Sampling and Analysis Plan for Site Reclamation and Surface Water, Groundwater, Biological, and Waste Rock Sampling

Willow Creek Watershed

Edited and Revised By:

Willow Creek Reclamation Committee
December 1999, April 2001, and May 2003

Sampling and Analysis Plan For Site Reclamation and Surface Water, Groundwater, Biological, and Waste Rock Sampling

Willow Creek Watershed

May 2003

The Willow Creek Reclamation Committee
P.O. Box 518
Creede, Colorado 81130
Phone: 719-658-0178

Edited and Revised By:

The Willow Creek Technical Advisory Committee in December 1999, April 2001, and May 2003.

Approval Signature Page

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May 6, 2003

I have read the above-referenced plan and provide my consent for the activities described in this plan to be performed under Clean Water Act grants provided to the Willow Creek Reclamation Committee. Members of the Willow Creek Reclamation Committee and the associated Technical Advisory Committee will administer and conduct all activities carried out under this Sampling and Analysis Plan. The Quality Assurance Project Manager for the project will be J.B. Alexander, retired chemical engineer and Chairman of the Technical Advisory Committee.

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Leigh Ann Vradenburg
(WCRC Coordinator)

Date

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Zeke Ward
(WCRC Chairman)

Date

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JB Alexander
(Quality Assurance Project Manager)

Date

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Kathleen Reilly
(Colorado Dept. of Public Health & Environment)

Date

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1.0 Introduction (Dated May 6, 2003)

This document presents the Sampling and Analysis Plan (SAP) for site reclamation, surface water monitoring, groundwater monitoring, and biological assessment activities to be conducted within the Willow Creek watershed, Mineral County, Colorado. This SAP is to be for all sampling activities conducted in our year 2003 reclamation activities at the following sites: Midwest Mine, Phoenix Mine, Phoenix Park Mill Site, Gormax Mine, and Park Regent Mine.

Monitoring and assessment activities will be performed by the Willow Creek Reclamation Committee (WCRC), a stakeholder group comprised of community, state, and federal agencies, and interested parties that are participating together in an effort to guide effective reclamation in the Willow Creek watershed. The WCRC is interested in developing an acceptable long-term program to provide consistent, measurable achievement of necessary site cleanup based on activities under their control or direction. Additional information concerning the WCRC's goals and objectives are contained at the Willow Creek Reclamation Committee's web site at http://www.willowcreede.org.

During the late 1800's, numerous mines were developed near the City of Creede, Colorado, to extract silver from the rich ore veins. These mines are located near both East and West Willow Creeks, which converge above Creede to form the mainstem of Willow Creek, a tributary of the Rio Grande River (Figure 1). Remnants from the mining activities, including draining mine adits, mill tailings, and waste rock, remain in both branches and the mainstem of Willow Creek. Prior to 1999, chemical and biological data for the Willow Creek watershed were limited both spatially and temporally, as discussed in the Preliminary Characterization Report (MFG, 1999a).

A three-year characterization project has resulted in an understanding of the nature and extent of pollution sources (above and below ground) and the potential for these contaminants to degrade water & ecological resources. From this information, plans will be designed that include appropriate remedial and restorative activities that remove, neutralize, or isolate pollution sources from interaction with the surface environment. These data will also be used as a baseline for monitoring the effectiveness of reclamation efforts.

This SAP describes site reclamation methodology and sampling procedures that will be conducted to provide additional data for the site characterization and effectiveness monitoring. The monitoring and assessment activities described in this SAP are designed to:

- Increase the understanding of metals loading in the Willow Creek watershed.
- Provide additional information regarding the influence of groundwater on metals concentrations in Willow Creek.
- Assess the effectiveness of Best Management Practices applied at selected mine and mill sites to reduce contamination and erosion.

This SAP is organized into separate sections that discuss the surface water monitoring, groundwater monitoring, biological monitoring, waste rock sampling, and site reclamation.

2.0 Surface Water Monitoring

Surface water sampling locations, sample collection procedures, and analytical parameters for the proposed surface water monitoring events are described in this section.

Surface water sampling events are conducted in conjunction with low-flow (fall) conditions, high-flow (spring) conditions and/or selected episodic storm events (e.g., those large enough to produce overland runoff), so as to provide seasonally relevant data consistent with our database. Our high-flow sampling coincided with the rising limb of the hydrograph and as close to high flow as is feasible. Surface water samples are also collected as deemed necessary by the Technical Advisory Committee to monitor changes in water quality during and/or after site remediation. These data are used to determine the effectiveness of remediation efforts in decreasing heavy metal and sediment inputs at the selected sites.

The surface water sampling schedule and locations are discussed in Section 2.1. Field data and sample collection procedures are presented in Section 2.2, and analytical parameters are described in Section 2.3. Any deviations from the defined procedures, due to field conditions or other factors, will be noted in the field logbook and presented to the QA/QC manager

2.1 Surface Water Monitoring Schedule and Locations

Based on the available data, metals concentrations in the Willow Creek watershed vary considerably under different flow regimes (MFG, 1999a). Therefore, surface water samples are collected during both low-flow (fall) and high flow (spring) conditions to help characterize metals loading in the watershed. Based on historical trends in flow rates and weather conditions, low-flow sampling is expected to occur in September and high-flow sampling is expected to occur in May or June.

Sampling locations include stations: (1) upstream and downstream of areas of BMP implementation; (2) at key points within these potential loading areas, including potential areas of groundwater influence; (3) at specific adit discharges, springs/seeps, or other tributary influences that may affect metals loading to the hydrologic system; and (4) at other locations in the watershed, when feasible, to maintain the database of water quality for the watershed (Table 1 and Figure 2). Additional samples are collected based on field reconnaissance during sampling, and if previously unobserved sources are found in investigative areas. Collection of additional samples is more likely during spring when small drainages may form ephemeral channels or when saturated conditions may cause the formation of seeps.

2.2 Sample Collection Procedures

Surface water field procedures consist of 1) stream-flow (discharge) measurements, 2) documentation of site conditions, 3) measurements of field water quality parameters, and 4) collection of water quality samples for laboratory analysis.

Unless otherwise dictated by field conditions or availability of sampling personnel, the

watershed is sampled from the most down-gradient site to the most up-gradient site to limit the potential for sample contamination and avoid biasing sample collection activities due to in-stream disturbances caused by sampling activities.

In the event of a significant precipitation event during either fall or spring collection efforts, sampling for that characterization event may be suspended until the effect of the precipitation, in particular increased stream-flow, and turbidity (sediment load) has decreased. However, opportunistic samples may be collected to characterize the effects of the precipitation event.

2.2.1 Discharge Measurements

Discharge measurements are performed in accordance with the procedures described in the National Handbook of Recommended Methods for Water Data Acquisition (USGS, 1977), to the extent practicable. Discharge is measured using one or more of three methods as dictated by stream-flow or channel characteristics. Depending on the stream channel characteristics and stream-flow rate, an area-velocity method, a portable flume, a volumetric method, or some combination of these methods, is used to obtain the stream discharge measurements. In cases where water depth is greater than 0.3 feet or the channel cross section is wide, flow generally is measured using the area-velocity method of stream-flow gauging as described in the above-referenced USGS Handbook. Using this method, the stream cross section is divided into a series of subsections where the average depth, average velocity, and width for the subsections are measured. Flow for the entire stream cross-section is computed using the formula:

$$Q = \sum (A_i * V_i)$$

Where: Q=Stream-flow in cubic feet per second (cfs)
A_i=Area of stream subsection in square feet
B_i=Velocity in feet per second

Subsection area is computed using the trapezoidal area method (USGS, 1977). Streams are spanned with a measuring tape and divided into a series of subsections. A top-setting wading rod is used to measure stream depths and to set the velocity sensor to the appropriate measurement depths. Velocity is measured using a Marsh-McBirney Model 2000 digital velocity meter with an electromagnetic sensor, or equivalent. In cases where stream depth is greater than or equal to 2.5 feet, velocity measurements taken at 0.2 and 0.8 stream depth is averaged to obtain the stream subsection average velocity. When stream depth is less than 2.5 feet, a single velocity measurement taken at 0.6 stream depth is used to estimate the average velocity through the subsection (USGS 1977). Measurements typically are made at sufficiently small intervals such that no more than 10% of the total stream flow occurs in any one subsection. Based on field calculations, smaller subsections are used if one subsection is greater than 10% of the flow (if this is possible depending on the size of the stream).

A portable cutthroat flume is used to gauge flow when low discharge and/or channel geometry preclude the use of a velocity meter. The flume has a throat width adjustable from 2 to 8 inches, which can be used to gauge flows from approximately 0.01 to 2.2 cfs. All water is routed

through the leveled flume, to the extent possible, after which the gauge height (to the nearest 0.01 foot), throat width, and leakage estimate (if any) is recorded. Discharge is calculated using these data and an equation that is specific to the flume size.

In cases where flows are too small or stream gradients are too great to be gauged using the area-velocity method or a cutthroat flume, measurements are made volumetrically using a calibrated collection container and a stopwatch. Stream-flow is routed through a PVC pipe and the time to fill a collection container to a known volume is measured. Several trials are executed for each volumetric measurement, and discharge is taken as an average of these trials. As with flume measurements, as estimate of any leakage around the routing pipe is recorded.

2.2.2 Surface Water Quality Sampling

Surface water quality samples are obtained in accordance with EPA Field Method Compendium FMC-SWSS-001 Surface Water Sampling (EPA, 1997). When a water quality sample is collected, site location and conditions, current and previous weather conditions, field personnel, and the sampling time and date are recorded on surface water field data sheets (Appendix A). Water quality samples are gathered in clean collection containers that have been supplied by the laboratory.

Surface water samples are analyzed for some or all of the parameters listed in Table 2, which include field parameters, general water quality parameters and filtered and unfiltered metals. For unfiltered samples, when possible, a water quality sample is composited from a series of at least four grab samples collected at approximately one-half water depth. These grab samples are taken at evenly spaced intervals across the stream cross section. If access to the stream is limited, such as may occur during high-flow conditions, a composite water sample may be collected from the water's surface near one or both banks. Filtered samples are pumped directly from the composite bucket into laboratory collection containers using a peristaltic pump and an in-line filter, or are removed from the bucket with a syringe and filtered through a disposable filter. After each filtration, the filters are changed and the tubing/syringe is decontaminated or replaced.

If a predetermined site (as identified by the preliminary reconnaissance) is changed or a new site is added, a stake or pole identifying the sampling station is placed at or near the sampling station for future identification of the location. Personnel record a brief description of the stake or pole location in relation to permanent landmark, and the sampling location in relation to the stake or pole.

2.2.2.1 Collection of Water Samples for Metals Analysis

As noted above, samples generally are collected from downstream to upstream locations to minimize the effect of sampling activities on the samples collected. Two metals samples are collected at each sample point: an unfiltered and a filtered sample. All samples for metals analyses are stored in either HDPE or LDPE sample containers that have been certified as clean by the laboratory (if possible). Sample containers and collection devices are rinsed three times with sample water before the sample is collected unless they have been pre-preserved. Bottle sizes, filtration, and preservation may change with the parameters analyzed and the lab used.

The following protocol is followed to collect surface water samples:

Prior to sample collection:

1. Label two 2-ounce bottles per station (this is according to the Riverwatch protocol) with the name of the river, sample number, date, and sample type (one each: "filtered" and "non filtered"). Write legibly with a permanent marker.

2. Check if a blank or duplicate should be measured today (refer to Quality Assurance Project Plan (QAPP), Appendix B). If so, label those bottles.

3. Put 12 drops of ultra-pure HNO_3 in each 2-ounce sample bottle (while wearing safety goggles). This is a Riverwatch protocol. This 1% acid solution increases the chance of contamination even from ultra-pure acid, but this amount of acid acts as a digestion for the sample and the metal concentration detected in the sample are "acid soluble" concentration. Because the samples are expected to have a low concentration of solids, we anticipate that the "acid soluble" concentration is comparable to standard total recoverable concentration. To evaluate this, approximately 5% (1 in 20) of the unfiltered metals samples may be split and sent to an outside laboratory for total recoverable metals analysis for the purpose of comparing the two methods.

If samples are to be filtered using the syringe/filter method, follow steps 4 through 7. If the samples are to be filtered using a peristaltic pump and in-line filter, skip to step 8.

4. Be careful to avoid introducing contamination into the bottles or filter. Powder free latex gloves are used at all times during filtration.

5. Place filter on holder and put holder together. Close tightly. The syringe and filter holder must be rinsed with ultra-pure HNO_3 acid rinse prior to each use, as described in Appendix A. Waste acid is disposed on site. The tubing and any other parts of this equipment that come into contact with the sample are replaced or decontaminated between samples.

6. Flush 120 mL of deionized water through the filter holder and syringe twice (240 mL). If filtering is difficult at this station, prepare two or more filter holders in this manner.

7. If an equipment blank is to be collected today, collect the equipment blank now. Remember that a blank is treated exactly as a stream sample except deionized or distilled water is used for the sample. As with a normal sample, prior to collection, be sure to flush 120 mL of deionized/distilled water through the syringe (and filter, if applicable). Remember to acid rinse after blank collection.

8. If a peristaltic pump and disposable filter are to be used to filter the samples, attach a length of tubing to a filter and insert the tubing into the pump head.

9. If an equipment blank is to be collected today, collect the equipment blank now. Remember that a blank is treated exactly as a stream sample except deionized or distilled water is used for the sample. Rinse the tubing and filter with approximately 100 mL of deionized/distilled water prior to collecting the sample.

In the field:

1. Choose a method for sample collection. Collect a composite sample by wading across the stream if you can; if not, obtain a grab sample from the bank in a representative part of the stream. The sample should be collected in an appropriately sized, decontaminated (with deionized/distilled water and acid rinse) bucket or other container. Always take the sample in representative flowing water upstream of your feet. If practical, take the sample upstream of any other in-stream activity to help ensure that the sample is representative.

2. Put on clean, powder-free gloves. Take care not to introduce contamination into the sample.

3. Flush equipment prior to sample collection. Flush the syringe (if using it for sample collection) twice with 60mL of deionized water (120 mL total). Rinse the syringe several times with stream water. Place filter holder on syringe. Run about 10 mL of river water through the filter. If you are using a pump, pump approximately 120 mL of stream water from the sample container through the tubing and the filter.

4. Collect the sample for analysis. If using the syringe/filter method, collect stream water from the sample container or dipper with the syringe. If using the pump, pump stream water directly from the sample container.

5. Open the "filtered" bottle and fill it with water from the syringe/filter or through the pump/filter tubing. Do not overfill. Fill to the neck of the bottle. If water does overspill, the acid to water ratio may not be appropriate. If you do overfill the bottle, see the note below. Close the bottle airtight when finished.

6. Place filtered sample in ice chest or keep refrigerated.

7. Open the "not filtered" bottle and fill it with the water from the collection container. Do not overfill the bottle. Fill it to the neck of the bottle. If water does overspill, the acid to water ratio may not be appropriate. If you do overfill the bottle, see the note below. Close the bottle airtight when finished.

8. Place unfiltered sample in ice chest or keep refrigerated.

Note: If the sample bottles are inadvertently overfilled, dump the water, rinse the bottle with sample water, put in 12 new drops of HNO_3, then refill the bottle.

2.2.2.2 Sample Collection for Non-Metals Laboratory Analysis

Immediately after samples for metals analysis have been obtained, the remaining laboratory samples are collected. All glass sample bottles should be filled to near the top, leaving a headspace approximately equal to the volume of liquid that would fill the bottle's cap. All plastic bottles should be filled completely. Samples may be collected from the sampling container using the peristaltic pump, syringe, or dipper.

1. Fill 250 mL plastic container with filtered, un-preserved sample water, cap tightly. This sample is for the analysis of chloride and sulfate. See "A" below.

2. Fill 250 mL glass container with filtered water, preserve with sulfuric acid, cap tightly. This sample is for the analysis of DOC.

3. Remove filter, fill 250 mL plastic bottle with unfiltered water, cap tightly. This sample is for the analysis of TDS and TSS. Alkalinity is measured in a field laboratory. Conductivity, pH, dissolved oxygen, and temperature are measured at each sample site, directly from the water body if possible.

4. Fill the 16-ounce bottle by pouring water from the bucket to the bottle (if you collected a composite), or fill the 16-ounce bottle by submerging it in the stream. Cap tightly. This sample is for the analysis of laboratory pH and alkalinity.

Immediately after sample collection, containers are labeled and placed in ice-cooled, insulated chests for storage pending delivery to the laboratory. Chain-of-custody forms are completed for all samples, signed by the appropriate personnel, and placed in each insulated chest.

A: Based on previous sampling in the Willow Creek drainage, nitrate concentrations are expected to be below the analytical detection limit; however, because nitrate may be an important constituent for the habitat model, nitrate+nitrite may be added to the analyte list for several select stations that coincide with biological monitoring points in order to provide confirmation of current conditions. The CDPHE also found TOC levels to be low in its previous study. Instead, dissolved organic carbon (DOC) is recommended for collection to assess the availability of dissolved carbon to bind metals.

Additional information regarding sample collection and shipment is provided in the QAPP, included as Appendix B.

2.2.2.3 Field Measurements

Temperature, pH, conductivity, dissolved oxygen may be measured in the field directly from the water body using portable meters. Alkalinity and hardness are measured immediately after sample collection using portable labs. All values are recorded on sampling forms. Methods for measuring pH and alkalinity are included in Appendices C and D, respectively.

2.3 Laboratory Analytical Parameters

Laboratory analytical parameters and anticipated detection limits for surface water samples are shown in Table 2. Detection limits may vary by lab and sample dilutions. Each surface water

sample may be analyzed in the laboratory for total dissolved solids (TDS), total suspended solids (TSS), dissolved organic carbon (DOC), alkalinity, chloride, sulfate, aluminum, calcium, magnesium, potassium, silica, and sodium. These parameters were selected to characterize general water quality and aid in the evaluation of metals loading. The surface water samples may also be analyzed for cadmium, copper, iron, lead, manganese, zinc, and arsenic. Both the total recoverable (unfiltered) and dissolved (filtered) fraction may be analyzed for each metal. These metals were selected based on previous site data, which are summarized in the Preliminary Characterization Report (MFG, 1999a). Parameters to be analyzed during a particular sampling event may be reduced or expanded based on funding and/or sampling objectives. Additional information concerning the analytical methods, sample containers, and preservation requirements, is provided in the QAPP (Appendix B).

Chromium and silver were not included in the analyte list because they were not detected in any samples previously obtained from the Willow Creek drainage. The same is true for total organic carbon (TOC).

3.0 Groundwater Monitoring

This section describes monitoring well locations and installation procedures, sample collection procedures, and analytical parameters for the groundwater monitoring events. Groundwater sampling events are conducted during the low-flow (fall) and high-flow (spring) surface water sampling events. Additional groundwater samples may be collected as deemed necessary by the Technical Advisory Committee to document or monitor changes in groundwater associated with reclamation activities. Monitoring well locations and installation procedures are described in Section 3.1, field data and sample collection procedures are presented in Section 3.2, and analytical parameters are presented in Section 3.3. Any deviations from the defined procedures, due to field conditions or other factors, are noted in the field logbook and presented to the QA/QC manager

3.1 Monitoring Well Locations and Installation Procedures

MW-1-MW-3

Prior to the 1999 low-flow sampling event, three shallow monitoring wells (MW-1,2,3) were installed in the Willow Creek floodplain downstream of the town of Creede, near the confluence of the Willow Creek and Rio Grand drainages. The wells were installed in the upper saturated portion of the alluvial aquifer. The approximate locations of these wells are shown on Figure 3.

The borings were drilled using 5" Odex drilling system (air percussion drilling through advancing casing) to the depth of the alluvial aquifer. Soil samples were collected in a minimum of 10' increments using a 2" split spoon sampler, or as dictated by field conditions, for the purpose of stratigraphic logging. Supervision of the drilling and borehole logging was conducted in accordance with the procedures outlined in MFG SOP No.1: Supervision of Exploratory Borings (Appendix E). Monitoring wells were constructed of 2" inside diameter, Schedule 40, flush-joint threaded PVC pipe. No solvents, glues, or cements were applied to the casing joints during construction of the wells. The screened portion of each monitoring well consisteded of 0.020" factory slotted PVC with a threaded end plug (sediment cap). All well screen and blank riser casing came from the same manufacturer and was pre-cleaned and individually pre-wrapped in plastic to ensure that all materials were contaminant-free and appropriate for collection of environmental samples. The annular space around the screened interval was packed with 10/20, washed filter sand to a depth of 2-3' above the top of the screen and then covered with a minimum 3' bentonite-pellet seal. The bentonite-pellet seal was hydrated using either distilled water or potable water from Creede. A 6' long protective steel casing, extending approximately 3' above the ground surface, was installed around the PVC casing and fitted with a locking cap. General procedures for monitoring well installations are outlined in MFG SOP No. 2: Installation of Monitoring Wells and Piezometers (Appendix E).

Monitoring wells were developed by alternately surging and bailing or pumping the well until the casing was reasonably free of fine sediments. At least 24 hours passed between completion of grouting the well and well development. Field parameters (pH, temperature, and specific conductance) were monitored during development, and were allowed to stabilize as an indication that well development was complete. At least 5 casing volumes of water were purged from each well. Details of the well development procedures are outlined in MFG SOP No. 3:

Monitoring Well Development (Appendix E).

MW-5,6,7,8,9,10,11,12,13,14,15; EW-1,2; NCC-1,2

In 2001, fifteen wells were installed in the floodplain below town (11 wells with prefix MW), below the Solomon Mine waste piles (2 wells with prefix EW), and near the Midwest Mine waste piles (2 wells with the prefix NCC) (Figures 3 and 4). Drilling and installation was directed by URS Corporation, and notes regarding these procedures were courtesy of their on-site scientists. Wells were installed between September 18 and 21, 2001, by ESN of Golden, Colorado. Borings were drilled using a Thunderprobe hydraulic direct push drill rig with a vibrating advance hammer. This technique did not permit collection of geologic bore descriptions. Wells were constructed of 1" S-40 PVC casing within a 2.25" diameter boring, and the screened portion consisted of 5-10' of 0.01" slotted PVC. The space around the casing was filled with natural formation that caved in during construction. The formation was topped with bentonite chips, and a steel casing was placed around the top of the well. The steel casing was secured with a concrete surface seal and topped with a locking cap.

MW-16,17,18,19,20

In 2002, five wells were installed in the Willow Creek floodplain below Creede by the United States Army Corps of Engineers. The decision on the depth of the screens was made in the field and based on current and historic water table elevation. Drilling was accomplished using 4¼-in ID hollow-stem augers with a continuous sample barrel. Conditions dictated switching to 6 1/4-inch ID hollow-stem augers with a continuous sample barrel. The field geologist noted in the field logbook soil characteristics, when changes in soil type occurred, and when groundwater was first encountered in order to prepare lithologic logs of each borehole.

A 1-foot thick layer of 20-40 Colorado Silica sand was poured into the borehole prior to casing placement (1-foot padding). Well casing consisted of 2-inch nominal diameter PVC pipe. The well screens were continuous slot, wire wound, non-clogging type screen, and were 10 feet in length. The boring was sufficiently deep to accommodate the 1-foot padding, 10 feet of screen, and at a minimum, 7 feet of solid PVC casing below ground surface (bgs). The well screen was sealed at the bottom with a solid cap. Solid casing attached to the top of the screen was of sufficient length to extend approximately 3 ft above the ground surface. Casing components attached via flush threaded joints, or PVC collars, without the use of glues.

Well completion following casing placement consisted of installing the filter pack, bentonite pellet plug, grout seal, and protective steel casing with locking cap. The filter pack, and bentonite seal, were placed by pouring down the annular space between the augers and well casing. The remaining annular space was grouted to the surface. The top of the filter pack was approximately 2 feet above the top of the well screen. A 2-foot thick bentonite plug was placed above the filter pack using 3/8-inch bentonite pellets. The pellets were allowed to hydrate for 2 hours before sealing the well with grout. The well was filled with enough grout (cement with 2% - 5% bentonite by volume) to fill the annular space surrounding the well casing to the ground surface. A 4-inch square by 5-foot long steel protective casing equipped with locking cap was placed into the grout to a depth of approximately 2 feet bgs. Due to concerns over the potential for frost heave, a well pad was constructed using crushed gravel. The well pad was approximately 4 feet in diameter, up to 3-inches thick adjacent to the well, and gently sloped away from the well.

3.2 Sample Collection Procedures

Each groundwater monitoring well is sampled to semi-annually (near each surface water sampling event, if possible). Groundwater field procedures consist of water level measurements, measurements of field water quality parameters, and collection of samples for laboratory analyses. Before collecting a groundwater sample, the well number, current and previous weather conditions, field personnel and the sampling date and time were recorded on the Groundwater Sampling Record (Appendix A). Listed below are general preparatory steps followed by subsections on specific measurements and analyses.

1. Minimize likelihood of contamination not laying sampling equipment on the ground.

2. Remove locking well cap, note location, time of day, and date on well sampling sheet.

3. Remove well casing cap.

3.2.1 Water Level Measurements

Prior to sample collection, the depth to water in each well is measured and recorded on the Groundwater Level Monitoring Record (Appendix A). A measuring point is marked on the top of each well casing. The water level measurements are made from the designated measuring points with an electronic water-level instrument. Both depth to water and total well depth are measured. All water-level measurements are recorded to the nearest 0.01 foot. The volume of water in each monitoring well is calculated based on the depth to water, total depth, and diameter of the well.

3.2.2 Well Purging and Field Measurements

Three to five well volumes are purged from each well prior to the collection of samples. Wells are purged and sampled using a disposable PVC bailer or other suitable apparatus, depending on the rate of yield from each well and sediment load in the purge water. Temperature, pH, and conductivity are monitored during the purging process and recorded on the Record. Protocols for the measurements of field parameters are provided in Appendix C. Groundwater samples are not collected until these parameters have stabilized (e.g. +/- 10%), and a minimum of three well volumes have been removed from each well. If the well yield from any well is low and the well is purged dry, the well is allowed to recover for up to 24 hours. If the well does not recover within a 24-hour period, the three volume minimum requirement is waived and the well is sampled using the second purged volume.

All groundwater sampling equipment (e.g., bailers, bailer cord, pump tubing) that comes in contact with a groundwater sample is either disposable or dedicated equipment which is only used at one sampling location to prevent cross-contamination. Possible parameters to be analyzed in the laboratory are listed in Table 2 and discussed below.

3.2.3 Sample Collection for Laboratory Metals Analysis

Sampling is planned to collect groundwater samples from wells known or suspected to contain the lowest concentrations of trace metals first, finishing with the groundwater samples known or suspected to contain the highest concentrations. In the event of field conditions, such as wind or rain, that might compromise the integrity of the filtered sample, unfiltered and unpreserved water is collected and delivered to the laboratory within 24 hours for the appropriate processing. Otherwise, the following protocol should be followed to collect groundwater samples.

Prior to sample collection:

1. Label one 2-ounce bottles per well with the name of the well, sample number, date, time, and sample type ("filtered"). Write legibly with a permanent marker.

2. Check if a blank or duplicate should be measured today (refer to Quality Assurance Project Plan (QAPP), Appendix B). If so, label those bottles.

3. Put 12 drops of ultra-pure HNO3 in each 2-ounce sample bottle (while wearing safety goggles).

If samples are to be filtered using the syringe/filter method, follow steps 4 through 7. If the samples are to be filtered using a peristaltic pump and in-line filter, skip to step 8.

4. Be careful to avoid introducing contamination into the bottles or filter. Powder free latex gloves will be used at all times during sampling.

5. Place filter on holder and put holder together. Close tightly. The syringe and filter holder must be rinsed with ultra-pure HNO_3 acid rinse prior to each use, as described in Appendix A. Waste acid will be disposed on site. The tubing and any other parts of this equipment that come into contact with the sample will be replaced or decontaminated between samples.

6. Flush 120 mL of deionized water through the filter holder and syringe twice (240 mL). If filtering is difficult at this station, prepare two or more filter holders in this manner.

7. If an equipment blank is to be collected today, collect the equipment blank now. Remember that a blank is treated exactly as a well sample, except deionized or distilled water is used for the sample. As with a normal sample, prior to collection, be sure to flush 120 mL of deionized/distilled water through the syringe (and filter, if applicable). Remember to acid rinse after blank collection.

8. If a peristaltic pump and disposable filter are to be used to filter the samples, attach a length of tubing to a filter and insert the tubing into the pump head.

9. If an equipment blank is to be collected today, collect the equipment blank now. Remember that a blank is treated exactly as a well sample except deionized or distilled water is used for the sample. Rinse the tubing and filter with approximately 100 mL of deionized/distilled water prior to collecting the sample.

In the field:

1. Attach a nylon line to a clean, decontaminated bailer or attach clean tubing to the pump.

2. Lower the bailer or end of pump tubing slowly and gently into the well, taking care not to shake the casing sides or to splash the bailer or tubing into the water. Stop lowering at a point adjacent to the screen.

3. Allow bailer to fill and then slowly and gently retrieve the bailer from the well, avoiding contact with the casing, so as not to knock precipitates or other foreign materials into the bailer. If using a pump, begin pumping water from the well.

4. Based on well volume calculations and field parameters, bail or pump at least three well volumes.

5. Remove the cap from the sample container and place it in a location where it will not become contaminated.

6. If using a bailer, slowly pour water from the bailer into a clean sample container. Flush syringe twice with 60 mL of deionized water (120 mL total). Rinse the syringe with water several times from the sample bucket. Fill the syringe with sample water. Place filter holder on syringe. Run about 10 mL of sample water through the syringe and filter holder.

7. If using a pump, attach filter to tubing, and allow at least 10 mL of water to pass through the filter.

8. Open the "filtered" bottle and fill it with water from the syringe or the tubing, holding the filter correctly. Do not overfill. Fill to the neck of the bottle. If water does overspill, the acid to water ratio may not be appropriate. If you do overfill the bottle, see the note below. Close the bottle airtight when finished.

9. Place filtered sample in ice chest or keep refrigerated.

Note: If the sample bottles are inadvertently overfilled, dump the water, rinse the bottle with sample water, put in 12 new drops of HNO3, refill the syringe with fresh sample water, then fill the bottle.

3.2.4 Sample Collection for Non-Metals Laboratory Analysis

Immediately after samples for metals analysis have been obtained, the remaining laboratory samples will be collected. These samples will be collected following the procedure outlined in EPA's Field Methods Compendium, Method GWS-001-1: Groundwater Well Sampling (EPA 1997). All glass sample bottles should be filled to near the top, leaving a headspace approximately equal to the volume of liquid that would fill the bottle's cap. All plastic bottles should be filled

completely.

1. Fill 250 mL plastic container with filtered, un-preserved sample water, cap tightly. This sample is for the analysis of chloride and sulfate.

2. Fill 250 mL glass container with filtered water, preserve with sulfuric acid, cap tightly. This sample is for the analysis of DOC.

3. Remove filter, fill 250 mL plastic bottle with unfiltered water, cap tightly. This sample is for the analysis of TDS.

4. Fill the 16-ounce bottle with unfiltered water. Cap tightly. This sample is for the analysis of laboratory pH and alkalinity.

Immediately after sample collection, containers are labeled and placed in ice-cooled, insulated chests for storage pending delivery to the laboratory. Chain-of-custody forms are completed for all samples, signed by the appropriate personnel, and placed in each insulated chest. Additional information regarding sample collection and shipment is provided in the QAPP, included as Appendix B.

3.3 Laboratory Analytical Parameters

Groundwater samples will be analyzed for the same laboratory analytical parameters as the surface water samples, with the exception of unfiltered metals and TSS. These parameters and anticipated detection limits are shown in Table 2. Each groundwater sample may be analyzed in the laboratory for TDS, DOC, alkalinity, chloride, sulfate, aluminum, calcium, magnesium, potassium, silica, sodium, cadmium, copper, iron, lead, manganese, and zinc. For the metals, only dissolved (filtered) fractions will be analyzed. Additional details concerning the analytical methods are provided in the QAPP (Appendix B).

4.0 Biological Assessment

Biological assessment of the Willow Creek watershed consists of several components, including evaluations of the fish community, benthic macroinvertebrate community, instream habitat characteristics, riparian habitat characteristics, and upland habitat characteristics. All of these components are necessary in assessing the aquatic community and the factors that may potentially be affecting those communities. This assessment is not intended to serve as an inventory of all of the available habitat types. Rather, it is designed to provide a sampling of the representative locations downstream of mine and mill sites that may be impacted by those sites. Such an assessment provides the necessary information to establish a baseline condition for the watershed that will allow for future reclamation effectiveness monitoring.

The following sampling and analysis procedures are followed for the purpose of this biological assessment and any deviations from the defined procedures, due to field conditions or other factors, will be noted in the field logbook and presented to the QA/QC manager. Experienced field team personnel are required for the bulk of this effort because some of the measurements made are subjective and require training and experience to make the assessments. Local volunteers are asked to participate in the biological assessment as appropriate.

Methods identified in USEPA's Revised Rapid Bioassessment Protocols for Use in Streams and Rivers (Barbour et al., 1997) provide the baseline of protocols for collecting fish, benthic macroinvertebrates, and instream physical habitat assessments. These methods are used to ensure that at a minimum: 1) consistent data are collected from year to year; and 2) data collected from year to year are comparable. Additional data are collected to satisfy the requirement of specific estimation procedures, including fish population estimates (e.g. Zippen removal, as presented in Platts et. al., 1983, and/or Habitat Quality Index (HQI) (Binns and Eiserman, 1979)).

4.1 Sampling Locations and Frequency

Sampling locations for the biological assessment consist of stream reaches that overlap water quality sampling locations and provide information about the stream relative to potential sources or source areas. Reaches overlap one or more water quality sampling locations. Possible sampling locations are presented in Table 3. Sampling frequency is dependent upon available funding and as deemed necessary by the Technical Advisory Committee to document or monitor changes associated with reclamation activities.

4.2 Field Methods

The field methods used to evaluate aquatic habitat, fish population, benthic macroinvertebrates, riparian habitat and upland habitat are described in this section.

4.2.1 Aquatic Habitat

The habitat assessment is conducted using the Rapid Bioassessment Protocol (RBP) methods described in Barbour et al. (1997):

1. The field team will conduct a pre-bioassessment reconnaissance of the watershed to

mark reach location, which will be done during or immediately following the period of the surface water quality sampling.

2. A stream reach will be equal to 40 times the stream width and be located in an area that has the best mixture of available habitat such as runs, riffles, and pools as well as include at least one water quality and slow sampling site. Each reach will be marked (e.g. marked at the upstream and downstream limits with flagging tape and located by GPS coordinates).

3. Habitat data will be recorded on the scoring form developed by Barbour et al. (1997) (Appendix F). The following 12 physical habitat parameters will be evaluated:
   - Epifaunal substrate/ instream cover
   - Embeddedness
   - Pool substrate
   - Velocity/depth
   - Sediment deposition
   - Channel flow status
   - Channel alteration
   - Frequency of riffles
   - Channel sinuosity
   - Bank stability
   - Bank vegetative protection
   - Riparian zone vegetative width

4. Stream discharge will be measured at each of the surface water sampling locations, as described in the previous section of the SAP. At each instream discharge measurement site, an estimate of the substrate size class for the dominant and subdominant substrate type will be made. This estimate is done at each vertical velocity measurement point along the width of the stream. Size classifications will be done according to ocular estimates within the size classes described for the Wentworth scale.

Additional observations are conducted to satisfy the requirements of the HQI model, and the Stream Reach Inventory/ Channel Stability Index (SRI/CSI) (Pfankuch, 1975) for each reach. Sample forms are included in Appendix G.

4.2.2 Fish

Electrofishing methods are employed to assess fish numbers and composition at each sample location. Fishing is done within each selected sample reach prior to other assessments and following the water quality sampling. Sufficient sampling is conducted to satisfy the requirements of the RBP's and the HQI models for assessing fish community integrity as well as making a determination of fish population abundance such as that described in Platts et al. (1983). A scientific collection permit is presently held by participating USFWS biologists and any additional fish collection personnel are included on the permit. A summary of the methods follows:

1. Fishing will be done from downstream to upstream through the sample reach using a two-pass removal method.

2. Shocking times will be recorded to the nearest second.

3. The field team will move in a zigzag motion up the stream, being sure to sweep the probes from side to side of the wetted channel as well as under any debris that may harbor fish.

4. Fish will be collected using dip nets as they are rendered immobile. Netted fish will be placed in buckets. All collected fish will be placed into an aerated bucket for holding until the necessary measurements can be completed.

5. A minimum of three persons will be required for the shocking effort (one carrying the backpack unit and two netters) while additional personnel will be required to weigh, measure, and record fish species collected.

6. Collected fish will be identified to the lowest possible level in the field. Voucher specimens will be collected for each species and kept as part of the reference collection for the watershed. Any unidentifiable species will also be preserved for identification.

7. All fish collected will be weighed to the nearest gram and length measured to the nearest millimeter. Physical condition will be observed and recorded on the fish log sheet. A sample fish collection log sheet is included in Appendix H.

4.2.3 Benthic Macroinvertebrates

Benthic macroinvertebrates are collected from each sample reach using a kick net and defined grid area (0.5 m) according to the methods defined in USEPA's *Macroinvertebrate Field and Laboratory Methods for Evaluating the Biological Integrity of Surface Waters* (Klemm et al., 1990) and Barbour et al. (1997). The multiple habitat approach described in Barbour et al. (1997) will be used according to the following procedures:

1. Habitats within the reach will be sampled based on their proportional abundance within a reach. For example, an estimate of the percent abundance of each habitat type will be made and the number of samples collected from each of these habitats will be proportional to the percent abundance. Pools, riffles, and microhabitats (snags, overhanging vegetation, etc. will be sampled. These habitats will be identified by the following characteristics:

    - Pools are identified as the portion of stream with reduced current velocity, often with water deeper than surrounding areas. They tend to be depositional areas.
    - Riffles are identified as the portion of the stream with shallow rapids where water flows over completely and partially submerged obstructions to

produce surface agitation. They may be erosional habitats, depending upon the bank condition and bottom substrate.

- Microhabitats are seeps, backwaters, wood, bedrock surfaces, leaf packs, algal mats, macrophyte beds, moss, etc.

2. Twenty "kicks" will be used to sample the habitats and the number of kicks will be proportional to the relative abundance of the habitat types. Each kick will be a one-minute effort using a bottom aquatic kick net with a maximum mesh size of 500 um.

3. "Kicking" will be accomplished by vigorously disturbing the substrate (either with the feet or hands) to dislodge insects. The net will be positioned downstream but immediately adjacent to the disturbed area, allowing the flow of water to carry the dislodged insects into the net. Alternatively, in habitats with reduced flow, dislodged organisms will be collected by sweeping the net through the water column.

4. Each collected sample will be composited into a water-filled bucket, until all samples from within the reach have been collected.

5. Large debris will be removed from the sample and inspected for attached insets before the debris is discarded.

6. One-third of the composite sample will be filtered through a 500um sieve. The bucket will be rinsed and inspected to insure that all organisms have been removed.

7. The sieved contents will be placed into a sample container and preserved with 70-80% ethanol. If necessary, soft-bodied forms will be fixed with 10% formalin prior to preservation.

8. The remaining two-thirds will follow the same procedure outlined above with each third becoming a sub-sample for a total of three sub-samples per reach.

9. Each sample container will have two labels, one written in pencil placed inside the container, and the other attached to the outside of the container. The following minimum information should be on each label:

    - Sample number, waterbody name, site location, sample date, habitat type/ sample type, and the collector's name

10. Samples will be kept cool for return to the laboratory and stored in a cool, dry, and location until analysis of the samples can begin. Sample forms for the benthic macro-invertebrate collection effort are presented in Appendix I. Benthic samples will be analyzed by a qualified taxonomist contracted by the WCRC.

4.2.4 Riparian Habitat

Riparian functions and conditions can have large effects on the aquatic community; therefore, the quality and quantity of riparian habitat available will be assessed. Platts et al. (1987) provides detailed methods for the assessment of riparian condition relative to the stream and its valley. These methods will be used to assess riparian conditions in the Willow Creek watershed. Because several of the measurements defined in Platts et al. (1987) overlap those for the aquatic habitat assessment, only those additional measures necessary for the riparian assessment will be conducted.

4.2.5 Upland Habitat

Observations made by a qualified upland range biologist may be made on the community compositions of upland plant species within the vicinity of the biological sampling sites. These assessments may be made based on observations of the dominant and subdominant herbaceous, woody shrub, and tree species.

4.3 Laboratory Analysis

Laboratory analyses associated with the bioassessment are only required for benthic macroinvertebrate samples. All materials from each subsample are sorted, and organisms removed from the material. Taxa are identified to the lowest possible level and a running tally of the numbers of each taxa will be made for each subsample from each reach. The following minimum levels of identifications are expected to be achieved:

- Insects- genus, species if possible
- Mollusca- family
- Annelida- class, family if possible
- Turbellaria- order
- Nematoda- phylum
- Cladocera, Copepoda, Ostracoda- order
- Isopoda, Amphipoda, Decapoda- lowest level possible
- Other Taxonomic Groups- lowest level possible

5.0 Waste Rock Sampling

This SAP is for Phase I screening of waste rock piles, tailings, and floodplain sediment in the Willow Creek drainage. A rigorous statistical resolution of contamination levels or of core drilling of the tailing piles is not presently included in the protocol. The purpose of Phase I is to narrow down the areas of concern and areas of highest priority for more extensive examination. Future detailed analyses, if necessary, may be addressed by an update to this SAP.

The purpose of this SAP is to describe the equipment and operations used for sampling surface and shallow depth soils. The objective is to ascertain the type, degree, and extent of soil contamination at a site according to a first pass low resolution and narrowing down of priority areas. The data can then be used to evaluate potential threats to human health or the environment, to evaluate potential exposure pathways, or to calculate environmental risks and allow the Willow Creek Reclamation Committee (WCRC) to focus on areas of highest concern.

This SAP outlines methods for soil sampling with routine field operations on WCRC projects. Site-specific deviations from the methods presented herein must be approved by the WCRC Technical Advisory Committee (TAC) and/or noted on datasheets for presentation to the QAQC manager. The project leader at the field site checks all exhibits and field log books for completeness and accuracy. Any discrepancies are noted and the documents are returned to the originator for correction. Each sampling includes the appropriate number of samples for statistical analysis, duplicate samples, and blanks.

Soil samples gathered in accordance with this SAP are analyzed for concentrations of lead, arsenic, cadmium, and zinc by Trace ICP according to the procedures in SW-846, 3rd edition, Method Number 6010B. Soil sample digestion is by method 3050B.

5.1 Source Area Sample Site Locations

Lack of homogeneity in sampling is the single biggest source of error in sampling waste dumps and is called the fundamental error. This concept is important and could have large impacts on remediation options related to both expense and procedure. Because the mine waste rock piles, tailing, and floodplain sediment areas (i.e. potential source areas) are relatively large and diverse, each of the areas is separated into homogeneous units as described below. General location maps of the potential sampling areas are presented in Appendix J.

Although it is likely that in many cases what is seen on the surface is similar to how it is at depth within the parent material, it is reasonable to expect that the material may also change dramatically with depth. To provide a screening level evaluation of the areas, each of the potential source areas is separated and mapped by rough units of general surface homogeneity by viewing features such as color, texture, and other surface features that may indicate similar material. In addition, aerial photography, if available, may be used to identify the homogeneous units within these potential source areas. Based on the visual observations, a sketch map of the homogeneous units is developed for each of the potential source areas. Each homogeneous unit is then sampled in accordance with Section 5.2.

5.2 Sample Collection

Once the homogeneous units within each potential source area are identified and mapped, three different types of samples are collected within each homogeneous unit. The samples to be collected include:

- Surface composite samples representative of each homogeneous unit,
- Surface samples within each homogeneous unit, and
- Depth samples within each potential source area.

Surface Composite Samples: At each homogeneous unit identified within a potential source area (waste pile, tailing, floodplain sediment), a total of thirty (30) random surface (0-4 inches) samples will be gathered. A smaller number of samples may be collected based on unit size or field conditions. These samples are located such that they provide a representative composite of the homogeneous unit. At each location, a plastic cup or clean trowel (See Section 5.8) is used to scoop a surface sample into a designated large (e.g. Gallon size) Ziploc bag for the composite sample. Once the surface samples have been gathered into the composited Ziploc bag, it is double bagged and labeled to indicate the location, date, sampler's initials, and remarks, if any.

Surface Samples: In addition to the composite sample described above, at five (5) of the thirty locations used for a composite in each homogeneous unit, an additional surface sample may be gathered. These five locations are representative of the homogeneous unit. At each location, a plastic cup or decontaminated trowel (See Section 5.8) is used to scoop the surface sample into a new designated large (e.g. Gallon size) Ziploc bag. Once the surface samples have been gathered, each is double bagged and labeled to indicate the location, date, sampler's initials, and remarks, if any.

Depth Samples: At each potential source area (i.e. waste pile, tailing, and floodplain sediment), one depth sample is gathered. Each depth sample is obtained by digging into the pile area with a clean shovel (See Section 5.8). The location of the depth sample is such that it best represents the source area based on field visual observations. The target depth for each sample is four (4) feet, depending on the percent slope, soil texture conditions. Care is taken to ensure that the upper materials do not contaminate the material to be sampled at depth. The depth sample is then placed in a new Ziploc bag. Once the depth samples have been gathered, each is double bagged and labeled to indicate the location, date, sampler's initials, and remarks, if any.

5.3 Field Paste pH and Conductivity

For each soil sample gathered as described above, a field paste pH and conductivity analysis is performed. The analysis is performed according to the Robertson Geoconsultants Inc. Method, as presented in Appendix K. Results of the analysis are recorded on the field data sheet provided in Appendix K.

5.4 Laboratory Analysis

In addition to the field paste pH and conductivity analysis, each of the soil samples gathered is packaged, labeled, and shipped (See Sections 6.0 and 7.0) to a designated laboratory for the following analysis:

- Leaching/Water Extraction for Metals Analysis (EPA Method ASA No.9, 10-2.3.2)
- Acidity as $CaCO_3$ (EPA Method M2310B).

The leaching/water extraction analysis is modified to a 2:1 liquid to solid ratio in accordance with a typical field analysis approach recommended by the State of Colorado's Department of Minerals and Geology. The metals analysis to be run includes arsenic, cadmium, copper, lead, and zinc.

Based on the laboratory results from the water extractions, several sites may be selected that have high levels of one or more water-extractable metals. These samples are further analyzed (if the storage date has not been exceeded), or the sites are re-sampled by the methods described above. Samples are analyzed using the Toxicity Characteristic Leaching Procedure (TCLP). Metals evaluated with TCLP are arsenic (As), barium (Ba), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), mercury (Hg), selenium (Se), silver (Ag), and zinc (Zn).

5.5 Recording and Sample Labeling

During the sampling activities a current field book is utilized to record the field conditions and sampling activities. At a minimum, the field book includes:

Date and Time:	i.e. September 21, 2001 @ 3:00pm
Sample Location:	i.e. Outlet Waste Rock Pile – Homogeneous Unit #3 as shown on map
Remarks:	i.e. Weather, soil color, coarseness, sample depth, tests performed and/or to be performed, and other miscellaneous observations.
Analysis:	i.e. Paste pH and conductivity

Samples gathered are labeled with the following information:

Name:	i.e., Willow Creek Reclamation Committee
Phone:	i.e. 719-658-0178
Project Name:	i.e. Waste Pile Characterization
Sample Site Name:	i.e. Outlet Mine – Unit #3
Date:	i.e. September 21, 2001 or 09/21/01
Time:	i.e. 3:00pm or 1500
Sample Depth:	3-inches
Collected By:	John and Jane Doe

5.6 Sample Shipment

The following steps are performed to ensure proper shipment of the samples gathered as part of this SAP.

- Make sure all samples are double bagged, tightly closed, taped and labeled correctly.
- Place samples in cooler or appropriate container. Pack the empty space of each cooler with packing paper or equivalent so the samples are not tossed around during shipment.
- Fill out properly and enclose a chain of custody form, one for each cooler. Place the form in a sealed Ziploc bag within the cooler. The samples are not valid without a chain of custody form.
- Close and secure each cooler with strapping tape to prevent tampering during shipment.
- Place the proper mailing label(s) on each cooler and ship to designated laboratory for analysis.

5.7 Equipment

The following equipment is required to perform the sampling described in this SAP.

- Soil samples are collected in new Ziploc bags with the use of new plastic cups, bowls, and knives.
- Permanent markers, plastic bottles, and paper towels.
- pH and Conductivity Meter with electrolyte and buffer solutions for calibration.
- DI (de-ionized) water.

5.8 Decontamination Procedure

Prior to sampling, equipment is washed in an Alconox soap solution, rinsed in de-ionized (DI) water, and placed in a new Ziploc bag or equivalent. The procedure for making Alconox soap solution is as follows:

- Put 2 packets of Alconox in a 1 gallon jug filled about 75% full of preferably warm water and shake well – use safety goggles and nitrile gloves when washing with or making this solution.

5.9 Laboratory Quality Control

The laboratory will meet standard quality control protocols, including method blank and blank spike analysis, matrix spike and duplicate analyses, calibration verifications and calibration blanks. All quality control sample results shall be within acceptable criteria in order for the data to be considered accurate and precise to the degree expected by the standard test method used. All discrepancies will be reported by the laboratory.

5.10 Data Quality Objectives

The soil samples are being collected and analyzed to evaluate the impacts, if any, of historic mining activities on surface soils at the site, including metals-containing materials (e.g., tailings transported by water, wind, or direct placement. Additional deeper samples should be collected if different conditions are expected. Based on these data, decisions must be made regarding the need to remediate soils at the site. This will require data that are accurate and precise to the levels expected by standard test methods, complete in coverage, and representative of the soils in question. The concentrations at each location, or a statistical representation of average conditions (e.g., the 95% upper confidence limit of the mean) can then be compared to the appropriate screening or cleanup standard for the site. Generally, data that do not meet the established acceptance criteria are cause for re-sampling and re-analysis. However, in some cases, data that do not meet acceptance criteria are usable with specified limitations. Data that are indicated as usable with limitations will be clearly noted.

5.11 Data Reporting

The results of the sampling and analysis program will be reported to Colorado Department of Public Health and Environment (CDPHE) including a description of sampling locations and procedures, a discussion of any deviations from this SAP, a summary of the data, a location map, and a discussion of data quality. The complete laboratory analytical report, including quality control test results, will be attached.

6.0 Site Reclamation

Four abandoned mine sites and one mill site have been selected for clean-up activities beginning in 2003. The sites (Gormax Mine, Phoenix Mine, Phoenix Park Mill, Midwest Mine, and Park Regent Mine) were selected because they are potential sources of non-point loading to Willow Creek and/or its tributaries. Maps of the sampling sites are attached as Appendix L. Voluntary cooperation has been established with the owners and agencies involved with these sites. These sites are not major contributors of metals to Willow Creek, but reclamation will be straightforward. Activities should result in measurable improvements to water and habitat quality by decreasing run-on/run-off and erosion. The following methods will be used to compliment the ongoing water, sediment, and biological sampling in the watershed. All sampling efforts will serve to document and/or quantify changes at each site and to evaluate the effectiveness of reclamation activities in decreasing sediment and heavy metal mobilization and in establishing vegetation.

6.1 Photopoint Documentation

Methodologies for collection of photopoints are modified from the Bureau of Land Management (Hindley, 1996). At each of the reclamation sites, at least 10 photopoints will be established to provide a visual accompaniment to quantitative and qualitative descriptions of changes. These series of repeated photos will be used to evaluate the rate, nature, and direction of change of the vegetation and other site characteristics.

6.1.1 Establishing a Photopoint

Photopoints will be established in sites that can be repeated; this means that they will be accessible regardless of seasonal limitations and that they will not be substantially modified by filling or digging during reclamation activities. All photopoints at a given site will be mapped and given unique numbers. Individual photopoints with be marked with a stake labeled with the site number. If possible, GPS locations will be obtained for stake positions. When practical, the pictures will include large or permanent features that will not be altered by the reclamation activities. This will allow for more precise positioning in future photographs. At each site, the photographer will completely fill out a Photopoint Datasheet (Appendix M). Photos will be taken with a digital camera to ensure collection of a good photo and so that all photos can be easily labeled and stored. Original photos will be printed and stored in a reference binder with their respective Photopoint Datasheets for future use in the field.

6.1.2 Replicating Photopoints

When possible, replicate photos will be taken during the same season and time of day as the original photos. This will allow for comparisons under the same vegetative growth stages and sunlight. Photos will also be used to document changes at each site during and after construction activities. The photographer will use previous photos and datasheets to replicate the angle and zoom at each photopoint. Photopoints will not be moved. If a photopoint is compromised by site modifications, a new site in a nearby location will be established to capture an angle similar to the abandoned point. This new site will receive a unique number and will be used from then on. All replicate photos and datasheets will be filed with the originals in the reference binder.

6.2 Erosion models

Two different models are currently anticipated to be employed in an effort to quantify the impacts of the site reclamation activities on erosion of the waste rock and tailings piles. Other models may be employed as we become aware of them, assuming that they have substantial applicability to the site.

The Revised Universal Soil Loss Equation may prove to be useful in quantifying sediment loss at the dumpsites. However, site-specific inputs to the model, based upon locally obtained measurements, will need to be made in order to refine the accuracy of the model output. Collection of site-specific input information will be made during annual data collection efforts.

The Pacific Southwest Inter-Agency Committee (1968) developed a qualitative sediment generation model that is based upon local site characteristics. Inputs into the model include information pertinent to soils, geology, topography, ground cover erosion characteristics and land use. The U. S. Geological Survey has applied this model in Colorado, and has recommended its use.

6.3 Vegetation Monitoring

Re-vegetation efforts at the reclamation sites will be organized with recommendations from the Re-vegetation sub-committee of the WCRC. Based on previous studies, this sub-committee will determine the appropriate combination of grasses, forbs, shrubs, and/or trees to be planted at each site.

The WCRC will monitor vegetative survival annually following planting. Monitoring and maintenance of the pile and surrounding areas will occur primarily during the year following reclamation work, and as deemed necessary by the sub-committee. Transects will be located at each pile (generally one for total cover) prior to, or in conjunction with planting or seeding. Monitoring will consist of measuring plant materials at transects at each site and counting live stems where applicable. Total cover estimates will be derived from field data produced at each transect. Cover estimates of less than fifteen percent in Year 2 will trigger maintenance seeding activities. Counts of live stems will be made at applicable sites in Year 2 and possibly Year 3. Stem counts of less than fifty percent live stems will trigger maintenance or re-planting activities. Site-specific adjustments to these percentages may be made based on coverage of nearby reference areas or other natural conditions, such as drought, that might occur.

Maintenance will consist of such remedial activities as inter-seeding with the appropriate grasses, forbs, shrubs, and/or trees, and amending the affected portions of the sites.

7.0 Report Preparation

All monitoring and assessment activities will be reported in the form of Summary Reports. The content and format of the Summary Reports will include tabular and graphical data presentation, data evaluation, and conclusions. Supporting data, documentation, and field forms will be attached as appendices as appropriate.

8.0 Health and Safety

All work described herein should be conducted consistent with applicable Occupational Safety and Health Administration (OSHA) requirements. If necessary, personnel involved in the work will be current with respect to the required OSHA training and refresher courses. Specific health and safety issues associated with sampling are addressed in the Site Health and Safety Plan (HASP) (MFG 1999b). The WCRC does not assume responsibility for the safety of volunteers or participating agency representatives, or responsibility for enforcing the provisions of the HASP.

9.0 References

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TABLES

Table 1. Potential Willow Creek and Rio Grande River drainage sampling locations. Sites are separated into stream segments as East Willow, West Willow, Nelson Creek, Mainstem Willow, Windy Gulch, and the Rio Grande.

EAST WILLOW				
Main Channel Site	**Other Inflows**	**Miles from Confluence w/ West Willow**	**Location**	**Notes**
EW-A		0.04	~150 ft u/s of conf. w/ West Willow	d/s of Mammoth Adit
EW-B		0.28	u/s of North Creede townsite	d/s of Mammoth Adit
	EW-MA	0.42	Mammoth Adit pipe discharge	Mammoth Adit discharge
EW-C		0.47	~60 ft u/s of Mammoth Adit discharge	u/s of Mammoth Adit
	EW-SWISp	0.55	Along road just south of SWI	Spring flow (source unknown)
	EW-SWI	0.57	Flow entering channel through diversion box	Possible spring flow
EW-D		0.66	u/s of surface water intake and diversion box	u/s of surface water intake
EW-E		0.8	near Kentucky Belle Mine	btwn Solomon and Mammoth Mines
EW-F		0.95	below Solomon Mine	btwn Solomon and Mammoth Mines
EW-G		1.04	~150 ft d/s of Solomon Mine	d/s of Solomon Mine
	EW-PS		West side of channel at Park Area	Spring flow (source unknown)
	EW-SMA	1.14	Solomon Adit	Solomon Adit discharge
	EW-SWD	1.17	Solomon wetland near discharge pipe or seep along road	Solomon wetland discharge
EW-H		1.21	u/s of Solomon Wetland; d/s of Payne's culvert	u/s of Solomon Mine
	EW-PC	1.25	Payne's Culvert discharge; u/s of Solomon Wetland on east bank	Spring flow (source unknown)
EW-I		1.42	u/s of waterfall near Ridge Mine	u/s of Ridge Mine
EW-J		1.93	d/s of Outlet Mine waste rock; u/s of culvert	d/s of Outlet Mine
EW-K		2.16	u/s of Outlet Mine; d/s of TRS	u/s of Outlet Mine
	EW-TRS	2.18	tributary entering channel from east	
	EW-TRN	2.37	tributary entering channel from east	
	EW-Trib 3		East side of road, north of TRN and south of culvert	
EW-L		2.58	d/s of Phoenix Park; ~5 ft u/s road culvert	d/s of Phoenix Park Mill Site
EW-M		2.84	u/s of Phoenix Park	u/s location
	EW-Sp	2.94	spring adjacent to EWN	potentially u/s groundwater location
	EW-N	2.94	tributary to channel; u/s of Phoenix Park	u/s location
	EW-PMA		Phoenix Mine Adit	Phoenix Mine Adit discharge
	EW-GMA		seep near Gormax Mine Adit	Gormax Mine discharge
WEST WILLOW				
Main Channel Site	**Other Inflows**	**Miles from Confluence w/ East Willow**	**Location**	**Notes**
WW-A		0.02	~30 ft u/s of conf. w/ East Willow	d/s of Commodore Mine area
WW-B		0.23	~25 ft u/s road culvert (near stop #2 on Bachelor	d/s of Commodore Mine area
WW-C		0.3	~100 yds u/s WWB	d/s of Commodore Mine area
WW-D		0.36	below first loadout building on east side of road	d/s of Commodore Mine area
WW-E		0.42	below discharge pipe from Commodore waste rock	d/s of Commodore Mine area
	WW-Seep	0.45	d/s Nelson Adit; on western side of rock pile	d/s Nelson Adit
WW-F		0.47	d/s Nelson Adit; u/s discharge pipe through waste rock	d/s Nelson Adit
	WW-NT	0.48	Nelson Adit surface discharge; 6" Parshall flume	Nelson Adit discharge
	WW-Tail 1		Commodore Tailings seep	Commodore Tailings seep
	WW-CT	0.54	Commodore Tunnel surface discharge	Commodore Tunnel discharge
WW-G		0.57	u/s wooden box culvert and trash gate	u/s of Commodore Mine area

Table 1. (cont.)

WEST WILLOW (cont.)				
Main Channel Site	**Other Inflows**	**Miles from Confluence w/ East Willow**	**Location**	**Notes**
WW-H		0.8	d/s Black Pitch section; d/s Stop #3 on Bachelor Loop	btwn Commodore and Amethyst Mines
WW-HH		1.02	u/s first road culvert after crossing Burro Bridge	btwn Commodore and Amethyst Mines
WW-I		1.44	d/s Amethyst waste rock; d/s confluence w/Nelson Creek	d/s of Amethyst Mine and Nelson Creek
	Nelson Creek	1.46	~150 ft u/s of conf. w/ West Willow	u/s of confluence w/ West Willow
WW-J		1.55	d/s Amethyst waste rock; u/s confluence w/Nelson Creek	d/s of Amethyst Mine; u/s of Nelson Creek
WW-K		1.7	~100 ft d/s of Amethyst Tunnel	d/s of Amethyst Tunnel
WW-L		1.8	u/s Amethyst Tunnel; ~100 yds u/s Last Chance Mine	u/s Last Chance Mine
WW-M		3.69	u/s Allen's Crossing	u/s location
NELSON CREEK				
Main Channel Site	**Other Inflows**	**Miles from Confluence w/ West Willow**	**Location**	**Notes**
NC-A		0.02	~150 ft u/s of conf. w/ West Willow	u/s of confluence w/ West Willow
NC-B		0.42	d/s of Midwest Mine; ~100 yds u/s road crossing	d/s of Midwest Mine
	NC-C	0.66	seep/spring d/s Midwest waste rock pile (east of NC-	d/s of Midwest Mine
NC-D		0.66	d/s Midwest waste rock pile (adjacent to NC-C)	d/s of Midwest Mine
NC-E		0.7	~150 ft u/s of Midwest Mine	u/s location
MAINSTEM WILLOW				
Main Channel Site	**Other Inflows**	**Miles from Confluence w/ Rio Grande**	**Location**	**Notes**
W-A		3.13	~100 yds d/s of confluence of East and West Willow	d/s of confluence
W-B		2.94	u/s of gravel settling ponds	u/s of settling ponds
	WNG		Windy Gulch	influenced by Bulldog Mine workings and waste rock piles
W-C		2.58	at gaging station; u/s of flume	u/s of flume
W-D		1.61	~200 ft d/s of flume at RR crossing	d/s of flume
W-E		1.52	u/s of braided channel; d/s of Creede	channel near Emperious Tailings
	W-EESeep	~1.36	d/s W-E; near white staining	possible leaching area
W-F		1.33	side channel on east side (possibly ephemeral)	side channel
	W-FSeep		u/s of railroad bridge area	
W-G		0.85	braided channel sections d/s of Emperious Tailings	d/s of Emperious Tailings
W-H		0.49	channel diversion to Wasson irrigation ditch	u/s of headgate
W-I		0.02	West channel, ~150 ft u/s of conf. w/ Rio Grande at bridge crossing	discharge to Rio Grande
W-J		0.02	East channel, ~150 ft u/s of conf. w/ Rio Grande at bridge crossing	discharge to Rio Grande

Table 1. (cont.)

WINDY GULCH				
Main Channel Site	**Other Inflows**	**Miles from Confluence w/ Mainstem Willow**	**Location**	**Notes**
WNG-A		0.01	at flume; ~150 ft u/s confluence w/ Willow Creek	Windy Gulch contribution to Willow Creek; d/s of Bulldog workings and waste rock piles
WNG-B		1.52	u/s Bachelor Loop road crossing	u/s of Bulldog workings and waste rock piles
RIO GRANDE				
Main Channel Site	**Other Inflows**	**Description**	**Location**	**Notes**
RG-7		Marshall Park	Bridge near Marshall Park Campground	u/s site
	MC-1	Miners Creek	near confluence w/ Rio Grande	tributary to Rio Grande btwn Deep Creek and Marshall Park
RG-5		Deep Cr. Bridge	u/s of Deep Creek	LAT 37 49 00N LONG 106 54 51W
RG-1		d/s Deep Cr.	d/s of bridge crossing and confluence with Deep	d/s of tributary source
RG-2		Upstream of Willow	u/s of confluence w/ west channel of Willow Creek	
RG-3		Downstream of Willow	d/s of confluence w/ east channel of Willow Creek	
RG-4		Wason Bridge		LAT 37 49 21N LONG 106 53 19W
	BC-1	Bellows Creek	near confluence w/ Rio Grande	tributary to Rio Grande near La Garita Bridge
RG-8		La Garita Bridge	u/s of Spring Creek	LAT 37 46 39N LONG 106 50 12W
	RG-Seep1	Seep d/s La Gari	seep on west bank of Rio Grande	LAT 37 46 54N LONG 106 50 11W
RG-10		Below seep	d/s of seep	d/s of potential tributary source
	SG-1	Spring Gulch	u/s of bridge on La Garita access road	tributary to Rio Grande near La Garita Bridge
RG-11		Railroad Bridge	in between La Garita and 4UR Bridges	
RG-12		Above gulch	u/s of dry gulch on west bank	u/s of potential tributary source
RG-13		Below gulch	d/s of dry gulch on west bank	d/s of potential tributary source
RG-9		4UR Bridge	u/s of Wagon Wheel Gap	LAT 37 46 01N LONG 106 49 51W

Table 2. Groundwater and surface water parameters, anticipated detection limits, methods, and holding times. Detection limits may vary based on the laboratory and dilutions.

Parameter	Detection Limit (mg/L)	Method	Holding Time (days)
pH	0.1 (units)	EPA M150.1 meter	field parameter
Temperature	na	na	field parameter
Conductivity	1.0 uS/cm	EPA M120.1 Wheatstone Bridge	field parameter
Dissolve Oxygen	0.2	Meter	field parameter
Total Dissolved Solids	10	EPA M160.1 Gravimetric 180 C	7
Total Suspended Solids	5	EPA M160.2 Gravimetric 105 C	7
Dissolved Organic Carbon	1	EPA M415.1 Combustion/IR Detection	28
Alkalinity	2	EPA M310.1 Titrimetric	14
Chloride	0.5	EPA M300.0 Ion Chromatography	28
Sulfate	0.5	EPA M300.0 Ion Chromatography	28
Aluminum	0.03	EPA 200.7 (ICP)	180
Calcium	0.2	EPA 200.7 (ICP)	180
Magnesium	0.2	EPA 200.7 (ICP)	180
Potassium	0.3	EPA 200.7 (ICP)	180
Silica	0.2	EPA 200.7 (ICP)	180
Sodium	0.3	EPA 200.7 (ICP)	180
Cadmium	0.0002	EPA 200.8 (ICP/MS)	180
Copper	0.001	EPA 200.8 (ICP/MS)	180
Iron	0.01	EPA 200.7 (ICP)	180
Lead	0.0001	EPA 200.8 (ICP/MS)	180
Manganese	0.005	EPA 200.7 (ICP)	180
Zinc	0.01	EPA 200.7 (ICP)	180

Table 3. Potential biological sampling locations for the Willow Creek Watershed.

Location	Description
WB-1	Willow Creek upstream of its confluence with the Rio Grande (includes both forks discharging to the Rio Grande)
WB-2	Willow Creek upstream of the USGS gaging station and above the gravel detention basins near the musuem and firehouse.
WWB-1	West Willow Creek upstream of the confluence with East Willow Creek
WWB-2	West Willow Creek upstream of the Nelson Tunnel, Commodore Tunnel (upstream of the trash rack).
WWB-3	West Willow Creek downstream of the Nelson Creek discharge and downstream of the Amethyst Mine
WWB-4	West Willow Creek downstream of the Last Chance Mine
WWB-5	West Willow Creek upstream of Allen's Crossing
EWB-1	East Willow Creek upstream of its confluence with West Willow Creek
EWB-2	East Willow Creek downstream of the Solomon Adit discharge from the wetland cells
EWB-3	East Willow Creek downstream of the Ridge Mine
EWB-4	East Willow Creek downstream of the Outlet Mine
EWB-5	East Willow Creek downstream of the Phoenix Park Mill
EWB-6	Upstream of the Phoenix Park Mill

FIGURES

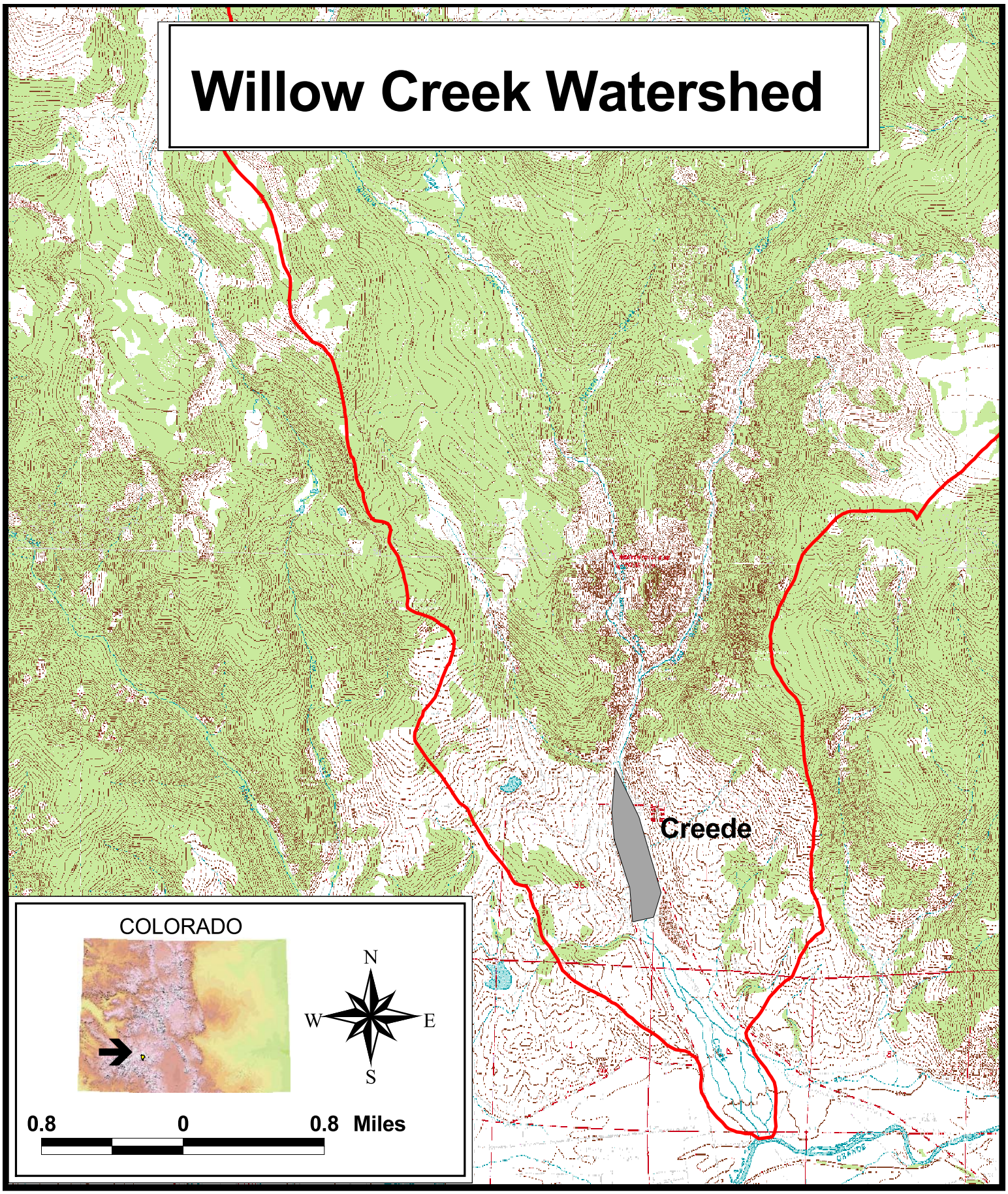

Figure 1. Willow Creek Watershed boundaries and placement in Colorado. The location of the city of Creede, Colorado, is shown in grey.

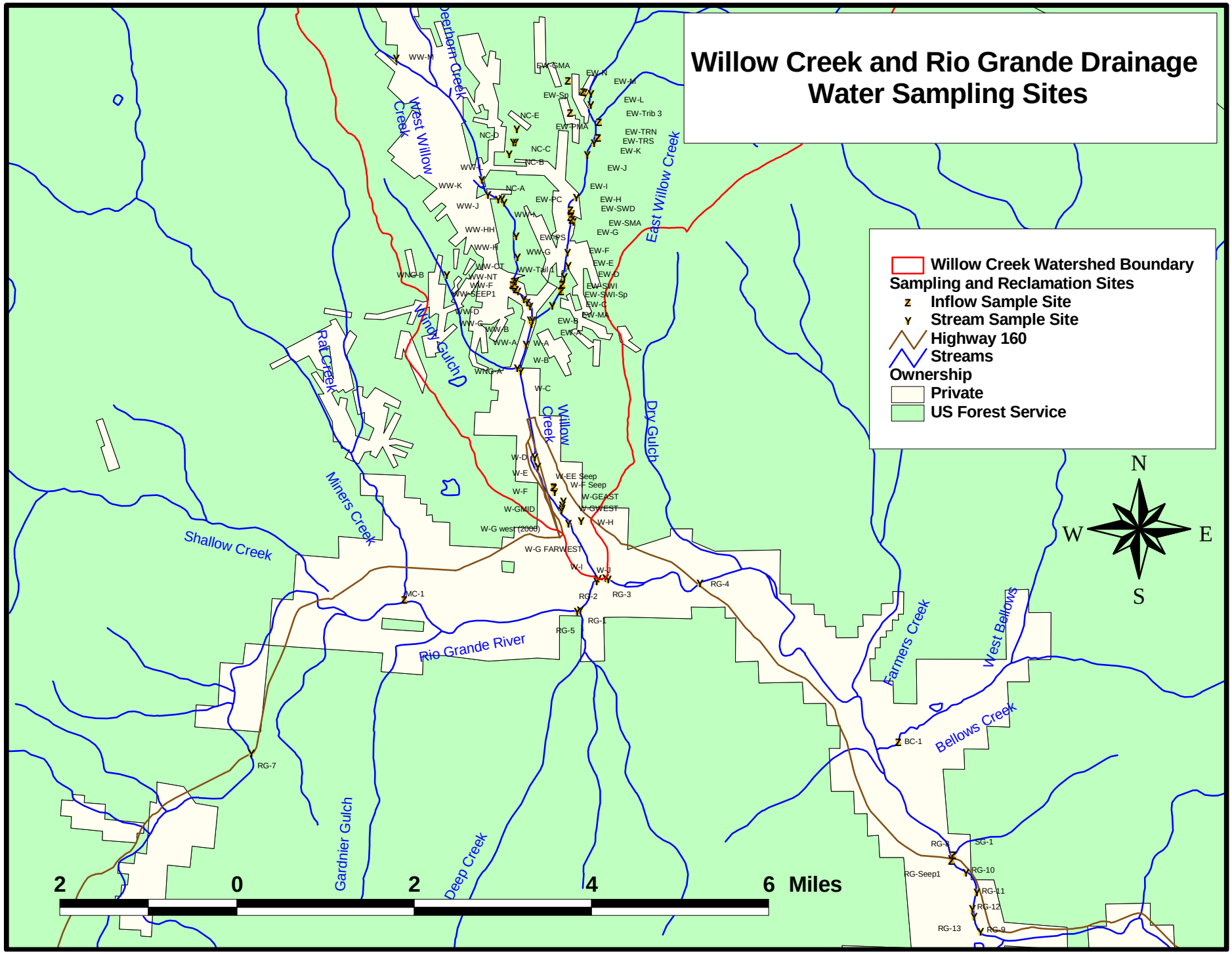

Figure 2. Surface water and inflowsampling sites in the Willow Creek and Rio Grande Drainages.

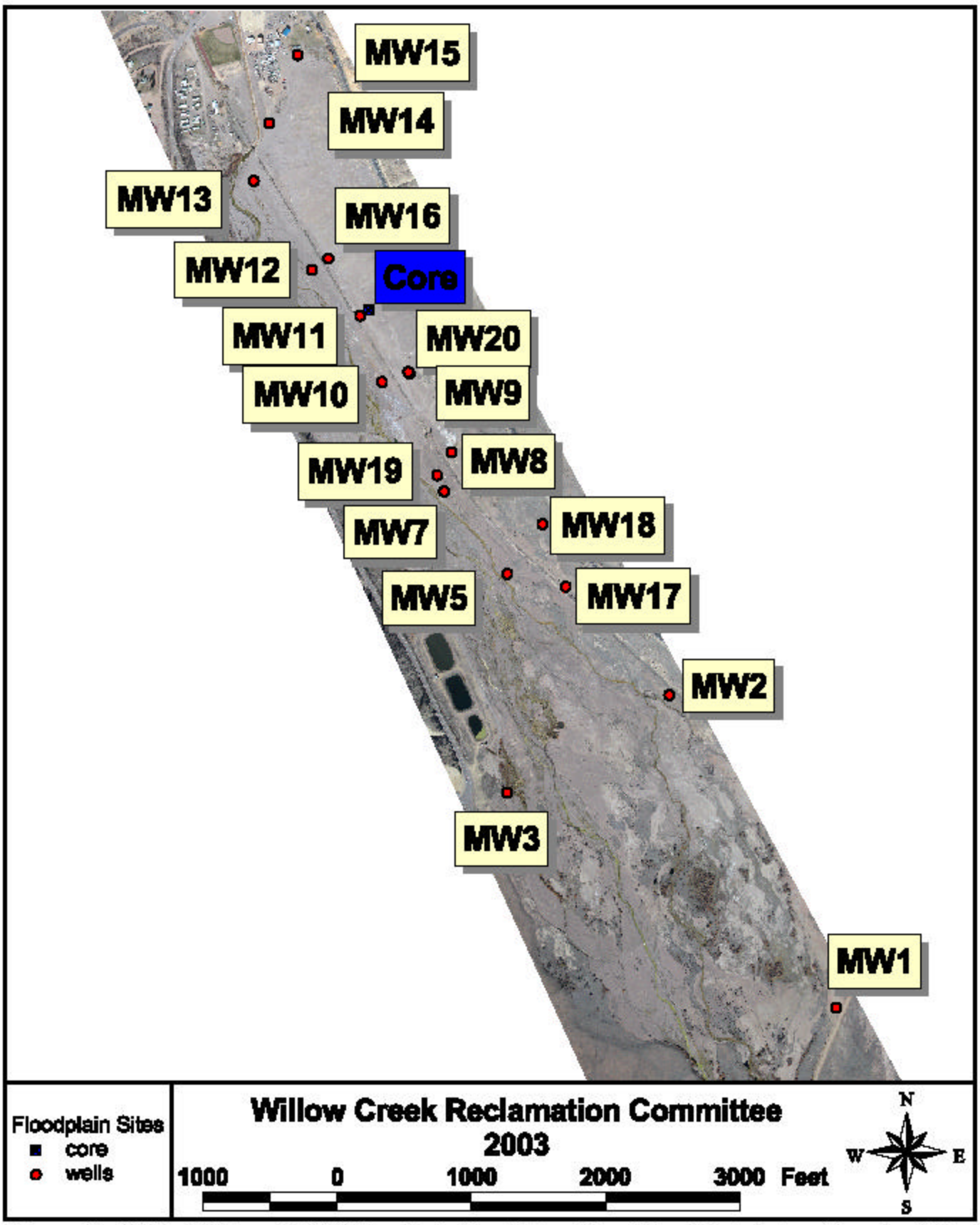

Figure 3. MFG, URS, and USACE wells in the Willow Creek floodplain below Creede, CO.

Alluvial Groundwater Wells at the Midwest Mine and Below the Solomon Mine Area

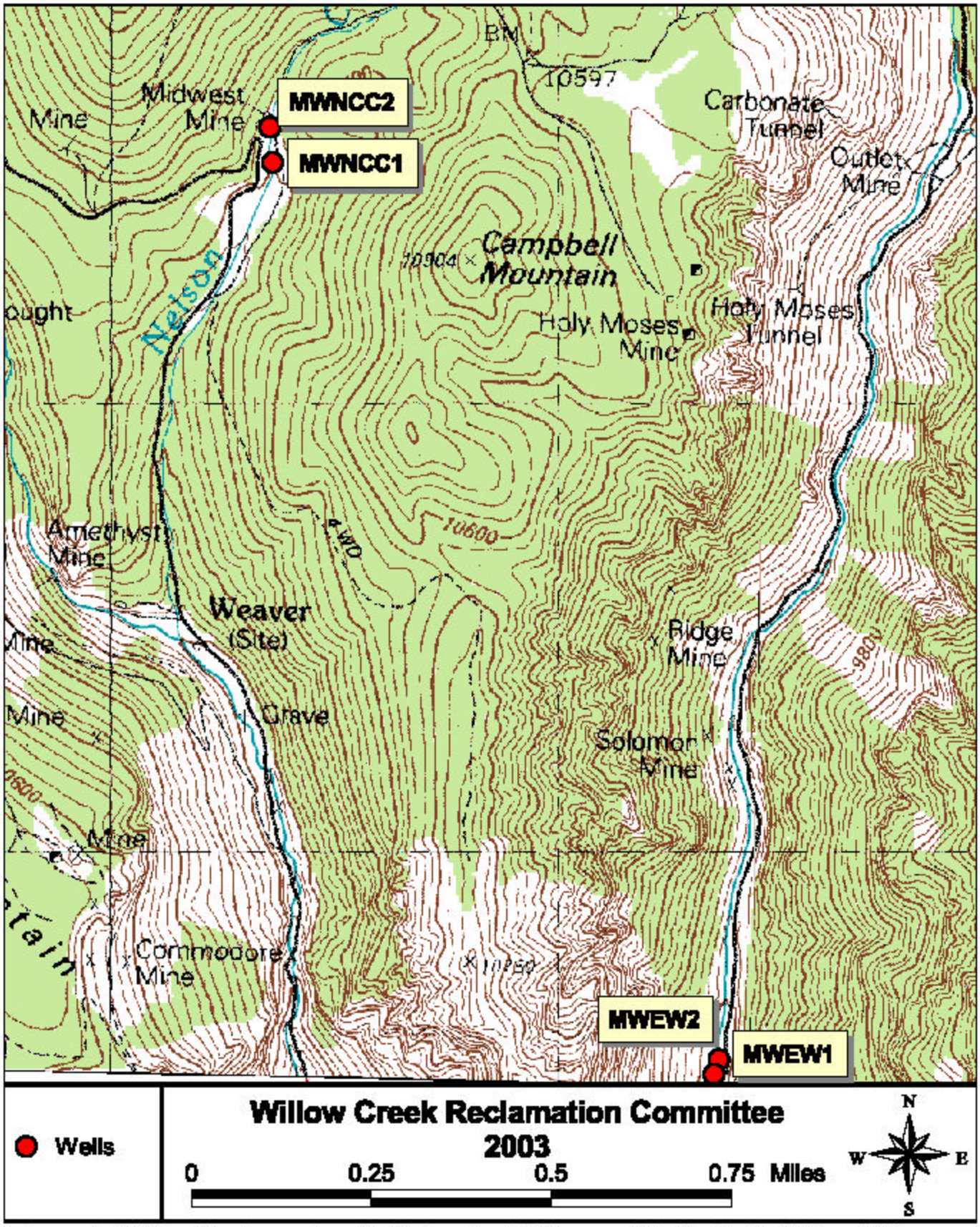

Figure 4. URS wells above Creede, Colorado. Wells associated with the Midwest Mine area are MWNCC1 and MWNCC2. Wells below the Solomon area are MWEW1 and MWEW2.

APPENDIX A

FIELD SAMPLING FORMS, EQUIPMENT LISTS, AND INSTRUCTIONS

INSTRUCTION FOR SURFACE WATER FIELD DATA SHEET

1. Every time a station is sampled the field data sheet needs to be completed. This can also serve as your hard copy of that particular station and sampling event. Complete every line of information. An incomplete data sheet is useless and a waste of effort.

2. Complete station name, sample number, river, date of sample and time of sample (use 24-hour time method. For instance if you collected a sample at 3:05 in the afternoon, the time would be 15:05).

3. Describe the weather and add any comments.

4. Check the appropriate box that describes sample as it is collected.

   Method of collection: grab or composite

   QA/QC: blank, duplicate or neither

5. Indicate which samples have been collected by checking the appropriate boxes. (i.e., Dissolved Metals, Total Metals, TDS/TSS, Chloride/Sulfate, DOC, Alkalinity/pH.)

6. Indicate the method by which a flow measurement was taken, and record the result (if available) with the appropriate units.

7. Record field parameter measurements (with the appropriate units). Record how/where the measurement was taken, including the make/model of any field meters used.

If sample site is frozen:

If sample site is frozen, follow these steps:

1. If possible, obtain an ice auger and auger through the ice at your station. Be safe. Note that you augured a hole in the Field Data Sheet comment section.

2. Walk up or down stream to the first open water and collect a sample there. Note where you collected the sample on the Field Data Sheet comment section.

3. If steps 1 and 2 are not possible, DO NOT collect a sample, but note why on Field Data Sheet comment section and file.

SURFACE WATER FIELD DATA SHEET

Sample Location:_____ Sample Number:_____

_____ Date of Sample:_____

Sampling Team:_____ Time of Sample:_____

Weather/Comments:_____

_____

Check the appropriate box describing sampling:	? Composite	? Blank
	? Grab	? Duplicate
	? Neither	? Neither

1. Sample Collection Inventory:

? Dissolved Metals - (Filtered, HN03)

? Total Metals - (Non-filtered, HN03)

? TDS, TSS -(Raw)

? Chloride, Sulfate - (Filtered, Unpreserved)

? DOC - (Filtered, H2SO4)

? Alkalinity, pH - (Raw)

2. Flow (from calculation sheet, A-3)

? Gauge Flume Estimate _____ (cfs, gpm)

3. Field Parameters

? pH (meter:_____) _____units at _____ °C

? Temperature (meter:_____) _____ °C

? Conductivity (@ 25 °C) (meter:_____) _____umhos/cm

? Dissolved Oxygen (meter:_____) _____mg/L _____% saturation

Other:_____

Data recorded by:_____ Date recorded:_____

DISCHARGE DATA

Volumetric Method:

Trial #1 _____minutes _____seconds volume _____gal/quarts/liters

Trial #2 _____minutes _____seconds volume _____gal/quarts/liters

Trial #3 _____minutes _____seconds volume _____gal/quarts/liters

Trial #4 _____minutes _____seconds volume _____gal/quarts/liters

Trial #5 _____minutes _____seconds volume _____gal/quarts/liters

Leakage Estimate:_____

Flume Method:

Type: Cutthroat / H / Parshall / Other Size:_____in./ft.

$Head_a$_____$Head_b$_____in./ft. Leakage Estimate:_____

Area-Velocity Method:

Distance (ft)	Depth (ft)	Velocity (ft/sec)	Width (ft)	Area (ft^2)	Discharge (ft^3/sec)	Dominant Substrate	Sub-dominant Substrate

TOTAL CFS_____ GPM_____

Additional Notes:

GROUNDWATER SAMPLING RECORD

SAMPLE NUMBER:

Page: ____ of ____

Project No.: _____ Project Name: _____ Date: _____

Sampling Location (well ID, etc.): _____

Sampled by: _____

Measuring Point (MP) of Well: _____

Screened Interval (ft. BGL): _____

Filter Pack Interval (ft. BGL): _____

Casing Stick-Up/Down (ft.): _____

Starting Water Level (ft. BMP): _____

Total Depth (ft. BMP): _____ Water Column Height (ft): _____

Casing Diameter (in. ID): _____ Multiplication Factor: _____

Casing Volume (gal.): _____ 2X: ____ 3X: ____ 4X: ____

Water Level (ft. BMP) at End of Purge: _____

Total Depth (ft. BMP) at End of Purge: _____

QUALITY ASSURANCE

METHODS (describe):

Cleaning Equipment: _____

Purging: _____ Sampling: _____

Disposal of Discharged Water: _____

INSTRUMENTS (indicate make, model, i.d.):

Water Level: _____ Thermometer: _____

pH Meter: _____ Field Calibration: _____

Conductivity Meter: _____ Field Calibration: _____

Other: _____ Field Calibration: _____

SAMPLING MEASUREMENTS

Date / Time	Purge Characteristics		Water Quality Data				Appearance		Intake Depth (ft. BMP)	Remarks
	Cumul. Vol. (gal)	Purge Rate (gpm)	Temp. (°C)	pH	Specific Conductance (umhos/cm) @ Field Temp	Specific Conductance (umhos/cm) @25°C	Color	Turbidity & Sediment		

SAMPLE INVENTORY

Water Level (ft. BMP) Before Sampling: _____ Recovery %: _____ Sample Intake Depth (ft. BMP): _____

Bottles Collected				Filtration(Y/N)	Preservation (type)	Analysis	Remarks Remarks (quality control sample, other)
Time	Volume	Composition (glass, plastic)	Quantity				

Chain-of-Custody Record No. _____

ABBREVIATIONS:
BMP - below measuring point
BGL - Below ground level
Cumul. Vol. - Cumulative volume removed
ID - Inside Diameter
C - Celsius
gal. - gallons
gpm - gallons per minute
in. - inches

GW Sample Form MAC/CAD Revised 9/8/95

MFG, Inc.

SHIPPING METALS SAMPLES

How to Ship

1. Make sure all bottles being shipped are tightly closed and are labeled correctly.

2. Put one frozen blue ice in the cooler with the samples and fill the empty space with packing paper or newspaper so the samples do not roll around.

3. DO NOT FORGET to enclose the CHAIN OF CUSTODY forms. Place these forms in a Ziploc storage bag in the cooler. Samples are not valid without a chain of custody form.

4. To close and secure the cooler, tape it shut with the strapping tape provided. This will inhibit tampering during shipment.

5. To mail, use the mailing labels provided in the back of this chapter of the sample plan. Use a photocopied label and tape it to the cooler.

6. We will ship through UPS. If a problem arises with UPS, please notify Barb Horn. When ever asked by anyone “What are you shipping?" reply "Water samples. " Do not say acid or chemicals. Trust us - you are not doing anything illegal.

Where to ship:

Colorado Division of Wildlife
6060 Broadway
Denver, CO 80216
Attention: Barb Horn

MAILING LABEL

STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WILDLIFE

6060 BROADWAY, DENVER, COLORADO 80216
Attn. Barb Horn

For: Willow Creek Reclamation Committee
PO Box 518
Creede, CO 81130

SAMPLE WATER QUALITY EQUIPMENT LIST

Large Action Packer Tub Containing:

filters (and container)*
1, HN03 (and container) for acid
2, filter holders
1, thermometer
2, permanent marker
2, syringes*
1, filter forceps*
1, deionized water wash bottle
3, droppers/bulbs
1, organizer tray
2, 32 oz. deionized water bottle
1 , 16 oz. acid rinse bottle
2, pairs of goggles
3, pH buffers (4,7, 10)
peristaltic pump with tubing
in-line filters
sample bottles
gloves
paper towels
garbage bags
Ziploc bags
waders/boots.

. * The number of supplies varies by river according to sampling plan.

Additional Supplies:

1, pH meter carrying case, pH probe, ATC probe and carrying solutions
1, dissolved oxygen meter
1, conductivity meter
1, cooler with ice
1, carboy for pure deionized water.

TITRATION EQUIPMENT LIST

Alkalinity Titration

Required Reagents

Indicator, Phenolthalein indicator, clear liquid 8 oz dropper bottle
Indicator, BGMR (Bromocresol-green methyl-red) orange liquid 8 oz dropper bottle
Titrant, H_2SO_4 (Sulfuric Acid) (0.02N) Automatic self-zero burette

Required Apparatus

Burette, Automatic self-zero, class A
Flask, Erlenmeyer, 125 mL
Cylinder, graduated, 50 mL

Dissolved Oxygen (Winkler Method)

Required Reagents

Reagent, Manganese Sulfate Solution 118 mL square dropper bottle
Reagent, Alkaline Iodide-Azide 118 mL square dropper bottle
Reagent, Sulfamic Acid Powder Pillows l pillow
Titrant, Sodium Thiosulfate Standard Solution, 0.025N yellow wash bottle, and 16 oz refill bottle
Indicator, Starch Solution Homemade, 1 oz dropper bottle

Required Apparatus

Bottle, glass-stoppered, BOD, 300 mL
Burette clamp, double
Burette, Class A, 25 mL
Clippers, for opening powder pillows
Cylinder, graduated, 250 mL
Flask, Erlenmeyer, 500 mL
Support stand

WATER QUALITY SAMPLING HIT LIST

Sample Preparation

1. Check to see what stations you are sampling that day. Check to see if you need to collect a duplicate and/or blank sample today.

2. Prepare data sheets for each station. Complete the top portions including crew members, date, sample number, and river.

3. Prepare, two-ounce bottles. Label the bottles properly and put in 12 drops of nitric acid. If this is a blank/duplicate day, prepare two more two-ounce bottles with the appropriate label. Prepare the filter holders.

4. If collecting an equipment blank sample today, do so now.

5. Gather the rest of equipment to take in the field, including sample bottles, field meters, a cooler with ice, deionized water, and so on.

In The Field

1 . Data recorder can fill in such information as time of sample, weather, and comments on the Field Data Sheet.

2. Flush the syringe twice with 60 mL of deionized water. Rinse the buckets (if applicable), 16 oz. bottle and syringe with river water.

3. Collect composite sample by wading, if possible. Otherwise, collect a "grab" sample from the bank if unable to do a composite.

Note: Safety is #1, you make the call!

4. First, collect your metals sample. Follow instructions on how to collect a metals sample (not filtered and/or filtered).

5. Collect any other samples (filtered and/or unfiltered), and place them in the iced cooler.

6. Someone can be taking field measurements of pH, conductivity, temperature and dissolved oxygen after the grab/composite sample has been taken from the stream. Dissolved oxygen should be taken at the bank in running water if possible. If you do analyze for dissolved oxygen from the bucket, do it first and right away. DO NOT stick your hands in the water.

7. If using a HACH kit for dissolved oxygen analysis, do the test at the site with the 60 ml BOD bottle. If analyzing dissolved oxygen by the Winkler titration method, collect sample using a 300 ml BOD bottle.

8. Fill the 16-ounce sample bottle by pouring the water from the bucket to the bottle, if you collected a composite. This will be for laboratory pH, alkalinity. Fill the 16-ounce bottle in running water off the bank if you collect a grab. Be sure to rinse the bottle and

take the sample in front of you. Remember pH and alkalinity samples must be analyzed within 14 days and kept refrigerated to be valid.

9. Neatly complete every blank line/box on the field data sheet.

At the Laboratory

1. Take the pH of the sample if the temperature is appropriate.

2. Perform the alkalinity and dissolved oxygen (if doing the Winkler method) titrations, following the instruction and completing the data sheets correctly.

3. Clean all equipment, such as Erlenmeyer flasks, acid rinse and wash syringe, etc. Store all your equipment clean.

4. Place samples in a refrigerator.

Shipping

Gather up your metals samples to be shipped and get a blank Chain of Custody form. Complete the form- include ALL required information or your samples are invalid. Place the samples in the cooler, be sure the lids are on tight. Put the ice on top of the samples. Stuff the cooler with paper. Put your Chain of Custody in a Ziploc bag on the top. Tape the cooler shut. Put the mailing label on the cooler and send it via UPS.

Sample Holding Times

Metals	6 months if preserved with nitric acid.
pH	24 hours if kept refrigerated. Test should be done at room temperature (20-25 °C).
Temperature	None
Alkalinity	14 days if kept refrigerated. Test should be done at room temperature if possible.
Hardness	24 hours if kept refrigerated. Test should be done at room temperature if possible.
Dissolved Oxygen Hach kit	None
Dissolved Oxygen Winkler	If "fixed" immediately with first three chemicals, 4-8 hours refrigerated in a dark place during this time

HOW TO COLLECT A COMPOSITE SAMPLE

Composite Sample

1. Take the two buckets provided (the buckets should only be used for sampling) to the station. Use one bucket to collect water and the other to hold the composite sample. All samples should be collected upstream of a bridge if possible.

2. Rinse the buckets with sample water.

3. Now you are ready to collect a composite sample. Do not let the bucket touch the stream bottom. Remember, you want to test the water column, not the stream sediment. With the sample bucket, go to the upstream left bank and fill the bucket with a representative sample of water. Pour this water into one third of the composite bucket. Go to the middle of the stream. If sampling from a bridge, use a rope to lower the sample bucket down to the river and fill one third of the bucket with a representative sample of river water. Dump this water into the composite bucket (which should be two thirds full now). Go to the upstream right bank and repeat this procedure. The composite bucket should be close to full with river water from three areas.

4. The composite bucket holds the water you will perform the chemical tests on. The order of the tests is now important due to possible contamination. From the bucket, take first the metals sample,* minimizing contact with the syringe. Secondly, fill the alkalinity and bottle, and the other sample bottles.

   * pH, temperature, conductivity and dissolved oxygen should be taken from one of the banks (both HACH and Winkler methods). If this is not possible, these parameters may be taken from the bucket with the following additions. Collect dissolved oxygen first (before metals) by pouring sample from the bucket very slowly into a round glass bottle. You do not want to introduce more oxygen in your sample. Note in the “comment" section of the field data sheet that you collected the dissolved oxygen sample from a bucket. Measure the other parameters and record.

5. Try to minimize time between collection of water in the bucket and all following steps. Try to keep the bucket out of sunlight.

6. Please check the box on your field data sheet to indicate whether the sample was a composite or grab, blank or duplicate, or check the neither box.

If Sample Site is Frozen

Please see instructions on what to do if your sample site is frozen.

HOW TO COLLECT A BLANK/DUPLICATE SAMPLE

These two types of QA/QC samples test the procedure you follow to collect for metals. This data validates your metals samples.

Blank Sample

A blank sample is a sample of deionized water, treated as a normal sample. This blank is collected to test the chemicals and procedures used as well as the person conducting the test. Specifically, a blank sample tests "how" the procedure of putting river water into a normal sample is done. A blank sample can detect sources of contamination.

1. Label an additional set of bottles as you normally would for one of your stations. Add "10" to the end of the station name. For example: the label for station, "below 5th Street Bridge" would read "below 5th Street Bridge 10" for a blank sample. A blank sample has the same sample number as the normal sample it is associated with.

2. Prepare sample bottles as if you are taking a normal sample.

3. Rinse the syringe (or pump tubing) with sample water (deionized water, in this instance). Even through this seems redundant, it is now "river" water.

4. Now you are ready to collect the blank sample. Collect samples in the same manner as you collected the normal samples. Be sure to fill all sample bottles.

5. Clean all equipment as you would after a normal sample collection.

6. Check the box on your field data sheet to indicate a blank sample was taken for this station.

Duplicate Sample

A duplicate sample is two samples containing the same "slug" of water. This sample is also a quality control sample. A duplicate checks the lab and the field crew. The lab does not know it is identical to another sample. Results should be the same for both samples if no contamination occurred.

1. Label an additional set of bottles as your normally would for one of your stations. Add the number "20" to the end of the station name. For example: the label for station, "below 5th Street Bridge" would read "below 5th Street Bridge 20" for a duplicate sample. A duplicate sample has the same sample number as the normal sample it is associated with.

2. Prepare sample bottles in the same manner as you would for a normal sample.

3. Collect enough stream water in your composite sampling container to fill two sets of bottles.

4. Fill the bottles for the normal and duplicate simultaneously, by adding water to each bottle in 1/4 volume increments, alternating bottles, until both bottles are filled. Repeat this procedure for each set of bottles to be filled at that station.

5. Clean all equipment as you would after a normal sample collection.

6. Check the box on your field data sheet to indicate a duplicate was taken at this station.

Note: Bottle blanks will be performed by the laboratory, so the field team will not be collecting them. Preservation blanks will not be collected because documentation of the laboratory analysis of each preservative will be requested from each laboratory. The blanks described on page A- 1 2 include equipment blanks which will be collected for all equipment that is used at more than one sample site (filtering apparatus, collection buckets, etc.).

INSTRUCTION FOR MAKING ACID RINSE

An acid rinse is used for "cleansing" the syringe and filter holders prior to collecting a sample. This is very important and should be taken seriously.

1. Fill the nitric acid pipette with HNO_3. Use the following technique:

    - Place the bulb on the end of pipette.
    - Squeeze the pipette before placing the tip into the nitric acid.
    - Place the pipette into the nitric acid and release the bulb. You should have a 3/4 s-full to **full** pipette. (Approximately 1 ml).
    - Squeeze the $HN0_3$ into the acid rinse bottle.
    - Put your $HN0_3$ away.
    - Fill the acid rinse bottle to the neck with deionized water.
    - Shake well.

When you run out of acid rinse, make more.

APPENDIX B

QUALITY ASSURANCE PROJECT PLAN

QUALITY ASSURANCE PROJECT PLAN
FOR THE
COLORADO NONPOINT SOURCE
MONITORING PROGRAM

COLORADO DEPARTMENT OF HEALTH
WATER QUALITY CONTROL DIVISION
SEPT 8, 1994

SIGNATURE/APPROVAL PAGE

_____Director Colorado Water Quality Control Division

Date:_____

_____Colorado 319 Program Manager

Date:_____

_____EPA Region VIII 319 Program Manager

Date:_____

_____Regional Quality Assurance Officer

Date:_____

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PROJECT/TASK ORGANIZATION

Figure 1 depicts the organizational structure for the State of Colorado Nonpoint Source Unit. The duties and responsibilities of positions in the Nonpoint Source Program involved in the data collection/operation process are as follows.

A.) The Nonpoint Source Unit Leader is responsible for overall program direction and objectives.

B.) The Monitoring Coordinator is responsible for ensuring that data collected through the Nonpoint Source Program supports specific project objectives, follows specific quality
assurance/quality control procedures, and fulfills requirements under the state's Quality Assurance Project Plan for the Colorado Nonpoint Source Program.

C.) The Water Quality Technician assists in data collection and analysis and is responsible for calibration and maintenance of Nonpoint Source Unit field equipment.

PROBLEM DEFINITION/BACKGROUND

This is a continuing data collection effort. The regulations which govern the Nonpoint Source Monitoring Program are 40 CFR 30.302(d) . Historical data for this program has provided the State of Colorado with the information necessary to continue the data collection effort. Historical data is available from state archives.

PROJECT/TASK DESCRIPTION

All chemical analyses and field analyses utilized for the Nonpoint Source Monitoring Program (NPSMP) are specified either in 40 CFR 136, state Standard Operating Procedures (SOPs), and/or the individual project-specific Sampling and Analysis Plan (SAPs) . Any deviation from standard methodologies published in the Federal Register (FR), 40 CFR 136, or state SOP's must be detailed in the project-specific SAP(s).

Schedules for monitoring events are specified within the project-specific SAPs.

WATER QUALITY CONTROL DIVISION

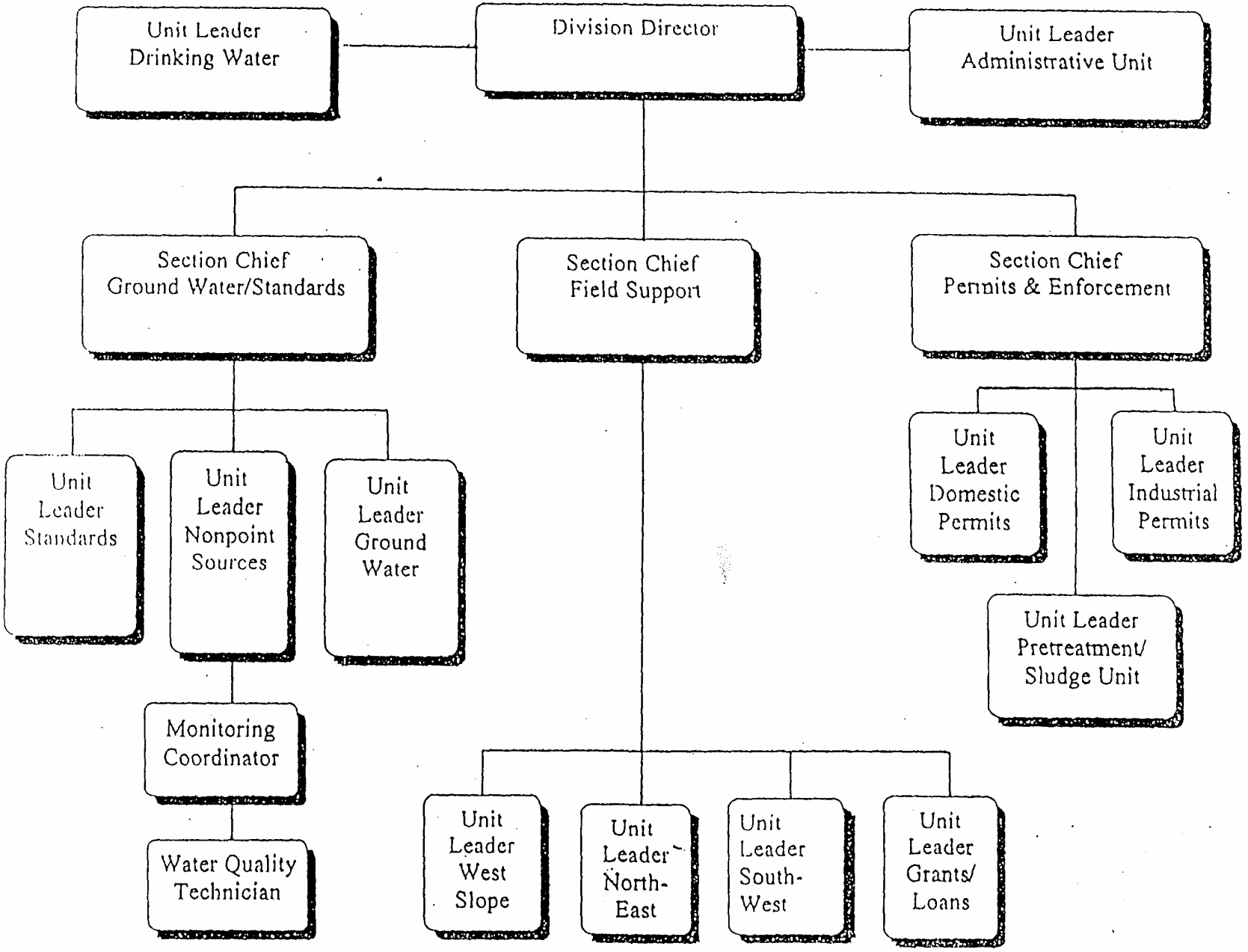

Figure 1

DATA QUALITY OBJECTIVES FOR MEASUREMENT DATA

Data collected under the Nonpoint Source Program is used to both target nonpoint source water quality problems and monitor the effectiveness of nonpoint source remedial projects. Sample site selection, analytical methods, and QA activities are designed to support project objectives. Therefore, the project-specific SAP will include a statement of the project objectives along with the geographical locale and all related environmental media being investigated in support of the project-specific monitoring activity. A "Schedule of Work to be Performed" will also be included within the site-specific SAP/workplan. other general criteria used in determine data quality are:

- Precision and accuracy. Analytical goals for the precision and accuracy of samples analyzed by the CDH Laboratory Division are addressed in the Laboratory QAPP/SOP. Precision is expressed as relative standard deviation and accuracy as absolute biases as a percentage.

- Completeness and comparability. Completeness is the percentage of all data collected which is acceptable. Experience gained during previous nonpoint source assessment suggests that 90 percent completeness or better is attainable. Comparability is the degree of confidence that data sets are comparable with each other. This is ensured by using standard procedures and standard reporting of data.

- Representativeness. Sampling should be conducted to ensure that data accurately and precisely -represent the population being studied. For the NPSAP, waterbodies are selected for study based on various policy criteria. sampling is intended to represent each waterbody at times of maximum contaminate loadings or potential adverse affects to beneficial uses. Multiple sampling sites and sampling from critical components of the chemical/physical/biological matrix are designed to accurately represent the system at these times.

SAMPLING PROCESS DESIGN

The sampling network design is covered within each project-specific SAP. A map depicting the locations of the surface and/or ground water Activities is attached with each SAP.

Each project-specific SAP will also provide a discussion of the rationale for the selection and monitoring of sampling locations.

SAMPLING METHODS REQUIREMENTS

Waterbodies are sampled by professionally trained personnel. Volunteer assistants are used on occasion, but remain under the immediate supervision of the project supervisor or designated professional.

Samples are collected and analyzed according to the State of Colorado Standard Operating Procedures (SOPs) listed below.

1. Standard Operating Procedures for the collection of flow, pH, temperature, and conductivity Measurements

2. Standard Operating Procedures for the filtration of water samples

3. Colorado Department of Health Laboratory Division QAAP/SOP

4. Standard Operating Procedures for the collection of macroinvertebrate samples

5. Standard Operating Procedures for- the collection of electrofishing samples

6. Standard Operating Procedures for habitat analysis

7. Standard Operating Procedures for photo documentation

8. Standard Operating Procedures for the calibration and maintenance of field equipment

All the above documents are available upon request from the Colorado Nonpoint Source Unit.

SAMPLE HANDLING and CUSTODY REQUIREMENTS

Sample custody consists of two components, documentation and actual physical custody of the official sample. Physical custody consists of two phases: custody in the field and custody in the laboratory. Sample custody is less stringent for the NPSMP than it would be for samples collected for enforcement or standards setting.

The following principles apply to all handling of samples from the point of collection through the placing of a sample in a secured location at the laboratory. The sample is considered in "custody" if:

1. It is in one's actual physical possession or view.

2. It is in one's physical possession so as not to be tampered with, i.e. under lock and restricted key or under official seal.

3. It is retained in a secured area with restricted access.

4. It is placed in a container and secured with an official seal(s) evidence tape such that the sample cannot be reached without breaking the seal(s).

The necessary sample field documentation will be filled out on site (date, time, sampler, notes). Water Quality Data - Stream Sample sheet (see CDH Laboratory Division QAPP/SOP) will be completed for those samples to be submitted to the CDH Laboratory. The Habitat Survey form will be filled out completely on-site as in situ measurements are made for each site (Habitat Analysis SOP).

Sample containers will be labeled with permanent marker or wax pencil directly on plastic bottles and on label tape on glass containers. The label shall contain the following sample identification information:

Waterbody Name and station number.
Date
Samplers' initials
Remarks - special processing such as filtration; split sample, etc.
Time - if multiple collections are made from same site.

Immediately after collection, samples will be kept in a cooler with ice at all times until they are transferred to the laboratory refrigerator or analyzed. Samples must not be allowed to freeze.

A separate field sheet is used for the sampling of fish, or collection of fish for tissue analysis (see Electrofishing SOP).

The sample custody, handling and shipment are specified within the project-specific SAP. Copies of all state forms are attached to the SAP. Depending on the project, the sample custody may or may not be an important factor within the sampling program. Record keeping procedures will be specified in the project-specific SAP.

ANALYTICAL METHODS REQUIREMENTS

The analytical methods, preservative needed, type of container used, and holding time information for the Nonpoint Source Monitoring Program efforts are specified in Table 1. Procedures for field determinations of total alkalinity, total hardness, and Winkler dissolved oxygen are those in Standard Methods for the Examination of Water and Wastewater, 1989 (Joint Editorial Board, Am. Public Health Assn., Am. Water Works Assn., and Water Pollution Control Fed., 17th Ed. Washington, D.C.)

Any deviation from the above methods are specified within each project-specific SAP.

QUALITY CONTROL REQUIREMENTS

Generally, unless otherwise specified in project plans, 10% of the analytical samples and 5% of the field samples are devoted to quality control requirements. Water chemistry quality control samples considered for each project are;

1. Sample replicates
2. Sample equipment blanks
3. Sample spikes
4. Blind samples

Field replicate samples will be used to establish field precision.

TABLE 1

ANALYTE	METHOD	PRESERVATIVE	HOLDING TIME	SAMPLE CONTAINER
METALS:				
Aluminum	ICP	Nitric Acid	6 months	Plastic
Antimony	ICP	Nitric Acid	6 months	Plastic
Arsenic	SDDC	Nitric Acid	6 months	Plastic
Barium	ICP	Nitric Acid	6 months	Plastic
Beryllium	ICP	Nitric Acid	6 months	Plastic
Boron	ICP	Nitric Acid	6 months	Plastic
Cadmium	AA, CF	Nitric Acid	6 months	Plastic
	ICP	Nitric Acid	6 months	Plastic
Chromium	AA, CF	Nitric Acid	6 months	Plastic
	ICP	Nitric Acid	6 months	Plastic
Chromium, Hex.	Color	Nitric Acid	24 hours	Plastic
Cobalt	ICP	Nitric Acid	6 months	Plastic
Copper	AA, CF	Nitric Acid	6 months	Plastic
	ICIP	Nitric Acid	6 months	Plastic
Iron	ICP	Nitric Acid	6 months	Plastic
Lead	AA, CF	Nitric Acid	6 months	Plastic
	ICP	Nitric Acid	6 months	Plastic
Manganese	ICP	Nitric Acid	6 months	Plastic
Mercury	Cold Vapor	Nitric Acid	28 days	Glass
		Nitric Acid	14 days	Plastic
Molybdenum	ICP	Nitric Acid	6 months	Plastic
Nickel	ICP	Nitric Acid	6 months	Plastic
Selenium	Fluorometric	Nitric Acid	6 months	Plastic
Silver	AA ' CF	Nitric Acid	6 months	Plastic
	ICP	Nitric Acid	6 months	Plastic
Vanadium	ICP	Nitric Acid	6 months	Plastic
Zinc	ICP	Nitric Acid	6 months	Plastic
MINERALS:				
Alkalinity, Tot.	Titration	Nitric Acid	14 days	Plastic
Calcium	ICP	Nitric Acid	6 months	Plastic
	Titration	Nitric Acid	6 months	Plastic
Hardness, Tot.	ICP	Nitric Acid	6 months	Plastic
	Titration	Nitric Acid	6 months	Plastic
Magnesium	ICP	Nitric Acid	6 months	Plastic
	Titration	Nitric Acid	6 months	Plastic
Potassium	ICP	Nitric Acid	6 months	Plastic
Sodium	ICP	Nitric Acid	6 months	Plastic

ANALYTE	METHOD	PRESERVATIVE	HOLDING TIME	SAMPLE CONTAINER
NUTRIENTS:				
Ammonia	Automated	Sulfuric Acid	28 days	Plastic
	Distilled	Sulfuric Acid	28 days	Plastic
Kjeldahl	Automated	Sulfuric Acid	28 days	Plastic
Nitrate	IC	Sulfuric Acid	48 hours	Plastic
Nitrate/Nitrite	Automated	Sulfuric Acid	28 days	Plastic
Nitrite	Color	Sulfuric Acid	48 hours	Plastic
	IC	Sulfuric Acid	48 hours	Plastic
o-Phosphorus	Color	Sulfuric Acid	48 hours	Plastic
	IC	Sulfuric Acid	48 hours	Plastic
Total Phosphate	Automated	Sulfuric Acid	28 days	Plastic
MISCELLANEOUS:				
BOD	Winkler	4 deg Celsius	48 hours	Plastic
Bromide	IC	4 deg Celsius	28 days	Plastic
Chloride	IC	4 deg Celsius	28 days	Plastic
	Titration	4 deg Celsius	28 days	Plastic
Chlorine	Amperometric	4 deg Celsius	2 hours	Plastic
COD	Titration	4 deg Celsius	28 days	Plastic
Conductivity	Meter	4 deg Celsius	28 days	Plastic
Cyanide, Direct	Color	4 deg Celsius	14 days	Plastic
Cyanide, Distilled	Color	4 deg Celsius	14 days	Plastic
Fluoride	ISE	4 deg Celsius	28 days	Plastic
Oil/Grease	Gravimetric	4 deg Celsius	28 days	Plastic
pH	ISE	4 deg Celsius	2 hours	Plastic
Phenol, Distilled	Color	4 deg Celsius	28 days	Plastic
Solids, Dissolved	Gravimetric	4 deg Celsius	7 days	Plastic
solids, Suspended	Gravimetric	4 deg Celsius	7 days	Plastic
Solids, Total	Gravimetric	4 deg Celsius	7 days	Plastic
Solids, Volatile	Gravimetric	4 deg Celsius	7 days	Plastic
Sulfate	Gravimetric	4 deg Celsius	28 days	Plastic
	IC	4 deg Celsius	28 days	Plastic
Sulfide	Color	4 deg Celsius	7 days	Plastic
RADIOACTIVITY:				
Alpha Beta	Count	Nitric Acid	6 months	Plastic
Plutonium	Electrodeposit	Nitric Acid	6 months	Plastic
Radium 226	ppt/count	Nitric Acid	6 months	Plastic
Radium 228	ppt/count	Nitric Acid	6 months	Plastic
Radon	Count	Nitric Acid	24 hours	Plastic
Uranium	Fluorometry	Nitric Acid	6 months	Plastic

METHOD ABBREVIATIONS:

ICP=Inductively Coupled Plasma
CF=Carbon Furnace
IC=Ion Chromatography
ISE=Ion Specific Electrode
AA = Auto Analyzer, Technicon
F = Fluorometric
G = Gravimetric

Field equipment blanks will be analyzed to assure samples are not being contaminated through incomplete rinsing between samples, contaminated rinse water, or through contaminated sample containers. Sample spikes may be submitted to verify the absence of matrix effects. Individual project plans will specify appropriate quality control samples. Results from quality control samples will be reviewed by the NPSMP project personnel on a continuing basis.

INSTRUMENT CALIBRATION AND FREQUENCY

Information on calibration of laboratory analytical equipment is included in the Colorado Department of Health Laboratory Division QAPP/SOP.

Parameters which are tested for in the field, and corresponding type of instrumentation, are listed below:

1. Stream discharge----- discharge meter

2. pH and temperature-- pH meter with automatic temperature probe

3. Conductivity---------- conductivity meter

4. Total hardness-------- field titration kit

5. Total alkalinity------- field titration kit

6. Dissolved oxygen---- Winkler Method

All instrument calibration procedures and scheduled maintenance are conducted in accordance with the state Standard operating procedures for the Calibration and Maintenance of Field Equipment.

If project specific procedures vary from the state SOP's, they will listed in the project-specific SAP.

ASSESSMENTS AND RESPONSE ACTIONS

Performance audits are independent checks, conducted on a planned frequency on components of the measurement system to arrive at a quantitative measure of output quality. The audit procedures for the CDH Laboratory are found in the CDH Laboratory Division QAAP/SOP. Audits of field procedures are conducted for the field chemistry kits.

Assessment and response to data generated by the CDH Laboratory Division is determined by the analyst and/or the QA officer in accordance with the CDH Laboratory QA plan. The NPSMP coordinator is responsible for ensuring that samples are collected and preserved properly.

For macroinvertebrate sampling, once a year QA/QC officers will visit selected overlap sites and perform replicate assessments. Results from the two independent assessments will determine if reproducible results are being attained.

Data which is determined to be unacceptable shall result in one or more of the following corrective actions:

1. Check for transcription or math error.

2. Review analysis with the chemist/technician responsible for generating the data in question.

3. Identify measures to prevent future problems such as training in sample collection,, preservation, or crosschecking on analysts.

4. Repeat sampling and analysis if necessary.

All such actions will be documented. Corrective actions may also be taken as a result of other QA activities including:

1. Performance audits

2. System audits

3. Interlaboratory/interfield comparison studies, or

4. Management System Reviews

Corrective actions and follow-up from these activities will be the responsibility of the NPSAP coordinator.

An audit may be conducted on the field or laboratory activities associated with the Nonpoint Source Monitoring Program at the discretion of the EPA Regional Project Officer(s) or Regional Quality Assurance officer. This audit extends to any contract or sub-contract thereof associated with these activities.

DATA REVIEW, VALIDATION, AND VERIFICATION REQUIREMENTS

Validation and verification procedures for analytical and biological data generated in the field (biological surveys, field temperature, dissolved oxygen, and total alkalinity) are described in the respective SOP'S.

The process to accept, reject, or qualify data generated from samples submitted to the CDH Laboratory Division for analysis is twofold.

1.) As part of the laboratory quality assurance/quality control process, the CDH Laboratory assures data accuracy, precision, etc. Specific criteria to accept or reject analytical results are documented in the CDH Laboratory QAAP/SOP.

2.) On a project specific basis, the Nonpoint Source Program reviews and assesses the quality of the field sampling process through analysis of split samples and field blanks.

A.) Split samples are here defined as two samples taken from the same water sample and field processed using identical SOP's. The splits are then submitted to the same laboratory for analysis using the same analytical methodology. Comparison of results between paired splits provides a measure of overall laboratory and field process precision. Methods for determining precision, and criteria to accept, reject, or qualify data are described in the following section.

B.) Field blank samples are prepared on site using water known to be free from the potential toxics of concern. Field blanks measure sample contamination due to sampling equipment and field procedures. Criteria to accept, reject, or qualify data based on results from field blanks are described in the following section.

VALIDATION AND VERIFICATION METHODS

Unless otherwise specified., acceptable precision for each analytical parameter (i.e. zinc) of a pair of split samples shall be < 30% expressed as relative percent difference (RPD). Where:

$$\text{Precision} = \text{RPD} = \frac{C - C}{\frac{C + C}{2}} \times 100\%$$

In the event split sample pairs are > 30% data from that site/time will be considered qualified and either deleted or interpreted with caution. Qualified data will be clearly denoted in the database.

Estimates of overall precision of a parameter (i.e. zinc) will be derived from the pooled standard deviations from all individual split pairs. The pooled standard deviation statistic is termed the root mean square (RMS) and is calculated:

$$\text{Percent relative standard deviation} = \%RSD = 100 \frac{SD}{\text{mean}}$$

$$\text{Root mean square} = RMS = \%RSD_1^2 + \%RSD_2^2 \ldots + \%RSD_n^2$$

Unless otherwise specified, acceptable RMS for each parameter is < 30%. If RMS is > 30% than the analysis for that parameter will be deleted from the data base, or considered as qualified data and interpreted with caution. Qualified data will be clearly denoted in the database.

Concentrations of contaminants allowable in field blanks will be project specific. Data from field blanks will be tabulated, reviewed, and interpreted in project reports. If contamination of field blanks occurs, corrective action will be initiated.

The decision process for determining the significance of blank contamination in terms of project and data quality objectives is presented in the following decision criteria.

Field Blank	Analytical value reported for sites	Outcome to database
1. < detection limit	> detection limit	no change
2. > detection limit	< detection limit	no change
3. > detection limit	< stream standard	no change
4. > detection limit	> stream standard	Qualified data (see below)

Decision criteria for qualified data

The decision to accept or reject qualified data is as follows:

1. If, after downward adjustment for possible contamination, the analytical values reported for ambient sites still exceed the designated standard (i.e. stream standard for zinc), than no change in the database is required.

2. If downward adjustment of the ambient site values eliminates exceeding of the designated standards, than the data point(s) are interpreted with caution and resampling at the site(s) is appropriate.

RECONCILIATION WITH DATA QUALITY OBJECTIVES

The results of the monitoring activities are routinely scrutinized against the DQO's established for each project. Procedures for resolution of any problems associated with failing to meet the DQO's are specified within the "Assessments and Response Actions" section of this document. It is the Nonpoint Source Program's management responsibility to assess whether or not new DQO's need to be established based upon the obtained data from each project.

Quality Assurance/Quality Control Plan (River Watch 2001)

A quality assurance and quality control (QA/QC) plan is necessary when performing water quality analyses. An effective quality assurance plan checks the precision and accuracy of an analytical result and maintains an acceptable level of analytical reliability. Good precision means the ability to repeat an analysis and obtain consistent results. In other words the method chosen for a particular analysis can repeatedly produce the same result for the same sample amount, within a margin of error. Accuracy refers to how close a measurement is to the true value. Thus, when a method is first developed or an existing method is applied in a new way, the quality assurance program validates the method. If the new method provides acceptable levels of precision and accuracy, it may be applied routinely.

After a method is chosen, a quality control program is initiated to maintain the reliability of the measurement process. This includes such things as minimizing contamination to equipment and stock chemicals, equipment operation and maintenance, sample tracking, duplicates, replicates, blanks and so forth. Quality control measures are routinely applied to reduce the occurrence of error.

The following items are included in the Rivers of Colorado Water Watch Network quality assurance and quality control (QA/QC) plan.

QUALITY ASSURANCE

Sample Training

A minimum of two students and one teacher from each participating school must attend a four-day workshop in which they are trained to operate the water quality sampling equipment. Training includes sample preparation, collection, analyses, shipping, recording, and QA/QC procedures. Participants must complete the cycle of sample preparation to analyses including all QA/QC procedures at least twice during the workshop. Each school receives a video tape with the sampling techniques and procedures to refer to after the workshop. A “kick-off” day is chosen for all schools to target collection of the first “real” sample. Hot line telephone numbers are also available to the teacher if they need to answer questions about sampling procedures. After training, teachers take practice runs prior to the “real” sampling event. Following training and the kick-off day, at least one QA/QC site visit occurs by trained DOW personnel.

Each school is visited annually, tested and certified for that year. An annual activity report is produced of each school’s QA/QC data.

The Sampling Plan

A specific sampling plan is outlined and agreed upon with each school during the four-day training workshop. Included in this sampling plan are sample station locations,

sample frequency, parameters and starting date. Sample station locations for surface water chemistry are school and river specific. In general stations will duplicate existing monitoring stations and be proximate to USGS gauging stations when ever possible. Sample frequency is a function of parameters, seasons, and school calendars. The minimum sample frequency for basic stream parameters is illustrated below:

Month	J	F	M	A	M	J	J	A	S	O	N	D
# of Samples	1	1	1	1	1	1	1	1	1	1	1	1

This is subject to change for special projects, parameters and/or schools.

Initially, each school takes measurements for temperature, alkalinity, hardness, pH, dissolved oxygen, and heavy metals. Individual metals may vary but usually include aluminum, arsenic, calcium, iron, cadmium, copper, manganese, magnesium, lead, selenium and zinc. Students analyze all the above parameters except metals. Metals samples are shipped to the CDOW laboratory in Ft. Collins. A trained technician performs the metals analysis. Heavy metals sampling may be phased out and organic or other parameters phased in as results are reviewed. Sampling parameters remain flexible since each river is a unique system.

Sampling Procedures

Sampling procedures, labeling, containers, and preservation follow Standard Methods (1989) and/or EPA guidelines (from Table II of 40 CFR 136). This would include such items as keeping samples chilled until analysis, compliance with sample holding time for respective parameters, using certified reagents and standards, and using appropriate detection (EPA, CDH and/or CDOW) limits. The accuracy and precision for each chemical parameter is determined by the CDOW but generally follows Standard Methods (1989) and/or EPA requirements. All equipment is frequently serviced, calibrated, cleaned, and maintained. The CDOW supplies all equipment and chemicals to the schools. Some parameters may be measured for educational not analytical purposes and thus may not follow all QA/QC procedures and/or EPA requirements (this does not include pH, temperature, alkalinity, hardness, and metals).

A teacher at each school is designated as the sample custodian and is responsible for the samples and records of the samples. The CDOW chain-of-custody procedure is followed when custody is exchanged . Samples are shipped and secured in taped coolers by UPS to the CDOW. The chain-of-custody record accompanies all samples and will be checked and signed by the appropriate sample custodian.

Data

Colorado Division of Wildlife standardized report forms will be utilized to record data. The use of these forms provide a consistent methodology to record data. The data is also

entered into a computer and files backed up regularly. Electronic data is checked against hard copies and validated. The primary validated databases will be located at the CDOW. The CDOW and schools will transfer data via hard copy and a modem. Data validation is performed by CDOW personnel. A standardized data management protocol is followed and part of the River Watch program documentation. All public data is validated prior to any access.

QUALITY CONTROL

Each school will collect field duplicates and blank samples for metals analysis. Duplicate metal samples will be collected and sent to the CDOW for analysis at a frequency of 1/5 samples per station. Field blanks will also be collected and sent to the CDOW for analysis at a frequency of 1/5 samples per station. Unknown standards for pH, alkalinity and hardness are prepared for the students to check their procedural accuracy as well as chemical accuracy at least twice a year. Students are instructed how to keep the equipment clean and techniques to minimize contamination. A duplicate test between each schools' and CDOW equipment is performed for alkalinity and hardness tests. An annual QA/QC report is completed with summaries of field, lab and data qa/qc.

Laboratory

This section refers to the Colorado Division of Wildlife Laboratory in Fort Collins where the metals analyses will take place. Students are encouraged to visit a laboratory or college to see how the Inductively Coupled Plasma atomic emission spectrometer (ICP) analyzes for metals. The laboratory will use pure standards, solvents and reagents. When applicable, reference standards solutions will be traceable to National Bureau of Standards. Each new lot of reagent grade chemicals shall be tested for quality of performance. Pure water is used in analytical procedures and the cleaning of glassware. The water is prepared by a special deionized water system.

There are several types of quality control samples, including a method blank, calibration standards, check standards, a QA/QC standard, spikes, and duplicate samples. Each of these are described in the following paragraphs.

A method blank containing distilled, deionized water and reagents is carried through the entire analytical procedure. Calibration standards (usually three) are prepared in the laboratory by adding a known amount of a pure compound in an appropriate matrix. The results obtained from these standards are used to generate a standard curve and thereby quantify the compound in the environmental sample.

A check standard is prepared in the same manner as the calibration standards. The check standard is used to verify that the existing concentration calibration standard file or calibration curve is still valid during analysis. The check standards can provide information on the accuracy of the total analytical method and of instrumental performance.

Every 10 samples analyses are bracketed by a blank and a control sample(QA/QC). A control sample of a known value is used to validate the calibration curve, the calibration standards, and the analytical procedure. The control sample is used for validation before and after analysis and the value obtained must fall within -/+ 10 percent of the true value for validation. This control sample is obtained from HIGH-PURITY Standards, HPS Certified Wastewater, Trace Metals [C]. N.I.S.T. Traceable – Standard Reference Material No. 3100 Series.

A matrix spike is prepared by adding a known amount of a pure compound to the environmental sample. The compound is the same as that being assayed for in the environmental sample. For example, if an environmental sample is being analyzed for iron, then pure iron is added to an environmental sample to make the matrix spike for iron. A random 5% of samples for each metal analyzed are spiked and reanalyzed. Matrix spikes simulate the background and interferences found in the actual samples. The calculated percent recovery of the matrix spike is considered to be a measure of accuracy of the total analytical method, sample preparation to analysis. The tolerance limits for acceptable percent recovery are usually those established by the EPA (usually 80 - 120 percent recovery).

Aliquots are made in the laboratory of the same sample and each aliquot is treated exactly the same throughout the analytical method. These aliquots are referred to as laboratory duplicates, similar to a field duplicate but prepared in the laboratory. Duplicate analysis will be performed on at least 5 percent of the samples. The difference between the values of the laboratory duplicate samples is referred to as the relative percent difference (RPD) and is a measure of the precision of the analytical method. The tolerance limit for percent difference between laboratory duplicates is usually those established by the EPA.

Metal concentrations will be reported as the mean of the three sample injections in the case of analyses by graphite furnace or three five second absorbance determinations in the case of analyses by flame. I.C.P. analyses concentrations are the mean of two sample emission readings.

Methods for Water Sample Analysis

Prepared by: Kathleen Stewart July, 1999

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Methods for Water Sample Analysis

Prepared by: Kathleen Stewart

Alkalinity Quantitation (Standard Methods)

Equipment required

125-mL Erlenmeyer flask
50-mL graduated cylinder
10-mL titration burette

Reagents required

deionized (DI) water
standard sulfuric acid solution (0.02N) phenolphthalein indicator solution (1% w/v in 70% isopropyl alcohol)
BGMR indicator solution
Dissolve 0.1 gm bromocresol green and methyl red in reagent alcohol (90% ethanol, 4% 100 mL methanol) and dilute to 100 mL with alcohol.
total alkalinity unknown solution (Environmental Research Associates cat.# 506)

Sample analysis

Samples must be stored in refrigerator and analyzed within 24 hours.

1. Rinse graduated cylinder and Erlenmeyer flask twice with sample water and measure known volume of sample into flask. Record volume on data sheet.

2. Add 15 drops of phenolphthalein indicator solution. If solution turns pink, continue with step 3. If the pH is less than 8.3, the solution should not turn pink. If the solution does not turn pink, go to step 6 .

3. Fill the burette with sulfuric acid and express any air bubbles in the tip with solution. Self-zero the burette.

4. Place the flask below the burette tip and add sulfuric acid drop by drop. Swirl after each drop and continue to add until solution becomes colorless. This is the endpoint for the phenolphthalein alkalinity. Record the mL added on the data sheet.

5. Enter the mL of sample used and the mL of sulfuric added in the Quattro Pro spreadsheet found in c:\data\sprdsbts\spmmddyy and save as spreadsheet with that date. The phenolphthalein alkalinity will be calculated in mg/L as calcium carbonate ($CaCO_3$). If calculating by hand, multiply mL of sulfuric acid by 80 for 25 mL of sample, 40 for 50 mL of sample. Adjust multiplier according to the mL of sample used. Continue with step 6.

6. Add 6 drops of BGMR indicator solution. Color should turn turquoise.

7. Continue to add sulfuric acid drop by drop, swirling after several drops. Toward the end of

the titration the solution should "flash" pink. Add drops slowly and solution should gradually turn from blue to blue-gray to gray to pink-gray. The pink gray is the endpoint for the total alkalinity. If you add a drop past the endpoint, the solution will turn peachy pink. Record the total mL of sulfuric acid added on the data sheet.

8. Enter the mL of sulfuric acid added in the Quattro Pro spreadsheet and the total alkalinity will be calculated as mg/L of calcium carbonate. If calculating by hand and using 25 mL of sample, multiply the mL of sulfuric acid by 40. Adjust multiplier according to the mL of sample used.

QA/QC

For each set of samples analyze an unknown for total alkalinity and record results on unknown data sheet. DOW uses unknown solutions made by Environmental Resource Associates, Denver, Colorado.

Reference: Clesceri, L. S., Greenberg, A.E. and Trussell, R.R., eds., 1989. Standard Methods for the Examination of Water and Wastewater, 17th edition, American Public Health Association, American Water Works Association, Water Pollution Control Federation.

Ammonia Quantitation as N by Ion Selective Electrode (EPA Method 350.3)

Equipment required

ion-specific ammonia electrode
pH meter capable of reading millivolts
50-mL beakers
small stir bars
magnetic stirrer
6-8 1 00-mL volumetric flasks
10-mL volumetric pipette
5-mL volumetric pipette
1 -mL adjustable pipettor with tips
semi-logarithmic graph paper with 4 cycles

Reagents required

deionized (DI) water
ammonia electrode filling solution
pH-adjusting solution (5M NaOH, 0.05M Disodium EDTA in 10% methanol)
1000 ppm ammonia NH_3-N as N standard
nutrient unknown from Environmental Resource Associates (ERA) catalog #505

Probe assembly (if Teflon membrane needs to be replaced)

1. Remove the inner body of the Orion ammonia electrode by unscrewing the upper cap where the cable is attached.
2. Remove cap on outer body and remove old membrane. Cover with new membrane, stretching to be sure there are no wrinkles. Replace cap and tighten.
3. Fill outer body with about 3 mL of electrode filling solution.
4. Place inner body into outer body and screw cap closed. Some solution should be extruded through weep hole near top of outer body.
5. Pull up gently on the cable near top cap several times and then shake like thermometer to remove air bubbles. For storage, return assembled probe to electrode filling solution.

Standard curve

Prepare with every set of samples to be run.

1. Make serial dilution of 1000 mg/L ammonia as N standard. Do not pipette directly out of stock bottle to prevent contamination of standard.
   a. 100 mg/L. Dilute 10 mL of standard solution to 100 mL with deionized (DI) water.
   b. 10 mg/L. Dilute 10 mL of solution a to 100 mL with DI water.
   c. 1 mg/L. Dilute 10 mL of solution b to 100 mL with DI water.
   d. 0.1 mg/L. Dilute 10 mL of solution c to 100 mL with DI water.
   e. 0.05 mg/L. Dilute 5 mL of solution c to 100 mL with DI water.

2. Attach assembled probe to pH/millivolts meter and immerse in DI water.
3. Turn pH/millivolts meter on and set to read millivolts (mV).

4. Rinse clean 50-mL beaker with most concentrated standard. Add about 25 mL of standard, add stir bar and place on plate so bar is stirring. Immerse probe in solution. Be sure that probe does not interfere with stirring action and that no bubbles are resting on the membrane.
5. Add pH adjustment solution until solution in beaker has bluish tinge.
6. After 3 minutes, record mV reading. Allow 4 minutes for solutions with 0.1 mg/L or less.
7. Rinse beaker and probe with DI water and next standard.
8. Repeat steps a-e for all standards. Electrode is very sensitive to residual ammonia at low concentrations, so be sure that beakers are well rinsed.
9. Repeat standard curve. It usually takes 2 times for electrode to equilibrate with the solutions.
10. Plot mV readings against concentrations on semi-log paper and connect dot to dot to make a standard curve. Place concentrations in mg/L on vertical log scale and mV on horizontal normal scale.

Unknown and sample analysis

Samples must be preserved with sulfuric acid to pH < 2 and must be analyzed within 28 days.

1. Place 25 mL of unknown or sample in clean beaker with stir bar that has been rinsed with DI water and sample to be analyzed.
2. Add pH adjustment solution until solution in beaker has bluish tinge.
3. After 3 minutes, record mV reading. Allow 4 minutes for solutions with 0.1 mg/L or less.
4. Determine concentrations of unknowns or samples from standard curve. Unknowns should read within 5% of actual calculated values.
5. Run 5 samples and then another unknown or standard in the 0.05-0.1 mg/L range. If mV readings of unknowns or standards change by more than 5mV, rerun standard curve. Curve generally becomes more sensitive in the lower range as more analyses are run.
6. Store assembled probe in probe soak solution. If mV readings start to drift or the slope of the standard curve decreases, replace membrane.

QA/QC

Prepare 2 dilutions of nutrient unknown--one to fall between .05 mg/L and 0.1 mg/L and one to fall between 0.1 and 0.2 mg/L. DOW uses ammonia unknown and standard solutions made by Environmental Resource Associates, Denver, Colorado.

Chloride Quantitation by Silver Nitrate Titration (Standard Methods)

Equipment required

125-mL Erlenmeyer flask
magnetic stir bar
magnetic stirrer
ringstand with burette clamp
25-mL filtration burette
50-mL graduated cylinder

Reagents required

deionized (DI) water
standard silver nitrate -solution (0.0141 N)
potassium chromate indicator solution (5% w/v)
chloride unknown solution (Environmental Research Associates cat.# 506)

Sample analysis

Samples may be stored at room temperature without preservation and have a holding time of 6 months.

1. Measure 25-50 mL of sample into Erlenmeyer flask. Since silver and hexavalent chromium are both heavy metals, use as few mL of sample as possible to conserve reagent. Add 5-6 drops of potassium chromate indicator solution.

2. Fill burette with standard silver nitrate solution and displace air from burette tip with solution. Record initial burette reading on data sheet.

3. Add stir bar and place flask on magnetic stirrer. Turn stirrer on.

4. Add silver nitrate titrant until yellow color just turns from yellow or cloudy yellow until orange color first appears. The color change may be very slight and orange is at most a hint of color.

5. Wait a few seconds to see if orange color persists. If it does, record the final reading on the burette. If not, continue titrating until orange appears again.

6. Enter the mL of sample used, initial and final burette readings into Quattro Pro spreadsheet to have final concentration of chloride calculated. If making calculations by hand, multiply mL of silver nitrate used by 10 for 50 mL of sample. Adjust multiplier for mL of sample used.

7. Dispose of sample in waste bucket, not down drain.

8. Rinse flask and graduated cylinder with next sample and repeat.

QA/QC

For each set of samples also quantitate a chloride unknown and record results on unknown data sheet. If analysis of unknown is not within 5% of actual value, determine cause and correct.

Reference: Clesceri, L. S., Greenberg, A-E. and Trussell, R.R., eds., 1989. Standard Methods for the Examination of Water and Wastewater, 17th edition, American Public Health Association, American Waterworks Association, Water Pollution Control Federation.

Hardness Quantitation (Standard Methods)

Equipment required

125-mL Erlenmeyer flask
50-mL graduated cylinder
10-mL titration burette
100-mL volumetric flask

Reagents required

deionized (DI) water
ammonia buffer (1% ammonium chloride, 4% ammonium hydroxide)
standard solution of ethylenediaminetetraacetic acid disodium salt (0.01 M EDTA)
Dilute 1 pack of EDTA DILUT-IT analytical concentrate to 2 L with DI water.
EBT indicator solution
Mix 2.5 gm of eriochrome black T thoroughly with 500 gm of sodium chloride.
hardness unknown solution (Environmental Research Associates cat.# 507)

Sample analysis

Samples may be stored at room temperature without preservation and have a holding time of 6 months.

1. Rinse graduated cylinder and Erlenmeyer flask twice with sample water and measure known volume of sample into flask. Record volume on data sheet.

2. Add about 15 drops of ammonia buffer and swirl to mix.

3. Add enough EBT indicator to turn solution violet-cranberry red. You should still be able to see through solution.

4. Fill the burette with EDTA and express any air bubbles in the tip with solution. Self-zero the burette.

5. Place the flask below the burette tip and add EDTA drop by drop. Solution will turn from red-violet to purple to blue-purple. The first drop that turns the solution a royal blue is the endpoint of the titration. Record the mL added on the data sheet.

6. Enter the mL of sample used and the mL of EDTA added in the Quattro Pro spreadsheet found in c:\data\sprdshts\spmmddyy and save as spreadsheet with that date. The hardness will be calculated in mg/L as calcium carbonate ($CaCO_3$). If calculating by hand, multiply mL of sulfuric acid by 40 for 25 mL of sample. Adjust multiplier according to the mL of sample used.

QA/QC

For each set of samples also quantitate an unknown for hardness and record results on unknown data sheet. If analysis of unknown is not within 5% of actual concentration, determine cause and correct.

Reference: Clesceri, L.S., Greenberg, A.E. and Trussell, R-R-, eds., 1989. Standard Methods for the Examination of Water and Wastewater, 17th editor@ American Public Health Association, American Water Works Association, Water Pollution Control Federation.

Nitrite Quantitation (EPA Method 354.1)

Equipment required

Ultraviolet-visible (UV-vis) spectrophotometer, e.g. Spectronic 20.
1-L volumetric flask
6-8 100 mL volumetric flasks
2 1/2"test tubes or tubes to fit your spectrophotometer that are absorbance-matched
125- or 250-mL Erlenmeyer flasks
1-mL volumetric pipette or adjustable pipettor with tips
5-mL volumetric pipette
10-mL volumetric pipette
50-mL graduated cylinder
Quattro Pro spreadsheets for standard curve and sample calculations

Reagents required

85% phosphoric acid
sulfanilamide
N-(1-naphthyl)ethylene-diamine dihydrochloride
deionized (DI) water
color reagent-

Make every 2 months or if solution shows pink color.

1. Add 25 mL 85% phosphoric acid and 2.5 g sulfanilamide to 200 mL of DI water in beaker.
2. Dissolve sulfanilamide completely.
3. Add 0.25 g N-(1-naphthyl)ethylene-diamine dihydrochloride and dissolve completely.
4. Dilute to 250 mL with DI water with 250-mL graduated cylinder.
5. Store in dark bottle and refrigerate.

nitrite unknown (Environmental Research Associates cat. # 695)
1000-mg/L nitrite standard solution

Spectrophotometer Adjustment

1. Turn on Bausch & Lomb Spectronic 20 and allow at least half an hour warm up. Adjust wavelength to 543 nm.
2. With top of spectrophotometer closed, use on-off knob to set transmittance to 0% (absorbance = infinity).
3. Fill 2 clean, 1/2 inch test tubes with deionized (DI) water.
4. Place 1 tube with DI water in spectrophotometer cell. Be sure that line on tube is aligned with the line on the spectrophotometer casing.
5. Close top and set transmittance to 100% (absorbance = 0) with right adjustment knob. Place 2nd tube in cell and check to see that transmittance is also 100%. If not, test other tubes until 2 are found that have the same transmittance.
6. Remove tube, close top and reset transmittance to 0%.

Standard curve

Run every 3 months.

1. Use 10 mL volumetric pipette to dilute 10 mL of stock nitrite solution (1,000 mg/L = 1,000, 000 ug/L) to 1000 mL in 1 L volumetric flask (final concentration = 10,000 ug/L). To prevent contamination of the standard solution, do not pipette directly out of the stock bottle
2. Using 10 mL volumetric pipette, dilute 10 mL of solution 1 to 100 mL (final concentration=1000 ug/L).
3. Make serial dilutions of solution 2 for standard curve. Label volumetric flasks with labeling tape.
   - 10 ug/L Dilute 1 mL of solution 2 to 100 mL.
   - 20 ug/L. Dilute 2 mL of solution 2 to 100 mL.
   - 50 ug/L. Dilute 5 mL of solution 2 to 100 mL.
   - 100 ug/L. Dilute 10 mL of solution 2 to 100 mL.
   - 200 ug/L. Dilute 20 mL of solution 2 to 100 mL.
4. Measure 50 mL of each standard into Erlenmeyer flask and 50 mL of DI water into another flask as reagent blank.
5. To each flask add 1 mL of color reagent from step 2 and swirl to mix. Pour reagent into a beaker to pipette. Do not pipette directly out of bottle, because the reagent easily becomes contaminated and will begin to show a pink color.
6. Allow 10 min. to 2 hours for color development. Fill 2nd tube with blank or standard solution and record transmittances. Readjust spectrophotometer as in step 1 if necessary.
7. Create standard curve in Quattro Pro.
   a. Open most recent file with nitrite standard curve (labeled no2_month_yr) on disk called “curves." Save as new filename with current date.
   b. In appropriate column, record values for standards and transmittances. Use regression tool to calculate the x-coefficient. Print out data and regression graph and place in notebook labeled "nitrite standard curves."
   c. Place current x-coefficient in next spreadsheet used to calculate nitrite concentrations for nutrient samples.

Sample analysis

Samples must be kept cold and analyzed within 48 hours of collection.

1. Allow sediment to settle as much as possible and then measure 50 mL of sample into Erlenmeyer flask. If sample is still very cloudy, it must be filtered.
2. Measure 50 mL of DI water into another flask as reagent blank.
3. Add 1 mL of nitrite color reagent from step 2 to blank and each sample, and swirl to mix.
4. Allow 10 min. to 2 hours for color development. Fill 2nd tube with blank or sample and measure transmittances. If transmittance is less than 15 percent, sample must be diluted with DI water and run again.
5. Enter transmittances in spreadsheet established for South Platte nutrient program and nitrite concentration will be calculated automatically in ug/L.
6. Record transmittances and concentrations on data sheet.

QA/QC

A nitrite unknown should be run each time a new standard curve is run. Dilute nitrite unknown from Environmental Resource Associates (ERA) catalog #695 to fall within range of the standard curve. Follow procedure for sample analysis and record results on unknown data sheet.

Measurement of pH by Glass Electrode (Standard Methods)

Equipment required

glass pH electrode
automatic temperature compensator (ATC) probe
pH meter
50-mL beakers
small stir bars
magnetic stirrer

Reagents required

deionized (DI) water
electrode filling solution
pH standard solutions referenced to National Institute of Standards and Technology (NIST)
pH unknown from Environmental Resource Associates (ERA) catalog #506 or 977

Probe preparation

1. Remove probe from probe soak solution and rinse off with DI water.
2. Slide plastic sleeve down to expose electrode filling hole. Fill with reference electrode solution if necessary.
3. Attach pH and ATC probes to pH meter.

Meter calibration

1. Place 30-40 mL of pH standard solution 7.0 in 50-mL beaker and add stir bar.
2. Rinse both probes with pH 7.0 solution and then immerse both probes in solution of pH 7.0 with magnetic stir bar stirring. Be sure enough solution is in beaker to cover the reference junction below gray sleeve and to prevent interference with the stir bar.
3. Turn meter on and press clear [C] button. You should see "Clr" on the readout.
4. Press the [pH] button and then the [STD] button. When the [eye] stops blinking you should see a ? by 1 STD and the pH should read 7.00± .15
5. Remove probes, rinse with DI water and then with pH 10.0 standard solution.
6. Immerse probes in pH 10.0 standard solution with stir bar stirring and press *only the* [STD] button. When the [eye] stops blinking you should see a ? by 2 STD and the pH should read 10.00± .15.
7. You should now see 4 arrows on the meter face: by pH, ATC, 1 STD and 2 STD. If you do not see 4 arrows, or if the standard solutions read outside the acceptable ranges, repeat procedure from step 2.

Unknown and sample analysis

1. Samples and unknowns should be at 20°C for analysis and may need to be warmed up before measurements are taken.
2. Rinse probes with DI and sample and immerse in 25 mL of unknown or sample in clean beaker that has been rinsed with DI water and sample to be analyzed. Bar should be stirring.
3. Press *only* [pH] button. You should see [eye] blinking. Press [eye] button and allow enough time for solution to establish equilibrium with low ionic-strength solutions, sometimes as long as 3 minutes. When display is stable, press [eye] button again.
4. When [eye] stops blinking, record pH and temperature reading of sample or unknown.

5. Repeat with next sample.
6. When finished, turn meter off, detach probes, cover solution hole with sleeve and return pH probe to soak solution.

QA/QC

Readings of unknown solutions should fall within 0.2 units of certified value.

Reference: Clesceri, L.S., Greenberg, A-E. and Trussell, R.R., eds., 1989. Standard Methods for the Examination of Water and Wastewater, 17th edition, American Public Health Association, American Water Works Association, Water Pollution Control Federation.

Sulfate Analysis (EPA Method 375.4)

Equipment required

Ultraviolet-visible (UV-vis) spectrophotometer, e.g. Spectronic 200
50-mL beakers
10-ml volumetric flasks
6-8 100 mL volumetric flasks
1-mL volumetric pipette or adjustable pipettor with tips
10-mL volumetric pipette
20-mL volumetric pipette
2 1/2 inch absorbance-matched test tubes or tubes to fit your spectrophotometer
Quattro Pro spreadsheets for standard curve and sample calculations

Reagents required

Hach SulfaVer powder pillows
deionized (DI) water
1000-mg/L nitrite standard solution
sulfate unknown solution (Environmental Research Associates cat. #(506)

Spectrophotometer Adjustment

1. Turn on Bausch & Lomb Spectronic 20 and allow at least half an hour warm up. Adjust wavelength to 420 nm.
2. With top of spectrophotometer closed, use on-off knob to set transmittance to 0% (absorbance = infinity).
3. Fill 2 clean, 1/2 inch test tubes with deionized (DI) water.
4. Place 1 tube with DI water in spectrophotometer cell. Be sure that line on tube is aligned with the line on the spectrophotometer casing.
5. Close top and set transmittance to 100% (absorbance = 0) with right adjustment knob. Place 2nd tube in cell and check to see that transmittance is also 100%. If not, test other tubes until 2 are found that have the same transmittance.
6. Remove tube, close top and reset transmittance to 0%.

Standard curve

Run every 3 months.

1. Dilute 10 mL of stock sulfate solution (1,000 mg/L) to 100 mL in 100-mL volumetric flask with DI water (final concentration = 100 mg/L). Do not pipette directly out of stock bottle.
2. Make serial dilutions of solution a for standard curve. Label volumetric flasks with labeling tape.
   - 10 mg/L. Dilute 10 mL of solution a to 100 mL.
   - 20 mg/L. Dilute 20 mL of solution a to 100 mL.
   - 50 mg/L. Dilute 50 mL of solution a to 100 mL.
3. With volumetric pipette, measure 10 mL of each standard solution into 50-mL beaker.
4. Measure 10 mL of DI water into another beaker as reagent blank.
5. To each beaker add 1 pillow of Hach SulfaVer reagent powder and swirl to mix.
6. Between 5 and 10 min fill 2nd tube with blank or standard solution and record transmittances. Readjust spectrophotometer as in step 1 if necessary.

7. Create standard curve in Quattro Pro.
   a. Open most recent file with sulfate standard curve (labeled so4_month_yr) on disk called "curves." Save as new filename with current date.
   b. In appropriate column, record values for standards and transmittances. Use regression tool to calculate the x-coefficient. Print out data and regression graph and place in notebook labeled "sulfate standard curves."
   c. Place current x-coefficient in next spreadsheet used to calculate sulfate concentrations for South Platte nutrient samples.

Sample analysis

Samples may be stored at room temperature and have a holding time of 6 months.

1. Allow sediment to settle as much as possible, then using Eppendorf pipette and 10-mL volumetric flask dilute each sample to fall within range of standard curve. If sample is still very cloudy, it must be filtered.
2. Conductivity may be used as a guide to determine the proper dilution:

0-500 uS/cm	No dilution required.
500-1500 uS/cm	Dilute 1: 10.
1500-2300 uS/cm	Dilute 1: 20--0.5 mL to 10 mL.
>2300 uS/cm	Dilute 1:50--1 mL to 50 with 50-mL volumetric flask.

3. Pour contents of 10-mL volumetric flask or measure 10 mL with volumetric pipette into 50-mL beaker. Measure 10 mL of DI water into another beaker as reagent blank.
4. To blank and each sample add 1 pillow of Hach SulfaVer reagent powder and swirl to mix.
5. Between 5 and 10 minutes fill second tube with blank or sample and measure transmittances. If transmittance is less than 15%, sample must be diluted with DI water and run again. If transmittance is greater than 85% and sample has been diluted, rerun at lower dilution.
6. Enter transmittances and dilutions in spreadsheet established for South Platte nutrient program and sulfate concentration will automatically be calculated.
7. Record transmittances and concentrations on sample data sheets.

QA/QC

A sulfate unknown should be run each time a new standard curve or samples are run. Dilute Environmental Resource Associates (ERA) standard #698 to fall within range of standard curve (10-50 mg/L) using Eppendorf or volumetric pipette and 10-mL volumetric flask. Follow procedure for sample analysis and record results on unknown data sheet.

Total Suspended Solids (TSS) [EPA Method 160.2]

Equipment required

500-mL filter flasks
Gooch porcelain crucibles
rubber crucible holders
glass funnels
graduated cylinders of varying capacities
vacuum pump
drying oven
glass fiber filter discs
dessicator
balance

Reagents required

deionized (DI) water
calcium chloride or other dessicant
TSS standard (Environmental Resource Associates cat.#510)

Sample analysis

1. Prepare crucibles by placing filter discs in bottom. Fill crucible with DI water and aspirate water.
2. Place crucibles in preheated oven @103-105°C for 1 hour.
3. Remove crucibles and place in dessicator with dessicant for about half an hour or until cool.
4. Weigh crucibles and record weight on data sheet with crucible #'s and sample #'s.
5. Thoroughly agitate samples and filter enough solution until it drips slowly or the liquid level in the flask reaches the bottom of the funnel.
6. Measure amount of solution filtered and record on data sheet.
7. Place crucibles in oven for another hour and again place in dessicator until cool.
8. Weigh crucibles again and record weight on data sheet.
9. Enter readings into spreadsheet and mg/L will automatically be calculated.
10. If calculating by hand, subtract initial crucible weight from final weight, and divide by mL x .001.

QA/QC

Occasionally quantitate an unknown for total suspended solids and record results on unknown data sheet.

APPENDIX C

PROTOCOL FOR FIELD PARAMETER MEASUREMENT AND EQUIPMENT CALIBRATION

PROTOCOL FOR FIELD PARAMETER MEASUREMENT

AND EQUIPMENT CALIBRATION

Temperature, pH, specific conductance, dissolved oxygen and, where needed, oxidation-reduction potential (Eh) measurements will be performed in the field at the time of sample collection. Data obtained from field water quality measurements will be entered on surface water quality sampling forms. Separate aliquots of water shall be used to make field measurements (samples for laboratory analysis will not be used or reopened for field measurements). Following are discussions of measurement and equipment calibration procedures.

TEMPERATURE

Temperature measurements will be made with a mercury-filled thermometer, bimetallic-element thermometer or electronic thermistor of an ORION 250A pH meter or equivalent. All measurements will be recorded in degrees Celsius (°C).

Thermometer calibration will be checked at the beginning of each sampling event by immersing the sensor in an ice-filled bath and verifying that the temperature read is O°C.

pH

The pH measurement will be made as soon as possible after collection of the field parameter sample using an ORION 250A digital pH meter or equivalent. The pH value displayed on the calibrated instrument will be recorded after the reading has stabilized.

HOW TO TAKE pH

1. Remove tape from probe.

2. Soak electrode (not ATC probe) in KCL solution for three minutes prior to first use of the day. If no KCL is available use pH 4 buffer solution.

3. If ATC probe or thermometer is plugged in, it must travel everywhere with the pH probe.

4. Rinse the probe and thermistor with deionized water and then dry.

5. Take the cap off the pH 7 buffer and put it top down in a safe place.

6. Rinse probes with pH 7 buffer solution.

7. Place both probes into the pH 7 buffer.

8. Turn the meter on and press [C].

9. Press the [pH] and then the [STD] keys. Press in sequence, not simultaneously. You should see a 0 by STD 1.

10. When the [eye] stops blinking, read the pH of the buffer. If it is between 6.85 and 7.15, you are in good shape. If not, try replacing the buffer, re-rinse the probe and try again.

11. Take the probes out and put the cap back on the pH 7 buffer.

12. Take the cap off the pH 14 buffer and put the cap upside down in a safe place (pH 10 buffer if pH > 7).

13. Rinse probes with pH 4(10) buffer solution.

14. Put the probes in the pH 4(10) buffer and press the [STD] key. When the [eye] stops blinking, read the meter. You should see a ? by STD 2. If the pH is between 3.85 and 4.15 (or 9.85 and 10.15) you are cool. If not, see step 10 above.

15. Put the cap back on the pH 4 or 10 bottle.

16. Rinse the probes off many times with sample water and then dry. Remember when drying, do not fail to soak all fluids out of the tip of the probe.

17. Put the probes in the sample you have collected. Remember to put some of the sample water in a clean vessel to take the pH - do not use the sample collection bottle.

18. Press the [pH] key. When the [eye] stops blinking read and record the pH and temperature on the Field Data sheet.

19. Rinse both probes with deionized water and then dry. Take another pH of your sample from another station if appropriate. If you are done for the day, turn the pH meter off. Place tape over pH probe by the white line.

20. Store it correctly.
    When original tape wears out, ideally replace it with white teflon pipe tape (it sticks to itself not the probe), electric tape and the last choice would be masking/scotch tape the less sticky the better.

POSSIBLE PROBLEMS WITH pH METER

These instructions are in the pH manual under "Measuring pH".

1. If the triangle points to the ATC label, that indicates the ATC probe is plugged in and actively reading a temperature.

2. If the triangle does not point to the ATC label then the ATC probe is NOT plugged in and the temperature compensation default is 25 degrees Celsius. The probe will read the pH but compensate at a temperature of 25 degrees Celsius.

3. If [Err] displays where a temperature should, check ATC connection and report if problem persists.

4. **[?]** indicates the batteries are low and need to be changed. See the pH manual. Request when ordering supplies.

5. **[?]** suggests the pH probe may be malfunctioning or your standards (or calibration) is wrong. If this happens try two things:

    a. Try a new batch of pH buffers. Empty the little bottles of old buffers. Rinse these three bottles with deionized water several times. Pour new buffers in the small bottles. Buffers can get contaminated. Now, recalibrate the meter and read your pH again.

    b. Make sure the pH probe is clean. Check the tip of the probe for white crystals. Make sure the hole near the top was open when you tried to read the buffers or pH.

Remember your pH meter is stupid - it will always give a reading regardless of what buttons are pressed or probes attached. You are the scientist - look at the face of the meter for feedback and respond accordingly.

TROUBLE SHOOTING WITH pH METER

1. Check your pH reading and see if it makes sense, especially if you have seasonal data to compare. A good scientist ALWAYS checks his/her answer for plausibility.

2. Check the range of buffers during calibration. If the buffers do not calibrate, change buffers and calibrate again.

3. There are troubleshooting instructions in the pH manual under "instrument functions and features." Follow the instructions, specifically the paper clip test, to see if the problem is the meter or the probe.

4. The CDOW will replace batteries, storage solution and KCL solution. DO NOT hesitate to call if you DO NOT understand how the probe or meter works or how the probe needs to be taken care of. Any problems PLEASE call. Good Luck!!!

WHAT THERE IS TO KNOW ABOUT THE pH METER

With the pH carrying case kit, you should receive the following:

3 buffers (which you already have refills for)
1 meter
1 bottle with KCL solution
1 ATC (Automatic Temperature Compensation) probe - the skinny probe
1 empty bottle
1 gel pH probe
instruction manual and instruction sheets

How to Assemble the Meter:

1. Plug pH probe cord into "pH" slot on meter. Plug in the ATC cord. Make sure to connect the pH probe cord to the probe.

2. The white line must be covered with tape when not in use. Remove the tape prior to use and immerse the probe in KCL solution for at least three minutes prior to calibration. Barb suggests filling a two-ounce bottle with KCL and storing it in the kit. The solution must be above the white line on the probe when reading pH.

SPECIFIC CONDUCTANCE

Specific Conductance will be measured using a Cole-Parmer 1481-61 conductivity meter or equivalent. The measurement will be made by immersing the electrode directly into the water source or into a field parameter sample to the manufacturer's recommended depth. Specific conductance will be reported in micromhos/cm at 25°C. If the meter is not equipped with an automatic temperature compensation function, then the unadjusted field value will be entered on the sampling form and adjusted at a later time using the sample temperature data and the following formula:

$$SC_{25} = \frac{SC_T}{1 + [(T - 25) \times 0.025]}$$

where: SC_{25}= specific conductance at 25-C
SC_T = specific conductance measured at temperature T (°C)
T = sample temperature (°C)

The specific conductance value displayed on the calibrated instrument will be recorded after the reading has stabilized. If the value falls outside of the selected range on the instrument, then the range setting will be changed to a position which allows the value to be read. This will sometimes necessitate recalibration before recording the sample specific conductance value.

At the beginning of each sampling day and prior to use at each sampling location, the conductivity meter will be calibrated with standardized potassium chloride (KC) or sodium chloride (NACI) solutions having conductivity values within the expected range. The battery charge of the meter will also be checked at the beginning of each sampling day. The conductivity probe will be checked periodically for signs of deterioration, and regenerated, replated, or replaced as needed.

DISSOLVED OXYGEN

Dissolved oxygen (DO) will be measured at surface water stations using a YSI 55 dissolved oxygen meter, the Hach titration method, or the Winkler Titration method. The reading will be recorded as mg/L.

DISSOLVED OXYGEN METER

If using the dissolved oxygen meter, DO will be measured by immersing the probe directly into the stream channel. In shallow or slow-moving streams, the probe will be moved up and down or horizontally approximately one foot per second while measuring.

The DO instrument will be calibrated using a saturated air method. The probe will be placed in air-saturated water or a 100% relative humidity chamber and calibrated to the altitude-corrected, saturated air concentration provided by the manufacturer. The DO meter will be calibrated at the beginning of each sampling day, at midday and after every change in altitude of approximately 1000 feet.

HACH KIT DISSOLVED OXYGEN

High Range Test

1. Complete the required information on the Dissolved Oxygen Using Hach Kit Data Sheet including the sample number, river name, date and time of sample and river temperature.

2. Fill the dissolved oxygen bottle (round bottle with glass stopper) with the water to be tested by allowing the water to overflow the bottle for two or three minutes. To avoid trapping air bubbles in the bottle incline the bottle slightly and insert the stopper with a quick thrust. This will force the air bubbles out. If bubbles become trapped in the bottle in steps 2 or 4, the sample should be discarded before repeating the test.

3. Use the clippers to open one Dissolved Oxygen 1 Reagent powder pillow and one Dissolved Oxygen 2 Reagent powder pillow. Add the contents of each of the pillow to the bottle. Stopper the bottle carefully to exclude air bubbles. Grip the bottle and stopper firmly; shake vigorously to mix. A flocculent (floc) precipitate will be formed. If oxygen is present in the sample the precipitate will be brownish orange in color. A small amount of powdered reagent may remain stuck to the bottom of the bottle. This will not affect the test results.

4. Allow the sample to stand until the floc has settled half way in the bottle, leaving the upper half of the bottle clear. Shake the bottle again. Again let it stand until the upper half of the sample is clear. Note the floc will not settle in samples with high concentration of chloride, such as sea

water. No interference with the test results will occur as long as the sample is allowed to stand for four or five minutes.

5. Use the clippers to open on Dissolved Oxygen 3 Reagent Powder pillow. Remove the stopper from the bottle and add the contents of the pillow. Carefully restopper the bottle and shake to mix. The floc will dissolve and a yellow color will develop if oxygen is present.

6. Fill the plastic measuring tube level full of the sample prepared in steps 1 through 5. Pour the sample into the square mixing bottle.

7. Add Sodium Thiosulfate Standard Solution drop by drop to the mixing bottle, swirling to mix after each drop. Hold the dropper vertically above the bottle and count each drop as it is added. Continue to add drops until the sample changes from yellow to colorless.

8. Each drop used to bring about the color change in step 7 is equal to 1 mg/L of dissolved oxygen (DO). Record total number of drops used on line 4 of Dissolved Oxygen Data Sheet.

9. If dissolved oxygen is greater than 3 mg/L, record answer from line 4 on line 8 as well. Calculate percent saturation (next page). If dissolved oxygen is less than or equal to 3 mg/L, go on to step 10.

Low Range Test

If the results of step 8 are very low (3 mg/L or less) it is advisable to obtain a more sensitive test. To do so:

1. Use the prepared sample left from step 5 in the High Range Test. Pour off the contents of the DO bottle until the bottle level just reaches the mark (30 ml) on the bottle.

2. Add Sodium Thiosulfate Standard Solution drop by drop directly to the DO bottle. Count each drop as it is added and swirl the bottle constantly to mix while adding the titrant. Continue to add drops until the samples change from yellow to colorless.

3. Each drop of Sodium Thiosulfate Standard Solution used to bring about the color change in step 9 is equal to 0.2 mg/L dissolved oxygen.

4. Record the number of drops used on line 6 and multiply by 0.2 mg/L. Record this number on line 7 and line 8 of the dissolved oxygen data sheet.

Percent Oxygen Saturation

1. Refer to the level of oxygen saturation chart on the Dissolved Oxygen data sheet. Find your river temperature on the top scale and your dissolved oxygen on the bottom scale.

2. Draw a straight line between the water temperature and dissolved oxygen measurement (oxygen mg. per liter).

3. Read the saturation percentage at the intercept on the sloping scale.

4. Record the percent saturation on the line provided to the right of the chart.

Dissolved Oxygen Using Hach Kit

Station Name_____ Sample Number_____

River_____ Date of sample_____

School_____ Time of sample_____

River Temperature_____ ^{o} Celsius

Dissolved Oxygen

1. Record the time the sample was taken above, Record the temperature of the river above.
2. Add drops of Sodium Thiosulfate to change the color from yellow to colorless. Keep track of the number of drops you use. Each drop of Sodium Thiosulfate added should change the color and is equal to 1.0 mg/L of dissolved oxygen.
3. How many drops did you add to change the color from yellow to colorless?
4. Multiply the number of drops added in line 3 by 1.0.
   Use the following formula:
   (Drops added) x 1.0 mg/L dissolved oxygen =_____mg/L dissolved oxygen
5. If the amount is in line 4 is greater than 3 mg/L dissolved oxygen, you are finished. Record the number in line 8 below.

If the sum in line 4 is equal to or less than 3 mg/L dissolved oxygen, follow steps 9-12 in the instructions to determine a more accurate number. Each drop of Sodium Thiosulfate used to bring about a color change in step 10 is equal to 0.2 mg/L dissolved oxygen,

6. Record the number of drops added:
7 Multiply the number of drops added in line 6 by 0.2. Use the following formula:
   (Drops added) x 0.2 mg/L dissolved oxygen =_____mg/L dissolved oxygen

8. Total dissolved oxygen _____mg/L dissolved oxygen

Level of oxygen saturation chart

To use the chart, draw a straight line between the water temperature at the test site and the dissolved oxygen measurement (Oxygen mg. Per liter), and read the saturation percentage at the intercept on the sloping scale.

Percent Saturation:_____

Data recorded by:_____ Date recorded:_____

Standard Winkler Titration Method DO

1. Record the station name, river, school, sample number, date and time of the sample on the Standard Winkler Method Dissolved Oxygen data sheet.

2. Record the temperature of the river on line 1 of data sheet.

3. Rinse 300-mL, BOD in sample water. Collect a water sample in a clean, 300-mL, glass-stoppered BOD bottle. Overflow the bottle for two or three minutes to remove any trapped air bubbles.

4. Add one mL Manganese Sulfate Solution and one mL Alkaline lodideAzide Reagent.

5. Immediately insert the stopper so that no air is trapped in the bottle. Invert several times and shake to mix. A flocculent precipitate will form. It will be orange-brown if oxygen **is** present or white/pale yellow if oxygen is absent. The floc will settle very slowly in salt water and in cold temperatures. Please wait an additional five minutes before proceeding with Step 6.

6. Wait until the floc in the solution has settled at least half the way. Again invert the bottle several times and wait until the floc has settled. Waiting until floc has settled twice assures complete reaction of the sample and reagents.

7. Remove the stopper and add the contents of one Sulfamic Acid Powder Pillow. Replace the stopper without trapping air in the bottle and invert several times to mix prepared sample. The floc will dissolve and leave a golden/yellow color if oxygen is present. Your sample is now prepared. See note for instruction if storage is necessary. Return to the lab.

8. Rinse the 500-mL Erlenmeyer flask and graduated cylinder with deionized water, Pour the prepared sample into a graduated cylinder to the 200-mL mark.

9. Pour the contents of the graduated cylinder into the clean 500-mL Erlenmeyer flask.

10. Rinse and seed the 25 ml burette with Sodium Thiosulfate by filling the burette to the 5 ml mark. Let 3 mls out to the 8 ml mark with Sodium Thiosulfate titrant ($Na_2S_2O_3$), 0.025 N. If you go past 8 mL, fill back to 8mL with more $Na_2S_2O_3$.

11. Record starting point on line 2 of Winkler Dissolved oxygen data sheet.

12. Add Sodium Thiosulfate to the prepared sample drop-by-drop, swirling the flask until the sample turns a pale, straw-yellow color. Compare color to the remaining sample in the BOD bottle. If solution in erlenmeyer flask is more gold than yellow, add more Sodium Thiosulfate.

13. Add 20 drops of Starch Indicator Solution or enough drops to make a dark blue (see page 74). Swirl to mix. A dark blue color will develop. If a dark green appears, it just means you could have gone to a paler yellow. It's okay to proceed.

14. Continue to titrate with.Sodium Thiosulfate. The titration endpoint is the first drop that causes the solution to change from dark blue to colorless or clear.

15. Record end point on line 3 of Winkler Method Dissolved Oxygen data sheet.

16. Calculate, by subtracting starting point from end point, and record ml dissolved oxygen on line 4 of Winkler Dissolved Oxygen data sheet. ml Titrant used equals mg/L dissolved oxygen

17. Calculate the percent saturation of dissolved oxygen, using the chart on the data sheet.

    a. Find your water temperature on the top scale and dissolved oxygen value on the bottom scale.

    b. Draw a straight line between the water temperature and dissolved oxygen measurement (oxygen mg. per liter).

    c. Read the saturation percentage at the intercept on the sloping scale.

    d. Record the percent saturation on the line provided to the right of the chart.

18. Drain burette, rinse erlenmeyer flask, graduated cylinder, and burette with deionized water and store upside down or store burette upright with remaining $Na_2S_2O_3$, and place foil or cover opening,

Instructions for Making Starch Indicator

1. You may make potato or cornstarch indicator or use purchased starch indicator. Cornstarch will last longer than potato due to mold.

2. For cornstarch follow these steps:

   a. Requirements: cornstarch, sauce pan and water.

   b. Use a 10:1 water to starch ratio.

   c. Add about I Tbsp. of water with a little cornstarch and mix until pasty.

   d. Add pasty mixture to about 1 cup boiling water and boil until all starch is dissolved. (about 1 cup water to 1/10 cup cornstarch.

   If mixture remains "pasty," take smaller portion and dilute it. Heat again until you have a solution, not a paste.

3. For potato starch follow these steps:

   a. Requirements: a small potato, sauce pan and stove.

   b. Fill pan with enough water to just cover potato. (Don't overfill). Remove potato.

   c. Bring water to a boil and place potato in pan.

   d. Boil potato for at least 1/2 hour or until "mush".

   e. Let water cool and potato settle.

   f. Pour the water (the top part) in to starch bottle,

   g. Ready to use as directed above.

Standard Winkler Method Dissolved Oxygen

Station Name_____ Sample Number_____

River_____ Date of sample _____

School_____ Time of sample _____

1. River temperature _____ ^{o} Celsius

2. Titrate start point_____

3. Titrate end point_____

4. Calculate the amount of titrant used to change the color from gold to colorless.(Subtract starting point from end point.)

ml of titrant used = mg/L dissolved oxygen _____ml dissolved oxygen

5. Determine the percent saturation of dissolved oxygen using the chart below.

Comments:_____
_____

Percent Saturation_____

Data recorded by_____ Date recorded_____

To use the chart, draw a straight line between the water temperature at the test site and the dissolved oxygen measurement (Oxygen mg. Per liter), and read the saturation percentage at the intercept on the sloping scale.

Solubility of Oxygen Exposed to Water

Purpose: This chart illustrates the influence of temperature on dissolved oxygen saturation (solubility), Colder water holds more dissolved oxygen than warmer water. Can you see the trend? On the next page, note how calibration values (saturation) changes with altitude (middle column), Water at higher elevations holds less oxygen than water at lower elevations (just like oxygen in air behaves). At sea level, altitude of 0 feet, saturation of dissolved oxygen is 100 percent. Water is holding as much oxygen as it can. At an altitude of 7749', saturation is 75 percent, or at that elevation 75 percent is 100 percent saturation.

To illustrate the relationship between temperature, altitude and their influence on dissolved oxygen saturation, do the following: Find your river, temperature, and solubility level on this chart, (eg. 6 °C = 12.45 mg/L) Find your altitude and corresponding calibration value (saturation value) on the next table. (eg. 5,067 feet = 83%) If you take 83 percent of 12.45 mg/L you get **10.3** mg/L. This is what the results of your dissolved oxygen test should have been for that temperature and altitude.

TABLE 1. Solubility of Oxygen Water Exposed to Water

SATURATED AIR AT 760 mm Hg PRESSURE

Temp °C	Solubility mg/L	Temp °C	Solubility mg/L	Temp °C	Solubility mg/L
0	14.62	16	9.87	32	7.31
1	14.22	17	9.67	33	7.18
2	13.83	18	9.47	34	7.07
3	13.46	19	9.28	35	6.95
4	13.11	20	9.09	36	6.84
5	12.77	21	8.92	37	6.73
6	12.45	22	8.74	38	6.62
7	12.14	23	8.58	39	6.52
8	11.84	24	8.42	40	6.41
9	11.56	25	8.26	41	6.31
10	11.29	26	8.11	42	6.21
11	11.03	27	7.97	43	6.12
12	10.78	28	7.83	44	6.02
13	10.54	29	7.69	45	5,93
14	10.31	30	7.56	46	5.84
15	10.08	31	7.43	47	5.74

TABLE II. Calibration Values-Atmospheric Pressures and Altitudes

Pressure			Altitude		
inches Hg	mm Hg	kPa	Ft.	m	Calibration Value(%)
30.23	768	102.3	-276	-84	101
29.92	760	101.3	0	0	100
29.61	752	100.3	278	85	99
29.33	745	99.3	558	170	98
29.02	737	98.3	841	256	97
28.74	730	97.3	1126	343	96
28.43	722	96.3	1413	431	95
28.11	714	95.2	1703	519	94
27.83	707	94.2	1995	608	93
27.52	699	93.2	2290	698	92
27.24	692	92.2	2587	789	91
26.93	684	91.2	2887	880	90
26.61	676	90.2	3190	972	89
26.34	669	89.2	3496	1066	88
26.02	661	88.2	3804	1160	87
25.75	654	87.1	4115	1254	86
25.43	646	86.1	4430	1350	85
25.12	638	85.1	4747	1447	84
24.84	631	84.1	5067	1544	83
24.53	623	83.1	5391	1643	82
24.25	616	82.1	5717	1743	81
23.94	608	81.1	6047	1843	80
23.62	600	80.0	6381	1945	79
23.35	593	79.0	6717	2047	78
23.03	585	78.0	7058	2151	77
22.76	578	77.0	7401	2256	76
22.44	570	76.0	7749	2362	75
22.13	562	75.0	8100	2469	74
21.85	555	74.0	8455	2577	73
21.54	547	73.0	8815	2687	72
21.26	540	71.9	9178	2797	71
20-94	532	70.9	9545	2909	70
20.63	524	69.9	9917	3203	69
20.35	517	68.9	10293	3137	68
20-04	509	67.9	10673	3253	67
19.76	502	66.9	11058	3371	66

APPENDIX D

ALKALINITY TITRATION INSTRUCTIONS AND DATA SHEET

NOTE: Before you begin, make sure the data on the bottom of this instruction sheet matches the date on the bottom of the data sheet -- if not-- see your teacher to get a matching date.

Instructions for Alkalinity Titration

1. Complete the information required above Part I on the alkalinity data sheet. If known, record your pH value. If not known, continue and record when pH has been tested.

2. Rinse the graduated cylinder and erlenmeyer flask once with deionized water and twice with sample water. Be sure you're using the erlenmeyer flask with an "A" label.

Part I

1. Fill graduated cylinder with 50 mls of sample, then pour into the "A" erlenmeyer flask. Record, on line one of Part 1 of the alkalinity data sheet, the amount of sample used.

2. If known, record your pH value on line two of Part 1. Answer the question: Is pH greater than 8.3? Based on the pH value, what color do you predict your sample will be?

3. Add up to 15 drops of phenolphthalein indicator to erlenmeyer flask. Answer question three in Part 1: Did the solution turn a faint pink? If answer is **YES**, go on to step 4.

NOTE: Phenolphthalein should not be "huge", as a general rule, not >2.0mg/L or 8.00mg/L $CaCo_3$. It should never be greater than total alkalinity or Part II answer. The greater the phenol, the higher your pH should be.

If your answer is NO and the sample did not turn pink but instead turned a cloudy white or remained clear, then record phenolphthalein alkalinity as 0.0 mg/L on line five of Part I and note this in the field data sheet comment section. It may mean the pH sample was too cold when pH was read, thus the pH reading is off slightly. Go to step 1, Part II.

4. Self zero the pipette with H_2SO_4, sulfuric acid. Be sure air bubbles are not in the stem of the flask by releasing a few drops and self zero the pipette again. Also make sure the tip of the pipette is not crusted with H_2SO_4.

5. Place the flask under the pipette and drop by drop add sulfuric acid. Swirl the flask after each drop. It should only take several drops. Do this until the next drop turns the solution clear. This is your endpoint for phenolphthalein alkalinity.

6. Read the pipette carefully. Record the reading on the data sheet in line four of Part I. Starting point should have been "0". Subtract starting point from endpoint. Multiply that difference by 40. This is the phenolphthalein alkalinity in mg/L of C_aCO_3. Record phenolphthalein alkalinity value in line four, Part I.

For example: endpoint = 0.2 ml start = 0.0 ml 0.2 ml x 40 = 8.0 mg/L phenolphthalein alkalinity as CaCO3.

You are **NOT** through, continue to Part II for BGMR alkalinity.

Part II

1. Place 6 drops of BGMR indicator into the same "A" erlenmeyer flask used above and swirl (color should be a turquoise). Answer the question on line one, Part II.
   a. If your phenolphthalein alkalinity was **less than or equal to** zero (< 0), automatically zero your burette with the bulb.

b. If your phenolthalein alkalinity was **greater than** zero (> 0), **DO NOT** zero the burette.

2. Place the flask under the pipette and drop by drop add sulfuric acid. Swirl the flask after each drop. This reaction is relatively fast. The solution may turn pink, but return to blue. The color change proceeds from turquoise to blue-gray to a clear gray, then a pink-gray and finally a pink-peachy-pink. The color changes from blue-gray to pink-peachy-pink are usually a drop a part. **Your endpoint is the pink-gray color not the pink-peachy-pink**. Stop when you are at your endpoint (change should be gradual if you go drop-by-drop).

3. Past the pink-gray endpoint, the solution will stay a pink-peachy-pink regardless of any additional H_2SO_4 you add. Learn your river's color transition. A viable technique is to titrate through the endpoint color if you read the burette after every drop. Thus, you have a reading for every color change and can choose the best endpoint.

4. Read the pipette carefully. Record the reading on the data sheet in line two of Part II. Starting point should have been "0". Subtract starting point from endpoint. Multiply that difference by 20. This is the Total Alkalinity in mg/L of $CaCO_3$. Record total alkalinity value. Record this value in line three of Part II.

For example: endpoint = 2.5 mlstart = 0.0 ml 2.5 ml x 20 = 50 mg/L Total Alkalinity as $CaCO_3$.

5. Dispose the solution in the flask into a waste bucket or sink. Rinse out erlenmeyer flask with deionized water and store UPSIDE DOWN.

Common mistakes

1. Misreading the burette—check twice, get a second opinion.

2. Passing the endpoint because:

   a. Students did not allow enough time between drops for reaction to occur.
   b. Students did not do one drop at a time.

3. Titrating only for phenolphthalein alkalinity and forgetting to titrate BGMR alkalinity, you will always have a BGMR alkalinity if pH is greater than 4.5.

4. Final multiplication is wrong.

Alkalinity—The "why"

What:

1. Alkalinity is the balance of carbon dioxide in the river. Specifically, alkalinity is the amount of HCO_3^-(bicarbonates) + CO_3^{2-} (carbonates) present. These bicarbonates and carbonates are anions. The dynamic equilibrium that exists in water is the following:

   a. $CO_2 + H_2O = CO_2$ (dissolved) $H_2O = H_2CO_3$ (carbonic acid)

   b. $H_2CO_3 = HCO_3^-$ (bicarbonate) + H^+

   c. $HCO_3^- = CO_3^{2-}$ (carbonate) + H^+

2. In equilibrium, all these reactions are happening. When pH is artificially pushed above seven to the basic end, all these reactions go to the right until all H_2CO_3 or CO_2 is converted to CO_3^{2-}. Conversely when pH is artificially pushed below seven or to the acidic end, all these reactions go to the left until all CO_3^{2-}, HCO_3^- or CO_2 is in the H_2CO_3 form. Thus, alkalinity, or the amount of $HCO_3^- + CO_3^{2-}$, present in your river is a function of pH.

3. See chart 4 for alkalinity's relationship to pH. Can you draw the lines in color to match each equation?

Chart 4:

4. Alkalinity is sometimes referred to as buffering capacity. Buffering capacity is the ability of H_2O to resist a change in pH when an acid (H^+) is added. Below pH 4.5, no alkalinity can be measured—there are no $HCO_3^- + CO_3^{2-}$ present. When an H^+ is added, it will hook up with a HCO_3^- and make H_2CO_3 or CO_3^{2-} and make HCO_3^- and pH will not change. If H^+ is added faster than HCO_3^- or CO_3^{2-} can react or if there are no $HCO_3^- + CO_3^{2-}$ left, the pH of your system **will** decrease. This is what happens in an acid rain/snow situation.

5. Alkalinity is measured as mg/L $CaCO_3$. Think of the CO_3 part of the unit as alkalinity. Water doesn't contain mg/L of $CaCO_3$ but behaves as if it does because $CO_3^{2-} + HCO_3^-$ are the main anions that neutralize acid (H^+s) in natural waters. An acid (H^+) in water can be neutralized by carbonates CO_3^{2-} to form a bicarbonate HCO_3^-, or by HCO_3^- to form H_2CO_3.

Why:

1. It is a measurement of the buffering capacity of a river system.

2. Mitigates or relieves metals toxicity by using available $HCO_3^- + CO_3$2- to take metals out of solution and unavailable to fish.

3. Varies seasonally.

How:

1. Acid/base titration with 0.02N sulfuric acid.

NOTE:
You are using up the buffer capacity. Adding two H^+ will cause CO_3^{2-} to be H_2CO_3.

Chemical reactions:

$$H^+ + IN^- \ ] \ HIN$$

Where H^+ is the acid you are titrating with, here it is H_2SO_4. IN^- is the color indicator and HIN is the color of the endpoint solution.

If pH is above 8.3, your CO_2 is in the form of $CO_3$2-plus some HCO_3-. Your IN^- will be pink after adding 15 drops of phenolthalein. When you add H_2SO_4 (an acid, H^+) eventually the solution turns clear—that is the HIN color.

NOTE:
Below a pH of 4.5, there are no more HCO3- left, all CO2 is in H_2CO_3 form; thus, the HIN can't get any pinker. You have used up all the solutions' buffering capacity.

If you pH is below 8.3 your CO_2 is all in the form of HCO_3-. Your IN^- will be turquoise after adding six drops of BGMR. When you add H_2SO_4 eventually the solution turns pink-grey-blue. That is the HIN color.

Alkalinity Data Sheet

Station Name _____ Sample Number___ ___ ___ . ___ ___ ___

River _____ Date of sample ___/___/___

School _____ pH _____

PART I C Phenolphthalein Alkalinity

1. Amount of sample used: _____ml

2. pH_____ Is pH greater than 8.3? 9Yes 9No

3. Add phenolphthalein indicator. Did solution turn pink? 9Yes 9No
   If you answered **YES**, continue with step 6.
   If you answered **NO**, record phenolphthalein alkalinity as 0.0 on line 5. Go to part II.

4. Titrate from a pink to a clear, record the mls of H_2SO_4 you added. _____ml H_2SO4
   Read burette carefully! This is the end point of titration.

5. Multiply ml of H_2SO_4 used by 40. (See question 4 above.) This is the phenolphthalein alkalinity. Use the following formula:
   (ml H_2SO_4 used) x 40 =_____ ppm(mg/L) phenolphthalein alkalinity as $CaCO_3$
   For example: (0.2 ml H_2SO_4 titrant used) x 40 = 8.0 mg/L

Phenolphthalein Alkalinity _____mg/L $CaCo_3$

6. Continue on to PART II (Step 9 on alkalinity titration instructions)

PART II - Total Alkalinity

7. Add BGMR indicator. Did solution turn blue? 9Yes 9No
8. Titrate from turquoise to pink-gray, record the mls of H_2SO_4 added. _____ml H_2SO_4

   Read burette carefully! This is the end point of titration.
9. Multiply ml of H_2SO_4 used by 20. (See question 2 above.) This is the total alkalinity.
   Use the following formula:
   (ml H_2SO_4 used) x 20 = _____ ppm (mg/L) total alkalinity as $CaCO_3$
   For example: (2.5 ml H_2SO_4 titrant used) x 20 = 50.0 mg/L

Total Alkalinity _____mg/L CaCo3

Comments:

_____

_____

Data recorded by_____ Date recorded _____

HOW TO DO AN ALKALINITY UNKNOWN

Read these instructions. More than likely, all your questions will be answered

1. Obtain the test tube containing- liquid with an A# label and an Alkalinity Unknown Data Sheet. It will look similar to the normal alkalinity data sheet.

2. Record the date you are analyzing- the unknowns in the appropriate spaces.

   If you make a mistake during- this test PLEASE explain it in the comment section of the data sheet.

3. There is a number on the "A" test tube. Record this number at the top, Alkalinity Unknown #: (A#)

4. Take your alkalinity erlenmeyer flask (the erlenmeyer flask with an "A" marked on it) and wash it with soap and water, then rinse it with tap water, then rinse it with deionized water. Rinse graduated cylinder with deionized water.

5. Pour the test tube solution into the 100 ml volumetric flask marked "A".

6. Rinse the tube with deionized water four times, pouring the water in the volumetric flask.

7. Fill the volumetric flask to the 100 ml line with deionized water, be careful not to go past the line. Use your deionized wash bottle. If you do go past the line see the NOTE on the left before continuing.

   Note: If you do use phenothalin, titrate to a clear, record total mls in comments multiplied by 40 and check the "oops " box in the phenothalin section of the data sheet. Continue test with BGMR indicator and follow rest of instructions.

   Second student - Remember NOT to use phenothalin indicator.

8. Screw the cap on and shake to mix the contents.

9. Measure 50 mls from the volumetric flask into your graduated cylinder, as you would a river sample. There should be 50 mls left in the volumetric flask. Put that aside for now. Answer question one on the data sheet.

10. Perform the alkalinity titration as you would a river sample, with the following exception: do not worry about pH or using the phenothalin indicator. You only need to add six drops of BGMR indicator, don t use phenothalin indicator (refer to alkalinity instructions - start with step 9) Also, do not rinse erlenmeyer cylinder with unknown solution. Deionized water is fine.

11. Read the burette and record how many mls of acid you put in the erlenmeyer flask in line 3 of the Alkalinity Unknown data sheet.

12. Multiply the mls above by 40, this is different than usual. Record the result on line 4.

13. Record your name legibly at the bottom of the data sheet.

14. Clean out the erlenmeyer flask with deionized water.

Second student should START here:

15. Another student should take the remaining- 50 mls in the volumetric flask and pour it into the clean erlenmeyer flask.

16. Perform the alkalinity titration as you would a river sample, with the following, exception: do not worry about pH. You only need to add six drops of BGMR indicator, don't use phenothalin indicator (refer to alkalinity instructions - start with step 9). Also, do not rinse erlenmeyer cylinder with unknown solution. Deionized water is fine. Answer question 6 on data sheet.

17. Read the burette and record how many mls of acid you put in the erlenmeyer flask on line 8.

18. Multiply the mls above by 40, this is different than usual. Record the result on line 9 of data sheet.

19. Record your name legibly on the bottom of the data sheet.

20. Calculate and record the average of BGMR Unknown Alkalinity I and 2 on line 10.

21. Clean out the erlenmeyer flask with deionized water.

22. The CDOW will put the real value of the unknown in the Alkalinity Unknown True Value space and compare it with your result by calculating a percent recovery.

Ship these standard data sheets to Denver with your regular shipment to data sheets. You should keep a copy on file.

Note: ***If you fill the volumetric flask past the line with water for either the alkalinity or hardness test, titrate the first 50 mls for alkalinity or hardness and record the result and your name in Value 1 and Observer 1 boxes.***

ALKALINITY UNKNOWN DATA SHEET

Affiliation _____ Alkalinity Unknown #: A:_____ Date of test __/__/_____

PHENOLPHTHALEIN ALKALINITY

Skip the phenothalin indicator and begin with step 9 on the Alkalinity instruction sheet.

? Oops. I accidentally put phenolphthalein in the sample. (Refer to note on Alkalinity instructions)

STUDENT 1 - Total Alkalinity

1. Amount of Alkalinity unknown standard used: ? =50 mls ? >50 mls _____mls
2. Add BGMR indicator. Did solution turn blue? ? Yes ? No
3. Titrate from turquoise to pink-gray-blue, record the mls of H_2SO_4 added _____ml H_2SO_4
   Read burette carefully! This is the end point of titration.
4. Multiply ml of acid used by 40. (See question 2 above.) This is the BGMR alkalinity. Use the following formula:
   Total Alkalinity Unknown 1 = (ml acid used) x 40 = ppm(mg/L) BGMR alkalinity as $CaCO_3$
   For example: (2.5 ml H_2SO_4 titrant used) x 40 = 100 mg/L _____mg/L $CaCO_3$

5. Continue with step l4 on Alkalinity Unknown instruction sheet.

STUDENT 2 - Total Alkalinity

6. Amount of Alkalinity unknown standard used: ? =50 mls ? >50 mls _____mls
7. Add BGMR indicator. Did solution turn blue? ? Yes ? No
8. Titrate from turquoise to pink-gray-blue, record the mls of H_2SO_4 added. _____ml H_2SO_4
   Read burette carefully! This is the end point of titration.
9. Multiply ml of acid used by 40. (See question 2 above.) This is the BGMR alkalinity. Use the following formula:
   Total Alkalinity Unknown 2 = (ml acid used) x 40 = ppm(mg/L) BGMR alkalinity as $CaCO_3$
   For example: (2.5 ml H_2SO_4 titrant used) x 40 = 100 mg/L _____mg/L $CaCO_3$

Comments:_____

_____

10. Unknown 1 & 2 Average (#4 and #9 above)
    _____mg/L $CaCO_3$

Alkalinity Unknown True Value_____ Percent Recovery _____% (CDOW completes)
(CDOW completes)

Student 1 signature:_____Date recorded:_____

Student 2 signature:_____Date recorded:_____

APPENDIX E

MONITORING WELL INSTALLATION AND DEVELOPMENT PROCEDURES

McCULLEY, FRICK & GILMAN, INC.
STANDARD OPERATING PROCEDURE No. 1

SUPERVISION OF EXPLORATORY BORINGS

1.0 INTRODUCTION

This Standard Operating Procedure (SOP) describes the protocol to be followed during the drilling and logging of exploratory borings by McCulley, Frick & Gilman, Inc. (MFG). Exploratory borings (pilot holes) may be drilled to obtain samples of the subsurface strata or to run borehole geophysical logs. Borings will be backfilled with grout or completed as monitoring wells or piezometers,

The procedures presented herein are intended to be of a general nature. As site-specific conditions become known, appropriate modifications of the procedures may be made and approved in writing **by** the MFG Project Manager. Drilling and logging of the borings will be conducted under the supervision of a State of California Registered Geologist.

2.0 DRILLING

Exploratory borings will be drilled using the hollow-stem auger method, the hydraulic rotary method, or the casing-hammer air rotary method. Drilling fluid, where necessary, will consist of bentonite and water. Synthetic polymer drilling fluid additive may be used only if a boring: (1) will not be sampled for chemical analysis; (2) will not be completed as a monitoring well; or (3) if cuttings return and/or borehole integrity cannot be achieved by any other method.

In general, exploratory borings for monitoring wells and piezometers will fully penetrate the targeted, relatively permeable deposit and will terminate in an underlying unit of relative low permeability. The actual depth of each exploratory boring will be specified by the MFG field geologist assigned to the drill rig. No solvents or petroleum-based products will be used for lubricating any drilling equipment (rods, bit, augers, mud pit, etc.) which will contact the borehole or the drilling fluid. For air rotary drilling, an air filter will be installed between the air compressor and the drill pipe to intercept oil droplets.

The drilling equipment in which fluid circulates, including drive samplers and bits, will be thoroughly steam cleaned before and after drilling of each exploratory boring. Only clean, potable water from a municipal supply will be used as makeup water for drilling, fluid and for decontamination of drilling equipment. An acid rinse (0.1 N HCL) or solvent rinse (methanol or hexane) may be used to supplement
these procedures if tarry or oily deposits are encountered during drilling. Drilling equipment cleaned in this manner will be thoroughly steam cleaned prior to reuse.

To ensure that the specified equipment has been provided by the drilling contractor, prior to drilling the MFG field geologist will measure and record the outside diameter of the drill bit or augers and, when using the hollow stem auger method, the inside diameter of the augers.

During drilling using the hollow stem auger method, the MFG field geologist will periodically measure and record the depth to water within the augers. The position of the augers will be recorded each time
a water level measurement is taken. When the total depth of a boring is reached, the water level within the augers will be measured.

The final borehole diameter will be sufficiently large to allow placement of a specified type and size of well casing, screen and filter pack if the boring is to be completed as a monitoring well or a piezometer.

The MFG field geologist will measure and record the total depth of the final borehole at the completion of drilling.

The MFG field geologist shall specify to the driller the penetration rate, depth of soil sample collection, method of sample retrieval, and any other matters which pertain to the satisfactory completion of the exploratory borings.

Soil cuttings and drilling fluid generated during drilling should be temporarily stored in steel drums or other approved container. Final disposal of the soil cuttings and drilling fluid will be conducted in accordance with all legal requirements and with procedures discussed in the MFG SOP entitled STORAGE AND DISPOSAL OF SOIL, DRILLING FLUIDS, AND WATER GENERATED DURING FIELD WORK.

3.0 SAMPLING AND LOGGING

Representative samples of cores and drill cuttings will be obtained and evaluated. A detailed log of these samples will be made.

Selected samples may be retained for grain-size (sieve) analysis, permeability testing, and measuring Atterberg limits, moisture content and/or dry density. Soil samples may also be obtained for chemical analysis. Sample collection and preservation for chemical analysis will be in accordance with the MFG SOP entitled SOIL/SEDIMENT SAMPLING FOR CHEMICAL ANALYSIS. Selected samples that illustrate specific geologic features may be retained and shall be labeled with boring number and appropriate sample interval.

3.1 OBTAINING SAMPLES

Samples shall be obtained by one or both of the following methods described below.

A. Coring -- Cores will be collected from selected intervals of the exploratory borings. Core barrels (94 mm wireline or HQ), Pitcher tubes, modified California drive samplers or other split-spoon drive samplers will be used to obtain the soil cores. The core diameter will be a minimum of 1-1/2 inches in diameter. The MFG field geologist will carefully record on a boring log information which applies to the coring, such as rate of penetration, coring smoothness, core recovery, intervals of core loss, zones of lost circulation of drilling fluid, and blow counts, as appropriate to the drilling method Cores may be retained for future examination and/or preserved for chemical or geotechnical analysis. The cores will be stored and labeled to show project, boring number, date, and cored interval.

.B. Collecting Cuttings -- The MFG field geologist may collect cuttings from the drilling- return fluid, air return from a cyclone separator, or the auger blade for every five-foot increment of the exploratory boreholes. Sampling and logging will be performed in accordance with the following procedures (Note: Items 2 through 6 do not apply to the hollow-stem auger method):

1. The height of the drilling table above ground surface, lengths of the drill bit, sub and drill collars, and length of drill rods or augers should be taken into account in calculating the depth of penetration.

2. A small diameter, fine mesh, hand screen shall be used to obtain a sample of the cuttings from the boring by holding the screen directly in the flow of the drilling return fluid or cyclone separator.

3. A sample will be obtained from the drilling return fluid or cyclone separator by leaving the screen in place only for the brief period required to collect an adequate sampling volume.

4. Whenever the driller stops advancing the hole and circulates drilling fluid or air prior to adding another joint of drill rod, the most representative cuttings samples may be obtained,

5. Keep in mind that the deeper the hole, the longer cuttings at the drill bit take to reach the surface. The travel time for cuttings to reach the surface may be estimated each time the driller adds a new length of drill rod by timing the first arrival of cuttings after fluid or air circulation is resumed. This travel time shall be used along with the depth of penetration to estimate the start and finish of each five-foot sampling interval.

6. In hydraulic rotary drilling, carefully wash the cuttings sample in a bucket of fresh water by slowly shaking the screen while the sample is submerged, to wash away the drilling fluid.

7. For all drilling methods, place the cuttings samples on a sampling table, labeled in consecutive order. If the sample is to be retained, place the sample in a plastic or cloth sample bag labeled with the boring number and sample interval. The retained samples will later be used during preparation of a detailed lithologic log.

3.2 LOGGING OF BOREHOLES

The drill rig operator and the MFG field geologist will discuss significant changes in material penetrated by the drill bit, changes in drilling conditions, hydraulic pressure, drilling action, and drilling fluid circulation rate. The MFG field geologist will be present during drilling of exploratory borings and will observe and record such changes by time and depth. In hollow-stem auger and air rotary drilling, the MFG field geologist will evaluate the relative moisture content of the samples and note zones that produce water. The MFG field geologist will record such field notes to use later in preparing a detailed lithologic log.

Core samples and selected cuttings that are collected and retained during the drilling of the exploratory borings shall be examined to evaluate the lithologic properties. A detailed lithologic log for the exploratory borings shall be completed using MFG's standard forms. The lithologic description of the log shall include soil or rock type, color, grain size, texture, hardness, degree of induration, calcareous content, indications of contamination, and other pertinent information. Color will be described using the Munsell Color Chart.

Lithology will be described using the Unified Soil Classification System. The lithology and drilling record of borings logged by cuttings will be recorded on a Field Log of Borehole by Cuttings form (Figure SOP-1-1). Logs of the cored intervals of the exploratory borings will be completed on a Field Log of Borehole by Coring form (Figure SOP-1-2).

Field notes recorded by the MFG field geologist during the drilling of each exploratory boring shall be transferred to the log forms. The original logs shall be sent to the MFG office and placed in the MFG project file. A copy of the logs will be retained in the field file for the project.

4.0 GEOPHYSICAL LOGS

The MFG SOP entitled GEOPHYSICAL LOGGING discusses in detail the steps to be followed when performing geophysical logs of exploratory borings. Geophysical logging will be performed generally in boreholes drilled using the hydraulic rotary method (uncased, fluid-filled boreholes). Following completion of the drilling, spontaneous potential, single-point resistance, lateral resistivity and/or natural gamma logs will be made for each exploratory boring immediately after the drilling fluid has been circulated to remove all of the cuttings. Geophysical logging shall be done as quickly and efficiently as possible, while the wall of the borehole is in good condition, to minimize the possibility of hanging up the downhole probes. Instruments on the logging unit shall be adjusted to give the maximum definition of strata boundaries.

5.0 SEALING AND ABANDONMENT

For borings (pilot holes) not used to install a monitoring well and/or piezometer, the exploratory borings will be abandoned by sealing the hole with cement grout or other approved sealing agents. If a cement/bentonite grout is used, the bentonite powder should be added to and mixed with the water before adding the cement. The MFG field geologist shall inspect the grout for adequate mixing prior to placement in the borehole.

If the borehole is dry and is less than ten feet deep, the grout may be poured slowly from the ground surface into the borehole. The grout should be added in one continuous pour before its initial set. If the borehole is greater than ten feet deep, or if more than two feet of water is present in any borehole, the grout shall be placed in one continuous pour by pumping through a tremie hose or pipe. The tremie hose or pipe initially shall be placed near the bottom of the bore hole and shall remain submerged in the grout during the entire grouting operation. Grout will continue to be pumped until return of fresh grout (uncontaminated by drilling fluid) is witnessed at the ground surface.

The grout mix shall be one (1) sack of Type I-II Portland cement, five (5) percent by weight of powdered bentonite, and 8.5 gallons of water. If a high-yield bentonite (trade names Quik-Gel, Super Gel X, etc.) is used, the powdered bentonite percentage should be reduced to two (2) percent. The grout mixture may be modified to meet local regulations or site-specific conditions.

LOG OF BORING BY CUTTINGS

LOG OF BORING BY CUTTINGS	BORING NO.:	PAGE 1 of ___

NAME:	PROJECT NO.:	BORING LOCATION:	
RILLING AGENCY:	DRILLER:	ELEVATION AND DATUM:	
DRILLING METHOD:		DATE STARTED:	DATE FINISHED:
IZE AND TYPE OF CASING:		DRIL BIT:	COMPLETION DEPTH:
SAMPLE METHOD:		LOGGED BY:	CHECKED BY:
AMPLER TYPE:	LENGTH: DROP:		

DRILLING TIME RECORD					DEPTH		HYDRAULIC PRESSURE	DRILLING ACTION	CALC. CONTENT	DESCRIPTION AND DRILLERS NOTES: (material, color, texture, hardness, and other notes)
DEPTH		TIME								
FROM	TO	FROM	TO	MIN.	FROM	TO				

ABBREVIATIONS:	CALC. CONTENT	HYD. PRESS.	McCulley, Frick & Gilman, Inc.
DRILLING ACTION	N: Non-calc. S: Slighly M: Moderately V: Very	N: None L: Low M: Medium F: Full	
E: Even, smooth C: Crunchy I: Intermittently rough r: Slightly rough R: Moderately rough B: Very rough	Bore by Cut, Page 1. MAC/CAD. Rev 9-8-95		

FIGURE SOP-1-1. FIELD LOG OF BOREHOLE BY CUTTINGS (Page 1 of 2)

SITE NAME:			LOG OF BORING NO.:	
BORING LOCATION:			ELEVATION AND DATUM:	
DRILLING AGENCY:	DRILLER:		DATE STARTED:	DATE FINISHED:
DRILLING METHOD:			DRILL BIT:	COMPLETION DEPTH:
SIZE AND TYPE OF CASING:			LOGGED BY:	CHECKED BY:
SAMPLING METHOD:				
SAMPLER TYPE:	LENGTH:	DROP:		

DEPTH (feet)	DESCRIPTION	USCS CLASS	DEPTH (feet)	SAMPLING RUN NO (Recov)	SAMPLING BLOWS/ 6 in.	REMARKS (drill rate, fluid loss, odor, etc.)
1			1			
2			2			
3			3			
4			4			
5			5			
6			6			
7			7			
8			8			
9			9			
10			10			
11			11			
12			12			
13			13			
14			14			
15			15			

Project No.:	McCulley, Frick & Gilman, Inc.	*Sheet 1 of*

FIGURE SOP-1-2. FIELD LOG OF BOREHOLE BY CORING (Page 1 of 3)

MCCULLEY, FRICK & GILMAN, INC.
STANDARD OPERATING PROCEDURE No. 2

INSTALLATION OF MONITORING WELLS AND PIEZOMETERS

1.0 INTRODUCTION

This Standard Operating Procedure (SOP) describes the protocol to be followed during installation of monitoring wells and piezometers by McCulley, Frick & Gilman, Inc. (MFG).

The procedures presented herein are intended to be of a general nature. As site-specific conditions become known, appropriate modifications of the procedures may be made and approved in writing by the MFG Project Manager.

2.0 MONITORING WELL INSTALLATION

Each monitoring well will be designed to register the potentiometric surface and to permit water sampling of a specific depth zone encountered beneath the drill site. Separate monitoring wells will be completed, as necessary, in the different water-yielding zones underlying the site. The MFG field geologist in consultation with the MFG Project Manager will specify the exact depths of screened intervals using the lithologic log and geophysical log (if performed) for control. Drilling and logging of the exploratory borings for the monitoring wells will be conducted in accordance with the MFG SOP entitled SUPERVISION OF EXPLORATORY BORINGS. Construction and completion of all monitoring wells will be in conformance with the following procedures.

2.1 SCREENS AND RISER CASING

The monitoring well assembly will consist of flush joint, threaded casing composed of mild steel, stainless steel or polyvinyl chloride (PVC) Schedule 40 (minimum). The threaded joints will have O-ring seals. Steel casing joints may be welded rather than threaded. The inside diameter of both the perforated and unperforated casing will be sufficiently large to permit easy passage of an appropriate water-level probe and equipment for development and purging of wells and for water sample collection.

The perforated casing (well screen) will be factory slotted. The perforations will be compatible in size with the selected filter material. These perforated casing sections are not intended to provide optimum flow but only to provide hydraulic connection between the pervious material in the water-yielding zone and the monitoring well.

Prior to well construction, the MFG field geologist will inspect the blank and perforated casing delivered to the job site to verify that it meets the project specifications.

When the total depth of a boring has been reached, and prior to installation of the well casing, the MFG field geologist will measure and record the depth to water in the borehole.

Upon completion of drilling, and/or geophysical logging, the monitoring well casing and screen will be assembled and lowered to the bottom of the boring. The monitoring well assembly will be designed so that the well screen is approximately adjacent to the water-yielding zone that is to be monitored. The bottom of the screen will be approximately flush with the bottom of the well and will be closed with a threaded PVC cap or plug, or a slip cap secured with stainless steel screws. No PVC cement or other solvents are permitted to be used to fasten the joints of casing or screen. Centralizers spaced at the top and bottom of the screened interval and not more than 40 feet apart alone, the casing will be used to center the well assembly in the borehole, unless the boring is drilled by the hollow-stem auger method $_{7ig}$ augers will be centered and the well is installed with the augers in place. Wells installed prior to pulling augers will be centered by the inside walls of the auger.

If casing assembly is being performed by a drilling subcontractor, the MFG field geologist will observe and inspect the assembly, insuring that the bottom cap is threaded or secured with stainless steel screws, 0-rings are properly placed in the joints, the joints are completely tightened, and the blank and perforated intervals are constructed as specified. The MFG field geologist will measure the precise location of the top and bottom of the perforated interval by measuring the distances from the joint above the perforated interval to the top slot and from the base of the bottom cap to the bottom slot.

When using the mud rotary drilling technique, after the monitoring well assembly has been lowered to the specified depth, clean water may be circulated downward through the well casing and upward through the annular space between the borehole wall and the monitoring well casing. Circulation will continue until the suspended sediment in the return fluid has been thinned.

If the well is greater than 50 feet deep, the casing assembly will be suspended from the drilling rig prior to emplacement of the filter pack and seal.

2.2 FILTER MATERIAL

Filter material will be a well graded, clean sand with less than 2 percent by weight passing a No. 200 sieve and less than 5 percent by weight of calcareous material.

Filter sand will be tremied into the annular space using a one-inch diameter (or larger) steel pipe, in a calculated quantity sufficient to fill the annular space to a level of about two feet above the top of the perforated casing. The depth to the top of the filter pack must be verified by measuring, using the tremie pipe or a weighted steel tape. When completing wells inside the hollow-stem auger, the filter sand may be poured slowly between the well casino, and the inside walls of the auger, and the auger flights may be removed in stages (use of tremie pipe riot feasible in this case).

2.3 SEAL

Once the depth to the top of the filter pack has been verified, a layer of bentonite pellets will be emplaced by pouring the pellets into the annular space in a calculated quantity sufficient to fill the annular space to a level at least one foot above the top of the filter pack. The depth to the top of the bentonite pellets layer must be verified by measuring, using the tremie pipe or a weighted steel tape. When the bentonite pellets are placed above the zone of saturation, they will be hydrated, after they have been emplaced, by adding deionized or distilled water. Approximately 3 gallons of water should be added for every foot of bentonite pellets. More water may be required when completing a well in relatively permeable material.

A bentonite/cement grout seal will be emplaced above the bentonite pellet layer. If the depth to the top of the bentonite pellet layer is dry and is less than 10 feet deep, the grout may be poured slowly from the ground surface into the annular space. The grout should be added in one continuous pour before its initial set. If the depth is greater than 10 feet deep, or if more than two feet of water is present in the annular space, the grout shall be placed in one continuous pour by pumping through a tremie hose or pipe. The tremie hose or pipe initially shall be placed near the top of the bentonite seal and shall remain submerged in the grout during the entire grouting operation. When constructing a well or piezometer inside a hollow stem auger, the auger may be used as a tremie pipe by pouring the grout down the annular space between the well casing and the inner wall of the auger. Grout will continue to be pumped until return of fresh grout is witnessed at the ground surface.

The bentonite/cement grout mix will be one (1) sack of Type I-II Portland cement, five (5) percent by weight (of cement) of powdered bentonite, and 8.5 gallons of water. If a high-yield bentonite (trade names Quik-Gel, Super Gel X, etc.) is used, the powdered bentonite percentage should be reduced to two (2) percent. An alternative grout mixture may be used if approved by the applicable regulatory agency and the MFG Project Manager. Only clean water from a municipal supply will be used to prepare the grout. The grout seal will extend from the top of the bentonite pellet layer to near the ground surface. After grouting, no work will be done on the monitoring well until the grout has set for a minimum of 48 hours.

When the casing hammer air rotary method is used to complete the borehole for a monitoring well, the protective casing will be jacked out of the borehole gradually as the filter pack, bentonite pellets, and cementing operations are in progress.

2.4 CAPPING MONITORING WELL

Upon completion of the work, a suitable water-tight, locking cap or plug will be fitted on the top of the well casing to prevent the entry of surface runoff or foreign matter. The well will be completed either (1) above the ground surface using a locking, steel protective well cover set in concrete, or (2) below the ground surface using a watertight, traffic-rated valve-box with a bolt-down cover. The cover of the valve box will be stamped or cast with "Monitoring Well."

2.5 DOCUMENTATION

A Well Construction Summary form for each monitoring well (Figure SOP-2-1) will be completed by the MFG field geologist and submitted to the MFG Project Manager when the work has been completed. In addition to the information requested on the Well Construction Summary, the MFG field geologist will record the volumes of well construction materials (filter material, bentonite, cement, etc.) used for each well. Also, the daily events and other items not covered in the Well Construction Summary form will be entered on a Daily Field Record form in accordance with the procedures contained in the MFG SOP entitled FIELD DOCUMENTATION.

3.0 PIEZOMETER INSTALLATION

Each piezometer will be designed to register the potentiometric surface of a specific depth zone encountered beneath the drill site. The MFG field geologist in consultation with the MFG Project Manager will specify the exact depths of the piezometers using the lithologic log and geophysical log (if performed) for control. Drilling and logging of the boreholes for the piezometers will be in conformance with the MFG SOP entitled SUPERVISION OF EXPLORATORY BORINGS. Construction, completion and development of the piezometers will generally follow the same procedures as those for monitoring wells (see Section 2.0), except that a piezometer may be completed with casing material of less than two inches in diameter and may use a porous tip (ceramic or other material) in place of perforated casing.

4.0 CLEANING OF EQUIPMENT USED IN DRILLING, WELL CONSTRUCTION

The drilling equipment will be thoroughly steam cleaned before and after installation of each monitoring well or piezometer. Only clean, potable water from a municipal supply will be used as makeup water for drilling fluid and for decontamination of drilling equipment. An acid rinse (0. *I* N HCI) or solvent rinse (i.e., hexane or methanol) may be used to supplement the steam cleaning if tarry or oily deposits are encountered. Equipment cleaned in this manner will be thoroughly steam cleaned prior to reuse.

The well casing will be steam cleaned thoroughly before it is installed. This cleaning is particularly critical to prevent cross contamination in a multi-aquifer environment. After cleaning, the casing will be covered with plastic to protect it from contact with dust or other contaminants.

WELL CONSTRUCTION SUMMARY

SITE:_____
PROJECT NO.:_____

McCULLEY, FRICK & GILMAN, INC.

WELL:_____ COORDINATES: N:_____ E:_____
ELEVATION: GS:_____ TOC:_____ SEC.:_____ T:_____ R:_____

LOCATION:_____
SUPERVISOR:_____
PROJECT:_____
STAFF:_____

DRILLING SUMMARY:

TOTAL DEPTH:_____
BOREHOLE DIAMETER:_____
DRILLER:_____
RIG:_____
BIT(S):_____
DRILLING FLUID:_____

CONSTRUCTION TIME LOG:

	START		FINISH	
DRILLING:	DATE	TIME	DATE	TIME
GEOPHYS.LOG:				
CASING:				
FILTER PACK:				
BENTONITE:				
CEMENTING:				
OTHER:				

WELL DESIGN:

BASIS: GEOLOGIC LOG ___ GEOPHYSICAL LOG ___

CASING STRING(S): C=CASING S=SCREEN

MATERIAL(S): CEM=CEMENT SND=SAND BNT=BENTONITE

CASING: C1:_____
C2:_____
C3:_____
C4:_____

SCREEN: S1:_____
S2:_____
S3:_____

CENTRALIZERS:_____

FILTER MATERIAL:_____

CEMENT:_____

BENTONITE:_____

DECONTAMINATION:

COMMENTS:

Well Const. Sum. Form Rev: 8-8-95

FIGURE SOP-2-1. WELL CONSTRUCTION SUMMARY

McCULLEY, FRICK & GILMAN, INC.
STANDARD OPERATING PROCEDLTRE No. 3

MONITORING WELL DEVELOPMENT

1.0 **INTRODUCTION**

This Standard Operating Procedure (SOP) describes the protocol to be followed during the development of groundwater monitoring wells. The procedures presented herein are intended to be of a general nature. As site-specific conditions become known, appropriate modifications of the procedures may be made and approved in writing by the McCulley, Frick & Gilman, Inc. (MFG) Project Manager.

2.0 **DEVELOPMENT PROCEDURE**

After construction of the monitoring well is complete, the well will be developed by surging, bailing and/or pumping (positive displacement hand pump, electric pump or pneumatic pump). At least 48 hours must pass between completion of grouting of the monitoring well and development to allow sufficient curing of the grout.

The total depth of the well will be measured in accordance with the procedures described in the MFG SOP entitled WATER LEVEL, IMMISCIBLE LAYER AND WELL DEPTH MEASUREMENT. The presence of sediment at the bottom of the well will be checked using a stainless steel bailer or positive displacement hand pump) Water and sediment will first be removed from the bottom of the well to ensure that the entire screened interval is open for water to flow into the well. The well should be balled or pumped until the water removed from the bottom of the well is relatively free of sediment. If a bailer is used, care must be taken to avoid breaking the bottom cap on the well casing.

After most of the sediment has been removed from the bottom of the well, a well development pump (positive displacement hand pump, electric pump or pneumatic pump) should be used to remove water from the well. Initially, the intake of the pump should be at the bottom of the well. The pump intake should be raised in two to three foot increments to the top of the water column after approximately one-half of a casing volume of water has been removed from each Intend].

Next, a PVC surge block should be used to develop the screen by forcing water in and out of the screened area. The surge block should be moved up and down in one-to two-foot increments creating a suction action on the upstroke and a pressure action on the down stroke. Development should begin at the top of the water column

and move progressively downward to prevent the surge block from becoming sand locked. After surging to the bottom of the well, the surge block should be moved progressively upward to the top of the water column.

If necessary, de-Ionized water may be added to the well to facilitate surging. The volume of de-ionized water added to the well should be noted on the Well Development Record form (Figure SOP-3-1).

After surging, the surge block should be removed and replaced with the pump. The intake of the pump should be at the bottom of the well to remove any sediment that may have collected in the bottom of the well. The pump intake should again be raised in two- to three-foot increments to the top of the water column after approximately one-half of a casing volume of water has been removed from each interval.

During development, the pH, specific conductance and temperature of the purge water should be periodically measured and documented on a Well Development Record form (Figure SOP-3-1). Parameter readings should be collected for at least every casing volume of water removed from the well.

The well should be alternately surged and pumped until the field water quality parameters have stabilized to within 10% for specific conductance, 0.05 pH units for pH, and 1 ^{o}C for temperature, and the water is relatively clear and free of sediment.

Water removed during well development should be temporarily stored in steel drums. Final disposal of all water generated during development procedures will be conducted in accordance with all legal requirements and with procedures discussed in the MFG SOP entitled STORAGE AND DISPOSAL OF SOIL, DRILLING FLUIDS, AND WATER GENERATED DURING FIELD WORK.

3.0 EQUIPMENT CLEANING

All equipment used in developing the monitoring well should be cleaned prior to and following use. Cleaning shall be accomplished by either (1) washing with a laboratory-grade detergent/water solution, rinsing with clean, potable, municipal water, then rinsing with distilled or deionized water, or (2) steam cleaning followed by rinsing with distilled or deionized water. An acid rinse (0.1 N HCl) or solvent rinse (i.e., hexane or methanol) may be used to supplement these cleaning steps if tarry or oily deposits are encountered. The acid or solvent rinse will be followed by thoroughly rinsing with municipal water and then with distilled or deionized water. After cleaning, equipment will be packaged and sealed in plastic bags or other appropriate containers to minimize contact with dust or other contaminants.

WELL DEVELOPMENT RECORD

WELL NUMBER:

Project No:_____ Project Name:_____ PAGE:_____of:_____

Date(s):_____

*Developed by:*_____

Measuring Point (MP) of Well:_____

Screened Interval (ft.BGL):_____

Filter Pack Interval (ft.BGL):_____

Casing Stick-Up/Down (ft.):_____

Starting Water Level (ft. BMP):_____

Total Depth (ft. BMP):_____ Water Column Height (ft.):_____

Casing Diameter (in. ID): _____ Multiplication Factor:_____

Casing Volume (gal.):_____

Water Level (ft.BMP) at End of Development:_____

Total Depth (ft. BMP) at End of Development:_____

QUALITY ASSURANCE

METHODS (describe):

Cleaning Equipment:_____

Development:_____

Disposal of Discharged Water:_____

INSTRUMENTS (indicate make, model, i.d.):

Water Level:_____ Thermometer:_____

pH Meter:_____ Field Calibration:_____

Conductivity Meter:_____ Field Calibration:_____

Other: Field Calibration:

DEVELOPMENT MEASUREMENTS

Date/ Time	Purge Characteristics		Water Quality Data				Appearance		Intake Depth (ft. BMP)	Remarks
	Cumul.Vol. (gal)	Water Level (ft. BGL)	Temp. (°C)	pH	Specific Conductance (µmhos/cm) @ Field Temp.	Specific Conductance (µmhos/cm) @ 25 °C	Color	Turbidity & Sediment		

Total Discharge (gallons):_____ Casing Volumes Removed:_____

Observations/Comments:_____

ABBREVIATIONS
BMP - below measuring point
BGL - below ground level
Cumul Vol - Cumulative volume removed
ID - Inside Diameter
C - Celsius
gal - gallons
gpm - gallons per minute
in. - inches

McCulley, Frick & Gilman, Inc.

Well Develop Form MAC/CAD Revised 9-8-95

FIGURE SOP-3-1. WELL DEVELOPMENT RECORD

APPENDIX F

HABITAT ASSESSMENT FORMS

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (FRONT)

STREAM NAME	LOCATION	
STATION #_____RIVERMILE_____	STREAM CLASS	
LAT _____ LONG _____	RIVER BASIN	
STORET #	AGENCY	
INVESTIGATORS		
FORM COMPLETED BY	DATE _____ TIME_____ AM PM	REASON FOR SURVEY

WEATHER CONDITIONS	**Now** ❑ ❑ ❑ ❑____% ❑	**Past 24 hours** ❑ storm (heavy rain) ❑ rain (steady rain) ❑ showers (intermittent) ❑____% cloud cover ❑ clear/sunny	**Has there been a heavy rain in the last 7 days?** ❑ Yes ❑ No **Air Temperature**_____^{0}C **Other**_____
SITE LOCATION/MAP	**Draw a map of the site and indicate the areas sampled (or attach a photgraph)**		

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (BACK)

STREAM CHARACTERIZATION	**Stream Subsystem** ❑ Perennial ❑ Intermittent ❑ Tidal **Stream Type** ❑ Coldwater ❑ Warmwater **Stream Origin** ❑ Glacial ❑ Spring-fed ❑ Non-glacial montane ❑ Mixture of origins ❑ Swamp and bog ❑ Other_____ **Catchment Area**_____km^2
WATERSHED FEATURES	**Predominant Surrounding Landuse** ❑ Forest ❑ Commercial ❑ Field/Pasture ❑ Industrial ❑ Agricultural ❑ Other _____ ❑ Residential **Local Watershed NPS Pollution** ❑ No evidence ❑ Some potential sources ❑ Obvious sources **Local Watershed Erosion** ❑ None ❑ Moderate ❑ Heavy
RIPARIAN VEGETATION (18 meter buffer)	**Indicate the dominant type and record the dominant species present** ❑ Trees ❑ Shrubs ❑ Grasses ❑ Herbaceous **dominant species present** _____
INSTREAM FEATURES	**Estimated Stream Width** _____m **Estimated Stream Depth** _____m **Surface Velocity (at thalweg)** _____m/sec **Estimated Reach Length** _____m **Canopy Cover** ❑ Partly open ❑ Partly shaded ❑ Shaded **High Water Mark** _____m **Proportion of Reach Represented by Stream Morphology Types** ❑ Riffle_____% ❑ Run_____% ❑ Pool_____% **Channelized** ❑ Yes ❑ No **Dam Present** ❑ Yes ❑ No
AQUATIC VEGETATION	**Indicate the dominant type and record the dominant species present** ❑ Rooted emergent ❑ Rooted submergent ❑ Rooted floating ❑ Free Floating ❑ Floating Algae ❑ Attached Algae **dominant species present** _____ **Portion of the reach with aquatic vegetation** ____%
WATER QUALITY	**Temperature**_____° C **Specific Conductance**_____ **Dissolved Oxygen** _____ **pH** _____ **Turbidity** _____ **WQ Instrument Used** _____ **Water Odors** ❑ Normal/None ❑ Sewage ❑ Petroleum ❑ Chemical ❑ Fishy ❑ Other_____ **Water Surface Oils** ❑ Slick ❑ Sheen ❑ Globs ❑ Flecks ❑ None ❑ Other_____ **Turbidity (if not measured)** ❑ Clear ❑ Slightly turbid ❑ Turbid ❑ Opaque ❑ Stained ❑ Other_____
SEDIMENT/ SUBSTRATE	**Odors** ❑ Normal ❑ Sewage ❑ Petroleum ❑ Chemical ❑ Anaerobic ❑ None ❑ Other_____ **Oils** ❑ Absent ❑ Slight ❑ Moderate ❑ Profuse **Deposits** ❑ Sludge ❑ Sawdust ❑ Paper fiber ❑ Sand ❑ Relict shells ❑ Other_____ **Looking at stones which are not deeply embedded, are the undersides black in color?** ❑ Yes ❑ No

INORGANIC SUBSTRATE COMPONENTS (should add up to 100%)	ORGANIC SUBSTRATE COMPONENTS (does not necessarily add up to 100%)

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (BACK)

Substrate Type	Diameter	% Composition in Sampling Reach	Substrate Type	Characteristic	% Composition in Sampling Area
Bedrock			Detritus	sticks, wood, coarse plant materials (CPOM)	
Boulder	> 256 mm (10")				
Cobble	64-256 mm (2.5"-10")		Muck-Mud	black, very fine organic (FPOM)	
Gravel	2-64 mm (0.1"-2.5")				
Sand	0.06-2mm (gritty)		Marl	grey, shell fragments	
Silt	0.004-0.06 mm				
Clay	< 0.004 mm (slick)				

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (FRONT)

STREAM NAME	LOCATION	
STATION #_____RIVERMILE_____	STREAM CLASS	
LAT _____LONG _____	RIVER BASIN	
STORET #	AGENCY	
INVESTIGATORS		
FORM COMPLETED BY	DATE _____ TIME _____ AM PM	REASON FOR SURVEY

	Habitat Parameter	Condition Category			
		Optimal	Suboptimal	Marginal	Poor
Parameters to be evaluated in sampling reach	1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
	SCORE	20 19 18 17	15 14 13 12	10 9 8 7	5 4 3 2 1
	2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
	SCORE	20 19 18 17	15 14 13 12	10 9 8 7	5 4 3 2 1
	3. Velocity/Depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Sow is < 0.3 m/s, deep is > 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/ depth regime (usually slow-deep).
	SCORE	20 19 18 17	15 14 13 12	10 9 8 7	5 4 3 2 1
	4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% (<20% for low-gradient streams) of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% (20-50% for low-gradient) of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% (50-80% for low-gradient) of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% (80% for low-gradient) of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
	SCORE	20 19 18 17	15 14 13 12	10 9 8 7	5 4 3 2 1
	5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
	SCORE	20 19 18 17	15 14 13 12	10 9 8 7	5 4 3 2 1

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (BACK)

Parameters to be evaluated broader than sampling reach

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE	20 19 18 17	15 14 13 12	10 9 8 7	5 4 3 2 1
7. Frequency of Riffles (or bends)	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ratio of >25.
SCORE	20 19 18 17	15 14 13 12	10 9 8 7	5 4 3 2 1
8. Bank Stability (score each bank) Note: determine left or right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE ___ (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE ___ (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10	8 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE ___ (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (BACK)

Total Score _____

HABITAT ASSESSMENT FIELD DATA SHEET—LOW GRADIENT STREAMS (FRONT)

STREAM NAME	LOCATION	
STATION #_____RIVERMILE_____	STREAM CLASS	
LAT _____LONG _____	RIVER BASIN	
STORET #	AGENCY	
INVESTIGATORS		
FORM COMPLETED BY	DATE _____ TIME _____ AM PM	REASON FOR SURVEY

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
1. Epifaunal Substrate/ Available Cover	Greater than 50% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	30-50% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	10-30% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 10% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE	20 19 18 17	15 14 13 12	10 9 8 7	5 4 3 2 1
2. Pool Substrate Characterization	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common.	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present.	All mud or clay or sand bottom; little or no root mat; no submerged vegetation.	Hard-pan clay or bedrock; no root mat or vegetation.
SCORE	20 19 18 17	15 14 13 12	10 9 8 7	5 4 3 2 1
3. Pool Variability	Even mix of large-shallow, large-deep, small-shallow, small-deep pools present.	Majority of pools large-deep; very few shallow.	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or pools absent.
SCORE	20 19 18 17	15 14 13 12	10 9 8 7	5 4 3 2 1
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% <20% for low-gradient streams) of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% (20-50% for low-gradient) of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% (50-80% for low-gradient) of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% (80% for low-gradient) of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE	20 19 18 17	15 14 13 12	10 9 8 7	5 4 3 2 1
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE	20 19 18 17	15 14 13 12	10 9 8 7	5 4 3 2 1

HABITAT ASSESSMENT FIELD DATA SHEET—LOW GRADIENT STREAMS (BACK)

Parameters to be evaluated broader than sampling reach

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE	20 19 18 17	15 14 13 12	10 9 8 7	5 4 3 2 1
7. Channel Sinuosity	The bends in the stream increase the stream length 3 to 4 times longer than if it was in a straight line. (Note - channel braiding is considered normal in coastal marshes and other low-lying areas. This parameter is not easily rated in these areas.	The bends in the stream increase the stream length 2 to 3 times longer than if it was in a straight line.	The bends in the stream increase the stream length 2 to 1 times longer than if it was in a straight line.	Channel straight; waterway has been channelized for a long distance.
SCORE	20 19 18 17	15 14 13 12	10 9 8 7	5 4 3 2 1
8. Bank Stability (score each bank)	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE ___ (LB)	Left Bank 10	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank) Note: determine left or right side by facing downstream.	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE ___ (LB)	Left Bank 10	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10	8 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE ___ (LB)	Left Bank 10	8 7 6	5 4 3	2 1 0

HABITAT ASSESSMENT FIELD DATA SHEET—LOW GRADIENT STREAMS (BACK)

	SCORE ___ (RB)	Right Bank	10	9	8	7	6	5	4	3	2	1	0

Total Score _____

APPENDIX G

ADDITIONAL CALCULATIONS SHEETS FOR FISH AND HABITAT ASSESSMENT MODEL CALCULATIONS

Table 2. [illegible]am Reach Inventory and Channel Stability Evaluation [illegible]rm (Pfankuch, 1975).

R-1 STREAM REACH INVENTORY and CHANNEL STABILITY EVALUATION

REACH LOCATION: Survey Date _____ Time _____ Obs. _____

Forest _____ Rgr. Dist. _____

P.W.I.

Stream _____ W/S No. ___-___-___-___-___-___-___-___

Reach Description & Other Identification _____

	Key #	Stability Indicators by Classes (Fair and Poor on reverse side) EXCELLENT		GOOD	
Upper Banks	1	Bank slope gradient <30%.	(2)	Bank slope gradient 30-40%.	(4)
	2	No evidence of past or any potential for future mass wasting into channel.	(3)	Infrequent and/or very small. Mostly healed over. Low future potential.	(6)
	3	Essentially absent from immediate channel area.	(2)	Present but mostly small twigs and limbs.	(4)
	4	90%+ plant density. Vigor and variety suggests a deep, dense, soil binding, root mass.	(3)	70-90% density. Fewer plant species or lower vigor suggests a less dense or deep root mass.	(6)
Lower Banks	5	Ample for present plus some increases. Peak flows contained. W/D ratio <7.	(1)	Adequate. Overbank flows rare. Width to Depth (W/D) ratio 8 to 15.	(2)
	6	65%+ with large, angular boulders 12"+ numerous.	(2)	40 to 65%, mostly small boulders to cobbles 6-12".	(4)
	7	Rocks and old logs firmly embedded. Flow pattern without cutting or deposition. Pools and riffles stable.	(2)	Some present, causing erosive cross currents and minor pool filling. Obstructions and deflectors newer and less firm.	(4)
	8	Little or none evident. Infrequent raw banks less than 6" high generally.	(4)	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	(8)
	9	Little or no enlargement of channel or point bars.	(4)	Some new increase in bar formation, mostly from coarse gravels.	(8)
Bottom	10	Sharp edges and corners, plane surfaces roughened.	(1)	Rounded corners and edges, surfaces smooth and flat.	(2)
	11	Surfaces dull, darkened, or stained. Gen. not "bright".	(1)	Mostly dull, but may have up to 35% bright surfaces.	(2)
	12	Assorted sizes tightly packed and/or overlapping.	(2)	Moderately packed with some overlapping.	(4)
	13	No change in sizes evident. Stable materials 80-100%.	(4)	Distribution shift slight. Stable materials 50-80%.	(8)
	14	Less than 5% of the bottom affected by scouring and deposition.	(6)	5-30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	(12)
	15	Abundant. Growth largely moss-like, dark green, perennial. In swift water too.	(1)	Common. Algal forms in low velocity & pool areas. Moss here too and swifter waters.	(2)
		EXCELLENT COLUMN TOTAL →		GOOD COLUMN TOTAL →	

Add values in each column and record in spaces below. Add column scores.

B.___ + C.___ + F.___ + P.___ = _____ Total Reach Score.

Adjective ratings: <38-Excellent, 39-76-Good, 77-114-Fair, 115+-Poor*

*(Scores above may be locally adjusted by Forest Hydrologist)

R1-Form 2500-5A Rev.1-75 Side 1.

INVENTORY DATA: (observed or measured on this date) Side 2

Stream Width ___ ft. X Ave. Depth ___ ft. X Ave. Velocity ___ f/s = ___ Flow cfs

Reach Gradient ___%. Stream Order ___. Turbidity Level _____. Stream Stage _____. Sinuosity Ratio _____.

Temperature °F or °C of: Air ___ Water ___, Others _____

	Key #	Stability Indicators by Classes FAIR		POOR	
Upper Banks	1	Bank slope gradient 40-60%.	(6)	Bank slope gradient 60%+.	(8)
	2	Moderate frequency & size, with some raw spots eroded by water during high flows.	(9)	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	(12)
	3	Present, volume and size are both increasing.	(6)	Moderate to heavy amounts, predominantly larger sizes.	(8)
	4	50-70% density. Lower vigor and still fewer species form a somewhat shallow and discontinuous root mass.	(9)	<50% density plus fewer species & less vigor indicate poor, discontinuous, and shallow root mass.	(12)
Lower Banks	5	Barely contains present peaks. Occassional overbank floods. W/D ratio 15 to 25.	(3)	Inadequate. Overbank flows common. W/D ratio > 25.	(4)
	6	20 to 40%, with most in the 3-6" diameter class.	(6)	< 20% rock fragments of gravel sizes, 1-3" or less.	(8)
	7	Moderately frequent, moderately unstable obstructions & deflectors move with high water causing bank cutting and filling of pools.	(6)	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	(8)
	8	Significant. Cuts 12"-24" high. Root mat overhangs and sloughing evident.	(12)	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	(16)
	9	Moderate deposition of new gravel & coarse sand on old and some new bars.	(12)	Extensive deposits of predominantly fine particles. Accelerated bar development.	(16)
Bottom	10	Corners & edges well rounded in two dimensions.	(3)	Well rounded in all dimensions, surfaces smooth.	(4)
	11	Mixture, 50-50% dull and bright, ± 15% ie. 35-65%.	(3)	Predominantly bright, 65%+, exposed or scoured surfaces.	(4)
	12	Mostly a loose assortment with no apparent overlap.	(6)	No packing evident. Loose assortment, easily moved.	(8)
	13	Moderate change in sizes. Stable materials 20-50%.	(12)	Marked distribution change. Stable materials 0-20%.	(16)
	14	30-50% affected. Deposits & scour at obstructions, constrictions, and bends. Some filling of pools.	(18)	More than 50% of the bottom in a state of flux or change nearly yearlong.	(24)
	15	Present but spotty, mostly in backwater areas. Seasonal blooms make rocks slick.	(3)	Perennial types scarce or absent. Yellow-green, short term bloom may be present.	(4)
		FAIR COLUMN TOTAL →		POOR COLUMN TOTAL →	

Size Composition of Bottom Materials (Total to 100%)

1. Exposed bedrock.....___%	5. Small rubble, 3"-6".....___%
2. Large boulders, 3'+ Dia....___%	6. Coarse gravel, 1"-3".....___%
3. Small boulders, 1-3'.....___%	7. Fine gravel, 0.1-1".....___%
4. Large rubble, 6"-1'.....___%	8. Sand, silt, clay, muck..___%

WRRI TROUT COVER RATING FORM

Stream _____ Location _____

Flow (cfs) _____ Average Discharge (cfs) _____ Date _____

Salmonid Species _____

Non-Salmonid Species _____

Standing Crop _____ lbs/acre _____ #/acre

Comments _____

Field Data Collected by _____

Office Calculations by _____

Transect #	Wetted Top Width (ft)	R-B Cover Width (ft)	Length of Section (ft)	Surface Area Represented (sq ft) (TW x L)	R-B Cover Area (sq ft) (Cover W/TW) x SA
TOTALS					

$$CR = \frac{L_{obc}}{L_t}(PF_{obc}) + \frac{Ar\text{-}b}{SA}(PFr\text{-}b)$$

where CR = cover rating
PF_{obc} = 0.75 (≥6.0") and 0.50 (<6.0")
PF_{r-b} = 0.25 (≥6.0") and 0.50 (<6.0")
L_{obc} = length available overhead bank cover (ft) = _____
L_t = length thalweg (ft) = _____
Ar-b = rubble-boulder area (sq ft) = _____
SA = total surface area (sq ft) = _____

CR(<6.0") = _____ CR(≥6.0") = _____ CR(mean) = _____

Table 4. Stream habitat attributes used in the Habitat Quality Index (source: Binns 1982)

Attribute	Symbol	Rating Characteristics				
		0	1	2	3	4
Late summer streamflow	x1	Inadequate to support trout (Critical period flow <10% average discharge	Very limited; potential for trout support is sporadic (CPF 10-15% AD)	Limited, CPF may severely limit trout stock every few years (CPF 16-25% AD)	Moderate; CPF may occasionally limit trout numbers (CPF 26-55% AD)	Completely adequate; CPF very seldom limiting to trout (CPF >55%)
Annual stream flow variation	x2	Intermittent stream	Extreme fluctuation, but seldom dry; base flow very limited	Moderate fluctuation, but never dry; base flow occupies 2/3 of channel	Small fluctuation, base flow stable	Little or no fluctuation
Maximum summer stream temp. (C)	x3	<6 or >26.4	6-8 or 24.4-26.3	8.1-10.3 or 21.5-24.1	10.4-12.5 or 18.7-21.4	12.6-18.6
Nitrate Nitrogen (mg/L)	x4	<0.01 or >2.0	0.01-0.04 or 0.91-2.0	0.05-0.09 or 0.51-0.90	0.10-0.14 or 0.26-0.50	0.15-0.25
Fish food abundance (no./0.1m^2)	x5	<25	26-99	100-249	250-500	>500
Fish food diversity (Ds)[a]	x6	<0.80	0.80-1.19	1.20-1.89	1.90-3.99	>4.0
Cover (%)[b]	x7	<10	10-25	26-40	41-55	>55
Eroding Banks (%)[c]	x8	75-100	50-74	25-49	10-24	<10
Substrate	x9	Submerged Aquatic vegetation (SAV) lacking	Little SAV	Occasional patches of SAV	Frequent patches of SAV	Well developed and abundant SAV
Water velocity (ft/sec)[d]	x10	<0.25 or >4.0	0.25-0.49 or 3.5-3.99	0.5-0.99 or 3.0-3.49	1.0-1.49 or 2.5-2.99	1.5-2.49
Stream width (ft)[e]	x11	<2 or >150	2-6 or 75-149	7-11 or 50-74	12-17 or 23-49	18-22

[a]For the purpose of the HQI, diversity score (Ds) is defined as follows: DS=anti-log /D/, where D is calculated for each taxon from the formula: Ds=Pi log10Pi. When Pi is defined as 1/n, and n is the number of organisms, then the formula reduces to D=log10n, as discussed in Watt (1968). /D/ is then the mean of all the values for the sample.
[b]%cover=total amount of cover/total area in study section.
[c]%eroding banks=total length of eroding stream banks (both sides) in section/total length (one side) of study section.
[d]Time of travel water velocity, using fluorescent dye. Velocity=thalweg length/time required for dye to traverse section.
[e]Width of water surface, less width of any islands.

Table 5. HQI Model I Calculation Sheets (source: Binns 1982, Wyoming Game and Fish Department).

Stream _____ Date _____
Study Sits # _____ Transect # _____
Location _____ Calculations by _____
HQI = H_s =

---

x_1 = _____ P = (x4) (x3) (x6) (x7) (X8) (x10) (x11)
X_2 = _____ P = ( ) ( ) ( ) ( ) ( ) ( ) ( )
X_3 = _____ P = _____

$Log_{10}(1+x_1) = Log_{10}$ = _____
$Log_{10}(1+x_2) = Log_{10}$ = _____
$Log_{10}(1+x_3) = Log_{10}$ = _____
$Log_{10}(1+x_4) = Log_{10}$ = _____

$Log_{10}(HQI+1) = [(-1.18257)+(.97329)Log_{10}(1+x_1)+(1.65824)Log_{10}(1+S_2)+(1.44821)Log_{10}(1+x_3)+(.30762)Log_{10}(1+P)]$
$Log_{10}(HQI+1) = [(-1.18257)+(.97329)(\quad)+(1.65824)(\quad)+(1.44821)(\quad)+(.30762)(\quad)] =$ A

Antilog$_{10}$ A = [_____] = C
HQI = C - 1.0 = _____
Habitat Value = $H_s = HQI \times \Theta_s$
= ( ) (1.19)
= _____ H.U.

where H.U. = Habitat units
Θ_s = Habitat unit coefficient for trout streams
= 1.19 = value of one habitat unit
H_s = Habitat value for a trout stream
HQI = Habitat Quality Index score (predicted trout standing crop)

		Rating
X_1	= Late Summer Streamflow	_____
X_2	= Annual streamflow Variation	_____
X_3	= Maximum Summer Stream Temperature	_____
P	= (X_4) (X_5) (X_6) (X_7) (X_8) (X_{10}) (X_{11}) =	_____
X_4	= Nitrate Nitrogen =	_____
X_5	= Fish Food Abundance =	_____
X_6	= Fish Food Diversity =	_____
X_7	= Cover =	_____
X_8	= Eroding Stream Banks =	_____
X_{10}	= Water velocity =	_____
X_{11}	= Stream Width =	_____

Table 6. HQI Model II Calculation Sheets (SOURCE: Binns 1982, Wyoming Game and Fish Department).

Stream_____ Date _____
Study Sits #_____ Transect #_____
Location _____ Calculations by _____
HQI= H_s=

---

x_1 = _____ F = ( ) ( ) ( ) ( ) = _____
X_2 = _____ S = ( ) ( ) ( ) = _____
X_3 = _____

$Log_{10}(1+x_1) = Log_{10}$ =_____
$Log_{10}(1+x_2) = Log_{10}$ =_____
$Log_{10}(1+x_3) = Log_{10}$ =_____
$Log_{10}(1+F) = Log_{10}$ =_____
$Log_{10}(1+S) = Log_{10}$ =_____

$Log_{10}(HQI+1) = [(-.903)+(.807)Log_{10}(1+x_1)+(.877)Log_{10}(1+S_2)+(1.233)Log_{10}(1+x_3)$
$+(.631)Log_{10}(1+F)+(.182)Log_{10}(1+S)]$

$Log_{10}(HQI+1) = [(-.903)+(.807)($ $)+(.877)($ $)+(1.233)($ $)+(.631)($ $)+(.182)($ $)] =$ _

$Antilog_{10}$ A = [_____] = C
HQI = C - 1.0 = _____
Habitat Value = $H_s = HQI \times \Theta_s$
= ( ) (1.08)
= _____H.U.

where H.U. = Habitat units
Θ_s = Habitat unit coefficient for trout streams
= 1.08 = value of one habitat unit
H_s = Habitat value for a trout stream
HQI = Habitat Quality Index score (predicted trout standing crop)

		Rating
X_1	= Late Summer Streamflow	_____
X_2	= Annual streamflow Variation	_____
X_3	= Maximum Summer Stream Temperature	_____
P	= $(X_4)(X_5)(X_6)(X_7)(X_8)(X_{10})(X_{11})$ =	_____
X_4	= Nitrate Nitrogen =	_____
X_5	= Fish Food Abundance =	_____
X_6	= Fish Food Diversity =	_____
X_7	= Cover =	_____
X_8	= Eroding Stream Banks =	_____
X_{10}	= Water velocity =	_____
X_{11}	= Stream Width =	_____

APPENDIX H

FISH FIELD COLLECTION FORMS

FISH SAMPLING FIELD DATA SHEET (FRONT)

page _____ of _____

STREAM NAME	LOCATION
STATION #________ RIVERMILE________	STREAM CLASS
LAT ____________ LONG ____________	RIVER BASIN
STORET #	AGENCY
GEAR	INVESTIGATORS
FORM COMPLETED BY	DATE ______ TIME ______ AM PM / REASON FOR SURVEY

SAMPLE COLLECTION	**How were the fish captured?** ❑ back pack ❑ tote barge ❑ other ____________ **Block nets used?** ❑ YES ❑ NO **Sampling Duration** Start time ________ End time ________ Duration ________ **Stream width (in meters)** Max________ Mean________
HABITAT TYPES	**Indicate the percentage of each habitat type present** ❑ Riffles____% ❑ Stream Banks____% ❑ Snags____% ❑ Banks____% ❑ Submerged Macrophytes____% ❑ Other ( )____%
GENERAL COMMENTS	

SPECIES	TOTAL (COUNT)	OPTIONAL: LENGTH (mm)/WEIGHT (g) (25 SPECIMEN MAX SUBSAMPLE)					ANOMALIES*							
							D	E	F	L	M	S	T	Z

SPECIES	TOTAL (COUNT)	OPTIONAL: LENGTH (mm)/WEIGHT (g) (25 SPECIMEN MAX SUBSAMPLE)					ANOMALIES*							
							D	E	F	L	M	S	T	Z

SPECIES	TOTAL (COUNT)	OPTIONAL: LENGTH (mm)/WEIGHT (g) (25 SPECIMEN MAX SUBSAMPLE)					ANOMALIES*							
							D	E	F	L	M	S	T	Z

* ANOMALY CODES: D = deformities; E = eroded fins; F = fungus; L = lesions; M = multiple DELT anomalies; S = emaciated; Z = other

APPENDIX I

BENTHIC MACROINVERTEBRATE FIELD AND LABORATORY LOG FORMS

BENTHIC MACROINVERTEBRATE FIELD DATA SHEET

STREAM NAME	LOCATION	
STATION #_____RIVERMILE_____	STREAM CLASS	
LAT _____LONG _____	RIVER BASIN	
STORET #	AGENCY	
INVESTIGATORS		LOT NUMBER
FORM COMPLETED BY	DATE _____ TIME _____ AM PM	REASON FOR SURVEY

HABITAT TYPES	**Indicate the percentage of each habitat type present** ❑ Riffles_____% ❑ Stream Banks_____% ❑ Snags_____% ❑ Banks_____% ❑ Submerged Macrophytes_____% ❑ Other ( )_____%
SAMPLE COLLECTION	**Gear used** ❑ D-frame ❑ kick-net ❑ Other _____ **How were the samples collected?** ❑ wading ❑ from bank ❑ from boat **Indicate the number of jabs/kicks taken in each habitat type.** ❑ Riffles_____ ❑ Stream Banks_____ ❑ Snags_____ ❑ Banks_____ ❑ Submerged Macrophytes_____ ❑ Other ( )_____
GENERAL COMMENTS	

QUALITATIVE LISTING OF AQUATIC BIOTA

Indicate estimated abundance: 0 = Absent/Not Observed, 1 = Rare, 2 = Common, 3= Abundant, 4 = Dominant

Periphyton	0	1	2	3	4	Slimes	0	1	2	3	4
Filamentous Algae	0	1	2	3	4	Macroinvertebrates	0	1	2	3	4
Macrophytes	0	1	2	3	4	Fish	0	1	2	3	4

FIELD OBSERVATIONS OF MACROBENTHOS

Indicate estimated abundance: 0 = Absent/Not Observed, 1 = Rare (1-3 organisms), 2 = Common (3-9 organisms), 3= Abundant (>10 organisms), 4 = Dominant (>50 organisms)

Porifera	0	1	2	3	4	Anisoptera	0	1	2	3	4	Chironomidae	0	1	2	3	4
Hydrozoa	0	1	2	3	4	Zygoptera	0	1	2	3	4	Ephemeroptera	0	1	2	3	4
Platyhelminthes	0	1	2	3	4	Hemiptera	0	1	2	3	4	Trichoptera	0	1	2	3	4
Turbellaria	0	1	2	3	4	Coleoptera	0	1	2	3	4	Other	0	1	2	3	4
Hirudinea	0	1	2	3	4	Lepidoptera	0	1	2	3	4						
Oligochaeta	0	1	2	3	4	Sialidae	0	1	2	3	4						
Isopoda	0	1	2	3	4	Corydalidae	0	1	2	3	4						
Amphipoda	0	1	2	3	4	Tipulidae	0	1	2	3	4						
Decapoda	0	1	2	3	4	Empididae	0	1	2	3	4						
Gastropoda	0	1	2	3	4	Simuliidae	0	1	2	3	4						
Bivalvia	0	1	2	3	4	Tabinidae	0	1	2	3	4						
						Culcidae	0	1	2	3	4						

page __ of __

BENTHIC MACROINVERTEBRATE SAMPLE LOG-IN SHEET

Date Collected	Collected By	Number of Containers	Preservation	Station #	Stream Name and Location	Date Received by Lab	Lot Number	Date of Completion		
								sorting	mounting	identification

Serial Code Example: B0754001(1)

B = Benthos (F = Fish; P = Periphyton) 0754 = project number 001 = sample number (1) = lot number (e.g., winter 1996 =1; summer 1996 = 2)

BENTHIC MACROINVERTEBRATE LABORATORY BENCH SHEET (FRONT)

page _____ of _____

STREAM NAME	LOCATION
STATION #_____ RIVERMILE_____	STREAM CLASS
LAT _____ LONG _____	RIVER BASIN
STORET #	AGENCY
COLLECTED BY DATE_____	LOT #
TAXONOMIST DATE_____	SUBSAMPLE TARGET ❑ 100 ❑ 200 ❑ 300 ❑ Other ____

Enter Family and/or Genus and Species name on blank line.

Organisms		No.	LS	TI	TCR	Organisms		No.	LS	TI	TCR
Oligochaeta						Megaloptera					
Hirudinea						Coleoptera					
Isopoda											
Amphipoda						Diptera					
Decapoda											
Ephemeroptera											
						Gastropoda					
						Pelecypoda					
Plecoptera											
						Other					
Trichoptera											
Hemiptera											

Taxonomic certainty rating (TCR) 1-5:1=most certain, 5=least certain. If rating is 3-5, give reason (e.g., missing gills). LS= life stage: I = immature; P = pupa; A = adult TI = Taxonomists initials

Total No. Organisms _____ **Total No. Taxa**

BENTHIC MACROINVERTEBRATE LABORATORY BENCH SHEET (BACK)

SUBSAMPLING/SORTING INFORMATION

Sorter _____

Date _____

Number of grids picked: _____

Time expenditure _____ No. of organisms _____

Indicate the presence of large or obviously abundant organisms:

QC: ❑ YES ❑ NO QC Checker _____

# organisms recovered by checker		# organisms originally sorted				% sorting efficiency
	÷		X	100	=	

≥90%, sample passes _____

<90%, sample fails, action taken _____

TAXONOMY

ID _____

Date _____

Explain TCR ratings of 3-5:

Other Comments (e.g. condition of specimens):

QC: ❑ YES ❑ NO QC Checker _____

Organism recognition ❑ pass ❑ fail

Verification complete ❑ YES ❑ NO

General Comments (use this space to add additional comments):

PRELIMINARY ASSESSMENT SCORE SHEET (PASS)

page _____ of _____

STREAM NAME	LOCATION
STATION #_____ RIVERMILE_____	STREAM CLASS
LAT _____ LONG _____	RIVER BASIN
STORET #	AGENCY
COLLECTED BY DATE_____	LOT # _____ NUMBER OF SWEEPS _____
HABITATS: ❑ COBBLE ❑SHOREZONE	❑ SNAGS❑ VEGETATION

Enter Family and/or Genus and Species name on blank line.

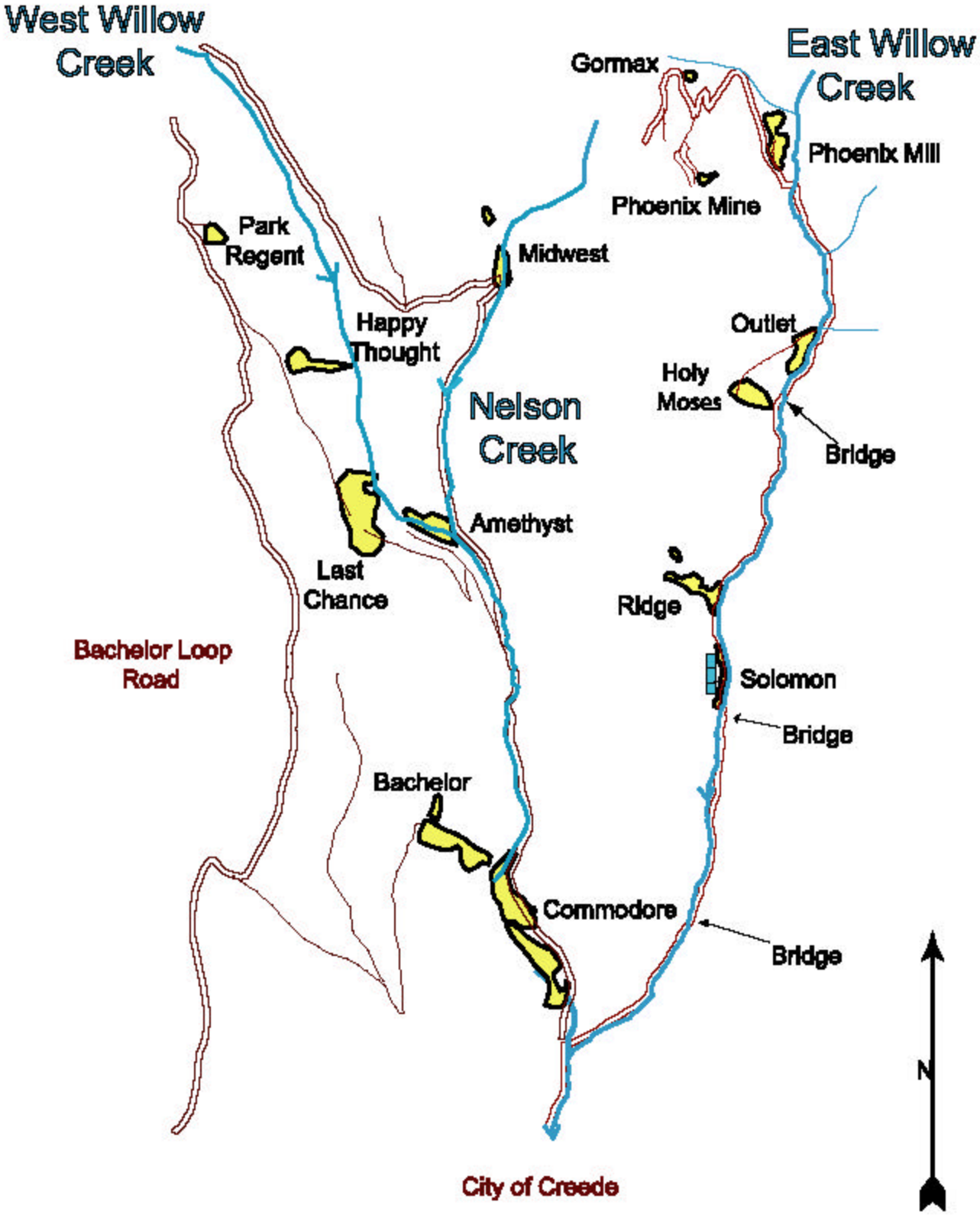
Organisms		No.	LS	TI	TCR	Organisms		No.	LS	TI	TCR
Oligochaeta						Megaloptera					
Hirudinea						Coleoptera					
Isopoda											
Amphipoda						Diptera					
Decapoda											
Ephemeroptera											
						Gastropoda					
						Pelecypoda					
Plecoptera											
						Other					
Trichoptera											
						Taxonomic certainty rating (TCR) 1-5:1=most certain, 5=least certain. If rating is 3-5, give reason (e.g., missing gills). LS= life stage: I = immature; P = pupa; A = adult TI = Taxonomists initials					
Hemiptera											

	Site Value	Target Threshold	If 2 or more metrics are ≥ target threshold, site is
Total No. Taxa			HEALTHY
EPT Taxa			If less than 2 metrics are within target range, site is
Tolerance Index			SUSPECTED IMPAIRED

APPENDIX J

WASTE ROCK, SEDIMENT, AND TAILINGS SAMPLING SITE MAPS

Waste Rock Sampling Locations
2001-2002



Map of waste rock sampling sites. Individual piles are shown in yellow.

APPENDIX K

PASTE PH AND CONDUCTIVITY PROCEDURE

Paste pH and Conductivity

Objectives

To determine the pH and conductivity of the pore water resulting from dissolution of secondary mineral phases on the surfaces of oxidized rock particles.

To indicated whether oxidation, and accumulation of contaminants in the form of secondary mineral phases, has occurred in the waste rock prior to collection of the sample.

Description of Test

Water is added to the sample to form a paste or slurry thus mobilizing secondary mineral phases and providing a medium accessible to the pH and conductivity or TDS probes. The probe is placed in the paste or slurry and the pH or conductivity value is read directly from the meter.

Equipment

1. pH meter equipped with a combination pH electrode.
2. Conductivity or TDS meter.
3. 50 mL beakers, or equivalent (disposable paper cups, bottom of pop can etc.)
4. Spatula or stirring rod (e.g. plastic coffee stirrers)
5. Litmus paper strips

Reagents

1. Standard buffer solutions, pH 4.00 and pH 7.00
2. Standard electrolyte solutions (for calibration of conductivity meter)
3. Distilled (or deionized) water

Procedure

1. Calibrate pH and conductivity or TDS meters using the standard solutions and following instructions provided with the meters.
2. Obtain approximately 25 g of fines (particles smaller than 1 mm if possible) from the rock sample to be tested, and place in a fresh or decontaminated beaker or testing container.
3. Add approximately 25 mL of distilled water to sample. (More water may be required if the sample is very dry or extremely fine).

4. Stir sample with fresh or cleaned spatula to form a paste or slurry. Paste should slide off spatula easily.
5. Tip the testing container to one side to allow a pool of water or slurry to collect in the corner. Dip each of the probes into the slurry, and allow the meter readings to stabilize. The conductivity reading should however be done first, as electrolyte from the combination pH probe may affect the conductivity of the solution.
6. Decontaminate probes and containers.
7. Record the measurements in field notebook along with a description of the rock type tested, and the general appearance of the sample.

Interpretation

High conductivity (or TDS) levels indicate there is considerable store of contaminant salts. These are usually sulphates, but can be other metal salts. When a sample is collected over depth, it is not always clear whether the stored salts are due to oxidation at that point in the sediment profile, or if the salts were generated somewhere higher in the profile and moved downwards to the sample location. Look for stains along the flow path that may indicate if this is the case.

Low pH readings indicate oxidation and acid generation has occurred, usually at the location from which the sample was collected. Readings taken on uncrushed samples in the field or lab usually provide a much better indication of the extent of oxidation than crushed samples do.

References

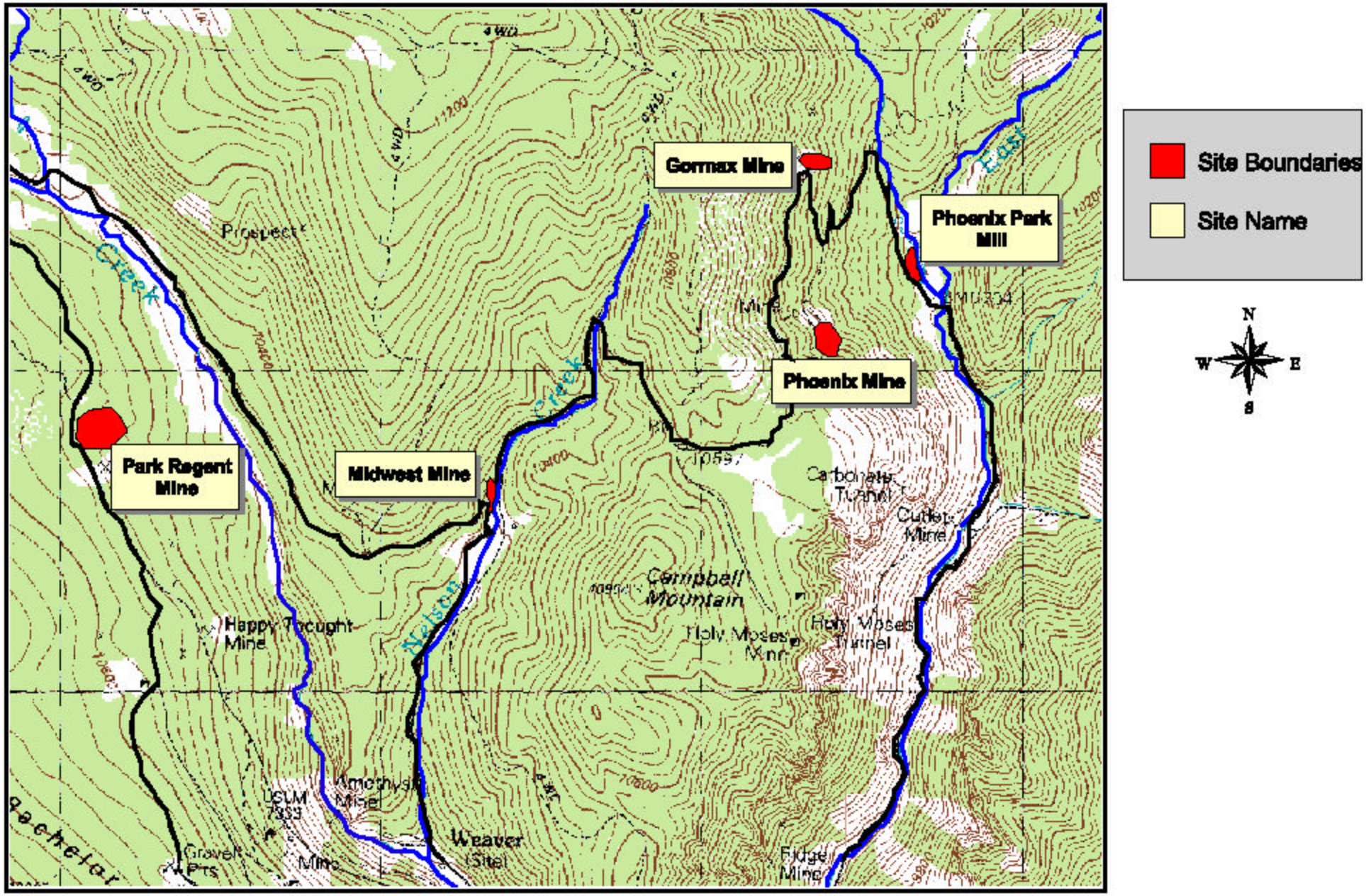
Sobek, A.A., Schuller, W.A. Freeman, J.R. and Smith, R.M. (1978), Field and Laboratory Methods Applicable to Overburden and Minesoils, EPA 600/2-78-054, 203 pp.

British Columbia AMD Task Force (1989), Draft Acid Rock Drainage Technical Guide, Vol I, Crown Publications, Victoria, B.C.

APPENDIX L

SITE RECLAMATION MAP

2003 Reclamation Sites



APPENDIX M

PHOTOPOINT DATASHEET

Photopoint Datasheet

Date:

Site:

Photopoint Site Number:

GPS Location:

View Direction (relative or compass):

Circle One: Original Duplicate

Photo Conditions

Time:

Weather/Lighting:

Camera:

Photographer:

Other:

Site Conditions

Vegetation:(cover, types, relative health)

Comments (Please indicate any notable characteristics, changes, or other factors which might not be obvious in the photo)