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Brine Contamination to Prairie Potholes from Energy Development in the Williston Basin: a Developing Integrated Science Project

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Project Background

In the United States, the Williston Basin occupies 143,000 square miles and includes portions of Montana, North Dakota, and South Dakota. Superimposed over this landscape is the Prairie Pothole Region (PPR) which includes critical wetland and grassland habitats of importance to breeding, nesting, and migrating waterfowl, and wetland and grassland birds. A potential impact of oil field activities on these important habitats is brine contamination from co-produced waters that leach from oil well reserve pits, injection wells, and transport lines. Previous studies have identified contamination of wetlands and groundwater resources, including drinking water aquifers, located on U.S. Fish and Wildlife Service (USFWS), tribal, and public lands, and numerous groups have expressed concern over the potential risk of contamination. Currently, the extent of such contamination across the Williston Basin is unknown, and there is a need for scientific-based information to assess this threat.

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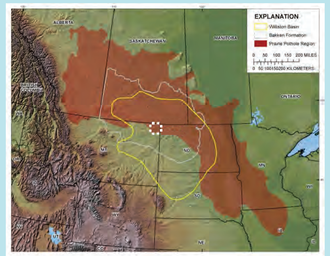


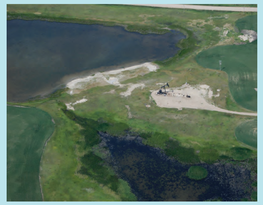
Objectives

The USGS has placed a focused effort on providing a comprehensive understanding of the Nation's energy and mineral resources and the environmental effects of their use. In response to this, a collaborative effort between scientists from Northern Rocky Mountain Science Center, Northern Prairie Wildlife Research Center, and Montana Water Science Center initiated work to gather spatial datasets to identify areas most at risk to contamination, assess the spatial extent of past and current oil well development, and assess the potential impacts on aquatic resources in the Williston Basin.

Currently, the team has located thousands of permitted oils wells in northeastern Montana and northwestern North Dakota. Wetlands and oil wells are often in proximity to each other throughout the area where the Williston Basin overlaps the PPR, and preliminary analysis in a representative drainage area in Montana indicated that there were 80 wetlands with oils wells within 50 meters of their edge.

Additionally, the team has worked with county, state, and federal agencies to identify agency needs related to specific research objectives which include.

1. Evaluate the spatial extent and potential risk to natural resources of past and on going energy development in the Williston Basin using Geographic Information System (GIS) analyses
2. Reassess brine contamination movement in pilot areas
3. Conduct a user needs analysis and design a prototype decision support system
4. Establish an Interagency Energy Contamination Science Team



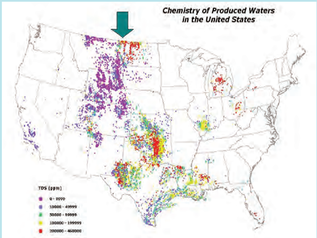
Brine salt scar in Medicine Lake National Wildlife Refuge (white area left of stuctures)

Produced Waters

Formation waters having high salinity that are coproduced with oil and gas resources

Produced water can enter the shallow groundwater system through spills, pipeline breaks, disposal pits or reserve pits created during drilling

Reserve pits, dug at **each oil well** to hold drilling muds and produced water, typically measure 150 ft x 60 ft x 10 ft and may contain **260 tons of salt**



Project Scope and Objectives

Scope

Field work will primarily focus on previously studied sites within the PPR and Williston Basin portions of Montana, North Dakota, and South Dakota. However, spatial analyses will include an assessment of all critical habitats within the entire Williston Basin. Likewise, efforts to develop decision support tools and to establish an Interagency Contamination Science Team will bring together stakeholders with an interest in environmental risks associated with oil production in the Williston Basin.

The initial focus will be on the Northeast Montana, Crosby (ND), and Lostwood (ND) Wetland Management Districts and their nearby national wildlife refuges, like Medicine Lake NWR (MT), Lostwood, Lake Zahl, and Des Lacs (ND) NWRs.

Methods

By studying sites previously examined by the USFWS, Montana Bureau of Mines and Geology (MBMG), and the USGS, the team will be able to determine the extent of oil brine contamination. This will include the collection of new data as part of this study, use of existing data that will be made available from cooperators, and use of proven scientific methodologies and extending their use to suit project needs. The team will also evaluate the needs of those who will use the data to develop appropriate and useful decision support system tools that help them assess the risk from energy development to the natural resources with which they are entrusted, especially wetlands that are part of National Wildlife Refuges.

Natural vs. Produced Water Chemistry

Natural Surface Waters

- Enriched in Na, Mg, SO and HCO
- Cl concentrations are minimal, often < 10 ppm
- Natural saline wetlands are sulfate and carbonate dominated

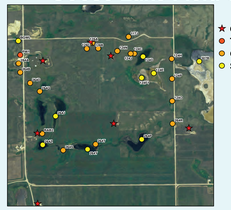
Produced Waters

- Enriched in Na and Cl
- Alkali chlorides and alkali earth chlorides comprise 90-99% of TDS
- Impacted wetlands are chloride dominated

This region contains many naturally saline wetlands with elevated Total Dissolved Solids (TDS). Reiten defined a Chloride Index (CI) as the ratio of chloride (mg/L) to the specific conductance (uS/cm) of water to detect brine contamination. Water samples in the study region with a CI above 0.035 are considered to be contaminated by produced waters.

Goose Lake Field Site

Goose Lake Field Site



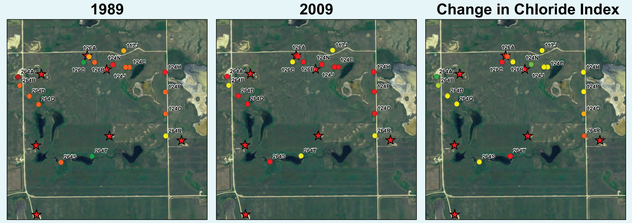
Defined as T36N, R58E Sec 27 and adjacent areas: the Rabenberg WPA is the southern half section

Located at the contact between glacial till and glacial outwash, the site is composed of roughly 40 ft of collapsed outwash overlying fractured till

Potential produced water sources in the study site:
Hammer M Battery (PW1) used for 45 years for produced water storage from mulitple wells

Abandoned and active oil wells (about 1000 in the county) within and adjacent to the section drilled in the 1960's

Chloride Index



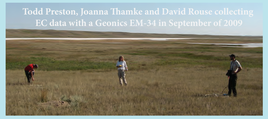
From the Chloride Index maps, two major temporal changes can be observed. First, in 1989 there were two groundwater wells, 126C and 264T, that were classified as uncontaminated. These wells exhibited contamination from produced waters in 2009. Second, sampled areas to the west generally show decreases in the Chloride Index while sampled areas to the east show a general increase. This is interpreted as a flushing of the system as the highly saline water moves down gradient through the underlying shallow sand and gravel aquifer towards the east.

Geophysical Surveys

Electrical Conductivity

- Measures electrical properties of soils and pore fluids in the saturated and vadose zone
- Excellent tool for delineating contaminated groundwater plumes due to the high conductivity of salts
- The EM-31 can determine the lateral extent of contaminant plumes, but is limited to an exploration depth of 3-4 meters
- EM-34 utilizes multiple coil orientations and spacings to provide lateral extent data and three exploration depths between 7-60 meters, providing depth profiles of plumes

Jon Reiten collecting EC data with a Geonics EM-31 in 2004

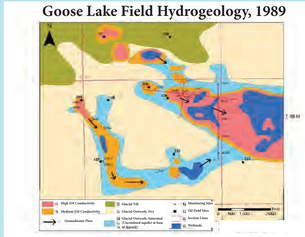


Todd Preston, Joanna Thamke and David Rouse collecting EC data with a Geonics EM-34 in September of 2009

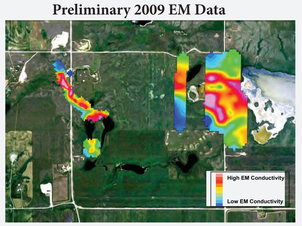
1989 EC Survey

- Elevated chloride levels were reported in 1975 in surface waters 1/2 mile below the Hammer Battery
- EM-31 and shallow EM-34 surveys in 1989 detected plumes in the slough below the Hammer Battery and emanating from sites 117, 124, 126 and 128
- Areas below the Hammer Battery and within the section were surveyed, while plume boundaries and EC values were extrapolated east of the section
- 18 wells were installed based on EM survey data

Goose Lake Field Hydrogeology, 1989



Preliminary 2009 EM Data



2009 EC Survey

- EM-31 Surveys of previously monitored areas for correlation between 1989, 2004 and 2009 data
- Selected portions of the Goose Lake Field study site were resurveyed with a Geonics EM-34
- Repeat surveying will allow temporal comparative analyses to determine rates of brine movement
- It is hypothesized that the increased depth profile will illuminate the potential for density driven flow of saline contaminated groundwater

Preliminary Conclusions

USGS Central Region Integrated Science (CRISP) Funds have been used to attract a nucleus of federal, state, tribal, and local groups to focus studies of produced waters in the Prairie Pot Hole Region. Preliminary work has begun at selected study sites.

Goose Lake in the Medicine Lake National Wildlife Refuge is one of the study sites of focused research. Preliminary results are:

- Water quality and electrical conductivity surveys show the area has become less contaminated from produced waters in the last 20 years as the maximum CI decreased from 0.83 to 0.43. However, two groundwater wells that were uncontaminated in 1989 have now been impacted.
- Despite an overall cleansing of the shallow sand and gravel aquifer, the surface water and groundwater resources in the area are still highly contaminated as evidenced by the 2009 Chloride Index data
- Water quality data indicate the heart of the contamination plume in the southern half section has migrated down gradient towards the west arm of Goose Lake (water body on eastern margin of maps)
- Strontium isotope study by Zell Peterman (GSA09 presentation) demonstrates: a) they are sensitive indicators of small amounts of produced water contamination allowing discrimination of sources of EC anomalies and b) systematic analyses allow precise calculations of degree of contamination

Project collaborators work together to assess the areas most at risk to contamination in the Williston Basin.

Study Partners

The Montana Department of Natural Resources Reclamation Development and Grants Program funded work on produced water contamination in the 1980's that was sponsored by the Sheridan County Conservation District (SCCD) and conducted by Jon Reiten of the Montana Bureau of Mines and Geology. EC survey and water-quality data have been collected at this site by Jon Reiten (1980s, 1990s, mid-2000s, and 2009), the U.S. Fish and Wildlife Service (USFWS) Karen Nelson (2005 and 2009) and David Rouse (2009), SCCD Mickey McCall (2005 and 2009), USGS Joanna Thamke (2009) and Todd Preston (2009). Kevin Johnson, USFWS contaminants program, helped formulate project plans. Christa Tyrrell of the Ft Peck Indian Environmental Department participated in project planning. Bruce Smith, Richard Sojda, Robert Gleason, and Joanna Thamke (USGS) are the principal investigators for the current project. Management units of the USFWS who aided the project include the Northeast Montana Wetland Management District (WMD) and Medicine Lake National Wildlife Refuge (NWR, Jerry Rodriguez). The USGS Energy Team has contributed data and expertise on energy resources and produced waters. Product, firm, or company names used are for descriptive use only and do not imply endorsement from the U.S. Government.