Site Investigation, Remediation, and Reclamation of Oil & Gas and Brine Spills in North Dakota

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Overview

- **Major Contaminants in the oil industry**
- **Field Screening methods**
  - Electrical Conductivity (EC)
  - Chlorides
  - Organic Vapors
- **Site Assessment**
  - Limited Site Investigation (LSI)
  - Corrective Action Plan (CAP)
- **Corrective Action**
  - Remediation/Excavation
  - Reclamation
- **Case Studies**

Major Contaminants in the oil industry

Produce Water (Brine)

Petroleum Hydrocarbons

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Field Screening Methods

Produced Water

- Electrical Conductivity
- Chlorides

Petroleum Hydrocarbons

- Organic Vapors

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Electrical Conductivity (EC)

- EC meter equipped with stainless steel probe
- Measures a material's ability to conduct an electric current
- Microsiemens per centimeter (µS/cm)

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Chlorides

- QuanTab® titration test strips
- Measures the chloride content from a solution
- Milligrams per liter (mg/L)

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Chlorides - Experiment

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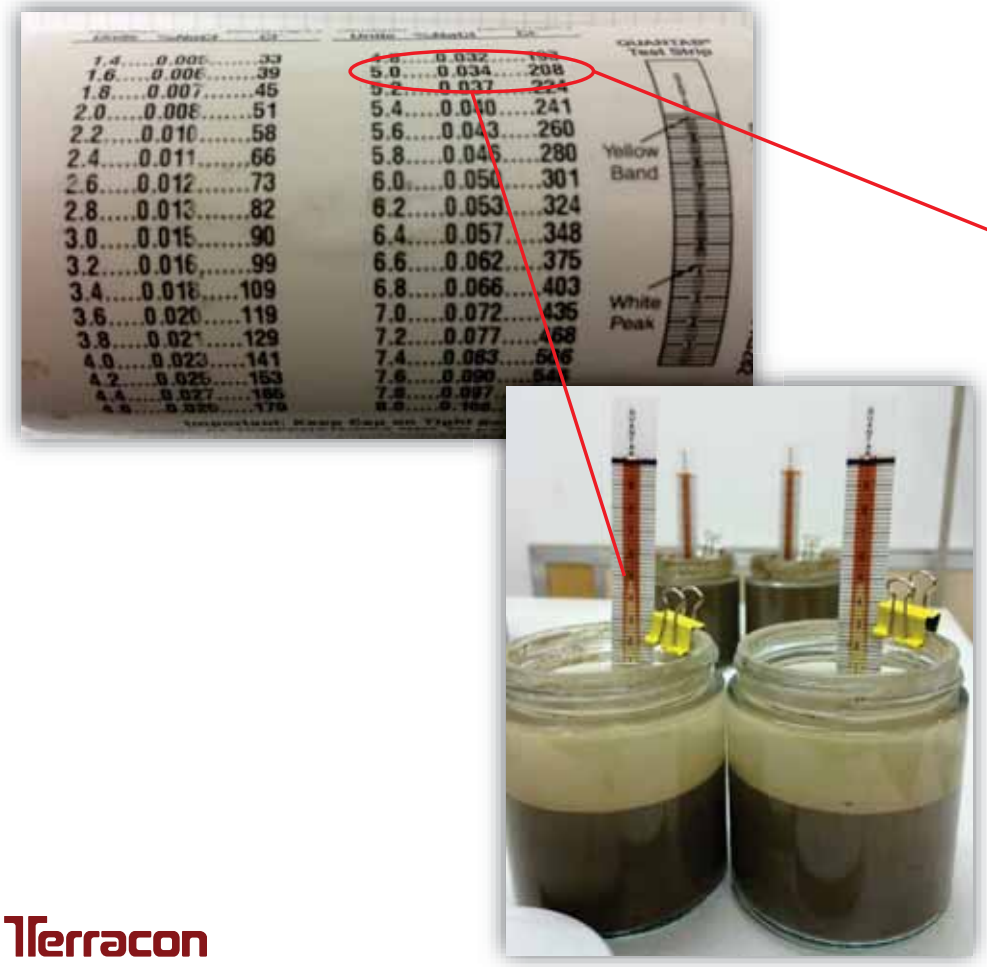
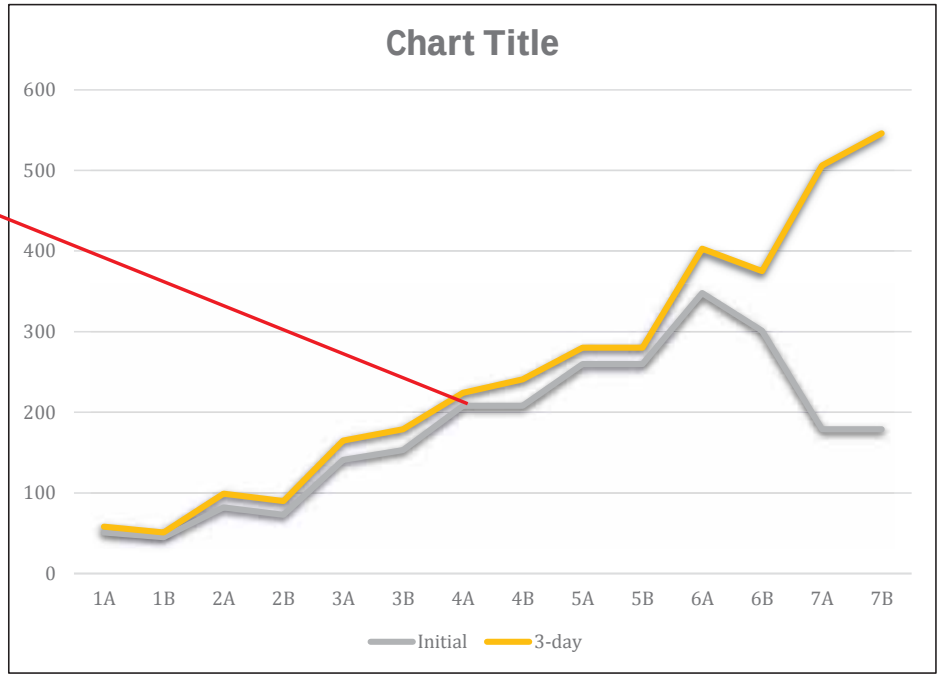
Chlorides - Experiment





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Organic Vapors

- Photoionization detector (PID) meter
- Measures organic vapors (isobutylene equivalents)
- Parts per million (ppm)

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Site Assessment

Limited Site Investigation (LSI)

- Evaluate the extent and magnitude, vertically and horizontally, of impacted material
- Assessing surface and depth (soil borings)
- Assess groundwater if soil borings extend to groundwater level

Corrective Action Plan (CAP)

- Designed after site investigation and results are evaluated
- Should address volume of contaminated material, analytical program, disposal, backfilling, and other site specific reclamation activities required

Limited Site Investigation

- Screen grid-like pattern at the surface
- Advance soil borings to help determine vertical and horizontal extent
- Install temporary groundwater monitoring wells if groundwater is encountered
- Screen soil and groundwater for EC, chlorides, and organic vapors

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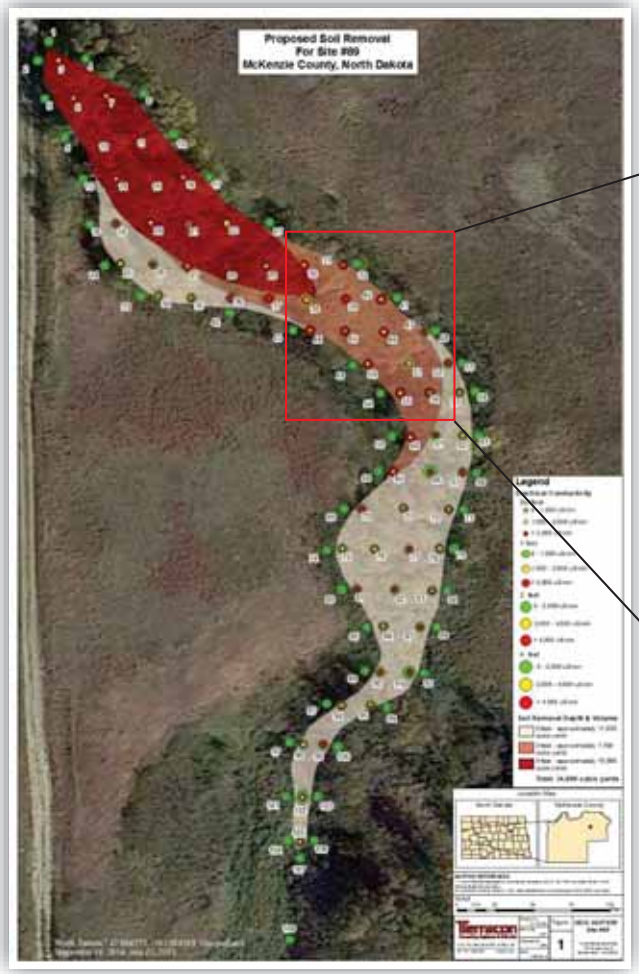
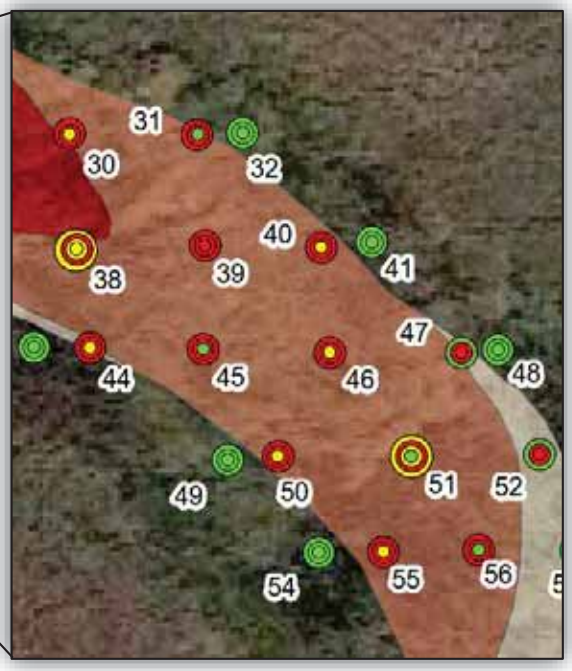
Limited Site Investigation





Electrical Conductivity

Field screened with an EC meter

Analyzed in laboratory for electrical conductivity

Legend

Electrical Conductivity

Surface
- 0 - 1,000 uS/cm
- 1,000 - 2,000 uS/cm
- > 2,000 uS/cm

1 foot
- 0 - 1,000 uS/cm
- 1,000 - 2,000 uS/cm
- > 2,000 uS/cm

2 feet
- 0 - 2,000 uS/cm
- 2,000 - 4,000 uS/cm
- > 4,000 uS/cm

4 feet
- 0 - 2,000 uS/cm
- 2,000 - 4,000 uS/cm
- > 4,000 uS/cm

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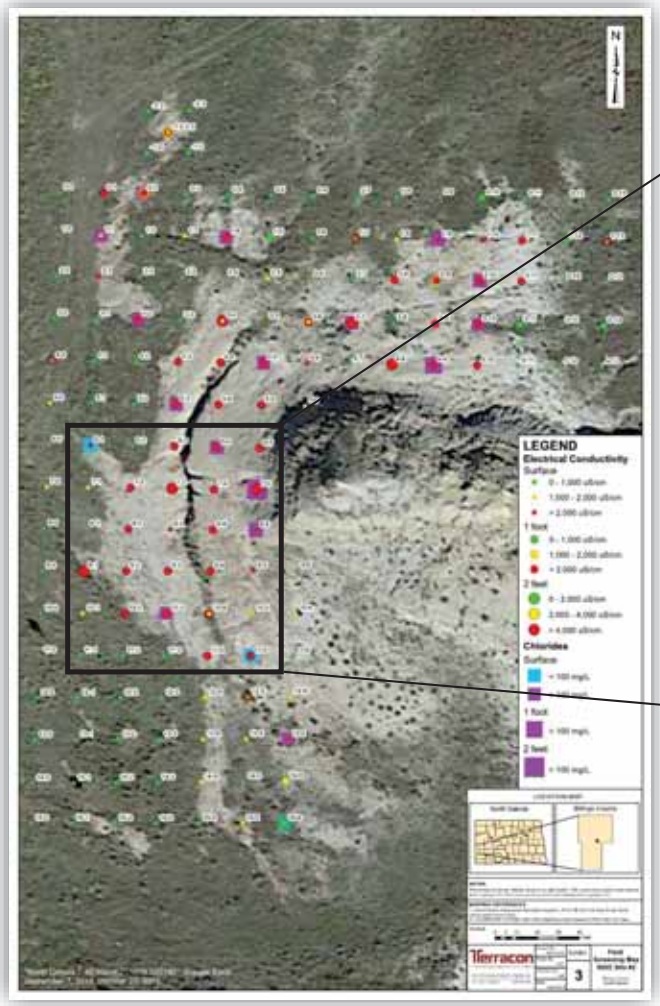
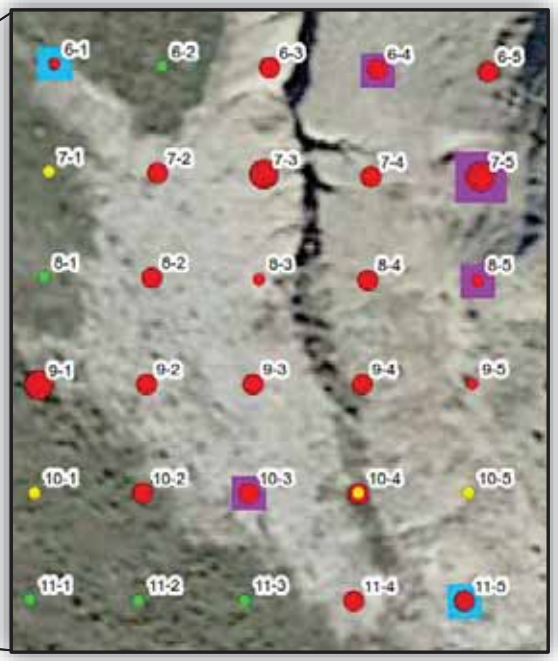
Limited Site Investigation





Chlorides

Field screened with chloride test strips

Analyzed in laboratory for chloride content

Chlorides

Surface

< 100 mg/L

> 100 mg/L

1 foot

> 100 mg/L

2 feet

> 100 mg/L

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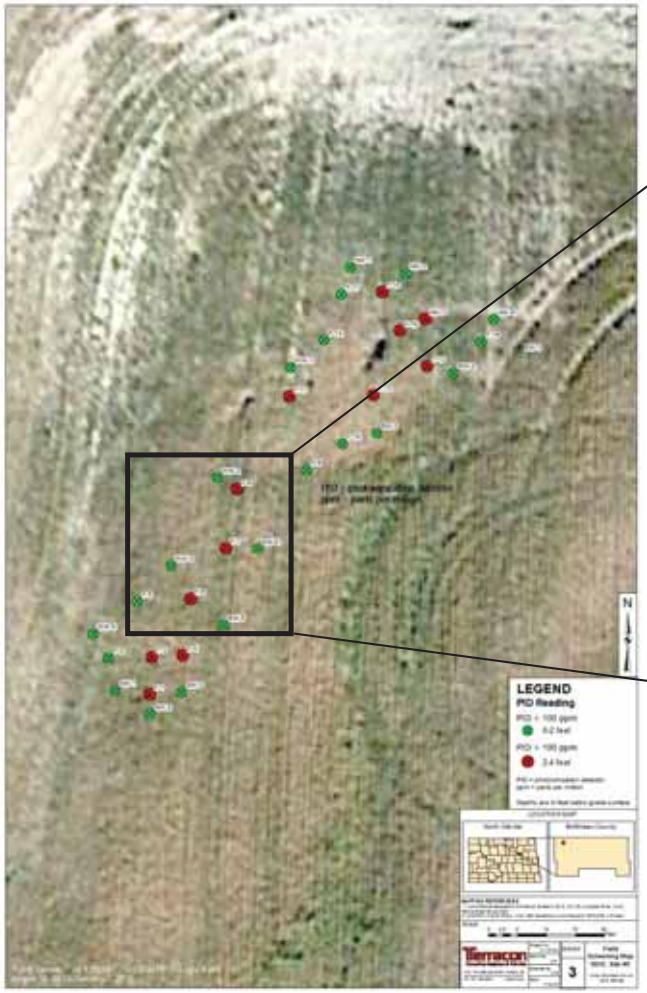
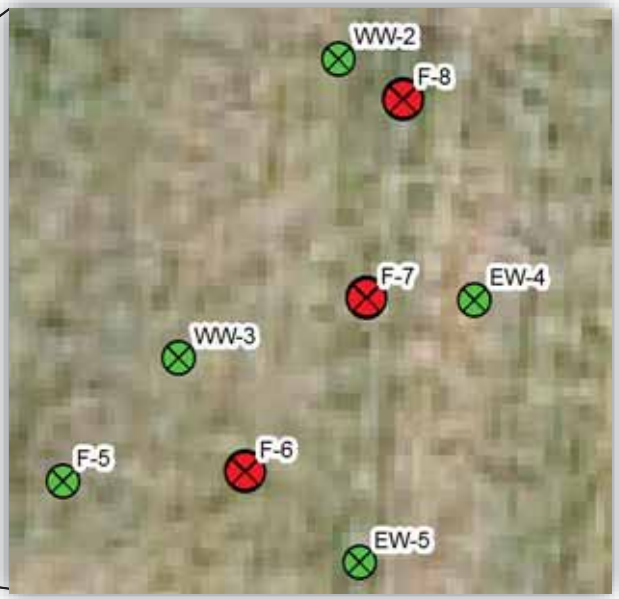
Limited Site Investigation





LEGEND

PID Reading

PID < 100 ppm

0-2 feet

PID > 100 ppm

2-4 feet

PID = photoionization detector
ppm = parts per million

Depths are in feet below grade surface

Organic Vapors

Field screened with a PID meter

Analyzed in laboratory for total petroleum hydrocarbons – GRO, DRO & ORO

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Limited Site Investigation

Drilling soil boring to collect soil samples and install temporary groundwater monitoring well.

Collecting groundwater sample from temporary groundwater monitoring well.

Split-spoon soil sampling – scoria, shale cuttings, and petroleum hydrocarbons.

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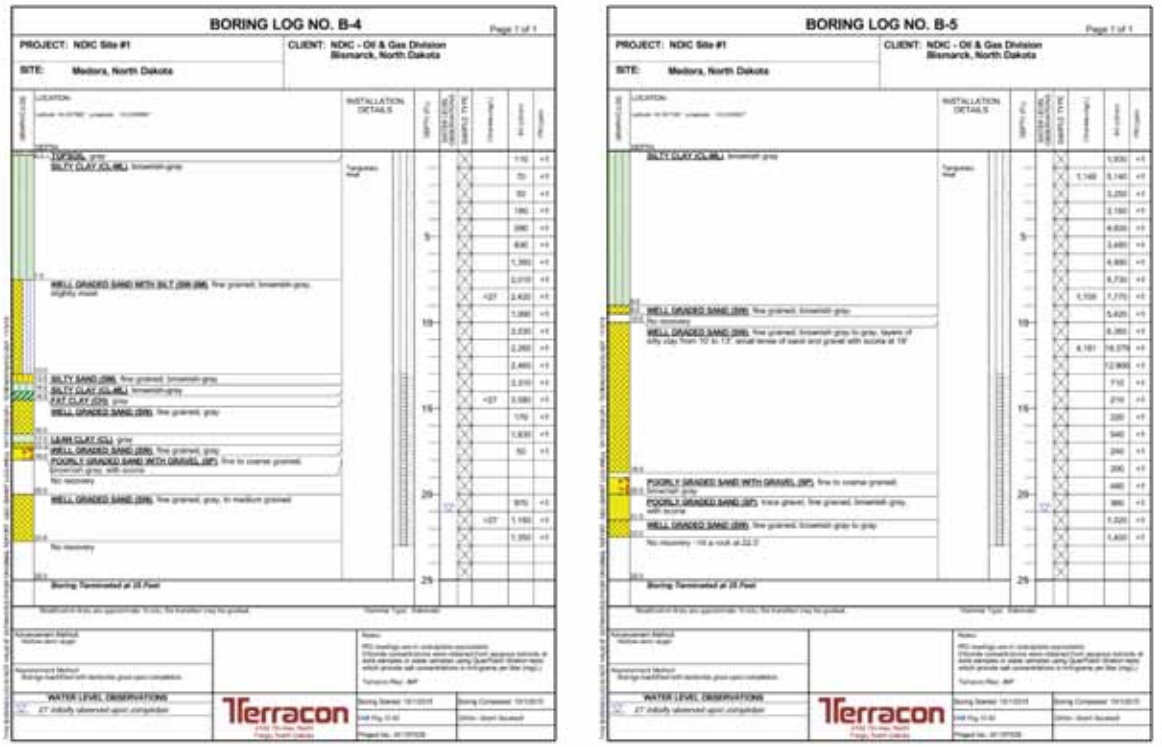
Limited Site Investigation

Site map and boring locations.



Boring logs with field screening results. Boring B-4 was completed for background results and B-5 was within the historical pit.

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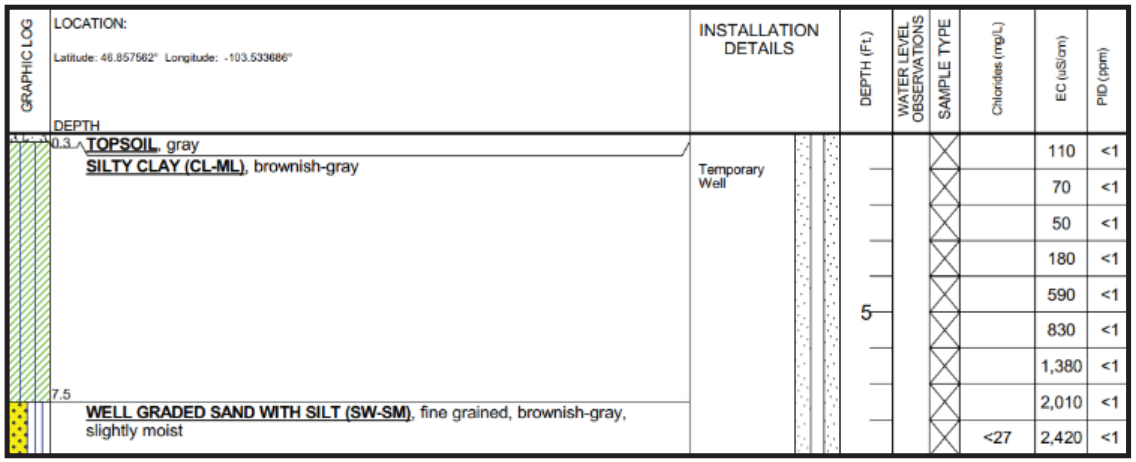
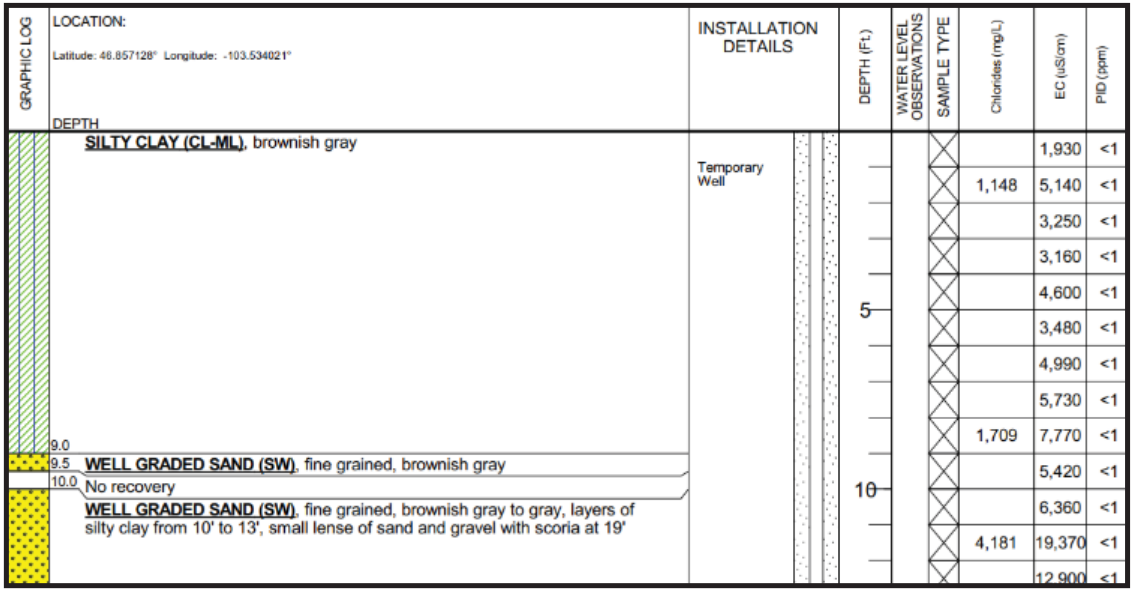
Limited Site Investigation



GRAPHIC LOG	LOCATION: Latitude: 46.857562° Longitude: -103.533686° / DEPTH	INSTALLATION DETAILS	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	Chlorides (mg/L)	EC (uS/cm)	PID (ppm)
	0.3 **TOPSOIL**, gray						110	<1
	SILTY CLAY (CL-ML), brownish-gray	Temporary Well					70	<1
							50	<1
							180	<1
			5				590	<1
							830	<1
							1,380	<1
	7.5						2,010	<1
	WELL GRADED SAND WITH SILT (SW-SM), fine grained, brownish-gray, slightly moist					<27	2,420	<1

Soil boring B-4 (background).

Soil boring B-5 (within the pit).



GRAPHIC LOG	LOCATION: Latitude: 46.857128° Longitude: -103.534021° / DEPTH	INSTALLATION DETAILS	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	Chlorides (mg/L)	EC (uS/cm)	PID (ppm)
	SILTY CLAY (CL-ML), brownish gray	Temporary Well					1,930	<1
						1,148	5,140	<1
							3,250	<1
							3,160	<1
			5				4,600	<1
							3,480	<1
							4,990	<1
							5,730	<1
	9.0					1,709	7,770	<1
	9.5 **WELL GRADED SAND (SW)**, fine grained, brownish gray						5,420	<1
	10.0 No recovery		10				6,360	<1
	WELL GRADED SAND (SW), fine grained, brownish gray to gray, layers of silty clay from 10' to 13', small lense of sand and gravel with scoria at 19'					4,181	19,370	<1
							12,900	<1

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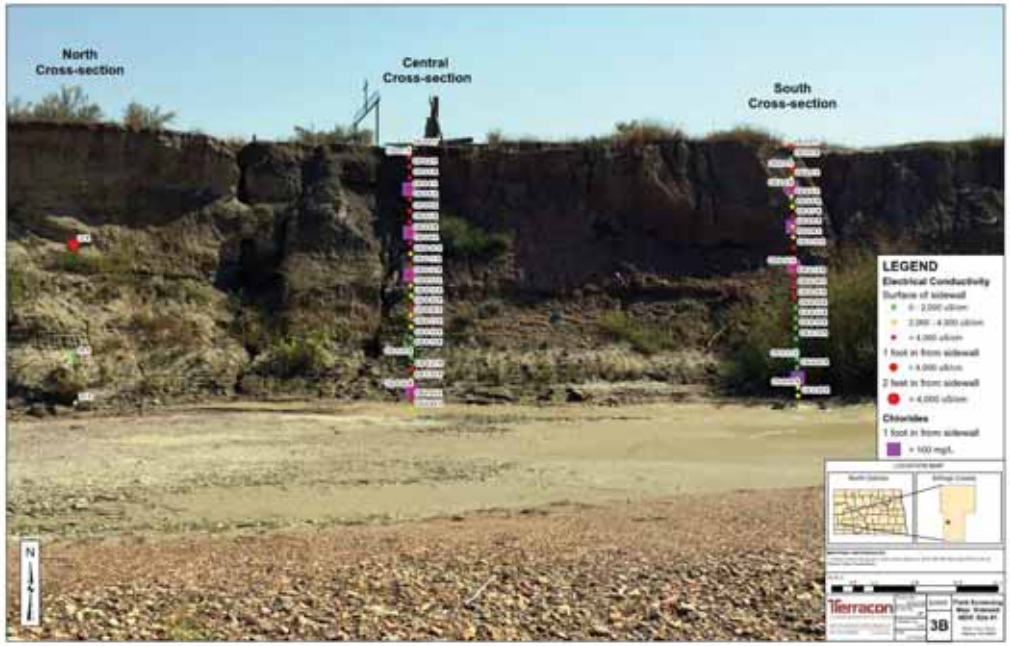
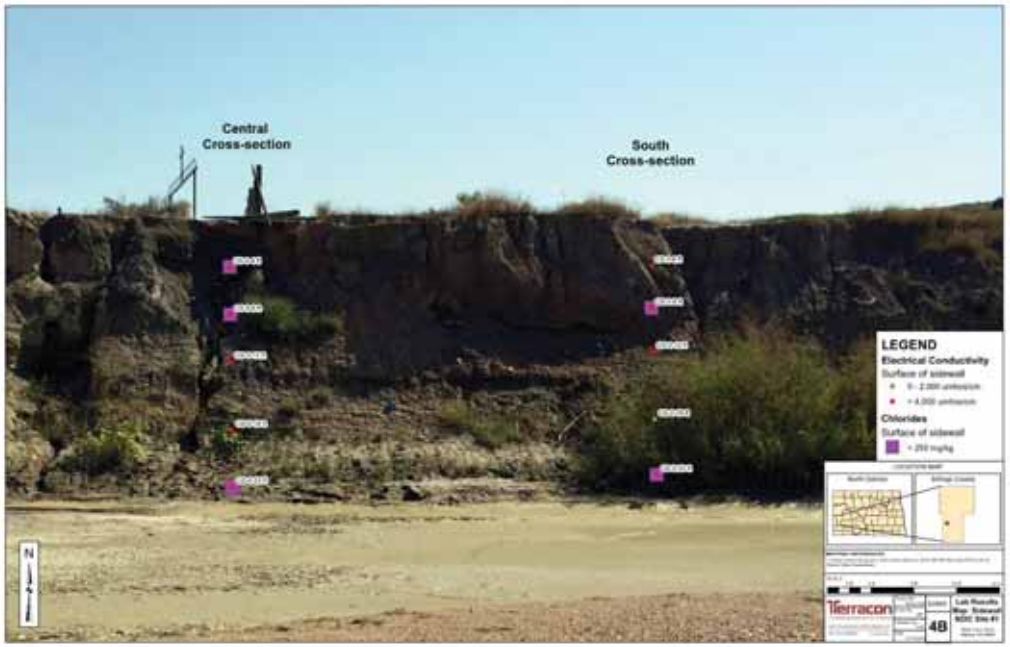
Limited Site Investigation



Field screening results every foot up to 20 feet bgs. Soil was screened up to 2 feet in from sidewall.



Laboratory results at the surface of the sidewall.

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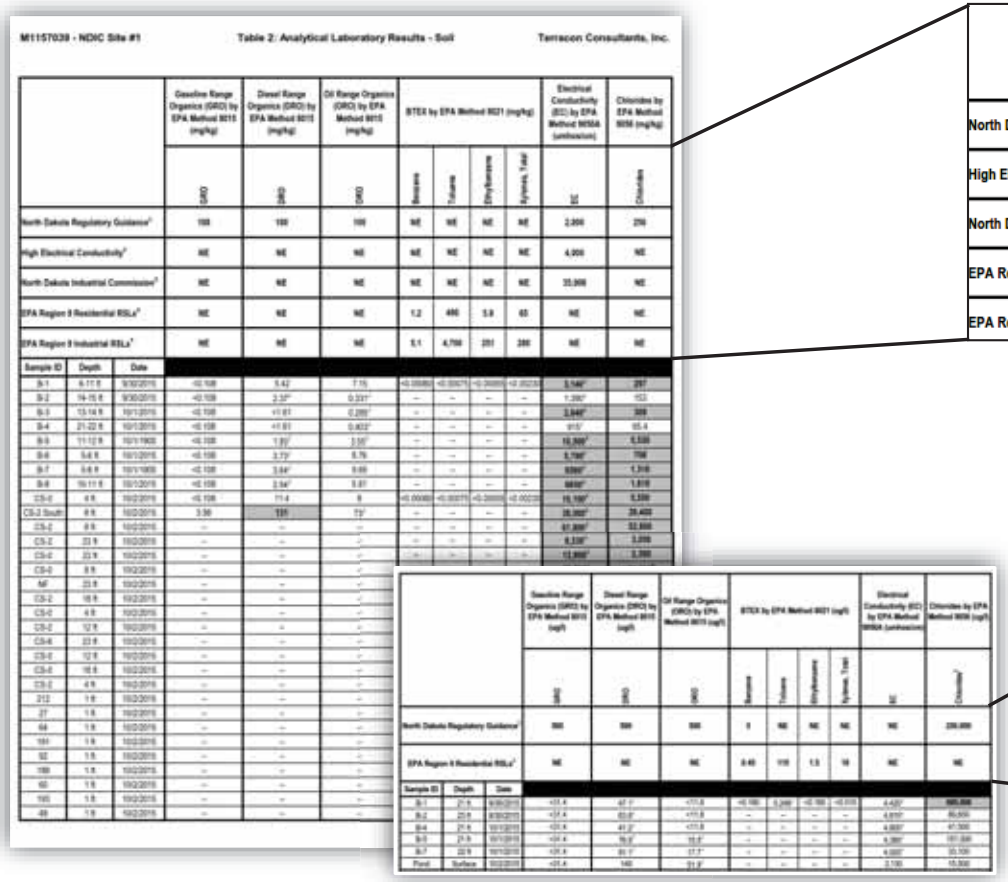
Limited Site Investigation


M11157039 - NDIC Site #1 — Table 2: Analytical Laboratory Results - Soil — Terracon Consultants, Inc.

Regulatory levels for soil

	GRO	DRO	ORO	Benzene	Toluene	Ethylbenzene	Xylenes, Total	EC	Chlorides
North Dakota Regulatory Guidance[1]	100	100	100	NE	NE	NE	NE	2,000	250
High Electrical Conductivity[2]	NE	NE	NE	NE	NE	NE	NE	4,000	NE
North Dakota Industrial Commission[3]	NE	NE	NE	NE	NE	NE	NE	35,000	NE
EPA Region 9 Residential RSLs[4]	NE	NE	NE	1.2	490	5.8	65	NE	NE
EPA Region 9 Industrial RSLs[4]	NE	NE	NE	5.1	4,700	251	280	NE	NE

Regulatory levels for groundwater

	GRO	DRO	ORO	Benzene	Toluene	Ethylbenzene	Xylenes, Total	EC	Chlorides[3]
North Dakota Regulatory Guidance[1]	500	500	500	5	NE	NE	NE	NE	250,000
EPA Region 9 Residential RSLs[2]	NE	NE	NE	0.45	110	1.5	19	NE	NE

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Limited Site Investigation

Information from North Dakota Department of Health: Guidelines for the Assessment and Cleanup of Saltwater Releases (September, 2016).

Information from the United States Department of Agriculture Natural Resource Conservation Services Soil Survey Handbook.

Information from North Dakota Industrial Commission: A Guide for Remediation of Salt/Hydrocarbon Impacted Soil.

EPA Region 9 Regional Screening Levels (RSLs) June, 2015 - Residential and Industrial Soil Screening Levels in mg/kg.

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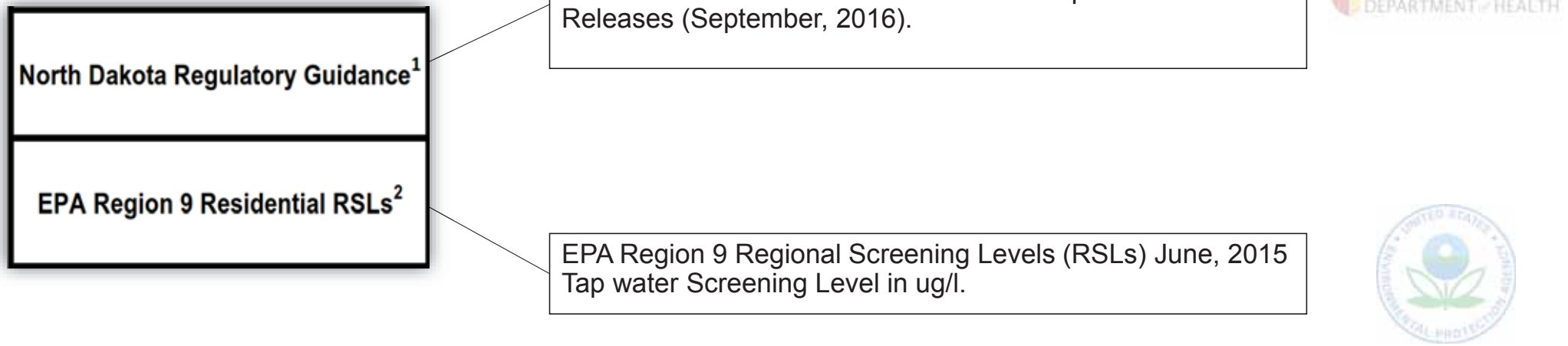
Limited Site Investigation



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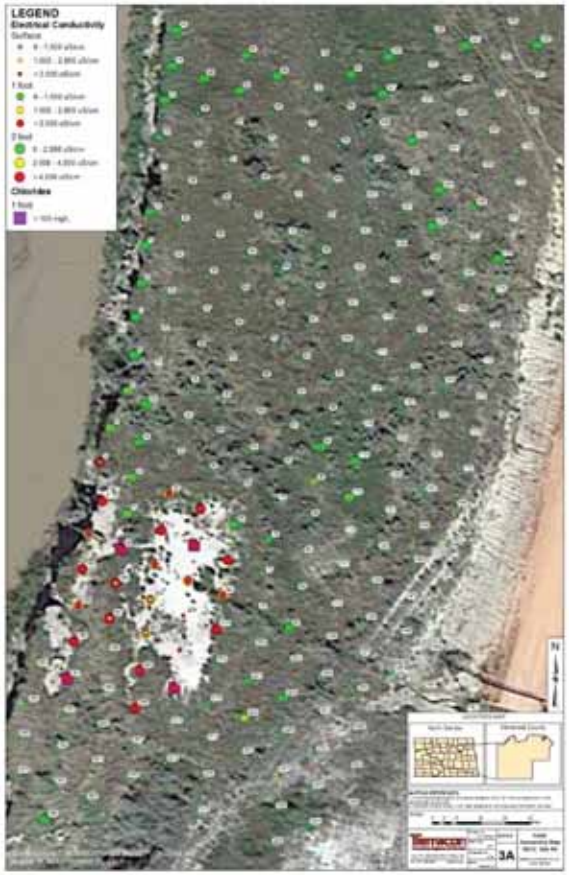
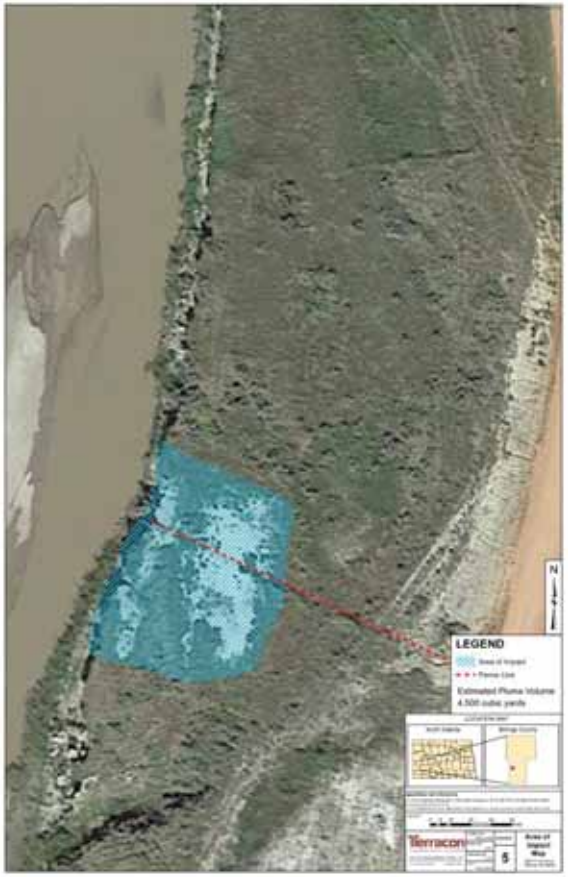
Limited Site Investigation



Field screening results up to 2 feet bgs.

Laboratory results up to 1 foot bgs.



Approximate area of impact anticipated from field and lab results.

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Corrective Action

Remediation/Excavation

- Extent of contamination will be determined in the field
- Contaminated material should be loaded directly in trucks for disposal or stockpiled on polyethylene sheeting
- Final field screening & lab samples should be collected and analyzed

Reclamation

- Backfill with material similar to what was there prior to excavation
- Topsoil thickness, revegetation, seed blend, and erosion prevention techniques are site-specific
- Visit site after reclamation

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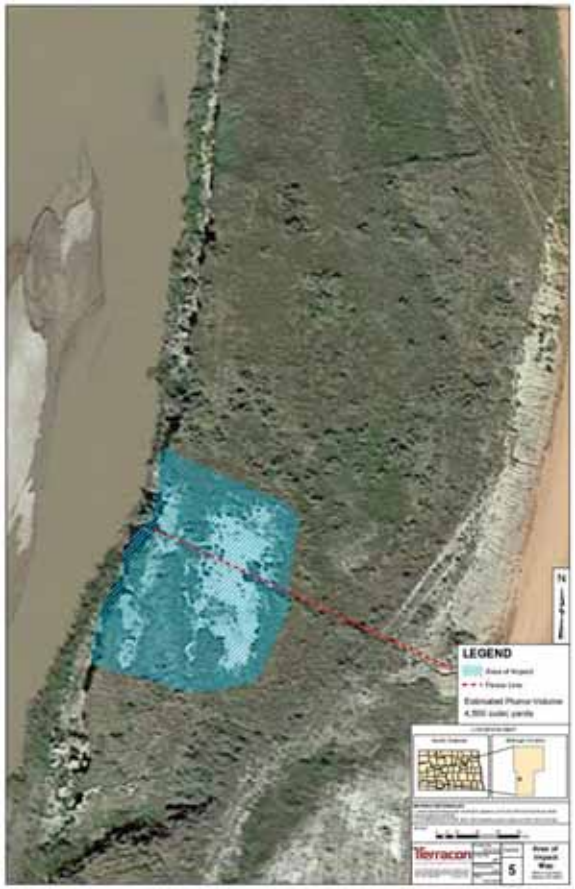
Remediation/Excavation



The area of interest.

The area of interest outlined by flags.

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Remediation/Excavation

Benched excavation of the NE sidewall.

View NE at the site.

Excavation of contaminated material.

Contaminated soil being loaded for disposal.

Contaminated material being stockpiled on polyethylene sheeting.

Covered stockpile of contaminated material.

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Remediation/Excavation

Sample ID	Location	Soil Chlorides (mg/L)	PID (ppm)	Depth (feet bgs)
Lab Samples				
1-5	Contaminated material from stockpile	>641	231.9	Stockpile
1-10	Contaminated material from stockpile	301	<1	Stockpile

Laboratory analytical data from stockpiled material.

Sampling of the backfill prior to being placed in excavated area for quality control.

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Remediation/Excavation

Continuous field screening during excavation.

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Remediation/Excavation

Excavation and flags outlining AOI.

View NE at the excavated area.

View at the material surrounding the well.

View east at excavated area and final sampling points (flags).

View at the excavation of the historical pit.

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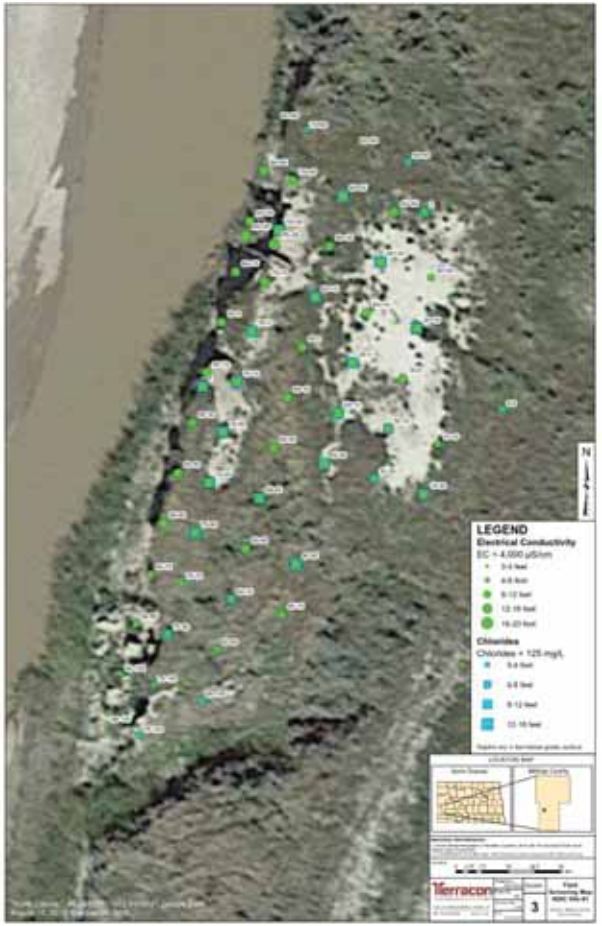
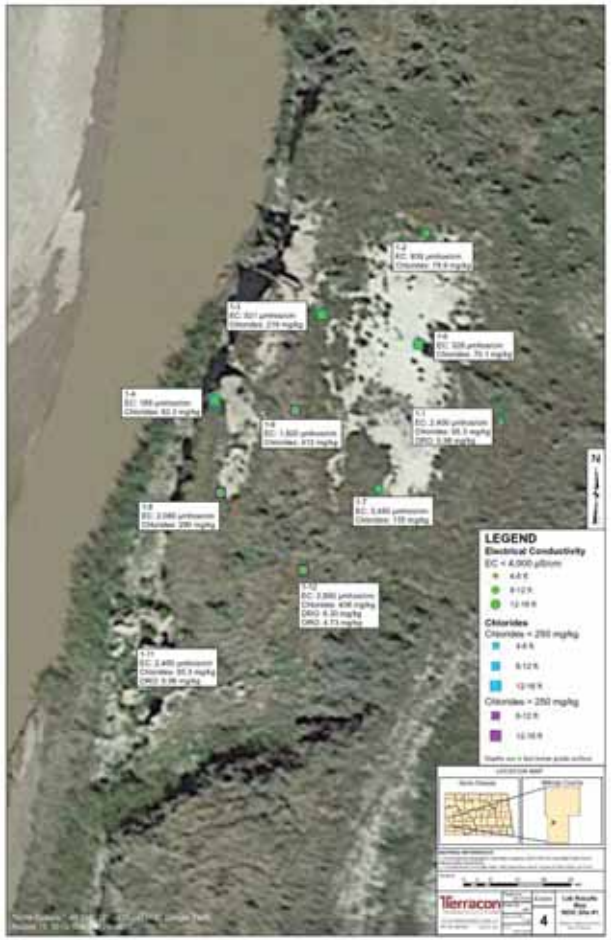
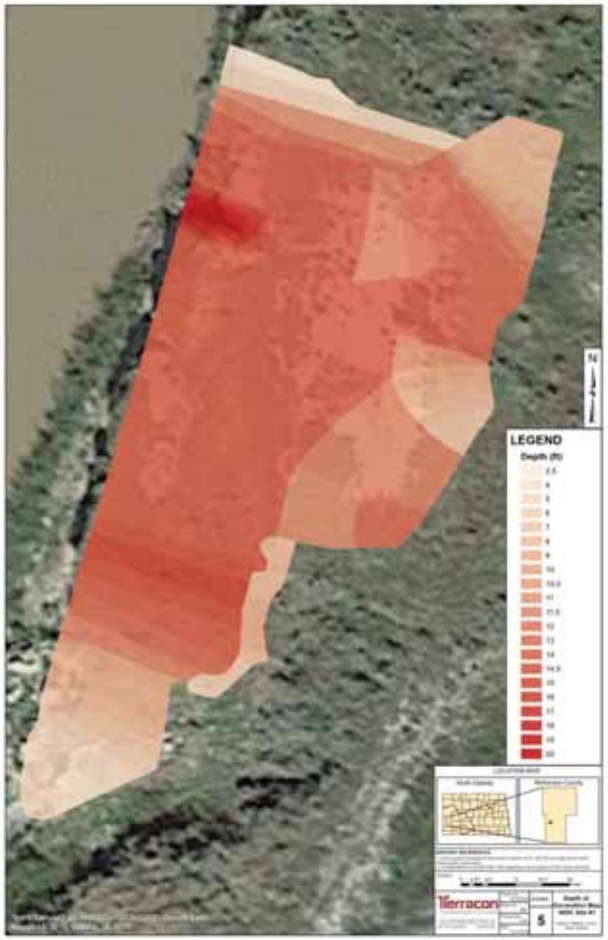
Remediation/Excavation



Field screening results (after excavation) up to 20 feet bgs.



Laboratory results (after excavation).



Map showing depth of excavation.

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Reclamation

Placing rip-rap along excavated area.

Backfilling with clay material and placing rip-rap along excavated area.

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Reclamation



Backfilling with clay material with rip-rap placement along excavated area.


Placement of straw matting after backfilling and seeding were completed.

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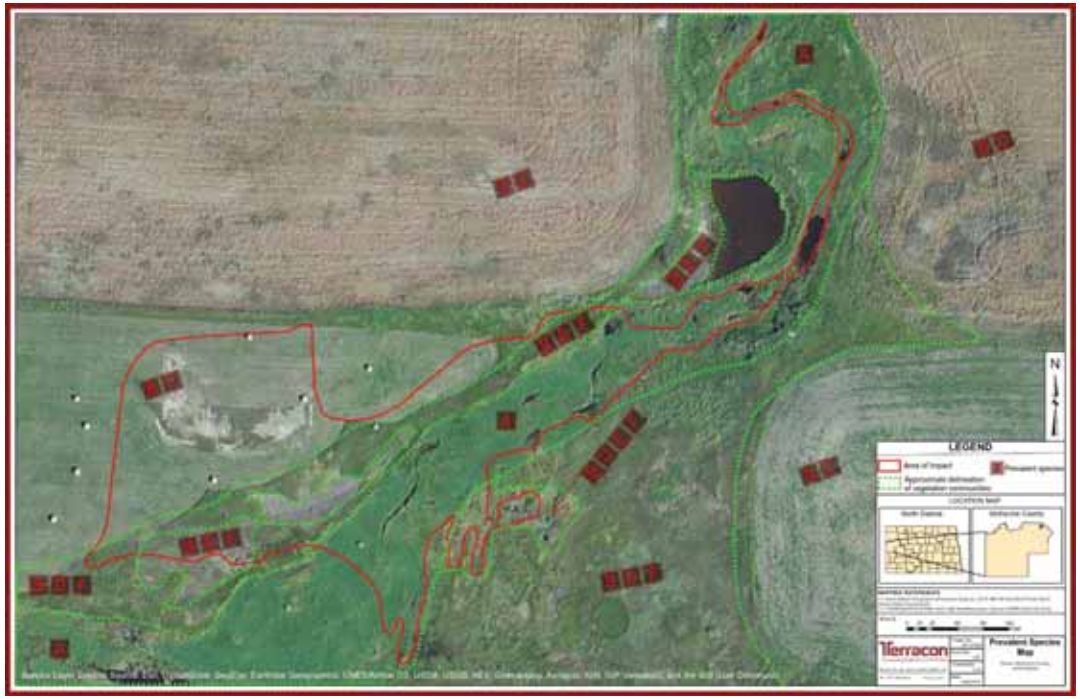
Reclamation



A study was completed to analyze what prevalent species of plants were growing at this specific site.

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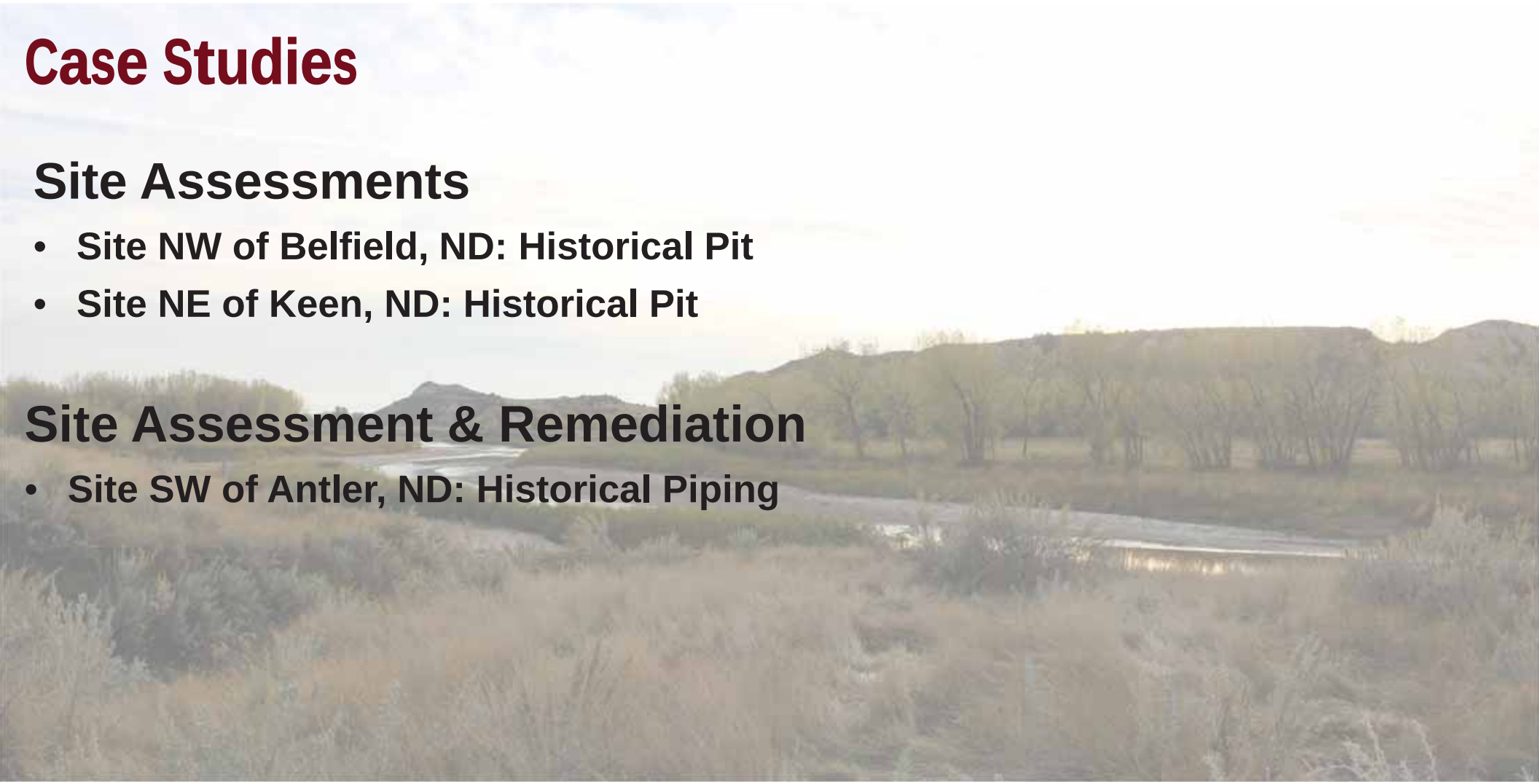
Case Studies



Site Assessments

- Site NW of Belfield, ND: Historical Pit
- Site NE of Keen, ND: Historical Pit

Site Assessment & Remediation

- Site SW of Antler, ND: Historical Piping

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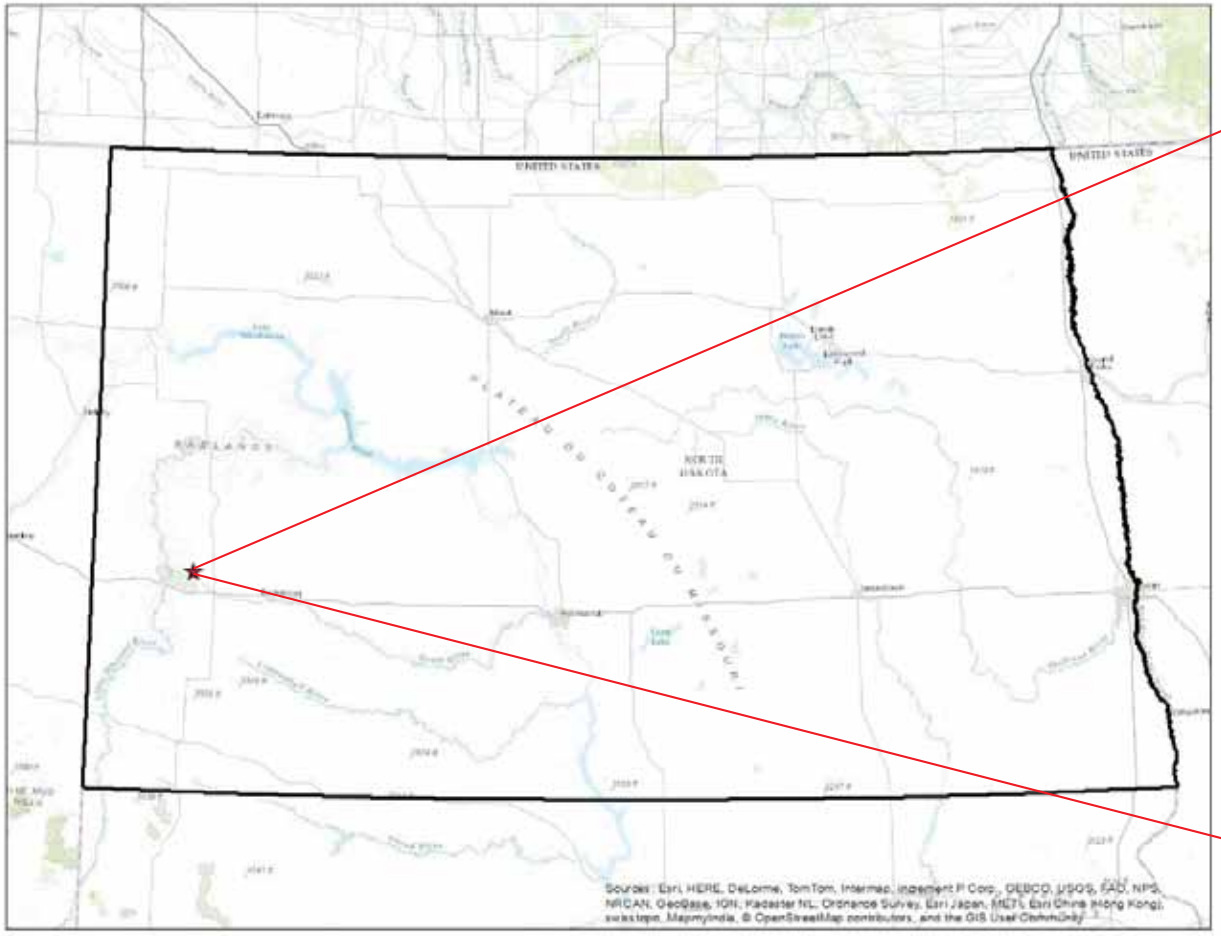
Site NW of Belfield, ND



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Site NW of Belfield, ND – Site Assessment

NW corner of site (secondary washout area).

Main washout area.

Exposed debris and oily residue in pit area.

Oily core sample.

Coal seam (NE corner of site).

Chloride test from samples collected.

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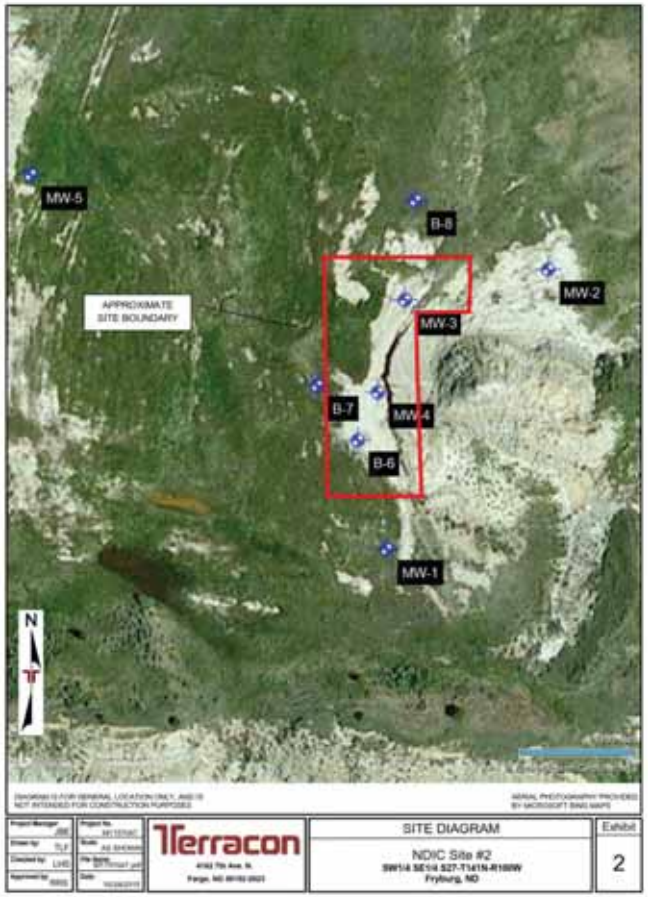
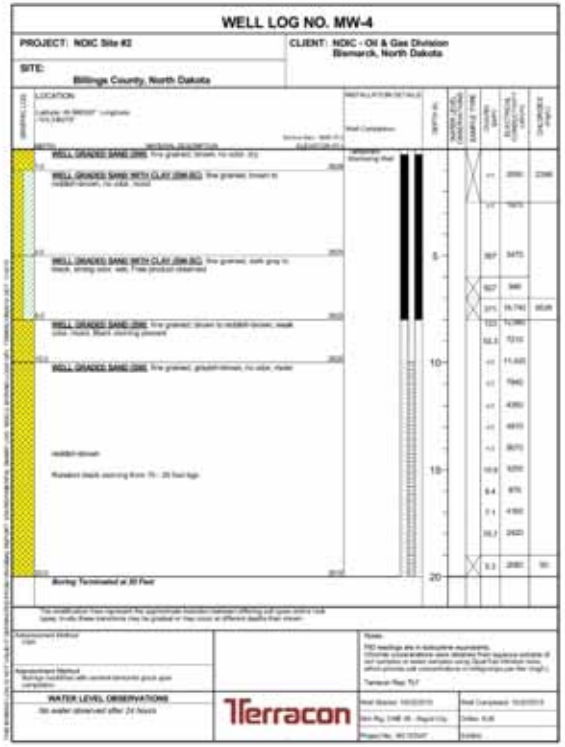
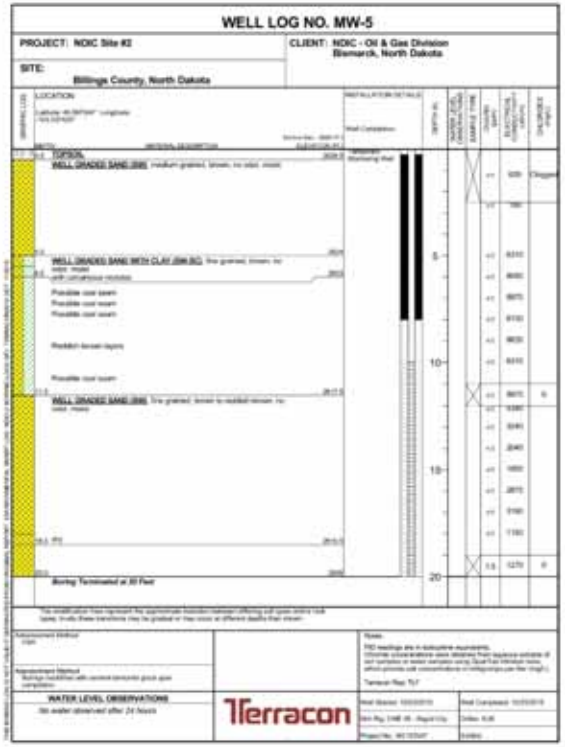
Site NW of Belfield, ND – Site Assessment



Site map and boring locations.





Boring logs with field screening results. Boring MW-5 was completed for background results and MW-4 was within the historical pit.

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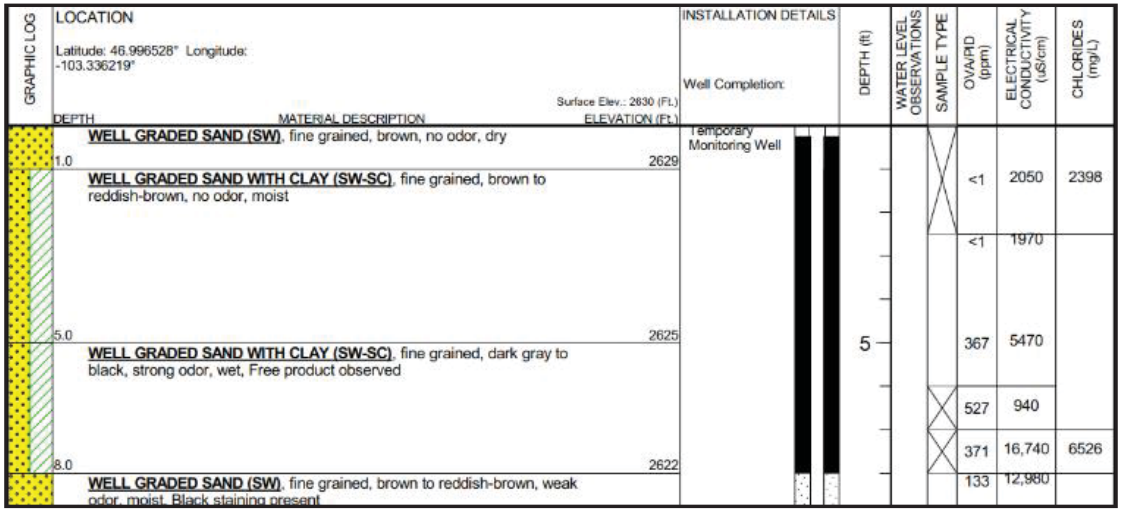
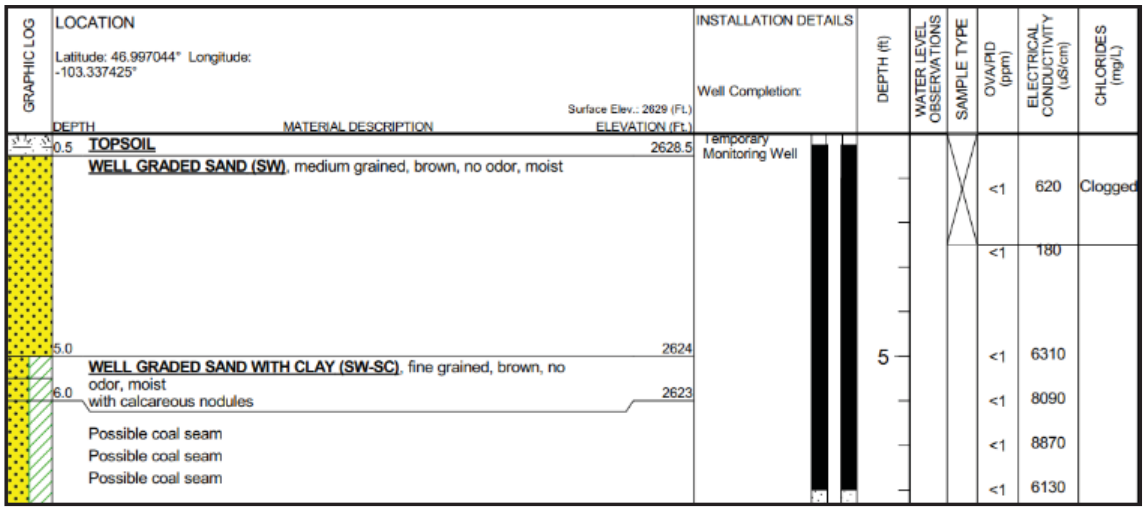
Site NW of Belfield, ND – Site Assessment



Soil boring MW-4 (within historical pit).

Soil boring MW-5 (background).



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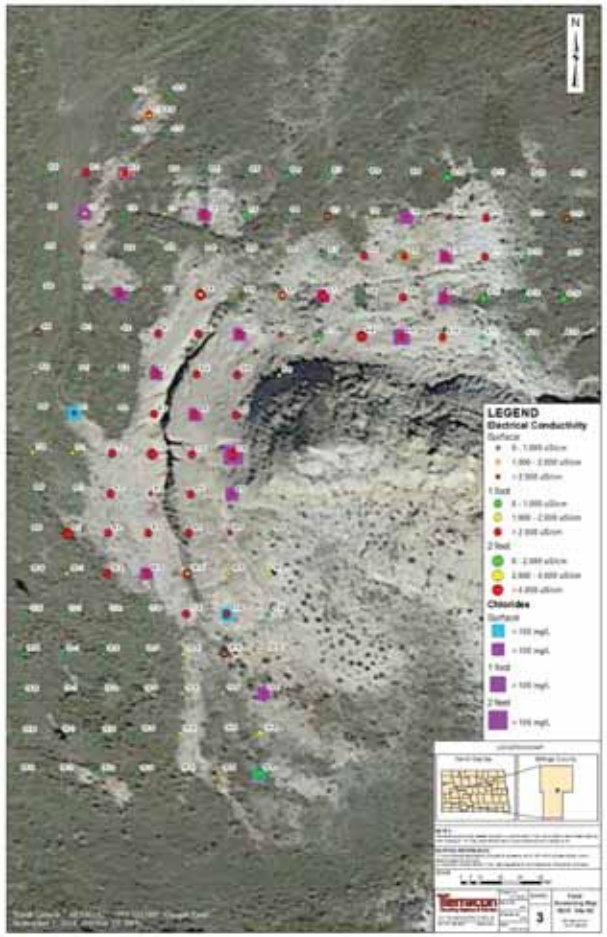
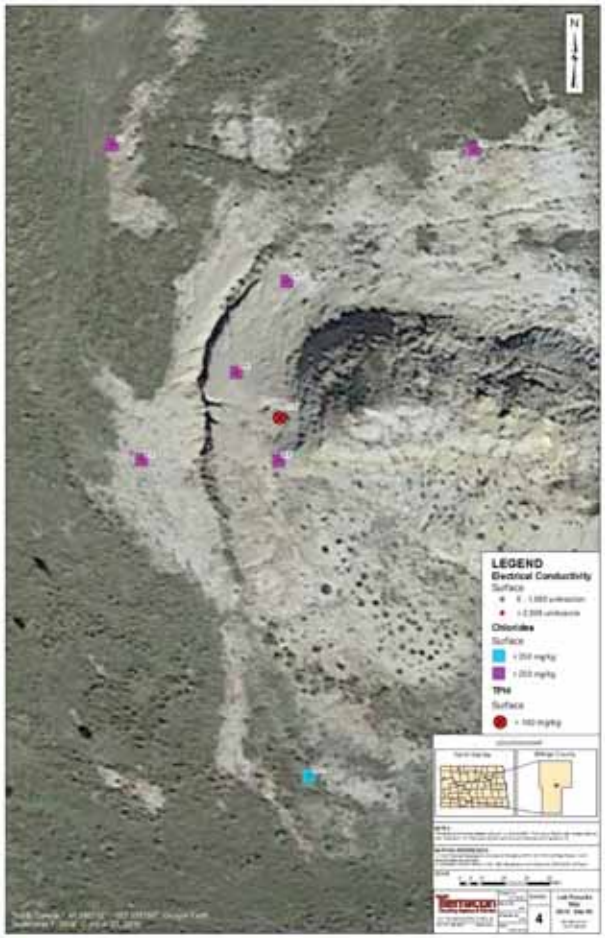
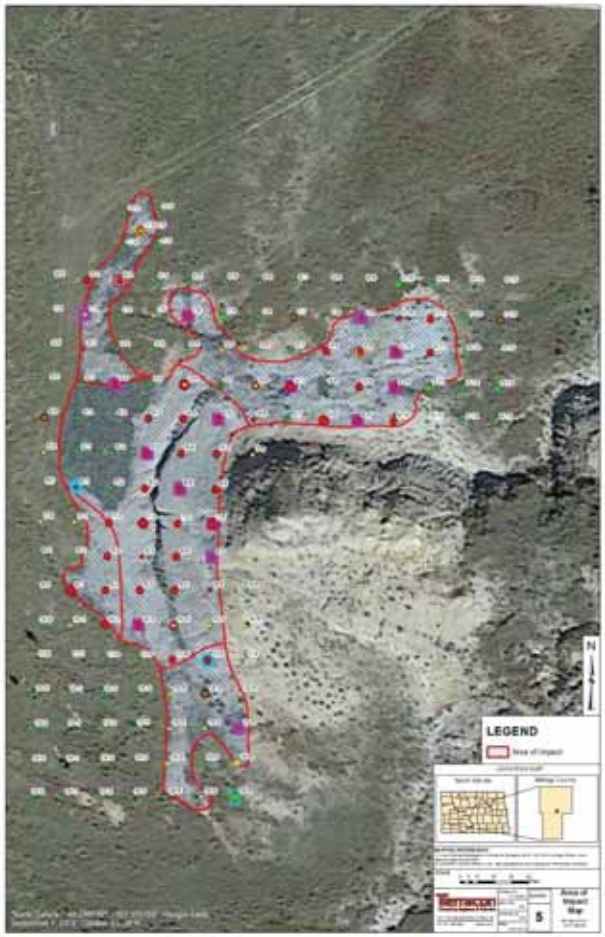
Site NW of Belfield, ND - CAP



Field screening results up to 2 feet bgs.



Laboratory results at the surface.



Approximate area of impact anticipated from field and lab results.

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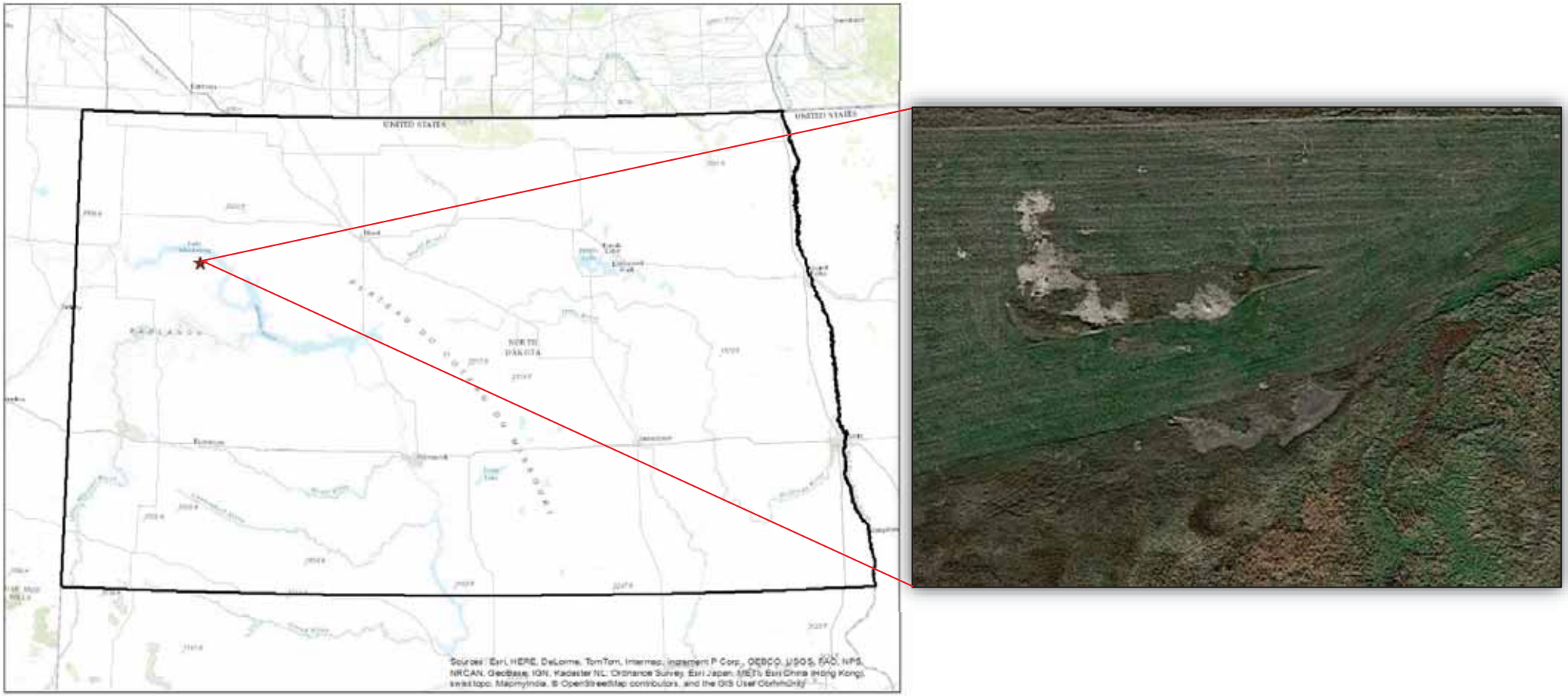
Site NE of Keen, ND



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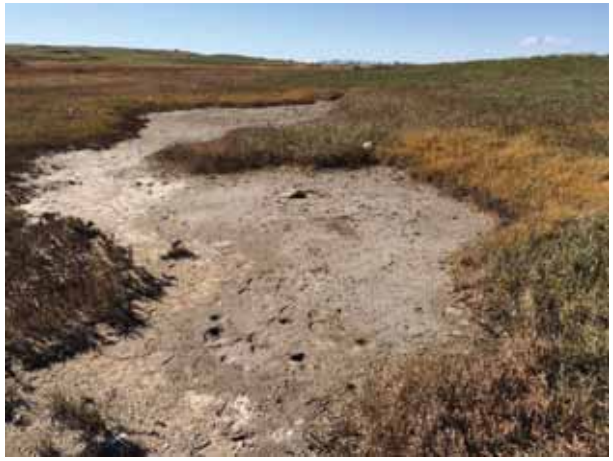
Site NE of Keen, ND – Site Assessment

View south at the historical brine pit.

View south at grid pattern.

Chloride testing in the field.

Soil staining from boring 4.



View at stressed vegetation SE of the historical brine pit.

Field screening soil with EC meter.

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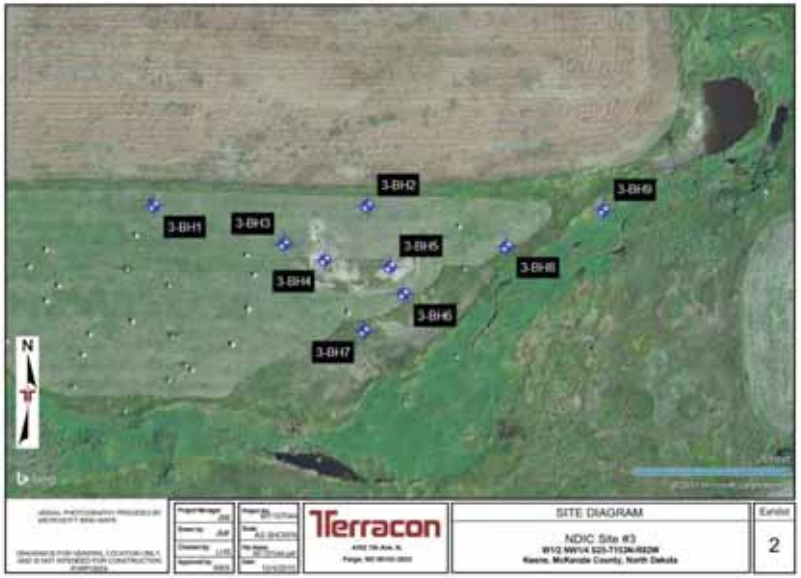
Site NE of Keen, ND – Site Assessment



Site map and boring locations.

Boring logs with field screening results. Boring 3-BH1 was completed for background results and 3-BH5 was within the historical pit.

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Site NE of Keen, ND – Site Assessment

GRAPHIC LOG	LOCATION: Latitude: 48.04893° Longitude: -102.84818° DEPTH	INSTALLATION DETAILS	DEPTH (FL)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	EC (µS/cm)	Chlorides (mg/L)	PID (ppm)
	1.0 **TOPSOIL**, brown, with some organics					370		<1
	2.0 **LEAN CLAY (CL)**, brown, medium stiff					940		<1
	3.0 **SILT (ML)**, light brown, medium dense					660		<1
	5.0 **SANDY SILT (ML)**, light brown, medium dense, with thin lenses of sand					1,110		<1
						1,750		1.1
	6.0 **LEAN CLAY (CL)**, light brown, medium stiff, with lenses and laminations of silt, moist		5			2,460		<1
	SILT (ML), brown, medium dense, with lenses and layers of clay, moist					1,930		<1

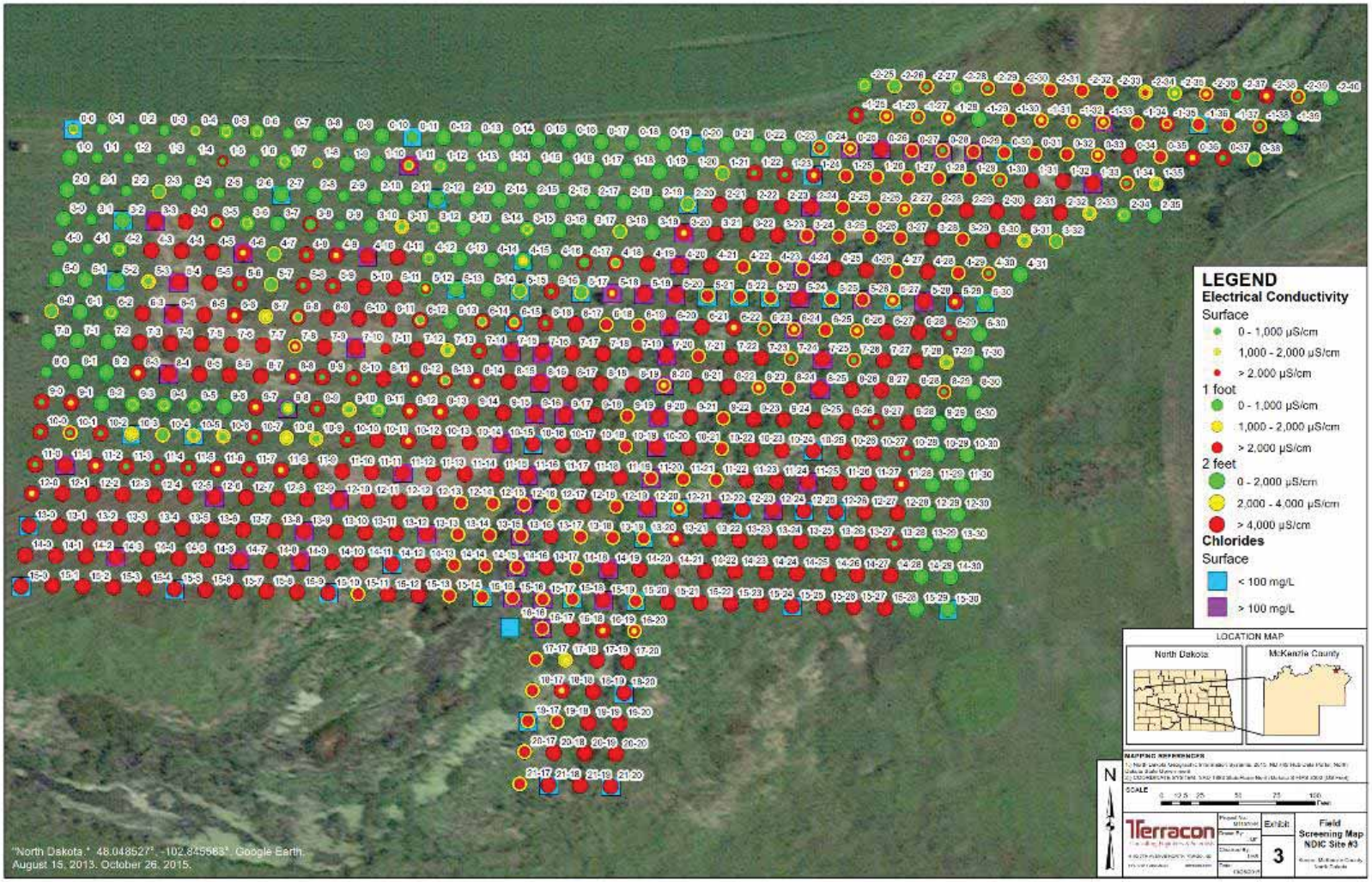
Soil boring 3-BH1 (background).

Soil boring 3-BH5 (within the historical pit).

GRAPHIC LOG	LOCATION: Latitude: 48.04866° Longitude: -102.84662° DEPTH	INSTALLATION DETAILS	DEPTH (FL)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	EC (µS/cm)	Chlorides (mg/L)	PID (ppm)
	1.0 **TOPSOIL**, trace gravel, brown, with staining					5,780		3.9
	SILT (ML), trace gravel, brown, medium dense, with lenses and layers of clay and trace organics					13,690	3,777	5.6
	thin layer of scoria at 2'					11,400		2.6
						14,730		3.2
						15,060		2.5
	salt precipitates at 5'		5			12,140		1.2
						11,220		2.2
	8.0					14,590		2.6

Terracon

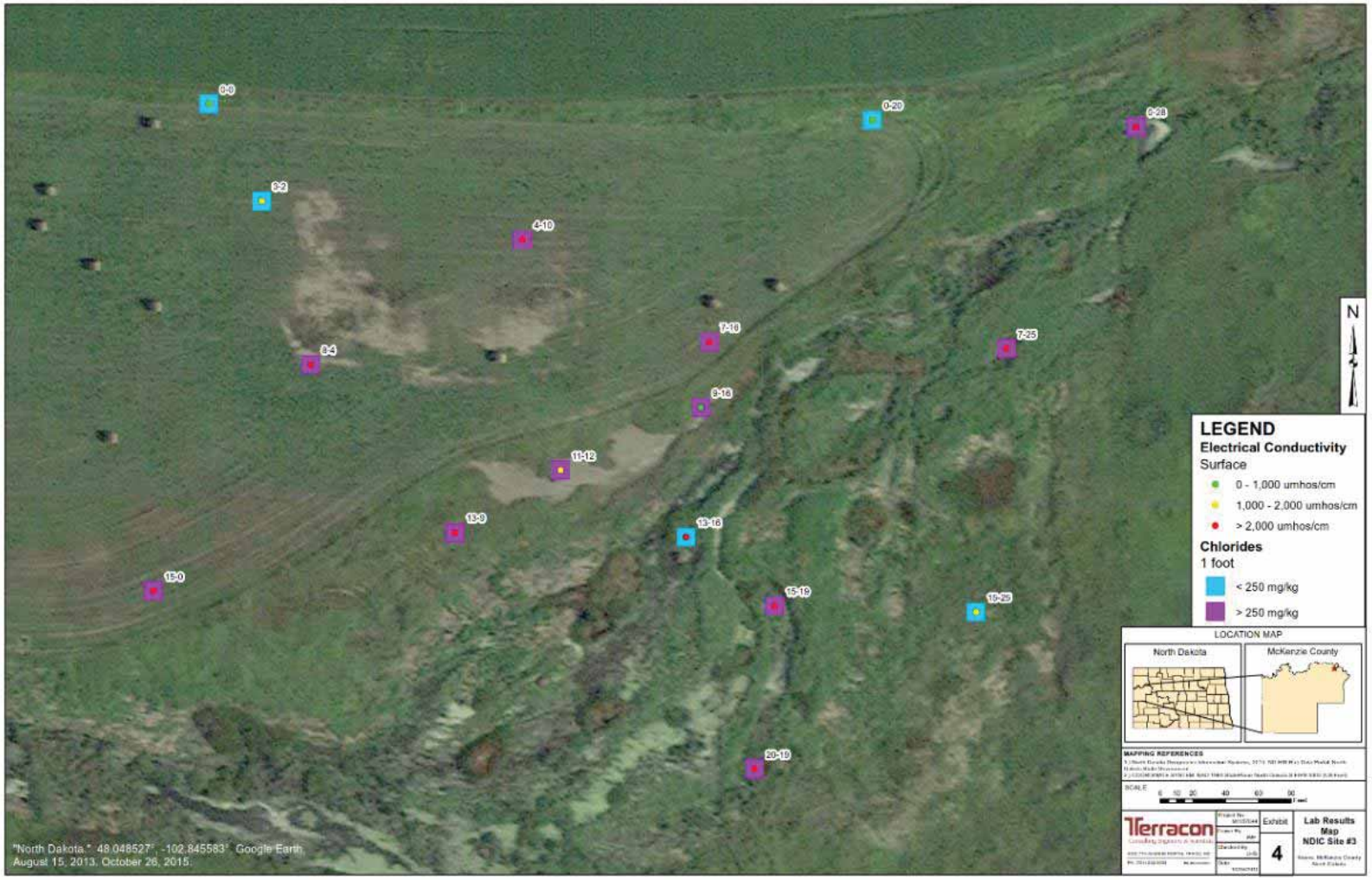
Site NE of Keen, ND - CAP



Terracon

Field screening results up to 2 feet bgs.

Site NE of Keen, ND - CAP



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Laboratory results at the surface and 1 foot bgs.

Site NE of Keen, ND - CAP

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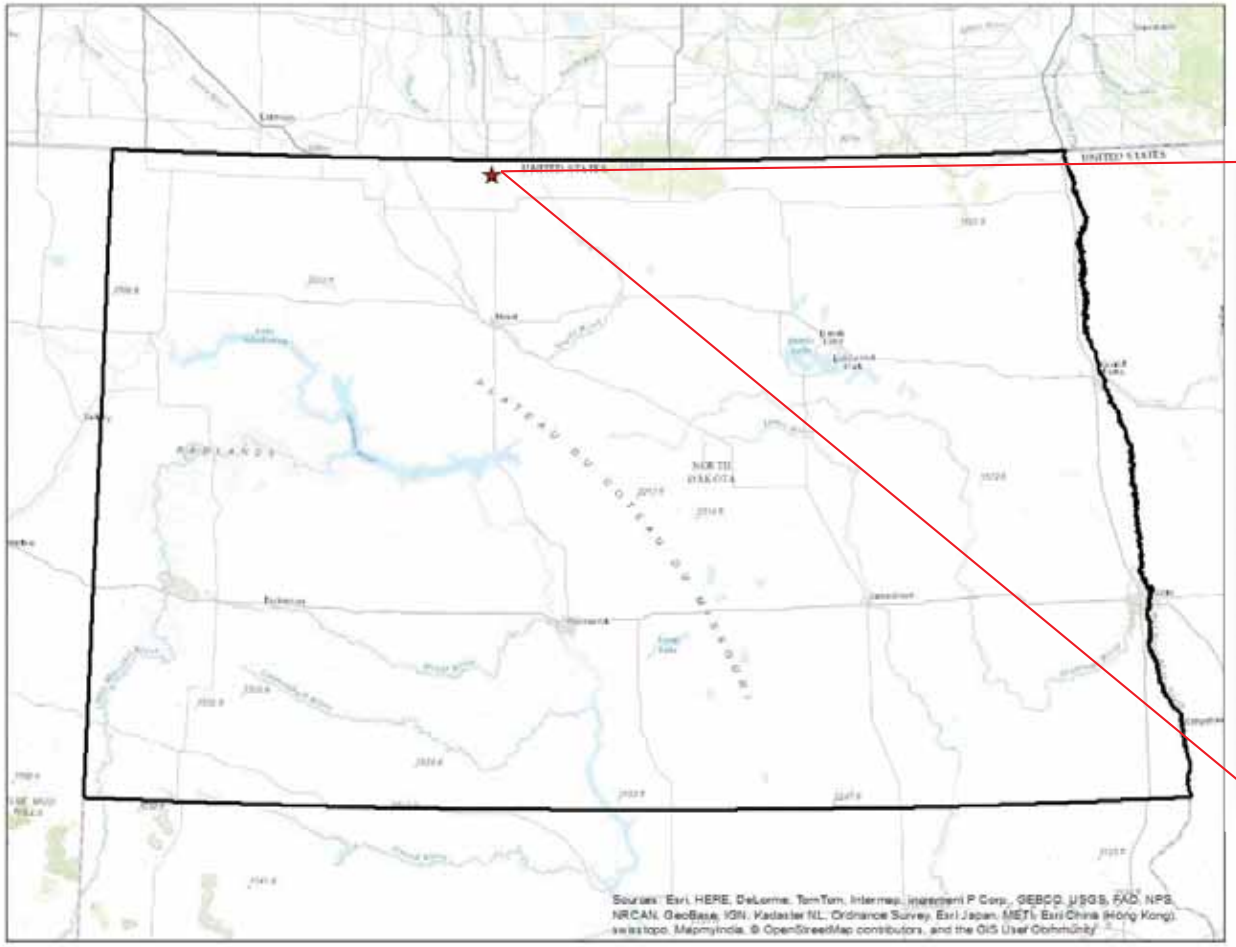
Approximate area of impact anticipated from field and lab results.

Site SW of Antler, ND



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Site SW of Antler, ND – Site Assessment

Petroleum hydrocarbons at surface from historical piping that leaked.

Petroleum hydrocarbon stained soil.

Approximate area of impact marked by flags.

Approximate area of impact from site assessment (visual).

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Site SW of Antler, ND – Site Assessment

View NW at the excavation area.

Layer of impacted soil near surface.

Petroleum hydrocarbon layer.

Locating extent of two-inch piping using electrical current.

Exposed two-inch piping.

Loose material removed during excavation.

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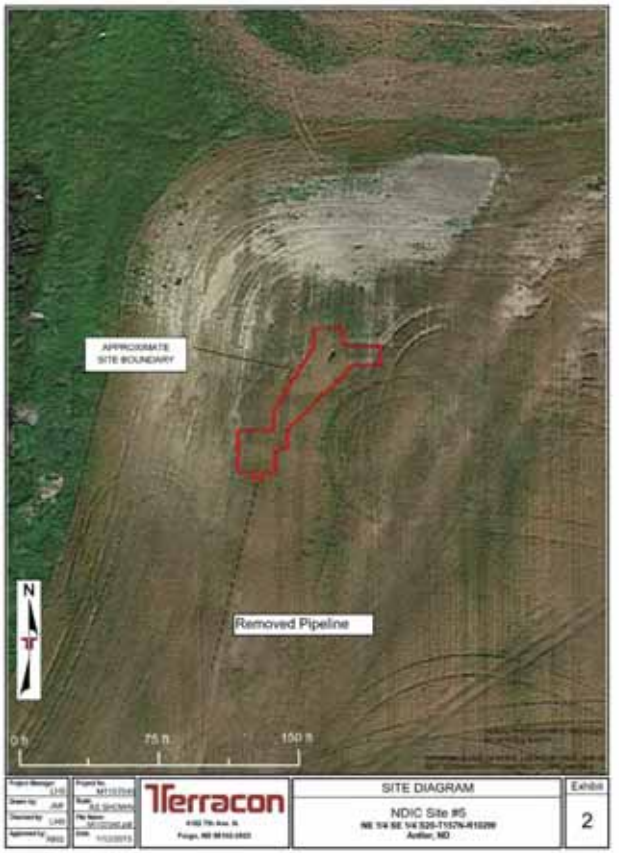
Site SW of Antler, ND

View NW at the excavation area.

Impacted material being removed and loaded on side-dump for disposal.

Soil excavation and backfilling.

Completion of backfill and topsoil placed within the excavated area.



Site Diagram showing excavated area and the piping that was removed.

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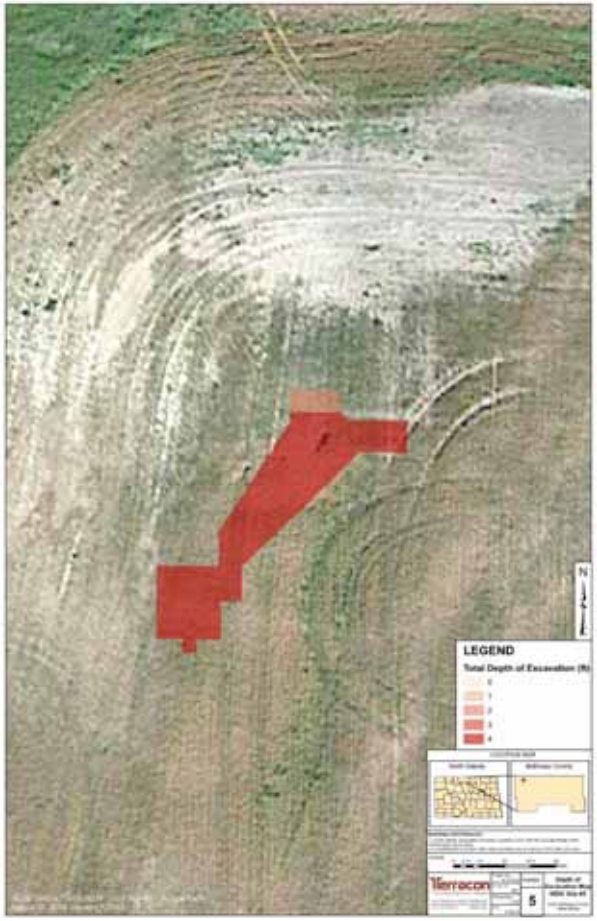
Site SW of Antler, ND - CAP

Field screening map.

Lab results map.



Area and total depth of excavation.

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