

# LAND RECLAMATION PERFORMANCE EVALUATION PROCESS AND STANDARDS USED AT THE ANACONDA SMELTER SITE, MONTANA<sup>1</sup>

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Abstract: Land reclamation is a vital component of remedial response actions used at historic mining and smelting sites throughout the west. In Montana, data-predicated decision tools have been developed to assist state and federal agency personnel in evaluating the success of reclamation efforts implemented on these impacted lands. This paper describes the process developed by EPA to evaluate whether land reclamation practices implemented at the Anaconda Smelter NPL site are meeting agency goals and numeric criteria. The tool is also being used to monitor vegetation condition and erosion stability so that effective maintenance can be performed as these plant communities develop over time. This paper provides an overview of land reclamation practices at this site, describes how the post-reclamation evaluation tool was developed, and discusses the established vegetation management process from seeding to assessing the performance of the reclaimed areas.

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## **Introduction**

The Environmental Protection Agency's (EPA's) record of decision for a portion of the Anaconda Smelter site requires that the reduction of risk and the protection of human health and ecological systems be accomplished through the establishment of self-sustaining assemblages of plant species. To accomplish this, the EPA and Montana Department of Environmental Quality (MDEQ) have developed an evaluation process and compliance standards for the site. This paper provides a brief overview of the land reclamation approaches being used at the Anaconda site, discusses the vegetation management process, and explains how the Agencies will determine compliance with the established remedial goals.

### **Smelting and Land Reclamation at the Anaconda Site**

#### **Smelting Historic and Environmental Impacts**

Smelting began in Anaconda (in southwest Montana) with the construction of the Old Works smelter in 1910 and continued up to 1980 at the facility on Smelter Hill. During the early years, the smelter smoke stacks released massive quantities of sulfur dioxide and other deleterious chemical compounds. The expulsion of S, As, Pb, Zn, and Cu compounds was especially high during the war years. Today, severe impacts to the environment are still clearly evident near the historic smelting facilities where hill sides remain denuded of vegetation (EPA 1997). In the less severely impacted areas, some native vegetation survived the initial perturbations and today they have some degree of vegetation production and plant community diversity. It has been estimated that the impacts of historic smelting at the Anaconda site cover an area greater than 300 square mile area. These impacts include complete annihilation of plant life and loss of topsoil near the smelting facilities to low cover, production and community diversity throughout much of the site.

#### **Evaluating Ecological Dysfunction and Reclamation Needs**

In the 1990s, EPA was confronted with the challenge of evaluating the degree of ecological dysfunction and determining the remedial requirements for range, forest, and riparian sites impacted by historic smelter fallout and fluvially deposited mine tailings at the Anaconda Smelter site. A major concern was how to obtain the necessary level of detail in data collected on very large areas so that reclamation designs could be developed in a timely manner. EPA recognized early in the assessment planning process that a formalized tool was needed to help

the planners quickly assess these extensive land areas and choose the most effective remedial techniques.

### Developing the Site Evaluation Tool

Refinement and validation of an assessment tool was accomplished in the late 1990s through an iterative process using set of test sites. The vegetation and soil parameters at each site were scored and then adjustments were made to the scoring system to better reflect actual site conditions and probable reclamation approaches for that area. During this process, the developers (Camp Dresser & McKee [CDM] Inc. and Reclamation Research Group scientists) conferred with staff from the responsible party, MDEQ, the Montana Department of Justice, the Natural Resource Conservation Service (NRCS), and other consulting scientists with site specific experience and expertise. Multiple reconnaissance trips to each site were made to discuss the full range of site conditions and to review the land condition maps and aerial photography. The knowledge gained during those trips, which included understanding historic perturbations, ecological succession, current soil contamination levels, visible phytotoxicity effects, plant community condition, habitat diversity, soil type and conditions, and historic reclamation achievements using various techniques, was used to refine the evaluation procedures and numeric metrics. After adding and deleting various field parameters and making numerous adjustments to the distribution of points among the parameters, satisfactory correlations between the numeric scores and qualitative condition rankings were achieved. Once this correlation was achieved, the tool (i.e., field methodology) was approved for use by EPA.

The land reclamation evaluation system (LRES) tool, as it became known, allowed the land evaluator to determine 1) the level of ecological dysfunction, 2) whether a remedial action was warranted (or if natural rehabilitation was likely to restore adequate ecological function in an acceptable time frame), 3) the type of remedial approach needed, and 4) the intensity of the intended action (EPA 1999). A major feature of this reclamation planning tool is that it can be quickly applied in the field to any size land unit: In addition, the tool:

1. Considers state and federal laws and regulations.
2. Uses numeric scores that a) address the mobility, bioavailability, and potential release or movement of mining or smelting contaminants and b) segregate land units (polygons)

into different categories based on the severity of dysfunction within the vegetation community.

3. Is precise even when applied by different evaluators.
4. Provides a level of accuracy for selecting initial remedial approaches (design basis).
5. Identifies all potentially important environmental, administrative, or reclamation process factors that can play a significant role in choosing and/or implementing a land reclamation practice. These are referred to as Modifying Criteria.
6. Have decision flowcharts to help guide the decision makers in identifying type and level of reclamation intensity.
7. Provides users a way to identify data and information gaps necessary for remedial design.

The LRES Modifying Criteria were identified to allow flexibility in selecting and implementing a reclamation technology and reflect the necessity of adjusting the action to reflect site specific concerns. For example, if the transport of contaminants to surface water is a compelling concern in a particular area, a more intensive and immediate remedial action may be required. Conversely, in an area designated for historical preservation, a less intensive action may be appropriate. Modifying Criteria include, but are not limited to:

- Land Ownership
- Natural Resource Damage Assessment Program Issues
- Watershed Boundaries
- Weeds
- Soil Texture/Parent Material
- Site Access
- Steep Slopes
- Existing Vegetation
- Rock (outcrops or boulder)
- Natural Vegetation Recovery
- Landscape Position
- 100-Year Flood plain
- Surface Water
- Storm Water Management
- Sediment Transport

- Groundwater
- Vadose Zone Water
- Current Land Use
- End Land Use
- Land Management Practices
- Viewshed
- Cultural and Historic Resources
- Rare and Endangered Species
- Development Permit System/Institutional Controls
- Designated Wetlands

### Application of the LRES Tool

The LRES tool was applied at the Anaconda site in a series of steps beginning with the delineation of land ownership boundaries and areas having similar ecological attributes on aerial photographs, and ended when sufficient data and information were generated from the fieldwork to guide (provide the basis for) the remedial design. The general steps in this process are as follows:

1. Use aerial photographs to delineate land ownership boundaries and preliminary polygons (upland and riparian zones including stream bank buffer areas).
2. Identify on the aerial photographs the probable level of ecological dysfunction: severe, moderate, or slight.
3. Conduct training session(s) and test field personnel to ensure precise data will be collected. Conduct field reconnaissance and adjust polygon boundaries.
4. Use the LRES form in the field to score each polygon and apply the logic decision flowcharts to recommend a preliminary remedial action(s).
5. Identify data gaps that need to be filled to define remedial action(s) and to satisfy initial remedial design specifications. These include soil pH, concentrations of contaminants in the soil profile, depth to permanent groundwater level, thickness of contaminated materials, acid-base account, organic matter level, and others.
6. Develop a sampling and analysis plan, and gather required data and information.
7. Identify decision modifying criteria for each polygon.

8. Choose a remedial alternative and the appropriate intensity of the remedial action for each polygon that will meet agency requirements, which include being protective of human health and the environment.
9. Begin remedial design/action process.

Over a two month field program, staff scientists from CDM and the Reclamation Research Group applied the LRES tool throughout the smelter affected area of the Anaconda site. This effort resulted in the delineation of more than 350 individual land units, or polygons, over approximately a 125 square mile area of the site.

#### Reclamation Approaches at the Anaconda Site

Following the initial fieldwork, the delineated polygons were grouped into remedial design unit (Fig. 1). The polygons within each design unit were then assigned a reclamation approach, based on the application of the pre-reclamation LRES tool. These polygons and the prescribed reclamation approach are shown for the Stucky Ridge remedial design unit in (Fig. 2). As indicated, several tillage depths (i.e., T12 [inches], T6) and cover material (i.e., soil, gravel) were prescribed.

There were four approaches used in steep-slope areas. Areas that had relatively little impact from the smelter and appear to be recovering naturally were designated for continued monitoring (i.e., Monitor-Well Vegetated). Some areas were designated for combinations of treatments and/or monitoring.

In addition to depth of tillage, soil treatments consisted of organic matter and lime applications, and all areas were fertilized. Seed mixtures and species of plant material used were prescribed for each remedial design unit and adjusted at the polygon level where needed.

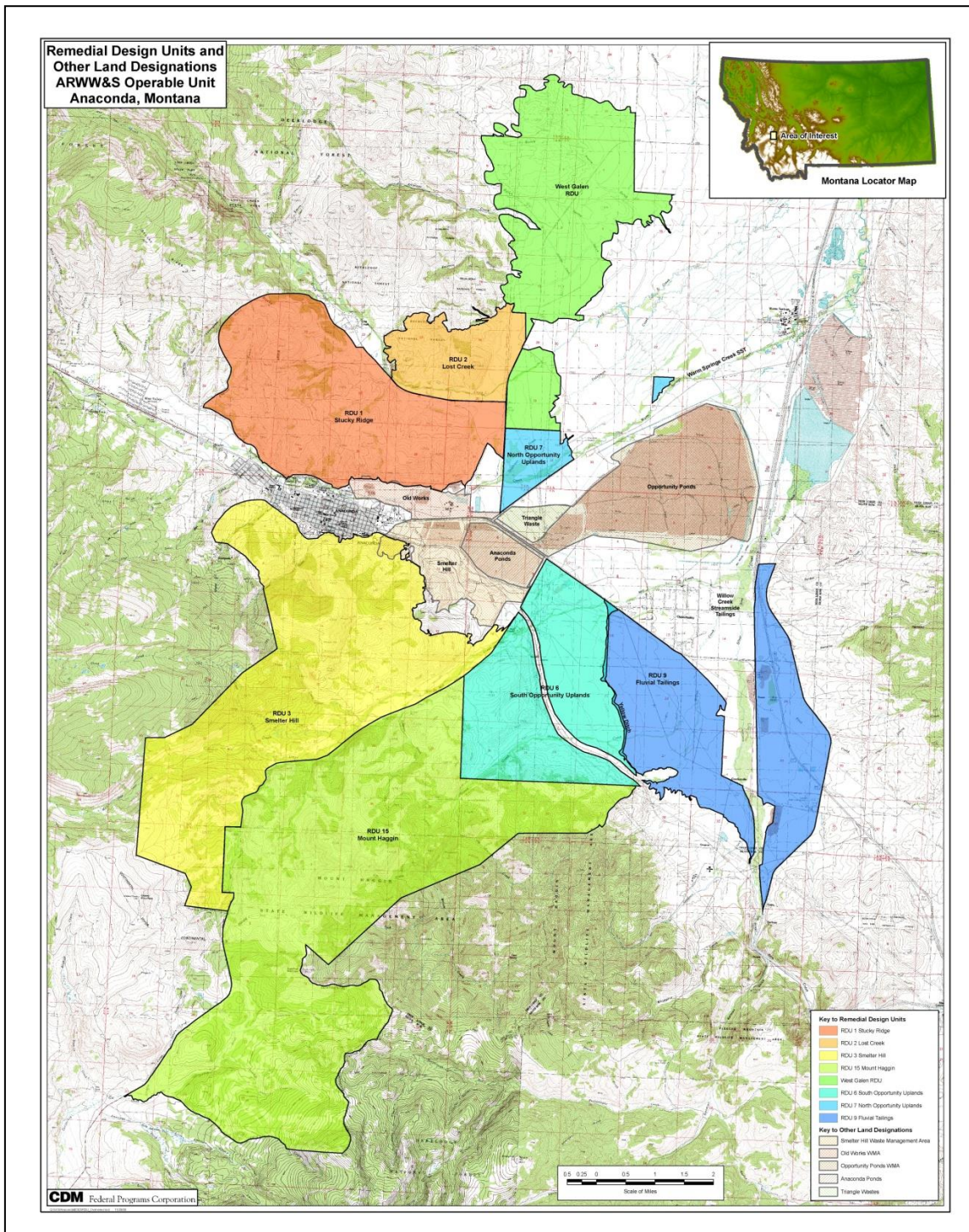


Figure 1. Remedial design units at the Anaconda site.



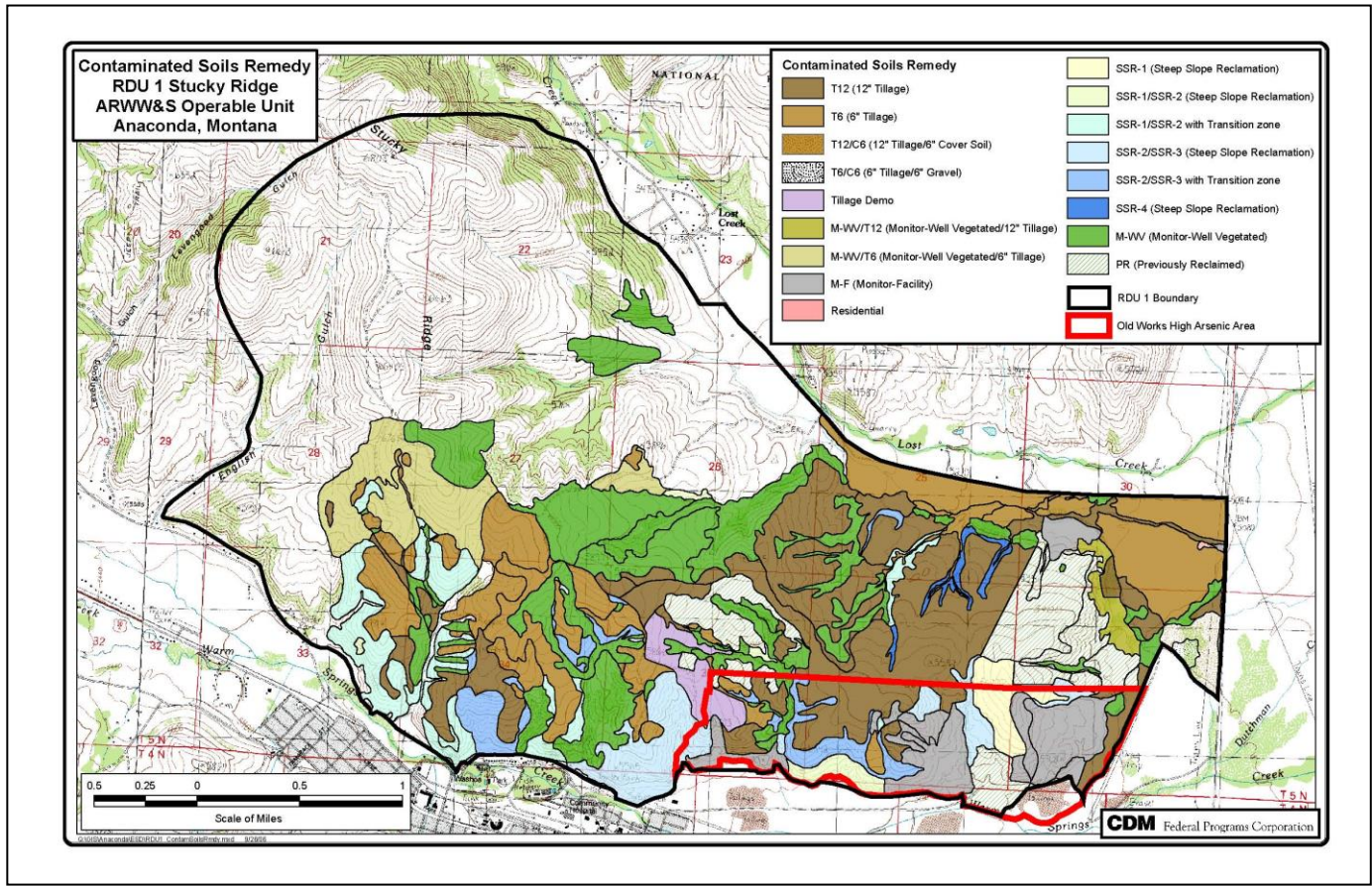


Figure 2. Reclamation approaches for the Stucky Ridge design unit near Anaconda.



## Reclamation Performance Evaluation Process

### Remedial Action Objectives and Goals

The Anaconda Smelter site record of decision requires that contaminated soils areas:

- Provide a permanent vegetative cover over contaminated soil material to prevent direct contact with As, thus reducing the potential risk of human exposure to acceptable risk-based levels;
- Provide a permanent vegetative cover over contaminated soil material to minimize transport of contaminants to ground water, which cause certain metals to exceed of ground water ARARs;
- Provide a permanent vegetative cover over contaminated soil material to minimize surface water erosion and contaminant transport to surface water in excess of surface water ARARs;
- Provide a permanent vegetative cover over contaminated soil material to minimize wind erosion and movement of contaminated soils onto adjacent lands, thus preventing risk of human and wildlife exposure;
- Reduce surface soil contaminant levels to allow re-establishment of vegetation, thus reducing risk to upland terrestrial wildlife above risk-based levels and allow re-establishment of wildlife habitat; and
- Remediate contaminated soils to be compatible with the existing and anticipated future land use with minimal future maintenance activities.

Human health As cleanup action levels for surficial soils at the Anaconda Smelter National Priorities List (NPL) Site are listed below.

<u>Action Level</u>	<u>Land Use</u>
250 ppm	residential land use
500 ppm	commercial/industrial land use
1,000 ppm	recreational/open space/agricultural land use
2,500 ppm	steep slope/open space

As defined in the record of decision, the remedial requirements for impacted soils/vegetation at the site are being addressed by:

1. Reducing As concentrations at the surface to below human health action levels using a combination of revegetation treatment techniques and/or engineered covers.
2. Customizing soil preparation and revegetation techniques to establish a diverse, effective, and permanent (i.e., self-sustaining) assemblage of plant species capable of stabilizing the soils against erosion, minimizing transport of contaminants to surface and ground water, maximizing water usage, reestablishing wildlife habitat; and accelerating succession processes.
3. Applying best management practices (BMPs) to control surface water runoff.
4. Using institutional controls (ICs) to maintain the integrity of remedial actions and prevent exposure to contaminated soil.
5. Providing operation and maintenance (O&M) that includes inspecting the vegetation and soil conditions and implementing repairs as necessary and auditing the institutional control components.

#### Vegetation Management Process and Performance Standards

Following completion of remedial action (i.e., reclamation construction), it must be demonstrated that remediated areas are on a trajectory to meet remedial goals and performance standards. Figure 3 shows the vegetation management process from remedial action through to the long-term inspection and maintenance phase.

The four stages at which remedial performance is evaluated are: 1) shortly after the remedial action is implemented, 2) during the performance monitoring and maintenance phase, 3) at the compliance determination step, and 4) during long-term inspection and maintenance.

The responsible party is currently implementing the remedial action (Step 1) and submitting construction completion reports to the Agencies (Step 2). During this initial phase, each polygon is evaluated to determine if the seeded vegetation is established (i.e., functional), the presence and abundances of noxious and undesirable weeds, and if the polygons are erosionally stable. Polygons with noted problems may require action to repair a gully, reseed areas having low seedling density, or conduct weed spraying to reduce weed infestations. Figure 4 shows a polygon in the early stages of plant establishment.

Performance monitoring and maintenance activities begin when construction (i.e., reclamation) is approved by EPA (Step 3). Following approval, each polygon is subjected to

several years of monitoring and maintenance before it is eligible for a compliance evaluation by EPA to determine if it meets the success standards set forth in the record of decision. This monitoring and maintenance (Step 4) includes conducting annual inspections, performing maintenance, and preparing annual reports for the Agencies. The objective of Step 4 is to identify areas requiring maintenance such as reseeding, replanting, weed control, or erosion control, and to conduct the necessary maintenance. Annual reports summarizing monitoring and maintenance activities across each polygon are submitted to the Agencies.

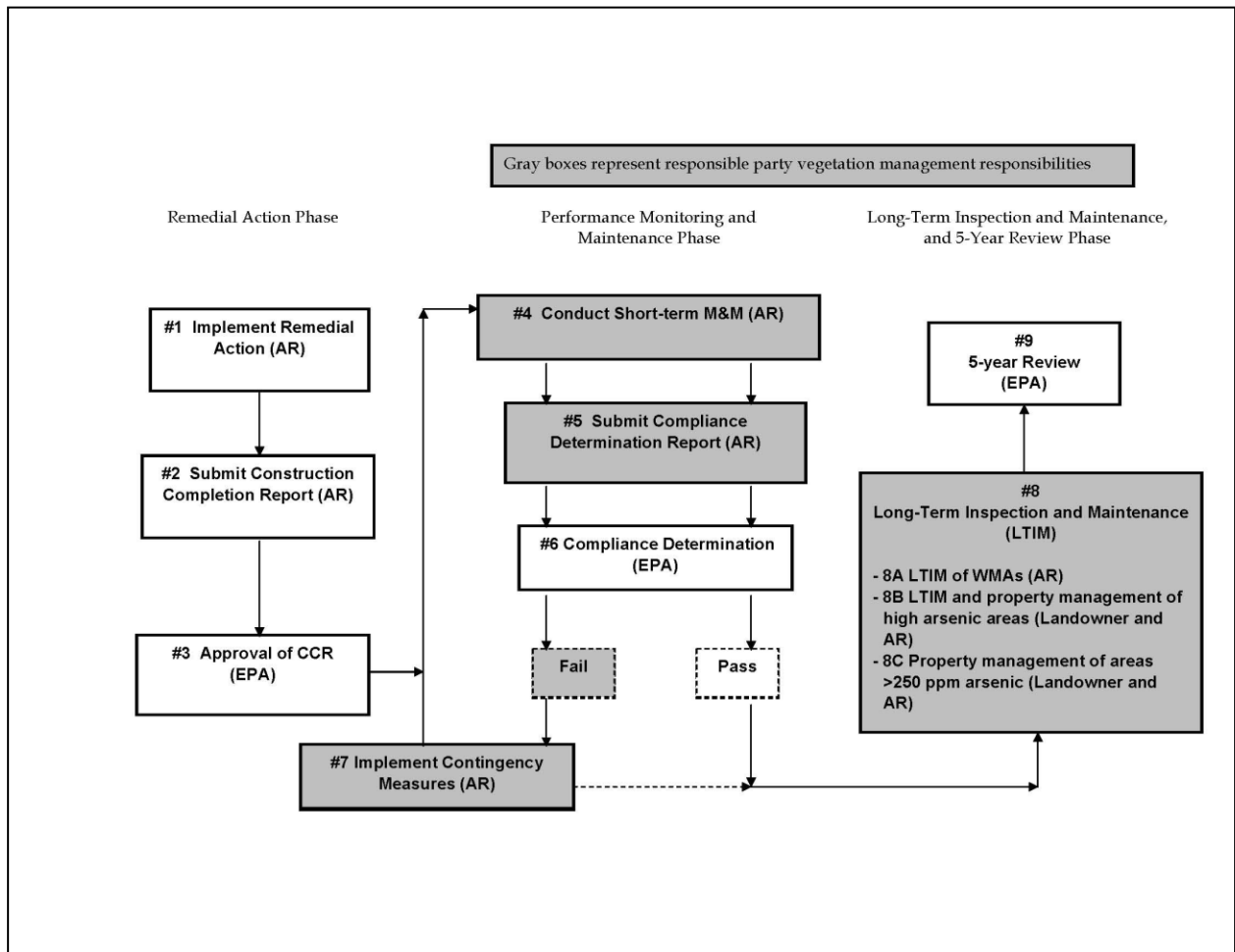


Figure 3. Vegetation Management Process Flowchart

During the performance monitoring and maintenance phase, the vegetation and site stability standards must be met for two years (within a 10 year period) for the site to be eligible for a compliance determination. Performance monitoring standards are shown in Table 1 and include an evaluation of the cover of desirable herbaceous plants, the cover and distribution of noxious weeds, the amount and percent of the polygon having bare ground, and the degree of erosion. These standards are applicable to lands placed in three categories: 1) waste management areas, 2) steep slope areas, and 3) non-steep, non-waste management areas.



Figure 4. Plant establishment in West Galen area in 2008; Anaconda smelter stack is distance. Perennial grass cover is low but relatively uniform.

Once these requirements are satisfied, EPA performs a compliance determination (Step 6). If a polygon fails to meet the compliance determination, EPA decides whether the area will continue in the performance monitoring phase or whether contingency measures can be applied to allow the area to move into the long-term inspection and maintenance/5-year review phase (Step 7). The latter occurs if it is believed that the ecological trend is improving. Periodic inspection and maintenance activities performed in Step 8 are conducted by the responsible party and five year reviews are conducted by EPA as Step 9.

Table 1. Vegetation Performance Standards

Polygon Attribute	Standard	Description
<b>Applicability: Waste Management Areas</b>		
Desirable, Live, Herbaceous Vegetation Cover	≥20% canopy cover	Total live, perennial, non-weedy canopy cover must exceed 20% over 90% of the polygon. Noxious weeds (Appendix B) and trees do not count toward desirable canopy cover. Undesirable weedy species (Appendix C) count a maximum of 5% toward canopy cover.
Noxious Weeds	≤1% canopy cover, rarely seen	Noxious weeds must not occur in more than 5% of a polygon. Within the 5% (maximum area) of occurrence, noxious weeds must be widely spaced and infrequently observed contributing to much less than 1% of the total live vegetation cover. Ninety-five percent (95%) of the polygon must have no Noxious Weeds
Bare Ground	≤10% of polygon and not >1,000 ft <sup>2</sup>	No large bare areas greater than 1,000 ft <sup>2</sup> are allowed. Rock outcrops do not count toward bare ground. Bare areas are defined as having less than 10% live vegetation cover including undesirable weedy species.
Erosion	BLM score ≤45	No significant erosion. No actively eroding gullies deeper than 6 inches are allowable. Rills, if present, are not deeper than 1 inch and spaced at intervals over 10 feet.
<b>Applicability: Steep Slope Areas</b>		
Noxious Weeds	No numeric standard.	Same as above.
Erosion	BLM score ≤45	Same as above.
<b>Applicability: Non-Steep, Non-Waste Management Areas</b>		
Vegetation and site stability.	LRES total score ≥115 points	Site is evaluated using LRES methodology.



## Conducting the Final Inspection

### ***The LRES Field Handbook***

The majority of land reclamation occurring at the Anaconda Smelter site is being conducted in non-steep, upland range sites. For these areas, EPA uses a modified version of the LRES tool and has developed an LRES field handbook that provides the step-by-step methodology that the Agencies (EPA and MDEQ) will use to determine if a remediated polygon meets the established performance standards. The handbook can be found as Appendix E-2 of the Vegetation Management Plan (ARCO 2008). This methodology is intended for use in the field by appropriately trained, qualified, and Agency-approved personnel. The Vegetation Management Plan defines the level of experience and site specific training required for evaluators prior to field application of the LRES tool. In conducting a compliance determination, knowledge is required of the remedial actions implemented, results of annual short-term monitoring and maintenance activities, and visible indications of plant community composition and landscape stability.

### ***Pre-Fieldwork Preparation***

Before conducting an LRES final inspection, the responsible party submits a package of information describing the remedial polygon(s) to be evaluated. For each candidate polygon, the application package must include:

- The construction completion report and the annual inspection and maintenance reports for the remediated polygon. Reports must include hard copy maps, recent air photographs, and GIS files of the subject area. Geographic Information System requirements include electronic orthophotographs, pre-remediation data, pre-remediation design polygons, post-remediation ‘as-built’ polygons, short-term inspection area boundaries, and current land ownership.
- A Final Inspection Application Form.
- A Polygon/Evaluation Area Attribute Form

The EPA reviews the submitted information and verifies that the polygon is a legitimate candidate for final inspection. It must be clear from the previous inspections that the polygon is a valid candidate for final inspection; otherwise the application is rejected by the Agency.

Prior to actual fieldwork, the Pb inspector (Agency person):

- Prepares a field assessment packet for the field crew are developed that include LRES Field Forms, aerial photographs, GIS maps, and the previously prepared reports listed above. The maps used in the field should document the polygon ID, general slope angle and aspect of site, polygon boundaries, property ownership boundaries, areas where maintenance has been conducted, contour lines, constructed features, and polygon acreage.
- Verifies site access for the polygons to be inspected.

***Conducting the Final Inspection***

Agency staff (or their designees) perform a preliminary walk-through of the entire polygon to 1) confirm boundaries for final inspection and 2) determine the number of LRES evaluation areas required to complete the final inspection. It is the intent of the inspection to obtain an LRES score that is representative of the conditions observed within the remedial polygon. EPA recognizes that ecological conditions will vary throughout a polygon; therefore, a number of assessment areas are used to account for this variability. Polygons with little variability across the landscape require fewer assessment locations to obtain a representative LRES score than polygons lacking uniformity. The number of assessment areas is determined by best professional judgment; however, the following can be used as a guide.

Size of Remediated Polygon (acres)	Recommended Number of LRES Assessment Locations		
	<i>high</i> polygon variability	<i>average</i> polygon variability	<i>low</i> polygon variability
< 2	2	1	1
2 - 5	3	2	1
6-20	4	2	1
21 - 50	5	3	2
51 - 75	6	3	2
76 - 100	7	3	2

At each assessment location within a remedial polygon, a soil pit is excavated to a depth of 18 inches or to bedrock, whichever occurs first. A GPS coordinate is entered at the location of the soil pit. A minimum of two digital photographs are required at each evaluation location, one of the soil profile in the pit and a second of the adjacent landscape condition. A compass bearing for the adjacent landscape image is also recorded. A dry erase board with the sample I.D., or equivalent record, is placed in at least one of the photographs to keep track of digital images collected. At each assessment area, defined as 2,500 ft<sup>2</sup> surrounding the soil excavation pit, the attributes defined in the LRES system are evaluated and a score recorded on the field form. For remediated polygons with multiple assessments locations, an area weighted average LRES score is calculated to determine whether the entire polygon passes or fails the threshold score of 115 points. Each of the scored attributes is described below.

Several attributes are scored based on ocular estimation. Ocular estimation of detailed site characteristics may be difficult in large polygons where visibility is limited; however, high accuracy is not required for LRES assessments. It is important to note that the LRES score is based on several attributes, and point weightings in the evaluation are based on the collective experience of plant ecologists, soil scientists, range professionals, and land managers involved in the development of this method.

Each factor in Table 2 is scored according to conditions observed at evaluation locations within the polygon. The LRES evaluator(s) estimates the parameter in question, selects the appropriate scoring category, and enters that value on the LRES field forms.

Table 2. Point distribution among the LRES parameters.

Parameter	Maximum Possible Point Score
1. Percent vegetation cover	25
2. Uniformity of vegetation cover	10
3. Evidence of reproduction	15
4. Plant litter accumulation	15
5. Community dominance and evenness	5
6. Plant density	10
7. Community richness	20
<b>Total for Vegetation Community</b>	<b>100</b>
8. Current water erosion	40
9. Soil pH	20
10. Wind erosion potential	15
11. Surface tailings and metal salts	0 (minus points for high pH)
<b>Total for Site Stability</b>	<b>75</b>
<b>Total Possible Reclaimed Area Points</b>	<b>175</b>

Compliance Determination

Compliance of a reclaimed area (i.e., polygon) is determined using a weighted mean of the individual locations evaluated within that area. As the vegetation and site stability parameters are being scored at each evaluation location, the evaluator records the absolute point values on the summary sheet as well as the percentage of the polygon represented by each evaluation area. Once all the evaluation areas have been scored, the evaluator calculates the weighted point values for each parameter and then tally these to derive a total LRES score for the polygon. Polygons that score  $\geq 115$  point pass the compliance determination and pass into the long-term monitoring phase.

## The Five-Year Review

EPA reviews the on-going inspection and monitoring information at least every five years to determine if the remedy is remaining protective of human health and the environment, or if corrective actions are needed to ensure that the area will again, in a short period of time, meet the risk management goals. It is anticipated that remedial corrective action may be needed for some areas to bring the property back into compliance.

## Conclusions

EPA and the responsible party have developed and are implementing effective reclamation techniques for large areas impacted by smelter emissions at the Anaconda Smelter NPL site. A vegetation management plan has been finalized that defines how these areas are to be managed to ensure that they meet the remedial action objectives and goals for the site. This process consists of a number of short-term monitoring and maintenance steps and a compliance determination step. Land reclamation practices under this program began in the late 1990s and are on-going. Site inspections over this period have shown that the reclamation techniques being employed are generally successful and that the reclaimed sites are on a trajectory to meet the compliance standards. The LRES compliance determination tool has been demonstrated to be adaptable to varying ecological conditions on rangeland sites and can be used to efficiently collect the data and information necessary to determine compliance.

## Acknowledgements

From the earliest conceptual stages, Dennis Neuman and Stuart Jennings of the Reclamation Research Group, Bozeman, Montana, have made significant contributions to the development and validation of the LRES tool. They have also been integral to defining an effective vegetation management process for the Anaconda Smelter site.

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