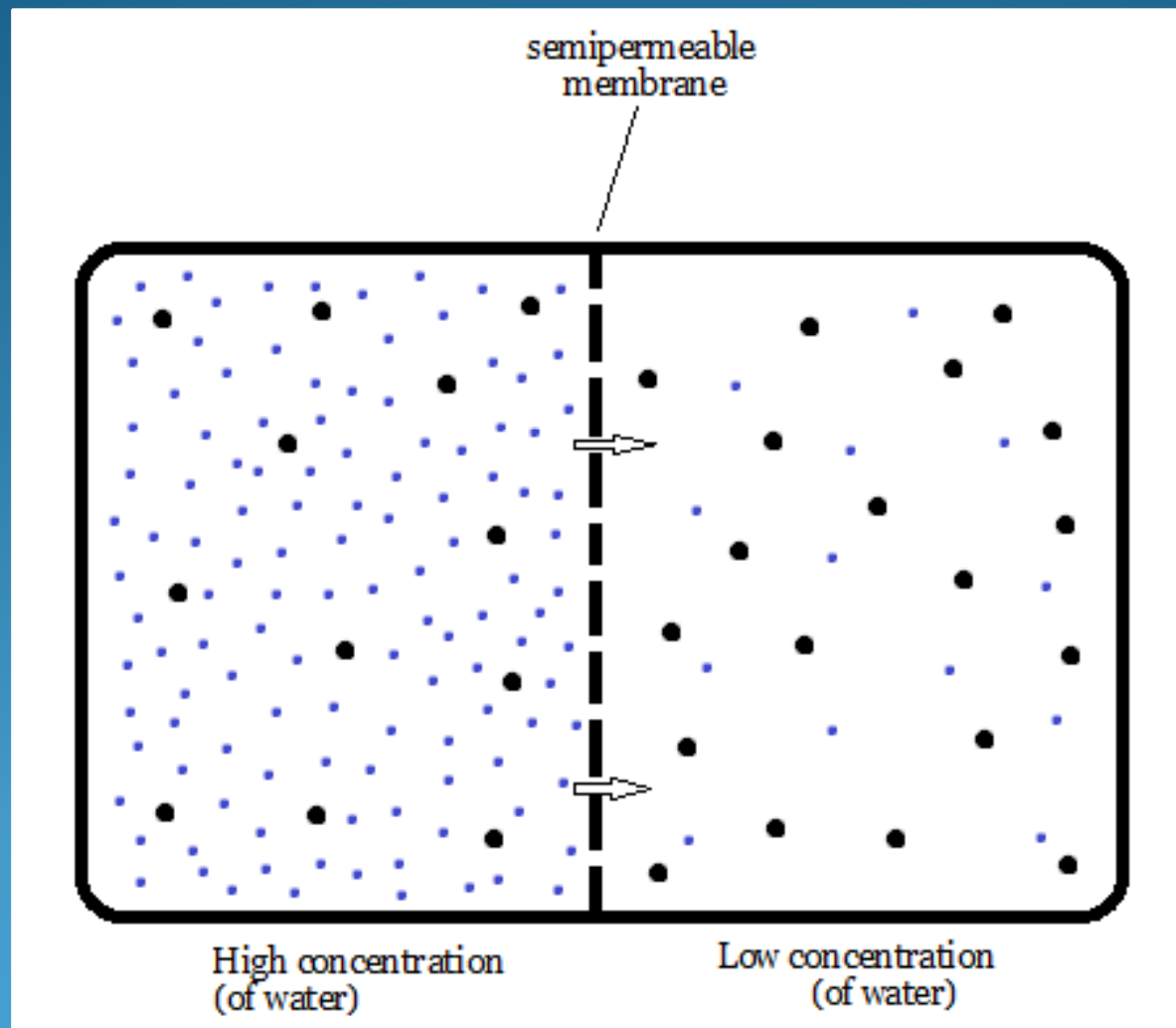
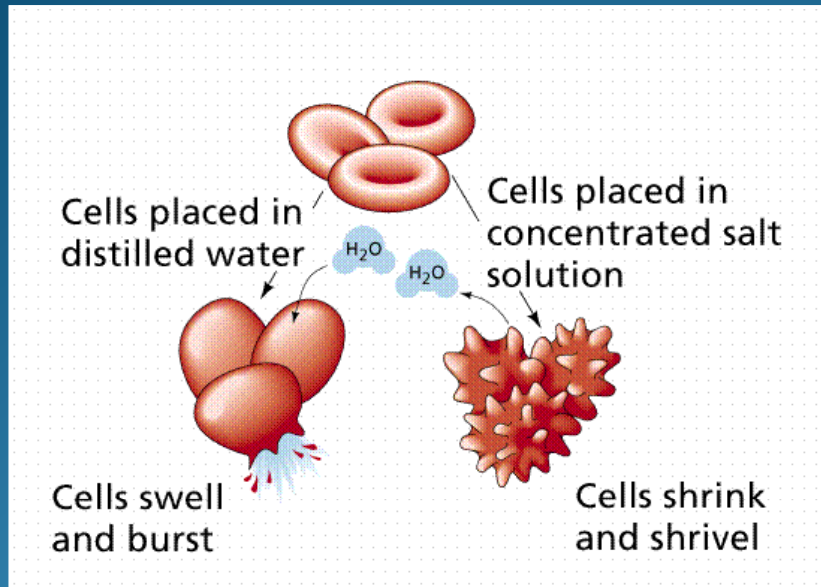


Harry Potter

AND THE
PRISONER
OF AZKABAN

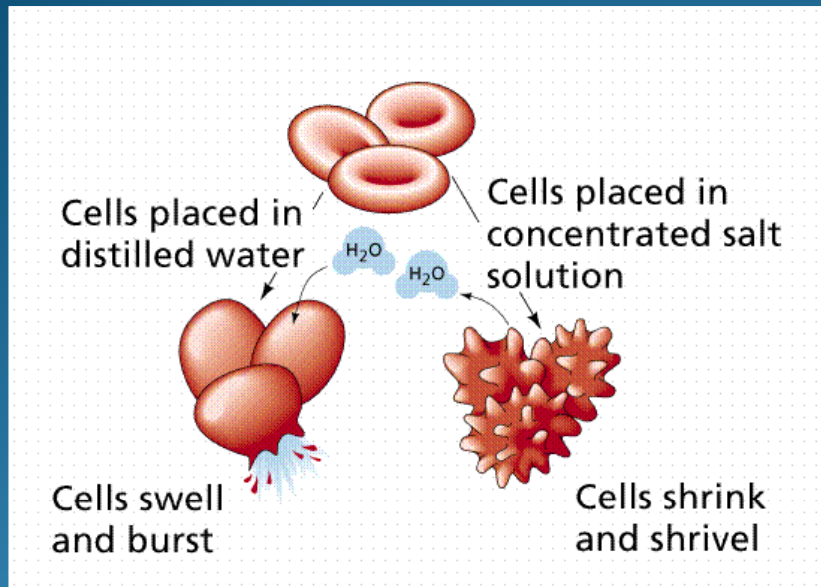






**Distilled
Water**

Brine



**Distilled
Water**

Brine





Sterile



6



- ~~Microbes~~
- ~~Earthworms~~
- ~~Nematodes~~
- ~~Plants~~

1 bbl oilfield brine = 87 lbs salt
≈ 700 salt shakers



Hagerman NWR, Texas

Brine spills

On National Wildlife Refuge System Lands



Pedro 'Pete' Ramirez, Jr.
US Fish & Wildlife Service
National Wildlife Refuge System
Energy Team



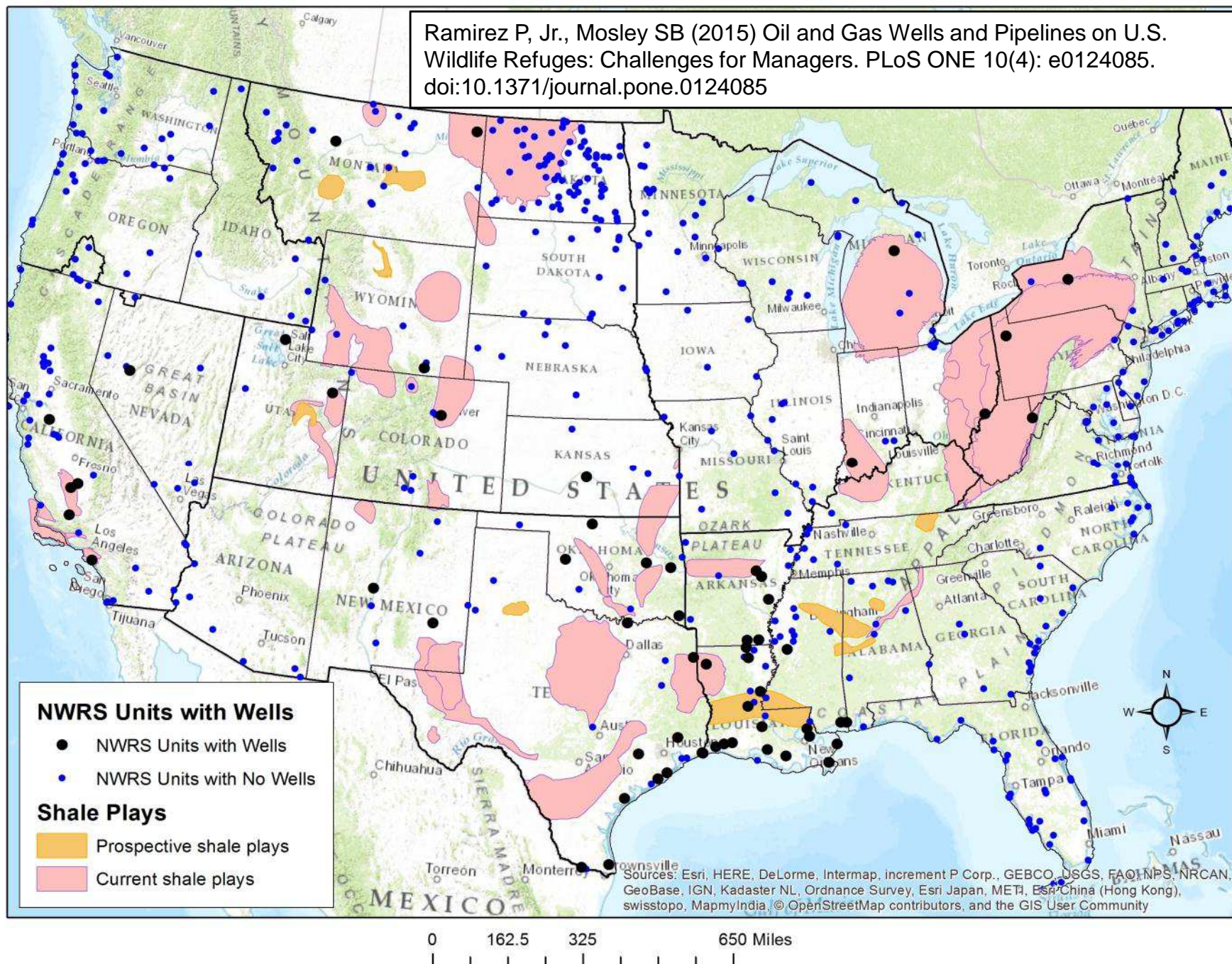
Deep Fork NWR, Oklahoma

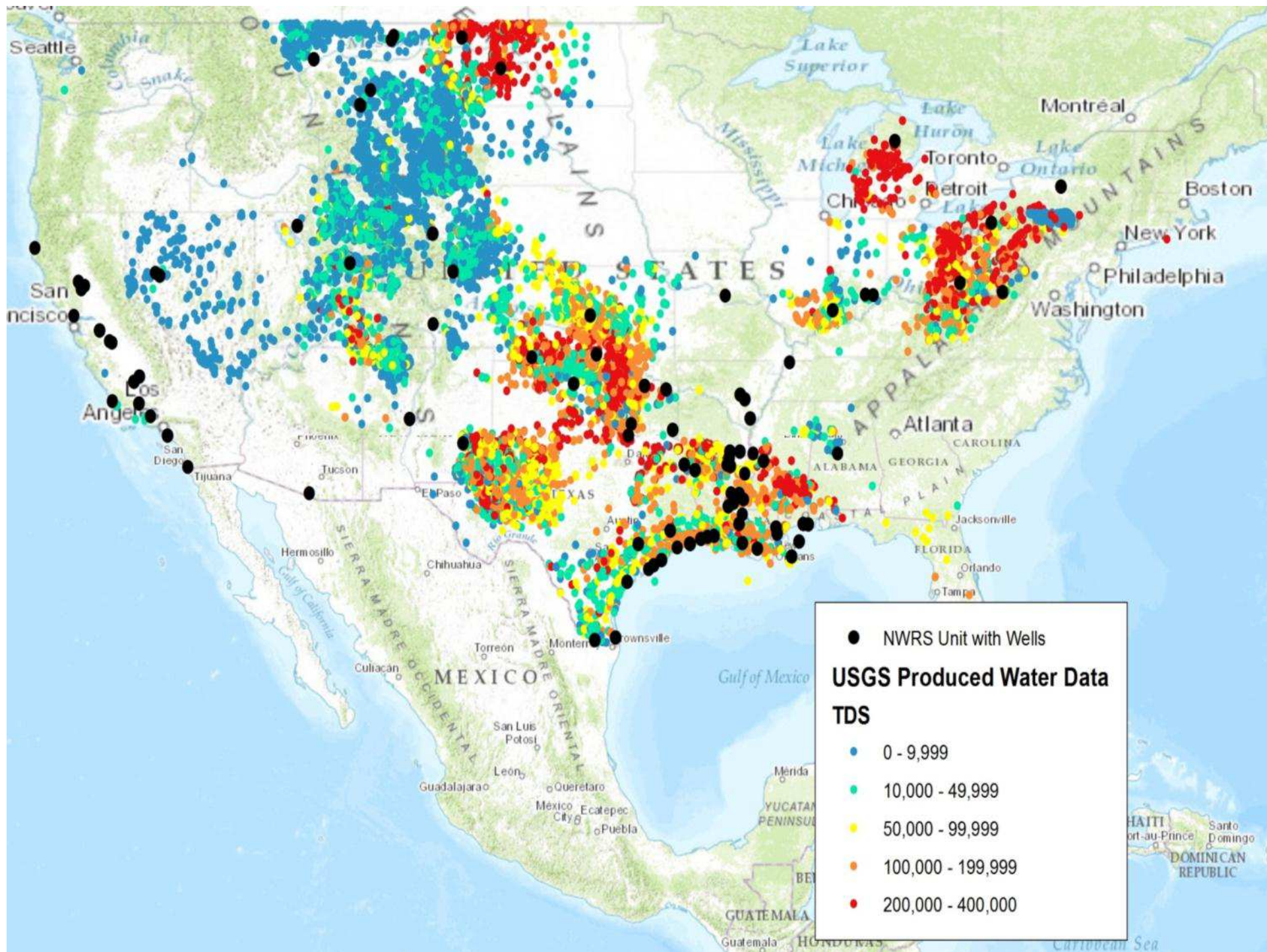
Why are there oil wells on Wildlife Refuges?

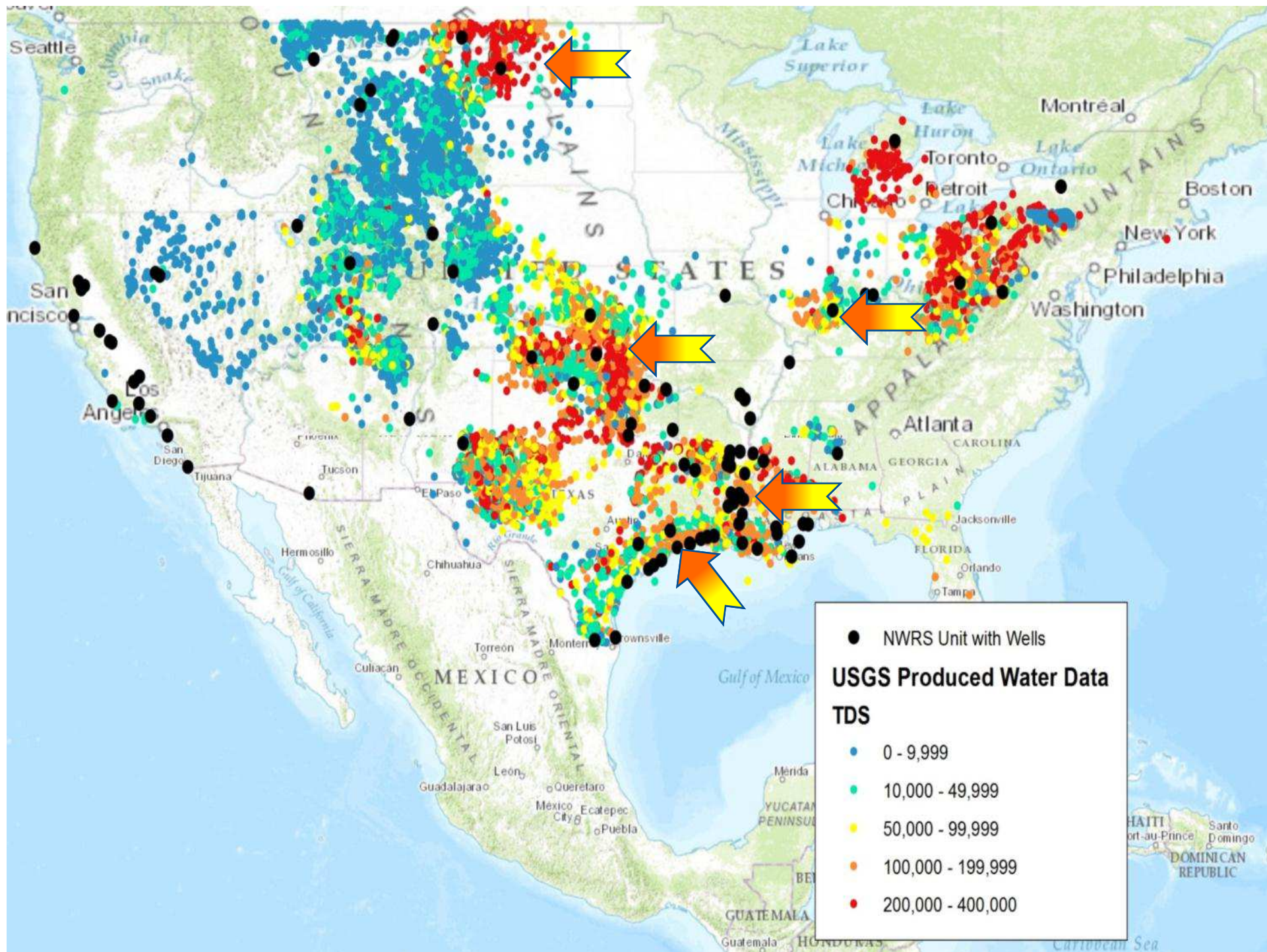


Beaver Lake Waterfowl Production Area, North Dakota

Ramirez P, Jr., Mosley SB (2015) Oil and Gas Wells and Pipelines on U.S. Wildlife Refuges: Challenges for Managers. PLoS ONE 10(4): e0124085. doi:10.1371/journal.pone.0124085









Hagerman NWR, Texas



Hagerman NWR, Texas



SWD well, Deep Fork NWR, Oklahoma



Delta NWR, Louisiana



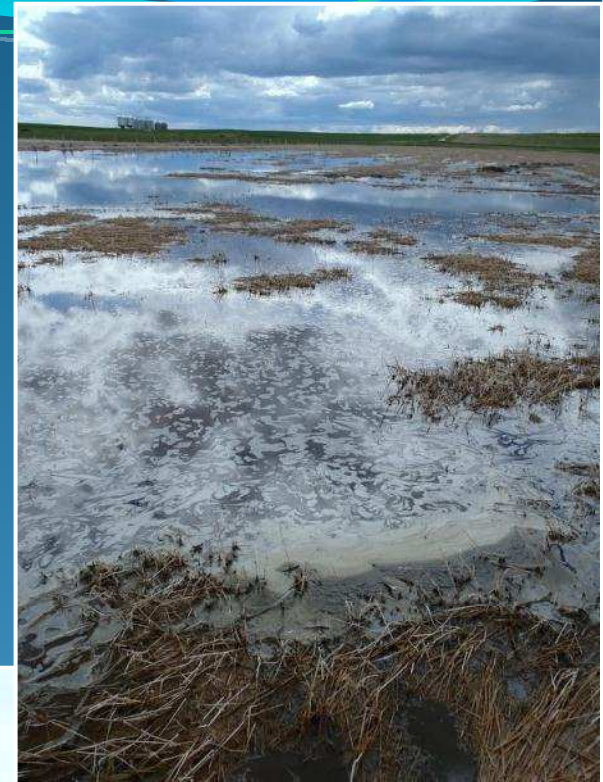
Deep Fork NWR, Oklahoma



Catahoula NWR, Louisiana



Delta NWR, Louisiana



Roosevelt County, Montana



Deep Fork NWR, Oklahoma





Roosevelt County, Montana



Burke County, North Dakota



Hagerman NWR, Texas

Biological Response Signature of Oil Brine Threats, Sediment Contaminants, and Crayfish Assemblages in an Indiana Watershed, USA

Thomas P. Simon · Charles C. Morris

Science of the Total Environment
Journal homepage: www.elsevier.com/locate/scitotenv

A GIS-based vulnerability assessment of brine contamination to aquatic resources from oil and gas development in eastern Sheridan County, Montana

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^c USGS Montana Water Science Center, 3762 W. Main Ave., Helena, MT 59601-6406, USA

HIGHLIGHTS

- Oil extracted from the Williston Basin is often co-produced with highly saline brine.
- We assessed potential brine contamination to aquatic resources from oil development.
- The assessment was based on oil well, geologic, and hydrologic characteristics.
- We analyzed surface and groundwater to determine the magnitude of contamination.
- The assessment did well in predicting sites with high and low levels of contamination.

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Water quality
Saline intrusions

ABSTRACT

Water (brine) co-produced with oil in the Williston Basin is some of the most saline in the nation. The Prairie Provinces Region (PPR), characterized by glacial sediments and numerous wetlands, covers the northern and eastern portion of the Williston Basin. Sheridan County, Montana, lies within the PPR and has a documented history of brine contamination. Surface water and shallow groundwater in the PPR are saline and sulfate dominated, while the deeper brines are much more saline and chloride dominated. A Contamination Index (CI), defined as the ratio of chloride concentration to specific conductance in a water sample, was developed by the Montana Bureau of Mines and Geology to delineate the magnitude of brine contamination in Sheridan County. Values >0.035 indicate contamination. Recently, the U.S. Geological Survey completed a county level geographic information system (GIS)-based vulnerability assessment of brine contamination to aquatic resources in the PPR of the Williston Basin based on the age and density of oil wells, number of wetlands, and stream length per county. To validate and better define this assessment, a similar approach was applied to eastern Sheridan County at a greater level of detail (the 1.69 km² Public Land Survey System section grid) and included surficial geology. Vulnerability assessment scores were calculated for the 736 modeled sections and these scores were divided into ten equal interval bins representing similar probabilities of contamination. Two surface water and two groundwater samples were collected from the section with the greatest average of Federal land in each bin. None of the forty water samples were at least one water sample from seven of the ten selected sections had CI values indicating contamination, and at least one water sample from seven of the ten selected sections had CI values indicating contamination. A correlation of CI values generally increased with increasing distance from the Williston Basin. © 2013 Elsevier B.V. All rights reserved.

friends

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Revegetation of a Hardwood Forest Site Brine

Published January, 1988

Revegetation of a Brine-killed Forest Site
L. R. AUCHMOODY* AND R. S. WALTERS

ACT
nts and forest tree seedlings
ern Pennsylvania was eval-
from producing oil wells
legheny hardwood stand
g the site unproductive
was eliminated, heavy
s in the soil to below
eed rapidly. Her-
shed in the first
ly to full stock-
ow that forest
v without mi-
ere is abun-

The increased drilling and pro-
rious disposal problems for the fl-
and recovered with the oil. The
connate brines that have high sal-
also included are fluids injected
hance oil production, dissolved
fluids used to bring wells into pro-
water used in hydrofracturing).
Brine fluids are an environmen-
that cannot be indiscriminately
or into waters of the USA. Becau-
tities produced, there is potentia-
spills to cause environmental da-
an average shallow oil well in
vania generates nearly 8 m³ of
drilling and up to 114 m³ of fract-
well is brought into production,
generates brine at about 0.3 m³ of
duction period (Waite et al., 1988).
Brine spills and accidental dis-
environmental threats. However,
the published literature does not
impacts of brine on forest vegeta-
totoxicity, or vegetative recolon-
brine-killed areas. The one ex-
Pennsylvania where impacts of
season application of brine on f-
water chemistry were reported. I-
pact of brine on forest vegetati-
was attributed to rapid leaching
the soil (DeWalle and Galeone,
In 1978, extensive oil develop-

Corresponding author.
Am. J. 52:277-280 (1988).



Lake Ophelia NWR, Louisiana



Deep Fork NWR, Oklahoma



Atchafalaya NWR, Louisiana





Legacy Spills

- Chronic spills
- Disposal in unlined pits
- Salt scald
- Long-term damage



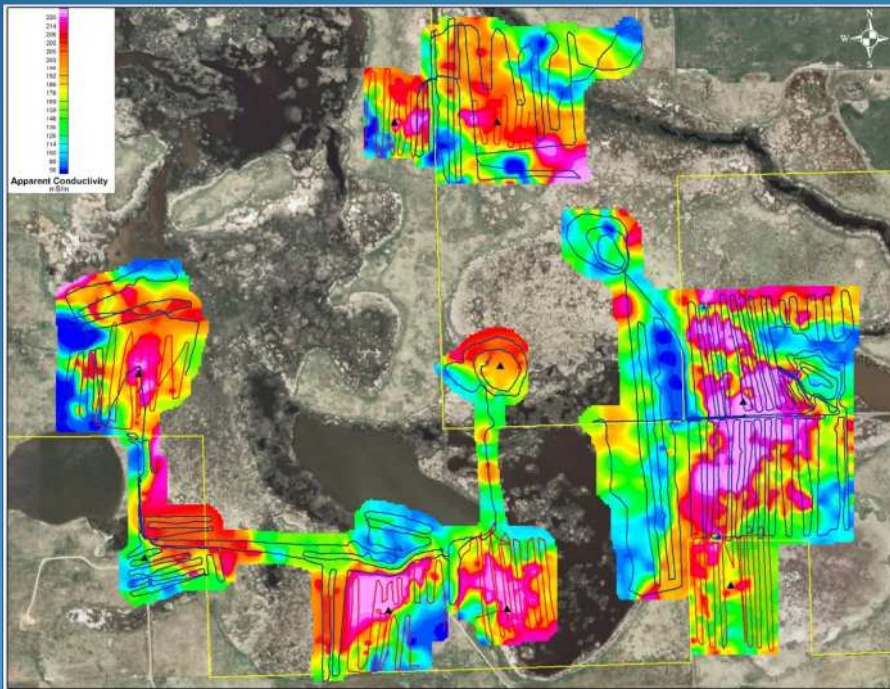
Salt Scald in Arkansas



Atchafalaya NWR, Louisiana

Legacy Spills

- Chronic spills
- Disposal in unlined pits
- Salt scald
- Long-term damage



Subsurface Brine Plume, Beaver Lake WPA, North Dakota



Salt Scald Beaver Lake WPA, North Dakota

Causes of Spills

- Corrosion
- Overflow
- Illegal Activity
 - Dumping
 - Vandalism
 - Theft
- Poor maintenance



Deep Fork NWR, Oklahoma

Source: Fisher JB, Sublette KL. Environmental releases from exploration and production operations in Oklahoma: Type, volume, causes, and prevention. Environmental Geosciences. 2005; 12: 89–99.

Brine Impacts



Soil



Water



Vegetation

Brine Impacts - Wildlife

Why deer can be attracted to gas drilling sites

NOVEMBER 26, 2013 | 4:24 PM

BY MARIE CUSICK

8 Comments

Email

Tweet 0

Recommend 2



JOHNWDAVISJR VIA FLICKR

Deer are attracted to salty spots, which can include areas exposed to flowback fluid from gas development.

Hunters have long known deer love salt. In Pennsylvania it's illegal to put out salt licks to try to attract deer. But there are still salty spots deer find on their own.

One of those places can be gas drilling sites. The brine water that comes back up after hydraulic fracturing (known as flowback) can be as much as 10 times saltier than seawater. It can also contain heavy metals and radioactive materials.

The state Department of Environmental Protection acknowledges that brine spills large and small do occur, and they have not studied its impacts to wildlife.



mediated deer lick areas, located near drill pit burial site. Inset photo technician's right (up slope) in the larger photo. Photos taken September 2011.

Adams et al. 2011. *Effects of development of a natural gas well and associated pipeline on the natural and scientific resources of the Fernow Experimental Forest*. Gen. Tech. Rep. NRS-76. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 24 p.

Brine Impacts - Wildlife

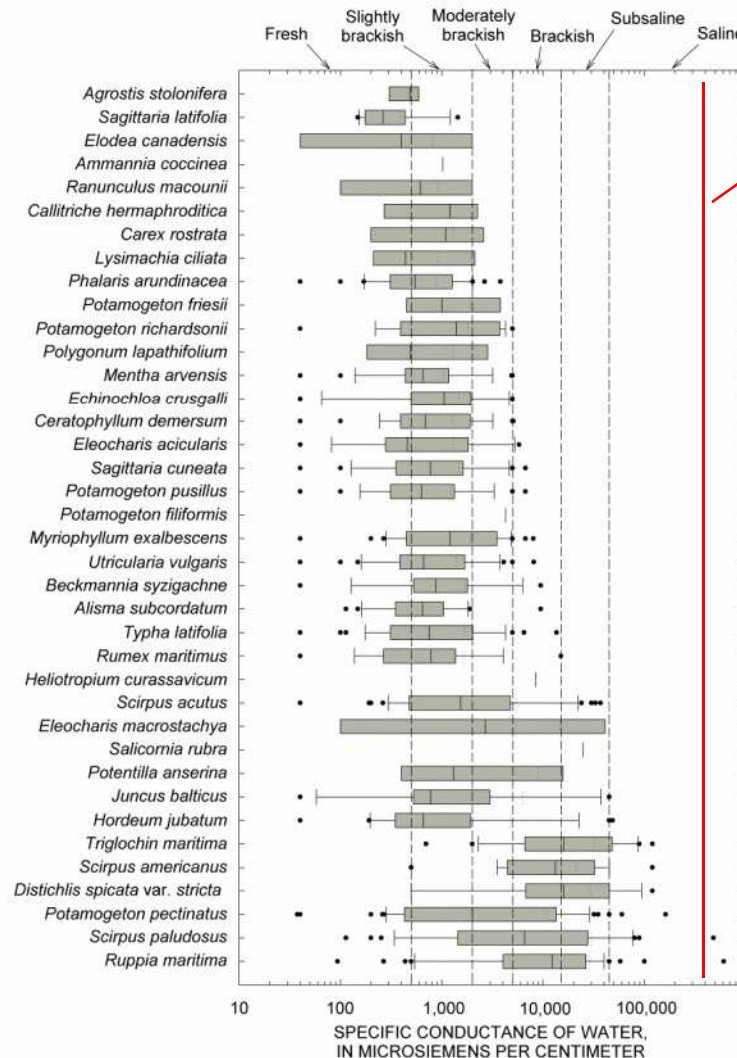
- Salinity increase
- Chlorides
- Residual Oil – Toxicity
- Biochemical O₂ Demand (BOD)*



Burke County, North Dakota

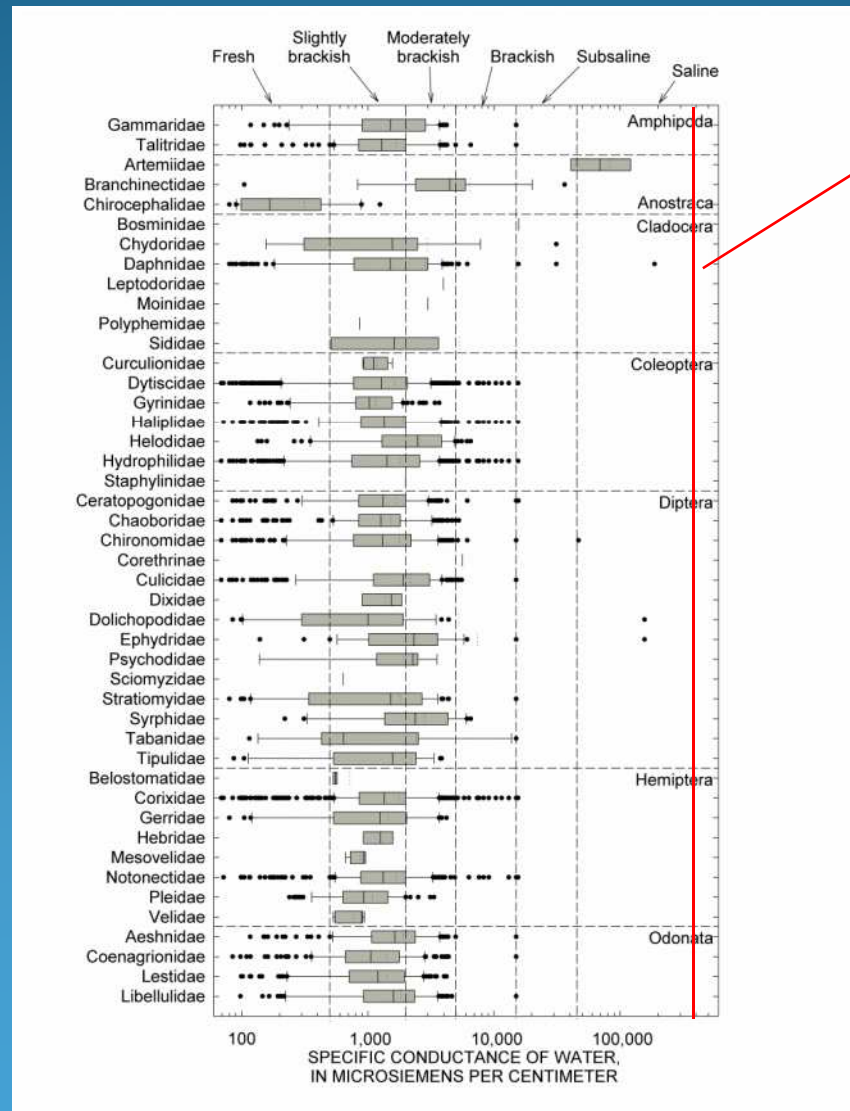
*Source: *The Fate and Effects of Oil in Freshwater*. Edited by J. Green and M.W. Trett. Elsevier Applied Science, NY. 1989.

Brine Impacts – Aquatic Plants



Oilfield Brine

Brine Impacts - Invertebrates



Oilfield Brine

Brine – How Much Is Too Much?

- Volume of Spill
- Chemistry of Brine
 - TDS
 - Chlorides
 - Bromides
 - Oil
 - Trace Elements
- Wetland Type, Size & Salinity



Sheridan County, Montana



Deep Fork NWR, Oklahoma

Damages

- Habitat Loss
- Soil Structure Damage

Restoration • None

Compensation • None



Deep Fork NWR, Oklahoma



2012

Hagerman NWR, Texas

Restoration

- Pending

Damages

- 84 Hardwood trees
 - 2 trees > 150 yrs old
 - >\$154,00K replacement value
- Soil Structure Damage



2014

Unreported Spills

- Remediation - ? Unlikely
- Impacts to wetlands - unknown



Sheridan County, Montana



Sheridan County, Montana

Impacts to Prairie Pothole Wetlands

- Natural – sulfate dominated salts
- Brine – chloride dominated salts
- Residual oil – high BOD



Sheridan County, Montana

- Toxicity - aquatic invertebrates
- Waterfowl Impacts
 - Food chain
 - Mortality risk to ducklings



Sheridan County, Montana



Sheridan County, Montana

Refuge Management Impacts

- 75 % - Mgmt of oil-related issues

- Enforcement – Refuge laws
- Recreation management
 - hunting, fishing
- Wildlife surveys
- Habitat restoration
- Maintenance



Sheridan County, Montana

Remediation

- Scrape & Haul



Mountrail County, North Dakota

- Additional damage
- Non-native soil
- Invasive species
- Erosion



Mountrail County, North Dakota

Remediation

- Tile drains & sumps



Waterfowl Production Area, Montana

- Native soil remains in place
- Move salt to sumps
- Recover saline fluid
- Time intensive
- Water to move salt

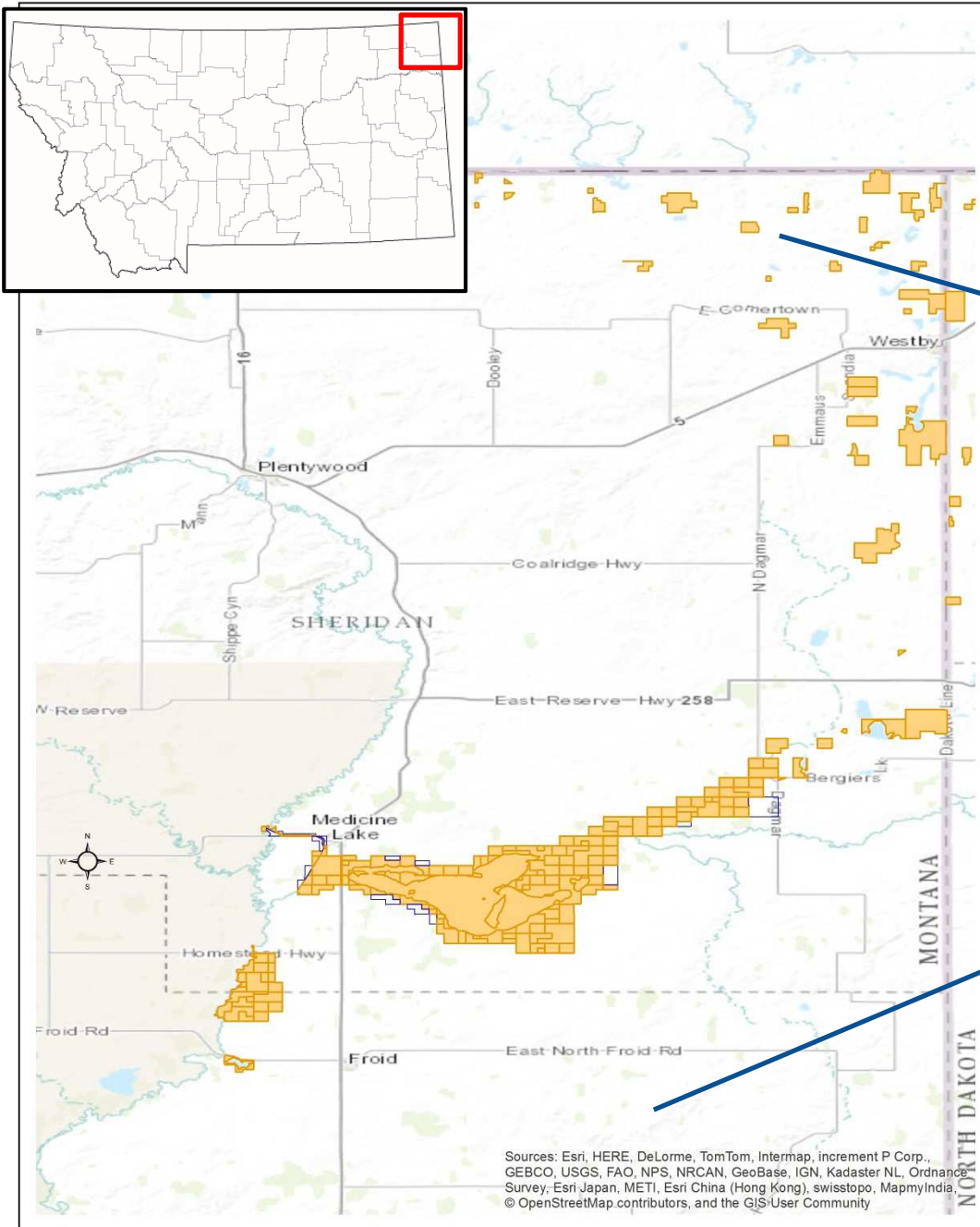


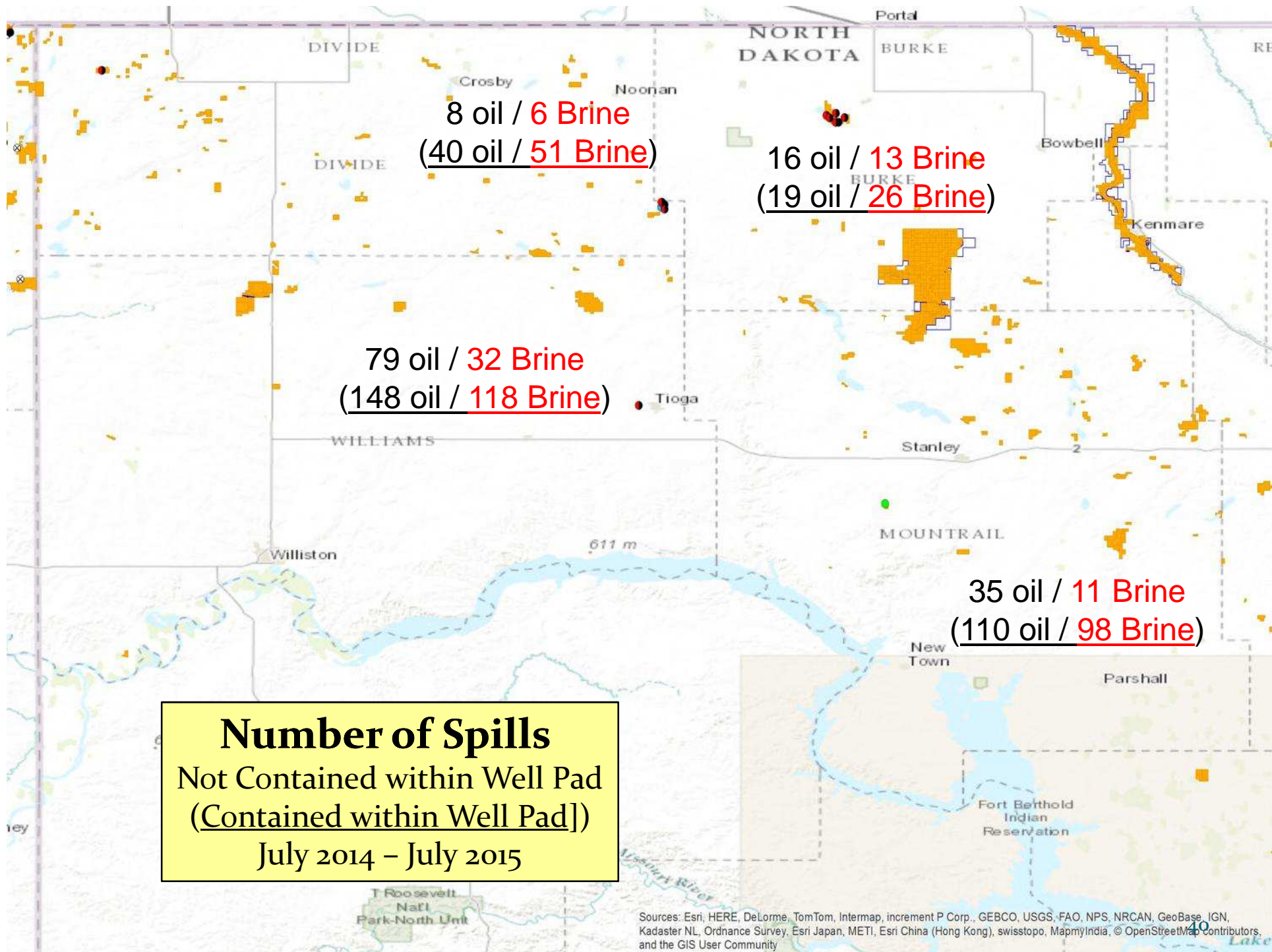
Waterfowl Production Area, Montana

Brine Spills

- Sheridan County, MT
 - 28-Mar-2013
 - 14-Jul-2013
 - 16-Jul-2013

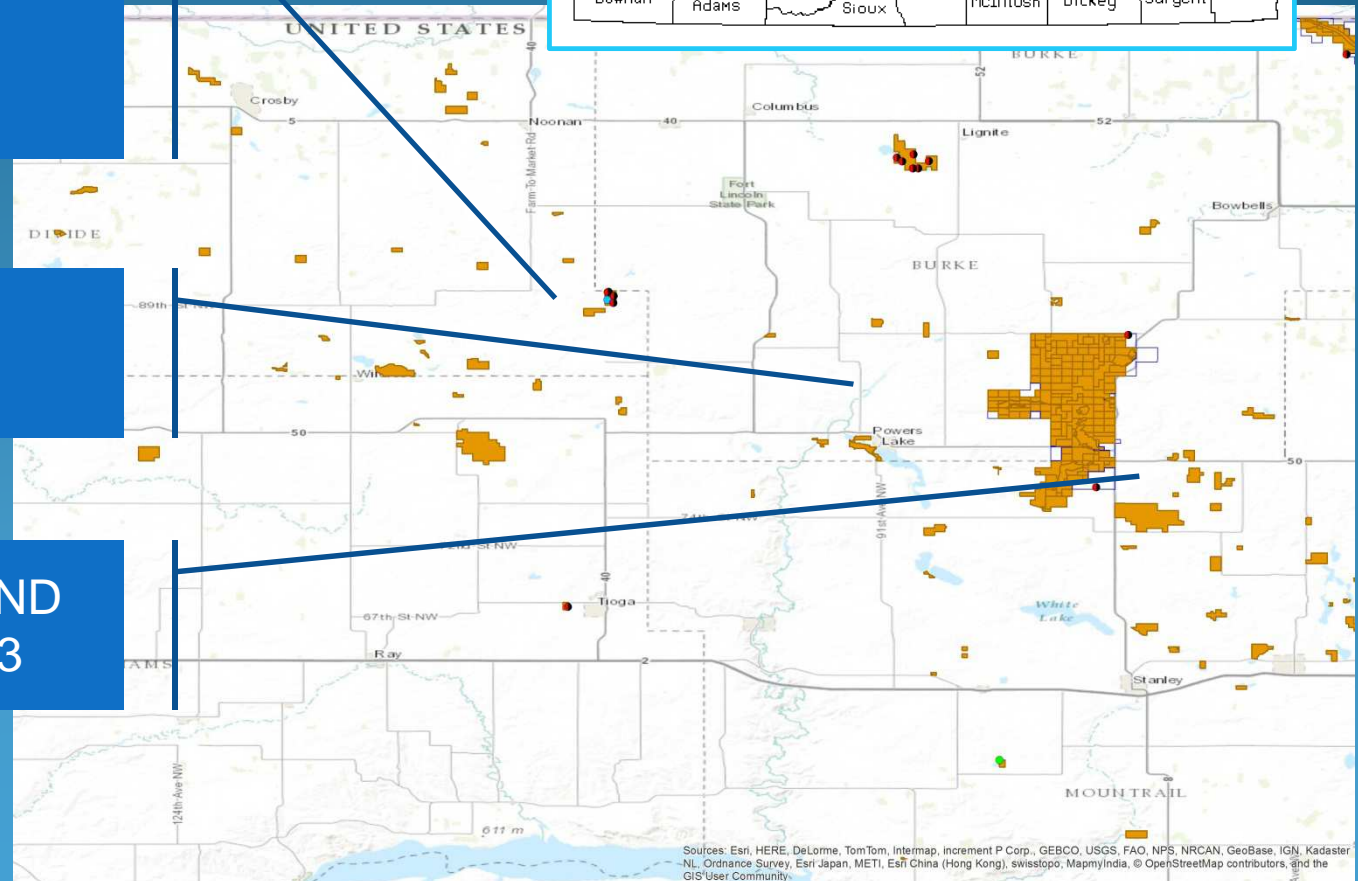
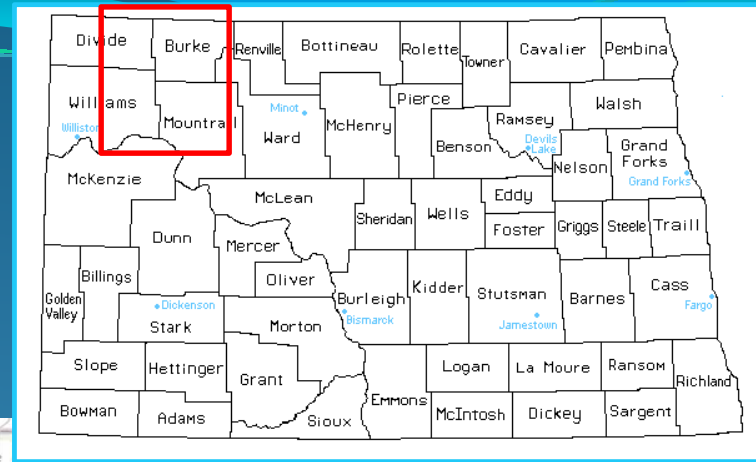
- Roosevelt County, MT
 - 22-May-2013
 - 27-Jun-2013
 - 10-Jul-2013



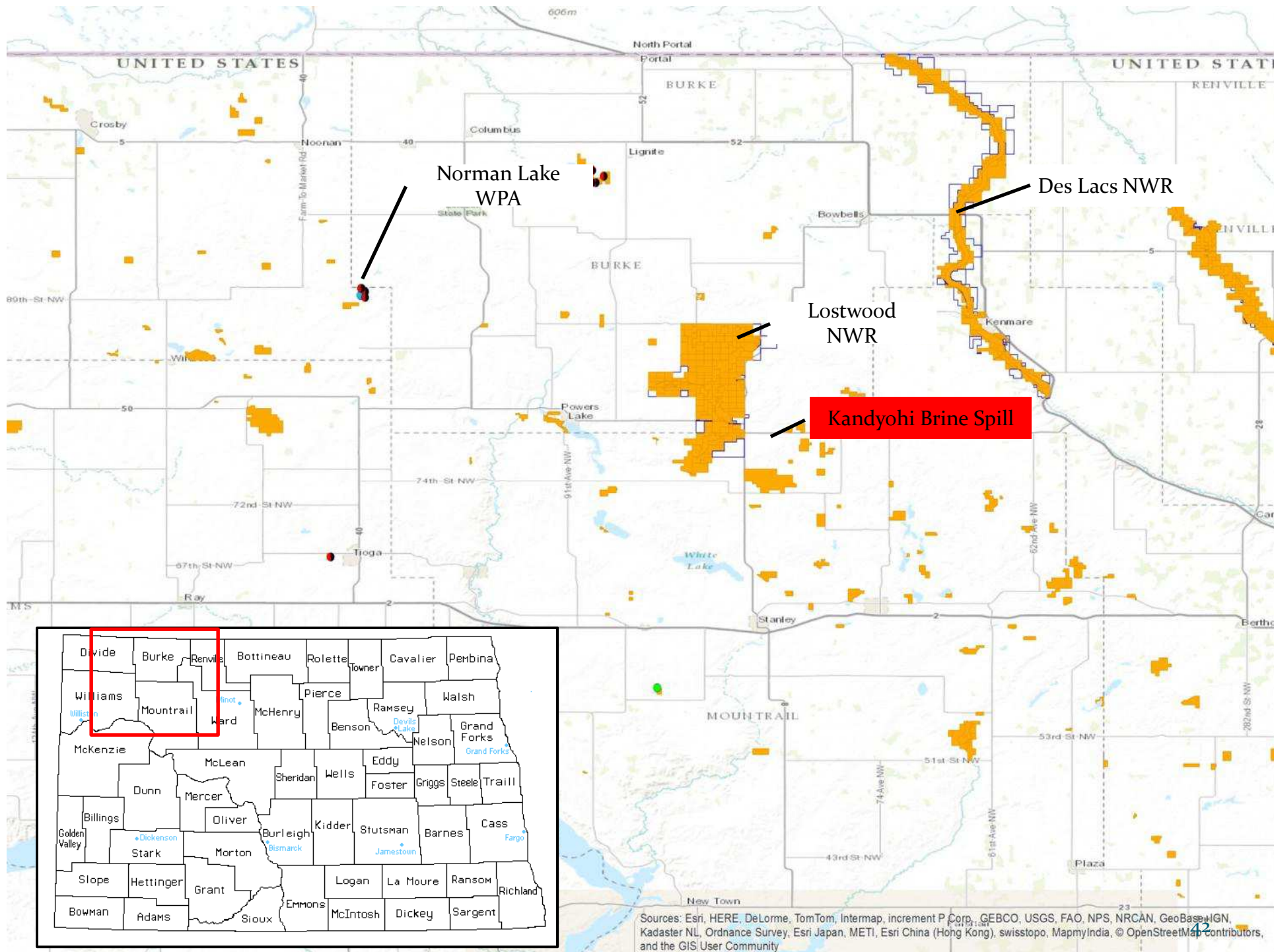


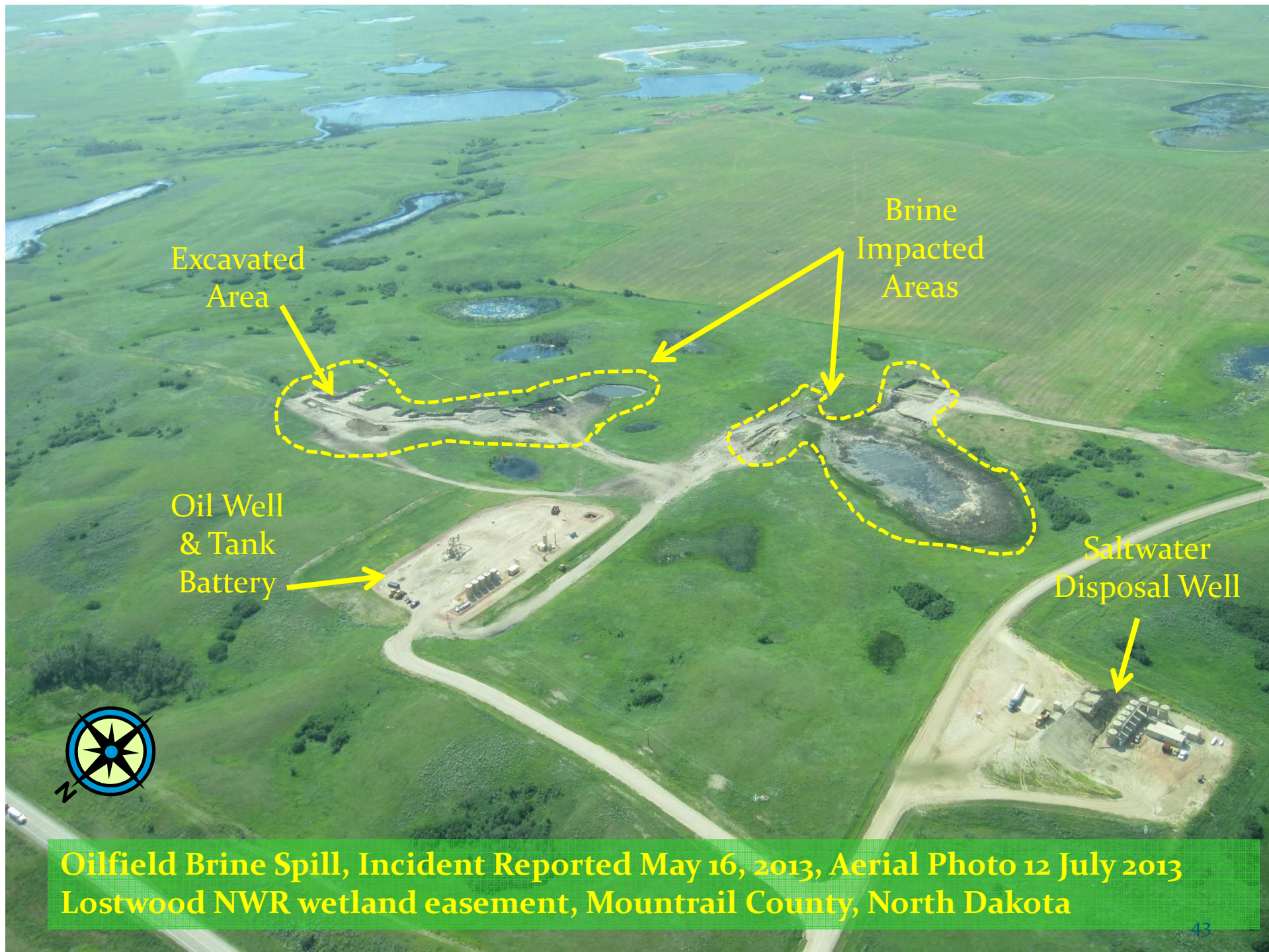
Brine Spills

- Divide County, ND
 - 1-Aug-2013
 - 25-Oct-2013
 - 4-May-2015
 - 12-Jun-2015
- Burke County, ND
 - 4-May-2015
- Mountrail County, ND
 - 16-May-2013



Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community





**Oilfield Brine Spill, Incident Reported May 16, 2013, Aerial Photo 12 July 2013
Lostwood NWR wetland easement, Mountrail County, North Dakota**









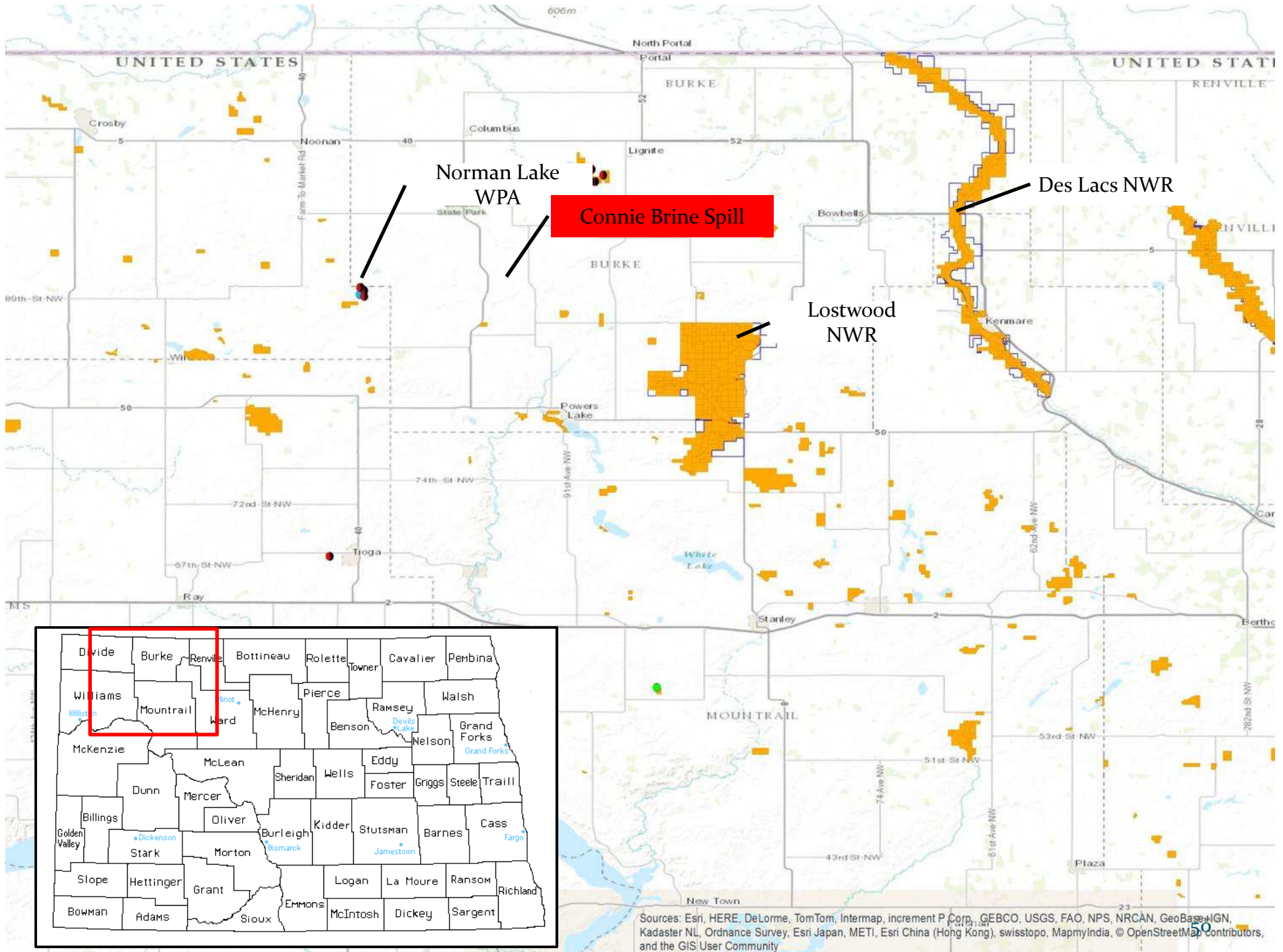




Wormwood



Barren Pond



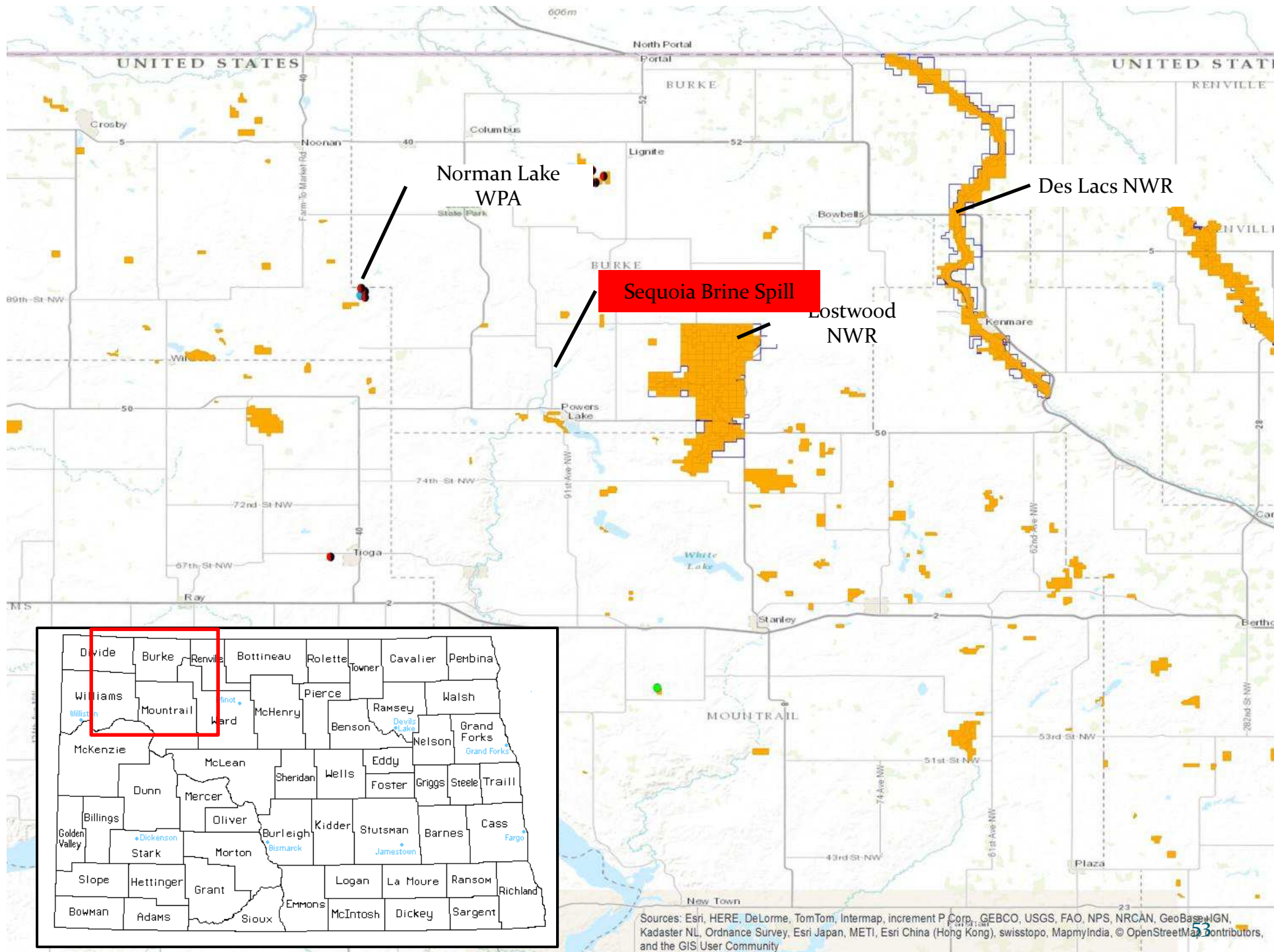


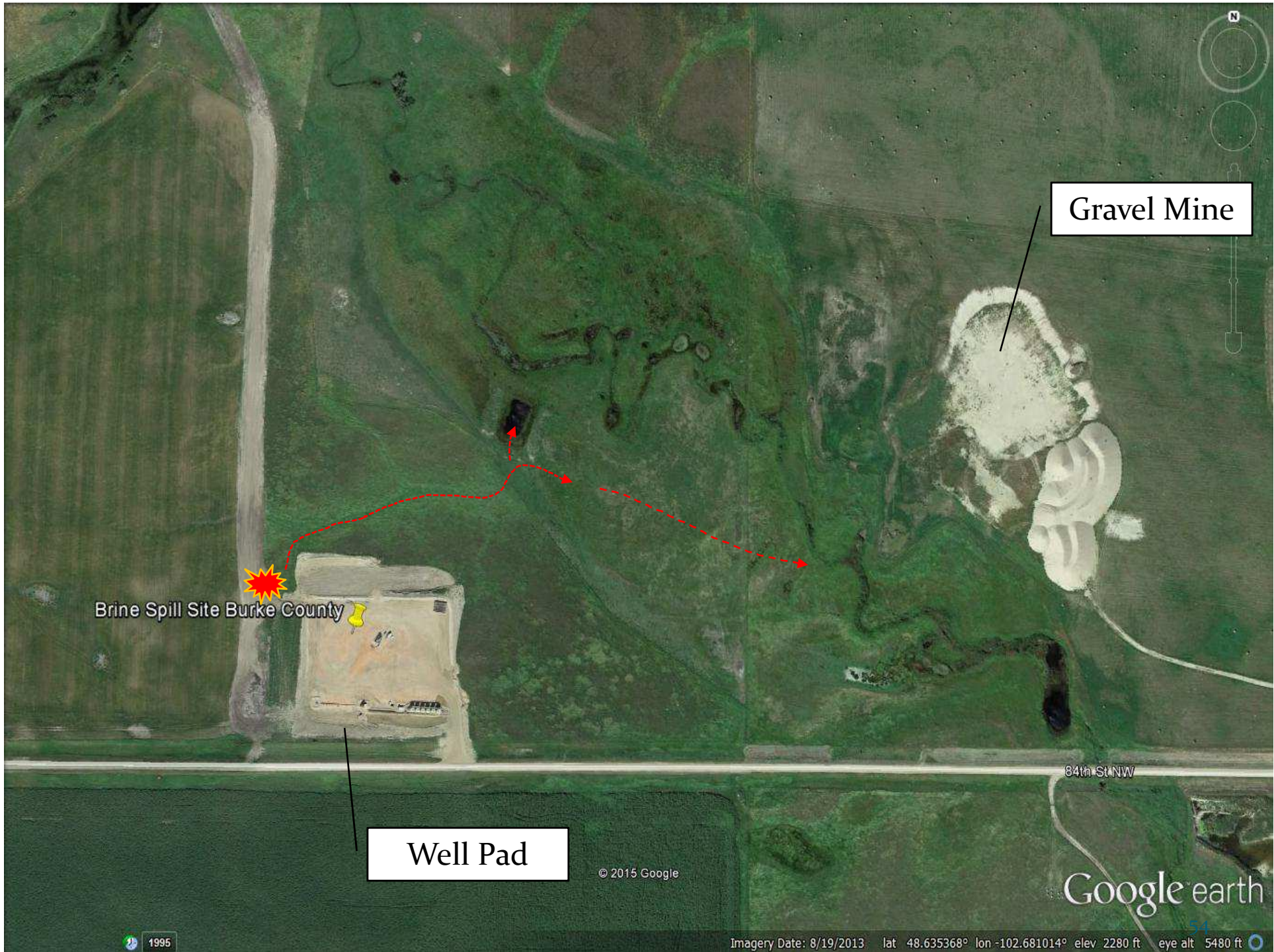
1995

Imagery Date: 8/19/2013 lat 48.720434° lon -102.717143° elev 2474 ft eye alt 4843 ft



06.09.2015 11:15





Gravel Mine

Brine Spill Site Burke County

Well Pad

84th St NW

© 2015 Google

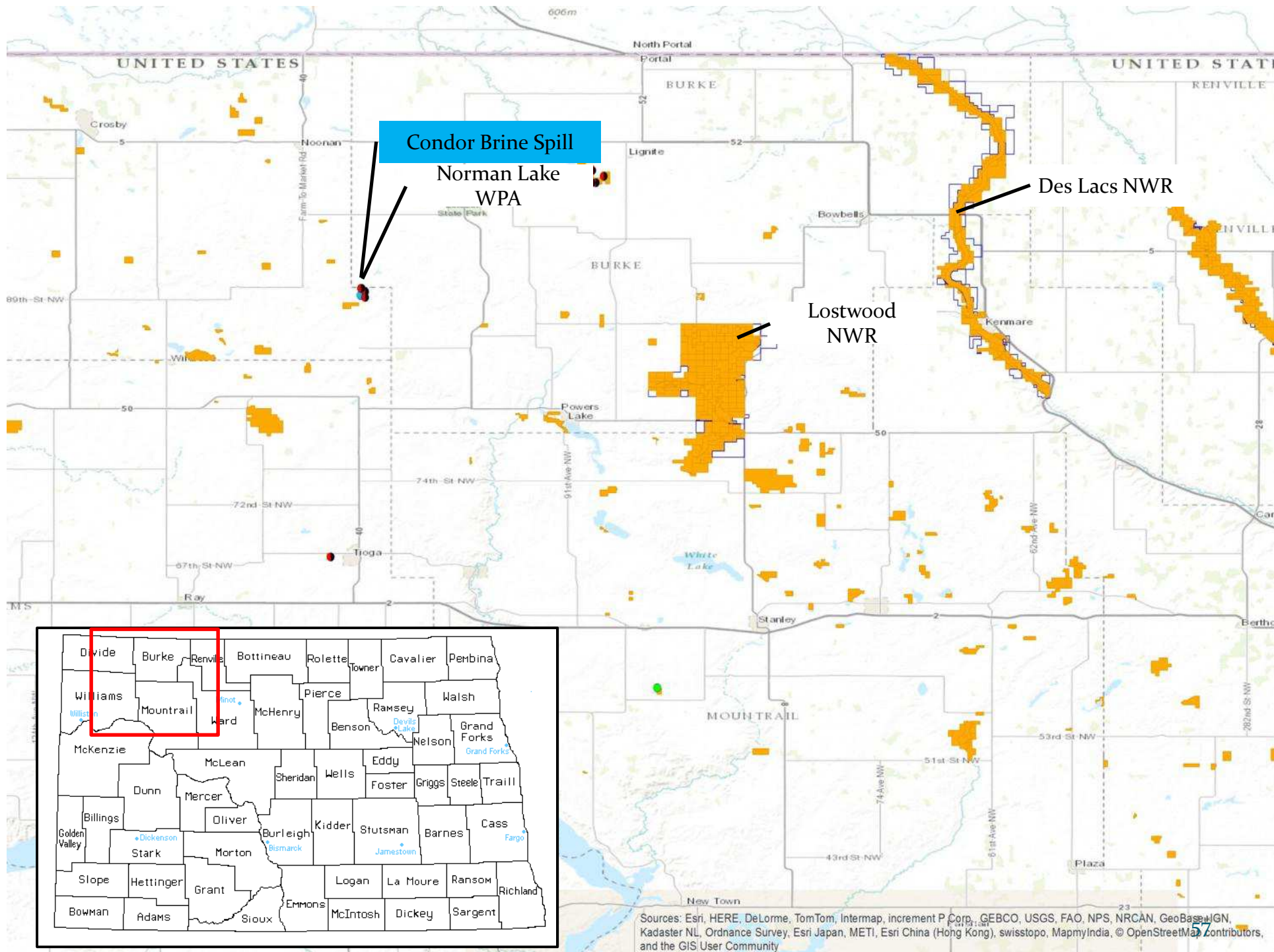
Google earth

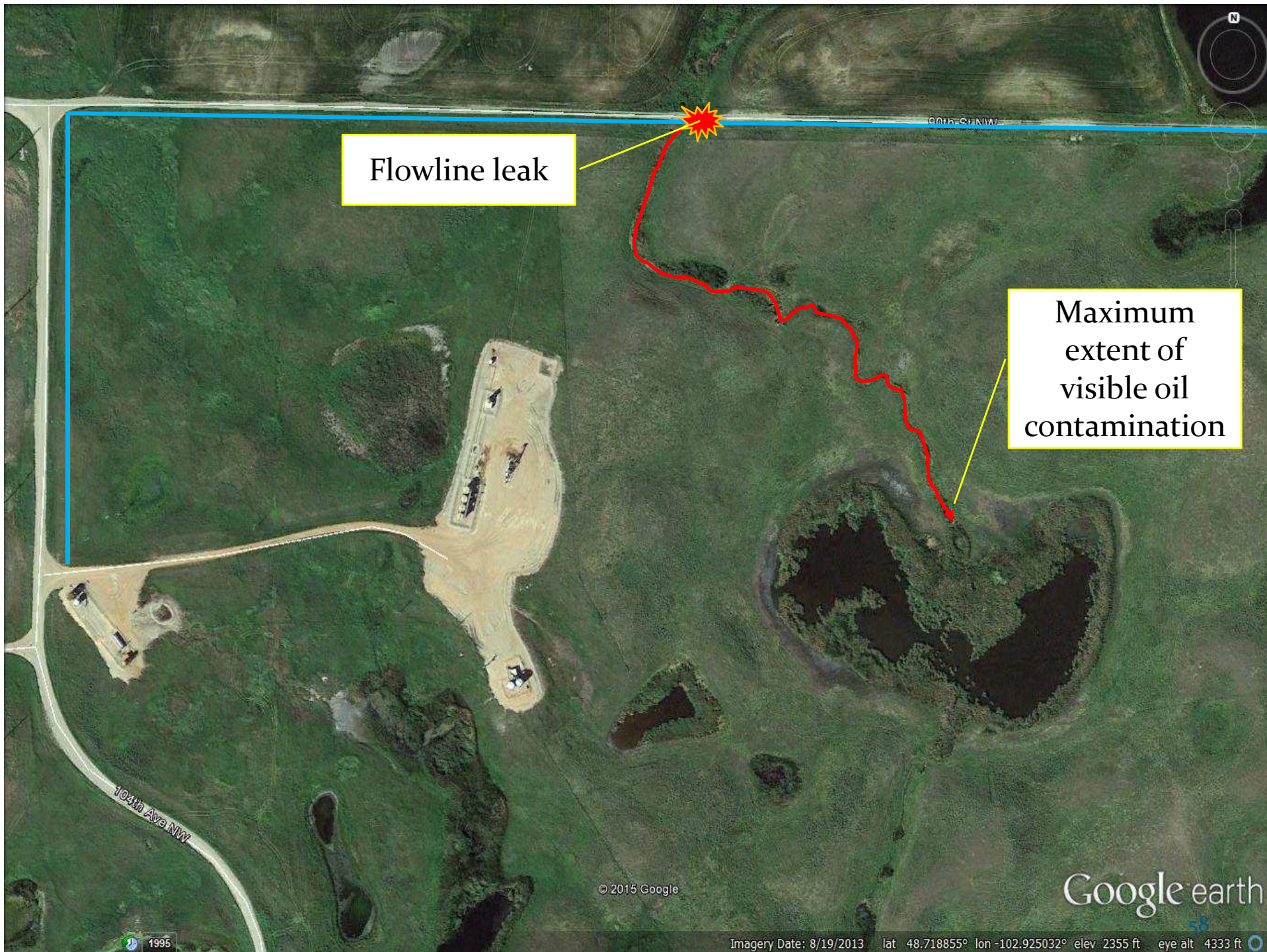
1995

Imagery Date: 8/19/2013 lat 48.635368° lon -102.681014° elev 2280 ft eye alt 5480 ft









Flowline leak

Maximum
extent of
visible oil
contamination



© 2015 Google

Google earth

Imagery Date: 8/19/2013 lat 48.715924° lon -102.922321° elev 2334 ft eye alt 7452 ft



Brine Spill Restoration Site, North Dakota

Data Needs

- Remediation Costs
- Frequency of Spills
- Revegetation success

Training Needs

- Reporting requirements
- Spill Response
- Remediation options
- Restoration



Sheridan County, Montana

Costs

Response & Remediation

- **Saltwater Disposal well July 2011**
 - > \$1 million - July 2014
- **Brine flowline – Jan 2006**
 - >\$3 million -July 2014
 - Remediation ongoing (8 yrs) - July 2014

*Source: ND Industrial Commission Oil & Gas Division



Leak Detection

- Subsurface flowlines
- Leaks undetected
- Damage to Natural Resources



Sheridan County, Montana

- Leak Detection
 - Early detection & response
 - Minimize damage
- Research & development



Sheridan County, Montana

Brine Spills on NWRS Lands

- Summary -

- Leak detection not immediate
- Long-term Damage to Natural Resources
- Loss of ecological functions & values
- Triage Management
- Reporting problems
- Aging infrastructure



Brine & oil spill, Divide County, North Dakota

Brine Spills on NWRS Lands

- Summary -

- Leak detection system for flowlines
- Data
 - number of spills
 - costs
- Assessment of O&M
- Research
 - Remediation
 - Restoration
- Outreach to field staff
 - Prevention
 - Reporting



Corroded flowline, Atchafalaya NWR, Louisiana

“Here is your country.”



Deep Fork NWR, Oklahoma

“Cherish these natural wonders, cherish the natural resources, ...”



Bosque del Apache NWR, New Mexico



Pelican Island NWR, Florida

“cherish the history and romance as a sacred heritage, ...”



St. Marks NWR, Florida



Charles M. Russel NWR, Montana

“...for your children and your children’s children.”
- Theodore Roosevelt



Two Ponds NWR, Arvada, Colorado



Sabine NWR, Louisiana

