

# Reserve Pit and Brine Pond Studies in North Dakota

Presented to the  
Energy Development and Transmission Committee  
Senator Rich Wardner, Chair  
Minot, ND  
April 8, 2014

Ed Murphy  
North Dakota Geological Survey  
Geologic Investigations No. 175

# RESERVE PIT & BRINE POND STUDIES

STRATTON SWD #1

FOSSUM NO.1



WINDERL  
NO.1

**1984-1986**

MADISON NORTH  
UNIT C133

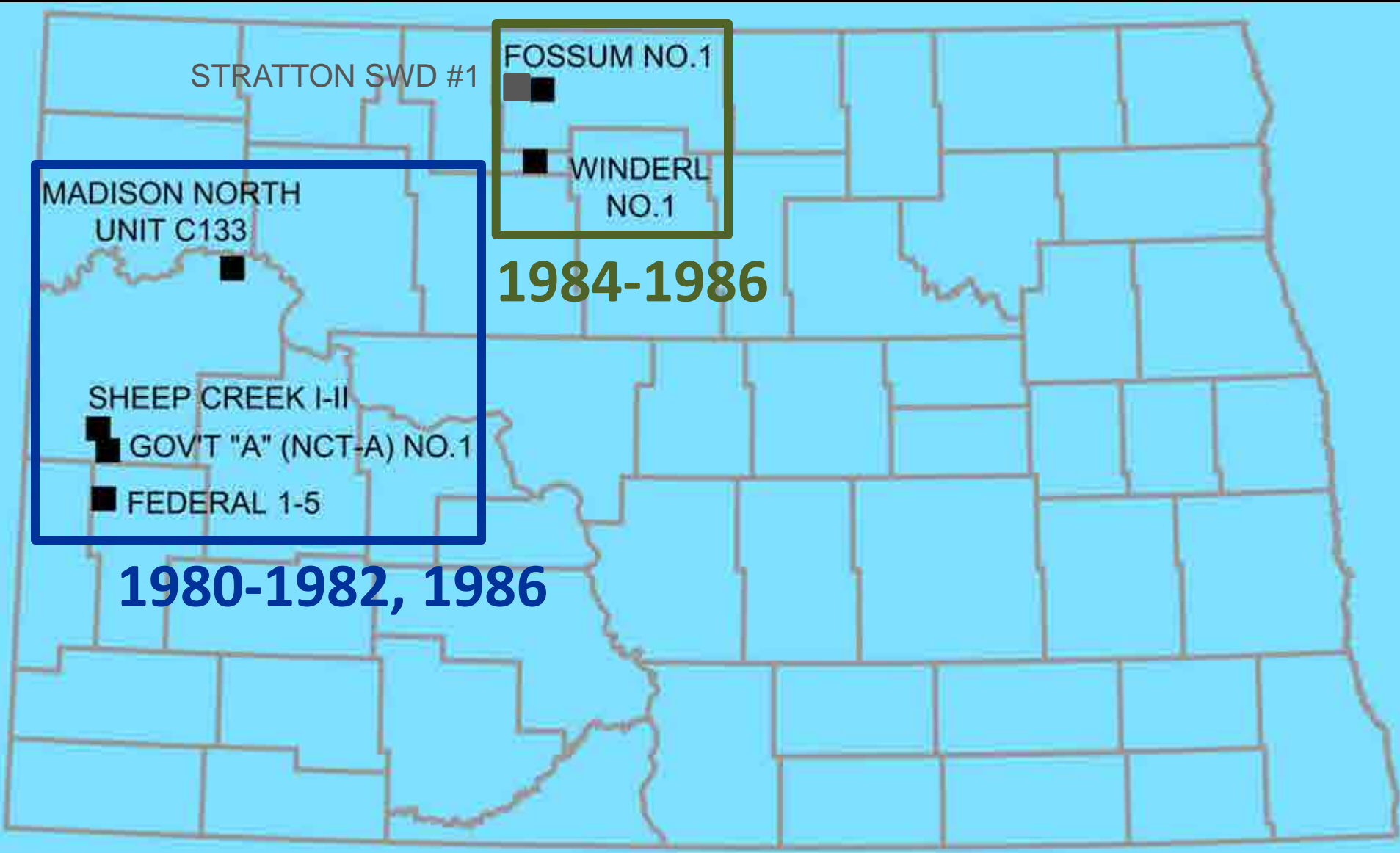


SHEEP CREEK I-II

GOV'T "A" (NCT-A) NO.1

FEDERAL 1-5

**1980-1982, 1986**



# RESERVE PIT & BRINE POND STUDIES

STRATTON SWD #1

FOSSUM NO.1



WINDERL NO.1



1984-1986

MADISON NORTH UNIT C133



SHEEP CREEK I-II



GOV'T "A" (NCT-A) NO.1

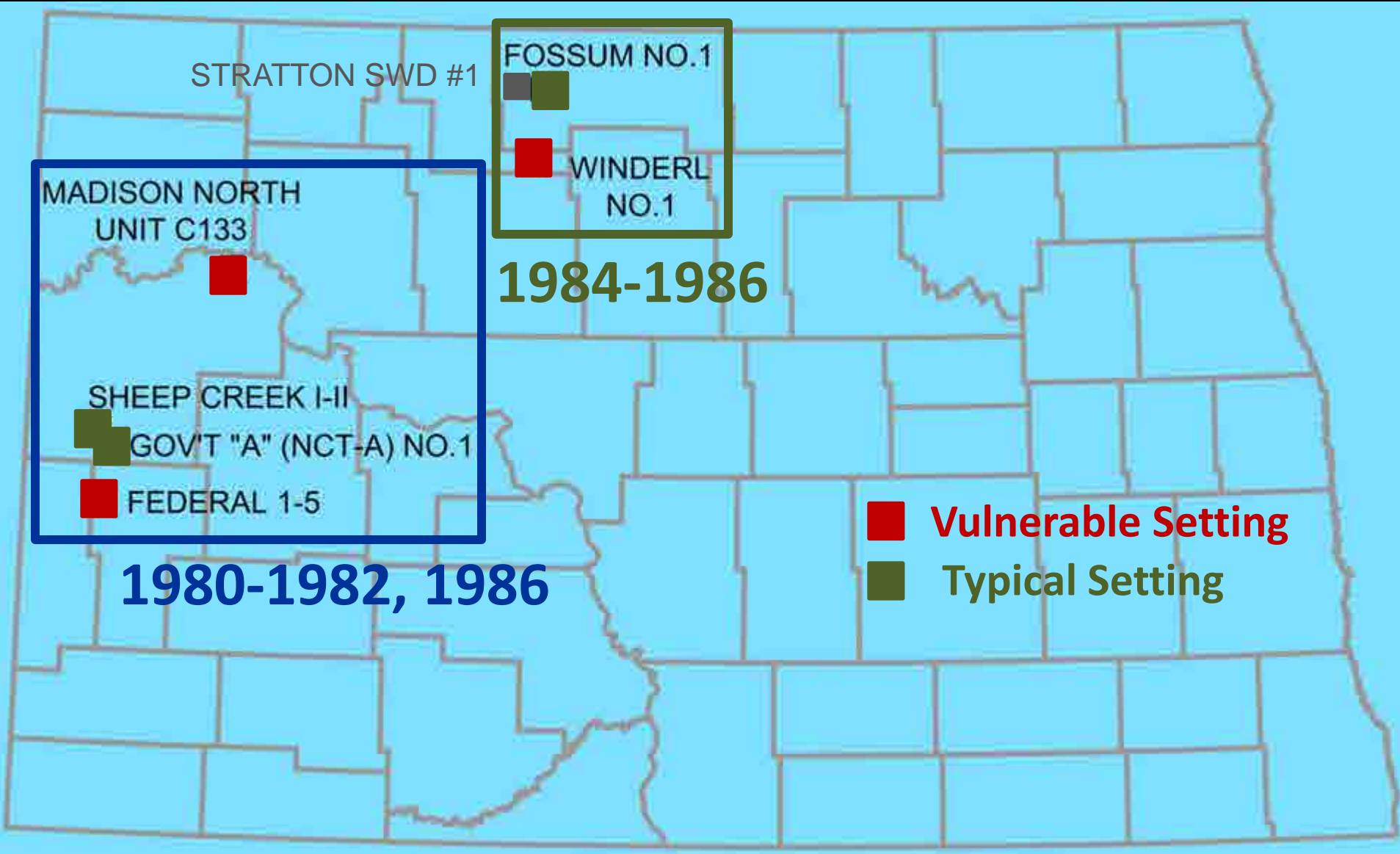


FEDERAL 1-5

1980-1982, 1986

 **Vulnerable Setting**

 **Typical Setting**



# NORTH DAKOTA GEOLOGICAL SURVEY

- **1980 - 1982** Studied four buried reserve pits in western North Dakota (one report, one paper, numerous presentations).
- **1986** Resampled Apache site (one report, one presentation).
- **1984 - 1986** Studied two buried reserve pits in north-central North Dakota (one report, several presentations).
- **1984 - 1985** Studied an abandoned brine holding pond in north-central North Dakota (two reports).

# EARTH RESISTIVITY SURVEY



SMALL ELECTRODE  
SPACING, A'

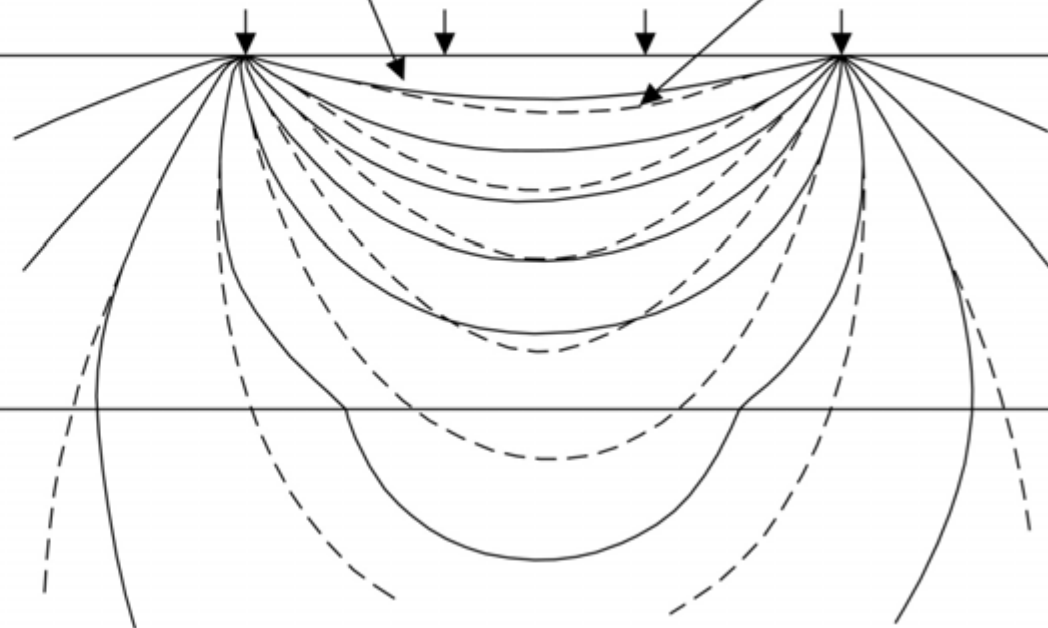
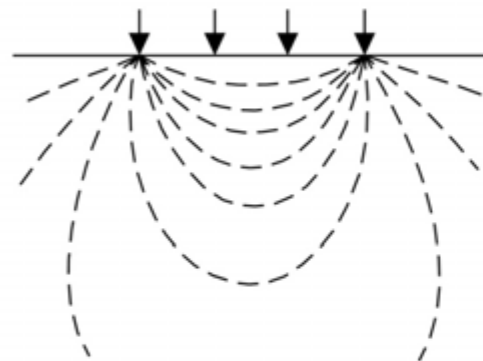
LARGE ELECTRODE  
SPACING, A''

ACTUAL CURRENT FLOW

NORMAL LINES OF  
CURRENT FLOW

$\rho_1$ , LOW

$\rho_2$ , HIGH





# MONITORING WELL (PIEZOMETER) INSTALLATION





# LYSIMETER (soil water sampler) INSTALLATION





# Reserve/Mud Pits

## Dimensions:

150 feet x 60 feet

10 feet deep

30,000 - 50,000 cubic feet  
of waste



1980





TEXACO GOV'T A (NCT-1) #1

drilled in 1960

BELCO PETROLEUM SHEEP CREEK BN 1-11

drilled in 1977





1980

TEXACO GOV'T A (NCT-1) #1 drilled in 1960





Google earth

TEXACO GOV'T A (NCT-1) #1

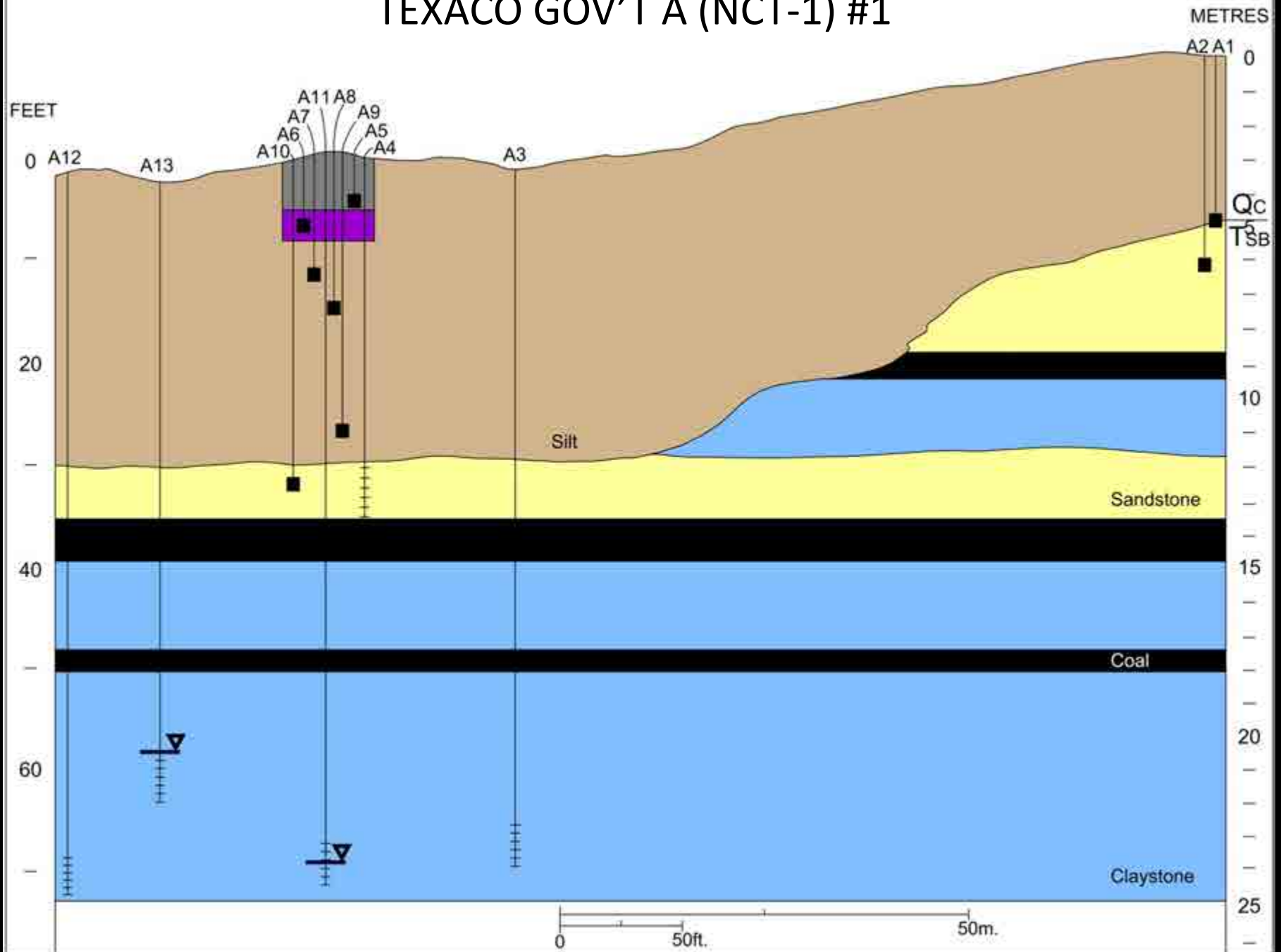
2011



SOUTHWEST

NORTHEAST

# TEXACO GOV'T A (NCT-1) #1



SOUTHWEST

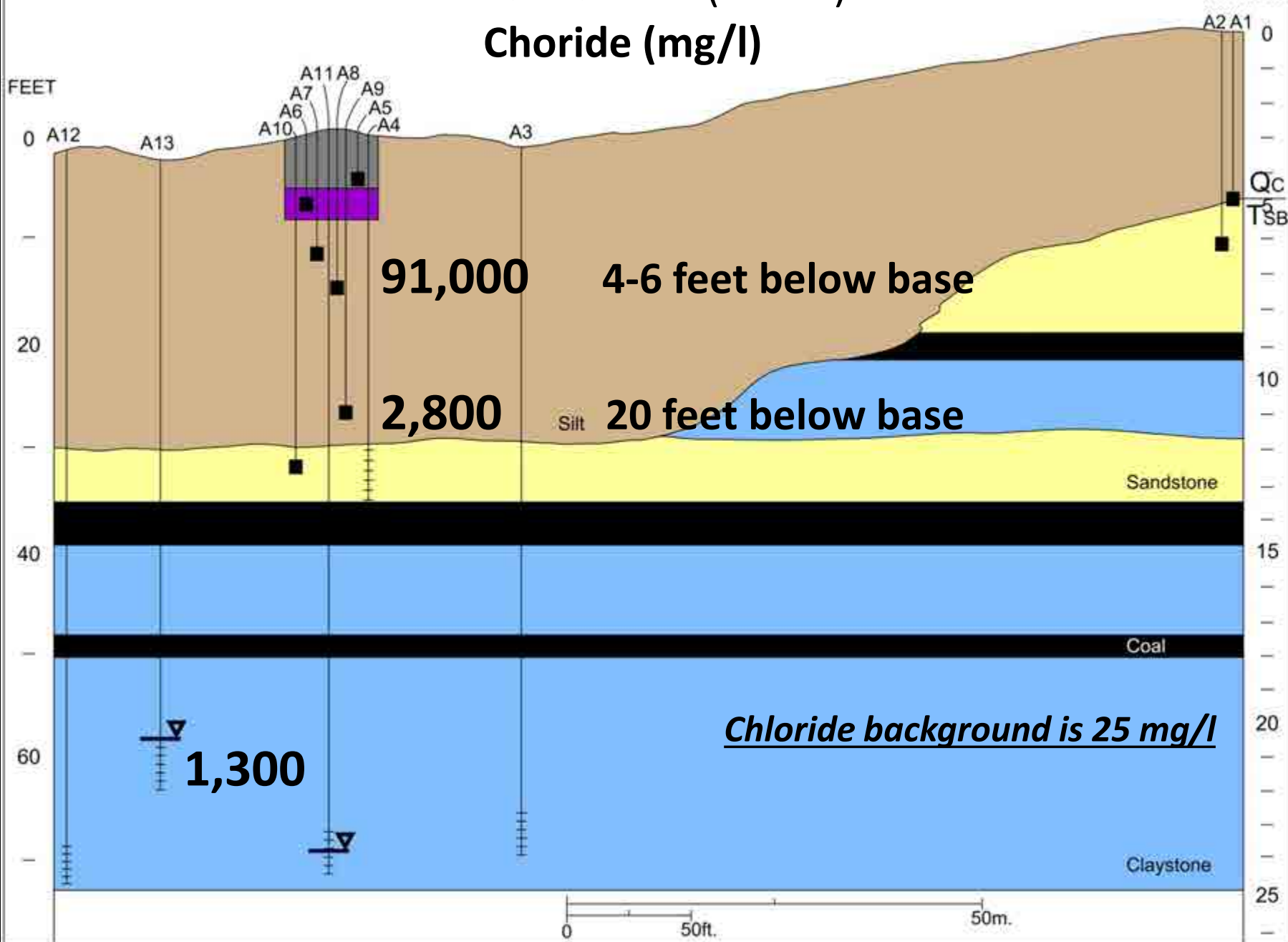
NORTHEAST

# TEXACO GOV'T A (NCT-1) #1

## Chloride (mg/l)

FEET

METRES





1980

BELCO PETROLEUM SHEEP CREEK BN 1-11 drilled in 1977





Google earth

100m

BELCO PETROLEUM SHEEP CREEK BN 1-11

2011

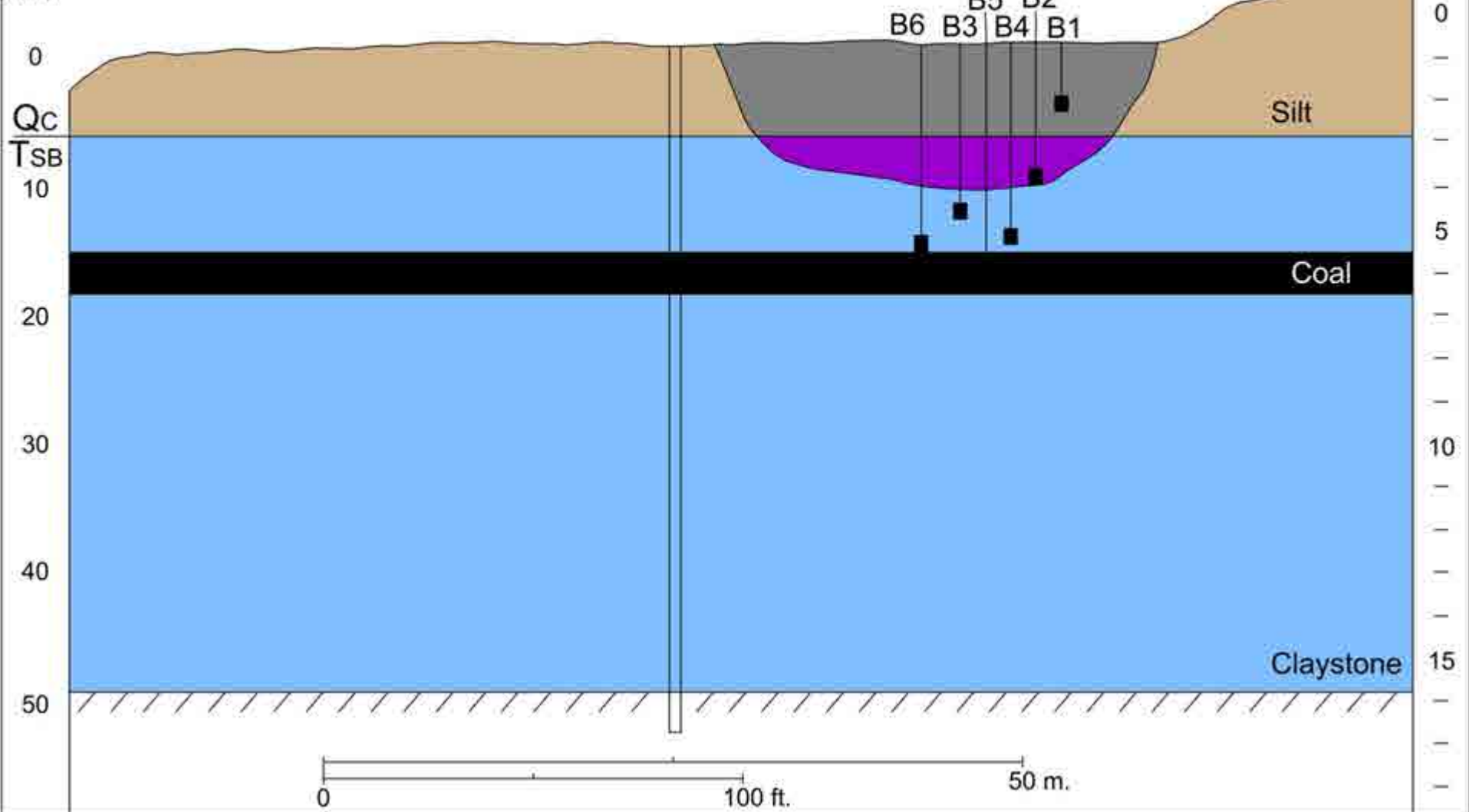
# PETROLEUM SHEEP CREEK BN 1-11

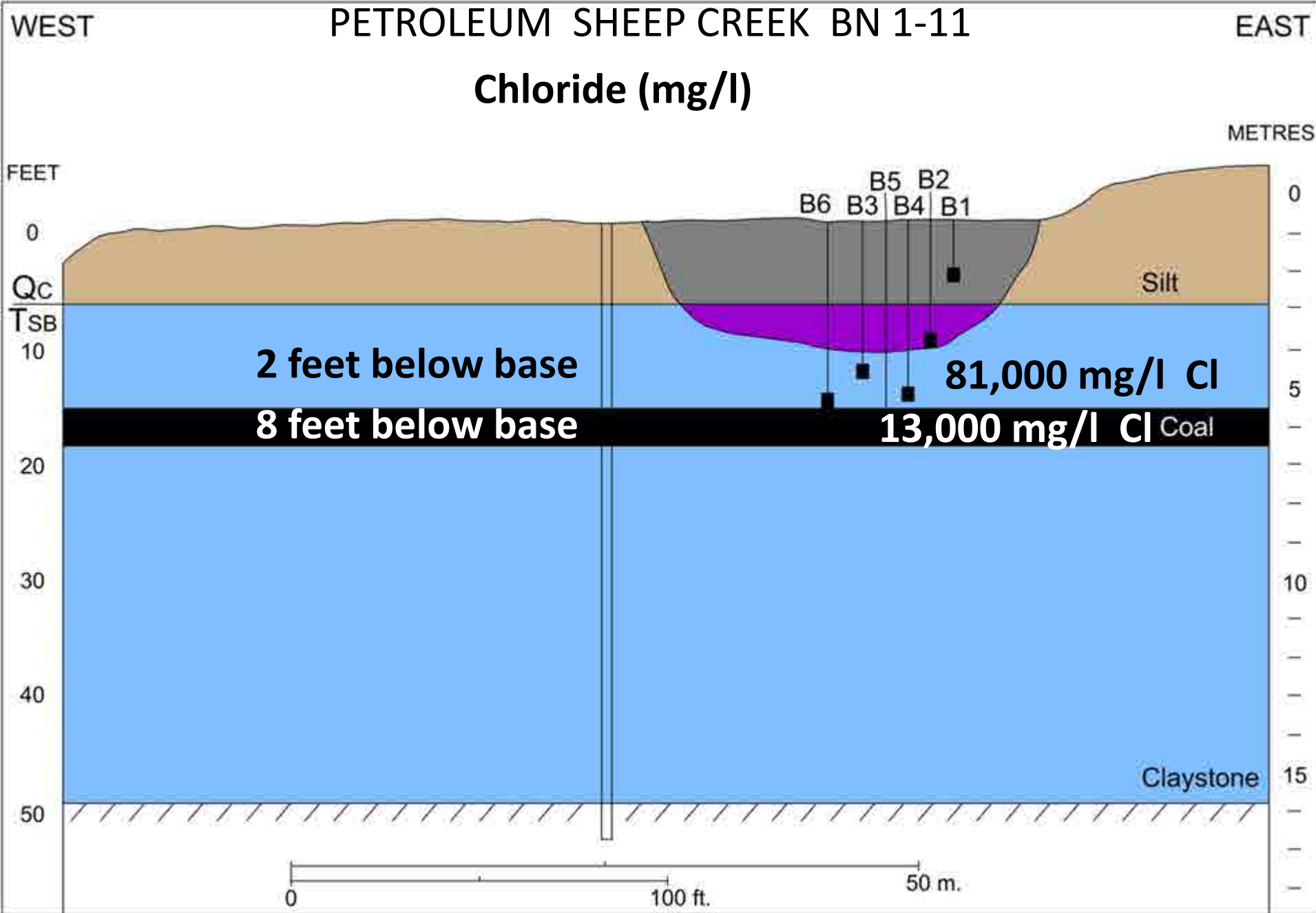
WEST

EAST

FEET

METRES









1981

TEXACO CHARLSON MADISON NORTH UNIT C133

drilled in 1955

# TEXACO CHARLSON MADISON NORTH UNIT C133



2010

Produced oil 1955-1966.

No brine pond in 1959 aerial photograph.

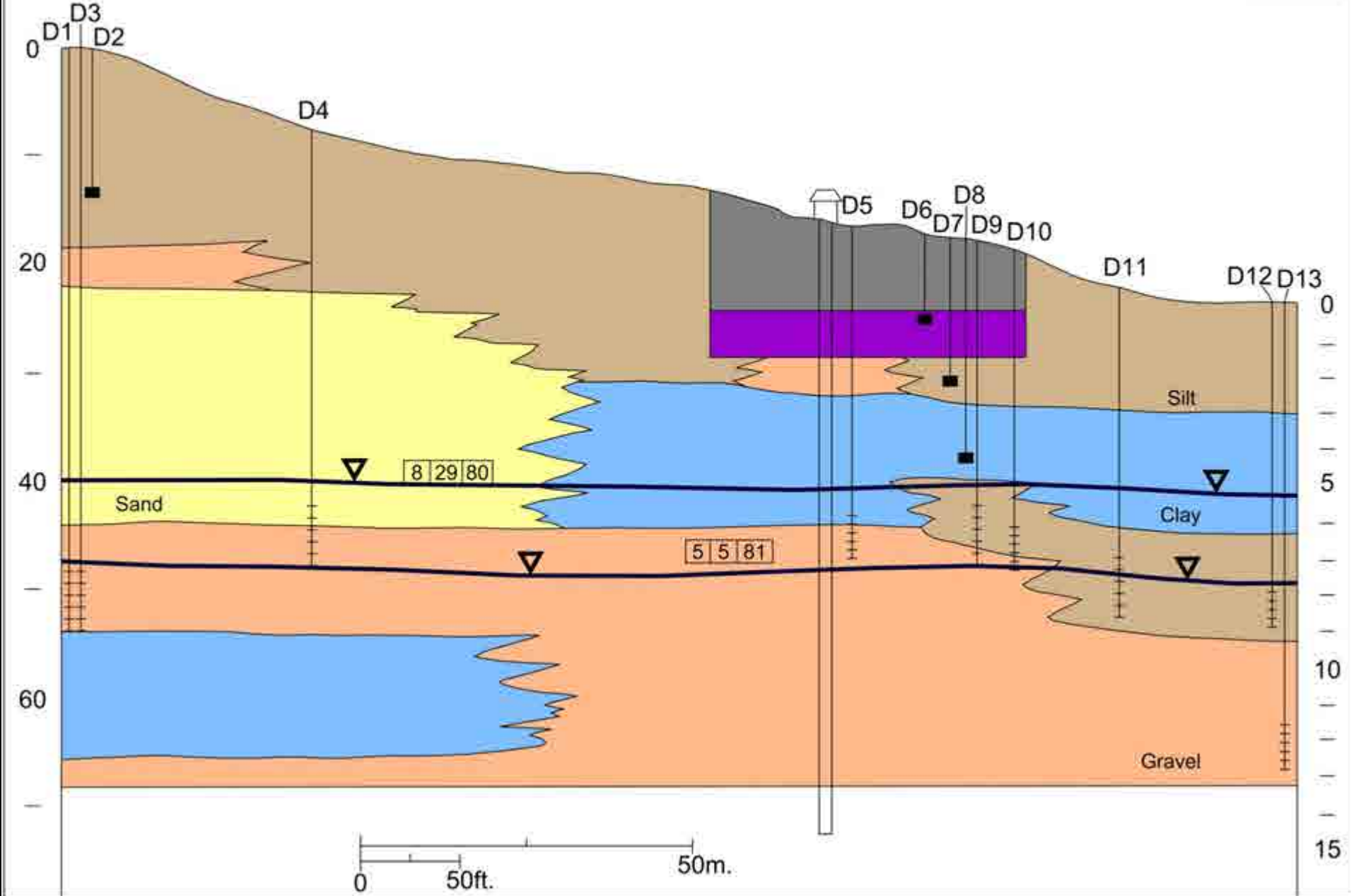
Saltwater injection well 1966 – 1982.

Plugged and abandoned in 1984.

# TEXACO CHARLSON MADISON NORTH UNIT #C133

SOUTH  
FEET

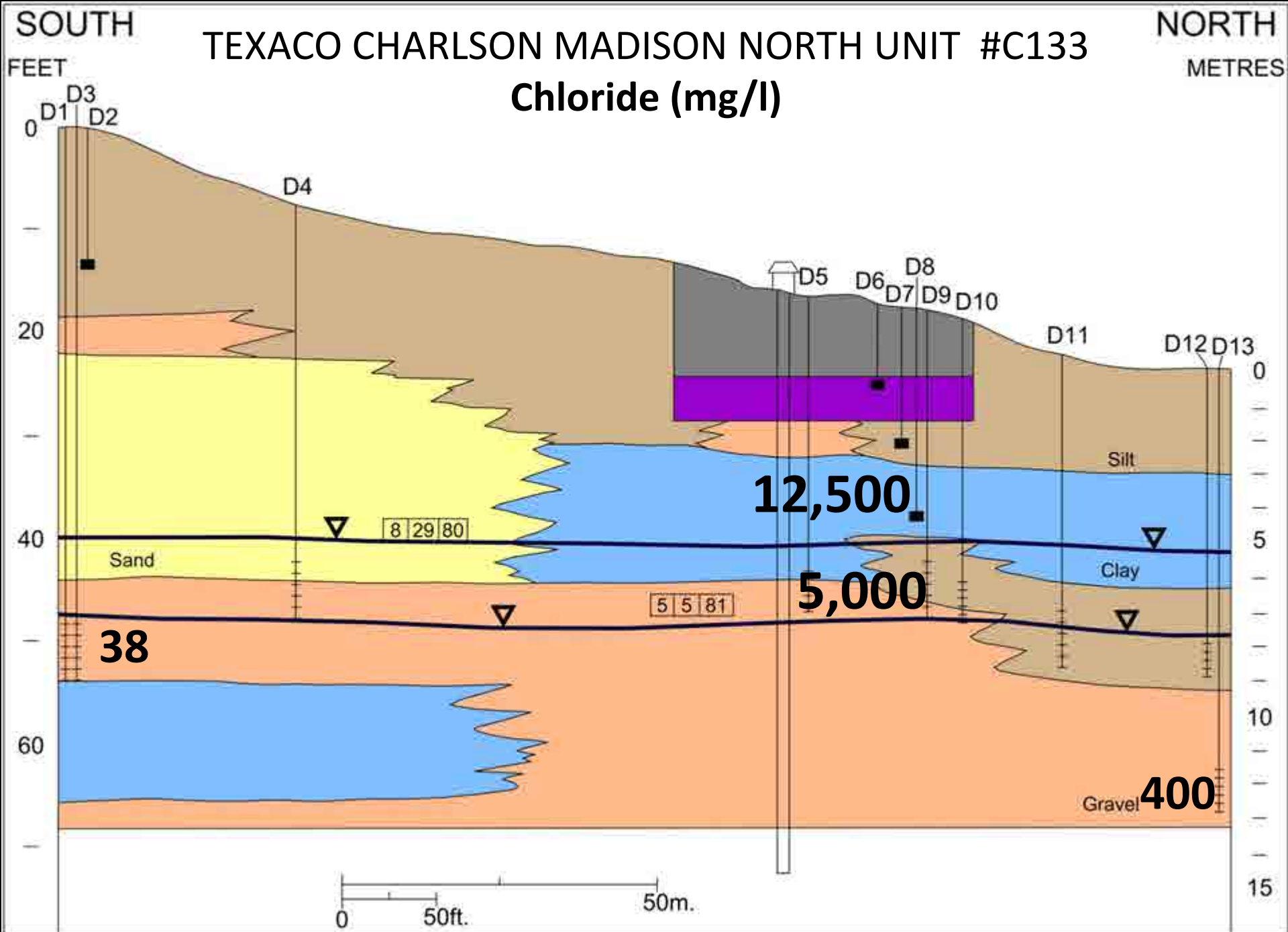
NORTH  
METRES

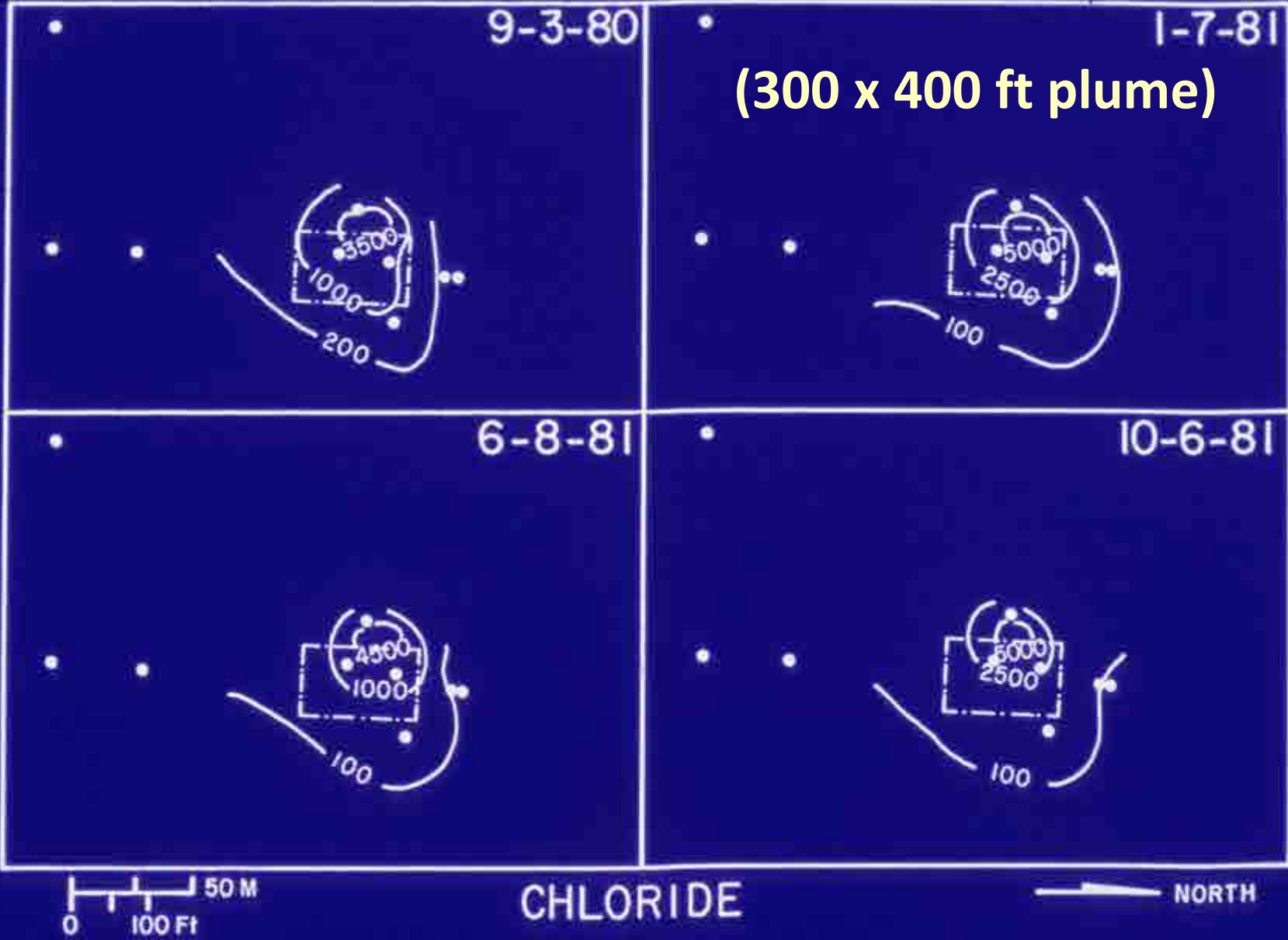




# TEXACO CHARLSON MADISON NORTH UNIT #C133

## Chloride (mg/l)





TEXACO CHARLSON MADISON NORTH UNIT #C133



1980

APACHE FEDERAL 1-5 drilled in 1979





1981

APACHE FEDERAL 1-5 drilled in 1981



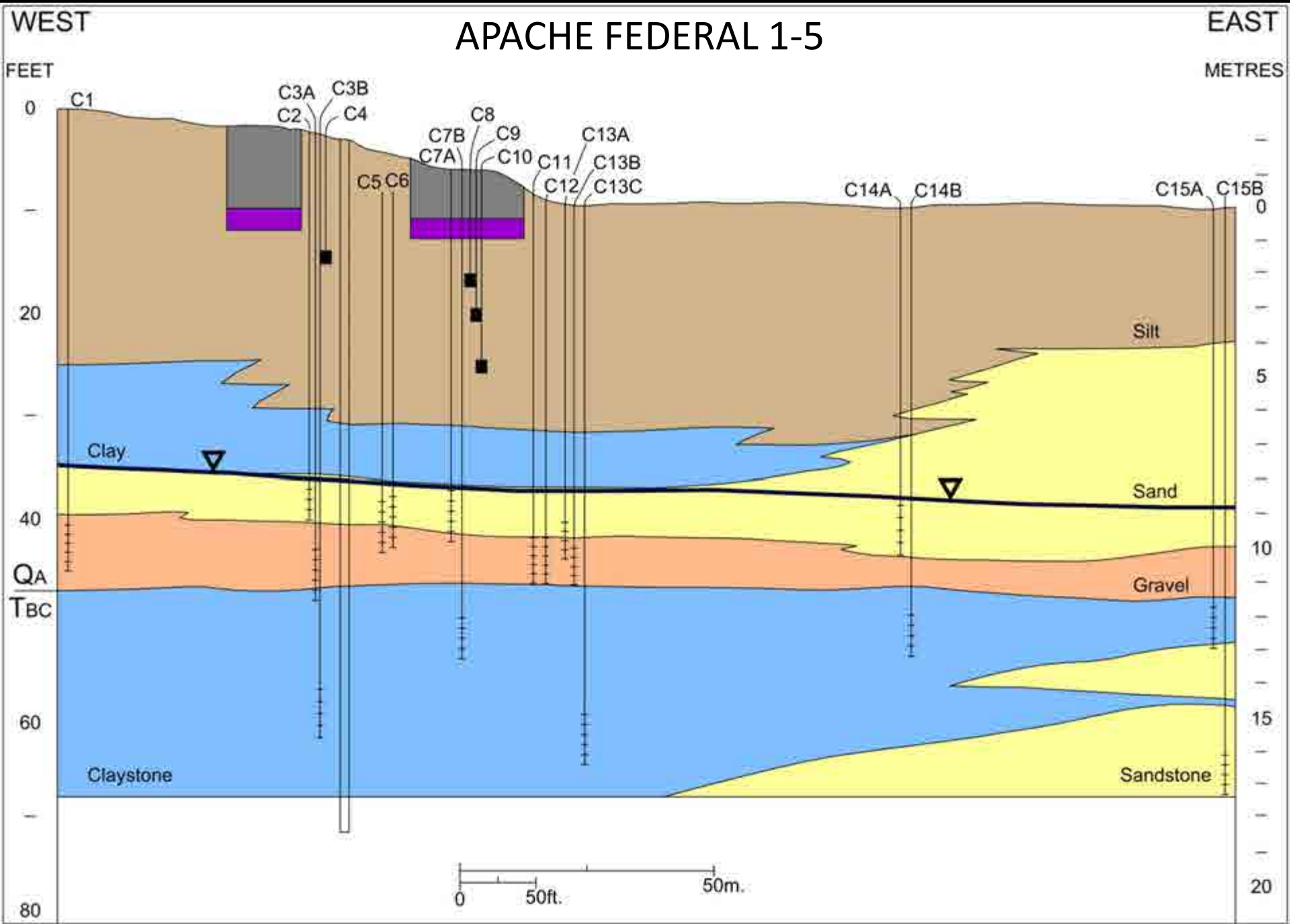
Apache Federal 1-5  
Produced oil from 1981 – 1984.  
Plugged and abandoned in 1984.

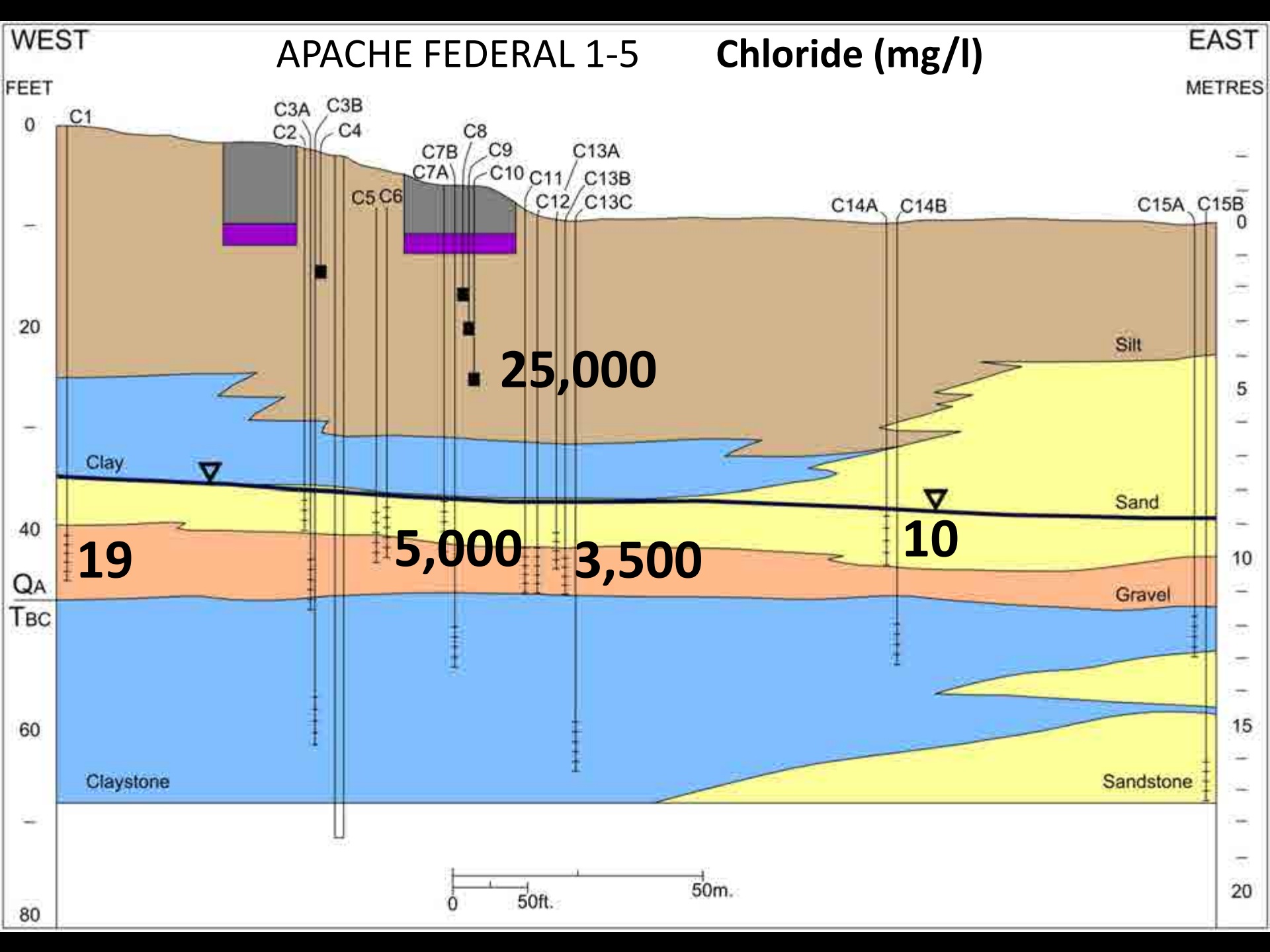




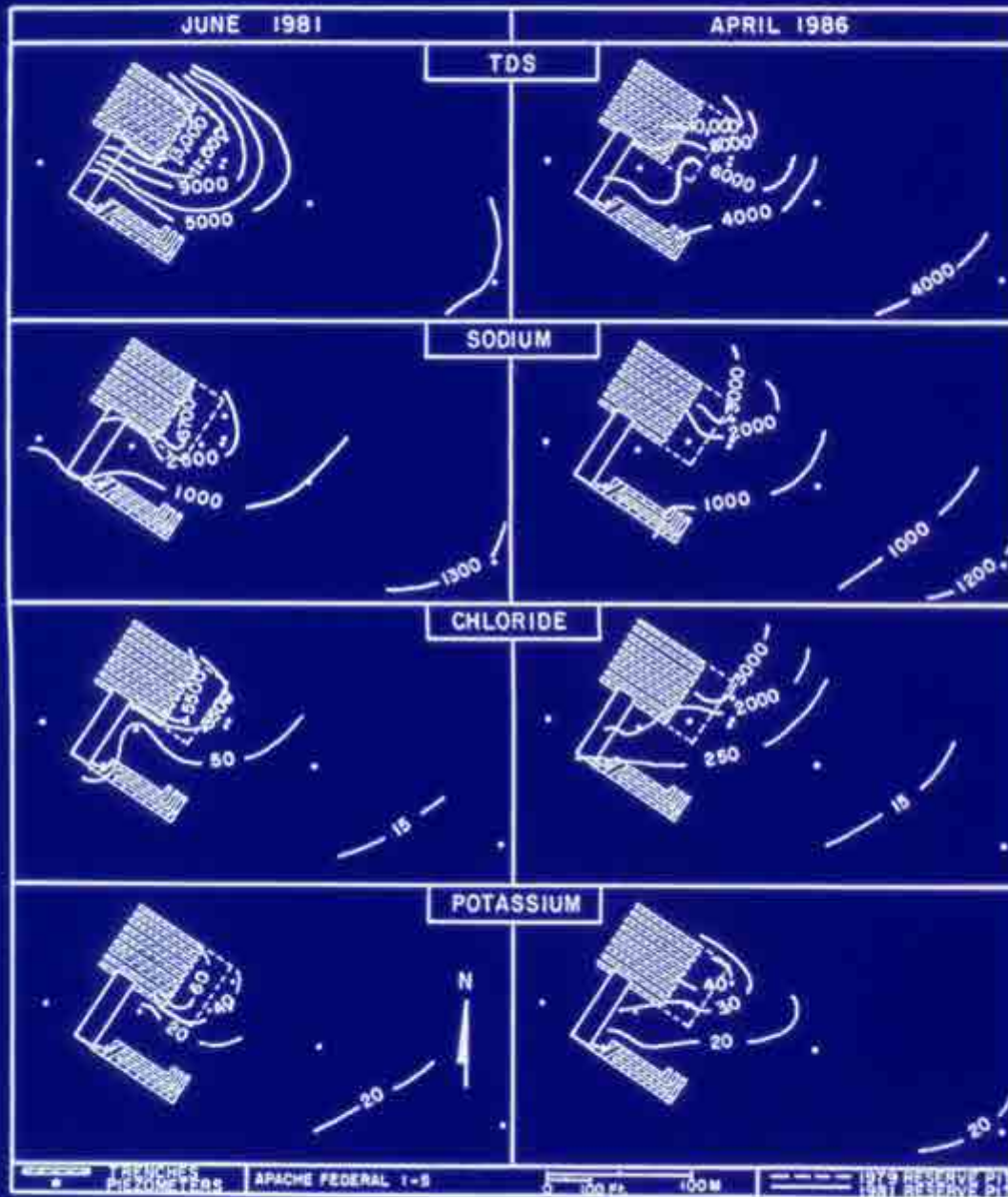
**APACHE FEDERAL 1-5**  
**Installing monitoring wells in 1981.**







# APACHE FEDERAL 1-5



**Plume is  
250 x 250 ft**



# RESERVE PIT STUDY

## WESTERN NORTH DAKOTA

- Leachate is being generated from buried drilling fluid at each of the four western ND study sites.
- The amount of leachate reaching the water table is assumed minimized by clay attenuation and evapotranspiration.
- Very little leachate is likely reaching the saturated zone at the two study sites in the Roughrider Field based on the reduction seen in the unsaturated zone.

# RESERVE PIT STUDY

## WESTERN NORTH DAKOTA

- Leachate at Federal 1-5 covers an area of 250 x 250 feet.
  - Chromates detectable in leachate within the unsaturated zone but not in the saturated zone – levels were higher in the saturated zone in 1986.
- Leachate plume in the Texaco Charlson Madison (North) Unit is approximately 300 x 400 feet in the upper saturated zone (top 40 feet).
- This study determined that leachate will be generated by the current method of reserve pit reclamation. Therefore, it is important to **focus attention in areas where leachate will degrade the groundwater.**

# RESERVE PIT STUDY: WESTERN NORTH DAKOTA

## 1986 CONCLUSIONS

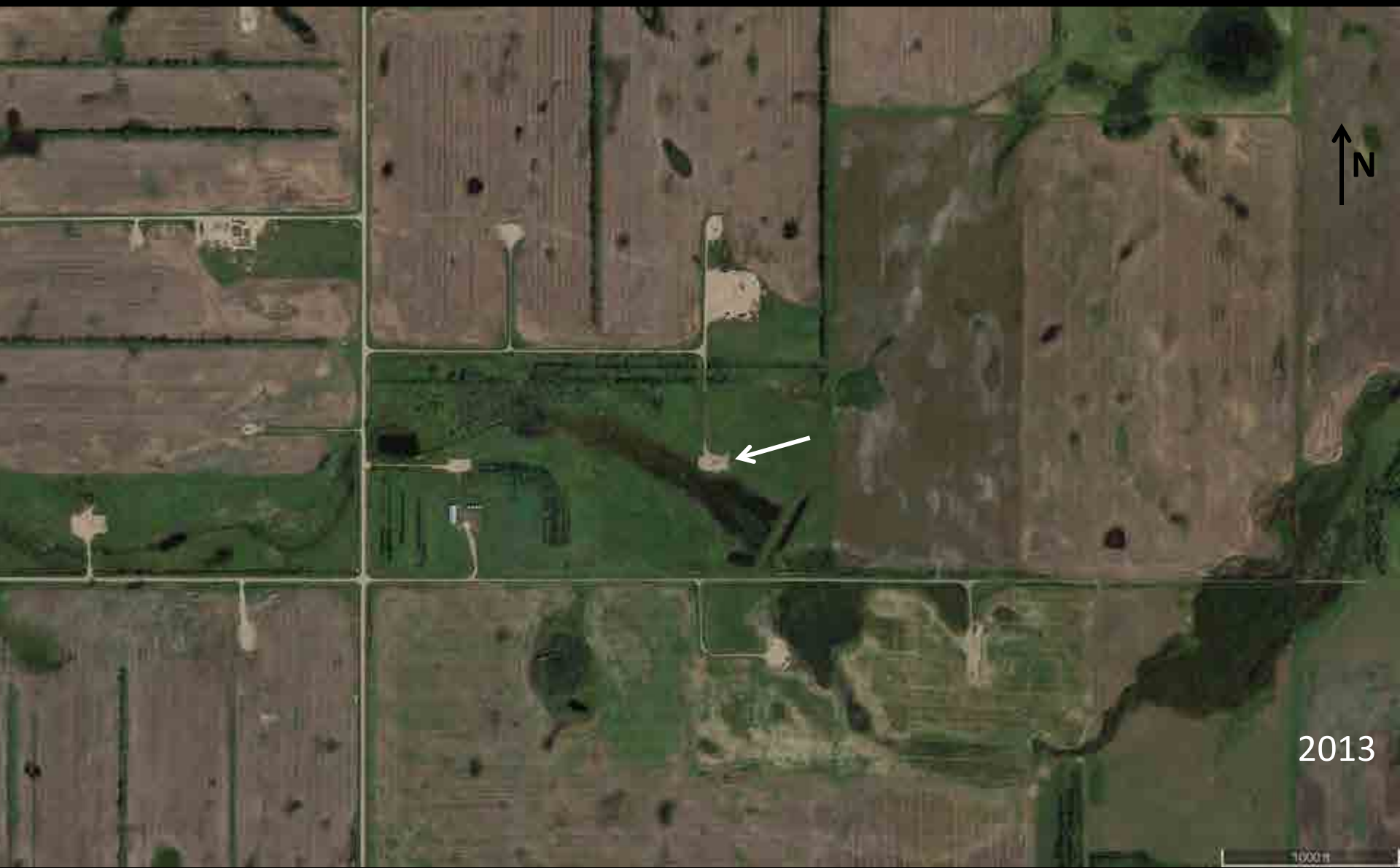
- In general, groundwater chemistries and the extent of the leachate plume relatively unchanged from 1981 to 1986 at Apache Federal 1-5 site.
- Suggested alternative methods for environmentally sensitive sites including closed mud system, solidification, solids control system, central disposal sites – noted central disposal sites must be carefully chosen because the increased volume increases the chances for widespread groundwater contamination.
- There are settings such as the Little Missouri River floodplain, Little Muddy, etc where there should be no burial of waste drilling fluid.



# RESERVE PIT STUDY

NORTH-CENTRAL N. DAK. 1984

- Two reserve pits studied; one in till (Fossum) the other in sand and gravel (Winderl).
- Installed 45 piezometers and 13 lysimeters, took 700 resistivity readings, obtained 160 water samples for analysis.

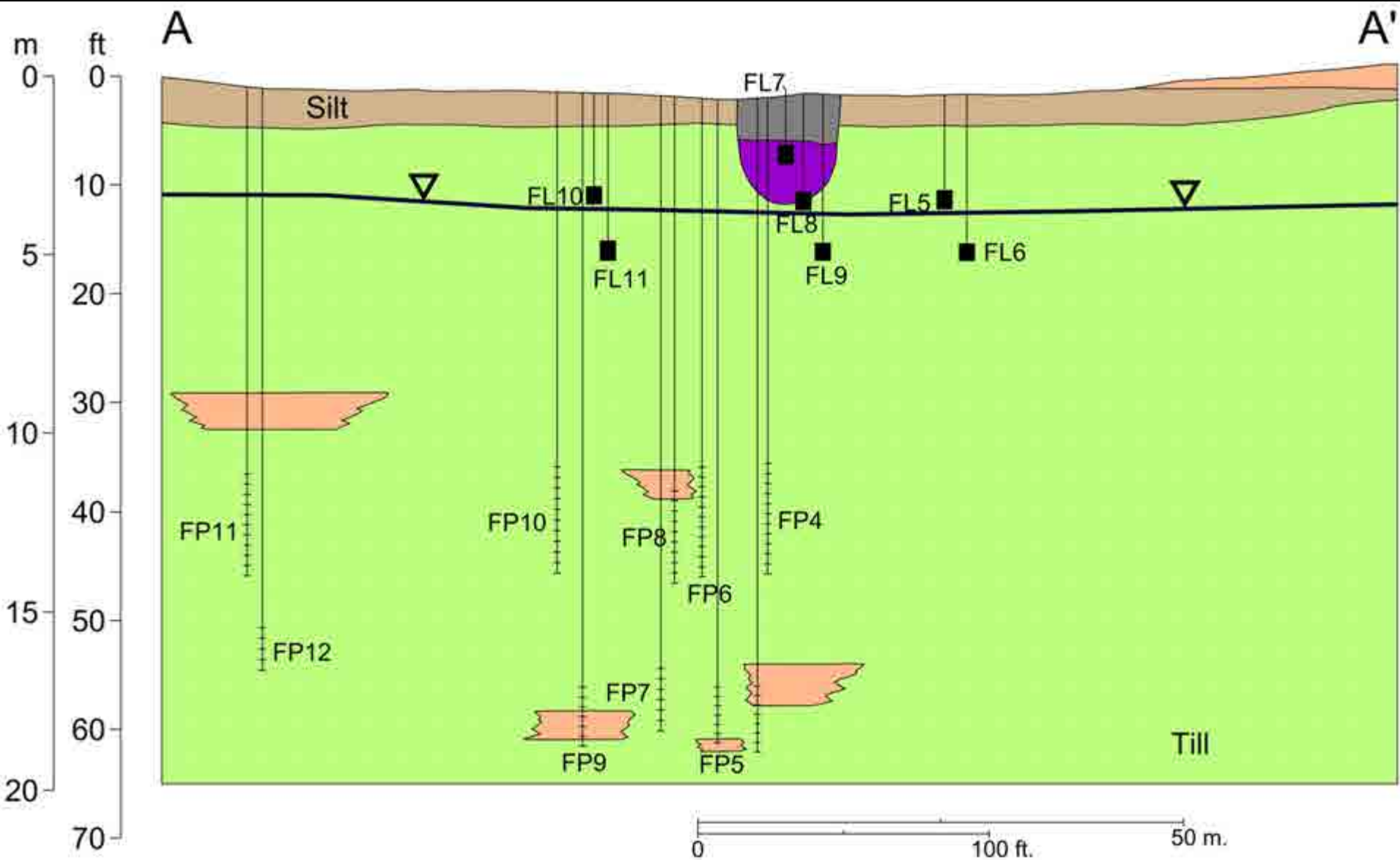


Fossum Federal # 4 drilled in 1978.  
Producing oil 1978 – to the present.

South

North

# Fossum Federal # 4

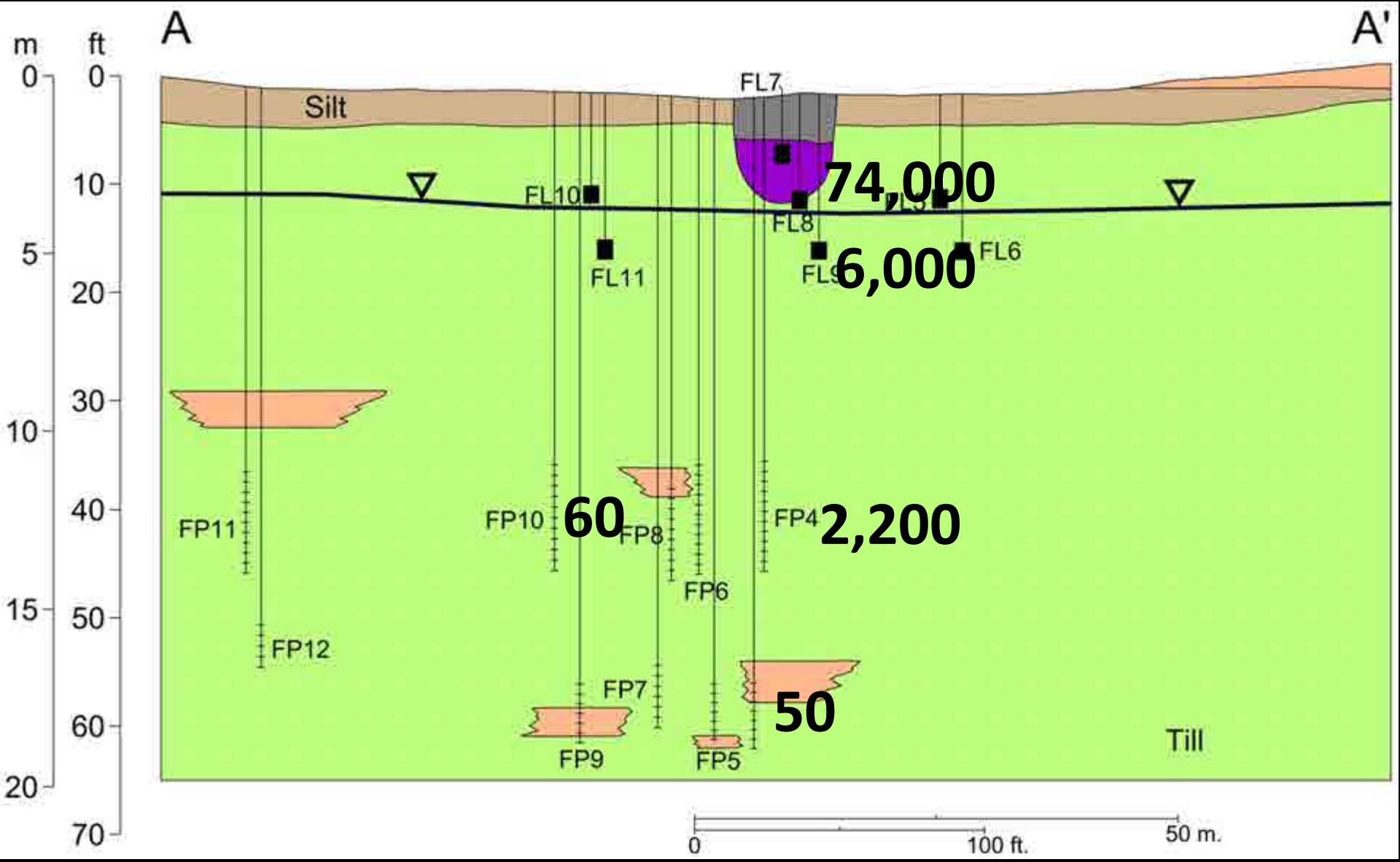




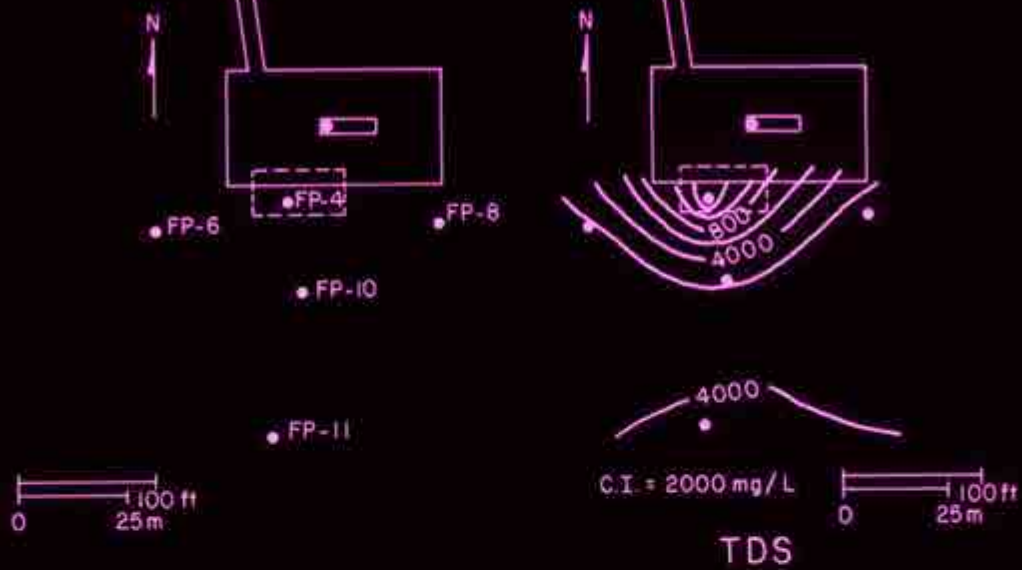
South

North

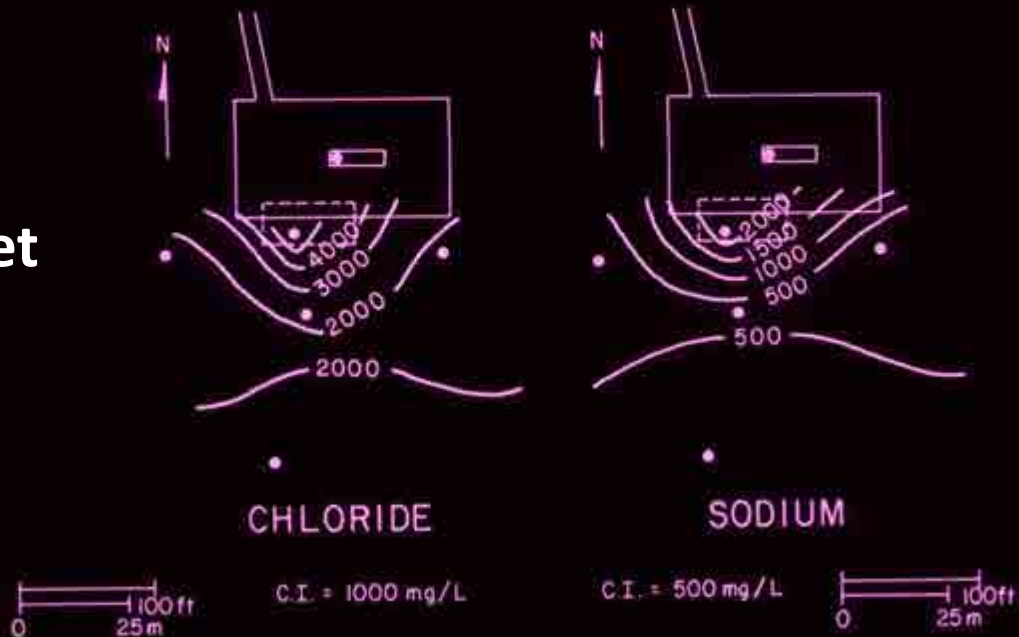
# Fossum Federal # 4 -- Chloride (mg/l)



# Fossum Federal # 4



**Plume is  
100 x 150 feet**





**J.J. WINDERL # 1** drilled in 1959 & 1980.  
Producing oil 1959 – to the present.

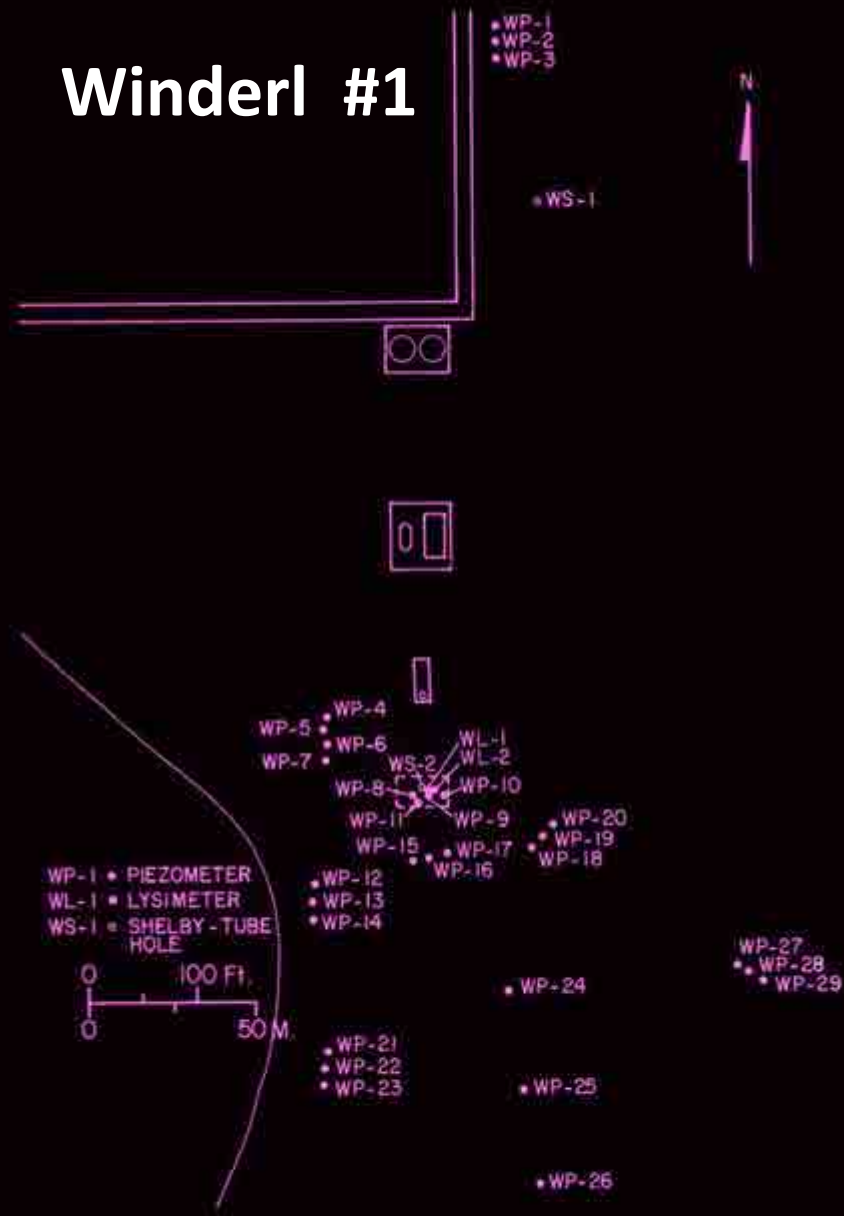




**Winderl #1**

**1961**

# Winderl #1

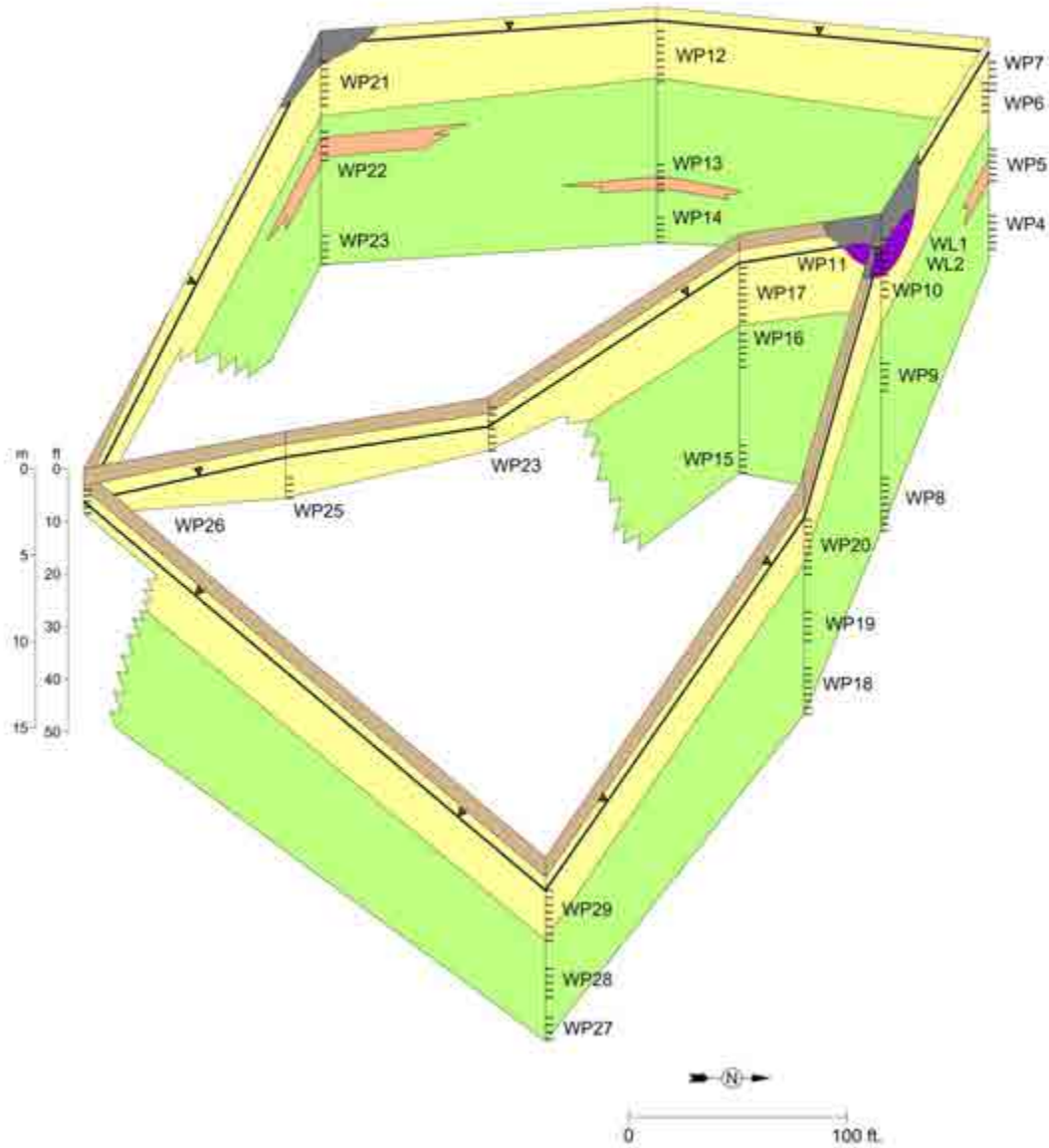
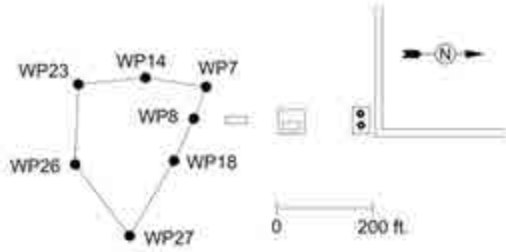


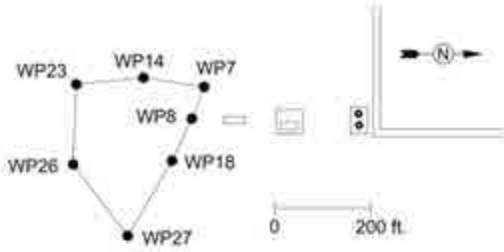


Winderl # 1 looking south



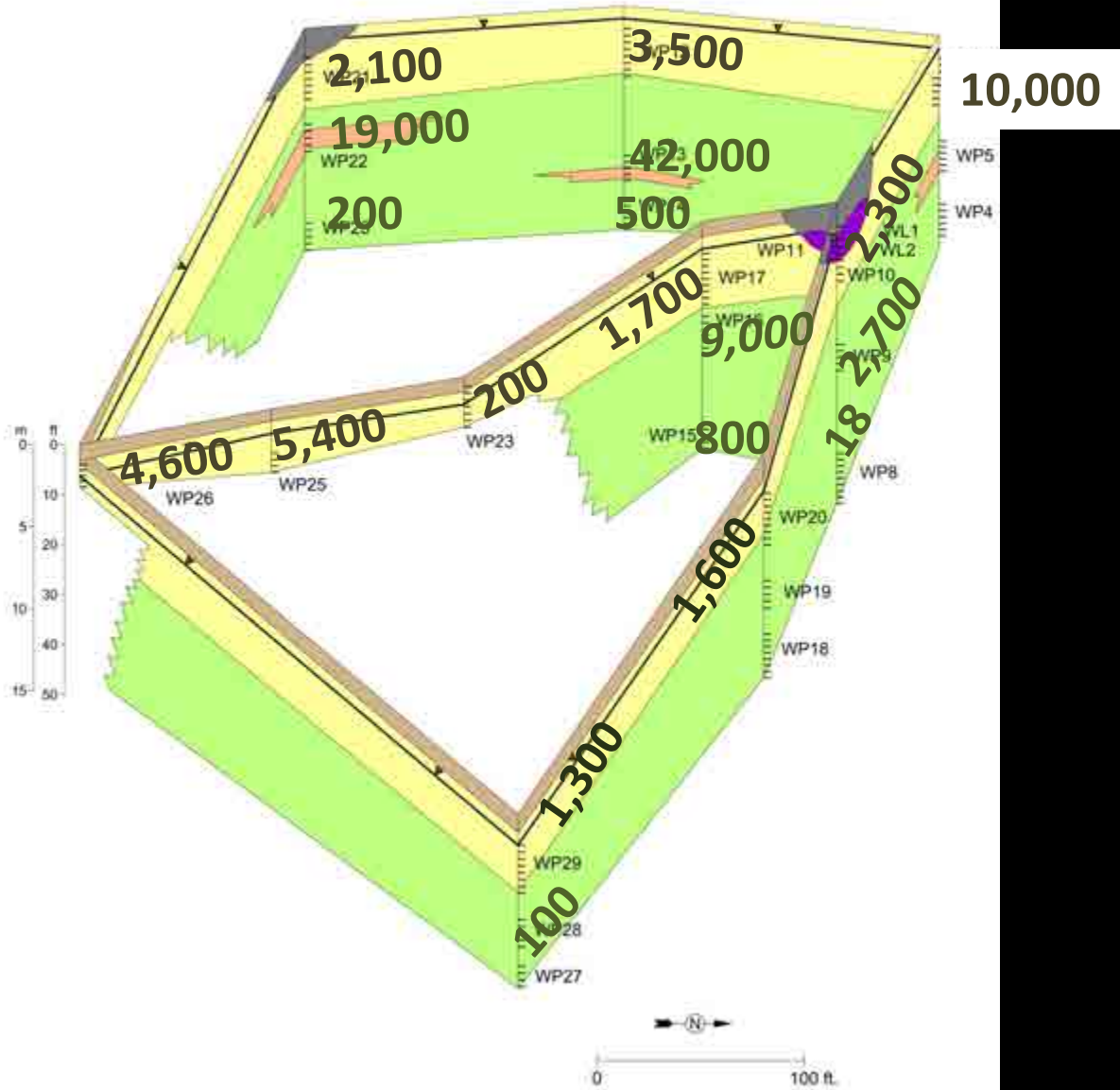
# WINDERL #1

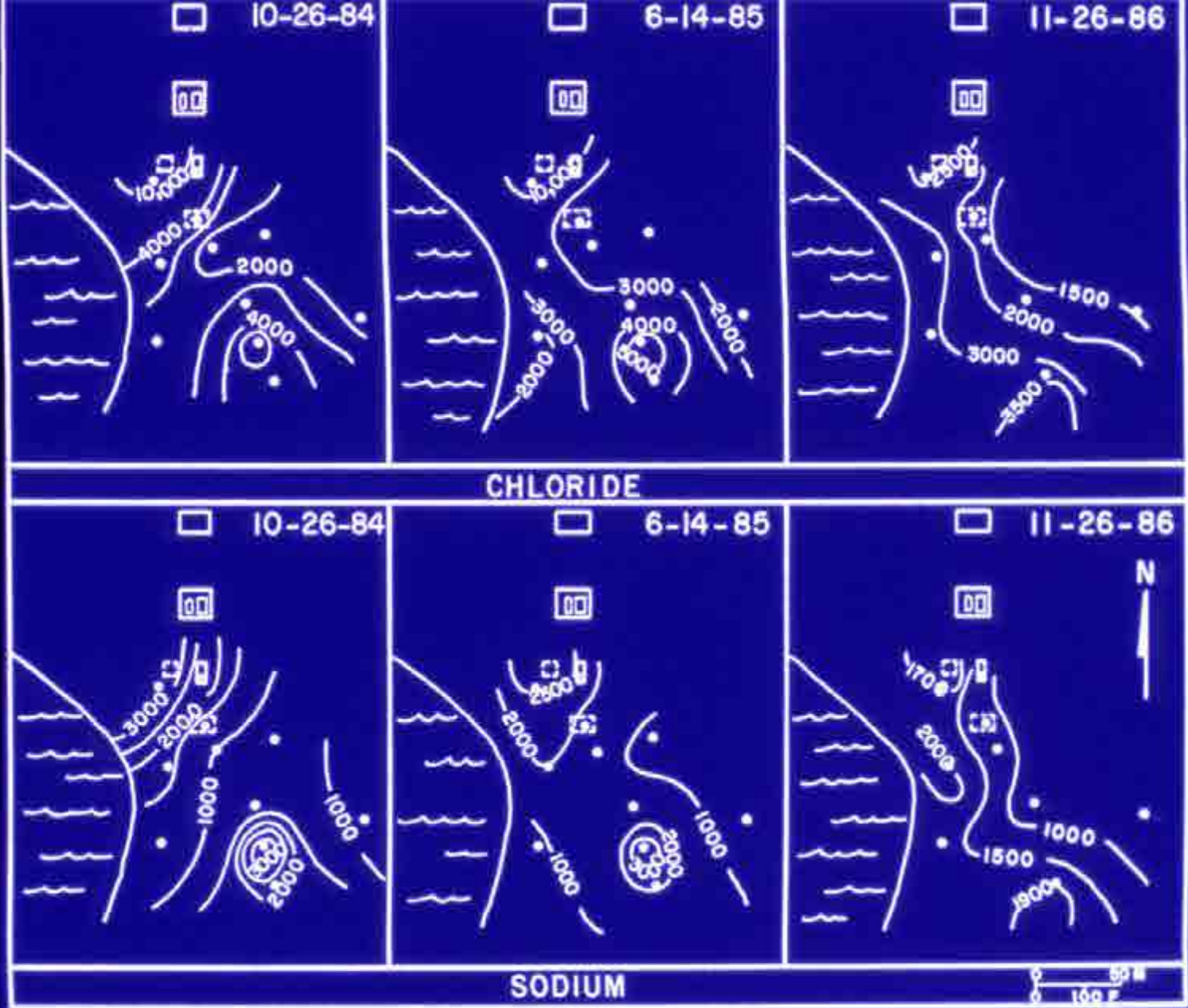




# WINDERL #1

## Chlorides (mg/l)





**Winderl #1 Plume is > 500 feet**



# RESERVE PIT STUDY: NORTH-CENTRAL N. DAK. 1985 CONCLUSIONS

- Leachate at Fossum site was detected in an area 100 x 150 feet and to a depth of at least 60 feet around the buried drilling mud.
- Leachate at the Winderl site migrated beyond the 500 foot study area.



2013

1000 ft

J.J. WINDERL # 1 drilled in 1959 and deepened in 1980



Under today's rules, these locations (X) would require a closed mud system due to a **high watertable** and **near surface sand and gravel** deposits.





Gravel pit

Abandoned  
Gravel pit

X

X

X

# BRINE HOLDING PONDS



1961

WILEY FIELD  
Madison Pool

CUMULATIVE PRODUCTION (as of 1/1/82)

9,078,035 Barrels of oil  
18,063,255 Barrel of salt water



Total Dissolved Solids (TDS) of brines in the Wylie Field range from 19,000 to 250,000 mg/l (seawater 30,000 – 50,000).



# BRINE HOLDING PONDS

Operated in North Dakota from 1951-1982.

NDGS personnel began field investigating and condemning brine holding ponds in the 1960s.

The exact number of brine ponds that existed from 1951-1982 is unknown (*est. 2,000 – 3,000*).

# BRINE HOLDING PONDS

## Dimensions:

45 x 60 ft up to 90 x 180 ft

4 to 9 feet deep

1) Unlined

2) Clay liner

3) Polyethylene liner

# WYLIE FIELD STUDY

1984-1985

NDSU Soil Science Department

NDSU Chemistry and Geology Department

NDSU Land Reclamation Research Center

UND Geology Department

ND Mining and Minerals Resources Research Institute

North Dakota Geological Survey

Doll, Wollenhaupt, Carter, Foss, Richardson, Prunty, Sweeney,  
Cudworth, Hoag, Kulla, McCarthy, Elless, Steinwand, Keller,  
Groenewold, Kehew, Beal, and Murphy.

440 page report

# STRATTON SWD #1

Stratton SWD #1

Fossum Federal #4

2013

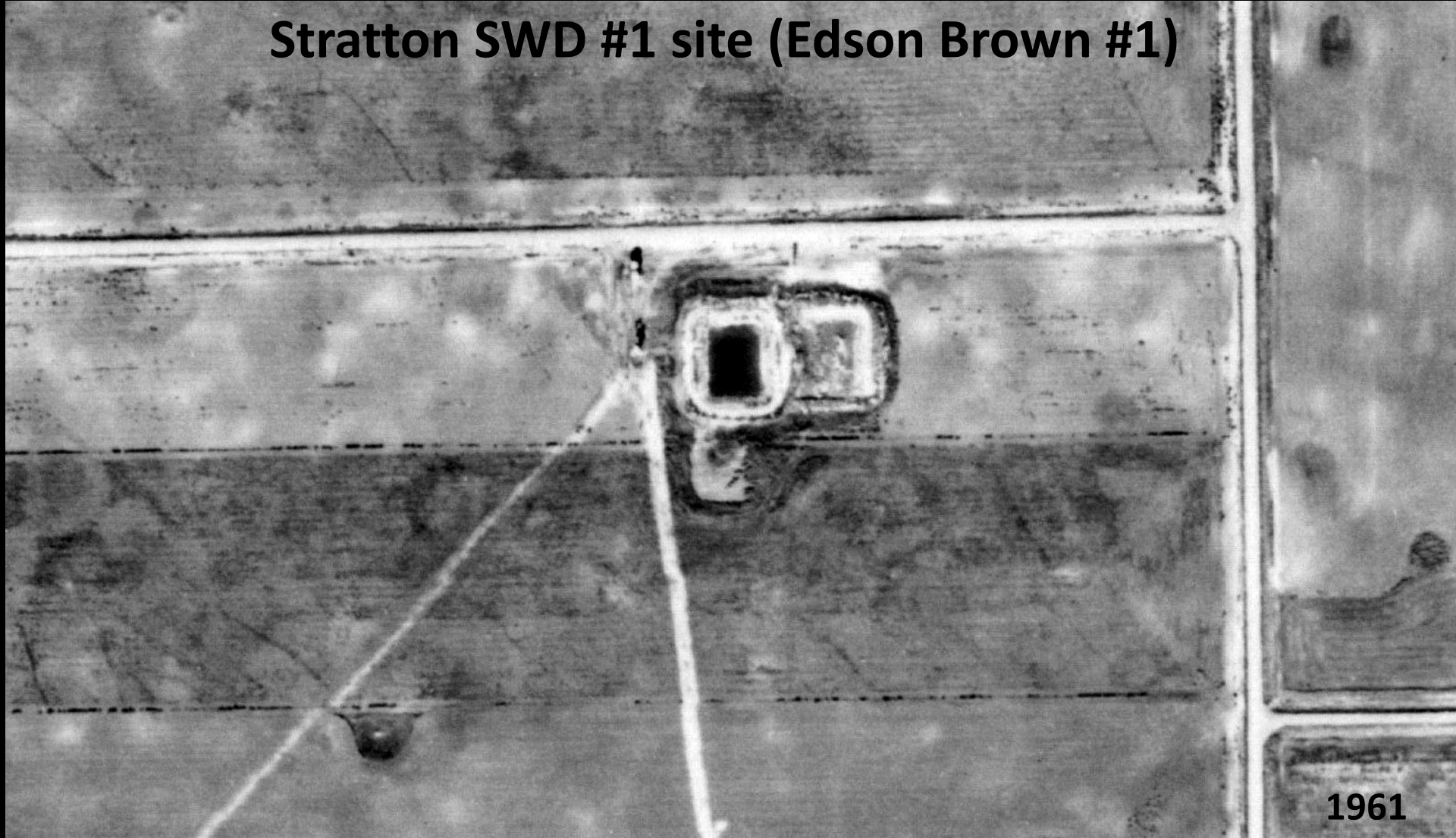






Drilled in 1959 by Cardinal Petroleum (**Edson Brown #1**). Produced oil from 1959-1970. Converted to a saltwater disposal well by Phillips Petroleum in 1978 (**Stratton SWD #1**).

# Stratton SWD #1 site (Edson Brown #1)



1961

The site contained two brine holding ponds from 1959 to at least 1970 (with dimensions of 100 x 90 ft and 60 x 100 ft and 5 feet deep). Produced 178,000 barrels of saltwater.

# WYLIE FIELD STUDY

1984-1985

NDSU Chemistry and Geology Department

NDSU Soil Science Department.

*Characterization of Detrimental Effects of Salts and Other Chemical Constituents Carried in Surface and Subsurface Water from Mine and Drilling Fluid Disposal Pits Buried During Oil Development*

Studied seven sites, Stratton SWD #1 is their F1 Site.

48 shallow Giddings cores (10-15 feet deep).

193 saturated paste extract

80 XRD analyses.

# WYLIE FIELD STUDY

1984-1985

## NDSU Land Reclamation Research Center

Eugene Doll, Nyle Wollenhaupt, Frank Carter

*Salt Movement in Buried Brine Disposal Pit Areas as Related to Chemical and Physical Properties of the Soil and Geologic Materials and to the Surrounding Landscape*

Studied two sites, Stratton SWD # 1 is their Fossum Site 1.

Electromagnetic soil conductivity meter (EM-38):

58 stations, 116 readings.

55 shallow Giddings cores (10-15 feet deep).

630 saturated paste extract analyses.



# Stratton SWD #1 (Fossum Site 1)



1985

NDSU estimated 500 tons of NaCl in the top 10 feet of the Stratton Site. This works out to 22 tons per acre for this site.

# WYLIE FIELD STUDY

1984-1985

## Soil Science Department, NDSU

John Foss, Jimmy Richardson, Lyle Prunty, Mark Sweeney,  
Doug Cudworth, Brian Hoag

*Identification of Salt–Seepage Areas from Oilfield Brine Pits*

Analyzed aerial photographs (existing and generated).  
Electromagnetic soil conductivity meter (EM-38).

**Stratton SWD # 1**



**1985**





**Stratton SWD # 1**

**1985**

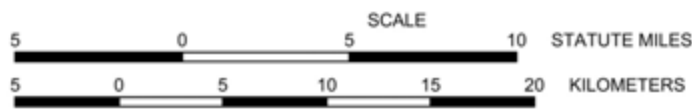
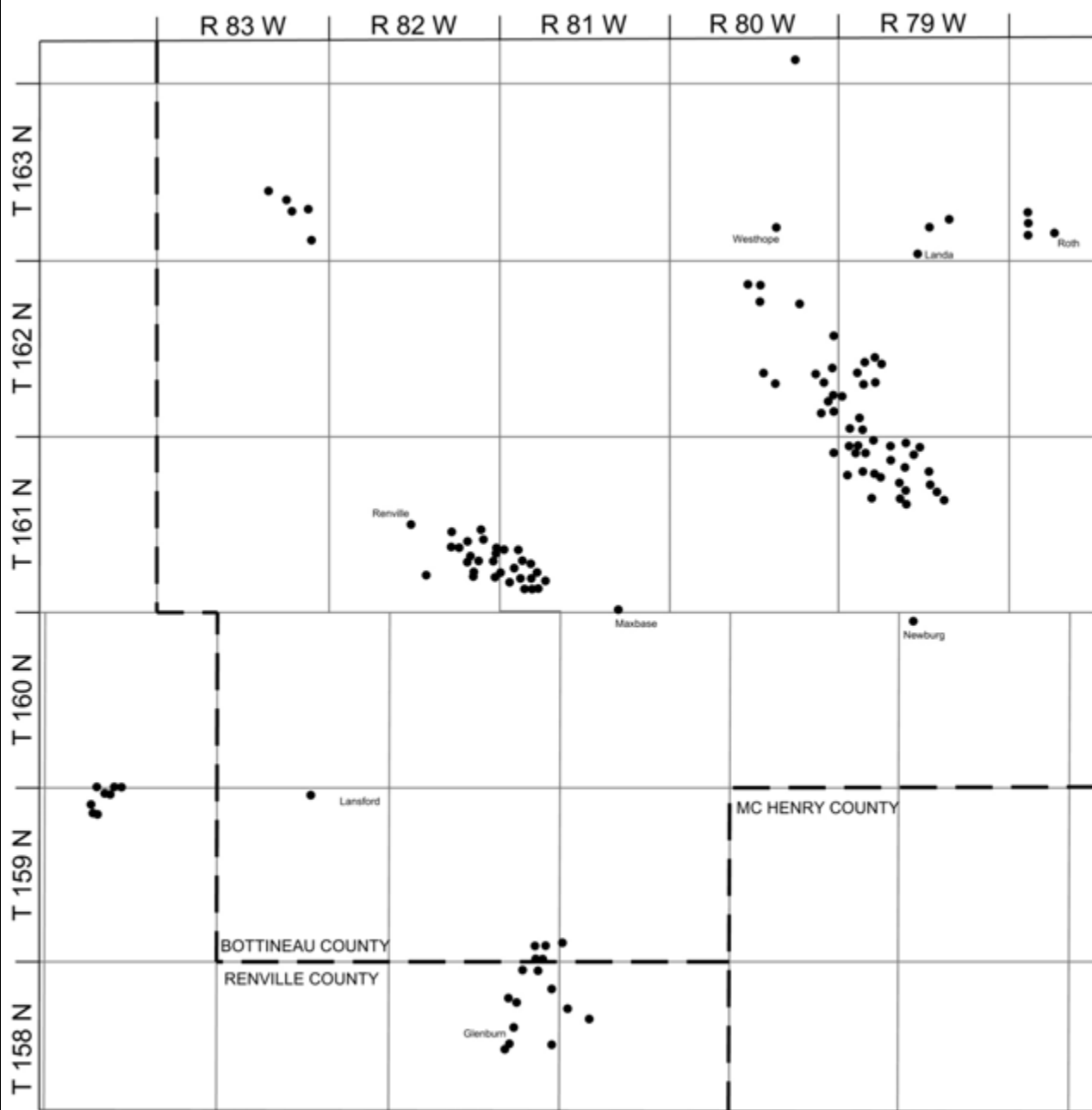


# NDSU SOILS DEPT 1984 STUDY

Identified 121 old brine pond sites in Bottineau and Renville Counties.

Estimated the area contaminated by old brine ponds at 1,450 acres (average of 12 acres per site).

Interpreted aerial photographs from various years and scales.

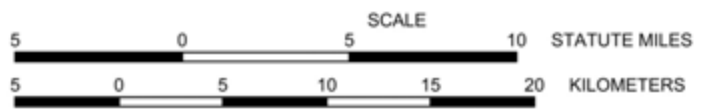
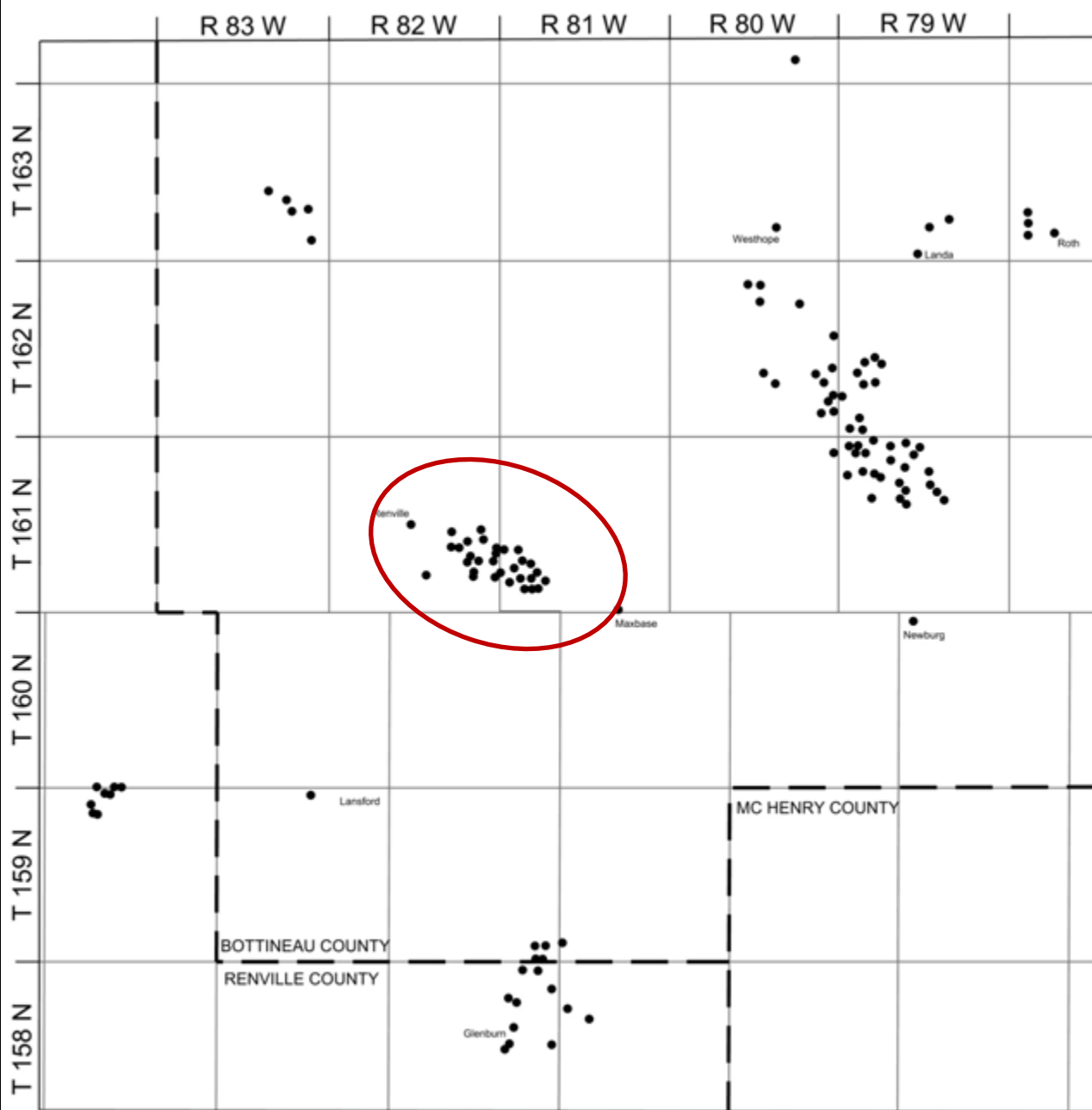


# NDSU SOILS DEPT 1984 STUDY

## Wylie Field

Studied an area of 15 square miles in Wylie Field and identified 60 old brine pond locations.

Interpreted aerial photographs from various years and scales.





# NDSU SOILS DEPT 1984 STUDY

## Wylie Field

Mapped 23 of the 60 sites.

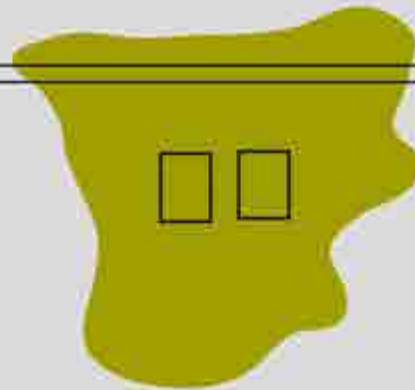
Salt-impacted area ranged from 0 to 42 acres at each site.

Average impact of 11.5 acres per site.

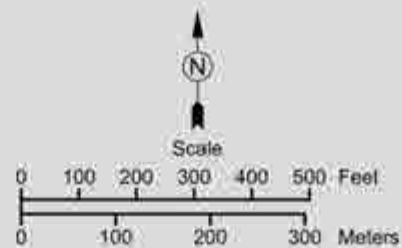
Total impact of 266 acres.

Electromagnetic soil conductivity meter (EM-38).

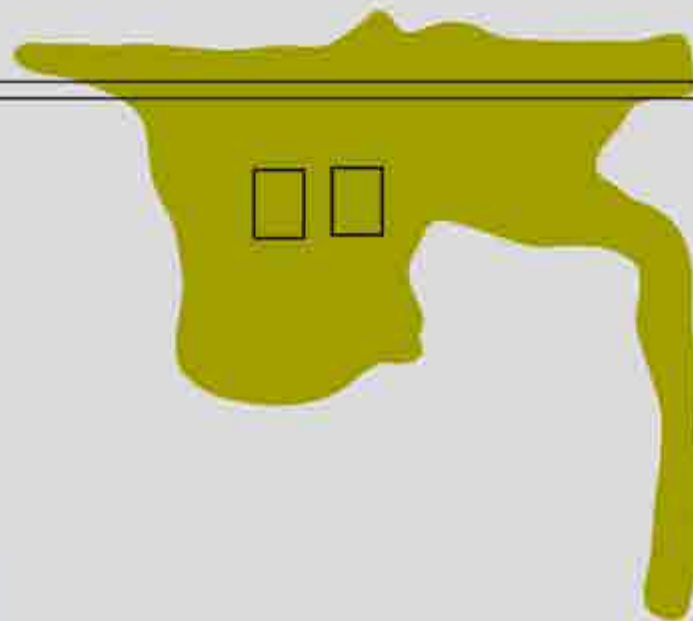
# Stratton SWD (Site 58)



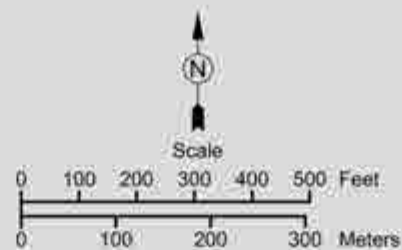
**1979**      **7 acres**



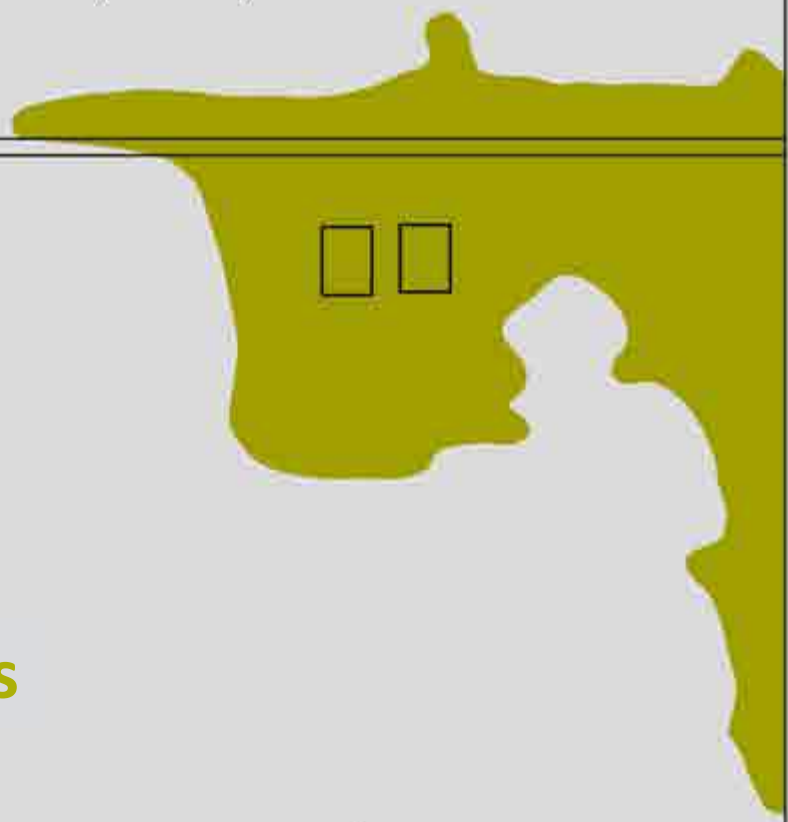
# Stratton SWD (Site 58)



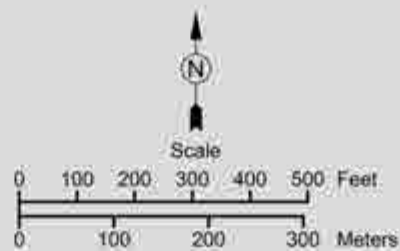
**1984**      **11 acres**



# Stratton SWD (Site 58)



**1985**      **15 acres**





# WYLIE FIELD STUDY

1984-1985

North Dakota Geological Survey

UND Geology Department

ND Mining and Minerals Resources Research Institute

Gerry Groenewold, Alan Kehew, Willie Beal, Ed Murphy

*Movement of Leachate From a Buried Oil and Gas Brine-Disposal Pond in the Wylie Field, Bottineau County, ND*

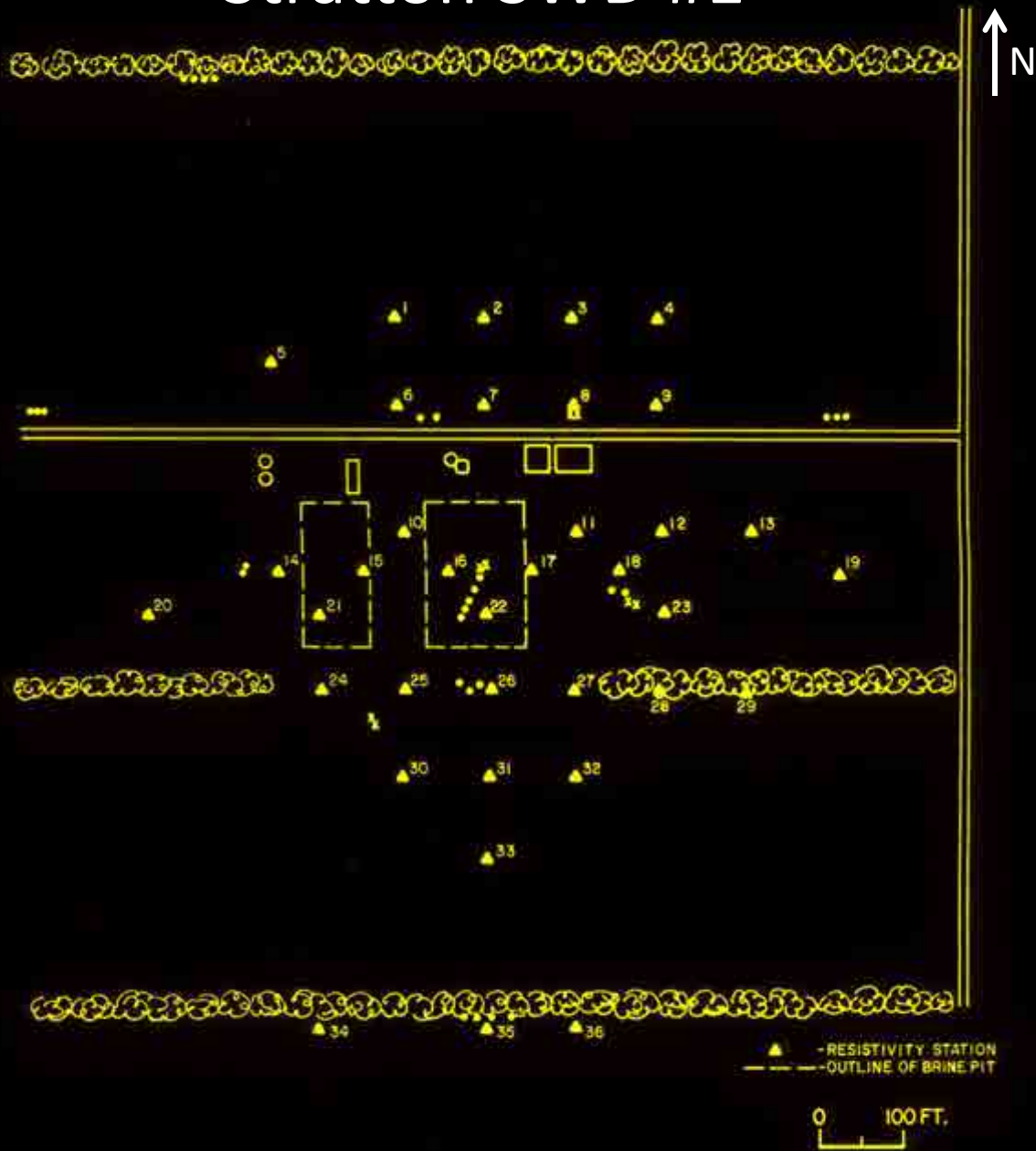
Studied only the Stratton SWD #1

28 piezometers (down to 220 feet), 8 lysimeters.

60 water samples.

36 resistivity stations (504 readings).

# Stratton SWD #1



# Stratton SWD #1



28 monitoring wells

8 lysimeters

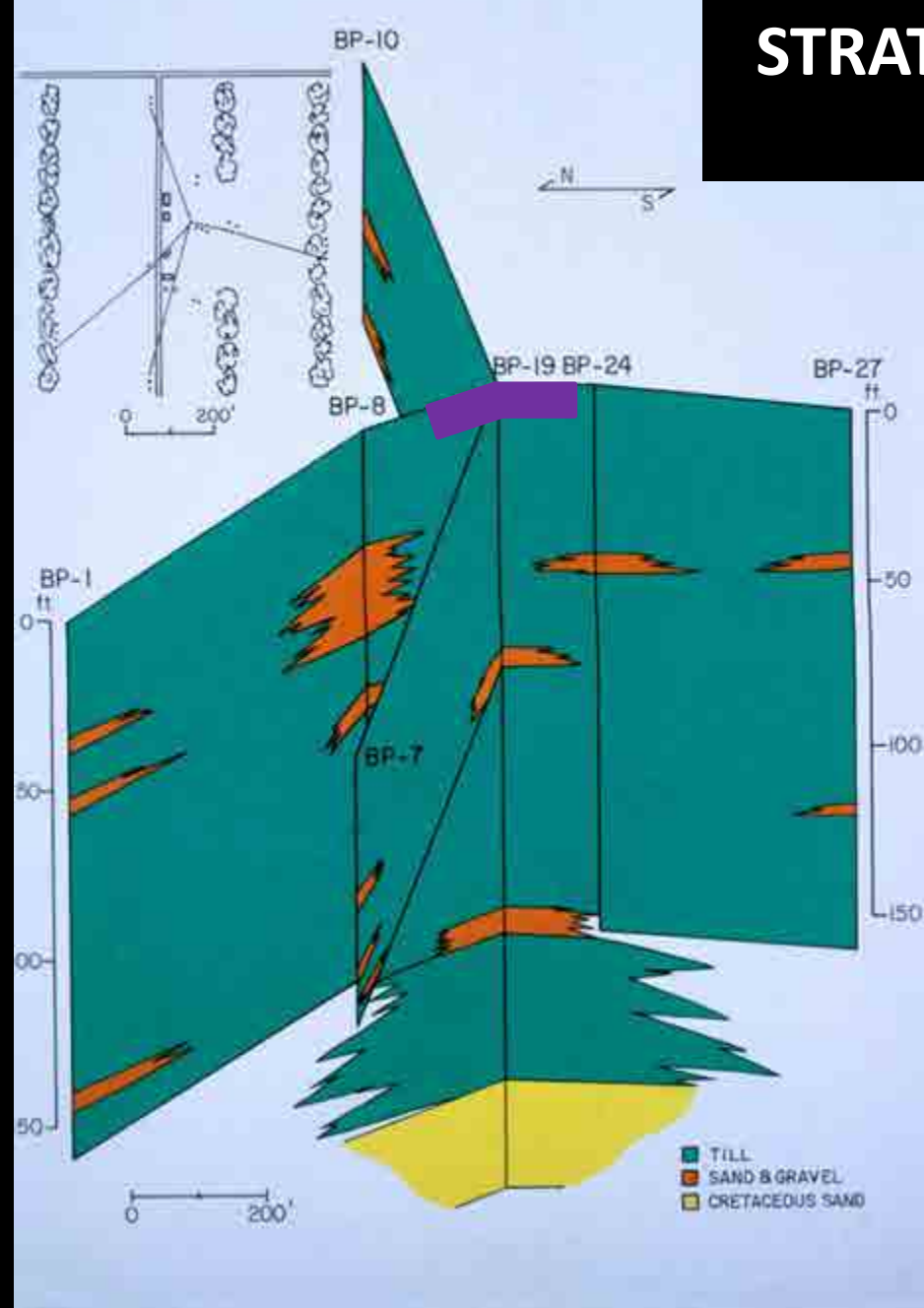
10 core holes



Installing monitoring wells at the Stratton SWD #1 in 1984.



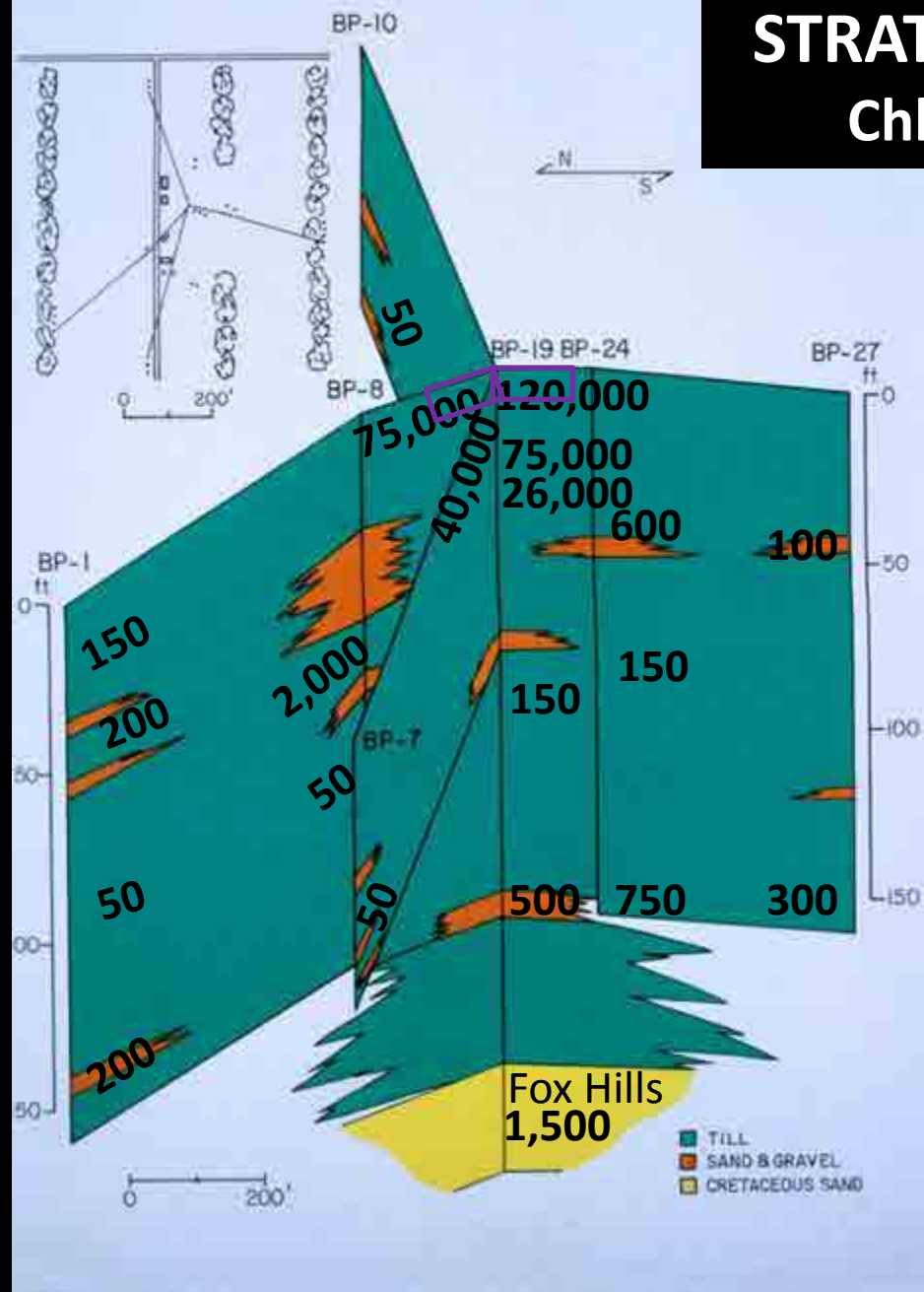
# STRATTON SWD #1



The site is underlain by 210 feet of till overlying the Fox Hills Formation.

# STRATTON SWD #1

## Chlorides mg/l



The site is underlain by 220 feet of till overlying the Fox Hills Formation.

# STRATTON SWD #1

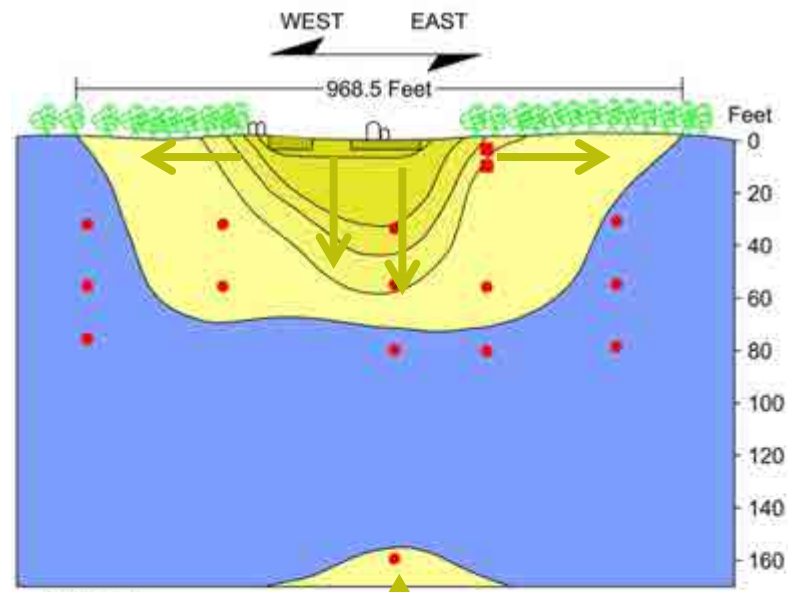
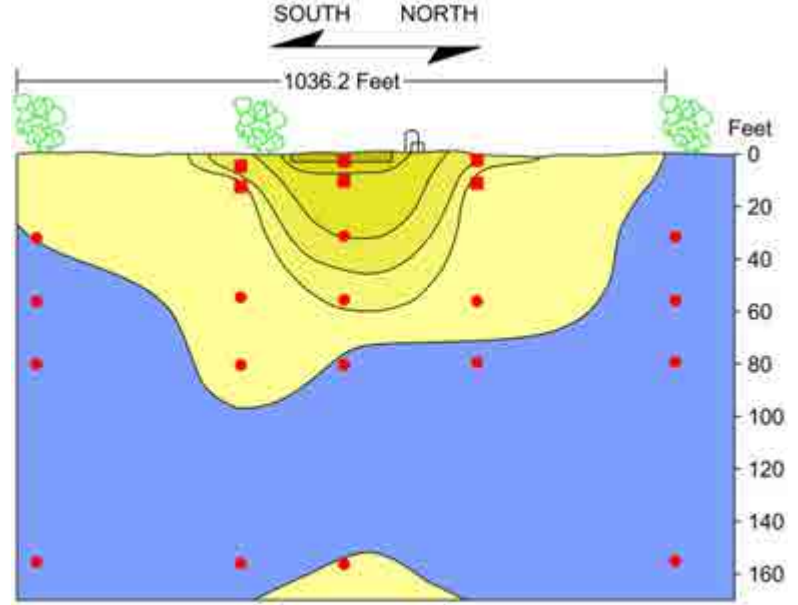
A high salt plume extends laterally around the site over an area of 250,000 ft<sup>2</sup> (about 6 acres).

This plume extends to a depth of more than 80 feet (highest concentrations in top 40 feet).

Brine plume restricted to till and not impacting any useable water supply (ND Health Dept concurred in 2006).

Chloride levels at 160 feet (500 - 750 mg/l) appear to be coming from the underlying Fox Hills Formation (hydraulic heads).

# Stratton SWD #1



- Cl<sup>-</sup> (Mg/l)
- BRINE PIT
- >100,000
- 75,000 - 100,000
- 50,000 - 75,000
- 25,000 - 50,000
- 500 - 25,000
- PIEZOMETER SCREEN
- LYSIMETER

Fox Hills

0 100 FEET  
(30.5m)  
VERTICAL  
EXAGGERATION  
OF 4X  
50 FEET (15.2m)

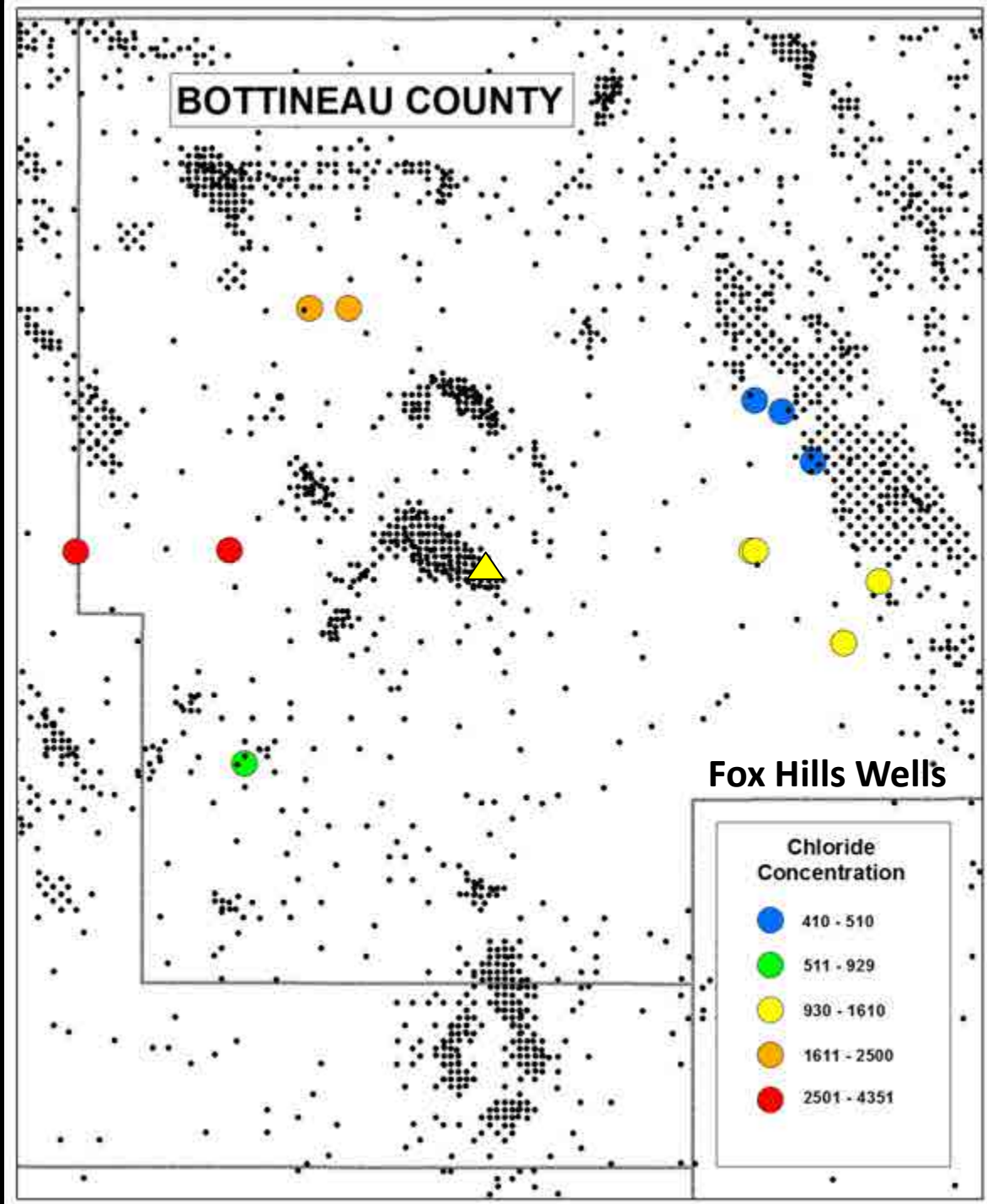


# CHLORIDE LEVELS IN THE FOX HILLS FORMATION

County	Average Chloride Concentration (mg/l)	Number of Water Samples	Number of Wells
<b>Billings</b>	<b>47</b>	43	29
<b>McKenzie</b>	<b>170</b>	34	NA
<b>Mountrail</b>	<b>265</b>	1	1
<b>Williams</b>	<b>491</b>	7	4
<b>Ward</b>	<b>NA</b>	0	0
<b>Divide</b>	<b>1220</b>	7	3
<b>Burke</b>	<b>NA</b>	0	0
<b>Renville</b>	<b>4351</b>	7	1
<b>West Bottineau</b>	<b>1514</b>	11	11
<b>McHenry</b>	<b>654</b>	41	24
<b>East Bottineau</b>	<b>192</b>	8	8
<b>Rolette</b>	<b>282</b>	4	1

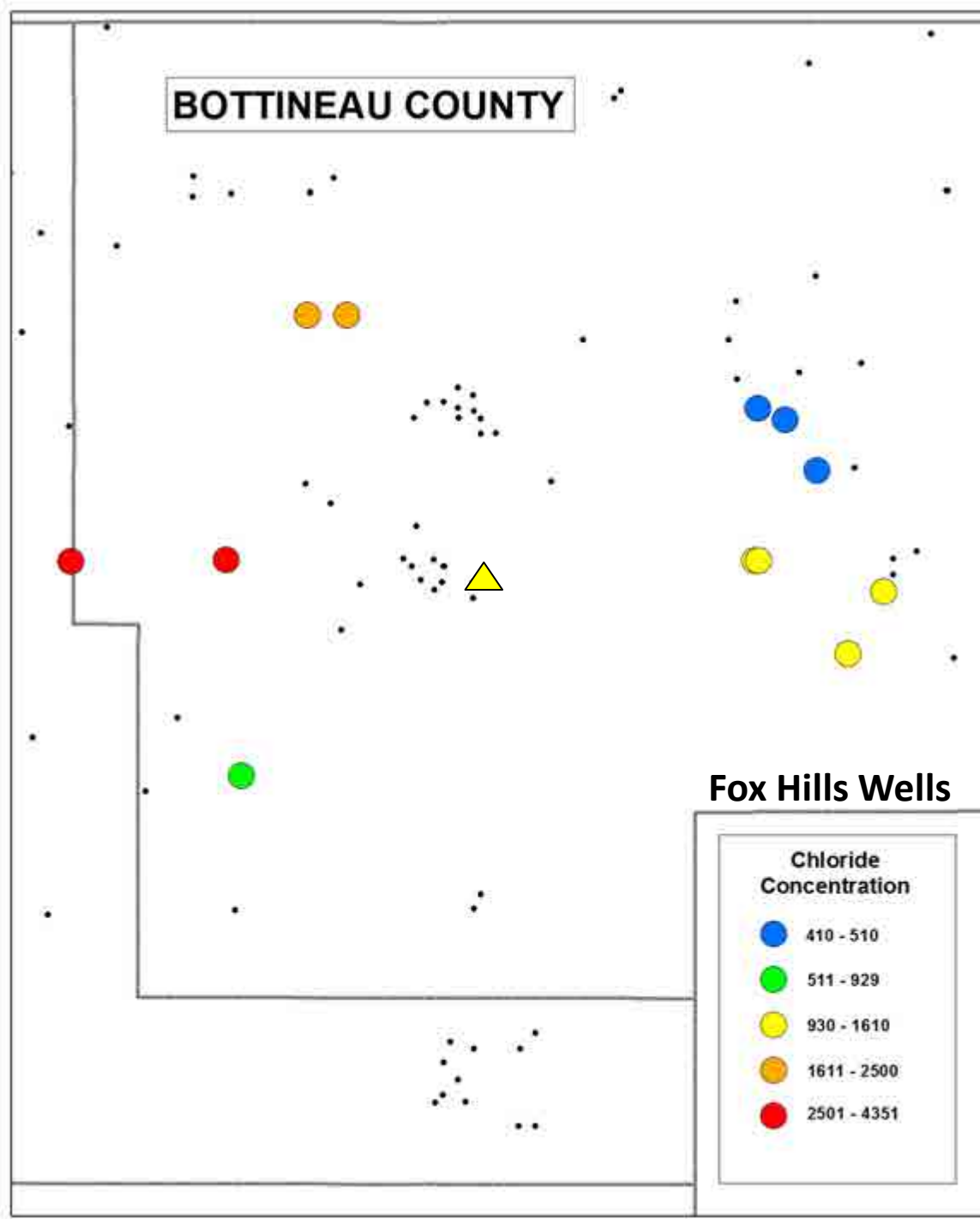
# FOX HILLS WELLS AND OIL & GAS WELLS

▲ Stratton Site



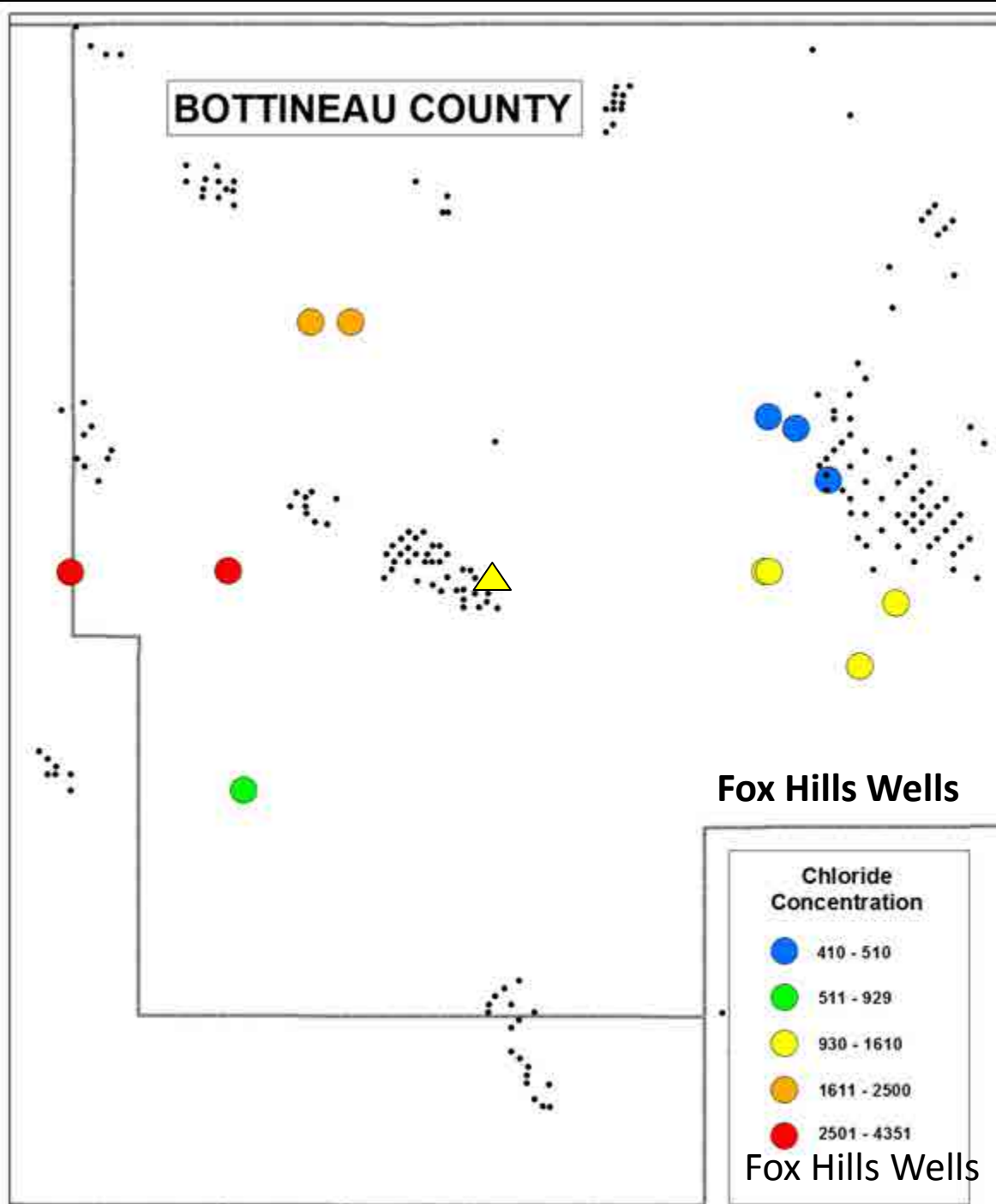
# FOX HILLS WELLS AND SALTWATER DISPOSAL WELLS

▲ Stratton Site



# FOX HILLS WELLS AND WATER INJECTION WELLS

▲ Stratton Site





# RECOMMENDED REMEDIATION METHODS

1985

## PUMPING WELLS

Hydraulic conductivity of the till is too low to be effective.

Expensive.

## IMPERMEABLE MEMBRANE

Would minimize the spread of brine in the unsaturated zone.

Bentonite.

Would not be a long-term solution.

## MOUNDING/CAPPING THE SITE

Would reduce the generation of brine leachate from overland flow.

Bentonite and fill.

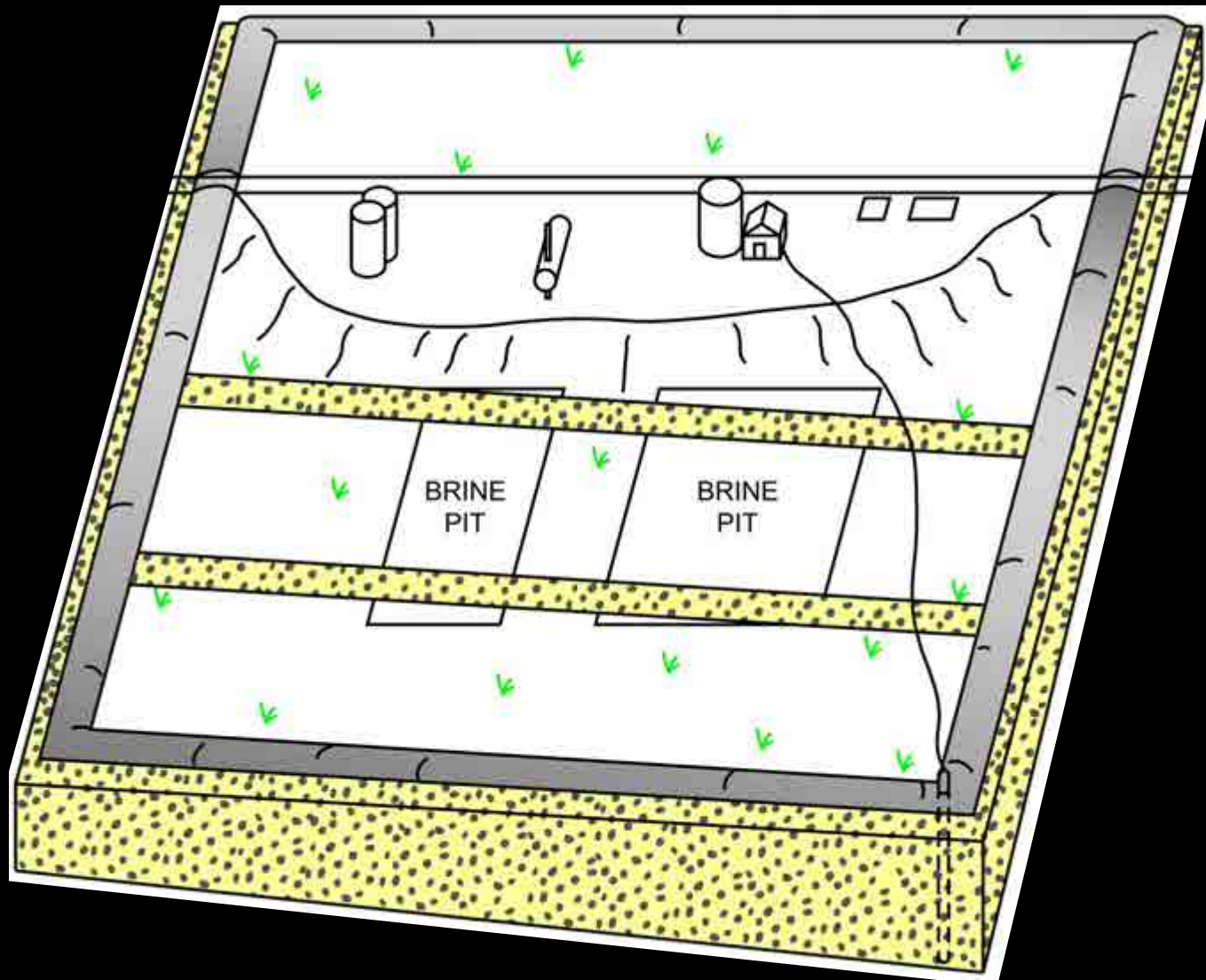
Would not be a long-term solution.

## INFILTRATION GALLERY (Gravel-filled ditch)

Would minimize the spread of brine in the unsaturated zone.

Would be a long-term solution.

# INFILTRATION GALLERY



# ERICKSON #1, BOTTINEAU COUNTY



1961

# ERICKSON #1, BOTTINEAU COUNTY



1961



# Erickson Central Tank Battery, Bottineau County

Drain Tile Trench 19\_?\_ -- 1997



Drain tile trench approximately 400 ft long, snow fence

1995

# Erickson Central Tank Battery, Bottineau County

Drain Tile Trench 19\_?\_ -- 1997



Drain tile trench approximately 400 ft long, snow fence

1995

# Erickson Central Tank Battery, Bottineau County



General consensus that vegetation recovered in the drain tile area.

# ATTEMPTS TO CLEAN UP OLD BRINE PONDS IN THE WYLIE FIELD 2006 – 2010

## Well Sites

Stratton D01 (Stratton SWD #1)

Bull B1R

Wilms A D01

Haugen B1

Durnin A & D01



# 2006-2010 Wylie Field Study Sites

Bull

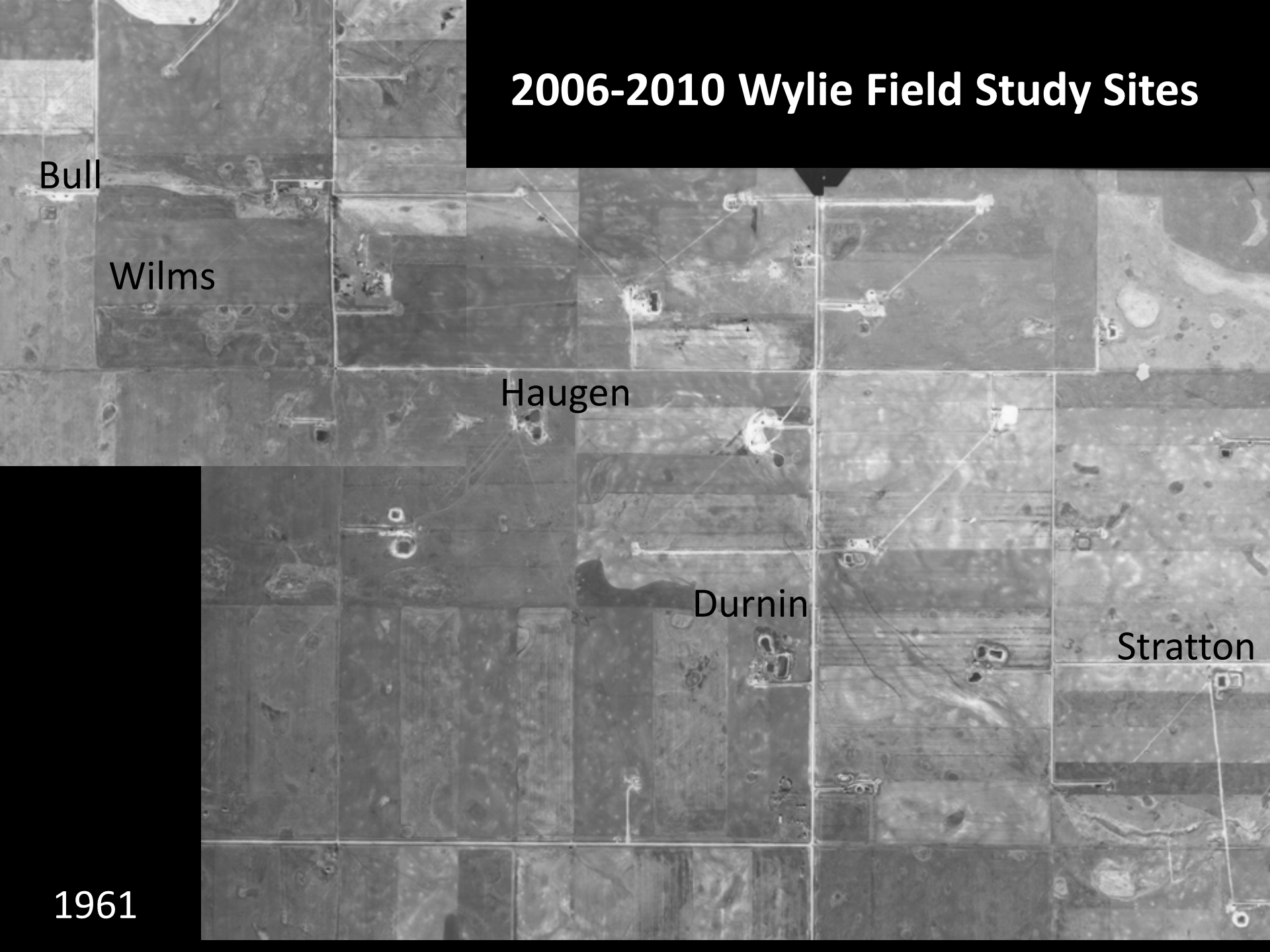
Wilms

Haugen

Durnin

Stratton

1961



# ATTEMPTS TO CLEAN UP OLD BRINE PONDS IN THE WYLIE FIELD 2006 – 2010

## Soil Parameter Monitoring

Sediment samples from 0-1 feet and 1-2 feet.

## Groundwater Monitoring

Durnin Site                      Three, 15 ft deep monitoring well.

Stratton Site                     Three, 15 ft deep monitoring well.

## Soil Amendment Application

Gypsum, fertilizer, manure, straw application-- lightly tilled.

## Water Application

Three times per week at each site due to drought conditions.

## Geophysical Survey

Conductivity and resistivity surveys at the Durnin site.

# ATTEMPTS TO CLEAN UP OLD BRINE PONDS IN THE WYLIE FIELD

2006 – 2010      *(50 – 80% reduction)*

## Stratton SWD #1 Site

Chloride levels exhibited a decreasing trend in soils.

Chloride levels did not decrease in groundwater.

Area of surface scaring reduced from 14 acres to 3 acres.

## Bull Site

Chloride levels exhibited a decreasing trend in soils.

Area of surface scaring reduced from 3.5 acres to 1 acre.

## Wilms Site

Chloride levels exhibited a decreasing trend in soils.

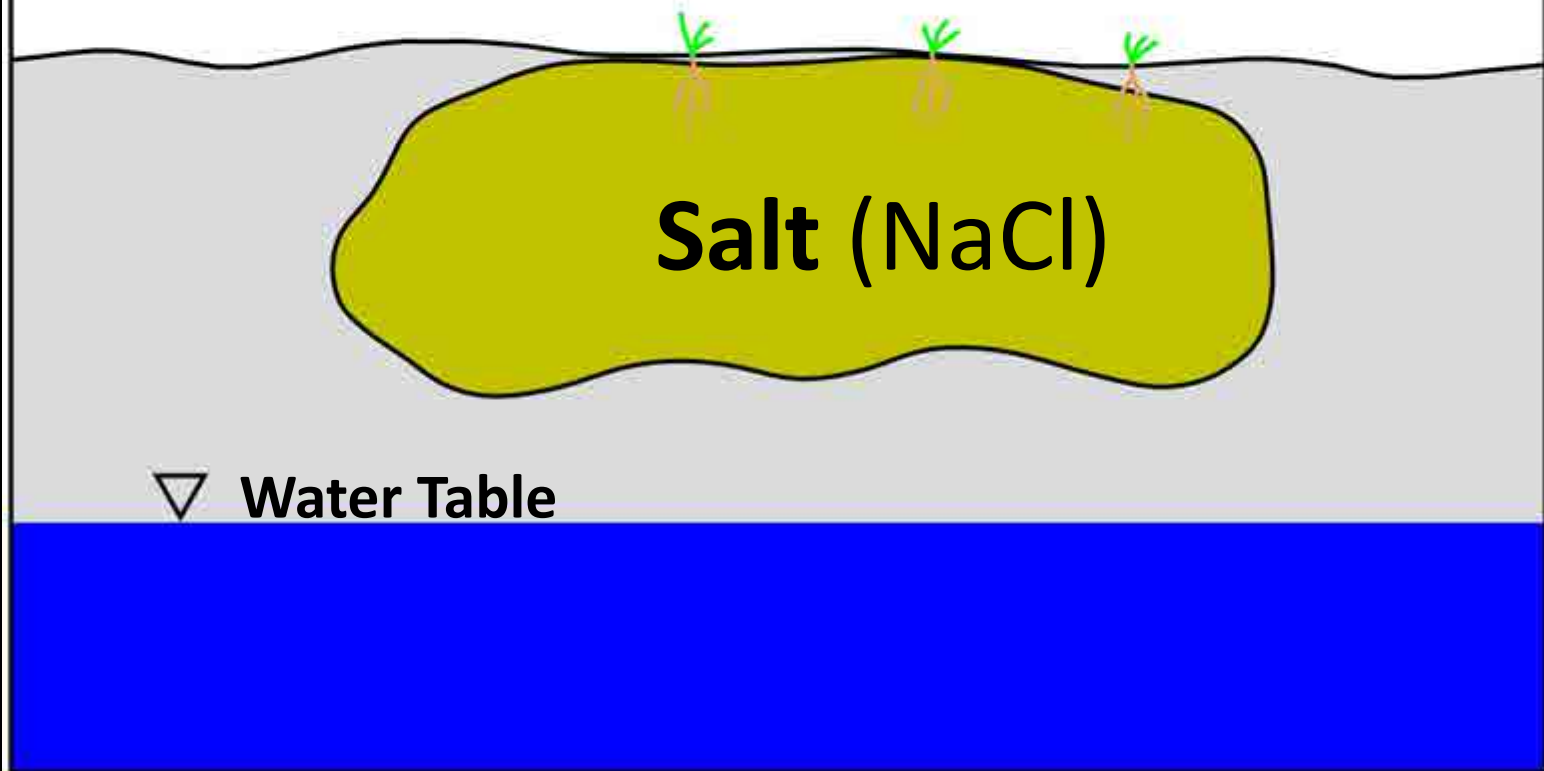
Area of surface scaring reduced from 1.5 acres to 0.5 acres.

## Haugen Site

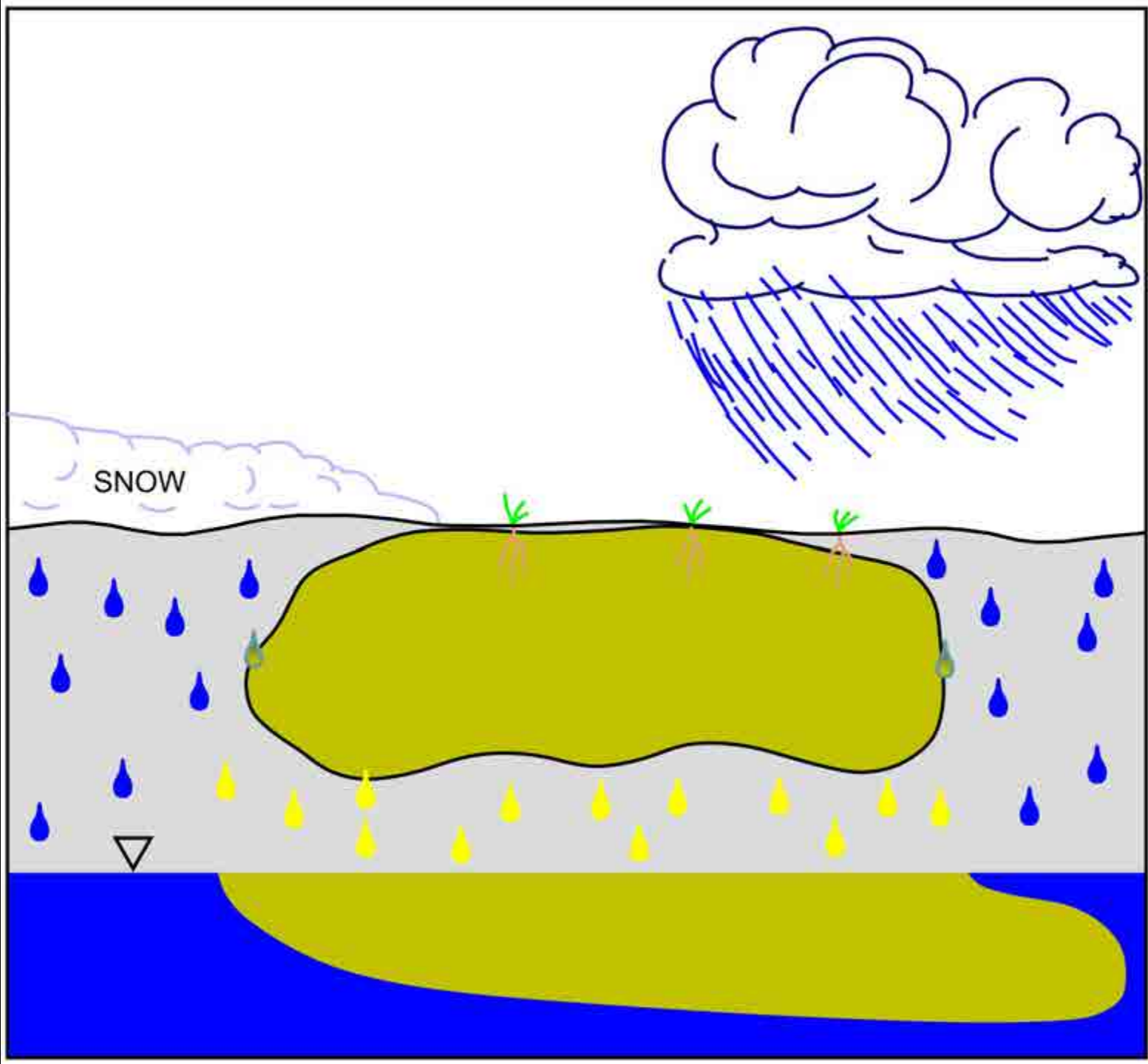
Chloride levels exhibited a decreasing trend in soils.

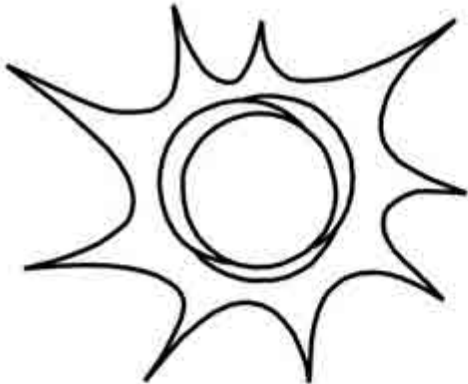
Area of surface scaring reduced from 3.5 acres to 1.75 acres.

# OLD BRINE POND SITE

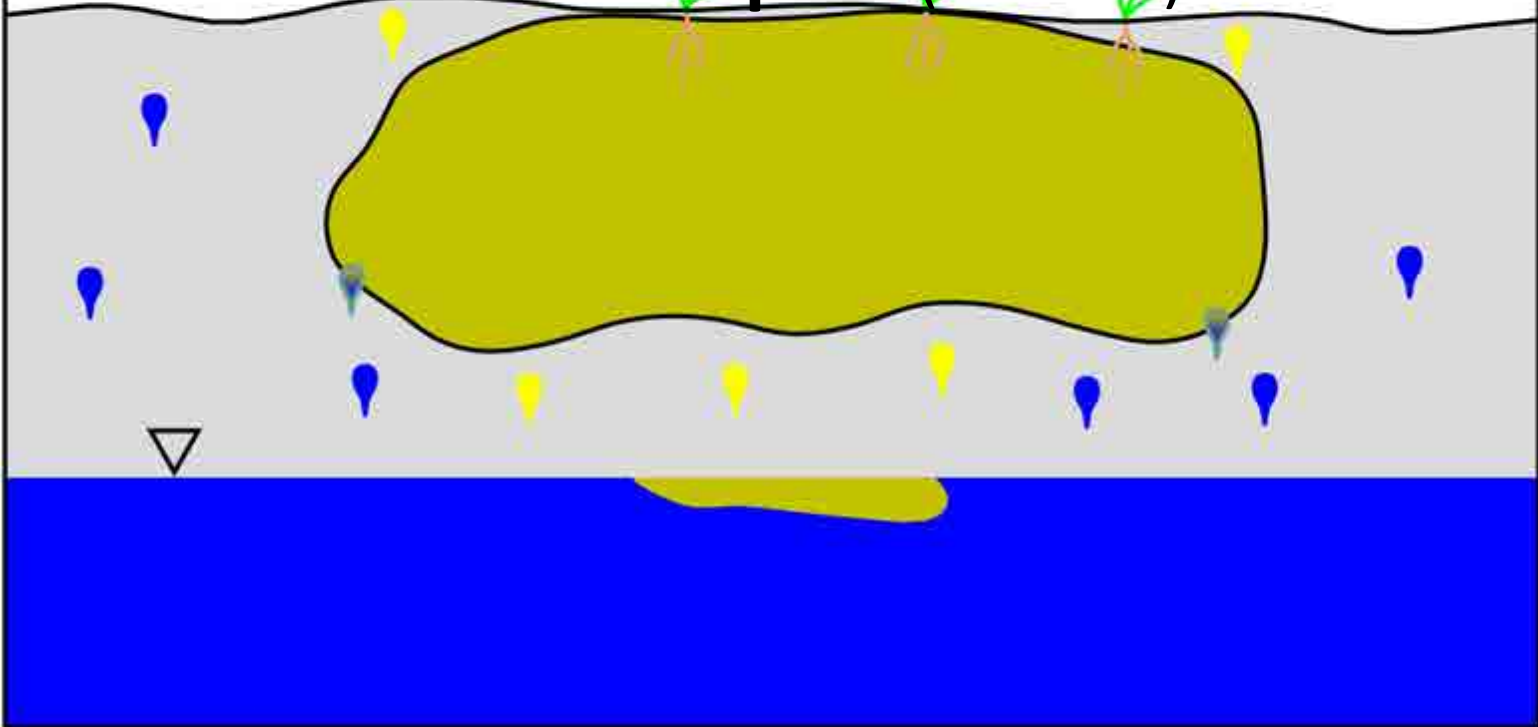


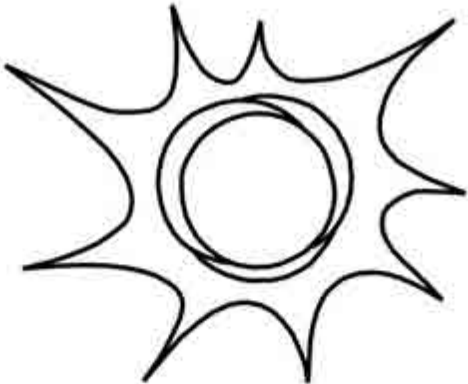






**Hardpan (sodium)**



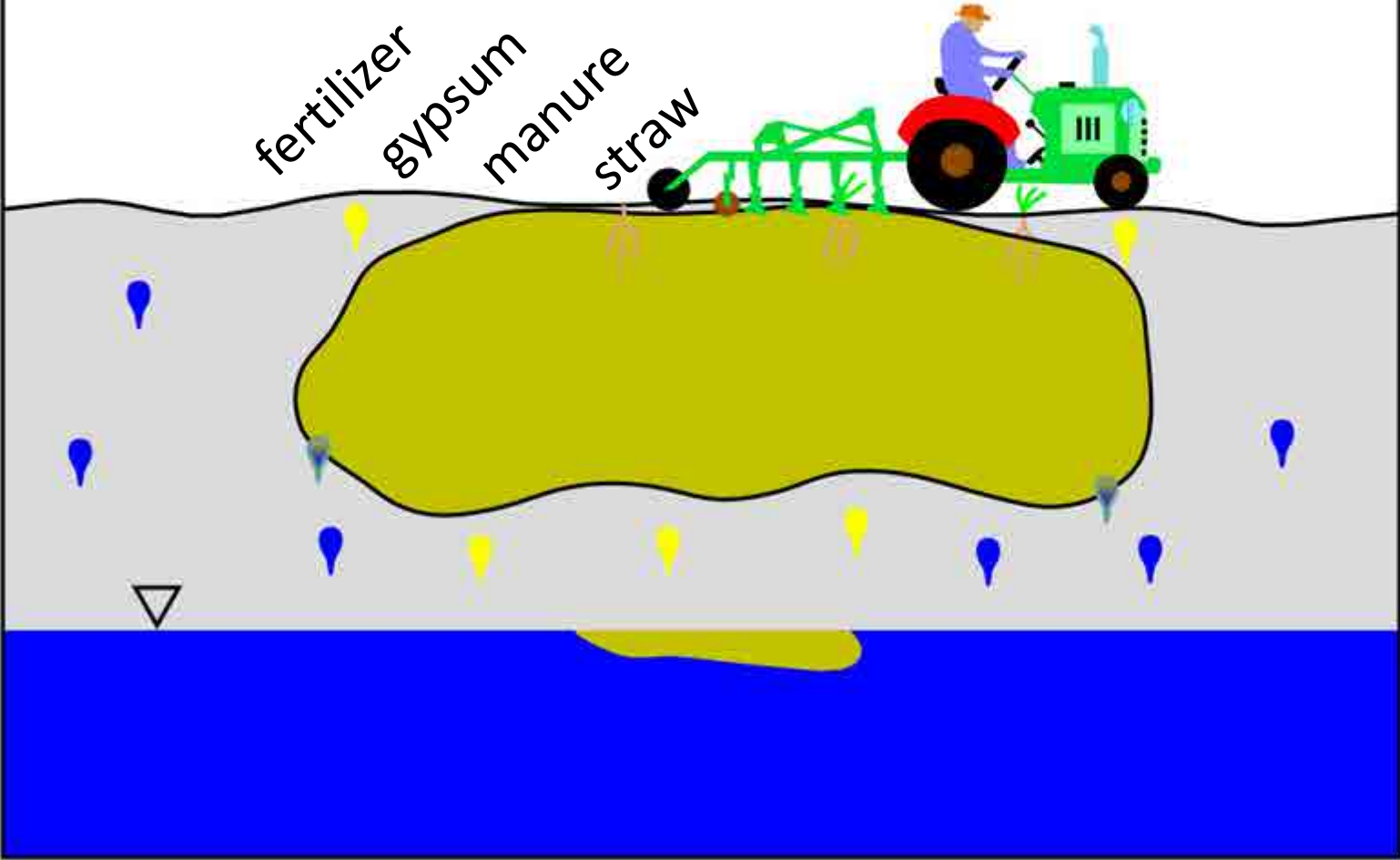


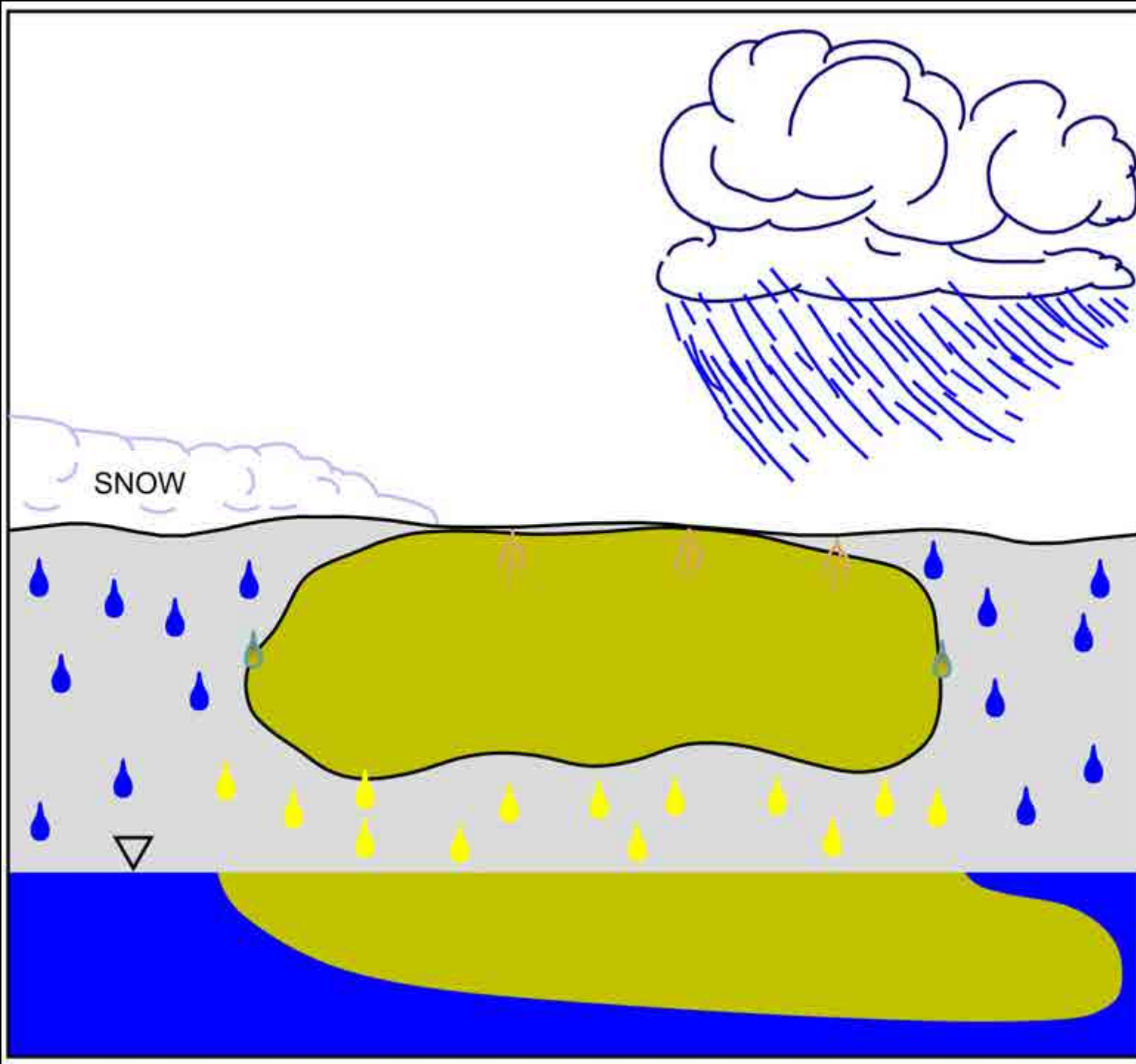
fertilizer

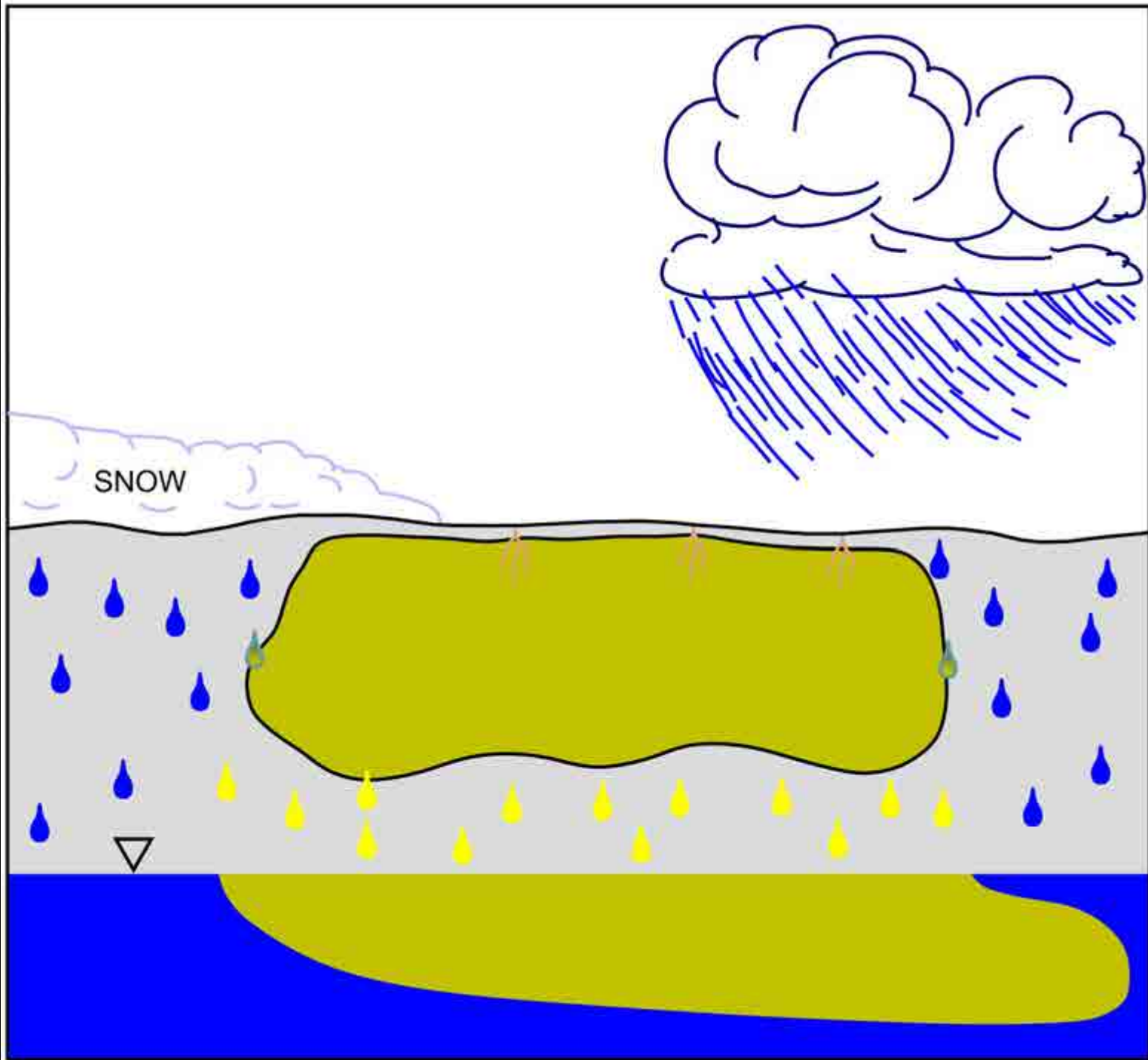
gypsum

manure

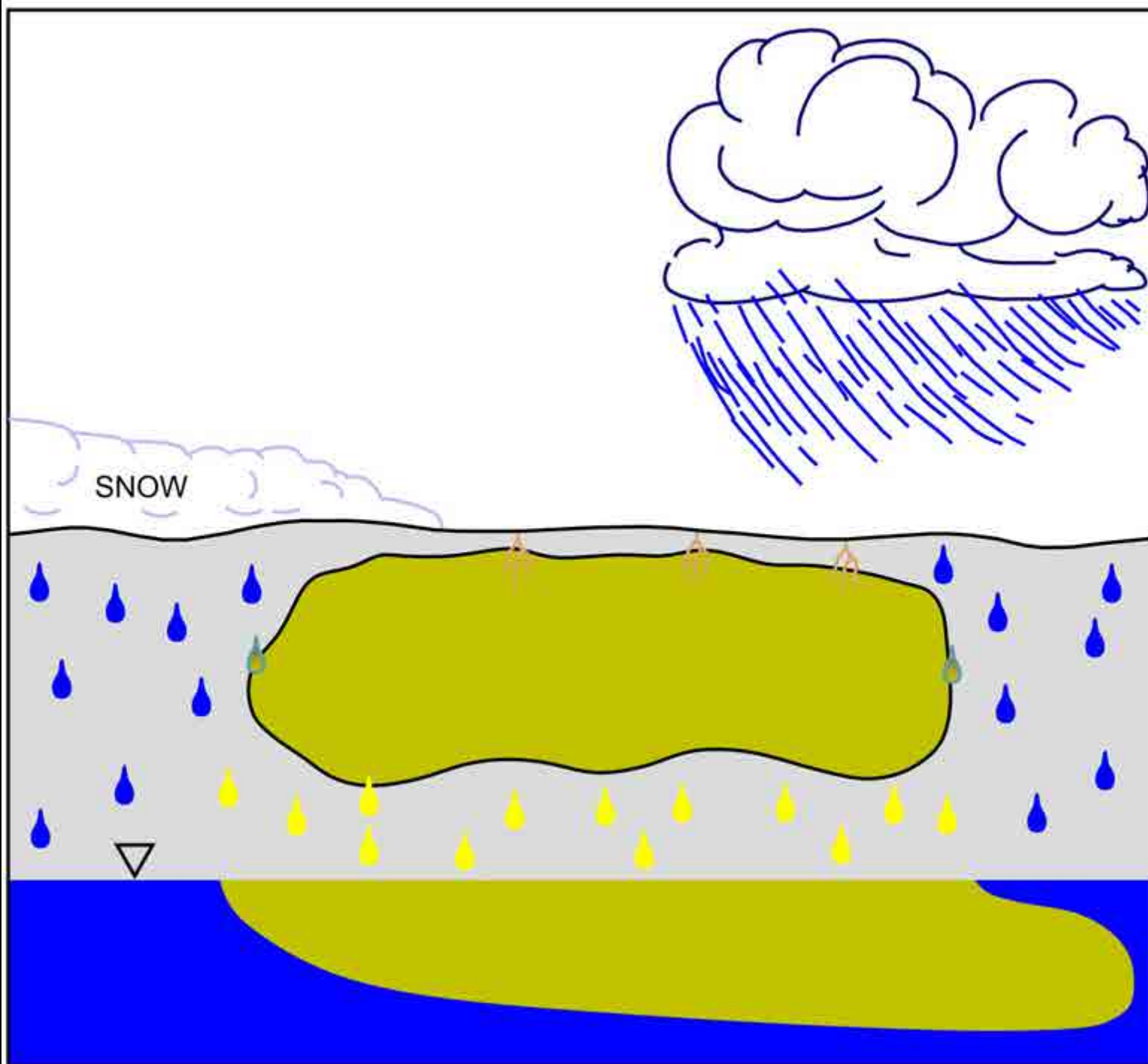
straw

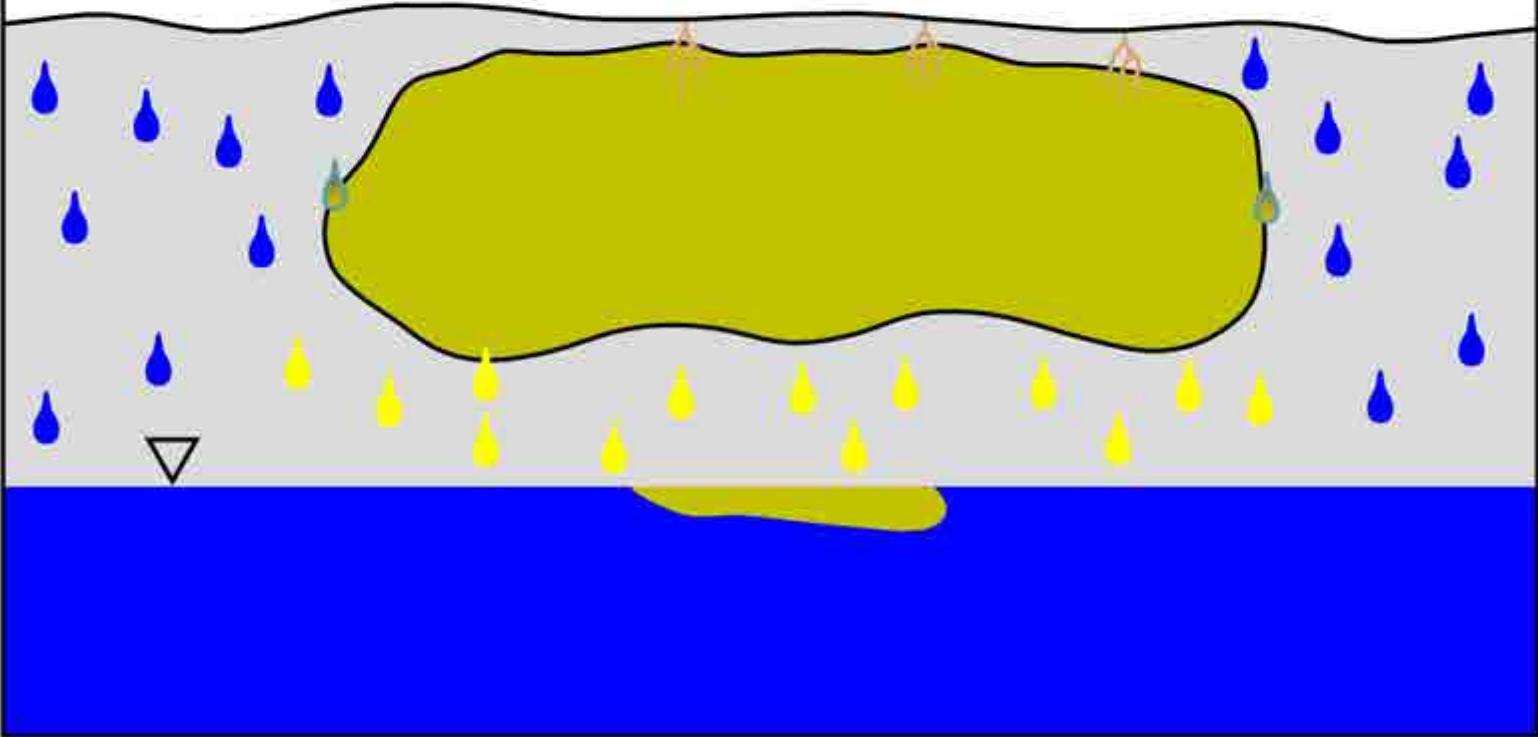
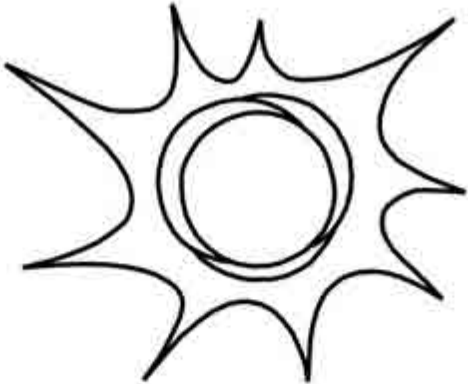




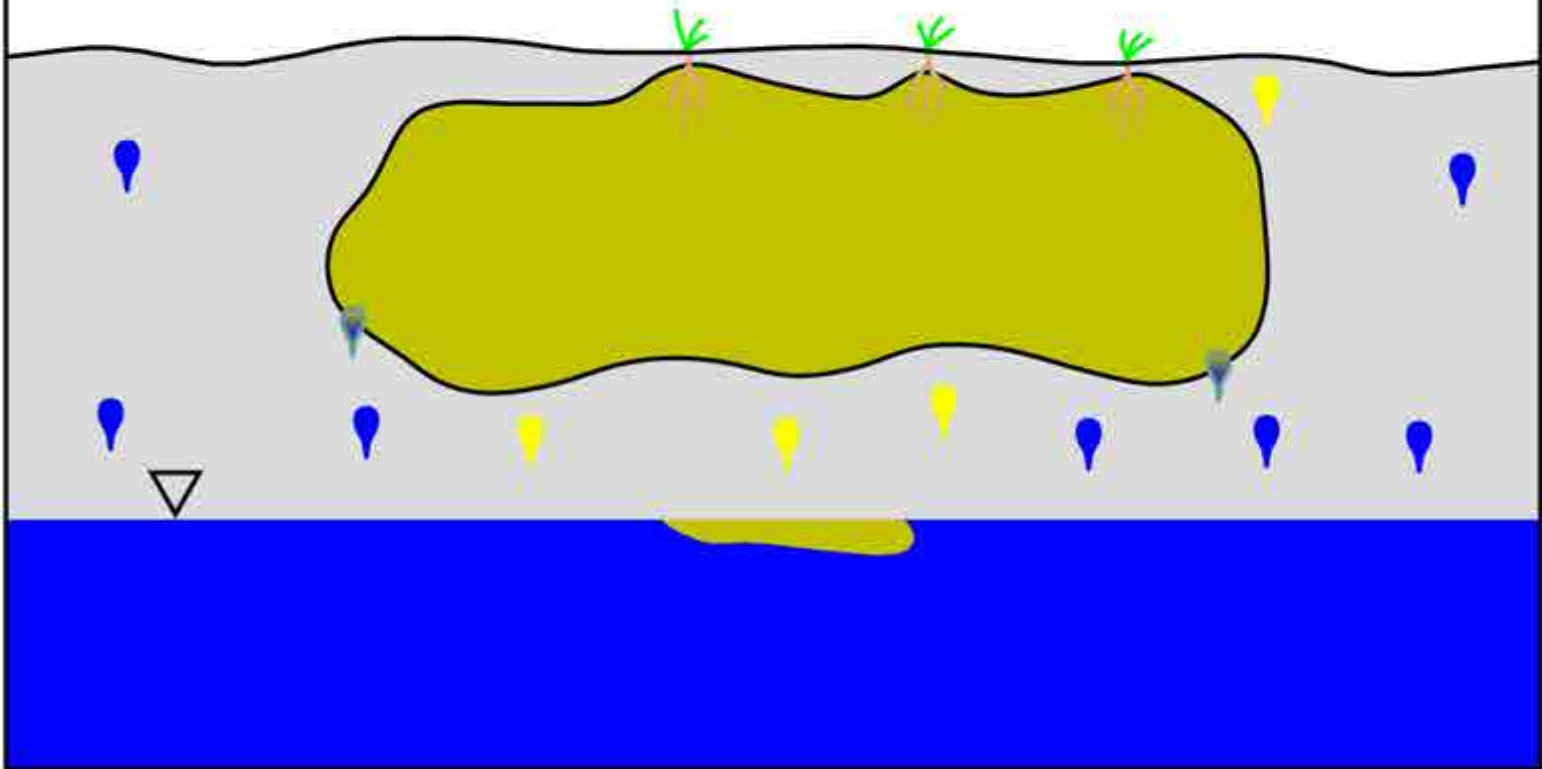
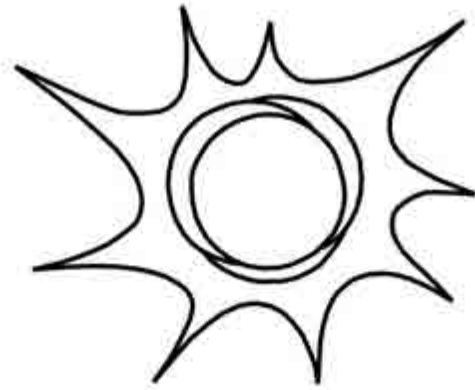




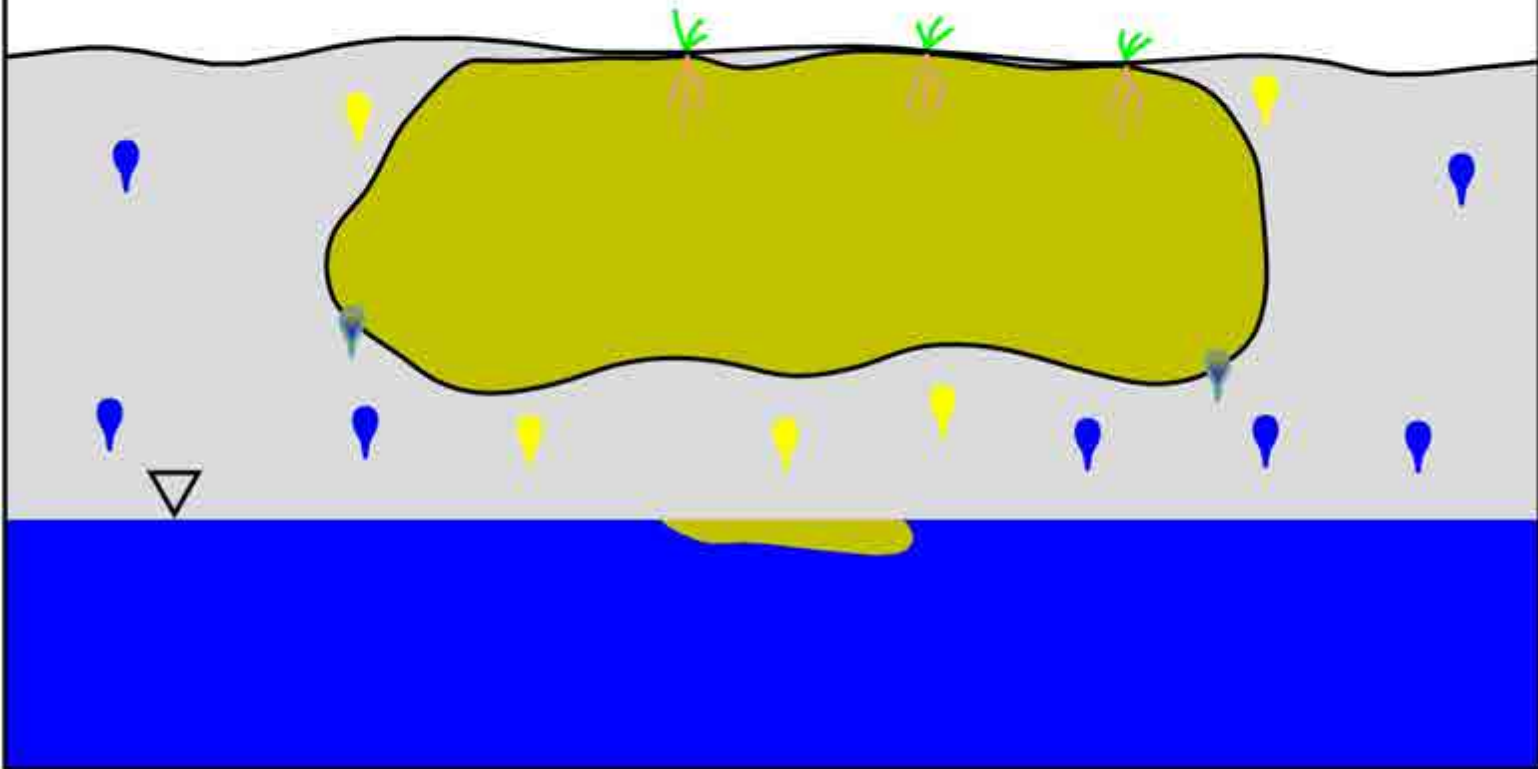
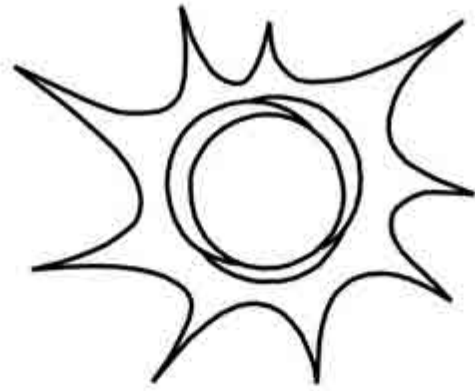




# Going Forward



# Going Forward



# DURNIN SITE

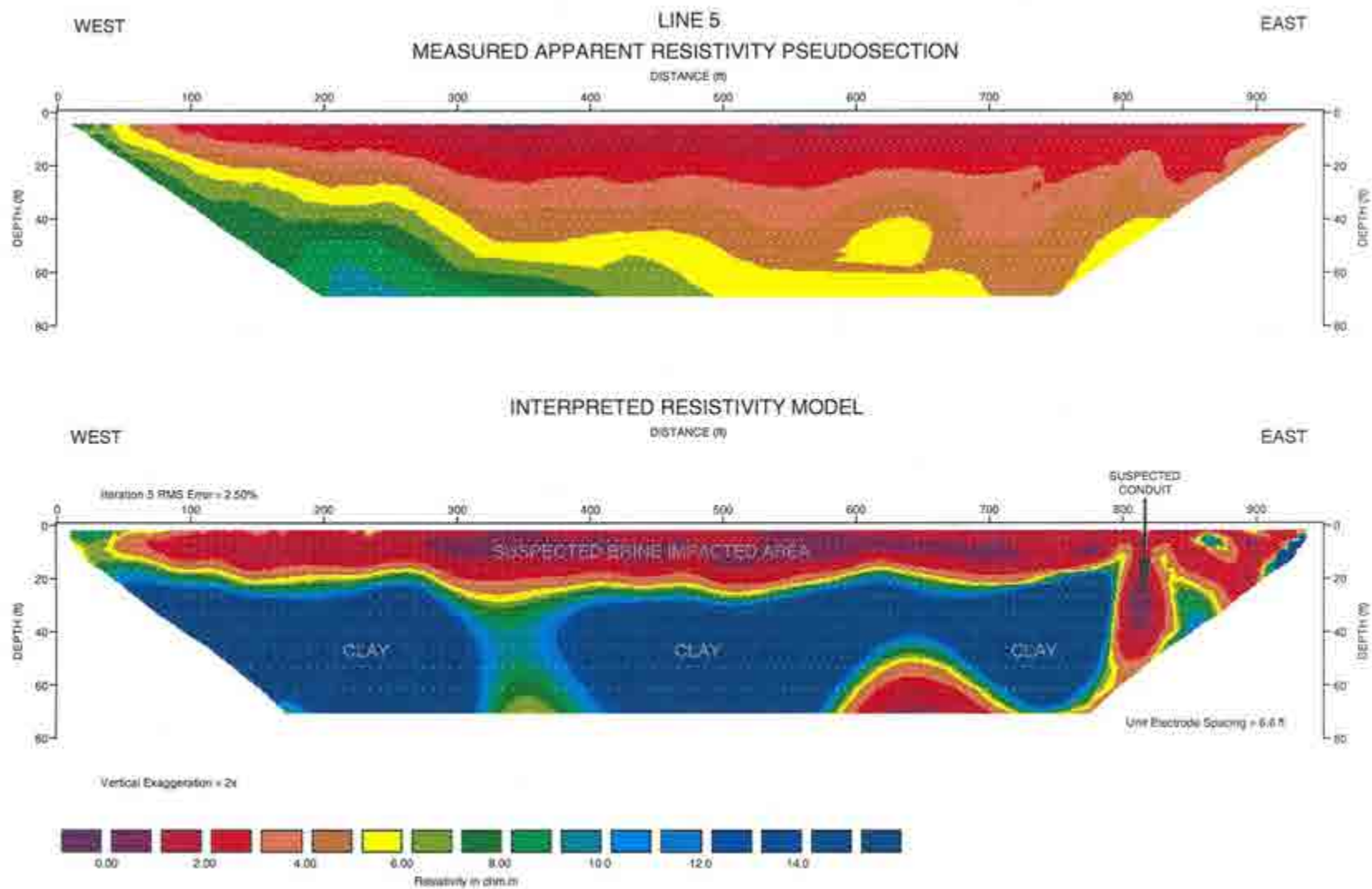


figure 7

ELECTRICAL RESISTIVITY RESULTS - LINE 5  
CONOCO PHILLIPS COMPANY - WILEY FIELD  
Bottineau County, North Dakota





# REJECTED REMEDIATION METHODS IN THE WYLIE FIELD 2006 – 2010

## REMOVE IMPACTED SEDIMENT

Evaluated removing salt impacted sediment across six acres to a depth of four feet (38,000 cubic yards).

Install a 30 mil plastic liner.

Replace with clean fill.

Risky due to likelihood that salt would find its way into the clean fill.

# REJECTED REMEDIATION METHODS IN THE WYLIE FIELD 2006 – 2010

## DRAIN TILE SYSTEM

Evaluated installing a drain tile system down to a depth of 20 feet to dewater and flush the system.

Potential for no viable disposal method.

Believe the groundwater impacted area extends beyond site and would continue to migrate into this site into the future.

# ADVANCES IN RESISTIVITY

Taken at depth of interest with vertical electrodes.

Surveys now use AC current verses DC current.

(measure actual soil /ground water resistivity vs. “apparent” resistivity).

Bulk soil measurements can be taken around an electrode, in planes between two electrodes.

Advances in statistical computer modeling can further increase the resolution of the electric data for 2-D or 3-D display.

# ADVANCES IN DRAIN TILE AND IRRIGATION FLUID CHEMISTRY



# INFILTRATION GALLERY

