RESTORATION OF THE FLOODPLAIN OF THE SOUTH FORK OF THE COEUR D' ALENE RIVER: A CASE STUDY OF APPLIED RESTORATION THEORY[1]

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Abstract. Remediation of the South Fork Couer d'Alene River floodplain (the Flats) in Smelterville, Idaho, offered a unique opportunity to test ecological restoration theories regarding the relationship between plant community establishment and abiotic environmental conditions. Successful re-creation of the abiotic environment is the primary consideration for restoration of a given plant community type. Failure associated with many wetland restoration projects can often be traced to inappropriate soils and hydrologic conditions for the target community. This paper reports the preliminary results of an 80 ha floodplain restoration project that occurred without artificial replanting of herbaceous wetland plant communities. Over 760,000 cubic meters of tailings-contaminated materials were removed from the floodplain. Ground-water modeling prior to excavation and re-grading served as the basis for developing post-excavation grading plans. Grading was coupled with placement of 15 cm of high quality native topsoil. Coversoils required relatively little amending following placement and establishment of final grades. No herbaceous wetland plants were installed on the site. Drill seeding with grasses and forbs helped stabilize upland areas and slopes. Woody plants were installed along the streambank and in places throughout the floodplain in the springs of 2001 and 2002. Four years later, the floodplain is naturally regenerating to a diverse and vigorous palustrine emergent marsh (PEM) community. Species currently established in wetlands on the site include sedges, rushes, cattail, reed, hardstem bulrush, and spike rush, among others. Additional woody species, such as cottonwood and willow, are naturally regenerating. By successfully establishing wetland hydrology and use of native topsoils, the project has been able to produce a diverse and vigorous PEM community capable of supporting wildlife and delivering at least some wetland functions that had not been available to the Coeur d'Alene basin for many decades while saving almost $900,000 in proposed replanting costs.

Additional keywords: wetlands, abiotic, palustrine emergent marsh, Superfund, CERCLA, remediation, wetland functional restoration

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Introduction

Restoration of habitat is an exercise that often follows a path similar to this: define the problem through site and watershed studies; design the habitat and prepare the bid package; install the project; monitor the newly planted area; develop excuses for poor performance; and find somebody to blame. This process is then repeated until enough failed projects accumulate to write a paper about how restoration is a promising technology that currently doesn't work, and including a list of the usual suspects.

Myriad reasons explain the failure of restoration projects when they occur. Meanwhile, restorationists present relatively few reasons for success. Clearly, the failure of restoration professionals to agree on what constitutes restoration success, and what does not, shoulders a significant portion of the failure burden. The Society for Ecological Restoration has attempted to add reason to the debate through a number of definitions. Over time, the definition has become more inclusive of a wider range of project types (SER, 2002), and while this adds clarity to the definition, it does little to quell the success versus failure issue. Whether the range of personalities and agendas associated with restoration – from regulators to designers, contractors, resource agencies, and others – will join in a consensus definition of restoration success remains doubtful. Indeed, is it any wonder that ecosystem restoration engenders controversy when ecologists can not just agree on the definition of restoration but when ecosystem definitions themselves suffer from significant limitations and biases (O'Neill et al., 1986)?

Failure of restoration projects has many ecological bases. We will briefly touch on four of these below.

What are you achieving and when

A general lack of understanding of site-specific ecosystem dynamics over large time scales places many restorationists in a position of attempting to create "instant ecosystems" or, at least, trying to bypass seral processes whose circumvention may not be realistic in short time frames. Surely, there are instances of successful endeavors in this regard (e.g., Munro, 1994), but whether these procedures are cost effective for large projects or applicable across large areas remains to be seen. While short-circuiting seral processes is a central theme of the restoration ethic, it suffers from this lack of a broader perspective and the resultant expectations of regulators and others regarding the promise of restoration.

Transplanting Costs

Outside of earth-moving activities, one of the most costly wetland restoration components is transplanting vegetation. The promise and problems of this technology are well documented within the restoration literature and elsewhere. Restorationists, in particular, are vigorous in their insistence upon use of native species in their projects. This, in turn, raises many questions regarding the native concept and its impact on projects, namely, from what geographical area can a seed source arise for a given project, what are the costs of collecting, propagating, and verifying custom vegetation for specific projects, what are the scheduling and logistics associated with propagation and client budgets, and so forth. Then too, the well-documented failures associated with transplanted vegetation, even when native species are used, cast at least some doubt upon this costly approach to reestablishing habitat (Gwin and Kentula, 1990).

Construction Issues

The reason for much of the failure to successfully establish targeted wetland plant communities rests at least in part with our uncertainty regarding all but the most general ideas of ecology and cultural requirements of native species, the influence of competition on their establishment, and, in particular, our inability to predict the exact environmental setting into which they will be placed. Irrespective of study, design, and oversight, it is the person on the bulldozer who ultimately has the greatest influence on the character of a restoration site. Wetland plant species tend to be quite sensitive to changes in hydroperiod, and small variations in water levels and/or durations often spell the difference between successful establishment and failure. Conscientious machinery operators can often achieve very accurate finish grades, but this comes at a cost of repeated tracking of the site. The end result is often sadly detrimental to the survival of planted vegetation as a result of soil compaction. Thus, we are often doomed by the very technology that we rely on to develop our projects.

Species Specific Functional Support

Ultimately, since the cost of native plant collection, propagation, shipping, and installation can be very high, projects often do not receive the value that native wetland plant production is trying to deliver. Ecologists can usually speak in general terms about the range of functions associated with different wetland community types (palustrine emergent marsh versus palustrine forested, for example). But for the possible exception of habitat (especially for sensitive wildlife species), ecologists usually fall short in defining the specific functional contributions made by given species within a community, much less in defending the exclusive use of that species. Yet, wetland restoration projects almost universally rely upon artificial regeneration either using species that are currently available on the wetland native plant market or spending several years collecting seed and propagating transplants. Ironically, our end product is an artificial assemblage of wetland plant species whose species-specific contribution to landscape function is unclear and whose survival is often doubtful.

The Fundamental Basis of Restoration: Restoring the Environmental Setting

While the horticulturalist in us suggests that active planting of wetland vegetation is needed in restoration projects, the body of evidence regarding their sustainability within restored systems suggests otherwise. This paper discusses an alternative to artificial establishment of vegetation by presenting a case study of project design and implementation at the Bunker Hill Superfund Site in northern Idaho. It focuses on the essential design criteria facing restorationists that are often ignored or marginalized during project planning and execution.

Thus, more than any other factor, the environmental setting of a habitat is the central driver behind success or failure of projects. This alternative sees restoration as fundamentally not the reestablishment of biotic components of ecosystem as much as the reestablishment of an environmental setting that ultimately supports those biota. The environmental setting is defined for the purposes of this paper as the physical surroundings of an ecosystem. Within a given climatic regime, this includes the hydrologic characteristics (the season, duration, source, and frequency of wetness, floodwater velocity and depth, and more) and the soil/site parameters (slope, aspect, soil depth, drainage, parent materials, texture, bulk density, organic matter content, soil moisture holding capacity, and more) essential for the survival and vitality of target plant species groups. The underlying importance of environmental setting to ecosystem restoration is underscored within the hydrogeomorphic classification system (Brinson, 1993) and is gradually being embraced by SER (Freeman, 1999). Importantly, failure to reestablish environmental setting exactly results in an inexorable shift of plant species over time from the plant assemblages desired by project proponents to those naturally adapted to the resultant environmental setting. Project success and failure are linked to the extent that designers and installers of habitat are able to match environmental setting to species.

In theory, if the environmental setting is appropriate and sufficient natural supplies of propagules are available, natural regeneration can largely take the place of artificial establishment in many, if not most, projects. Why hasn't this approach received more scrutiny within the restoration discipline? Success using natural regeneration has several fundamental assumptions, and if these assumptions are not met, the success associated with natural regeneration will be reduced. First, the restoration effort must take place within a watershed where adequate natural seed sources exist. For wetlands, these seed sources generally should reside upstream (or upslope) of the target site in order to be carried to the site in floodwaters or by other means. Second, the watershed must be relatively free of exotic and/or noxious weeds that could outcompete the desired vegetation for site occupation. Unfortunately, in many, if not most, watersheds this second assumption can be considered rather spurious, and so, embedded within this postulate is a third assumption that a level of vegetation management will be implemented on the site irrespective of whether natural or artificial regeneration is pursued. The intensity of vegetation management is expected to be commensurate with the potential for weed invasions. This third assumption can be extended for herbivory management as well.

Clearly, these last two assumptions address a second important cause of failure in restoration projects: lack of follow-up cultural care. The most successful restoration projects are those with adequate long-term management. It is the rare project indeed that, by design, happenstance, or pure luck, meshes design perfectly with construction to yield a project that can succeed on its own without further manipulation. Rather, providing at least an opportunity for future management and continual oversight is the best route to project success. This is a lesson well known by natural resource professionals, learned after many decades of experience with forest, range, and agricultural systems. Unfortunately, too few project owners are prepared for such an endeavor. This is an important reason why many restorationists encourage project owners to implement and manage their projects with volunteer groups. Volunteers often gain a sense of ownership of projects and can be called upon later to provide simple follow-up cultural care and facilitate long-term establishment while minimizing costs.

Cost of Current Restoration

A central challenge before restorationists is developing technologies that by-pass seral stages in a cost-effective manner. Some approaches to this include wholesale transfer of intact soil/plant systems (Munro, 1994), increasing organic matter content of soils through topsoil transfer, use of biosolids (Adegbidi et al., 2000; Griebel et al., 1979), composts or other organically-enriched media, tree-planting, and others. Sometimes, these approaches cannot be applied because of cost or project-related logistics. Often, techniques that significantly advance a system toward a late successional status are cost-prohibitive at large scales or on logistically difficult areas. As one example, the Smelterville Flats Site (the Flats) is relatively far away from significant population centers, increasing the cost of applying virtually any material because of high shipping and mobilization costs.

Site Background

The Bunker Hill Mining and Metallurgical Complex Superfund Site (the Site; Figures 1 and 2) is located in the northern Idaho county of Shoshone. The Site, part of the Bitterroot Mountains, lies in the Silver Valley of the South Fork of the Coeur d'Alene River (SFCDR). The Silver Valley is a steep mountain valley that trends from east to west and, as the name suggests, is rich in precious metals and other minerals of economic importance. The Site has an elevation of approximately 685 meters above mean sea level (MSL). Interstate 90 (I-90) bisects the Site east to west and more or less parallels the SFCDR through this area.

The Site has a history of mining and metallurgy that spans 115 years. Mining first began in the area during the mid 1880s. While various ore concentration methods were employed at the site prior to this time, actual smelting of ore did not begin until 1917 when the lead smelter began operations. Zinc smelting began 11 years later. Milling of ore produced by-products (tailings) that were routinely disposed into surface waters. This disposal occurred from both on the Site and upstream milling sites. In 1910, mining companies constructed a plank and pile dam

Figure 1. Smelterville Flats looking west. Note branch of the South Fork Coeur d'Alene River on the right. In immediate foreground are metals-contaminated tailings that were subsequently excavated and transported to another location for long-term containment (Photo taken in November 1996).

along the SFCDR to retain the tailings. Unfortunately, the dam failed during the 1930s which resulted in extensive reworking of tailings on the floodplain of the Flats that continued from that time until Flats remediation occurred in the late 1990s (Figure 1). Other tailings impoundments included Page Ponds, built in 1926, and the Central Impoundment Area (CIA), first constructed in 1928 with continual additions until closure in the late 1990s.

From the time smelting was initiated through the 1960s, the Site was dominated by industrial activity. Mining and the production of lead, zinc, silver, sulfuric and phosphoric acids, and fertilizer were the primary activities occurring in the area. Ultimately, milling capacity at the site reached about 2,540 Mg per day. The 1970s began an era of increased environmental concern about the site. A fire in the baghouse of the lead smelter stack led to increased emissions of lead particulates into the environment. This, in turn, resulted in studies showing significantly increased blood lead levels in children living in the immediate area. Subsequent actions taken during the 1970s resulted in at least partial reduction in blood lead levels. Also, in 1977, mining companies constructed tall stacks to help disperse contaminants, including sulfur dioxide, from the site.

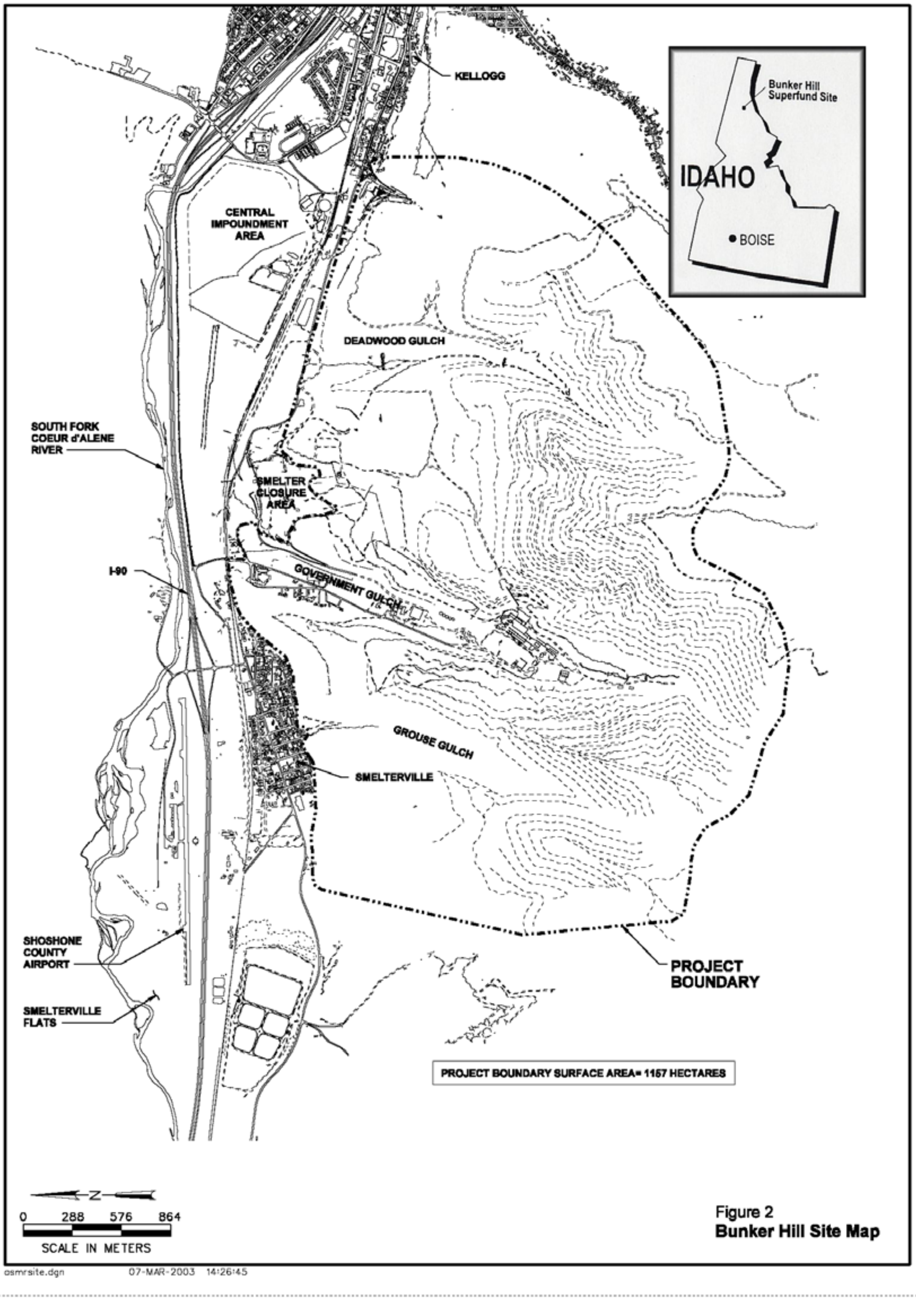

Figure 2
Bunker Hill Site Map

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The decade of the 1980s was one of official recognition of the Site as an environmentally contaminated area by the federal government. Studies aimed at remediating this contamination began along with some initial remedial work. The Site was placed on the National Priorities List in 1983. This year marks both the beginning of Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA; US EPA) presence in the Silver Valley and the initiation of CERCLA enforcement investigations at the site. Various studies examined both populated and non-populated areas of the site and served to identify the range of contamination and the assignment of liability associated with it.

The 1990s ushered in a number of important environmental decision documents and the beginning of EPA-directed cleanup work. Two Records of Decision (RODs), one for the populated areas of the Site (Residential Soil ROD, 1991) and one for the non-populated areas (US Environmental Protection Agency, 1991; US Environmental Protection Agency, 1992), were released. In addition, three Administrative Orders on Consent were released from 1990 to 1992 directing work on the hillsides, the Mine Operations Area, and elsewhere. Design and implementation of cleanup of the hillsides, the gulches, the Flats, the Central Impoundment Area, Page Pond, the Smelter Complex, and the Mine Operations Area were begun at this time.

Smelterville Flats Remediation

As mentioned previously, the SFCDR received tailings from numerous mines and mills in the Silver Valley both in, and upstream, of the Complex. Tailings were initially retained by constructing dams within the floodplain of the SFCDR. Subsequent flooding caused tailings and historic smelter complex waste to be spread throughout the valley floor and to be mixed with alluvial sediments. Cleanup of this contamination ensued in the late 1990s.

The Flats remediation project area is bounded by the northern reach of the SFCDR floodplain on the north, the Union Pacific Railroad bridge that crosses over the SFCDR west of Pinehurst Narrows on the west, the town of Smelterville on the south, and the I-90 West Kellogg interchange on the east. Several test pit investigations performed by Terragraphics (contractor to the State of Idaho) in 1995 and 1996 and soil borings drilled by CH2M HILL (contractor to the US EPA) in September 1995 found the depth of tailings to extend from 0.3 m to potentially greater than 3 m below the ground surface.

Following the release of the ROD, decisions were made by the US EPA and the State of Idaho to maximize contamination removal within the available funds. This approach exceeds the removal actions suggested by the ROD to be protective of human health and the environment. As such, the US EPA and the State of Idaho have removed nearly all of the tailings within the Flats area north of I-90. Morrison Knudsen (construction contractor for the project) transferred the tailings to the CIA for containment.

Soil-removal actions followed an intent of maximizing source control via contamination removal. To that end the decision was made to remove as much mine waste tailings as possible to the CIA for containment. The project team linked soil-boring results to visual identification of tailings and native alluvium by a Removal Verification Team (RVT). Representatives of the US EPA, Idaho Department of Environmental Quality, and the US Army Corps of Engineers formed the RVT. The RVT acted in concert with limited verification sampling to determine how much contaminated material should be removed from any given area. Lab analysis identified the levels of lead and zinc within verification samples. If necessary, further excavation occurred beyond the level established by visual inspection based on these sample analyses. The project team determined that removal of tailings to a level cleaner than the sediments carried by the river was impractical. Consequently, the RVT set 3,000 mg/kg lead and 3,000 mg/kg zinc as removal goals. These are the concentrations found in the sediments typical of the SFCDR. Ultimately, over 760,000 cubic meters of material were removed from the Flats floodplain and transferred to the CIA for stabilization.

Flats Hydrology

As part of, and after, removal of tailings, the majority of the Flats floodplain was graded to create new wetland habitats that would deliver specific natural functions to this area, with flow-control structures installed in the Flats and along the channel of the SFCDR to facilitate these functions. The design of this work was intended to meet the ROD objectives of improving ground water and surface water quality by protecting sediments and remaining contamination from transport during flood events due to erosion during high overbank river flows. The ROD also states that bank stabilization measures will incorporate aquatic habitat considerations and that design should maximize benefits to aquatic resources. Performance standards for the low-flow channels and floodplain were established in the 30% design report (CH2M HILL et al., 1996) as:

- Conveyance of the estimated 2-year recurrence-interval peak flow without increasing water surface elevations upstream of the Theater Bridge beyond those that would occur for this flow under existing conditions.
- Conveyance of the estimated 100-year recurrence-interval peak flow without increasing water surface elevations upstream of the Theater Bridge beyond those that would occur for this flow under existing conditions.
- Maintain the current level of flood protection for I-90 and the airport for the 100-year recurrence-interval peak flow.
- Eliminate impact to current flood flows in the SFCDR downstream of the project area.
- Develop a "stable" low-flow channel and floodplain system, keeping the low-flow channels along the northern part of the valley similar to existing conditions.
- Develop a river system consistent with a functioning native species fishery.

<u>Flood Hydrology</u>. Estimation of recurrence-interval peak flows is commonly performed by two methods. Provided sufficient gaging station data are available, annual peaks can be analyzed using an extreme value distribution, such as a Pearson Type III distribution (Chow et al., 1988). If sufficient gaging station data are not available, recurrence-interval flood flows can be estimated via a watershed model such as the US Army Corps of Engineers HEC-HMS (US Army Corps of Engineers, 1990; US Army Corps of Engineers, 1992; US Army Corps of Engineers, 2001a) that simulates the precipitation-runoff process

At Smelterville Flats, data are available from gaging stations on the SFCDR at Silverton, Elizabeth Park, Kellogg, and Smelterville, ID. Observations from the stations spanned from 1968 through 1995. However, the records for stations near the Flats were discontinuous and considered too short to be statistically relevant. There were eight observations for the Smelterville station from 1967 through 1974, nine for the Kellogg station from 1974 through 1982, and nine for the Elizabeth Park station from 1987 through 1995. The Silverton station had 21 observations from 1968 through 1990. To remedy these small and disparate data, peak flows were synthesized for the Flats area. First, the peaks for the gaging stations on the SFCDR were compared on a drainage-area basis for years with overlapping records. Using the ratio of the peak discharge rates to their drainage areas, return frequency peak flows were determined for the Flats.

Water Surface Profiles. To meet the ROD objectives, the restored SFCDR fluvial system design needed to account for high- and low-flow conditions. During high-water periods, the design needed to address the vulnerability of newly established areas to scour and erosion. These areas include the unvegetated streambanks at the river's edge and the seeded, but un-established, areas of vegetation in the floodplain. Successful restoration of the floodplain would also require a sufficient supply of water during low-flow conditions to keep designated areas sufficiently wet.

As mentioned previously, the SFCDR through the Flats is controlled at the downstream end by the Pinehurst Narrows. At the upstream end of the Flats, the flow is similarly confined and controlled by a bridge crossing known as the Theater Bridge. Between these two control points, the river has created multiple main flow channels along the north side of the floodplain corridor. These channels are bounded on the south by the broad tailings-contaminated floodplain area (Smelterville Flats), which is in turn bounded on its south limits by the Shoshone County airport and I-90. During high flows the Flats becomes inundated. During extreme events, erosive flows result in migration of the main channels, which has extended into the Flats in the recent past.

Water-surface profiles and average velocities for normal flow and for common recurrence interval flood events were calculated using the US Army Corps of Engineers HEC-RAS (2001b). In addition to these computed water-surface elevations and velocities used to establish the design of the grading and other grade control improvements, shear forces were calculated along the streambanks to assure that the improvements would withstand erosive forces. Finally, surface and subsurface riverbed materials were collected and analyzed to assist in estimating scour potential.

Groundwater Hydrology. Groundwater in the Flats fluctuates seasonally in response to extreme runoff events, as indicated by data from groundwater wells in the Flats and in nearby areas that were monitored weekly for more than a year. This groundwater surface was then plotted and mapped onto the project's digital surface model of the area. These static water-surface elevation maps were converted into implied magnitude and direction of groundwater gradient and static water-level fluctuations.

Floodplain Design Criteria

Surface and groundwater studies and observations supported the development of design criteria for the floodplain surface, the streambanks, and the targeted SFCDR channel configuration. This process is described in the following sections.

Floodplain Surface. Test pits were excavated in the floodplain early in the project in order to measure the thickness of tailings, as well as gain other soil property and groundwater information. These data were used to construct a digital thickness model of the tailings, which provided starting elevations for the final grading of the Flats' restored floodplain. The Project Team divided the Flats floodplain area into three potential hydrologic categories based on the normal duration of inundation; continual, intermittent, and upland, with the related features that would be incorporated into the design, i.e., ponds, wetlands, and upland areas. It was also recognized there would be periods when the entire floodplain would be inundated. However, since these events typically occur during dormant periods (i.e., outside the growing season), they were not considered to drive the environmental conditions that would support sustainable, native plant communities. Grading and grade-control structures were designed with shallow (20 percent or less) slopes throughout, with very shallow (10 percent or less) slopes in the seasonal groundwater fluctuation zone. Slopes were extended beyond this latter zone to account for the uncertainty of groundwater fluctuations.

Surface Water. Based on the hydraulic analysis and other observations described above, the Project Team adopted several design criteria for the grading, grade-control structures, and bank stabilization measures. Maximum design velocity of 0.75 meters per second was selected, largely based on observations of overbank flows and the results of water surface profile calculations. This relatively low velocity occurs due to the Flats' broad floodplain cross section. In addition, earthen berms were placed across the floodplain just downstream of the ponds and perpendicular to the direction of flow with staged notches to control floodplain flow.

The Project Team designed streambanks to withstand calculated shear forces using a combination of slopes and materials using common stabilized bank cross sections. Rather than expend resources in establishing a high level of immediate protection, it was felt the streambanks would, in time, be revegetated with naturally occurring species, and the streambanks would phase into natural processes – undercutting, sloughing, revegetation, etc. In the interim, the design intent was to maintain stability against a 10-year peak for a period of 5 years.

Finally, the design considered circumstances when a large flow event resulted in overbank flow. In order to mitigate the undesirable effects of streambank overflow, the streambanks were breached with rip-rapped notches to allow the floodplain waters to rise slowly as the channel flows increase. This way, when the streambanks overflowed, the floodplain would already be full. This allows for the floodplain to function as an overflow for the river while protecting the floodplain during its most vulnerable state.

Flats Soils: Initial Design Approach

The conceptual report for the Flats (CH2M HILL et al., 1996) contained relatively little emphasis on native topsoil resources. This is because early in the project, team members considered the importation of topsoil to be cost-prohibitive in comparison with manufactured coversoils. Consequently, the project focus shifted to the preparation of topsoil-like materials or "growth media". Growth media, in the context of the project, is distinctly different than topsoil. Unlike native topsoil, growth media is an artificially constructed material. The criteria for growth media contained many of the characteristics important to the productivity of natural topsoil such as certain ranges of soil particle size (sands, silts, clays) and organic matter content. Initially, the project team assumed that adequate mineral sources for use in growth media were available from on-site sources and that these mineral sources would be mixed with organic amendments, fertilizer, and other materials to meet specified requirements.

As the project evolved, however, the Project Team came to realize that adequate quantities of fine-textured mineral materials were not, in fact, available. As a result, the contractor faced the task of producing soil particle size ranges largely through the crushing of on-site rock. In the meantime, organic matter content was to be enhanced through the introduction of various organic materials.

Throughout the development of growth media approaches, the project team recognized that the preparation of growth media was inferior to the use of native topsoil because of the lack of a native seed bank, lack of sufficient native microflora and microfauna, proportionately lower stable organic matter contents, and other factors. Yet, it appeared at the time to be the only cost-effective approach available on this remote site.

This perception changed when cost estimates for producing growth media became available. While the initial cost estimates of growth media appeared relatively cost-effective, once all the factors associated with its production (such as rock hauling and crushing) were included, the project team realized that native topsoil was available at relatively little increase in cost from that needed for growth media production while simultaneously providing a significantly better long-term substrate for plant growth. As such, the project team obtained and placed native topsoils throughout the Flats area.

Topsoil Borrow Sources and Characteristics. The project had excellent sources of topsoil available to it. The Flats Project Team obtained the topsoil from areas slated for development near Hayden Lake, Idaho. The soils from this area are commonly referred to as "Rathdrum Prairie Soils" and are composed primarily of Avonville fine gravelly silt loams (loamy-skeletal, mixed, frigid, Andic Xerumbrepts). The soils originally formed in loess and volcanic ash mixed with glacial outwash (USDA-National Cooperative Soil Survey, 1981). These soils are medium acid to neutral. Additional soil types found in this map unit and potentially used on the Flats include Kootenai gravelly silt loam, McGuire gravelly sandy loam, Marble sandy loam, Bonner gravelly silt loam, and Narcisse silt loam.

Soils used on the Flats were analyzed prior to their use to ensure that the soils met specified requirements. The actual characteristics of the topsoil used on the Flats are summarized in Table 1 and included:

- Organic matter content: over 10 percent, much of which is in stable humus forms
- Acidity: acid with *p*H approximately 5.3
- Texture: gravelly silt loam to gravelly silty clay loam (USDA texture). No rocks greater than 5 cm (TrecLen Laboratories, 1998).

Soil Design. Throughout the site, an average of 15 cm of native topsoil was placed above the residual soil left following excavation and grading. Although it is usually more desirable to have more topsoil than this, the proximity of the site to groundwater coupled with the cost of topsoil importation was such that this relatively thin veneer of topsoil was considered adequate to serve the needs of the site. This soil was amended with approximately 2.5 Mg CCE lime per ha prior to seeding with a standard erosion control mix. Lime rates applied were provided to increase pH levels above those present during testing in order to enhance P availability and other factors. However, this level of liming was not done to specifically raise pH to a target level.

Flats Vegetation

Selection of species, collection of seed, propagation of plants and their installation is the normal approach for most wetland restoration projects. Our initial designs followed this path and ultimately led to a cost estimate for construction of this portion of the work.

Initial Design Approach. Flats revegetation concepts called for a complex assemblage of ponds, wetlands, and grasslands. The project team considered three options for floodplain restoration early in design: seeding only; seeding plus planting of wetlands and pond margins; and seeding combined with planting the entire site with a broad array of herbs, shrubs, and trees. Of these options, the middle one was chosen. This was later enhanced to include planting of a 9 m wide streamside buffer zone with several tree species.

Wetland community types included a mixture of PEM, palustrine scrub-shrub (PSS), and palustrine forested (PFO) wetlands along with a riverine forested community. Designers developed ponds to be supported by groundwater and located each plant community within specific elevational ranges as defined by hydrologic modeling.

Wetland benches were placed within areas of fluctuating groundwater but where sites would still be wet enough to maintain saturation irrespective of the time of year. Planting of bulrushes, reed, sedges, and cattail were planned. Grassland areas would grow on areas above fluctuating groundwater that were expected to remain more or less dry except during large flood events.

Native species would be planted throughout. Species included in the streamside zone were Sitka alder (*Alnus sinuata*), water birch (*Betula occidentalis* var. *occidentalis*), Western red cedar (*Thuja plicata*), grand fir (*Abies grandis*), blue elderberry (*Sambucus cerulea*), black elderberry (*Sambucus racemosa* var. *melanocarpa*), black cottonwood (*Populus balsamifera* var. *trichocarpa*), black hawthorn (*Crataegus douglasii* var. *douglasii*), willow, red-osier dogwood (*Cornus stolonifera*), aspen (*Populus tremuloides*), Douglas-fir (*Pseudotsuga menziesii*), and Rocky Mountain maple (*Acer glabrum*).

Table 1. Characteristics of topsoil imported from Hayden Lake, ID sources for use at the Bunker Hill Smelterville Flats project site.

Parameter	Unit	Mean (n=8)
Organic matter content	Percent	10.9
*p*H	Standard units	5.34
Salinity	dS/m	0.11
Exchangeable sodium	Percent	< 0.5
Lead	µg /g	15.3
Zinc	µg /g	66.8
Arsenic	µg /g	6.4
Cadmium	µg /g	< 0.2

Specifications called for use of native planting stock irrespective of whether the species was woody or herbaceous. A combination of cuttings, live stakes, containerized stock, and bare-root stock were to be used along with seeding, mulching, and fertilizing. Depending on the species, allowances were made for use of mycorrhizally-inoculated plants.

Aside from excavation, topsoil placement, and hydroseeding, cost of revegetating this 80 ha area was estimated at one time to be nearly $1,000,000. As a result of the modified approaches discussed below, however, total cost of the project is expected to be only 15 to 20 percent of the original estimate.

<u>Modified Approach</u>. Because of the early success of natural regeneration on Flats areas first excavated and restored, the project team elected to postpone most of the artificial revegetation effort across the majority of the floodplain. The only exception to this was the acquisition of shrubs and trees for the immediate streamside riparian zone, defined as a more or less linear feature extending approximately 9 m south of the new SFCDR embankment. Additional areas were planted in the interior of the floodplain as well. This represented a total revegetation effort of approximately 29,500 installed plants in comparison with the original 188,000 installed plants - a reduction of over 158,000 installed plants. As a result, active restoration work, while originally proposed for the entire floodplain using both wetland and upland herbaceous and woody species, was limited to installation of woody species alone. Approximately 85 percent of

the transplantation cost was contained within the wetland herb installations. Nevertheless, the goals of the Flats project with respect to wetland establishment remained the same.

Importantly, the project team elected to manage vegetation in order to reduce the incidence and/or spread of specific noxious weeds. At a minimum, field teams are required to conduct surveys for noxious weeds and treat as necessary. At least the following weeds are part of this survey: meadow hawkweed (*Hieracium partense*), spotted knapweed (*Centaurea maculosa*), purple loosestrife (*Lythrum salicaria*), and Dalmatian toadflax (*Linaria dalmatica*). Each of these weeds is known to occur in the area, and so is the focus of vegetation management.

Results to Date

Current Vegetation at Emerald Pond

Emerald Pond, located along the western portion of the Flats area, was one of the first areas from which tailings were removed and has had more time to develop wetland communities. In the summer of 2002, Emerald Pond supported a large PEM community composed of hardstem bulrush (*Scirpus acutus*), spikerush (*Eleocharis* spp.), and young cattail (*Typha latifolia*). Along pond margins and along interior drainages feeding the pond, cottonwood (*Populus trichocarpa*) and willow seedlings were regenerating in profusion (*Salix* spp.; Figure 3).

In contrast, during the summer of 2000, no noxious weeds were noted in this area. This was particularly encouraging since it is often during early succession, when soils are relatively barren, that many noxious plants can gain a foothold. Because much of the existing soil surfaces of Emerald Pond and its surroundings are rapidly revegetating, we are cautiously optimistic that spread of noxious weeds in the wetland areas can be held to a minimum.

Current Vegetation in other Wetlands of the Flats

The remainder of the Flats contains systems that were excavated during 1998, and, as a result, are somewhat younger than the Emerald Pond system. Nevertheless, these other downstream wetlands are also developing significant wetland vegetation through natural

Figure 3. Example of naturally-regenerated palustrine emergent marsh, Smelterville Flats, Smelterville, ID (Photo taken in July 2000).

regeneration (Figure 3). Water foxtail (*Alopecurus aquaticus*), cattail, and daggerleaf rush (*Juncus ensifolius*) have initially covered the downstream wetlands while cottonwoods and willows are regenerating here as well. Overall, herbaceous vegetative cover is rapidly advancing in these areas, although the overall physiognomy is somewhat smaller in stature than near the pond. As with Emerald Pond, noxious weeds are not currently a problem in wetland areas of the Flats.

Aquatic areas such as shallow ponds and drainages contained water in September 2002 (Figure 4). Large woody debris, retained during clearing of the site prior to tailings excavation, has been replaced throughout the lower Flats wetlands areas. These structures are meant to provide refuge habitat for fish as well as roosting and resting areas for birds and amphibians. Currently, vegetation in inundated areas includes hardstem bulrush (*Scirpus acutus*), pondweeds (*Potamogeton* spp.), and various species of spikerush (*Eleocharis* spp.).

Current Vegetation of the Embankment and Streamside Zone

Currently, vegetation on SFCDR embankments and streamside zones is not well developed beyond the original grasses and forbs seeded there for erosion protection. The lack of natural regeneration on these sites is primarily the result of somewhat drier conditions than are present in wetlands on the floodplain, coupled with relatively compact soils on the embankments. Much of the embankment area was originally used as a transportation corridor during tailings excavation, and this has left this area highly compacted and unable to support a good seedbed. As such, artificial approaches have been taken along these areas to facilitate establishment of woody species. Soils were loosened along the embankment, and cuttings and containerized seedlings were installed. Establishment of woody species began in the spring of 2001 and continued into 2002. Noxious weed control began in the summer of 2001. An early visual survey of the entire upland of the Flats showed that small colonies of both spotted knapweed and Dalmatian toadflax have invaded the area. Noxious weed control calls for monthly observation of the Flats, flagging areas for control, and applying either herbicides or

Figure 4. Off-channel habitat has naturally regenerated to sedges, rushes, cattail, and other palustrine emergent marsh species without need for artificial planting. Note the remedial grade control structure in the right foreground that conveys water from the river to the floodplain through the constructed streambank (photo taken in July 2000).

mechanical control methods to identified areas. Noxious weed control requirements for the Flats also requires removal of these pests before they reach 1.6 cm in height, thereby minimizing the chance for these species to flower and produce seed. Provided that early and repeated control efforts are implemented in this manner, capture of the site by desirable plant species is possible.

Discussion

The Flats has become a living laboratory for riparian restoration. Hydrologically, the site appears to be performing similarly to what was expected with groundwater elevations driving water surface elevations. Much of the site remains inundated throughout the growing season, and interior drainages between areas of inundation are either inundated themselves or are saturated to the surface. Imported topsoil carried a seed bank to the site that appears to be quite diverse, although it is difficult to separate those plants arriving from the borrow site from those entering the Flatson floodwaters. However, suffice it to say, many and varied plant species are capturing the Flats site and many of these are upland plants, not subject to floodwater inundation. This suggests that at least some of the plant diversity associated with the Flats is the result of seed bank importation.

Wetland areas are currently supporting a vigorous plant community dominated by wetland grasses and forbs that have invaded the site naturally. Many genera are currently represented, though only a few are dominating the site. Functional analysis is slated to begin in the fall of 2002 and the US Fish and Wildlife Service (USFWS) has begun monitoring use of the Flats by small mammals.

Conclusions

The Flats area supports the hypothesis that ecological restoration starts with restoring the environmental setting of the site. It is an example of how, with appropriate study and design attention given to hydrology and soils, wetlands can be restored while minimizing the need for replanting efforts. Much of the area is on a trajectory that will restore off-channel habitat composed of PEM, PSS and, eventually, PFO wetlands. Assuming that efforts to replant trees and shrubs in the uplands are successful, these naturally regenerated wetland areas will intermingle with extensive buffer plantings leading to a highly functional riparian habitat along the river.

The Flats is becoming an important winter range for elk, and a number of elk sightings have already occurred there. Reportedly, the presence of elk on the Flats is unique in the lifetimes of at least some of the residents. It is expected that elk use of the area will also result in importation of new plant species and spreading of existing plant species on the site. While observation of larger animals is always welcome, USFWS is searching for evidence of soil-dwelling fauna (such as field mice). Other research could include monitoring for use by invertebrates (particularly those important to fisheries) and other animals lower on the food chain. As with soils and hydrology, restoration of primary producers is important to the subsequent development of viable wildlife species higher on the food chain. Presence of primary producers precedes that of many other wildlife species and can serve as an early indicator of success of this effort.

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