GUIDELINE NO. 2

VEGETATION REQUIREMENTS FOR EXPLORATION BY DOZING, REGULAR MINES, AND IN SITU LEACHING

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This document is a guideline only. Its contents should not be interpreted by permittees, interested members of the public or organizations or Department of Environmental Quality, Land Quality Division (LQD) staff, or other local, state or federal governmental agency staff as mandatory.

Except for specifically referenced regulations, this document has not been subject to rulemaking procedures and the contents are not to be interpreted as regulatory requirements. This guideline is based upon applicable provisions of the Wyoming Environmental Quality Act (WEQA) and LQD NonCoal Rules and Regulations (NonCoal R&R) and it contains statements of LQD policy and statements of LQD preferred procedures. If permittees or other interested parties do not understand the guideline content, they should resolve those differences with the appropriate LQD staff before collecting and submitting the vegetation baseline.

Section 1. General Inventory Procedures for Preparing Vegetation Baseline Information for Regular Mine, Exploration by Dozing and In Situ Mining

A. Introduction

This section details accepted methodology for characterizing the vegetation and establishing reference areas for the required baseline vegetation information for Regular Mining, Large-Scale Exploration by Dozing and In Situ Mining permitting actions. The same information is required for new permits, amendments, and updates which only applies to bentonite mining.

Guideline No. 24 http://deq.state.wy.us/lqd/guidelines.asp details the necessary information required for a permit submittal. The Permittee is strongly encouraged to contact DEQ-LQD to arrange a pre-application meeting to discuss permit requirements. Vegetation baseline sampling requirements differ depending on the type of proposed noncoal operation. Table 1 contains a summary of vegetation baseline information required for a proposed regular (large) noncoal mine, large-scale exploration by dozing and in-situ mining.

Table 1. Required vegetation baseline information for three noncoal operations.

Proposed noncoal operation	Required baseline vegetation information	Applicable Wyoming Statute or DEQ-LQD Noncoal Regulation
Exploration by Dozing (LE) >40 acres in any 4 contiguous 40 ac parcels (40 ac = 1/16 of a section)	Application shall conform to requirements governing surface mining (See Regular Mine).	Ch. 2, Sect. 2(a)(i)(B) (I), (II) & (III)
Regular (a. k. a. Large) Mine	A vegetation cover description to include common and scientific names of predominating species and their estimated abundance within the proposed permit area. Indicate Federally listed endangered or threatened plant species and noxious weeds.	Ch. 2, Sect. 2(a)(i)(B) (I), (II) & (III)

In Situ Leaching (ISL)	A survey of vegetative cover and species diversity on the proposed affected land determined by scientifically acceptable sampling procedures. Indicate Federally listed endangered or threatened plant species and noxious weeds. Vegetation productivity may or may not be required.	W. S. §35-11-428(a)(i) Ch. 2, Sect. 2(a)(i)(B) (I), (II) & (III) Ch. 11, Sect. 3(a)(v)

B. Sampling Plan

It is recommended to submit a plan for baseline sampling and have it approved by the WDEQ/LQD before sampling. An approved sampling plan describes acceptable methodology and when followed will avoid resampling or additional sampling. Failure to receive prior approval for procedures may cause significant delays during permit review, and rejection of the sampling methods and procedures if it does not result in an equivalent data base.

The components of a sampling plan should include the following.

- Table listing the proposed vegetation communities and their acreage
- Define the reference area that will be used for revegetation success
- Describe the sampling methods and intensity
- Provide a map showing the proposed permit boundary and the vegetation communities

C. Vegetation Baseline Requirements for Large Extent Exploration Dozing, Regular (Large) Mines and ISL Operations

The vegetation information which will be required for baseline includes:

1) Map of vegetation communities
2) Land units for evaluating revegetation success
3) Vegetation cover data
4) Threatened and Endangered Species survey
5) Noxious Weed survey
6) Species list for each vegetation community
7) Information for Cropland or Hayland
8) Photos of each community type
9) Additional Data Collection if required

C.1. Mapping of Vegetation Communities

The vegetation communities for the entire proposed permit area should be delineated on an aerial mosaic photograph or topographic base map. Communities less than 2 acres should be described and do not need to be mapped. The mapping should be extended to adjacent areas (0.4 km) on all sides of the proposed permit area boundary or study area boundary and can be used in the future for incidental boundary revisions (IBR). This suggested extension beyond the permit area applies only to mapping of community types. Cover sampling is not required beyond the proposed permit boundary.

The map shall include:

- Permit boundary
- Each vegetation community delineated;
- The location of each sample point and transect direction;
- The location, orientation and identification of each photograph.
- A map title and legend that includes scale
- Delineation of any existing disturbances

C.2. Establishing Revegetation Success Evaluation Area

For measuring the vegetation success of the reclamation, areas called Reference Areas (REFA), that will not be affected by mining or other activities need to be identified. It is recommended that the vegetation on the entire permit be sampled for baseline and then all of the land unaffected by mining activities is an Extended Reference Area (EXREFA) and can be used to evaluate revegetation success for bond release. The other option, the Limited Reference Area (LREFA) is a specific area at least five acres in size that will not be disturbed. This Limited Reference Area is sampled separately from the lands that will be affected by mining and then statistically compared to demonstrate that the two areas are similar.

If all of a vegetation community is going to be affected then a reference area will need to be identified that is the same vegetation community, similar soils, similar topography and similar land management. See Appendix IV Glossary for a definition of Control Area.

C.3. Vegetation Cover Sampling

C.3.a Cover data should be obtained by vegetation community, considering the entire proposed permit area without distinction between affected and non-affected areas. Sampling the entire proposed permit area also allows for use of the Extended Reference Area when evaluating revegetation success for bond release and allows for future changes to the affected area without requiring additional sampling. See the glossary for a complete definition of Reference Areas. Acceptable methods for collecting cover data include point-intercept transects and quadrats.

P**oint-intercept Transects** should apply the following:

1) Be at least 50 meters in length. Each transect shall have a minimum of 50 intercept points per transect, unless otherwise approved in the sampling plan prior to the initiation of sampling.
2) Orientation of each transect shall be randomly established.
3) If a transect runs out of the Sample Unit (vegetation community), a new random orientation will be selected at the point where the transect leaves the Sample Unit which directs the transect back into the Sample Unit.
4) Each transect of sample points is considered a sample size (n) of one (1) for statistical calculations.
5) Only the first hit should be used when estimating cover.

Quadrats should apply the following:

1) Each quadrat shall cover a minimum of $0.1m^2$ (standard 20cm x 50cm Daubenmire frame), but not more than $1.0m^2$.
2) Percent cover by areal extent at the 1% level.
3) Each quadrat shall be considered a sample size (n) of one (1) for statistical calculations.
4) If multiple quadrats are used along a transect, they shall be evenly spaced. The

quadrats will be averaged and considered a sample size (n) of (1) for statistical calculations.

The data should be summarized to present:

1) % absolute vegetation cover by species
2) % total vegetation cover (= sum of all species)
3) % bare ground
4) % rock cover
5) % litter cover
6) % total ground cover (= vegetation + litter + rock)

For sampling purposes rock may be considered any stone or mineral matter at least one square centimeter in size. Litter is any plant part, lying on the ground surface, whose structural integrity remains recognizable.

C.3.b. Timing of Sampling

Cover sampling should occur during peak growing season (usually May-July) Sampling for all areas should occur within a three-week period. Grazing should be withheld until after sampling.

C.3.c. Choosing Sample Locations

The location of all sample points shall be chosen by random or systematic procedures, in accordance with the following considerations:

1) The same procedures shall be used for choosing sample locations in each Sample Unit and corresponding Reference Area;

2) Sample locations shall be readily located in the field, such as by pacing from easily identifiable landmarks or by use of Global Positioning System equipment;

3) Sample locations that fall within a barren or otherwise seemingly atypical area shall not be discarded only because the area is barren or atypical; although; and

4) Areas obviously disturbed by human activities shall be excluded from sampling.

C.3.d. Sample Intensity

Sampling intensity for each vegetation community can follow Table 2 or utilize the one-sample Sample Adequacy Formula (Equation 1) below.

Table 2. Sample Size for Each Vegetation Community

Acreage	total number of samples
< 2	0 (described)
2 to < 10	5
10 to < 40	10
40 to < 80	15
80 to < 160	20
160 to ≤ 640	Sample to adequacy with 20 min.to 50 max.
> 640	Contact DEQ-LQD

For an amendment or update the administrator may approve decreased sampling intensity when there are at least five data sets for each of the vegetation communities for the permit that is being updated or amended. With LQD approval data sets from another permit or older than 20 years may be acceptable. The five data sets must be identified in the sampling plan (see Section B) or during the pre-application process. Appendix D-8 of the application should reference the five data

sets but the actual data does not need to be included.

Table 3 contains the acceptable decreased sampling intensity.

Table 3. Sample Size for Updates and Amendments for Each Vegetation Community

Acreage per vegetation community	total number of samples
< 20	0 (mapped and described)
20 to < 40	5
40 to < 160	10
160 to < 640	15
> 640	Contact DEQ-LQD

Equation 1. The One-sample Sample Adequacy Formula

The minimum number of samples (n′) required to ensure 90% confidence (α =0.10) that the sample mean will be within 10% (*d*) of the true mean is:

$$n' = \frac{(sz)^2}{(d\overline{x})^2}$$

where: s is the sample standard deviation

z is the critical value from the normal distribution with α/2 in each tail (1.645),

d is the percentage of the sample mean that constitutes an acceptable difference between the sample mean and the true population mean (0.10), and

$\overline{x}$ is the sample mean

If sample adequacy is not met with the minimum number of samples in Table 2 the operator should consult with LQD and provide the following information to help LQD in determining if further sampling is necessary:

- The confidence level (d value) achieved by solving for d (assuming n actual = nmin)
- Present a brief explanation of why the sample was unusually variable and thus formula adequacy was not achieved.

When using sample adequacy the minimum number of transects shown in Table 1 of this section must be collected. The Permittee should always present analyses of sample adequacy using the nmin formula even if Table 1 is used. If adequacy is not met, the Permittee should provide the confidence level. These analyses are best presented in a tabular format (**see Appendix C, Table 2**). In order for the data to be checked, all parameters of the formula must be clearly presented.

C.4. Threatened and Endangered (T&E) Plant Survey or other Determination

The permit actions in Table 1 require consultation with both the Wyoming Game and Fish Department (WYG&F) and the U. S. Fish and Wildlife Service (USFWS) prior to submission of the proposed permit application [Ch. 2, Sect. 1(f)]. During this consultation a request should be made for the potential T & E plants that could occur in the proposed permit area. Dependent upon the results of the consultation, USFWS may require a survey for T & E plants. Appendix C, Table 8 contains the contact information for the USFWS Wyoming Field Office in Cheyenne and the Wyoming Game and Fish Department.

C.5 Weed Survey

Wyoming Weed and Pest Control Act designated or prohibited weeds (Appendix C, Table 8)

that may be present in the proposed permit area should be listed. Additionally, any weeds listed by the local Weed and Pest office in the county of the proposed permit should also be included. Appendix C, Table 2 contains contact information for county Weed and Pest offices. The weed list for the proposed permit should include some indication of the abundance of the weeds present [Ch. 2, Sect. 2(b)(II)].

C.6. Species Inventory

An inventory of all plant species observed in the proposed permit area should be compiled during the initial field mapping and updated during field sampling. This list should include plant species observed in addition to those recorded during sampling. The plant species should be listed by scientific binomial and common name under life-form categories (e.g. annual grasses, perennial grasses, grass-like species, forbs, succulents, full shrubs, subshrubs, trees).

C.7. Production Data for Cropland or Hayland

Land units which have been managed as cropland or hayland (see glossary for definitions of "cropland and hayland") should be delineated and identified on the vegetation map. Cropland and Haylands do not need to be sampled for any of the vegetation parameters outlined in Section I.C. The current and historical management of these lands and their production must be provided. Harvest data should be presented in units of grams per square meter and tons per acre or bushels per acre. Production sampling of croplands and haylands may be needed if there is no historic data or if there is no area that can be used as a reference area. The sampling plan should present the procedures that will be used on croplands and haylands. The historical production data, a reference area or average area agricultural statistics information may serve as reclamation success standards per **Chapter III, Section 2(d)(vi)(F).**

C.8. Photos

A 3 1/2" x 5" (or larger) photograph or a 2-3 frame panoramic sequence showing the general features of each community type and REFA should be provided in the vegetation report. High quality color copies are acceptable. The location of all photographs should be noted on the vegetation map.

C.9. Other Data Collection

Additional information may be required. Potentially, vegetation production data may be required for in-situ leaching (ISL) operations as part of the baseline (see Appendix B for procedures).

C.9.a. Wetlands

Surveys for wetlands may be necessary. Surveys for wetlands may be performed at the same time as the other vegetation surveys but the results will be presented in Appendix D-10.

C.9b. Tree Density and Composition

Trees must be counted. If there are few trees, direct counts may be the most accurate and efficient method. If there are many trees then, in conjunction with the cover transects, using the Point-Center-Quarter plotless method or belt transects is acceptable. The trees will also be classified in size in the following manner and their species recorded:

- 9 inch or greater DBH (timber)

- 6 to 9 inch DBH (poles)
- Less than 6 inch DBH (neither)

D. General Format for Appendix D-8

The following is a suggested outline for organization of Appendix D-8.

1. Table of Contents - A summary of the major entries, including lists of figures, tables, and maps.
2. Introduction - A description of the location and general features of the proposed permit area and the personnel (or firm) conducting the baseline inventory.

3. Methods - A description of <u>all</u> procedures used in the baseline inventory, which includes:
   1) Delineation and mapping of plant communities, REFAs and other land units.
   2) cover sampling of plant communities;
      a. Specific calendar dates of all sampling
      b. Selection of sample points
      c. Transect procedures
      d. Sampling intensity and confidence level reached
   3) Selection and Sampling REFAs;
   4) Species List;
   5) Data for Cropland or Hayland;
   6) Any Other Required Data.

4. Results and Discussion - A presentation and interpretation of the vegetation data, to include:
   1) Description of plant communities or other land units.
   2) Description of each REFA and discussion of its representative nature.
   3) Tabular summary of the total acreage of each vegetation community and affected acreage of each vegetation community (see Table 1, Appendix C).
   4) Summarized cover sampling data for each vegetation community (see Table 3, Appendix C).
   5) Evaluation of sample adequacy and confidence level achieved for each vegetation community (see Table 2, Appendix C).
   6) Species list, selenium indicators, species of special concern and noxious (designated) or declared weeds (see Tables 7 and 8, Appendix C).
   7) Results of other data if required.

5. Literature Cited

6. Raw Data

E. Literature Cited

Mueller-Dombois, D. and H. Ellenberg. 1974. Aims and Methods of Vegetation Ecology. John Wiley & Sons. New York, New York.

Daubenmire, R. 1970. Technical Bulletin 62. Washington State University College of Agriculture. Pullman, Washington. 131 p.

SECTION 2. DEVELOPING A REVEGETATION PLAN

A. Introduction

This section of Guideline 2 details the information required in the Reclamation Plan for revegetation for Regular Mining, Large-Scale Exploration by Dozing and In Situ Mining operations. Practices for revegetation are also described in this section.

Table 1. Required revegetation information for Reclamation Plan for three noncoal operations.

Proposed noncoal operation	Required Reclamation Plan Revegetation information	Applicable Wyoming Statute or DEQ-LQD Noncoal Regulation
Exploration by Dozing (LE) >40 acres in any 4 contiguous 40 ac parcels (40 ac = 1/16 of a section)	Application shall conform to requirements governing surface mining (See Regular Mine).	Ch. 5,Sec.1(c)(ix) and Ch. 2, Sec. 2(b)(iii)(C)
Regular (a. k. a. Large) Mine	A plan to assure revegetation of all affected land in accordance with Ch. 3, Sec. 2(d). The plan shall include the method and schedule of revegetation, including but not limited to species of plants, seeding rates, seeding techniques, mulching requirements or other erosion control techniques, and seeding times to be used in a given area for reclamation purposes.	Ch. 2, Sect. 2(b)(iii)(C)
In Situ Leaching (ISL)	Application shall conform to requirements governing surface mining (See Regular Mine).	W. S. §35-11-428(a)(iii)(G) Ch. 2, Sect. 2(b)(iii)(C) Ch. 11, Sect. 5(a)

B. General Considerations (Land Use and Plant Communities)

The goal of reclamation is to establish a permanent and self-renewing vegetative cover that will stabilize the site, restore wildlife habitat and support the proposed land uses. The reclaimed Grazinglands must have equal or better cover than the REFA and the reclaimed Croplands must have equal or better production then the REFA or the County average. Reclamation is not expected to restore the exact pre-mining plant communities because pre-mining conditions cannot always be duplicated and communities may have been in poor condition due to historic mismanagement. Reclamation should reestablish functionally equivalent or superior plant communities that will support the proposed future land uses.

The following information should be considered in the development of the revegetation plan:

- The **composition of the pre-mining plant communities**, to include the major life

forms, plant species and the distribution of these communities on the landscape.

- The **pre-mining land uses** and the plant communities and species that support those uses. The pre-mine native vegetation is generally the best indicator of what plant species are adapted for the site specific conditions. This is particularly true in the semi-arid environments in Wyoming.

- The **proposed land uses** and the plant communities and species that will contribute to those land uses. The proposed land uses should be of equal or higher value or utility than the pre-mining uses. The proposed uses should be specific. Proposed changes in land use from premining land use will require administrator approval.

- The **topography of the reclaimed landscape** and the plant communities and species that will be adapted to different positions in that landscape. Different plant communities should be designed for different environments in the reclaimed landscape. Bottom-lands and drainage-ways should be planted with a seed mix designed for moist sites. Upland areas should be seeded with a seed mix consisting of species with lower water requirements. The distribution of different plant communities on the reclaimed land should generally attempt to mimic the distribution of communities in the pre-mine landscape, both in terms of location and areal extent.

- **Reestablishment of wildlife habitat**. Generally, wildlife will benefit from the establishment of diverse landforms with a diversity of plant communities, species and life forms, including shrubs. Recommendations of the Wyoming Game and Fish Department and the U.S. Fish and Wildlife Service should be incorporated into the revegetation plan. For areas containing designated critical or important habitat, the Wyoming Game and Fish Department shall be consulted for recommended reclamation standards for shrub density, cover, distribution and species composition. For US Forest Service Lands the US Forest Service will be contacted about Sensitive Plant Species.

- **Input and concurrence of the surface landowner**. The surface owner should be contacted for input on seed mixes.

C. Current and Historical Land Use

The best available information on the historical and current management of the lands proposed for disturbance should be presented. For grazinglands the approximate carrying capacity of the land in AUMs should be presented. For croplands, historical production data should be provided and the source of this information identified.

D. Seed Mixes

Different seed mixes should be developed for each of the plant communities to be established on the reclaimed landscape. In order to insure the development of diverse plant communities, the seed mixes should be composed of some different species and life forms all of which must be self-renewing except for Cropland. The major native species identified in the baseline survey should be major components of the seed mixes for each of the plant communities. After considering seed availability, growth form, seasonal variety, prevailing dominant species, soils, topography, climatic conditions and postmine land use; each proposed seed mixture should:

1) Contain no fewer than four (4) herbaceous species, unless the postmine land use is of managed cropland requires fewer species;
2) In general, all seed mixes should total at least 10 pounds pure live seed per acre

(PLS) when drilled and the application rate should be doubled when broadcasted;

3) Contain the native dominant herbaceous species which support the postmining land uses(s);

4) Contain native forb species if natural reinvasion of forbs will be limited by site conditions;

5) Contain full shrub and/or subshrub species when these species will support the postmining land use of Grazingland. If appropriate, to increase postmining species diversity, shrub mixtures may be developed and seeded separately from the herbaceous mixtures;

6) Introduced species, such as crested wheatgrass, alfalfa, yellow sweet clover and smooth brome grass should be avoided unless they are for a specialized land use that will be managed for haying.

LQD suggests that a list of alternative species for each life form be developed in the event that species in the seed mix are not available.

The proposed postmining location of each seed mixture should be illustrated on a postmining contour map.

Seed mixtures for temporary stabilization of sites, stockpiles or other special uses should also be developed considering site-specific characteristics. The LQD strongly discourages the use of aggressive introduced plant species, particularly crested wheatgrass, on topsoil stockpiles. The concern lies in the possible carryover of such species to postmine lands during the replacement of stockpiled topsoil, which could ultimately result in problems (on the permittees part) in meeting species diversity requirements at the time of revegetation success due to the predominance of the above mentioned introduced species. Other native, vigorous, rhizomatous species are readily available for such uses.

E. Seeding Practices

A proper seedbed must be prepared by tilling the soil prior to seeding. Tillage may include ripping, chiseling, scarifying, plowing, or disking operations. The intent is to relieve compaction, break up any surface crust and create a rough and friable soil surface that will allow moisture penetration. **As per Non-Coal Rule and Regulation Chapter 3, Section 2(d)(iv) drill seeding shall be on the topographic contour, unless for safety reasons it is not practicable, or perpendicular to the prevailing wind on flat areas**.

As per Non-Coal Rule and Regulation Chapter 3, Section 2(d)(iv) seeding of affected lands shall be conducted during the first normal period for favorable planting conditions. This is generally after October 15 and before May 1 to take advantage of winter and spring moisture. Seeding should not be conducted when the soils are powder dry, frozen or muddy. Seeding depth should be 1/4 to 1/2 inch when drilled. Small seeded species (i.e. big sagebrush, winterfat, blue grama etc.) establish best when the seed is broadcast and lightly covered and should not be placed too deep. Often it is more effective to broadcast the small seeds separately.

Broadcast seeding should be utilized on rough surfaces where a drill cannot be maneuvered. The seed should be **lightly** covered after broadcasting by pulling a light drag or harrow over the surface. Care should be taken not to bury the seed too deeply. If the soil surface is very rough then dragging to cover the seed may not be necessary. The seeds will fall into cracks and will be covered as the surface weathers.

Mulching is recommended because it improves soil moisture retention and soil stability.

Mulch should be applied at a rate of 1-2 tons per acre. The mulch should be crimped into the soil using a mulch crimper. The mulch should contain only plant species that are beneficial to the reclamation if volunteer seeds became established. Straw mulch is recommended because it has the stem length and the volunteer plants stop regenerating within a few years. However native hay mulch may be used only if it contains native species. Often native hay mulch does not have the stem length and contains introduced species and weed seeds.

A seeded stubble mulch is an acceptable alternative to crimped hay or straw. The seeded mulch, generally a grain crop, is planted one growing season before the final reclamation seed mix. The reclamation seed mix is then drilled into the standing stubble.

F. Vegetation Maintenance and Husbandry Practices

The Permittee should list the postmining maintenance and husbandry practices it expects to use on revegetated communities and briefly describe how they will be used. The husbandry and maintenance practices generally accepted are grazing, mowing, haying, fertilizing, and weed control.

Chapter 3, Section 2(d)(viii) requires that newly seeded areas must be protected from livestock grazing for a minimum of two (2) years or until the vegetation community is capable of renewing itself under proper management practices. The newly seeded areas must be protected by fencing or other management practices which meet the intent of this rule.

G. Restoration of Wildlife Habitat

As required by **Chapter 3, Section 2(a)(ii).** Operators are required to restore wildlife habitat, whenever the Administrator determines that this restoration is possible, on affected land in a manner commensurate with or superior to habitat conditions which existed before the land became affected, unless the land is private and the proposed use is for a residential or agricultural propose which may preclude its use as wildlife habitat. This requirement is met by seeding a diverse seed mix consisting of native species.

For areas containing designated crucial, critical or important habitat, the Wyoming Game and Fish Department shall be consulted for recommended reclamation standards for shrub and/or tree density, cover, distribution and species composition.

H. Wetlands Mitigation

Reclamation plans for postmining mitigation of jurisdictional wetlands shall be reviewed and approved by the US Army Corps of Engineers (ACOE) and the WDEQ/LQD and incorporated into the permit application. The seed mix should be listed under the seed mixes for reclamation. The location of the wetlands should be shown on the Reclamation Plan map.

I. Plan for Measuring Revegetation Success

The Reclamation Plan should contain a discussion of the permittees proposed methods for evaluation of revegetation success or a commitment to follow Section III of this Guideline for Revegetation Success. If a discussion on the proposed methodology is included it should address all qualitative and quantitative success goals using the procedures described in Section III of this Guideline. R & R Chapter III Section 2(d)(vi) defines the following success goals for:

A. Grazingland

The following should to be addressed for success:

1) Postmining cover is equal to premining cover, tested by comparing reclamation to the REFA for one year.

2) Species composition and species diversity capable of supporting the postmining land uses.

B. Fish and Wildlife Habitat

The following should be addressed for success:

1) Areal distribution of shrubs and trees on the postmining landscape.

2) Species occurring and estimated density of each.

3) Methods used to establish shrubs and trees.

4) Assessment of the quantitative and qualitative aspects of the postmining shrub and tree communities in terms of providing wildlife habitat.

C. Cropland

The following should be addressed for success:

1) Productivity must be at least equal to the REFA for two consecutive years or;

2) Productivity must be at least equal to County wide average for two consecutive years.

D. Other Land Uses

Success standards for the postmine land uses of commercial, residential, developed water resource, recreation and forestry will be determined by the WDEQ/LQD on a site by site basis.

J. Format for Reclamation Plan

The discussion of elements A - F should be formatted for the Reclamation Plan. The Table of Contents for the Reclamation Plan should include all tables, figures and maps. Also all pages should be numbered with unique numbers. The following elements should be included in the Reclamation Plan.

A. General Considerations. This section should list the current and historical land uses and the plant communities that will support those land uses with the acreage planned for each postmine vegetation community.

B. Seed Mixes. This section should include a table that lists all seed mixes that will be used for permanent and temporary reclamation. The location of where each seed mix will be applied should be shown on the Reclamation Plan map.

C. Seeding Practices. This section should include a discussion of the tilling, seeding, time of seeding and mulching practices that will used for seeding the permanent and temporary reclamation.

D. Vegetation Maintenance and Husbandry Practices. This section should include a discussion of the protection of the reclamation, husbandry practices and weed control that will be used on the reclamation.

E. Restoration of Wildlife Habitat. This section should include a discussion of the wildlife habitat that will be restored.

F. Plan for Measuring Reclamation Success. This section should include a discussion on the methods that the Permittee will use to measure their reclamation success.

G. Reclamation Plan Map. A map should be submitted showing the location of each proposed postmine vegetation community. The base for the map should be on the proposed reclaimed topography contour map. The scale should be 1" equals 500 feet or greater. The preferable contour interval is 5 feet.

Section 3. Evaluation of Revegetation Success (Bond Release)

A. Introduction

This section of Guideline 2 details the information required for measuring and obtaining revegetation success for Regular Mining, Large-Scale Exploration by Dozing and In Situ Mining operations. The statistical procedures are also described in this section.

Table 1. Required information for revegetation success for three noncoal operations.

Proposed noncoal operation	Required Revegetation information	Applicable Wyoming Statute or DEQ-LQD Noncoal Regulation
Exploration by Dozing (LE) >40 acres in any 4 contiguous 40 ac parcels (40 ac = 1/16 of a section)	Application shall conform to requirements governing surface mining (See Regular Mine).	Ch. 5,Sec.1(b) and Ch. 3,Sec.2(d)(vi)
Regular (a. k. a. Large) Mine	The Administrator shall not release the entire bond of any operator until such time as revegetation is completed, if revegetation is the method of reclamation as specified in the operator's approved reclamation plan.	Ch. 3, Sect. 2(d)(vi)
In Situ Leaching (ISL)	Application shall conform to requirements governing surface mining (See Regular Mine).	W. S. §35-11-428(a)(iii)(G) Ch. , Sect. 2(d)(vi) Ch. 11, Sect. 5(a)(xii) Ch. 3, Sect. 2(d)(vi)

Chapter 3, Section 2(d)(vi) defines the following success standards for all operators.

Revegetation shall be deemed to be complete when:

1) The vegetation species of the reclaimed land are self-renewing under natural conditions prevailing on the site;
2) The total vegetation cover of perennial species (excluding noxious weed species) and any species in the approved seed mix is at least equal to the total vegetation cover of perennial species (excluding noxious weed species) on the area before mining;
3) The species diversity and composition are suitable for the postmining land use;
4) The requirements of (1), (2), and (3) are achieved during one growing season, no earlier than the fifth full growing season on the reclaimed lands.

The success standards for cropland and hayland are defined in **Chapter 3, Section 2(d)(vi)(F).** When the approved reclamation plan is to return to cropland, reclamation shall be deemed to be complete when productive capability is equivalent, for at least two consecutive crop years, to the premining conditions or approved reference areas. For cropland and hayland the productivity must be at least equal to the REFA or County wide average for cropland or hayland for two consecutive years.

The five full growing seasons begin after fertilizing, seeding, irrigation or other work to ensure revegetation has been completed.

B. Sampling Plan

It is recommended to submit a plan for sampling for revegetation success and have it approved by the WDEQ/LQD before sampling. An approved sampling plan describes acceptable methodology and when followed will avoid resampling. The components of a sampling plan should include the following.

- Table listing the proposed Sample Units and their acreage
- Reference area that will be used for comparison
- Methods that will be used for sampling
- Statistical procedures identified
- Map showing the reclaimed area and the reference area

C. Sampling Procedures for Evaluating Revegetation Success

The qualitative and quantitative vegetation information which will be required for revegetation success includes:

1) Map of the of the Sample Unit(s) and Reference Areas (REFAs)
2) Species list for each Sample Unit
3) Cover Data for Sample Unit(s)
4) Data for Cropland or Hayland (if applicable)
5) Species Diversity and Species Composition
6) Any Permit specific requirements such as shrub reclamation, tree replacement etc.

C.1. Sample Units

The operator may need to separate the proposed revegetation success area into several Sample Units. This decision is based on several factors. If the area has multiple plant communities, then each vegetation community should constitute a separate Sample Unit. Differences in vegetation communities may occur because of seed mix composition, topsoil depth, date of seeding, or topography. Grouping of noncontiguous areas should be approved by WDEQ/LQD.

C.2 Reference Areas (REFA)

The REFA that was established during baseline sampling should be used. Where a REFA was not established during baseline or the REFA(s) was disturbed, another type of land unit may be established for purposes of evaluating revegetation success. These units, termed Comparison Areas (COMA), are selected in cooperation with LQD, and included in the sampling plan. The COMA is representative for vegetation, soils, and topography of the reclaimed area before it was disturbed. When evaluating revegetation success, data from the REFAs or COMAs are directly compared by statistical procedures to data from a reclaimed vegetation community.

A REFA or COMA should be at least five acres in size.

C.3. Mapping of Plant Communities

The Sample Unit and REFA should be delineated on an aerial mosaic photograph or topographic base map. The map shall include:

- The boundaries of each Sample Unit and REFA;
- The location of each sample point and transect direction;
- The location of any wildlife features;

- The general location of trees;
- The location, orientation and identification of each photograph.
- A map title and legend

The map should be at a scale of 1" equals 500 feet or greater and should be the same as used in other sections of the revegetation success application.

C.4. Sampling for Vegetative Cover

Cover sampling shall be gathered using point-intercept transects or quadrats. Sample Units and REFAs should not be grazed prior to and during sampling. The reclamation and REFA should be sampled for the following parameters:

1) % absolute vegetation cover by species;
2) % absolute vegetation cover (= sum of all species);
3) % absolute cover lichens and moss;
4) % absolute bare ground;
5) % absolute rock cover;
6) % absolute litter cover; and
7) % absolute total ground cover (= vegetation + litter + rock + lichens + moss)

For sampling purposes, rock may be considered any stone or mineral matter at least one square centimeter in size. Litter is any plant part lying on the ground surface, whose structural integrity remains recognizable. Cover data for annual species and noxious weeds will be collected but these values will not contribute to the evaluation of revegetation success for percent total vegetation cover. Cover data for lichens and moss will be collected but will not count as vegetation cover.

C.4.a. Cover Sampling - Timing of Sampling

Cover sampling should occur during peak herbaceous production usually June-July. Sampling for all areas should occur within a three-week period. Grazing should be withheld until after sampling.

C.4.b. Cover Sampling - Choosing Sample Locations

The location of all sample points shall be chosen by random or systematic procedures, in accordance with the following considerations:

1) The same procedures shall be used for choosing sample locations in each Sample Unit and corresponding Reference Area;

2) Sample locations shall be readily located in the field, such as by pacing from easily identifiable landmarks or by use of Global Positioning System equipment;

3) Sample locations that fall within a barren or otherwise seemingly atypical area shall not be discarded only because the area is barren or atypical; although; and

4) Areas obviously disturbed by human activities shall be excluded from sampling.

Random procedures are discussed in most standard statistical texts. The selection of sample locations must be done objectively in the lab or office, not in the field. For a 50 meter transect, grid line intervals (when used) should be no more than 65 meters on the ground.

The method of determining the starting point and direction of the transect should be clearly described in the methodology section of the permit.

Systematic samples are acceptable only if each vegetation community is entirely covered and *all*

sample points are sampled (see glossary for definition). Calculations for systematic samples may be done by assuming the sample is random.

C.4.c. Cover Sampling – Point Intercept and Quadrat Requirements

The following apply to the use of point-intercept transects:

1) All transects shall be at least 50 meters in length. Each transect shall have a minimum of 50 points per transect, unless otherwise approved in the sampling plan prior to the initiation of sampling.
2) Transects shall be the same length and have the same number of sample points along each transect in a Sample Unit and associated REFA;
3) The orientation of each transect shall be randomly established;
4) If a transect runs out of the Sample Unit or REFA, a new random orientation will be selected, at the point where the transect leaves the Sample Unit or REFA, which will return the transect to the Sample Unit or REFA.
5) Point samples shall be determined using a pin drop, ocular sighting device, such as a laser or cross-hairs, or a sharpened rod(s) in a fixed frame projected vertically downward to the sample location on the transect; and
6) Each transect comprises a sample size (n) of one (1) for statistical calculations.

The following apply to the use of cover quadrats:

1) Each quadrat shall cover a minimum of 0.5, but not more than 1.0 square meter.
2) A method that determines percent cover by areal extent at the 1% level shall be used.
3) Sample Units and REFAs shall use the same quadrat size.
4) If multiple quadrats are used along a transect, a minimum of two quadrats shall be arranged evenly along each transect. The quadrats will be averaged and considered a sample size (n) of (1) for statistical calculations.
5) Each quadrat (or the average of quadrats along a transect) shall be considered one observation for statistical calculations;

C.4.d. Sample Intensity and Statistical Tests

To determine the adequate sample size and the statistical procedures for revegetation success see Addendum A.

Table 1 (below) lists minimum sample sizes to be used in the statistical tests in Addendum A based on the size of the reclamation and REFA. All areas must be sampled to the minimum sample size.

Table 1

#acres		minimum sample size
< 2	description and photographs	
Reclamation and REFA area less than 10 acres		10 transects
Reclamation and REFA more than 10 acres		20 transects

The Permittee should always present analyses of sample adequacy using the nmin formula. Sample adequacy shall be based on total vegetation cover including the species lacking credible value (SLCV). If adequacy is not met, the Permittee should provide the confidence level. These analyses are best presented in a tabular format (see Appendix III, Table 2). In order that LQD personnel may check these data, all input factors for the formula must be presented.

C.5 Species List

An inventory of all plant species observed within each Sample Unit and Reference Area should be compiled. This list should include plant species observed but not actually recorded during sampling in accordance with the following requirements:

1) The species list should be compiled during the initial field mapping and updated during the field sampling.

2) The plant species should be listed by scientific binomial and common name under life-form categories for each vegetation community. Suggested categories include annual grasses, perennial grasses, grass-like species, forbs, succulents, full shrubs, subshrubs, trees, and weeds.

C.6. Describing the Vegetation Communities

Each reclaimed vegetation community and the representative REFA should be verbally described. The description should include the general vegetation composition, the dominant plant species, characteristic topography, soil types, average slope, aspect and interspersion with or relationship to other community types. The land use and any special wildlife habitat should be noted in the description.

The presence of selenium indicators (Appendix II) should also be noted and their distribution discussed.

A 3 1/2" x 5" (or larger) photograph or a 2-3 frame panoramic sequence showing the general features of each reclaimed community type and the REFA should be provided in the vegetation report. High quality color copies are acceptable. The location of all photographs should be noted on the vegetation map.

C.7. Evaluation of Restored Cropland or Hayland

Sampling for total annual herbaceous production on lands which carry the cropland land use designations shall be conducted in accordance with one of the following methods:

1) Total annual herbaceous production may be estimated on the crop and Sample Unit and approved cropland Reference Area using quadrats as described in Addendum B. The sample numbers in Table 1 above apply; or

2) Total annual herbaceous production may be evaluated on the cropland Sample Unit by harvesting the entire crop. The cropland harvest shall be compared to appropriate county production data for the same harvest year. Alternatively, total harvest may be compared to production from a nearby cropland unit for the same harvest year. No statistical test is used.

C.8. Evaluation of Shrub and Tree Density

Chapter III, Section 2(a)(ii) requires that wildlife habitat be restored on affected land in a manner commensurate with or superior to habitat conditions which existed before the land became affected. In order to evaluate the success of wildlife habitat restoration techniques used on the affected area, the operator should present a discussion of the following parameters:

1. Areal distribution of shrubs and trees on the postmining landscape.
2. Species occurring and number or estimated density of each. (direct count or plotless field method)
3. Methods used to establish shrubs and trees.
4. Assessment of the quantitative and qualitative aspects of the postmining shrub and tree communities in terms of providing wildlife habitat.

C.9. Species Composition and Species Diversity

Chapter 1 of LQD Rules and Regulations defines species composition as the "...number, kinds, amount and quality of species" and species diversity as the "...number of species per unit area". Chapter 3, Section 2(d)(vi) establishes suitable postmining species diversity and composition as revegetation success goals for all operators.

Table 4 in Appendix III. Table 4 should be completed and a discussion that includes the following:

- Discussion of the reclaimed community species and their ability to support and maintain the postmining land uses;
- The role of these species in secondary succession;
- A qualitative comparison of the species composition of the premining and postmining communities.

D. Suggested Timetable for Components of the Revegetation Success Vegetation Sampling

Create Sampling Plan	Any time - discuss with WDEQ/LQD well in advance of field sampling season.
LQD inspection	Prior to field sampling and LQD approval of sampling plan.
LQD approval of Sampling Plan	Prior to field sampling.
Construct species list	First list should be generated in the spring when forbs are blooming and the list updated at the time of sampling.
Sample for vegetation parameters. REFAs and Sample Units should be sampled at the same time to permit valid comparisons of data.	June through August, depending on period of peak herbaceous production. Sampling must be completed within a three week period and grazing withheld until after sampling has been completed.

E. Elements of a Revegetation Success Application

The components of a complete proposal for an evaluation of revegetation success should contain the following:

1) Table of Contents - A summary of the major entries, including lists of figures, tables, and maps.

2) Introduction - A description of the location and general features of the permit area, the areas contained in the revegetation success application, and the personnel (or firm) conducting the revegetation success vegetation inventory.

3) Background – a brief discussion on the following:
   a. The pre and postmine land use of the Sample Unit
   b. Acreages of the Sample Unit and REFA
   c. The reclamation practices to include approximate topsoil depth, seed mix and rate, seeding date(s) and husbandry practices used such as weed control, fertilizing and grazing.
   d. The management practices used on REFA

4) Methods - A description of procedures used for measuring the following:
   a. Cover sampling for Sample Unit(s) and REFA to include dates of sampling.
   b. Species Inventory to include dates of collection.
   c. Diversity
   d. Shrub and Tree stocking
   e. Evaluation procedures and dates for cropland or hayland if applicable.

5) Results for each Sample Unit
   a. A map showing the location of Sample Unit and its corresponding REFA which includes the sample locations and photo locations.
   b. Cover Sampling data summary (see Appendix III, Table 5 for presentation)
   c. Results of statistical analysis for cover (Follow flow Chart in Addendum A)
   d. Evaluation of sample adequacy or confidence level and its representative REFA (Appendix III, Table 6).
   e. Species Inventory
   f. Diversity Evaluation
   g. Shrub and/or Tree Inventory and Evaluation
   h. Evaluation of Productivity for cropland or hayland if applicable.

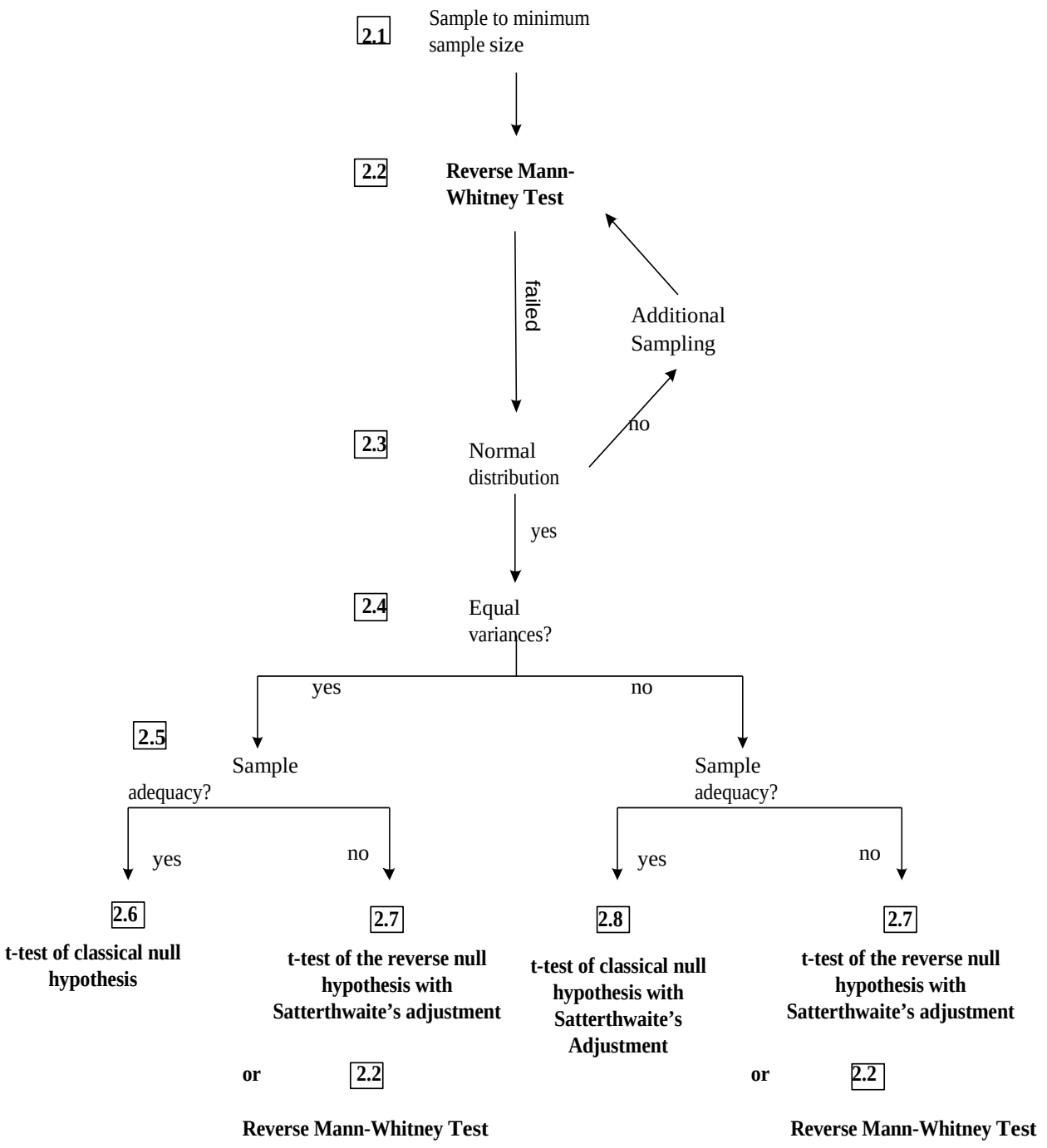
6) Literature Cited

7) Raw Data

Addendum A – Statistical Procedures for Revegetation Success Evaluation

This addendum provides the statistical procedures approved by LQD for revegetation success evaluation. The flowchart contains a set of sequential questions to be answered "yes" or "no" by the user. Each pathway through the flowchart will end in a statistical procedure that is appropriate for that particular data set. Examples of most of the equations are attached. The flow chart and equations are for comparing the reclaimed (Sample Unit) to a Reference Area (REFA).

Two-Sample Procedures for Comparison to a REFA, Control, or Comparison Area



Additional samples may be collected for re-evaluation of the data if the minimum sample size does not yield successful test results or sample adequacy.

Equations and Procedures

2.1 LQD Minimum Sample Size

Reclamation and REFA area less than 10 acres	10
Reclamation and REFA more than 10 acres	20

2.2 Mann-Whitney Test of Reverse Null Hypothesis

The reverse null hypothesis for the Mann-Whitney reverse null test is that the revegetation values tend to be less than 90% of the REFA values.

$$H_o : revegetation\ values \leq 0.9 * reference\ values$$
$$H_a : revegetation\ values > 0.9 * reference\ values$$

•Evidence in support of revegetation success is obtained when the null hypothesis is rejected.
•There are no assumptions that need to be met for this test.
•With small sample sizes (≤20), there are exact probabilities of observing the sum of the ranks when the null is true (Addendum A, Table 4). When testing sample sizes greater than 20, calculate the approximate Z statistic and compare the calculated value to the critical Z value in Appendix VI, Table 1.

The approximate test statistic for sample sizes beyond the values in Appendix VI, Table 4 is:

$$Z = \frac{\sum_{i=1}^{n} R(br_i) + \frac{1}{2} - n_{br}\frac{(n_{br} + n_{ref} + 1)}{2}}{\sqrt{\frac{n_{br} n_{ref}(n_{br} + n_{ref} + 1)}{12}}}$$

where $\mathbf{R(br_i)}$ are the ranks of the observations in the revegetation sample,
$\mathbf{n_{br}}$ is the revegetation sample size, and
$\mathbf{n_{ref}}$ is the REFA sample size.

Before ranking the entire dataset, every observation in the REFA sample is multiplied by 0.9. Ranks are determined by sorting the combined observations from both data sets from smallest to largest value. Ranks are then assigned starting with 1, and ending with the combined sample size (n_{ref} + n_{br}). Equal values are given equal ranks, determined by calculating the average of the summed rank values. For example, two equal values might be ranked 9 and 10, so each would be assigned a rank of 9.5. The ranks are then summed for the revegetation area ($R(br_i)$). (**see Example 2.2**).

Revegetation is successful when the one-sided null hypothesis is rejected: the test statistic is greater than

$Z_{1-\alpha}$, the conclusion is that the values from the revegetation distribution tend to be greater than 90% of the values from the REFA distribution.

2.3 Assessment of Normality in Dataset

Normality may be assessed using a Normal Probability Plot, the Shapiro-Francia Test described below, or by evaluating the distribution of the plotted data. If a t-test is used for revegetation success evaluation, the data must meet the assumption of a normal distribution.

Normal Probability Plot

A normal probability plot is created by plotting the ordered sample data against a sample of the normal order statistics. The normal order statistics are calculated by adjusting the ranked data and calculating the inverse of the cumulative standard normal distribution:

$$p_i = (R_i - .5)/n$$
$$z_i = \Phi^{-1}(p_i)$$

Where R_1 are the ranks of the data, n is the sample size, p_i are the transformed ranks used for calculating the order statistics, ϕ^{-1} is the inverse cumulative standard distribution function, z_i are the normal order statistics. The rank of an observation is its position among the set of observations when arranged from the smallest to largest. The order statistics represent the expected values of the data if they came from a normal distribution. If the data are normally distributed, the actual data will be close to the expected values and the plot will be a straight line. Extreme non-normality is present if the graph is visually very different from a straight line. (see Example 2.3 Normal Probability Plot).

Shapiro-Francia Test

The Shapiro-Francia test with alpha equal to 0.01 is used to test if a data set is normally distributed. The null hypothesis for the Shapiro-Francia test states that the sample data are normally distributed. The test statistic is:

$$W' = \frac{(\sum_{i=1}^{n} b_i y_i)^2}{\sum_{i=1}^{n} (y_i - \overline{y})^2}$$

with

$$b_i = \frac{z_i}{(\sum_{i=1}^{n} z_i^2)^{\frac{1}{2}}}$$

where y_i is the sample data, $\overline{y}$ is the sample mean, n is the sample size, and z_i is the order statistic corresponding to y_i. We reject the null hypothesis when the test statistic is small, i.e. the probability of observing the test statistic under the null hypothesis of normal data is small (less than 0.01). The data meet the assumption of normality when the test statistic W' ≥ the critical value, and the conclusion is that the regular t-tests give precise approximations for p-values. The data do not meet the assumption of normality when the null hypothesis is rejected (the test statistic W' < the critical value determined using Table 2) (**see Example 2.3 Shapiro-Francia Test**).

2.4 Equal Variances - Levene's Test for Homogeneity of Variance

Levene's test is used to determine if the variances in two sample populations are "substantially" different, which would invalidate the two-sample t-test for differences in means. The two-sample t-test for differences in means is precise (robust) for approximately normal data unless the variances are quite different. For this reason, Levene's test of equal variances is conducted at the conservative level of alpha

= 0.01 (two-sided test), making the test fairly easy to pass. The null hypothesis for Levene's test states that the variance of the revegetation sample data is equal to the variance of the REFA sample data.

$$H_o : \sigma_{br}^2 = \sigma_{ref}^2$$
$$H_a : \sigma_{br}^2 \neq \sigma_{ref}^2$$

The test statistic is the two-sample t-statistic for the absolute deviations of every observation from the sample mean. For each sample, calculate the absolute deviations for each observation as

$$Z_{br_i} = \left| y_{br_i} - \overline{y}_{br} \right|$$
$$Z_{ref_i} = \left| y_{ref_i} - \overline{y}_{ref} \right|$$

and test for differences between the mean Zbr and mean Zref using the two-sample t-test. The variances are unequal if the null hypothesis is rejected; the test statistic is less than $t_{.005,nbr + nref-2}$ or greater than $t_{.995,nbr + nref-2}$. If variances are unequal, then the Satterthwaite's adjustment must be used (**see Example 2.4 Levene's Test**).

2.5. Two-sample Sample Adequacy Formulas with Alpha Adjustment

In all two-sample situations, use the one-sample sample adequacy formula for each sample (revegetation and REFA) with an adjustment to the alpha level to account for the fact that two samples are to be compared. This will result in different sample sizes for each sample, with more samples required for the more variable sample. The number of samples for each area required to ensure 90% confidence (α =0.10) that each sample mean will be within 10% (d) of the true mean simultaneously is:

$$n = \frac{(sz)^2}{(d\overline{x})^2}$$

where **n** is the number of sample points needed within each study area,
s is the sample standard deviation for the respective study area,
z is the critical value from the normal distribution with .025 in each tail (1.96),
d is the percentage of the sample mean that constitutes an acceptable difference between the sample mean and the true population mean (0.10), and
$\overline{x}$ is the sample mean (**see Example 2.5 Sample Adequacy**).

2.6 Two-sample T-Test of Classical Null Hypothesis

The one-sided null hypothesis for the classical two-sample test is that the mean of a given vegetation parameter in the revegetation area (μ_{br}) is equal to or greater than the mean in the REFA (μ_{ref}).

$$H_o : \mu_{br} - \mu_{ref} \geq 0$$
$$H_a : \mu_{br} - \mu_{ref} < 0$$

Evidence in support of revegetation success is obtained when the null hypothesis is accepted. Assumptions for this test include approximate normality of both data sets, independence of observations, and approximate equality of variances between the two groups.

The test statistic is:

$$t = \frac{\overline{x}_{br} - \overline{x}_{ref}}{\sqrt{\frac{(n_{br}-1)s_{br}^2 + (n_{ref}-1)s_{ref}^2}{(n_{br}+n_{ref}-2)}(\frac{1}{n_{br}} + \frac{1}{n_{ref}})}}$$

where

$\overline{x}_{br}$ is the revegetation sample mean,

$\overline{x}_{ref}$ is the REFA sample mean,

s^2_{br} is the revegetation area variance,

s^2_{ref} is the REFA variance,

n_{br} is the revegetation area sample size, and

n_{ref} is the REFA sample size.

Revegetation is successful when the one-sided null hypothesis is not rejected (accepted): the test statistic is greater than $t_{\alpha, n_{br}+n_{ref}-2}$. **(see Example 2.6)**

2.7 Two-sample T-Test of Reverse Null Hypothesis with Satterthwaite's Adjustment

Satterthwaite's adjustment is used in the two-sample t-test of reverse null hypothesis because the b in the hypothesis implies that the variances will not be equal (i.e., when the values in the REFA set are multiplied by b then the standard deviation is multiplied by b and the variance is multiplied by b^2).

The reverse null hypothesis states the mean of a given vegetation parameter in the revegetation area (μ_{br}) is equal to or less than 90% of the mean on the REFA (μ_{ref}).

$$H_o : \mu_{br} - 0.9 * \mu_{ref} \leq 0$$

$$H_a : \mu_{br} - 0.9 * \mu_{ref} > 0$$

Evidence in support of revegetation success is obtained when the null hypothesis is rejected. Assumptions for this test include approximate normality and independence of observations between the two groups.

The test statistic is:

$$t = \frac{\overline{x}_{br} - 0.9\overline{x}_{ref}}{\sqrt{\frac{s_{br}^2}{n_{br}} + \frac{(0.9 * s_{ref})^2}{n_{ref}}}}$$

and the degrees of freedom are:

$$df_{sat} = \frac{SE_{sat}^4}{(\frac{SE_{br}^4}{n_{br}-1} + \frac{(0.9 * SE_{ref})^4}{n_{ref}-1})}$$

where $\overline{x}_{br}$ is the revegetation sample mean,

$\overline{x}_{ref}$ is the REFA sample mean,

$\mathbf{s^2_{br}}$ is the revegetation area variance,

$\mathbf{s^2_{ref}}$ is the REFA variance,
$\mathbf{SE_{br}}$ is the revegetation area standard error of the mean,
$\mathbf{SE_{ref}}$ is the REFA standard error of the mean,
$\mathbf{SE_{sat}}$ is the denominator of the t-statistic,
$\mathbf{n_{br}}$ is the revegetation area sample size, and
$\mathbf{n_{ref}}$ is the REFA sample size.

Revegetation is successful when the one-sided null hypothesis is rejected: the test statistic is greater than $t_{1-\alpha,df_{Sat}}$. The conclusion is that the revegetation mean is greater than 90% of the REFA mean **(see Example 2.7).**

2.8 Two-sample t-test of Classical Null Hypothesis with Satterthwaite's Adjustment

Satterthwaite's adjustment is used in the standard t-test when Levene's test results in the conclusion that the variances of the two data sets are not equal at the alpha equal to 0.01 level of significance. The one-sided null hypothesis for the classical two-sample test is that the mean of a given vegetation parameter in the revegetation (μ_{br}) is equal to or greater than the mean in the REFA (μ_{ref}).

$$H_o : \mu_{br} - \mu_{ref} \geq 0$$
$$H_a : \mu_{br} - \mu_{ref} < 0$$

Evidence in support of successful reclamation is obtained when the null hypothesis is not rejected. Assumptions for this test include approximate normality and independence of observations.
The test statistic is:

$$t = \frac{\overline{x}_{br} - \overline{x}_{ref}}{\sqrt{\frac{s^2_{br}}{n_{br}} + \frac{s^2_{ref}}{n_{ref}}}}$$

and the degrees of freedom are:

$$df_{sat} = \frac{SE^4_{sat}}{\left(\frac{SE^4_{br}}{n_{br}-1} + \frac{SE^4_{ref}}{n_{ref}-1}\right)}$$

where $\overline{x}_{br}$ is the revegetation sample mean,

$\overline{x}_{ref}$ is the REFA sample mean,
$\mathbf{s^2_{br}}$ is the revegetation area variance,
$\mathbf{s^2_{ref}}$ is the REFA variance,
$\mathbf{SE_{br}}$ is the revegetation area standard error,
$\mathbf{SE_{ref}}$ is the REFA standard error,
$\mathbf{SE_{sat}}$ is the denominator of the t-statistic,
$\mathbf{n_{br}}$ is the revegetation area sample size, and
$\mathbf{n_{ref}}$ is the REFA sample size.

Revegetation is successful when the one-sided null hypothesis is not rejected (accepted): the test statistic is greater than $t_{\alpha,df\,sat}$. The conclusion is that the revegetation mean is greater than the REFA mean. (See Example 2.8)

Statistical Tables

Table 1. Critical values of the student's t distribution with specified degrees of freedom (df) and alpha. The z critical values of the normal distribution are in the last row of the table.

df	$t_{.005}$	$t_{.010}$	$t_{.025}$	$t_{.05}$	$t_{.10}$	$t_{.90}$	$t_{.95}$	$t_{.975}$	$t_{.990}$	$t_{.995}$
1	-63.657	-31.821	-12.706	-6.314	-3.078	3.078	6.314	12.706	31.821	63.657
2	-9.925	-6.965	-4.303	-2.920	-1.886	1.886	2.920	4.303	6.965	9.925
3	-5.841	-4.541	-3.182	-2.353	-1.638	1.638	2.353	3.182	4.541	5.841
4	-4.604	-3.747	-2.776	-2.132	-1.533	1.533	2.132	2.776	3.747	4.604
5	-4.032	-3.365	-2.571	-2.015	-1.476	1.476	2.015	2.571	3.365	4.032
6	-3.707	-3.143	-2.447	-1.943	-1.440	1.440	1.943	2.447	3.143	3.707
7	-3.499	-2.998	-2.365	-1.895	-1.415	1.415	1.895	2.365	2.998	3.499
8	-3.355	-2.896	-2.306	-1.860	-1.397	1.397	1.860	2.306	2.896	3.355
9	-3.250	-2.821	-2.262	-1.833	-1.383	1.383	1.833	2.262	2.821	3.250
10	-3.169	-2.764	-2.228	-1.812	-1.372	1.372	1.812	2.228	2.764	3.169
11	-3.106	-2.718	-2.201	-1.796	-1.363	1.363	1.796	2.201	2.718	3.106
12	-3.055	-2.681	-2.179	-1.782	-1.356	1.356	1.782	2.179	2.681	3.055
13	-3.012	-2.650	-2.160	-1.771	-1.350	1.350	1.771	2.160	2.650	3.012
14	-2.977	-2.624	-2.145	-1.761	-1.345	1.345	1.761	2.145	2.624	2.977
15	-2.947	-2.602	-2.131	-1.753	-1.341	1.341	1.753	2.131	2.602	2.947
16	-2.921	-2.583	-2.120	-1.746	-1.337	1.337	1.746	2.120	2.583	2.921
17	-2.898	-2.567	-2.110	-1.740	-1.333	1.333	1.740	2.110	2.567	2.898
18	-2.878	-2.552	-2.101	-1.734	-1.330	1.330	1.734	2.101	2.552	2.878
19	-2.861	-2.539	-2.093	-1.729	-1.328	1.328	1.729	2.093	2.539	2.861
20	-2.845	-2.528	-2.086	-1.725	-1.325	1.325	1.725	2.086	2.528	2.845
21	-2.831	-2.518	-2.080	-1.721	-1.323	1.323	1.721	2.080	2.518	2.831
22	-2.819	-2.508	-2.074	-1.717	-1.321	1.321	1.717	2.074	2.508	2.819
23	-2.807	-2.500	-2.069	-1.714	-1.319	1.319	1.714	2.069	2.500	2.807
24	-2.797	-2.492	-2.064	-1.711	-1.318	1.318	1.711	2.064	2.492	2.797
25	-2.787	-2.485	-2.060	-1.708	-1.316	1.316	1.708	2.060	2.485	2.787
26	-2.779	-2.479	-2.056	-1.706	-1.315	1.315	1.706	2.056	2.479	2.779
27	-2.771	-2.473	-2.052	-1.703	-1.314	1.314	1.703	2.052	2.473	2.771
28	-2.763	-2.467	-2.048	-1.701	-1.313	1.313	1.701	2.048	2.467	2.763
29	-2.756	-2.462	-2.045	-1.699	-1.311	1.311	1.699	2.045	2.462	2.756
30	-2.750	-2.457	-2.042	-1.697	-1.310	1.310	1.697	2.042	2.457	2.750
40	-2.704	-2.423	-2.021	-1.684	-1.303	1.303	1.684	2.021	2.423	2.704
50	-2.678	-2.403	-2.009	-1.676	-1.299	1.299	1.676	2.009	2.403	2.678
60	-2.660	-2.390	-2.000	-1.671	-1.296	1.296	1.671	2.000	2.390	2.660
70	-2.648	-2.381	-1.994	-1.667	-1.294	1.294	1.667	1.994	2.381	2.648
80	-2.639	-2.374	-1.990	-1.664	-1.292	1.292	1.664	1.990	2.374	2.639
90	-2.632	-2.368	-1.987	-1.662	-1.291	1.291	1.662	1.987	2.368	2.632
100	-2.626	-2.364	-1.984	-1.660	-1.290	1.290	1.660	1.984	2.364	2.626
500	-2.586	-2.334	-1.965	-1.648	-1.283	1.283	1.648	1.965	2.334	2.586
1000	-2.581	-2.330	-1.962	-1.646	-1.282	1.282	1.646	1.962	2.330	2.581
	$z_{.005}$	$z_{.010}$	$z_{.025}$	$z_{.05}$	$z_{.10}$	$z_{.90}$	$z_{.95}$	$z_{.975}$	$z_{.990}$	$z_{.995}$
z	-2.576	-2.326	-1.960	-1.645	-1.282	1.282	1.645	1.960	2.326	2.576

Table 2. Lower critical values of the empirical percentage points of the approximate W' test from Shapiro and Francia (1972). When the calculated W' test statistic is less than the critical value, the null hypothesis of normal data is rejected.

Sample Unit Size	**Lower critical value for test with alpha 0.01**
35	0.919
50	0.935
51	0.935
53	0.938
55	0.940
57	0.944
59	0.945
61	0.947
63	0.947
65	0.948
67	0.950
69	0.951
71	0.953
73	0.956
75	0.956
77	0.957
79	0.957
81	0.958
83	0.960
85	0.961
87	0.961
89	0.961
91	0.962
93	0.963
95	0.965
97	0.965
99	0.967

Table 3. Lower critical values of the exact binomial probabilities for the reverse sign test. When the number of minuses is less than or equal to the lower critical value, the null hypothesis is rejected at the alpha equal to 0.10 level.

Bond Release Sample Size	M
5	0
6	0
7	1
8	1
9	2
10	2
11	2
12	3
13	3
14	4
15	4
16	4
17	5
18	5
19	6
20	6

Table 4. Upper critical values of the exact binomial probabilities for the reverse Mann-Whitney test. When the sum of the ranks in the bond release dataset is greater than or equal to the upper critical value, the null hypothesis is rejected at the alpha equal to 0.10 level.

Sample Unit Size	REFA sample size															
	5	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
5	34	37	41	44	47	51	54	57	61	64	67	71	74	77	81	84
6	43	47	51	55	59	63	67	71	75	79	83	87	91	94	98	102
7	54	58	63	67	72	76	81	85	90	94	99	103	108	112	117	121
8	65	70	75	80	85	91	96	101	106	111	116	121	126	131	136	141
9	77	83	89	94	100	106	112	117	123	129	134	140	145	151	157	162
10	91	97	103	110	116	122	128	135	141	147	153	160	166	172	178	184
11	105	112	119	126	133	139	146	153	160	167	173	180	187	194	201	207
12	120	128	135	143	150	158	165	172	180	187	194	202	209	216	224	231
13	137	145	153	161	169	177	185	193	201	209	217	224	232	240	248	256
14	154	163	171	180	189	197	206	214	223	231	240	248	257	265	273	282
15	172	182	191	200	209	218	227	236	246	255	264	273	282	291	300	309
16	192	202	211	221	231	241	250	260	269	279	289	298	308	317	327	336
17	212	223	233	243	253	264	274	284	294	305	315	325	335	345	355	365
18	233	244	255	266	277	288	299	309	320	331	342	352	363	374	384	395
19	256	267	279	290	302	313	325	336	347	358	370	381	392	403	415	426
20	279	291	303	315	327	339	351	363	375	387	399	410	422	434	446	458

Example Data and Calculations

The following dataset is used in the example calculations. The calculations of the mean, variance, standard deviation, and standard error used throughout this section and are shown here. When two- sample procedures are demonstrated, the revegetation (Sample Unit) sample data will be compared to Reference Area (REFA) data.

Observation number	**Sample Unit data**	**REFA data**
1	14	24
2	23	15
3	8	9
4	25	10
5	17	19
6	20	28
7	28	7
8	22	11
9	18	9
10	10	10
11	14	14
12	21	22
13	9	14
14	31	26
15	20	21
Data Summaries		
Sum	280	239
Mean	18.67	15.93
Variance	46.24	47.35
Standard Deviation	6.80	6.88
Standard Error of Mean	1.76	1.78

The mean ($\overline{X}_{br}$) of these data is calculated as

$$\overline{X} = \frac{\sum_{i=1}^{N_{br}} x_i}{n_{br}}.$$

For the Sample Unit data, the sum of the observations (numerator of mean formula) is 280 and the sample size is 15 (n_{br}), therefore the mean is 18.67:

$$\overline{X} = \frac{280}{15} = 18.67 .$$

The variance (s^2) of these data is calculated as

$$s^2 = \frac{\sum_{i=1}^{n_{br}} (x_i - \overline{x})^2}{n-1}$$

For the revegetation sample data, the sum of the squared observations minus the mean (numerator of mean formula) is 647.33 and the sample size is 15 (n), therefore the variance is 46.24:

$$s^2 = \frac{647.33}{14} = 46.24$$

The **standard deviation (s_{br})** of these data is calculated as

$$s = \sqrt{s^2} = \sqrt{\frac{\sum_{i=1}^{n_{br}} (x_i - \overline{x})^2}{n_{br} - 1}}$$

For the revegetation sample data, the variance is 46.23, therefore the standard deviation is 6.80:

$$s = \sqrt{46.24} = 6.80 .$$

The **standard error of the mean (SE_{br})** for these data is calculated as

$$SE = \frac{s}{\sqrt{n_{br}}}$$

For the revegetation sample data, the standard deviation is 6.80 and the sample size is 15 (n), therefore the standard error of the mean is 1.76.

$$SE = \frac{6.80}{\sqrt{15}} = 1.76 .$$

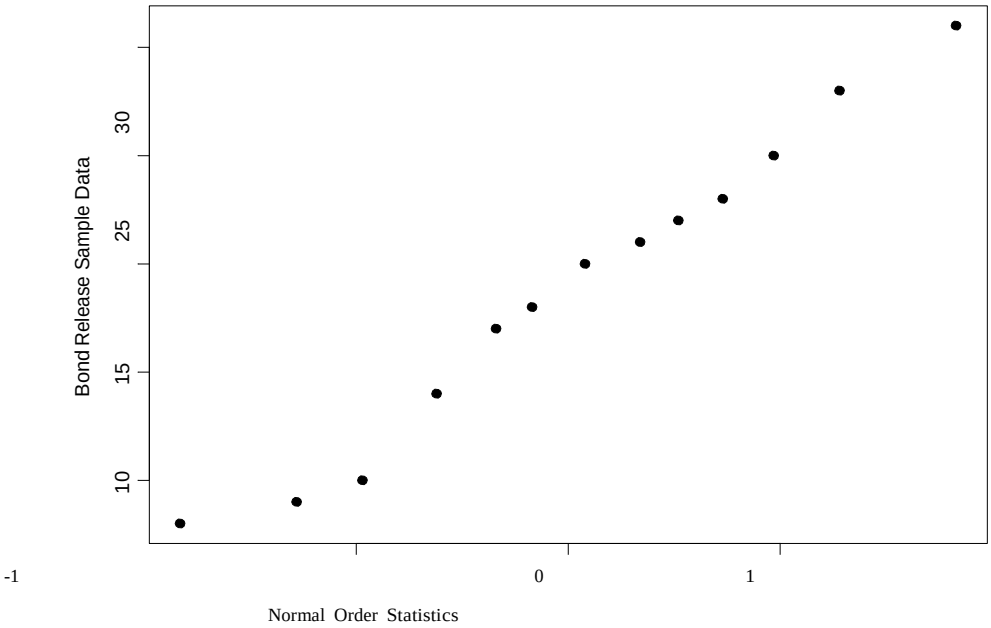
2.2 – Example - Two-sample Man-Whitney Test of Reverse Null Hypothesis

Observation number	BR data	REF data	REF @ 0.9
1	**14**	24	22
2	**23**	15	14
3	**8**	9	8
4	**25**	10	9
5	**17**	19	17
6	**20**	28	25
7	**28**	7	6
8	**22**	11	10
9	**18**	9	8
10	**10**	10	9
11	**14**	14	13
12	**21**	22	20
13	**9**	14	13
14	**31**	26	23
15	**20**	21	19
Data Summaries			
Sum	280	239	
Mean	18.67	15.93	
Variance	46.24	47.35	
Standard Deviation	6.80	6.88	
Standard Error of Mean	1.76	1.78	
Number of samples	15	15	

BR and REF data	Rank	
6	1	1
8	3	2
8	**3**	**3**
8	3	4
9	**6**	**5**
9	6	**6**
9	6	7
10	**8.5**	**8**
10	8.5	9
13	10.5	10
13	10.5	11
14	13	12
14	**13**	**13**
14	**13**	**14**
17	**15.5**	**15**
17	15.5	16
18	**17**	**17**
19	18	18
20	20	19
20	**20**	**20**
20	**20**	**21**
21	**22**	**22**
22	**23.5**	**23**
22	23.5	24
23	**25.5**	**25**
23	25.5	26
25	**27.5**	**27**
25	27.5	28
28	**29**	**29**
31	**30**	**30**
BR value	= 274	

Using the example data, the revegetation sample size is 15 and the REFA sample size is 15. The sum of the ranks of the revegetation sample is 274. Using Table 4, the upper critical value corresponding to sample sizes of 15 and 15 is 264. Since the observed sum of the ranks, 274, is greater than 264, the null is rejected; the revegetation values tend to be statistically greater than 90% of the REFA values. The Sample Unit passes. The z-statistic would be 1.74.

2.3 Example - Assessment of Normality



The plot of the sample revegetation data is an approximately straight line indicating no serious departures from normality.

2.3 Example - Francia Shapiro

Using the example data for the revegetation sample, the rank of an observation (Ri) is the position of the observation when the data are ordered from smallest to largest. The transformed rank (pi) is the rank (Ri) minus 0.5 and divided by 15 (n). The order statistic (zi) is the cumulative normal distribution quantiles of the pi (can be calculated with the Microsoft excel function norminv (pi,0,1)). The order statistics are squared, summed and square rooted to obtain the denominator of the bi's. Each bi is multiplied by the corresponding yi, these numbers are summed and squared to obtain the numerator of the W' statistic. The mean of the raw data ($\bar{y}$) is subtracted from each yi, squared and summed to obtain the denominator of the W' statistic. The numerator is divided by the denominator to obtain W'. The normal probability plot is obtained by plotting the yi by the zi.

Observation number	Bond Release Data	Ranked Bond Release Data	Transformed Ranks	Order Statistics	Squared Order Statistic	Order Statistic / $(\Sigma z_i^2)^{1/2}$	Numerator of W'	Denominator of W'
	y_i	R_i	p_i	z_i	z_i^2	b_i	$b_i * y_i$	$(y_i - \bar{y})^2$
3	8	1	0.0333	-1.8339	3.3632	-0.4948	-3.9582	113.7780
13	9	2	0.1000	-1.2816	1.6424	-0.3458	-3.1118	93.4440
10	10	3	0.1667	-0.9674	0.9359	-0.2610	-2.6101	75.1110
1	14	4.5	0.2667	-0.6229	0.3880	-0.1681	-2.3529	21.7780
11	14	4.5	0.2667	-0.6229	0.3880	-0.1681	-2.3529	21.7780
5	17	6	0.3667	-0.3407	0.1161	-0.0919	-1.5626	2.7780
9	18	7	0.4333	-0.1679	0.0282	-0.0453	-0.8153	0.4440
6	20	8.5	0.5333	0.0837	0.0070	0.0226	0.4514	1.7780
15	20	8.5	0.5333	0.0837	0.0070	0.0226	0.4514	1.7780
12	21	10	0.6333	0.3407	0.1161	0.0919	1.9303	5.4440
8	22	11	0.7000	0.5244	0.2750	0.1415	3.1126	11.1110
2	23	12	0.7667	0.7279	0.5299	0.1964	4.5169	18.7780
4	25	13	0.8333	0.9674	0.9359	0.2610	6.5251	40.1110
7	28	14	0.9000	1.2816	1.6424	0.3458	9.6812	87.1110
14	31	15	0.9667	1.8339	3.3632	0.4948	15.3382	152.1110

$\bar{y}$ =18.67 $\quad$ Σz_i^2=13.74 $\quad$ $\Sigma b_i * y_i$ = 25.24 $\quad$ $\Sigma(y_i - \bar{y})^2$ = 647.33

$(\Sigma z_i^2)^{1/2}$ = 3.71 $\quad$ $(\Sigma b_i * y_i)^2$ = 637.22

$$W' = \frac{637.22}{647.33} = 0.9844$$

The W' statistic is 0.9844. Using table 2, the lower critical value of the W' distribution is 0.919 (using sample size of 35). Since the test statistic, 0.9844, is greater than the lower critical value, 0.919, the null is retained, the data is normally distributed.

2.4 Example - Levene's Test for Homogeneity of Variance

Using the example data, the mean for the revegetation data (18.67) was subtracted from each bond release observation and the mean for the reference area data (15.93) was subtracted from each reference area observation to obtain the absolute difference for each observation. The mean of the absolute differences for the

bond release data was 5.42 with a standard deviation of 3.84. The mean of the absolute differences for the reference data was 5.92 with a standard deviation of 3.13. The two-sample t-test statistic is -0.39:

$$t = \frac{5.42 - 5.92}{\sqrt{\frac{(14*3.84^2)+(14*3.13^2)}{28}*(\frac{1}{15}+\frac{1}{15})}} = -0.39.$$

The two-sided t-statistic is compared to t critical values with alpha equal to 0.005 and 0.995 and 28 degrees of freedom (-2.76 and 2.76, Table 1). Since the calculated t-statistic, -0.39, is not less than -2.76 and not greater than 2.76, the null is retained and the conclusion is that the variances are not significantly different.

2.5 Example - Two Sample Adequacy Formulas with alpha Adjustment

$$n \square \quad \frac{(sz)^2}{(dx)^2}$$

Revegetation Area sample adequacy

Using the example data for the revegetation sample, the standard deviation s is 6.80, the z critical value with 0.025 probability in each tail is 1.96, the d is 0.10, and the sample mean $\bar{x}$ is 18.67. The number of samples required to reach sample adequacy is calculated as:

$$n_{br} = \frac{(6.8 \bullet 1.96)^2}{(0.10 \bullet 18.67)^2} = 50.96 \text{ or } 51$$

REFA sample adequacy

$$n_{\text{ref}} = \frac{(6.88 \bullet 1.96)^2}{(0.10 \bullet 15.93)^2} = 71.66 \text{ or } 72$$

2.6. Example -Two-sample t-test of Classical Null Hypothesis

Using the example data, the revegetation sample mean is 18.67, the variance is 46.24 and the sample size is 15. The REFA sample mean is 15.93, the variance is 47.35 and the sample is 15. The t-test statistic is 1.10

$$t = \frac{18.67 - 15.93}{\sqrt{\frac{(14 \bullet 46.24) + (14 \bullet 47.35)}{28} \bullet \frac{1}{15} + \frac{1}{15}}} = 1.10$$

The t-statistic is compared to a t critical value with alpha equal to 0.10 and 28 degrees of freedom (-1.31). Since the calculated t-statistic, 1.10 is greater than the t critical value, -1.31, the null is retained, the revegetation mean is statistically greater than or equal to the REFA mean. Note that this is an example, since the data did not meet sample adequacy this test would not have been performed.

2.7 Example - Two-sample t-test of Reverse Null Hypothesis with Satterthwaite's Adjustment

Using the example data, the revegetation sample mean is 18.67, the variance is 46.24 and the sample size is 15. The REFA sample mean is 15.93, the variance is 47.35 and the sample size is 15. The t-statistic is 1.82;

$$t = \frac{18.67 - (.9*15.93)}{\sqrt{\frac{46.24}{15} + \frac{(.81*47.35)}{15}}} = 1.82$$

The degrees of freedom are:

$$df_{sat} = \frac{\left(\sqrt{\frac{46.24}{15} + \frac{(.81*47.35)}{15}}\right)^4}{\left(\frac{1.76^4}{14} + \frac{(.9*1.78)^4}{14}\right)} = 27.89 \quad or \quad 28$$

The t-statistic is compared to a t critical value with 0.10 probability in the right tail ($t_{0.90}$) and 28 degrees of freedom (1.31). Since the calculated t-statistic, 1.82 is greater than the t critical value, 1.31, the null is rejected, the revegetation mean is statistically greater than or equal to 90% of the REFA mean. Revegetation success is supported by the data.

2.8 Example -Two-Sample T-Test of Classical Null Hypothesis with Satterthwaite's Adjustment

Using the example data, the bond release sample mean is 18.67, the variance is 46.24 and the sample size is 15. The REFA sample mean is 15.93, the variance is 47.35 and the sample size is 15. The t-statistic is 1.10:

$$t = \frac{18.67 - 15.93}{\sqrt{\frac{46.24}{15} + \frac{47.35}{15}}} = 1.10.$$

The degrees of freedom are:

$$df_{sat} = \frac{\left(\sqrt{\frac{46.24}{15} + \frac{47.35}{15}}\right)^4}{\left(\frac{1.76^4}{14} + \frac{1.78^4}{14}\right)} = 27.99 \quad or \quad 28.$$

The t-statistic is compared to a t critical value with 0.10 probability in the left tail (t0.10) and 28 degrees of freedom (-1.31). Since the calculated t-statistic, 1.10, is greater than the t critical value, -1.31, the null is retained, the bond release mean is statistically greater than or equal to the reference mean.

ADDENDUM B - PRODUCTION DATA COLLECTION

Production sampling may be used for cropland and hayland baseline sampling. Production sampling may be used in addition to cover sampling to confirm the equal to or better production of the reclamation. If an operator wishes to use production sampling the following procedures should be used.

Sampling

The term production is the weight of the total herbaceous standing crop biomass which is measured at or near the expected peak of the standing crop. If production is being measured for grazingland herbaceous production is collected by species and total herbaceous production should be done for each community type and its representative Reference Area (REFA). For cropland and hayland the seeded plant species would be harvested and compared to the County average or its REFA or EXREFA.

Grazing Exclosures

All harvest for production should be taken from within grazing exclosures or grazing withheld from the pasture. Random sample points (exclosure locations) should be established before the growing season. The exclosures should be placed in the field on or before April 15th or as soon after snowmelt as field conditions permit. Cages should be placed at this time to avoid possible data complications from snow accumulation through the winter.

The number of cages needed should be based upon reaching sample adequacy and can be estimated from preliminary sampling, from results of previous vegetation sampling on-site or from other vegetation surveys in similar vegetation types in the area. Permittees should establish several extra exclosures in each vegetation type and REFA to accommodate possible loss of some exclosures due to destruction by cattle, inaccessible locations, placement in an inclusion, etc.

One square meter quadrats are standard for production sampling although other sized may be used if approved by LQD. The exclosure must be sufficiently large to accommodate the sample quadrat and to provide a buffer area which reduces the potential for serious edge effects.

All exclosures should be removed when the inventory is complete.

Field Sampling

Grazingland

The standing crop biomass of all herbaceous species should be harvested in each quadrat. Full shrubs, succulents, annual grasses, annual forbs, Yucca spp., noxious weeds, cushion plants and trees should not be harvested. The seasonal growth of subshrubs should be harvested (see Appendix II) when accurate density data are unattainable. If annual grasses and/or annual forbs are major community components, these life forms should be clipped.

Appendix I

List of Prohibited and Restricted Noxious (Designated) Weeds for the State of Wyoming.

Accessing the web site for the Wyoming Weed and Pest Council at wyoweed.org/weed_lists.html will provide the most current List of Prohibited and Restricted Noxious (Designated) Weeds for the State of Wyoming and the County Declared List of Weeds and Pests.

The State Weed and Pest Coordinator can also be reached at:
State Weed and Pest Coordinator
2219 Carey Ave.
Cheyenne, WY 82002
(307)-777-5585

County Weed Control supervisors can also be contacted for additional lists of declared weeds.

Appendix II

Plant Species of Special Concern

For the most current official list of Rare, Threatened or Endangered Plant Species access the web site of US Fish and Wildlife Service, Mountain Prairie Region at www.r6.fws.gov/wy/html.

The US Fish and Wildlife Service can also be reached at:

US Fish and Wildlife Service
Wyoming Field Office
4000 Airport Parkway
Cheyenne, WY 82001
(307) 772-2374

For the most current list of sensitive species and species of local concern listed with US Forest Service contact the regional office nearest the location of your mine.

Primary Selenium Indicator Plants

This list was developed from Beath (1982). Nomenclature follows Dorn (1977).

Astragalus bisulcatus	Haplopappus multicaulis
Astragalus flavus	Haplopappus wardii
Astragalus grayi	Stanleya pinnata
Astragalus pectinatus	Stanleya tomentosa
Astragalus racemosus	Stanleya viridiflora
Xylorhiza glabriuscula	

Appendix III

The following tables are the suggested tabular format for data presentation.

EXAMPLE

Table 1. Acreages of Mapping Units of Permit

	Affected Area		Unaffected Area		Total Permit Area	
Mapping Units	Total Acres	% of Area	Total Acres	% of Area	Total Acres	% of Area
. Upland grassland	204.2	58	40.0	53	244.2	57
Streamside meadow	31.4	9	5.4	7	36.8	9
Sagebrush Shrubland	60.4	17	18.6	24	79.0	19
Cropland	42.9	12	6.0	8	48.9	11
Disturbed areas	10.7	3	5.9	8	16.6	4
Reservoirs	1.3	1	0.1	<1	1.4	<1
TOTAL	350.9		76.0		426.9	

EXAMPLE

Table 2.Summary of Sample Adequacy for Baseline % Vegetation Cover using the formula of Section I.A.C.3 Cover Sampling

	Vegetation Cover (%) x+1 S.D.	Actual Sample Size	Computed Adequate Sample Size	Computed* ??z-value	Confidence Level Achieved
AFFECTED AREA					
1. Streamside Meadow	66.4 ± 7.3	26	4	N/A	N/A
2. Upland Grassland	20.4 ± 8.6	29	58	0.90	81.6
3. Scoria Grassland	51.0 ±13.5	33	23	N/A	N/A
4.. Big Sagebrush	28.1 ± 6.9	25	20	N/A	N/A
5. Silver Sagebrush	63.4 ±19.8	21	32	1.04	85.1
LIMITED REFA AREA Grasslands					
1. Streamside Meadow	55.3 ±11.1	15	14	N/A	N/A
2. Upland Grassland	33.8 ±19.3	20	107	0.55	70.9
3. Scoria Grassland	52.7 ±14.9	29	27	N/A	N/A
4. Big Sagebrush	21.6 ± 3.5	15	9	N/A	N/A
5. Silver Sagebrush	53.3 ±15.6	15	29	0.94	82.6

* These values should be calculated only if the computed sample size exceeds the maximum number of samples required to be collected.

If an EXREFA is going to be used for measuring reclamation success then all of the affected and unaffected areas for each vegetation community are sampled as one unit and the LIMITED REFA (LREFA) category would not apply.

EXAMPLE

Table 3. Summary of Cover Sampling Data for Baseline, for the Upland Grassland Community. All values are means.

	(%) Absolute Cover	
Life Form/Species	Upland Grassland	LREFA*
PERENNIAL GRASSES & GRASS-LIKE SPECIES		
Agropyron smithii	44.7	48.1
Agropyron trachycaulum	0.4	0.8
Bouteloua gracilis	1.1	1.0
Stipa comata	0.1	0.2
Stipa viridula	3.0	2.8
Subtotal*	49.3	52.9
ANNUAL GRASSES		
Bromus japonicus	0.1	0.2
FORBS		
Achillea lanulosa	0.3	0.3
Aster adscendens		0.2
Taraxacum officinale	0.8	0.9
Unknown Rosette	0.1	
Subtotal*	1.2	1.4
SUBSHRUBS AND SUCCULENTS		
Artemisia ludoviciana	0.7	0.5
Ceratoides lanata	0.1	0.2
Gutierrezia sarothrae	0.4	0.2
Subtotal*	1.2	0.9
FULL SHRUBS		
Artemisia tridentata	0.1	0.2
Atriplex canescens	0.2	0.4
Subtotal*	0.3	0.6
TOTAL VEGETATION COVER	52.2	56.0
Litter	30.5	27.5
Rock	5.7	3.1
Total Ground Cover	88.4	86.6

* If a LREFA (Limited Reference Area) will be used to measure revegetation success then it is sampled separately and the data collected from it would go in this column. If an EXREFA (Extended Reference Area) is used then this column would not be required.

NOTE: A similar table should be constructed for each community type and each LREFA (if a limited reference area is used).

EXAMPLE

Table 4. No. of Species with greater than 2% Relative Cover

Lifeform	Reclaimed Upland Grassland[1] – Sample Unit		Upland Grassland REFA	
	total # of species	# species with > 2%	total # of species	# species with > 2%
Cool Season Perennial Grass				
Warm Season Perennial Grass				
Weeds				
Forbs				
Subshrubs				
Shrubs				
Succulents				
Trees				

[1]Use the actual plant communities in the permit area.

EXAMPLE

Table 5. Summary of Cover Sampling Data for Revegetation Success for the Upland Grassland Sample Unit. All values are means.

	Absolute Cover (%)	
Life Form/Species	Sample Unit	Reference Area
Perennial Grasses and Grasslike		
Pascopyron smithii	26.7	5.4
Elymus lanceolatus	4.8	
Pseudoroegneria spicatum	0.2	1.0
Koeleria macrantha	0.2	1.0
Poa secunda		2.8
Hesperostipa comata		0.2
Nassella viridula	0.2	0.2
Carex stenophylla		0.2
Subtotal*	32.1	10.8
Forbs		
Achillea lanulosa	0.3	1.2
Vicia americana		0.2
Taraxacum officinale	0.2	0.2
Phlox hoodii		1.0
Subtotal*	0.5	2.6
Subshrubs and Succulents		
Artemisia ludoviciana		1.2
Opuntia polycantha		0.2
Subtotal*		1.2
Full Shrubs		
Artemisia tridentata	0.2	8.2
Atriplex canescens	0.2	
Ericameria nauseosa		0.2
Subtotal*	0.4	8.4
TOTAL PERENNIALS	**33.0**	**23.0**
Annuals		
Bromus japonicus	0.8	4.2
Bromus tectorum	27.4	8.6
Alyssum desertorum	2.4	6.0
Plantago patagonica	.2	2.6
Subtotal*	30.8	21.4
TOTAL VEGETATION COVER	63.8	44.4
Litter	23.2	20.6
Lichens		0.6
Rock	2.2	1.4
Total Ground Cover	89.2	67.0
Bare Ground	10.8	33.0

* Subtotal across all species within a given life form category

NOTE: A similar table should be constructed for each community type and each reference area

EXAMPLE

Table 6. Summary of Sample Adequacy Calculations for Revegetation Success using Equation 2.5 of Addendum A

	Vegetation Cover (%) x+1 S.D.	Actual Sample Size	Computed Adequate Sample Size	Computed* z-value	Confidence Level Achieved
SAMPLE UNIT					
Upland Grassland Unit 99-UG-1	20.4 ± 8.6	29	58	0.90	81.6
Big Sagebrush Unit 02-BS-3	28.1 ± 6.9	25	20	N/A	N/A
REFERENCE AREA					
Upland Grassland REFA	33.8 ±19.3	20	107	0.55	70.9
Big Sagebrush REFA	21.6 ±15.6	15	9	NA	NA

* These values should be calculated only if the computed sample size exceeds the number of samples collected.

Appendix IV - Glossary

"Affected Land" (Affected Area) means the area of land from which overburden is removed, or upon which overburden, development waste rock or refuse is deposited, or both, access roads, haul roads, mineral stockpiles, mill tailings, impoundment basins, and all other lands whose natural state has been or will be disturbed as a result of the operations.

"Adjacent Areas" means land located outside the permit area upon which air, surface water, groundwater, fish, wildlife, or other resources protected by the Act may reasonably be expected to be adversely impacted by mining or reclamation operations. Unless otherwise specified by the Administrator, this area shall presumptively be limited to lands within one-half mile of the proposed permit area.

"Baseline Vegetation Inventory" is a vegetation sampling program executed prior to any significant surface disturbance caused by proposed mining activities. The inventory will provide a verbal and mental picture of the prevailing plant communities and will quantitatively and qualitatively classify the different plant communities to the specifications of Wyoming State Law.

"Comparison Area" see Reference Area.

"Control Area" see Reference Area.

"Cool-Season Plant" is a species which grows and flowers during the spring. Its growth usually slows or becomes dormant during the hotter, drier portions of the summer, but the species may resume growth in the fall with the advent of cooler temperatures and available soil moisture.

"Cover" is the proportion (percentage) of the ground surface covered by a vertical projection of objects on or above that ground surface. The absolute cover categories add up to 100%. The following cover categories are of interest to LQD:

1. Absolute cover of litter means the percent of the ground surface overlain by litter. Litter means, for the purposes of estimating ground cover, the uppermost layer of organic debris, usually considered to be the standing dead, freshly fallen or slightly decomposed vegetal material on the soil surface. Decomposing plant material which has lost its structural integrity or which is no longer recognizable as plant tissue is not litter.
2. Absolute cover of rock means the percent of the ground surface which is covered by rock. Rock for the purposes of estimating ground cover, means mineral or rock fragments which are one square meter in size or larger and occur on or in the soil.
3. Absolute cover of vegetation means the percent of the ground surface which is covered by the vertical projections of all live vascular plants.
4. Absolute cover by species means the percent of the ground surface covered by individual live vascular plants;
5. Absolute cover of cryptogams means the percent of the ground surface which is covered by cryptogams. Cryptogam means a plant (vascular or non-vascular) that reproduces by spores rather than seeds. Lichens, Bryophytes, and Pteridophytes % would be considered cryptogams.
6. Absolute cover of total ground cover means the sum of vegetation, cryptogams, litter and rock.
7. Absolute cover of bare ground means the percent of the bare ground which is not

covered by the vertical projection of vascular plants and cryptogams, litter or rock.

"Cropland" is land used for the production of adapted crops for harvest, along or in a rotation with grasses and legumes, and includes row crops, small grain crops, hay crops, nursery crops, orchard crops, and other similar specialty crops.

"Density" is the number of individuals per unit area.

"Dominance" refers to the collective size or bulk of individual plant species or life forms and their relative influence on other components of the ecosystem.

"Extended Reference Area" see Reference Area.

"Forestry" means land used or managed for the long-term production of wood, wood fiber, or wood derived products.

"Full Shrub" is a perennial woody plant which differs from a tree by normally being shorter in height and by often having several stems arising near the base.

"Grazing Exclosure" is a fence or other device utilized to prevent grazing by large herbivores in order to more accurately estimate production of a land unit.

"Grazingland" includes rangelands and forest lands where the indigenous native vegetation is actively managed for grazing, browsing, or may occasionally be cut for hay production and occasional use by wildlife.

"Land Use" refers to the specific uses or management-related activities which a given unit of land experiences. Land use is directly supported by, but not directly defined by the existing plant communities. See definitions of cropland, pastureland, grazingland, forestry, or appropriate discussion in LQD Rules and Regulations, Chapter I, under "land use".

"Life Form" is a category of growth morphology which appears to have some adaptive significance. Examples of life forms include trees, full shrubs, sub-shrubs, perennial grasses, annual forbs, succulents, cushion plants, etc.

"Line Intercept" is a cover estimation method based upon the measurement of the proportion of a line transect intercepted by the vertical projection of plant parts. Absolute cover, when using the line intercept method, is defined by the formula

$$\% \text{ cover of A} = \frac{\text{sum of all segments intercepted by A}}{\text{total length of the line transect}} \times 100$$

"Litter" means any recognizable plant parts or structures which are lying on the ground surface. Decomposing organic matter which has lost its structural integrity or which is no longer a recognizable plant part is not litter.

"Noxious Weeds" are agriculturally non useful or troublesome plants whose seeds are totally prohibited from or severely limited in any amounts in commercial crop seed offered for sale. These designations are made by State law.

"Prohibited Noxious" (designated) weeds are those species whose seed is not allowed in the seed of crops under any amounts. Restricted noxious (designated) weeds are those species whose seed is tolerated in the seed of crops only under small amounts. Declared weeds are those species which are of a particular concern to a specific county which may or may not be considered noxious (designated) under State law.

"Pastureland" is land used primarily for the long-term production of adapted, domesticated forage plants to be grazed by livestock or occasionally cut and cured for livestock feed.

"Permit Area" is the area of land and water within the boundaries of the approved permit or permits during the entire life of the operation and includes all affected lands and water.

"Vegetation Community" (Vegetation Type, Plant Community) is a relatively homogeneous combination of individual plants existing under common environmental conditions.

"Plotless Sampling" means estimation of vegetation parameters without the use of two-dimensional areal reference units.

"Point Intercept" is a cover estimation method based upon the lowering of a "pin" through the vegetation at objectively established sampling points. The "pin" may be an ocular siting device (e.g. crosshairs), a sharpened rod or a series of sharpened rods. Absolute cover, when using the point intercept method, is defined by the formula:

$$\% \text{ cover of A} = \frac{\text{number of hits on A}}{\text{total number of hits}} \times 100$$

"Production" is an estimate of the total standing crop biomass of herbaceous species (grass, grass-like, forb and some subshrub species). The estimate is made at a time near the expected peak of the current year's growth and is reported on a per unit area basis.

"Quadrat" is a two-dimensional areal unit which is superimposed on the ground surface for the purposes of estimating one or more vegetation parameters.

"Reference Area" There is three types of reference areas. Limited Reference Area, Extended Reference Area and Comparison Area. Below are the definitions for each.

Limited Reference Area (LREFA) means a land unit which is representative, in terms of physiography, soils, vegetation and land use history, of a vegetation community affected by mining activities. The representative nature of the LREFA is verified by statistical comparison (confidence level of 90%, $\alpha = 0.1$) of its absolute values of % vegetation cover, % total ground cover and total herbaceous production to similar data from the vegetation community it typifies. Species composition and species diversity are also subjectively (non-statistically) evaluated.

Postmining quantitative vegetation data from the LREFA are directly compared by standard statistical procedures (confidence level of 80%, $\alpha = 0.2$), to data from a reclaimed vegetation type when evaluating revegetation success for revegetation success.

A LREFA should be at least two (2) acres in size and should be managed in a fashion

which will not cause significant changes in the vegetation parameters used to evaluate revegetation success.

Extended Reference Area (EXREFA) means all the undisturbed portion of a vegetation type which has experienced disturbance by mining activities. The representative nature of the EXREFA is verified by evaluation of vegetation mapping procedures, the adequacy of premining quantitative and qualitative vegetation data, soils data, physiography and land use history information.

Postmining quantitative vegetation data from the EXREFA are directly compared by standard Statistical procedures (confidence level of 80%, $\alpha = 0.2$) to data from a reclaimed vegetation type when evaluating revegetation success. Qualitative data are compared by standard procedures agreed to between the Permittee and LQD.

An EXREFA should be managed in a fashion which will not cause significant changes in vegetation parameters used to evaluate revegetation success.

Comparison Area means a land unit which is representative, in terms of physiography, soils, vegetation and land use history, of a premining vegetation community from which no vegetation data were collected prior to disturbance. The representative nature of the Comparison Area may be validated by a subjective field reconnaissance of the site or by an objective evaluation of vegetation data generated by a sampling program. The selection of the comparison area should be approved by LQD.

Control Area means a land unit that used in the past for evaluating reclamation success. If the permit allows a Control Area, Land Quality Division should be consulted for the procedure.

"Relative Cover" is the expression of any number of cover categories e.g. vegetation + litter/rock + bare ground) in relation to each other, such that the sum of the relative cover values for those categories totals 100%. Relative Cover is calculated by the formula:

$$\% \text{ Relative Cover of A} = \frac{\text{Absolute Cover of A}}{\text{Sum of the Absolute Cover of categories A + B + ...n}} \times 100$$

"Selenium Indicator Plants" are plant species which may selectively concentrate selenium in their tissue and/or be tolerant of high selenium concentrations in the soil. These species, when grazed by cattle or sheep, may produce toxic reactions known as selenium poisoning.

"Species Composition" means number, kinds, amount, and quality of species.

"Species Diversity" means number of species per unit area.

"Study Area" means the full extent of the surface area which was sampled during the baseline vegetation inventory. The study area may coincide with or exceed the permit area.

"Subshrub" is a perennial plant which is partly woody, usually at the base, but also partly herbaceous. The individual plant generally dies back to the woody tissue after each year's growth.

"Systematic Sampling" means a sampling design where sample locations are selected using a uniform spatial pattern, such as a grid, that covers the entire sample population area, and where all locations are sampled. The first sample point is randomly selected, and the locations of all other sample points are determined by the initial location. Calculations for systematic sampling may be done by assuming the sample is random.

"Transect" is a sampling method which involves the establishment of a long, continuous line or strip. The starting point and orientation of the line should be randomly established.

"Warm-Season Perennial Grass" is a grass species which produces most or all of its growth during the late spring and summer, subsequently flowering in the late summer or autumn.