Final Work Plan

Environmental Assessment and Characterization
Colorado School of Mines Research Institute Site
Flood Plain Area
Golden, Colorado

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WORK PLAN APPROVALS	
Date: August 31, 2010	
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List of Acronyms and Abbreviations

Acronym or Abbreviation	Definition
°C	Degrees Celsius
ALARA	as low as reasonably achievable
As	Arsenic
avg	Average
bgs	below ground surface
BMP	Best Management Practice
CDPHE	Colorado Department of Public Health and Environment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
Ci	Curie(s) (unit of radioactivity)
cm^2	square centimeter(s)
COC	contaminant(s) of concern
COPC	Contaminant(s) of potential concern
CSM	Colorado School of Mines (School)
CSMRI	Colorado School of Mines Research Institute
cy	cubic yard(s)
DOT	U.S. Department of Transportation
dpm	Disintegrations per minute
DQO	data quality objective(s)
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
FWS	U.S. Fish and Wildlife Service
ft	Foot, feet
GIS	geographic information system
GPS	global positioning system
Hg	Mercury
kg	Kilogram
kW	Kilowatt
LCS	Laboratory control sample
LCSD	Laboratory control sample duplicate
LOD	limit of detection
max	Maximum
MCL	maximum contaminant level
MDA	Minimum detectable activity
Mg/kg	Milligram per kilogram
Mo	Molybdenum
mrem	millirem
MS/MSD	Matrix spike/matrix spike duplicate
NaI	Sodium-iodide (detector)
NWP	Nationwide Permit

Acronym or Abbreviation	Definition
ORP	Oxidation-reduction potential
OSHA	Occupational Safety and Health Administration
Pb	Lead
pCi/L	PicoCuries per liter
pH	percent Hydrogen
PPB	parts per billion
PPE	Personal protective equipment
ppm	parts per million
PRP	potentially responsible party
PVC	Polyvinyl chloride
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan
Ra	Radium
RCRA	Resource Conservation and Recovery Act
rem	Roentgen equivalent man (unit of ionizing radiation)
RDL	required detection limit
RI/FS	Remedial Investigation/Feasibility Study
RML	Radioactive Materials License
ROD	Record of Decision
RPD	relative percent difference
RSO	Radiation Safety Officer
SAP	Sampling and Analysis Plan
School	Colorado School of Mines (CSM)
SSHASP	Site-specific Health and Safety Plan
SSL	Soil Screening Level
SWMP	Stormwater Management Plan
TCLP	Toxicity Characteristic Leaching Procedure
Th	Thorium
U	Uranium
µg/L	micrograms per liter
USACE	U.S. Army Corps of Engineers
V	Vanadium
VSP	Visual Sampling Plan
XRF	X-ray fluorescence

Executive Summary

To date at the CSMRI Site, buildings, foundations, and infrastructure have been demolished and taken off-site, and the upper terrace soils along with some flood plain soils have been remediated. Also, the Clay Pits Area and the former U.S. Environmental Protection Agency (EPA) stockpile location have been investigated and removed from the Site boundaries. The remaining known impacted area from former research operations by CSMRI is an isolated dissolved uranium plume in groundwater located on the flood plain area where the former settling pond was located. This area was initially the subject of a EPA removal action based on radium in soils. Preliminary characterization work addressed many of the comments received from the Site Potentially Responsible Parties (PRPs) regarding a prior draft of this work plan and yielded the following information:

Uranium concentrations in soil are pervasive across the flood plain. The majority of test pits in the flood plain area have uranium concentrations at less than twice ambient levels with the exception of the west end where concentrations are higher.

- Dissolved uranium in groundwater at concentrations above State groundwater standards is present across the Site in decreasing concentrations toward the east. Coupled with other Site data, this indicates the likely contaminant source for groundwater is in the vicinity of well CSMRI-8 where the higher uranium soil concentrations were identified and artificial fill was observed in test pits. Essentially all dissolved uranium occurs as highly soluble U^{+6} in the form of a carbonate complex, and the Site-specific partitioning coefficient for uranium is very low at less than 0.2 L/kg.
- Geochemical modeling concluded very little soil adsorption of uranium occurs across the Site, and the shape of the uranium plume appears to be controlled by dilution from upper terrace waters and infiltration of water from Clear Creek.
- The ambient concentration of uranium in soils is 6.45 mg/kg (mean plus 2 standard deviations), elevated from background by historic mining activities along the entire upgradient area of the Clear Creek drainage system.
- Geochemical modeling determined that ambient uranium in soil could result in groundwater uranium concentrations as high as 400 ug/l (parts per billion [ppb]) based on the Site-specific partitioning coefficient. However, this was determined using an EPA test method that is considered to be very aggressive and provides a partitioning coefficient that can be considered to be a conservative value for the Site, meaning that the actual concentrations of uranium in groundwater as caused by ambient uranium soil concentrations is expected to be less than 400 ppb.
- One test pit (CLT-1) showed contaminants other than uranium exceed tentative cleanup goals.

This work plan presents an assessment and characterization plan for the flood plain that is similar to the approach used successfully on the main, upper terrace portion of the Site, as well as for the previous EPA removal action for the former settling pond in the flood plain area. This plan describes how the sources of contamination, especially the uranium plume contamination, will be characterized by excavation and sampling and analysis. The origin of the groundwater plume is believed to be uranium in the subsurface soils, including soil beneath the groundwater table. Successful characterization by segregation and sampling and analysis should significantly reduce the source of the contamination to the point where groundwater uranium concentrations are reduced to acceptable levels.

The characterization plan is based on interpretation and analysis of aerial photographs, existing groundwater chemical data, existing groundwater physical data, Site operational information, professional environmental engineering judgment, past assessment efforts at this Site, and historical document review. The plan proposes characterizing areas of the flood plain thought to be the most likely to contain significant sources of contamination resulting from CSMRI activities.

The characterization effort will begin near well CSMRI-8, an area known to contain fill material containing CSMRI process contaminants. Field reconnaissance of this area has identified two former process outfall pipes still present on the hillside that were not removed by EPA and may be embedded in research waste material. The area suspected of containing materials above the Site tentative cleanup goals is in the vicinity of well CSMRI-8 and is thought to total approximately 3,000 cubic yards.

Assessment and characterization of the soils above the groundwater will be completed in 1-foot lifts with the soil being segregated between clean (soil less than Site tentative cleanup goals, including uranium at 14 mg/kg (parts per million [ppm]) and impacted soil above Site tentative cleanup goals. Complete characterization by segregation to bedrock is anticipated in some areas of the flood plain barring data that clearly demonstrate soils below the groundwater table are not impacted.

Excavated soils will be transported to a staging area at the top of the terrace in an area prepared for future use as a parking lot. The stockpile will be periodically inspected and maintained as needed until final remedy selection and implementation. Upon project completion and while remedial option alternatives are evaluated, the stockpiled soil will be sampled and analyzed for constituents affecting remedy selection. Remedy selection and implementation will occur later and are beyond the scope of this work plan.

1 Introduction

The S.M. Stoller Corporation (Stoller) prepared this work plan on behalf of the Colorado School of Mines (School). This plan is the controlling work document for assessment and characterization of the flood plain portion of the Colorado School of Mines Research Institute Site (CSMRI) Site (Site) to determine the sources, cause, and the nature and extent of the elevated concentrations of uranium in the groundwater above the groundwater standard of 30 micrograms per liter (µg/L) uranium and of other contaminants of concern (COCs). This work plan has been modified since being originally submitted to the Colorado Department of Public Health and Environment (CDPHE) in February 2010. Modifications stem from comments received from the CDPHE and Site potentially responsible parties (PRPs) as well as the results and analysis of newly collected data from preliminary flood plain characterization work completed in June 2010. This work plan will commence after CDPHE approval.

The objective of the project is to assess and characterize the nature and extent of uranium-bearing material in the flood plain area at the Site that is acting as the cause of uranium groundwater contamination and of other COCs. In addition, the project aims to determine the sources and cause of contamination in the flood plain. Uranium-bearing material believed to be the source of the groundwater contamination, and material containing other COCs at concentrations of concern, will be identified and excavated from the flood plain area. Excavated soils will be stockpiled nearby and will be characterized to determine the nature and extent of contamination, as well as to develop information necessary to plan for remediation of the stockpile. Groundwater will be monitored after the excavation to determine whether the flood plain contamination has been successfully characterized.

This work plan is designed to guide activities needed to evaluate the flood plain utilizing existing and newly collected data. Sufficient data are needed to determine nature and extent, sources, and causes of groundwater contamination, and allow development of remedial options for final disposition of the impacted soil. The work plan details how the nature and extent of impacted material at the flood plain will be determined using the proposed cleanup goals. This assessment and characterization will result in a Remedial Investigation/Feasibility Study (RI/FS) report that describes the assessment and characterization activities, describes the nature and extent of contamination and whether it has been fully characterized, explains the ongoing monitoring of the groundwater, evaluates several options for the disposition of the stockpile of contaminated soil, and proposes one of the evaluated options for the final remedy for the stockpiled contaminated soil. This final report will be submitted to CDPHE for review and approval.

1.1 Site Location and Description

The Site is located in Golden, Colorado, along Clear Creek between the Creek and the School's sports fields near the intersection of Maple and 11th Streets. More generally, the Site is located on the south side of Clear Creek, east of U.S. Highway 6, in the northeast quarter of the northwest quarter of Section 33, Township 3 South, Range 70 West and is specifically depicted on Figure 1-1. The main entrance to the Site is located at the west end of 12th Street. An 8-foot chain-link fence restricts access to the Site.

The Site includes an area that was the location of a former settling pond. The pond was remediated and closed by the U.S. Environmental Protection Agency (EPA) as part of an emergency removal action under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). That action was one of a series of environmental investigation, characterization, and response projects at the Site.

The Site boundaries have been reduced over the past years following investigations and response actions. Originally, the Site consisted of a fenced area – which once included Research Institute buildings that were eventually demolished – located north of the intersection of Birch and 12th Streets, along with an unfenced area known as the Clay Pits (Figure 1-1) and an unfenced area at a current location of the softball field where EPA had stockpiled contaminated soil from the former settling pond excavation project. The Clay Pits were deleted from the Site boundary following a site investigation in 2007 that determined no impacts could be detected in the Clay Pits area from CSMRI activities. The softball field area was also deleted from the Site boundary in the late 1990s after the EPA stockpile was disposed off site, and further investigation work demonstrated the appropriateness of eliminating this area from the Site boundary. A large portion of the Site, known as the upper terrace soils, is pending elimination from the Site boundary following a cleanup completed in 2007. Currently, a portion of this upper terrace area is beneath a newly constructed soccer field.

The remaining portion of the Site boundary for purposes of the assessment and characterization work described in this work plan is demarcated by an area shown on Figure 1-2 as the "Flood Plain Characterization Area." Neither the Clay Pits nor the upper terrace is part of the current investigation and characterization covered by this work plan, and they are no longer considered part of the Site in this document.

In this work plan, the Flood Plain Characterization Area covers an area of about two acres and is currently defined by the area shown in Figure 1-2. Practically speaking, however, the terms "on-site" or "Site" refer to the areal extent of contamination and all suitable areas in very close proximity to the contamination, such as the area where the contaminated soils excavated from the Flood Plain Characterization Area will be stockpiled and related access roads. Consequently, the Site boundary may be modified or expanded to address the needs of the assessment and characterization and subsequent cleanup work.

1.2 Site History

Numerous industrial mineral research projects involving materials that contained naturally occurring radionuclides and metals were conducted on the Site from 1912 until about 1987. Sixteen buildings once occupied the six-acre, upper terrace portion of the Site. The CDPHE has issued a Radioactive Materials License (RML) to CSMRI for the Site. The License authorizes storage of "naturally occurring, source, and byproduct radionuclides."

In 1992, a City of Golden water main broke and released water into an inactive settling pond on the Site. This prompted the EPA to undertake an emergency removal action pursuant to CERCLA. This activity involved the excavation of 22,000 cubic yards (cy) of soil from the vicinity of the pond. The material was later disposed as "solid waste" at a local solid waste landfill. The EPA removal action ended in 1997. For additional details about EPA's removal action, refer to Volume 1, *Summary Report on Site Investigation and Removal Activities, CSMRI Creekside Site, Golden, Jefferson County, Colorado*, dated March 17, 1993, and prepared by Ecology and Environment, Inc., on behalf of the EPA.

Aboveground structures on the Site, including concrete slabs, asphalt-paved areas, and most subsurface footers for the buildings have been demolished and disposed off site at local solid waste landfills or at recycling facilities.

Numerous environmental assessments have been completed for the upper terrace portion of the Site. The more recent assessment identified 13 COCs. The COCs for the upper terrace include the radium isotopes Ra-226 and Ra-228; the thorium isotopes Th-228, Th-230, and Th-232; the uranium isotopes U-234, U-235, and U-238; and the metals arsenic (As), lead (Pb), mercury (Hg), molybdenum (Mo), and vanadium (V). Where radionuclides were present, they were part of naturally occurring decay chains and minerals. The metals generally occur together with the radioactive COCs.

These COCs occur naturally in the bedrock formations and in the surficial deposits that comprise the Site. The following three studies concerning background were completed between 2000 and 2004.

- *Background Characterization Report, prepared for Colorado School of Mines Environmental Health and Safety*, prepared by URS Greiner Woodward Clyde International-Americas, Inc., July 7, 2000 (URS 2000)
- *Colorado School of Mines Research Institute Supplementary Background Characterization draft final report*, prepared by URS Corporation, January 28, 2002 (URS 2002)
- *Remedial Investigation/Feasibility Study and Proposed Plan*, prepared for Colorado School of Mines Research Institute Site, prepared by New Horizons Environmental Consultants, Inc., January 21, 2004 (New Horizons 2004)

In 2002, the School contracted with New Horizons Environmental Consultants, Inc. to provide surface and subsurface sampling and analysis of the Site, as defined at that time, and to generate a report. New Horizons performed the Site characterization work and prepared a report dated January 21, 2004. The report outlined several alternative remedial options, with the School preferring one as the proposed remedial action plan for the Site. After public comment, the remedy was selected and published in another report dated March 31, 2004. The Record of Decision (ROD)-selected remedy was excavation of soils and off-site disposal at landfills. This work constituted Phase I of the New Horizons environmental assessment and response work.

In the January 2004 report, New Horizons divided the affected soils into two classes. "Class I soil" was described as soil that required disposal at a U.S. Ecology facility in Idaho because the radionuclide concentrations were expected to exceed that allowed at a local landfill. New Horizons estimated that the amount of Class I soil that would be excavated during the remedial action would be approximately 500 cy. "Class II soil" was described as soil that could be disposed of at the local landfill. New Horizons estimated that the amount of Class II soil that would be excavated during the remedial action to be approximately 9,500 cy.

In 2004, New Horizons was selected to identify, excavate, and dispose off-site, the contaminated soils at the Site. Field work began in April 2004 and constituted Phase II of the New Horizons environmental assessment and response. New Horizons began its field work by first excavating the Class I soil and placing the Class I soil into bags for shipment to the U.S. Ecology facility in Idaho. By May 2004, less than one fifth of the Site had been excavated. However, the volume of excavated Class I soil reached approximately 1,870 cy, which exceeded the 500-cy volume estimated by New Horizons. It became apparent that the extent of contamination at the Site was not fully understood by New Horizons. Therefore, remedial work was halted by the School and the Site was stabilized. The contract with New Horizons was terminated for cause by the School in 2004. At the time of the contract termination, an estimated 100 cy of the bagged soil had been shipped from the Site for disposal leaving an estimated

1,776 cy remaining for transport and disposal. CDPHE stated that additional Site characterization should be performed before accurate cleanup options and cost estimates could be developed.

Stoller was then hired by the School. Bagged soil staged at the Site by New Horizons had been initially slated for disposal at a U.S. Ecology facility in Idaho. In December 2004, Stoller collected representative soil samples from a portion of the 455 super-sack containers staged at the Site to evaluate potential alternative disposal options for the bagged soil. Results were submitted to the CDPHE for review in the April 2005 report, *Dose Assessment for the Emplacement of the CSMRI Site Containerized and Remaining Subsurface Soil into a RCRA Subtitle D Solid Waste Landfill* (Stoller 2005). After review of the dose assessment report, the CDPHE approved shipment of the bagged material and up to 30,000 cy of similar yet-to-be-excavated soils to the BFI Foothills Landfill on Highway 93 in Jefferson County, Colorado (now operated by Allied Waste) in a letter dated August 26, 2005. The bagged material was shipped from the Site to the BFI Foothills Landfill in December 2005.

Stoller was contracted to continue assisting with characterizing the Site, as defined at that time, to determine the nature and extent of contamination. An investigative work plan was prepared for the upper terrace soils that avoided many of the issues that led to the unsuccessful New Horizons effort. That work plan detailed an investigation of the nature and extent of contamination during which impacted soils were segregated into stockpiles based on contaminant levels. Once the investigation was completed, Stoller prepared a modification to the New Horizons January 2004 report (Stoller 2007a), followed by a modification of the New Horizons March 2004 report (Stoller 2007b). After public involvement and CDPHE approval, a revised remedial action was implemented – excavation, removal, and local landfill disposal of about 11,000 cy of impacted soil – and reported in the *Remedial Action Implementation Report* (Stoller 2008). After the implementation of the remedial alternative, groundwater monitoring was conducted to determine whether the remedial action resulted in decreasing contaminant concentrations at various locations within and around the Site. Uranium concentrations not only persisted in groundwater located on the flood plain beneath the former pond location, but a newly installed well in the flood plain area detected significant uranium concentrations that had not been previously detected in such high concentrations at the Site during past groundwater monitoring by EPA and the School. The recent groundwater results warrant the new investigation described herein. The results of the groundwater monitoring are described in more detail in the quarterly monitoring reports over a two-year period (Stoller 2006-2009).

On June 2 and 3, 2010, eight test pits were dug on the flood plain and data collected as part of a preliminary Site characterization. The results of this investigation were used to (1) prepare for the work described herein and (2) address concerns brought forth by the CDPHE and the PRPs. The findings of the preliminary flood plain characterization are described in the *Preliminary Flood Plain Characterization* report presented as Appendix A. Data from this preliminary work and how it is being used to assist in the flood plain characterization are presented in Sections 2 and 3 herein.

1.3 Site Geology

The Site is located along the front range of the Rocky Mountains adjacent to Clear Creek as shown in Figure 1-2. The bedrock underlying the Site consists of four steeply dipping formations overlain by four surficial geologic units. The bedrock formations are the Pierre Shale, the Fox Hills Sandstone, the Laramie Formation, and the Arapaho Formation. A geologic map of the bedrock formations is provided as Figure 1-3. These formations range from fine-grained shale and coal beds to coarse-grained sandstones and conglomerates. The coal bed within the Laramie Formation was historically mined. A plaque near the Site commemorated the loss of life that took place in the mineshaft that underlies a portion of the Site. Each of the four bedrock formations has a different chemical composition and can be expected to have different background concentrations of metals and radionuclides.

Four younger surficial deposits in the vicinity of the Site overlie the bedrock formations. These younger deposits are Louviers Alluvium, Post Piney Creek Alluvium, Colluvium, and artificial fill. These surficial deposits are the most impacted by research activities at the Site, with minor impacts to the underlying bedrock formations. Only the Louviers Alluvium and Post Piney Creek Alluvium are present in the area of the flood plain characterization work. Detailed lithologic descriptions of these units are contained in the report prepared by Stoller in 2007 (Stoller 2007a). A geologic map showing the extent of these four deposits is presented as Figure 1-4. Each of these four deposits has different chemical composition and can be expected to have different background concentrations of metals and radionuclides.

1.4 Site Hydrology

Groundwater at the CSMRI Site can be divided into the upper terrace area and the flood plain area. Eleven monitoring wells installed on site have been sampled quarterly for the past three years for geochemical data and contaminant data. The wells on the flood plain have identified a uranium groundwater plume that has triggered the need for this investigation/characterization of the soils that may be causing the contamination plume.

Groundwater on the upper terrace occurs under unconfined conditions in the alluvium/colluvium deposits that overlie the bedrock formations. Depth to the water table ranges in the upper terrace from about 14 to almost 27 feet below ground surface (bgs). Groundwater on the upper terrace area generally flows to the northeast and north toward the flood plain and Clear Creek. The surficial deposits are mainly recharged by infiltration of precipitation and to a limited extent by irrigation of the natural turf baseball field. Uranium has recently been detected in two groundwater monitor wells on the upper terrace at concentrations that fluctuate around the groundwater quality standard of 30 µg/L.

Groundwater in the flood plain also occurs under unconfined conditions. Groundwater flow in the flood plain area is heavily influenced by the seasonal fluctuations of Clear Creek. Hydrographs of flood plain monitor wells show a strong relationship between the stage height of Clear Creek and a recorded response in the chemistry and water elevation. Depth to the water table in the flood plain ranges from 3 to 5 feet bgs but will rise almost 2.5 feet, as it did during the June sampling event, due to an increase in flow of Clear Creek. Water chemistry is variable on the flood plain, fluctuating between a slightly reducing environment when the flood plain is losing groundwater and one rich in dissolved oxygen when receiving groundwater flow from the creek.

The results of the quarterly sampling events indicate persistent exceedances of uranium above the groundwater standard at monitor well CSMRI-8, located at the western end of the flood plain, since the well was initially installed in February 2007. Exceedances for uranium have recently also been detected in monitor well CSMRI-4, but at significantly lower concentrations than that in well CSMRI-8. Since 2005, the concentration of uranium at this location had been below to slightly above the groundwater standard. However beginning with the groundwater standard exceedance in the December 2008 sampling event, the concentration of detected uranium has continued to increase in well CSMRI-4. The cause for this increase is strongly suspected to be improvements on the upper terrace, which allowed surface water to flow directly onto the flood plain.

In late 2008 and through 2009, artificial turf athletic fields with storm water drainage beds were constructed on the upper terrace. Storm water passes through the drainage beds and is conveyed via a 24-inch pipe to an outlet at the edge of the upper terrace approximately 30 feet northeast of monitor well CSMRI-9. The discharged water then runs down the upper terrace slope onto the flood plain. Only after the new discharge pipe was in place did the concentration of uranium at monitor well CSMRI-4 significantly increase. The discharge pipe has since been relocated so that storm water no longer enters the flood plain area from the new discharge pipe. The uranium concentrations in well CSMRI-4 have since decreased from the highs detected when the discharge pipe was feeding storm water into the flood plain.

During the preliminary characterization work in the flood plain, five temporary piezometers were installed on the flood plain to provide better detail on the groundwater surface elevation and gradient to be used during the characterization work. Groundwater samples were also collected from each water-bearing test pit and analyzed, the results of which are presented in Sections 2 and 3.

1.5 Regulatory Framework and Permitting Issues

The main goal of the current characterization of the flood plain area is to assess environmental and health risks, provide data to plan for the management of the risks, and eventually terminate the RML. This project is one of several that have been conducted at the Site since 1992, and it continues the process of investigating and characterizing the Site in order to determine the nature and extent of contamination and develop cleanup alternatives. This project will culminate with a report describing the nature and extent of contaminant impacts, a determination whether remediation of the contamination is necessary, which is probable, and a likely recommendation of a remedial alternative for the stockpiled soils and a groundwater monitoring plan. The remedial action is not covered by this investigative work plan because a remedy cannot be developed before the nature and extent of the contamination and the source of groundwater contamination are determined.

1.5.1 Site Licensing History

The Site licensing and regulatory history is described in the New Horizons January 2004 report (pp. 4-12 through 4-44). This history is incorporated by reference. Additional licensing information and history is provided in Appendix B of this work plan. Previously excavated soils from the Site have been disposed offsite as solid waste at solid waste landfills. These activities were completed under the RML of the contractors performing the work.

1.5.2 Radioactive Materials Licenses

CDPHE has issued RML Number 617-01 to CSMRI for the Site. Consequently, CDPHE has determined that any investigation, characterization, and/or remediation work must be completed under a radioactive material license. The CSMRI flood plain Site characterization work will be completed under the Stoller RML Number 1094-01. The Stoller Radiation Safety Officer (RSO) is Joseph Gordon. The requirements of the Stoller license are incorporated throughout this work plan. The Stoller RML is provided in Appendix C of this work plan.

1.5.3 Permits

During preparation of this work plan, it was determined that three regulatory permitting agencies potentially had oversight requirements for this work. Details of the permitting process are described in the following paragraphs.

U.S. Fish and Wildlife Service (FWS) Endangered Species Act Incidental Take Permit:
Ute Ladies' Tresses Orchids, an Endangered Species Act (ESA) threatened-status plant, were first observed in July 2009 in the flood plain area. A follow-up inventory by an ecological consultant for the City of Golden determined that approximately 100 plants are located predominately within the delineated wetlands area as well as to the west of the wetlands.

In a telephone call with the FWS, Colorado Field Office, it was determined that neither an Incidental Take Permit under Section 10 of the ESA nor a Habitat Conservation Plan would be needed if construction excavation activities were to encounter the orchid in the flood plain area. At the request of the FWS, a concurrence letter was generated and submitted for review. The concurrence letter discusses the scope of the characterization action in the flood plain area and presents information regarding the population of Ute Ladies' Tresses Orchids in the flood plain.

A response from the FWS regarding its concurrence that an incidental take permit is not required was received by Stoller on December 18, 2009. The letter states that the FWS concludes that the project in the flood plain is not likely to affect either the Ute Ladies' Tresses Orchids or the Preble's mouse population and that an incidental take permit is not required. A copy of this letter is included in Appendix D.

U.S. Army Corps of Engineers (USACE) Nationwide Permit No. 38:
Under the Nationwide Permit (NWP) 38, "specific activities required to effect the containment, stabilization or removal of hazardous or toxic waste materials that are performed, order, or sponsored by a government agency with established legal or regulatory authority provided the permittee notifies the district engineer in accordance with the "Notification" general condition." This permit required a Biological Assessment be performed on the flood plain, which led to the Division of Wildlife issuing a biological opinion. The USACE then issued CSM a Nationwide Permit No. 38 (valid through March 17, 2012), which allows the work detailed in this plan to be completed. A copy of this permit is included in Appendix D.

A Pre-Construction Notification will be completed and submitted to USACE at least 45 days in advance of any field activities to comply with the "Notification" requirement for a NWP 38.

City of Golden Storm Water Permit:
The City of Golden is a designated Qualifying Local Program by the CDPHE Water Quality Control Division. Consequently, construction sites less than five acres are automatically covered under the State's General Permit for Construction Activities with a City permit.

A Stormwater Management Plan (SWMP) has been prepared detailing erosion/sediment controls, maintenance, and inspection methods, and it is provided in Appendix E. The plan describes the best management practices that will be used to reduce the pollutants in stormwater discharges associated with characterization and reclamation activities. The SWMP and a completed City of Golden, Stormwater Quality Permit Application will be submitted at least 30 days before any field work activities begin. The permit will be available in the Site office trailer during all Site work.

City of Golden Grading Permit:
The City of Golden requires a grading permit for all work over 200 cy and over one-half acre. The Site is anticipated to exceed both of these conditions. The grading regulations are outlined in Chapter 15.18 of Golden's Municipal Code. The grading permit must be submitted and approved by the Public Works Department prior to any excavation work beginning on the Site. As part of the permit process, a grading plan will be submitted to the Public Works Department for approval. This grading plan will show replacing the topography exactly as it existed prior to the start of excavation on the Site. The final elevations on the Site will reflect the original elevations within a given tolerance (plus or minus 2 inches). The City of Golden Public Works Department will be worked with closely and directly throughout this permitting process.

1.6 Current Site Conditions

The Site is currently overgrown with grasses, willows, and other low vegetation. Three groundwater monitoring wells are located on the flood plain, and an additional eight groundwater monitoring wells are located on the upper terrace. Two surface water locations along with all the monitoring wells have been sampled on a quarterly basis since February 2005. This monitoring program will remain in place during the characterization described in this work plan. The Site is currently in a stable configuration.

The School has constructed a synthetic surface soccer field south of the flood plain, and a planned parking lot will be located between the soccer field and the flood plain. The parking lot, access road, and a proposed bike path are currently in the design phase.

1.7 Project Organization

Figure 1-5 presents the project organization chart, which identifies key management roles and diagrams areas of responsibility for the scope of work outlined in this work plan.

The management structure should not be confused with the project lines of communication. It is Stoller's and the School's intent to maintain open communication among all entities involved in this work plan. Stoller recognizes that the oversight role of the CDPHE personnel may require open access to the field activities, laboratory activities, community relations activities, and project quality assurance/quality control (QA/QC) information. Stoller will work with CDPHE personnel to keep them informed of the ongoing activities.

Primary responsibility for the achievement of the work plan objectives lies jointly between Linn Havelick, the School Principal Representative, and Stephen Brinkman, Stoller Project Manager. The Stoller Project Manager will be on the Site at the commencement of the project activities and periodically thereafter. Stoller's Project Lead, Michael (Harry) Bolton has the responsibility of ensuring that field activities conducted by Stoller and its subcontractors are performed in conformance with the approved work plans. Various Stoller employees will act in technical support capacities and perform those portions of the flood plain characterization that fall within their individual areas of expertise.

Radiation safety is the responsibility of the RSO. Joseph Gordon is the primary RSO, and Jerry Mattson is the alternate RSO and will have field implementation responsibilities.

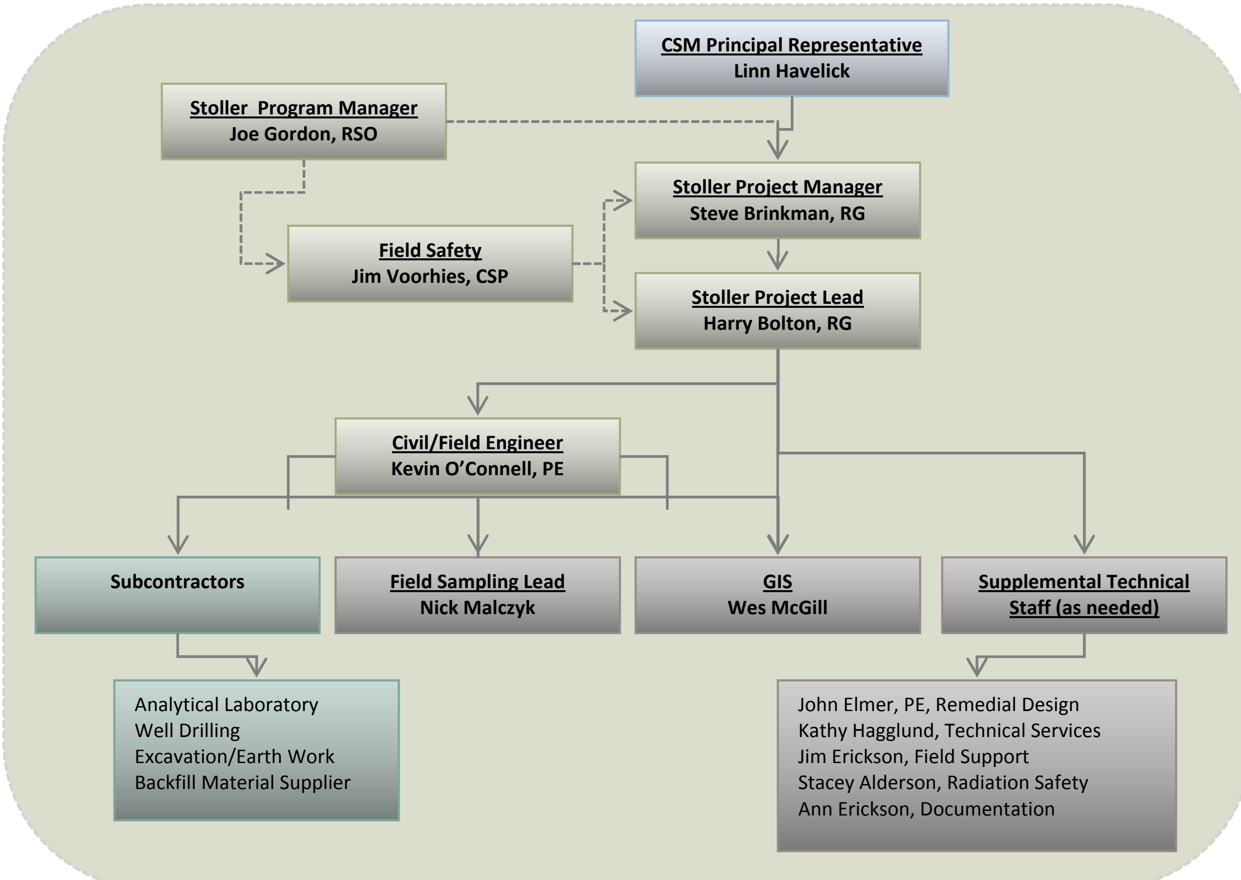

Figure 1-5. Project Organization Chart

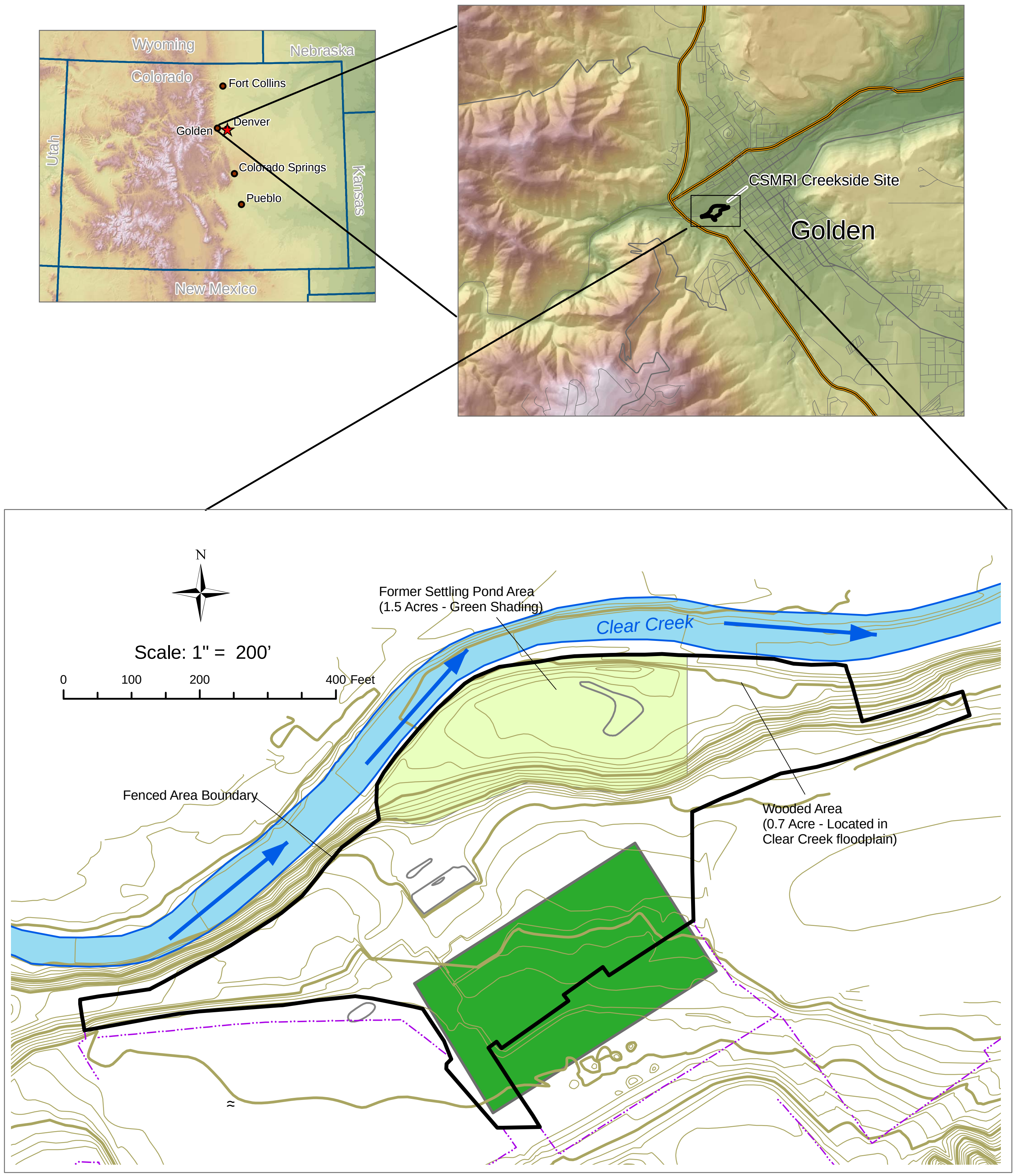

Figure 1-1

CSMRI
Original 2006
Site Location Map

Explanation

- 2006 CSMRI Creekside Site Boundary
- Fences
- Topography (1 ft Intervals)
- Topography (5 ft Intervals)
- Former Settling Pond Area
- Aproximate Location of Soccer Field

CSMRI
Flood Plain
Characterization
Work Plan

Explanation

- Existing Monitor Well
- Topography (Depressions)
- Topography (10 Ft Intervals)
- Stoller Field Office
- Potential Staging Location
- Flood Plain Characterization Area
- Soccer Field
- Wetlands

N
W E
S

Scale: 1" = 75'

0 37.5 75 150 Feet

Figure 1-2
Current Site Location Map

CSMRI
Flood Plain Site Characterization
Work Plan

Stoller

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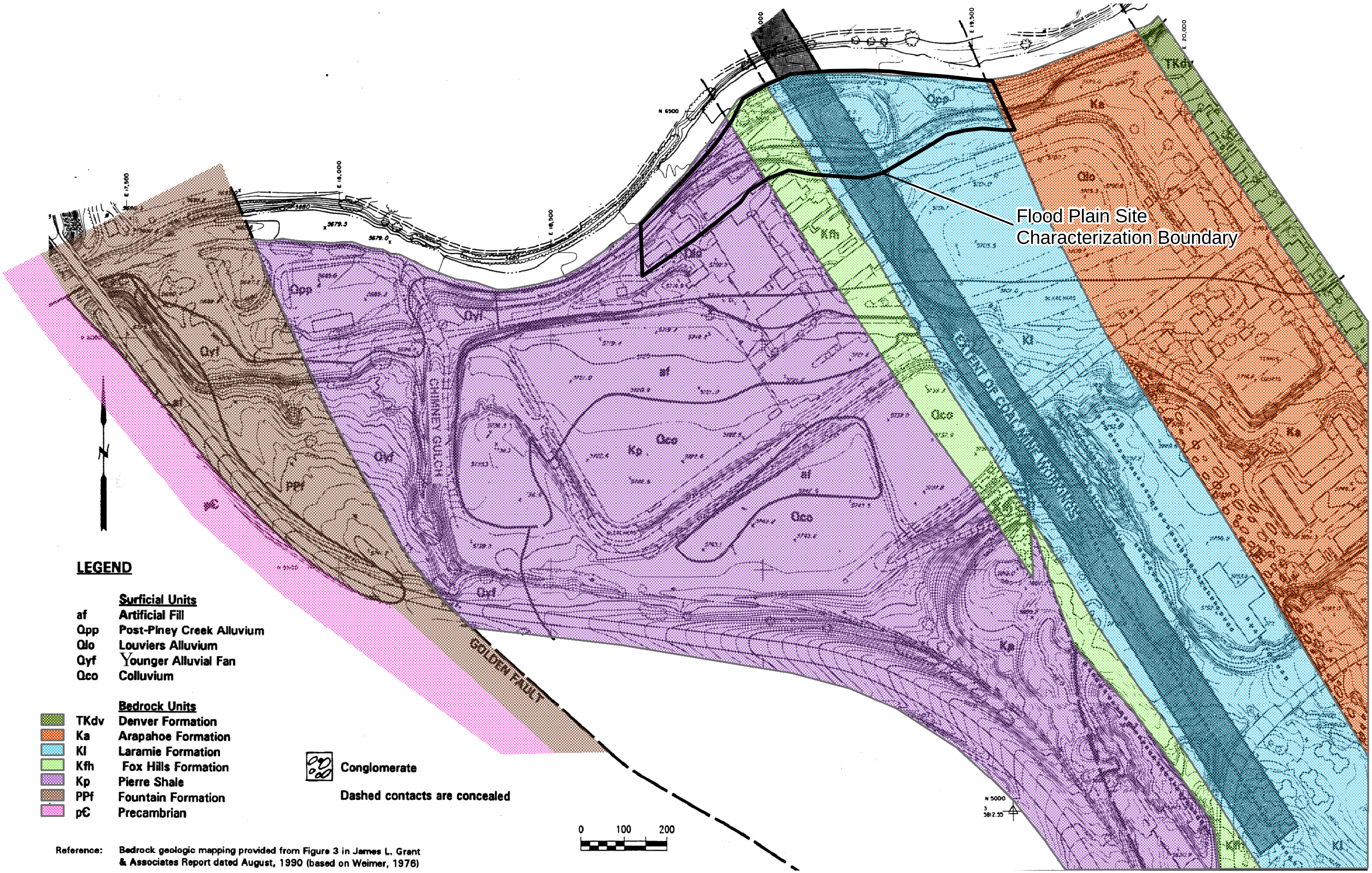

Figure 1-3

CSMRI
Bedrock Geologic Map

CSMRI
Flood Plain
Characterization
Work Plan

Stoller

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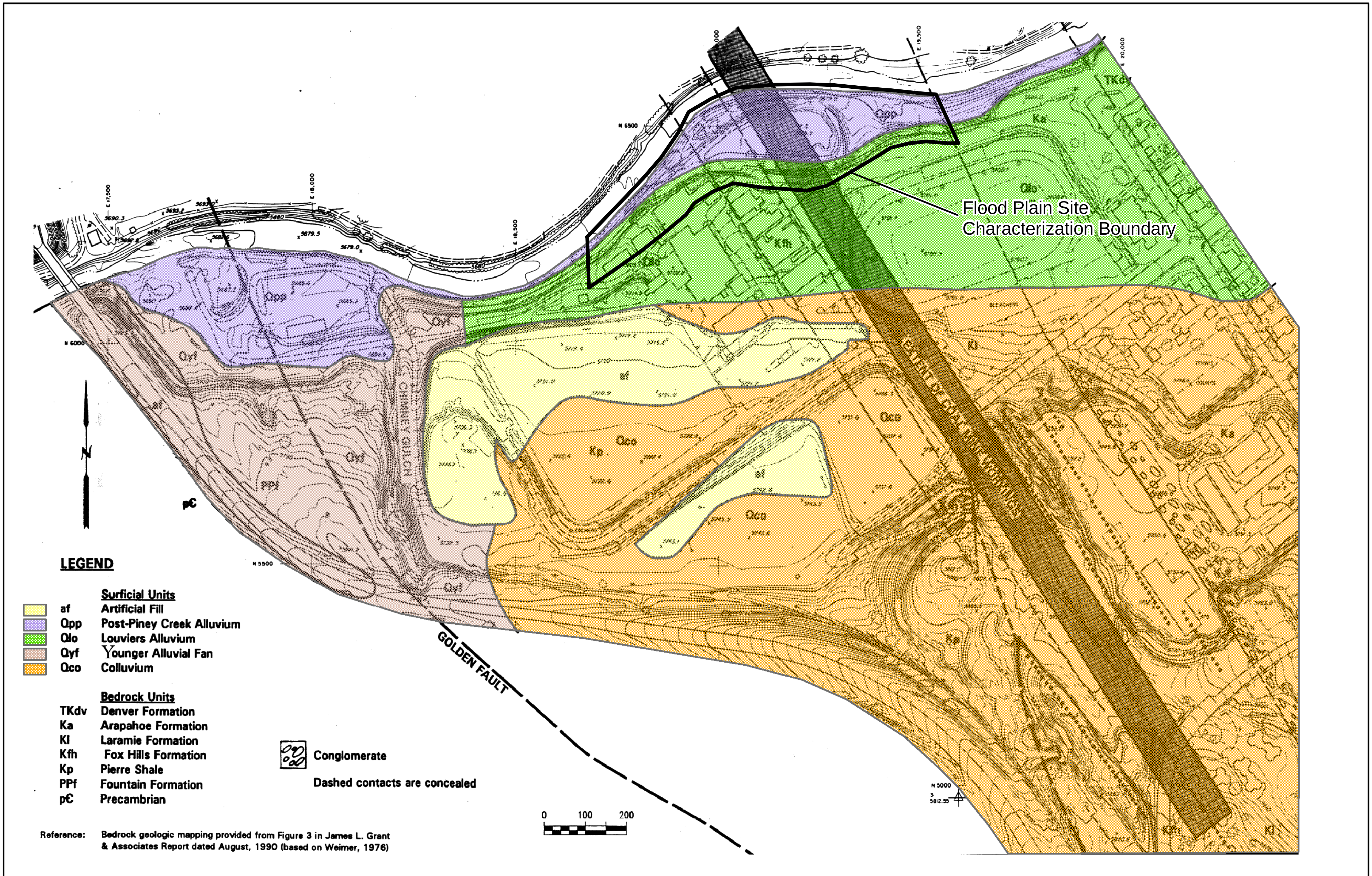

Figure 1-4

CSMRI
Surface Geologic Map

CSMRI
Flood Plain
Characterization
Work Plan

Stoller

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2 Flood Plain Assessment and Characterization Objectives and Approach

The objectives of this flood plain characterization are to

- Efficiently and accurately assess and evaluate the nature and extent of contamination and causes of the contamination in the flood plain area using a combination of pre-existing data and newly collected data;
- Develop flood-plain-specific cleanup goals, including sub-groundwater soil, that are protective of public health and the environment;
- Characterize the soils excavated from the flood plain during the investigation for flood plain COCs;
- Continue monitoring the groundwater to evaluate the success of the characterization; and
- Develop sufficient data to evaluate the feasibility of several remedial alternatives for the flood plain and excavated soils.

This work plan is limited to flood plain assessment and characterization activities. The ultimate goal of the School's environmental assessment and response work is to properly assess, manage, and address the risks at the Site and attain CSMRI's RML termination. This work plan is designed to meet the immediate objectives and move toward that ultimate goal.

Key tasks described in this work plan include:

- Preparation of the work area by establishing access roads, abandoning groundwater wells located within the area of planned soil excavation, and establishing staging areas and Site office facilities.
- Preparation of locations to store stockpiled soils generated during characterization activities.
- Calibration, determination of any bias(es), and correlation of field instruments to each other and to COC laboratory data.
- Excavation of areas of suspected contamination based on existing information (groundwater data, visual observation, test pit data, and photograph interpretation).
- Determination and segregation of vertical and lateral extent of impacted soil within the flood plain characterization area using a combination of in-situ field measurements, visual observation, and laboratory analytical data.
- Collection of verification samples for field laboratory and offsite laboratory confirmatory analyses.
- Estimation of volume of segregated soil with contaminant concentrations exceeding the proposed cleanup goals.
- Characterization of remaining materials in flood plain area for use in determining appropriate remedial alternatives.
- Characterization of impacted segregated soil for use in determining appropriate remedial alternatives.
- Replacement of abandoned groundwater wells and installation of additional wells.
- Performance of flood plain backfilling.
- Monitoring of groundwater wells after backfilling.

Each of these tasks is described in further detail in separate sections of this work plan. Section 3 summarizes the existing flood plain Site assessment data and identifies data needs. Section 4 presents the tasks to be completed to prepare for the field work. Section 5 details the field activities, including soil characterization/excavation, soil segregation, and in-situ measurements. Sampling and analysis information is provided in Section 6, Sampling and Analysis Plan (SAP). The Quality Assurance Project Plan (QAPP) is provided in Section 7. Section 8 presents an approach for the replacement of existing monitoring wells, installation of new wells, and monitoring of wells.

The tentative schedule for the activities covered by this work plan is provided in Appendix F. The schedule includes all major activities that Stoller will perform during the characterization.

The proposed cleanup goals for radionuclides (except for total uranium, which is 14 parts per million [ppm]) for this project are presented in Table 2-1. These cleanup goals are identical to those used for the characterization of the upper terrace portion of the Site performed in 2006 with the addition of total uranium metal of 14 ppm.

Table 2-1
Radionuclide-Specific Tentative Cleanup Goals

Isotope	Activity (pCi/g)
Ra-226	4.14
Ra-228	4.6
Th-228	6.47
Th-230	11.53
Th-232	3.88
U-234	254.9
U-235	4.97
U-238	21.8

pCi/g – picocuries per gram

Metals of concern for the Site include As, Hg, Mo, Pb, U, and V. Metals concentrations will be compared to the CDPHE soil cleanup standards, with the exception of uranium and arsenic for which Site-specific standards have been calculated. The cleanup standards are summarized in Table 2-2.

Table 2-2
Site-Specific Metals Tentative Cleanup Standards

Metal	Concentration (ppm)
As	39
Pb	400
Hg (Total)	23
Mo	390
U	14
V	78

ppm – parts per million

Due to the elevated concentrations of uranium in groundwater and the characteristics of the flood plain area, the tentative uranium cleanup standard is discussed in more detail below. The soil cleanup goal for uranium is 14 ppm in soil. This cleanup goal was partially derived by geochemically determining the partitioning coefficient for uranium using Site soil and water samples. The results of this study are presented in Appendix A.

The tentative cleanup goal was determined by evaluating (1) the ambient concentration of uranium from the background study, (2) the results of geochemical modeling, (3) field screening instrument sensitivity, 4) published risk-based soil standards for uranium from EPA Region 3, and (5) Site data. Each of these items is discussed in more detail below:

- The background study undertaken determined that the ambient uranium concentration from a nearby analogous depositional environment upstream of the Site is 6.45 micrograms per kilogram (mg/kg). This value was statistically derived by using the mean uranium value of the sample population 3.05 ppm plus two standard deviations of 1.7 ppm.

- Geochemical evaluation of groundwater was performed to determine a Site-specific soil partitioning coefficient (Kd) and calculate a Soil Screening Level (SSL). The evaluation involved batch adsorption testing of soil and groundwater samples collected from the flood plain. The results of this testing found Kd values 0.01 to 0.19 L/kg resulting in SSL calculated values of 0.114 to 0.219 ppm. Geochemical modeling of the leachate was performed using PHREEQCi to speciate the solution and evaluate potential precipitation and sorption mechanisms that may attenuate uranium concentrations along the groundwater flow path. The geochemistry determined that virtually all uranium present in Site groundwater was in the soluble form U^{+6} present as carbonate. Given these results, ambient uranium in soil could result in groundwater uranium concentrations as high as 400 parts per billion (ppb). However, this was determined using an EPA test method that is considered to be very aggressive and provides a partitioning coefficient that can be considered to be a conservative value for the Site.

- The field screening instrument that is going to be critical for the success of this effort is the x-ray fluorescence (XRF) instrument. Real-time analysis of COC concentrations is the key to being able to perform the characterization of soil from beneath the water table without handling and treating groundwater. The XRF has a limit of detection of 7 ppm for uranium using a 2-minute count time and assuming less than 3 percent total metals in the sample (high metals concentrations shield the soil response which elevates the detection limit). A tentative cleanup goal for uranium that can be achieved with a degree of certainty using the field instrumentation is 2 times the limit of detection or 14 ppm.

- The tentative cleanup goal of 14 ppm is consistent with the EPA Region 3 Mid-Atlantic Risk Based Assessment. This assessment assumes what little source of uranium exists in the groundwater would never communicate in the bedrock formations to a receptor; this assumption is consistent with known Site conditions. The risk-based assessment determined that a screening level of 14 ppm for uranium in soil is protective of groundwater at the 30 µg/l (ppb) maximum contaminant level (MCL).

- Uranium concentrations in soil are pervasive across the flood plain. The majority of the Site has uranium concentrations at less than twice ambient levels with the exception of the west end where concentrations are higher. Dissolved uranium in groundwater is present across the Site in decreasing concentrations toward the east indicating a likely contaminant source for groundwater in the vicinity of well CSMRI-8. Soil uranium concentration values determined from test pits indicate that using a tentative Site cleanup goal of 14 mg/kg (ppm) will remove this source material from the Site. Test pit CLT-6, which identified uranium concentrations exceeding the tentative cleanup goal, was installed to determine the geotechnical characteristics of the berm in the event a low-permeable barrier wall was determined to be necessary. The berm is a Site feature that consists of an elevated strip of land immediately adjacent to Clear Creek. Because of the risks that characterization activities have of impacting the creek, a 5- to 10-foot setback from the creek has been established for this work. This may result in elevated uranium being left in place within the berm.

The ambient uranium concentration for soil in Clear Creek Alluvium is 6.45 mg/kg as determined from sampling and analysis presented Appendix A. The proposed soil cleanup goal of 14 mg/kg (ppm) for uranium is inclusive of the ambient concentration. The geochemically derived cleanup level that is protective of groundwater is highly dependent on water chemistry. Factors affecting the mobility of uranium in groundwater include, but are not limited to

- Dissolved oxygen,
- pH,
- Organic carbon,
- Oxidation-reduction potential (ORP),
- Alkalinity,
- Sulfate,
- Iron,
- Phosphate, and
- Microbial activity.

The water chemistry in the flood plain is highly variable making the derived soil cleanup level for uranium conservative due to the inputs and mechanical techniques used to derive an adsorption coefficient for geochemical modeling.

Based on the distribution of uranium concentrations in flood plain groundwater, uranium in soil is suspected to be exceeding the proposed cleanup level in the vicinity of groundwater well CSMRI-8. Further, historic air photographs and test pit data suggest that a potential source for uranium in groundwater exists in the vicinity of monitoring well CSMRI-8. Section 3 presents further details.

3 Existing Flood Plain Assessment Data

The flood plain portion of the Site has had previous investigation and cleanup activities. Based on recent groundwater data, it appears the EPA removal action did not successfully delineate the complete nature and extent of contamination. However, the following studies have yielded varying quantities/qualities of data that have been used to prepare this work plan.

- EPA emergency removal action
- Eastern Flood Plain Investigation
- Preliminary Flood Plain Test Pit Characterization
- Ongoing groundwater monitoring
- Evaluation of historic air photographs
- Investigation of the upper terrace

In concert these studies have provided sufficient data to identify COCs, establish tentative cleanup goals, and move forward with further investigation of the flood plain. Details of each of these are presented below.

The EPA emergency removal action was completed due to a release to Clear Creek from the former settling pond located on the flood plain. Data collected during the EPA-managed emergency pond removal in 1992 were evaluated by Stoller to determine if any data could be used to determine nature and extent of COCs in soil. Surface samples, test pit samples, and samples from borings were analyzed to determine whether the resulting data were representative of soil remaining on site or soil removed during the removal action. Surface samples were collected by EPA from the entire area surrounding the settling pond in a uniform grid prior to the excavation portion of the removal action. The soil represented by the data was removed from the Site during the removal action. Because the EPA action had cleanup levels of 5 pCi/g and 15 pCi/g for radium-226 (the Uranium Mill Tailings Radiation Control Act or UMTRCA standard, and CDPHE Part 18 Radiation Control regulations standard), very little characterization data and no confirmatory data included uranium concentrations. Thus, the data generated during that work were of limited use in this effort to develop data for uranium, but the information is useful for providing existing data on radium-226 concentrations remaining in soil. The groundwater is currently contaminated with uranium, not radium-226.

The eastern flood plain (i.e., portions of the flood plain that are to the east of the current flood plain working area subject to this investigation work plan) investigation and remediation were completed by Stoller on a portion of the flood plain east of the former settling pond where EPA performed its removal action. Stoller's effort focused on metals (not including uranium) and radium, identical to the investigation/removal completed on the upper terrace. This effort did not generate uranium-specific data useful for this investigation.

The preliminary flood plain characterization was completed in June 2010 by Stoller to fill data gaps identified by the Site PRPs and CDPHE. This preliminary characterization focused on collecting geologic and hydrologic information that will assist with the flood plain characterization activities as well as uranium concentration data in both soil and water across the flood plain area. Also completed were the collection and analysis of samples used to determine a site-specific cleanup level for uranium that would be protective of groundwater, and the collection and analysis of background samples to determine background uranium concentrations. Appendix A presents the results of this work.

Since the EPA removal action ended in 1997, characterization work on the flood plain area cleaned up by EPA has consisted of the installation and quarterly sampling of groundwater monitoring wells and Stoller's preliminary characterization. Data from the groundwater wells indicate the presence of a dissolved uranium plume underlying a portion of the flood plain. The highest detected concentration of uranium in groundwater is located in the area of well CSMRI-8, which is located at the upgradient (west) end of the flood plain. The uranium plume has also been detected in wells CSMRI-4 and CSMRI-5 but at a much lower concentration. This plume geometry is indicative of a cause area located in the vicinity of well CSMRI-8. This was further supported by the analytical results of bulk groundwater samples and potentiometric surface data collected during the Stoller preliminary characterization.

Historic air photographs were acquired and evaluated for indications of potential areas of releases and changes to the Site, both natural and human caused. The air photographs evaluated included photos from 1888, 1951, 1972, 1989-1993, 1995, and 2002-2004. Copies of the most informative photographs are included in Appendix G and include the years 1888, 1951, 1972, 1991, and 1992.

The 1888 photo provides a glimpse of Clear Creek prior to being channeled and of the CSMRI site prior to being developed. This photo also appears to show a large sand and gravel bar located approximately where the present-day flood plain is located, separated from the main CSMRI Site by a significant channel of Clear Creek. This channel will be referred to in this work plan as the "suspected channel."

The next informative photograph is from 1951, which clearly shows a discharge pipe from then-established research facilities leading to Clear Creek immediately upstream from the location where the suspected channel was located. The suspected channel is no longer an active channel at this time and is thought to have been possibly filled in by research activity or other fill. During this timeframe, the research facility was performing research on uranium and radium ores and may have been storing or disposing of the uranium-containing materials on the Clear Creek flood plain near monitoring well CSMRI-8. In addition, research was performed on other ores that naturally contained elevated levels of uranium, although the research was focused on non-uranium metals. It remains unclear if the tails went into the Creek, and possibly into the suspected channel, or were pushed over the edge of the terrace in an effort to channelize the creek and create additional land for development; but each of these may have occurred given the lack of regulatory controls and practices at that time. A 1987 environmental assessment report indicated that Building 109 was built on land created in just such a manner (Jacobs 1987).

The next air photograph with relevant information was from 1972, and it shows a feeder ditch running from discharge points near Building 109 to the west end of the settling pond. Combined with the 1991 pre-EPA and 1992 post-EPA removal action air photographs that show the extent of the removal action being limited in the area of the feeder ditch, it indicates that possible contaminated soils resulting from the feeder ditch may have remained after EPA's removal action ended, and that any material that may have been placed in that area prior to construction of the feeder ditch may also remain.

In summary, while site data are limited, there is sufficient data to plan the investigative work in a manner to target the likely areas to contain suspected contaminated soil. The characterization will focus on the soils in the vicinity of well CSMRI - 8. Details of this plan are presented in Section 5.

The investigative method proposed herein is to sample and identify the impacted soil, excavate the impacted/suspected source soils, and segregate these soils near the flood plain for further sampling and analysis to determine the nature and extent of contamination.

Stoller determined that a conventional investigation through taking multiple soil borings across the flood plain would be ineffective to determine the nature and extent of contamination because the operational history and the unique geology, lithology, and water features of the Site create an unpredictable, non-homogenous patchwork of contamination that is very different than a traditional site where contamination is homogenous and uniform. EPA used the excavation/segregation method of investigation method to identify radium-contaminated soils and to remove the sources. New Horizons' attempt to use soil borings to characterize the upper terrace soils failed, whereas Stoller's excavation/segregation method was effective in determining nature and extent of contamination in the upper terrace.

The estimated cost of using this excavation/segregation method of investigation is comparable to the cost for the traditional multiple soil borings and test pits method of investigation. In addition, the excavation/segregation method substantially increases the degree of confidence to determine the nature and extent of the contamination to reliably estimate remediation alternatives and costs consistent with professional guidelines, unlike the more traditional soil boring investigation methods. The excavation/segregation method of investigation is not a remedy.

Therefore, to maintain fiscal responsibility and to improve the level of confidence to estimate nature and extent of contamination and meet professional guidelines for evaluating potential remedies, this plan adopts and describes the site characterization technique of excavating and segregating impacted material. Field screening tools will be used to guide the excavation. Laboratory analyses will be used to confirm that the use of the field screening tools successfully achieves the proposed cleanup goal.

4 Field Work Preparation

This section describes the planning, administrative, training, mobilization, and Site preparation activities that will be completed prior to initiation of field work.

4.1 Planning

This work plan contains the Sampling and Analysis Plan (Section 6), the Quality Assurance Project Plan (Section 7), the Site-Specific Health and Safety Plan (Appendix H), the Backfill Plan (Appendix I), the Emergency Response/Spill Prevention Plan (Appendix J), and the Stormwater Management Plan (Appendix E). Additional plans that will be prepared shortly before mobilization include the City of Golden Grading Plan for the temporary haul road and the Traffic Control Plan. These plans will be available for inspection and review in the Site office trailer upon mobilization.

4.2 Administrative Tasks

Administrative activities related to Site preparation and field investigation activities are listed in Table 4-1. Site administrative controls, including signage for traffic control, stockpile designation, deliveries, site access etc., will be placed at the conclusion of the site preparation activities described in Section 4.4.1.

Table 4-1
Administrative Activities Related to Field Work

Activity	Requirements
Notifications	The project manager will notify the School, CDPHE, and the City of Golden before the start of field activities.
Utility Clearance	The field project lead will call the Utility Notification Center of Colorado for utility locates after site preparation, but prior to excavation activities.
Permits	The project manager will submit the stormwater management and erosion control plan to the City of Golden in order to acquire a Stormwater Management Permit at least 30 days in advance of field activities. A U.S. Army Corps of Engineers Nationwide Permit No. 38 to permit with conditions encroachment into the wetlands and associated waters of the State has been acquired.
Site Access Logs	The field project lead will maintain a log for all personnel and equipment entering and leaving the Site. The project lead will provide a list of authorized personnel to the School representative prior to initiation of mobilization activities. Visitors will not be allowed onsite without School approval. Approved visitors will require an escort while onsite and will be required to read the SSHASP and attend a safety briefing.
XRF License	The Stoller team will use a portable XRF on the Site. It will be registered with the State of Colorado in accordance with Hazardous Materials and Waste Management Division, Radiation Control, 6 CCR 1007-1 Part 8. The license will be provided with the leased instrument and will be available for inspection and review in the Site office trailer.
Postings	Copies of the following documents will be posted in the Site office trailer or available onsite: • CDPHE Rules and Regulations Pertaining to Radiation Control, Part 10:

Table 4-1
Administrative Activities Related to Field Work

Activity	Requirements
	Notices, Instructions, and Reports to Workers: Inspections (6 CCR 1007-1 Part 10) • CDPHE Rules and Regulations Pertaining to Radiation Control, Part 4: Standards for Protection against Radiation (6 CCR 1007-1 Part 4) • The CSMRI Site Radioactive Materials License (No. 617-01) • The Stoller Radioactive Materials License (No. 1094-01) • The operating procedures applicable to activities under the license • The approved site-specific work plan • The SSHASP and a list of all persons who have completed safety training for the Site • State, Federal, and OSHA jobsite postings

4.3 Training

Prior to any field work, all project personnel will be trained in accordance with the Site-Specific Health and Safety Plan (SSHASP), which is provided as Appendix H of this work plan. In addition, all field personnel must comply with Stoller's corporate health and safety program training requirements before mobilizing to a project site. Training records will be maintained in the Site office trailer.

4.4 Mobilization

Mobilization will include Site preparation, Site access and security, Site organization, receiving materials and equipment, and establishing ground control for global positioning system (GPS) equipment as detailed in the following sections. It is anticipated that mobilization will take approximately one week.

4.4.1 Site Preparation

The areas needed for temporary haul roads, office trailer, parking areas, and soil stockpiles will be cleared and grubbed, as necessary, to provide a safe working environment and, in the case of the haul roads, to provide a suitable surface for road construction. Erosion and sediment controls will be placed in accordance with the Stormwater Management Plan (Appendix E). These controls may include silt fencing and erosion control logs or other acceptable Best Management Practices (BMPs). Some site grading may be necessary to control runoff and achieve positive drainage.

Temporary retaining structures may be used to prevent the material being characterized from entering the Creek. These may include jersey-type barriers or others placed between the excavation area and the Creek. These barriers will be removed as soon as work is completed.

The City of Golden has underground raw and treated water lines on the western portion of the Site where a source for groundwater contamination is thought to exist. These water lines cross the Site from Clear Creek to the top of and along the terrace slope. Prior to performing any subsurface excavation work, the water lines will be located using a hydrovac excavation system. This system uses water and vacuum technology to quickly and cleanly blast through dirt and rocks to expose pipeline, utility, and electrical systems or to open the ground for future work. The hydrovac provides a safe and non-destructive alternative to conventional backhoes or other mechanical means.

The characterization of soil within the utility corridor will begin after the utility lines are exposed and their location known with certainty. Soil both surrounding and beneath water lines will be surgically removed with short sections of pipe exposed and then backfilled with a self compacting 3/8-inch aggregate (squeegee or similar). During excavation, the project engineer will determine if shoring or pipe supports are needed, such as lumber, and direct the subcontractor as necessary to safeguard the water lines.

4.4.2 Site Security

Stoller will be responsible for Site security throughout the project. The access gates will be locked when the Site is unattended. They will be unlocked during working hours; however, all visitors will be required to check in at the project office. Visitors shall be escorted while onsite. Stoller and subcontractor personnel will produce proper identification upon request. All visitors will be required to read and sign the SSHASP and attend a safety briefing prior to access to the Site.

4.4.3 Site Organization, Locations, and Boundaries

The current and 2006 Site characterization boundaries are described in Section 1 and the Site boundaries are shown on Figure 1-2. Intrusive excavation activities outside these boundaries will require prior approval from the project manager and the School Principal Representative.

The staging area shown in Figure 1-2 is the proposed location of the field office, parking pad, soil stockpiles, and equipment laydown area. All materials and equipment will be stored in accordance with manufacturer's specifications to prevent damage, disfigurement, etc.

Stoller will provide a temporary field office trailer for onsite personnel. The field office will be located north of the soccer field in what eventually will be the parking lot. A gravel pad for parking will be placed around the trailer, and electrical power will be provided by a portable generator. A project identification sign, including the name of the contractor and emergency contact information, will be erected in front of the field office. Mobile telephones will be provided at the field office and/or carried by designated field personnel. The trailer will be equipped with bottled drinking water and fire extinguishers. Temporary sanitary facilities will be established at the field office and within the work area.

During characterization activities, two stockpiles of excavated soil will be generated. These stockpiles are described in more detail in Section 5.6. The approximate location of these stockpiles will be in the staging area shown on Figure 1-2. Haul roads to the characterization area will be prepared as necessary.

A decontamination area will be designated on or near the impacted material stockpile area. It is anticipated that the decontamination area will be addressed during any subsequent remedial action regarding the stockpiles.

4.4.4 Material and Equipment

The following is a tentative list of materials and equipment that may be mobilized to the Site:

- Temporary Facilities
  - Office trailer
  - Portable generator
  - Mobile storage unit - secured storage container for tools, equipment, and sample management and preparation
  - Portable toilets and hand-wash facilities
- Heavy Equipment
  - Track excavator
  - Trench box
  - Backhoe
  - Articulated wheel loader
  - Gradall
  - Dump trucks
  - Bulldozer
  - Smooth drum roller
  - Motor grader
  - Water truck
- Field Instruments
  - Field portable XRF
  - GPS survey station
  - Handheld GPS
- Sampling Equipment and Supplies
  - Nitrile gloves
  - Decontamination solution
  - 4-gallon plastic buckets
  - Oven to dry soil samples
  - Tool box
  - Disposable soil scoops
  - Stainless steel mixing bowl
  - Bowl liners
  - Field logbooks
  - Laptop computer
  - Sample containers
  - Sample labels
  - Chain-of-custody forms and tape
  - Plastic bags
  - Coolers for shipping samples
- Radiological Control Instrumentation and Supplies
  - Sodium Iodide (NaI) gamma scintillation detector
  - Dual alpha/beta scintillation counter
  - Alpha/beta scintillation probe with appropriate survey meter
  - Radiation dose rate survey meter (i.e., MicroR meter)
- Erosion Control Materials

  - Silt fencing
  - Straw wattles
  - Straw bales
  - Erosion mat
  - Stakes
  - Hand tools
- Miscellaneous
  - Water meter and fire hose
  - Diesel-fueled generator (35 kW)
  - Gas generator(s) for hand tools and air monitors
  - Fire extinguishers
  - Hand tools
  - Emergency eyewash station
  - Absorbent pads/Spill kit (fueling)
  - Air horns
  - First aid equipment
  - Mobile telephones/walkie talkies
  - Personal protective equipment (PPE)
  - Designated vehicle with emergency supplies - designated Stoller vehicle supplied with first aid equipment, to be used only in the event of an emergency
  - Trash bags, trash dumpster, and recycling containers
  - Poly sheeting

4.5 Positional Surveying Equipment

Ground control for surveys will be provided by an on-site differential GPS. The GPS will consist of a base station and one or more backpack-type mobile receivers. The GPS will be capable of locating positions within 10-mm horizontal and 15-mm vertical.

The base station will be placed in a location where its transmitter can "see" the entire survey area and that provides clear signal reception from at least one GPS satellite. The base station location will be established using conventional land survey methods from an established benchmark. The location of the base station will be identified by a Colorado-registered land surveyor.

The GPS shall require coordinates in the following projection:

- Projection UTM
- Zone 13
- Datum NAD83

5 Site Characterization

The investigation is designed to identify and characterize impacted soils that are acting as a continuing source for contamination, including the dissolved uranium plume. Uranium-impacted soils are the source of the uranium groundwater contamination; however, during the characterization, all site COCs will be included for characterization. Recent test pit data, historic photographs, groundwater monitoring data, and data from earlier investigations were used to identify the potential source area and COCs that will be characterized. Details of the investigation are provided in the following sections.

5.1 General Approach

The investigation will identify contaminated soils acting as the dissolved uranium groundwater plume. The potential source area for the plume has been identified through historical air photograph analysis, preliminary characterization data, and review of historical documents. The area indicated by the data as containing the material causing the groundwater contamination is in the vicinity of CSMRI-8 shown on Figure 1-2.

The general investigative method used to characterize the nature and extent and concentration of Site COCs-contaminated soils consists of starting from the surface and excavating successive 1-foot vertical lifts of impacted material until non-impacted material is encountered or groundwater is reached. Once a non-impacted soil layer is encountered, the bottom and sidewalls of the excavation will be sampled and analyzed for total uranium to verify characterization is complete. If analytical results detect Site COCs including total uranium above the tentative cleanup goals, characterization will continue in the direction of the exceedence until field screening data indicate, and laboratory data confirm, the tentative cleanup goals have been achieved. This process will be continued until the data indicate that the tentative cleanup goals have been achieved for the bottom and sides of the excavation, which will then be backfilled.

Stoller's experience during the terrace soils characterization demonstrated that this approach worked better than attempting to identify the extent of contamination using a series of borings drilled on a grid. As soil layers were removed during the upper terrace characterization, it was evident that the heterogeneity of the geology and fill materials on the Site required a different approach than test borings to ensure the lenses of impacted materials would be discovered during assessment.

If the groundwater surface is reached in an excavation and field screening data indicate that additional impacted soil likely exists below the water table, then excavation will continue without further delineation until the top of bedrock is encountered (average depth of approximately 7 feet bgs on the flood plain). The soil below the water table will be handled in this way because it is not possible to remove this material in 1-foot lifts or reliably evaluate the uranium content, and because it is likely that all of the material is contaminated due to contaminant mobility in saturated conditions. The general procedures of the characterization technique are described below.

A field portable XRF device will be used to guide characterization activities. In addition, a hand-held gamma scintillator and/or MicroR meter will be kept on site to monitor for gamma-emitting material that may create a worker exposure potential or indicate the presence of radionuclides in soil. Any material that does indicate an exposure potential will be segregated and managed in the impacted material stockpile on-site until disposal methods are determined after the investigation is complete.

The XRF will be used to guide the excavation of soil exceeding the site tentative cleanup goals, including uranium concentrations exceeding 14 ppm. The XRF instrument can detect in-situ uranium concentrations in soils in the 5 to 7 ppm range using a two-minute count time. Prior to using the XRF for field decisions, bulk samples will be collected and sent to an offsite laboratory for analysis to establish correlations between field screening data and laboratory data. A discussion of the sampling, analysis, and quality assurance of soil samples collected during the remediation is detailed below and in Section 6.

A Ludlum Model 44-10 is a 2-inch by 2-inch NaI gamma radiation scintillation detector that will be used with the Ludlum Model 2350-1 digital ratemeter/scaler to identify elevated gamma emissions from site soil. This 2350-1 or similar instrument along with a Ludlum Model 19 microR meter will determine if gamma-emitting radionuclides are present. If gamma radiation is present at more than 2 times background the soil will be managed as impacted and segregated from site soils as required by CDPHE.[1] A location for the determination of background will be selected during mobilization activities, will be agreed to by the CDPHE, and used for the duration of the project. The gamma radiation detection instrumentation used during the flood plain characterization will be the same instrumentation used during the upper terrace characterization and will follow the use procedures in the Stoller RML.

Sampling, excavation, and segregation of impacted material (guided by field screening data) will be performed until the extent of the impacted material has been identified, segregated, and stockpiled or until bedrock is reached. Upon completion of segregation activities, post-characterization samples will be taken in the remaining excavation areas to confirm that the impacted material has been segregated and the tentative cleanup goals have been achieved.

The source area appears to be surrounding monitor well CSMRI-8. This is evidenced by the dissolved uranium plume concentrations, data recovered during the preliminary characterization work, information gleaned from air photographs, and site historical information. The characterization will proceed from this area guided by field screening instrument results.

The dissolved uranium plume, shown on Figure 5-1, indicates that the highest concentration of dissolved uranium (540 ppb) is in well CSMRI-8 (June 2010). In addition, a water sample collected from the surface water seep located just west of CSMRI-8 detected dissolved uranium at 360 ppb.

The dissolved uranium data combined with the groundwater potentiometric surface map shown on Figure 5-2 lead to the conclusion that a concentrated cause area is located near CSMRI-8. This conclusion is further supported by the elevated total uranium concentrations (33 and 19 ppm) along with other site COCs detected in soil samples collected from test pit CLT-1 dug west of CSMRI-8 during the preliminary characterization. Both this test pit and CLT-2 dug in close proximity to CSMRI-8 encountered artificial fill material from surface to bedrock. The remaining test pits penetrated soils interpreted as being native alluvial material. Only one test pit location (CLT-6) dug in the native alluvial material detected uranium concentrations above the tentative cleanup goal at 24 and 19 ppm. This test pit was dug in the site berm and is partially within the setback from Clear Creek established to protect this water of the State from characterization activity impacts.

[1] Per phone conversation between Steve Brinkman and Edgar Ethington, August 6, 2010.

Analysis of air photographs of the 1972 photograph (Appendix G) shows a feeder ditch running from the west into the former settling pond. CSMRI-8 is located within the former ditch area. Comparison of the 1992 and 1993 photos (the “before EPA removal action” and “post-EPA removal action” photographs) shows very little removal from along this ditch area. Field inspection of this area identified two former process pipe outfalls emanating from the former buildings at the CSMRI Site. These outfall pipes are suspected to have discharged to the former feeder ditch providing further evidence that EPA removal from this area was limited. The EPA removal included only soils above the water table, which means that the EPA did not address saturated soils below the water table, which may continue to act as causation material for the dissolved uranium groundwater plume. After EPA excavated soil above the water table, 6,000 cy of clean fill were brought in as part of its reclamation work.

The characterization approach proposed for this area includes the segregation of all non-bedrock soil above the water table using the tentative cleanup goals, including uranium at 14 ppm. The soils will be characterized in 1-foot vertical lifts as described in Section 5.1. Once the water table is encountered, characterization will continue to bedrock without further sampling if field screening data or field conditions indicate the likely presence of uranium causation material below the water table. The field conditions that warrant further excavation would be the presence of artificial fill that due to its heterogeneous nature may contain source material below the water table where our ability to conduct field screening is limited. It is anticipated that most if not all of the non-bedrock material in the area west of and surrounding CSMRI-8 will be segregated. This includes both the material under the water table and the material above the water table. Due to the known presence of uranium in groundwater above regulatory limits, material characterized from below the water table will be placed in the impacted material stockpile.

Challenges with excavating soil from this area include the presence of several City of Golden water lines, the steep meander scarp that develops near well CSMRI-8 and becomes steeper to the west, and the proximity to Clear Creek. Undermining of the water lines will be minimized or avoided. As characterization progresses, pipeline stakeholders (City of Golden Department of Public Works) will be kept apprised of contaminant levels, and if significant levels exist beneath a pipeline and excavation of this material is deemed necessary for the success of this characterization, shoring or other stabilization methods may be used during the characterization process. Additional details for excavating near underground utilities are included in the Backfill Plan (Appendix I).

The investigation area will focus on the area near CSMRI-8. This area was selected based on the expected area of causation material from field observation made during the earlier characterization of the terrace soils and the preliminary characterization data and from interpretation of historic photographs. The characterization area will have a geographic boundary to the north, being the location of Clear Creek, where a 5- to 10-foot buffer zone will be maintained to prevent Clear Creek water from flowing onto the Site and prevent sediment from flowing into Clear Creek. All other boundaries will be determined by achieving complete characterization of site COCs. Soil segregation will proceed horizontally in all directions (limited to the north and west by Clear Creek) based on field characterization. Segregation will stop when soil is reached that is less than the tentative cleanup goals, including uranium at 14 ppm.

5.2 Abandonment of Monitoring Wells CSMRI-8, CSMRI-7B, and Temporary Piezometers

Two existing monitoring wells within the suspected limits of this characterization project will be abandoned during the project before the excavation work begins. Additionally, the five piezometers installed during the preliminary characterization will be removed from the backfilled test pits following collection of the data for which they were intended, and following this characterization work. Section 8 of this work plan describes the rationale for installation of replacements wells. The abandonment of wells CSMRI-7B and CSMRI-8 will be conducted per State of Colorado, Division of Water Resources, Office of the State Engineer, Rule 16, *Standards for Plugging, Sealing, and Abandoning Wells and Boreholes*. The saturated section of each well will be abandoned by filling the well to the static water level with clean sand or clean gravel and then filling with clean native clays, cement, or high solid bentonite grout to the ground surface. Actual fill materials will be selected at the time of abandonment based on current Site conditions and availability of materials. The surface well protector and concrete pad will be removed, and the upper 5 feet of hole will be filled with materials less permeable than the surrounding soils, and these will be adequately compacted to prevent settling.

During the segregation process described in Section 5.1, monitoring well CSMRI-8, which will have been abandoned, will be excavated with the impacted soil in its vicinity. CSMRI-8 will be abandoned according to state regulations prior to soil segregation.

Removal of the piezometers will consist of pulling them out of the ground by hand, or if necessary using a strap attached to the excavator bucket to provide additional lift. Plugging of the resulting hole will be completed using native clean material.

5.3 Instrument Bias/Correlation Sampling

During characterization activities, field portable XRF instrumentation in conjunction with field gamma instrumentation will be used to guide excavations. To confirm the effectiveness of this instrumentation for detecting metal COCs and gamma radiation above background, including uranium above the tentative cleanup goals, samples will be taken for analyses by an offsite laboratory. Data generated using field instruments will be cross-correlated as well as compared to laboratory data.

A background area adjacent to the work site will be selected to provide for daily gamma instrument calibration to background gamma concentrations. This area will be agreed to by the CDPHE and will be used for the duration of the project.

After the data have been compiled, a thorough data review and comparison will be made to determine if any biases exist and, if so, whether there is a statistically valid correlation between the different measurement techniques. If correction factors are necessary and appropriate, the basis for determining the factors will be documented.

A minimum of 20 sampling locations representing a range of field readings will be selected based on the field XRF readings. After the laboratory data have been obtained, a correlation curve will be generated and in-situ measurements will be corrected using the applicable correlation factor. If the correlation is not well defined, a conservative correction factor will be used. Due to the relatively low concentrations of uranium in Site soil, the samples collected may be analyzed with the XRF using the Method of

Standard Addition[2]. Using this method, some samples may be prepared with the addition of a known concentration of uranium to reduce the error bar introduced by the instrument reading near the limit of detection and create a better correlation curve.

Sample collection and analysis information to evaluate correlations is presented in Section 6. If results of the correlation study indicate the instrumentation will allow reliable semi-quantitative assessment of contaminant levels, the correlations and biases will be documented and the field work will continue. If, after this step, it has been determined the instrumentation will not provide a reliable, semi-quantitative tool for determining the extent of contaminated soils, the field work will stop and a re-evaluation of the screening instrumentation will be made.

The XRF is designed to work primarily with solid materials. While it can be used to sample water, it cannot be operated in water. It is therefore impractical to use the XRF for characterization once groundwater has been reached. In addition, the interstitial soil between the cobbles in the alluvium that is impacted cannot be removed independent of the cobbles; therefore, XRF data become less useful for characterization and gross removal becomes most practicable.

5.4 Lateral and Vertical Extent Determination

Following the analysis of correlation data and establishment of field screening levels, soil characterization will begin. The soil segregation will be guided by the tentative cleanup goals, including 14 ppm total uranium. The characterization will be constrained by physical limitations as described in Section 5.4.2.

5.4.1 Soil Characterization

Areas of soils exceeding the tentative cleanup goals will be assessed using a hand-held XRF starting in the area near CSMRI-8 shown on Figure 1-2. Survey coordinates of the measurement locations will be made using the GPS (all GPS data are collected and processed electronically). The result of the reading will be displayed on the ground by a circle of spray paint or survey flags using the following scheme:

- Red for above the proposed cleanup goal,
- Yellow for near the proposed cleanup goal, and
- Green for below the proposed cleanup goal.

Visual observations of impacted material, whether corroborated by XRF data or not, shall be documented on a field log. Soils that are confirmed to be above the tentative cleanup goals will be segregated and placed in the appropriate stockpile as described in Section 5.6. Overburden requiring segregation to allow access to soils exceeding the tentative cleanup goals will also be placed in the appropriate stockpile. This process will be repeated until all contaminated soil within the constraints of the Site has been identified and segregated to a stockpile where it will await the results of the remedial option determination.

[2] E-mail communication from David Walters Technical Representative Olympus Innov-X / Summit Scientific 7/30/2010.

5.4.2 Characterization Constraints

Soil characterization may be limited at some locations within the Site due to existing underground utilities and Clear Creek (Figure 1-2). The utilities will likely limit the depth to which portions of the characterization area can be characterized, and utilities and the creek will limit the lateral extent to which the area can be characterized. In neither instance will the integrity of the utilities be compromised, and a 5- to 10-foot buffer will be maintained between the characterization and the creek. In both cases, vertical extent characterization will stop at bedrock.

5.5 Confirmation Sampling

At the conclusion of characterization activities, confirmation soil sampling will be performed. Decisions regarding whether or not the Site has achieved the tentative soil cleanup goals will be made in accordance with *Methods for Evaluating the Attainment of Cleanup Standards*, Volume 1: Soils and Solid Media (EPA 1989).

The final soil survey for site COCs will be performed in accordance with Visual Sample Plan (VSP) criteria to ensure adequate sampling is performed. VSP is a software application that can be used to select the appropriate number and location of environmental samples to ensure that the results of statistical tests performed to provide input to environmental decisions have the required confidence and performance. The VSP software provides sample-size equations or algorithms needed by specific statistical tests appropriate for specific environmental sampling objectives. The program is highly visual and graphic, runs on personal computers, and is designed primarily for project managers and users without expertise in statistics. The software is applicable to any two-dimensional geographical population to be sampled (i.e., surface soil, a defined layer of subsurface soil, building surfaces, water bodies, and other similar applications). VSP has been successfully used by Stoller on a number of past environmental investigations, including the CSMRI Site upper terrace area.

5.6 Material Handling

Soil stockpile locations will be constructed during the mobilization phase and will be completed and ready to receive soil prior to the start of characterization activities.

- Stockpile A will receive all material segregated from the site with COC concentrations above the site tentative cleanup goals and will be located as shown on Figure 1-2.
- Stockpile B will receive soil below the site cleanup goals, including overburden and other “clean” soil needing temporary segregated from the site. The location of this stockpile is yet to be determined.

Each stockpile will be managed to avoid material loss due to either wind or precipitation.

5.6.1 Daily Management of Stockpile

Water will be applied to the stockpiles to provide dust suppression each day soil is added to the pile. Sufficient water will be added at the end of each day to create a crust. The bermed and lined stockpile will be inspected daily for any indication of potential run-on or run-off. Any identified issue will be corrected the same day.

5.6.2 Break Management of Stockpile

If a break in the work is taken (weekends, holidays, etc.), a heavy crust will be established on each stockpile using a water spray. If the break is longer than two days, a qualified technician will check the piles to ensure adequate crust exists and/or to apply additional water as deemed necessary. In addition, erosion/sediment controls will be inspected and repaired as necessary.

5.6.3 Stockpile Management during Remedial Alternatives Analysis Period

Upon completion of the segregation activities, the impacted soil stockpile will be sampled and analyzed to characterize it for remedial alternative analysis. Stockpile sampling and analysis activities are described in Section 6.12, Sample Acquisition – Stockpile Samples.

During the time period when a final remedial alternative is being selected, the stockpiles will be stabilized with a surfactant or other application that will effectively eliminate the potential for releases. Erosion and sediment controls will be installed around the perimeter of the stockpiles and will consist of silt fence, straw wattles, straw bales, or other BMPs. Drainage will be established that is protective of the waters of the State, and the site will be checked weekly or after storm events to ensure proper controls remain effective and functional.

5.7 Site Backfill

Upon conclusion of the site characterization, any excavations created as a result of soil segregation during the field activities will be backfilled. The backfilling of excavations will occur as characterization is completed in individual areas and may be performed concurrently with the ongoing characterization activities. This goal is to minimize the amount of active investigation areas open at any one time and reduce the footprint of the active site. In addition, minimizing the size of the open areas is a critical element to ensure slope stability during characterization activities at the foot of the terrace scarp.

Site backfill for the characterization area will consist of returning the topography back to pre-characterization grade per the approved City of Golden Grading Plan. The backfill material will not include the soil from Stockpile B as defined in Section 5.6 and will consist solely of imported "clean" fill from an offsite source. The soil will be amended as needed to promote vegetative growth and once all areas are backfilled, all areas disturbed during field activities will be revegetated per the City of Golden Revegetation Requirements. The final disposition of the stockpile containing soils below the tentative site cleanup goals will be addressed in the remedial action plan. A detailed description of the backfill plan is provided in Appendix I.

5.8 Health and Safety Control

The SSHASP is provided in Appendix H. The administrative controls, engineering controls, personnel protection, and monitoring practices to ensure worker safety during the characterization activities are summarized in the following subsections, with details provided in the SSHASP.

5.8.1 Work Area Air Particulate Control and Monitoring

Based on data generated during previous site work, airborne metals and radionuclides are not anticipated for this project; however, a single low-volume particulate monitoring station will be deployed. The air monitoring station will be located east (downwind) of the work area, on the flood plain, and will be operated during work hours. Filters will be collected from the monitoring station weekly and submitted to the analytical laboratory for analysis of the complete list of site COPCs as shown on Table 6-1 in the following section.

Radiological surveys will be ongoing in the work zone, and should survey results indicate the presence of alpha or beta contamination in excess of background, work will be suspended and further evaluation will be made. Dust suppression water will be applied as needed to haul roads, stockpiles, work areas, or any other area within the Site where dust is being generated.

Engineering controls will be used to minimize dust generation during field excavation activities. Water will be used as a dust suppressant during all excavation work that has the potential to create fugitive dust, as well as on haul roads as necessary. Wind speed and direction will be monitored, and when windy conditions are creating visible dust that cannot be adequately controlled using water, the project lead will shut down field activities.

Based on the maximum Site metals concentrations presented in the Stoller 2007a report, calculations (provided in the SSHASP) show that air concentrations of metals will not exceed permissible exposure limits published by the Occupational Safety and Health Administration, assuming adequate dust suppression water is used. Based on this determination, no personal air samples will be taken or analyzed for metals.

5.8.2 Work Area Dose Rate Monitoring

Work areas will be monitored daily for ionizing radiation. Monitoring will be performed using a Ludlum Model 19 MicroR or a Bicron MicroRem meter. Occupational exposure monitoring for external radiation is required if a worker is likely to exceed 500 mrem per year from sources external to the body, per 6 CCR 1007-1, Part 4. Stoller has established an ALARA guideline of 100 mrem per year in accordance with the company Radiation Protection Program. These limits are not anticipated to be exceeded on this Site; therefore, personal dosimetry will not be required. If area dose surveys indicate that personnel may receive a dose greater than 100 mrem/year, a dosimetry program will be implemented. Additional details are provided in Section 6.4.

5.8.3 Radiological Contamination Control Procedures

All vehicles entering and leaving the area of the Site where investigation activities are being performed will be surveyed to verify that they are free of radioactive contamination. If a vehicle is excessively dirty, it may be cleaned and dried prior to the survey being performed. A Ludlum Model 2360 in conjunction with a 43-89 alpha/beta scintillation probe or similar instrument will be used to survey surfaces (e.g., tires, cab floors, and excavation attachments) for total (fixed plus removable) contamination. Smears will also be taken from the surfaces and counted for alpha and beta activity if the total measured activity, or minimum detectable activity for the survey instrument, is greater than the limit for removable contamination. Table 5-1 shows the maximum total and removable contamination limits.

Table 5-1
Total and Removable Contamination Limits

Contamination Type	Removable (dpm/100 cm^2)	Total (fixed + removable) (dpm/100 cm^2)
Gross alpha	20	100 avg, 300 max
Gross beta	1,000	5,000 avg, 15,000 max

From U.S. Nuclear Regulatory Commission Regulatory Guide 1.86, based on most restrictive alpha limits (Ra-226, Th-228, Th-230)

All personnel and equipment leaving the potentially contaminated area of the work site will be thoroughly surveyed for contamination. Levels of contamination on materials and equipment listed in Table 5-1 must be met prior to being released from the area. Personnel frisking will be performed after removal of protective clothing. Personal items, such as notebooks, papers, and pens, will be subject to the same frisking requirements. Personnel found with detectable contamination on their skin or clothing will be promptly decontaminated. Contaminated equipment may be decontaminated or disposed. Survey requirement details are provided in Section 6.5.

Instrument calibration and performance testing requirements for the survey instruments are provided in Section 6.4 of this plan. Equations to calculate detection limits and convert these limits to count rates are also provided in the standard operating procedures for the instrument.

Equipment release surveys shall be documented on radiological survey form, ST-RAD-GEN-005, or equivalent (Appendix K). The following information shall be recorded, at a minimum:

- Equipment identification in sufficient detail to make the record unique (i.e., description, serial number, license plate number, etc.)
- Model and serial numbers of survey instrument(s)
- Name of person performing the survey
- A sketch of the equipment showing survey and/or smear locations, as applicable
- Date and time of the survey

If surveys indicate that a vehicle or equipment is contaminated greater than the acceptable contamination limits (Table 5-1), it shall be decontaminated and resurveyed. The repeat survey shall be recorded on a separate survey form. Personnel shall be frisked, as warranted, after leaving the excavation area prior to entering the field office or leaving the Site.

5.8.4 Personal Protective Equipment

Personnel working on the Site—with the exception of the area inside and immediately surrounding the office trailer—will wear Level D protective gear, including sturdy over-the-ankle work boots, a high-visibility safety vest, hard hat, and safety glasses (Level D). In addition, personnel working on the ground in the excavation areas will wear Tyvek coveralls, boot covers, and gloves (nitrile, latex, or equivalent) (modified Level D) as appropriate and directed by the field safety representative. Contamination control PPE will be doffed prior to entering the office trailer or departing the Site.

5.8.5 Decontamination Procedures

Prior to release from the Site, heavy equipment will be cleaned using dry and/or wet decontamination procedures. Excessively dirty equipment will be cleaned by brushing or scraping excess soil from the equipment. This technique should be used only when the soil is wet or damp to prevent an airborne dust hazard. Following initial cleaning, water may be used for wet decontamination. Equipment will be positioned in the designated decontamination area during the cleaning process. Radiological surveys will be performed on the equipment as described in Section 5.8.3.

5.9 Waste Management

The majority or all of the Site-generated or investigation-derived waste (excluding the stockpiles) is expected to be stored in onsite trash cans that are emptied weekly, the contents of which will go to a solid waste landfill. Materials identified as recyclable will be evaluated to determine if recycling is the most effective option for final disposition. Recyclers have been identified that are capable of receiving scrap metal and concrete; however, depending on the condition of these materials, disposal may be the preferred option.

Vegetation removed from the areas of characterization will be chipped onsite and will be used as a soil amendment to assist in the reclamation of the disturbed areas. Unmixed chipped material will not be placed in lifts exceeding 6 inches in thickness.

5.9.1 Sanitary Waste

Site-generated wastes that are not directly associated with sampling or remediation efforts will be collected in trash bags as routine sanitary wastes. These wastes may include packaging, water bottles, food waste, and office waste. Recyclable materials such as cardboard, plastic, and paper will be segregated when practicable from the sanitary waste and taken to a local recycling facility. Other wastes that are associated with Site sampling or remediation efforts will also be managed as sanitary wastes, as described below, but will have additional handling controls.

5.9.2 Personal Protective Equipment and Disposable Sampling Equipment

Used PPE and disposable sampling equipment will be collected in plastic bags and managed as sanitary waste. The bags will be securely closed prior to disposal. This waste includes used Tyvek suits, gloves, booties, sample scoops, smear papers, and other wastes generated in the onsite project trailer. Damp materials, such as towels with decontamination solution used to wipe down sample bottles, will be packaged with sufficient dry material so that no free liquids are present in the waste. The PPE and sampling equipment will not contain appreciable quantities of soil. Based on the levels of radioactivity on this Site, the levels of radionuclides on this material will be well below the U.S. Department of Transportation (DOT) levels that would require transportation as radioactive material, both in terms of total activity in the consignment and the activity concentration.

5.9.3 Sample Disposal

Excess samples will be stored onsite for as long as they might reasonably be useful for Site characterization. Samples that are to be discarded will be added to one of the soil stockpiles onsite, depending on the levels of contaminants in the sample. Empty sample containers will be disposed as sanitary waste.

5.9.4 Miscellaneous Waste

Site-generated wastes that do not fit in one of the above categories will be characterized and managed appropriately. Liquid waste streams are not anticipated at the Site. Dust suppression water will be applied as a mist and will not be used in quantities that require collection or treatment. Equipment cleanup will be performed in an area of the site that will require future remediation activities, such as the contaminated soil stockpile locations. The application rate and quantity of water that will be used for decontamination will be limited to the quantity that will be absorbed by the soil in the stockpile location. The water will not be permitted to “run off” or potentially contaminate other parts of the Site.

5.9.5 Waste Minimization

As described above, recyclable materials such as cardboard, paper, and plastic will be segregated from the sanitary waste stream where practicable. However, sanitary waste from field sampling or characterization activities that may be contaminated with low levels of metals and/or radionuclides will not be recycled but will be managed as sanitary waste. Large-volume waste streams that are recyclable but potentially contaminated will be evaluated to determine if conducting free release surveys (with possible decontamination) would be feasible and cost effective. This might include scrap metal recovered from excavations onsite.

Explanation

- Existing Monitor Well
- Surface Water Sample Location
- Seep
- June 2010 Uranium Dissolved - Inferred
- June 2010 Uranium Dissolved
- Roads
- Topography (Depressions)
- Topography (10 Ft Intervals)
- Flood Plain Characterization Area
- Soccer Field

The Values next to the wells represents Dissolved Uranium Concentration in micrograms per Liter (µg/L)
NT = Not Tested, No Water Present

N
W E
S

Scale: 1" = 100'

0 50 100 200 Feet

Figure 5-1
Dissolved Uranium
Concentration (µg/L)
June 2010

CSMRI
Flood Plain Site Characterization
Work Plan

Stoller

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Figure 5-2
Groundwater Potentiometric
Elevation Map - June 2010

CSMRI
Flood Plain Site Characterization
Work Plan

Stoller

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6 Sampling and Analysis Plan

The sampling and analysis activities associated with this characterization project will be a combination of in-situ measurements and samples submitted to an offsite analytical laboratory. This SAP describes:

- The Site COCs and the field and laboratory methods proposed to evaluate them,
- Field instrumentation requirements,
- Techniques for identifying sampling locations,
- Sample collection methodologies, including types and frequencies of field QC samples,
- Sample labeling, control, packaging, and shipping requirements, and
- Sample analysis requirements for measurements performed in the offsite laboratory.

The purpose of this SAP is to provide the necessary guidance to investigate the flood plain for contamination by properly identifying soils that exceed the proposed cleanup goals and to provide guidance for collection and analysis of post-segregation samples. Support activities for radiological control of the Site and worker protection are also covered in this SAP.

6.1 Site COCs Field and Analytical Methods

The Site COCs for characterization include those identified on the upper terrace with the addition of uranium and will be evaluated similarly. The list of COCs and the field and laboratory tests to be performed are identified in Table 6-1.

Table 6-1
Site COCs

Compound	Field Measurement	Analytical Measurement
Metals		
Arsenic	XRF	EPA 3050/6010B and 7471A
Lead	XRF	
Mercury (total)	XRF	
Molybdenum	XRF	
Vanadium	XRF	
Uranium	XRF	
Radioisotopes		
Radium 226	NaI gamma scintillation detector	Radium (Bi/Pb-214) (226/228)
Radium 228		
Thorium 228		Isotopic Thorium (228, 230, 232)
Thorium 230		
Thorium 232		
Uranium 234		
Uranium 235		
Uranium 238		

The field portable XRF identified in Table 6-1 will need to be correlated to site conditions prior to use. The correlation techniques are detailed in Sections 6.2.

6.2 Portable Field XRF and Initial Correlation Study

An Innov-X-Systems field portable XRF, or equivalent, will be used to make in-situ measurements of the metal COCs during excavation activities to delineate extent of metals contamination. The XRF is supplied with a current calibration from Innov-X-Systems. It will be operated by trained field personnel in accordance with the instrument operating procedure. A QC check is required daily prior to operation, and every four hours during operation thereafter. The instrument has built-in software that prompts the operator to perform the required performance checks, as required. The QC check data are captured by the Innov-X software.

The XRF is designed to work primarily with solid materials. Although it can be used to sample water, it cannot be operated in water. It is therefore impractical to use for characterization once groundwater has been reached. In addition, the interstitial soil between the cobbles in the alluvium that is impacted cannot be removed independent of the cobbles so XRF data become less useful for characterization and gross removal becomes most practicable.

The estimated limits of detection (LOD) for the COCs for the XRF instrument (Innov-X Model “Omega”) are presented in Table 6-2.

Table 6-2
Field Portable XRF Estimated Limits of Detection

Element	LOD in ppm [1]
As	13
Hg	14
Pb	16
Mo	20
U	7*
V	20

[1] The limit of detection for uranium is based on a two minute instrument count time and assumes less than 3% total metals in the sample

As discussed in Section 5, the first step in field operations will be to complete a correlation study to determine instrument bias due to matrix interferences. The magnitude of this bias is dependent on the sample matrix and sample conditions (i.e., moisture content). To evaluate and quantify the potential bias for the materials on this project, samples will be collected both in areas of suspected contamination and in non-impacted areas. These areas will be identified by a combination of in-situ measurements and historical data. Collected samples will be submitted to the offsite laboratory for analyses. The laboratory will return the prepared soil samples, which will be evaluated for by the XRF. In-situ uranium measurements, the XRF measurements on the returned samples, and the laboratory data will then be correlated with each other. A correlation curve will be generated. Subsequent in-situ measurements will be corrected using the applicable correlation factor. If the correlation is not well defined (correlation coefficient less than 0.80), a conservative correction factor will be used. The quality of the correlations and the magnitude of the bias(es), if present, will be evaluated to validate the effectiveness of using the in-situ measurement techniques to guide characterization activities. If a good data correlation cannot be achieved, the proposed SAP scheme will be re-evaluated and modified as necessary.

This approach complies with EPA Method 6200 for uranium in soils. During characterization activities duplicate in-situ soil samples will be collected for 10 percent of the sample population and submitted to the offsite laboratory for QA/QC analysis of Site COCs to verify field XRF measurements. These samples will be prepared as described above so that the laboratory sample is representative of the in-situ soil.

6.3 Post-Characterization Sampling

During the ongoing subsurface characterization activities, XRF readings will be taken as described in Section 5 and in the applicable Sample Acquisition section of this SAP. When the in-situ measurements (corrected for any identified bias) indicate that the area is contaminated above the proposed cleanup goal for metals, the contaminated material will be excavated and taken to the applicable stockpile.

Upon completion of excavation activities, post-characterization sampling will be performed in accordance with guidance provided by VSP, which is described in Section 5.5. In-situ XRF measurements for uranium will also be taken at the sampling locations, and samples will be submitted to an offsite analytical laboratory. A duplicate sample will be collected for up to 10 percent of samples for QA/QC analysis. The in-situ XRF data will be used – before samples are sent to the laboratory – to increase the confidence that the contaminated soil has been excavated and the remaining soils are not contaminated. Offsite laboratory data of post-characterization samples will be used to demonstrate that all materials that exceed the proposed cleanup goal have been excavated and stockpiled and that the extent of contamination has been identified. Although the XRF measurements will be used to initially categorize the soil for placement in the "contaminated" and "clean" stockpiles, only offsite analytical laboratory data will be used to evaluate remedial options for the stockpiles.

The composite samples collected from the contaminated stockpile will be analyzed following the guidance shown in USEPA SW-846, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods* to assure they accurately represent the stockpiled materials.

6.4 Field Radiation Detection Instrumentation

A variety of radiation detection instruments will be used on this project. Radiation detectors will be purchased or leased from certified vendors and will have current calibrations. Documentation of the calibration will be maintained onsite. Performance checks will be performed on all detectors prior to use in accordance with the applicable operating procedure(s).

- Sodium-iodide (NaI) 2-inch by 2-inch gamma scintillation detector – Used during excavation activities as a screening tool to identify areas of elevated gamma radiation activity that may contribute to an exposure potential. Instruments such as the Ludlum Model 2350-1 scaler/ratemeter coupled with a Ludlum Model 44-10 will be used for these surveys. Applicable Procedure: SOP-RAD-001, *Portable Radiation Survey Instrument Operation*
- Hand-held alpha/beta scintillator probe – Used for frisking and general surveys. Instruments such as a Ludlum Model 2360 alpha/beta scaler/ratemeter will be used in conjunction with a Ludlum Model 43-89 detector. Applicable Procedure: SOP-RAD-001, *Portable Radiation Survey Instrument Operation*
- Dual alpha/beta scintillation counter – Used to count swipes and air sample filter papers. Instruments such as a Ludlum Model 2929 with a Model 43-10-1 detector will be used. Applicable Procedure: SOP-RAD-031, *Counting Systems Operation*

- Ludlum Model 19 MicroR meter (or equivalent) – Used for dose rate surveys. Applicable Procedure: SOP-RAD-001, *Portable Radiation Survey Instrument Operation*

6.5 Contamination Control and Radiological Protection Instrumentation

Radiological surveys will be performed during project characterization and sampling activities to ensure that fugitive radiologically impacted material is not dispersed beyond the Site, as well as to provide worker protection and monitoring.

6.5.1 Swipe Sampling and Counting

Swipe samples will be taken to monitor for removable alpha and beta contamination prior to release of samples, equipment, and vehicles that were in areas of potential radiological contamination. Swipe samples will be collected in accordance with procedure SOP-RAD-002, *Swipe Sample Collection*. These swipes will be counted on a Ludlum Model 2929 alpha/beta scaler with a Model 43-10-1 sample counter (or equivalent) in accordance with procedure SOP-RAD-031, *Counting Systems Operation*. Release limits for removable contamination are presented in Table 5-1.

6.5.2 Personnel and Equipment Survey Requirements

All personnel and equipment leaving the contaminated area of the work site will be surveyed for contamination using a Ludlum Model 2360 alpha/beta data logger with a Ludlum Model 43-89 alpha/beta scintillation probe (or equivalent). Unrestricted release criteria provided in Table 5-1 must be met prior to equipment being released from the area. Personnel found with detectable contamination on their skin or clothing will be promptly decontaminated as described in the SSHASP. Contaminated equipment may be decontaminated or disposed.

Surveys for the release of equipment will be documented on a Radiological Survey Form, ST-RAD-GEN-005, or similar form that identifies, at a minimum, the released equipment, survey instrument used, survey results, background at the time of the survey, and name of the surveyor (Appendix K). If short-lived radionuclides potentially cause elevated removable alpha readings, the equipment will not be released until the swipes have been allowed to decay and a recount meets the unrestricted release limit.

6.5.3 Air Monitoring

Air monitoring will consist of a single low-volume particulate monitoring station located on the flood plain east of the work area and will be conducted in accordance with SOP-RAD-018, *Long-Lived Airborne Radioparticulate Surveys*. Placement of the monitoring station will be directed by the Health and Safety Officer (HSO) and may be modified, if necessary, by the HSO.

The filter will be identified using the sampler number, the date the filter was deployed (On Date), and the date the filter was removed from the sampler (Off Date). The sampler will be run continuously during the characterization field work. Operational hours of the sampler will be recorded for use in calculating air volume. The filter will be changed and analyzed on a weekly basis when active soil sampling/excavation is being conducted. Samples will be counted in the field laboratory using a Ludlum Model 2929 alpha/beta scaler with a Model 43-10-1 detector in accordance with procedure SOP-RAD-031. Measured count rates (counts per minute) will be converted to dpm using the efficiency of the detector. The measured dpm values will be converted to microcuries and divided by the total volume of air sampled in ml for comparison to the effluent concentration standards listed in Table 6-3. Filters will be then be submitted to the analytical laboratory for analysis of the complete list of site contaminants of potential concern (COPCs) as shown on Table 6-1.

The chemical form of the radionuclides on this Site is unknown. Therefore, the limits for Class W compounds, which are the most restrictive, will be used.

Table 6-3
Effluent Concentration Standards[1]

Isotope (Class W)	Concentration (µCi/ml)
Ra-226	9E-13
Ra-228	2E-12
Th-228	3E-14
Th-230	2E-14
Th-232	4E-15
U-238	1E-12

[1] *6 CCR 1007-1 Part 4, Appendix 4B, Standards for Protection Against Radiation*

6.5.4 Personnel Dose Monitoring

Occupational exposure monitoring for internal and external radiation dose is required if a worker is likely to exceed 500 mrem per year total effective dose equivalent (TEDE), per 6 CCR 1007-1, Part 4. Stoller has established an ALARA guideline of 100 mrem per year in accordance with the company Radiation Protection Program. These limits are not anticipated to be exceeded on this project. Area dose rate surveys will be performed using a Ludlum Model 19 MicroR meter, or equivalent instrument, in accordance with procedure SOP-RAD-033, *External Dose Rate Tracking*. If an area dose greater than 50 microrem/hr above background is observed, the planned work activities will be evaluated and every effort will be made to limit personnel time in the area. If this evaluation indicates that the external dose to any worker could exceed 100 mrem per calendar year, dosimeters will be issued.

6.6 Sample Acquisition – General Guidelines

Samples will be taken for a variety of purposes during this project. General guidelines for sample collection of all sample types are provided in this section. Specific information on each sample type is provided in the following sections. All samples must be collected, handled, documented, analyzed, and reported in a defensible manner.

Use Disposable Equipment and Take Representative Samples. Samples will be collected and prepared using disposable soil scoops or, if necessary, gloved hands. The samplers shall ensure that a representative proportion of each type of soil present in the sampling location is included in the sample and that different types of soils are not over- or under-represented. Rocks and cobbles larger than 3 cm and other extraneous material such as vegetation and roots will be excluded and/or manually removed from samples. Samples may be grab samples or composite samples, as specified in the sample acquisition guidelines for the specific type of sample being collected.

Log all Sampling Events. All sampling events will be documented on the Sample Collection Log. Samples that will be submitted to the offsite laboratory will be recorded on a chain-of-custody form.

Use Clean Containers. Certified clean sample containers shall be used for all samples submitted to the offsite laboratory. These containers will be supplied by the laboratory.

Take Field QC and Split Samples. Field QC samples will be used to assess sample variability and evaluate potential sources of contamination. Field duplicates are the only type of QC sample that will be collected for this project. Field duplicate samples are collected at the same time and from the same source and placed in separate sample containers. Duplicate frequencies are specified in the following sections for each type of sampling. These samples will be submitted to the offsite laboratory for the same analysis(es) as those requested for the original sample. Duplicate data will be used to measure the precision of the entire sampling and analysis procedure. Samples will be assigned unique numbers and will not be identified as duplicates to the laboratory. Equipment rinsates will not be required, as all sampling equipment will be disposable.

6.7 Sample Identification and Labeling Requirements

Samples shall be identified using a unique 5-digit number. Sample type ("in situ" vs. "lab"), date, time, GPS location, and depth of lift will be tracked as separate fields in a sampling and analysis database.

Sample labels will be pre-printed whenever possible to reduce the possibility of misidentification of samples. Labels will include, at a minimum, the following information:

- Sample number
- Name of the sample collector
- Date and time of sample collection
- Client (Stoller)
- Location (CSMRI)
- Analysis(es) to be performed at the laboratory
- Preservative, if applicable

6.8 Sample Handling and Custody Requirements

Components of the chain of custody include sample labels, custody seals, chain-of-custody form, field logbook, and sample collection logs. Samples will be stored in a secure place with restricted access until they are hand-delivered to the offsite laboratory. A chain-of-custody record will be signed by each person who has custody of the samples and will accompany the samples at all times. At a minimum, the chain-of-custody form will include the following information:

- Site name
- Signature and initials of sample collector
- Date and time of sample collection
- Sample ID
- Sample matrix
- Sampling type (e.g., composite or grab)
- Sampling location
- Number of sample containers shipped
- Requested analysis(es)
- Sample preservation information

- Method of shipment/name of carrier
- Signatures of persons in the chain of custody
- Date and time of each change in sample custody
- Name of laboratory

Chain of custody will begin once the samples are collected. To ensure proper traceability, all samples will be properly labeled at the time of acquisition. Samples to be stored onsite will be placed in a locked storage area with the corresponding chain-of-custody form. Samples requiring laboratory analysis may be allowed to accumulate onsite prior to delivery to the laboratory.

Samples will be hand delivered to the laboratory in coolers sealed with custody seals if handled by more than one individual. The original chain-of-custody form will be transported with the samples. Upon receipt of the samples by the laboratory, the laboratory sample custodian will inventory the samples by comparing sample labels to those on the chain-of-custody forms. The laboratory shall maintain documented chain of custody through the laboratory analytical process.

6.9 Sample Packaging and Shipment

Prior to packaging for shipment, sample containers shall be swipe sampled to verify absence of external removable radiological contamination in accordance with procedure SOP-RAD-002, *Swipe Sample Collection*. The DOT release criteria for removable contamination are shown in Table 6-4. Containers with contamination above this level will be decontaminated using wet wipes until they are below this level.

Table 6-4
DOT Removable External Contamination Limits

Contaminant	Maximum Limit* (dpm/cm^2)	Maximum Limit (dpm/100 cm^2)
Alpha-emitting radionuclides	2.2	220
Beta and gamma emitters	22	2,200

*From 6 CCR 1007-1 Part 17, Section 17.15.8.1 Table 3. Equivalent to DOT limits in 49 CFR Part 173.443 when the 0.10 swiping efficiency is included.

Sample packages will also be surveyed using a dose ratemeter such as a Ludlum Model 19 MicroR meter. Limited quantity radioactive materials must have a surface dose rate that does not exceed 0.5 mrem/hr at any point on the external surface of the package.

Sample containers will be placed into a sealed plastic bag. Samples will then be packed in a cooler lined with a large plastic bag. The chain-of-custody form will be placed into a zip-locked bag and taped on the inside lid of the cooler. Each cooler will be sealed with a custody seal.

Verification samples are expected to have levels of radionuclides exempt from DOT classification as radioactive material based on the Site cleanup goals; therefore, these samples will be shipped as general freight with no special shipping provisions.

Coolers will be transported to the laboratory and hand-delivered to the analytical laboratory. The coolers will be clearly labeled with sufficient information on the waybill to ensure positive identification.

6.10 Sample Acquisition – Initial Correlation Study

The following sections describe how soil samples will be collected and analyzed to generate correlation data prior to using the XRF for characterization.

6.10.1 Sampling Locations

Prior to the start of field activities, a minimum of 20 samples will be collected and submitted to the offsite laboratory for analyses of Site COCs (Section 6.1 provides more information on the correlation study).

Samples will be taken in three types of areas:

- Areas known to be impacted,
- Areas that are slightly impacted (close to the proposed action level), and
- Areas that are believed to be non-impacted.

Sample locations will be biased to collect most of the samples close to the action level, as this is the main area of concern for good correlation between field and laboratory results. The sampling locations will be selected based upon historical data and field XRF measurements. Samples will be taken in areas with different soil types, so that the diversity of this Site will be well represented in the correlation data. Sampling locations will be selected by the project lead. The basis for determining the sampling locations shall be documented.

6.10.2 Sample Collection

Prior to collecting each soil sample, a GPS reading and an in-situ XRF measurement will be taken and the sample ID and sampling location will be documented on the Sample Collection Log. A 1-minute count will be used for areas where the concentration of uranium is at or below the proposed cleanup goal. In areas of significant uranium contamination, shorter count times may be used by setting the XRF to stop counting once 3X the action level is exceeded. The soil will be homogenized thoroughly in place before filling individual sample containers. Sufficient soil will be collected for the samples listed in Table 6-5 using a grab sampling technique. If a duplicate will be taken, sufficient soil will be collected to fill the original and duplicate sample containers. Each sample container will be provided by the laboratory and certified clean. Sample containers will be labeled as described in Section 6.7. Samples collected for the offsite laboratory will be recorded on a chain-of-custody form.

Table 6-5
Initial Correlation Study Samples

Constituent of Concern	Laboratory Method	Sample Container	Preservation	Holding Time
EPA 3050/6010B and 7471A	ICP metals (As, Hg, Pb, Mo, V, U) (ICP/CVAA)	Poly container, 4-ounce wide mouth	4°C	28 days

6.10.3 Field QC

A field duplicate will be collected for 10 percent of the samples (assuming ≤ 20 samples are collected, 2 will be duplicated).

6.11 Sample Acquisition – Continuing Characterization Survey Sampling

The following sections describe location, frequency, and collection of soil samples for characterization.

6.11.1 Sampling Locations

Samples taken during the characterization activities will be analyzed by the field XRF. The data generated by this analysis will be used to guide excavation decisions. The locations and frequency of samples will be based on in-situ XRF measurements, as well as visual indicators.

If the in-situ measurements from the XRF instrument are less than the proposed cleanup goal, and there are no visual indications that any impacted areas remain, samples will be collected in a systematic fashion in the excavated area. The information from these analyses will be used for confirmatory measurements to verify that the impacted material has been excavated. If impacted material is visually indicated, despite the lack of in-situ measurement evidence, additional biased samples may be collected around the suspect location.

If the in-situ XRF data are inconclusive due to extreme variability or are close to the proposed cleanup goal, samples will be collected, as necessary, to adequately characterize the excavation.

6.11.2 Sample Collection

An XRF measurement will be performed at each sampling location. All in-situ measurements and characterization grab samples will be located with the GPS. Sample collection frequency will be at a minimum one sample for every 100 square feet of lift surface. Samples for laboratory analysis require that only 4 ounces of material be collected and placed in a wide-mouthed plastic jar.

Characterization samples will be collected using a grab sampling technique using a disposable soil scoop or gloved hand. Each sample container will be labeled as described in Section 6.7. Field notes and photographs will be used, as necessary, to document sampling activities and any deviations from this plan. Sample information will be recorded on the Sample Collection Log. The Sample Collection Log will be used to record all samples collected onsite, including sample ID numbers, dates, and times for samples as applicable for the sample type.

GPS coordinates will be recorded in the field electronically and downloaded to the master database at the completion of each day's field work. These data will be stored in the corresponding meters with either waypoints or ID numbers as the reference point and will be downloaded daily into a database. GPS coordinates will be maintained in the database and will document each in-situ measurement and sample location.

6.12 Sample Acquisition – Post-Characterization Samples

Post-characterization samples will be collected to allow quantification of the success of the characterization and depict areas where characterization may be incomplete due to geographical boundaries.

6.12.1 Sampling Locations

After the extent of contamination has been delineated and the excavated materials stockpiled, the underlying soil must be evaluated to verify absence of COCs above the proposed cleanup goals. Post-characterization sampling locations will be established in the excavation in a systematic manner. Locations of the samples will be selected by laying an imaginary grid over the flood plain in areas where excavation occurred, assigning consecutive numbers to units of the grid, and selecting locations to be sampled using a random number table. VSP will be used to guide this process and to confirm the minimum number of samples required to adequately characterize the excavation.

6.12.2 Sample Collection

If the location is in an excavation, the sample will be taken at the exposed surface or in bedrock if the excavation reaches total depth in bedrock. The sample will have adequate volume so that all horizontal components are equally represented in the sample. Soil samples will be collected from below the water table consistent with the methods described in Appendix A, Section 3.3. Samples will be collected with a scoop or gloved hand. The sample will be mixed and homogenized before being transferred into the sample container. A GPS reading of the sampling location will be made. Each sample container will be labeled as described in Section 6.7. Samples going to the offsite laboratory will be recorded on a chain-of-custody form. Table 6-6 shows the sample requirements and the laboratory analysis to be ordered.

Table 6-6
Post-Characterization Samples

EPA Method	Laboratory Method (COCs)	Sample Container	Preservation	Holding Time
ASTM D3972-90M	Isotopic Thorium (228, 230, 232)	Poly container, 16-ounce wide mouth [1]	None	None
ASTM D3972-90M	Isotopic Uranium (234, 235, 238)			
EPA 901.0M	Radium (Bi/Pb-214) (226/228)			
ASTM 2216-96	Percent Moisture			
EPA 3050/6010B and 7471A (Hg)	ICP metals (As, Hg, Pb, Mo, V, U) (ICP/CVAA)	Poly container, 4-ounce wide mouth	4°C	28 days

[1]The samples for Ra, Th, U, and percent moisture can be submitted in a single sample container.

6.12.3 Field QC

Duplicate samples will be taken for 10 percent of the sampling locations and submitted to the offsite laboratory.

6.13 Sample Acquisition – Stockpile Samples

The following sections describe how stockpile samples will be collected to characterize the contaminants in each pile so that its final disposition can be determined.

6.13.1 Sampling Locations

Samples taken from the both the “contaminated” stockpile (Stockpile A) and the “clean” stockpile (Stockpile B) will be analyzed as shown in Table 6-7. The results will be used during the evaluation of remedial options for the stockpiled materials.

Table 6-7
***Tentative Stockpile Samples**

EPA Method	Laboratory Method	Sample Container	Preservation	Holding Time
ASTM D3972-90M	Isotopic Uranium (234, 235, 238)	Poly container, 16-ounce wide mouth	None	180 days
EPA 3050/6010B and 7471A (Hg)	ICP metals (As, Hg, Pb, Mo, V) (ICP/CVAA)	Poly container, 4-ounce wide mouth	4°C	28 days
EPA 901.0M	Radium (Bi/Pb-214) (226/228)	Poly container, 16-ounce wide mouth	None	180 days
EPA 1311	TCLP 8 RCRA metals	Poly container, 4-ounce wide mouth	4°C	28 days

*This list may be modified as the final list of analysis required for stockpile samples will be based on feasibility study design and/or each individual disposal facility's waste acceptance criteria and determined during the remedial option analysis.

The number of composite samples necessary to characterize each stockpile will be calculated according to the requirements in SW-846 using a simple random sampling scheme. Locations of the samples will be selected by laying an imaginary grid over the stockpile, assigning consecutive numbers to the units of the grid, and selecting the locations to be sampled using a random number table. Exact positional information for these samples is not required; however, a sketch of sampling locations shall be made in the sampler's field notes.

6.13.2 Sample Collection

Within each selected grid location, composite samples will be generated by collecting five equal aliquots of approximately 500 cubic centimeters each into a disposable plastic container or a lined stainless steel bowl. The locations of the five sampling areas will be randomly placed within the identified grid location for each sample. The composite shall be thoroughly mixed. If the material is extremely heterogeneous, this may require quartering the sample, mixing each quarter separately, and combining the quarters. This process shall be repeated, as necessary, until a homogeneous mixture has been achieved.

After the sample has been homogenized, an XRF measurement will be taken on the composite. The sample thickness at the point of measurement must be greater than 1 cm so that the sample container does not interfere with the XRF measurement. The composite shall be used to fill the applicable sample container(s), as listed in Table 6-7. Each sample container will be labeled as described in Section 6.7 and custody sealed. Excess composited material shall be discarded back into the stockpile. Sample collection will be documented on a Sample Collection Log and chain-of-custody form.

6.13.3 Field QC

Duplicate samples will be collected for a minimum of 10 percent of all the stockpile samples.

7 Quality Assurance Project Plan

The purpose of this QAPP is to document the procedures required for QA, QC, data verification and validation, and data quality assessment for the sampling and analysis activities for the flood plain investigation at the CSMRI Site. The goal of the QAPP is to identify and implement the QA/QC practices associated with sampling and analytical methodologies that limit the introduction of error into analytical data. The QAPP provides the methodology to ensure that project data will be of adequate quantity, quality, and usability for their intended purpose, and further ensures that such data are authentic, appropriately documented, and technically defensible.

QA elements are the procedures used to control those immeasurable components of a project such as using the proper sampling techniques, collecting a representative sample, specifying the proper analysis, etc. Although not measurable, QA procedures are essential to produce quality information.

QC data are the data generated to estimate the magnitude of bias and variability in the processes for obtaining the environmental data. These processes include both the field processes for obtaining the data and the laboratory analyses.

Data quality assessment is the overall process of assessing the quality of the environmental data by reviewing the application of the QA elements, the analysis of the QC data, and results of the data verification and validation. Quality assessment encompasses both the measurable and immeasurable factors affecting the quality of the environmental data. Assessment of these factors may identify limitations that require modifications to procedures or protocols for sample collection and analysis or affect the desired interpretation and use of the data.

This QAPP was developed in accordance with the requirements in Guidance for Quality Assurance Project Plans (EPA 2002). This QAPP augments the information and requirements described in other sections of this work plan.

7.1 Project Management

A description of the project management and a project organization chart are provided in Section 1.7.

7.2 Project Description

A complete description of this project and project goals is provided in Sections 1 and 2 of this work plan. A schedule of project activities is provided in Appendix F.

The objective of this project is to complete the tasks necessary to characterize the nature and extent of COCs in soil and groundwater within the flood plain area of the Site. The impacted soil is serving as a source of continued groundwater uranium concentrations above regulatory requirements. Once the nature and extent are characterized, remedial options can be evaluated, selected, and implemented. Eventually, the goals of the School are to have the Site's risks managed properly, the RML terminated, and the Site returned to beneficial use. To achieve the goals, data will be collected during the project to:

- Direct and control investigation and segregation of soils that exceed the proposed cleanup goals,

- Characterize the stockpiled soil for nature and extent determination and to evaluate remedial options for the stockpiled soil,
- Verify that the nature and extent of soil contamination has been determined, and
- Provide radiological monitoring and control.

The SAP in Section 6 discusses the collection of field measurements and samples needed to generate the necessary data. When the nature and extent of contamination have been identified and the contaminated material segregated, post-segregation sampling will be performed in accordance with the VSP application, which is described in Section 5.5.

7.3 Data Quality Objectives

The overall data quality objective is to develop and implement procedures for field measurements, sampling, laboratory analysis, and data analysis and reporting that will provide results that are technically sound, legally defensible, and capable of supporting Site characterization and soil disposition decisions. The data quality objectives to achieve the primary objective were determined using the systematic planning process as outlined in the EPA guidance document *Guidance for the Data Quality Objectives Process* (EPA 2000).

7.3.1 Problem

Groundwater monitoring was performed in and near the flood plain area and the upper terrace area where the School's remedial action was previously completed on the upper terrace. The monitoring attempted to determine whether that remedial action resulted in decreasing levels of uranium in the groundwater. That monitoring has indicated that source material is present in the vicinity of well CSMRI-08. Well CSMRI-08 is located at the upstream end of the area known as the flood plain, an area formerly containing the CSMRI settling pond, which was addressed by an EPA remediation effort in 1992-1997. The source material investigation that is the subject of this work plan will begin in the area of well CSMRI-08.

During characterization activities, impacted materials will be segregated and stockpiled. Following segregation, post-characterization samples will be collected and analyzed by an offsite laboratory to confirm that materials exceeding the proposed cleanup goals have been identified. In addition, the soil stockpile that is generated during characterization activities will be sampled and analyzed for parameters necessary to evaluate the nature and extent of contamination and potential remedial options.

7.3.2 Decisions

Data necessary to answer the following questions must be generated.

- Was sufficient material investigated, segregated, and sampled to define the nature and extent of impacted material?
- Were the post-segregation in-situ materials and the stockpiled material adequately characterized to determine remedial options?
- Were adequate work practices employed to protect the onsite worker and surrounding community during characterization activities?

7.3.3 Inputs to the Decision

The following sources of information will be used during the course of characterization activities.

- Data generated during the preliminary characterization will be used to identify known contaminated material that will be excavated at the inception of the field activities, primarily around well CSMRI-8.
- Air monitoring will be used to ensure that appropriate dust control practices are used.
- Area dose surveys (and dosimetry data, if found to be necessary) will be used to monitor and control worker exposure to external radiation.
- Field portable XRF, used to quantify contaminant contaminations, will be used for segregation control.
- Laboratory analytical data will be used to quantify method bias and determine bias correction factors (in-situ contaminant analyses), and if necessary, generate data for the post-segregation samples and to characterize the soil stockpile.
- GPS and survey data will provide positional information for segregation and sampling.

7.3.4 Boundaries

Spatial boundaries for the characterization activities are expected to be limited by underground utilities and an existing wetlands area. The site boundaries are described in Section 1.

7.3.5 Decision Rules

A number of decision rules will be used to guide characterization activities, as well as protect the health and safety of Site workers and the surrounding community.

7.3.5.1 Occupational Health Requirements

Occupational exposure monitoring for ionizing radiation is required if a worker is likely to exceed 500 mrem per year from sources external to the body, per 6 CCR 1007-1, Part 4. Stoller has established an ALARA guideline of 100 mrem per year in accordance with the company Radiation Protection Program. These limits are not anticipated to be exceeded on this Site; therefore, personal dosimetry will not be required. Dose rate surveys will be conducted daily, in accordance with procedure SOP-RAD-033, *External Dose Rate Tracking*, to monitor external employee exposure, using Ludlum Model 19 MicroR meter, or equivalent. If dose rates greater than 50 microrem/hr above background (based upon a 2,000-hour work year) are observed, steps will be taken to limit personnel time in the area. In the event that this is not possible, and extrapolation of the dose rate indicates that the 100 mrem per year limit may be exceeded, the dosimetry program will be implemented.

7.3.5.2 Field Portable XRF

The field portable XRF will be used to measure contaminant concentrations in situ. Results from these measurements will be compared to the tentative cleanup goals. Count times will be established based on field data that allow a detection limit sufficiently below the action level. Soil that is contaminated above this level will be segregated.

7.3.5.3 Site-Specific Cleanup Goals

The proposed cleanup goals for radionuclides (except for total uranium, which is 14 ppm) for this project are presented in Table 7-1. These cleanup goals are identical to those used for the characterization of the upper terrace portion of the Site performed in 2006 with the addition of total uranium metal of 14 ppm.

Table 7-1
Radionuclide-Specific Tentative Cleanup Goals

Isotope	Activity (pCi/g)
Ra-226	4.14
Ra-228	4.6
Th-228	6.47
Th-230	11.53
Th-232	3.88
U-234	254.9
U-235	4.97
U-238	21.8

pCi/g – picocuries per gram

Metals of concern for the Site include As, Hg, Mo, Pb, U, and V. Metals concentrations will be compared to the CDPHE soil cleanup standards, with the exception of uranium and arsenic for which Site-specific standards have been calculated. The cleanup standards are summarized in Table 7-2.

Table 7-2
Site-Specific Metals Tentative Cleanup Standards

Metal	Concentration (ppm)
As	39
Pb	400
Hg (Total)	23
Mo	390
U	14
V	78

ppm – parts per million

7.3.5.4 Soil Stockpile Sampling Requirements

The material in the "clean" stockpile is expected to remain onsite and be used as backfill somewhere other than on the lower terrace. Sampling the contaminated stockpile is included in the scope of this work plan; however, disposition of the material is not. The contaminated soil stockpile will be sampled and analyzed to provide information for nature and extent determination and future disposition decisions.

The number of samples necessary to characterize the stockpile will be determined using the guidance in SW-846. To determine the number of samples that must be taken to adequately characterize the stockpile, the average and standard deviations for contaminants will be determined using data generated during the segregation activities. Samples will be collected from the contaminated stockpile and submitted for analysis by an offsite laboratory. The regulatory thresholds used for these analyses will depend upon the remedial options being considered.

7.3.6 Limits on Decision Errors

7.3.6.1 Occupational Health Requirements

A Ludlum Model 2929 alpha/beta scaler with 43-10-1 Sample Counter (or equivalent) will be used to count swipes and, as necessary, air filters. The count time will be adjusted to achieve a minimum detectable activity (MDA) (95 percent confidence limit) that is adequate for the intended use of the data. The MDA is calculated as follows:

$$MDA\,(dpm) = \frac{\dfrac{2.71}{T_S} + 3.29\sqrt{\dfrac{C_B}{T_S} + \dfrac{C_B}{T_B}}}{Eff}$$

Where:
T_S – Count time for sample filter (minutes)
T_B – Count time for background (minutes)
C_B – Background count rate (cpm)
Eff – Efficiency of detector

Swipes
Swipes used to monitor for removable contamination will be counted for alpha and beta activities. The most restrictive swipe release limits are 20 dpm/100 cm^2 alpha and 1,000 dpm/100 cm^2 beta. If the area swiped is not equal to 100 cm^2, these values will be adjusted proportionally. The estimated count time to achieve an MDA of 5 dpm alpha (the most restrictive) is 1 minute. The actual MDA based on actual field conditions will be calculated for the proposed count time using the equation presented above. MDAs will be recorded along with the count data. Count times may be adjusted, as necessary.

Survey Meter
The Ludlum Model 2360 alpha/beta data logger with 43-89 scintillator (or equivalent) will be used for monitoring for total contamination (fixed plus removable) on personnel and equipment. The Ludlum 43-89 probe used for these surveys has an alpha scanning detection limit of 100 dpm/100 cm^2 at a distance of one-quarter inch and a rate of ≤ 0.5 inch per second. The static alpha detection limit is 85 dpm/100 cm^2. The beta scanning detection limit is 2,500 dpm/100 cm^2 using the same scanning parameters with a static beta detection limit of 800 dpm/100 cm^2. These detection limits are adequate to demonstrate compliance with the release criteria of 100 dpm/100 cm^2 alpha and 5,000 dpm/100 cm^2 beta specified in NRC Regulation 1.86. When an audible response is observed, the probe should be placed in a static location over the area where the initial response was heard for 5 to 10 seconds to provide adequate time for instrument response.

7.3.6.2 Laboratory Detection Limits and Methods for Site COCs

The laboratory required detection limits (RDLs) and laboratory analytical methods are given in Table 7-3.

Table 7-3
Laboratory Analyses Required Detection Limits

Analyte	Method Description	Specific Method	Matrix	RDL
Ra-226/Ra-228	Gamma Screening	EPA 901.0	Soil	2 pCi/g
	Gamma (Bi/Pb-214 Ingrowth)	EPA 901.0	Soil	0.2 pCi/g
	Radon emanation	EPA 903.1	Air Filter	1 pCi/filter
Th-228, Th-230, Th-232	Alpha Spectroscopy	ASTM D3972-90	Soil	0.1 pCi/g
			Air Filter	0.25 pCi/filter
U-234, U-235, U-238	Alpha Spectroscopy	ASTM D3972-90	Soil	0.1 pCi/g
			Air Filter	1.0 pCi/filter
ICP Metals (Total) As, Pb, Mo, U, V	Inductively Coupled Plasma-Atomic Emission	EPA 3052 (Acid Digest Total) EPA 6010B	Soil	0.1 ppm
Metals (Total) - Hg	Cold Vapor Atomic Adsorption	EPA 7471A	Soil	0.1 ppm
TCLP Metals (As, Pb, Hg)	ICP-AES/CVAA	EPA 1311	Soil	0.1 ppm

The detection limits for the field XRF data are less than the action levels for the metal compounds. The potential bias in the field XRF data will be evaluated during the initial correlation study described in Section 6.1. Data corrections will be applied as necessary. The data from the field XRF are considered screening level measurements; therefore, these data will be used only for excavation control.

7.3.6.3 Soil Stockpile Sampling Requirements

The probability level (confidence interval) for sampling the stockpile is 80 percent. However, since the upper limit of the confidence interval is compared to the regulatory threshold, only one side (tail) of the distribution curve is relevant. Therefore, the effective confidence is 90 percent.

7.3.7 Optimize Project Design

The excavation is partially guided by the field portable XRF data. This method is shown to be effective and rapid in determining the location of impacted soil. The final contaminated soil stockpile sampling will be designed based on the size of the pile and the expected range of contamination. The VSP application will be used to determine the sampling effort. Section 5.5 provides information on VSP.

7.4 Measurement Data Acquisition and Performance Criteria

The data quality indicators that will be used to assess the laboratory data include precision, accuracy, representativeness, completeness, and comparability.

7.4.1 Precision

Precision measures the degree of agreement among repeated measurements of the same characteristic (EPA 1986). It may be determined by calculating the standard deviation (for three or more determinations or relative percent difference [RPD] for two samples) for samples taken from the same place at the same time. The EPA National Functional Guidelines set RPD as one of the required measurements of laboratory precision. Generally, precision is calculated for compounds positively detected in both the original and duplicate samples. For two samples, the following formula is used:

RPD = |(original-duplicate)/((original + duplicate)/2)|

Precision can be measured in laboratory analyses by evaluating matrix spike and matrix spike duplicate (MS/MSD) pairs and pairs of "unspiked" samples and the corresponding duplicates, as specified in each analytical report. The acceptable RPD range, called "advisory limits" is given on the Form III for each analytical report (EPA 1999). Analytical results in which the RPD is above those limits, is qualified, usually with an asterisk (*) or a "P".

7.4.2 Accuracy

Accuracy measures how close results are to the true value and is determined by comparing analysis of standard or reference samples to their actual value (EPA 1986). In practice, accuracy is determined by measuring the level of contamination in method and equipment rinsate blanks; evaluating performance against known laboratory control samples (LCS); evaluating surrogate recovery; and validating MS/MSD samples.

Results for blanks agree with values generally obtained in field investigations. The affected samples have been qualified and the detection limits have been appropriately corrected to reflect the accuracy of laboratory analyses.

EPA protocols tightly control LCS and LCS duplicate (LCSD) failures. The LCS percent recovery must be within the QC limits for the sample data to be accepted (EPA 1999). When an analytical run has LCS or LCSD failures that directly impact the analytes requested, the samples must be re-analyzed. Due to these tight controls, LCS and LCSD samples demonstrate that accuracy was met for each analytical run.

7.4.3 Representativeness

Representativeness is a qualitative measure that evaluates whether samples and measurements are collected in a manner such that the resulting data appropriately reflect the property to be measured (EPA 1998). Representativeness can be affected by the collection of the sample or by the analysis. Problems with representativeness arise if the samples collected do not extract the material from its natural setting in a way that accurately captures the qualities to be measured, or if a subsample is not representative of the sample because the subsample was collected from the most accessible portion of a non-homogenized sample (EPA 1998). Representativeness is most commonly addressed by defining protocols based on standard techniques and adhering to them throughout a study (EPA 1991). These standard techniques are most commonly addressed by using standard sample collection techniques (from SW-846 and other EPA guidance) and homogenizing samples prior to subsampling. The standard techniques to be used in this study are detailed in this work plan and will be implemented during field sampling activities.

7.4.4 Completeness

Completeness is the comparison between the amount of valid or usable data originally planned to be collected and the amount of data actually collected (EPA 1986). Because Stoller's plan is investigative in nature and the extent of the impacts are not known, the quantity of data to be collected during this plan is unable to be determined. The final survey will collect data that will strive for an excess of 90 percent completeness.

7.4.5 Comparability

Comparability measures the extent that data can be compared between sample locations and periods of time within a project or between projects (EPA 1986). Data collected for the current CSMRI field work should be comparable with data collected from previous CSMRI field work, as long as past consultants followed the procedures outlined by the EPA (chemical data were obtained using EPA SW-846 methods [EPA 1986] and standard sampling techniques [from SW-846 and other EPA guidance]). Approved laboratories performed all analyses.

7.5 Special Training and Certifications

All field personnel are required to read the SSHASP, this work plan, and applicable procedures, as well as attend a safety briefing prior to commencement of work activities. Completion of required reading will be documented using a required reading checklist or equivalent. Morning safety meeting attendance will be documented on a safety form.

A Colorado-licensed professional land surveyor will perform all required surveys. Personnel using GPS equipment will be given instrument-specific training prior to using the equipment in the field. This training will be recorded using a training roster or equivalent form. Personnel using field instrumentation (i.e., field portable XRF, scintillators, and other detectors) will be trained on those instruments prior to their use, and training will be recorded on a training roster or equivalent form.

7.6 Documentation and Records

Field-generated documentation will consist of field logbooks, instrument calibration and operation logs, field survey and excavation documentation sheets, and sample collection logs. Standardized field forms are provided in Appendix K.

Requirements for documentation include the following:

- Logbooks will be bound, with consecutively numbered pages.
- Removal of any logbook pages, even if illegible, is prohibited.
- Entries will be made legibly with black (or dark) waterproof ink.
- Entries will be made while activities are in progress or as soon afterward as possible.
- Name of person making the entry will be recorded.
- Each consecutive day's first entry will be made on a new, blank page.
- At the conclusion of the field activities for the day, any unused space on the field logbook page will be "Z'd out" to prevent later entries.
- Unused portions of field forms and chains of custody will be "Z'd out" to prevent later entries.
- The date and time, based on a 24-hour clock (e.g., 0900 for 9 a.m. and 2100 for 9 p.m.) will appear on each page.
- Any photographs taken at the sampling location will be noted on the field sheets.

Documentation will be reviewed for discrepancies, missing information, missing signatures, etc., on a weekly basis (minimum) by the project lead, or designee, as evidenced by a review signature in the logbook or on the record sheet. Documentation deficiencies will be directed to the appropriate personnel as soon as possible for correction or augmentation.

Corrections to any document will be made by drawing a single line through the original entry allowing the original entry to be read. The corrected entry will be written alongside the original. Corrections will be initialed and dated and may require a footnote for explanation.

All documentation generated during this project will become part of the project record files.

7.6.1 Field Logbook

All field activities and observations that are not noted on other types of field-generated paperwork will be noted by the project lead in a field logbook. The field logbook will be a bound document containing the following information, at a minimum:

- Date and time of each entry,
- Personnel onsite, including documentation of any visitors,
- Area(s) being worked and types of samples collected,
- General observations, and
- Any changes that occur at the site (e.g., personnel, responsibilities, deviations from this work plan) and the reasons for these changes.

The project lead is responsible for ensuring that the field logbook and all field data forms are correct and complete. The descriptions will be clearly written with enough detail so that participants can reconstruct events later, if necessary.

In addition to the preceding requirements, the person recording the information must initial and date each page of the field logbook. If more than one individual makes entries on the same page, each recorder must initial and date each entry. The bottom of the page must be signed and dated by the individual who made the last entry.

7.6.2 Sample Collection Log

The Sample Collection Log will be used to document sample collection of all soil samples. Radiological surveys and dose rate surveys will be recorded on appropriate forms as described in Section 6, SAP. Forms shall identify, at a minimum, the released equipment (or personnel name, as appropriate), survey instrument used, survey results, background at the time of the survey, and name of the surveyor.

7.7 Sample Handling Requirements and Controls

All samples will be collected and handled in accordance with the requirements in Section 6, SAP. After collection, samples will be placed in the onsite sample staging locker or in a custody-sealed cooler with the corresponding chain of custody until they are shipped to the offsite laboratory. Metals samples will be stored in coolers on ice and shipped to the laboratory within one day of collection.

7.7.1 Field Procedures

The following steps must be taken by field personnel to ensure chain of custody on field samples.

- Use only approved containers for acquiring samples.
- Properly label all sample containers at the time of sample acquisition.
- Record all required sampling information in field logs and/or sample collection logs, as applicable.
- Ensure that labels are legible and intact after sampling or write information directly on sample container.
- Immediately place samples in a designated container (cooler, etc.) that accompanies the sampling personnel until custody of the samples is transferred.
- Place the sample in a secure location if not transferring to another individual.
- Document all changes of sample custody such as transfer to the onsite laboratory or the offsite laboratory.
- Use an appropriate custody seal on the sample container during shipment to ensure no tampering in route to the laboratory.
- Fill out the applicable chain of custody form.

7.7.2 Approved Sample Containers

Samples will be placed and transported in containers appropriate to the sample matrix and analytical parameters. Sample containers for samples submitted to the offsite laboratory are supplied by the laboratory. The bottles are required to be pre-cleaned and certified. The appropriate size and type of sample containers for the analytes being collected are specified in the applicable Sample Acquisition section of the SAP in Section 6.

7.7.3 Sample Label Requirements

Sample labels will be pre-printed whenever possible. Specific sample collection information, such as collection time, will be written on the sample labels at the time of sampling. Sample labels will be filled out with indelible ink. Samples will be labeled with the following information, at a minimum:

- Date and time sample was collected
- Unique sample number
- Name of sampler
- Requested analysis(es)
- Preservative, if applicable
- Client (Stoller) – Only required for offsite samples

7.7.4 Sample Documentation

Sampling activity is documented on a Sample Collection Log.

7.7.5 Preservatives

Metals samples shall be preserved with ice (4 ± 2°C).

7.8 Analytical Methods Requirements

Samples collected for method correlation or post-characterization sampling, as well as occupational health samples (if necessary), will be analyzed at a CDPHE-certified environmental/radionuclides laboratory. Samples designated for laboratory analysis will be analyzed in accordance with laboratory-specific internal procedures for the specified analytical method. The laboratory methods used for this project and the required detection limits are listed in Table 7-3.

The field portable XRF will be operated by personnel who have received instrument-specific training on its use. The estimated limit of detection for uranium for this instrument is 5 to 7 ppm based on a 2-minute count time (Innov-X Model "Omega"). The actual detection limit will be affected by field conditions and will be determined during use.

7.9 Quality Control Requirements

The following sections describe the QC requirements anticipated for this project.

7.9.1 Sampling Quality Control Requirements

Samples must be collected from representative material using clean sampling equipment and the proper sample containers. Collection of the sample must be well documented. The samples must be properly stored and shipped. The project lead will supervise sampling personnel to verify sampling, storage, and shipping procedures are followed. If discrepancies are noted, corrective action will be initiated, which may include retraining and/or revising procedures.

Every effort will be made during the soil sample collection to produce well-mixed soil samples free of excessive gravel, pebbles, or organic material. Duplicate soil samples will be collected from a minimum of 10 percent of all sample sites. New disposable sampling equipment or reusable items that have been lined with a disposable liner will be used to collect all samples. Sufficient sample quantity will be provided for internal laboratory QC operations.

7.9.2 Field Portable XRF

Daily performance checks, in accordance with the instrument operating procedure, are required at the beginning of the shift and after every four hours of operation. The operator is prompted to perform the required checks by the instrument software. Evaluation of the performance check data is done automatically by the software. If results of the performance check are not acceptable, the instrument shall be tagged out of service and shall not be used until the problem is resolved.

7.9.3 Radiation Detection Instrumentation

Daily performance checks shall be completed prior to instrument use each day. Results of the performance checks shall be documented, as specified in the applicable instrument operating procedure.

7.9.4 Laboratory Quality Control Requirements

Laboratory QC shall be performed in accordance with established internal laboratory procedures. Standard QA/QC procedures include initial calibration, continuing calibration, reagent blanks (where applicable), laboratory control samples (for radionuclide samples), laboratory duplicates, serial dilutions (as needed), tracer samples (both chemical and radionuclide), and MS/MSD (i.e., addition of known quantities of chemicals or radionuclides).

All laboratory quality control samples shall be reported along with the standard sample analyses. Problems with laboratory QC shall be reported in the laboratory data package. Analyses that are out of accepted laboratory QC ranges shall be reported to the project manager or QA manager to determine if the samples need to be re-run. Problems with QC shall be corrected as soon as possible and affected samples may require re-analysis. In some instances, technical judgment may be required to determine if flagged data are of adequate quality for project needs.

7.9.5 Survey Data

Positional data will be recorded onsite through the use of GPS. Continual checks of the accuracy of these data will be made by maintaining GIS maps of the accumulated information and checking the locations against adjacent, mapped locations.

7.9.6 Documentation

Significant documentation shall be generated by this project. Documentation will be reviewed for discrepancies, completeness, etc., on a weekly basis (minimum) by the project lead or designee. Documentation deficiencies will be brought to the attention of the appropriate personnel as soon as possible for correction.

7.10 Instrument/Equipment Testing, Inspection, and Maintenance

All instrumentation used for this project requires testing, inspection, and maintenance. Equipment problems will be identified in a timely manner and the instrument will be repaired or replaced as soon as possible. Instrumentation that may be used on this project includes:

- Hand-held radiation survey instruments
- Field portable XRF
- Various air sampling pumps (if found to be necessary)

Manufacturer- or vendor-specified preventive maintenance procedures and/or consumable item replacement schedules shall be strictly followed for all field instrumentation/equipment. Field instrumentation/equipment will be function checked and/or calibrated before being assigned to the field activity. Function testing and/or calibration in the field will be performed daily or in conformance with the manufacturer's recommendations and recorded on the equipment log sheet. A sufficient inventory of repair items and consumable components will be maintained on the Site to keep the field instruments and equipment in service. Arrangements will be made with offsite vendors and service companies for repair and maintenance of instruments that require specialized equipment or skills. Maintenance problems shall be brought to the attention of the project lead if data quality is affected.

7.11 Instrument Calibration and Frequency

The portable XRF is calibrated by the instrument manufacturer. This calibration is a one-time event unless repairs are performed on the instrument.

Radiation detection instrumentation shall be calibrated annually, according to manufacturer's procedures. The calibrations shall be National Institute of Standards traceable and documentation of the calibration shall be available in the field office.

7.12 Inspection/Acceptance of Supplies and Consumables

Certified clean containers, supplied by the laboratory, shall be used for all samples submitted to the offsite laboratory.

Receipt of supplies and consumables shall be verified against the purchase order to verify that the order was properly and completely filled. If items were ordered with specification requirements, documentation of specification compliance (i.e., certificates, etc.) shall be reviewed for compliance.

7.13 Data Management

Data for this project will be generated in written and electronic form. Field data will be recorded in field notebooks, sample collection logs, chain-of-custody forms, instrumentation visual output, instrumentation digital output, and software-generated digital output. Laboratory data shall be delivered in electronic form in addition to the hard-copy report. These data must be accurately recorded and cross-checked to verify quality data are produced. The objectives for data management on this project are as follows:

- Track and organize all data pertaining to field activities, including surveys, in-situ measurements, collection of samples, and data from associated laboratory analyses
- Ensure that the description of each data point is meaningful and complete
- Ensure that large volumes of data can be handled efficiently
- Ensure that each data point is accurate and readily accessible

Data created by the field work activities include the following:

- Field measurement data (radiological surveys and in situ uranium data)
- Survey information
- Sample collection and tracking information
- Field laboratory analytical results
- Offsite laboratory analytical results

Surveys will be performed to set the boundaries and depths for each excavation, and all post-characterization sample locations will be recorded. Coordinate information will be uploaded to a survey database. Sampling event forms will be completed. Confirmation samples and stockpile characterization samples will receive Level III analyses and full validation. Analytical results will be uploaded into the test and results database. These data files will be used in a geographic information system (GIS) to produce maps that illustrate the characterization project.

Data will be entered into the data management system through manual data entry, downloading from data loggers, and electronic files supplied by the laboratories. Data from the sampling event forms will be manually entered into the project database. Hard copies of these data will be generated and scrutinized for errors, omissions, and problems. Identified errors and omissions will be corrected. Problems will be researched and corrected before sampling has terminated. Field personnel will be closely involved in verifying and providing complete information regarding sampling events to ensure that QA/QC sampling objectives are met. Data quality assurance will consist of a variety of techniques depending on the source of the data. Manually entered data will be randomly verified. Newly entered data from all sources will be evaluated using queries to check for outliers or anomalous data. The data will be transferred into final database tables only after data quality has been assured by the project lead or designee. Hard-copy original data sheets will be maintained in the project files until project completion and closeout at which time project files will be turned over to the client.

7.14 Assessment and Response Actions

The project lead will perform or direct performance and system audits to verify that activities are performed in accordance with the procedures established by or provided in the SAP and this QAPP. Audits will include a review of applicable records, record-keeping practices, and field operations. Additionally, a field audit will take place at the commencement of the project to determine that personnel are aware of and capable of executing project activities in accordance with established procedures. Follow-up audits or surveillances will be conducted to ensure that established procedures continue to be followed. At least one project-wide follow-up audit will be performed. Audits may also be performed to verify the implementation of specified corrective actions. The project lead will prepare a written record of any audits performed. Findings, including corrective actions recommended or required, will be included in this record.

The project lead will undertake the following actions when/if a malfunction or procedural non-compliance is discovered or reported:

- Identify the item that is not functioning properly.
- If possible, determine how long the item has been malfunctioning.
- Remove the item from service and order its repair or replacement.
- Instruct affected personnel in the proper procedure.
- Evaluate the effect of the malfunction or non-compliance on current and past operations or on data quality.
- Conduct follow-up inspections, observations, or audits to ensure that the procedure is being properly utilized.

The project lead will make a written record of the corrective action. If the condition results in the impairment of the quality of data already collected, the Project Lead will identify the affected data, evaluate the effect of the problem, and take appropriate action to correct the affected data, if possible. Corrected data will be noted as such, together with a statement of how the correction was performed. Data that cannot be corrected will be identified, and limitations on the future usability will be noted. The project lead will conduct a follow-up investigation to ensure the effectiveness of the corrective action.

In the event that project personnel discover errors or inconsistencies with laboratory data, the project lead will initiate an investigation to determine if laboratory data are impaired and if a corrective action is required. The laboratory is required to inform the project lead of any laboratory corrective actions and identify any data whose usefulness may be affected. This requirement applies for corrective actions initiated by the laboratory as well any corrective actions ordered by the project lead.

7.15 Reports to Management

The project lead will submit the start-up audit report to the project manager, as well as daily updates on project progress and issues. The project manager will submit a weekly status report to the client.

7.16 Data Review, Validation, and Verification Requirements and Methods

Data review and validation will be performed that addresses the following parameters:

- Data Completeness
- Holding Times and Preservation
- Initial and Continuing Calibration Verification
- Contract Required Detection Limit
- Preparation/ Initial / and Continuing Calibration Blanks
- Interference Check Sample Results
- Matrix Spike Results
- Duplicate Sample Results
- Laboratory Control Samples Results
- Serial Dilution Sample Results
- Compound Quantitation and Reporting Limits (full validation only)

A summary of QA activities, including conditions or situations affecting data completeness or quality, corrective actions, and outcomes of corrective actions will be prepared as part of the final report. The report will address completeness and reliability of data generated during project activities, quality and completeness of documentation, and identify data and documentation that is incomplete or not in conformance with the project requirements.

8 Groundwater Monitor Well Activities

The groundwater monitor well replacement, installation, and deepening activities will be conducted after the flood plain investigation and backfill activities are completed and prior to any revegetation. Two monitor wells – CSMRI-7B and CSMRI-8 – will be abandoned just prior to investigation activities as described in Section 5. CSMRI-8 and the surrounding soil will be removed during the characterization. Both of these wells will be replaced, and three additional monitor wells (CSMRI-12, CSMRI-13, and CSMRI-14) will be installed as presented on Figure 8-1. Further, two existing wells – CSMRI-6C and CSMRI-11B – will be deepened to allow better assessment of water quality.

The locations of all replacement, new, and deepened monitor wells will be surveyed to the nearest foot and the elevation of the top-of-casing will be surveyed to 0.01 feet. As-built diagrams and lithology profiles for each monitor well will be completed and submitted with State of Colorado, Office of the State Engineer Well Construction and Test Report forms. The monitor wells will be integrated into the existing groundwater sampling program for sampling frequency (quarterly) and the identical analytical parameters. The monitoring will occur for two years unless the data indicate, and the CDPHE agrees, project objectives have been met.

8.1 Water Quality

Groundwater occurs under unconfined conditions in the alluvium/colluvium of the Site. Depth to the water table ranges from about 3 to 30 feet bgs, depending on distance to the creek and depth to bedrock. Based on surface and bedrock topography, groundwater on the bench terrace area generally flows to the northeast toward the flood plain and Clear Creek. The alluvial/colluvial deposits are mainly recharged by infiltration of precipitation and to a limited extent by Clear Creek during periods of high flow. The alluvial/colluvial system naturally discharges to Clear Creek.

Groundwater sampling is conducted at the CSMRI Site on a quarterly basis (March, June, September, December) and reported to CDPHE, Radiation Unit, through submitted summary reports. Uranium has been detected in several groundwater monitor wells at concentrations that exceed the current groundwater quality standard of 30 μg/L. The results of the quarterly sampling events indicate persistent high exceedances of State groundwater standards for uranium at monitor well CSMRI-8, located at the western end of the flood plain, since the well was installed in February 2007.

Spikes in exceedances for uranium have recently been detected in monitor well CSMRI-4. In late 2008 and through 2009, artificial turf athletic fields were constructed upon and south of the former CSMRI Site. The soccer field and the artificial turf football practice field to the south of CSMRI are both underlain with drainage beds. Precipitation that falls on the fields passes through the drainage beds and is conveyed via a 24-inch pipe to an outlet approximately 30 feet northeast of monitor well CSMRI-9. The discharged water then runs down the bench terrace slope onto the flood plain. Since 2005, the concentration of uranium at this location had been below to slightly above the groundwater standard. However beginning with the groundwater standard exceedance in the December 2008 sampling event, the concentration of detected uranium has continued to increase.

8.2 Rationale for Monitor Well Additions and Replacements

Additional groundwater analytical data are needed to understand the geochemistry of the alluvial aquifer and the interaction of Clear Creek with the flood plain system, determine nature and extent of groundwater contamination in the flood plain, and evaluate the success of the investigation work to determine the nature and extent of soil contamination as it impacts groundwater.

Two new alluvial groundwater monitor wells will be installed in the alluvial aquifer of the flood plain area after the soil investigation is complete. One deep groundwater monitor well will be installed in the Laramie-Fox Hills bedrock aquifer, and four existing monitor wells will be either abandoned and either replaced at the same location (CSMRI-8), relocated (CSMRI-7B), or deepened (CSMRI-6C and -11B) so that consistent, quarterly groundwater samples can be collected, not just when the fluctuating water table rises above the screened interval. Figure 8-1 shows the existing monitor well network, the proposed new monitor wells, and the monitor wells that will be abandoned and replaced.

The additional groundwater monitor wells will provide the data necessary to track the effectiveness of the characterization excavation. The data will confirm the success of determining the nature and extent of contamination as it relates to elevated uranium concentrations in groundwater at the site. The additional wells will also refine the knowledge of the following elements:

- The direction of water flow across the site, especially in the flood plain area, and
- Groundwater quality both up and down gradient across the site.

8.3 Replacement for Monitor Well CSMRI-8

Monitor Well CSMRI-8 was installed in February 2007 at the western end of the flood plain area. Groundwater analytical data indicate this well has consistently exceeded the groundwater quality standard for uranium. When the monitor well was installed, bedrock was encountered at 7 feet bgs with about 2 feet of saturated alluvial material overlying the bedrock. Investigation activities associated with the segregation of contaminated soil will result in this monitor well being abandoned per State of Colorado, Division of Water Resources, Office of the State Engineer regulations. The monitor well will be replaced very close to its current location. Continued monitoring of groundwater quality at this location will provide analytical data to assess the effectiveness of the source characterization.

8.4 Replacement for Monitor Well CSMRI-7B

Monitor Well CSMRI-7B was installed in February 2007 and is located on the upper bench terrace downgradient of the CSMRI Site. Weathered bedrock was encountered at about 10.5 feet bgs and competent bedrock at 14 feet bgs. The monitor well was screened across the overlying alluvial material and weathered bedrock contact. The presence of groundwater at this location has been very sporadic. Since installation, only four of ten quarterly sampling events had sufficient groundwater for depth-to-water level measurements, and only one event had sufficient groundwater for a quarterly (June 2007) sample. The single groundwater sample analytical result indicated the presence of uranium at a concentration of 68 µg/L.

Because of the sporadic nature of the presence of groundwater and sample collection, this monitor well will be abandoned and replaced with another monitor well that will be located approximately 40 feet to the south. The new location will position the replacement monitor well on a slope between a proposed

City of Golden bike path and a parking lot that would be associated with the soccer fields. The monitor well will be drilled to bedrock and screened across the bedrock-alluvial contact.

8.5 Proposed Flood Plain Monitor Wells CSMRI-12 and CSMRI-13

To assess the effectiveness of the investigation to identify the nature and extent of contamination in the flood plain area, two new alluvial groundwater monitor wells will be installed. Both wells will be located outside of the delineated wetlands area and will be located east of monitor well CSMRI-8 (Figure 8-1). The wells will be constructed after the segregation and backfill in the flood plain are complete but prior to revegetation. Each monitor well will be drilled into bedrock and screened across the bedrock - alluvial contact.

8.6 Proposed Bedrock Monitor Well CSMRI-14

This bedrock monitor well will be installed in the flood plain area and will be screened in the Laramie-Foxhills aquifer. The well will be positioned as an offset (located several feet distance) to a new alluvial monitor well to allow for identification of any vertical migration of uranium and to allow a comparison of shallow alluvial/flood plain groundwater quality to deeper bedrock water quality.

Grant (1990) reports that groundwater primarily occurs in the lower sandstone units of the Laramie Formation and the upper sandstone and siltstone units of the Fox Hills Sandstone. The lithology of the existing monitor wells will be reviewed to determine the type of bedrock material and formation each monitor well penetrated so that monitor well CSMRI-14 can be optimally placed. Proposed monitor well CSMRI-14 will be located so that it can penetrate the aquifer bearing materials of either the lower Laramie Formation or the upper sandstone/siltstone unites of the Fox Hills Sandstone, as defined by Grant (Figure 1-3). The approximate location of proposed bedrock monitor well CSMRI-14 is shown on Figure 8-1.

Because the groundwater in the flood plain exceeds groundwater quality standards, surface casing for the bedrock monitor well will be installed from the ground surface and into several feet of the underlying bedrock. The casing will be cemented in place to prevent vertical migration of potentially contaminated alluvial flood plain water into the underlying aquifer. Water within the casing will be removed prior to advancing the boring deeper into bedrock. It is anticipated that this monitor well will extend approximately 50+ feet into the underlying bedrock aquifer. The monitor well annular space above the 10-foot screened interval will be sealed with bentonite grout so that there is no downward vertical migration of alluvial flood plain groundwater into the well screen section.

8.7 Deepening of Monitor Wells CSMRI-6C and CSMRI-11B

These two monitor wells were installed in June 2008 after the original monitor wells were abandoned due to construction associated with the artificial turf soccer field. An auger-type drill rig was used to install these wells. Due to subsurface conditions (auger refusal), the depth of the monitor wells did not fully penetrate the alluvial water table nor were the wells as deep as the original monitor wells. Due to the fluctuating water table, collection of a complete analytical suite for groundwater characterization has been sporadic. Typically sufficient groundwater is present for a water level measurement and a partial groundwater sample.

Monitor well CSMRI-6C is 30.2 feet bgs with bedrock (Pierre Shale) at approximately 33 feet bgs (based on borehole CSMRI-6B). This well is located on the western edge of the soccer field and serves as a background water quality monitor well. Stoller proposed to remove the flush-grade monitor well protector and drill/core out the existing polyvinyl chloride (PVC) well materials and extend the depth of the monitor well another 5 to 6 feet. The resulting monitor well will extend approximately 2 to 3 feet into the underlying Pierre Shale and will be screened across the full saturated thickness of the alluvial aquifer that is found at the top of the Pierre Shale.

Monitor well CSMRI-11B is 26 feet bgs with bedrock (Fox Hills Sandstone) at approximately 29 feet bgs (based on borehole CSMRI-11). This well is located on the eastern edge of the CSMRI Site and serves as a cross-gradient water quality monitor well. Stoller proposes to remove the above-grade monitor well protector and drill/core out the existing PVC well materials and extend the depth of the monitor well another 4 to 5 feet. The resulting monitor well will extend approximately 3 feet into the underlying bedrock and will be screened across the full saturated thickness of the alluvial aquifer.

8.8 Monitor Well Replacement and Installation Approach

This section describes the installation of the replacement and new groundwater monitoring wells at locations shown on Figure 8-1. Drilling and installation work for the wells are summarized in Table 8-1 and detailed in the narrative below.

Table 8-1
Summary of Wells, Borings, Estimated Depths, and Completion Details

Well/Boring Number	Estimated Depth of Boring (ft bgs)	Estimated Depth to top of Screen (ft bgs)	Screen Length	Well Diameter (inches)	Type
6C (extend depth)	35	25	10	2	Monitoring
7C (replacement)	20	15	5	2	Monitoring
8B (replacement)	15	5	10	2	Monitoring
11B	35	25	10	2	Monitoring
12	15	5	10	2	Monitoring
13	15	5	10	2	Monitoring
14	50+	40+	10	2	Monitoring
Total Footage	115		65	2	Monitoring

- Monitor/Observation Wells – The monitor wells will consist of 2-inch inside diameter schedule 40 PVC completed in the alluvial/colluvial aquifer at four locations and in bedrock at one location. The alluvial wells shall be installed to maximum depths of about 20 feet bgs and completed with minimum of 5 feet of machine-slotted PVC screen. The actual well depths will be determined in the field by examination of drill cuttings by the Stoller geologist. All wells will be developed by surging and bailing.

- Core Samples – The drilling subcontractor will use a sonic drilling system that produces continuous core as the borehole is advanced. Samples of the core will be collected at the discretion of Stoller's geologist, based on inspection and screening of the core. Stoller will note on the boring log the area of the boring containing the highest screened gamma activity in the event laboratory analysis is desired. Samples of the core are not anticipated to be sent to the analytical laboratory but will be held pending the outcome of the groundwater analyses. If groundwater analyses identify elevated concentrations of site COCs, the samples of the core will be considered for possible laboratory analysis to help understand the nature and source of the elevated groundwater concentrations.

8.9 Monitoring Well Specifications and Requirements

Specifications and requirements for the drilling and sampling tasks are presented in this section. Some factors such as final well location and final borehole depth are subject to change as conditions in the field dictate.

Drilling and well completion activities will follow the procedures contained in ASTM D5092-90 (reapproved 1995). The boreholes and installed wells will be sufficiently plumb and straight and will have no interference with the installation, alignment, operation, or future removal of pumps or other down-hole equipment. Only non-hydrocarbon-based lubricants will be used on any down-hole equipment or tools. The use of contaminating additives (diesel fuel, oil), hydrocarbon-based lubricants (grease or oil) in the boreholes or monitor wells is strictly forbidden. Monitor well installation materials (sacks of bentonite, screens, casings, etc.) will be delivered to each well site in factory-sealed containers and remain in such until used in the well installation.

8.9.1 Drilling Methods

The drilling rig selected for installing the monitoring wells is a track-mounted sonic rig that has the capability of preserving sample integrity while having the capacity to drill through cobbles. The proposed drilling method and equipment are capable and rated to penetrate and advance through clay, loose sand, and gravel with cobbles to cobbles reaching a depth of at least 50 feet. Lithologic samples should be provided from all depth intervals during drilling due to the use of the sonic drilling system. A sonic drill rig was used in February 2007 with excellent results for the installation of eight monitor wells at the CSMRI Site and the sampling of the clay pits characterization task.

8.9.2 Lithologic Logging

The sonic drilling rig has continuous core capabilities that will be used to provide continuous representative samples. The driller will provide to the Stoller geologist drill cores from the monitor well locations at a minimum of every 10-feet-depth interval or as directed by the Stoller geologist for lithologic logging purposes. If necessary, shorter interval coring will be requested at selected intervals to assess subsurface lithologic changes at depth, particularly when the water table in encountered and depth to bedrock. The cores will be used to determine the desired total depth of the boring and the screened interval for each monitor well.

8.9.3 Well Installation and Completion

Installation of the well materials will be completed immediately after the desired total depth of the borehole is reached, as determined by the Stoller geologist. The Stoller geologist will track measurements of the depth of materials added to the monitor well to the nearest tenth of a foot. The borehole diameter will allow a minimum of 3-inch annular space between the borehole and the well casing.

The monitor wells shall be constructed using the following materials:

- Johnson well screen and casing (or equivalent) nominal 2-inch inside diameter
- Schedule 40 PVC
- 0.020-inch machine slotted screen fitted with an end cap (no sump)
- 10-20 Colorado silica sand (or equivalent) for the primary filter pack
- 16-40 Colorado silica sand (or equivalent) for the secondary upper pack
- 3/8-inch bentonite pellets/chips seal
- Schedule 40 PVC blank casing
- 30 percent solids bentonite grout or cement-bentonite grout with minimum 2 percent bentonite
- Lockable steel well cover embedded in concrete pad.

The monitor wells will be constructed in accordance with the following guidelines:

- Installation of the well screen and casing will begin when the desired total depth of the borehole is reached.
- Well installation will continue with placement of the primary filter pack to 2 feet above the top of the screen or as determined by the Stoller geologist. Pre-completion well development will be performed, if necessary and as determined by the Stoller geologist, to ensure a uniform and complete filling of the annular space with the filter pack that is free of voids or bridges.
- The well installation will continue with the placement of a minimum 3 feet secondary filter pack.
- When the top of the secondary filter pack is at the correct height, as determined by the Stoller geologist, the placement of a 5-feet bentonite seal (3/8-inch bentonite pellets/chips) will be completed. The bentonite pellets/chips will be hydrated by adding 5 gallons of tap water and allowing at least a 15-minute period for hydration and expansion of the seal.
- The 30 percent solids bentonite grout or cement-bentonite grout seal in the annular space from the top of the bentonite seal to the ground surface will be installed. The placement of the grout will be completed by pumping it through a tremie pipe in one continuous action, completely filling the annular space. The grout will be prepared in accordance with the manufacturer's instructions and supervision of the Stoller geologist.

8.9.4 Well Development

Wells will be developed by a combination of surging and bailing. The development will continue until the well is free of sediment, as determined by the Stoller geologist. Development water will not be retained but diverted away from the drill pad site.

8.9.5 Well Head Protection

The following well head protection for the monitor wells will be installed:

- A steel casing extending 30 inches above the surface fitted with a locking, weather-proof lid (about 2 inches of clearance) shall be placed over the riser casing of each well and cemented 3 feet in place, with a ⅛-inch drain hole drilled near the base. Stoller will supply the locks for the lids.

- The top 2 feet of the borehole shall be excavated and tapered away from the casing to allow the concrete to be placed below the frost line.
- 3-feet wide, 3-feet long, and 6-inch thick concrete pad (centered on the casing) having a slight slope away from the well casing shall be installed around each new monitoring well.
- The annular area between the cover and the riser casing shall be filled with ¼-inch pea gravel or coarse environmental sand up to 6 inches below the top of the riser. The finished height of the PVC casing shall be cut square and about 2 feet above ground level. The top of the casing shall be equipped with a schedule 40 PVC slip cap or lockable J-plug.
- The PVC well head will be surveyed by a licensed surveyor. Coordinate locations of each monitor well will be on the State of Colorado coordinate system; the elevation of each PVC well head will be recorded to within the nearest 1/100th of a foot (0.01).

8.9.6 Drill Cuttings and Fluid Disposal

Drill cuttings will be surveyed for gamma radiation activity and if no elevated readings are noted, they will be spread evenly on the ground surface around the borehole after each monitor well is completed. Elevated activity will be considered to be twice background and these cuttings will be retained in 55-gallon open top drums for later characterization and disposition.

8.9.7 Utilities Clearance

Stoller will stake each proposed drilling location prior to the start of work. Stoller will contact the Utility Notification Center of Colorado (1-800-922-1987) to notify the utility companies no earlier than seven days and no later than 48 hours prior to start of work. Stoller will coordinate and escort the utility locators to each proposed monitor well location. Stoller will verify all utilities located, such as power lines or pipelines that might reasonably be expected to exist within the work area, prior to commencement of work.

8.9.8 Permits and Licenses

Stoller will provide necessary access permits, well permits, and permits for cuttings/fluid disposal as required by federal, state, or other controlling agencies. The driller will be responsible for drilling and/or contractor license(s) and other permits required by federal, state, or other controlling agencies. The drilling subcontractor shall furnish a copy of a valid Colorado driller's license.

8.10 Health and Safety

Health and safety requirements and procedures are summarized in the following sections.

8.10.1 Safety Requirements and Briefings

The Stoller geologist, in collaboration with the Stoller site safety supervisor, will be responsible for operational health and safety coverage during the drilling activities. Onsite personnel shall comply with the Stoller corporate health and safety regulations and the SSHASP.

A safety tailgate meeting will be held prior to the start of each day's work. All personnel working on that day's shift shall attend. The topic of discussion and attendee signatures will be recorded on an attendance form. A copy of each daily record will be maintained by the Stoller project manager.

The Stoller geologist and/or the drilling subcontractor will suspend work when an unsafe practice or condition is observed. Work will not proceed until the unsafe practice or condition is corrected and the Stoller geologist, or designee, approves the resumption of work.

Drilling rig trucks and/or carriers shall conform to applicable federal, state, and local safety requirements and regulations. Each truck or carrier shall be equipped with two DOT-approved, fully charged 2A:40BC dry chemical fire extinguishers, with current inspection tags.

8.10.2 Training

No special hazardous waste or radiation worker training is required for drilling and well installation activities at the CSMRI Site.

8.10.3 Equipment Inspections

The Stoller geologist will inspect the subcontractor's drilling rig and other subcontractor-furnished equipment at the start of the project and at other times, as necessary, and record the conditions on an appropriate form. The subcontractor shall inspect its drilling equipment on a daily basis and document the inspection on the drilling report form each day. The subcontractor shall maintain and operate its equipment in accordance with applicable regulations.

8.11 Monitor Well Sampling

8.11.1 Groundwater Sample Collection

The newly installed monitor wells will be integrated into the existing CDPHE-approved sampling and analytical plan that governs all monitor well sampling protocol on the CSMRI Site. Sampling is conducted quarterly (March, June, September, December) with an expanded list of metals analytes during the June quarterly sampling event when Clear Creek is at its seasonal high flow period. Quarterly monitoring will continue for two years after the soil segregation portion of the investigation is complete unless conditions warrant early relaxation of this and the CDPHE agrees.

Representative groundwater samples will be collected from the newly installed monitor wells. Physical dimension and water levels referenced to the top of casing of each monitor well will be measured to an accuracy of 0.01 foot vertically prior to sampling. Three casing volumes of water will be purged and field measurements of temperature, pH, conductivity, turbidity, ORP, DO, and conductivity recorded on field data sheets after each casing volume of purge water is removed from the well. Detailed field sampling procedures are presented in Stoller's RML procedure, SOP-RAD-024.

8.11.2 Sample Containers, Preservation, and Holding Times

Soil samples and groundwater samples will be placed in laboratory supplied, screw-cap poly-containers, sealed, and labeled with the sample identification number, date and time of collection, analysis to be performed, and initials of the sampler. Filtering and sample preservation with nitric acid of aqueous samples will be conducted in the field. Preserved aqueous samples will have their pH checked in the field using narrow ranged pH paper strips prior to sealing. Additional nitric acid may be added in the field to achieve the requisite pH 2 or lower. The pH paper strips will not be dipped into the aqueous sample container, rather a small portion of the sample will be poured onto the paper strip. It is anticipated that several drops of aqueous sample will run-off the pH paper strip. Samples will be placed in a pre-cooled ice chest for shipment via courier to the contract laboratory. A completed chain of custody will accompany each ice chest submitted to the contract laboratory. Copies of the chain of custody will be included in the quarterly report.

8.11.3 Quality Control Samples

One set of water quality samples will be collected as an equipment blank. Distilled water will be passed through a decontaminated sample bailer and submitted for identical analyses as a groundwater monitor well sample. Any elevated detects of tested analytes will prompt a review of field decontamination procedures and possible revision of decontamination methods.

QA is defined as the program used to define procedures for the evaluation and documentation of investigation/characterization activities to provide a uniform basis for collecting, managing, and reporting data and information. QC is defined as the procedures and activities related to measuring the accuracy and precision of data and information and implementing corrective action to meet data quality objectives (DQOs). DQO as well as the QAPP presented in Section 7 of this document will be followed during this site work.

8.11.4 Sampling Procedures and Analytical Protocols

Sampling procedures to be used in this investigation are described in Stoller's Radioactive Materials License Application, SOP RAD-024. Laboratory analyses to be performed with their corresponding frequency are presented in Table 8-2.

Table 8-2
Groundwater Analytical Parameters and Frequency

Analyte	Upstream CSMRI-1	Bench Terrace CSMRI-1B, 7B, 9, and 10	Flood Plain CSMRI-4, 5, 8, and new wells	Surface Water SW-1, -2, and -3	Upgradient CSMRI-2
Anions (HCO_3, CO_3, [alkalinity], Cl, SO_4, NO_3/NO_2)	Qtrly	Qtrly	Qtrly	Qtrly	Qtrly
Cations (Ca, Mg, K, Na)	Qtrly	Qtrly	Qtrly	Qtrly	Qtrly
General Chemistry (pH, conductivity, DO, ORP, TOC)	Qtrly	Qtrly	Qtrly	Qtrly	Qtrly
Metals (As, Ba, Cd, Cr, Pb, Mn, Hg, Mo, Ag, Se, V, Zn) (dissolved)	June	June	June	June	June
Uranium (dissolved)	Qtrly	Qtrly	Qtrly	Qtrly	Qtrly
Isotopic Ra (226, 228)	Qtrly	Qtrly	Qtrly	Qtrly	Qtrly
Fe3/Fe2 (Ferric/Ferrous Iron)	Qtrly	Not Sampled	Qtrly	Not Sampled	Not Sampled

8.12 Data Reduction, Validation, and Analysis

Data reduction will be accomplished through performance of a data quality review and construction of computer databases as necessary to compile and reduce data to usable data sets that meet the DQOs established for the project. Analytical data from the laboratory will include full EPA Level 4 documentation, including radiochemistry case narrative, raw data package, QA summary reports,

laboratory bench sheets, standards traceability documents, and initial calibration standards traceability. Data validation will be conducted by an independent validator not associated with the laboratory.
The groundwater data will be compared to the MCL and other standards for the COCs. The minimum radionuclide detection activity for this project will be at or below 1.0 picoCuries per liter (pCi/L) for water samples. Table 8-3 lists MDLs and various regulatory standards that may be used for data evaluation.

Table 8-3
MDLs and Standards for Selected Analytes

Analyte	Method Detection Limit	Standard
Radionuclides		
Radium 226	<1.0 pCi/L	Combined Ra 226 and 228 = 5 pCi/L (MCL, GW)
Radium 228	<1.0 pCi/L	
Uranium (Total isotopes)	1.0 pCi/L	Total U = 30 µg/L (Groundwater/Surface Water Standard/MCL)
Metals		
Silver	0.01 mg/L	0.05 mg/L (GW)
Arsenic	0.01 mg/L	0.010 mg/L (MCL, GW)
Barium	0.1 mg/L	2 mg/L (MCL, GW)
Calcium	1.0 mg/L	No MCL, GW Established
Cadmium	0.005 mg/L	0.005 mg/L (MCL, GW)
Chromium	0.01 mg/L	0.1 mg/L (MCL, GW)
Mercury	0.0002 mg/L	0.002 mg/L (MCL, GW)
Potassium	1 mg/L	No MCL, GW Established
Magnesium	1 mg/L	No MCL, GW Established
Molybdenum	0.01 mg/L	No MCL, GW Established
Sodium	1 mg/L	No MCL, GW Established
Lead	0.003 mg/L	0.015 mg/L (AL); 0.05 mg/L (GW)
Selenium	0.005 mg/L	0.05 mg/L (MCL, GW)
Vanadium	0.01 mg/L	0.1 mg/L (GW Agric. Std.)
Uranium	0.01 mg/L	0.030 mg/L (MCL, GW)
Zinc	0.02 mg/L	5.0 mg/L (GW Drinking Water Std.); 2.0 mg/L (GW Agric. Std.)

ug/L – micrograms per liter
mg/L – milligrams per liter
pCi/L – picoCuries per liter
MCL = Maximum Contaminant Level, Colorado Primary Drinking Water Regulations
AL = Action Level, Colorado Primary Drinking Water Regulations
GW = Colorado Basic Standards For Ground Water Regulations

Data will be plotted on a Site map so as to depict the extent of the impacted water. Data validation documentation as well as data summaries will be presented in report form for ease of viewing and understanding.

Explanation

- ▲ Existing Monitor Well
- Abandoned then Replaced Monitor Well
- ✱ Proposed Alluvial Monitor Well
- ■ Proposed Bedrock Monitor Well
- ● Surface Water Sample Location
- Roads
- City Of Golden Property Line
- Flood Plain Characterization Area
- Soccer Field
- Wetlands

N
W E
S

Scale: 1" = 150'

0 75 150 300 Feet

Figure 8-1
Monitoring Well Location Map

CSMRI
Flood Plain Site Characterization
Work Plan

Stoller

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