Montana Water Center
Annual Technical Report
FY 2011

Introduction

The Montana University System Water Center is located at Montana State University in Bozeman, was established by the Water Resources Research Act of 1964. Each year, the Center's Director at Montana State University works with the Associate Directors from the University of Montana - Missoula and Montana Tech of the University of Montana   Butte, to coordinate statewide water research and information transfer activities. This is all in keeping with the Center's mission to investigate and resolve Montana's water problems by sponsoring research, fostering education of future water professionals and providing outreach to water professionals, water users and communities.

To help guide its water research and information transfer programs, the Montana Water Center seeks advice from an advisory council to help set research priorities. During the 2011 research year, the Montana Water Research Advisory Council members were: Gretchen Rupp, Director and Steve Guettermann, Assistant Director for Outreach, Montana Water Center

John LaFave, Montana Tech of the University of Montana, Montana Bureau of Mines, and MWC Associate Director

William Woessner, University of Montana and MWC Associate Director

Jim Darling, Fisheries Division - Montana Fish, Wildlife & Parks

John Kilpatrick, Director - Montana Water Science Center; U.S. Geological Survey

Bonnie Lovelace, Water Protection Bureau Chief Montana Department of Environmental Quality

Rick Mulder, Montana Department of Agriculture

Tom Pick, Natural Resource and Conservation Service

Jeff Tiberi, Montana Association of Conservation Districts, Executive Director

Kathleen Williams, MT Legislature (Water Specialist),

Laura Ziemer, Trout Unlimited

Research Program Introduction

Through its USGS funding, the Montana Water Center partially funded two new water research projects in 2011and completed funding for four other projects for faculty at three of Montana's state university campuses. Those projects funded in 2010 or early submitted final reports in spring 2011 and these reports were included in the 2010 Annual Report. The Montana Water Center requires that each faculty research project directly involve students in the field and/or with data analysis and presentations.

This USGS funding also provided research fellowships to five students involved with water resource studies. Here is a brief synopsis of the researchers' and students' work, with the two faculty research projects initiated in 2011 listed first.

Dr. Kevin Chandler of Montana Tech of the University of Montana initiated work on Methods for estimating wetland evapotranspiration through groundwater flow modeling of diurnal groundwater fluctuations. He received $14,900 for this study.

Dr. Glenn Shaw of Montana Tech of the University of Montana initiated work on Using 222Rn and Isotopic Tracers to Trace Groundwater-Lake Interactions. He received $10,622 for this study.

Interim reports from these researchers are presented later in this annual report.

Student Fellowships funded in 2011

William Kleindl of Montana State University received a $2,000 award to support his work on "Methods to parse changes in riparian health resulting from climate from those of land use over the last 30 years using data from LandSat and climatic models".

Joe Naughton of Montana State University received a $1,000 award to support his work on " Population-scale effects of hypoxia on the distribution and abundance of fishes in Silver Bow Creek".

Molly Smith of University of Montana received a $1,000 award to support her work on "An Assessment of Drought Climatology, Vulnerability, and Mitigation in the Clark Fork River Basin of Montana".

Shane Vatland of Montana State University received a $2,000 award to support his work on " Evaluation of the spatial and temporal availability of coldwater thermal refugia in the upper Big Hole River watershed,and comparison of the use of coldwater thermal refugia by native (Arctic grayling and mountain whitefish) and nonnative salmonids (brown trout, brook trout and rainbow trout)".

Chris Welch of Montana State University received a $1,000 award to support his work on "Snowpack Changes Caused by Mountain Pine Beetle".

Final reports from these students are presented later in this research report.

During 2011 three MUS faculty researchers were selected for grants that the Montana Water Center administers under the USGS 104(b) research program, two from the University of Montana and one from Montana State. In addition, nine students were awarded fellowships to help support them as they pursue water-related research and education. These grants and fellowships will be funded with 2012 USGS 104(b) funds. The faculty and fellowships are:

Dr. Laurie Marczak, Assistant Professor of Aquatic Invertebrate Ecology at the University of Montana, received an award to study "Nutrient dynamics and ecosystem function in coupled aquatic-terrestrial ecosystems during a mountain pine beetle infestation of whitebark pine." Dr. Marczak's work will key on the climate change induced mountain pine beetle outbreak that is radically altering high elevation habitats dominated by whitebark pine in the Greater Yellowstone Ecosystem. She proposes to link to ongoing research on terrestrial biogeochemical responses to determine how this massive infestation will alter rates of debris processing and food web structure in high elevation stream systems.

Dr. Geoff Poole, Assistant Professor in the Department of Land Resources and Environmental Sciences, will use USGS funds for his study titled "Assessing hydrologic, hyporheic, and surface water temperature responses to stream restoration." Dr. Poole's research combines a variety of field and numeric modeling techniques to create a complete picture of the residence time distribution for hyporheic water on the site for both pre- and post- restoration conditions. Data will document the effects of channel re-alignment on hyporheic exchange, hyporheic flow path lengths, residence time, and ultimately, channel temperature. Poole expects this research to provide local and regional fishery managers with the information necessary to begin to incorporate hyporheic restoration strategies into their management plans.

Dr. Andrew Wilcox, Assistant Professor of Fluvial Geomorphology at the University of Montana, was awarded a grant for his proposal "Thresholds in fluvial systems: Flood-induced channel change on Montana rivers." The proposed work will combine flow and sediment transport analysis, aerial photograph analysis, hydraulic modeling, and field data collection of two Montana gravel-bed rivers. The research will provide insights into relationships between floods, sediment transport, woody debris, and channel adjustment.

The student fellowships to be awarded with 2012 USGS 104(b) funds went to one undergraduate and eight graduate students. Jared Bean, a master's student in the Geosciences Department at the University of Montana, will evaluate controls on bull trout spawning habitat in mountain streams in northwestern Montana.

Erika Colaiacomo is also a master's student in Geosciences at the University of Montana. She is working on quantifying the geomorphic effects of dam removal in western rivers.

Katie Davis, a master's student in environmental engineering at Montana State University, will work on a wastewater investigation project at the Bridger Bowl Ski Area.

Fred Kellner, whose work revolves around quantifying the sensitivities of spring snowmelt timing to the diurnal snowmelt cycle, is a master's student in UM's Geosciences Department.

Mike LeMoine is a PhD student in Wildlife Biology at the University of Montana. His fellowship will support his work to study nongame fish assemblage response to changing stream temperatures.

Eric Richins, is a UM master's student studying the invasive New Zealand mud snail and its effects on stream food webs and stream eutrophication.

Anthony Thompson, a junior in Geography at the University of Montana, received a fellowship to help support him as he studies the Columbia River Treaty review and negotiation process between the United States and Canada.

Karl Wetlaufer is a first year master's student at MSU in the Earth Sciences Department. His research will combine a study of field-based snow hydrology with GIS analysis to quantify how snow water equivalent is distributed throughout the landscape.

Brett Woelber, a master's student in the Geosciences Department at the University of Montana, will further the study of how snowpack, soil, and stream systems interact at the local scale.

Methods for estimating wetland evapotranspiration through groundwater flow modeling of diurnal groundwater fluctuations

Basic Information

Title:	Methods for estimating wetland evapotranspiration through groundwater flow modeling of diurnal groundwater fluctuations
Project Number:	2011MT239B
Start Date:	3/1/2011
End Date:	2/28/2013
Funding Source:	104B
Congressional District:	At-large
Research Category:	Climate and Hydrologic Processes
Focus Category:	Wetlands, Models, Methods
Descriptors:	
Principal Investigators:	Kevin Chandler

Publication

1. None

Methods for estimating wetland evapotranspiration through groundwater flow modeling of diurnal groundwater fluctuations

PI: Kevin Chandler, Montana Tech- The University of Montana

Equipment Installation

Field work at Gartside wetland site started April 29th, 2011 with site visit and the installation of the first shallow well, Gart 1. A pressure transducer was installed in the well and set to record hourly water levels and water temperature. The rancher leasing this parcel of state land was visited and he showed interest in the project. The rancher provided valuable information concerning the best way to access the study site. Locations for the well transects were selected to best represent the varied vegetation types found in the wetland.

Installation of multiple wells in transects started during a site visit May 31st through June 2nd. Eight wells were installed using a 4.0 inch diameter hand auger to depths ranging from 4.5 to 20 feet below land surface (figure 1). Well logs were recorded for each borehole and sediment samples collected for sieve analyses. All wells were cased with 2.0 inch diameter PVC casing and screened with 2.0 inch diameter factory slotted PVC well screen with 0.020 inch slots (figure 2). The boreholes were backfilled with 10/20 silica well sand around the screened sections and bentonite chips above the sand to the ground surface. A 12 volt sampling pump was used to develop the wells and to sample the wells for initial field water chemistry measurements.

Figure 1: MSU-B student Erika Peters drilling the borehole for Gart 3 next to Gart 2.

Figure 2: MSU-B student Erika Peters holds the well casing before installation in Gart 4, one of the deeper wells (screen section at the bottom 3 feet).

Seven additional wells were installed during a site visit in early July. The locations of all wells were recorded using a hand held GPS unit. The relative elevations of the wells were measured using a site level. The wells were pumped and field chemistry measurements were recorded for all 16 wells. Data loggers were installed in all 16 wells and set to record hourly water levels and temperatures. Well pairs, deep and shallow, were installed in most of the locations to measure the vertical hydraulic gradient. Figure 3 shows the locations of the wells relative to Gartside Reservoir. Most of the data loggers were removed from the wells during a site visit on November 16th. The wells with water levels above ground surface were winterized. Several data loggers were left to record winter water levels and temperatures hourly.

Gartside was revisited in March of 2012, but many of the wells were still frozen. Late in April data loggers were deployed in six wells and wells damaged by the winter were repaired. Also during this site visit two new wells were installed in areas of similar vegetation, and screened in the upper water bearing zone. The new wells installed in April, 2012 are not shown in figure 3.

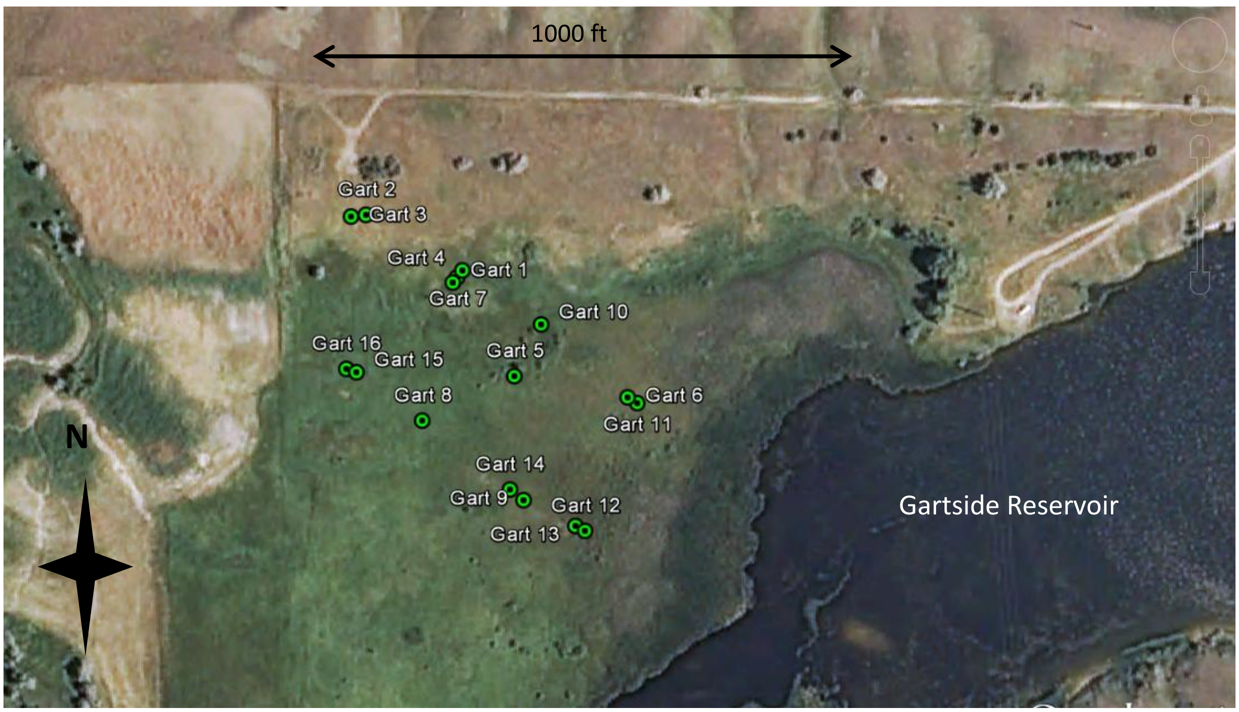

Figure 3: Google Earth image showing the locations of the wells installed in the summer of 2011.

Initial Findings

We were able to intercept two different water bearing units and to log the different sediment layers using hand auger drilling. The lower coarse sand and gravel encountered in Gart 9 and 12 produced artesian flow greater than five gallons per minute (gpm). Several feet of clay and silt above the coarse sand and gravel act as a confining unit. There appears to be a vertical upward head gradient across this confining bed of approximately two feet of water. The land surface in area between the line of wells

Gart 8, 5, 10 and the wells closer to reservoir feels like a giant water bed when walked upon. Below the root level, we encountered a saturated peat layer which caved around the auger in the drilling of Gart 6, 11, 12, 13 and 14. This made it very difficult to remove the auger from depths more than 5 feet. We overcame this problem by using a thin walled 4 inch PVC casing to support the peat, and boring inside the casing with a 3 inch auger. Each time the 3 inch auger was filled and pulled, the outer casing could be advanced. The outer casing was removed after the drilling was finished allowing the formation to collapse around the 2.0 inch well casing. Wells completed in the upper water bearing sediments have heads nearly the same as the land surface in most of the area.

Analyses of the water-level data downloaded from the data loggers show strong diurnal water-level fluctuations in some of the wells (Figure 4). The recovery spikes shown in figure 3 are the result of cool rainy days in June. The water levels from late in June and in early July show consistent diurnal cycles resulting from warm sunny days. Hydrographs from different Gartside wells are plotted in figure 5 for comparison purposes. A period of days showing consistent diurnal water-level cycles in late June was selected for this plot and similar periods will be used as calibration targets for the model. Water-level fluctuations are nearly absent in in some of the Gartside wells (figure 5). This is most likely related to the well depth (Gart 3, 9.8 ft), or the well being completed in a zone with readily available groundwater (Gart 9, >5 gpm).

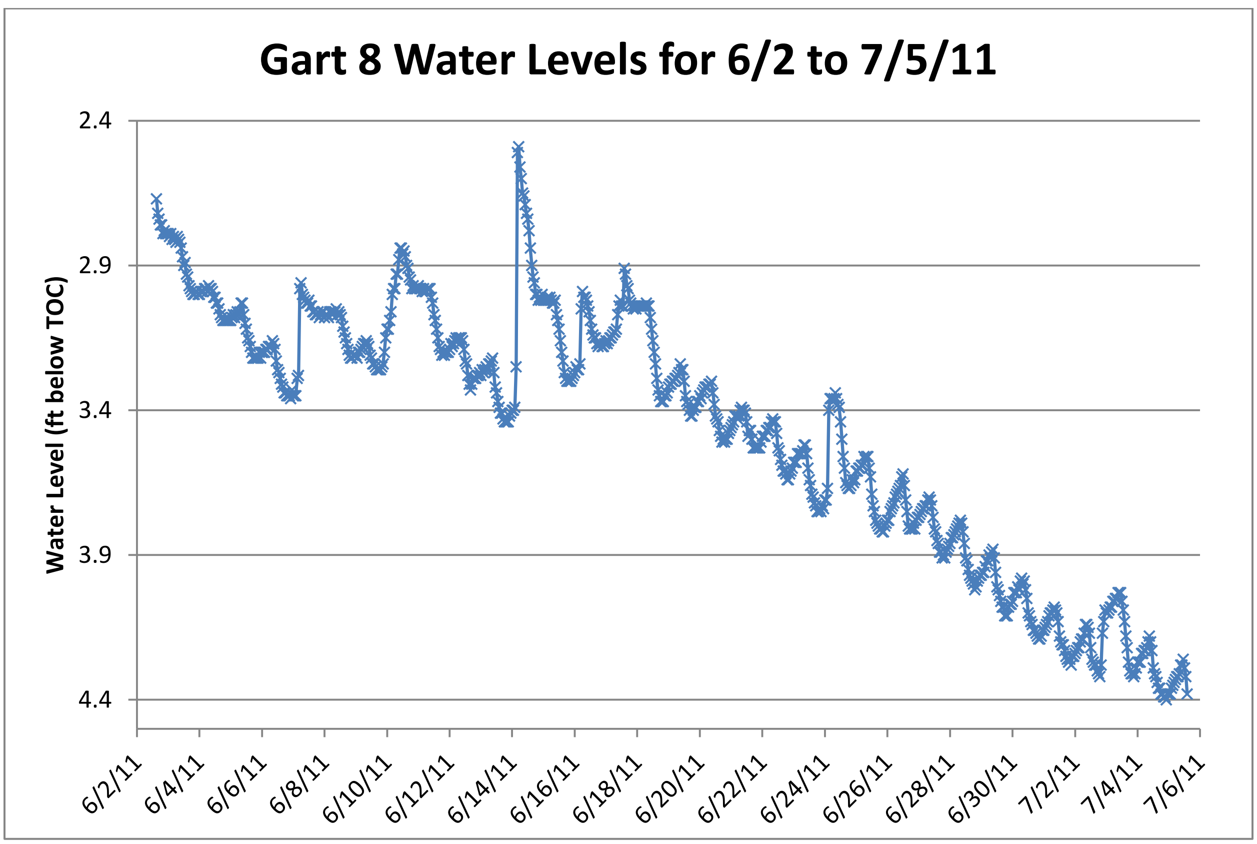

Figure 4: Water-level fluctuations recorded in Gart 8 show strong diurnal cycles.

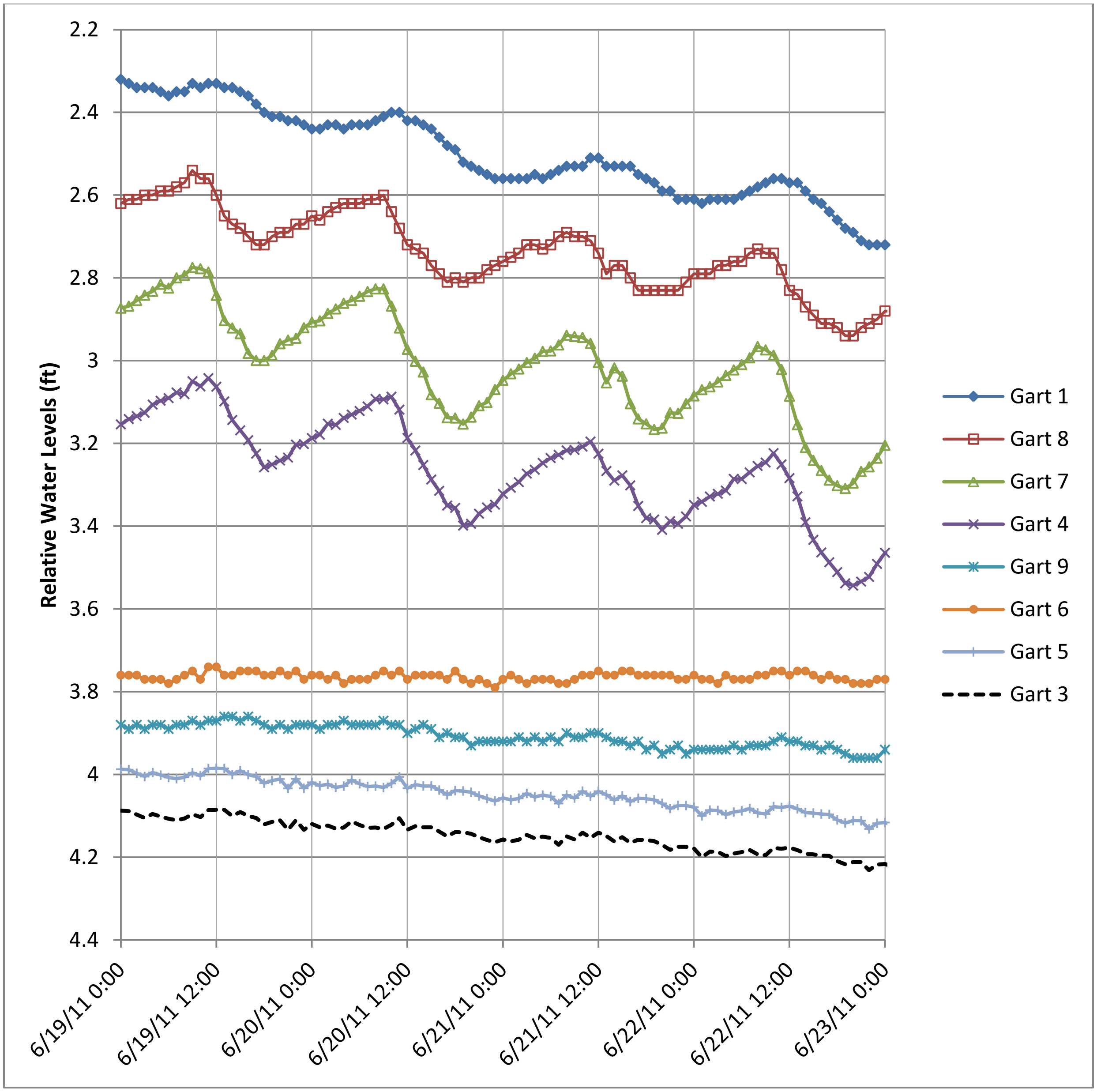

Figure 5: Water- level fluctuations for various Gartside wells. The water levels have been shifted on the Y axis to separate the traces and may not reflect the actual water level below the top of the casing.

Work Planned for the 2012 Summer Season

Flows from the drains on the west side of the Gartside wetland will be collected, and pan evaporation from the reservoir will be measured. Existing wells will be instrumented with data loggers as they become available. This project only has six dedicated data loggers, but additional data loggers are being borrowed from other MBMG projects for short-term use when they are available. The Gartside data loggers will be downloaded at each visit and the data analyzed for periods of consistent diurnal cycles. One or two additional wells will be installed into the lower more productive sand and gravel unit which appears to be supplying water to the wetland system. They will be used as pumping wells during several short-term aquifer tests. Water levels will be recoded in all the Gartside wells during the aquifer tests.

The Gartside wells will be surveyed with the Leica GPS survey unit when it is available from MBMG in Butte. We have observed “frost jacking” in the area monitoring wells which increases the well stick-up each year (figure 6). It appears that the stick-up for some of the wells installed in the summer of 2011 increased by approximately four inches over the winter. We are interested in documenting this phenomenon. Student helpers will be used for field work and to conduct sieve analyses in the lab at MSU-B on the aquifer materials collected during well installation. Groundwater flow modeling will start in June, and will most likely expose data gaps. This should allow ample time to collect additional data if needed.

Richland County Conservation District has been helpful with this project and they are very interested in our findings. We will continue to work with them this year. We are planning to present the preliminary results of this project at Montana AWRA conference this fall.

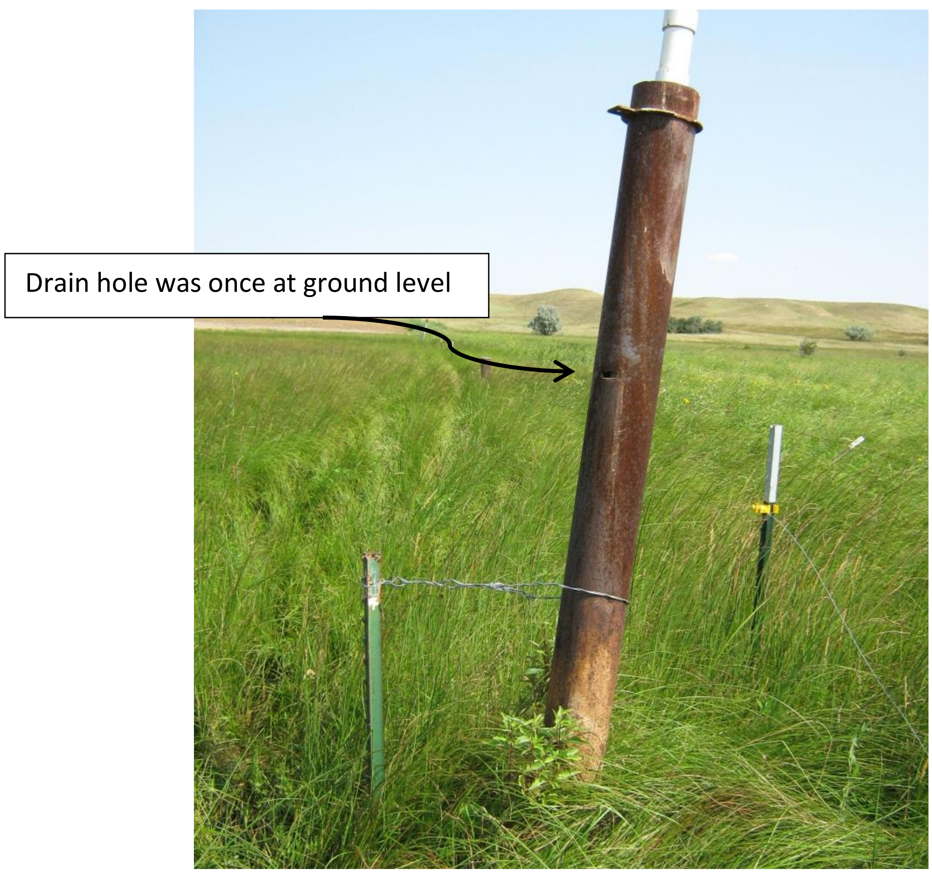

Figure 5: This monitoring well installed in January of 1988 shows the evidence of “frost jacking”.

Using 222Rn and Isotopic Tracers to Trace Groundwater-Lake Interactions

Basic Information

Title:	Using 222Rn and Isotopic Tracers to Trace Groundwater-Lake Interactions
Project Number:	2011MT241B
Start Date:	3/1/2011
End Date:	2/28/2013
Funding Source:	104B
Congressional District:	At-large
Research Category:	Ground-water Flow and Transport
Focus Category:	Groundwater, Surface Water, Nutrients
Descriptors:	
Principal Investigators:	Glenn Shaw

Publications

There are no publications.

MONTANA WATER CENTER SEED GRANT INTERIM REPORT

For

Using ^{222}Rn and Isotopic Tracers to Trace Groundwater-Lake Interactions

PI: Glenn Shaw, Ph.D., Assistant Professor, Department of Geological Engineering, Montana Tech, Butte, MT 59701, 406-496-4809 (office), 406-496-4260 (fax), gshaw@mtech.edu.

Abstract

Several geochemical and isotopic tracers were used to investigate groundwater and lake interactions in Georgetown Lake, Granite County, MT. Georgetown Lake is a large high elevation lake experiencing rapid growth and high recreation use. It was classified as eutrophic or mesotrophic in the 1980s. Spatial variations of geochemistry combined with physical measurements to develop a conceptual understanding of how groundwater and surface water interact. Radon samples were used to show that groundwater primarily enters the lake along the eastern shore of the lake through karst caverns and fractures. Physical and solute mass balances indicate that the lake is a flow through lake, with groundwater exiting on the western side of the lake. This is consistent with water levels and the west dipping bedrock in the region. Stable isotopes of the water molecule were used to perform an endmember mixing analysis. From this analysis there appear to be three water types mixing in the lake. The first type is precipitation, which represents the overland flow component. The second endmember is groundwater, and the third endmember is lake water that has been highly evaporated. The third endmember was most likely derived from the first two endmembers and represents a process controlling the lake. The western side of the lake has the most evaporated water, which is consistent with the conceptual model of groundwater entering along the eastern shores and exiting along the western shores. The average lake composition suggests that the lake is roughly 27.4% groundwater, 34.8% precipitation, and 38.1% evaporated lake water. These fractions are also consistent with the groundwater and surface water components derived from the mass balances. Spatial variations of nutrients show no direct correlation of groundwater sources of nutrients (i.e. septic systems leaking to the lake).

Problem Statement

This report is to provide a status update for the Montana Water Center Seed Grant proposal, "Using ^{222}Rn and Isotopic Tracers to Trace Groundwater-Lake Interactions", funding cycle March 2011 to March 2013. The purpose of this project was to investigate groundwater and lake interactions using geochemical and isotopic tracers in Georgetown Lake, Granite County, Montana (Figure 1). Georgetown Lake is one of the most highly used year-round recreation areas in Montana. Uses include: homes, motels, sight-seeing, boating, water skiing, fishing, hunting, picnicking, camping, snowmobiling, cross-country skiing and downhill skiing at Discovery Basin. Subdivision of land for home sites has remained steady and rapid urbanization could have negative impacts on water quality and quantity. Georgetown Lake was classified as eutrophic or mesotrophic (Knight, 1981), and there are currently concerns about decreasing dissolved oxygen during winter months from increasing biological oxygen demand (BOD). The Georgetown Lake Homeowners association is concerned about the water quality of the lake, and several studies have been conducted looking at dissolved oxygen and nutrient dynamics within the lake to better understand the source of nutrients (i.e. Craig Stafford at the University of Montana, Montana Department of Environmental Quality Total Maximum Daily Load Program, and several theses and dissertations from MSU and U of M). Our interest is primarily to identify and quantify groundwater dynamics within the lake, but we also investigated nutrients to see if there is any correlation between nutrient loading and groundwater. The justification is that in order to accurately characterize the chemical and biological processes occurring within a drainage basin, the physical processes must also be well constrained. Our research questions are i) How much groundwater mixes with Georgetown Lake? ii) Is Georgetown lake a gaining, losing, or through flow lake? iii) Where does groundwater mix with Georgetown Lake? and iv) Are the high levels of nutrients coming from groundwater sources such as septic systems, and do they mix with the lake?

Methods

In order to answer the objective questions, several spatial samples were collected for a variety of analytes. Several mass balance approaches were used to help develop a conceptual understanding of groundwater-lake interactions and quantify groundwater inflows and outflows. Approximately 100 samples were collected in Georgetown Lake (70), groundwater from residential wells near Georgetown Lake (20), and surface water and snowmelt (10) between March and September 2011 (Figure 2). Samples included water quality parameters (temperature, specific conductivity, dissolved oxygen, pH, and Eh), major ions (N^+, K^+, Ca^{2+}, Mg^{2+}, F^-, Cl^-, NO_3^-, SO_4^{2-}), nutrients (H_2S, NH_4^+, PO_4^{3+}, NO_2^-, NO_3^-), stable isotopes of water ($\delta^{18}O$ and δ^2H), and radon (^{222}Rn). The lake samples were primarily collected during ice cover in March and April to prevent radon and other gases from degassing. The surface water was collected during snowmelt and baseflow (low flow period in late summer), and groundwater was collected in August and September after meeting with the Georgetown Lake Homeowners Association and gaining permission to sample several wells. The project provides a snapshot in time during late winter and early spring. Although groundwater was sampled later in the year, it is assumed that groundwater concentrations remain relatively constant throughout the year in most cases. Radon was used to determine the locations where groundwater enters the lake. Radon, Sc, and Cl^- mass balance approaches were combined with a physical hydrologic budget to quantify groundwater inflows and outflows. Stable isotopes were used in an endmember mixing analysis (EMMA) to identify the sources of water or processes controlling lake water. Each sample in the lake was separated into their respective endmembers. The following is a summary of these methods. Spatial variations of nutrients were also investigated to help answer research question (iv).

Results

Conceptual understanding of groundwater flow within the lake

Spatially, radon concentrations are elevated in all groundwater samples in comparison with the lake samples. Surface water and snow samples have little to no radon. The radon activity on the western two thirds of the lake is relatively low. Radon concentrations are elevated along the eastern side and part of the southern boundary of the lake. This suggests that groundwater primarily enters the lake on the east side (Figure 3). These groundwater dynamics appear to be largely controlled by physical geology, as the western portion of the lake is primarily metasedimentary Belt deposits and the eastern portion of the lake is primarily limestone overlain by some tillite (Figure 4). The eastern and western portions of the lake are also separated by the Georgetown Thrust Fault. The samples closest to the thrust fault are also the most elevated in radon suggesting that the thrust may be a conduit for groundwater flow. However, it is apparent that groundwater enters the lake through the limestone through fractures and karst caverns, as there are two large springs (one with flows similar to Flint Creek) located within the limestone.

In general water levels are typically deeper along the western portion of the lake, and the belt deposits dip to the west. This suggests that the lake is most likely a through flow lake with groundwater entering the lake on the east side and groundwater slowly exiting over the larger portion of the Belt deposits. This assumption is further validated by one domestic well sample collected in the southwest corner of the lake because the groundwater major ion and isotope concentrations have compositions nearly identical with the lake chemistry.

Quantification of Groundwater Inflows and Outflows

Four mass balance approaches were used to determine the rates of groundwater inflow and outflow within the lake. The first mass balance approach was derived from a physical water balance. This approach uses values of precipitation, evaporation, surface water inflows and outflows, and is used to solve for the difference between groundwater inflows and outflows. Chemical mass balances were used to separate the groundwater inflows and outflows.

The physical mass balance is as follows:

$$\frac{\partial \mathrm{V}}{\partial t} = PA - EA + Q_{gwi} - Q_{gwo} + Q_{Si} - Q_{SO} \tag{1}$$

where:

$\partial \frac{\mathrm{V}}{\partial t}$	= Change in Volume with time; Storage
A	= area of the lake (ft^2)
P	= precipitation (ft/day)
E	= evaporation (ft/day)
Q_{gwi}	= groundwater flux into the lake (ft^3/day)
Q_{gwo}	= groundwater flux out of the lake (ft^3/day)
Q_{si}	= surface water flux into the lake (ft^3/day)
Q_{so}	= surface water flux out of the lake (ft^3/day)

A chemical mass balance is as follows:

$$\frac{\partial C_L \mathrm{V}}{\partial t} = Q_{gwi}C_{gw} + Q_{Si}C_{Si} + FA_b - Q_{gwo}C_{gwo} - Q_{so}Q_{so} - kAC_w - \lambda V C_L \tag{2}$$

where:

F	= diffusive flux from underlying sediments
A_b	= area of lake bottom
k	= gas transfer velocity
λ	= radioactive decay constant (0.18 day^{-1})
V	= volume of the lake (ft^3)
C_L	= concentration of the lake (pCi/L)

Sc and Cl^- mass balances use equation 2, but the decay term and diffusion terms are not included. The radon mass balance included the decay term, but diffusion was assumed to be negligible. Parameters for the mass balance were determined from direct measurements in this study or from a DNRC report submitted to the Georgetown Lake Homeowners Association (Amman, 2011). The parameters used are shown in Table 1, and the calculated results are for groundwater inflows and outflows are found in Table 2.

Groundwater inflow and outflows estimated from the radon mass balance approach are too high, but the results from the Cl^- and Sc mass balances are within the correct order of magnitude (with total flows similar to surface water flows). One possible explanation for the discrepancy could be from not including a diffusive flux of radon from the sediment pore water. One should note that the solute mass balance approach may also be just an order of magnitude estimate as diffusion of solutes from sediment was also not included in the study. Further, the lake samples were collected at the bottom of the lake during a time when the lake was stratified. This may also result in groundwater inflows and outflows that are either too high or too low.

Endmember Mixing Analysis

Isotope samples were used in an endmember mixing analysis. The lake samples tend to plot in a triangular shape when plotted against the meteoric water line (Figure 5). The three corners of the triangle represent source waters mixing, or processes occurring on the lake water. These endmembers are described as:

EM1:	Groundwater, isotopically depleted which is representative of fresh snowmelt recharge. Position on Figure 13: $\delta^{18}O$ = -18.3 ‰ , $\delta^{2}H$ = -136 ‰
EM2:	Evaporated water, isotopically enriched Position on Figure 13: $\delta^{18}O$ = -12.8 ‰, $\delta^{2}H$ = -121 ‰
EM3:	Average annual precipitation Position on Figure 13: $\delta^{18}O$ = -15.5 ‰, $\delta^{2}H$ = -115 ‰

Precipitation samples from Butte, MT were used to define the precipitation end member. Samples were reported from Gammons et al. (2006). The groundwater endmember concentrations were derived from average groundwater values in this study, and the evaporated water was taken from the most extremely evaporated water sample within the lake. Each sample in the lake falls within this triangle and represents a mixture of each of these endmembers. The three endmember mixing results are plotted on a trilinear diagram, and shows that the most highly evaporated samples are located on the west side of the lake (Figure 6). The east side continues to receive groundwater and Flint Creek water that is not highly evaporated, but the water on the west side tends to be more stagnant and is influence more from evaporative processes prior to exiting the lake as groundwater or surface water. These results fit with our conceptual understanding from radon and the mass balances. When all lake samples are averaged, the calculated fractions suggest that the lake is 27.4% groundwater, 34.8% precipitation, and 38.1 percent evaporated lake water (this last endmember could be water that was originally groundwater or precipitation).

Nutrient Budget

The nutrients collected in Georgetown Lake vary spatially, while the groundwater concentrations are generally low in H_2S, PO_4^{3-}, and NH_4^+ (Figure 7-9). There seems to be a slight correlation between groundwater inputs resulting in lower H_2S concentrations, but there is no conclusive evidence. Other nutrients, (ammonium and phosphate) show no direct correlation between high nutrients and groundwater inputs. This and the low nutrient concentrations in groundwater suggest that the locations we sampled are not influenced by septic systems discharging to the lake. This does not translate to an absence of seepage from septic systems. We suspect that diffusion of nutrients may play an important role in controlling the nutrient dynamics in the lake.

Products and Outreach

The following list summarizes reports, theses, incoming graduate students, presentations and posters that resulted or are pending from this project.

Theses and Presentations

1. White, Elizabeth. (2012) *(Unpublished Master of Science Thesis)*. Montana Tech, Butte, Montana.
2. Malsom, Jacob, and Robyn Fisher. (2011) Groundwater/Lake Interactions at Georgetown Lake, MT. Presentation at the Montana Tech Undergraduate Research Fair.
3. Bramlett, E., and G. Shaw, Using geochemical tracers to trace groundwater interactions with Georgetown Lake, Granite County, Montana, *American Water Resources fall meeting poster*, October 2011, Great Falls, MT.
4. Shaw, Glenn, and E. White. (2012) Using ^{222}Rn, Water Isotopes and Major Ions to Investigate a Large Alpine Through-Flow lake, *Goldschmidt Spring Meeting*, Montreal, Canada (Pending, June 26).
5. Shaw, Glenn (2012) Using environmental tracers to track groundwater-lake interactions in a large alpine lake. BYU Idaho Geology Department Seminar (Pending Seminar September 13th)

Outreach

6. Shaw, Glenn, and Elizabeth White, (2011) Source Water and Water Quality of Stewart Mill Spring. Personal Report to Ms. Diana Neely (Home Owner who provided access to a large spring discharging to Georgetown Lake).
7. Shaw, Glenn. (2011) Groundwater and Surface Water at Georgetown Lake, MT. Presentation at the Georgetown Lake Homeowners Association.

Student Involvement

Elizabeth Bramlett White, M.S. student geoscience with a hydrogeology option at Montana Tech. Elizabeth came to Montana Tech in January 2011 and completed her M.S. degree in three semesters. She was funded by the Alfred Sloan Foundation on a Native American Sloan Scholarship for tuition. Elizabeth was the first graduate student and primary researcher on this project. She received a B.S. in Geology from the University of Wyoming in 2010, and an M.S. in Geoscience with a hydrogeology option at Montana Tech in 2012.

Jacob Malsom, undergraduate student in geological engineering at Montana Tech. Jacob is an undergraduate student from western WA. He came to Montana Tech in the fall of 2010 and was funded by the Montana Tech undergraduate research program. Jake was instrumental in getting both field and lab work completed for this project. I'm currently waiting to see if the Montana Tech URP program will fund Jake's stipend for an additional year to continue working on this project.

Robyn Fisher, undergraduate student in geological engineering at Montana Tech. Robyn is an undergraduate student from northern Alberta. She came to Montana Tech in the fall of 2010 and was funded by the Montana Tech undergraduate research program. Robyn was also instrumental in getting both field and lab work completed for this project. I'm currently waiting to see if the Montana Tech URP program will fund Robyn's stipend for an additional year to continue working on this project

Katie Mitchell, M.S. student in geoscience with a hydrogeology option at Montana Tech. Katie is an incoming graduate student who will attend Montana Tech starting in August 2012. She graduated with a B.S. in Geology and a B.S. in Public Administration in December 2011 from Stephen F. Austin State University-Nacogdoches, TX. Katie served in the Army National Guard from 2002 to 2008 and earned the rank of Sgt. She was deployed in Iraq from 2003 to 2005. She will attend Montana Tech to work towards an M.S. in Geoscience with an option in Hydrogeology.

Budget to date

Currently, we've spent roughly half of the allotted budget, which will allow us to continue to focus on the project for another year. We have completed primary lake sampling that the proposal initially targeted, but we've found ways to significantly cut cost on sample analyses. For example, Elizabeth White drove to the University of Montana to analyze cation samples herself reducing the cost of sample analyses from $25 per sample to roughly $7 per sample. The University of Wyoming has decreased isotope sample cost from $10 to $7 per sample. Some of the equipment rental cost was spared because a gas powered auger was loaned to our research group rather than rented. I also acquired an ALPHAGUARD 2000 PRO Radon Analyzer with an AQUA Kit for my laboratory, which cuts ^{222}Rn costs down from $25 per sample to essentially free.

Future work

Although the work from this project has helped tremendously in developing a conceptual model of groundwater flow to the lake and developing a water budget, the quantification of groundwater inflows and outflows was very much dependent on solute mass balance approaches. Our methods of sampling consisted of monitoring the lake bottom during a time when the lake was stratified, which may skew the groundwater inflow and outflow rates. Furthermore, diffusion of solutes from the lake sediment pore water is not accounted for in the mass balances. Further characterizing the diffusive fluxes of solutes and radon may be very important in developing a complete solute and radon mass balance, which will affect the hydrologic budget. We also need to look vertically within the lake water column and temporally at the distribution of solutes and radon within the lake.

There was no direct correlation between nutrient sources and groundwater inputs. This also strengthens the argument that much of the nutrient loading within the lake comes from vertical diffusion from lake sediments and the rates should be determined.

From a groundwater flow perspective, the spatial variations of Rn suggest that the highest rates of groundwater seepage may be along the thrust fault boundary within the lake. We would like to map radon along the fault boundary to determine if this is a large conduit of groundwater to the system. We would also like to investigate groundwater fluxes throughout the entire lake rather than just the perimeter

Seepage zones identified from ^{222}Rn should also be compared with seepage meters and mini-piezometers. This may allow further development and calibration of quantifying fluxes from seepage meters and from estimating fluxes from ^{222}Rn.

Summary

To date, a significant amount of work has been accomplished at Georgetown Lake from the Montana Water Center seed grant, and significant cost savings for the work has been obtained. From the combination of physical geology, water levels, physical mass balances, solute and radon mass balances, spatial mapping of radon and other solutes, and isotope endmember mixing analyses we have determined that Georgetown Lake is a through flow lake with groundwater primarily entering along the eastern side of the Georgetown Lake thrust fault. Groundwater appears to exit the lake through Belt deposits along the western side of the lake. We are gaining a better understanding of the magnitude of groundwater inflows and outflows, but more work needs to be conducted on investigating the role of solute diffusion from sediment pore water. Nutrients are elevated in the lake, but the sources are also still not well understood. Additional work in this area can also be conducted and coupled with solute mass fluxes from sediment pore water as well. The use of tracers is a relatively cheap and powerful method for investigating groundwater-lake interactions in complex terrain such as Georgetown Lake.

References

Amman, D. (2011). *Georgetown Lake Homeowners Association*. Retrieved from Flint Creek Dam Advisory Committee Uptate: April 14, 2011: www.georgetownlakehomeowners.com/files/86711303233131SnoPackApril11-2011Sum.pdf

Gammons, C., Pellicori, D., Reed, P., Roesler, A., & Petrescu, E. (2006). The hydrogen and oxygen isotopic composition of precipitation, evaporated mine water, and river water in Montana, USA. *Journal of Hydrology, 328*, 319-330.

Henne, W. (2011). Using Chemical and Isotopic Tracers to Track Biogeochemical Processes Under Ice Cover at Georgetown Lake, MT. *(Unpublished Master of Science Thesis)*. Montana Tech, Butte, Montana.

Knight, J. C. (1981). An Investigation of the General Limnology of Georgetown Lake, Montana. *(Unpublished Doctoral Dissertation)*. Montana State University, Bozeman, Montana.

Lonn, J. D., McDonald, C., Lewis, R. S., Kalakay, T. J., O'Neill, J. M., Berg, R. B., & Hargrave, P. (2003). *Preliminary Geologic Map of the Philipsburg 30' x 60' Quadrangle. Western Montana.* Montana Bureau of Mines and Geology.

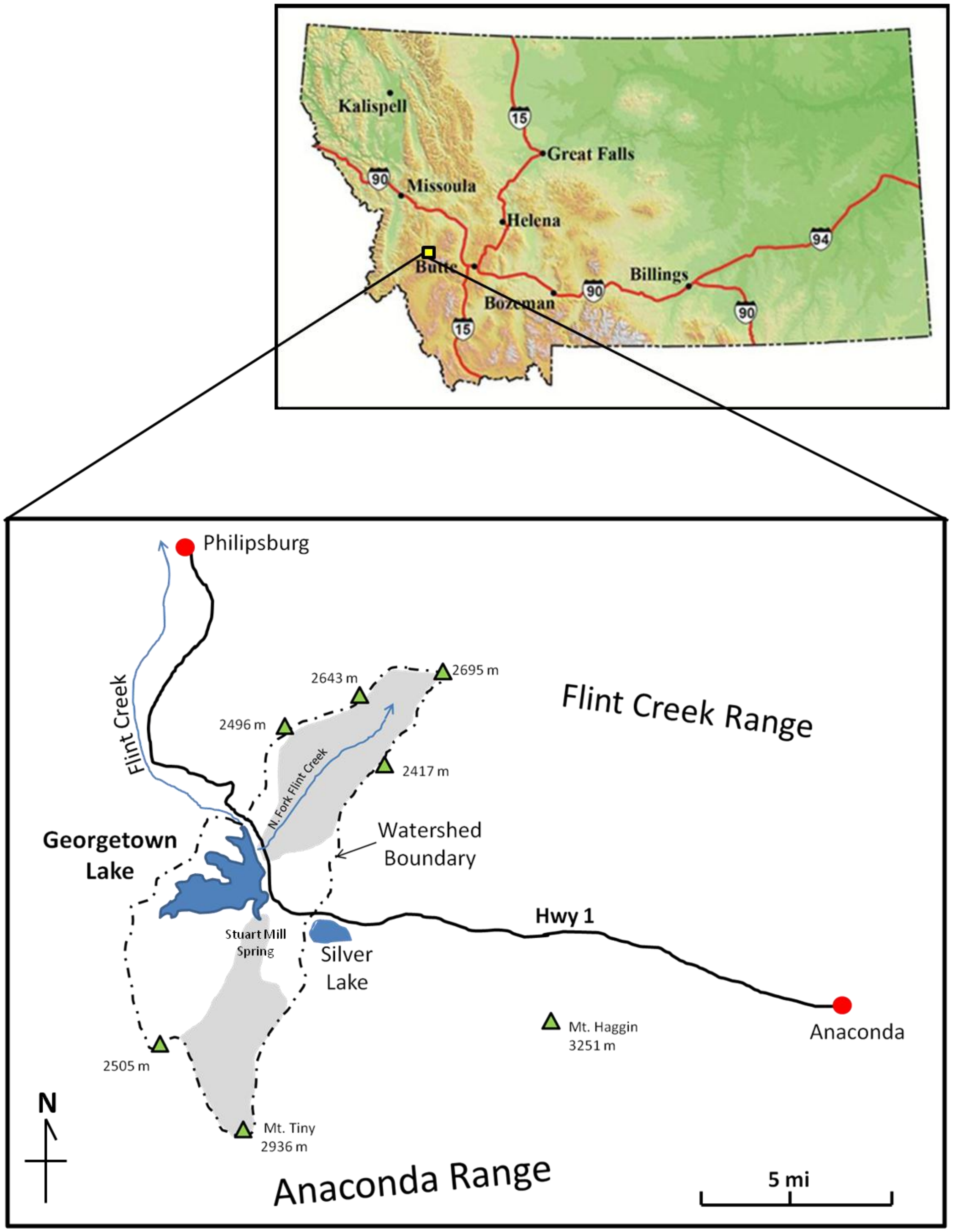

Figure 1: Map of the Georgetown Lake area.
Drainage areas recharge Flint Creek and Stuart Mill Spring. Modified from Henne (2011)

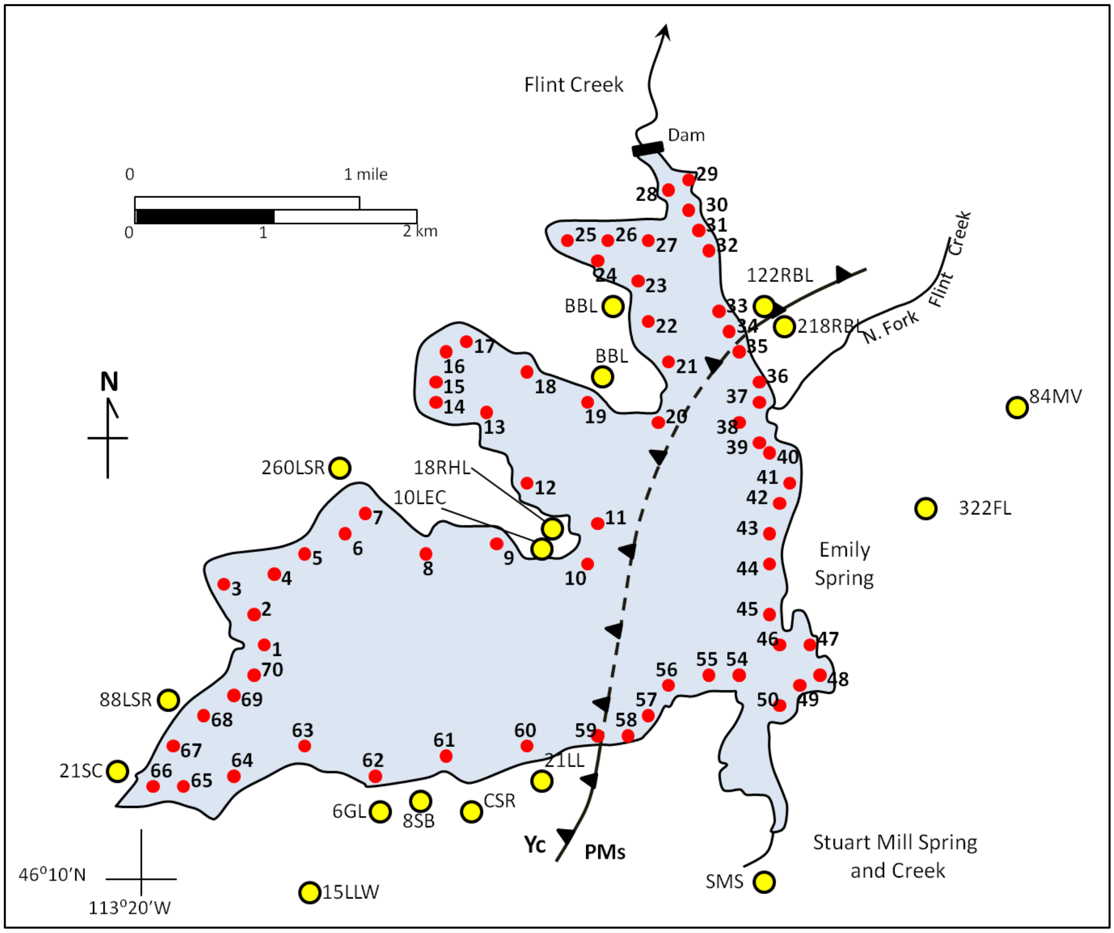

Figure 2: Map showing sampling locations around Georgetown Lake, Montana.

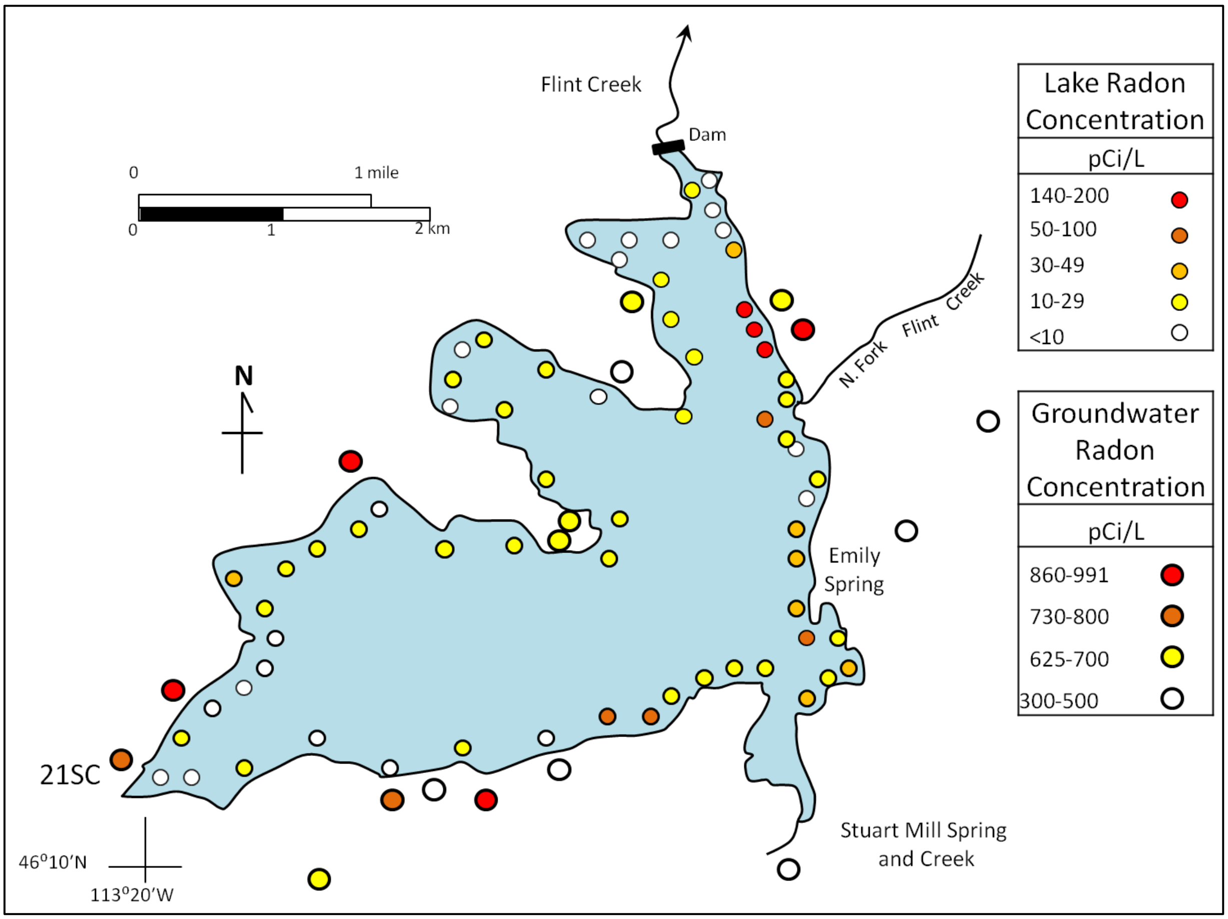

Figure 3: Spatial distribution of radon concentrations in Georgetown Lake and groundwater samples.

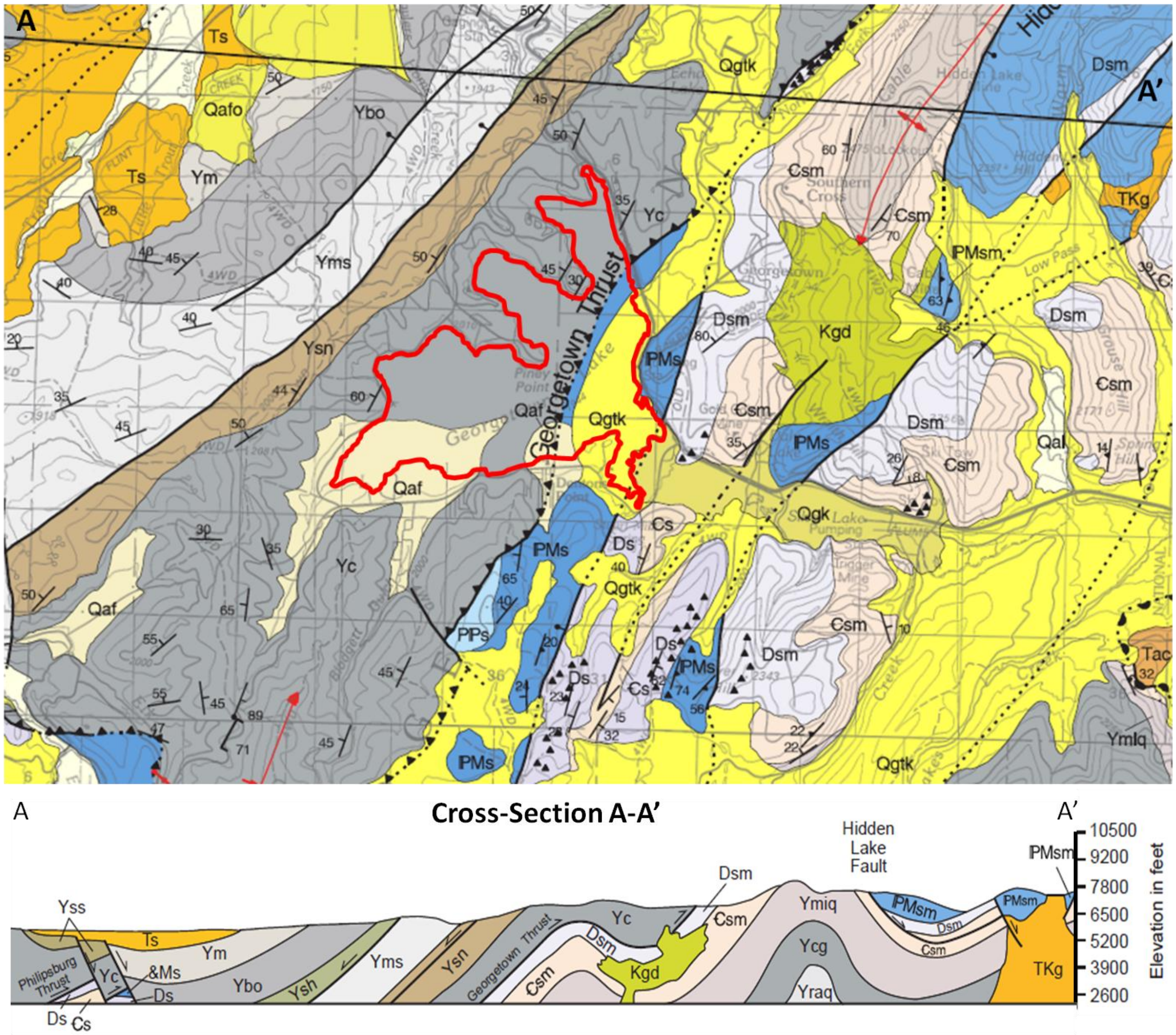

Figure 4: Montana Bureau of Mines and Geology of the Philipsburg quadrangle.
(Lonn and others, 2003)

Table 1: Parameters used in Radon mass balance and Sensitivity Analysis

	March & April	Sensitivity on Model
Q_{SI}	2.87×10^6 ft^3/day	High
Q_{SO}	2.16×10^6 ft^3/day	High
V	2.8×10^9 ft^3	High
A	1.31×10^8 ft^2	
Storage	3.36×10^5 ft^3/day	Low
P	0	Low
E	0	Low
λ	0.18 day^{-1}	
C_{gwi}	449.7 pCi/L	High
C_{gwo}	24.7 pCi/L	High
C_{SO}	6.51 pCi/L	High
C_{SI}	10.2 pCi/L	High
C_L	24.7 pCi/L	High

Table 2: Estimated Groundwater Flux from Mass Balance Methods

	Groundwater Influx (ft^3/day)	Groundwater Outflow (ft^3/day)	Outflow - Influx (ft^3/day)
Radon	2.18×10^7	2.25×10^7	7.13×10^5
Specific Conductivity	1.31×10^6	2.36×10^6	1.04×10^6
Cl^-	9.47×10^5	1.99×10^6	1.04×10^6

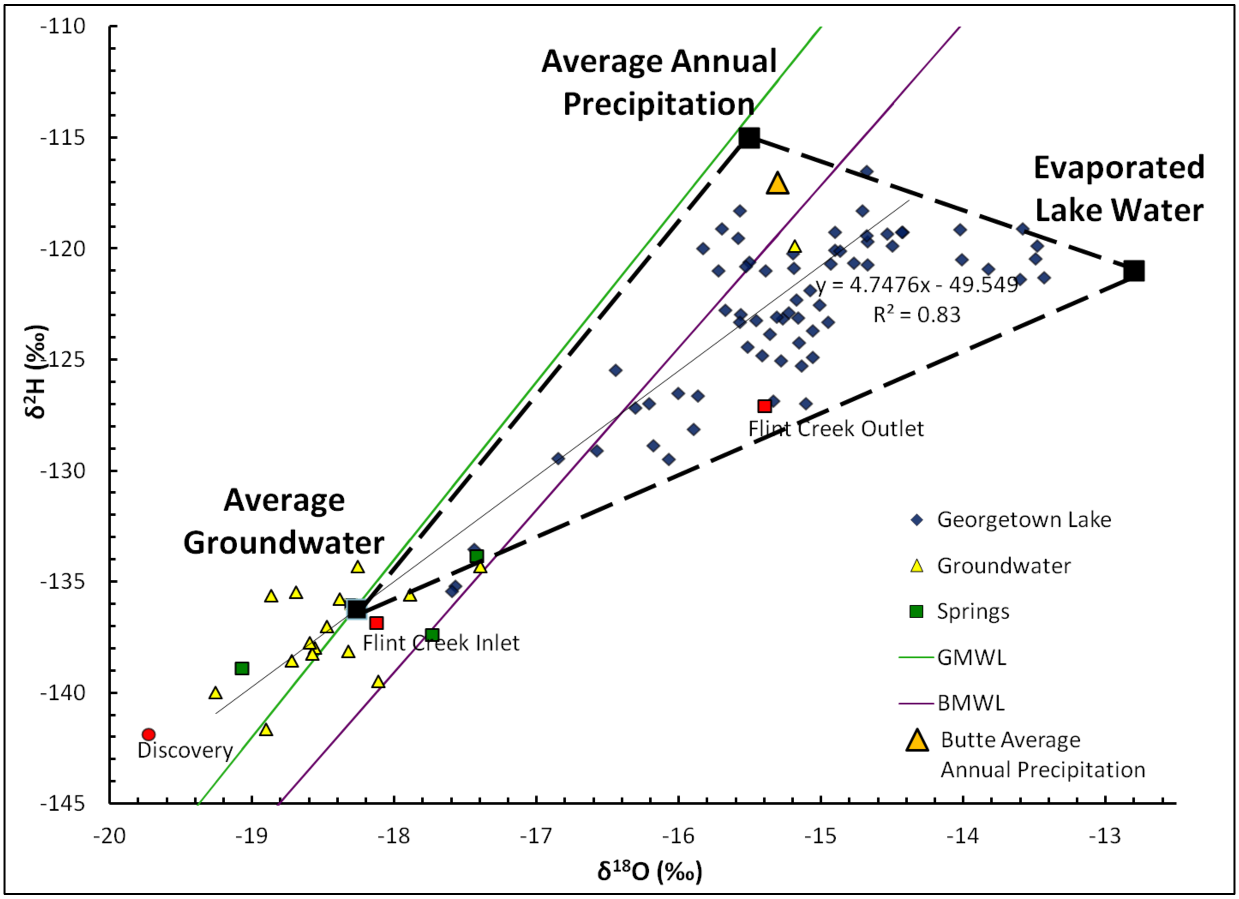

Figure 2: End Member Mixing Analysis. Three sources are identified: average groundwater, average annual precipitation and evaporated lake water.

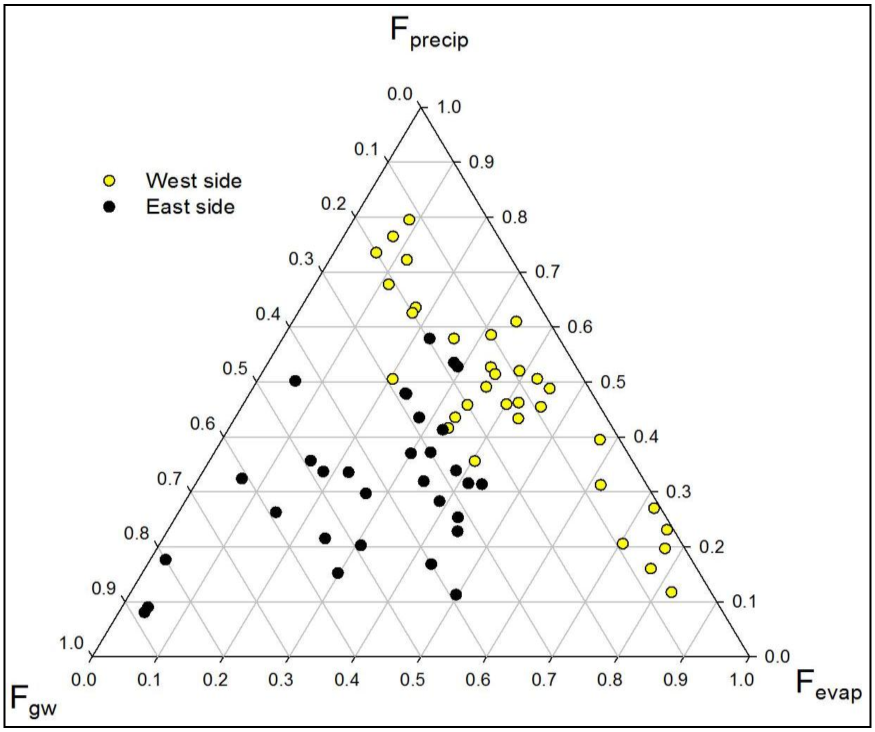

Figure 6: Ternary Plot showing origin of lake water three end members (groundwater, precipitation, and evaporated lake water.

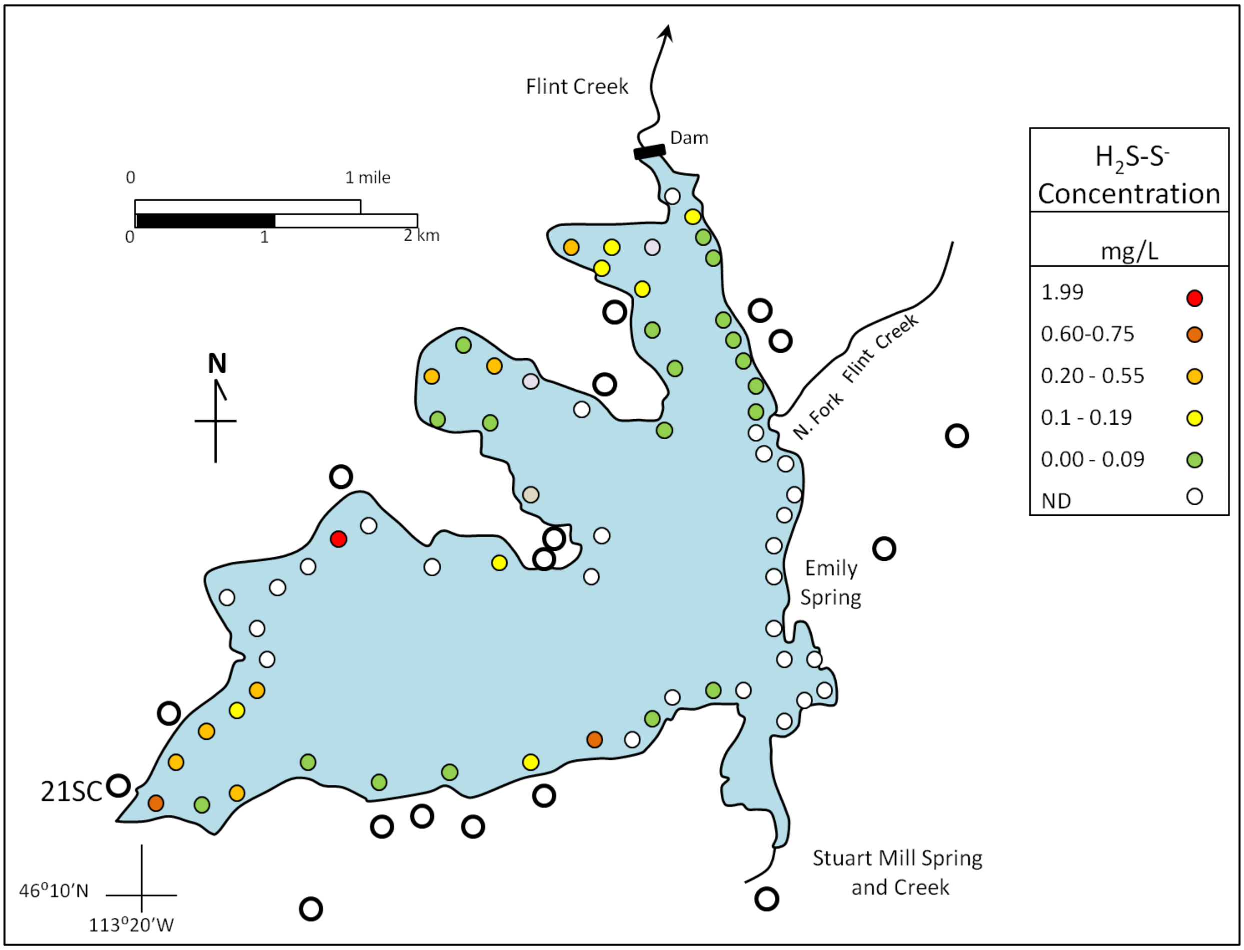

Figure 7: Spatial distribution of hydrogen sulfide around Georgetown Lake, Montana. No H_2S is detected in any of the groundwater wells.

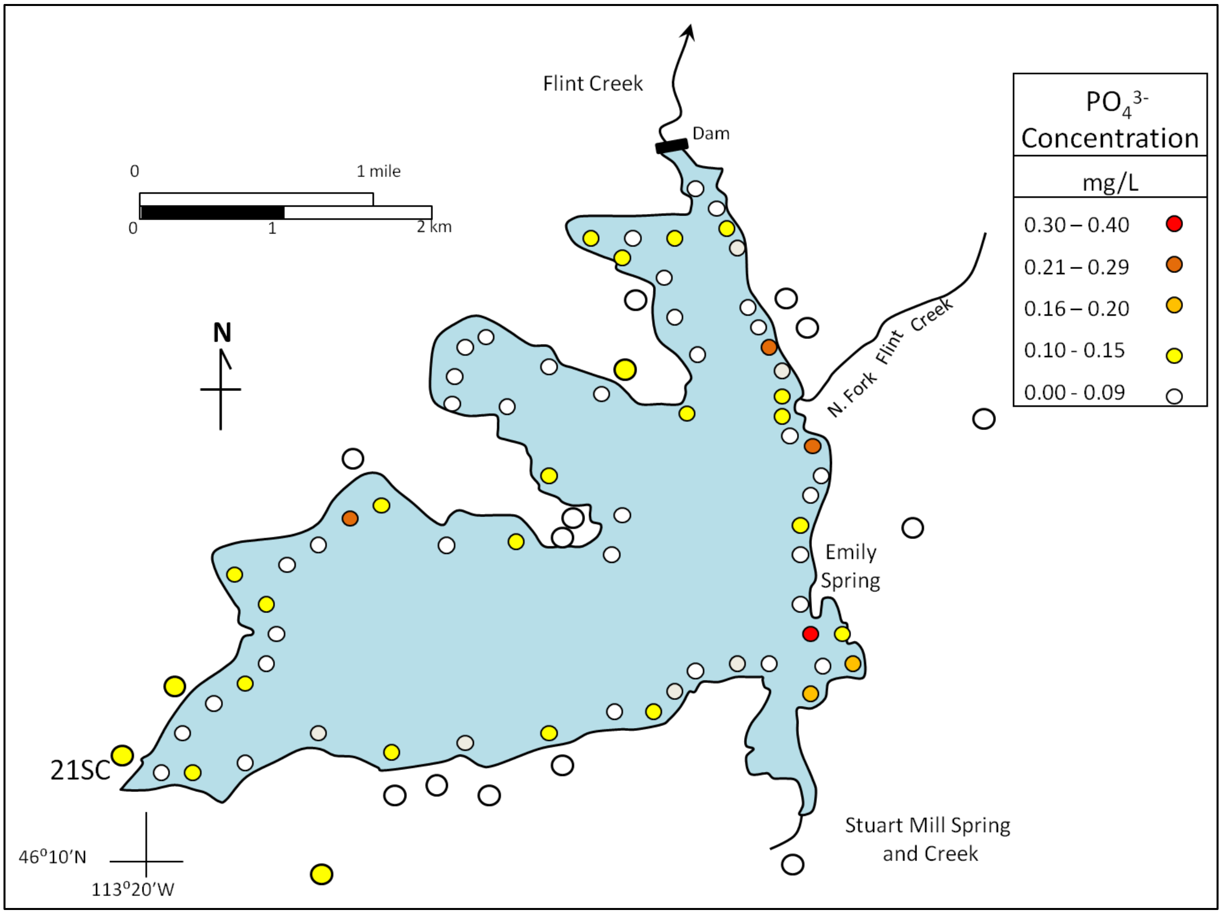

Figure 8: Spatial distribution of phosphate concentrations around Georgetown Lake, Montana.

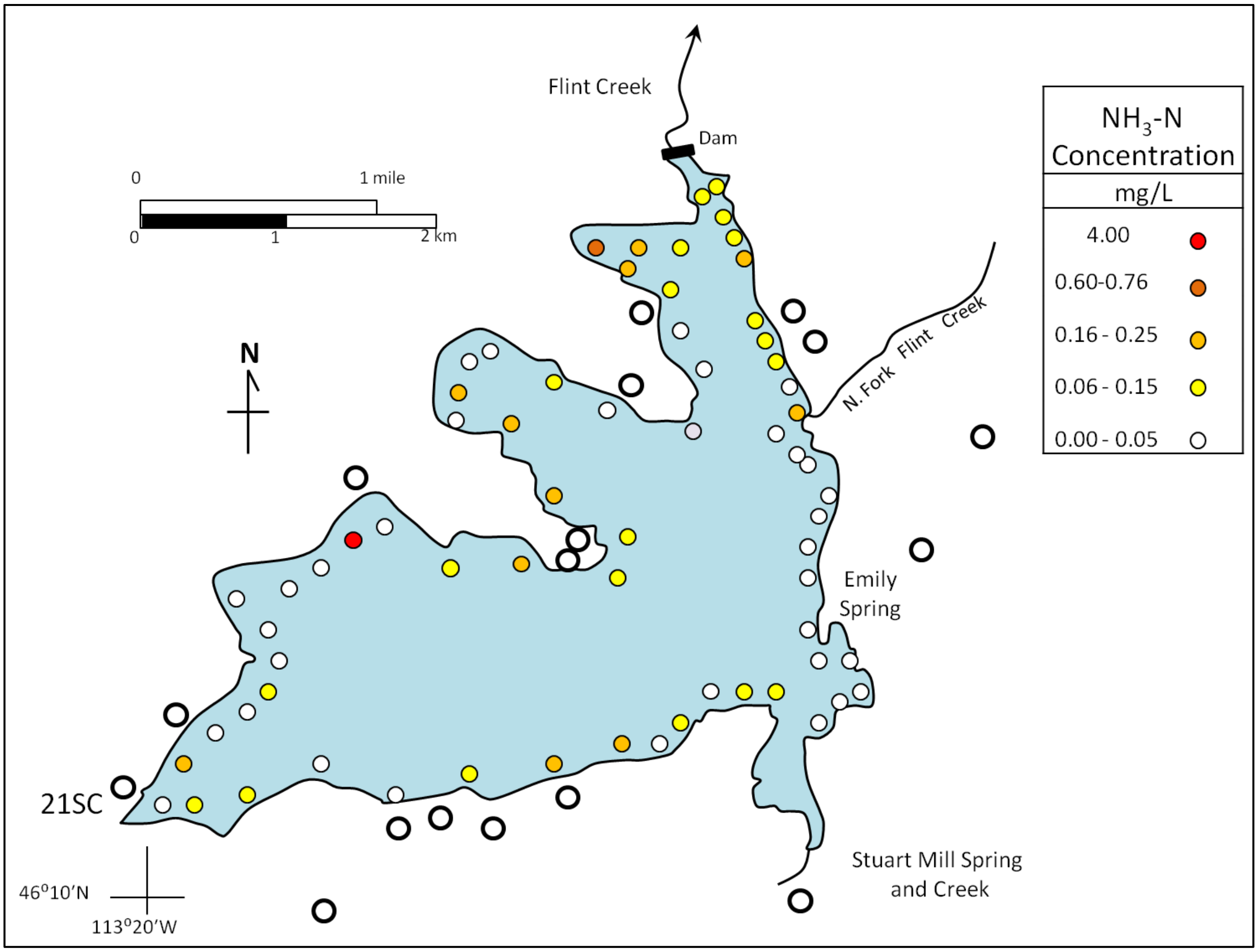

Figure 9: Spatial distribution of Ammonium concentrations around Georgetown Lake, Montana.

Student Fellowship: Development and Testing of a Model that Assesses the Effects of the Stress of Climate Change on Ecosystem Condition

Basic Information

Title:	Student Fellowship: Development and Testing of a Model that Assesses the Effects of the Stress of Climate Change on Ecosystem Condition
Project Number:	2011MT242B
Start Date:	3/1/2011
End Date:	2/28/2012
Funding Source:	104B
Congressional District:	At-large
Research Category:	Climate and Hydrologic Processes
Focus Category:	Climatological Processes, None, None
Descriptors:	
Principal Investigators:	William Kleindl

Publications

There are no publications.

2011MT242B William Kleindl Fellowship Final Report

Gretchen Rupp and Steve Guettermann 101 Huffman Building Montana State University Bozeman, MT 59717

RE: Fellowship Final report Dear Ms. Rupp: First, I would like to thank you for this fellowship. It has been very helpful during this phase of my PhD effort. During this fellowship funding period, over the last half of 2011, I have completed a watershed scale ecological conditional assessment of Glacier National Park. This publication is part of the National Park Service monitoring and assessment program and is intended to assist in prioritization of future monitoring and management efforts within the park:

> Kleindl, W.J., F.R. Hauer, B. Ellis, S. Kimball, K. Kunkel, P. Matson, C. Muhlfeld, J. Oyler, C. Servheen, K. Smucker. *In Review*. A Natural Resource Condition Assessment for Glacier National Park. Natural Resource Report NPS/XXXX/NRR—2011/0XX. National Park Service, Fort Collins, Colorado.

The Glacier effort has commanded the bulk of my time for the last year. Following the completion of that document I returned to the proposal I sent to you for this fellowship with fresh eyes and have refined and focused the theoretical and applied approach. I am focusing my study area to the Flathead system, using the wilderness area of the Middle and South Forks to devise metrics that measure the dynamic equilibrium of the riparian areas as affected by 30 years of natural land cover and climate change in the contributing basins. These metrics will then be applied to the anthropogenically altered North Fork. The hope is to devise a method to parse changes in riparian health resulting from climate from those of land use over the last 30 years using data from LandSat and climatic models. The timeline for completion is May 2013 and the proposed papers are:

> Kleindl, W.J., and F.R. Hauer. In Prep. Grain extent of conditional assessment models. Likely Published in: Environmental Monitoring and Assessment Likely Submission Date: June 2012
>
> Kleindl, W.J., B.L. McGlynn, M.C. Rains and F.R. Hauer. Proposed. Changes in stream hydrology over 30 years of climate and land use change. Likely Published in: Journal of American Water Resources Association Likely Submission Date: September 2012
>
> Kleindl, W.J., F.R. Hauer, J.S. Kimball, M.S. Lorang, and S.L. Powell. Proposed. Riverscape Stable States: Riparian Patch Dynamics across 30 Years of Climate and Land Cover Changes. Likely Published in: Ecology. Likely Submission Date: February 2013
>
> Kleindl, W.J., F.R. Hauer, M.S. Lorang, and M.C. Rains. Proposed. Parsing Landscape Scale Land Use Impacts from Climatic Change in Riparian Areas. Likely Published in: Journal of the North American Benthological Society. Likely Submission Date: May 2013

Student Fellowship: Population-scale effects of hypoxia on the distribution and abundance of fishes in Silver Bow Creek

Basic Information

Title:	Student Fellowship: Population-scale effects of hypoxia on the distribution and abundance of fishes in Silver Bow Creek
Project Number:	2011MT244B
Start Date:	3/1/2011
End Date:	2/28/2012
Funding Source:	104B
Congressional District:	At-large
Research Category:	Ecological Processes
Focus Category:	Surface Water, Nutrients, Toxic Substances
Descriptors:	None
Principal Investigators:	Joe Naughton

Publications

There are no publications.

Name.-Joseph P. Naughton, Montana State University, Department of Ecology, P.O. Box 173640, Bozeman, MT, 59717-3460.
Research Project Title.-Population-scale effects of hypoxia on the distribution and abundance of fishes in Silver Bow Creek

Project Objectives.-The goal of this project is to evaluate the effectiveness of Superfund remediation in reestablishing fish populations in the treated portion of Silver Bow Creek and to prioritize further restoration needs. Preliminary evidence suggests that remediation has substantially reduced heavy metal concentrations in Silver Bow Creek. However, ammonia pollution and summertime hypoxia may severely limit the recovery of fish populations in the stream.
Progress.-In 2011, data collection activities were completed for this project. I was pleased that we were able to increase the extent of our 2011 study area by 10 km without compromising the continuous sampling design of the previous year. In July, we completed spatially continuous electrofishing surveys throughout 37 km of Silver Bow Creek and the lower portions of two tributaries. During these surveys we PIT-tagged 888 fish, bringing our total to 3,277 fish tagged. In addition, we conducted four seasonal (April, May, September, and December) mobile antenna surveys throughout the mainstem sections (35 km). These mobile antenna surveys allow us to understand both fish movement patterns and seasonal changes to patterns of fish abundance. Additionally, we conducted six short (3-10 km) mobile antenna surveys intended to assess the efficiency of these survey methods. As in 2009 and 2010, five stationary antennas monitored fish movements at specific locations in the stream network from April to December. Habitat assessments of the study area were conducted in 2011. Synoptic water samples for monitoring dissolved oxygen, ammonia, and heavy metal concentrations were collected and analyzed every two weeks. A small grant from the Butte Greenway Service District provided funds to employ two additional water quality technicians, and to improve the frequency and detail of synoptic water sampling.
Preliminary findings.-As in 2010, we observed severe hypoxia in Silver Bow Creek, and there were few trout in corresponding stream sections. However, in stream sections adjacent to the hypoxic zone, trout abundance was greater in 2011 compared to 2010. Our data coupled with longer term monitoring by Montana Fish Wildlife and Parks suggests that overall trout abundance is increasing steadily in remediated stream sections that are not affected by hypoxia. In particular, westslope cutthroat trout populations appear to be recolonizing Silver Bow Creek. By extending the survey 10 km downstream into an unremediated stream section that is geologically unique, it was possible to investigate the effects of habitat complexity and heavy metal concentration on trout abundance. Results suggest that hypoxia is limiting trout abundance in Silver Bow Creek, and it appears that hypoxia is also affecting fish movement. A major challenge will be to understand how more subtle factors, such moderate variation in heavy metal concentrations and habitat complexity, may also affect fish abundance and movement.
Presentation of Results.-Results from 2010 sampling were presented at the 2011 AWRA conference in Great Falls. Findings from the more recent 2011 data will be presented at the American Fisheries Society- Montana Chapter conference in February 2012. I expect to complete my thesis and present finalized results in May or June 2012. Thesis chapters will focus on, 1) the seasonal fish distribution and abundance patterns in Silver Bow Creek and how these patterns are influenced by variation in water and habitat quality, 2) the overall fish movement patterns in the Silver Bow Creek stream network, and 3) the recolonization of Silver Bow Creek

by westslope cutthroat trout and other fishes.

Student Fellowship: An investigation of drought climatology, vulnerability and mitigation in the Clark Fork River Basin of Montana

Basic Information

Title:	Student Fellowship: An investigation of drought climatology, vulnerability and mitigation in the Clark Fork River Basin of Montana
Project Number:	2011MT245B
Start Date:	3/1/2011
End Date:	2/28/2013
Funding Source:	104B
Congressional District:	At-large
Research Category:	Climate and Hydrologic Processes
Focus Category:	Climatological Processes, Water Quantity, Water Use
Descriptors:	None
Principal Investigators:	Molly Smith

Publications

There are no publications.

Final Report for "An Assessment of Drought Climatology, Vulnerability, and Mitigation in the Clark Fork River Basin of Montana" by Molly Smith, 210 S. 5th St. W, Missoula, MT 59801.

Progress: The purpose of my research is to synthesize data on historic flow patterns, precipitation patterns; to assess water user perceptions of drought/water scarcity and how future drought/water scarcity can be mitigated; to assess how other Western states have addressed similar problems of future water scarcity/drought. Since last fall, I have made substantial progress towards completing my research objectives. While I still have a significant amount of work to do before my thesis will be completed, I am still on track with my research agenda.

My first objective, to synthesize historic flow/precipitation data, is still a work in progress. I have developed a list of resources where this data can be found, but my next task is to sort through this information and create a narrative describing past precipitation regimes. Originally I hadn't though about including a historic overview of drought mitigation policy in Montana, but that is something that I have decided to include. Developing a picture of past precipitation regimes and how Montanans have responded to such climactic variations will establish an in-depth and well-rounded context for my research and help the Clark Fork River Basin Task Force develop a drought mitigation plan that integrates lessons learned from the past.

My second objective, to assess perceptions of drought in the Clark Fork basin, is nearly complete. I have finished conducting interviews with water users and I'm now in the process of reviewing the recorded interviews to pull out key themes and observations. Emerging themes from these interviews include: desire for conversations on drought mitigation, despite the flooding last spring; that the Task Force is the proper entity to develop a drought mitigation plan; and that adaptive management is an important component of a future drought mitigation plan.

My third objective, to assess drought responses in other Western states, is nearly complete. I have finished conducting interviews with water managers and I'm now in the process of reviewing the recorded interviews to pull out key themes and observations. Many of these water managers expressed the importance of adaptive management and the need to shift the conversation from identifying the level of drought or climate change to thinking about climate variability and how people might adapt to the extremes of climate variation.

Key Lessons: I think it would have been really helpful for me to read, not just academic articles about drought and vulnerability in preparing to do this research, but also to read publications geared for a non-academic audience. I think this would have helped me gain a start to finish perspective that may have shaped or altered how I framed my research. For example:

Interview questions should be minimal and broad. People want to talk about water, and their concerns related to water issues; it doesn't take a lot of questions to get the conversation going. My questionnaire consists of 4 or 5 main questions, but lots of little probes. Going down each question makes the conversation feel really scripted (which it is); interviews that feel more conversational, and informative, are ones where I do more of the listening and only ask clarifying questions.

I am not an advocate for drought awareness. Early in the interview process, I struggled with situations where I'd ask people to talk about their drought related concerns only to find that they had none. In later interviews, I became much more aware of my role as the information gatherer; the attitude that I bring into the interview really shapes the dynamic of the conversation. Although a one-on-one interview is not a multi-party negotiation situation, I am still playing the role of a third-party facilitator and setting the tone for a confidential conversation.

Student Fellowship: Evaluating availability and use of coldwater thermal refugia for native and nonnative salmonids: implications for Arctic grayling conservation in Montana

Basic Information

Title:	Student Fellowship: Evaluating availability and use of coldwater thermal refugia for native and nonnative salmonids: implications for Arctic grayling conservation in Montana
Project Number:	2011MT246B
Start Date:	3/1/2011
End Date:	2/28/2012
Funding Source:	104B
Congressional District:	At-large
Research Category:	Ecological Processes
Focus Category:	Conservation, Ecology, Management and Planning
Descriptors:	None
Principal Investigators:	Shane Vatland

Publications

There are no publications.

Final Report for Shane Vatland, Montana State University

2011-2012 Water Center Fellowship Recipient

December 30, 2011

I made significant progress with my dissertation research in 2011. A majority of my efforts involved managing and analyzing a relatively large database of physical and biological data collected since 2007. Recently, I have been concentrating on refining my analyses, results, and manuscript/dissertation writing. As in previous years, I have continued to participate in professional society and graduate student activities (e.g., presenting research at professional meetings and participating as the graduate student representative in the Ecology Department). Below, I briefly summarized my research objectives, approach, general conclusions, and my future plans.

As outlined in my fellowship proposal, I had two general research objectives for my dissertation: 1) evaluate the spatial and temporal availability of coldwater thermal refugia in the upper Big Hole River watershed; and (2) compare and contrast the use of coldwater thermal refugia by native (Arctic grayling and mountain whitefish) and nonnative salmonids (brown trout, brook trout and rainbow trout). Past climate and stream monitoring data were collected to assess trends in summer air temperature, stream discharge, and stream temperature. To evaluate the present extent of suitable thermal habitat, stream temperatures were surveyed with a combination of remote sensing (thermal infrared-TIR), continuous longitudinal temperature profiling, and fixed-station water temperature loggers. Thermal infrared imaging and continuous longitudinal profiling were cost-effective methods for evaluating explicit spatial patterns in temperature data at multiple spatial scales, and fixed temperature loggers enabled an explicit evaluation of temporal variation in stream temperature. Using this combination of data, I characterized the distribution of thermally suitable habitat during the summer and identified associated habitat attributes (e.g., riparian vegetation, channel morphology, and discharge). Suitable thermal habitat was patchily distributed throughout the study area, and cold-water tributaries likely provide critical cold-water thermal refugia. These spatially and temporally explicit thermal data were incorporated into statistical stream temperature models, and future changes in thermal habitat were assessed based on regional climate change predictions. Under scenarios of increasing and more variable summer air temperatures, I predicted a significant increase in the occurrence of stream temperatures that exceed chronic and acute thermal tolerance thresholds for salmonids. Evaluating spatial patterns in observed and predicted stream temperatures allowed me to identify areas critical to maintaining suitable coldwater habitat in the future.

I plan to complete my doctoral degree program at MSU by the end of this spring semester. Upon completion, I plan to continue my research efforts in fisheries ecology as a postdoctoral fellow at a national research institute in Thonon les bains, France, where I will be collaborating with research scientists and graduate students on applied freshwater fish ecology questions. I am particularly excited about the opportunity to work with brown trout in their native range (as compared to working with brown trout in their introduced range here in Montana).

Student Fellowship: Effects of the mountain pine beetle on snow hydrology in Montana

Basic Information

Title:	Student Fellowship: Effects of the mountain pine beetle on snow hydrology in Montana
Project Number:	2011MT247B
Start Date:	3/1/2011
End Date:	2/28/2012
Funding Source:	104B
Congressional District:	At-large
Research Category:	Climate and Hydrologic Processes
Focus Category:	Climatological Processes, Water Quantity, Hydrology
Descriptors:	None
Principal Investigators:	Chris Welch

Publications

There are no publications.

Snowpack Changes Caused by Mountain Pine Beetle Montana
Final Fellowship Report
Chris Welch, Montana State University

Our efforts to study the change in snowpack dynamics caused by Mountain Pine Beetle infestation in Tenderfoot Creek Experimental Forest have spanned a year and we are embarking on the second winter. In 2011, with the copious amount of snowfall, our instruments provided us with a plethora of snow accumulation and melt data. The season also provided an outlook on improvements that could be made to logistics, instrumentation, and data collection. We have kept busy this fall season revamping systems, analyzing current data and preparing for the upcoming winter.

In October and November of 2010 we installed one micrometeorological station including full energy budget instrumentation in a subcanopy location with impending beetle attack. This station also included instruments measuring snow pressure, snow CO2 flux, snow depth, and snow surface temperature. A snow density profile was performed monthly in the adjacent area within a 30 meter radius. Additionally, the tower is 30 meters from another tower with full energy budget instrumentation above the forest canopy that is being operated by the MSU Watershed Hydrology Lab under Dr. Brian McGlynn. A snow temperature ladder was also installed by the McGlynn group in October.

A similar micrometeorological tower already exists in a clearcut with approximately the same elevation and aspect. We added Snow depth, snow CO2 flux, and snow pressure instrumentation. A snow temperature ladder was also installed by the McGlynn group in this location. Snow density profiles were made monthly here as well.

One of the first logistical challenges we faced included finding a representative site that had already experienced beetle attack. However, we found a suitable stand that was in the red phase of canopy degradation near quartzite ridge. Although elevation and slope is similar to the other two sites, we had to settle for a change in aspect. This will no doubt have a pronounced effect on the amount of incoming solar radiation, but not without useful comparisons. In February and March of 2011, we constructed a temperature ladder and a small tower to measure Net radiation and snow surface temperature in this beetle infected stand.

In December of 2011, we added another tower in a healthy stand adjacent (<35 meters) to the tower near Quartzite ridge to provide more direct comparisons. This new, 'healthy' site includes the same instrumentation found at the beetle infected site. Air temperature and relative humidity (T/RH) measurement capabilities were added to this site, with the assumption that T/RH will not vary significantly between the two sites, as they are less than 35 meters apart.

As these sites provided time series data, snow courses were taken monthly to capture some of the variability across space. These course locations were chosen to compare how slope, elevation, and aspect can affect snow depth and snow water equivalent. In the fall of 2011, robust litter baskets were installed in many of these snow course locations. Litter baskets were also installed around the forested instrument stations.

Our outlook for this upcoming winter is positive, with logistics and all instrumentation running smoothly thus far. Setbacks from last year include brief power outages and instrument failure. However, one advantage to holding our study in TCEF includes the instrumentation of other research projects and SNOTEL sites that hold as reference sites to crosscheck meteorological events. We feel confident these setbacks will have little effect on the overall study, and more importantly, have provided insight on how to better prepare for this upcoming winter season.

At this point, my focus has shifted from field preparation to data analysis.

Information Transfer Program Introduction

Supporting students to become water science professionals is a core mission of the Montana Water Center. To that end, the center worked closely this year with faculty researchers to engage students in water-related research, and subsequent reports and published papers. Center staff frequently encouraged aquatic science, engineering and students in related disciplines to apply for student fellowships. This outreach increased the diversity of students with whom the center worked. Faculty researchers who received research funding from the Water Center are required to actively mentor students in the research projects. The Water Center also encouraged students engaged in water resource studies to present at conferences. The list of presentations and publications of faculty and students attests to the support given to students to both take on research and also present it at local and national meetings as well as follow through to publication in national journals.

In addition to working with faculty and students, Water Center programs reached thousands of other water resource professionals, teachers, farmers, ranchers, engineers, drinking water and wastewater system operators and other professionals throughout the state. Specific information transfer activities include the following.

* Published twelve Montana Water e-newsletters and distributed them monthly to almost 2,000 professionals, students and decision makers concerned with water resource management. Newsletter archives are posted at http://water.montana.edu/newsletter/archives/default.asp.

* Continued the web information network MONTANA WATER, at http://water.montana.edu. Known as Montana's clearinghouse for water information, this website includes an events calendar, news and announcement updates, an online library, water-resource forums and water source links, an expertise directory, water facts and more.

* With Federal stimulus money administered through the Montana Department of Natural Resources and Conservation, has completed production of seven water science training modules for local Montana elected officials and state legislators. Surveys show that often decision makers are asked to make decisions that impact water quality and quantity, but frequently have no or little education, or understanding of, basic hydrology or other relevant water science topics that might be helpful for them to make informed decisions. These modules help fill some of the gaps. Its major topics are 1) wetlands, 2) water quality, 3) basic hydrology, 4) floodplain and riparian zone management, 5) Montana land use changes and water resources, 6) water data and modeling and 7) Montana water law. Three modules have been presented via webinars and other trainings, including a hydrology training to state legislators early in the 2011 legislative session. The four other modules are in the final stages of production and webinars and live trainings are being scheduled.

* With funding from the EPA, the Montana Water Center completed production of training CDs for small drinking water systems titled Arsenic and Radionuclides: Small Water System Treatment Experiences. The Center worked with five drinking water systems to profile their issues of choosing treatment protocols and the subsequent operating of their systems to meet drinking water standards for arsenic or radionuclides. The purpose of the training is to enhance the technical capacity among small water utility personnel and those who provide technical assistance, funding or regulatory oversight; provide a better understanding of the advantages and pitfalls of various options for dealing with source waters having elevated concentrations of arsenic or radionuclides and mitigation of hazard from treatment residuals.

* Maintained and circulated a small library of paper documents related to Montana water topics.

* Held a state water meeting with the Montana Section of the American Water Resources Association in Great Fall, MT on October 6-7, 2011. The theme of this conference was Montana's Water Resources: Adapting to Changes in Supply and Demand. A field trip led by Montana Bureau of Mines and Geology researchers and a

private engineering firm concentrated on the Ten Mile Creek area, an area negatively impacted by historic mining and which is being reclaimed. The conference attracted over 175 Montana researchers and policy makers and 25 students. Over forty researchers presented information on their latest findings along with nearly 30 poster displays. The web-based archive of this meeting is found at http://awra.org/state/montana/events/conf_archives.htm.

*Scheduled two webinars in it Decision-Maker's Guide to Montana's Water series. Montana Hydrology was presented on September 14, 2011, and Floodplains and Riparian Issues was presented September 28, 2011. There are seven courses in this series which is designed to help local-government officials understand the physical and biological processes at work, basic law and regulations, and what their responsibilities are regarding the water resources in their jurisdictions.

* Responded to numerous information requests on water topics ranging from invasive aquatic species to water rights to streamside setbacks to contaminants and pollutants in Montana's surface and ground water, and ways to better manage ground and surface water.

* Assisted elected and appointed officials, particularly those serving on the Montana Legislative Environmental Quality Council, the Water Policy Interim Committee (WPIC), and the Governor's Drought Advisory Committee, with water resource issues.

* Sponsored and participated in Montana's 77th Annual Water School October 2011 at Montana State University for 300 staff members of water and wastewater utilities. The school primarily helps prepare new system operators to pass the certification exam, and familiarizes participants with other resources they may find helpful in the future.

* Created and distributed 1,500 copies of the black-and-white Montana Water 2012 calendar to elected officials, water resource managers and other partners and supporters. Designed to educate the public about water issues and aquatic life, photographers from all over the state contributed to the calendar.

* The Montana Watercourse, which is part of the Montana Water Center, provides comparable outreach to watershed groups, teachers, developers, realtors and landowners. The Watercourse continued to provide the following services and trainings in 2011. - Volunteer water monitoring training for communities and schools - Assistance with local water education program development - Publications and guides on water resource and watershed topics, for example, Guide to Montana Water Management-Who Does What with the Water Resources, and Montana's Groundwater A Citizen's Guide to Understanding and Protecting Ground Water. - Teaching trunks filled with interactive water resource activities - Educator workshops, trainings and tours using Project WET and other curricula and materials - Direct support of landowners on such things as groundwater education, preventing nonpoint source pollution and other water quality issues. - Helping teacher, student and citizen volunteers monitor Montana's waters

Statewide Education and Outreach

Basic Information

Title:	Statewide Education and Outreach
Project Number:	2011MT250B
Start Date:	1/1/2011
End Date:	2/28/2012
Funding Source:	104B
Congressional District:	At-large
Research Category:	Not Applicable
Focus Category:	Education, Water Quality, Water Quantity
Descriptors:	None
Principal Investigators:	Steve Guettermann

Publications

There are no publications.

Final Report for Project 2011MT 250B. Stephen Guettemann, Principal Investigator

The Montana Water Center with many partners conducts conferences and events that disseminate the latest research findings on water resources and management. It also develops on-the-ground and on-the-web outreach channels on water information for decision-makers, scientists, water resource managers, K-12 educators and the general public throughout the state. It stays in contact with water management approaches from other states that could hold promise in Montana. These approaches have been presented at conferences and professional gatherings the Water Center sponsors. Stephen Guettermann, Assistant Director for Education and Outreach of the Montana Water Center throughout 2011 was instrumental in fulfilling the Water Center's role in most of these activities.

In 2011 Guettermann functioned within most of the activities presented in the Introduction to Information Transfer presented in this Annual Report. He was often assisted by the student funded by this project. To offer a few examples:

* He developed or acquired most of the information and Feature Topics published in the Montana Water e-newsletters which is distributed monthly to almost 2,000 recipients.

* He developed much of the material used in the web information network MONTANA WATER.

* He helped develop the seven water science training modules for local Montana elected officials and state legislators. The major topics of these modules were 1) wetlands, 2) water quality, 3) basic hydrology, 4) floodplain and riparian zone management, 5) Montana land use changes and water resources, 6) water data and modeling and 7) Montana water law.

* He helped generate materials used in a small library of paper documents related to Montana water topics which is circulated.

* Working with the officers of the Montana Section of the American Water Resources Association and using Water Center personnel including the student funded by this project, he helped plan and facilitate a very successful conference of the Section in Great Fall, MT on October 6-7, 2011 which had over 175 participants.

* He was instrumental in the success of two webinars in it Decision-Maker's Guide to Montana's Water series on hydrology and floodplains.

* Working with faculty from Montana State University Department of Civil Engineering and a faculty member from Montana Northern, he helped develop Montana's 77th Annual Water School in October 2011 at Montana State University for 300 staff members of water and wastewater utilities.

Stephen Guettermann resigned from the Montana Water Center at the end of 2011.

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	3	0	0	0	3
Masters	5	0	0	0	5
Ph.D.	4	0	0	0	4
Post-Doc.	0	0	0	0	0
Total	12	0	0	0	12

Notable Awards and Achievements

Publications from Prior Years

1. 2009MT189B ("Tracking Human-Derived Nitrogen through Stream Food Webs in a Rapidly Developing Mountain Watershed") - Articles in Refereed Scientific Journals - Gardner, K.K., B.L. McGlynn, and L. Marshall. 2011. Quantifying watershed sensitivity to spatially variable N loading and the relative importance of watershed N retention mechanisms. Water Resources Research. W08524, doi:10.1029/2010WR009738.
2. 2009MT189B ("Tracking Human-Derived Nitrogen through Stream Food Webs in a Rapidly Developing Mountain Watershed") - Articles in Refereed Scientific Journals - Covino. T.P., B.L. McGlynn, and R. *McNamara. 2012. Land use / land cover and scale influences on in-stream nitrogen uptake kinetics. Journal of Geophysical Research - Biogeosciences. doi:10.1029/2011JG001874.
3. 2009MT189B ("Tracking Human-Derived Nitrogen through Stream Food Webs in a Rapidly Developing Mountain Watershed") - Articles in Refereed Scientific Journals - Mason, S.J.K., B.L. McGlynn, and G.C. Poole. 2012. Journal of Hydrology 438 439:125 136
4. 2009MT189B ("Tracking Human-Derived Nitrogen through Stream Food Webs in a Rapidly Developing Mountain Watershed") - Articles in Refereed Scientific Journals - Piper, L., B.L. McGlynn, and W. Cross. In preparation. Toward quantifying kinetics of coupled nitrogen and phosphorus uptake in stream ecosystems. Journal of Geophysical Research Biogeosciences.
5. 2009MT189B ("Tracking Human-Derived Nitrogen through Stream Food Webs in a Rapidly Developing Mountain Watershed") - Articles in Refereed Scientific Journals - Piper, L., W. Cross, and B.L. McGlynn. In preparation. Early indicators of human influence on stream ecosystems across a developing mountain watershed.
6. 2009MT191B ("Quantification of Coal-Aquifer Baseflow in Montana Rivers Using Carbon Isotopes") - Articles in Refereed Scientific Journals - Meredith, E.L., and S.L. *Kuzara. In press, Identification and quantification of baseflow using carbon isotopes. Ground Water.
7. 2010MT216B ("Ecohydrologic Model Development for the Assessment of Climate Change Impacts on Water Resources in the Bitterroot Valley") - Articles in Refereed Scientific Journals - Maneta, M. P., Wallender, W. W. Pilot-point based multi-objective calibration in a surface-subsurface distributed hydrologic model. . Hydrologic Sciences Journal. Submitted Jan, 2012
8. 2010MT216B ("Ecohydrologic Model Development for the Assessment of Climate Change Impacts on Water Resources in the Bitterroot Valley") - Articles in Refereed Scientific Journals - Maneta, M. P., Silverman, N. A spatially-distributed model to simulate water, energy and vegetation dynamics using information from regional climate models. Environmental Modelling and Software, submitted May 2012
9. 2005MT62B ("STUDENT FELLOWSHIP: Environmental conditions associated with the extent and composition of woody riparian vegetation within the West Fork of the Gallatin River watershed") - Articles in Refereed Scientific Journals - Shoutis, L., D. T. Patten, and B. McGlynn. 2010. Terrain-based predictive modeling of riparian vegetation in a northern Rocky Mountain watershed. Wetlands 30(3):621-633.