Water Resources Research Institute
Annual Technical Report
FY 2002

Introduction

The Idaho Water Resources Research Institute (IWRRI), University of Idaho is dedicated to supporting and promoting water and water-related applied investigations and solutions, education, and information transfer throughout Idaho. IWRRI collaborates with scientists and educators from all of the Idaho state universities in order to provide a broad-based, diverse, and interdisciplinary effort in helping to solve water issues.

The Idaho Water Resources Research Institute is the only mechanism in the state that provides an autonomous statewide source of support for water and water-related, problem-solving research and training, without regard to specific topic or discipline area.

We support and direct water research for the State of Idaho and the region. Our research results routinely lead to cutting-edge discoveries in such vital topics as water quality, water supply and water management. More important, these discoveries regularly lead to a greater understanding of our surroundings, and offer sensible solutions toward maintaining a healthy balance between the economy and the environment.

Research, Education, and Information Transfer are the three mandates to the public with which the Idaho Water Resources Research Institute is charged.

Research: We believe in the sparks of discovery that come from working together with diverse experts. In that spirit of cross-campus cooperation, we bring together the top scientific experts from Idaho's three universities; University of Idaho, Idaho State University and Boise State University. That cooperation extends to numerous research and education opportunities with local, state, and federal agencies, and a variety of industry partners.

Education: Our research projects regularly involve graduate and post graduate students, thereby contributing to their total educational experience. This training also provides an important step in creating future scientists and nurturing scientific creativity. In addition, we sponsor programs such as Project WET (Water Education for Teachers) that work directly with teachers and young students to help them better understand Idaho's water related issues.

Information Transfer: The third vital component in the institute's mandate is to distribute its research results to the general public. In addition to formal research reports published in technical journals, our scientists regularly publish results and make presentations designed for a lay audience. We sponsor a range of timely conferences and short-courses and produce audio-visual materials including educational videos.

Research Program

The Idaho Water Resources Research Institutes research plan is comprised of the following objections and goals:

1. To promote research that is relevant to state and regional needs for conservation of water and related land resources with emphasis on economic resource development, preservation and enhancement of environmental quality and social well-being of people.

2. To stimulate, coordinate and provide leadership for water resource research in the established units of the universities of the State of Idaho and to cooperate with the sister institutions in adjoining states. Such research should utilize an interdisciplinary approach and provide an opportunity for training students.

3. To cooperate with and help local entities, state and federal government agencies to carry out their responsibilities concerned with water and related land resources and to provide public involvement in identifying research needs.

4. To provide for dissemination of research findings in an expeditious and comprehendible manner to all interested parties.

5. To promote water education in the state, both at the K-12 level and undergraduate/graduate levels of higher education.

6. To develop funding for needed research and to encourage cooperation with regional research organizations in conducting an efficient and productive research effort.

Metal(loid) Flux from Sediments of Lake Coeur d’Alene, ID

Project 2002ID6G was not funded for FY2002.

Title: Metal(loid) Flux from Sediments of Lake Coeur d'Alene, ID

Statement of critical regional and State water problem

Lake Coeur d'Alene (CDA) in Idaho is the second largest natural lake in the Inland Northwest, providing drinking water for five communities and serving as a primary recreational area for the region. The St. Joe and Coeur d'Alene Rivers contribute 94% of the inflow volume to Lake CDA (Horowitz et al., 1993). The South Fork of the Coeur d'Alene River flows through the Coeur d'Alene mining district, an area that produced approximately 3.1 x 10^7 kg of Ag, 7.3 x 10^9 kg of Pb, 2.0 x 10^9 kg of Zn, 1.7 x 10^4 kg of Cu, and 1.6 x 10^4 kg of Au (Bennett, 1989; Hoffman, 1995) from 1884 and 1991. The major minerals mined in this area were primarily sulfidic, with galena (PbS) and sphalerite (ZnS) being the principal constituents of the ore. Sulfidic minerals including pyrite (Fe_2S_2), chalcopyrite ($CuFeS_2$), arsenopyrite (FeAsS), and tetrahedrite ($(Cu, Fe, Zn, Ag)_{12}\ Sb_4S_3$) were also often found associated with the Zn and Pb sulfides (Wai et al., 1985).

As a result of mining activities, tailings enriched in Pb, Zn, As, Cd, and other trace elements were deposited along the South Fork and main stem of the Coeur d'Alene River. These materials have been regularly resuspended during periods of high stream flow and transported into Lake CDA. Numerous studies have been carried out in this region, all confirming that sediments enriched in As, Cu, Cd, Pb, Sb, and Zn have been deposited throughout the lake (Woods, 1989; Horowitz et al., 1992, 1993, 1995; Harrington et al., 1998a; 1998b; Kuwabara et al., 2000).

Recent monitoring efforts indicate that Zn concentrations in Lake CDA surface waters often exceed Idaho water quality guidelines. Pb concentrations are typically in compliance with these guidelines, but elevated concentrations have occurred in the last several years (Harvey, personal communication). A major concern of management agencies responsible for lake water quality is the potential release of the accumulated metal(loids) into the overlying water column. This concern is illustrated by the fact that sediment pore water metal concentrations, in many cases, greatly exceed limits considered to be chronically toxic (Harrington et al., 1998b). Metals accumulated in the sediments thus pose a potential threat to lake biota and human health.

Lake CDA is believed to be oligo-mesotrophic in nutrient status. One of the principal means of keeping toxic trace elements immobilized in the sediments may be to carefully manage the lake nutrient status. It has been assumed that the development of an anoxic hypolimnion due to eutrophication would promote trace element release (Woods, 1989). This prediction is based on the assumption that metals in the lake near the sediment-water interface are sorbed to or precipitated as metal oxyhyroxides. Anoxia favors the dissolution of certain metal oxides and can thereby enhance metal desorption and mobilization. Although the potential importance of metal and nutrient flux from the sediments has been established (Kuwabara et al., 2000), mechanisms responsible for metal retention and cycling remain poorly quantified for the lake, making accurate predictions of altered environmental contamination with changes in lake nutrient status difficult.

Without increased understanding of sediment biogeochemistry it is impossible to accurately describe metal transport within the watershed let alone evaluate the response of the lake water to proposed management strategies. The Coeur d'Alene Tribe, Idaho Department of Environmental Quality, EPA, USGS, and local citizens groups need such information in order to develop a plan for managing ever increasing use of the lake resource. It is feared that continued development within the region will alter lake nutrient status leading to eutrophication and trace element release (Woods, 1989). This prediction is based on controversial assumptions concerning the mechanisms responsible for metal speciation and partitioning.

Statement of results or benefits

We will collect a comprehensive data set that will be used to define the magnitude and direction of metal flux across the sediment-water interface in Lake CDA and the processes that control concentrations of metal(loid)s in the pore water. This research entails determining the composition of pore water and overlying water, and identifying the mineralogy of the oxide and sulfide phases in the sediment where the metal(loid)s reside. Our overall objective is thus to develop a clear understanding of sediment biogeochemistry, providing appropriate data that will contribute to the development of models focused on the fate of metal(loid)s within the lake. Ultimately such models will be used to quantitatively describe how anthropogenic alteration of the lake will modify water-quality trends in metal(loid) cycling and transport. This research will contribute to the protection of regional water resources impacting northern Idaho and eastern Washington.

Nature, scope, and objectives of the research

It has been clearly demonstrated that the sediments of Lake CDA contain elevated concentrations of a number of different metal(loids) as a result of mining activities within the region. The relative importance of factors regulating the release of these metals from the sediment and their flux into the overlying water column remain controversial. Our objective is to rectify this situation by filling holes in our current understanding of sediment biogeochemistry.

The current controversy concerning the sediments of Lake CDA and phase associations of metal(loid) contaminants is best illustrated in the publications of Horowitz et al. (1992), Harrington et al. (1998a; 1998b), and the associated exchange of communications between the two research groups (Horowitz et al., 1999; Harrington et al., 1999). Horowitz et al. contend that Fe, Cd, Zn, As, and Cu in surficial sediments are primarily associated with an operationally defined ferric-oxide phase. Core samples obtained from the sediments also indicated that Fe oxide plays a dominant role in metal sequestration (adsorption). In contrast, Harrington et al. (1998a; 1998b) argue that trace elements are predominantly associated with a sulfidic phase, implying that the resulting complexes are of authigenic origin and not detrital. Disagreement between the two groups stems partially from the contention that Horowitz et al. failed to maintain anaerobic conditions during sample storage and analysis. The interpretation of heavy mineral flotation data is also a point of contention. Horowitz et al. argue that the lake sediment contains very little (<1%) of the heavier sulfidic fraction and it is thus inconceivable that the sulfidic phase could play a major role in heavy metal sequestration. This contention is countered by Harrington et al. based on the fact that density separations may not yield accurate information when applied to authigenic materials.

Investigators have been forced to go forward with metal-flux measurements and modeling without this information. Balistrieri (1998) performed benthic-flux calculations and concluded that the sediment of Lake CDA appears to be a source of Zn, Cu, Mn, and possibly Pb to the overlying water. However she acknowledged that the model input data available may have been inaccurate because oxidation occurred during storage and sample processing. More recent flux investigations were conducted with an in situ sampling device and incubated cores (Kuwabara, 2000). The investigators concluded that the flux of metals from the sediment may be as significant to lake water as riverine inputs. However, this was a one-time sampling and the investigators recommended that a systematic study be performed to address temporal and spatial relationships. Existing information on the lake, particularly our own peeper studies, clearly provides motivation to better quantify the processes that explain the quality and magnitude of these sediment-water interactions.

We are currently conducting USGS-funded research to predict the flux of Pb, Zn, Cd, and As from the sediments of Lake CDA to the overlying water column. This is a collaborative project with Laurie Balistrieri, U.S. Geological Survey, Univ. of Washington, Seattle, WA and R. Frank Rosenzweig, Univ. of Montana, Missoula, MT. We have established four sites in the lower third of the lake. The sites cover a range in sediment contamination values ranging from relatively uncontaminated sediments near the mouth of the St. Joe River to highly contaminated sediments near the mouth of the Coeur d'Alene River. During the last 1.5 years we have collected sediment pore waters using equilibrium samplers referred to as peepers. Microbiological characterization and the role of sulfidogenesis is sulfur biogeochemical cycles is also being ascertained.

Current data show that sediments are oxic or suboxic only in the first several centimeters of sediment, after which a large increase in soluble Mn is first observed followed by soluble Fe (Fig. 1). Correspondingly, SO_4^{2-} concentrations decrease in the sediment as it becomes a terminal electron acceptor and is reduced. The formation of soluble Fe and Mn results in the release of substantial amounts of As into sediment pore water (Fig. 2). Although additional data cannot be reported because of space limitations, a summary of our major results are provided below to illustrate our accomplishments and to identify additional research requirements. We now have temporal data that consistently show trends of increased soluble iron with depth in the sediment. We suspect that it is these high Fe(II) concentrations that are responsible for our inability to detect sulfide in any of the pore water samples using voltammetric techniques. However, there is no evidence from Fe concentration data that the amount of sulfide is sufficient to scavenge a significant amount of the Fe(II). Thiosulfate was detected in pore water samples using ion chromatography, indicating the potential importance of

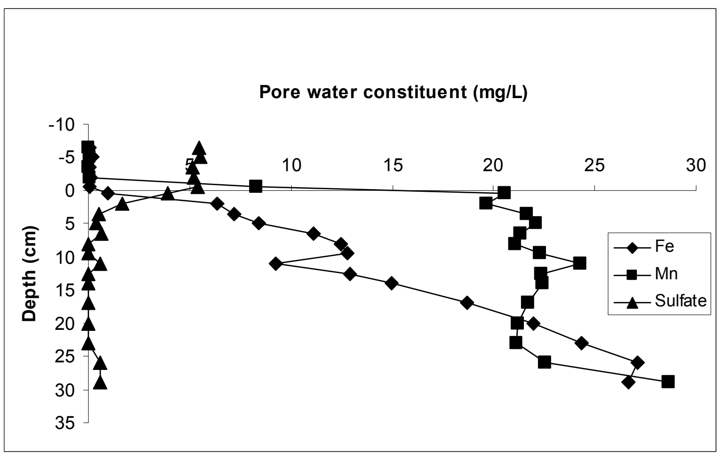


Fig. 1. Fe, Mn, and sulfate in sediment pore waters sampled in Lake CDA during the summer of 2001.

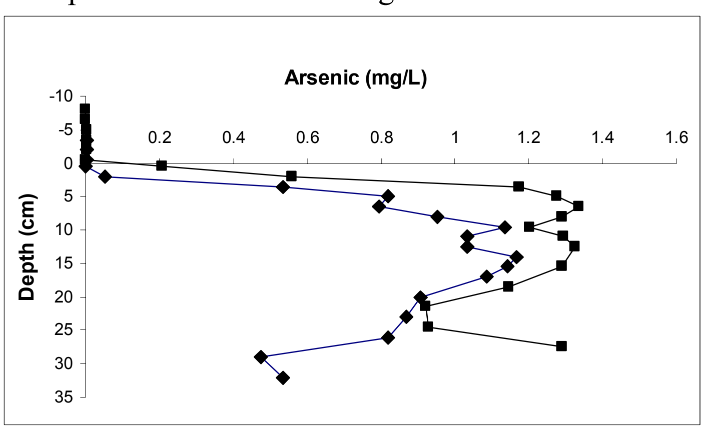


Fig. 2. Arsenic in sediment pore waters sampled in Lake CDA during the summer of 2001.

partially oxidized sulfur species in internal S cycling reactions. Pb concentrations were near our detection limits and Cd was not detected in any of the samples using ICP-AES. Zn concentrations in the pore waters were variable, possibly reflecting extreme spatial heterogeneity. This spatial heterogeneity and limitations in having to combine data from several peepers caused difficulty with the charge balance calculations. Given these caveats, benthic fluxes calculated from our summer 2001 data indicate the transfer of dissolved Fe, Mn, As, Zn, and P from the sediment into the water column.

Our overall objectives to predict metal(loid) flux from the sediments of Lake CDA and define the processes responsible for metal(loid) mobilization in the sediments have not changed. However, it has become apparent that pore water sampling alone is insufficient to achieve these goals. Our ability to interpret pore-water data is limited by the lack of biogeochemical characterization of the sediments as related to sources and sinks for the soluble metals measured. Our specific goals are to 1) collect the physical and chemical data necessary for benthic-flux modeling of Cd, Pb, Zn, and As, 2) characterize the solid phases responsible for metal(loid) sorption/retention using spectroscopic and related techniques, and 3) quantify metal(loid) concentration gradients in the water column.

Methods, procedures, and facilities

We are currently sampling exclusively in the southern part of Lake CDA along a transect that displays a gradient in metal concentrations. We will continue to sample a relatively uncontaminated site near the mouth of the St. Joe River, but will establish two new sites farther north in the lake that better represent a larger proportion of lake area. Exact site locations will be established in consultation with Dr. Paul Woods (USGS, Boise). We will deploy peepers, sample the sediment, and collect water column samples. The study will be conducted over two annual cycles and samples will be collected in the spring, summer, and fall of each year in order to define temporal changes.

Peeper construction. Peepers 20 cm wide and 50 cm in length have been constructed by machining two rows of 25 cells each into a 1.9-cm thick plexiglass sheet. Cells are spaced 1.5 cm apart and hold 10 mL in volume. A 0.2-µm Nylon filter (Osmonics) will be placed over the cells, followed by mosquito netting (to protect filter integrity) and a 0.6-cm thick plexiglass cover with machined openings matching those for the main peeper body. The filter is sandwiched between the two plexiglass sheets and the entire unit is held together using nylon screws. The bottom of the peeper is machined into a wedge shape to facilitate insertion into the sediment. Care is taken to clean and wash the peepers to eliminate contaminants. Peepers are stored and transported to the deployment site in an oxygen-free distilled water environment.

Peeper deployment and retrieval. Scuba divers will insert the peepers into the sediment, leaving 4 peeper cells above the sediment-water interface. Site location will be recorded using a GPS unit and marked with buoys. Peepers are left in the sediment for an equilibration time of 4 wks. Divers retrieve the peepers by first attaching a clip to the peeper to mark the sediment-water interface and then inserting a plexiglass sheet along the vertical face of the membrane-side of the peeper. This plexiglass sheet is kept in place as the divers ascend in order to trap sediment at the filter surface and decrease the likelihood of pore water contamination by lake water.

Pore water samples for metals analysis will be withdrawn from each peeper cell using a metal-free, nitrogen-purged syringe and placed in screw-top polyethylene tubes containing HNO_3. Pore water samples for anion analysis, pH, and alkalinity will be extracted from the peeper cells with a syringe and injected into vials previously prepared in a glove box containing an oxygen-free atmosphere. We will decrease our problems associated with spatial heterogeneity by increasing the number of peepers deployed at each site and conducting analyses critical to charge balance on pore-water samples from one peeper. Volume limitations previously limited our ability to use an individual peeper for analyses germane to charge-balance relationships. Redox-sensitive samples will be placed in air-tight boxes along with ice packs and the entire box purged with N_2. The samples will be stored in this fashion during transport to the laboratory.

Water-column analyses. At each location and time of peeper retrieval, water-column samples will be collected using trace-element protocol (Kuwabara et al., 2000). These samples will be stored in acid-washed polyethylene bottles in darkness, in an ice chest, until samples are processed in a particle-controlled environment. The filtered and/or acidified samples will then be analyzed for dissolved trace metals, macronutrients and dissolved organic carbon. James Kuwabara, U.S. Geological Survey, Menlo Park, California will advise on sample collection and processing protocols as well as loan necessary sampling equipment.

Sediment cores. Nine sediment cores will be collected from each of the three different sites in each of the two years. Scuba divers will insert 5-cm diameter, 50-cm long thin-walled polycarbonate tubing into the sediment, cap the top, and remove a sediment core with approximately 5 cm of overlying water. The bottom of the tube will be capped and the cores transported to the surface. Cores will be carefully sealed and stored upright in an air-tight box flushed with N_2 gas and cooled with ice packs.

Pore water analyses. Pore water analyses will be performed with the specific objective of providing necessary data for equilibrium modeling of metal speciation and benthic flux calculations for Pb, Zn, As, and Cd. The parameters to be analyzed are those shown in Table 3.

Table 3. Analyses to be performed on sediment or porewater samples obtained from CDAL.

Equilibrium modeling
- pH
- temperature (as determined at the sediment water interface)
- alkalinity
- major cation and anion concentrations (Na^+, K^+, Mg^{+2}, Ca^{+2}, Cl^-, SO_4^{2-})
- total dissolved metal concentrations
- concentrations of dissolved sulfur species

Benthic flux
- porosity of sediment (calculated from water content data of cores)
- temperature of bottom water
- metal gradient across the sediment-water interface

All equipment necessary to perform the analyses are available within the laboratories of the investigators, except that necessary for Pb and Cd. Major elements as well as Zn and As will be measured using a Thermo Jarrell Ash IRIS ICP-AES. Pb and Cd will be measured using ICP-MS in cooperation with Washington State University. Anions will be determined using a 500DX Dionex Ion Chromatograph. Alkalinity will be determined using standard titration techniques.

Sediment characterization. Intact cores will be taken into an anaerobic chamber containing an atmosphere of N_2:CO_2:H_2 gas in the ratio of 80:15:5 and extruded from bottom to top. Total elemental concentrations of C, N, S, and the metal(loids) of interest will be determined on sediment samples at 2-cm depth increments of three cores. The remainder of the cores will be frozen for use in further characterization experiments as detailed below.

Oxidation state and molecular structure of the contaminants in the sediments will be determined by collecting x-ray absorption fine structure (XAFS) spectra on the samples. XAFS spectroscopy is an ideal tool for analysis of geologic samples since they can be run with little alteration of the sample, and the redox status of the samples can be preserved.

In this study we will use XAFS spectroscopy to study the mineralogy of the Fe and Mn oxides and Fe sulfides since they are the most active minerals that affect contaminant mobility.. The distribution of these minerals will suggest dominant biogeochemical processes and help resolve the contrasting perspectives on metal speciation and partitioning cited above. We will also study the oxidation state and molecular spectroscopy of As and Zn contaminants since they are known toxins in aquatic systems and are most likely undergoing continuous changes in solubility as a function of the dynamic redox cycles occurring in the sediments. XAFS spectroscopy has two important regions, the near-edge (XANES) and the extended region (EXAFS). The excitation edges (electron binding energy) for As, Fe, Mn and Zn are 11,867, 7,122, 6,539, and 9,659 eV, respectively. Since the position of the edge shifts with oxidation state, analysis of the XANES spectra allows for determination of oxidation state. In addition, the shape of the XANES spectra can be used to interpret the identity of the molecular environment. Analysis of the EXAFS spectra yields molecular coordination information that can be used to provide additional speciation information.

Sediment samples will be loaded in an anaerobic glove-box into polycarbonate sample holders, sealed with Kapton tape, placed into air-tight plastic bags and frozen. To preserve oxidation state the sediment samples will be scanned frozen using a liquid-nitrogen cryostatted sample holder. The fluorescence spectra emitted from the samples at specified energies will be collected using a Stern-Heald detector or, for low concentration samples a multi-element solid state detector. The incoming polychromatic x-ray beam will be focused to selected energies using either a parallel Si (111) or (220) crystal monochromator detuned by 25-40% to reduce higher order harmonics.

Analysis of the XANES and EXAFS data will be done by comparing spectral features with standards via a least-squares linear-combination analysis, or, for EXAFS spectra, ab-initio calculations will be done to derive the first and second shell atomic coordination environments; this includes backscatterer identity, bond distance, coordination number, and structural order. This information is unique for each type of mineral or contaminant species present.

In addition to XANES and EXAFS, we intend to use X-ray diffraction (XRD) and transmission electron microscopic (TEM) techniques to help identify solid phases in the sediments. The fine grain size, the expected complex mixture of phases, and the possible existence of amorphous or poorly crystalline material may complicate the use of XRD. However, over the past decade, advances in powder X-ray diffraction instrumentation (especially the advent of solid-state detectors) and computational methods have made quantification of multiphase mixtures much more realistic. Detection limits of 0.1% to 1.0% by volume are easily attained in routine work. Our colleague in the Department of Geological Sciences, Dr. Mickey Gunter, and his co-workers have taken advantage of these methods to analyze 500-600 multiphase samples from the Phosphoria Formation in southern Idaho using the XRD instrument at the University of Idaho and the Rietveld method. The lower detection limit of this method has been shown to be at least 0.01% by Bish and Chipera (1991). Thus, using advanced instrumentation and methods, we are confident that some information on the mineralogy of the sediments may be obtained using XRD. In our case, it will be important to avoid oxidation of the sediments. All sample transfers will be performed in an anaerobic glove-box where subsamples will be mounted on XRD slides and sealed with Mylar film.

We are fully aware that we may encounter some problems with XRD studies, which is why we are also proposing the use of TEM. The TEM instrument we have available has a resolution of 1 nanometer, and provides the ability to identify phases via electron diffraction as well as via morphology. It is possible to identify phases of very small grain size by TEM, so this technique should also yield some useful information regarding the mineralogy of the sediments.

Equilibrium modeling. Equilibrium modeling will be done to determine the speciation of metals in the porewater and to assess the importance of various processes in mobilizing metals from solid phases into the porewater. Speciation calculations will consider complexation with inorganic (Cl^-, SO_4^{2-}, CO_3^{2-}, OH^-, HS^-, and polysulfides) and organic thiol ligands. Cysteine will be used as a model compound for the organic thiols because the relevant stability constants are available for cysteine but not for the naturally occurring organic thiols (Huerta-Diaz et al., 1998). The model will consider the role of solubility with sulfidic phases by calculating ion activity products (IAP) and comparing them with solubility constants for the sulfidic phases. In addition, the data will be fit to determine binding constants for metals with solid phases (Benoit et al., 1999). Interactions between metals and solid phases within the anoxic zone will be defined as adsorption reactions onto solid phase organic thiol ligands or as co-precipitation either with metal monosulfides or as pyritization of the metal.

The computer program PHREEQC will be used in the modeling. Reactions between metals and bisulfide, between metals and cysteine, and those describing the solubility of sulfidic phases and formation of polysulfides will be taken from the literature and added to the database (Uhler and Helz, 1984; Davison, 1991; Daskalakis and Helz, 1992; 1993).

There are definite limitations to modeling sulfidic waters. Paramount is that the solubility products of metal sulfide phases and the complexation constants with bisulfide and other reduced sulfur species are either poorly or not known. Complexes that are formed are limited to those for which equilibrium constants are available. In some cases, model compounds for which there are available stability constants must be substituted for naturally occurring compounds. In addition, the calculations assume equilibrium and, therefore, do not account for kinetic factors.

Benthic flux calculations. The flux of dissolved elements across the sediment-water interface by molecular diffusion is calculated using Fick's First Law; *i.e.*,

$$J_s = -\Phi\ D_s\ [\delta C/\delta x] \qquad (1)$$

where J_s is the benthic flux (g cm^{-2} d^{-1}), Φ is the porosity just below the sediment-water interface, D_s is the diffusion coefficient for the element in the sediment (cm^2 d^{-1}), and $\delta C/\delta x$ is the concentration gradient of the element across the sediment-water interface (g cm^{-4}) (Berner, 1980).

Diffusion coefficients in the sediment (D_s) are related to molecular diffusion coefficients in water (D_0) as follows:

$$D_s = D_0/(\Phi\ F) \qquad (2)$$

where F is the sediment resistivity. For high porosity sediments, as in Lake CDA, F can be approximated as Φ^{-3} (Ullman and Aller, 1982). Therefore,

$$D_s = D_0/\Phi^{-2} \qquad (3)$$

Values of D_0 at infinite dilution for a variety of ions are tabulated in Li and Gregory (1974). These values depend on speciation of the metals. Metal speciation is a function of pH, redox potential, and the presence of complexing ligands such as carbonate, dissolved organic carbon, and sulfide.

Diffusion coefficients also are a function of temperature. The Stokes-Einstein relationship is used to temperature correct the diffusion coefficients to in-situ conditions as follows:

$$(D_0\eta^0/T)_{T1} = (D_0\eta^0/T)_{T2} \qquad (4)$$

where η^0 is the viscosity of water and T is absolute temperature ($T^0C + 273.15$). The temperature dependence on the viscosity of water is tabulated in Dorsey (1940).

The concentration gradient ($\delta C/\delta x$) across the sediment-water interface is calculated as:

$$\delta C/\delta x = [(Me^{2+})_{BW} - (Me^{2+})_{PW}]/\Delta d \qquad (5)$$

where $(Me^{2+})_{BW}$ is the concentration of the dissolved metal (Me^{2+}) at the bottom of the water column just above the interface (g cm^{-3} or g L^{-1}), $(Me^{2+})_{PW}$ is the concentration of dissolved metal in the porewater just below the interface (g cm^{-3} or g L^{-1}), and Δd is the distance between the location of the bottom water and porewater sample (cm).

There are several limitations in determining fluxes using the above approach. First, flux calculations assume that molecular diffusion is the only process affecting transport of elements across the interface. Other physical and chemical processes that could either increase or decrease transport, such as bioturbation or mineral precipitation at the interface, are not considered. Using Rn and Br measurements and a benthic flux chamber in Lake CDA, Kuwabara et al. (2000) found that benthic fluxes in this lake are diffusive. Second, the calculations assume that there are linear gradients in metal concentrations across the interface. The thickness of the sampling interval is critical for elements that have large changes in concentration with depth, as the measured metal concentration is the average for that depth interval. With greater sampling resolution near the sediment-water interface, an exponential model can be used to quantify the gradient (Klump and Martens, 1981). This model generally indicates that the diffusive flux is underestimated by the linear gradient assumption. And third, these calculations indirectly determine the flux. There are methods, such as benthic flux chambers and core incubations, that directly determine fluxes (Berelson et al., 1990; Kuwabara et al., 1996; Smith et al., 1997). Direct determinations of fluxes eliminate uncertainties due to bioturbation or non-linear gradients.

Related research

In addition to those studies on lake chemistry noted in the previous section, microbiological characterization of the sediments has been performed. Although contaminated sediments are largely devoid of macro-invertebrates, total microbial abundance can exceed 10^8 cells g^{-1} wet weight sediment (Harrington et al., 1998a). Furthermore, bacterial enrichment cultures inoculated with sediments collected near the Coeur d'Alene River delta reveal abundant populations of cultivable iron- and sulfate reducing bacteria (SRB) (Harrington et al., 1998a; Cummings et al., 1999a; 1999b). Specifically, MPN indicate that the abundance of cultivable SRB ranges between 10^3-10^6 cells g^{-1} wet weight. Altogether these observations suggest that there are microbes in these sediments capable of supplying a pool of sulfide that can precipitate soluble metals as their corresponding sulfides. We are collaborating with R.F. Rosenzweig, the principal investigator in the studies cited above, on our current USGS 104(G) project. AVS data and S35 tracer experiments have been performed to more fully understand the role of microbial activity in metal cycling reactions.

We have received a second much smaller grant ($15,000) from the USGS 104(B) program to speciate sediment S using XANES spectroscopy. Sulfur in cores collected from Lake CDA in April 2002 will be speciated at the National Synchrotron Light Source in Brookhaven, NY. We have previously used XANES to speciate S in humic materials (Morra et al., 1997). Preliminary investigations have shown that we can identify S species in sediment cores from Lake CDA.

Training potential

One undergraduate student will be involved in this research, working full-time during the summer and approximately 10 h per week during the academic year. We will hire a student interested in environmental science and attempt to retain that student for the duration of the project. The Ph.D. and M.S. students involved in this work will obtain degrees in Soil Science, Geology, or Environmental Science. We will continue to fund a current Ph.D. student (Gordon Toevs) to work on this project and will recruit one new M.S. student.

Statement of government involvement

Laurie Balistrieri, U.S. Geological Survey, University of Washington, Seattle, WA, will be directly responsible for benthic flux calculations. We are collaborating with her on our current USGS 104(G) proposal. We are coordinating our efforts to assure that all data necessary for benthic flux calculations are collected. James S. Kuwabara, U.S. Geological Survey, Menlo Park, CA, will advise us on trace element protocols and provide sampling equipment for water column efforts. Paul Wood, U.S. Geological Survey, Boise, ID, will provide advice on sampling locations and assist with data interpretation. The investigators have extensive experience with Lake CDA and have participated in previous sampling efforts.

Information transfer plan

We regularly attend meetings of the Coeur d'Alene Basin Interagency Group in Coeur d'Alene, ID and have given two presentations at these gatherings. The meetings are organized by Jack Gundermann of the Coeur d'Alene Tribe and are meant to facilitate interaction among the various groups representing regulatory, civic, and political, and business interests. We will continue to interact with representative from the Coeur d'Alene Tribe, USGS in Boise, EPA, and the Idaho Department of Environmental Quality at these meetings and by way of personal communications. All reports and manuscripts resulting from our work will be distributed to these agencies. Publication of our results in peer-reviewed journals will facilitate national and international distribution of our conclusions.

References

Balistrieri, L.S. 1998. Preliminary estimates of benthic fluxes of dissolved metals in Coeur d'Alene Lake, Idaho. U.S. Geological Survey. Open-File Report 98-793.

Bennett, E.H., P.L. Siems, and J.T. Constantopolous. 1989. The geology and history of the Coeur d'Alene mining district, Idaho. Guide book to the geology of northern and western Idaho and surrounding area. Idaho Geol. Surv. Bull. 28:137-156.

Benoit, J.M., C.C. Gilmour, R.P. Mason, and A. Heyes. 1999. Environ. Sci. Technol. 33:951-957.

Berelson, W.M., D.E. Hammond, D. O'Neill, X-M Xu, C. Chin, and J. Zukin. 1990. Geochim. Cosmochim. Acta 54:3001-3012.

Berner, R.A. 1980, Early diagenesis. Princeton University Press, 241 p.

Bish, D.L. and Chipera, S.J. 1991. Clays Clay Minerals 39: 437-445.

Cummings, D.E, F. Caccavo, S. Spring, and R.F. Rosenzweig. 1999a. Arch. Microbiol. 171:183-188.

Cummings, D.E., F. Caccavo, S.E. Fendorf, and R.F. Rosenzweig. 1999b. Environ. Sci. Technol. 33:723-729.

Daskalakis, K.D., and G.R. Helz. 1992. Environ. Sci. Technol. 26:2462-2468.

Daskalakis, K.D., and G.R. Helz. 1993. Geochim. Cosmochim. Acta 57:4923-4931.

Davison, W. 1991. Aquat. Sci. 53/4:309-329.

Dorsey, N.E. 1940. Properties of ordinary water-substance, Reinhold, 673 p.

Harrington, J.M., M.J. LaForce, W.C. Rember, S.E. Fendorf, and R.F. Rosenzweig. 1998a. Environ. Sci. Technol. 32:650-666.

Harrington, J.M., S.E. Fendorf, and R.F. Rosenzweig. 1998b. Environ. Sci. Technol. 32:2425-2430.

Harrington, J.M., S.E. Fendorf, B.W. Wielinga, and R.F. Rosenzweig. 1999. Environ. Sci. Technol. 33:203-204.

Hoffman, M.L. 1995. Characterization of heavy metal contamination in two lateral lakes of the Coeur d'Alene river valley, Northern Idaho. M.S. Thesis, University of Idaho.

Horowitz, A.J., and K.A. Elrick. 1993. Hydrol. Processes 7:403-423.

Horowitz, A.J., and K.A. Elrick. 1999. Environ. Sci. Technol. 33:201-202.

Horowitz, A.J., K.A. Elrick, J.A. Robbins, and R. Cook. 1992. US Geol. Surv. Open file Report 1992, 92-109.

Horowitz, A.J., K.A. Elrick, J.A. Robbins, and R.B. Cook, 1995. J. Geochim. Expl. 52:135-144.

Huerta-Diaz, M.A., A. Tessier, and R. Carignan, 1998. Applied Geochem. 13:213-233.

Klump, J.V., and C.S. Martens. 1981. Geochim. Cosmochim. Acta 45:101-121.

Kotronarou, A., and M.R. Hoffmann. 1991. Environ. Sci. Technol. 25:1153-1160.

Kuwabara, J.S., W.M. Berelson, L.S. Balistrieri, P.F. Woods, B.R. Topping, D.J. Steding, and D.P. Krabbenhoft. 2000. Benthic flux of metals and nutrients into the water column of lake Coeur d'Alene, Idaho: Report of an August, 1999 Pilot Study. US Geol Surv. Water-Resources Investigations Report 00-4132, 74 p.

Morra, M.J., S.E. Fendorf, and P.D. Brown. 1997. Geochim. Cosmochim. Acta 61:683-688.

Smith, K.L., Jr., R.C. Glatts, R.J Baldwin, S.E. Beaulieu, A.H. Uhlman, R.C. Horn, and C.E. Reimers. 1997. Limnol. Oceanogr. 42:1601-1612.

Uhler, A.D., and G.R. Helz. 1984. Geochim. Cosmochim. Acta 48:1155-1160.

Ullman, W.J., and R.C. Aller. 1982. Limnol. Oceanogr. 27:552-556.

Wai, C.M., W.M. Mok. 1985. Arsenic speciation and water pollution associated with mining in the Coeur d'Alene mining district, ID. Research Technical Completion Report G903-06. U.S. Geological Survey, U.S. Department of the Interior, Washington D.C.

Woods, P.F. 1989. Hypolimnetic concentrations of dissolved oxygen, nutrients and trace elements in Coeur d'Alene Lake, Idaho. U.S. Geological Survey. Water-Resources Investigations Report 89-4032.

Physically Based Models for Hydraulic Properties of Swelling Soils

Basic Information

Title:	Physically Based Models for Hydraulic Properties of Swelling Soils
Project Number:	2002ID13B
Start Date:	3/1/2002
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	1
Research Category:	Ground-water Flow and Transport
Focus Category:	Hydrology, Solute Transport, Agriculture
Descriptors:	Hydraulic Properies, Solute Transport, Modeling
Principal Investigators:	Markus Tuller

Publication

1. Tuller, M., and D. Or, 2003. Hydraulic Functions for Swelling Soils: Pore Scale Considerations. Journal of Hydrology, 272:50-71.
2. NA
3. NA
4. NA
5. NA
6. Tuller, M., D. Or, and B. Muhunthan, 2002. Theoretical and experimental studies on retention and transport properties of swelling porous media. Abstracts of the INRA-INEEL Subsurface Science Symposium, October 13-16, Boise, Idaho. Tuller, M., D. Or, and B. Muhunthan, 2002. Evolution of textural pore space of clay-sand mixtures under variable water potential: Experimental studies on water retention and saturated flow behavior. SSSA Annual Meeting Abstracts, November 10-14, Indianapolis, Indiana.

Problem and Research Objectives:

Some of the most productive agricultural soils contain appreciable amounts of active clay minerals and exhibit shrink-swell behavior in response to changes in soil water content and chemical composition of the soil solution. Swelling and dispersion of clay minerals modify hydraulic soil properties and lead to increased surface runoff with negative impacts on water quality of rivers and lakes. Furthermore, cracks forming in dry clay soils provide fast preferential pathways for rapid transport of chemicals leading to potential risks for ground water contamination. In addition to myriad agricultural management and engineering problems associated with changes in mechanical properties and trafficability of such land surfaces, hydrologic predictions of flow and transport processes are seriously hampered. Changes in soil volume and pore space induced by shrink-swell behavior present a challenge to the development of predictive models for flow and transport, in particular to the development of constitutive hydraulic functions. Despite well-developed theory for crystalline and osmotic swelling of clay minerals, translation of lamellar-scale theory to formulation of constitutive hydraulic functions is lacking.

The objectives of the proposed study are based on the long term goals to develop a fundamental understanding and accurate description of water and solute behavior in environmental and agricultural systems with appreciable amounts of clay minerals, and to provide enhanced quantitative tools for environmental and agricultural management practices to control surface runoff, leaching, soil erosion, salinization, and sodicity. This requires the development of physically based pore- and sample-scale models for liquid retention and hydraulic conductivity considering the swelling and shrinking behavior of clay minerals. Within this context the specific objectives of the project were to:

(1) Develop a model for geometry and changes in clay fabric pore space with hydration state, clay mineralogy, and solution composition.

(2) Incorporate other textural fractions (e.g., sand, silt) toward developing a complete pore scale model for clayey soils.

(3) Derive hydraulic functions for clay fabric and simple sand-clay mixtures

Methodology:

The framework for modeling pore space changes is based on consideration of the soil clay fabric as an assembly of colloidal-size tactoids with lamellar structure. The arrangement of clay tactoids and the spacing between individual lamellae are functions of clay hydration state quantifiable via the disjoining pressure, dominated by a large electrostatic repulsive component. The DLVO theory developed by Derjaguin and Landau [1941], and Verwey and Overbeek [1948] was applied to derive relationships between lamellae spacing and bulk matric potential.

Silt and sand textural constituents are represented as rigid spheres interspaced by clay fabric in two basic configurations of "expansive" and "reductive" unit cells. Bulk soil properties such as clay content, porosity and surface area serve as constraints for the pore-space geometry. Liquid saturation within the idealized pore space is calculated as a function of chemical potential considering volume changes due to clay shrink-swell behavior. Closed-form expressions for prediction of saturated hydraulic conductivity are derived from calculations of average flow velocities in ducts and between parallel plates, and invoking proportionality between water flux density and unit hydraulic gradient.

A flexible wall permeameter is used to measure saturated hydraulic conductivity of clay-sand mixtures. Feedback from measurements is used for evaluation and refinement of the theoretical modeling efforts.

Principal Findings and Significance:

We made significant progress in developing a pore space evolution model and derived physically based analytical solutions for liquid retention and saturated hydraulic conductivity as a function of soil chemical potential. Preliminary model calculations compare favorably with published data, and show great potential for upscaling considerations. The findings of this project were published in the Journal of Hydrology and disseminated through numerous invited presentations.

A NSF-EPSCoR equipment grant also allowed us to purchase a state-of-the-art flexible wall permeameter. We started a series of measurements to determine effects of clay type, clay content, electrolyte type, and electrolyte concentration on hydraulic properties of clay-sand mixtures. These data are quite unique and extremely valuable for refinement and evaluation of our modeling approach. Everybody dealing with clays is aware that experiments are extremely time consuming and complicated due to the swelling behavior. Nevertheless we were able to develop sample mixing and saturation procedures that allow repeatable series experiments.

Future work will include a comprehensive measurement series and the development of a physically based upscaling scheme for sample and profile scale predictions of hydraulic conductivity.

The developed modeling framework offers a means for systematic data collection and a unified representation of important hydraulic properties of swelling porous media that otherwise involve inseparable and often competing processes.

Additionally, results of this study should benefit water management in swelling soils leading to improved infiltration and water use efficiency. Due to the sensitivity of clay soils to irrigation water quality, a framework such as developed could benefit salinity and sodicity management by quantifying the impact of irrigation strategy on soil hydraulic properties. At the extreme end of these considerations are insights on clay dispersion and surface sealing with potential for soil erosion, and colloidal-facilitated transport of agro-chemicals. Another area of potential application is the design of clay liners for hydrologic isolation of waste disposal sites. Improved understanding of hydrologic processes in clayey formation becomes increasingly important for the design of nuclear waste repositories currently under consideration in the Boom Clay formation in Belgium and in a similar formation in Switzerland.

Factors Controlling the Availability of Phosphorus for Transport into Surface Water from Manure Amended Soils in Southern Idaho

Basic Information

Title:	Factors Controlling the Availability of Phosphorus for Transport into Surface Water from Manure Amended Soils in Southern Idaho
Project Number:	2002ID14B
Start Date:	3/1/2002
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	1
Research Category:	Ground-water Flow and Transport
Focus Category:	Water Quality, Surface Water, Non Point Pollution
Descriptors:	Transport, Agriculture, Surface Water, Phosphorus
Principal Investigators:	Daniel Strawn

Publication

1. In preparation: Phosphorus Speciation in Manure-Amended Alkaline Soils, Jeremy C. Hansen, Daniel G. Strawn, Barbara Cade-Menun. Kinetics of P Release from Manure-Amended Alkaline Soil, Jeremy C. Hansen and Daniel G. Strawn.
2. NA
3. In preparation MS Thesis. Phosphorus reactions in manure-amended alkaline soils, Jeremy Hansen, 2003.
4. NA
5. Reaction Processes of Phosphorous in Manure-amended Alkaline Soils, Daniel G. Strawn, Jeremy C. Hansen, 2003.
6. NA
7. In preparation Phosphorus Speciation in Manure-Amended Alkaline Soils, Jeremy C. Hansen, Daniel G. Strawn, Barbara Cade-Menun. Kinetics of P Release from Manure-Amended Alkaline Soil, Jeremy C. Hansen and Daniel G. Strawn.

Problem and Research Objectives:

The goal of this study is to investigate the availability of P as a function of its molecular form and soil type. There are two species of P that are commonly found in soils, inorganic (Pi) and organic (Po). Most research has focused on Pi. Recent research suggests that the two P forms have unique sorption and transport properties. Since manure is a significant source of Po, and Idaho has an intensive cattle industry, it is imperative that the factors controlling P availability from manure amended soils be understood. In southern Idaho precipitation of Ca-phosphates are important P retention mechanisms, however, the factors that affect the formation and dissolution of these minerals are poorly understood. Thus, the results from this study will provide valuable information that can be used to better manage manure application to soils and reduce non point P pollution.

Methodology:

We have made measurements of P release kinetics from soils using two different methods, batch desorption experiments and continuous replenishment experiments. The batch desorption experiments involve incubating the soil with a weak electrolyte solution and measuring the time necessary for the system to come to steady state. The continuous replenishment experiments refresh the soil suspension with new electrolyte solutions. We have also done speciation experiments on extracts from the soils and manures using NMR spectroscopy. We used both a weak background electrolyte and an EDTA-NaOH solutions to extract the soils.

Principal Findings and Significance:

The goal of the research presented in this paper is to investigate the desorption behavior and speciation of P in manure-amended alkaline soils. Desorption behavior was measured on a soil that received two separate treatments, one treatment was solid-dairy manure applied prior to the growing season, the other was liquid manure byproduct held in lagoon ponds and applied throughout the growing season. The P desorption rate from both treatments was similar, initially fast followed by a slower reaction. The total amount of P available for desorption in the surface soils was similar for both treatments, while in the subsurface soil P from the liquid lagoon manure was much more available for desorption than the solid-manure treatment. When applied to various kinetic models it was found that the data were best fit with a modified Elovich equation. The speciation results showed that the soluble-organic P being desorbed is insignificant. However, total organic and inorganic P measurements on the soil and manure samples showed that there are significant amounts of organic P present. NMR spectroscopy results revealed that the predominant species of P in the extracts was orthophosphate, and that organic P is present as predominantly monoester P compounds, with lesser amounts of diester P compounds and polyphosphates. Results from this study provide new insights into P desorption rates and mechanisms in manure-amended alkaline soils that can be used to improve the accuracy of predicting P availability for leaching and runoff into ground and surface waters.

Metal(loid) Release from Contaminated Sediments in Lake Coeur d’Alene, Idaho

Basic Information

Title:	Metal(loid) Release from Contaminated Sediments in Lake Coeur d’Alene, Idaho
Project Number:	2002ID15B
Start Date:	3/1/2002
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	1
Research Category:	Water Quality
Focus Category:	Sediments, Toxic Substances, Geochemical Processes
Descriptors:	Contamination, Toxins, Water Quality, Heavy Metals
Principal Investigators:	Matthew John Morra

Publication

1. NA
2. NA
3. NA
4. NA
5. NA
6. NA

Problem and Research Objectives:

Lake Coeur d'Alene (CDA) in Idaho is the second largest natural lake in the Inland Northwest. Lake CDA provides drinking water for at least five communities and serves as a primary recreational area for inhabitants of the Pacific Northwest. Over the last century Lake CDA became, and continues to be, the major collecting bed for contaminated sediments produced during mining and ore processing activities. As a result of these mining activities tailings enriched in Pb, Zn, As, Cd, and other trace elements were deposited in stream banks and bars along the South Fork and main stem of the Coeur d'Alene River. These materials have been regularly resuspended during periods of high stream flow and secondarily transported into Lake CDA. Our objectives are to 1) determine whether there is currently a significant flux of metal contaminants from the sediment of Lake CDA to the water column and 2) predict how anthropogenic alteration of lake trophic status will influence this flux. It has been assumed that eutrophication will promote trace element release (Woods, 1989). This prediction is based on the assumption that metals in the lake occur predominantly in their oxide and hydroxide forms, and that there is no anoxic metal binding mechanism. Thus one of the principal means of keeping toxic trace elements immobilized in lakebed sediments may be to carefully manage the lake nutrient status to avoid the development of anoxic conditions. Others have suggested that a large fraction of metal(loid) contaminants partition with a chemically refractory sulfidic phase (Harrington et al., 1998; 1999) and that these metal sulfides are inherently stable under reducing condition. The mechanisms responsible for metal retention and cycling remain uncertain, making accurate assessments of current flux and predictions of future environmental contamination difficult. Our proposed research is focused on resolving the controversy by directly determining the dominance of sulfidic phases in the sediments.

Methodology:

To determine S species in the lake sediment pore waters we are using several approaches, including cyclic voltammetry and chromatographic separation. However, these techniques are designed for analysis of the solution phase only. Harrington et al. (1998) used selective sequential extractions on sediments to determine the S-metalloid associations. These experiments are based on operationally defined S pools. Interpretation of geochemical cycling data will be greatly improved by using direct techniques to speciate sediment S. To speciate solid phase S we used X-ray absorption near edge spectroscopy (XANES). Sulfur has multiple oxidation states that have been observed to range from -2 to +6. XANES is ideally suited for determining oxidation state and in many cases can provide information about molecular speciation. Since the formation of S complexes and precipitates with the metal(loid) contaminants in the sediments is dependent on the oxidation state, the information obtained from XANES will be extremely valuable for this project.

Sample Collection and Handling. Sediment cores were collected by divers from the southern end of Lake CDA located in Northern Idaho on April 8, 2003. Three principle sites were chosen for detailed study, one site near the mouth of the uncontaminated St. Joe River to be used as a control and two sites near the mouth of the Coeur d'Alene River which transports the contaminated sediments from the Coeur d'Alene mining district to the lake. Divers collected 36-

cm cores in acid washed 4.7-cm diameter polycarbonate tubes. The divers capped the cores prior to bringing them to the surface where they were immediately sealed and placed upright in nitrogen-filled containers maintained at 4˚C until delivered to the laboratory. Duplicate cores were taken at each site.

The cores were individually placed in an Innovative Technologies, Inc., Model SI nitrogen-filled glove box prior to extruding them from the polycarbonate cores. The cores were sectioned and representative samples were taken from 3 cm, 6 cm, 12 cm, 24 cm, 30 cm and 36 cm. Care was taken to eliminate sediment smearing between sampling depths. The representative samples were placed in acid washed and rinsed wide mouth 20-mL polypropylene vials. The vials were then placed in double zip lock bags prior to removing from the glove box and maintained on ice until XANES analysis was preformed at Brookhaven, N.Y. Duplicate cores were sectioned for each site.

XANES Spectroscopy. Spectroscopic analysis was performed at the National Synchrotron Light Source (NSLS) in Brookhaven, NY. XANES data collection was done on beamline X-19A using a Si(111) crystal monochromator. This beamline is designed for collecting spectra from samples in the lower energy range (2100 - 8000 eV) and has a sample chamber environment that is appropriate for our materials. Sediment samples were mounted on filter paper and placed in the spectrometer. All analyses were performed under a He gas atmosphere. Each sample was scanned twice from 2372 to 2550 eV. The white-line peak maximum of sulfate was set at 2483.1 eV and used for reference.

Principle Findings and Significance:

XANES analysis was performed on duplicate cores of the three sites from Lake CDA; St. Joe, Peaceful Point, and Harlow Point. Prior research confirmed St. Joe can be used as the control site and Peaceful Point and Harlow Point can be used as the contaminated sites. Sulfur has multiple oxidation states that range from -2 to +6. Four sulfur oxidation states were identified and further identification of organic and inorganic sulfur was possible due to the distinct absorption edges of the inorganic sulfides. Sulfate, a sulfur species with an oxidation state of +6, decreases with depth at all sites as observed in Figs. 1-3. This is corroborated by the data analysis of pore water which indicates an increase in reducing conditions with depth (Fig. 4), an environment where oxidized forms of sulfur are unstable. Pyrite, an iron sulfide in which sulfur has an average oxidation state of -1, increases with depth at all sites as observed in Figs. 1-3. The increase in reducing conditions with depth also supports this finding. Pyrite was found in the near surface samples at all sites because it is a primary mineral found in the Coeur d'Alene mining district and is episodically transported to the lake during flood events. The remaining two species are organic forms of sulfur which would be unavailable to form complexes with contaminants. It would not be possible for inorganic sulfate to exist at the reducing conditions found with depth, which indicates that the sulfate remaining below the redox boundary is most likely in the form of an organic ester-bonded sulfate.

This project has resolved the disagreement between the findings of Horowitz (1992, 1999) and Harrington with respect to the oxidation status of the sediments. The near surface sediments exist in an oxidizing environment as indicated by the presence of nitrate and sulfate in the pore water (Fig. 4). However within 2.5 cm the manganese (Mn) redox boundary exists as evidenced by the presence of Mn in the pore water. Within 5 cm of the (Mn) redox boundary the sulfate anion concentration is below the detection limit which would indicate sulfate reduction and concomitant production of the sulfide ion. The sulfide ion has significant binding capacities with metal contaminants. Further research is necessary to determine if the sulfide ion is present in an amount that significantly affects the mobility of the metal contaminants.

We have shown that metal contaminants in the top 2.5 cm of sediment are most likely associated with oxidized solid phases or reduced solid phase materials which are relatively stable in the presence of oxygen. Metals below 2.5 cm must be associated with reduced solid phase materials that include diagenetically produced pyrite. Metal associations with oxidized solid phase materials in the upper layer of the sediments will be altered if Lake CDA's trophic status shifts to a eutrophic state.

Literature Cited

Harrington, J.M., S.E. Fendorf, B.W. Wielinga, and R.F. Rosenzweig. 1999. Response to comment on "Phase associations and mobilization of iron and trace elements in Coeur d'Alene Lake, Idaho". Environ. Sci. Technol. 33:203-204.

Harrington, J.M., M.J. LaForce, W.C. Rember, S.E. Fendorf, and R.F. Rosenzweig. 1998. Phase associations and mobilization of iron and trace metals in sediments of Lake Coeur d'Alene, ID. Environ. Sci. Technol. 32:650-666.

Horowitz, A.J., and K.A. Elrick. 1999. Comment on "Phase associations and mobilization of iron and trace elements in Coeur d'Alene Lake, ID". Environ. Sci. Technol. 33:201-202.

Horowitz, A.J., K.A. Elrick, J.A. Robbins, and R. Cook. 1992. US Geol. Surv. Open file Report 1992, 92-109.

Woods, P.F. 1989. Hypolimnetic concentrations of dissolved oxygen, nutrients and trace elements in Coeur d'Alene Lake, Idaho. U.S. Geological Survey. Water-Resources Investigations Report 89-4032.

Descriptors: heavy metals, mining, sediments, contaminant flux

Articles in Refereed Scientific Journals: NA

Book Chapters: NA

Dissertations: NA

Water Resources Research Institute Reports: NA

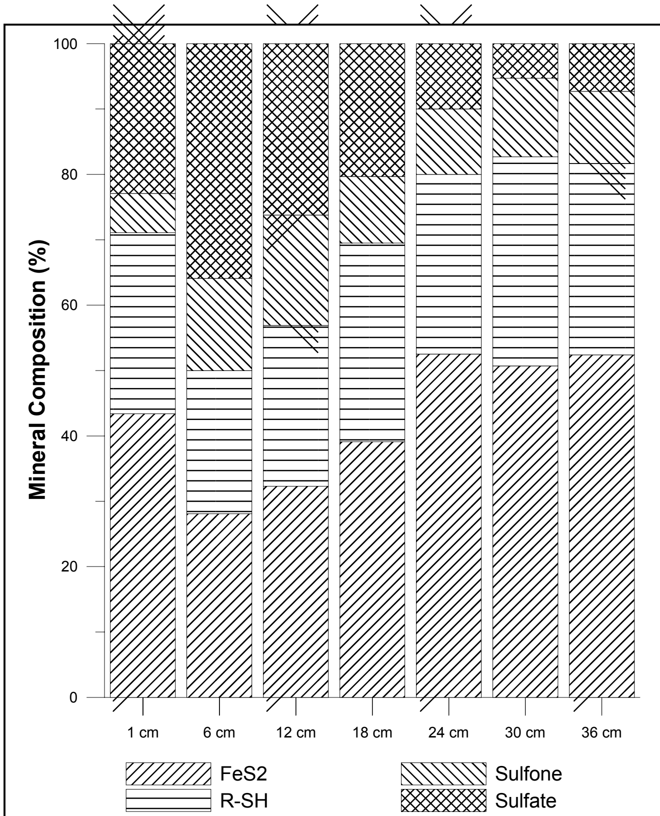


Figure 1: St Joe XANES spectra analysis by sediment depth

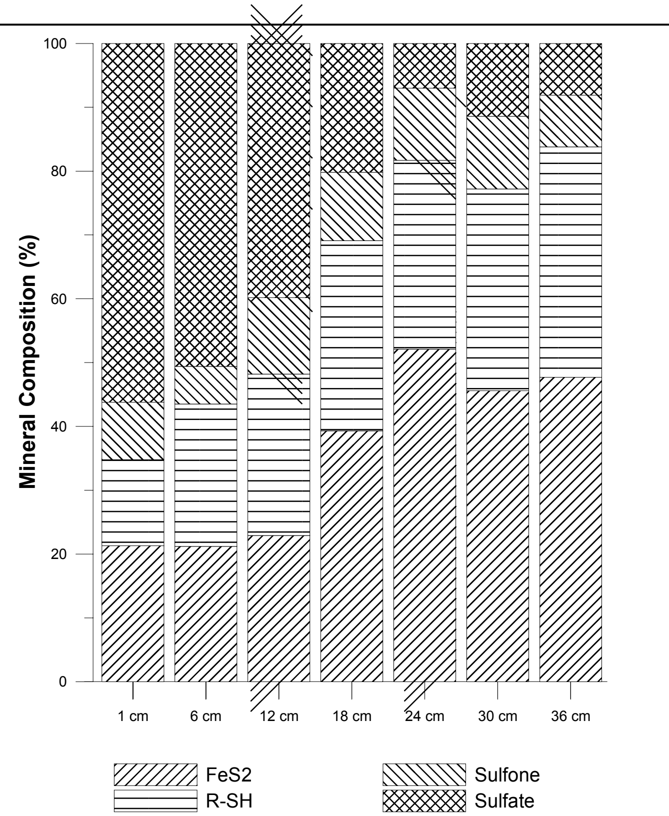


Figure 2: Peaceful Point XANES spectra analysis by sediment depth

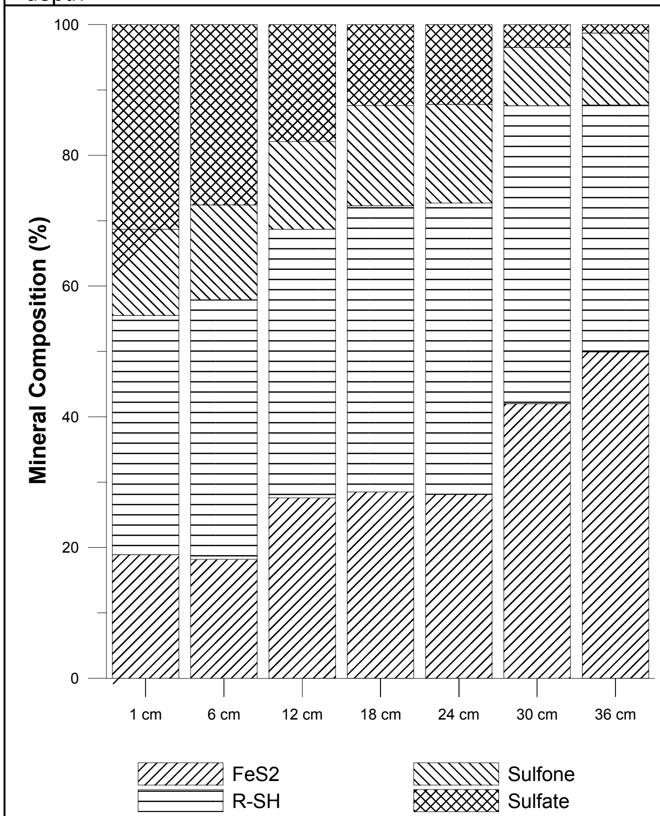


Figure 3: Harlow Point XANES spectra analysis by sediment depth

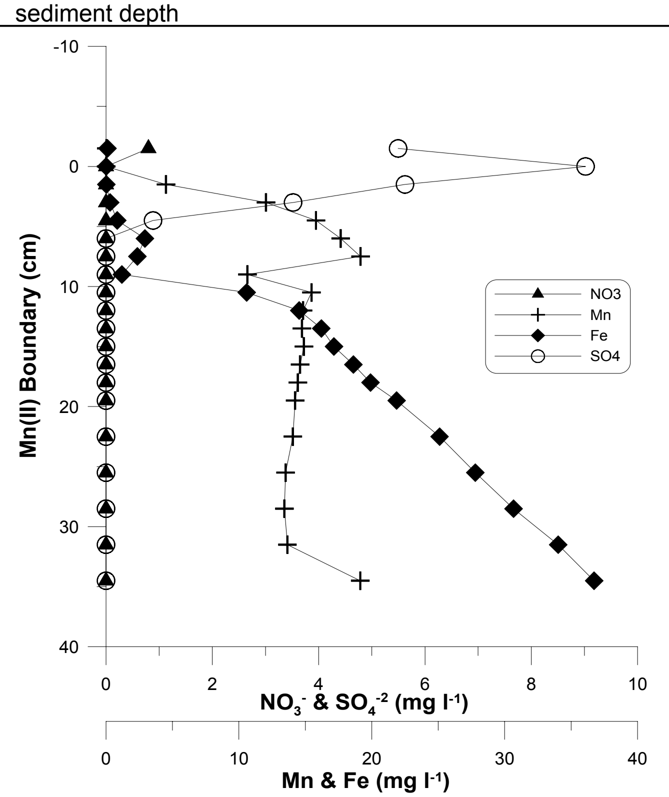


Figure 4: Pore water concentration of redox sensitive elements from Peaceful Point site, May 2003.

Community-Directed Water Protection Strategy: Focus Communities in North-central Idaho, including the Nez Perce Indian Reservation

Basic Information

Title:	Community-Directed Water Protection Strategy: Focus Communities in North-central Idaho, including the Nez Perce Indian Reservation
Project Number:	2002ID16B
Start Date:	3/1/2002
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	1
Research Category:	Social Sciences
Focus Category:	Management and Planning, Non Point Pollution, Water Quality
Descriptors:	Agriculture, Land Use, Geographic Information, Indian Water Issues
Principal Investigators:	Piotr Jankowski

Publication

1. NA
2. NA
3. Owen, Amy, 2003, Community-Directed Water Protection Strategy: Focus Communities in North-central Idaho, including the Nez Perce Indian Reservation, Ph.D., Department of Geography, College of Science, University of Idaho, Moscow, Idaho, pp 13.
4. NA
5. NA
6. NA

Problem, Research Justification and Research Objectives:

Problem Statement: Under enhancements to the 1974 Safe Drinking Water Act that were enacted in 1996, all states are now required to develop plans to assess all public drinking water sources (USEPA, 2002). For many states, this involves the defining of the geographical protection zones for all of the public water sources within the state. In Idaho, as in the majority of the United States, the actual protection of the water source zone is voluntary and must be implemented by the community or water system. In Idaho the delimited source zones and a preliminary potential contaminant inventory and susceptibility report are delivered to the public water systems. It is up to a community to develop a plan to protect that water system using this information. With states due to have all delineations complete by 2003 (notwithstanding extensions and exceptions) the implementation of protection plans by communities is immanent all across the United States.

The federal government provides funding and guidance to the states to develop source assessments, but it is largely up to the states to determine how the actual protection planning by the communities in the state will be completed. Most states, including Idaho, have a voluntary program that leads to certification when the planning requirements have been met. While a voluntary approach is likely the most appropriate, there is a noted lack of motivation for communities to develop plans, the development of plans that lack involvement from the greater community, and a lack of action in implementing adequate protective measures (Bokor and Harper, 2002). Additionally, there is a lack of a way to track the progress and effectiveness of community protection planning of communities across the United States. The social nature of planning and the voluntary and diverse mechanisms within different regions and states makes it very difficult to devise a way to track the overall effectiveness of the community planning. In essence, there is funding being spent for states to assess water sources of communities, and a lack of a mechanism to ensure effectiveness and to track progress.

Research Need and Justification Communities: All over the United States will be planning for protection for their drinking water sources in the near future. Most of the states will be providing drinking water source assessments, geographical zones that depict the origination and protection zones for each water source. There is a real and immanent need for better methods for communities to be able to access information that will assist them in understanding their unique water sources and the potential threats to these sources in order to devise appropriate protection mechanisms. There is also a need for better ways to involve the entire community in the planning process so that implementation of the protective measures is carried out in reality. Finally, there is a need to measure progress in a way that centers on communities in different regions, social, economic and cultural settings and is useful to the states and the federal government.

Research Goal: The purpose of this research is to provide new information on community drinking water protection planning and evaluation for specific use with the source assessments and protection programs determined by states and assisting entities.

Research Question, Goals and Objectives: The research questions are as follows:

- How can communities more effectively involve and increase the awareness and education of community members and therefore develop and implement plans more effectively?
- How can the effectiveness of community planning be measured in a way that is useful to the states and the federal government?

The aim of this research is to provide new information on community drinking water protection through the following goals:

- The use of information tools and other techniques within the current drinking water management guidelines used in the selected area to increase participant understanding of the water source and awareness of the means to protect it that lead to more effective implementation.
- The development of a model based on the new information for use with state source assessment and protection frameworks to assist both communities and drinking water managers by increasing the knowledge base and involvement of the community participants.
- The development an evaluation element that is centered on community planning that is social in nature and hard to measure, that works in locals that differ socially, economically and culturally and may be useful at state and federal levels in tracking progress and effectiveness over time.

To address the research goals the following objectives are used to design and guide the experimental design and selection of methodology:

Protection Planning Field Experiment

- Set guidelines to select participating communities.
- Design a field experiment to develop and test techniques to increase participant education, awareness and involvement in protection planning.

Evaluation Measure Development

- Utilize information from existing Federal guidelines, the mapping and planning experiments, and a drinking water manager survey to develop methodology for the evaluation of community drinking water protection plans.

Model Development

- Draw conclusions on the results and present recommendations in the form of a model that includes this new information on increasing participant involvement and education and an evaluation methodology.

Statement of Results or Benefits:

In a large sense, this project addresses the problem of encouraging and tracking the effectiveness of participatory decision making at the community level. Specifically, the results will add to the knowledge base of community efforts in implementing effective water management measures in a way that is beneficial to the communities and useful to the state programs the manage their drinking water sources.

On a regional level, the results of the study will directly benefit the volunteer communities and constituents and the Nez Perce Tribe (most of the communities reside within 1836 Treaty Boundaries.

Nature and Scope of the Research:

Nature of Research: The testing of methods to increase community awareness, involvement and evaluation in drinking water protection planning with volunteer communities within Idaho. The methods are tested within the accepted Idaho State drinking water plan certification process. A model is developed that includes an evaluation element for use by communities and drinking water managers. This project continues research by utilizing the data gathered and analyzed during the 2001-2002 project "Integrated Drinking Water Protection on the Clearwater Plateau of Idaho, including the Nez Perce Indian Reservation." The graphic tools developed during that phase are used in the planning experiment as graphic tools for planning.

Scope of Research: The scope of the research is the development of a theoretical generalization drawn the results of the observation and testing of methods within the actual drinking water protection planning of several communities in Idaho. The focus for the planning experiment is voluntary participation at the municipal level. The manager survey focus is voluntary participation from drinking water managers from each state in the United States.

Methods and Results:

Planning Experiment

Planning Experiment Design: The following general guideline for municipal source protection planning in Idaho was used as the initial study framework:

1. Several communities expressed a desire to develop a protection plan.
2. The Idaho Rural Water Association (which follows steps that lead to Idaho certification) assists in planning.
3. The State source assessment is used to develop the plan through a planning team.
4. Once the requirements have been completed, the plan is state certified.
5. The plan is reviewed every 3 years for re-certification.

The following options to increase the awareness and involvement of the community were presented to the community and through the planning team. Facilitation was offered to assist in the increased involvement efforts (beyond the current procedure outlined above).

1. Use of graphic tools by the planning team and in public meetings.
2. Enhanced public notification methods to increase involvement of the greater community beyond the planning team.
3. Public meeting to inform the greater community of planning and to gather more support and interested planning team members.
4. Public open house to raise public awareness and gather comments and ideas from the community for the draft plan.

The options were offered objectively and without positive or negative feedback, with the understanding that they could choose from them freely. Variable in the experiment are choices made by planning teams and the observed use or non-use of these options. The results were noted through observation and digital photographs taken at the public meetings.

Selection of Communities for Planning Experiment Participation: The communities of Nezperce, Orofino, Winchester and Lapwai were selected as potential participants using the selection criteria. All four communities had recently been delivered a source assessment from IDEQ, had not yet developed protection plans, had expressed interest in protection planning, had participated in the mapping study, and had distinct water protection issues. The city council was given a brief presentation on the planning process and the additional opportunities that would be presented as part of this research.

Nezperce is concerned about high levels of nitrate in the deep aquifer, from which the source water is drawn. Orofino is chiefly concerned that the current source of water, the Clearwater River, is unprotected from the major highways that lie adjacent to the entire source area. Winchester indicated concerns about land use and contaminants, mainly regarding recreation and water quantity and quality. Lapwai expressed concerns about pesticides in the groundwater and about growth and planning in an area with little remaining buildable land. All of the communities immediately agreed to participate in the planning experiment.

Enhanced Notification Options: The planning team is customarily formed through selection of the city council; either volunteer or recruited participants make up the planning team. Options were presented for the purpose of reaching more people in the community. The community was notified of the upcoming water planning, and offered an opportunity to participate in planning.

Table 1 lists the options for enhanced notification

Table 1. Options for Increasing Public Notice of Drinking Water Plan

Action	Options
Public Notification	▪ Notice in Water Bill ▪ Notice in School Flyers (focus on 6th and middle school) ▪ Flyer or Bulletin Posted in Areas of High Visibility ▪ Local paper Community Service Posting ▪ Special Invitation Letters to Resource Managing Entities

	and Landowners
Content of Above Public Notice Options	▪ Drinking Water Planning is Beginning for this Community ▪ Planning Committee Being Formed ▪ Announce Public Meeting (if selected) ▪ Community Involvement Opportunities

All four communities elected to send out public announcements. All communities elected to announce the planning process and an upcoming public meeting in the local newspaper and as a notice sent in the water bill to each household. Orofino additionally sent out a school "take home" notice to parents of elementary school students and also sent an extensive special invitation list to natural resource and other entities that may be helpful in planning such as the US Army Corps of Engineers and the State Highway Department. Both Orofino and Nezperce posted flyers at convenience stores and other high traffic areas. Lapwai sent a color bulletin to each household (Lapwai's own option).

Public Meeting Options: The public meeting attendance was generally low despite the enhanced pubic notification methods. Orofino had 8 attendees, mostly natural resource entity representatives and no community members present that were unconnected to the city council. Lapwai and Nezperce had 7 attendees, with 2 and 3 community members respectively. Winchester had the largest attendance of 10 at the public meeting, with the highest number of community members at 5. It is likely that Orofino's good response from the natural resource and related entities is due to the many special invitation letters that were sent out to these parties. It is more difficult to determine the reason for the relatively high turnout of community members at Winchester's public meeting. With the special color bulletins sent to each household in Lapwai, it was expected that Lapwai would have the largest turnout of community members. The time of year is also important. The Lapwai City Clerk suggested that Lapwai's public meeting might have had lower attendance due to the date's proximity to the holidays.

A power-point presentation was given by the facilitators. Following that, a question and answer session provided further understanding to participants. The maps developed in the first year were used to assist in providing understanding, as discussed in more detail in the following section on use of graphic tools.

Although there were not many participants, those that attended were very positive about the planning process and water protection. It was well noted that at the beginning of the meeting there was a very low awareness level of the water source what protection entailed. It was striking at the speed at which the participants put together extremely complex hydrogeological ideas. The use of the PowerPoint presentation in conjunction with the maps was very effective. The reason for this is likely that the participants have at their disposal a storehouse of anecdotal information about their locality and water source. The maps help them visualize the overall water source in a larger context, with the added layers of protection planning process, contaminant threats, geological setting, and land use and ownership patterns. These help the participant form a pattern or context in which to frame all that they know about their location.

Workshop Options: Table 2 lists options that were presented to each planning team for an open house to present the draft plan and to get input from the community members.

Table 2. Options for public workshop for community education and input on plan

Action	Options
Display of draft Drinking Water Plan	▪ Display maps from mapping project ▪ Display maps that show source protection areas in detail ▪ Display of major points of plan on signs or posters ▪ Display of other (name)
Water Education Materials	▪ Display of literature and pamphlets to "take home" ▪ Demonstration of groundwater model ▪ Other (name)
Getting Input on Plan from Participants	▪ "Talking Tables" where they give input on each part of Plan ▪ Open-speaking floor for community members ▪ Mapping exercise, participants write over maps to show ideas/and or add to the contaminant inventory ▪ Other (name)
Workshop Facilitation	▪ Researcher and IRWA ▪ IDEQ assists or is present ▪ Planning Team assists or is present ▪ Other (name)
Public Announcement of Workshop	▪ Post in Newspaper Draft Plan and Invitation to Workshop (at least 2 weeks prior to workshop) ▪ Take home note to schools (name age group) ▪ Flyers posted ▪ Other (name)
Serving Food to Make Open House more Attractive	▪ Coffee and refreshments ▪ Dinner items such as chili, corn bread, hot dogs, nachos and sub sandwiches ▪ Brownies, cookies, etc.

All four communities elected to have workshops for the purpose of presenting the draft plan and getting ideas and input from the community on the plan. The communities requested all of the items that were offered on the option list.

Visual aids were displayed - large, laminated, color wall maps that were developed during the first year of research. Tables were set up to display water protection literature. A large felt and Velcro board displayed the draft water plan, with three sections: an introduction to water planning, the threats to water quality for that community's water source, and draft management options that the planning team had recommended.

A table was set up with the Idaho Rural Water Association groundwater model. This model shows a life-like visual of a working aquifer. It has layers of sand and impermeable layers complete with wells, streams and lakes. When red ink is injected into the wells, it infiltrates other wells, different aquifer layers, and eventually the lake and stream.

The tables were set up in a horseshoe fashion, with food placed at the beginning of the circuit. This was to encourage the community members to see everything and to feel free to stop and ask questions. Planning team members and the facilitators were on hand during this beginning informal "information browsing" period.

A ring of chairs was set up at the open end of the horseshoe pattern. Following the informal perusal of information, participants were called to sit at the chairs. A flip chart was set up in front, and two facilitators were present. One facilitator answered questions about the water plan, management options and threats to water quality. The second facilitator solicited participant input and wrote it down without comment.

Public notification of the workshops was through articles in the most popular local newspapers. In addition, small flyers and large color bulletins were posted in public areas. The city of Nezperce arranged for a radio interview, as radio is a popular form of communication in that locale. The cities of Winchester and Lapwai sent out notices in water bills. The City of Orofino has a plan that includes several communities working together, and placed articles in two separate newspapers. In addition, a lighted sign that flashes community information announced the open house.

Attendance at the open houses was better than at the first round of public meetings. Nezperce had 22 community members, Winchester 14 and Lapwai 17. These figures do not include the planning team and facilitators. These were fairly good turnouts considering the small size of these communities. Orofino, with a multi-community plan and a larger population surprisingly had the lowest turnout of 7 community members.

During the information period the participants gravitated to the visual and graphic tools – the colorful large maps and the groundwater model. They preferred looking at large graphics and talking with the facilitators and planning team to reading materials. The information board, water protection information and a large comment board were of far less preference. In fact, only one comment was left on an unattended comment board during all four open houses.

During comment sessions, the participants at first asked many questions of the discussion facilitator. At every open house, the participants were reluctant to write the comments on an unattended comment board. Yet they became very free with offering comments as a group in front of a flip chart. These comments showed a good understanding of the water source and ideas for protection. Again, in every case, the planning team found the comments useful. In addition, the participants showed an interest in becoming more involved in protection planning. They voiced a new understanding that the community needed to be involved in order that changes would be implemented. They conveyed an understanding that water protection would be ongoing and may change over time as the protection needs changed. This was evidence that the open houses served the purpose of raising awareness.

Use of Graphic Tools: The graphic aids were developed during the first year of research. These are large, laminated, color wall maps that depict the water source, source protection area, hydrogeology, land use, ownership, potential contaminants and contaminants of concern to the communities. Many participants noted the helpfulness of the maps in assisting them in understanding the water source and how protection may be implemented. It was notably observed that the participants spent the most time at the maps in comparison with other displays. Virtually every participant spent time at the maps, and most spent more time at the maps than at other displays. Many of the participants commented that after looking at the maps they understood what their water source was, where it came from and the need and means for protecting it.

The planning experiment determined which methods for increased pubic involvement were selected and the response to those methods by four communities in Idaho. The following conclusions were drawn:

1. Community leaders (planning teams) have a desire to increase the awareness and involvement of community members.
2. Creative methods are needed for notification of the community of water planning and public meetings. These will vary by the community.
3. More than one public meeting is more effective. As the community becomes familiar with the idea of planning, public meeting attendance will rise.
4. Large, colorful maps that utilize state source assessment; land use, ownership, hydrogeological and contaminant information are invaluable tools for increasing public awareness in water protection.
5. Public meeting participants prefer visual water protection information over written.
6. Public meeting participants prefer to give water protection comments in a facilitated group over individually.

Evaluation Measure and Model Development The evaluation measures are designed to be useful to communities for effective planning and for updating and determining progress on existing plans. In addition, the measures are intended to provide information that is useful to states in their source assessment and protection programs and for the federal government in assisting in evaluating local plan strategy and effectiveness. The effectiveness of municipal or local protection plans is difficult to measure, yet remains a goal at the state and federal level. USEPA guidance, a state drinking water protection manager survey, the results of the planning experiment, and the city council survey and mapping experiment (field study conducted the first year of research) are used to develop the evaluation measures.

EPA Source Protection Strategy: As part of a source protection strategy, EPA is working closely with states and others to determine if contamination prevention efforts making a contribution to public health. A draft of a protection strategy and a matrix of measures (USEPA, 2003) were used as a guideline in the development of the evaluation measures in order to provide information from local source protection plans that will be useful to states and to the USEPA in tracking the progress of local plans. The USEPA matrix and the strategy were used to guide the questions that were asked of state drinking water protection managers and the city council members, as well as in the design of the planning experiment. The following elements in the strategy were identified as guidelines that would be useful in evaluating local or community protection plans:

A local protection strategy or plan includes these elements:

- A local team or partnership
- A process for using state source water assessment information
- A preventative action list
- A contingency plan for an alternative water source

Measure of implementation of the above elements:

- All four elements above are implemented
- There is partial implementation of these elements
- The strategy is not implementing the elements

<u>Drinking Water Protection Manger Survey</u>: All 50 states plus Washington DC (which has its own water source) were selected as the sample for a special group survey. The managers represent a special group of state drinking water professionals. The manager from each state is selected as the most knowledgeable manager in that field for that state. The results are not presented as representing individual states or state policy, but as an experienced state manager group that can provide information on current and past protection planning efforts.

The selected sample group is professional state drinking water source protection managers, and there are 51 (state) units that each has a central office manager. Because the sample size is relatively small all participants were highly encouraged to respond to increase the validity of the results.

The survey was tailored to provide information on ways that experienced managers feel that progress can be evaluated and barriers overcome. A partially open-ended survey was created to allow participants to easily add more information and to encourage response on often-sensitive drinking water protection issues. The survey, responses to the survey, comments from participants and ranking analysis are detailed in Appendix B. There were eleven semi-open ended questions. Eight of the questions asked for a ranked response to several given responses (highest or best response to lowest or least). In addition, an "other" selection was placed in the responses to give the participants the choice to add a response of their own. Two questions were yes/no or either/or and one was fill in the blank.

A telephone interview was offered in order to further encourage reluctant or busy participants. The surveys were sent by email following an introductory email that described the objectives for the research and the survey. The drinking water manager contact names and email addresses were obtained from a USEPA website (2002d). Up to 7 follow-up emails were sent to non-respondents. Subsequently, up to 3 telephone calls were made to selected participants that had as yet failed to respond and/or return the survey. The telephone messages offered a telephone survey as an alternative to the electronic response. Of the 51 that were selected for the sample group, 100% participated.

The survey questions were analyzed by adding the number of participants that responded to a question with each ranking level. For instance, those ranking a question as being of highest priority were added, those ranking a selection as second highest priority and so on. A group ranking was derived by selecting the answer that had the highest response in each category. The following conclusions are drawn from the survey and interviews:

1. Over half of State Drinking Water Protection managers do not think community protection plans actually protect the water source.
2. In current planning efforts, funding, technical support and networking with other communities is what is lacking in effective planning.
3. The major barriers to water protection that the communities face is local land use practices, lack of motivation and lack of “buy in”.
4. Success in planning is best measured by the presence of an ongoing committee, the degree and number of land use changes such as zoning, and improvements in contaminant levels.
5. The factors that best define Adequate/appropriate protection mechanisms are the community is educated on sources and threats, the plan is truly representative of community and the community members feel involved.
6. A state can best assist communities in planning though funding incentives, decreasing regulation, facilitating workshops and seminars and providing spatial data for education.
7. The federal government can best assist states in assisting communities by increasing protection funding, greater flexibility in fund use and responding to each state’s unique character.
8. Communities can best foster their own protection planning by forming true working water committees, creative and effective pubic notification, education and workshops and seminars.
9. Entities that should work closely with the communities in protection planning are county/extension, other water source related communities, non-government/non-profits, and the state.
10. The percentage of state protection planning programs that are voluntary is 86%.
11. Approximately 18% of community protection plans are completed in the US (a very rough figure as reported by the state managers at the time of writing).

<u>Survey of City Council Members</u>: The members of the city councils of 12 communities were given a brief survey to determine major water protection needs during the first year of research. The survey was given to the city councils and those that assisted the council. The survey design was semi-open, with four questions asked, several possible choices

offered and an option to provide an answer that was not listed. Conclusions drawn from the survey are as follows:

1. The biggest issues facing the communities in protecting drinking water sources are financial (77%), contamination (42%), political/jurisdictional (42%), land use (32%), and growth/planning (30%).
2. These issues are best resolved by receiving information on contaminants (46%), land use and ownership (42%), water source boundaries (40%), jurisdictional (35%), and infrastructure (33%).
3. The communities specified that they would be most comfortable in working on drinking water protection activities with the State (81%), County and Conservation Districts (47%) and Federal (12%) entities.
4. Government resource managing entities could do more to assist in drinking water protection by more technical assistance (77%), data sharing (56%), financial assistance (16%) and better regulatory assistance (7%).

Mapping Experiment Results: The results of the mapping experiment during the first year of research are summarized below:

1. The largest barriers to accessing the data and to motivation in protection planning are trust and privacy issues, and concern for increased regulation and associated cost.

2. When given access to graphic data from the state and state source water assessment, the communities elect to design large, color wall maps for community education purposes.

3. Communities select graphic data that addresses water protection issues that are unique combinations in each place as related to political, jurisdictional, and infrastructure as well as land use, hydrogeology, terrain, potential contaminants and risk of pollution to the source.

4. Although these issue combinations are complex and unique to each place, similar sets of spatial data and display formats are chosen to address them.

Evaluation Matrix: An evaluation matrix was developed by designing requirement categories from the USEPA evaluation strategy and matrix (Table 3). The results from the state drinking water manager survey, city council survey and mapping experiment (first year research) and the planning experiment were used to develop measures within the requirement categories.

The measures are designed to provide information from the communities that will be useful in tracking progress as well as for state and federal reporting, tracking and management. The matrix has an easy to read and mark format, and contains buttons that can be linked to databases and accessed from websites.

Table 3. Community Drinking Water Plan Evaluation Measures

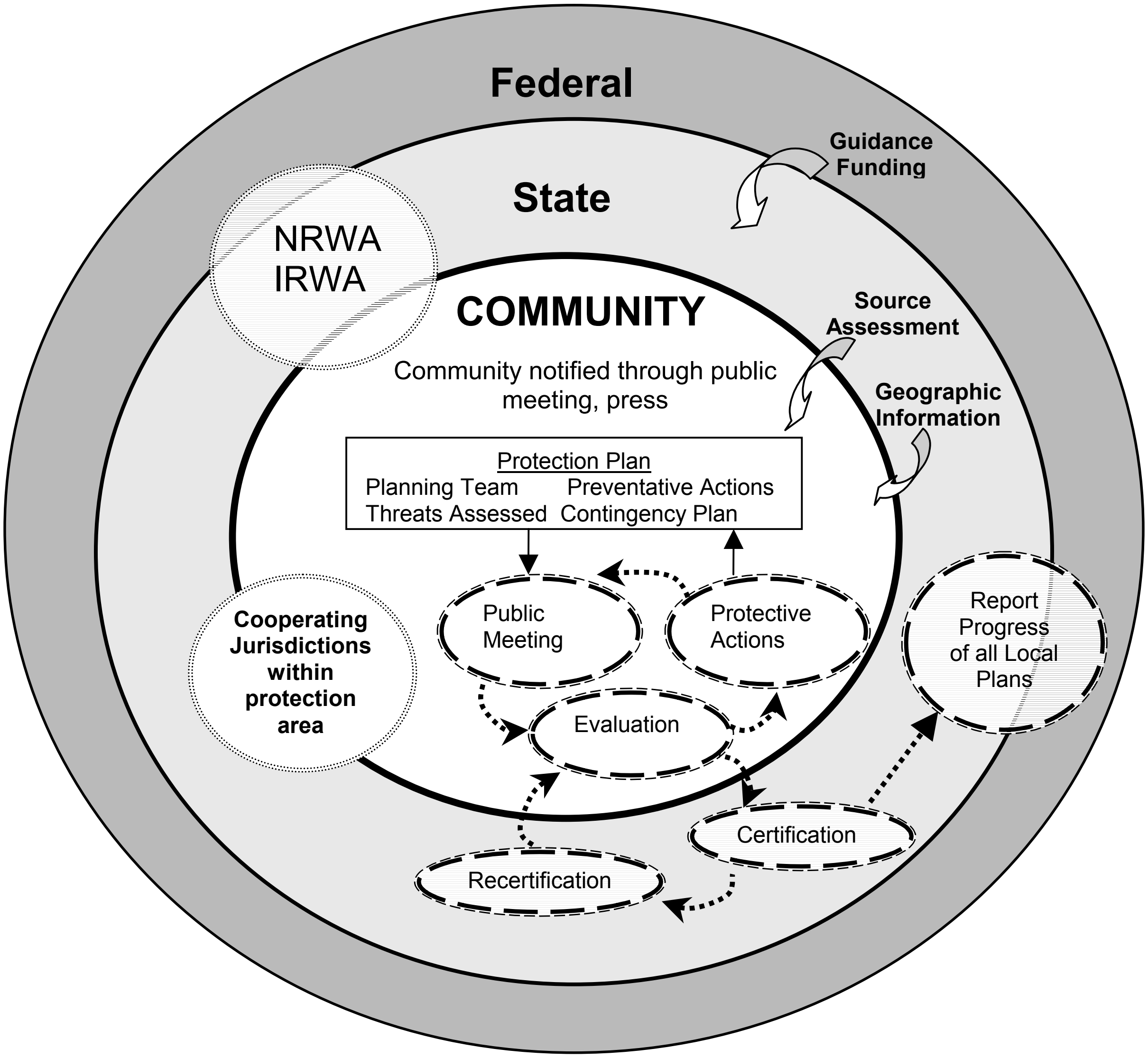
USEPA/State Requirement	Community/Local Planning Evaluation Measure	None	Partial	Fully
Local Planning Team	Community leadership declared intention to develop a local water source protection plan			
	Concerns expressed by community leadership were addressed by the state/assisting entities			
	Community leadership notified constituents of the protection planning process			
	Community leadership provided constituents with an opportunity to participate in planning			
	A protection planning team was formed from local constituents			
	Public events such as open houses were given by the planning team to gain support/input from community			
	The planning team remains or forms a committee to manage and track progress on the plan			
Use of State Source Assessment	A complete state source assessment was provided to the community planning team			
	Graphic information that includes source area was developed with/by planning team			
	Graphic information that includes source area was made available to community constituents			
	Community feels it has access to spatial and tabular data as requested by the community			
	The community met (any) state requirements for a contaminant inventory			
	The local plan utilizes and adequately portrays the state source assessment, including water source vulnerability/susceptibility rating			

Preventative Action	Preventative/management actions adequately address threats			
	Water quality standards are within state/federal requirements			
	An implementation committee or board composed of local constituents meets at least twice a year to manage plan actions			
	Preventative actions to involve and update the community are present in the plan			
	Preventative actions have been implemented this plan period (under state certification)			
	If protection zone reaches beyond municipal limits, zoning or other mechanisms have been implemented to provide adequate protection			
Contingency Plan	A contingency or emergency back-up plan is in place to provide an alternate water source to the community			
	Specific water distribution means and/or locations have been designated to provide efficient water distribution in case of source failure			

<u>Model for Increased Participant Involvement</u>: A model to increase public awareness and involvement in community or municipal drinking water protection was developed using the results of the first and second years of research (Figure 1). The model is designed for use by communities with the assistance of the state and the facilitating or assisting entities. The research tested education and involvement methods within an existing state protection-planning format that leads to state certification in Idaho. The model applies results and conclusions drawn from the mapping experiment and city council survey (first year research) and the community planning experiment (second year research).

The model is a non-linear flow-loop with the community as its focus and center. The state is nested within the United States, and the community is nested within a state. The National Rural Water Associations and Idaho Rural Water Association (used as an example in the model for working with communities in the state of Idaho) are assisting entities that work with municipalities to assist them in developing water protection plans. Any assisting entities that work within a state framework can be substituted.

Figure 1. Model for Local or Community Drinking Water Planning and Evaluation



The federal government provides the states with funding and guidance for developing water source assessments and overall protection plan guidance. The community or local protection plan is developed by the community with the assistance of the state and/or assisting entities and with any municipalities or jurisdictions that lie within the geographic water source protection area. Once community leadership has expressed a commitment to develop a plan, the entire community is notified and given the opportunity to participate through the most effective press avenues for the local and/or public meetings. The state provides the planning community the source assessment and any information that is requested that would be useful in education and increasing awareness for the purpose of informed decision-making. There is a decided emphasis on spatial or geographic information due to the effectiveness in educating people and the preference that communities show in selecting and using it over tabular or written information. Developing a protection plan involves four elements that are recognized in USEPA guidance: a planning team, use of the source assessment to assess threats, preventative actions and a contingency plan.

Community leaders, especially in smaller municipalities, often develop the protection plan. The greater community is given the opportunity to understand the water source and major threats to quality, the proposed preventative actions and given a chance to give feedback and ideas at public meetings and workshops. Revisions to the plan are made following gathering of public input and comment. The implementation phase begins, and the plan is evaluated by the community (see evaluation measures in previous section). The state reviews the plan and determines whether it will be certified. Plan revision continues in an ongoing loop of implementation, more public input, and re-evaluation and possible re-certification. In the State of Idaho plans are re-certified every 3 years. The evaluation measures are developed to be useful on an ongoing basis. Documentation and reporting of the certification and evaluation of the local or community plans is reported and tracked at the federal level for overall progress in the United States.

The advantage of this model is that it was developed using very low constraint methods, and the results have little likelihood of being influenced internally by experimental control. Yet, there is much variation among communities in the United States, and there is a higher likelihood of external factors such as cultural or social bias or variation in this area. The model should be tested further before conclusions can be drawn on efficiency and widespread applicability.

Literature References

Bokor, J. and M. Harper, 2002. Water Protection Specialists, Idaho Rural Water Association. Personal Communication.

USEPA, 2002. Office of Groundwater and Drinking Water, fact sheets on sourcewater assessments. Website: http://www.epa.gov/safewater/protect/swap.html

USEPA, 2003. Office of Groundwater and Drinking Water, Prevention Strategy and Matrix of Measures, Website: http://www.epa.gov/safewater/protect/contamprev.html

Information Transfer Program

Consistent with our mandate, the Idaho Water Resources Research Institute, University of Idaho has endeavored to meet the charge of promoting and coordinating education and information transfer. These efforts have been in coordination with Idahos water resource agencies, and the Idaho Department of Education. Following is a list of water quality education/information transfer programs which emphasize cooperation and collaboration:

Project WET (Water Education for Teachers), Idaho, an interdisciplinary, supplementary water education program for Idaho educators, was established this past year. The goal of Project WET is the facilitate and promote an awareness, appreciation, and understanding of Idahos water resources through the development and dissemination of classroom-ready teaching aids. Like other successful natural resource education programs, Project WET emphasizes teaching students how to think, not what to think.

Idaho Streamwalk, a citizen volunteer monitoring program, also contributes strength to the IWRRIs outreach program. This program, coordinated through the Institute, was designed by the Environmental Protection Agency, Region 10. The goals of Streamwalk are to encourage citizen commitment to protecting, streams, educate people about the relationship between streams and the watersheds, equip individuals with a screening tool to identify potential problem areas, provide a standardized data collection method so regional and trend comparisons can be made, and focus experts limited resources on suspected problem areas.

SITE, Students Investigating Todays Environment is a youth education program which provides the opportunity for students to experience firsthand the excitement of real world science. The goals of the program are to develop student science literacy by the process of collecting information, analyzing data, and documenting environmental quality at test locations, illustrate the application of science and technology, increase student awareness of science-related career activities, and develop alliances with public and private organizations to improve science education throughout local communities.

EM*Power is a 4-H Environmental Restoration and Waste Management youth education program. This program was developed in response to DOEs objective of increasing the level of awareness and understanding of environmental restoration and waste management. The 4-H youth component curriculum is well rounded so that youth can be taught "how to think, not what to think" in relation to waste management and environmental restoration. This provides 4-H youth with hands-on activities to gather factual information, make informed decisions and develop creative solutions in the realm of waste management and environmental restoration.

Information Transfer & Education Activities include: WET 25 WET 6 WET 18 WET 13 WET 18 WET 17 WET 8 Rangeland Resources Teacher Workshop 27 Idaho Science Teachers Conference 248 Idaho Environmental Education Summit 110 Columbia Basin Initiative Workshop 78 Harvesting Clean Energy (Geothermal) 110 Idaho Water Awareness Week 202 teachers/4018 students SPLASH Water Festivals (Moscow) 180 students/11 teachers/25 vols (Weiser) 184students/7teachers/13 vols Boise School Dist. 4th Gr. Science Workshop 45 Water Integration Project (INEEL) 15 Groundwater Awareness Project (Aquifer Academy) 13

USGS Summer Intern Program

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	5	0	0	0	5
Masters	9	0	0	0	9
Ph.D.	5	0	0	0	5
Post-Doc.	0	0	0	0	0
Total	19	0	0	0	19

Notable Awards and Achievements

Dr. Chuck Slaughter Idaho Water Resources Research Institute University of Idaho Boise, Idaho

The following research was funded through a grant from US AID.

The Rio Villalobos watershed encompasses Guatemala City, the political and economic heart of Guatemala. The watershed and river are subject to long-term degradation, exacerbated by Hurricane Mitch in 1998. Hydrologic research supported by US AID was initiated in 2000, to obtain better hydrologic and hydraulic understanding of the Rio Villalobos and its contributing watershed. Information is being acquired and analyzed to provide authorities with the foundation to better manage the river/watershed system to reduce channel destabilization, lateral and vertical channel erosion, physical damage to bridges and other infrastructure, and rapid sedimentation and water quality degradation of Lake Amatitla. IWRRI is in the third year of this study and working with Guatemalan companies and government to:

(1) Improve data (the first phase of research highlighted the pressing need for longer-duration, continuous time series of river discharge and sediment loading); (2) Evaluate the degradation of Lake Amatitlan (all water and associated pollutants from the Rio Villalobos River and watershed contribute directly to Lake Amatitlan, a freshwater lake of high economic, scenic and cultural value to Guatemala. Water from Lake Amatitlan is used for hydroelectric power, municipal water supply, irrigation, and recreation); (3) Evaluate human health (the surface waters of the Rio Villalobos basin are over-appropriated, re-used, and severely degraded in quality, only sporadic, very limited data are available on water quality in the Rio Villalobos and its tributaries. There is strong evidence that contaminated water from tributary streams and the main river being used for domestic supply is contributing to major health degradation of the population of the basin); (4) Groundwater (major groundwater extraction within the Rio Villalobos watershed, primarily for agricultural use, has the potential for (and probably already is) impacting the river regime through altered aquifer storage and recharge, return flow directly to the river, and altered water quality.); (5) Advanced Modeling (integration of (a) landscape information via GIS systems, (b) hydrologic and climatic regime, (c) sediment production, transport and deposition, (d) river channel dynamics, (e) groundwater, and (f) water quality and water-related health issues, for the Rio Villalobos watershed and Lake Amatitlan requires highly sophisticated modeling capabilities); and, (6) Adaptive management (gains an

understanding of the Rio Villalobos watershed/stream system and Lake Amatitlan will only be useful when incorporated into policy and management strategies).

Dr. Dale Ralston Idaho Water Resources Research Institute University of Idaho Moscow, Idaho

The following research is a statewide initiative funded through a congressional appropriation, administered by the EPA, Region 10.

The purpose of the project is to provide hydrogeologic assistance to small community water systems to solve ground water quality and quantity problems. The issues addressed include: decreases in well yield, problems with use of springs; locating new wells; contaminant related water quality issues; natural water quality problems and protection of water quantity and quality. Delineation of subsurface geology is common to most of the studies undertaken by the project team. In some cases, several weeks of geologic mapping and field data collection are needed. In other cases, the problem can be solved by a single visit and the analysis of available data.

Education is a major aspect of project work at all sites. Our education program is packaged under the acronym "GWEMO" (Ground Water Education for Municipal Officials). Education has taken place in meetings with community leaders, talks in public meetings and via both executive summary and full project reports. Talks also have been presented to state agency personnel and to water plant operators (organized by the Idaho Department of Environmental Quality IDEQ). Finally, project personnel presented a four-hour short course entitled "Identifying Problems with Wells" as part of the 2003 annual meeting of the Idaho Rural Water Association (IRWA). The project web site includes information on all aspects of the project. The web address is as follows: www.webs.uidaho.edu/gwemo/index.htm.

Dr. Gary Johnson Department of Hydrogeology Idaho Water Resources Research Institute University of Idaho Idaho Falls, Idaho

This work was funded by the U.S. Bureau of Reclamation.

River/aquifer response functions that have been generated describe the relationship between ground water use and river depletion. These relationships have been determined for each cell of the numerical ground water flow model of the Snake River Plain aquifer. Mapping of the response functions illustrates the degree that different reaches of the Snake River are impacted by pumping or artificial recharge. A spreadsheet has been developed to help water managers and users understand the attenuation of ground water pumping impacts on the river and to assist in mitigation. State agencies have adopted the use of the response functions in aquifer management and the results are likely to appear in state water management regulations.

Publications from Prior Projects

1. 2001ID4521B ("Statistical Model Development for Predicting Winter and Spring Precipitation Over Northern Idaho") - Articles in Refereed Scientific Journals - Harshburger, Brian, Hengchun Ye, John Dzialoski, March 2002, Statistical Model Development for Predicting Winter and Spring Precipitation Over Northern Idaho, Journal of Hydrology, Vol 264, pp 157-169.