Report as of FY2006 for 2006ND125B: "Effect of flow path processes on the geochemistry and quality of water discharged along the seepage face at Pigeon Point, Sheyenne delta aquifer, Ransom County, North Dakota"

Publications

- Water Resources Research Institute Reports:
  - Gerla, Philip J. and William Lenarz, 2007, "Effect of Land Cover and Pattern on the Quality of Groundwater Discharged from Springs and Seeps at Pigeon Point, Southeastern North Dakota", Technical Report ND07-01, North Dakota Water Resources Research Institute, North Dakota State University, Fargo, North Dakota.
- Conference Proceedings:
  - Lenarz, William and Philip J. Gerla, 2007, "Effect of Land Cover and Pattern on the Quality of Groundwater Discharged from Springs at The Nature Conservancys Pigeon Point Preserve, Southeastern North Dakota", Third International Water Conference, International Water Institute, Grand Forks, March 13-15.

Report Follows

EFFECT OF FLOW PATH PROCESSES ON THE GEOCHEMISTRY AND QUALITY OF WATER DISCHARGED ALONG THE SEEPAGE FACE AT PIGEON POINT, SHEYENNE DELTA AQUIFER, RANSOM COUNTY, NORTH DAKOTA

DESCRIPTION OF THE CRITICAL STATE OR REGIONAL WATER PROBLEM TO BE INVESTIGATED

The proposed focuses on the relationship between land use, infiltration processes, and the quality of water discharged along the expansive seepage face at Pigeon Point, an area of springs and fens in the Sheyenne delta aquifer. Interestingly, the lowest seeps, suggesting longest pathlines, have the least mineralized water (350 uS/cm) while springs and seeps at higher elevation reveal increasing mineralization (500 uS/cm). Results of the work will address the following questions:

• The Sheyenne delta aquifer constitutes an important source of high quality groundwater in southeast North Dakota and may provide water for Fargo in the future. To what extent doesgeomorphology and land cover influence infiltration, recharge, and groundwater quality in the Sheyenne delta aquifer?

• What are the vadose and phreatic processes that result in changes to hydrogeochemistry of water along a flow path?

• Why do shorter groundwater pathlines that discharge at the Pigeon Point seepage face produce more mineralized water? How is the greater mineralization reflected in relative concentrations of cations and anions?

• How might future land use changes influence the quality of groundwater discharged in the Pigeon Point nature preserve? How can other parts of the Sheyenne delta aquifer be managed to best protect groundwater quality?

SCOPE AND OBJECTIVES OF THE PROPOSED RESEARCH

The goal of this research project is to determine changes in groundwater quality along aquifer pathlines that discharge at the Pigeon Point seepage face, Ransom County, North Dakota. The objectives are:

(1) characterize the infiltration characteristics of soils in the recharge/capture zone,
(2) document the changes in the composition of infiltrating water as a function of depth, soil type/geomorphology, and land cover, and
(3) explain the reason for spatial variability of hydrogeochemistry across the site.

The proposed study area covers about six square kilometers within the recharge/capture zone of Pigeon Point, which lies along the south side of the Sheyenne River where it transects the Sheyenne delta aquifer (Figure). The landscape and surficial geology of this area was developed by glacial deposition during the Wisconsinan glacial period, especially due to the formation, deposition, and eventual draining of glacial Lake Agassiz. During the period of time that glacial Lake Agassiz was at the Herman and Campbell levels, approximately 11,000 to 13,000 years ago, the Sheyenne Delta formed in eastern Ransom County. The delta likely resulted from large load deposition as the Sheyenne River emptied into glacial Lake Agassiz. Well-sorted sand dunes comprise the southern portion of the Pigeon Point site, with fluvial-lacustrine fine sands lying northward, which are eroded and exposed along the Sheyenne River.Till underlies most of the site at a depth ranging from 20 to 30 meters. Within the Pigeon Point area there is an extensive seepage face comprised of springs and fens. Eight major springs at the seepage face coalesce to form four small, perennial streams that flow into the Sheyenne River. Fens, or groundwater-fed wetlands, occur along nearly the entire seepage zone. These wetlands slope northward and host several rare and unusual boreal plant species, which do not occur elsewhere in North Dakota or at any locations farther south than Pigeon Point.

METHODS, PROCEDURES, AND FACILITIES

At the site there are two wells in place that can be used for sampling groundwater. Six shallow
wells and eleven soil-water samplers in three nests across the study area have been installed along a single selected pathline. One of the nests was placed in the dunes toward the southern border of the study area, while the other two nests were placed in the pasture and restored prairie down-gradient near the seepage face and the Sheyenne River. The placement of the three nests allows for synoptic collection of the soil water and groundwater within spring and seep capture zone. Either The Nature Conservancy or the U.S. Forest Service, Sheyenne National Grassland, owns the area encompassed by the study site. There is land under private ownership bordering the study site, but this study can be conducted without accessing these areas.

Within each of the three nests, soil-water samplers were installed at different depths depending on the water table depth and the thickness of the root zone. Because of large infiltration and recharge rates in the dunes, the water table tends to be very shallow (< 1.5 m) in small intra-dune basins. Samplers were placed at the following depths: 0.7, 1.0, 1.5 m. In all cases, samplers were placed beneath the densest root zone to help assure collection of deeply infiltrating water. The ceramic cup of the samplers was packed with 200-mesh silica flour and when water samples are collected, the sampler is evacuated at approximately -0.4 MPa (-60 psi) and sampled 6 to 12 hours later.

Three-foot, 1-¼ inch stainless steel well points with galvanized steel casing were driven about one-two meters below the water table for sampling groundwater. In addition to the samples that are collected from the three nests, each of the two wells already in place supplement the samples collected from each nest. To complete the water sample collection, samples from each of the six largest springs along the seepage face are also collected for analysis.

During the course of the research project, there will be three sampling periods. Each of these sampling periods will take place during a different season to determine if groundwater quality and chemical transport vary across/through the study area. The seasonal samples will also illustrate how dissolved constituents in groundwater change during different times of the year, and how concentrations vary throughout the year. The first round took place in October. The second round of sampling will take place in April to sample water influenced by the spring thaw and winter run-off. The final sampling will take place in mid to late summer when drier conditions are likely, providing a different view of concentrations and oxidation/reduction. This sampling period will ideally take place after significant precipitation in order to study infiltration and chemical transport during a wet pulse following the growing season.

During each sampling period, standard operating procedures for the collection and preservation of groundwater samples for chemical analysis will be followed, as set forth by the North Dakota State Department of Health (field sampling protocol report published in 1995). These methods will be supplemented with the following ASTM standard guides:

D4696-92(2000) Pore-Liquid Sampling from the Vadose Zone
D5903-96(2001) Planning and Preparing for a Groundwater Sampling Event
D6517-00 Field Preservation of Ground-Water Samples
D6564-00 Field Filtration of Ground-Water Samples
D6634-01 Purging and Sampling Devices for Ground-Water Monitoring Wells

While in the field, samples are measured for temperature, pH, conductivity, and dissolved oxygen. After collection, the samples are transported to the Environmental Analytical Research Laboratory (EARL) on the University of North Dakota campus in Grand Forks for further analysis.

The analytical work done in the EARL lab comprises a large portion of the project time and expense. Using the equipment in the lab, and knowledge already obtained in the operation of this analytical equipment, a large expense has been saved by personally analyzing all samples instead of having them sent out for analysis. The three main analytical methods used will are flame atomic absorption spectrometry (FAAS), total organic carbon analysis (TOC), and ion chromatography (IC). The flame atomic absorption spectrometer is used to analyze samples for major cations, including calcium, magnesium, and sodium; the ion chromatograph is used to analyze for these major anions: chloride, sulfate, and nitrate, while the TOC carbon analyzer is used to analyze samples for both total organic carbon and inorganic carbon.

Oxidation-reduction conditions likely control the variability in groundwater composition. The upper parts of the seepage face shows discharge of groundwater with elevated Fe concentration, suggesting reducing conditions. Pathline analysis strongly suggests that recharge of these waters takes place within nearby wetlands and soils with a well-developed, organic-rich A-horizon. Lower springs, which may be more oxidizing, receive water from dunes. Because of disequilibrium and multiple redox couples, redox probes will likely have little value (e.g. Lindberg and Runnells, 1984). Instead, we propose to track qualitatively redox conditions at the sample site by analyzing directly pumped and filtered groundwater for DO, nitrate, iron, and manganese using a portable spectrophotometer. Results should be sufficient to use pE-pH diagrams to show the spatial variability of redox.

In conjunction with soil water and groundwater sampling and analysis, work to better understand the physical conditions of infiltration and recharge will be completed during the project. At and near the instrumentation sites, matric potential, moisture content, and soil permeability will be estimated using transducer tensiometers, portable time-domain reflectometry surveys, and a disk infiltrometer. Significant differences in hydrology between different land cover, slope, and aspect are anticipated. These data will be used to create basic numerical models of infiltration and recharge using the USDA Salinity Laboratory's HYDRUS-2D code. Equipment and software for this work is available from UND and The Nature Conservancy.

Interpretation:

When the water samples from each of the sampling periods have been analyzed in the laboratory, the results will be interpreted in relationship to the infiltration, recharge, and groundwater flow processes. The analytical results will reveal the chemical mass and redox changes as water flow through the vadose zone and along the flow path to the springs. By examining the results from each of the three sampling periods, we will be able to determine the spatial and temporal control on groundwater ionic and redoxchemical signature. Through these interpretations, we will better understand the hydrogeochemical processes that lead to the water quality in the springs and the aquifer as a whole.

ANTICIPATED RESULTS AND BENEFITS FROM THE PROPOSED STUDY

Through the analysis of the water samples taken from across the site at the different times of the year, it will be possible to develop a conceptual model of the hydrogeochemistry that leads to the groundwater quality in the springs and seepage face, and for the aquifer as a whole. The benefit of this will be a better understanding of physical and geochemical processes operative in this portion of the Sheyenne delta aquifer, and how these may influence the water quality within both the Sheyenne River and the Sheyenne delta aquifer. In addition, the apparent reversed pattern of elevation and dissolved solids found in the seepage face will be explained. This type of situation may benefit understanding of the environment surrounding seepage faces and fen-producing environments. The study can benefit downstream cities, such as Fargo, as they continue to search for options to enhance the municipal supply of high quality water. Understanding the relationship of land cover and land use to hydrogeochemistry will be crucial in balancing the fresh water needs of society, agriculture, and the natural habitat in the unique Sheyenne delta ecosystem. In addition to these results, the work will lead to the completion of a master’s degree at the University of North Dakota.

PROGRESS TO DATE

This project officially started during the spring 2005 semester. Research began with a literature review of relevant articles to the study environment, types of sampling procedures and analyses, and chemical redox processes. Throughout the spring 2005 semester, the approach to the field work was continually refined until the current layout was selected. It was finally determined that three instrument nests would be necessary to successfully sample the water moving along a pathline through the Sheyenne delta aquifer. Supplies were purchased and collected during the months of May, June, and July. During a period of three weeks in August all of the sampling and monitoring instruments were installed in compliance with the research outline. Continued site development was continued during the month of September to ensure that a successful sample collection would take place in October. During the month of September there was also sediment collection at each of the three instrument nests. Using a hand auger, sediment samples were collected from the ground surface to the top of the water table. The sediment samples that were collected will be used to determine overall grain size changes across the study site. This information will be useful when studying the infiltration rate of surface water to the aquifer across the study site. On October thirteenth the first sampling took place. Over the two weeks following the sample collection, the water analyses took place in the EARL lab on the UND campus. The water analyses of the first water samples have been completed.

An initial observation of results from the water analyses clearly illustrates a general trend of reducing environments moving from south to north towards the Sheyenne River. Beginning at the instrument site situated in the dunes on the southern most portion of the study site and moving north along the pathline through sites two and three, the following observations can be made:

- The level of dissolved oxygen decreases from site one to site three.
- Manganese levels increase steadily from site one to site three.
- Iron is virtually undetectable at sites one and two, but appears at site three.
- Chloride and calcium both increase steadily from site one to site three.
- Potassium and sodium rise only slightly from site one to site three.
- The level of total carbon and inorganic carbon nearly double from site one to site three
- The level of total carbon and inorganic carbon is significantly different between the spring samples collected at higher elevations (Springs 1-4) compared to the spring samples collected at a lower elevation (Spring 5-6).

Based on the observations made above, it is clear that there is a more reduced environment closer to the springs and the Sheyenne River. This initial sample collected and interpretation supports the idea that the water flowing from the springs at the higher elevation is indeed coming from a more reduced environment. In addition, the more reduced water samples collected at the higher elevation springs lends support to the hypothesis that the recharge area for the higher springs is closer to the springs themselves, while the recharge area for the lower springs (more oxidized) is likely coming from further away in the dunes. Additional sample collection in April and July will provide additional results to further support the results from the first sample collection.

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