BUTTE RECLAMATION EVALAUTION SYSTEM[1]

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Abstract. The Environmental Protection Agency (EPA) designated Montana's Silver Bow Creek a Superfund site in 1983. By 1987 it was recognized that mine waste piles within the city of Butte, Montana posed a significant health risk to local residents and represented a major source of contamination to the Creek. The city of Butte was then added to the Silver Bow Creek Superfund site. Beginning in 1988 and continuing to date, EPA has performed response actions to address waste piles within the Butte Priority Soils Operable Unit (BPSOU). Response actions have focused on addressing mine waste "in-place". These response actions include land reclamation techniques using coversoil caps and revegetation. The Butte Reclamation Evaluation System (BRES) was developed as an evaluation tool designed to ensure that the integrity of all reclaimed land, including soil cover caps or other forms of engineered caps covering mine-waste left-in-place, are maintained at a level that provides for the long-term protection of human health and the environment in an urban-upland setting. EPA will utilize the BRES over the long-term to assess the condition of response action sites, identify problem areas, specify corrective action, and determine long-term monitoring schedules. During the development of the BRES, stakeholder representatives (County, State, EPA, and the Potentially Responsible Party Group) worked together to establish overarching objectives, develop site assessment methodologies, provide guidance, and identify evaluation parameters. Reclamation evaluation parameters include ground cover, erosion, condition of site edges, exposed waste material, bulk soil failure or land slumps, barren areas, and gullies. This paper describes the BRES field evaluation parameters used to characterize response action sites in terms of meeting human health and environmental risk objectives and the evaluation parameter performance standards that collectively determine the appropriate corrective action.

Additional Key Words: revegetation, assessment.

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Introduction

The Butte Reclamation Evaluation System (BRES) is a tool intended to be used by Environmental Protection Agency (EPA) to evaluate the integrity of all reclaimed land, including soil cover caps or other forms of engineered caps covering mine waste material left-in-place in Butte, Montana. The EPA is required to ensure that caps covering mining wastes are maintained at a level that provides for the long-term protection of human health and the environment.

The Butte Priority Soils Operable Unit (BPSOU) is part of the Silver Bow Creek/Butte Area National Priorities List (Superfund) Site within and near Butte, Montana. Multiple historic mining sites situated entirely within an urban setting, encompass much of the city of Butte and adjacent Walkerville, Montana. Mine wastes and mill tailings, accumulated from over 100 years of gold, silver, and especially copper mining, are dispersed throughout Butte and Walkerville, posing health risks to human and environmental receptors.

Response actions for mine-impacted lands have involved a variety of reclamation and engineering applications including removals, vegetated coversoil caps, concrete and other non-vegetated caps, and storm water controls. Within the Butte Superfund Site, approximately 182 individual areas have been impacted by mining-related wastes or are potential sources of arsenic and metal contaminants (PRP Group, 2001). Land reclamation has been a vital component and will continue to play an important role in future EPA-sanctioned response actions in Butte. Since 1992, several soil and vegetation parameters have been used to provide information regarding the efficacy of reclamation efforts on these mine lands. From this work, EPA recognized the need for a formalized evaluation tool that would allow agency personnel to determine whether sites under their jurisdiction were meeting the remedial goals and if those trends were likely to continue. The EPA recognized the need to evaluate the stability, integrity, and degree of protection attained by reclamation.

The BRES was specifically designed for use in Butte, and can be used to evaluate multiple land uses: recreational, commercial/industrial lands, and areas reclaimed as open space within the urban setting. The system enables assessors to quickly and effectively collect information describing post reclamation conditions with a minimal amount of field equipment. Overall, the BRES was designed to assess whether response actions for mine wastes left-in-place continue to mitigate risks to human and environmental health.

Goals and Objectives

The objectives for developing the BRES were to; define which vegetation and landscape stability attributes should be evaluated for all response action sites, define how the system should be applied in the field, and define how the BRES couples to long-term tracking, monitoring, and maintenance of reclaimed sites within the Butte portion of the Superfund site.

The EPA and several other entities were involved in the conceptual design and field calibration, and will be involved with future application of the system. Since Butte lies within a Superfund site, representatives of the potentially responsible parties, the Montana Department of Environmental Quality (MDEQ), and the Butte-Silver Bow County (BSB) government were instrumental in BRES development. In addition to these groups, individuals from citizen's or environmental advocacy groups also attended technical and management meetings during the development process. The intent of this partnership building was to develop a system based on shared goals and objectives, which would be embraced by the different stakeholder groups. The following goals were defined for the development of the BRES tool. The system should:

- Emphasize soil and vegetation parameters critical to maintaining site stability, integrity, and overall protectiveness of the response action;
- be easily and quickly applied in the field due to the numerous sites that require evaluation;
- utilize a minimum amount of field equipment;
- be simple to learn by new evaluators; and
- provide precise (i.e., reproducible) results when applied by different evaluators.

Initial Development and Iterations

Two overarching objectives were identified prior to the calibration and validation of the BRES. These were to: (1) develop a system that could accommodate the environmental variability within sites and adequately describe the conditions at a site, and (2) formalize a decision-making process in terms of the recommended maintenance of vegetated caps. The general approach to the calibration and validation process was to define the vegetation and

erosional attributes that were to be used in the system and then to test and refine these attributes in an iterative manner. Thirteen sites, that represented much of the complexity and variation of reclaimed areas, were evaluated to develop the BRES field form and decision logic for technical recommendations for a site. Specific decision diagrams were created for each of the parameters evaluated in the BRES and a time frame for evaluations and cap repairs was established. The final system (CDM/RRU, 2003a) that was presented to EPA achieved the Agency's goal of having a cost-effective procedure that would yield accurate and reproducible results.

Process and Procedures

The BRES process begins with aerial photographs of each of the reclamation sites to be evaluated. A GIS database is used to delineate site boundaries, distinct polygons within a site (see Polygon section below), special features such as storm drains, mineshaft caps, channels, sedimentation basins, and other features. Supplemental information for each site relevant to the field evaluation is also gathered which may include details of previous response actions (e.g., coversoil depth and initial seed mix) and maintenance activities (e.g., weed spraying). Field assessment of each site, or distinct polygons within a site, are scheduled during peak standing vegetation biomass, which in the Butte area generally occurs between late June and early August. The BRES field form is used to assess the status of the reclaimed site or polygon. Assessment parameters include vegetation cover, erosion, edges of the reclaimed area, exposed waste materials, land slumps, barren areas, and gullies. Based on the data and information collected, decision logic matrices are used to determine whether monitoring or corrective action is required at the site. These actions are based on threshold values for some parameters or evidence of problems for other parameters. An evaluation schedule is also suggested as part of the BRES protocols.

Evaluation Parameters

The following parameters are assessed using a BRES Field Form (Figure 1) within a reclaimed site or within a defined area (or polygon). Corrective actions may be instituted as a result of applying the system to a site or polygon. These corrective actions vary according to site

BRES FIELD FORM **Site Name:** _____ **Date:** _____

Team Members (Circle your name): _____

_____

Number of Polygons: _____ Slope: _____ Aspect: _____ Area Description: _____

Polygon Evaluation	1	2	3
Vegetation (% live)			
Erosion (BLM score)			
% live weedy species			

Vegetation: % of ground covered by:	POLYGON 1	2	3
Live (desirable) species			
*Live (undesirable weedy) species			
*Noxious weeds			
TOTAL % LIVE			
Litter			
Rocks > 2”			
*Up to 5% of undesirable species and 0% of noxious weeds may count toward live cover.			

Erosion (BLM Form)	POLYGON 1	2	3
Surface Litter			
Surface Rock Movement			
Pedestalling			
Flow Patterns			
Rills			
Gullies			
Soil Movement			

Other BRES Trigger Items
Identify trigger areas (using #) on air photo

3. Site Edges: Are polygon edges (outer edges of site only) significantly different than remainder of the polygon?
Y_____ N_____ (check applicable items)

☐ **lime rock barrier** ☐ **depositional area**
☐ **more weeds** ☐ **steeper slope**
☐ **increased erosion** ☐ **less vegetation**
☐ **gullies** ☐ **other**_____

Estimate width of affected edge _____

4. Exposed Waste Material? Y_____ N_____

- Estimated pH_____
- Approximate area _____
- Number of areas with exposed waste _____

1. Percent live: please check appropriate category:

1	☐ **0-20**	☐ **21-39**	☐ **40-100**
2	☐ **0-20**	☐ **21-39**	☐ **40-100**
3	☐ **0-20**	☐ **21-39**	☐ **40-100**

2. Total BLM score 1____, 2____, 3____. Please check appropriate category.

1	☐ **0-40**	☐ **41-65**	☐ **66-100**
2	☐ **0-40**	☐ **41-65**	☐ **66-100**
3	☐ **0-40**	☐ **41-65**	☐ **66-100**

5. Is there evidence of: Y_____ N_____

☐ **bulk soil failure** ☐ **land slumps**
☐ **subsidence**

Species Present:	Dominant	Frequent	Infreq.
Sheep fescue	☐	☐	☐
Crested wheatgrass	☐	☐	☐
Slender wheatgrass	☐	☐	☐
Yellow sweetclover	☐	☐	☐
Alfalfa	☐	☐	☐
Other:			
_____	☐	☐	☐
_____	☐	☐	☐
_____	☐	☐	☐
_____	☐	☐	☐

Weeds Present:	Dominant	Frequent	Infreq.
Spotted knapweed	☐	☐	☐
Dalmation toadflax	☐	☐	☐
Cheatgrass	☐	☐	☐
Baby’s breath	☐	☐	☐
Kochia	☐	☐	☐
Thistle	☐	☐	☐
Other:			
_____	☐	☐	☐
_____	☐	☐	☐
_____	☐	☐	☐

6. Barren Areas: Y_____ N_____

- At Least 75 ft^2
- Not a rock outcrop
- Less than 10 % total cover (live & litter)

Number of barren areas _____
Do barren areas cover over 25% of polygon? Y____N____
Polygon barren area(s) located in (circle) 1 2 3

7. Gullies (over 6” in depth):
Y_____ N_____
Are any gullies actively eroding?
Y_____ N_____
Number of gullies _____

Figure 1. BRES Field Form

condition, and range from additional monitoring to complete re-implementation of site reclamation.

- **Ground cover** - includes ocular assessments of live vegetation cover, litter, undesirable weedy species, noxious weeds, and rock. Percent **live cover** refers to the percentage of ground surface covered by the current season's plant growth; exceptions include undesirable weedy species and noxious weeds, which are defined below. Standing live, dead, or senescent plant materials from the current year are included in the estimate of percent live vegetation cover. Percent live vegetation cover of desirable species is used as a trigger item in the BRES. **Litter** is defined as the uppermost layer of organic debris composed of dead plant material from previous years growth or other slightly decomposed organic materials. **Undesirable weedy species** are plants with certain life history characteristics that could undermine the integrity of the response action at the site. For example, these species might be shallow rooted, or have a short seasonal, annual or biennial life cycle; characteristics that reduce the stability of a vegetative cap. Undesirable weedy species are identified using a plant list compiled by the potentially responsible parties. **Noxious weeds** are defined as all Category I-IV plants included on the state and county noxious weed lists. Noxious weeds are those regulated by law or those that are difficult to control. In general, noxious weeds are non-native plants that compete with desirable plants for nutrients, water, and/or space. Noxious weeds do not count towards the estimate of percent live vegetation cover. For BRES purposes, **rocks** are defined as any solid material greater than 5 cm on at least one side. Material smaller than 5 cm is considered bare ground when estimating total ground cover.

- **Erosion** – The BRES uses a modification to the Bureau of Land Management erosion evaluation manuscript (BLM 1981) to classify erosional conditions on rangeland areas across the western United States. It is a multi-variable evaluation system that gives a numeric value, which is then translated into one of 5 specific erosional classes. A high score on the erosion evaluation is considered a trigger item.

- **Edges of the site** - Large differences between the interior of some vegetation caps and their edge(s) were noted during initial development of BRES, therefore site edges are assessed separately in the BRES.
- **Exposed waste materials -** Exposed waste material includes mine tailings and waste rock, as well as any soils that have been contaminated by metals, arsenic, or acid materials from mining operations in the BPSOU. When the chosen response action is a vegetated soil cap over waste left-in-place, exposed waste material indicates some failure of the cap material to provide adequate cover and an increased potential for human or environmental receptors to come into contact with contaminants of concern (COCs). The existence of exposed waste material at a site is considered a trigger item for corrective action.
- **Bulk soil failure or Land slumps -** Bulk soil failure or land slumps indicate a current or potential path for underlying waste material to become exposed. The existence of bulk soil failure or land slumps at a site is considered a trigger item for corrective action.
- **Barren areas -** Barren coversoil can compromise the stability of vegetative caps by leaving the coversoil vulnerable to erosion by water and wind, which may eventually expose contaminated materials. Areas devoid of vegetation may also signify a problem with cover soil quality or thickness. In addition, barren areas may represent areas of current or imminent exposed waste and pose a risk to human health and the environment. For the BRES evaluation, barren areas are defined as an area greater than 7 square meters with less than 10 percent total plant cover (live cover + litter). The presence of barren areas within a site or polygon is considered a trigger item for corrective action.
- **Gullies** – The presence of gullies indicate that soil loss by water erosion is occurring or has occurred in the past, which increases the chance of exposing covered mine waste materials. An active gully has unstable sidewalls with little or no vegetation or recent soil loss by erosion. If a gully is actively eroding it may jeopardize the stability of the vegetation cap and is therefore considered a trigger item for corrective action. Conversely, a healing gully is identified by the reestablishment of vegetation on the sidewall and reduction in soil loss in the channel bottom. A healing gully is not considered a trigger item.

Polygons

To improve the precision (or repeatability) of the BRES evaluation, it is necessary to divide some reclaimed sites into smaller land units based on factors such as vegetation homogeneity, slope angle and aspect, and land type, which may include residential lawns, parking lots, open space, and driveways. These smaller units reduce within-polygon variability with respect to BRES evaluation parameters and thereby increase assessment precision. Sites that have been reclaimed with rangeland vegetation but have differences in aspect or slope may also be subdivided into polygons because these differences can control site vegetation and erosional characteristics.

Polygons divide the land area within a site into more internally homogeneous units and thus increase the repeatability of estimates made for each of the evaluation parameters. This increase in repeatability has been observed by researchers working with similar evaluation systems and other statistically based sampling techniques (BLM, 1981); (Hansen, 1995); (CDM/RRU, 1999); (BLM, 2000). Figure 2 is an example of a site that was delineated into two separate polygons.

Figure 2. This site was separated into two polygons. The two land units are now more internally homogeneous, which increases the repeatability of estimates made for each evaluation parameter.

Application of BRES

Because of the large number of response action sites in Butte, BRES evaluations will take place in four-year cycles. Preliminary evaluations indicate there may be as many as 180 sites at which it may be appropriate to use the BRES. The BRES is designed to assess all response

action sites, therefore it is important to develop and review a comprehensive list of sites to determine if any sites will not require a BRES assessment. Some of these sites may have only a small portion of reclaimed ground because they have been paved or have had a structure built on them. Site review, and reconnaissance if necessary, should be conducted for all sites to determine the appropriateness of using the BRES.

The large number of sites necessitates dividing them into groups and staggering the BRES evaluations and associated corrective actions over a four-year period. A four-year cycle was chosen for two reasons:

- The decision logic for the BRES states that after any corrective action is completed at a site or within a polygon, the area should be evaluated with the BRES three full growing seasons after the work is completed; a four year cycle provides the correct timing between the site work and the recurrent BRES evaluations.
- The division of BRES sites into four groups allows adequate time for pre-assessment preparation and field evaluations during the peak standing biomass period of the growing season. A shorter cycle might not allow enough time to perform evaluations on the number of sites to be completed in a year, and a longer cycle would not provide correct timing between BRES evaluations, as articulated in the BRES decision logic.

All sites in the same group will be evaluated during the same year. Groups should not be split once they are created because of the complications that would arise in BRES scheduling and site tracking. The long-term schedule for the BRES is presented in Table 1.

Table 1. Long-Term BRES Schedule.

	Initial identification	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**
BRES Site Evaluations	Polygon delineation	Group A	Group B	Group C	Group D	Group A	Group B	Group C	Group D	
O&M work if necessary			Group A	Group B	Group C	Group D	Group A	Group B	Group C	Group D
Polygon Boundary Re-evaluation										All Groups

Polygons will be delineated for all sites at one time. Once polygons are delineated at sites, they will remain fixed until the official review period in year nine of the BRES process. Re-evaluation of polygons in year nine allows two full BRES cycles to occur before polygon boundaries are re-evaluated.

Corrective Action Triggers

A decision logic diagram was developed for each trigger item in the BRES. During the development of BRES, the rationale for the triggers and threshold values was established.

- **Vegetation -** The logic diagram for the vegetation cover category (Figure 3) makes distinctions among the three live vegetation cover categories. For polygons that fall in the lowest live vegetation cover category (less than 21 percent), the technical recommendation is that the site undergoes either vegetation improvement or reclamation improvement.

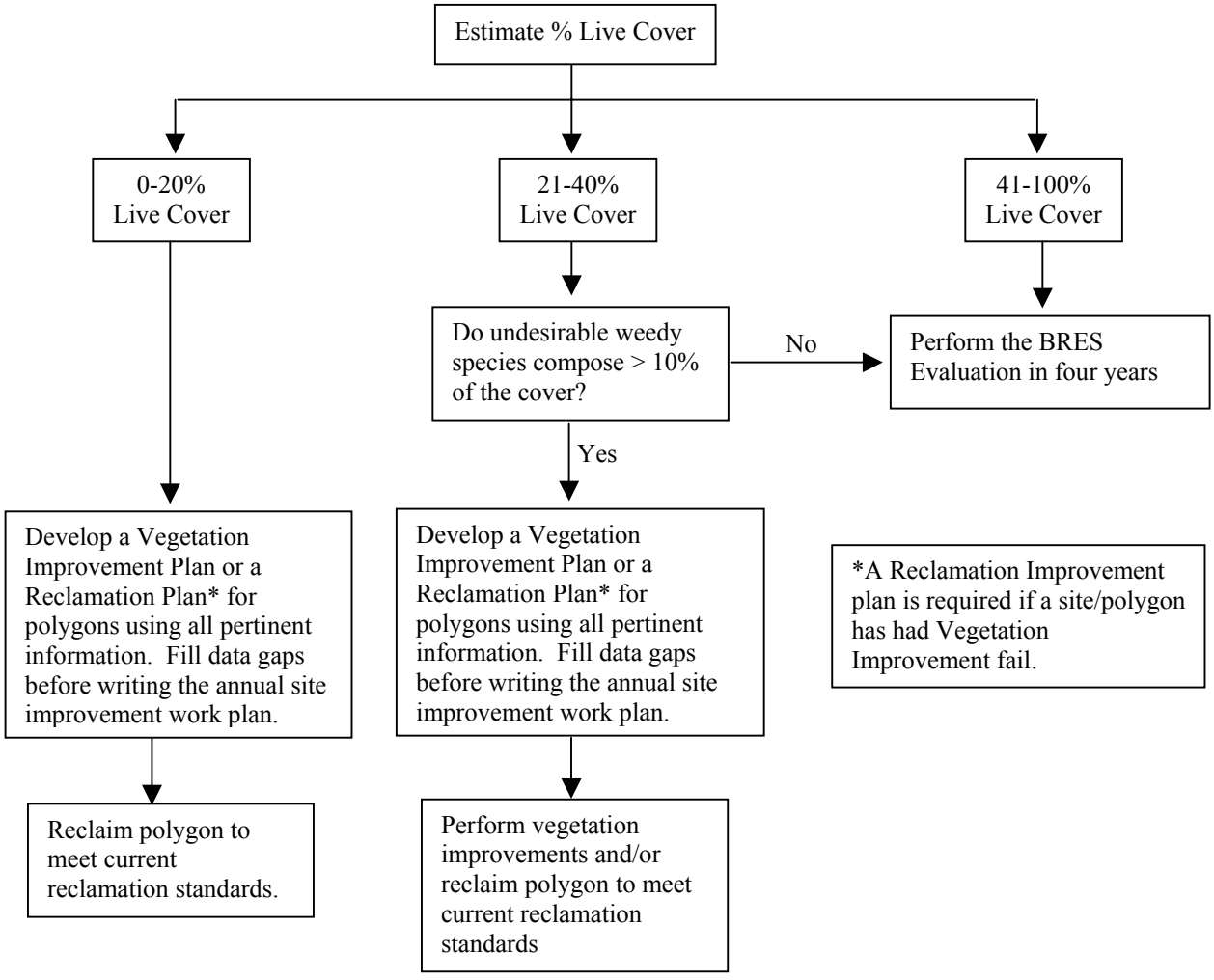

Figure 3. Vegetation Logic Diagram

Vegetation improvement (VI) may include re-seeding, fertilization, mulching, weed control, addition of compost, or more coversoil. These actions may allow the site to be compliant with the BRES. Reclamation improvements (RI) are actions taken that are compliant with a set of

reclamation practices and specifications (Butte Hill Revegetation Specifications) developed specifically for the Butte Hill in 1999 (CDM, 1999). The VI or RI are to be completed on the polygon within a calendar year of the BRES evaluation and the polygon should undergo another BRES evaluation three years following VI or RI work (i.e., the four-year BRES evaluation cycle). If a site undergoes VI, and then falls into the less than 21 percent live cover category again during any future BRES evaluations, the polygon is then required to undergo RI, and meet the Butte Hill Revegetation Specifications (CDM, 1999). For polygons that fall into the middle live vegetation cover category (21-40 percent), undesirable weedy species are considered. If greater than 10 percent of the polygon is covered by undesirable weedy species, then VI should be implemented. If less than 10 percent of the area of the polygon is covered by undesirable weedy species, then the polygon should undergo a regularly scheduled BRES evaluation in four years. Polygons that fall into the upper vegetation cover category (41-100 percent) should be re-evaluated using the BRES in four years.

- **Erosion -** If the erosion evaluation score is 55 or less (Figure 4), no immediate action is required and the polygon will continue on the regular BRES evaluation schedule of every four years. A score of greater than 55 triggers a recommendation for corrective action. An engineering assessment on the erosional and flow patterns should be performed to determine the appropriate type of corrective action needed to mitigate the erosion problem. The approved corrective action plan should be implemented within the calendar year. The area repaired should be monitored at least yearly and also after large storm events. If the erosion control actions are failing, the site should be repaired immediately. The polygon will undergo a full BRES evaluation three years following the maintenance work.

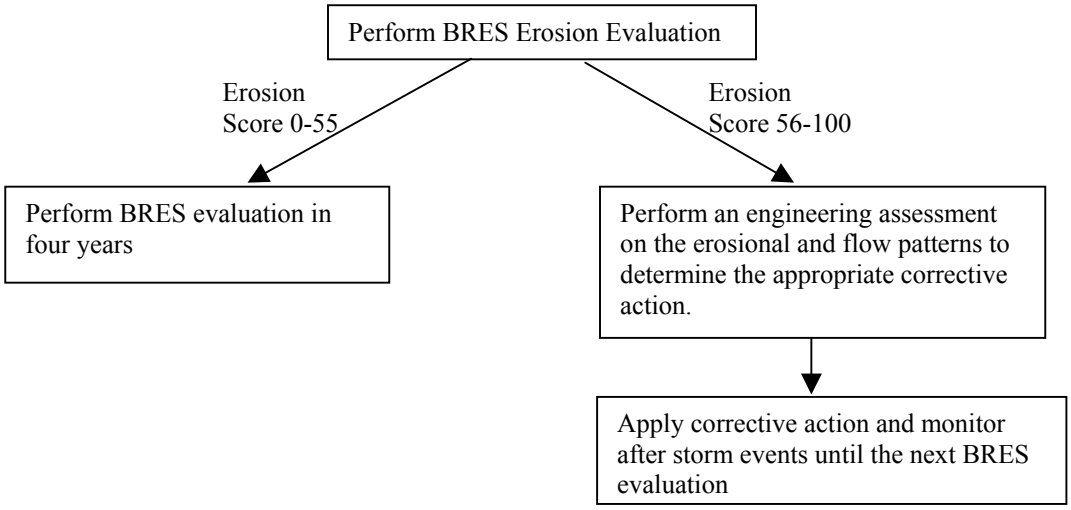

Figure 4. Erosion Logic Diagram

- **Site Edges -** The site edge parameter is primarily a monitoring category, except when gullies or exposed waste materials are present. Site edges are specified as an evaluation parameter because problems often arise in the transitional zone between reclaimed and unreclaimed land areas. Gullies or exposed waste material along the site edge trigger a recommendation for a corrective action to repair the gully, and remove or cover the exposed waste material. Maintenance work should be completed within a calendar year of the BRES evaluation and then the site should undergo a full BRES evaluation three years following maintenance work (i.e., four-year BRES evaluation cycle). If neither gullies nor exposed waste exist, yet a significant difference has been identified between the site edge and the site interior, then the area should be tracked in the GIS and maintenance databases for future trend analysis to determine whether site edge condition is improving or declining. These sites should undergo a regularly scheduled BRES evaluation in four years.

- **Exposed wastes -** Exposed mine waste on a site triggers a recommendation for corrective action (Figure 5). An engineering assessment should be performed on the area of exposed waste to determine the appropriate type of action needed to repair the cap. The approved corrective action plan must be implemented within the calendar year. The site should undergo a full BRES evaluation three years following the maintenance work.

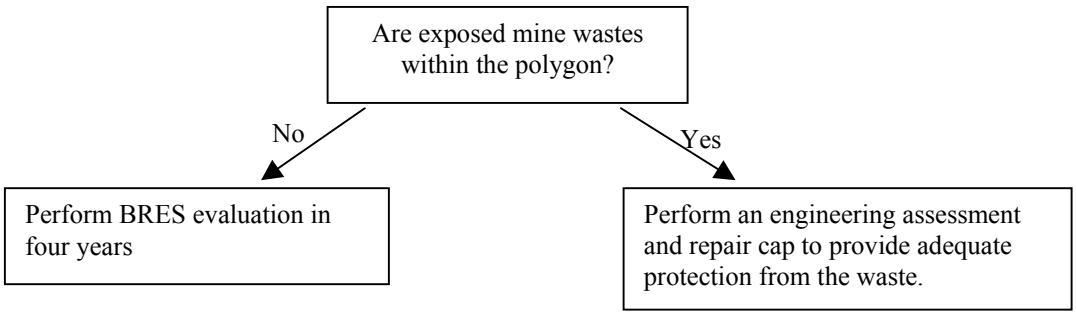

Figure 5. Exposed Mine Waste Logic Diagram

- **Bulk soil failure or land slumps -** Signs of bulk soil failure or land slumps trigger a recommendation for corrective action (Figure 6.0). An engineering assessment should be performed on the area to determine the appropriate type of corrective action needed to repair the cap. The approved corrective action plan must be implemented within the calendar year. The area repaired should be monitored after large storm events until the next BRES evaluation, which should be completed three years following the corrective action. If the corrective actions are failing, the area must be repaired immediately.

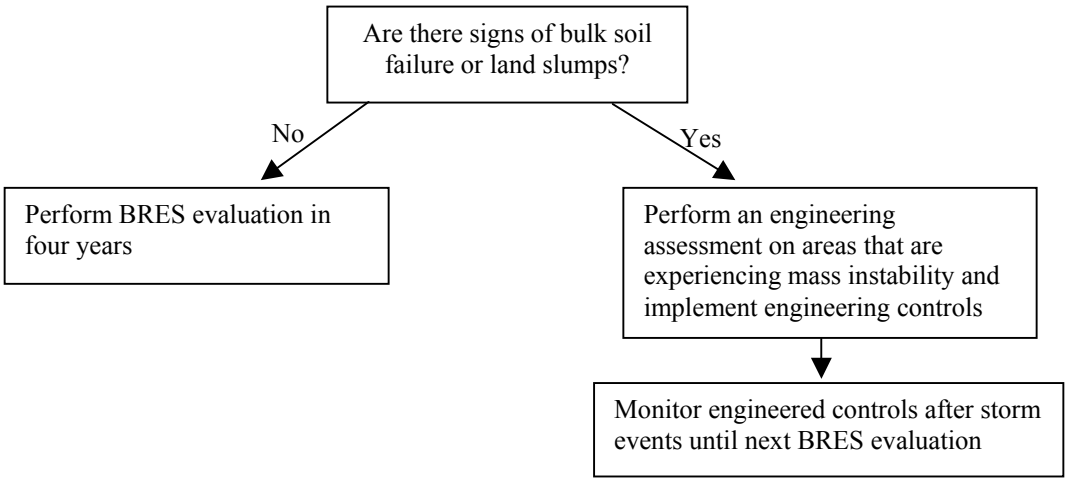

Figure 6. Bulk Soil Failure/Land Slump Logic Diagram

- **Barren areas** - If barren area(s) are located within a polygon (Figure 7) but cover less than 25 percent of the polygon, a VI plan and/or a RI plan is to be developed to repair only the

barren area(s). All pertinent historic data or recent management records should be reviewed prior to plan development. If a VI plan is implemented and the next BRES evaluation indicates that the VI actions failed, the barren areas must be reclaimed in accordance with the Butte Hill Revegetation Specifications. If barren area(s) cover over 25 percent or more of a polygon, the same decision logic is used, except that the VI plan and/or RI plan must include the entire polygon, not just the barren areas. If a VI plan is implemented and the next BRES evaluation indicates that the VI actions fail, a RI plan must be developed and approved and the entire polygon must then be reclaimed in accordance with the Butte Hill Revegetation Specifications. Under each of the above circumstances, corrective action must be completed within a calendar year of the BRES evaluation and the polygon should then undergo a full BRES evaluation three years following corrective action.

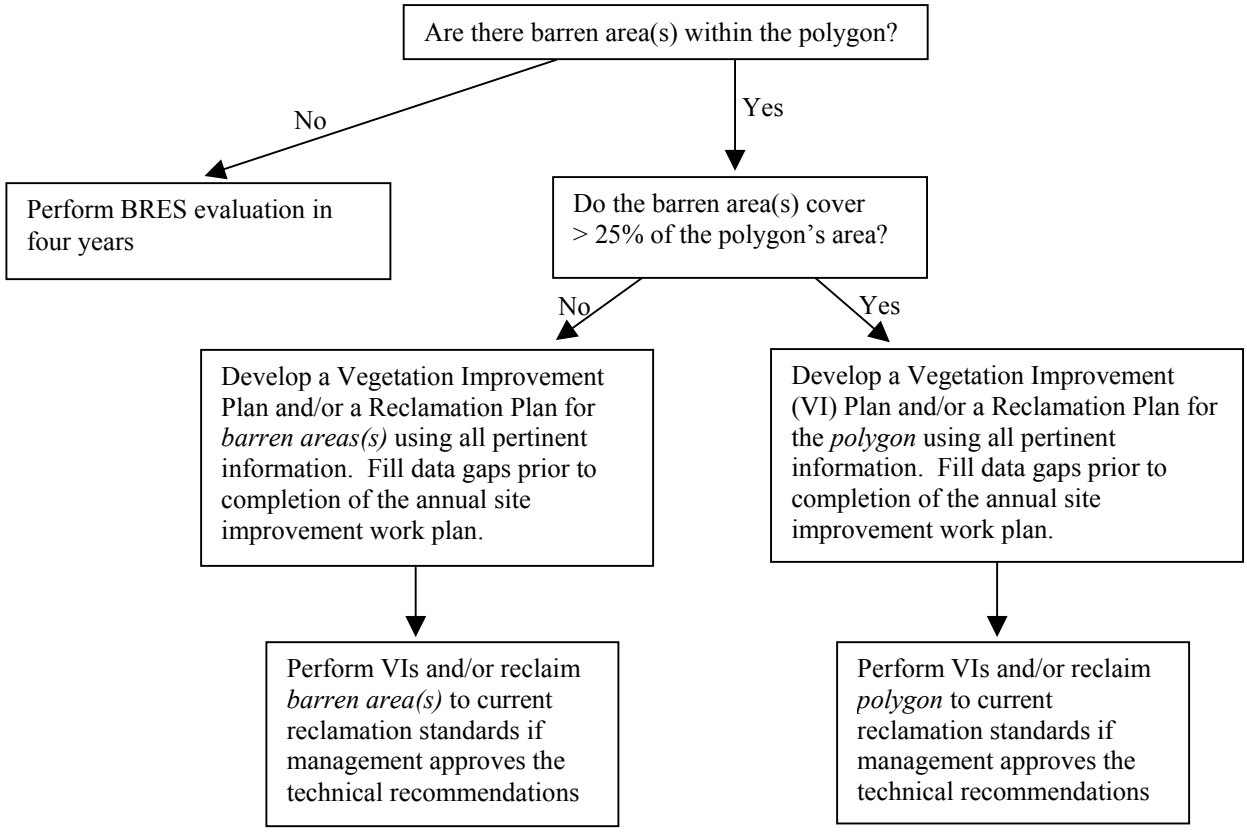

Figure 7. Barren Area Logic Diagram

- **Gullies** - If a gully or gullies exist(s) within a polygon, their presence should be noted on the field evaluation form whether the gully/gullies are actively eroding or healing. If the gully/gullies are healing as defined by the BRES, no immediate action is required and the polygon will continue on the regular BRES evaluation schedule of every 4 years. If the gully/gullies within the polygon are actively eroding, then corrective action is recommended (Figure 8). An engineering assessment of the gully/gullies should be performed and an approved plan to repair them should be implemented within the calendar year. The area repaired should be monitored at least yearly and also after large storm events, until the next BRES evaluation (3 years following completion of repair work). If the corrective actions are failing, the area should be repaired immediately.

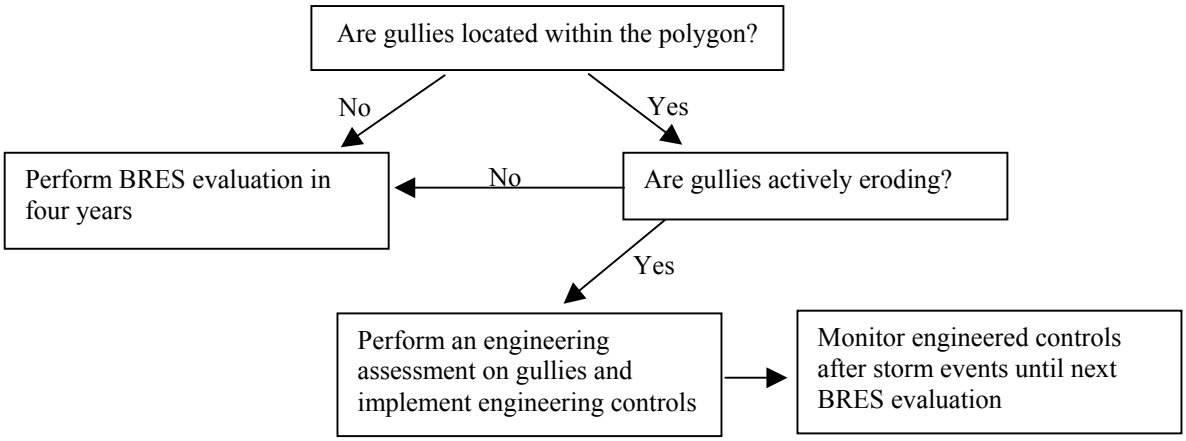

Figure 8. Gully Logic Diagram

Summary

The BRES is not a remedy for mine-impacted lands nor will it be used prior to the EPA's Record of Decision document to determine the remedial fate of mine-impacted sites within Butte and Walkerville. The BRES is a tool to evaluate the stability, integrity, and degree of human and environmental protectiveness afforded by EPA-sanctioned response actions initiated on lands impacted by mining within Butte and Walkerville. If specified by EPA in the Record of Decision document, the BRES will be the assessment methodology and will contain the performance standards by which all reclaimed/revegetated land and other forms of EPA response actions will be continuously evaluated and maintained in perpetuity. Results from the

application of the BRES after the Record of Decision document will be used to trigger corrective action measures that ensure the response actions are maintained at a condition protective of human health and the environment.

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