3). A mid-high elevation seed mixture and mountain sorrel seeds were spread on the islands along with slow release fertilizer. Success of the planting and seeding was assessed in June 2010. The extremely dry weather experienced in summer 2009 resulted in high tree mortality, however the grass plugs and seed mix are growing successfully. These sites will be reworked in 2010 by breaking up the soil, adding additional growing medium and seeding.

Natural ingress of vegetation is occurring in the less steep and wetter sites. Planting in 2010 will involve exploiting natural sites not already supporting vegetation. Natural bowl areas on the steeper slopes and the bench above the tailings pond water line will be targeted for micro-sites. A technique of "lasagna gardening" (Lanza, 1998) will be employed to provide an increased chance for plant survival. Lasagna gardening involves layering different material to allow the ground to stay cool and damp, reducing the need for watering. Alternating layers of peat moss and organic materials provide the planting sites for willow, willowherb and mountain sorrel plugs and subalpine fir seedlings. Willow stakes will also be planted in wet areas.

Borrow 7

Borrow 7 was developed during the construction phase, and provided various materials (granular, till, and rockfill) for the dam construction. This borrow did not have a development plan, and stripped materials were stockpiled in various locations throughout the borrow area. This has created numerous challenges for reclamation.

An old soils dump in the western portion of the borrow had previously failed, moving as an earth flow. This area was initially recontoured in 2006, which improved stability. However, surficial sloughing and slumping still occurred in 2007 and additional work was required in 2009 to improve stability. A NAG rock toe berm was constructed along the base of the slopes, additional recontouring was then conducted to further reduce the slope angle, followed by installation of willow brush layers to provide additional stability and control seepage water.

Catch ditches and settling ponds were constructed in 1999 to control sediment and water coming from the active borrow area. The main drainage paths through the borrow were recontoured and modified in 2009 to distribute runoff and freshet flows over a wider area. The ditch and ponds were also deactivated, with the rough and loose principle applied to the disturbed areas. The south face of Borrow 7, adjacent to the tailings dam, is subject to a number of groundwater seepages that present seasonal challenges for erosion prevention. Bioengineering, including live staking and construction of wattle fences, has been used in this area to create miniature catch benches and promote vegetation growth. In addition, the surface has been recontoured to be rough and loose, which lengthens the path of the seepage water, and also creates a number of small, intermediary sediment catch basins.

South Dam Borrows

Three separate borrow areas were developed for the construction of the freshwater diversion system in the area of the South Diversion Dam. These borrows have been the target of annual progressive reclamation works since 2003. Works in this area include recontouring of slopes, decommissioning of access roads, and select spreading of organic stockpiles. Lodgepole pine and white spruce seedlings were planted in 2008, at a rate of 1200 stems/ha coincident with the planting of the tailings dam buttresses. Seeding prior to 2007 was done using an agronomic seed mix, however supplemental planting of native species and some additional live willow staking is planned for the 2010 season.

Waste Dumps

A waste rock characterization program was established at the beginning of mine operations to properly identify and store waste rock based on long-term predicted geochemical behaviour. Waste rock identified as non-acid generating (NAG) was stored in the Main NAG Waste Dump for permanent, final storage. Waste rock identified to have a potential for acid generation (PAG) was stored in temporary waste dumps until it could be rehandled to the open pit for final, subaqueous disposal. Since 2006, approximately 7.6 Mt of 16.2 Mt has been rehandled from temporary stockpiles for final storage in the Pit.

The Main Waste Dump comprises approximately 169 Mt of NAG waste rock and reached final volume as of August 2009. The final footprint was realized in 2005, with subsequent waste rock stored in lifts. The waste dump comprises four main sections known as Lower NAG, Middle NAG, Upper NAG, and Leach Cap Waste. The waste dump was constructed such that the slopes rest at angle of repose.

Full-scale resloping of the waste dump commenced in early 2009. A resloping method utilizing horizontal pushing has been established from the crest down to the toe of each lift to reduce the overall dump slope to between 26º and 28º. To improve vegetation productivity, the recontoured slopes have been capped with overburden growth media. After overburden placement, the rough and loose prescription is applied. To date, approximately 56% of the total slopes (approximately 186,000 m^2) have been recontoured to between 26º and 28º. Overburden placement and surface preparation has been completed on approximately 48 ha of the NAG dump slopes in preparation for planting lodgepole pine and willow in summer 2010.

Vegetation trials were established on the lower NAG slope in 2009 to assess appropriate planting densities for the larger Waste Rock Dump, maximizing groundcover, while promoting development of self-sustaining ecosystems. The trials consist of three 1 ha areas segmented into thirds. Each hectare was treated with a different density of broadcasted native seed (i.e., 75, 25, and 0 kg/ha). The broadcast seed was not collected from site, but includes a selection of species found in the low to mid elevation (1200 m to 1350 m) at Kemess: Blue Wildrye, Mountain Bromegrass, Western Fescue, Bluejoint, Ticklegrass, Canada Milkvetch, and Fireweed. Within each hectare, the thirds were treated with different densities of ecological islands (eco-islands). The eco-islands consist of relatively closely planted communities (i.e., not uniformly spaced) of specifically selected plants based on use of early successional species observed at site. Species are native (i.e., not introduced through agronomic mixes), suited to the local climate, and establish quickly on disturbed areas. Efforts were made to utilize plants propagated from seed collected at the mine site. Each eco-island comprises 5 to 7 plants, including 1 tree, 1 to 2 shrubs, 1 to 2 forbs, and 1 to 2 grasses. The species selected for the 2009 trials were lodgepole pine, willow, arctic lupine, and altai fescue based on what was collected at site in 2008. Preliminary observations indicate good survivorship of all species planted. Further evaluation will occur over the summer of 2010 to assess treatment differences.

Progressive Reclamation

Reclamation activities have been ongoing at the Kemess mine site since 1999. Early activities primarily included works to promote sediment control and improve erosion protection of disturbed construction areas. This involved hydroseeding, construction of settling ponds, and regrading disturbed areas to drain into contained areas, among other things. Construction roads and accesses no longer needed for operations were also reclaimed as the areas were available. These areas include road access to Mill Creek, and a secondary alignment cut parallel to the tailings access road (Photo 4). Recontouring, seeding and planting, and coarse woody debris placement was completed and these areas are considered reclaimed.

Photo 4. Reclaimed construction right of way

SUMMARY

The general reclamation strategy for the Kemess South Mine site marries long-term erosion control with successional reclamation principles. For disturbed areas, this requires application of appropriate growth media, proper preparation of surfaces, and introduction of native pioneer species to initiate successional processes of recovery. Although major reclamation works began only two growing seasons ago 2008, we are already seeing success in the maintenance of surface stability and ingress of native species on the tailings dam and waste rock dump.

REFERENCES

Lanza, P. 1998. Lasagna Gardening. Rodale Organic Gardening Books. Distributed by St. Martin's Press.

Polster, D.F. 2005. Soil Bioengineering for Land Restoration and Slope Stabilization – Course Material for Training Professional and Technical Staff. Polster Environmental Services, Duncan, BC. 95 p + Appendices.

Polster, D.F. 2009. Natural Processes: The Application of Natural Systems for the Reclamation of Drastically Disturbed Sites. Proceedings of the 33rd Annual British Columbia Mine Reclamation Symposium. BiTech Publishers Ltd., Richmond BC.