THE BUNKER HILL HILLSIDES: SITE HISTORY AND PLANNING FOR EARLY SUCCESSIONAL RESTORATION ON THE NATION'S LARGEST SUPERFUND SITE[1]

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Abstract. Good project planning is essential to developing appropriate and achievable restoration programs. This paper discusses the history of the Bunker Hill site and its prior condition. It further discusses the planning approaches that were used and the guidance statements that were obtained. These guidance statements generated clarity for prescription development and measurement of success on the Bunker Hill hillsides project in the Silver Valley of northern Idaho. The hillsides are part of the Bunker Hill Superfund site, a 54 km^2 area centered in Kellogg, Idaho that has been contaminated by heavy metals from a long history of mining and metallurgical activity. Environmental documentation found within the site's remedial investigation/feasibility study (RI/FS) and Record of Decision provided some general concepts of restoration work that could occur on the site but was insufficient to avoid long-term conflicts between stakeholders. In particular, a 425 ha area on the south end of the site was composed of steep, heavily eroded, denuded, and inaccessible hillsides that were contributing substantial quantities of sediment to the Coeur d'Alene River basin. Successful restoration of the hillsides required agreements between stakeholders with respect to specific goals, objectives, performance standards, and monitoring methods. These and other guidance elements guide design and execution of the restoration program. Accordingly, the authors convened a series of three workshops with project stakeholders that outlined project-specific guidance statements for this undertaking to ensure that conflicts were minimized and that the path forward for the project was well-founded. These statements have guided project development, execution, monitoring, and mid-course corrections and has resulted in a successful project with few to no stakeholder conflicts.

Additional keywords: conflict resolution, goals, objectives, performance standards, monitoring methods.

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Introduction

European cultures first settled in the intermountain western United States partly in response to the vast deposits of mineral ores. Miners migrated to the Silver Valley of northern Idaho in search of precious metals such as gold and silver, and stayed to mine lead, copper, and other metals. Wealth and prosperity followed in the valley. However, mining practices and the processing of ores left a footprint of human and ecological health problems for future generations.

The heart of the Silver Valley and the source of many of its environmental problems was the Bunker Hill mining and metallurgical complex near the towns of Smelterville and Kellogg, ID. Activities by the complex heavily impacted the surrounding landscape. In 1996, the U.S. Environmental Protection Agency (EPA) asked CH2M HILL to evaluate the conditions of a portion of this landscape - the 425 ha southern Bunker Hill hillsides - and design revegetation prescriptions for them. The hillsides are draped across portions of Portal, Deadwood, Magnet, Government, Page, and Grouse Gulches. The hillsides (Figure 1) pose extreme challenges for landscaping work including a remote site with poor access, steep slopes, and high levels of topsoil loss. Over the course of the next four years, planning workshops, field studies and trials, designs, and innovative implementation approaches have resulted in the good plant establishment across most of the area. Plant communities are composed of mostly native grasses and forbs (Figure 2). This work is setting the ecological stage for further development of the hills with the long-term goal of establishing a forested landscape.

This is the story of early successional restoration on the hillsides. This and its companion papers (White et al., 2003; Mengel and White, 2003) include discussions of site history and project planning, site studies underlying project design, and portrays a cutting-edge technology for implementation of large-scale restoration of remote areas. This paper also discusses the restorative elements that were employed in the project and, in doing so, examines the role that such projects can play both in the study and implementation of restoration.

Figure 1. Fire, smelter emissions, and erosion produced hillsides largely devoid of vegetation. Note small western white pine seedling in foreground (photo taken in September 1997).

History of the Bunker Hill Site

Gold was discovered in the Coeur d'Alene basin in 1881 and the mining industry identified most of the lead and silver deposits by 1886 (Alt and Hyndman, 1989). Commercial mining for lead, zinc, silver, and other metals began at the Bunker Hill site in 1883. Mineral processing and smelting followed in the early 1900s and continued until 1981. During this time, the Silver Valley became one of the most important centers of metals mining and processing in the world. Through 1978, this area produced 28.2 X 10^9 grams of silver, 6.9 X 10^6 metric tons (t) of lead, 3.0 X 10^6 t of zinc and 139,850 t of copper with an approximate total value of $3.25 billion (Springer in Gott and Cathrall, 1980). During the 1970s, as the nation's second largest smelter, Bunker Hill produced nearly one-fifth of the processed lead in the world and one-fifth of the nation's lead and zinc (James, 1972).

The mining and metallurgical industry of the Silver Valley brought jobs and prosperity to the region, but simultaneously subjected these hillsides and the surrounding landscape to many

Figure 2. While many challenges remain for restoration of the Bunker Hill hillsides, most of the treated hillsides show substantial recovery. This ridgeline along the west side of Deadwood Gulch has as much as 75 percent cover after receiving lime, seed, and fertilizer in the fall of 1998 (photo taken in June 2000).

decades of sulfur and metal emissions and deposition (US EPA, 2000). Several forest fires moved through the general area, including the great 1910 fire and a smaller fire in 1931 (Chapman, 1994). These events destroyed much of the timber cover between Government Gulch and Milo Gulch to the east. This fire, combined with the depositions noted above, resulted in a chronic, broad scale denuding of the landscape surrounding the industrial facilities, from the early 1930s to the present (Figure 1). The loss of vegetation, combined with the naturally steep slopes of the hills, resulted in high levels of soil erosion which contributed large quantities of sediment to the Coeur d'Alene River basin.

During the period from 1965 to 1981, the smelter and associated facilities released more than 2.7×10^6 kg of lead into the environment (Woodward and Clyde Consultants and Terragraphics, 1986) leading to subsequent environmental and human health issues. Milling of ore resulted in tailings that were routinely disposed into surface waters. Heavy metals also entered the food chain, causing serious human health concerns. At one time, over 98 percent of children who were tested had blood lead levels that exceeded 40 $\mu g\ mL^{-1}$ (Aiken, 1998), levels that are of serious concern. By comparison, at the national level, only 2 to 6 percent of children between the ages of 2 and 11 have blood lead levels that exceed 10 μg mL^{-1} (Johnson, 2000).

In 1983, the federal government listed the 5400 ha Site on its National Priorities List. Shortly thereafter, EPA presented various orders to the companies held responsible for the contamination (the Potentially Responsible Parties; PRPs) in an effort to begin remediation of the environmental problems existing on the Site. PRP-supported investigations ensued for about 10 years. EPA performed some emergency yard cleanup to address the acute health and safety risks associated with lead contamination. The PRPs conducted a Remedial Investigation and Feasibility Study (RI/FS) which resulted in the development of two EPA decision documents (Records of Decision; RODs). The first ROD addressed the human health concern and identified residential yard cleanup to mitigate lead contamination within the communities (USEPA, 1991). The second ROD (USEPA, 1992a) described the required remedy for the Non-Populated Areas of the Site.

This second ROD serves as the primary decision document for the hillsides as well as other non-populated areas. The second ROD described cleanup of the smelter and mining facilities, gulch areas, and hillsides. Overall, the extent of contamination in the vicinity of Bunker Hill was too extensive for complete removals. The ROD-required remedies rely on waste containment, management, and education.

In 1992 and 1994, two PRPs went bankrupt. As a result, EPA and the State of Idaho assumed responsibility for the majority of the Non-Populated Areas cleanup. While two PRPs signed Consent Decrees with EPA and committed to implementing some remedial actions in the Non-Populated Areas of the Site, none of this work was specific to the hillsides. Agency driven remedial actions to date include, but are not limited to, demolition and removal of structures including the tall stacks, tailings clean-up along the SFCDR and gulch creeks, closure of the smelter site, hillsides revegetation, and other activities (USEPA, 2000).

Remediation activities on the 425 ha hillsides project area (hillsides) that are reported here represent work on approximately 8 percent of the Site (Figure 3). This area presents the most barren viewshed to people living and moving through the region. Readers should note that the hillsides are part of the larger southern hillsides project area as shown in Figure 3.

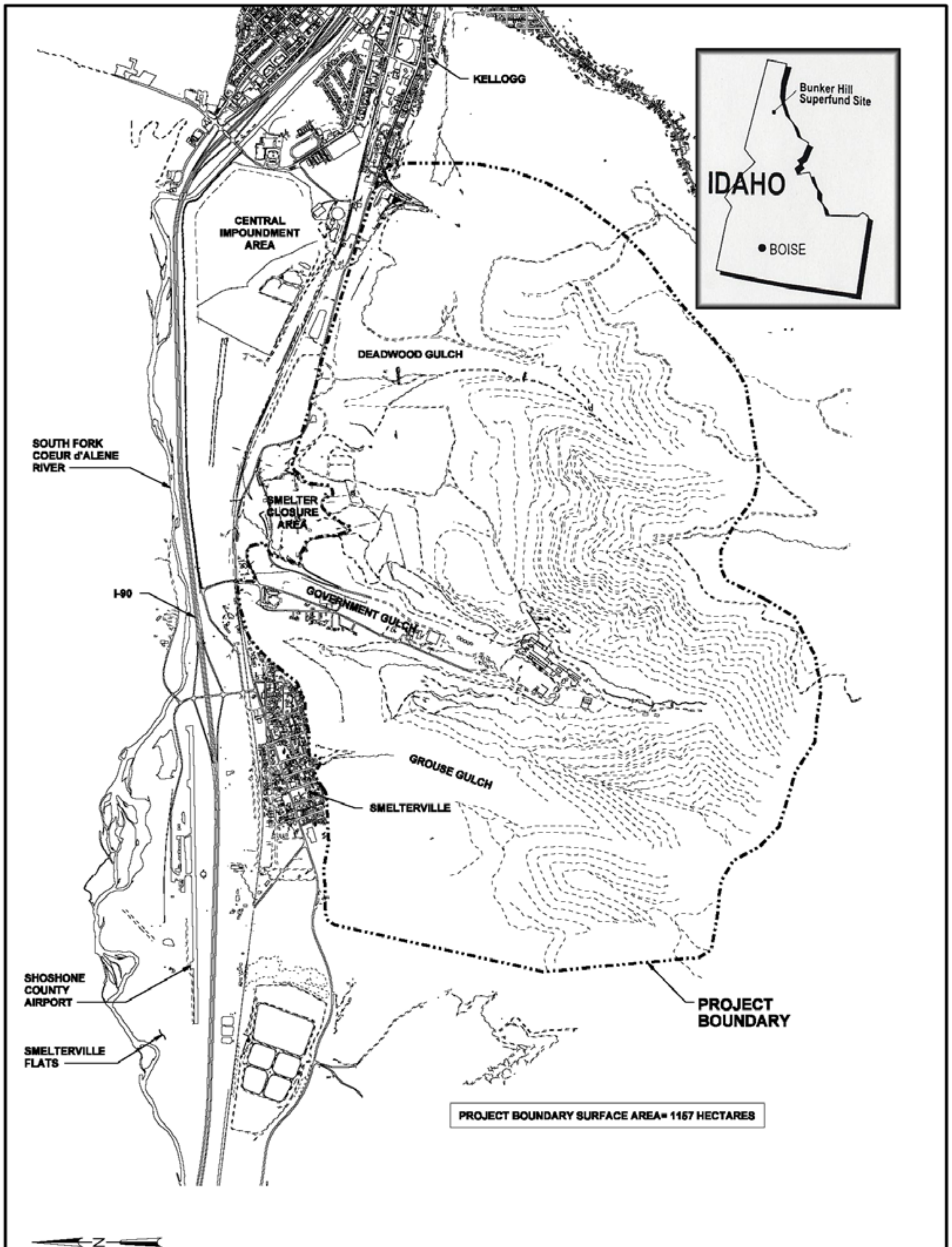

Figure 3
Bunker Hill Site Map

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Numerous attempts at revegetating the hillsides have occurred. This work is summarized in Winterhalder (2000). Work primarily focused on tree planting (Pommerening 1977; Eisenbarth and Wrigley, 1978; Pommerening, 1982) and research in support of it (Carter and Loewenstein 1978; Hansen and Mitchell 1978). Additional trees were planted from the early 1990s (Pintlar Corporation, 1992) until 1994 (William Hudson, personal communication). In total, approximately 2 million trees were planted on the general Superfund site including these hillsides. Species planted included western white pine, Douglas-fir, ponderosa pine, western larch, and lodgepole pine.

Gulf Resources/Pintlar conducted early remediation work on the hillsides project area by installing many miles of bench terraces and planting millions of tree seedlings on these hillsides and elsewhere on the Superfund Site up to the early to mid-1980s (Pommerening, 1982). Other tree planting efforts followed in the early 1990s and were terminated by 1994. Current efforts to revegetate the hillsides included provisions for minimizing the long-term impact of competition to the approximately five to ten year-old trees while meeting other project objectives.

Current Existing Conditions

The base of the hillsides lie at approximately 640 m elevation and their uppermost ridges reach to approximately 1200 m. Four streams drain the majority of the hillsides: Deadwood, Magnet, Government, and Grouse Creeks. Portions of the Page Creek watershed and Portal Gulch are also part of the project area.

The RI/FS examined the existing conditions of the Hillsides Project Area in detail (Dames & Moore, 1990). CH2M HILL substantially enhanced this information during their site characterization work in 1998–1999 (White and Mengel, in preparation). According to these reports, most of the hillsides area does not have levels of metal contamination of great concern to revegetation efforts. Much of the aerially deposited metals contamination from the smelters is presumed to have eroded from these steep and barren slopes subsequent to deposition.

Climate

The climate at Bunker Hill is sub-humid with warm, dry summers and cold, moist winters. Much of the annual precipitation is delivered during the winter months as snow (Golden, 1989).

Summer rainfall is generally low and summer temperatures can be hot. This distribution of precipitation is an important consideration with respect to the restoration of the Bunker Hill hillsides. Consequently, hillside vegetation experiences two relatively short growing seasons, one in the early spring and one in the late fall when precipitation and soil moisture conditions are more amenable to plant growth.

Geology

The hillsides lie within the Belt Supergroup of the Bitterroot Mountain range. The steep hillside slopes are underlain by Precambrian metasedimentary rocks consisting mostly of quartzite, dolomite, and argillite as well as volcanic ash. The slopes can be very dynamic. In places, these materials are relatively loose and slide downslope in response to runoff and undermining of slope toes.

Landforms

Slopes on the hillsides range from 45 to 90 percent (McCulley, Frick, and Gilman, Inc., 1992). In combination with the loss of topsoil, this characteristic results in severe moisture deficiency. Although the area receives 750 mm of precipitation a year, the inability of the denuded hill slopes to retain this moisture for any significant period of time yields a system that is functionally much drier. Areas capable of retaining moisture generally have the most luxuriant vegetation. Conversely, areas unable to store moisture are relatively barren. Therefore, the extent to which project approaches can enhance the ability of the hillsides to retain moisture is critical to the success of early successional restoration.

Terraces

Terraces were cut into the hillsides as a first step in a program of hillside stabilization. Original terrace work was initiated in the 1940s. Pintlar Corporation substantially increased the extent of the terrace network in 1992 (USEPA, 1992b). These terraces were designed to effectively detain surface runoff from a 5 cm event, assuming no infiltration (Harbert, 1992). The highest terrace bench slows runoff at an elevation of about 1130 m. In total, approximately

Figure 4. Terrace benches of the hillsides are relatively flat but cut and fill slopes are steeper than ambient slopes creating difficult revegetation conditions both above and below the benches. Most benches are intact. However, as shown here, water pools in places, saturating underlying soils and overloading the bench. This can produce mass movement and further gully down-cutting along the fill slope (photo taken in 1997).

111 km of terraces were built in the project area. In places, terraces collect water but fail, resulting in additional down-cutting (Figure 4).

Soils

Hillside soils are dominated by Tigley, Hugus, and Honeyjones-Ahrs series. They were extensively eroded over many decades and this produced a site with relatively low fertility (Golden 1989). CH2M HILL embarked on a comprehensive site-wide soil and plant tissue sampling program in 1998 aimed at describing the existing nutritional status of the site. A total of 477 soil samples and 126 tree foliar tissue samples were acquired and submitted for laboratory analysis (CH2M HILL, 1999). This program generated more than 14,000 geographically-referenced data points upon which to base prescription development (White and Mengel, in preparation). A summary of soils data is presented here. The range in concentration for specific

Table 1.Selected soil measurements on the Bunker Hill Hillsides during the comprehensive site characterization study (White and Mengel, in preparation).

Parameter (unit)	Mean	Median	Range
$NO_3 + NH_4$ (μg g^{-1})	12.9	10.3	4 – 57
P (μg g^{-1})	20	16	2 – 84
K (μg g^{-1})	82	77	16 – 183
Ca (cmol kg^{-1})	1.1	0.9	0.4 - 4.2
Mg (cmol kg^{-1})	0.26	0.2	0.1 - 1.7
Available S (μg g^{-1})	45	30	2 – 1742
Total S (%)	0.04	0.03	0.03 - 0.59
Mn (μg g^{-1})	19	15	2 – 155
Zn (μg g^{-1})	66	28	2 – 539
Al (cmol kg^{-1})	1.2	1.1	0.1 – 5.0
Cd (μg g^{-1})	1.6	0.8	0.1 - 15.8
Pb (μg g^{-1})	89	23	1 – 3060
Cation Exchange Capacity (cmol kg^{-1})	9.7	9.7	2.6 - 24.7
Organic Matter Content (%)	1.95	1.90	0.5 - 4.50
1:1 *p*H	4.9	4.9	3.1 - 6.9

elements can be quite large (Table 1). The maximum levels of lead, zinc, and cadmium, for example, are particularly high in comparison with normal soil levels. Yet, mean and median values listed in Table 1 suggest that elemental concentrations across most of the hillsides are much lower. This leads to decidedly different revegetation approaches than might be developed by focusing on maximum levels alone. Our challenge was to develop revegetation designs specific to soil conditions while accounting for site and budgetary constraints.

Comparing soil levels with data obtained from similar areas in 1976 (Hansen and Mitchell, 1978) provides some idea of how the site has changed over the ensuing 22 year period. Importantly, statistical analysis of these comparisons was not possible and no statistical significance is implied here. Nevertheless, in general, we found that metals, organic matter content, and cation exchange capacity appeared lower while P, K, Mg, and pH appeared higher than 1976 levels. Ca levels appeared relatively unchanged. This suggests that continued erosion since 1976 produced loss of organic matter, adsorbed metals, and possibly acid-generating sulfur compounds ironically resulting in improvements to these parameters. In particular, this comparison showed that pH were from 0.2 pH unit to 0.8 pH unit higher in 1998 than in 1976. The apparent increase in pH alone provides many well-known ancillary benefits to plant growth.

Vegetation

Prior to the start of the current restoration program, most of the hillsides had little to no vegetative growth except for previously planted trees. Yet, many of these trees were stunted and provided little above-ground protection from hillsides erosion. However, recent visual evidence suggests that many of these trees are concentrating their photosynthate into root production (Figure 5). This pattern of carbon allocation is consistent with trees grown under stressful conditions (White 1989) and the resulting higher root surface area can result in rapid above-ground growth response to improvements in nutrients and moisture.

Summary of Critical Existing Conditions

Based on the above discussion, the Project Team (stakeholders) composed of representatives of the US Environmental Protection Agency, the State of Idaho's Department of Environmental Quality, the US Army Corps of Engineers, the Bureau of Land Management, and others were faced with six revegetation challenges:

- Topsoil loss resulted in a hillsides environment suffering primarily from a lack of available soil moisture
- Soils were uniformly acidic with an average pH of 4.9
- Soils were generally low in N, P, and K
- The Bunker Hill Superfund site is distant from large metropolitan areas leading to high shipping costs for amendments and other revegetation materials
- Hillsides watersheds are generally steep and difficult to access by land-based equipment
- The survival and vigor of thousands of tree seedlings was important to long-term ecosystem development

Figure 5. Some planted white pine seedlings are extending their root systems deep into the soil profile in search of moisture. The over 2 meter taproot on this six to seven year-old western white pine was exposed by side-wall cutting in the deep gully. Seedling height is approximately 60 cm. The investigator's right foot points to the bottom of the taproot.

Ironically, while issues regarding metals contamination dominated much of the early thinking associated with revegetation, our soils studies revealed that while metals contamination was important in scattered areas, the issues noted in the bullets above were more widespread and, as such, elevated their importance to developing site prescriptions for the general project site.

Developing Project Guidance

Project stakeholders often have different perspectives of how a landscape should be managed. Because of these differences, it is imperative that the stakeholders reach an understanding of the reasons for the project before it is designed and implemented. A clear understanding of project drivers helps minimize conflicts during or after the project has been implemented. Preparing a set of project guidance statements is an effective way to reach this understanding and it can be particularly effective when consensus-based approaches are used to develop them. We followed this approach to guide this project.

The Project Team participated in three workshops to develop guidance statements for the Hillsides Project. The focus of the workshops was to turn the broad ROD language into specific actions that could be implemented on the site. We used a "straw man" approach to build each guidance statement. The approach begins with proposed guidance statements (straw men) and works constructively toward the development of consensual statements.

The straw man approach results in active, constructive dialog among the participants. We found it useful to hold several sessions to allow stakeholders to retreat, rethink, react, and respond to prior guidance statements. These consensus-based workshops facilitated the project in a number of ways. The workshops:

- Allowed an equitable, non-confrontational approach to planning
- Ensured that constructive, product-focused interaction occurred and reduced the number of "sidebar" discussions
- Increased stakeholder understanding of other participants points of view
- Helped create consensus agreement regarding value-laden terms thereby reducing potential for future conflicts.

As the team built the hillsides action plan (conceptual model), many natural resource terms were invoked. Participants developed a project-specific glossary to ensure that the team agreed to their definition. The Team considered the language for each term carefully. We found that discussing specific words within these definitions was particularly effective at teasing out subtle differences of opinion among team players that otherwise would have remained hidden only to surface as a source of conflict later. This approach fostered a greater sense of understanding among team members and we believe it helped reduce conflicts as we moved into project design.

Project Guidance Statements

Workshops were held on January 21, 1998, April 7, 1998, and April 27, 1999 where we followed an iterative process for identifying goals, objectives, performance standards and monitoring methods. The results of only the first two workshops are discussed here.

The Project Team considered several factors when defining the guidance statements for the Bunker Hill Hillsides Project (Table 2). Each statement had to concur with the ecological conditions of the site and the available resources to accomplish them. In the case of goal statements, for example, several options were evaluated and the following questions were posed to the Project Team:

- Do the goals of the project include restoring hillside ecosystems to their former forested state?
- Are they to reduce discharge of sediments and heavy metals to the watershed?
- Are they to achieve a specific level of aesthetic appeal for future viewers of the landscape?
- Are they all or parts of the above?

Ultimately, the project purpose and a set of two goals and eight objectives drive the development of design and implementation approaches for this project (Table 2). Goals recognize both the need to reduce pollutant discharge and the need to develop ecologically and socially sustainable ecosystems in the process. The project intends to do this through the achievement of eight objectives linked to these goals. These objectives identify specific areas for revegetation, the need to ameliorate site characteristics that limit plant growth including chemical and physical limitations, to establish plant species that can naturally regenerate on the site, and to manage the site for noxious weeds. Achievement of each objective is measured via performance standards described in Table 3.

<u>Adaptive Management</u>. Importantly, the final objective recognizes the inherent experimental nature of such a large scale and difficult project by allowing for adaptive management. Ecosystems are not static by nature but are instead highly dynamic, constantly changing landscape entities. In essence, the end product of the hillsides revegetation will not be a permanent feature of the landscape, but will change over time as it grows into a mature system. Along the way, its development may slowed due to reductions in site fertility or be disrupted by invasion by non-native plant species, fires, windstorms, landslides, or flooding. These events often result in a more structurally-diverse landscape capable of supporting more kinds of habitat. However, as landscapes change, land managers must adjust their approaches to accommodate modified conditions. This allows for the incorporation of new information and better

Table 2. Bunker Hill Hillsides Project Purpose, Goals, and Objectives

Purpose

Improve the condition and safety of the human and natural environments which have been impaired by actual or threatened releases of hazardous substances from this site in the Silver Valley, Idaho, through the implementation of selected response actions for the hillsides.

Goals

1. Improve watershed function by reducing runoff, soil erosion, and transport of pollutants within and from the site.
2. Establish adapted plant communities capable of natural regeneration and providing ecological and/or societal values.

Objectives

1. Establish herbaceous cover on sites with less than 50 percent cover with priority to areas with high contaminant levels and/or sites with less than 25 percent cover.
2. Establish check dams in gullies and on terraces.
3. Establish herbaceous and woody vegetation in gullies and on terraces.
4. Ameliorate soil physical and chemical constraints to watershed function and plant growth.
5. Reduce runoff from terraces.
6. Establish self-regenerating species and, where needed, soil-building species.
7. Minimize colonization by noxious weeds.
8. Manage the Bunker Hill hillsides using adaptive management techniques.

management decisions. Thus, management plans are always “works in progress” and, as such, they are able to accommodate innovation without compromising established goals.

It was clear to the Project Team that early successional restoration of the hillsides would not come easily. Recovery of the hillsides required steps to mitigate site dryness while staying within budgetary constraints (White et al., 2003). Few if any options exist that could provide dramatic results without being cost prohibitive. Consequently, we needed to adjust our perceptions of site recovery to be consistent with the capacity of the site and the available resources for restoring these hills.

Adaptive management recognizes that the design elements described for the project (White et al., 2003) are the starting point, rather than the end point, of hillside restoration -- that there is no

Table 3. Bunker Hill Hillsides Project Interim Performance Standards

Interim Performance Standard #1

Herbaceous plant canopy cover of regeneration species shall exceed 50 percent within each planting area designated in each task order specification within two (2) full growing seasons after installation. Actual determination of canopy cover will be measured on each 5-acre management unit block. Any management unit with less than 50 percent cover will be evaluated further to determine the appropriate course of action including, but not limited to, reseeding, addition of soil amendments, lime, or fertilizer, or additional monitoring to determine rate of cover expansion.

Interim Performance Standard #2

Check dams, built and installed as specified, shall be constructed in all major gullies and adjacent to major gullies on terraces. Each check dam shall be inspected following precipitation events (including rain, rain-on-snow, and specific snowmelt events) sufficient to cause sheet erosion runoff from the barren hillsides. The inspection shall determine if each check dam is retarding or retaining water flow by ensuring that water is not bypassing or "short-circuiting" each check dam. Any check dam exhibiting short-circuiting of water shall be repaired immediately. Monitoring shall continue within each gully-check dam system until Objective 3 (as measured by Performance Standard #3 below) is achieved for that gully.

Interim Performance Standard #3

Vegetation cover of regeneration species shall exceed 70 percent of each major gully bottom and terrace within 2 full growing seasons after completion of installation.

Interim Performance Standard #4

4A. Within five (5) years after completion of plant establishment projects, the following ratios of runoff volume to precipitation shall decrease:

- Runoff volume to precipitation (per annual monitoring period)
- Hourly runoff volume to hourly rainfall intensity

4B. Water quality of discharges is within Bunker Hill project targets for heavy metals, and turbidity decreases within five (5) years after completion of plant establishment projects.

Interim Performance Standard #5

Water shall not flow from the terraces into major gullies with sufficient energy to initiate sediment transport and down-cutting, but shall instead be retained or retarded until it infiltrates, evaporates, or slowly discharges onto the hillsides. The check dams shall also not result in any terrace being breached due to operation of the check dams. This shall apply to the vicinity of check dams only and until such time as vegetation becomes established and stops sediment movement. This would be observed during rain and/or snowmelt events of sufficient intensity to cause sheet runoff from barren hillsides.

Interim Performance Standard #6

Evidence of regeneration of site species must be present on at least 50 percent of each

Table 3. Bunker Hill Hillsides Project Interim Performance Standards
management unit within 3 years following execution of a given Task Order. Evidence of potential for regeneration includes but is not limited to one or more of the following: 1. Seed production of on-site plant species and presence of newly germinated seed. The presence of newly germinated seed must be linked to on-site seed production from existing plant species (either artificially planted or naturally invading from surrounding areas) to ensure that newly germinated seed did not arise from previous seeding operations and/or a short-term invasion from off-site species. 2. Expansion of cover by vegetative production of new shoot growth from rhizomes or other underground structures. 3. Evidence of sprouting from damaged or cut stems of woody species.
Interim Performance Standard #7 1. Comply with State of Idaho Noxious Weed regulations.
Interim Performance Standard #8 1. Use information derived from the Monitoring Program in an iterative fashion to determine the effectiveness, utility, and validity of each of the performance standards in the project.

single "silver bullet" solution to the complexities presented in the hillside landscape. Its remote location, steep terrain, lack of access, lack of topsoil, and other constraints all combined to present a daunting task. Consequently, the team prepared to use an adaptive approach to revegetation that included preliminary studies and staged implementation while anticipating a need for repair and maintenance as the hillsides expressed the results of the revegetation efforts. To date, the adaptive management approach has resulted in modifications to seed mixes and application prescriptions as the project has unfolded. Continual improvement in the effectiveness of the revegetation efforts is expected by following adaptive approaches.

Workshop II: Interim Performance Standards. Interim performance standards (IPSs; Table 3) define project expectations at the finest scale. The IPSs contained herein represent the collective best professional judgment of workshop participants. The "interim" modifier recognizes this and the fact that adaptive management approaches will drive the project forward. As the name suggests, the IPSs presented here are deemed interim at this time. As monitoring information is gathered, IPS may either be assigned permanent status or revised as necessary to reflect the actual function of the hillsides.

Readers should note that reference ecosystems provide a useful means of measuring ecosystem trends. The surrounding watersheds are home to forested ecosystems that, in the long-term, could be used as references for the hillsides. However, the hillsides have lost vast amounts of soil over the decades and, along with that loss, substantial depletions in stable organic matter, cation exchange capacity, available water capacity, seed banks, microbial activity and other processes important to ecosystem development. It is not unlikely that the substantial nature of these losses has produced functionally different site types from the surrounding landscape. Nevertheless, early successional restoration relies upon initial reintroduction of these characteristics and processes to the hillsides. Yet, the Project Team did not believe comparisons of mature forested landscape composition and function with that of the early successional hillsides would result in information useful to management decisions within the timeframe and context of this project. This decision is reflected in project purpose and goals (Table 2). As such, comparisons to nearby reference systems have been limited to surface water quality comparisons between flows emanating from reference areas and the hillsides. Nevertheless, future research could include comparisons of community composition, physiognomic measures, soil function, and other factors to enhance our understanding of ecosystem recovery in these harsh realms.

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