ACHIEVING RECLAMATION SUCCESS GLOBALLY – PEABODY ENERGY'S EXPERIENCE IN MONGOLIA[1]

V. R. Pfannenstiel[2] and Davganamdal Tumenjargal

Abstract: The Ereen Coal Mine operated as a Peabody joint venture project in Mongolia, suspended operations in early 2009. Peabody developed a reclamation and environmental stewardship plan for the site which was initiated in spring 2009. The project would also fulfill the spirit and intent of the 2006 Mongolian Minerals Law. Project development included analysis of environmental baseline conditions and application of best reclamation practices necessary to create a non-erosive and sustainable landform, establish perennial vegetation and restore traditional land use. Mongolian scientists and engineers from Ulaanbaatar teamed with U.S. Peabody engineering and environmental staff to develop and implement a plan to meet Mongolian regulatory requirements and restore pre-mine land capability. The mine area, out of pit dumps and adjacent undisturbed lands were surveyed to develop a post-mining landscape design to establish through drainage and return a stable landform. Backfill material was sampled to identify any spoil that could be unsuitable for plant growth or acid forming. Backhoes, trucks and dozers accomplished the backfilling, final grading and replacing a 20 centimeter topsoil depth. Analysis of adjacent native vegetation was used to develop a seed mix of four native species. Ground water encountered was traced to an alluvial system allowing development of a well and pond for domestic and livestock use. The project was partially completed in 2009, with final topsoiling and seeding in summer 2010. The Mongolian work force spearheaded on-site management and field implementation, including use of a new type of seeder. A management and monitoring plan was implemented. Monitoring results show excellent perennial vegetation establishment, 4X the biomass production of the native reference site and more than 20 native species established, all indicative of successful outcomes for the objectives. The project successfully reclaimed the 18 ha site to pre-mine conditions and accomplished the first complete coal mine reclamation project in the history of Mongolia.

---

[1] Paper was presented at the 2012 National Meeting of the American Society of Mining and Reclamation, Tupelo, MS ***Sustainable Reclamation*** June 8 - 15, 2012. R.I. Barnhisel (Ed.) Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

[2] Vern. R. Pfannenstiel Peabody Energy, 3001 W. Shamrell Blvd, Flagstaff, Arizona 86001 USA Dr. Davganamdal Tumenjargal School of Natural Sciences, Mongolian State University of Agriculture, Ulaanbaatar, Mongolia

Proceedings America Society of Mining and Reclamation, 2012 pp 436-452
DOI: 10.21000/JASMR12010436

http://dx.doi.org/10.21000/JASMR12010436

Introduction

Mongolia, Land of the Eternal Blue Sky, has a rich environmental and cultural heritage dating back to the time of Chinggis Khan. This tradition reflects the Mongolian people's necessity to protect and properly use the country's natural resources. Economic development and growth is vital to modern Mongolia. As a result, the economy is transitioning from an agricultural/livestock base to development of its abundant mineral resources. This necessary economic development has come at a cost with numerous abandoned mines, associated unreclaimed lands and compromised traditional land use and cultural values. The government, realizing these impacts and a need for action, has enacted a number of laws and regulations including the Minerals Law of Mongolia (Mongolia 2006). An example of this needed action is the successfully completed Ereen Mine reclamation project which has achieved compliance with regulations, demonstrated reclamation best practices and restored vegetation and sustainable land use. The Ereen Mine Reclamation Project not only represents a milestone for Mongolia as the country's first complete coal mine reclamation project, it has been called a benchmark for the future. The project accomplished this in the relatively short time of two field seasons.

The Ereen Coal Mine, located in north central Mongolia approximately 400 kilometers northwest of the capital city Ulaanbaatar, operated from 2004 until closing in early 2009 (Fig. 1).

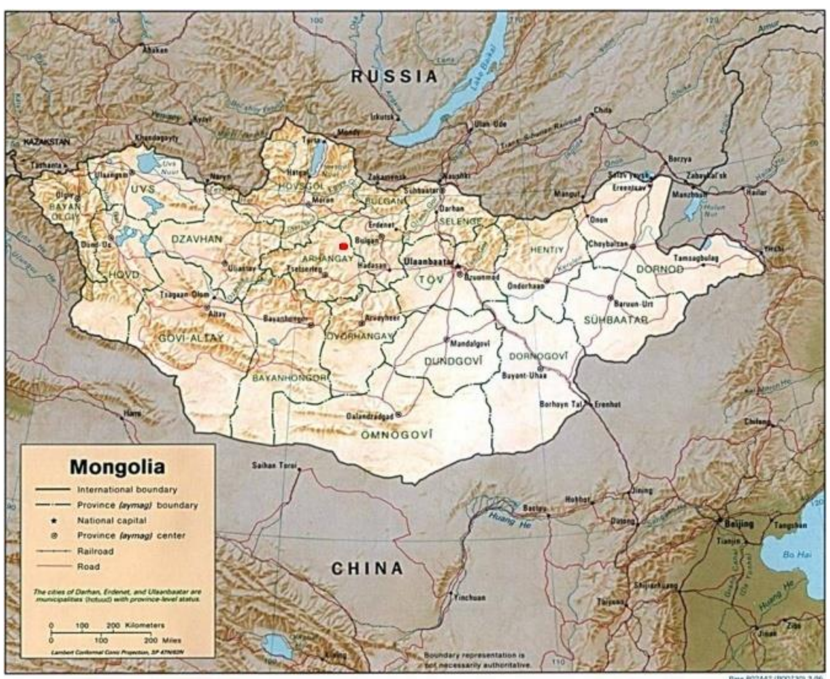

Figure 1. Ereen Mine location (red circle).

During the latter period, Peabody Energy operated the Ereen mine as a joint venture with Peabody Winsway Resources LLC (both herein referred to as Peabody). Approximately 80,000 metric tons of coal were mined during active operations. Upon closure of the mine in 2009, it was determined that the mine site would be reclaimed according to Mongolian regulatory requirements and a best practices approach to reclaim mining and related disturbances. In 2008, Peabody Energy prepared a document for the Mongolian government titled "Reclamation and Environmental Best Practices for Coal Mining Operations – Recommendations to the Mongolian Government" (Peabody 2008). The best practices presented in that document were incorporated as the basis for the Ereen Mine reclamation project. Since Peabody had many years of experience and technical expertise in applying best practice reclamation procedures in the U.S., it took the lead on the Ereen reclamation project with capable support of the Mongolian based Peabody Winsway staff.

Environmental Setting

The Ereen mine is located in the Khangai mountain geographical zone at an elevation of 1620 meters. It is a rolling landscape of broad valleys dotted with low elevation peaks (Fig. 2). The geology is typically sedimentary but with later igneous activity in the region.

Figure. 2. The Ereen mine and surrounding steppe landscape.

The soils are dominated by Chernozem loess (brown) soils of the arid grasslands with a depth of 30 to 40 centimeters and an A horizon of approximately 15 to 20 centimeters. Cemented layers may occur in the profile below 40 centimeters. The mine occurs in the steppe zone (grassland) but is transitional to the forest steppe zone. The steppe type vegetation is dominated by grasses, sedges, and low growing forbs and sub-shrubs. Common plant species occurring on the site include *Agropyron cristatum, Poa attenuata, Koeleria cristata, Bromus inermis, Stipa krylovii, Carex sp., Allium sp., Potentilla sp., Galium sp., Arenaria sp. and Artemisia sp.* The land use is focused on the Mongolian tradition of nomadic livestock herding. Wildlife is relatively sparse in the region with greatest diversity among avian and small mammal species.

The regional climate is arid continental characterized by very cold winters and short warm summers. Most precipitation occurs during the summer months. Average high and low values for peak winter temperatures are -9^{o} C and $- 26^{o}$ C, respectively but can be as low as $- 40^{o}$ C. The winter temperatures are common for five or more months of the year. The summer low and high peak summer temperatures range between 9^{o} C and 22^{o} C with few days greater than 30^{o} C. Warm temperatures typically occur only over a four month period resulting in a short growing season of approximately 200 days. Average annual precipitation is approximately 282 mm with 78 % received from late May into September. Winter precipitation is sparse in most years. Evaporation is 600 to 700 mm per year. Resulting moisture deficits are compounded by strong winds common in the region. Average wind speeds are over 4.5 m s^{-1} but commonly reach 20 m s^{-1} or higher.

Plan Development

As the first complete coal mine reclamation project undertaken in Mongolia, partnership with the government was important for successful completion and insuring the project would serve as a model for future reclamation in Mongolia. Consistent with Mongolian regulatory and mining license requirements, the Ministry of Nature, Environment and Tourism (MNET) and the Ministry of Mineral Resources and Energy (MMRE) were notified of the intent to reclaim the Ereen Mine. Accordingly, a reclamation plan for ministry review and approval was developed jointly by Peabody U.S. technical resources, the Peabody staff in Mongolia and Mongolian engineering consultants. The plan was comprehensive and technically focused on best practices detailed in the Peabody document presented to the Mongolian government in 2008. At the same time, baseline information to support the plan was assembled from existing site information and new data from the Ereen area. Examples of the baseline information include estimates of available topsoil, sampling for suitability of the backfill material for plant growth, survey of existing topography and study of adjacent native vegetation to develop a native seed mix.

Insuring suitable plant growth media in the rooting profile is an essential reclamation best practice. Observations of spoil and carbonaceous materials in the Ereen Mine pit and out of pit dumps indicated the presence of pyrite. Pyrite and associated carbonaceous materials have the potential to create acid and toxic forming conditions detrimental to vegetation performance. Also of interest was the possible presence of any saline or alkaline conditions in the backfill materials. In addition, topsoil salvage by the previous operator was haphazard and it was believed to be necessary to verify its suitability for plant growth. Accordingly, 18 topsoil and spoil samples were collected of representative materials to be used for reclamation at the Ereen mine site. Parameters studied were pH, acid base potential (ABP), electrical conductivity (EC), and sodium adsorption ratio (SAR). To assess plant growth suitability, the U.S. Wyoming LQD Guideline 1 standards for mined land soil reconstruction (Wyoming DEQ-LQD 1994) were used. With the exception of one sample containing significant oxidized coal (pH of 5.0), all materials were found to be suitable for mine soil reconstruction and plant growth. Results are summarized in Table 1.

Table 1. Summary of plant growth media suitability data, Ereen Mine site, 2009.

Parameter	pH	EC(dSm^{-1})	SAR	ABP($t\ 1000t^{-1}$)
Range	5.0-7.9	0.25-4.14	0.36-5.22	-0.11- 435
Average	7.1	0.88	1.44	63.5
EQ-LQD Standard[A]	5.5-8.5	0-8	0-10	< -5

[A] Wyoming DEQ-LQD 1994

The post-mine topography design was a key component of the reclamation plan necessary to achieve a final stable landform and successful revegetation. The mine pit, out of pit dumps and stockpiled topsoil were surveyed to determine the land configuration prior to reclamation and to provide information for a mass balance calculation, post-mine topography design and quantity of available topsoil. Important design criteria included reestablishment of through drainage on the site, stable slopes that approximated the natural landscape contours and smooth blending of reclaimed lands with the undisturbed topography. Using these input data, the post-mine topography was designed by U.S. based Peabody engineering staff using Maptek's Vulcan 3D mine planning software. The mine disturbance topography as of April 2009 is shown in Fig. 3 while the final post-mine topography design is illustrated in Fig. 4.

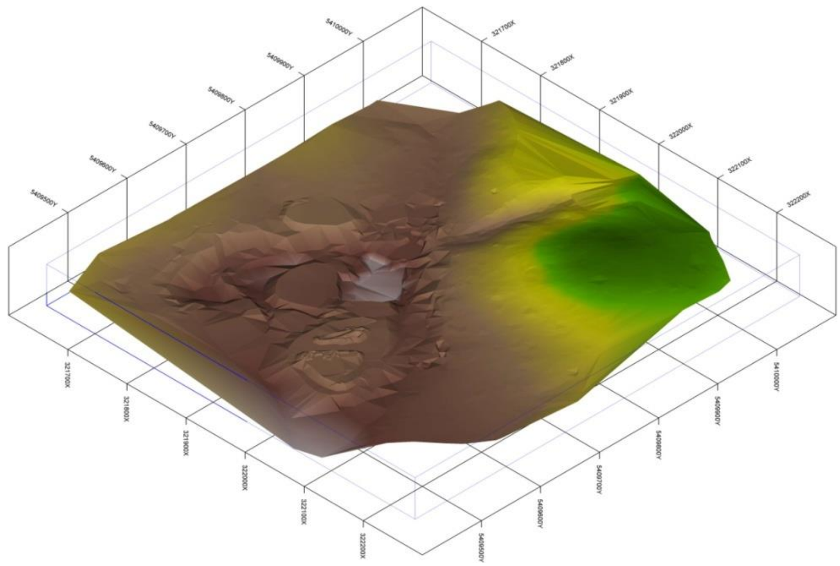

Figure 3. Ereen Mine disturbance topography, April 2009.

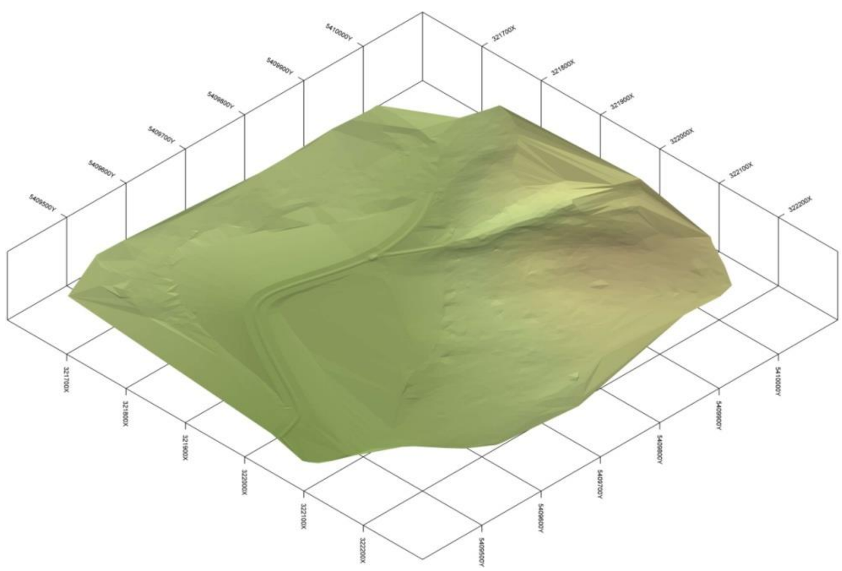

Figure 4. Ereen Mine reclamation final post-mine topography design.

Revegetation planning was initiated with a search for a suitable seeding contractor and seed sources in Mongolia. Investigations found no suitable revegetation contractor in Mongolia which necessitated some innovation. Inquiries led to contact with Dr. Tumenjargal, a professor specializing in revegetation research at the Mongolian State University of Agriculture in

Ulaanbaatar. Dr. Tumenjargal's work focuses on plant material development and reseeding of abandoned cropland in Mongolia and is cooperative with the Green Gold Pasture Ecosystem Management Project (NGO) and the Mongolian Forage Seed Producers Association. Discussions with this team, a visit to the research sites, availability of the team staff and equipment, and the ability of this group to acquire scarce native plant materials answered the revegetation issue with one exception – lack of adequate seeding equipment. Peabody reclamation personnel in the U.S. addressed this need by locating and purchasing a used John Deere 450 drill seeder. It was shipped in February 2010 from Wyoming to the Ereen project site where it arrived in May 2010. The seeder, used successfully for many years in the U.S. but not previously in Mongolia, was chosen for simplicity, ruggedness, parts availability, and effectiveness in applying best practice seeding technology. The seed mix criteria included forage species native to the region and sufficient availability and quantity of the desired species. On site baseline investigations identified a short list of possible species and discussions with Dr. Tumenjargal and her team confirmed that four of the native species would meet the criteria and that they could provide the required quantity of clean viable seed from resources available to them. Table 2 lists the selected native species and the seeding rates.

Table 2. Ereen Mine site reclamation native seed mix and seeding rates.

Scientific Name	Common Name	Seeding Rate (kg ha^{-1})
Medicago varia	Alfalfa	0.6
Bromus inermis	Smooth brome	3.4
Agropyron cristatum	Crested wheatgrass	3.7
Stipa sibiricus	Siberian needlegrass	2.3
Total		10.0

During mining operations ground water was noted seeping into the upper end of the mine pit. As a result of site visits in 2009 by the local community and government officials, it was requested that the water source be developed as a part of the reclamation project. A shallow alluvial ground water source was confirmed in a backhoe pit dug a short distance above the mine area. Water flow and quality samples indicated good potential for both domestic and livestock water. The Mongolian engineering firm USNY Erchim Co., Ltd designed the collection system, the well and a pond downstream in the reclamation that would provide persistent livestock water via an underground pipe from the well overflow. The well, pond and a livestock tank would be installed during parallel reclamation operations.

Project Implementation

The post-mine topography design was provided to the Mongolian engineering team and loaded into the surveyor's GPS units to establish correct drainage profiles and insure the final backfilled and graded topography met design criteria. Backfilling of the pit began in spring 2009 using backhoe excavators and 35 metric ton end dump trucks. Any carbonaceous or other potentially acid forming material that might affect plant growth were placed low in the backfilled pit to insure a minimum of one meter of tested and suitable brown spoil material would be at the surface prior to topsoiling. The highwall slope on the east side of the pit was backfilled and graded to a 1v:4h concave slope and blended with the similar undisturbed slope was the steepest reclaimed slope on site. The less steep west side was similarly blended. The major drainages were developed as backfill was placed in the pit and were configured to create a stable and constant slope of the stream. The main drainage centerline was tied to undisturbed contours upstream and downstream to achieve through drainage. An additional small drainage was established during grading operations on the west side of the project to address drainage onto the site from a swale on adjacent undisturbed land. All final grading was achieved with two dozers and a road grader. Final backfilling and grading was completed in spring 2010.

Topsoiling is a critical best practice to insure revegetation success and sustainability of land use. Ideally, as a best practice prior to mining operations, topsoil resources are documented and salvaged to insure sufficient quantity is available for replacement depths necessary to establish the intended vegetation communities. Volumetric estimates of the salvaged topsoil at Ereen indicated that an approximate 20 cm topsoil replacement depth might be possible. Observation of native soil profiles indicated that this would approach the minimum desired depths. To insure maximum use and critical application of the limited topsoil resource, the team on site developed an innovative approach (Fig. 5). After determining how much area at a 20 cm depth would be covered by an average truck load, a dumping grid was located on the final graded surface. The backhoe operators loaded each truck as consistently as possible. After sufficient dumping was completed on the grid, a dozer was used to spread the topsoil to the 20 cm depth. Importantly, the most skilled dozer operators were chosen for this aspect of the project and trained to maintain close tolerances in topsoil spreading. To verify results of these efforts, 33 depth measurements were taken in a systematic grid on 6 hectares of replaced topsoil. Replaced topsoil depths averaged 22.6 cm (s=5.51) which reflected conscientious team and operator efforts. In spite of these efforts as the project neared completion, it was apparent that topsoil would be short. Sufficient additional topsoil to complete the project was found a short distance from the project site in topsoil stockpiled during construction of the mine access road which was to be retained as a permanent road for local community use. Topsoil replacement was completed in spring 2010.

Figure 5. Application of scarce topsoil was completed through an innovative approach.

Following topsoil application, final minesoil reconstruction and seedbed preparation were completed. Heavy equipment traffic can cause severe compaction on reclaimed sites. To mitigate these conditions at the Ereen site, contour ripping best practices were applied using a D6 dozer with a triple shank ripper attachment. Ripping depth was approximately 0.4 m with shank spacing at 0.9 m. All operations were conducted on the contour (Fig. 6). This best practice aided in erosion protection, improved infiltration and soil moisture and enhanced root zone physical conditions. Following ripping, the soil was contour disked to reduce clods and establish seedbed conditions that promote good soil to seed contact when seeding.

Seeding was conducted in late May 2010 following proper seeding season best practices (seed prior to anticipated optimum moisture conditions). The 4 m wide John Deere 450 drill seeder, equipped with small and large seed boxes, accurate seed metering and double disk furrow openers, aided best practice seeding (Fig. 7). The John Deere tractor used to pull the seeder had

Figure 6. All areas were deep ripped on the contour. Note smooth blend of topography.

Figure 7. Proper seeding equipment was critical to achieving revegetation best practice goals.

been modified with Russian standard hydraulic hose couplings making it incompatible with the drill seeder. Quick and innovative action by the mechanics on site modified the drill seeder to take a Russian standard hydraulic cylinder and avert a significant problem in timely completion of the reclamation project. The seeder was then calibrated to accurately apply the desired seeding rate and was periodically checked to insure continued calibration. Proper seeding rate was not only important in achieving the desired stand characteristics, but also to avoid waste of the scarce seed available for this project. The alfalfa seed was placed in the small seed box for broadcast application (shallow seeding depth) while the three larger grass species were placed in the large seed box for seeding into the disk furrow (moderate seeding depth). All seeding was conducted on the contour. Small areas of the site not accessible to the seeding equipment were hand broadcast seeded on roughened surfaces.

In spring 2010, the well and pond downstream of the well were constructed and a simple but sturdy Mongolian pump was installed on the well. A pipe providing a continuous flow of well water to the pond was also installed at this time. Domestic and livestock water sources were separated for sanitation. An additional livestock water source was constructed adjacent to the well by using a used large equipment tire with the sidewall removed, placed in a concrete base and filled from the well pump through grating and a pipe (Fig. 8). Common in the western U.S.,

Figure 8. The Ereen project provided domestic and livestock water not previously available in the area.

this inexpensive and very sturdy tank had not been used previously and was of high interest to Mongolian land managers for use at other locations. The simple and effective design is easily replicated and addresses infrastructure utility and longevity. To insure sustainability of the new water sources, community outreach meetings were held to explain sanitation, management, and maintenance as well as to select a local caretaker family for the well and associated facilities. The well water meets domestic drinking water standards and water samples continue to be taken to verify water quality. In the fall of 2011, an insulated well house was constructed over the well pump to better insure an available domestic and livestock water supply during the critical winter months on the steppes.

Monitoring

Following final revegetation activities in June 2010, an ongoing vegetation monitoring program was initiated to assess establishment and success of revegetation. Twelve permanent monitoring points were established in the revegetated area to measure plant density of individual seeded species and document vegetation establishment. The monitoring points serve as sampling locations to measure additional vegetative parameters such as cover and biomass production and evaluate trend. Figure 9 shows the Ereen project site, permanent monitoring points, mine site subunits and the final post-mine topography. Monitoring, including cover, will continue for several years.

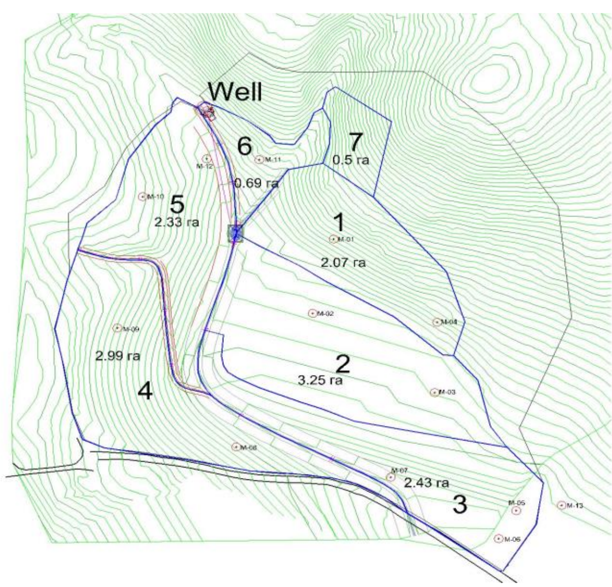

Figure 9. Ereen Mine site subunits, monitoring points and final post-mine topography (note that "ra" equals ha).

The monitoring program was developed by the U.S. Peabody staff and Dr. Tumenjargal and is being conducted by students from the Mongolian State University of Agriculture under her direction. The students assisted with the revegetation at the Ereen site and are using that experience and the monitoring data as part of their research for graduation requirements. The monitoring program also addresses various ministry concerns about methods to evaluate success of the project, gain official approval for release of the mining license and return of the site to local herders. Using procedures developed at U.S. Peabody operations, reclaimed area cover and biomass production data will be compared to similar data collected from adjacent undisturbed areas and used to assess revegetation success. Both areas will be un-grazed. Statistically valid sampling methods will be used to provide appropriate data for any necessary statistical evaluations. Success evaluations will be conducted once monitoring information suggests reclaimed areas have successfully established sustainable perennial vegetation. Experience at Peabody's Western U.S. operations with similar site conditions indicates that perennial plant dominance may be expected by year three after final seeding and demonstration of revegetation success may be achieved as soon as five years after seeding. This is a new approach in Mongolia but is anticipated to be an effective method to assist Mongolian ministry and inspection officials.

Seedling density evaluations were conducted in 1.0 m^{-2} plots at the 12 monitoring points. Seedling density measurements in four sampling periods (2010 and 2011) are summarized in Table 3. The decline in seeded species density in the second year has been commonly observed in the U.S. and is reflective of the system coming into equilibrium. Successful stands can be expected with seedling densities of 21 seedlings m^{-2} (Valentine 1971). The sampled density of 26.8 seedlings m^{-2} by the end of the second year at the Ereen reclaimed site is indicative of successful perennial vegetation establishment.

In 2011 biomass sampling and seeded species height measurements were conducted in addition to seeded species seedling density sampling. Biomass sampling was conducted at 20 random sampling sites in reclamation and 20 random sites in the adjacent native areas which were within the fenced reclaimed area and excluded from grazing. Native areas were comprised of typical perennial native vegetation of the steppe grasslands in the region. Sampling was by complete harvest with no separation by species or growth forms. Species composition in most reclaimed plots was observed to be predominantly perennial seeded species. As can be seen in Table 4, biomass production increased steadily from June through September and was consistently over 4X the native biomass production in each sampling period. The rate of increase over the growing season was essentially the same for native and reclaimed sites. The high rate of biomass production for the young reclaimed site is similar to reclaimed sites in western U.S. reclamation and is expected to taper off to a lesser level as the site equilibrates. Nutrient flush is common for a period in newly reclaimed sites with re-spread topsoil and may also play a role here. At Ereen, native areas have a fairly shallow restrictive zone in the subsoil and this was eliminated in reclaimed sites through mixing and then deep ripping. Moisture levels received during the growing seasons in 2010 and 2011 were also good.

Table 3. Established individuals of perennial seeded species m^{-2}, Ereen Mine reclaimed lands[A] .

	Average number m^{-2}				
Species[B]	Medvar	Broine	Agrcri	Stisib	Total
Jul 2010	5.7	15.8	10.5	13.8	45.8
Oct 2010	9.7	19.4	16.3	2	47.4
Jul 2011	6.8	9.3	6.7	6.5	29.3
Sep 2011	6.6	7.8	6.3	6.1	26.8

[A] Data averaged from 12 permanent monitoring points
[B] Medvar = *Medicago varia*, Broine = *Bromus inermis*, Agrcri = *Agropyron cristatum*, Stisib = *Stipa sibericus*

Table 4. 2011 biomass sampling results, Ereen Mine reclaimed lands[A] .

	Average Biomass production kg ha^{-2}			
Area	June 2011	July 2011	August 2011	September 2011
Reclaimed	1928	3931	7734	8706
Native	406	515	1789	1789
Reclaimed vs. Native	4.7x	7.6x	4.3x	4.9x

[A] Data averaged from 20 reclaimed and 20 native sample points (Grazing excluded)

Seeded species height averaged 9.4cm in May 2011 and increased to an average of over 78cm by September. By fall 2011, more than 20 native plant species, including several early colonizer native annuals, had been identified in the reclaimed areas. Small mammals, a variety of birds, several raptors and numerous insects including pollinators were commonly present. These many indicators point towards a return of ecosystem function.

A critical need for herders in the region is winter forage. Severe winter condition two years before the reclamation effort devastated livestock populations resulting in average losses of 25 % or more to herder's livestock numbers. The high forage production at Ereen and the potential for sustaining those levels may value the site as a hay production area as opposed to a grazing site. To evaluate this potential, a $600m^{-2}$ hay study plot was established in September 2011 to study sustainability of this use. Hay cut in the study will be fed to the local caretaker's livestock and qualitative observations made of animal response.

Conclusion

Use of proven best practices in planning and implementation resulted in the success of the Ereen Mine reclamation project and demonstrated their applicability in Mongolia. The Ereen Mine reclamation project has generated a great deal of interest in Mongolian ministry, regulatory, industry and academic circles because of the well documented process and results and access to the site to observe the results first hand. The project has been used as a Mongolian case study for the public's information and understanding about reclamation (Asia Foundation 2010). Nearly all of the resources needed to complete the project were available from Mongolian sources and the best practices approach identified those areas where outside assistance was required. The project has identified those areas where skills, processes and resources should be further developed in Mongolia. Examples include post-mine topography design, an expanded plant materials industry, spoil and soil analytical services and experienced reclamation contractors and operators with access to appropriate equipment to achieve best practices.

Post-mine topography was designed to be practical and effective. Strict adherence to the design during construction established a stable regional landform that drains positively. Management during backfilling and grading insured suitable plant growth media was maintained in the upper graded profile. Topsoil replacement procedures insured adequate replacement depths and conservation of the resource. Deep ripping and seedbed preparation completed effective minesoil reconstruction and proper seedbed conditions. Use of native species and proper seeding techniques established an effective vegetative cover. The John Deere seeder was instrumental in completing critical revegetation practices. Following project completion, the seeder was donated to Dr. Tumenjargal for use in revegetation research and continued revegetation of disturbed lands in Mongolia. Site monitoring has documented initial establishment of desired vegetation and demonstrated the benefits of a systematic best practices approach to reclamation. Revegetation monitoring results indicate successful establishment of native seeded and volunteer perennial species which dominate the site. Biomass production determined from 2011 sampling was excellent and by the end of the 2011 season, was over 4X the native reference condition. Further, over 20 native species, mostly perennial, have established on site.

The best practices necessary for each unique operation are sequential, mutually supporting and reflect comprehensive and technically based approaches necessary to achieve reclamation success. In an ongoing and active mining operation, the same best practices approach applies, but with an additional critical best practice – an integrated mine and reclamation plan to achieve cost effective and successful mining and reclamation. The best practices reclamation approach has proven successful at Peabody's U.S. operations and was the key to successful reclamation at the Ereen mine site on the steppes of northern Mongolia, a historical first for this country (Fig. 10).

REFERENCES

Asia Foundation (2010) Land Reclamation – A Mongolian Citizens Guide. Produced by the Securing Our Future Program of The Asia Foundation in Mongolia. 2010.

Peabody (2008) Reclamation and Environmental Best Practices for Coal Mining Operations – Recommendations to the Mongolian Government. May 2008. Unpublished document presented to the Mongolian Parliament, Ministry of Nature, Environment and Tourism (MNET) and the Ministry of Mineral Resources and Energy (MMRE) in December 2008.

Mongolia (2006) The Law of Mongolia, The Minerals Law (Amended). July 2006.

Valentine (1971) 'Range Development and Improvements'. (Brigham Young University Press: Provo Utah)

Wyoming EQ-LQD (1994) Wyoming Department of Environmental Quality, Land Quality Division. Guideline No.1, Topsoil and Overburden. August 1994


June 2009


May 2010


September 2011

Figure 10. Progression of the Ereen Mine site from end of active operations in 2009, final reclamation activity in 2010 and in 2011 one year after completion of reclamation showing stable landforms, establishing vegetation and successful reclamation.