# FARO MINE COMPLEX REVEGETATION ACTIVITIES

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**ABSTRACT**

In preparation for remediation and closure of the Faro Mine Complex (FMC), significant work has been completed to develop and test revegetation methods at the mine site. Development and implementation of various revegetation field trials and strategies has been occurring since 2007 to gain knowledge on successful revegetation techniques at this challenging northern site. This paper focuses on revegetation efforts and subsequent monitoring at the Grum Overburden slope and Grum Sulphide Cell (GSC).

Grum Overburden site revegetation activities involved the implementation of trials covering approximately two hectares on soils to be used as a reclamation cover. Different grass seed mixes were applied with and without fertilizer, and woody species (alder, willow, and poplar) were planted in the seeded plots. Four years of monitoring have demonstrated that revegetation success was primarily dependant on fertilization and erosion protection was heavily influenced by site preparation method.

Revegetation at the GSC will provide ground cover for erosion protection and develop a long-term, self-sustaining system integrated with the mine surroundings. Building on results from Grum Overburden site, the 2012 revegetation prescriptions included hydroseeding, fertilization, planting of woody species, and testing of fertilization and hydration-paks. Early monitoring results from the summer of 2013 will provide insight on the success of the revegetation works at the GSC site.

**Key Words**: Fertilizer; Nurse and Native Seed; Surface Treatment; Teabags; Hydroseeding; Grum.

## INTRODUCTION

Government of Yukon – Assessment and Abandoned Mines (YG-AAM) branch is responsible for planning for remediation and closure of the Faro Mine Complex (FMC), a large abandoned lead, zinc, silver and gold mine site in central Yukon. In preparation for closure, significant work has been completed to develop and test revegetation methods at the mine site. Establishing vegetation in FMC soils requires some initial care and maintenance to ensure success. The short growing season, nutrient poor soils and the physical properties of the soils all combine to make establishment of vegetation at the FMC challenging. Revegetation must advance quickly to achieve the short-term goal of reducing soil erosion but also must also consider of longer term goals such as allowing for natural succession trajectories.

Revegetation activities and trials have been conducted by EDI Environmental Dynamics Inc. (EDI) at two sites at the FMC: the Grum Overburden site and the Grum Sulphide Cell (GSC). Grum Overburden trials (~2 ha) were designed to identify the most effective combination of surface treatments and revegetation options to establish vegetation and mitigate erosion. The GSC revegetation activities (~26 ha) were conducted using knowledge gained from outcomes at the Grum Overburden trials. Additional variation/experimentation was included to further refine, evaluate and provide additional direction for future revegetation practices at the FMC.

This paper provides an overview of revegetation activities conducted and results and observations from the Grum Overburden trials and preliminary observations from GSC revegetation treatments implemented in 2012.

## METHODOLOGY

Grum Overburden Trials

Grum Overburden re-vegetation trials established in 2009 include the following variables:

- 3 grass seed mixes (agronomic, native, and nurse and native; Table 1);
- 3 woody plant treatments (horizontal and vertical stakes and alder seedlings);
- some seeding of spruce and dwarf birch collected at site;
- 2 fertilizer treatments (unfertilized and fertilized [8-38-15], 400 kg/ha and 200 kg/ha for first year and second year, respectively); and
- 3 soil surface treatments (micro-rill, planar, and rough-and-loose).

*Table 1. Summary of seed mix and application rates*

| Seed Mix and Application Rate | | Seeds by Weight | |
|---|---|---|---|
| Agronomic | (40 kg/ha) | Red Fescue (Arctared) | 15% |
| | | Meadow Foxtail (Common) | 11% |
| | | Kentucky Bluegrass (Nugget) | 5% |
| | | Slender Wheatgrass (Adanac) | 49% |
| | | Alsike clover (Common) | 20% |
| Native | (29 kg/ha) | Slender Wheatgrass | 10% |
| | | Northern (Rocky Mountain) Fescue | 20% |
| | | Glaucous Bluegrass | 37% |
| | | Tufted Hairgrass | 33% |
| Nurse and Native | (33.5 kg/ha) | Slender Wheatgrass | 14% |
| | | Northern (Rocky Mountain) fescue | 27% |
| | | Glaucous Bluegrass | 58% |
| | | Barley | 0.5% |

The study randomized the seed mix; woody plant; fertilizer; and soil surface treatment variables as follows (Figure 1):

- Seed mixes within each surface treatment;
- Fertilizer treatments within each seed mix treatment;
- Woody plant treatments within fertilizer treatments.

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Surface Treatment** | Planar | | | | | | Micro Rills | | | | | | Rough-and-loose | | | | | |
| **Fertilizer** | x | | | x | x | | | x | x | | | x | x | | | x | x | |
| Distance from toe of slope / **Seed Mix:** | agronomic | | nurse + native | | native | | native | | agronomic | | nurse + native | | nurse + native | | native | | agronomic | |
| 70 m | | | | | | | | | | | | | | | | | | |
| 60 m | horiz. 7 | alder 14 | vert. 21 | horiz. 28 | vert. 35 | alder 42 | alder 49 | vert. 56 | alder 63 | vert. 70 | horiz. 77 | alder 84 | vert. 91 | horiz. 98 | alder 105 | alder 112 | horiz. 119 | vert. 126 |
| 50 m | not planted 6 | horiz 13 | alder 20 | vert. 27 | alder 34 | vert. 41 | vert. 48 | alder 55 | vert. 62 | horiz. 69 | vert. 76 | horiz. 83 | alder 90 | alder 97 | horiz. 104 | horiz. 111 | alder 118 | vert. 125 |
| 40 m | alder 5 | vert. 12 | horiz. 19 | vert. 26 | horiz. 33 | horiz. 40 | horiz. 47 | horiz. 54 | horiz. 61 | alder 68 | alder 75 | vert. 82 | horiz. 89 | vert. 96 | alder 103 | vert. 110 | vert. 117 | alder 124 |
| 30 m | white spruce seed, alder & horiz. | white spruce seed, alder & horiz. | white spruce seed, alder & horiz. | white spruce seed, alder & horiz. | white spruce seed, alder & horiz. | white spruce seed, alder & horiz. | dwarf birch, alder, & horiz. | dwarf birch, alder, & horiz. | dwarf birch, alder, & horiz. | dwarf birch, alder, & horiz. | dwarf birch, alder, & horiz. | dwarf birch, alder, & horiz. | alder and horiz. | alder and horiz. | alder and horiz. | alder and horiz. | alder and horiz. | alder and horiz. |
| 20 m | horiz. 3 | alder 10 | vert. 17 | alder 24 | vert. 31 | horiz. 38 | alder 45 | horiz. 52 | horiz. 59 | vert. 66 | alder 73 | vert. 80 | alder 87 | vert. 94 | horiz. 101 | vert. 108 | horiz. 115 | alder 122 |
| 10 m | Alder 2 | horiz. 9 | alder 16 | horiz. 23 | horiz. 30 | vert. 37 | horiz. 44 | vert. 51 | vert. 58 | alder 65 | horiz. 72 | alder 79 | vert. 86 | horiz. 93 | vert. 100 | alder 107 | vert. 114 | horiz. 121 |
| Toe of slope = 0 m | vert. 1 | vert. 8 | horiz. 15 | alder 22 | Stakes 29 | alder 36 | vert. 43 | alder 50 | alder 57 | horiz. 64 | vert. 71 | horiz. 78 | horiz. 85 | alder 92 | vert. 99 | horiz. 106 | alder 113 | horiz. 120 |
| Distance along toe of slope | 90m | 75m | 60m | 45m | 30m | 15m | 90m | 75m | 60m | 45m | 30m | 15m | 78m | 55m | 42m | 39m | 26m | 13m |

*Figure 1.* *Grum Overburden Dump trial layout. 3 surface treatments; 3 seed mixes. Half of each seeded section was fertilized. Woody species planted in blocks throughout the site (alder = alder seedlings; horiz = willow and poplar stakes planted horizontally; and vert. = willow and poplar stakes planted vertically).*

During monitoring from 2010 to 2012, percent vegetation cover was estimated visually in each plot. In 2011 and 2012, percent cover was estimated using a rectangular quadrat (0.5 m²), six subsamples per plot, and calculating average percent cover.

All live stems of poplar, willow, alder, and other woody plants were also counted in each plot. Live stems are defined as any shoot, or cluster of shoots, emerging independently of other shoots.

<u>Grum Sulphide Cell Revegetation</u>

The Grum Overburden trials focused on grass mixes, physical surface treatments, fertilizer effects, and inter-planting woody and herbaceous species. Key treatments in the 2012 GSC revegetation program included the following treatments:

- Surface treatment similar to rough and loose, ripping across the slope
- Nurse and native seed mix (hydroseed)
- Fertilizer (included in hydroseeding)
- Planting woody species
    - Plugs
    - Horizontally staked willow and poplar cuttings
- Fertilizer teabags

YG-AAM was responsible for overseeing and implementing the soil surface preparation. Prior to planting, a D7 Caterpillar dozer using three rippers on the back excavated furrows of 10 – 30 cm depth perpendicular to the slope. Soil surface preparation was completed between July 9 and August 8, 2012.

The GSC was hydroseeded from August 11 – 13, 2013. A native seed mix was used with annual rye grass as a nurse crop. The seed mix consisted of the following grasses:

- 54.1% Slender Wheatgrass 19 kg
- 17.1% Northern (Rocky Mountain) Fescue 6 kg
- 0.5% Glaucous Bluegrass 0.185 kg
- 7.1% Tufted Hairgrass 2.5 kg
- 21.2% Annual Rye Grass 7.5 kg

Experience from hydroseeding on site indicated nurse crops, if applied properly, have immediate effective response that helps address short term revegetation goals. The native mix allows for better establishment over the long term. The seed was applied at a rate of 35 kg/ha over the 26 ha GSC. Additives to the hydroseed mix included fertilizer and mulch/tackifier mix (Hydrostraw® Guar Plus).

The key driver to revegetation cover at the Grum Overburden site was fertilizer. Fertilizer used at the Grum Overburden trial was 8-38-15; limited or no vegetation grew in areas with no fertilizer application. Nitrogen was found to be very low in all GSC soil nutrient analysis results and a higher nitrogen fertilizer composition (18-18-18; 400 kg/ha) was more appropriate for the site and for the establishment of native grasses.

Experimental plots were set up on the GSC to study further refine, evaluate, and provide additional direction for future revegetation practices at the FMC. The study was set up as a complete randomized design with six treatments and seven replicates, resulting in 42 experimental plots; each experimental plot measures 30 m x 50 m. Plots are marked out with wooden posts and plots labeled with tags on the northeast posts of the plots.

In preparation for general planting works at the FMC, locally collected dwarf birch (*Betula nana* L.) and alder (*Alnu*s sp.) seed, as well as cuttings from locally collected balsam poplar (*Populus balsamifera* L.) and willow (*Salix* sp.) were sent to Peel's Nurseries Ltd., Mission, BC, in March 2011 for propagation. The propagated plugs were shipped to FMC in August of 2012 and included the following: Alder (2,660), Birch (4,320), and Poplar and Willow (8,190). Planting of native woody vegetation plugs at the GSC is not only for long term erosion control and site stabilization, but also to initiate the restoration of the site to a more natural state, along local successional trajectories.

The propagated plugs were supplemented by the on-site collection of dormant poplar and willow stakes prior to planting horizontally at the GSC. Horizontal staking has been successful at surviving in the less than ideal soil conditions at the FMC and can produce multiple stems per cutting compared to the one stem a vertical stake produces. Horizontal staking also has the potential to assist in the reduction of erosion due to positioning the stake across the slope, slowing runoff moving down the slope.

Over 14 ha of the 26 ha GSC were planted with woody species in either experimental plots or general planting plots. One entire slope and areas outside of the plots were left as a control to compare revegetation establishment without the planting of woody vegetation; these areas were hydroseeded and fertilized consistent with all areas. Experimental treatments also included three teabag products intended to improve establishment of plugs in disturbed areas.

Specific experimental treatments, outlined in Figure 2, are as follows, with additional details on each in the sections below:

- Plugs only (P plots);
- Stakes only (S plots);
- Plugs and stakes (PS plots);
- Plugs with Fertilizer-pak (Chilcotin blend) teabag (Pf);
- Plugs with Hydration-pak teabag (Ph);
- Plugs with Genesis-pak teabag (Phf).

Plots not containing stakes were planted with 375 plugs: birch (116), alder (72), and balsam poplar/willow (187). Plots with plugs and stakes were planted with birch (58), alder (36), balsam poplar/willow plugs (94), and balsam poplar/willow stakes (~188). Stakes only plots were planted with approximately 400 stakes of a mix of balsam poplar and willow. The density of the plots with plugs (P plots) was 2,500 plugs per hectare and plots with stakes (S plots) was approximately the same, 2,500 stakes and/or plugs per hectare. Some mortality is expected.

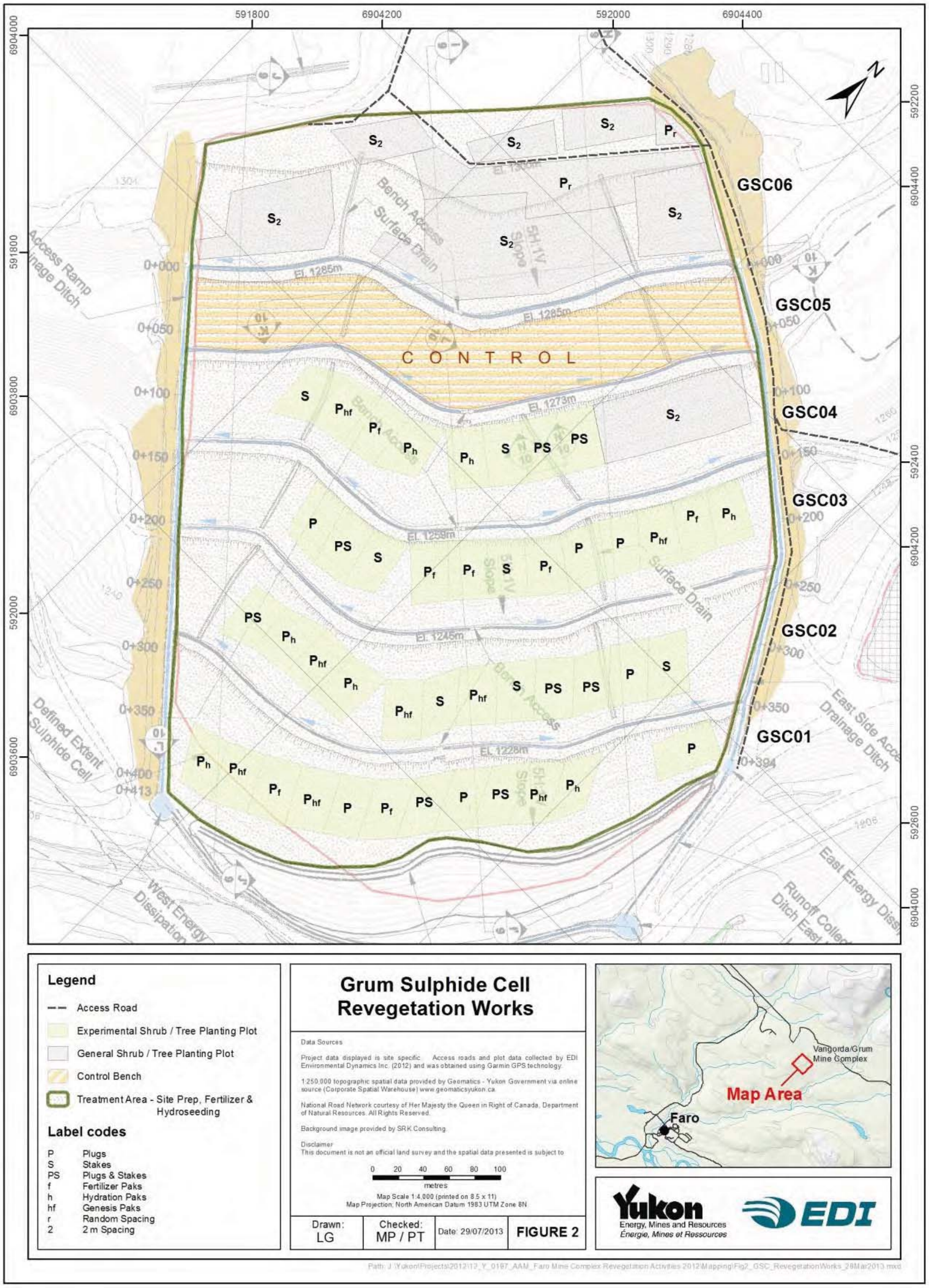


*Figure 2. Grum Sulphide Cell Revegetation Works.*

*Plugs Only (P plots)*
Woody vegetation plugs were planted without any amendments. The 'plugs only' treatment tests plug success and also acts as a control for the treatments involving teabags.

*Staking (S Plots)*
Balsam poplar and willow species stakes were collected at the FMC, near the GSC, within days of planting. Stakes were cut in September as plants were going into dormancy and stored in a ponded area east of the GSC. Stakes were bundled and soaked in water for one to two days prior to planting. Stakes were cut to ~45 cm in length and laid horizontally in shallow trenches that were dug perpendicular to the slope, and backfilled at approximately 10 to 20 cm below the ground surface.

*Plugs and Staking (PS plots)*
Stakes were planted alternately with plugs, both across and with the slope.

*Fertilizer-Paks (Pf plots)*
Chilcotin blend teabags (17-5-7) are used for disturbed planting sites with low levels of organic matter. One 10-gram teabag was placed in a separate hole, immediately upslope of the plug, about 5 cm below the soil surface. Placing the Chilcotin teabag in the separate hole prevents the fertilizer from burning the plug roots. The Chilcotin blend teabag releases the following ingredients over twelve months: total nitrogen 17%; available phosphate 5.0%; soluble potash 7.0%; magnesium 1.2%; sulfur 10.4%; humic acid (leonardite-derived) 4.5%; kelp extract (*Ascophyllum nodosum* (L.) Le Jolis) 4.0%; co-polymer of acrylamide 4.0% (intended to help retain moisture during periods of reduced soil moisture).

*Hydration-paks (Ph plots)*
Hydration-pak teabags (16-8-5) are similar to the Chilcotin-pak fertilizer, but they also contain more moisture-retaining polymer to assist seedlings with establishment during times of moisture stress. One 10-gram hydration-pak teabag was placed in the planting hole with the plug. Placing the hydration-pak in the same hole is possible because the moisture retaining polymer swells and protects the roots from the fertilizer. The hydration-pak includes the following ingredients: total nitrogen 16.0%; available phosphate 8.0%; soluble potash 5.0%; sulphur 6.6%; co-polymers of acrylamide 19.0%.

*Genesis-pak (Phf plots)*
One 40-gram Genesis-pak was placed in the planting hole and broken open prior to planting the plug. Genesis-paks release the following ingredients over twelve months: total nitrogen 8.0%; available phosphoric acid 5.0%; soluble potash 5.0%; sulfur 2.0%; boron 0.037%; humic acid (leonardite-derived) 7.5%; kelp meal (*Ascophyllum nodosum* (L.) Le Jolis) 5.0%; composted vegetative matter 30%.

*General Shrub/Tree Planting Plots (S2 plots; Pr plots)*
In addition to the experimental plots, larger plots were set up in areas to add woody plant material treatments on a larger scale. Poplar and willow stakes were buried at a spacing of 2.5 m (S2 plots). Approximately 3,350 plugs remained after all experimental plots were planted and were planted on the uppermost slope in a random arrangement (Pr plots). Some areas were planted at very high densities to simulate a more natural setting; other areas were planted with regular 2.5 m spacing.

## RESULTS AND DISCUSSION

Grum Overburden Trials

Monitoring of Grum Overburden trials found that fertilizer application is necessary to establish herbaceous vegetation at the FMC. Unfertilized plots had minimal growth and all other treatments were secondary to the application of fertilizer. Results from 2012 indicated that all seed mixes and surface treatments resulted in equally successful vegetation coverage over time in the fertilized plots.

All seed mixes demonstrated increased coverage in the third year after seeding; however, if the objective is to have more immediate coverage, the appropriate seeding may need to contain more nurse crop seed; low amounts of barley (0.168 kg/ha) were applied at the Grum Overburden site. In 2010 and 2011, the native seed mix provided the least cover, suggesting that the nurse crop seed is beneficial for the success of native species establishment. In 2012, the native seed mix provided the same amount of vegetation cover as the other two mixes indicating the native species needed more time to establish. The ratio of nurse crop and native seed that will provide the best balance between immediate cover and sustainability is unclear; however, recent work at the GSC may provide additional insight.

Regarding woody plant establishment, it is unclear whether fertilizer application influenced success of willow/poplar stakes; however, alder seedlings showed a negative response to fertilizer application, likely due to competition with herbaceous vegetation. Results also showed consistently higher stem counts for horizontal staking in contrast to vertical staking.

Of all the surface treatments, the most effective at controlling erosion due to run-off was the rough-and-loose surface treatment, even in the areas with minimal vegetative cover. The rough-and-loose surface treatment at the Grum Overburden site created micro-sites providing areas for pooling water, ideal for germinating seeds. The micro-sites in the depressions were areas of dense grass growth to the point where it may have negatively affected woody plant growth.

The soils and the climate at the former Faro Mine site make revegetation challenging. The amount of vegetation cover established during these trials was not at a level that will meet the objectives of controlling erosion and stabilizing slopes alone. Nonetheless, the Grum Overburden trial results indicate that selection of proper site preparation methods can help address erosion issues at the site and thus provide more time for vegetation to establish. The rough-and-loose treatment with seeding, horizontal staking and fertilization is a method that appeared to achieve the goals of revegetation and controlling erosion. Additional work on seed mixes and fertilization ratios/rates may further improve overall revegetation cover.

Grum Sulphide Cell

Monitoring and data collection will be conducted at the GSC in July/August 2013 and as such preliminary results will be presented during the Northern Latitudes workshop.

Monitoring of the 2012 GSC revegetation activities will be conducted over multiple years to gather data to determine revegetation success, site stability, most effective methods, and if trial objectives have been met. The following activities will take place each year as components of the GSC monitoring program.

- Soil sampling;
- Photo point monitoring;
- Estimation of herbaceous vegetation percent cover;
- Determination of woody vegetation densities;
- Assessment of woody vegetation health and vigor.

In addition to the suggested monitoring activities, general observations of treatments and the site will be recorded, including any observations of natural recruitment of native and non-native species at the GSC.

# Overcoming Northern Challenges

Proceedings of the 2013 Northern Latitudes Mining Reclamation Workshop and

38th Annual Meeting of the Canadian Land Reclamation Association

Whitehorse, Yukon September 9 – 12, 2013

CLRA | ACRSD
Canadian Land Reclamation Association
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Northern Latitudes Mining Reclamation Workshop

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| Knight | Galena Hill, Yukon, Ecosystem Mapping Project |
| Polster | Natural Processes: An Effective Model For Mine Reclamation |
| Dustin | Implementation of contaminated water management system upgrades to allow for dewatering of two open pits at the Vangorda Plateau, Faro Mine Complex, Yukon |
| Kempenaar, Marques and McClure | Tools for Arctic Revegetation: What's in Your Toolbox? |
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## NORTHERN LATITUDES MINING RECLAMATION WORKSHOP

The Northern Latitudes Mining Reclamation Workshop is an international workshop on mining, land and urban reclamation and restoration methods. The objective of the workshop is to share information and experiences among governments, industry, consultants, Alaska Natives, northern First Nations and Inuit groups which undertake reclamation and restoration projects, or are involved in land management in the north or in comparable environments.

The first Workshop was held in Whitehorse, Yukon Territory, Canada in 2001 and it has been held every two years since, alternating between Canada and Alaska. The primary sponsors of the Workshop include the Yukon Geological Survey, Indian and Northern Affairs Canada, Natural Resources Canada, US Department of the Interior Bureau of Land Management, and the State of Alaska Department of Natural Resources.

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The CLRA/ACRSD is a non-profit organization incorporated in Canada with corresponding members throughout North America and other countries. The main objectives of CLRA/ACRSD are:

- To further knowledge and encourage investigation of problems and solutions in land reclamation.
- To provide opportunities for those interested in and concerned with land reclamation to meet and exchange information, ideas and experience.
- To incorporate the advances from research and practical experience into land reclamation planning and practice.
- To collect information relating to land reclamation and publish periodicals, books and leaflets which the Association may think desirable.
- To encourage education in the field of land reclamation.
- To provide awards for noteworthy achievements in the field of land reclamation.

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- The Conference Papers and Posters Committee: Andy Etmanski, Bill Price, Chris Powter, David Polster, Diane Lister and Scott Davidson
- The Conference Sponsors (see next page)
- The Conference paper and poster presenters
- Dustin Rainey, Jocelyn Douheret and Brian Geddes for permission to use their photos on the Cover, Papers and Posters pages, respectively

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