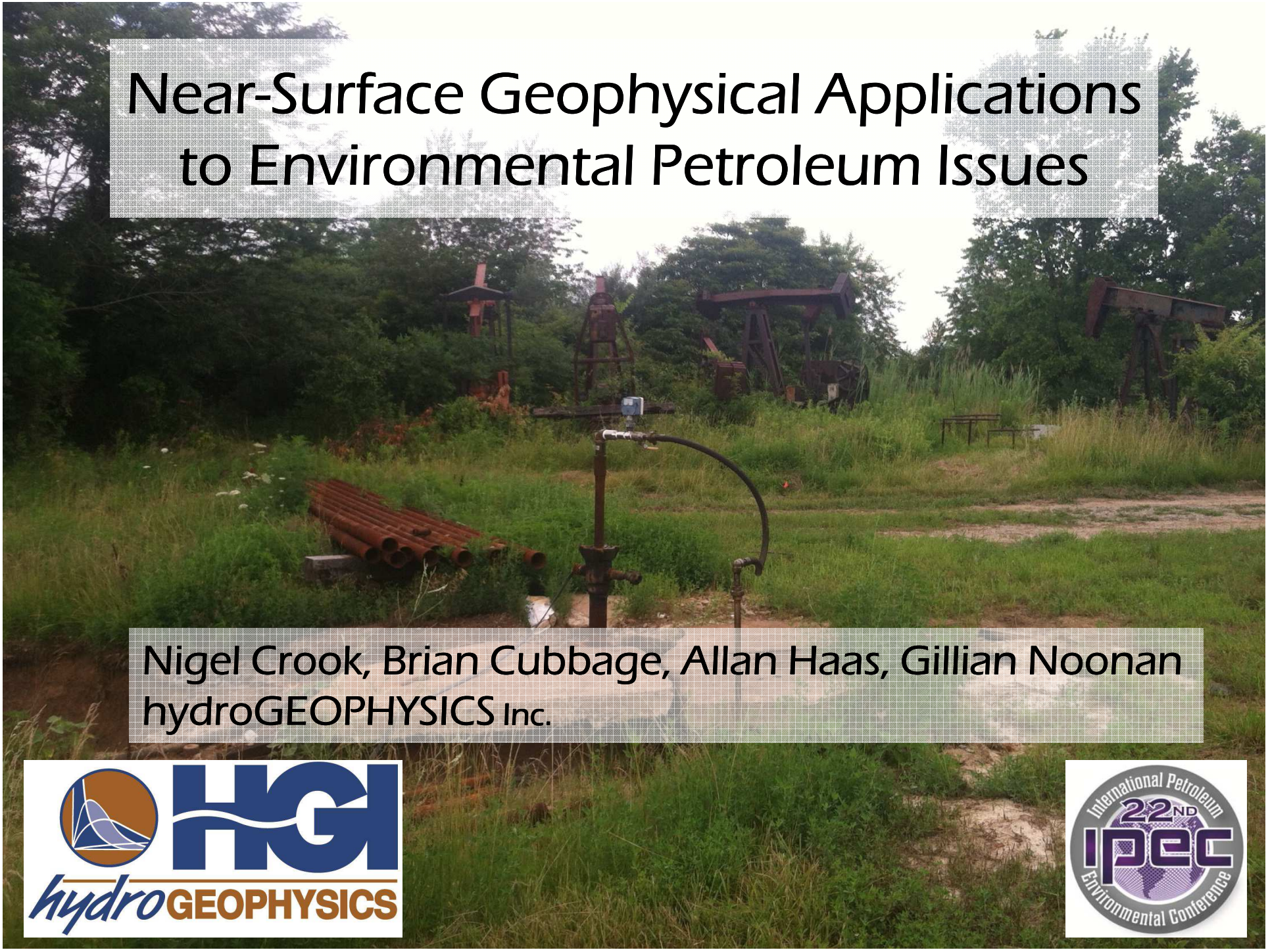
Near-Surface Geophysical Applications to Environmental Petroleum Issues



Nigel Crook, Brian Cubbage, Allan Haas, Gillian Noonan
hydroGEOPHYSICS Inc.

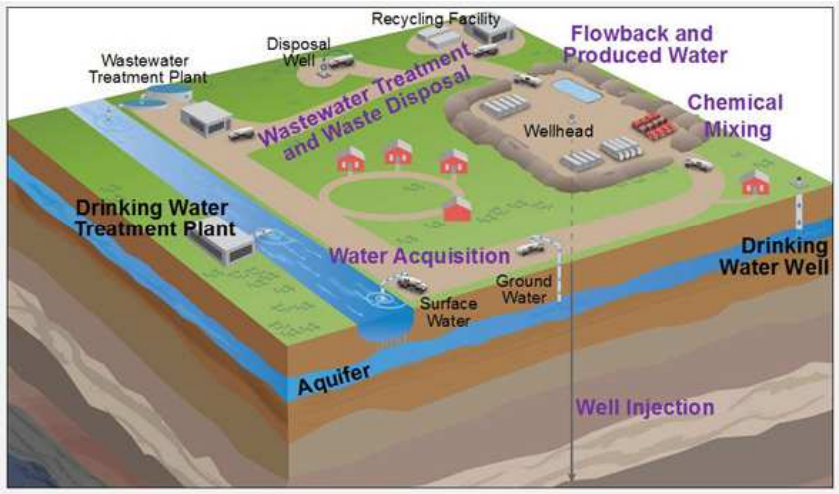
HGI hydroGEOPHYSICS

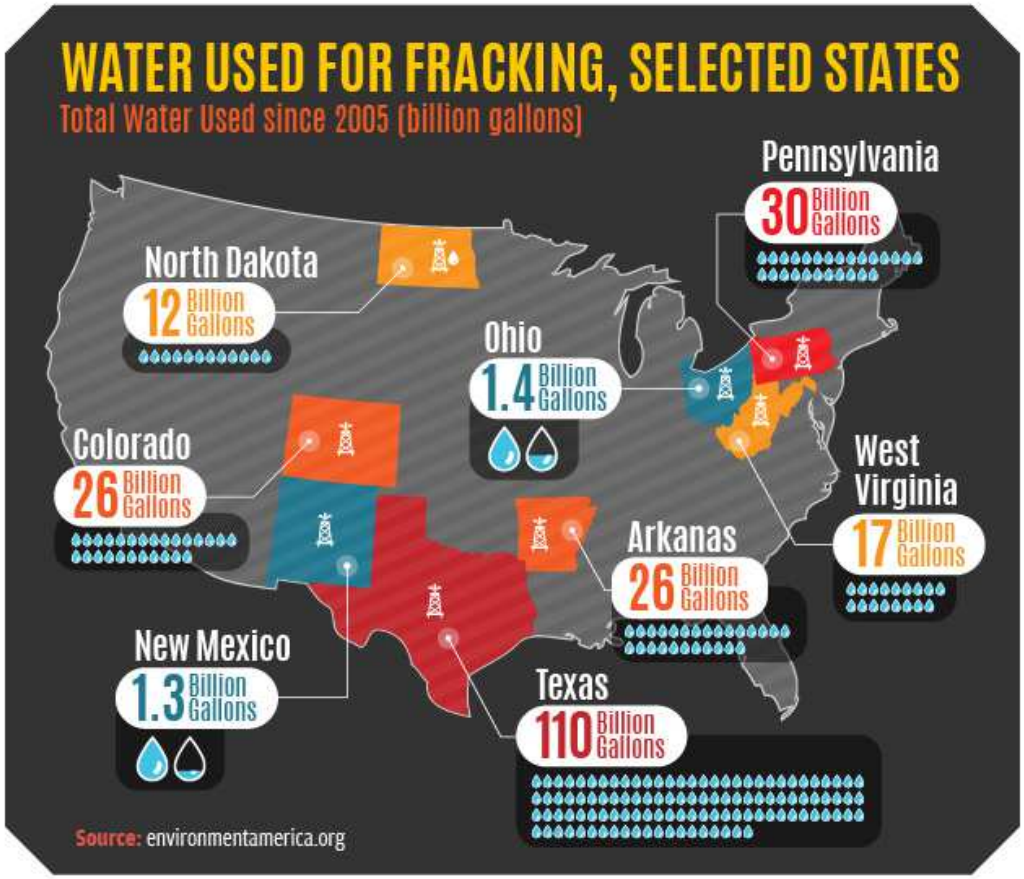
International Petroleum 22ND IPEC Environmental Conference

Water

Fracking Water

Fracking Process





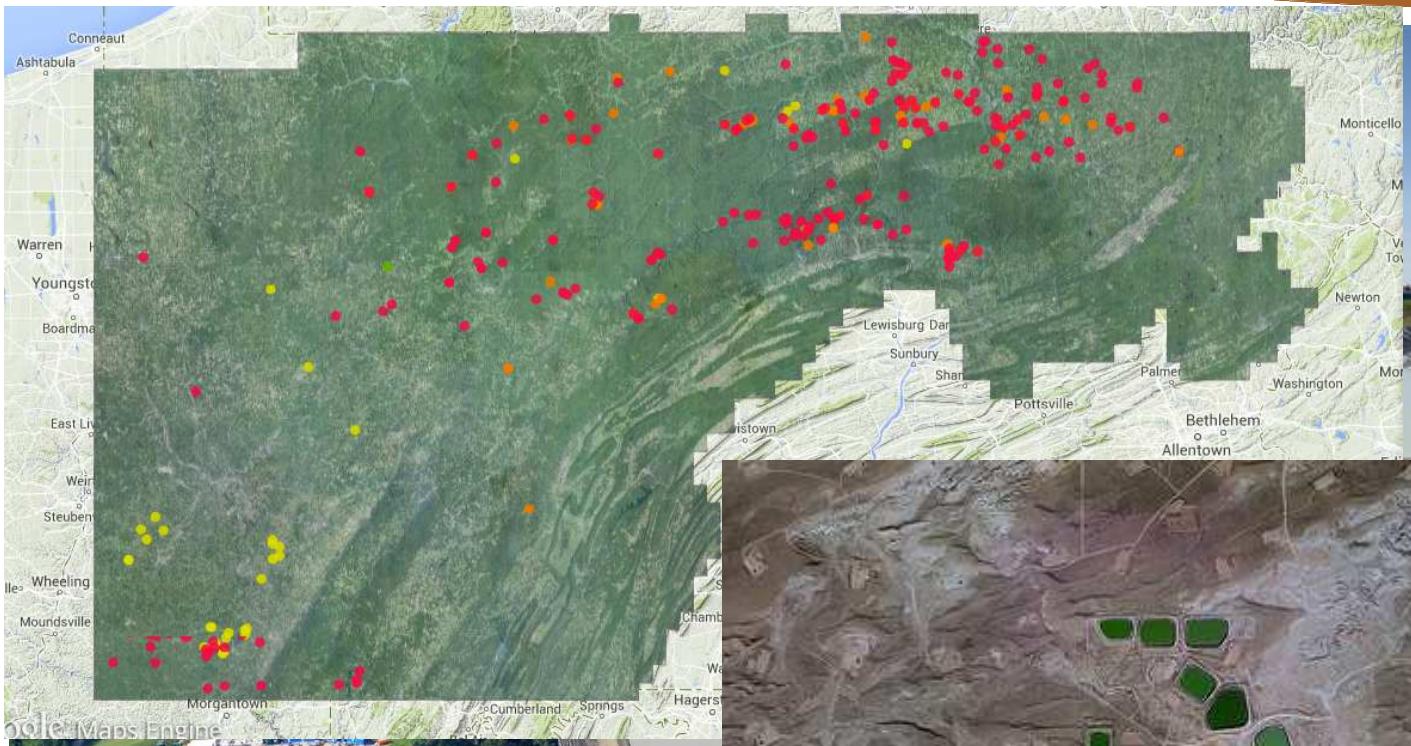
Typical volumes of water:

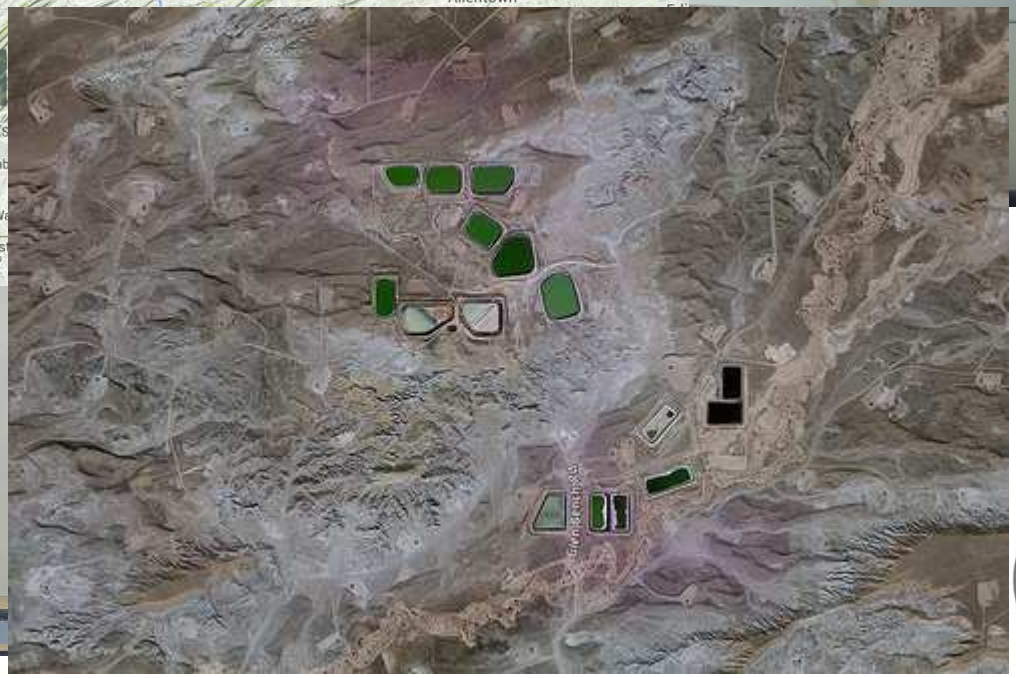
4 - 5,00,000 gallons for horizontal wells

670,000 gallons for vertical wells

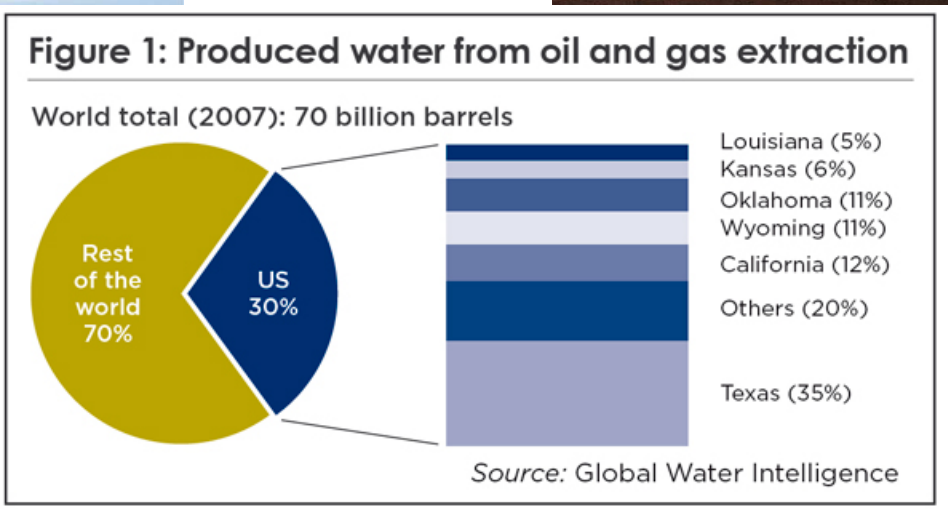
Flowback Storage

Flowback Storage





Produced Water

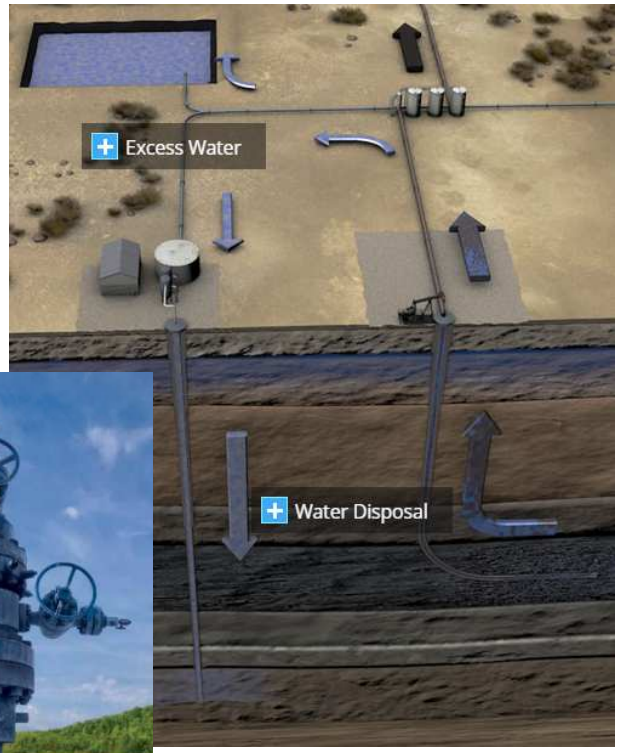


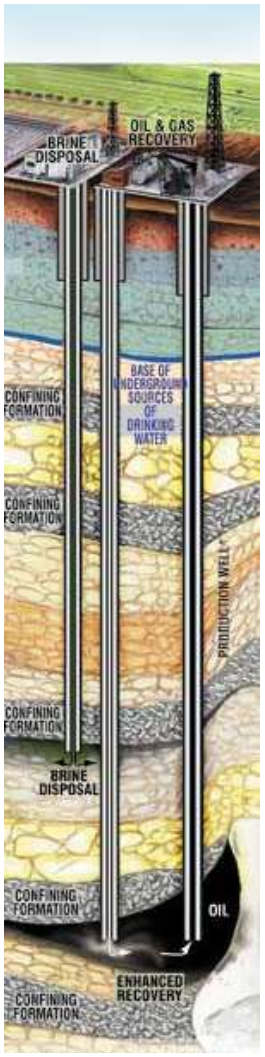
Typical volumes of water:

Average in N. America, 8 barrels of produced water for every barrel of oil

In CA, 15 barrels of produced water for every barrel of oil

Disposal





~80% of wells for enhanced oil recovery (EOR)
~20% of wells for waste water disposal

Problem

Spills and leaks of waste water

Nearly 3 Million Gallons Of Drilling Waste Spill From North Dakota Pipeline

BY KATIE VALENTINE JAN 22, 2015 9:28AM

In this Dec. 17, 2014 photo, workers tend to oil pump jacks behind a natural gas flare near Watford City, N.D.

Share 29,481 Tweet 2,621

Almost 3 million gallons of saltwater drilling waste spilled from a North Dakota pipeline earlier this month, a spill that's now being called the state's largest since the North Dakota oil boom began.

The brine, which leaked from a ruptured pipeline about 15 miles from the city of Williston, has affected two creeks, but it doesn't currently pose a threat to drinking water or public health. The pipeline's operator — Summit Midstream Partners — discovered the spill on Jan. 6, but officials didn't find out about the true size of the spill until this week.

The pipeline company has been trying to clean up the spill by vacuuming water from the creek, but in doing so, they're also capturing a lot of fresh water.

Problem

Spills and leaks of waste water

Published November 18, 2013, 10:19 AM

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Saltwater spills can cause lasting damage

BISMARCK - More than 55,000 barrels of saltwater — about 2.3 million gallons — produced by the oil and gas industry have been spilled on North Dakota land in the past 22 months, posing an environmental risk to soil, plants and freshwater resources in dozens of cases, a Forum News Service review of incident reports found.

By: **Mike Nowatzki**, Forum News Service

BISMARCK - More than 55,000 barrels of saltwater — about 2.3 million gallons — produced by the oil and gas industry have been spilled on North Dakota land in the past 22 months, posing an environmental risk to soil, plants and freshwater resources in dozens of cases, a Forum News Service review of incident reports found.

State regulators highlight that most of the saltwater was contained and cleaned up on well sites.

Reports show 81 percent of the 1,085 releases of saltwater — some of it mixed with oil, diesel fuel or other liquids — were contained on site or within the leaking pipeline's right-of-way.

And nearly 70 percent of the saltwater was reported as recovered, usually by vacuuming up the briny liquid or hauling the contaminated soil to the landfill, or both, according to incident reports filed with the state Department of Health from Jan. 1, 2012, to Oct. 29 of this year.

Saltwater Spill

Oil company workers from Encore Energy Partners Operating LLC pump saltwater out of a creek in the Badlands in Billings County after an Oct. 30 spill. Photo Courtesy of North Dakota Department of Health

More...

- Oil companies testing water recycling technologies
- Environmental problems from ND evaporation pits linger
- Equipment failure, human error most likely causes of spills

Still, at least 15 percent of the spills — more than 13,000 barrels — weren't contained, and the issue is considered a high enough priority that the department is trying to assemble a task force of university experts, industry representatives, state regulators and others to look this winter at new ways of dealing with saltwater spills, said Dennis Fewless, director of the department's Division of Water Quality.

"Are there new, better approaches to remediating this saltwater? Because that's actually harder to clean up than the oil," he said.

The amount of saltwater spilled in the state since 2012 would fill nearly four Olympic-size swimming pools. By comparison, during roughly the same time frame, 751 oil spills were reported in North Dakota, spilling a total of about 4,528 barrels of oil, the Associated Press reported last month. Those figures don't include a 20,600-barrel oil spill discovered near Tioga in September.

Western North Dakota landowners have become more organized and vocal in their concerns about saltwater spills. Last month, landowners and a lawyer led a tour of so-called "salted lands" in Bottineau County, where pockets of farmland sterilized by spills and pipeline leaks dot the landscape.

"Saltwater is far more devastating to our environment than oil is," said Galen Peterson, who farms near Maxbass in Bottineau County and is secretary of the Northwest Landowners Association.

Public notice in works

Incident reports show about four-fifths of the saltwater spills since 2012 were 50 barrels or fewer, and almost half involved five barrels or fewer. A barrel is 42 gallons.

Nearly 3 Million Gallons Of Drilling ill From North Dakota Pipeline

AN 22, 2015 9:28AM

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Problem

Spills and leaks of waste water

Oil drillers' brine spills blight land

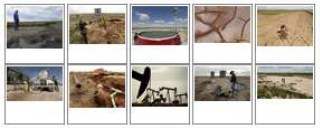
Story | Image (15) | Print | Font Size:

Previous | Next

AP Photo/Charlie Riedel

Oil drillers' brine spills blight land

ADVANCE FOR USE TUESDAY, SEPT. 8, 2015 AND THEREAFTER - In this April 24, 2015 photo, Carl Johnson, left, and his son, Justin, walk across a stretch of pasture left barren after an oilfield wastewater spill on their ranch near Crossroads, N.M. The ranchers have been fighting oil companies for decades over spills of briny, polluted water.



View all 15 images in gallery.

Posted: Tuesday, September 8, 2015 2:30 am

Associated Press |

CROSSROADS, N.M. — Carl Johnson and son Justin, who have complained for years about spills of oilfield wastewater where they raise cattle in the high plains of New Mexico, stroll across a 1 1/2-acre patch of sandy soil — lifeless, save for a scattering of stunted weeds.

Five years ago, a broken pipe soaked the land with as much as 420,000 gallons of wastewater, a salty drilling byproduct that killed the shrubs and grass. It was among dozens of spills that have damaged the Johnsons' grazing lands and made them worry about their groundwater.

"If we lose our water," Justin Johnson said, "that ruins our ranch."

Their plight illustrates a side effect of oil and gas production that has worsened with the past decade's drilling boom: spills of wastewater that foul the land, kill wildlife and threaten freshwater supplies.

An Associated Press analysis of data from leading oil- and gas-producing states found more than 180 million gallons of wastewater spilled from 2009 to 2014 in incidents involving ruptured pipes, overflowing storage tanks and even deliberate dumping. There were some 21,651 individual spills. The numbers are incomplete because many releases go unreported.

Though oil spills get more attention, wastewater spills can be more damaging. Microbes in soil eventually degrade spilled oil. Not so with wastewater — also known as brine, produced water or saltwater. Unless thoroughly cleansed, salt-saturated land dries up. Trees die. Crops cannot take root.

"Oil spills may look bad, but we know how to clean them up," said Kerry Sublette, a University of Tulsa environmental engineer. "Brine spills are much more difficult."

In addition to extreme salinity, the fluids often contain heavy metals such as arsenic and mercury. Some ranchers said they have lost cattle that lapped up the liquids or ate tainted grass.

"They get real thin. It messes them up," said Melvin Reed of Shidler, Oklahoma. "Sometimes you just have to shoot them."

Nearly 3 Million Gallons Of Drilling ...ill From North Dakota Pipeline

Tweet 0 | Share 5 | G+1 0 | Print | E-mail

...sting damage

...er — about 2.3 million gallons — produced by the oil and gas ... in the past 22 months, posing an environmental risk to soil, plants ...orum News Service review of incident reports found.

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Saltwater Spill

Oil company workers from Encore Energy Partners Operating LLC pump saltwater out of a creek in the Badlands in Billings County after an Oct. 30 spill. Photo Courtesy of North Dakota Department of Health

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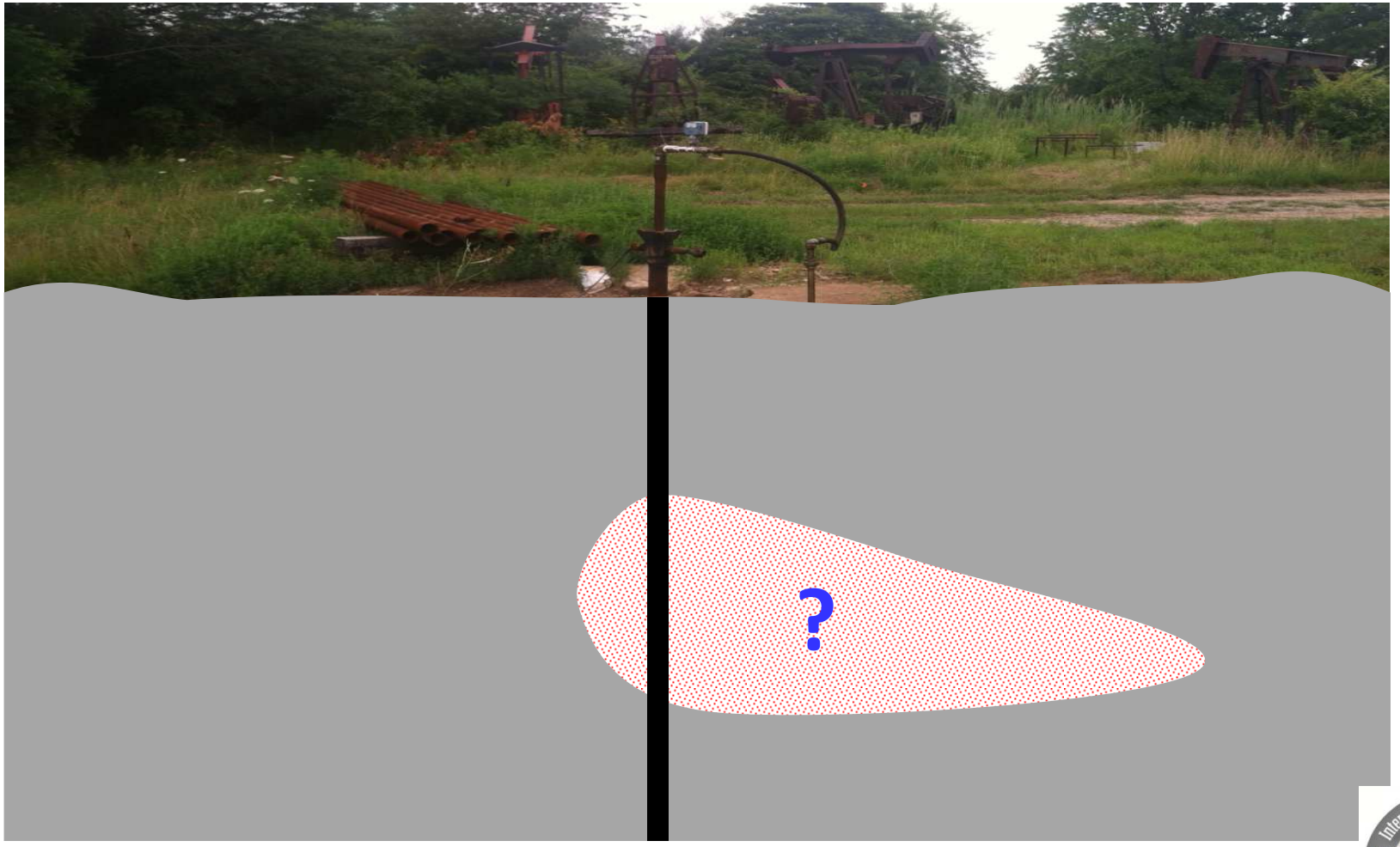
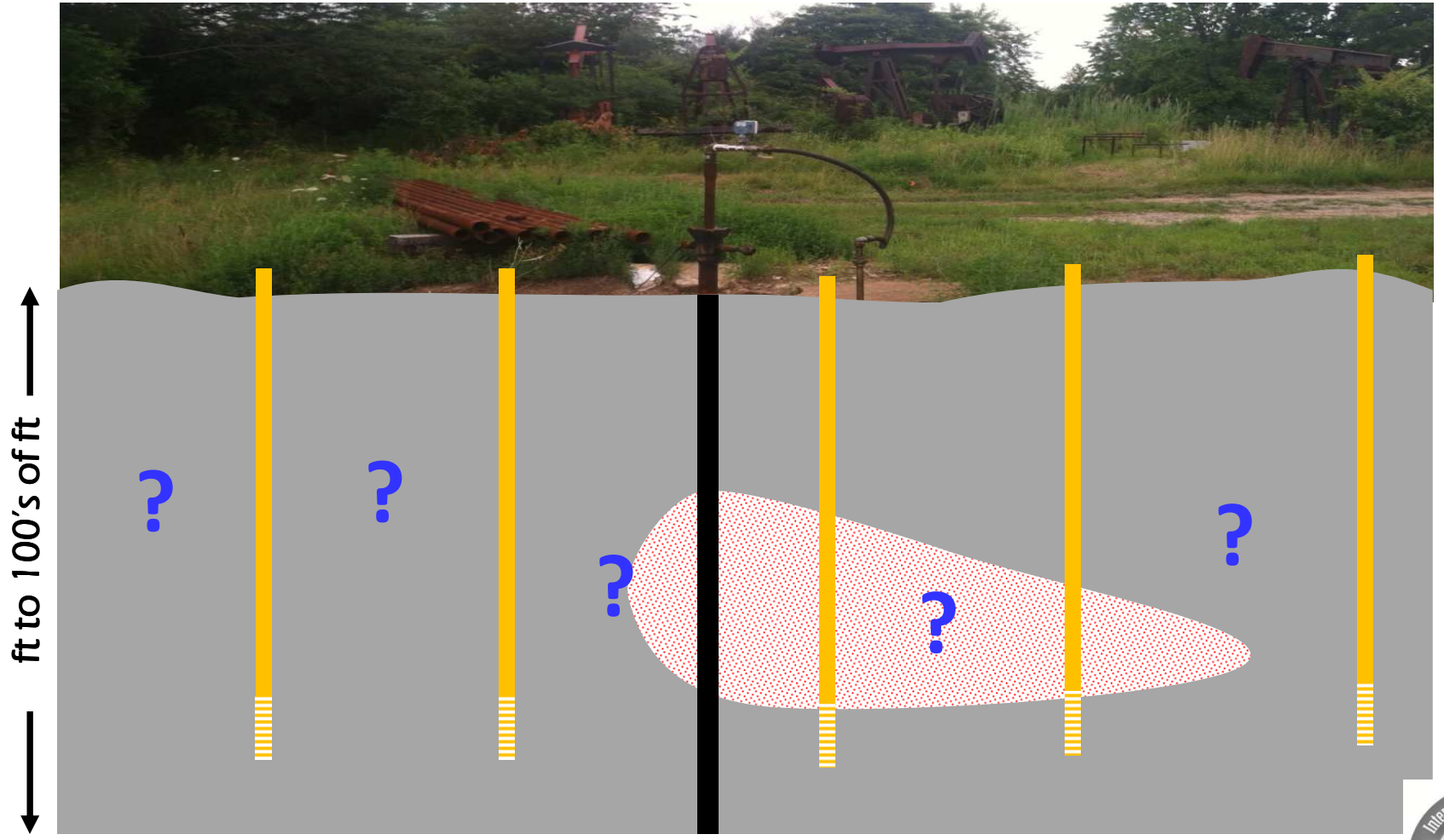


Traditional solutions

Traditional solutions

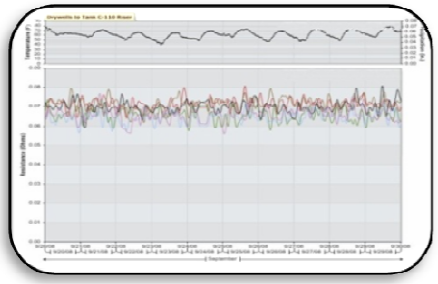


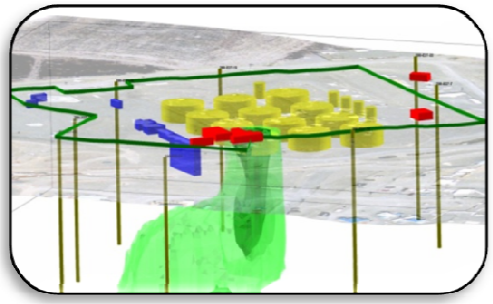
Geophysical Methods

Present Conditions

- Geophysics
  - Monitoring
    - Fluid Flow / Movement
      - Mine Leach Pad
      - Infiltration / Injection
      - Aquifer Testing
    - Leak Detection
      - Dams
      - Ponds
      - Pipes
      - Tanks
  - Characterization
    - Environmental
      - Landfills
      - Leak Detection
      - Industrial
      - Plumes
    - Resources
      - Water
      - Geologic
      - Exploration
      - Mining

Past Events

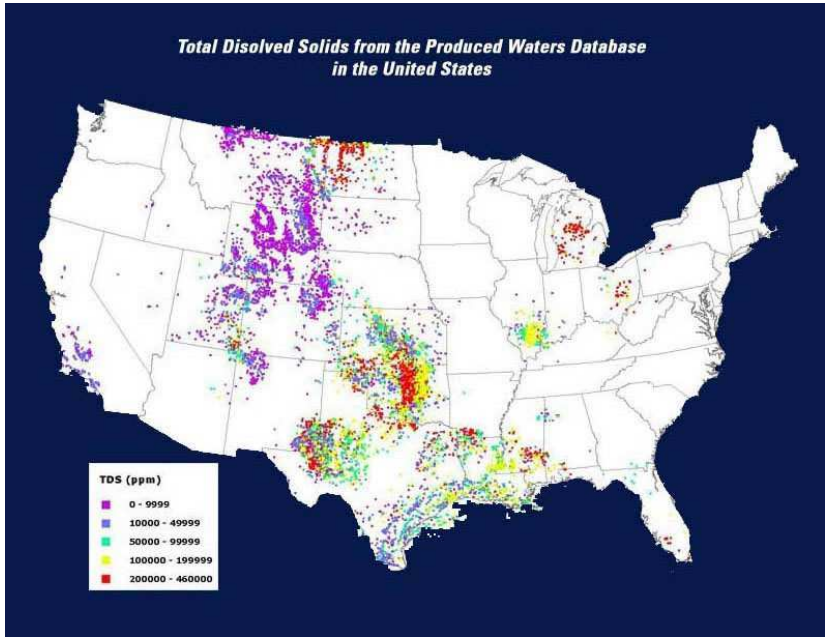




Method choice

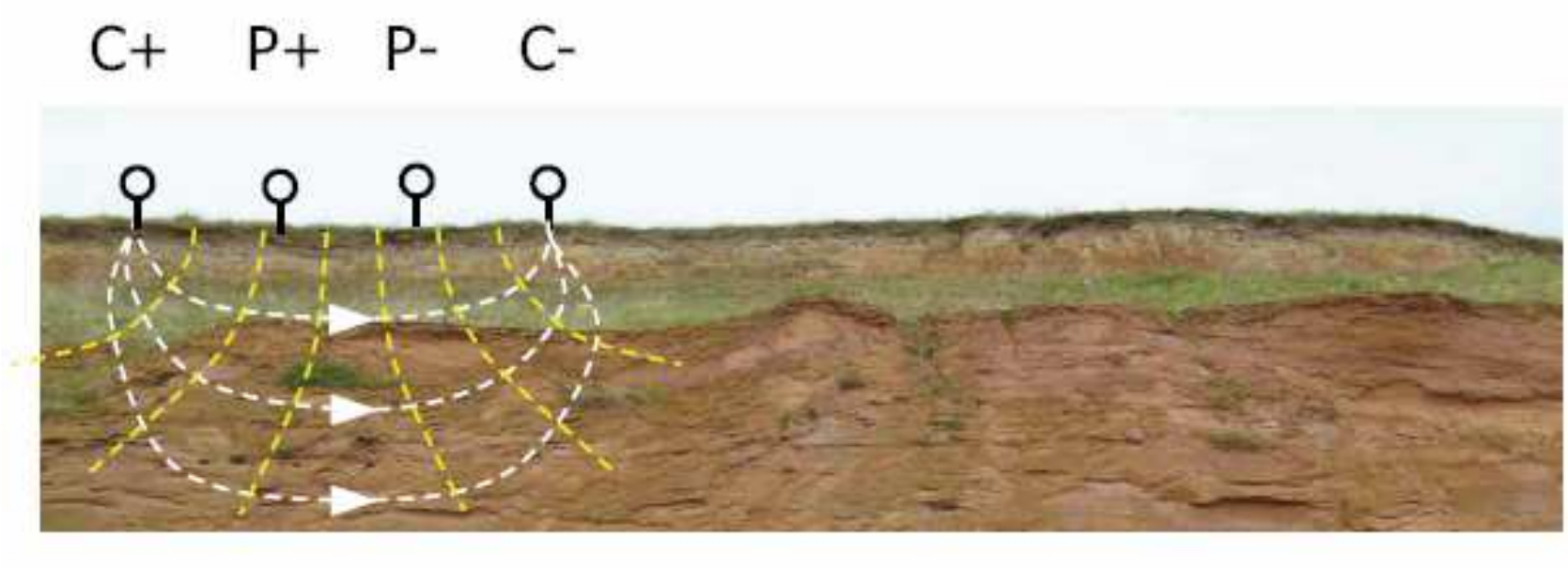
Produced water characteristics

Parameter	Blended	Flowback/Produced	Groundwater (Freshwater)
Total Dissolved Solids (TDS) mg/L	11,100	35,600	233
Conductivity (µmhos/cm at 25C)	30,400	139,000	449
pH	6.36	6.57	7.74
Chloride (mg/L)	6,300	22,900	18.1
Sodium (mg/L)	2,680	8,120	6.75
Calcium (mg/L)	811.0	2,610.0	81.6
Magnesium (mg/L)	59.7	183.0	19.9
Sulfate (mg/L)	4.62	3.3	36.2



Electrical resistivity imaging

Principle

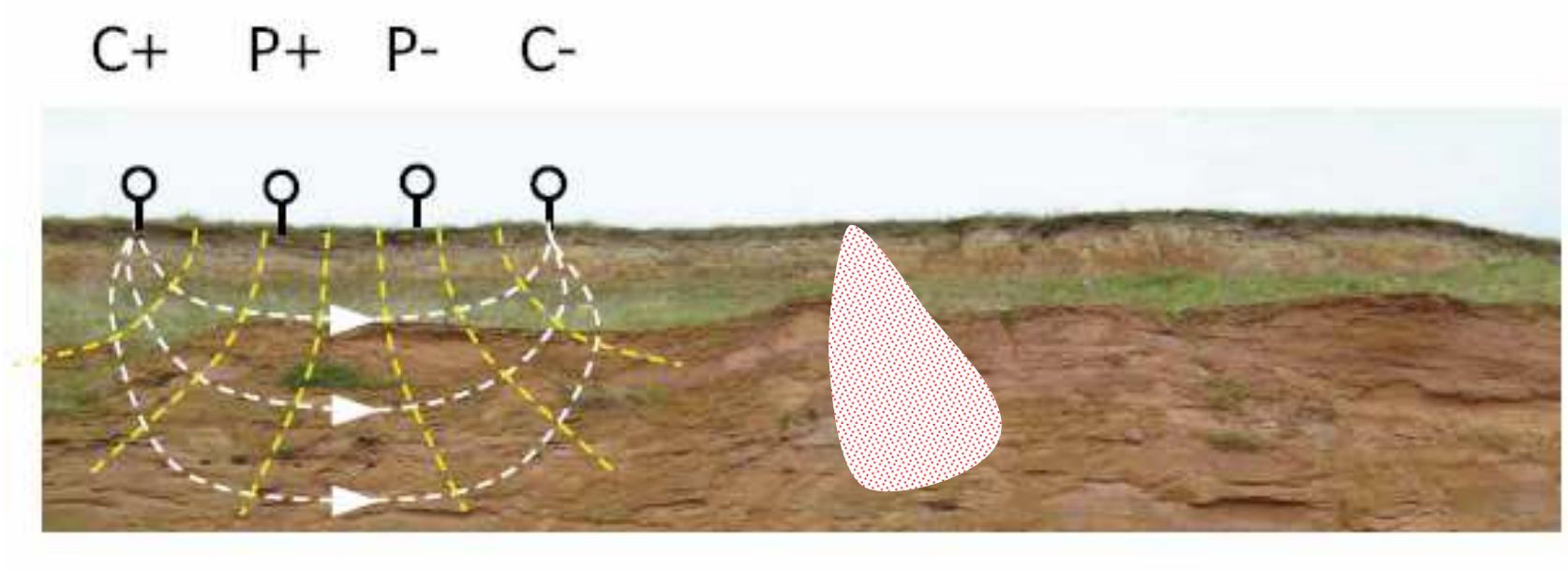


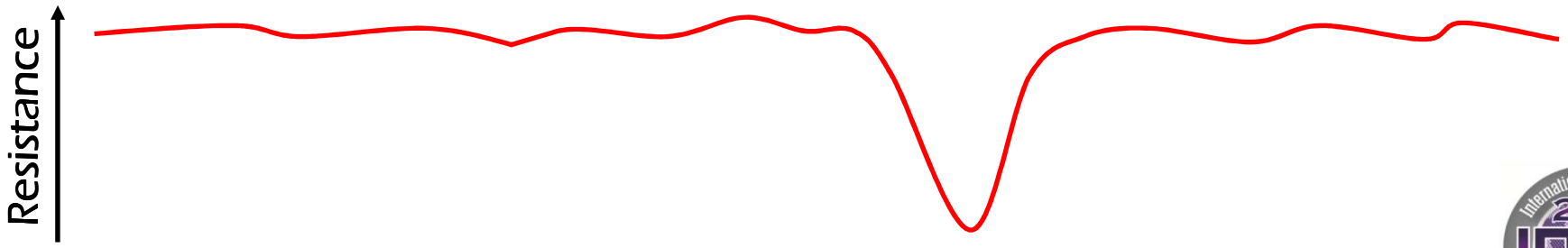
The voltage difference is a function of the injected current and the resistivity beneath the electrode array

Ohm's Law: $V = I R$

Electrical resistivity imaging

Measurement response





Electrical resistivity imaging

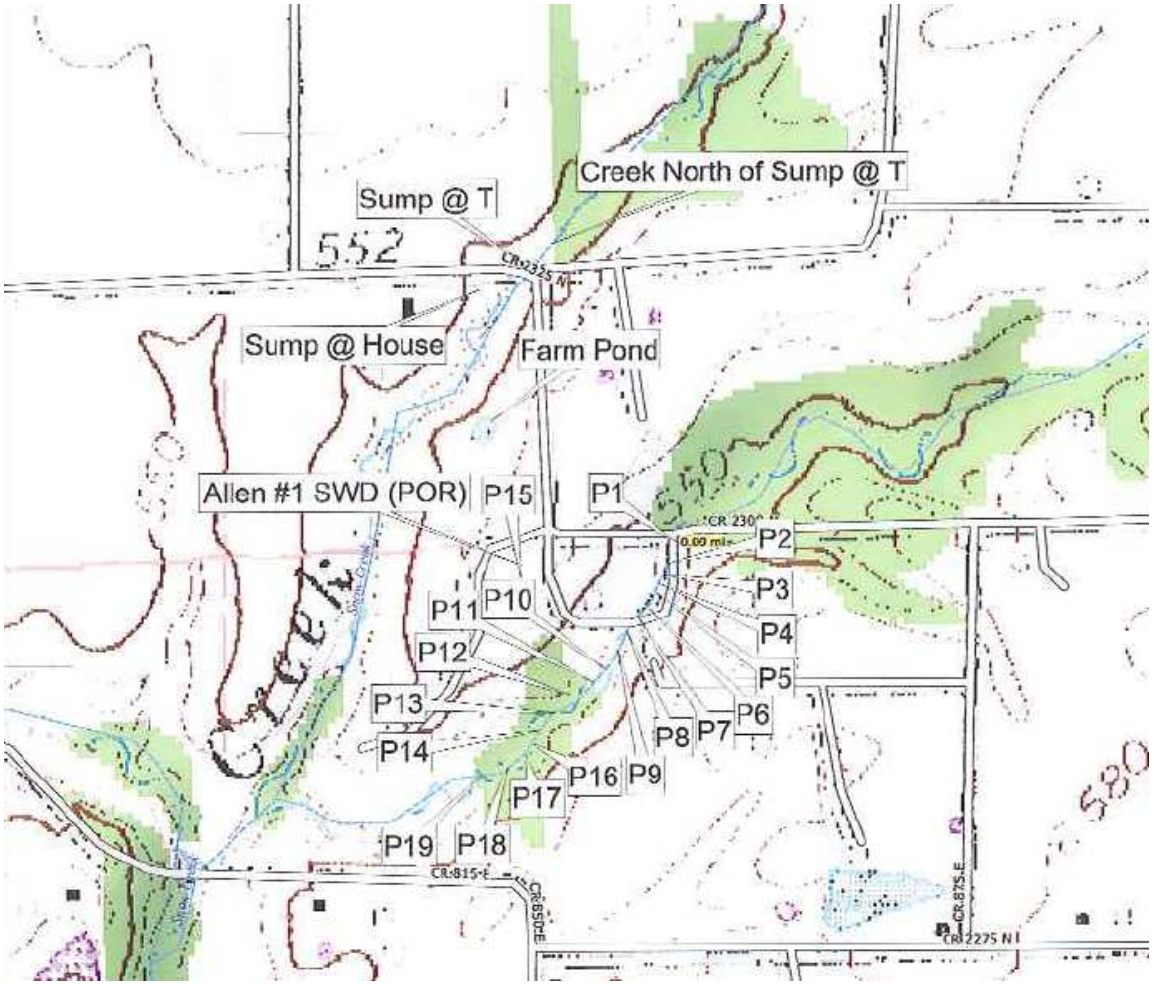
In reality

Case study

Release from a Saltwater Disposal Well

Case study

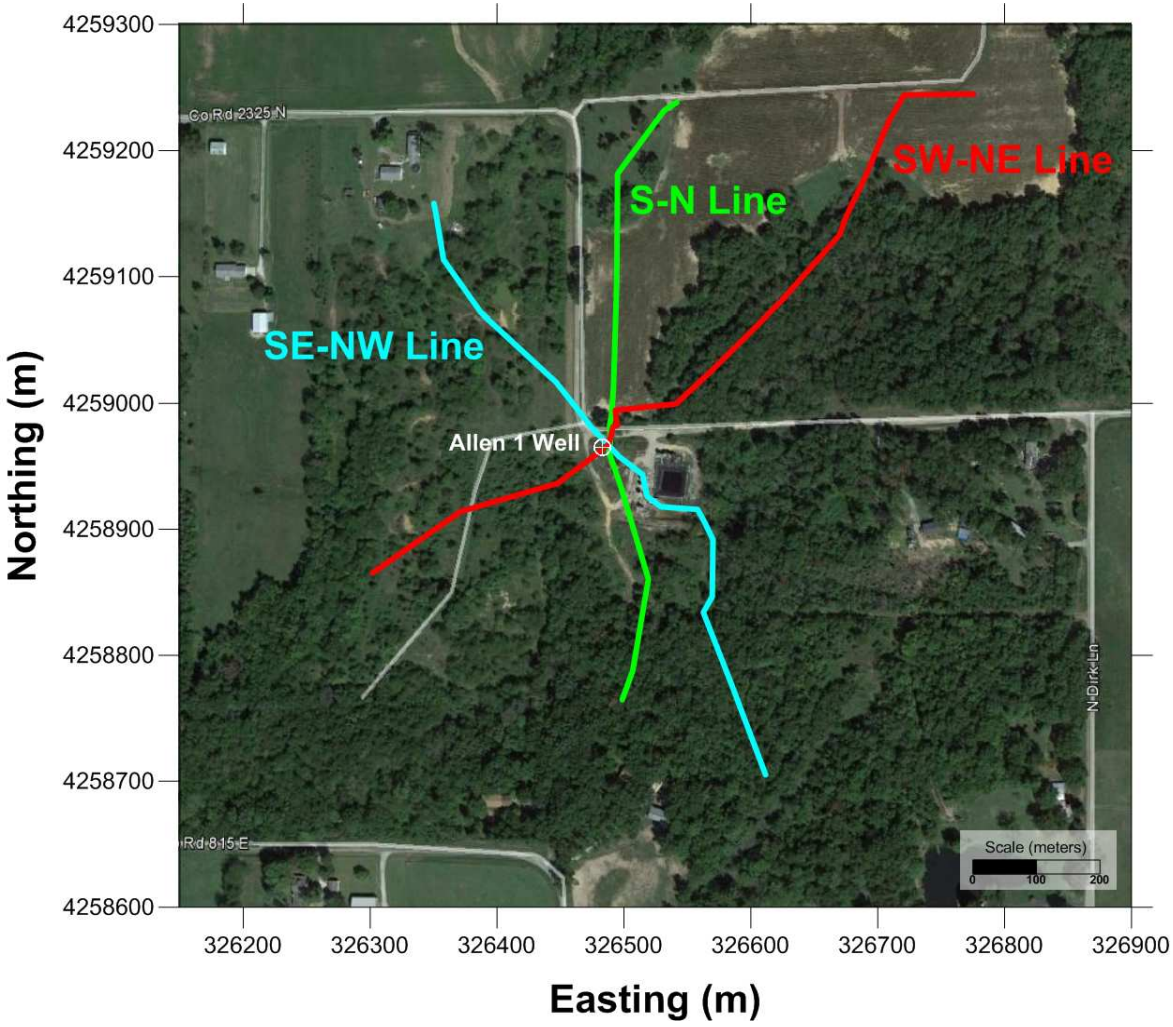
Site and conditions

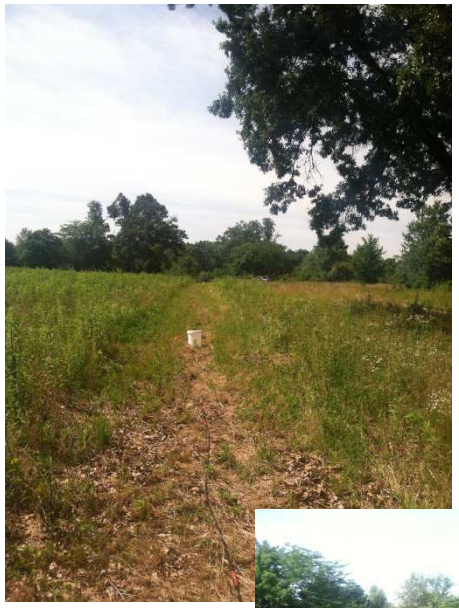


Site	Chloride (mg/l)
P-1	1,000
P-4	904
P-7	2,030
P-10	2,920
P-13	5,560
P-15	3,330
Farm Pond	2,820
Sump @ house	16,200
Sump @ T	17,100
Creek (north of sump @ T)	1,410

Survey Layout

Data collection

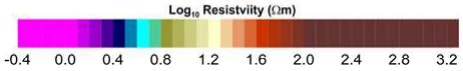


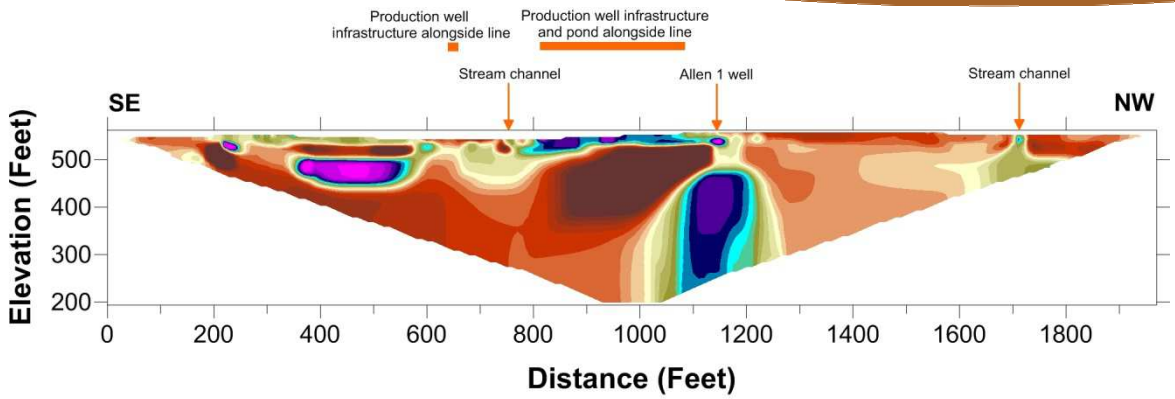


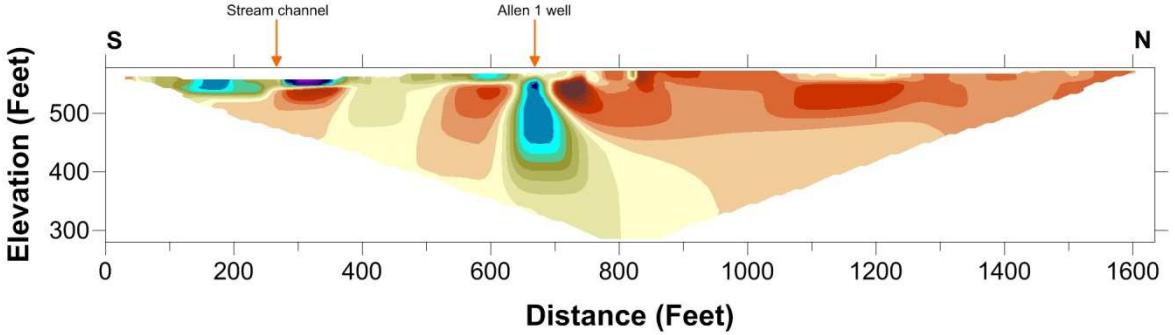
International Petroleum 22ND IPEC Environmental Conference

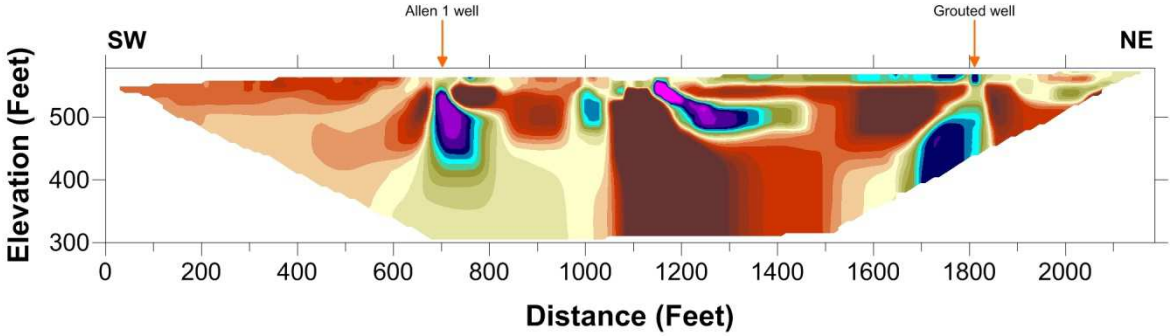
Results

Resistivity results



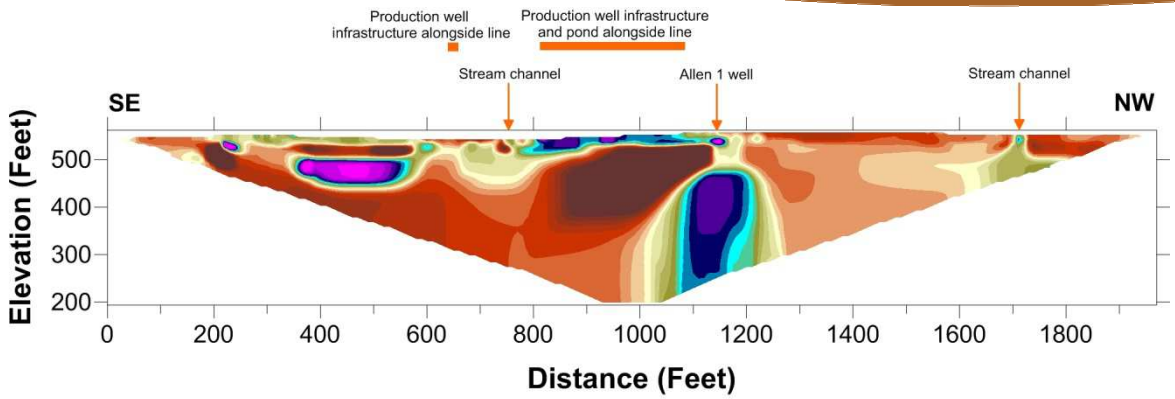


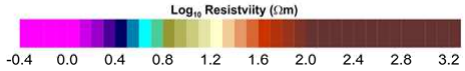


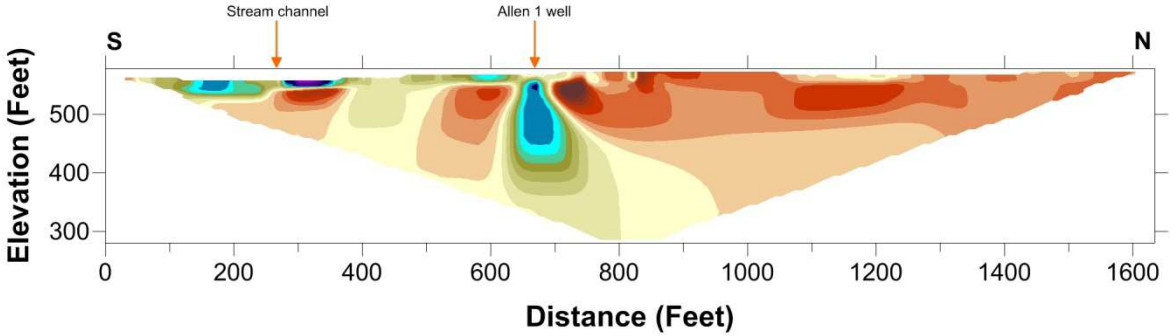


Case study

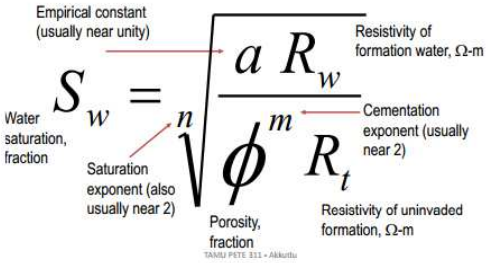
Resistivity results

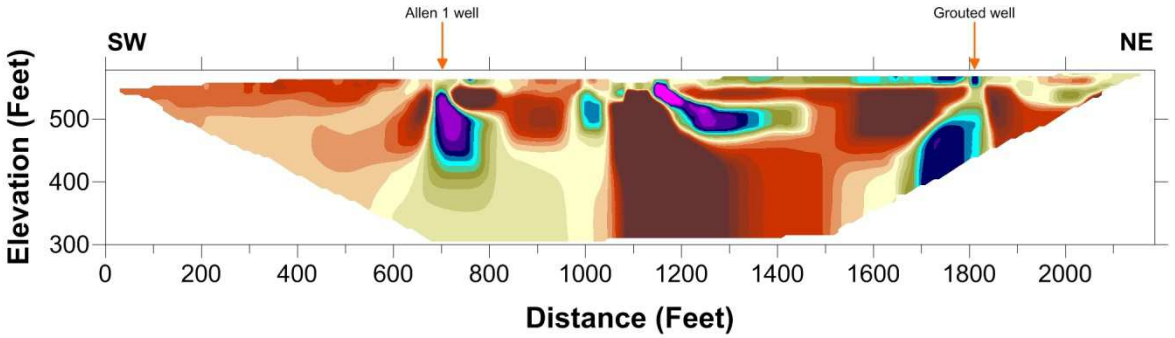






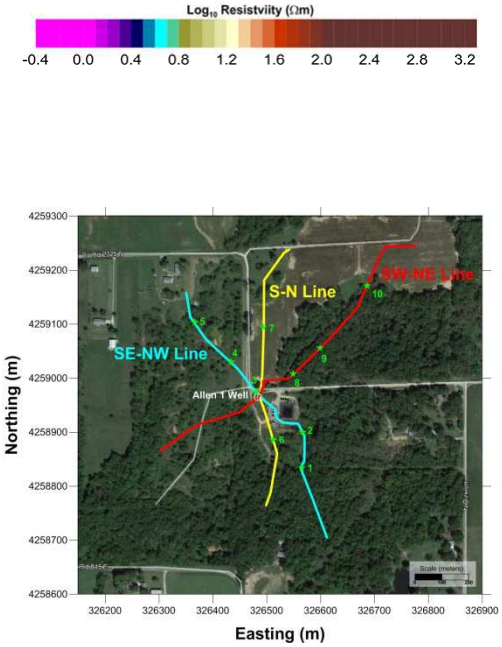
Archie's Law:

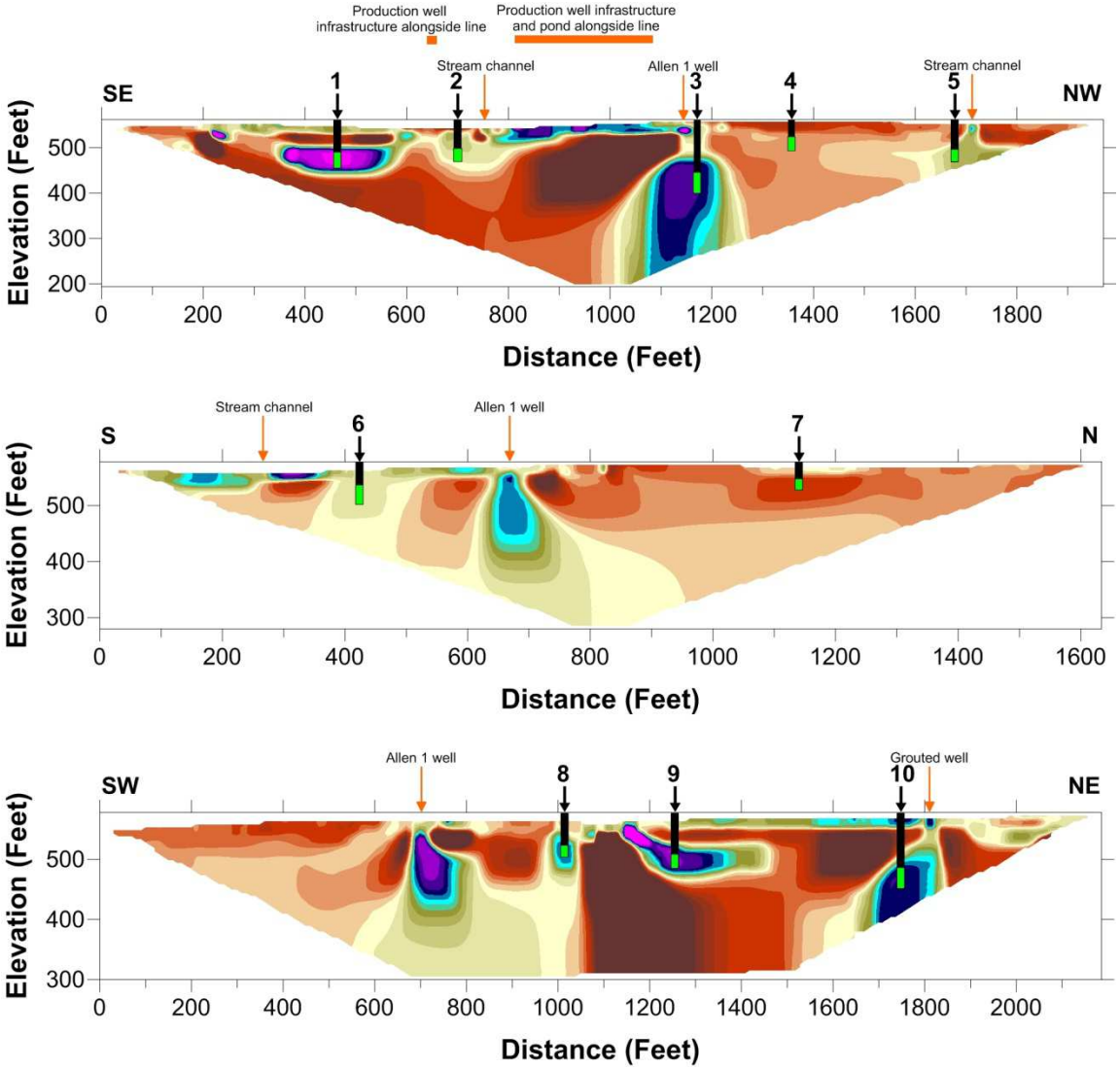




Case study

Ground truthing





Case study

Summary

- Electrical resistivity technique proved to be successful in delineating regions impacted by the brine spill.
- The plume in proximity to the injection well indicate the leak originated at depth, consistent with other leaking wells in area.
- Based on the subsurface geology in the area we were able to use Archie's law to provide a resistivity range for the subsurface regions impacted by the brine for this reconnaissance survey.
- Geophysical results use to aid in placement of follow-up monitoring wells. The sampling results from these wells correlate well to the resistivity results.

  Unfortunately the drilling technique was unable to penetrate the shallow bedrock and so still awaiting further quantitative results.

Questions / Comments ?

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LEAK DETECTION
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Website Resources:

- General: hgiworld.com
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- Leak Detection: hgileakdetection.com