DEVELOPMENT AND APPLICATION OF PRE-REMEDIAL DESIGN TOOL FOR THE CLARK FORK RIVER SUPERFUND SITE[1]

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Abstract: In 2004, the Environmental Protection Agency released a Record of Decision for the remediation of one of the nation's largest Superfund sites – the upper Clark Fork River in western Montana. Fluvially deposited hard rock mine, mill, and smelter wastes from the Butte/Anaconda industrial complex have contaminated the river's floodplain. These acid metalliferous materials vary in depth from a few centimeters to at least one meter. Phytotoxic conditions limit agricultural production, barren river banks are unstable, and the amount of Cu released to the river results in both acute and chronic impacts to aquatic receptors. As stipulated in the Record of Decision, exposed tailings are to be removed, backfilled with appropriate quality cover soil, and revegetated. Streambanks will be stabilized by "soft" engineering – vegetation fabric, willows, logs, and root wads. Areas of impacted soils and vegetation will be treated in place, using careful addition of lime and other amendments, soil mixing, and revegetation. The Record of Decision also specified all land within the site be classified so impacted areas requiring remediation could be identified. Such a classification system, called the Riparian Evaluation System (RipES) uses key indicators of landscape stability and plant community dysfunction to categorize delineated portions of the site as unique polygons. Each polygon is associated with exact location, surface area, waste volume, and other attributes displayed as geographic information system layers over base area photographs. During the 2006/2007 field seasons, the first 80 km of floodplain were classified into one of four major types: (1) streambank length classified by stability type, (2) exposed tailings, (3) impacted soils and vegetation areas, or (4) slightly impacted soils and vegetation areas. For each of these polygons, a RipES score was derived to determine the most appropriate cleanup remedy specified by the record of decision. In this paper, the RipES system will be described and examples of remedial polygons will exhibited. This pre-remedial design approach is applicable to other large metal-contaminated watershed sites.

Additional key words: reclamation, mining, Superfund, impacted land classification

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Introduction

Mining for Au, Ag, and especially Cu began in the late 19th Century in the Butte-Silver Bow Creek area of southwest Montana. Milling and smelting of these ores produced vast wealth, and concurrently, mining, milling, and smelter wastes and process waters were released into Silver Bow Creek. These wastes contained elevated levels of several metals and arsenic, as well as the acid-producing mineral pyrite. These wastes were fluvially transported downstream and into the Clark Fork River. Large flood events, particularly in 1908, distributed the metal bearing wastes along the entire Upper Clark Fork River floodplain. Mining wastes from the Old Works Copper Smelters in Anaconda, Montana were also transported via Warm Springs Creek and other creeks into the Upper Clark Fork River.

The Environmental Protection Agency designated the Clark Fork River Operable Unit (CFR OU) of the Milltown Reservoir/Clark Fork River Superfund Site as a Superfund Site and placed it on the National Priorities List in 1984. The CFR OU is defined as "surface water, bed sediments, tailings, impacted soils, groundwater, aquatic resources, terrestrial resources, irrigation ditches and related tailings deposits, and air located within and adjacent to the historic 100-year floodplain of the Clark Fork River" (EPA 1995). The CFR OU extends from the outflow from Warm Spring Ponds some 193 km (120 miles) to the upstream end of the Milltown Reservoir Operable Unit (Fig. 1). A Remedial Investigation defining the nature and extent of contamination was completed in 1998. Treatability Studies designed to evaluate some potential alternatives, and both Human and Ecological Risk Assessments to quantify threats to human health and environmental receptors were completed. A Feasibility Study describing and evaluating remedial alternatives was completed and EPA (2004) issued a Record of Decision defining the selected remedy for the CFR OU.

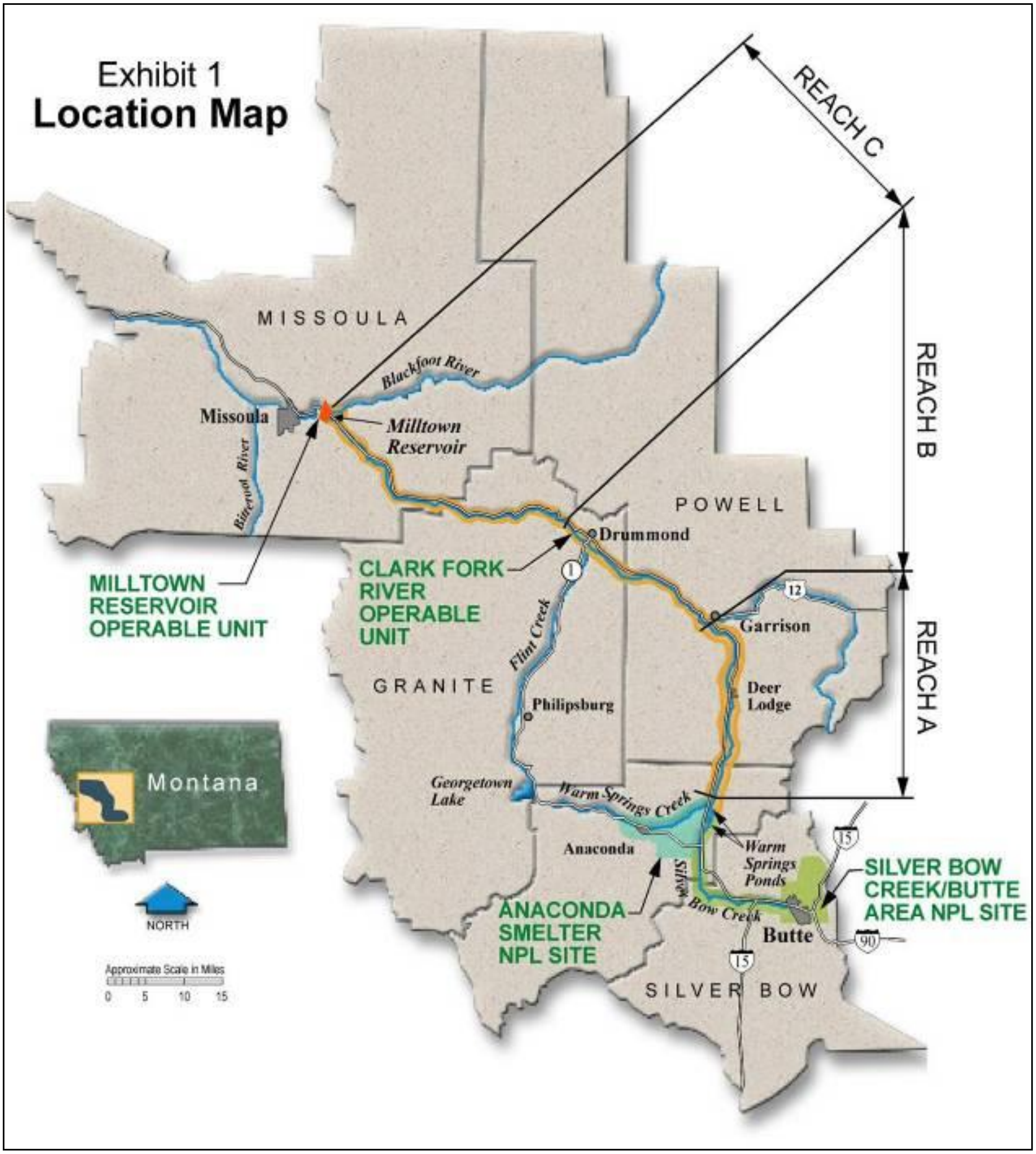


Figure 1. Location of Clark Fork River Operable Unit within the Superfund complex in southwest Montana.

As part of the Record of Decision, EPA specified the streambanks and adjacent lands be classified using a university developed process (RRU and BRI 2004). This process, Clark Fork River Riparian Evaluation System or CFR-RipES, is a tool that links the Record of Decision to remedial actions to be implemented. CFR-RipES is a consistent and repeatable way to classify all lands within the flood plain into one of three categories: exposed tailings; areas of impacted soils and vegetation; and areas of slightly impacted soils and vegetation. In addition, the river's streambanks are to be categorized into one of three classes depending on the amount of vegetation they support and their potential for erosion. The Record of Decision document specified the following cleanup strategy for each of the RipES-classified areas.

- Exposed tailings will be removed, backfilled with cover soil, and revegetated, with a limited exception.
- Streambanks will be stabilized by "soft" engineering – vegetation fabric, willows, logs, and root wads.
- Areas of impacted soils and vegetation will be treated in place, using careful addition of lime and other amendments, soil mixing, and revegetation.
- Weed areas and jurisdictional wetlands will be identified.

Objectives

In the Record of Decision, EPA mandated a process be developed to classify the landscape within the 100-year flood plain of the Clark Fork River so remedial designs and actions would be consistently applied on a site specific, refined, and definitive basis. The objective of this paper is describe the CFR-RipES process and to its application to the floodplain of the Clark Fork River. Results of the two years of field classifying polygons and displaying result are provided. The purpose of this process was to provide a data predicated decision tool to identify and categorize polygons (delineated areas of land) based on landscape stability, contamination severity, and plant community attributes within the CFR OU. This process was implemented to make classifications and determine actions consistent with the standards set forth in the Record of Decision. The system was to contain the following elements:

- Definitions and scoring for three types of soils polygons and three types of streambank and riparian corridor buffer polygons;
- A 100 % accounting of all areas in the historic 100-year floodplain within the CFR OU among the three types of soil polygons in Reach A and portions of Reach B (see Fig. 1 for designated Reaches on the Clark Fork River);

- Numerical components with threshold scores distinguishing the severity of contamination of the floodplain soils, and thresholds separating streambank riparian corridor buffer polygons into three classes; and
- A process for identification of data and information required to complete remedial designs for each polygon.

Definitions for Types of CFR-RipES Polygons

Exposed Tailings

Because of phytotoxic condition, these areas are generally devoid of vegetation, supporting less than 25 % live plant canopy cover. Tufted hairgrass (*Deschampsia cespitosa*) is present, if there is any live vegetation. Efflorescent metal salts are visible on the soil surface during dry periods. For mapping purposes these exposed tailings must meet the above criteria and be at least 37 m^2 (400 sq ft) in area.

Impacted Soils and Vegetation Areas

The degree of phytotoxicity in these areas is quite variable, but they do sustain at least 25 % live plant canopy cover. Tufted hairgrass (*Deschampsia cespitosa*) has greater than 1 % canopy cover. Efflorescent metal salts may be visible on the soil surface during dry periods. Small, individual areas of exposed tailings (that appear as small slickens) may be present. Soils in these impacted areas generally have Cu concentrations exceeding 300 mg kg^{-1} within the profile and are considered impacted by mining-related activities. The minimum polygon size is 37 m^2 (400 sq ft).

Slightly Impacted Soils and Vegetation Areas

These areas express no evidence of phytotoxicity and have less than 1 % bare ground caused by contaminated tailings. Tufted hairgrass (*Deschampsia cespitosa*) has < 1 % canopy cover. No efflorescent metal salts are visible on the soil surface during dry periods. Soils in these areas generally have Cu concentrations less than 300 mg kg^{-1} within the profile and are considered only slightly impacted by mining-related activities.

Class 1 Streambank

Phytotoxic conditions exist as demonstrated by an inability of the active channel areas to support and sustain significant amounts of woody and herbaceous vegetation. Streambanks are actively eroding and are significant contributors of contaminant release to the river. Remedial actions for this class include removal of phytotoxic materials and revegetation with deep, binding, woody vegetation.

Class 2 Streambank

These streambanks demonstrate some current woody and herbaceous vegetation, but are contaminated, unstable, and eroding. Remedial actions for this class include supplemental revegetation and planting of deep, binding, woody vegetation. Reconfiguration of the streambanks may require minor removal or *in-situ* treatment.

Class 3 streambanks

These streambanks are contaminated but they may have varying amounts of deep, binding, woody vegetation holding the streambank in place. Remedial actions possible for these areas include no action or minor actions to enhance woody vegetation within the buffer corridor and/or BMPs.

Streambank Treatments

Woody vegetation is the "glue" that holds the streambanks together. However, mining contamination has greatly reduced the amount of woody vegetation along the Clark Fork

River resulting in increased streambank erosion. With this in mind, the ROD defined a 50-ft buffer zone along the river in which various treatments would be developed to maximize the establishment of woody vegetation within this buffer zone, thereby greatly reducing the rate of streambank erosion. Five levels of treatment for streambank stabilization were specified in the ROD; they vary from none (No Treatment) to intense remedial work (Treatment 4) as follows:

- No Treatment – Adequate deep, binding woody vegetation is already in place and no additional work on the streambank is necessary.
- Treatment 1 – Relatively stable, but lacks appropriate amounts of woody vegetation to stabilize the streambanks. These streambanks will be planted with additional woody vegetation.
- Treatment 2 – Limited rate of erosion, but requires some streambank work to reduce the rate of erosion.
- Treatment 3 – Moderate rate of erosion, requiring a moderate treatment to reduce eroding streambanks and corresponding loss of property.

- Treatment 4 – Excessive rate of erosion, requiring an extensive treatment to reduce eroding streambanks and high rates of loss of property. After the streambanks were classified by RipES, a proposed treatment was assigned to each bank.

Methods and Application of CFR-RipES

Field Maps

In May 2006, high resolution photography of Reach A of the Clark Fork River floodplain was obtained and high quality maps were produced. Boundaries depicting parcels of land ownership were obtained from local county or state tax/revenue offices and these were superimposed on these maps. Cultural features – roads and fences, the historic 100-year floodplain and a 15 m (50 ft) streambank buffer zone were added as layers on the maps. These maps were used by the field teams to delineate individual polygons of exposed tailings, areas of impacted and only slightly impacted soils and vegetation, and to classify streambanks. These polygons were hand drawn on the maps for future digitizing. Information for each polygon was entered into dropdown menus of programmed Trimble GPS instruments, and digital images were collected and associated with GPS locations.

Delineating and Classifying Polygon Types in the Field

Delineating Exposed Tailings Polygons. Exposed tailings areas are contamination-caused and are mostly bare ground. Scattered throughout Reach A, these areas number in the hundreds, are usually a fraction of an acre in size, and are too toxic to support most vegetation or soil organisms. The field team delineated exposed tailings by first walking to an edge of the tailings and then walking the perimeter of the wastes and outlining this perimeter on the project map. The perimeter was defined as where the ground surface changes from one that is barren (< 25% cover) or populated by tufted hairgrass only, to a surface that is occupied by a mixed plant community, most often redtop (*Agrostis stolonifera*), baltic rush (*Juncus balticus*), and associated woody shrub species.

For mapped exposed tailings polygons, the following data were entered into the GPS instrument: parcel or land ownership number, polygon identification, current land use, location (longitude and latitude), depth of tailings obtained by excavating a soil pit or by using an Oakfield soil probe, and whether the polygon was adjacent to a streambank, and digital images.

Delineating Impacted and Slightly Impacted Soils and Vegetation Polygons. Delineating impacted and slightly impacted soil and vegetation areas or polygons was accomplished by first conducting a reconnaissance of the suspected area and noting the vegetation and presence or absence of tufted hairgrass and efflorescent metal salts, and estimating the overall live cover (Daubenmire 1959) and cover of tufted hairgrass. The field team then determined the perimeter of the polygon and drew the polygon on the project map. The CFR RipES scoring matrix, as dropdown menus on the GPS device, was then used to determine whether this polygon is representative of impacted soils and vegetation area or a slightly impacted soils and vegetation area. Predetermined numerical values were assigned by the field team to describe the following attributes of the soils and vegetation within the polygon: live vegetation canopy cover; cover of tufted hairgrass; amount of bare ground caused by tailings; soil pH as measured in the field using a 1 to 1 ratio of soil to distilled water and a calibrated pH meter; and the presence or absence of efflorescent metal salts on the soil surface. A soil sample from the top 30 cm (12 in) was collected for determination of Cu concentration if necessary. Polygons that achieved a polygon score above a predetermined threshold value were designated as only slightly impacted, while polygons receiving a score below the threshold were defined as impacted soils and vegetation polygons. For mapped impacted and slightly impacted polygons the following data were entered into the GPS device; parcel number, polygon identification, current land use, location (longitude and latitude), depth of visible mine wastes obtained by excavating a soil pit or by using an Oakfield soil probe, field pH, and whether the polygon was adjacent to a streambank, and digital images.

Classifying Streambanks. The streambank and riparian corridor buffer was delineated by measuring from the "bank full" stage (the lateral extent of inundation by the 1.5-year mean return flow - bank full on the Clark Fork River is a seven year event due to the influence of the Warm Springs Ponds (Fig. 1) - on each side of the stream out approximately 15m that is flexible or variable in width, or where the historic 100-year floodplain elevation is reached. The streambank and riparian corridor buffer along each side of the river was then broken into polygon units based on three types of river planar morphology: convex curvatures (outside curves), concave curvatures (inside curves), and straight channel stretches no longer than 150 m. A minimum mapping unit (MMU) of 6 linear meters was used to delineate the polygons. For each polygon, three attributes were evaluated and numerical values were assigned. These attributes were the amount of live vegetation cover within the buffer, the completeness of the canopy of deep, binding, woody vegetation within the buffer, and the percentage of the streambank polygon that exhibited active lateral cutting. Streambanks were then delineated or placed into one of three classes by pre-determined numerical threshold scores. Streambanks achieving predetermined threshold scores were categorized as: Class 1 (low score), Class 2 (medium score), or Class 3 (high score).

Streambank Treatments. After the streambanks were classified by RipES, a proposed treatment was assigned to each bank. Remedial treatments assigned to the classified streambanks were based on three criteria: 1) tailings or impacted soil and vegetation polygons within 6 m of the river's edge of the streambank; 2) active laterally cutting streambanks; and 3) other streambanks. Criteria 1 and 2 were further delineated based upon whether the streambanks are on the inside of a meander bend (limited erosive energy), along a straight reach, or along the outside of a meander bend (maximum erosive energy). The "other streambanks" were delineated into those with less than 80 % canopy cover of preferred woody vegetation and those with more than 80 % canopy cover of preferred woody vegetation. The three criteria resulted in streambanks being identified as no treatment and treatments 1-4, with treatment 4 being the maximum or most intense remedial treatment as defined in the Record of Decision (EPA 2004).

Data Merging and Development of Web-based GIS Display

All information and data from the field observations and measurements were collected and sent to a central facility for processing. The types of information included the high resolutions maps on which polygons were drawn, and digital information pertaining to polygon attributes (e.g. percent cover, soil pH, depth of visible tailings, amount of lateral cutting, GPS coordinates, land owner parcel, copper concentration in soils, land use, date, time, field crew identification, etc.). Information contained on maps was scanned and digitized; other data required entry into databases. Seventeen different data streams were then collated in a SDE geodatabase as shown schematically in Fig. 2.

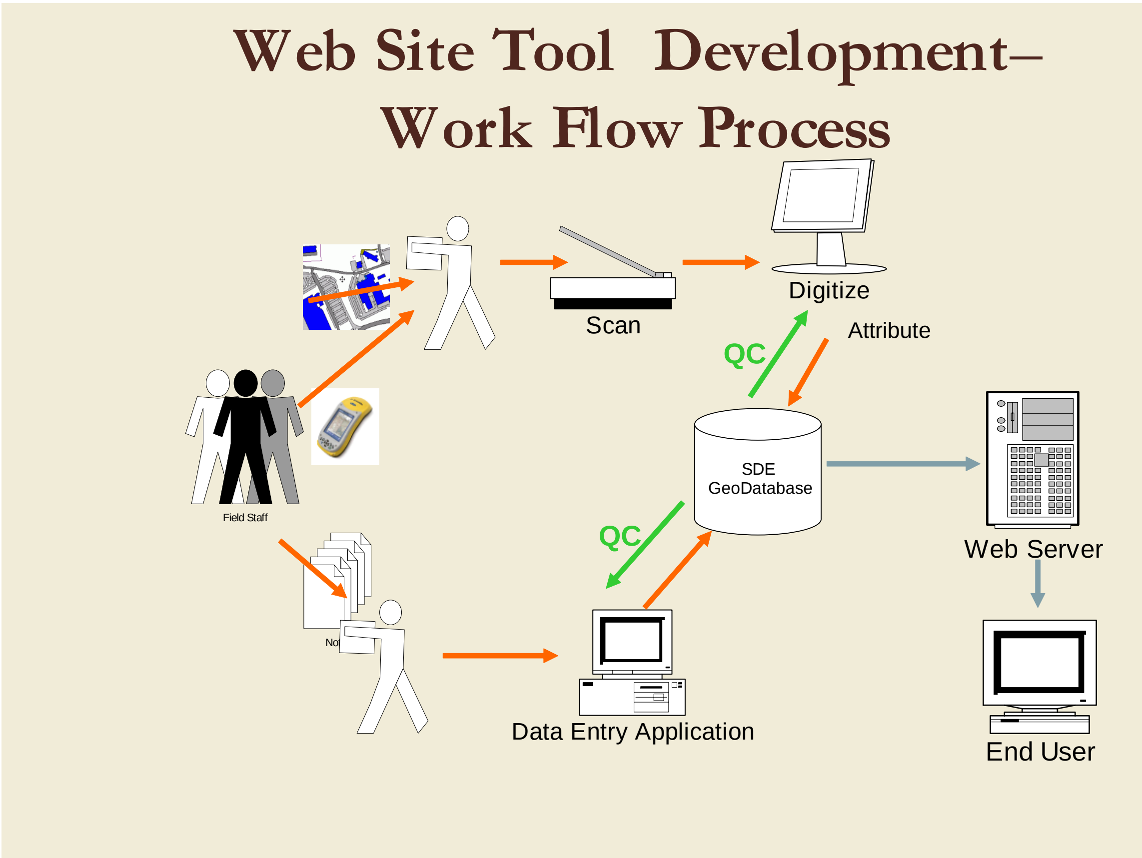


Figure 2. Schematic of CFR-RipES data and information and access via web server.

Data and information were subjected to several layers of quality control from raw data generated in the field to ensuring accurate data output, to many data queries. Data can be accessed by end users via a dedicated web server. Several layers of security are designed so that some users can only view data, while others have full access to the information. It is EPA's intent that the information will be used for remedial design, construction oversight, and success monitoring after remediation is completed.

<u>Results of Application of CFR-RipES</u>

During the 2006 and 2007 field seasons, approximately 4023 hectares of land and 187 km of streambanks within the upper Clark Fork River historic flood plain were classified. The classifications were represented by 388 parcels of land owned by 153 separate property owners. An example of the CFR-RipES tool map and data shows a portion of the meandering Clark Fork

River with land parcels delineated in red (Fig 3). The different layers of information available to the user are exhibited in the right and left panels.

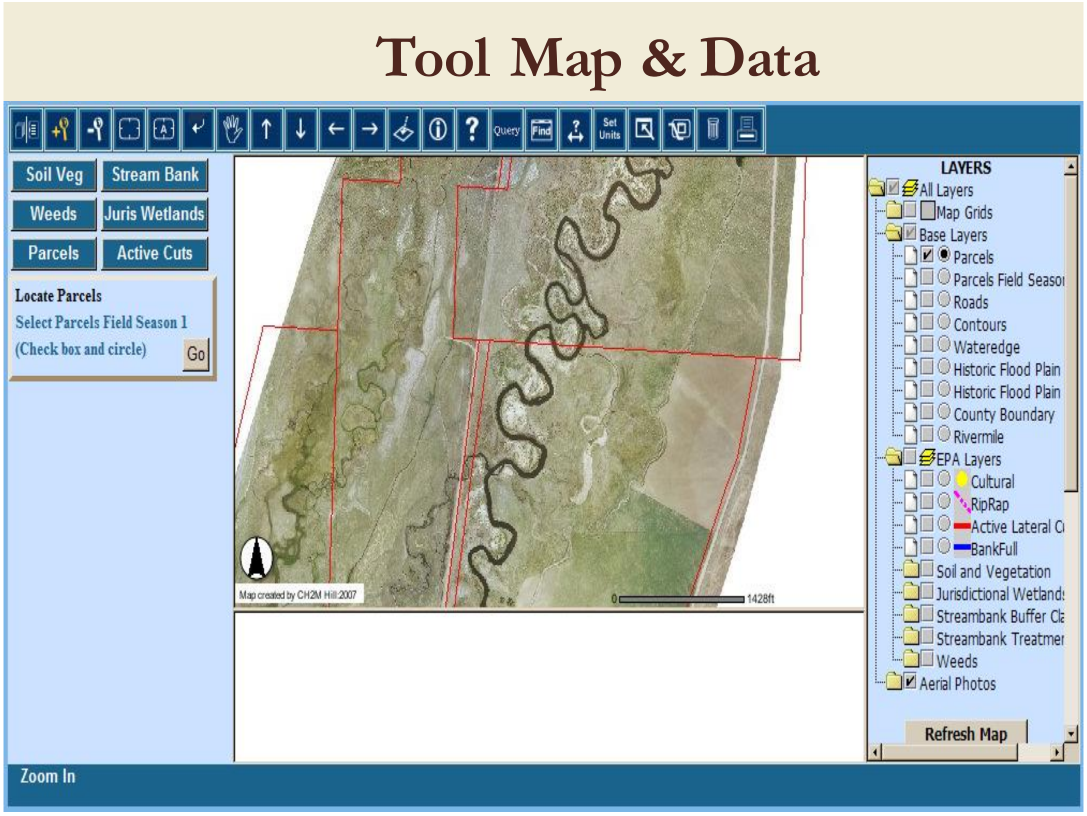


Figure 3. CFR-RipES tool map and GIS layers.

<u>Exposed Tailings Polygons.</u> An example query for exposed tailings for a selected portion of the floodplain would generate a map showing the location of the tailings (Fig. 4, in red); associated queries could include the number of individual tailings areas, their sizes and volumes of contaminated materials. Data point locations for samples collected for determination of tailings pH and Cu concentration, and digital images (Fig. 5) are all available. All together, 590 individual tailings area representing 30 ha (74 acres) were located and mapped.

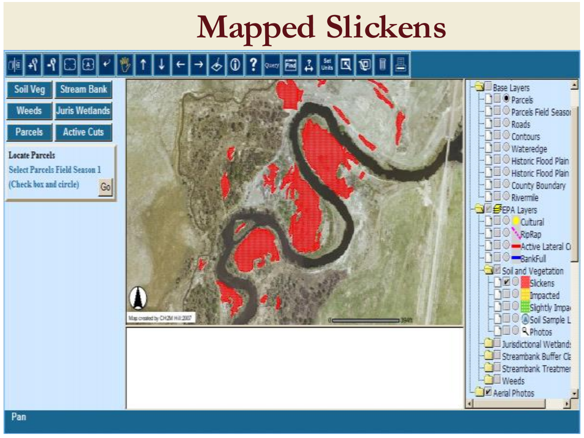


Figure 4. Exposed tailings in red color.

Figure 5. Example of exposed tailings.

Impacted Soils and Vegetation Polygons. A query for areas of impacted soils and vegetation would generated the map showing locations of these polygons (Fig. 6); associated data relating to number, sizes, volumes, percentages of land within the parcel impacted, etc. can also be displayed. A digital image example of an impacted soils and vegetation, with the low CFR-RipES score of 12 % is displayed in Fig. 7.

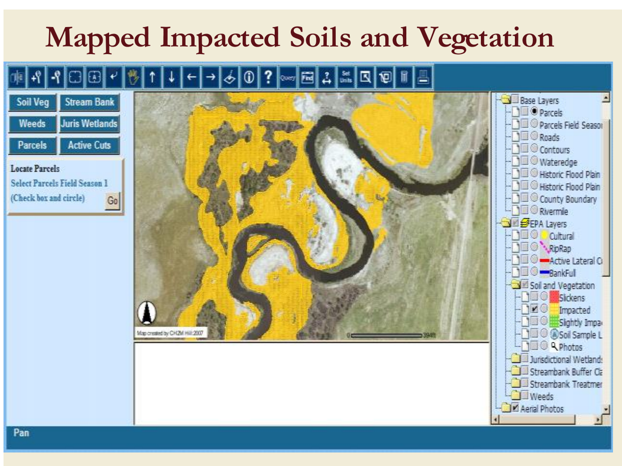


Figure 6. Impacted soils and vegetation areas.

Figure 7. Example of impacted area.

A total of 929 impacted soil and vegetation polygons representing 128 ha (319 acres) were located and mapped during the two field seasons.

Slightly Impacted Soils and Vegetation Polygons. Areas of only slightly impacted polygons for the same selected portion of the flood plain are shown in green in Fig. 8. A digital image of a slightly impacted soil and vegetation polygon with a high CFR-RipES score of is displayed in Fig. 9.

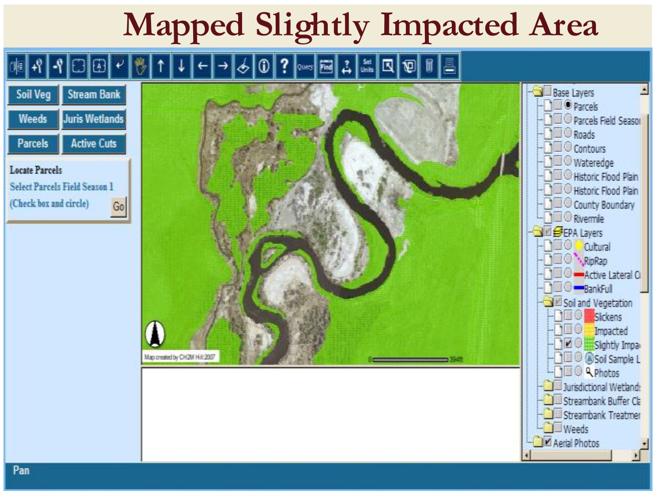


Figure 8. Slightly impacted area in green.

Figure 9. Slightly impacted polygon.

Streambank Classes. A query of the CFR-RipES for streambank classes for any selected portion of the Clark Fork River would generate a map (Fig. 10) displaying the 15 meter riparian buffer with bank classes delineated by color: red for Class 1, yellow for Class 2, and green for Class 3. An example of a Class 1 streambank with a low score of 7.7% is shown in Fig. 11.

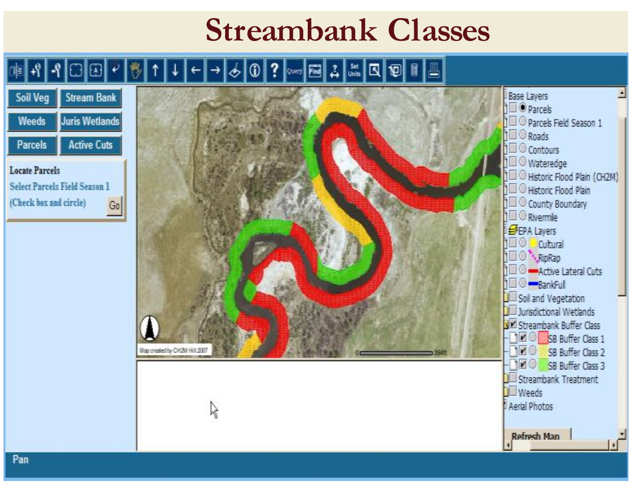


Figure 10. Streambank Classes.

Figure 11. Class 1 streambank.

Examples of Streambank Class 2 (CFR-RipES score of 53%) and Class 3 (100%) are exhibited in Figs. 12 and 13.

Figure 12. Class 2 streambank.

Figure 13. Class 3 streambank.

Streambank Treatments. A query of the CFR-RipES for streambank treatments for any selected portion of the Clark Fork River would generate a map (Fig. 14) displaying the meandering river, and streambanks treatments: Treatment 1 (green color); Treatment 2 (yellow color); Treatment 3 (orange color); and Treatment 4 (red color) as mapped RipES field team. Bank treatment lengths are calculated for each treatment (Fig. 15).

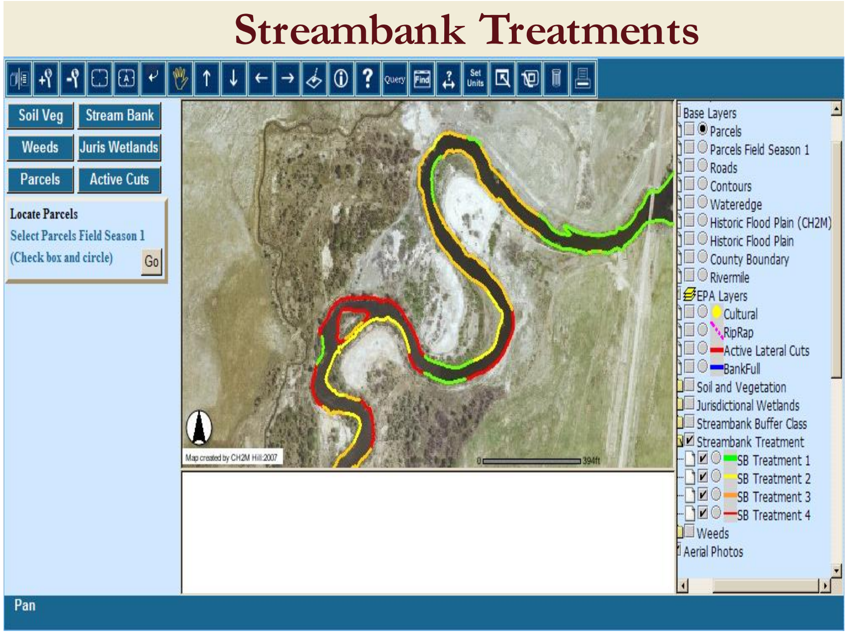
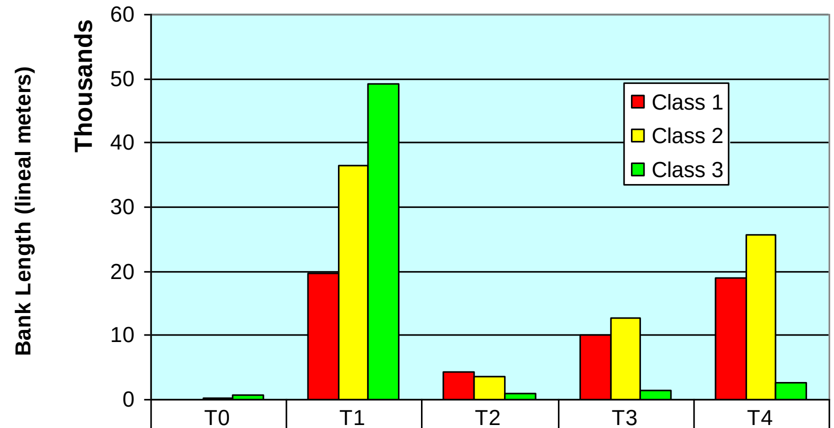


Figure 14. Streambank treatments.



	T0	T1	T2	T3	T4
Class 1	109	19679	4255	10135	18844
Class 2	224	36586	3701	12611	25784
Class 3	803	49318	923	1535	2533

Figure 15. Streambank length (meters), treatment and class.

A total of 187,041 m (116.2 miles) of streambank were categorized into Classes (1 2, and 3), and remedial treatment intensity was assigned as no treatment (T0), minimal treatment (T1) through maximum treatment intensity (T4). Some 105,583 m (65.6 miles) of streambanks will require minimal treatment (T1), while 47,161 m (29.3 miles) of streambanks will require maximum treatment (T4). Remedial designs for these treatments were provided in the Record of Decision document (EPA 2004).

Discussion

The application of the CFR-RipES landscape classification tool to the historic 100-year floodplain of the Clark Fork River is intended to help develop detailed remedial designs for the cleanup of one of the nation's largest Superfund sites. It is estimated this tool will save several million dollars in preremedial costs by clearly delineating the locations at which exposed tailings are to be removed, where impacted areas require treatment, and which streambanks are to be stabilized. Remedial cost estimates can be more closely defined, and landowners will be able to modify agricultural practices to accommodate remediation of their property.

Parts of the CFR-RipES system have been applied to smaller streams, specifically Warm Springs and Willow Creeks in the Anaconda (Montana) Smelter Superfund site (RRU/MSU

2005). This landscape classification system can be tailored to other large and small sites impacted by acid metalliferous hard rock mining sites in the western US.

Acknowledgements

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