FINAL REPORT FOR TNC TRAINING IN MONGOLIA 31-March-2016

NOTE: THE TRAINING PROVIDED THROUGH TNC TO MEGD BY THE CONSULTANT, S. E. WILLIAMS (DBA: S.E.WILLIAMS AND ASSOCIATES, LLC) WAS CONDUCTED AS A SHORT COURSE ENTITLED:

RECLAMATION AND RESTORATION OF DISTURBED LANDS IN MONGOLIA

Staging Narrative: In the Fall of 2014, S. E. Williams (Retired Professor of Soil Science at the University of Wyoming and now with S. E. Williams and Associates, LLC) was approached by The Nature Conservancy (TNC) to participate in a training exercise focused on mine land reclamation in Mongolia. The training was to be conducted for selected employees of the Ministry of Environment, Green Development and Tourism (MEGD). Williams participated in a proposal constructed by TNC. In September of 2015, Williams traveled to Mongolia and conducted the training in part at a conference facility in Hustai National Park and in part at several of the coal mines in the Gobi.

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INTRODUCTION/OVERVIEW:

Assessment of regional soil conditions in the mineralized zones of the Gobi Desert

OVERALL FOCUS: The development of mining projects in the Gobi and elsewhere in Mongolia will have unavoidable impacts on soil conditions and thus on the entire ecosystem they support: from plants to animals and humans and including impacts on water and air resources. Reclamation of mined areas will be highly dependent on identification and preservation of suitable soils during the mining process and utilization of these materials appropriately.

BASIC GOALS:

a. Provide training to staff members from MEGD on the methods for evaluating possible soil contamination resulting from development of mining projects in this area. The training included identification of soils that are suitable for reclamation of the mined areas after mining has been completed.
b. The training covered strategies for developing soil sampling plans.
c. Also included were analytical methods that can be used (including in field tests and laboratory support) to determine soil quality.
d. Quality assurance/quality control methods were also a part of the training as well as data interpretation and analysis.

This training has included classroom training sessions and field sampling programs. The sampling exercise allowed collection of samples that will be tested as much as possible in the field but also submitted to an analytical lab to establish baseline conditions for the area. For this exercise, the class was divided into multiple groups to sample different soil and their profiles in the environment. However all of the groups were exposed to all sites sampled in a given area. All of the trainees were involved in sampling and field analysis. Further, during this part of the exercise, there was coordination with mining companies, to arrange for their participation. While the training was aimed at the theoretical side of monitoring, it was also mixed with the practical side too. Further, the samples collected were sent to the analytical laboratory for testing. Further, the Consultant organized a workshop with the student-participants presented group plans for post-mining reclamation. This was done as group exercises where each group submits a preliminary plan for reclamation of a particular mine site. The ultimate objective of this task was to provide MEGD personnel with the background and capabilities to monitor possible impacts related to the mining sector.

OBJECTIVES:

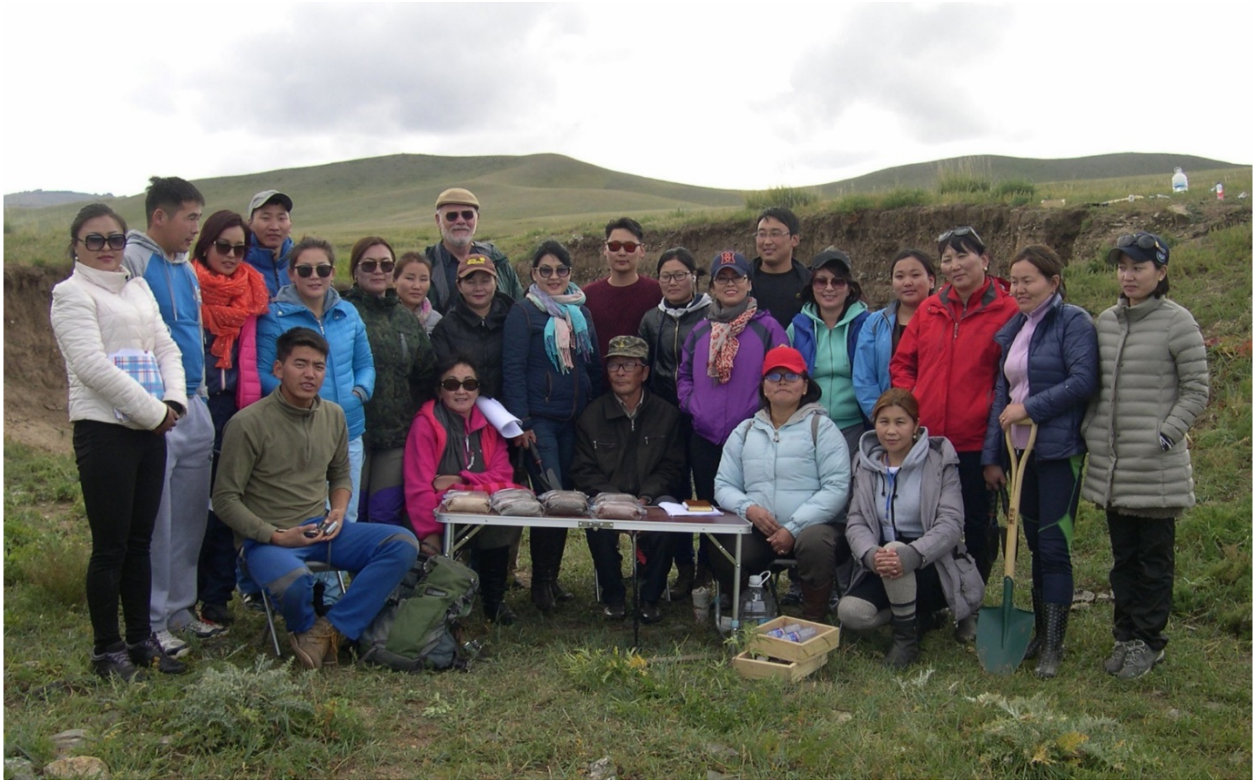
Part of this training was to provide an overview of environments typical of Mongolian environments that are likely to be disturbed during mineral extraction and energy development. These will most likely will be arid steppe soils but may also include some typical steppe environments and perhaps some forested situations: all were addressed in this training. Attention was given to the role that soils have as components of ecosystems and how they can be stockpiled during disturbance and then used later. Restoration of lightly disturbed sites was addressed as well as reclamation of heavily disturbed site.

Disturbance of soils can lead to situations that resist reclamation and may lead to toxic materials being released into the soil nutrient pools that supports ecosystems (e.g. plants and grazing organisms). These toxic materials may include heavy metals (e.g. Mercury, lead, copper, and others) as well as non-metals (e.g. Selenium, Sulfate). Evaluation of soil contamination during disturbance was addressed in this training.

PARTICIPANTS:

Twenty three persons from the Mongolian Government participated in this training. All were from the Ministry of Green Development, Environment and Tourism, but were from through-out the country. Two attendees were from Ulaanbaatar, one each from Khenti, Dornod, Sukhbaatar, Khovd, Bayankhongor, Gobi Sumbar, Bulgan, Khuhsgul, Arkhungai, Karkan-Uul, Gobi-Alti, Uvurkhangui, Orkhon, Dungobi and Zarkhan provinces, and three from both Umnugobi and Dornugobi provinces. In addition, one person was from the TNC office in Ulaanbaatar (Naranzul Bazarsukh). The two instructors were Stephen E. Williams, PhD. (DBA S. E. Williams & Associates) the instructor and Ariunaa Jalsrai, PhD, interpreter. A full listing of attendees is given in **Appendix A**.

The participants included 15 women and eight men. Most were in the first few years of their career, but some had more than a decade of experience and one had more than two decades of experience.



Photograph of the 23 student-trainee participants from MEGD as well as the instructor (S. E. Williams in back-row left of center, white beard) and the interpreter and coordinator (Ariunaa Jalsrai, seated, dark pink jack at left end of table). The picture was taken at Hustai National Park near the headquarters. In the background is a soil horizon along an erosion cut that was sampled during the first major field trip (trip b). Photo by Narazul Bazarsukh.

SUMMARY OF TRAINING TOPICS:

Over the course of the period from September 14 through September 24, 2015, S. E. Williams (SEW) and A. Jalsrai (AJ) met with the student trainees in classroom as well as field settings. The following topics were addressed through presentations in the classroom as well as during field trips. The course syllabus in **Appendix B** describes these topics more fully. **Appendix C** provides the actual schedule of the training.

A. Introductory Section.
   a. Introduction of Instructors and Student Trainees.
   b. Discussion of basic soil science and soil biology.
   c. Introduction to reclamation of mined lands.
   d. Class discussion of Mongolia's five most difficult reclamation problems.

B. Basic Information.
   a. Presentation on soils as components of ecosystems.
   b. Introduction to collection and analysis of soils in the field using the soil analysis kits.
   c. Presentation on Arid Range/Grassland soils.

C. Mine Land Reclamation
   a. Presentation on Reclamation in Mongolia
   b. Topsoil and overburden definition and discussion.

c. Soil contamination by oil wastes, metals and non-metals.
d. Presentation and discussion of saline and sodic soils
e. Presentation on Reclamation Standards
f. Laboratory Analysis and Quality Control/Quality Assurance

D. Student Team Projects
   a. Student trainees work in teams of five or six to prepare a reclamation plan for a hypothetical mining operation.
   b. Organization of reclamation plans by student teams and approval of plan outlines by instructors
   c. Presentation by student groups on reclamation plans for various mines (see syllabus).

E. Safety Training
   a. Rules for working in groups in the field.
   b. Safety training at the Tavan Tolgoi Mines.

F. Introduction to the Mines at Tavan Tolgoi
   a. Introduction to the mine by the mine manager of the main mine.
   b. Presentation by the manager of the small, local mine at Tavan Tolgoi. Addressed economics of mining and mine land reclamation.

G. Field Trips. For more information, see the Field Trips major heading below.
   a. Field demonstration on using the soil kits: a preliminary field trip.
   b. Examination of soil diversity in the field: Construction of pits along a soil gradient.
   c. Examination of sand-land soils in the field including analysis, vegetation identification and location using hand held GPS units.
   d. Examination of saline soils, deep and shallow grass land soils, and a soil containing permafrost in the field. Collection and analysis of soils, identification of slopes, biological components and GPS locations.
   e. Construction of pits on disturbed and native, undisturbed sites at the Tavan Tolgoi mines as well as collection of soils samples. View and discussed reclamation trials.
   f. Construction of pits on native, undisturbed sites during transport back to Ulaanbaatar.

FIELD KITS AND PROCEDURES:

Various components of the field kits were used during the training session held in September of 2015. Because the full kits are relatively expensive ($475 USD per full kit), only the most important components of the kits were provided to the student trainees. During the field trips the modified kits were used. **Appendix D** lists the components of the full kits. It should be noted here that two full kits were provided to MEGD. Each student-trainee received the modified kit.

<u>Modified Soil Kit Contents</u>

¼ c (60 ml) measuring scoop: Purchased in UB and provided as needed to student-trainees.
Black permanent marker: Provided as needed to student-trainees.

Bottle of distilled water: Bottled drinking water was used mostly for this function.
Bottle of HCl (10%): Obtained in UB and provided to students as needed.
EC meter: Provided to student-trainees.
Instruction manual: Mongolian copy provided to each student.   See **Appendix E.**
Measuring tape (metric & English): Provided as needed to student-trainees.
Munsell Soil Color Book: One page from the color book was provided to each student and three copies of key pages provided to MEGD.
pH meter: Provided to student-trainees.
Plastic cups: Provided as needed.
Plastic quart (liter) bags: Provided as needed
Soil sieve: one provided for each student-trainee.

FIELD TRIPS: For more information, see **Appendices D and E,** the course syllabus and schedule. Field trips are shown in the schedule.

a. Field demonstration on using the soil kits: This was a very brief preliminary field trip taken just inside Hustai National Park where and exposed soil profile along a drainage ditch was viewed and examined for textural properties, horizon identification, pH and EC. The objective of this field trip was to expose the students to soil descriptions and field analysis.
b. Examination of soil diversity in the field: Construction of pits along a soil gradient. This was the first major field trip and was taken along an east to west transect of about 200 meters just inside the boundary of Hustai National Park, very near the conference center. The class was divided into four groups of five or six person per group and each group was assigned a location to dig a soil pit, describe the sequence of horizons and conduct texture, color (for organic matter estimate), pH and EC. After the pits were constructed and described, all students toured all of the pits and the student-trainees who constructed each pit and determined the characteristics, explained their pit to the rest of the student-trainees. The objectives of this field trip was to show the students the high level of variation that exists among soils in a fairly limited geographical area as well as give them practice in field analysis.
c. Examination of sand-land soils in the field including analysis, vegetation identification and location using hand held GPS units. This major field trip was taken to the sand lands north of Hustai National Park some 10 km. As is field trip b, the students were divided into four groups, each group constructing a pit, describing the soil there, doing the analysis and finally explaining their soil pit to the rest of the class. The objective of this field trip was to show the students the variability of sandy soils in this ecologically very important zone, give the students practice in analysis and identification of plants and to consider the ease or difficulty in reclaiming soils have very sandy textures.
d. Examination of saline soils, deep and shallow grass land soils, and a soil containing permafrost in the field.   This field trip took place near the center of Hustai National Park near a location known as the Old Research Station. Here as in field trips b and c, students were again divided into four groups, each assigned a location to construct a soil pit, described and explained the soil to the rest of the class.   Collection and analysis of soils, identification of slopes, biological

components and GPS locations were all objectives of this field trip. However, objectives also included examination of these very different soil sites.

e. Construction of pits on disturbed and native, undisturbed sites at the Tavan Tolgoi mines as well as collection of soils samples. This was the first of two field trips as Tavan Tolgoi. During this part of the training, the class was reduced down to six student-trainees. Therefore all pits were excavated together with the instructors and often with some of the mine officials. The objectives of this field trip were to examine characteristics of stored topsoils as well as native soils as well as view and discussed reclamation trials.
f. Construction of pits on native, undisturbed sites during transport back to Ulaanbaatar. This final field trip was informal and really only constituted examination of sites and soils as the instructors and some class members made their way back towards Ulaanbaatar.

Student-trainees under the direction of Ariunaa Jalsrai (left, standing) as they perform soil analysis in the field. Photograph by Narazul Bazarsukh.

LABORATORY RESULTS AND LABORATORY COMPARISONS:

One of the crucial principles of analysis of sites for mine development as well for the potential for reclamation after mining, is consideration of the soil on the site. When examination of soils is done in the field, it is very convenient to be able to do some analysis in the field. Portable pH meters and EC (Electrical Conductivity) meters are often very useful to measure the acidity or alkalinity of soils (e.g. pH) and for measuring salt content (e.g. EC). Soil color can provide an estimate of the organic matter content of the soil, and hand texturing can provide a good indication of the proportion of sand, silt and clay in the soil. All of these measures, pH, EC, Color and Texture, can be done in the field and with practice a person can become proficient enough to make preliminary estimates of soil properties and the potential for using any given in reclamation. The Soil Kits that were used during the September 2016 training conducted by S. E. Williams were all provided so that the trainees can provide information in the field. This information can be used to make preliminary decisions about the suitability of a site for mining and for reclamation, but data from certified soil analysis laboratories should be used to make final decisions.

During the field trips, soil samples were taken by the student-trainees not only for their field analysis and descriptions, but also replicate samples were taken for laboratory analysis. Soil samples were taken not only from sites in Hustai National Park, but also from stored top soils at mines in the Gobi as well as native sites in the Gobi. In total, there were 54 soil samples taken.

A full set of soil samples were given to the Institute of Geography and analyzed through their soils laboratory in Ulaanbaatar (UB Lab). Of the 54 samples given to them, they analyzed 51 of the samples. It is not known why they did not analyze the last three samples.

Samples were also sent to a laboratory in the United States. This laboratory, the Intermountain Labs (IML), is located in Sheridan, Wyoming. S. E. Williams is very familiar with the lab and is aware of their high level of certification as well as their reputation throughout the region.

It proved to be much more difficult to ship the samples from Mongolia to the IML labs that was originally conceived. Essentially it took an additional two months to secure the necessary permits and permissions to send the soil samples, which arrived at the IML Labs in late November of 2015. Naranzul Bazarsukh of the TNC office in Mongolia was instrumental in the shipping of the samples as well as securing permits, permissions etc.

Soil analyses were finalized from both labs in early January of 2016 with the results from the UB lab were obtained in late October of 2015 and the results from the IML lab done in early January.

The Soils Laboratory at the Institute of Geography in UB was visited by the consultant (S. E. Williams and his interpreter, Ariuna Jalsrai) in late September of 2015. This was done to deposit the soil samples in the laboratory, indicate the kind of analysis needed and to visit with the director of the laboratory and also with the staff of the laboratory. Payment for the analysis was also done at this time. It is not known what kind or level of certification this laboratory has, but it is a well-known and generally well respected laboratory across Mongolia. For more information on the lab contact:

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The IML laboratory in Sheridan, Wyoming is Accredited and Certified by the Environmental Protection Agency (EPA) Region VIII as well as numerous State Agencies across the USA. The Laboratory maintains an up-to-date permit to receive soil from any location in the world as regulated by the USDA Animal and Plant Health Inspection Service (APHIS). The consultant (S. E. Williams) has used the laboratory previously for soils work conducted for mine land reclamation studies including work done in Mongolia. For more on IML see: https://www.google.com/?gws_rd=ssl#q=intermountain+labs

It is not the intent of this report to use the soils information secured from field measurement done by the trainees using the soil kits, from the UB Soils Lab, or the IML Soils lab to make any decisions regarding the utility of the soils for reclamation. This was a training exercise and the mines in the Gobi area were gracious enough to allow the trainees and consultants as guests on their leases and to allow samples to be taken under the condition that the information secured from the samples be used for training purposes only. Instead, the intent of this section is to mostly provide information about the accuracy of the analysis conducted in the field using the soil kits, the accuracy of the UB Soils lab and the IML Soils lab. Still, there are some analyses made in the field that should be reported and pointed out with the idea that they should be followed on at a later time when a more complete analysis can be had.

COMPARISION BETWEEN LABS: Comparison of fundamental soils data between the UB Lab and the IML Labs (see **Appendix F, Table 1**) shows that the two labs are in reasonable agreement for analyses of pH, phosphate, potassium, carbonate, sand and silt. In these analyses, there may be differences in the final analyses from these labs, but the differences are consistent enough that correlations are statistically highly significant. However, there is inconsistency between the labs on EC, organic matter and clay %.

The two labs were compared through the field information that was collected by the trainees (see **Appendix F, Table 2**). Here the UB lab was in general agreement with the values the trainees obtained for pH but not for EC. The IML lab was in agreement with both the pH and the EC values obtained by the trainees in the field.

SOILS MANIFEST: The 54 soil samples were taken from 20 different pits that were constructed by the trainees at the four transects at Hustai National Park as well as the seven sites examined in the Gobi (**Appendix F, Table 3**). The various soils varied considerably over the landscape as reflected by the horizon depth and designation (**Appendix F, Table 3**).

FULL ANALYSIS BY THE UB LAB: The UB laboratory did analysis on 51 of the 54 samples provided to them. It is not known why the final three samples, 52, 53 and 54 were not included in the analysis. However, the full analysis conducted by this lab are shown (**Appendix F, Tables 4 and 5**).

FULL ANALYSIS BY THE IML LAB: The IML laboratory did analysis on 29 samples. These analyses are shown in **Appendix F, Tables 6, 7, 8 and 9**. The samples analyses are fairly routine although there are some issues. The most significant issue is the presence of some toxic metals in some of the samples.

RECOMMENDED RECLAMATION STANDARDS:

The following are Mine Land Reclamation Recommendations for Mongolia. These are very similar to the mine land reclamation standards for the State of Wyoming in the USA. Mongolia and Wyoming are very similar in terms of climate, geological materials, topography and organisms (plants and animals) that inhabit the areas. *These recommendations are general recommendations and therefore do not cover all possible situations in mine land reclamation.*

The objective of mine land reclamation is to return the land to a function equivalent or better than before mining. This generally means that overburden and soil removed during mining are replaced in a sequence that results in a topographic setting (slope and aspect) similar to the pre-mine setting. The general objective also includes restoration of the vegetation to composition similar to the pre-mine plant composition. The post mining vegetation should be self-perpetuating without additions of fertilizer or irrigation water or other artificial additives. The final restored vegetation should be composed of species present in the pre-mined condition. These are usually native plants.

The reclamation of the mined sites and restoration of vegetation indicates that the site needs to be carefully examined before mining so that soil characteristics are known, and the plant communities are identified. Further, it is often desirable to take drilled cores into and through the overburden to examine the characteristics of this material to be sure there are no physical or chemical characteristics of this material that might interfere with the reclamation process and especially the restoration of the surface vegetation. This analysis also insures that the overburden material(s) contain no leachable materials that will contaminate ground water.

It is necessary also to know not only the species composition of the pre-mine plant communities but also the density of the community components so that post-mining monitoring can be done to insure that the post-mining vegetation attains the pre-mining condition.

The objectives of mine reclamation strongly imply that considerable planning needs to be done prior to mining. This planning should be done by the firm that intends to do the mining, although such a firm may find it necessary to contract with others having expertise in certain aspects of mine planning. Ultimately, however, this planning should be summarized in a report or a mine plan that addresses not only how the land will be impacted before, during and after mining, but also how water and air resources will be impacted. Surface water (streams and lakes) as well as ground water issues need to be addressed in the mine plan. Air quality may be compromised before, during and after mining by wind borne particulates from soil or overburden or from the ore or deposit being mined (such as coal dust).

The mine plan should also address how the entire mining activity from start to completion of reclamation will impact wildlife, domesticated animals and human populations. A careful inventory of wildlife that use the area should be made and at minimum it should be determined how their populations and health will be impacted. Obviously if domesticated animals use the area for grazing, they will be impacted and the human herders that use the area will also be impacted economically and perhaps culturally. Other persons that live on the land or in towns in the mined area or nearby have also the risk of being negatively as well as positively impacted by the mining activity. The mine may provide employment for local people, but it may also burden local communities with the need to provide infrastructural resources for mine employees and their families that move into the area from elsewhere. This could impact needs for housing, schools, medical facilities, food and water need and others.

Once the mine plan has been written, it should be reviewed by an independent agency. Here an independent agency would be an agency that has no conflict of interest in the success or failure of the mine. This agency should have as its sole object the desire to see the full mining activity done properly and completely with restoration of the ecosystem and maintenance of the ecological health of the system as well as maintenance of the economic, physical and mental health of the human community of the area.

It is important to be sure that the reclamation of the mined area and the restoration of vegetation is carried out even if the economics of mining the ore or deposit becomes less favorable. This is done by making an estimate of how much the full reclamation and restoration effort will cost. This amount of money is then posted to an account that is overseen by usually an independent party. This reclamation and restoration bond is held until the reclamation is completed and then is returned to the company. Sometimes this bond can be accommodated by the mining company taking out an appropriate insurance policy that will cover the costs of the reclamation and restoration. A further nuance of bonding is that sometimes accommodation can be made such that a certain percentage of the bond is returned to the company once an equivalent percentage of the reclamation and restoration has been completed.

POST MINING SCENARIO: The ideal post-mining final situation is where the surface is stable enough so there is little wind or water erosion. Further, the sub-surface has been reconstructed so there is not post-mine subsidence, and that there is no contamination of ground or surface water by toxic materials that might have been produced during the process of mining.

In considering successful mine land reclamation, there are three elements that need to be considered. These are (1) the overburden, (2) the soil, and (3) the vegetation. The training that was conducted in September of 2015 through the auspices of The Nature Conservancy, was designed to focus mostly on the soils, somewhat on revegetation, but addressed overburden considerations only slightly.

REVEGETATION: This is usually initiated by re-seedling the impacted area with native plants. Seed viability is important as is the absence of weed seed in seed stocks. Storage of seed until it is used is very important. Many seed require fairly specific storage conditions such as temperature and humidity, to retain their viability. Location of good quality seed can be a challenge. Seed can be harvested from lands that have a similar plant composition to the desired final plant composition of the area to be mined. In places where there is much mining activity and need to restore plant communities, often private seed companies become established that can provide seed and sometimes seedlings that can be transplanted to the field.

Much of the life-cycle of the plants to be re-established on the mine land needs to be known. This is important in determining the time of year to plant the seed, the depth of planting in the soil and the needed moisture content of the soil. There are often plant propagules (such as seeds, tubers, bulbs, roots) that remain viable in the soil if the soil has been properly handled. Those propagules may also aid in the re-establishment of appropriate vegetation. Soils too, as well as poor quality commercially available or seed harvested from grasslands, may also be a reservoir for seed of undesirable or weedy plants. Caution should be exercised where such plants are concerned. It is usually easier to discard poor quality seed than it is to try to control undesirably plants after they have germinated and especially after they have become established.

SOILS: There are physical, chemical and biological properties of soils that should be considered in re-vegetation planning and implementation. Some soils are of such low quality that their characteristics obviate them being used in reclamation and restoration. Soils should be treated as biological entities because the plant propagules in the soil as well as the various micro-arthropod, other fauna and microorganisms (bacteria, fungi and others), are very important to the re-establishment of plants and healthy plant communities. The challenge is that during mining soil often has to be stored. Soils will lose their biological properties if stored for excessive lengths of time or if they are stored under undesirable conditions.

Identification of soils suitable for restoration should be done prior to disturbance and should be a major part of the reclamation plan for a particular site. The **Appendix E** to this report, Soil Kit Instructions, is key to determining the various soil characteristics that can and should be used to determine soil suitability. The fundamental soil properties that determine soil suitability are pH, EC, texture and gravel percentage. The sodium absorption ratio (SAR) can also be used. During the training sponsored by TNC, SAR was treated as an advanced topic and not covered in detail. Careful consideration of pH and EC can be used as a partial substitute for SAR.

pH (ACIDITY OR ALKALINITY): Measurement of pH should be done according to the Soil Kit Instructions. Suitable pHs are between 5.5 and 8.5. Marginal pHs are between 5.0 and 5.5 as well as between 8.5 and 9.0. Unsuitable pHs are less than 5.0 or greater than 9.0.

EC (ELECTRICAL CONDUCTIVITY). Electrical conductivity is a measure of the amount of salt in a soil. In the laboratory usually a saturation extract is made of the soil and the EC of that extract used to determine salt content. In the field, it is impractical to make a saturation extract. Instead, a mixture of 1 part soil to two parts water (1:2; soil to water) is used. See the Soil Kits Instructions for details.

Suitable EC range is between 0 and 8 dS/m for saturation extracts or 0 to 1.6 dS/m for the 1:2; soil to water mixture. Marginal is when EC is between 8 and 12 dS/m for saturation extracts or between 1.6 and 2.0 dS/m for the 1:2; soil to water mixture. Unsuitable is when saturations extracts are greater than 12 or when the 1:2; soil to water mixture is greater than 2.0.

TEXTURE: Suitable textures for soils to be used in reclamation are those that lies near the center of the textural triangle. These are soils that are normally less than 28% clay, less than 50% silt and less than 50% sand. When the texture is determined by feel (see soil kit instructions), generally loams are considered suitable for reclamation. Intergrades (e.g. Clay loam, sandy loam, and silt loams) are considered marginal, where as those soils described as clay, silt or sand are unsuitable.

GRAVEL OR COARSE FRAGMENTS: Gravel or coarse fragments are described as the fraction of the soil that has a diameter greater than 2mm. Suitable coarse fragment levels are less than 25% by volume. Marginal is when the coarse fragment level is between 25 and 35%. Unsuitable levels are when coarse fragments are greater than 35%.

SODIUM ADSORPTION RATIO (SAR): The SAR is not addressed in the soil kit instructions. It is essentially based on an analysis of soluble sodium, calcium and magnesium in the saturation extract of soils. Suitable SARs are between 0 and 10. Marginal SARs for clay soils are between 10 and 12 and for other soils between 10 and 15. Unsuitable SARs for clays are greater than 12 and for other soils greater than 15.

Many soils will have properties that fall outside of the suitable range of characteristics. However, many of these soils support very important plant communities that are adapted to these soil conditions. Such soils can be reclaimed, but restoration of plant communities may require special techniques and often will take longer to reclaim than more normal soils.

More information about guidelines for suitable soils can be found at http://deq.state.wy.us/lqd/guidelns/guide1.pdf

SUMMARY OF COURSE FEEDBACK: The following feedback from the students was obtained and compiled by TNC Mongolia staff. This was obtained by the consultant (S. E. Williams) from the main project coordinator, Naranzul Bazarsukh.

Training name: Soil training

Number of participants: 24 (23 from MEGD and one from TNC, Mongolia)
Number of participants who gave feedback: 21

1. Was the lecture understood for you?
   Yes -21
   No -0
   Not sure-0

2. Was the field practice understood for you?
   Yes - 21
   No -0
   Not sure - 0

3. Rate the logistic work and organizational preparation of this training.
   Very good - 21
   Good - 0
   Bad - 0

4. How important was this training for your work?
   Important -21
   Not important-0
   Not sure-0

5. Do we need to continue this type of training in the future?
   Yes - 20
   No-0
   Not sure-1

6. **Most important part of the training:**

- This training combined practice and theory, and teached us the most relevant soil type for reclamation, reclamation methods, barriers and conditions.
- Practice work of soil investigation. Got a knowledge of soil reclamation/5/.
- Soil log and structure. /6/
- Field practical work was very important and beneficial. Our knowledge is increased because soil logs were different.

- It was important that we learned about soil analysis, reclamation and soil classification. /3/
- I learned very important things related soil.
- This training was very helpful to prevent the soil from staying with disturbance because of bad reclamation also to monitor the reclamation of mining companies.
- It was important working by team /2/.
- This training showed us how to make soil log and how test it using instruments.
- The most important thing was field practices of soil log and identification of pH and EC in the soil./2/
- The training was interesting and undersandable because field trips, individual presentation, classroom lectures were all included.

7. **Other comments**

- Continual conduction of this type of training would be a important contribution to the state development and capacity building of government officers who controls reclamations of mining areas. Therefore, thank you for your organization.
- This training was very helpful for aimag's officers especially for who is responsible for underground resource and mining reclamation.
- We want to go to abroad by exchange trip of soil analysis. /4/
- Thank you for all organizations that helped to conduct this training. I am ready to attend other trainings in the future. /5/
- It would be beneficial if you provide us to see other reclamation practices except Mongolia.
- Eagerly waiting for soil kits to be delivered us.
- The instrument of pH and EC is important for officers who responsible for environmental pollution.

RECOMMENDATIONS FOR FURTHER TRAINING: The consultant would highly recommend that a course similar to the one offered entitled "Restoration and Reclamation of Disturbed Lands in Mongolia" be offered on a regular basis to additional trainees from governmental agencies in Mongolia and particularly those involved in regulation of mining activities in their districts. Also, a similar course should be offered to individuals engaged in mine land reclamation through private firms. Funding for presentation of the course should come from the private firms engaged in mining in Mongolia.

Practice and review sessions could and should be organized where the trainees involved during September of 2015 as well as future classes could come together and practice using instruments and taking, for example, textures of soil samples. Practice in the field is very important.

Lastly, there should be continued training of the September 2015 class perhaps in the United States in a landscape setting similar to Mongolia. Trainees could come to the USA and particularly to Wyoming where they could be shown large scale, on-going reclamation projects at various open pit mines. Further they could be exposed to environmental monitoring activities as well as visit a laboratory that specializes in soil and overburden analysis (IML in Sheridan). A visit to a company that collects, grows and sells seed for reclamation as well a visit to the State of Wyoming Seed Certification lab would be further important portions of this visit.

ASSESSMENT OF THE TRAINING BY THE CONSULTANTS: The principle consultant on this project (S. E. Williams, PhD) was joined by Ariuna Jalsrai PhD who served to help coordinate activities as well as served in a translation capacity especially oral translations during classroom meetings and field trips.

The student-trainees were prepared, considerate, engaged and enthusiastic. It was a pleasure to work with them.

The infrastructure of the training was very good. The training facility as well as accommodations and meals at Hustai National Park were all excellent. In the training facility, the rooms used for classroom activities as well as the break room were more than satisfactory. There were occasional issues with the power point set up and projector, but the staff at Hustai National Park were always quick to help and solve problems.

Transportation to Hustai as well as transportation to field sites and finally transportation to the mineralized zone of the Gobi was all very good.

All of the student-trainees were interviewed individually by the consultant and using Ariunaa Jalsrai as a consultant. The breadth of these conversations was beyond the scope of this report, but all were asked about their academic and experiential training in preparation for this course. Although the trainees were are all well-educated and experienced in their respective disciplines, few had much experience with or course work in Soil Science. The consultant (S. E. Williams) would highly recommend that all of the trainees as well as future trainees secure more courses in Soil Science. Such courses would include a basic soil science course, and perhaps coursed in Soil Chemistry, Soil Physics and Soil Biology. See **Appendix G**.

APPENDICES

APPENDIX A: LIST OF PARTICIPANTS

No	Name	Position	Organization	Tel	E-mail
1.	Bolormaa.S	Officer for camping areas	**Ulaanbaatar's** environment and green development agency	323780	boloroo_3366@yahoo.com
2.	Sergelen.R	Officer for special needs areas	**Ministry of** Environment, Green development and tourism	89167551	sergelen_1103@yahoo.com
3.	Oyunmandal.N	Officer for water supply and environmental pollution	**Khentii province,** Environment and tourism department	93014915	noospher_m@yahoo.com
4.	Urantogos.S	Officer	**Dornod province**, Environment and tourism department	93013495	togos1222@yahoo.com
5.	Tumenjargal.T	Officer for environmental pollution	**Sukhbaatar province,** Environment and tourism department	89334342	t.tumee_08@yahoo.com
6.	Ariundolgor.B	Officer for underground resource and reclamation	**Khovd province**, Environment and tourism department	99859438	b_ariuka270@yahoo.com
7.	Byambasuren.G	Officer for environmental pollution	**Bayankhongor province,** Environment and tourism department	88258556	byba_0605@yahoo.com
8.	Ankh-Amgalan.G	Officer for underground resource and reclamation	**Gobisumber province**, Environment and tourism department	89008524	amgaa518@yahoo.com
9.	Altantsetseg.M	Officer for environmental pollution	**Bulgan province,** Environment and tourism department	99718018	m_altan_173@yahoo.com
10.	Purevdorj.Kh	Officer for underground	**Khubsugul province,**	89197113	an_1956@yahoo.com

		resource and reclamation	Environment and tourism department	70384908	
11.	Chuluun-Erdene.D	Officer for environmental pollution	**Arkhangai province,** Environment and tourism department	99666324	eki_0506@yahoo.com
12.	Bolor-Erdene.N	Laboratory engineer for climate, environmental monitoring	**Darkhan-Uul province**, Environment and tourism department	99141471	n_bolor.bolor@yahoo.com
13.	Khandarmaa.T	Officer for environmental pollution	**Gobi-Altai province,** Environment and tourism department	99976357	tkhandarmaa@gmail.com,
14.	Boldbaatar.Ts	Officer for underground resource and reclamation	**Uvurkhangai province**, Environment and tourism department	99948990	nt_boldoo@yahoo.com
15.	Mendbayar.Ts	Laboratory engineer for climate, environmental monitoring	**Orkhon province,** Environment and tourism department	99832243	mendbayar_0429@yahoo.com
16.	Gantsatsral.D	Officer for environmental pollution	**Dundgobi province,** Environment and tourism department	88020153	de_tsatsaa@yahoo.com
17.	Battsetseg.B	Officer for environmental pollution (waster and air pollution)	**Zavkhan province**, Environment and tourism department	88948834	esoo_524@yahoo.com
18.	Orgilmaa.B	Officer for underground resource and reclamation	**Umnugobi province**, Environment and tourism department	99074877	orgio_78@yahoo.com
19.	Soyolmaa.T	Ranger of Tsogttsetsii soum	**Umnugobi province,** Environment and tourism department	88555000	tsoyoloo@yahoo.com
20.	Punsantsogvoo.T	Ranger of Bulgan soum	**Umnugobi province,** Environment and tourism department	88600865	tsogvoo_172@yahoo.com
21.	Suren.D	Head of Environment and tourism department	**Dornogobi province,** Environment and	99745399	suren_dovdonbaljir@yahoo.com

			tourism department		
22.	Bolormaa.D	Officer	**Dornogobi province,** Environment and tourism department	99043151	dbolorjin@yahoo.com
23.	Amarbileg.Sh	Officer for climate	**Dornogobi province,** Environment and tourism department	99063081	amarbileg_sh@yahoo.com
24.	Naranzul.B	Project officer	**TNC**	99124670	naranzul.bazarsukh@tnc.org

Instructor: Stephen Earl Williams, PhD: Professor Emeritus (University of Wyoming, Laramie)

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Phone: +1 307 760-6120.
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Assistant and Interpreter: Ariuna Jalsrai, PhD: Available through S. E. Williams and Associates, LLC (above).
j_ariunaa@yahoo.com

APPENDIX B: SYLLABUS

This general syllabus was written before the members of the trainee class was met for the first time. It was modified somewhat based on the needs articulated by the class and those determined during the class by the instructor. Many of the topics below were covered in great detail, others were covered very lightly.

The focus of these topics were on desert, desert steppe, steppe desert and typical steppe soils and environments but will also include some discussion of meadow steppe and forest steppe environments. Mongolian soils are largely extensively managed. That is they are not plowed and seldom artificially fertilized. The resources produced from these areas are native plant biomass and usually harvested by domestic grazing animals. Wildlife are also key components of these extensively managed environments, and include a diversity of creatures from predators to grazers; from song birds to burrowing animals; from complex, multi-cellular lines to single celled entities.

Intensively managed soils are environments where plowing and fertilization is common, seedling with crop plants is practiced and resources are often harvested by some sort of human or mechanical means and the plant product are processed into food stuffs. Intensively managed environments will be addressed in this training, but largely in the context of reclamation of disturbed lands. Often lands disturbed during mining require some fertilization, artificial seeding, and control of invasive plants.

Topic I: Soil Environments: Objective to provide an over view of extensively manage environments, what they are, what importance they have, why they are worthy of study.

A. The Soil State Equation and variation in climate, topography, parent materials and organisms across extensively managed environments.
B. Introduction to uses of Forest and Range Environments.
C. Differentiation between Extensive Management and Intensive management.

Topic II: Historical Perspectives of Land and Soil Management: Extensively managed environments have been important to humans for much of their existence: For food, fuel, shelter. However, there is also an attachment through literature, poetry and song; attachments culturally and traditionally. In modern times all of these remain, but they are also a source of recreation.

A. Historical Considerations
    a. Defining a philosophical basis for Land and Soil Use
    b. The Political structure for land and soil management
B. The overall Mongolian Environment.

Topic III: Description, Management and Geography (Microgeography to Macrogeography) of Soils along Climatic, Vegetal and Topographic Gradients: This chapter presents the basic generalized soil unit, and the state equation factors that are their basis. Characteristics that will be examined for all of these soils include pH, Electrical Conductivity, soil nutrients, clays, silts, sands, coarse fragments, soil organic matter and the sequence of soil horizons expected in each of the soil categories below. Further, soil characteristics that influence the toxic nature of soils and problems and potentials in reclamation after being disturbed during mining will be discussed. Special emphasis will be given to the release of toxic materials into soils and water during mining activities. These toxic materials may originate with the soils themselves or they may be generated through the mining activity. In field analysis of the soils will be emphasized as well as laboratory analysis.

A. Alpine/Tundra Soils
B. Forest Soils
    a. Coniferous Forests
    b. Deciduous Forest
    c. Forest-grassland Ecotones
C. Transition Soils
    a. General Environment
    b. Pine to Shrub Transition
    c. Shrub lands
D. Arid Steppe Soils
    a. Environments
    b. Precipitation
    c. General soil Properties
    d. Plants
    e. Aspect
    f. Typical soils
E. Upland Steppe Soils
    a. Environment
    b. Sagebrush Study
F. Typical Steppe and Meadow Steppe Soils
    a. State Equation
    b. Geography
    c. Mollic Epipedon
    d. Mollisols
G. Bog Soils (Histosols) and other riparian soils

Topic IV: Descriptive Techniques for Soils: This essentially focuses on taking the soil members from Topic III and working them into levels of maps, levels of utilization, and levels of sustainability (soil health).

A. Variability of soils
    a. Determination of Soil Variability
    b. How variability affects plant growth
B. Mapping Techniques
C. Soil Health Criteria

Topic V: Nutrient Management in Forest and Steppe Soils—Biological Diversity and Productivity.

A. Fertilization: General Nature
B. Steppe Fertilization
C. Management of Biological Nitrogen Fixation
D. Soil Organic Matter and Productivity

a. In Rangeland Ecosystems including below ground carbon dynamics and assimilation by grassland soils

E. Mycorrhizae
F. Fire
G. Release of toxic materials into soils during disturbance.
H. Summary of the Soils State Equation
    a. Abiotic factors domination of the landscape
    b. Biotic factor domination of the landscape

Topic VI. Water in forest and Range Soils

A. General Soil Water
B. Water Conservation
C. Soil Water in Range Systems
D. Impacts of Soil Properties especially chemicals on Water
    a. Quantity and quality

Topic VII: Soils of Extreme pH and Salt content

A. Saline Sodic Soils and their management
    a. Indicator Vegetation
    b. Description and Properties
    c. Management
B. Highly leached, acid soils and their management
    a. Indicator Vegetation
    b. Description and properties
    c. Management

Topic VIII: Impact of Soil on Biota

A. Soil Plant Relations.
    a. State factors
    b. Distribution and diversity
B. Biological Crusts
    a. State factors
    b. Distribution and diversity
C. Soil Wildlife Relations
    a. State factors
    b. Habitat and nutrition
    c. Distribution and diversity
D. Other Biota.
E. Impacts of toxic materials on domestic animals as well as wildlife.

Topic IX: Desertification and Reclamation of Desertified Areas

A. Global Deserts
B. Use and abuse by Grazing animals
    a. Effects of animal Wastes
    b. Compaction and Erosion
    c. Germination of Seeds
    d. Soil structure impacts
    e. General Function

C. Atmospheric toxicants
D. Aqueous and non-aqueous toxicants
E. Mining
    a. Topsoil conservation and erosion
    b. Toxic materials in soils resulting from disturbance and contamination by humans
    c. Connection between soil characteristics and reclamation
    d. Reestablishment of shrubs
    e. Man's impact on soil properties
    f. Interface between human occupied soils and Natural Systems (the boundary between intensive management and extensive management).

APPENDIX C: ACTUAL SCHEDULE

The following schedule reflects details and events as they happened during the time that the consultants, S. E. Williams and A. Jalsrai, were in Mongolia.

SOILS TRAINING
POST TRAINING SCHEDULE DETAILS
HUSTAI AND TAVAN TOLGOI

Date	Class Day	Session	Day	TOPIC
6-Sep				Ariunaa Arrive in UB: MIAT Flt 5302; 11:30 pm
9-Sep				Steve Arrive in UB: MIAT Flt 5302; 11:30 pm
10-Sep				Breakfast with Jim Oakleaf of TNC. Noon meeting with Ariunaa Jalsrai. in PM went to TNC building & met with Gala and Nara.
11-Sep			FRI	Completed a reclamation planning document that was taken to Nara for translation into Mongolian. Worked with Ariunaa to get items for field trips. Ariunaa did most of this work.
12-Sep			SAT	Ariunaa and her friend, Nyamka, picked me up at 9 am and we went to Hustai National Park to look at the conference facility and plan the field trips. Met the Botanist there, Tseeggi (Tserendulam Tserenochir). On the way to the Park we bought supplies for the field trips.
13-Sep			SUN	Packed and made final preparations for the trip to Hustai N. P.
				A. HUSTAI
14-Sep	1	10:00 AM	MON	Left the TNC Office in UB for Hustai National Park
	1	Noon	MON	Arrived at Hustai. Trainees, instructors and staff check in
	1	1:00 PM	MON	Lunch
	1	2:15	MON	Introductions: Instructors and Trainees

		PM		
			MON	Course Objective. Geographical ID of trainee's Imag: Map
		3:30 PM	MON	Group discussions: Why are trainees here & what wanted
			MON	Report of groups to the class as a whole.
		4:00 PM	MON	Coffee Break
		4:15 PM	MON	Questions and discussion of basic soil and biology concepts
		5:15 PM	MON	Adjourn
15-Sep	2	9:00 AM	TUES	Soils as components of Ecosystems PP, questions from class
		11:00 AM	TUES	Coffee break & group ID Mongolia's 5 most difficult reclamation issues.
		12:30 PM	TUES	Introduction to soil analysis in the field using the soil kits.
		1:00 PM	TUES	Lunch
	2	2:00 PM	TUES	Examination of soils in the field: a preliminary field trip.
		5:15 PM	TUES	Adjourn
16-Sep	3	9:00 AM	WED	Saline and Sodic soils.
		10:15 AM	WED	Discussion of Final Projects
	3	10:30 AM	WED	Reclamation Mongolia PP and reclamation standards
		11:30 AM	WED	Walk to field site and construction of pits.
		1:00 PM	WED	Return from field for Lunch
		2:00 PM	WED	Field: return to field, continue examination of Soils.
		5:00 PM	WED	Return to ger camp. Adjourn
17-Sep	4	9:00 AM	THURS	Review of previous day's field trip: See Chronosequence PP
		9:30 AM	THURS	Continue Reclamation Mongolia PP and discussion
	4	12:30 PM	THURS	Students groups work on their reclamation plans.
		1:00 PM	THURS	Lunch break.
		2:00	THURS	Transport to the Sand lands North of Hustai for field trip

		PM		
		5:30 PM	THURS	Return from sand lands. Adjourn
18-Sep	5	8:30 AM	FRI	Left for field trip to soils in the middle of the park.
		1.30 PM	FRI	Returned from field trip. Lunch Break.
	5	3:30 PM	FRI	Conversation about final projects.
		5.00 PM	FRI	Adjourn
19-Sep	6	9:00 AM	SAT	PP presentations on the Sandlands and Middle Hustai Trips.
		10:00 AM	SAT	Topsoil definitions and discussion
	6	11:45 AM	SAT	Degradation of waste oil on soils, PP and discussion
		1:00 PM	SAT	Lunch Break
		2:00 PM	SAT	Arid Range Soils PP
		4:00 PM	SAT	Discussion: Reclamation Standards and student projects.
		5:15 PM	SAT	Adjourn
20-Sep	7	10:00 AM	SUN	Discussion with the trainee group doing the Erdenet Mine (Cu)
		11:00 AM	SUN	Discussion with the trainee group doing Dundgobi Mine (Florite)
	7	Noon	SUN	Discussion with the trainee group doing Altan Dornod Mine (Au)
		1:00 PM	SUN	Lunch
		2:00 PM	SUN	Open time for trainees to work on mine reclamation presentations
		6:00 PM	SUN	Discussion with the trainee group doing Tavan Tolgoi Mine (Coal).
21-Sep	8	9:00 AM	MON	SPECIAL TOPIC reports by trainees: Altan Dornod Gold Mine
		10:15 AM	MON	SPECIAL TOPIC reports by trainees: Dundgobi Florite Mine
	8	11:30 AM	MON	SPECIAL TOPIC reports by trainees: Erdenet Copper Mine
		1:00 PM	MON	Lunch Break

		2:00 PM	MON	SPECIAL TOPIC Reports by trainees: Tavan Tolgoi Coal Mine
		3:30 PM	MON	Awards presentation: Trainees received a participant certificate
				B. GOVI
22-Sep	**9**	AM	TUES	Drive to UB and dropped off all but the trainees from the Govi area
		AM	TUES	Noon: left for the Gobi area.
	9	PM	TUES	All afternoon and into the evening we drove towards the Govi.
		PM	TUES	We reached the TT mines and camp at 10:30 pm
23-Sep	**10**	AM	WED	Safety training at the TT mine. Tour of mine. Sampled top soil.
		AM	WED	Introduction to the mine by the manager. Viewed reclamation.
	10	PM	WED	Sampled native sites near the mine & stockpiled soils on the mine
		PM	WED	Visited the small, local mine, presentation by manager. Sampled native sites as well as disturbed sites. Returned to camp 830 pm.
24-Sep	**11**	AM	THURS	Left the mine camp. Sampled native sites as we drove out
		AM	THURS	More sampling of native sites and discussion of reclamation
	11	PM	THURS	Transport from the TT areas to Ulaanbaatar.
		PM	THURS	Returned to Ulaanbaatar about 10 pm. Said good-bye to trainees.
25-Sep	**12**	AM	FRI	Transported soil samples to the Institute of Geography's soil lab.
		AM	FRI	Conversation with director of the soils lab.
	12	PM	FRI	Returned to UB hotel
		PM	FRI	
26-Sep			SAT	Rest and report generation
26-Sep				Ariunaa Leaves UB: MIAT Flt 5301; 11:55 pm
27-Sep			SUN	Rest, start final report
28-Sep			MON	Worked at the TNC office in UB processing soils. Enkhtuya and I met for an hour or so. Report generation

29-Sep	TUES	Worked on processing soil samples. PM had dinner with Mike Heiner of TNC and Chandsaa, a newly minted PhD out of Colorado State University.
30-Sep	WED	Gave an unscheduled lecture to 20 or so students from the SIT Study Abroad program. They were under the guidance of Sanjaasuren Ulziijargal, the academic director. TNC-Mongolia took me to lunch at the Shangri-La hotel. Very nice. In the PM we (Nara and I) discovered we did not have all of the required paper work to send the samples to the IML labs in Sheridan. We will work to get the paper work.
1-Oct	THURS	Worked on report.
2-Oct	FRI	Packed and worked on reports.
3-Oct	SAT	Steve Leaves UB: MIAT Flt 301; 8:45 am

During the first several hours of meeting with the trainees (see 14-sept, day 1 above), we discussed the objectives of the course as I viewed them, but they were asked specifically why they were in the course and what did they want to get out of the training. The following recommendations were made by the class:

RECOMMENDATION: That the Consultant also provide perspective on reclamation of land/soils disturbed during mining (reclamation of areas directly disturbed, decommissioned roads, pipelines, etc.).

RECOMMENDATION: That the Consultant provide information about decomposition of petroleum and petroleum products that might be spilled on and contaminate soils.

RECOMMENDATION: That the Consultant provide information on how mining and mining activities impact the human populations that live in the vicinity of the mine areas.

RECOMMENDATION: That the Consultant provide information on restoration of lands that have been over-grazed by domestic animals.

The Consultant included discussion of all of these recommendation in the classroom and field environments during the course of this training.

APPENDIX D: SOIL KIT CONTENTS

¼ c (60 ml) measuring scoop
1413 conductivity calibration solution
Amber storage bottle for clear bottle of HCl
Black permanent marker
Bottle of distilled water
Bottle of HCl (10%)
EC meter
Instruction manual
Line level to determine slope
Magnifying glass
Measuring tape (metric & English)
Measuring tube
Metal thermometer
Munsell Soil Color Book
pH 10.0 buffer solution
pH 4.0 buffer solution
pH meter
Plastic cups
Plastic quart bags
Plastic spoons
Plastic tool box
Red flags and nails
Safety goggles
Soil sieve
Trowel

APPENDIX E: METHODOLOGY FOR USE OF SOIL TEST KITS

(See Supplementary and Advanced Topics in USDA Field Book for Describing and Sampling Soils, version 2.0, included in the kit)

All of this appendix has been translated into Mongolian and is available through the consultant and through TNC Mongolia.

The purpose of this protocol is to aid in the use of the Soil Test Kits produced through the University of Wyoming Reclamation and Restoration Center. The purpose of these kits and protocol is for the user to collect basic soil information in the field, without having to take soils to an analytical soils laboratory. Much of the information that can be obtained using this protocol and kit are approximations. The value of the information will be dependent on the care, skill and training of the user. Many users who have had formal training in ecology, chemistry and soil science will find the use of theses kits straightforward. However, there is no substitute for formal training and practice. The soils information one can secure from proper use of these kits is not a substitute for soils information that can be had from certified soil testing laboratories. The field information one can secure can supplement lab information or might help direct the type of analysis a certified lab may do, but especially for most research or legal effort certified information may be required.

The University of Wyoming does offer a complete Soil Testing Laboratory. Information about this laboratory can be secured online (http://ces.uwyo.edu/Soil_Main.asp) or it can be accessed through the Wyoming Reclamation and Restoration Center web page (http://uwyo.edu/WRRC/).

Supplies and Tools: It is assumed that the user(s) of these kits will have the following items:

- Shovels or other digging implements of sampling and pit construction
- Distilled water. A 16 oz bottle of distilled water is provided, however, users are expected to replenish this supply as needed on their own (this can be purchased at a grocery store in gallon containers-a gallon of distilled water is adequate for approximately 10 to 20 full soil evaluations as done using the kits).
- Cups for pH and EC. A small supply of cups is provided. Other containers can be used. Plastic or paper cups of an 8 oz. size are convenient.
- It is assumed that users will have maps or a geographic position device to determine location and elevation.

Pit Construction: At most sites a pit should be excavated so that horizons, roots, geological substrata, etc. can be examined and possibly photographed. With this in mind, each pit should be oriented such that the target pit face (e.g. the vertical face that will be viewed and sampled) is well lighted. This means that the target pit face should face or approximately face the Sun.

The pit should be excavated such that when sampling is finished, it can be closed and returned to an approximate visual state equivalent to its original undisturbed state. This is sometimes unnecessary (such as in deep sand), impossible (such as in clay) or impractical. However, the restoration effort can be enhanced by keeping the surface horizons(s) intact such that when the hole has been filled, the surface material can be replaced. This works well, usually, in forest or sod environments. Other sites may be more difficult.

Soil Depth (Items needed: “red eye” nail markers, nails, measuring tape, shovel): Depth of the soils examined should be determined, and depth to consolidated rock be attempted. Determination of depth to consolidated rock is sometimes impractical and/or not possible. Usually construction of a pit to 50 cm (20 inches) (sometimes to as deep as a meter (40 inches)) provides most of the depth needed to describe physical, chemical and biological characteristics. Soil depth will be sub-divided into horizons. Often the upper most horizon is made up of un-decomposed organic matter. In soil science, this un-decomposed organic material is considered to lie on top of the soil.

Although it is often possible to identify taxonomically soils from diagnostic horizons and other information that can be derived from profile descriptions, such determinations are beyond the scope of this protocol. Those desiring more taxonomic information should refer to soil surveys for given locations (note that soils surveys are not completed for parts of Wyoming) or go to the National Soil Survey web page (http://soils.usda.gov).

Measurement should be made and recorded in both metric units and English units, here in centimeters (cm) and inches (in).

Soil Color (Items needed: Munsell Color Book): Most of the information needed on soil color is in the Munsell Color Book.

Soil color is important for identifying soils that may be classified as Mollisols. Mollisols are high organic matter, high base-status (fertility) soils. They have an organic matter content of 1% (organic carbon of 0.56%) or higher. The organic matter content can be estimated using the Munsell Color Charts.

Geology/Parent Materials: Most soils are weathered products of the geological materials immediately under them. Although this is not always true, efforts should still be made to identify underlying rocks and geological associations.

In many cases there is a discontinuity between the below ground geology and the parent material of the soil. This is most obvious in organic soils where the parent material is organic matter. However, many soils are formed in material that may have been wind or water deposited and composed of materials very different from the underlying geology.

Climate: Climate is extremely important in soil weathering, often interacting with organisms to form the principle factors that generate soils. Most of the sites do not have climatic data available. Usually, though, there are sites nearby or at similar sites where climatic data is available.

One of the key themes in Wyoming environments is that of variability. Nowhere is this more evident than where climate is concerned. Averages (such as average annual precipitation, average snowfall, and average temperature) can be meaningless because the variability from one period to another is so high.

Climatic factors, such as average precipitation, can be misleading. Sites, as judged by vegetation, may be more arid or more udic than expected because, respectively, water may run off quickly and not penetrate the soil or because water runs from adjacent areas and ponds or pools in an area. This can result in desert like environments under areas of very high rainfall and conversely areas of high biological activity in areas of vanishingly low rainfall. For example, the Namid Desert on the southeastern coast of Africa receives almost no measurable precipitation. But plants and animals, abundant in the area, take into moisture from fog that rolls in off of the nearby ocean almost daily. The Jornada del Muerto (Spanish for "Journey of Death") receives less than 150 mm (6 inches) of annual precipitation, but even in long dry periods, mesquite (genus Prosobis species) remains verdant and green because its deep root system, sometimes 30 m deep (98 feet), can access sub-surface water. This water moves into porous rock far below the surface, from mountains sometimes a great distance away.

Soil Temperature (Items needed: thermometer): When a pit is first opened, soil temperature should be determined immediately. Temperature measurements will be taken at the bottom of the pit, at 50 cm (20 inches), at 15 cm (6 inches), just below the surface and in the air. In shallow pits, this may be modified, but temperatures should always be taken at least at the maximum depth of any given pit. In a newly opened pit, temperatures will be taken by inserting the temperature probe(s) into the wall of the pit a minimum of 5 cm. The temperature is recorded when stabilized (about three minutes).

Soil Structure (Items needed: trowel and Munsell Charts): Peds (vis. clods) are aggregates of soil particles that are usually easily distinguished from other such aggregates. Often in soils, boundaries sometimes appearing as cracks separate one ped from another. Where boundaries are indistinct visually, surfaces of separation may be more obvious as soil is chipped away mechanically or broken physically. Peds may be very small, the size of a crumb, to massive (essentially having no discernable boundaries or no structure). Peds may be block-like (blocky), prismatic, columnar, platy, or crumb-like, and may have angular and sub angular point on the peds (see Munsell Book and Figure 1).

The boundaries around peds represent lines of weakness established by physical processes such as freezing and thawing, wetting and drying, shrinking and swelling. Pressure from root penetration may accentuate ped boundaries. Water entering soils often flows around peds and along the boundaries more rapidly than through the peds. Oxygen diffusion into peds may be retarded and carbon dioxide diffusion out of peds may be slow.

Texture (Items needed: 2 mm sieve): Texture is defined as the proportion of sand, silt and clay of the fine fraction of the soil. The fine fraction is that soil that will pass through a 2 mm sieve. Coarse fragments, that fraction larger than 2mm, can be very important to physical, chemical and biological soil properties, but generally the fine fraction of the soil has the most impact on soil properties.

Texture can be determined very quantitatively in the lab, but nearly as accurate and much more fun is hand texturing, which can also be done in the field. The textural triangle (Figure 2) is an aid in defining sand, silt and clay percentages as well as textural classes. The method for hand texturing (Figure 3) shows the method and criteria for making texture judgments. It is not always necessary to hand texture to ascertain texture. For example, nearly pure sands and clays have obvious textures.

Consistence: Soil consistence should be noted while texture is being determined. Here, the stickiness of the soil, when wet will be noted (nonsticky, slightly sticky, sticky or very sticky) as well as rupture resistance (see Field Book for Describing and Sampling Soils).

Aspect and Slope: (Items needed: level): Aspect, the direction a slope faces, can be measured with a compass or similar instrument. Slope can be estimated visually or measured. The method for expressing aspect is to simply record the degree reading (east 90°, south = 180°, etc.) although cardinal direction are also used (e.g. *NE,* ENE, etc.).
Slope is measured in percentage where the standard, 45° slope, is 100%. For more information refer to the Geomorphology tab in the Field Book.

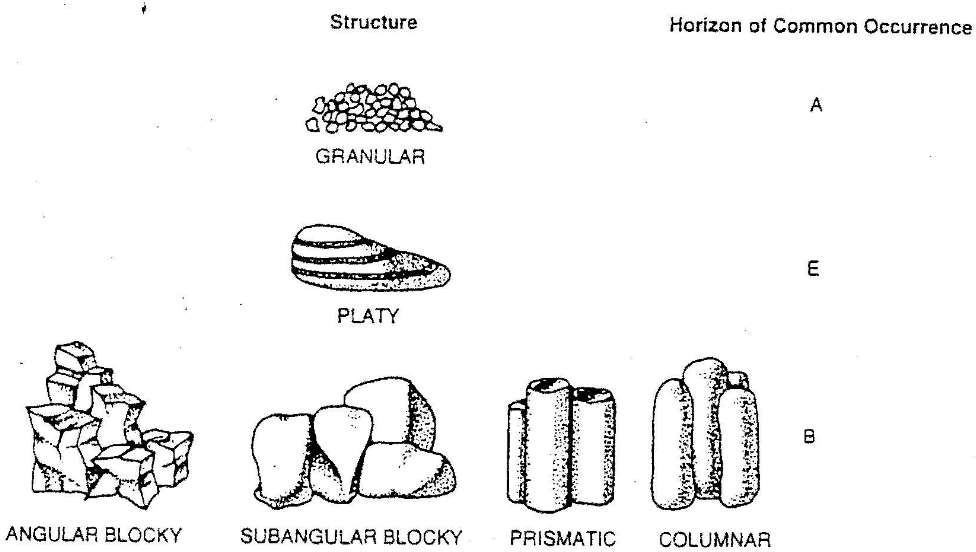

Figure 1. Types of soil structure.

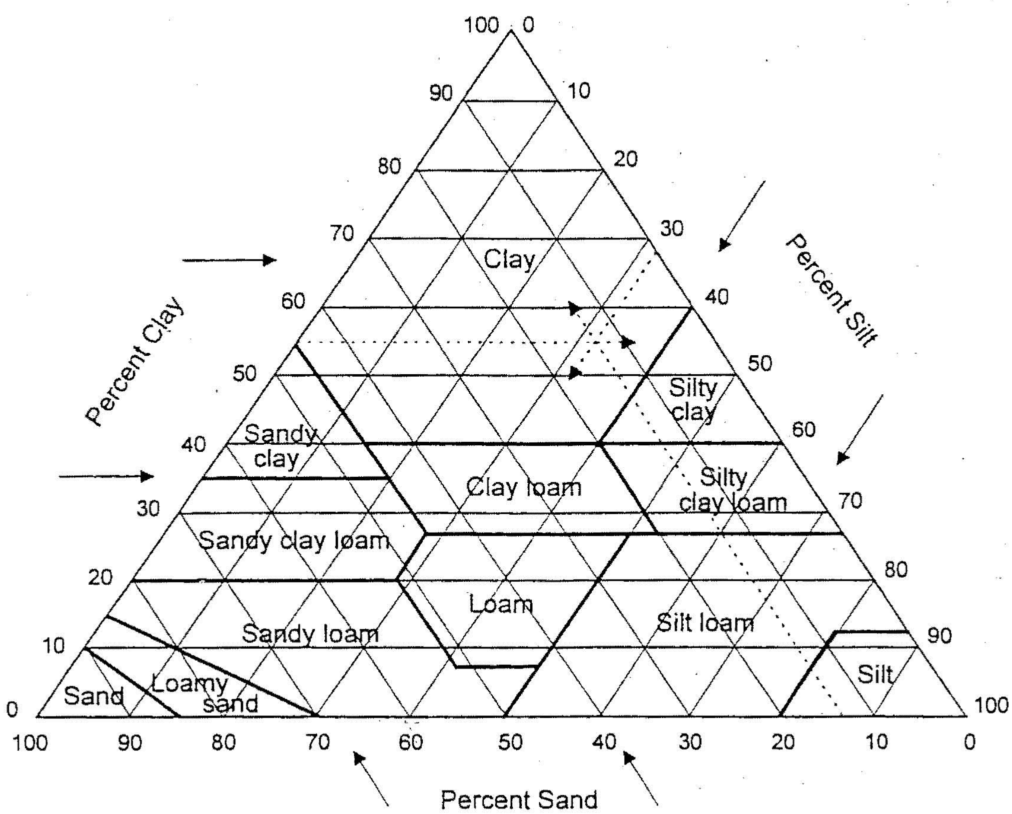

Figure 2. The Textural Triangle. This shows the textural classes as percentages of sand, silt and clay. The intersection of the dotted lines show a clay soil with a composition of 55% clay, 32% silt and 13% sand. Note the direction used to plot data point from each of the axes.

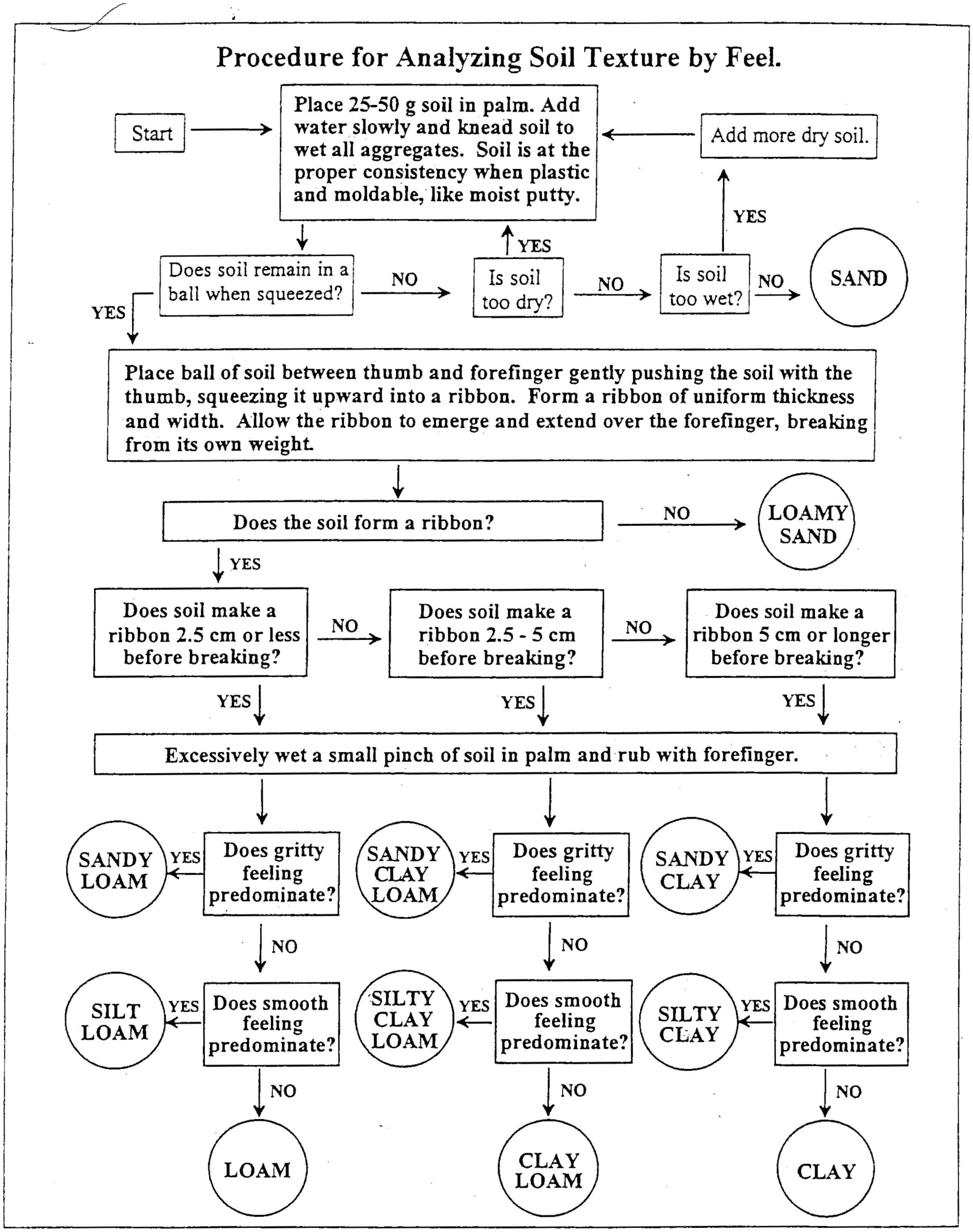

Figure 3. Determining soil texture by the feel method.

Carbonates: Carbonates are present sometimes in soils of neutral to high pH. Their presence is often related to the parent material of the soil. Limestone and many types of sandstone contain carbonates and on weathering impart these to the resulting soil.

Lime content of soil can be generally determined by adding a few drops of dilute hydrochloric acid (0.10 N HCl) to a few grams of soil. Bubbles emanating from the soils (effervescence) indicates the presence of carbonates. The amount of effervescence is directly related to the amount of carbonate present. The rate of effervescence is related to the kind of carbonate present. Sodium carbonates (Na_2C0_3, $NaHC0_3$) effervesce rapidly whereas carbonates associated with divalent metals (e.g. $CaC0_3$, $MgC0_3$) effervesce more slowly (see Field Book under the Chemical Response tab).

pH (Items needed: pH 4.0 and 10.0 buffers, pH meter, cups, distilled water, ¼ cup measuring cup): pH is the measure of the hydrogen ion activity of the soil. The definition, precisely, is the -log of the hydrogen ion activity { pH = -log(H-) }. Hydrogen ion activity can be viewed as approximately equal to the hydrogen ion concentration, and when hydrogen ions are dilute, concentration and activity are for all practical purposes, equal. Figure 4 shows conceptually the relationship between hydrogen ion activity and concentration.

Activity coefficients are not explained here (see Figure 4) but when pH is measured hydrogen ion activity, not a concentration, is being measured. High pHs (very low H+ activity) are nearly equal to concentration, but low pH (less than 7) increasingly under estimate concentration as they become lower and lower.

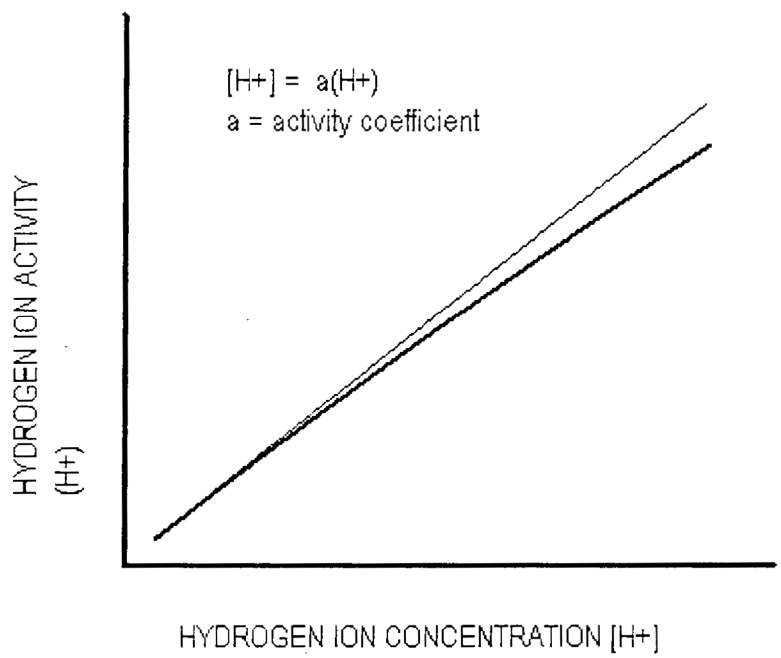

Figure 4. Hydrogen ion activity as a function of hydrogen ion concentration. Note: The light line is a 1:1 relationship between concentration and activity. The dark line is the actual relationship between concentration and activity. These are nearly the same at low concentrations and increasingly different at high concentrations.

Measurement of pH is done by taking a weight of soil and adding twice as much deionized water (1:2; soil to water), mixing and then waiting five minutes before taking a pH measurement (using a hand held portable pH meter and probe). For instance take ¼ cup of soil (well packed) and add it to a plastic drinking cup (8 oz or so). Add ½ cup of distilled water and mix well. In cases where there is some suspicion that there is considerable sodium in the soil, the ratio of soil to water will raise to 1:5. These are mixed and allowed to interact for 5 minutes before measurements are taken. The pH meter should be standardized daily (see pH meter instructions).

Electrical Conductivity: On the same solution used for pH, electrical conductivity will also be measured. For solutions, their capacity to transmit electricity is directly proportional to the amount of salt in solution. Electrical conductivity is, therefore, a measure of the salinity of a soil or soil from which the solution was derived (Bower and Wilcox 1965).

Many plants are sensitive to high levels of salt in the soil. Many native plants have adapted to the salt contents of the soils on which they have developed, however, in highly salty areas, there are usually plants that have adapted to the salt (see Table 1).

Table 1. Impact of salinity of the soil 1:2 extract electrical conductivity (EC 1:2) on plant growth. Plants listed are tolerant in a particular category. (Note: Field dS/m column are the kinds of E.C. readings a user will get using the 1:2 soil to water method prescribed for use with this soil kit. Lab dS/m column is the equivalent result if the E.C. is determined on a saturation extract).

Field dS/m	Lab dS/m	Plant Salinity Effects
< 0.4	< 2	Non-Saline. Most plants will grow well, no injury.
0.4 -0.8	2-4	Very slightly saline. Yields of plants of low salt tolerance maybe reduced by 50%. (Ladino clover, red clover, red fox tail, and strawberry).
0.8-1.6	4-8	Slightly saline. Yields of some crop plants may be reduced 50%. (orchard grass, birdsfoot trefoil, sunflower, corn, oats, onion).
1.6-2.4	8-16	Moderately saline. Yield of virtually all crop plants significantly reduced. Yield reduction of 50% may occur in the most sensitive forage and field crops (barley, wheatgrass, rape, sugarbeet, spinach, asparagus, and beets).
2.4-3.2	16-32	Strongly saline. Only highly salt-tolerant forage and field crops. Yield satisfactorily.
> 3.2	> 32	Very strongly saline. Only a few highly salt-tolerant grass, herbaceous plants and certain shrubs and trees will grow (salt grass, alkali sacaton, grease wood).

Adapted from Gavlak et al., 1994

Aromas: The odor a soil gives off can say much about processes ongoing in the soil. Most soils of reasonable biological activity have an earthy smell. Mostly bacteria, filamentous bacteria, in the order Actinomycetales-the actinomycetes, produce this smell. These organisms are active in most soils where oxygen is present at some level.

When oxygen drops very low, often disappearing, other aromas develop. In highly water saturated soils or highly reduced soils; gasses such as methane and hydrogen sulfide are produced. Methane does have an odor, but it is subtle. In can, however, be ignited and burned off. Hydrogen sulfide (H_2S) has a very strong odor-that of rotting eggs.

The method for determining odors is very simple. Take a modicum, half a handful, of freshly exhumed soil, and sniff.

Biota: For all of the sites, a description of biota is very important! Most of what is observable macroscopically are eucaryotic organisms-plants, animals and fungi. Other eucaryotes such as protista and micro-arthropods, are also present and functional. Unseen macroscopically, except rarely are the Prokaryotes and the Archaea. These organisms are manifest almost entirely as microscopic entities. Some of the cyanobacteria may form scums on ponds or crust on soils and symbiotically associate with fungi to form certain lichens, and thereby can be seen macroscopically; but the prokaryotes and Archaea are physically invisible without the aid of a microscope. Smells from soils, bubbles from pond sediments, gleying in soils, soil organic matter, etc. are all manifestation of these microorganisms.

At each site, vegetation will be generally identified. Some plants are clear indicators of soil conditions. Other plants, when present, imply certain associations between themselves and distinct groups of below ground biota.

In the soil, root depth and root density will be described at least in general terms.

Reports: Attached is a template for soils data.

References:

Bower, C. A., and L. V. Wilcox. 1965. Soluble salts. In: C. A. Black (ed.) Methods of Soil Analysis. Agronomy 9:933-951.

Gavlak, R., D. Horneck, R. O. Miller, and J. Kotuby-Amacher. 1994. Soil Analytical Methods, Soil pH and Electrical Conductivity. From: Plant, Soil and Water Reference Methods for the Western Region. WREP 125.

Thien, S. 1. 1979. A flow diagram for teaching texture-by-feel analysis. 1. Agron. Ed. 8:54-55.

SOILS DATA TEMPLATE

LOCATION: ____________ ELEVATION: ________ ASPECT: _________ SLOPE: _____

PARENT MATERIAL:

CLIMATE:

Horizon	Depth	Color	Carbonate	Texture	Stickiness	Structure	Temp.	pHw	pH1:5w	EC	Comments

AROMAS:

BIOTA:

SOIL TAXONOMY:

APPENDIX F: COMPARISON OF SOIL ANALYSIS FROM FIELD SITES DONE IN THE FIELD WITH ANALYSIS CONDUCTED BY TWO SOILS LABORATORIES.

One of the crucial principles of analysis of sites for mine development as well for the potential for reclamation after mining, is consideration of the soil on the site. When examination of soils is done in the field, it is very convenient to be able to do some analysis in the field. Portable pH meters and EC (Electrical Conductivity) meters are often very useful to measure the acidity or alkalinity of soils (e.g. pH) and for measuring salt content (e.g. EC). Soil color can provide an estimate of the organic matter content of the soil, and hand texturing can provide a good indication of the proportion of sand, silt and clay in the soil. All of these measures, pH, EC, Color and Texture, can be done in the field and with practice a person can become proficient enough to make preliminary estimates of soil properties and the potential for using any given in reclamation. The Soil Kits that were used during the September 2016 training conducted by S. E. Williams were all provided so that the trainees can provide information in the field. This information can be used to make preliminary decisions about the suitability of a site for mining and for reclamation, but data from certified soil analysis laboratories should be used to make final decisions.

During the training, numerous sites were examined and many soil samples were taken. Many of the soil samples were analyzed in the field, almost all were analyzed in the Soils Laboratory in the Institute of Geography in Ulaanbaatar, and a sub-set of the samples were sent to the Intermountain Laboratories (IML Laboratories) in Sheridan, Wyoming in the USA.

The Soils Laboratory at the Institute of Geography in UB was visited by the consultant (S. E. Williams and his interpreter, Ariuna Jalsrai) in late September of 2015. This was done to deposit the soil samples in the laboratory, indicate the kind of analysis needed and to visit with the director of the laboratory and also with the staff of the laboratory. Payment for the analysis was also done at this time. It is not known what kind or level of certification this laboratory has, but it is a well-known and generally well respected laboratory across Mongolia. For more information on the lab contact

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The IML laboratory in Sheridan, Wyoming is Accredited and Certified by the Environmental Protection Agency (EPA) Region VIII as well as numerous State Agencies across the USA. The Laboratory maintains an up-to-date permit to receive soil from any location in the world as regulated by the USDA Animal and Plant Health Inspection Service (APHIS). The consultant (S. E. Williams) has used the laboratory previously for soils work conducted for mine land reclamation

studies including work done in Mongolia. For more on IML see:
https://www.google.com/?gws_rd=ssl#q=intermountain+labs

It is not the intent of this report to use the soils information secured from field measurement done by the trainees using the soil kits, from the UB Soils Lab, or the IML Soils lab to make any decisions regarding the utility of the soils for reclamation. This was a training exercise and the mines in the Gobi area were gracious enough to allow the trainees and consultants as guests on their leases and to allow samples to be taken under the condition that the information secured from the samples be used for training purposes only. Instead, the intent of this section is to mostly provide information about the accuracy of the analysis conducted in the field using the soil kits, the accuracy of the UB Soils lab and the IML Soils lab. Still, there are some analyses made in the field that should be reported and pointed out with the idea that they should be followed on at a later time when a more complete analysis can be had.

COMPARISION BETWEEN LABS: Comparison of fundamental soils data between the UB Lab and the IML Labs (Table 1) shows that the two labs are in reasonable agreement for analyses of pH, phosphate, potassium, carbonate, sand and silt. In these analyses, there may be differences in the final analyses from these labs, but the differences are consistent enough that correlations are statistically highly significant. However, there is inconsistency between the labs on EC, organic matter and clay %.

The two labs were compared through the field information that was collected by the trainees (see Table 2). Here the UB lab was in general agreement with the values the trainees obtained for pH but not for EC. The IML lab was in agreement with both the pH and the EC values obtained by the trainees in the field.

SOILS MANIFEST: The 54 soil samples were taken from 20 different pits that were constructed by the trainees at the four transects at Hustai National Park as well as the eight sites examined in the Gobi (Table 3). The various soils varied considerably over the landscape as reflected by the horizon depth and designation (Table 3).

FULL ANALYSIS BY THE UB LAB: The UB laboratory did analysis on 51 of the 54 samples provided to them. It is not known why the final three samples, 52, 53 and 54 were not included in the analysis. However, the full analysis conducted by this lab are shown (Tables 4 and 5).

FULL ANALYSIS BY THE IML LAB: The IML laboratory did analysis on 29 samples. These analyses are shown in table 6, 7, 8 and 9. The samples analyses are fairly routine although there are some issues. The most significant issue is the presence of some toxic metals in some of the samples.

Several of the samples taken near the Old Research Station (ORS) in Hustai National Park (samples 26 through 38, Table 9) had notable levels of Arsenic—up to 0.41 ppm or 410 ppb. Samples from the Gobi region did not show detectable levels of Arsenic. Arsenic is a very toxic metal that tends to bio-accumulate.

Only a few samples showed any detectable Cadmium and these were just barely detectable in a couple of ORS samples in Hustai.

Copper was detectable in all samples be they from Hustai or the Gobi. Levels ranged from a low of 0.29 ppm to 3.59 ppm (Table 9). Copper is a necessary nutrient in standard metabolism, but at high levels can be toxic.

Iron was detectable in all soils and was very high in some soils especially at some of the ORS sites in Hustai National Park. Soils having the highest iron were wet soils and probably anaerobic to a degree. Under such conditions iron is chemically modified to a very soluble form.

Detectable levels of lead were found throughout the samples taken from ORS at Hustai as well as in the Gobi (Table 9). The presence of this toxic metal suggests a need for a more complete study of lead in these areas.

Manganese was detected at some level in all samples reported (Table 9) and range from a low of 1.55 ppm to a high of 20.6 ppm. A more complete study of Manganese is likely warranted and should start with a review of this metal to determine toxic levels.

Selenium was below the detection level in these soils.

There were a few samples that contained some zinc, but most sample were below the detection limit (Table 9). Zinc is generally considered as a very important micro-nutrient, but at high levels can have some toxic properties.

All of the soils in this study were below the detection limit for Mercury.

Table 1. Correlation (R) between analyses taken from the same soil samples but by two different laboratories, one the Soil Lab at the Institute of Geography in Ulaanbataar, Mongolia (UB Lab) and the other the Intermountain Lab (IML Lab) in Sheridan, Wyoming, USA. Correlation analysis shows that the two laboratories were in relatively strong agreement on Soil pH, Extractable P, Extractable K, Carbonates and regarding texture, the percent of sand, and silt in the sampled soils. The labs did not agree on E.C, Organic Matter or percent clay. A further evaluation of texture showed that on transforming the sand, silt and clay percentages to textural classes, the two laboratories were in agreement eight times out of a total of 24 tries.

	1:2.5; Soil To Water		Extractable	Extractable	Organic	Carbonate		Texture	
	pH	E.C.	Phosphate as P	Potassium as K	Matter %	%	Sand %	Silt %	Clay %
n	24	24	24	24	29	26	24	24	24
R^2	0.696	0.043	0.664	0.753	0.038	0.516	0.532	0.693	0.037
R	0.831	0.208	0.815	0.868	0.194	0.718	0.729	0.833	0.1191

Significance	**	NS	**	**	NS	**	**	**	NS

Table 2. Correlations between field data for soils (pH and EC) taken in the field by trainees and the analytical results for the same parameters examined in a laboratory setting by the UB Lab and the IML Lab. Comparative data sets were examine for fourteen pairs of analysis where each pair comprised one analysis from the UB lab and the other from the IML lab. The correlation (R) between field data and lab data showed that for pH both the UB lab and the IML lab field pHs and lab pHs were correlated and significant at an alpha of 0.01 or less (e.g. **). For ECs, only the IML lab showed a highly significant correlation (alpha of 0.01 or less **) whereas the UB lab data was not significantly correlated even at an alpha of 0.05 (*).

Field Data		pH	E.C.
UB Lab	n	14	14
	R^2	0.727	0.222
	R	0.851	0.4708
	Significance	**	NS
IML Lab	n	14	14
	R^2	0.863	0.564
	R	0.929	0.751
	Significance	**	**

Table 3. Listing of soils samples taken during the training session conducted under the auspices of The Nature Conservancy during September, 2915. Samples were taken at Hustai National Park as well as in the Tavan Tolgoi area of the Gobi in south central Mongolia. This table shows data measurements taken and recorded by the trainees during several field excursions at Hustai. Fuller sample analysis is presented in other tables.

Sample		Pit	Horizon	Depth cm	Field pH	Field EC uS/cm	Field EC mS/cm or dS/m
UB Lab Number	IML Number		Measurements taken by trainees				
HUSTAI							
	Pits 1, 2, 3 and 4 constitute a soil chronosequence very near the headquarters buildings of Hustai National park.						
1		1	A	0 - 35	8.05	70	0.07
2		1	B	36 - 56	8.34	170	0.17
3		1	Bk	56 +	8.73	150	0.15
4		2	IA	0 - 17	7.35	120	0.12
		2	IB	17 - 27			
5		2	IIA	27 - 37	7.7	130	0.13
		2	IIIC	37 - 53			
6		2	IVA	53 - 66	8.4	190	0.19
7		2	IVB	66 - 80	8.3	300	0.3
		2	VC	80 - 100			
8		3	A	0 - 39	7.1	70	0.07
9		3	B1	39 - 52	6.8	140	0.14
10		3	B2	52 +	6.9	120	0.12
11		4	A	0 - 17	6.9	120	0.12
12		4	B1	17 - 37	7.7	230	0.23
13		4	B2	37 - 57	6.3	200	0.2

14		4	IIC	57+			

Pits 5, 6, 7 and 8 constitute a soil chronosequence across landscape types in the sand lands just north of Hustai National Park Headquarters.

15		5	A1	0-16	6.9	60	0.06
			A2	16-25			
			C1	25-37			
16		5	A2	37-52			
			C2	52-60			
17		5	C3	60-105	6.8	30	0.03
18		6	A1	0-20	7.4	60	0.06
19		6	C2	20-43	7.6	50	0.05
20		6	A3	43 +	7.3	70	0.07
21		7	A	0-40	6.8	110	0.11
22		7	C	40-75	6.7	90	0.09
23		8	A	0-20	5.8	140	0.14
24		8	C1	20-60	6.5	50	0.05
25		8	C2	60 +	6.6	50	0.05

Pits 9, 10, 11 and 12 constitute a soil chronosequence across landscape types near the center of Hustai National Park, near the old Research Stn.

26	26'	9	A	0-25	10	260	0.26
27	27'	9	C1	25-69	10	1400	1.4
28	28'	9	C2	69-74	10.2	1800	1.8
29	29'	9	C3	74-90	10	1030	1.03
30	30'	10	A	0-20	8.07	180	0.18
31	31'	10	B	20-40	6.7	190	0.19
32	32'	10	C	40 +	7.24	70	0.07
33	33'	11	A1	0-20	5.6	370	0.37
34	34'	11	A2	20-40	7.6	270	0.27
35	35'	11	A3	40-70	8.3	170	0.17
		11	A4	70-80	8.1	200	0.2
36	36'	12	A	0-9	8.2	130	0.13
37	37'	12	Bk	9 to 42	8.95	120	0.12
38	38'	12	C	42-60	9.05	130	0.13

GOBI

At the Tavan Tolgoi Coal Mine in Omnogovi Imag (Tsogttsetsii Soum).
Three year old stockpiled topsoil.

39	39'	I	A?	0-20
40	40'	I	A?	40-60
41	41'	I	A?	80-100

At the Tavan Tolgoi Coal Mine in Omnogovi Imag (Tsogttsetsii Soum).
One year old stockpiled topsoil.

42	42'	II	A?	0-20
43	43'	II	A?	40-60
44	44'	II	A?	80-100

Tavan Tolgoi, Native area
Native site very near pit II.

48	48'		Coal Dust	Surface
45	45'	III	A	0-20
46	46'	III	B	20-36
47	47'	III	C	36-60

Tavan Tolgoi, Disturbed area
Three year old stockpiled topsoil

49	49'	IV	A?	0-20

Tavan Tolgoi, Native area
Site appears to be wet much of the time.

50	50'	V	A1	0-7
51	51'	V	A2	7 to 41

Tsogttsetsii Soum, Native
area

	Native sandy site centered on Nitrarium			
52	52'	VI	Dune Sand	
53	53'	VI	A	0-20
	Tsogttsetsii Soum, Native area Native site: "Typical Gobi."			
54	54'	VII	A	0-20

Table 4: Soil analysis conducted by the Soils Laboratory at the Institute of Geography which includes analysis for pH, $CaCO_3$, Organic Matter, EC, P_2O_5 and K_20. In the accompanying report this laboratory is often referred to as the UB Lab.

Soil laboratory

Institute Geography-Geoecology
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Phone: (976)-99712339, email:batkhishig@gmail.com

Soil analyses

Order by: *TNC, Prof. Stephen E. Williams*

Analysys	Methods
Sample preparation	*Air dry, 2 mm sieve*
pH	*soil : water (1 : 2.5) pH meter*
$CaCO_3$	*Volumetric*
Conductivity	*soil : water (1 : 2.5) EC meter*
Organic content	*Titration (wet combustion: potassium bichromate and sulfuric acid)*
Mobile Phosphorus	*Specrtophometer (1 %, ammonium carbonate)*
Mobile Potasium	*Flame spectrophotometer*
Texture	*pippete*
Conductivity	*EC meter (1 : 2.5)*

2015.10.02

Soil chemical properties

Sample #	pH_{H2O} (1:2.5)	$CaCO_3$ %	Organic matter %	$EC_{2.5}$ dS/m	Mobile, mg/100g	
					P_2O_5	K_2O
1	6.30	0.00	2.545	0.097	1.14	16.0
2	7.43	6.18	1.633	0.204	1.13	12.0
3	7.93	6.18	1.279	0.323	1.35	7.0
4	8.03	0.00	1.153	0.070	0.66	11.0
5	7.56	0.00	1.640	0.097	0.82	15.0
6	7.60	2.54	0.978	0.145	1.72	14.0
7	7.62	2.18	1.352	0.131	1.56	12.0
8	7.66	0.00	3.781	0.045	2.58	63.8
9	6.83	0.00	1.017	0.037	1.78	27.0
10	6.97	0.00	4.042	0.029	2.15	29.6

11	6.98	0.00	2.404	0.013	1.51	21.7
12	7.33	0.36	2.100	0.092	0.87	18.0
13	7.59	3.27	2.558	0.102	0.66	22.6
14	7.55	0.45	0.754	0.060	0.92	20.9
15	7.59	0.00	1.087	0.050	1.24	22.6
16	7.58	0.00	0.655	0.042	0.98	13.0
17	6.87	0.00	0.640	0.024	1.72	7.0
18	6.79	0.00	0.696	0.042	0.44	12.0
19	6.91	0.00	0.373	0.046	0.34	11.0
20	6.88	0.00	0.297	0.033	0.44	84.0
21	6.86	0.00	0.470	0.035	0.87	18.0
22	6.72	0.00	0.239	0.024	0.82	13.0
23	6.27	0.00	0.890	0.060	1.62	11.0
24	6.34	0.00	0.390	0.036	1.19	11.0
25	6.41	0.00	0.400	0.067	1.46	8.0
26	9.40	6.54	0.723	1.333	3.38	100.0
27	9.48	6.54	0.843	1.417	4.76	120.0
28	9.45	6.54	0.898	1.164	2.11	76.2
29	9.27	10.91	0.624	1.054	1.86	38.3
30	7.49	5.45	0.987	0.216	0.60	19.0
31	7.58	0.00	1.234	0.077	1.01	28.7
32	7.65	0.00	1.025	0.083	1.99	32.2
33	6.26	0.00	1.938	0.334	3.25	25.2
34	6.20	0.00	2.019	0.224	2.80	23.5
35	7.43	0.61	2.951	0.127	2.48	18.0
36	7.34	7.63	2.190	0.129	0.40	31.0
37	7.59	12.00	2.012	0.112	0.07	14.0
38	7.72	1.45	1.174	0.109	0.15	9.0
39	7.48	1.09	0.601	0.387	0.89	14.0
40	7.76	0.73	1.273	0.124	0.23	11.0
41	7.69	1.82	1.145	0.172	0.23	8.0
42	7.75	2.54	0.985	0.412	0.89	33.0
43	7.82	3.64	1.842	0.416	1.01	28.7
44	7.89	3.64	1.627	0.508	0.48	33.0
45	7.73	0.73	1.024	0.178	0.19	32.2
46	7.83	1.09	1.066	0.128	0.19	11.0
47	7.86	1.82	0.952	0.196	0.07	8.0
48		0.24	0.813			
49	7.50	1.82	0.621	0.533	0.80	21.7
50	7.56	2.18	1.591	0.623	4.54	90.0
51	8.12	2.54	0.725	0.260	1.46	66.7

Table 5. Additional analysis performed by the Institute of Geography Soil Laboratory. These analyses include strictly the mechanical separates of the soil and are reported as sand, silt and clay. Note that 54 samples were provided to the laboratory, but the last three (52, 53 and 54) were not reported. Reason for this is unknown.

Soil laboratory

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Soil analyses

Order by: *TNC, Prof. Stephen E. Williams*

Soil texture 2015.10.02

Sample #	Particle, % (size by mm)		
	Sand (2-0.05mm)	Silt (0.05-0.002mm)	Clay (< 0.002mm)
1	52.8	26.2	21.0
2	54.2	29.8	15.9
3	51.3	31.2	17.5
4	57.2	28.1	14.7
5	48.4	32.3	19.3
6	46.9	31.6	21.5
7	60.1	27.1	12.8
8	54.2	26.6	19.1
9	55.7	29.7	14.6
10	49.9	33.1	17.1
11	58.6	27.1	14.3
12	52.8	28.4	18.8
13	55.7	28.7	15.6
14	48.4	34.4	17.2
15	65.9	24.3	9.8
16	68.9	22.4	8.7
17	70.3	22.7	7.0
18	76.2	14.3	9.5
19	73.3	19.5	7.3
20	74.7	17.1	8.2
21	71.8	18.7	9.5
22	76.2	16.8	7.0

23	80.6	12.1	7.3
24	83.5	11.6	4.9
25	82.0	11.0	7.0
26	46.9	34.7	18.4
27	48.4	36.0	15.6
28	38.1	43.2	18.7
29	33.8	45.9	20.3
30	36.7	48.0	15.3
31	30.8	54.4	14.7
32	33.8	48.9	17.4
33	45.5	39.9	14.6
34	54.2	33.9	11.8
35	51.3	36.3	12.4
36	63.0	27.1	9.9
37	57.2	31.6	11.2
38	55.7	29.8	14.4
39	68.9	22.8	8.3
40	70.3	22.5	7.1
41	67.4	23.1	9.5
42	61.6	30.3	8.2
43	58.6	30.1	11.2
44	52.8	34.2	13.0
45	57.2	31.8	11.1
46	55.7	31.6	12.7
47	60.1	29.7	10.2
49	61.6	30.0	8.4
50	58.6	30.3	11.1
51	57.2	30.1	12.7

Table 6. Soil analysis conducted by the Intermountain Labs in Sheridan Wyoming. In the text, this lab is often referred to as the IML lab. These analyses include pH of the saturation extract and of the 1:2.5 soil to water, EC of the saturation extract and of the 1:2.5 soil to water, Organic matter, carbonates, total carbon and total organic carbon. A few samples were examined for total Sulphur mainly because of their relatively low pH. These sample represent about half of the samples taken during the training. This was done as a check Quality Assurance and Quality Control. Some analyses were made because the UB soils lab was unable to make them. Shipping of these samples from Mongolia to the USA was done under the APHIS permit that IML has.

SampleID	pH s.u.	pH 1:2.5 s.u.	Electrical Conductivity dS/m	EC 1:2.5 dS/m	Organic Matter %	CO3 %	Total Carbon %	TOC %	Total Sulfur %
26	9.8	9.9	4.66	1.73	1.4	6.7	1.1	0.3	
27	9.8	10.0	3.49	1.46	2.7	12.5	2.1	0.5	
28	9.9	10.0	2.68	1.50	2.6	10.2	1.7	0.4	
29	9.8	9.9	4.30	1.81	2.5	14.9	2.4	0.6	
30	7.3	7.5	0.49	0.40	5.9	4.5	3.3	2.8	
31	6.4	6.6	0.21	0.13	3.6	1.1	1.8	1.7	
32	6.9	7.2	0.19	0.10	1.7	2.3	0.9	0.7	
33	6.0	6.6	1.19	0.53	3.9	1.1	2.4	2.3	0.03
34	7.7	7.9	0.68	0.27	2.4	1.5	1.3	1.1	0.02
35	7.9	8.1	0.55	0.27	2.6	3.3	1.6	1.2	0.02
36	6.9	6.9	0.45	0.23	5.6	1.1	3.0	2.9	
37	8.0	8.2	0.32	0.20	1.1	8.8	1.5	0.4	
38	8.1	8.4	0.26	0.17	0.1	4.4	0.5	<0.1	
39	7.8	8.3	2.04	0.41	0.3	3.8	0.6	0.1	
40	8.1	8.6	0.48	0.16	<0.1	3.4	0.5	<0.1	
41	7.7	8.5	0.97	0.23	<0.1	4.2	0.4	<0.1	
42	7.8	8.5	2.85	0.60	1.8	5.6	1.0	0.3	
43	7.9	8.5	2.90	0.59	1.5	5.8	0.8	0.2	
44	7.7	8.6	3.54	0.70	1.3	6.3	0.9	0.2	
45	8.0	8.5	0.72	0.22	0.5	4.1	0.5	<0.1	
46	8.0	8.6	0.51	0.17	<0.1	4.8	0.6	<0.1	
47	8.4	8.8	0.49	0.18	0.1	5.1	0.5	<0.1	
48					3.9	3.1	1.6	1.2	
49	7.4	8.0	19.6	6.19	3.0	5.5	1.1	0.5	
50	7.5	7.8	3.33	1.52	7.9	6.2	4.4	3.7	
51	8.2	8.6	1.04	0.44	3.4	6.9	1.3	0.5	
52	8.0	8.0	1.82	0.55	0.9	1.3	2.0	1.8	
53	8.1	8.4	0.44	0.18	0.6	3.4	0.5	0.1	
54	8.3	8.5	0.35	0.14	<0.1	2.2	0.3	<0.1	

Table 7. IML lab analyses for Calcium, Magnesium and Sodium to construct the SAR as well as textural analysis (Sand Silt and Clay) as well as coarse fragments.

Sample ID	PE Calcium meq/L	PE Magnesium meq/L	PE Sodium meq/L	SAR	Sand %	Silt %	Clay %	Texture	Coarse Fragment %
26	3.75	3.30	40.4	21.5	38.0	36.0	26.0	Loam	<0.1
27	5.80	3.99	29.2	13.2	28.0	42.0	30.0	Clay Loam	<0.1
28	12.5	7.79	32.1	10.1	26.0	45.0	29.0	Clay Loam	<0.1
29	9.81	6.54	40.4	14.1	24.0	45.0	31.0	Clay Loam	<0.1
30	3.01	0.56	0.89	0.67	30.0	42.0	28.0	Clay Loam	<0.1
31	0.73	0.39	0.95	1.27	20.0	52.0	28.0	Clay Loam	<0.1
32	0.54	0.21	1.17	1.91	24.0	48.0	28.0	Clay Loam	<0.1
33	15.7	3.69	0.32	0.10	44.0	41.0	15.0	Loam	<0.1
34	5.10	1.45	0.73	0.40	42.0	34.0	24.0	Loam	<0.1
35	3.50	0.78	0.17	0.12	36.0	38.0	26.0	Loam	<0.1
36	2.68	0.71	0.40	0.30	46.0	33.0	21.0	Loam	<0.1
37	1.88	0.92	0.56	0.47	46.0	31.0	23.0	Loam	<0.1
38	1.10	0.60	0.52	0.56	56.0	26.0	18.0	Sandy Loam	1.5
39	9.20	3.23	7.88	3.16	68.0	14.0	18.0	Sandy Loam	2.3
40	1.65	0.77	1.54	1.40	78.0	7.0	15.0	Sandy Loam	4.2
41	3.55	1.56	3.43	2.14	76.0	8.0	16.0	Sandy Loam	7.0
42	6.09	3.25	15.8	7.31	60.0	15.0	25.0	Sandy Clay Loam	4.2
43	7.10	4.00	23.5	9.96	60.0	17.0	23.0	Sandy Clay Loam	1.4
44	6.61	3.88	23.7	10.3	60.0	17.0	23.0	Sandy Clay Loam	5.4
45	3.31	1.15	1.93	1.30	64.0	14.0	22.0	Sandy Clay Loam	4.8
46	1.70	0.68	2.97	2.73	72.0	11.0	17.0	Sandy Loam	5.8
47	3.52	1.25	1.57	1.01	70.0	13.0	17.0	Sandy Loam	4.5
48									
49	52.7	25.4	232	37.1	38.0	20.0	42.0	Clay	2.5
50	15.9	6.60	13.7	4.08	26.0	32.0	42.0	Clay	<0.1
51	3.25	1.70	9.56	6.07	20.0	29.0	51.0	Clay	<0.1
52	7.81	3.97	9.45	3.89	78.0	10.0	12.0	Sandy Loam	0.4
53	3.00	1.12	1.00	0.69	70.0	13.0	17.0	Sandy Loam	<0.1
54	3.43	1.19	1.27	0.83	76.0	9.0	15.0	Sandy Loam	<0.1

Table 8. Additional analysis done by the IML here of nitrogen as nitrate, total kjehdahl nitrogen, total nitrogen, potassium and phosphorus.

Sample ID	Nitrate(as N)	TKN	Total Nitrogen	Potassium	Phosphorus
	ppm	ppm	ppm	ppm	ppm
26	<0.1	623	623	1120	44
27	<0.1	613	613	447	28
28	<0.1	495	495	508	27
29	<0.1	602	602	290	24
30	2.2	3020	3020	182	18
31	<0.2	1890	1890	216	21
32	<0.1	714	714	246	26
33	12.7	2520	2530	179	76
34	11.1	1100	1110	147	24
35	5.7	1500	1510	138	39
36	2.6	2650	2650	265	20
37	0.3	571	571	82	6
38	<0.1	377	377	74	4
39	19.0	359	378	93	7
40	1.0	134	135	68	7
41	2.0	109	111	51	5
42	14.4	531	545	261	10
43	3.1	424	427	220	8
44	1.9	391	393	212	7
45	5.8	461	467	274	6
46	2.0	241	243	84	4
47	0.5	159	160	56	5
48	2.5	818	821		
49	12.4	782	794	186	13
50	133	3750	3880	855	92
51	0.3	1680	1680	529	25
52	26.4	717	743	333	27
53	2.4	352	354	224	10
54	0.2	119	119	86	6

Table 9. Metals extractable from the soils using a chelating agent (DTPA), done by the IML labs. Mercury was done as total mercury.

Sample ID	DTPA Arsenic ppm	DTPA Cadmium ppm	DTPA Copper ppm	DTPA Iron ppm	DTPA Lead ppm	DTPA Manganese ppm	DTPA Selenium ppm	DTPA Zinc ppm	Total Mercury mg/Kg
26	0.14	<0.05	1.42	12.8	0.46	4.31	<0.05	<0.05	<0.2
27	0.08	<0.05	1.36	14.9	0.41	3.80	<0.05	<0.05	<0.2
28	<0.05	<0.05	1.18	13.4	0.44	3.66	<0.05	<0.05	<0.2
29	0.06	<0.05	1.25	17.6	0.34	5.39	<0.05	<0.05	<0.2
30	0.21	0.06	2.58	180	1.41	20.6	<0.05	1.11	<0.2
31	0.41	0.06	3.59	301	2.27	13.7	<0.05	0.71	<0.2
32	0.33	<0.05	2.96	86.6	1.24	4.68	<0.05	<0.05	<0.2
33	0.26	<0.05	1.70	104	0.41	25.1	<0.05	1.68	<0.2
34	0.08	<0.05	1.11	12.9	0.28	5.55	<0.05	0.17	<0.2
35	<0.05	<0.05	1.20	15.5	0.25	5.44	<0.05	0.06	<0.2
36	0.18	<0.05	0.80	29.6	0.26	6.73	<0.05	<0.05	<0.2
37	<0.05	<0.05	0.65	5.11	0.22	1.80	<0.05	<0.05	<0.2
38	<0.05	<0.05	0.49	4.02	0.33	1.72	<0.05	<0.05	<0.2
39	<0.05	<0.05	0.43	3.05	0.32	2.89	<0.05	<0.05	<0.2
40	<0.05	<0.05	0.29	2.28	0.24	1.52	<0.05	<0.05	<0.2
41	<0.05	<0.05	0.35	3.00	0.24	1.92	<0.05	<0.05	<0.2
42	<0.05	<0.05	0.79	4.54	0.36	7.73	<0.05	<0.05	<0.2
43	<0.05	<0.05	0.88	4.13	0.45	6.59	<0.05	<0.05	<0.2
44	<0.05	<0.05	0.84	4.16	0.43	5.16	<0.05	<0.05	<0.2
45	<0.05	<0.05	0.59	5.23	0.33	2.76	<0.05	<0.05	<0.2
46	<0.05	<0.05	0.49	2.42	0.27	2.25	<0.05	<0.05	<0.2
47	<0.05	<0.05	0.41	2.35	0.30	2.13	<0.05	<0.05	<0.2
48									
49	<0.05	<0.05	1.39	2.94	0.76	6.95	<0.05	<0.05	<0.2
50	0.05	0.06	2.02	13.0	1.79	20.7	<0.05	0.94	<0.2
51	<0.05	<0.05	2.23	14.3	1.64	13.8	<0.05	<0.05	<0.2
52	<0.05	<0.05	0.32	12.4	0.29	6.14	<0.05	<0.05	<0.2
53	<0.05	<0.05	0.44	4.29	0.38	2.86	<0.05	<0.05	<0.2
54	<0.05	<0.05	0.29	1.96	0.23	1.53	<0.05	<0.05	<0.2

APPENDIX G: Interviews

All trainees were interviewed by myself and Ariunaa Jalsrai. The interviews clearly showed that almost all of the participants were involved at one level or another with mine land reclamation or with the mining sector in one way or another. About a third of the participants said they were involved with problems with the micro-miners (sometimes these are called Ninja miners). The word that kept coming out in these interview was that they were "fighting" with the Nina miners.

All of the trainees had appropriate degrees from Universities. These were often degrees in Ecology but also included degrees in Chemistry, Botany, Natural Resource Management, Geography, Meteorology, Environmental Protection and Forest Management.

A third or less had any classroom experience in studying soil science. In a question and answer session held the first day, the consultant realized that there was a lot of basic soils information that the group lacked. This was provided periodically during the training.