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SPILLS CLEANUP PRIMER

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This primer is intended to provide the reader with a fundamental understanding of hydrocarbon and brine spills from oil and gas production and the related remediation and reclamation of these spills.

As oil and gas production in the Williston Basin has increased, the number and volume of spills have also increased. Although this simple statement is accurate, it only provides a partial representation of the issue. Read on to learn more about spills, how spills are regulated, measures taken to minimize their impacts, and how spills are cleaned up.

Material presented in this document regarding techniques, processes, and technologies to address spills is intended to be informational; actual performance of spill-related activities will vary.

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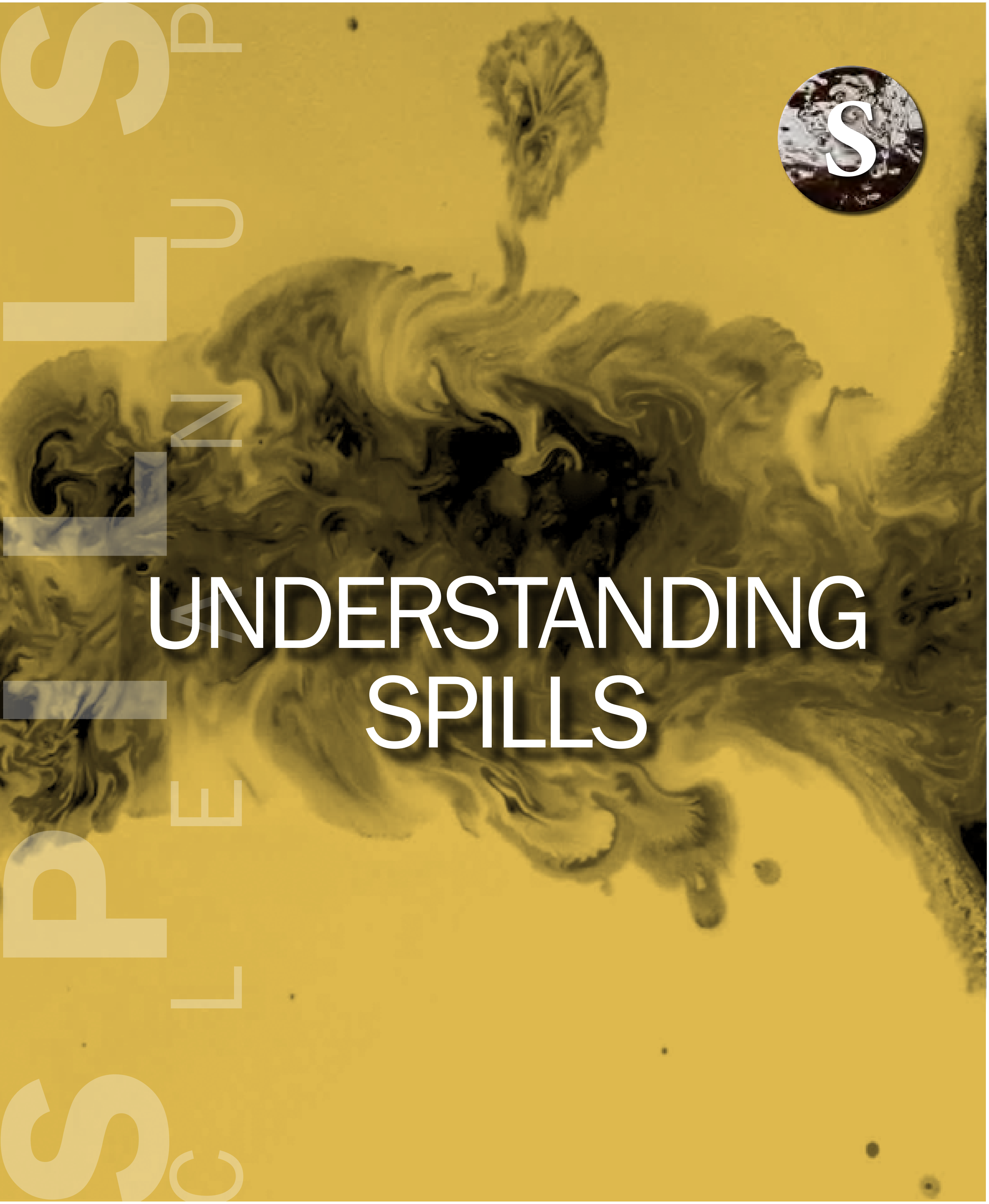
Notice

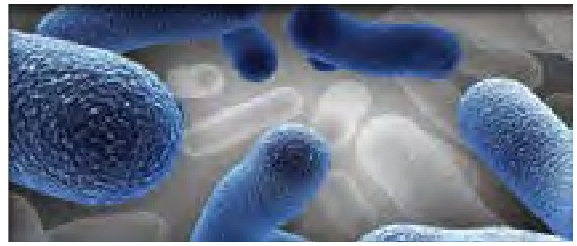
Table of Contents



UNDERSTANDING SPILLS

Definition of Terms

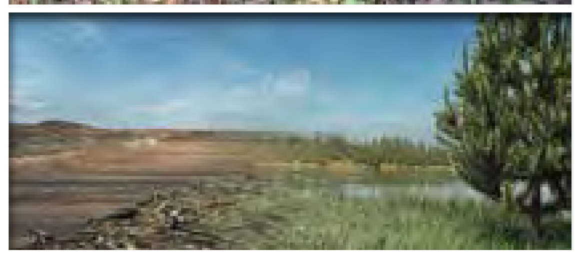
Bioremediation – a process by which organisms in the soil break down soil contaminants.



Brine – water produced with oil and gas that is typically high in sodium chloride.

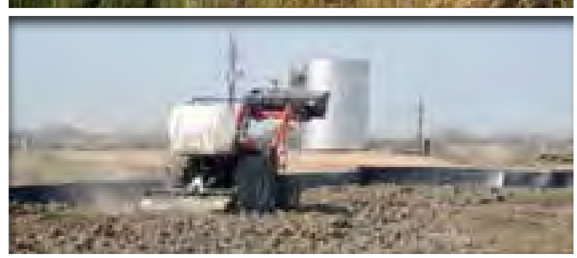
EC – electrical conductivity, a measure of how well soil conducts electrical current. Soil salinity is measured indirectly using EC.

End points – quantifiable thresholds that determine when a site has been completely remediated and/or reclaimed.

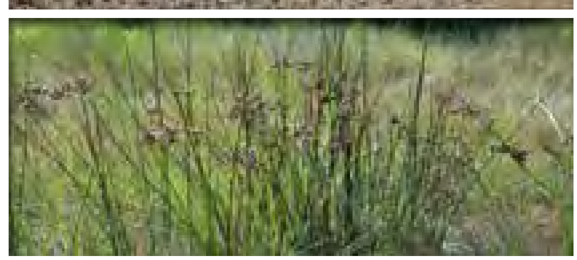


Halophytes – plants that are more tolerant of saline conditions.

Landfarming – a bioremediation process where an environment is created to allow naturally occurring organisms in the soil to break down hydrocarbons (primarily in an aerobic environment). This is accomplished by incorporating nutrients, amendments, and oxygen into the soil with tillage while maintaining adequate moisture.



Phytoremediation – the direct use of green plants and their associated microorganisms to stabilize or reduce contamination in soils, surface water, or groundwater.

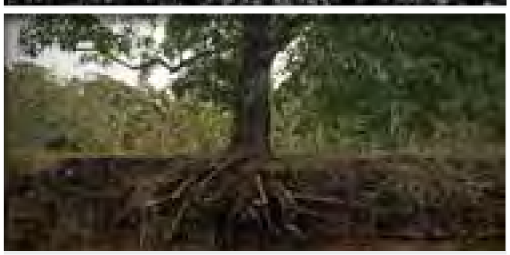


Reclamation – the act of returning land to its natural or productive state.

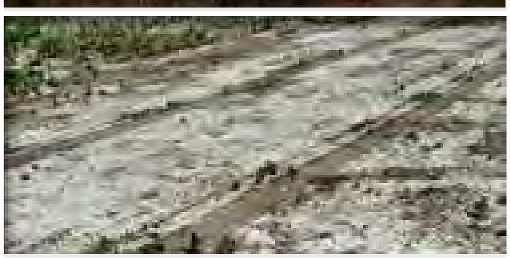
Remediation – the act of correcting an environmental disturbance, typically a produced fluid impact (i.e., oil and brine).

Saline – a description of soluble salts in water and soil (i.e., Ca, Mg, Na, K, Cl, NO_3, and SO_4).

Salt – pertains to sodium chloride in produced water/brine.



SAR – sodium adsorption ratio, a measure of the sodic content of soil, or the ratio of sodium to calcium and magnesium.



Sodic soil – soil that contains sufficient sodium to interfere with the growth of most crop plants.

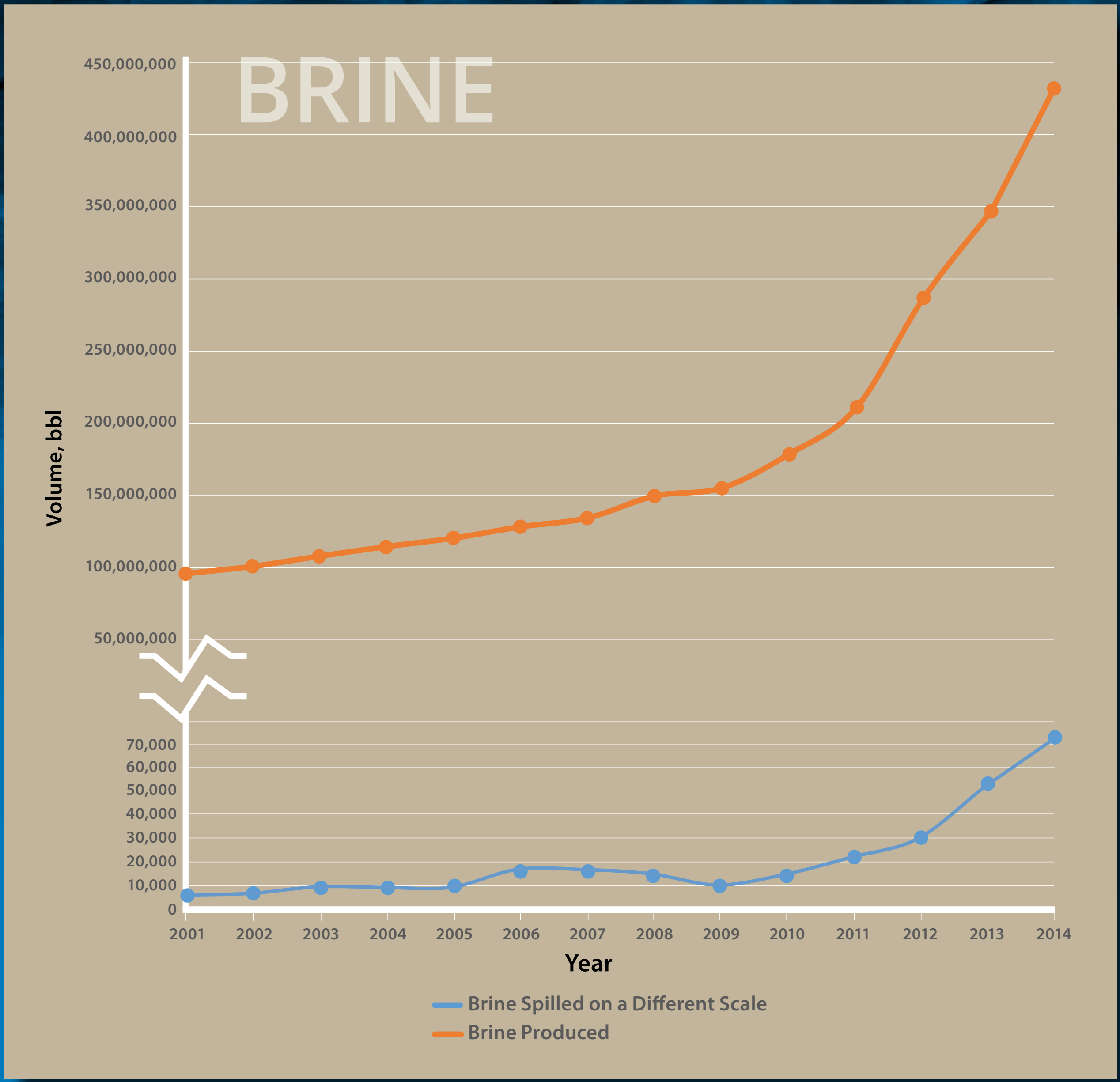
TPH – total petroleum hydrocarbons, a measure of the quantity of oil-related compounds in a given quantity of soil.

Spill Statistics

Data presented were obtained from the North Dakota Department of Health (NDDH) Oilfield Environmental Incidents database. Analysis was performed on spill data from 2001 through 2014, representing approximately 7 years prior to development of the Bakken Formation and 7 years after Bakken development.

Oil and saltwater spills represent only 0.01% of their respective volumes extracted, which means the industry safely produces and transports over 99.99% of the volume it handles.

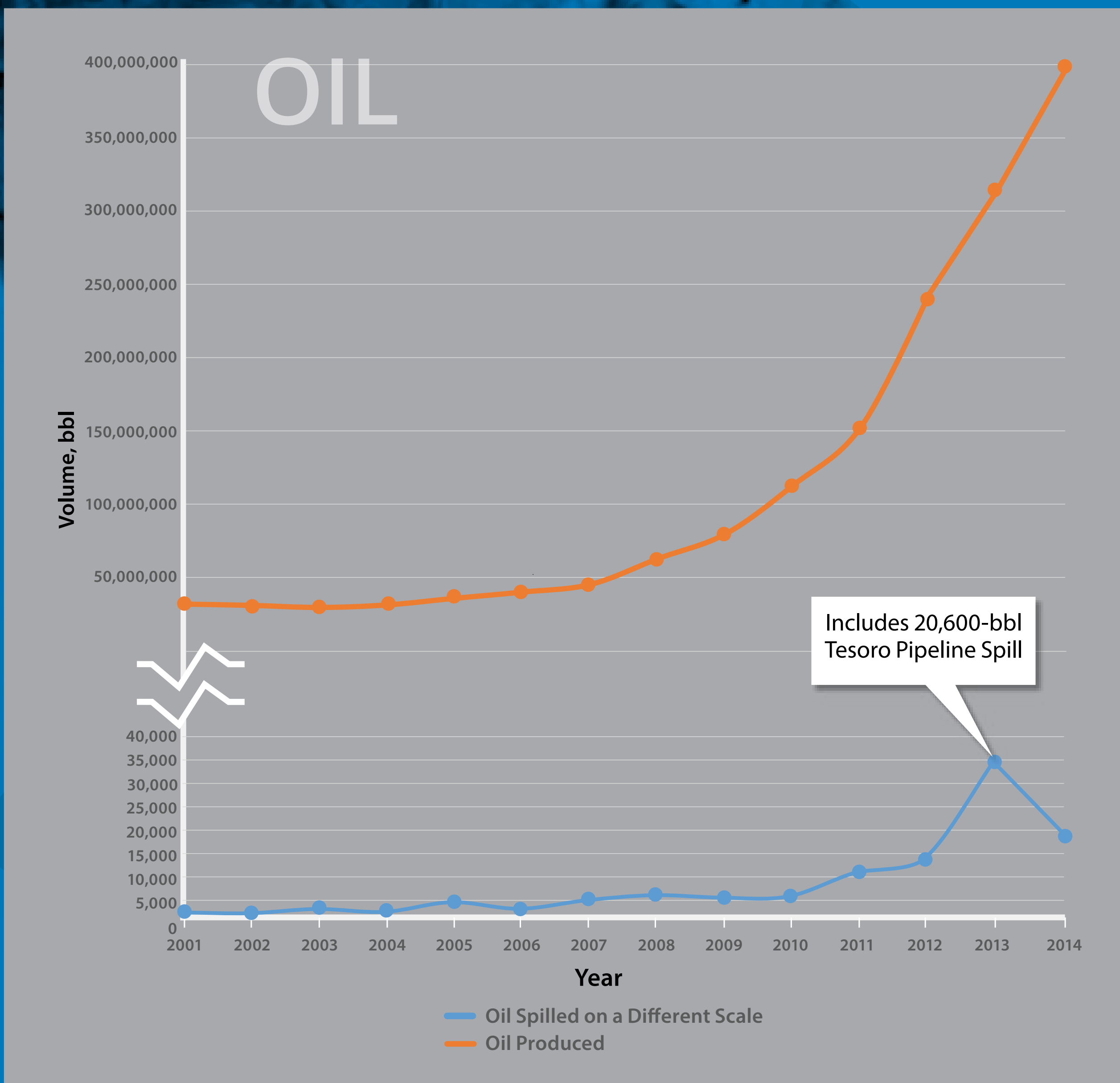
75%–80% of all spills are contained (meaning the spill does not leave the bermed production location).



From 2001 through 2014, greater than 91% of the spills were less than 100 barrels in size and represent approximately 20% of the spilled volume. Conversely, 9% of the spills were greater than 100 barrels in size and represent 80% of the spilled volume.

Annual brine spill volumes have been typically 2–3 times more than the annual volume of oil spills.

Beginning in 2011, freshwater spills have become a significant portion of the "other" category of spills as well as the total spill volume. From 2011 to 2014, freshwater spills represented 24% to 90% of the "other" category of spills and between 4% and 43% of the total annual spill volume (i.e., the 2013 freshwater spill volume was 69,644 barrels or 43% of total annual spill volume and more than either the oil or brine spill volume that year).

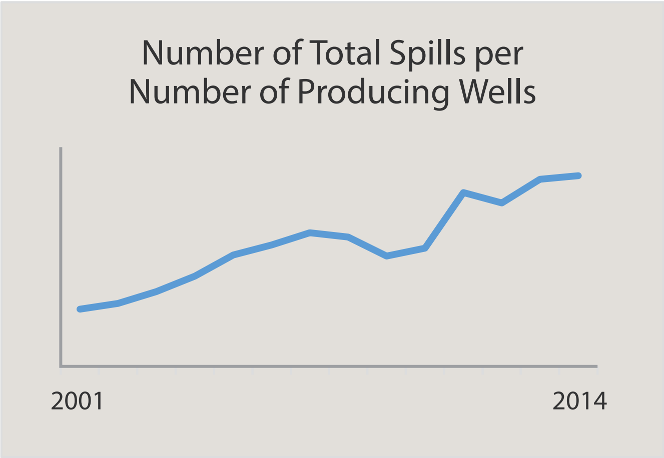


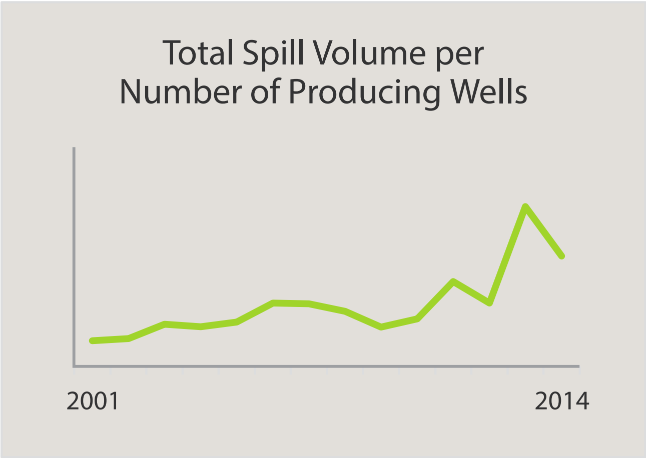
Spill Statistics (continued)

The total annual number and volume of spills have increased, although the number of spills and annual spill volumes as a function of oil extracted are essentially unchanged from the year 2001 and have decreased since peaking in the years 2006 and 2007.

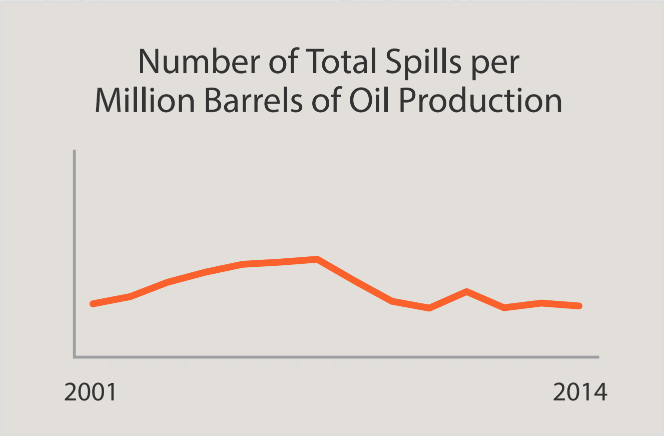
To this point, the annual spill data from 2001 through 2014 are presented two ways (note that the spike in spill volume in 2013 is largely due to the 20,600-barrel Tesoro pipeline release as well as nearly 70,000 barrels of freshwater spilled).

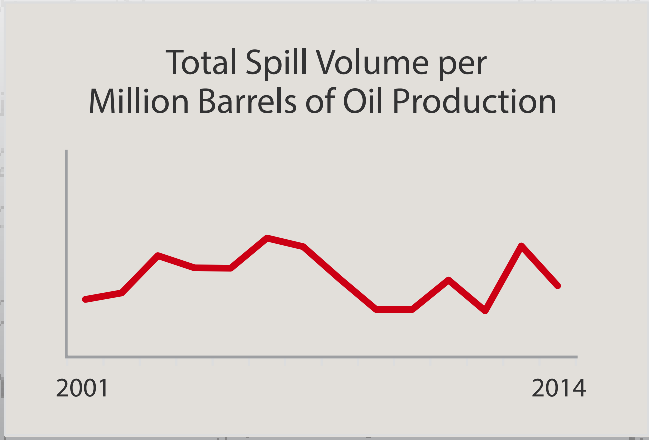
These two graphs are the annual number of spills and spill volumes as a function of the number of producing wells.





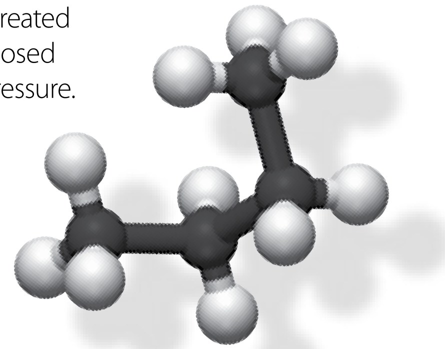
These two graphs are the annual number of spills and spill volume as a function of the annual oil production in million barrels.





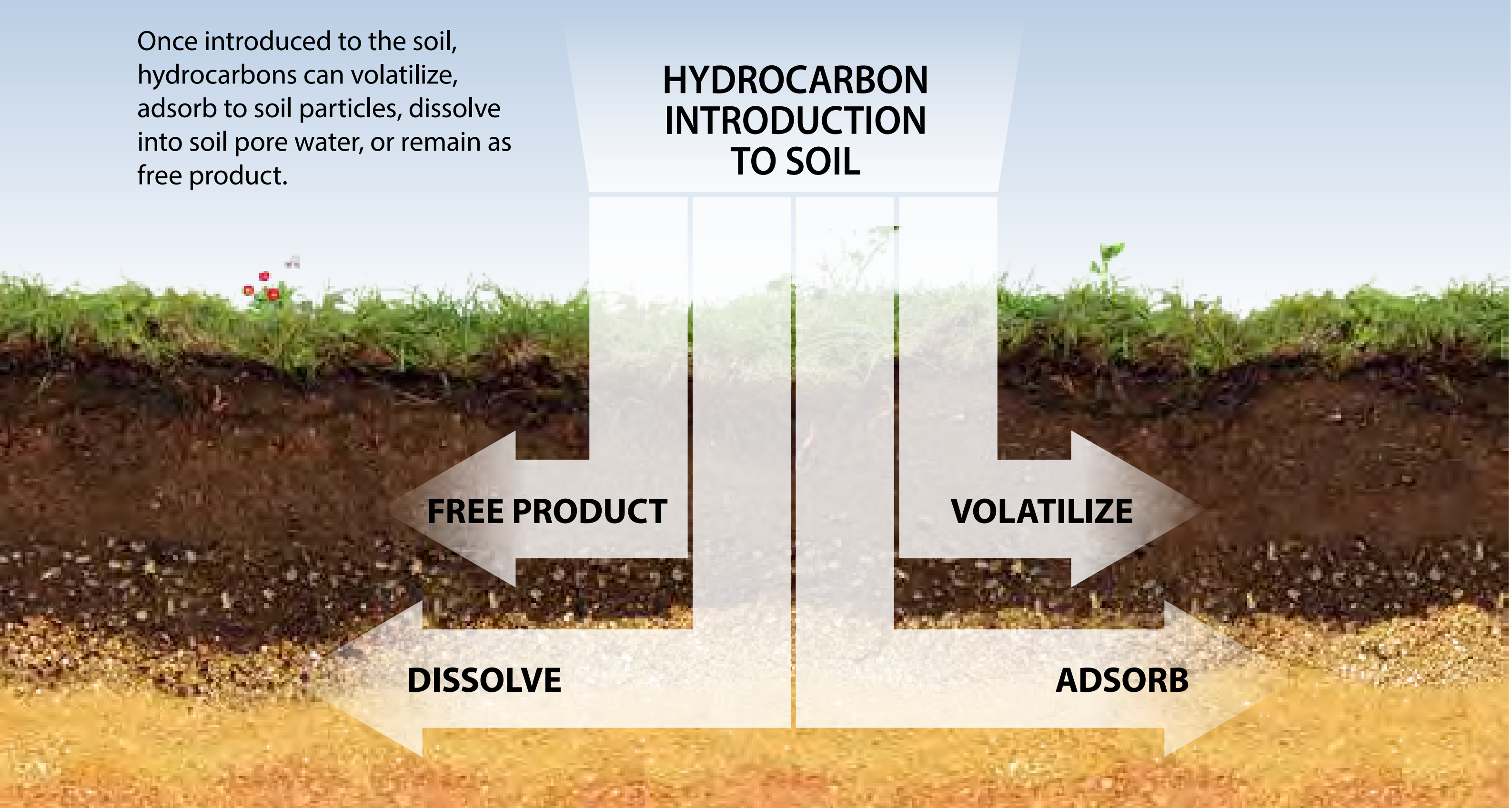
Hydrocarbon Interaction with Soil

Crude oil is a complex mixture of hydrocarbons created when dead organisms from the past are decomposed over long periods of time under high heat and pressure.



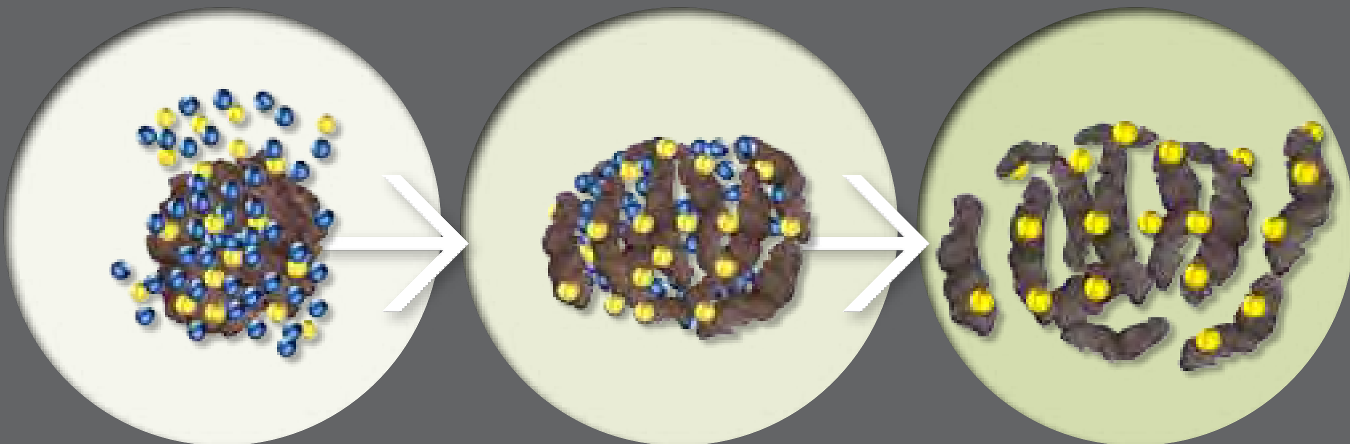
Bakken crude oil is much lighter than the “black gold” many people think of when they think of crude oil. Because of this, it is much more biodegradable.

Once introduced to the soil, hydrocarbons can volatilize, adsorb to soil particles, dissolve into soil pore water, or remain as free product.



Saltwater Interaction with Soil

Soil salinity is quantified by measuring the electrical conductivity (EC) of soluble salts in solution. Brines such as produced water from oil and gas production are saline and have high concentrations of sodium and chloride ions.



Salts can have a long-lasting effect on soils and vegetation. Salts impact soils by dissolving in the soil moisture and chemically interacting with clay in the soil matrix, swelling the clay particles and causing the clay particles to disperse. This results in soil that allows little water infiltration and is vulnerable to erosion. Salt-impacted soil has been successfully remediated employing various calcium-based soil amendments.

Salts affect vegetation by creating osmotic conditions that tend to pull water away from the plant roots and injure the plant. Salts also negatively impact soil microbe communities by lowering the osmotic potential of soil water and preventing cell growth.

HOW SPILLS ARE REGULATED

Summary of Spill and Reclamation Regulation

Any spill or other incident that could adversely affect human health or the environment must be immediately reported by the responsible party.

Observed spills and suspected leaks needing immediate attention may also be reported by the public.

Wastes listed below are RCRA (Resource Conservation and Recovery Act)-exempt wastes and are reported as oilfield-related incidences, examples; would include:

- Produced fluids such as crude oil, water, or oil–water emulsion before ownership transfer takes place (i.e., a release from the producer's lease, flow lines, or tank battery before being trucked off-site or going into crude transportation pipeline).
- Brine water from a commercial disposal facility.
- Condensate from gas lines or a gas plant before leaving the gas plant in the transportation pipeline.

All other releases should be reported to NDDH and are categorized as general environmental incidences.

The following site-specific characteristics play an important role in determining the remediation and reclamation plan as well as the ultimate cleanup goals:

- Quantity and type of product released
- Surficial geology
- Potential environmental and public health impacts
- Proximity to surface water and groundwater
- Site use and accessibility

Reporting Spills

North Dakota Department of Emergency Services: 24-hour hotline, (800) 472-2121

North Dakota Department of Health: (701) 328-5210 or (701) 328-5166

North Dakota Industrial Commission Department of Mineral Resource Oil and Gas Division: (701) 328-8020, www.dmr.nd.gov/oilgas/mvc/wincident/

Regulatory Jurisdiction

NDDH: spills and releases outside of the bermed oil and gas production pad. Oil and Gas: spills and releases on the bermed oil and gas production pad and, in some cases, gathering pipeline networks.

Public Access to Spill Information

Public access to reported spills is provided by NDDH at **www.ndhealth.gov/EHS/Spills/.**

NORTH DAKOTA DEPARTMENT *of* HEALTH

SPILLS

CLEANUP

HOW INFRASTRUCTURE IS BUILT

Construction Methods
Designed to Minimize Spill Impact

TOPSOIL – Topsoil is removed from construction areas and is preserved in a stockpile to be replaced at the time of reclamation. When topsoil is stockpiled, it is typically reseeded to stabilize the pile from erosion and prevent weeds from growing. Other erosion controls may also be employed.

TANK BATTERY – Oil and gas production sites typically include several tanks used to temporarily store oil and produced water (brine) until they can be hauled away by trucks for either sale or disposal.

TANK BATTERY BERM – Tank batteries are constructed with several features to contain spills, including earthen or artificial berms, thick clay layers below the tank and, in some cases, liners under the tanks.

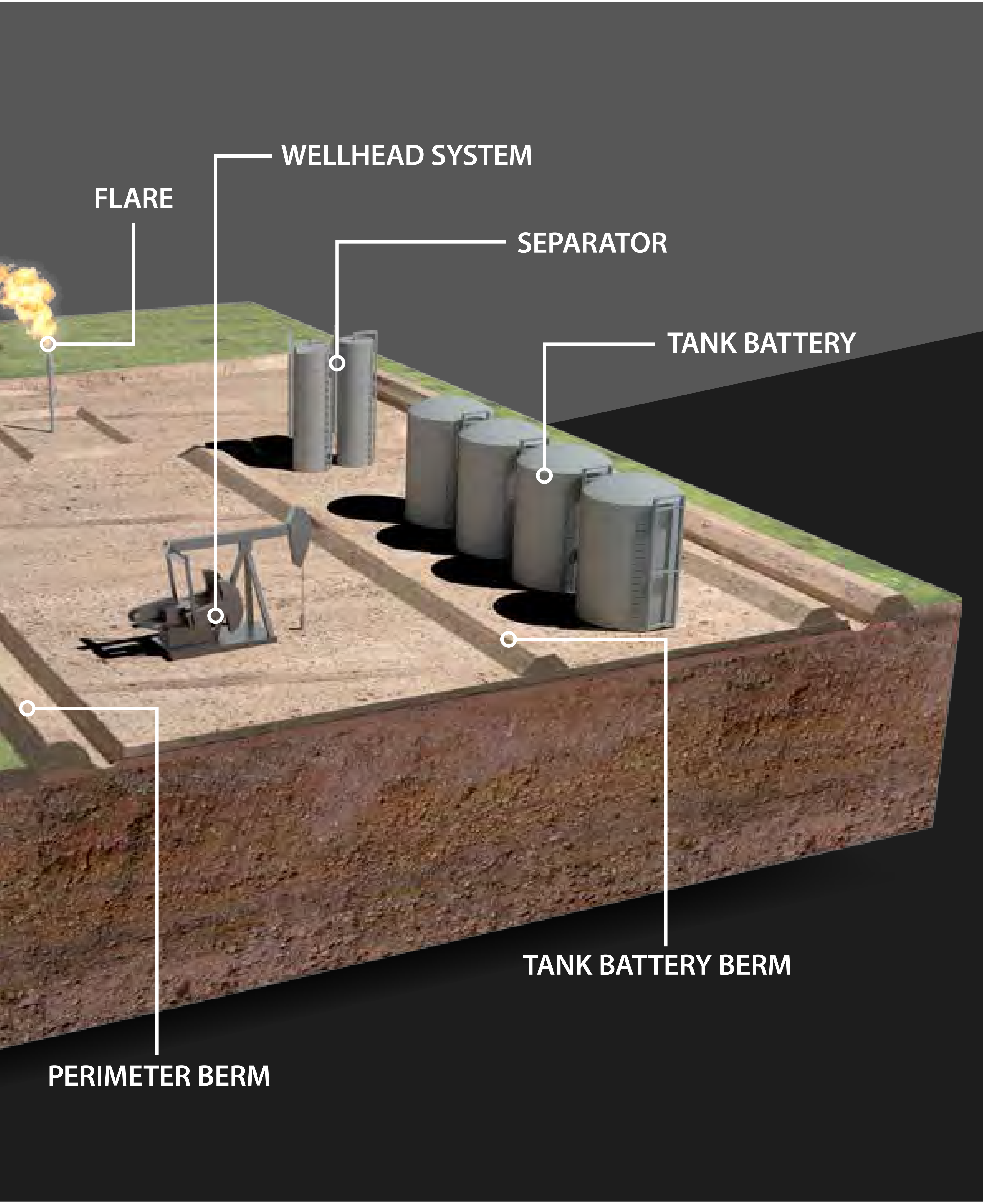
PERIMETER BERM – Construction of clay perimeter berms surrounding the entire location provides complete containment on-site.

WELLHEAD SYSTEM – An interface is installed between the individual casing strings and the blowout preventer (BOP) stack. This interface is required for four main reasons:

- To contain pressure through the interface with the BOP stack.
- To allow casing strings to be suspended so that no weight is transferred to the drilling rig.
- To allow seals to be made on the outside of each casing string to seal off the individual annulus.
- To provide annulus access to each intermediate casing string and the production casing string.

FLARE – Flares are a necessary component to allow gas to be diverted during times of excess gas production or system upset. Flares are required even when the well is connected to a gas-gathering system.

SEPARATOR – The separator is a device that processes the initial production and separates the oil, gas, water, and sediment. After the separator, the oil and water are piped to on-site tanks while the gas is conveyed into a gas-gathering network.


WELLHEAD SYSTEM
FLARE
SEPARATOR
TANK BATTERY
TANK BATTERY BERM
PERIMETER BERM

Wellsite Construction Phases

Initial Pad Construction – Drilling Phase

Individual site evaluation (proximity to water bodies, drainages, wetlands) is conducted, and construction plans are adjusted to provide appropriate countermeasures (additional berms, ditch blocks, etc.) to protect those areas.

Preconstruction test holes provide information related to soil types and depth to groundwater. Construction practices are adjusted to meet the conditions present on location.

Compaction of the pad surface at time of initial construction reduces the chance of contaminant infiltration into the subsurface.

Construction of clay perimeter berms surrounding the entire location provides complete containment on-site.

Pads are constructed to promote drainage to the outer edges of the location, where they collect in ditches at the toe of the berms and are graded to flow to the containment areas.

Addition of clay-lined containment areas allows for more efficient recovery of fluids from a central location in the event of a spill.

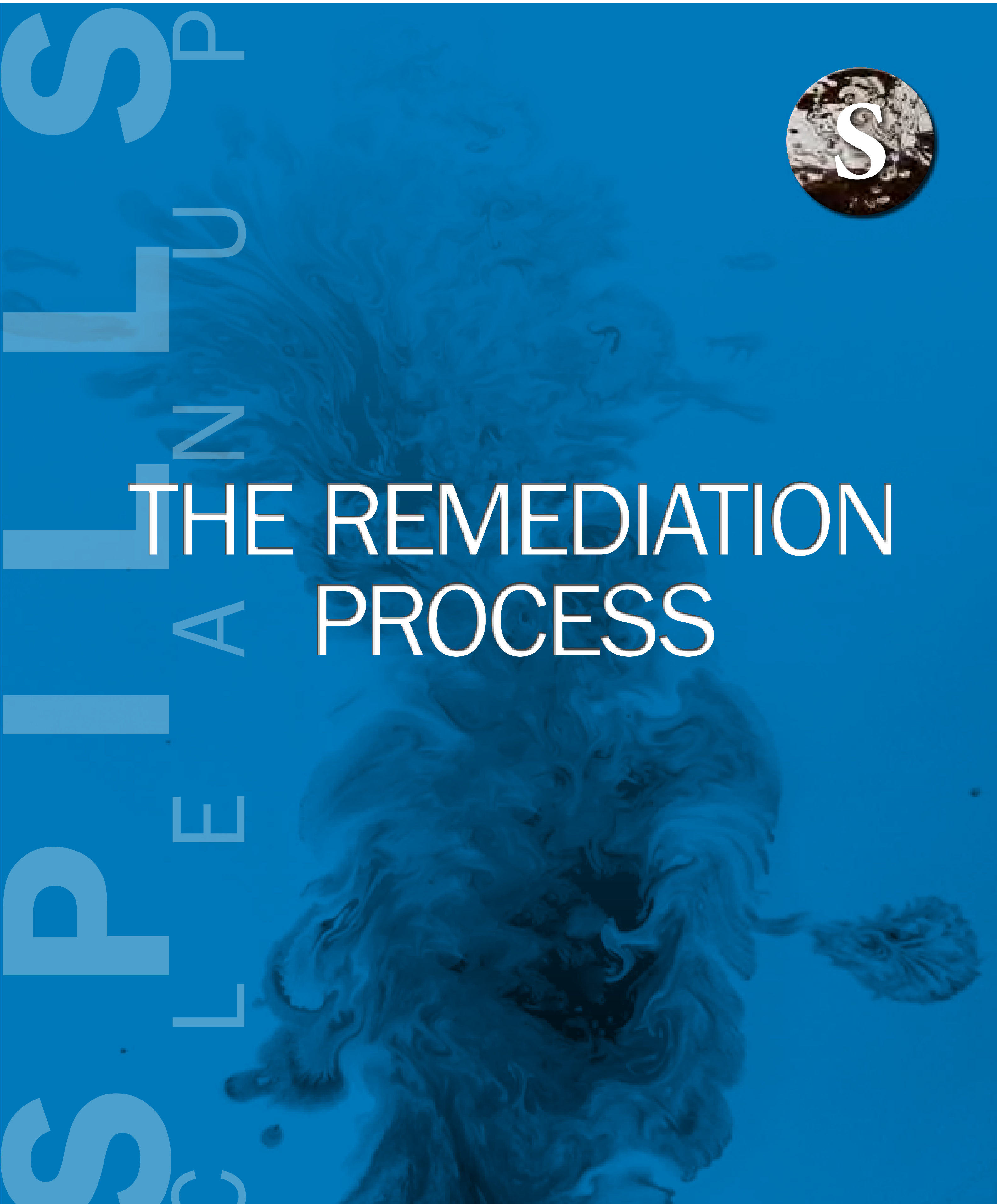
Interim Reclamation – Production Phase

Site-specific review of production layout and development of a reclamation-grading plan facilitate movement of fluids away from areas of heavy traffic.

Regrading and compaction of the pad surface (in accordance with plan) more efficiently move fluids to containment areas.

Redesign and construction of berms, ditches, and containment areas meet the needs of the reclaimed location.

Regrading and topsoiling of cut/fill areas assist in establishment of vegetation and provide stable cover to the exterior of berms, aiding in berm erosion prevention.



THE REMEDIATION PROCESS

Remediation
Cleanup of Spills

	In Situ Remediation
Pros	• Less overall disturbance to the site. • Less truck traffic. • Preserves native topsoil and subsoil which maintains native soil structure and ecological function.
Cons	• Remediation and reclamation process can take years to complete. • Requires qualified personnel to visit site periodically to collect and interpret samples.

Hydrocarbon Remediation Process

	In Situ Remediation	Excavation
Goal	Create an environment for natural bacteria to thrive and consume hydrocarbons as a food source, thus cleaning up the spill site.	Remove source of contamination.
Keys to Success	• Good contact between bacteria and the hydrocarbons • Adequate nutrients • Adequate oxygen • Adequate moisture • Appropriate pH • Proper soil temperature	

Step 1	– Collect and dispose of free product and standing liquid (if present).
Step 2	– Collect background information.
Step 3	– Collect soil samples from spill area and control area.
Step 4	– Install erosion control measures (if needed).
Step 5	– Apply amendments, and till site.
Step 6	– Till site periodically (adding additional amendments as necessary).
Step 7	– Collect soil samples periodically to assess remediation success.
Step 8	– Once remediation is complete, submit notice of completion.

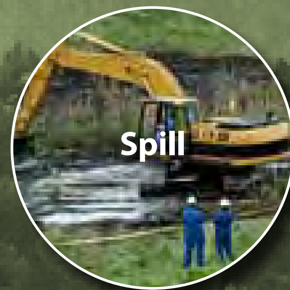
	Excavation
	• Contamination source is removed quickly.
	• Excavated subsoil and topsoil must be replaced with "harvested" soil from another site. • Cost to haul and dispose of hydrocarbon-impacted soil at a special waste landfill. • Potential long-term liability of impacted soil placed in a special waste landfill. • Added expense of replacing the removed soil with uncontaminated topsoil of similar textural class. • The potential introduction of weeds not previously observed at the site prior to the spill. • Creates an ecological island with distinctly different soil ecology and plant communities.

Brine Remediation Process

	In Situ Remediation	Excavation
Goal	Mobilize the salt ions (typically sodium and chloride) below the root zone where they can be recovered or where they will not impact sustained vegetative cover.	Remove source of contamination.
Keys to Success	• Sufficient application of calcium to replace sodium in the soil • Performance of remediation activities quickly after release	

Step 1	– Collect and dispose of liquid (if present).
Step 2	– Collect background information.
Step 3	– Collect soil samples from spill area and control area.
Step 4	– Install erosion control measures (if needed).
Step 5	– Apply amendments.
Step 6	– Collect soil samples periodically to assess remediation success.
Step 7	– Once remediation is complete, submit notice of completion.

SPILL REMEDIATION DECISION TREE



- Ensure safety of personnel and public.
- Isolate spill source.
- Gather spill information.
- Notify regulatory agency(ies).
- Collect liquid (if present).

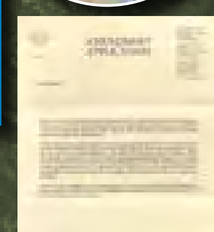
- Perform site investigation to delineate impacts and identify receptors.
- Develop remediation plan with input from regulatory agency and landowner.

Excavation

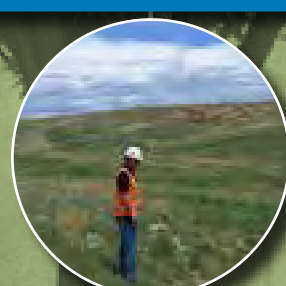
- Excavate impacted soil.
- Dispose of soil in approved landfill.
- Replace with appropriate fill.

Remediation

- Perform remediation.
- Monitor.

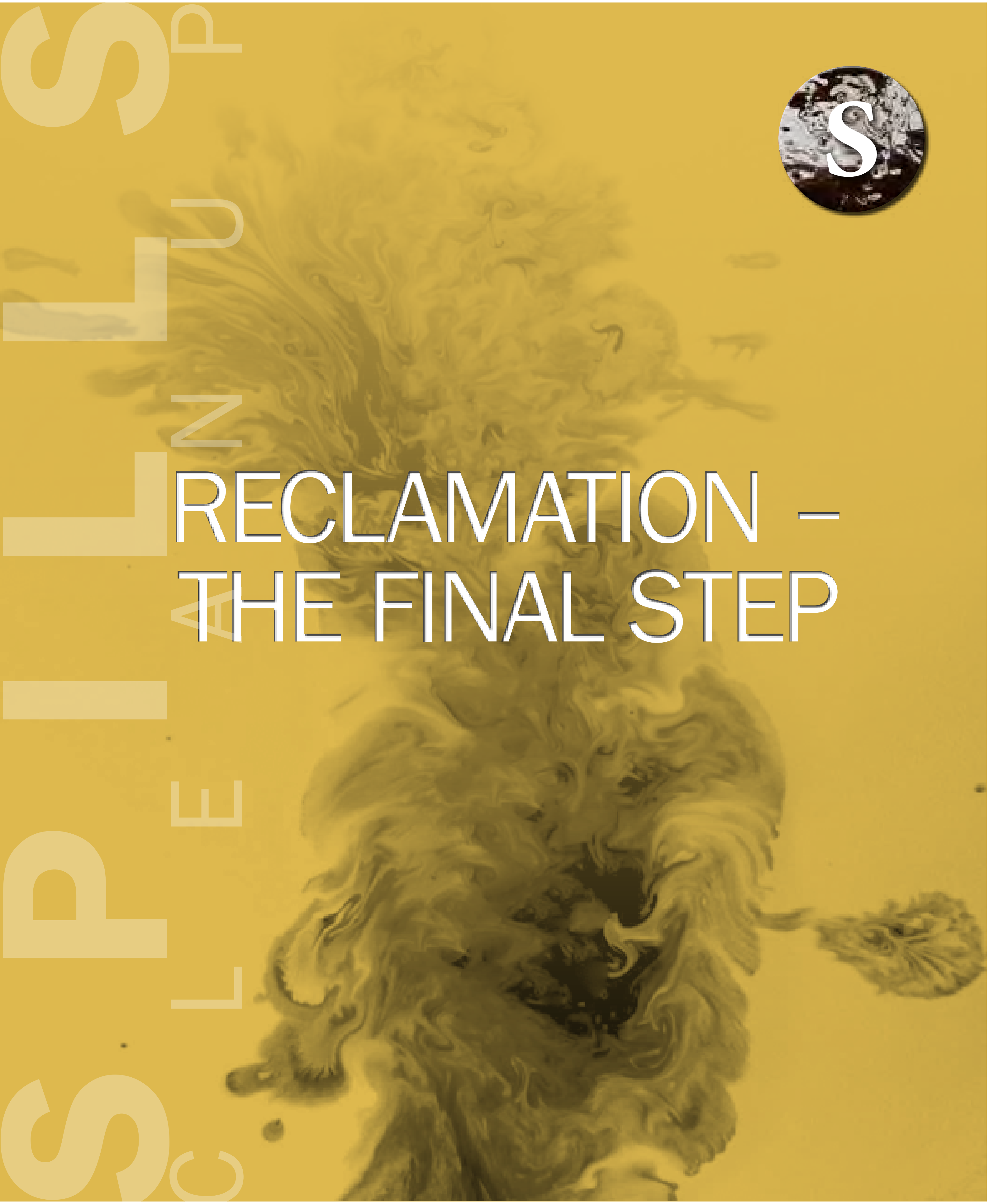


Submit "notice of completion" report to regulatory agency.



“No further action” required by regulatory agency.

SPILLS
CLEANUP



RECLAMATION – THE FINAL STEP

Reclamation

Reclamation – Returning the Land to Productive Use

GOAL: restore a site disturbed during installation of infrastructure or contaminated by a brine or hydrocarbon spill to its predisturbance productivity.

Disturbed Areas

Step 1 – Perform a thorough preconstruction inventory to document site-specific information and ecosystem function.

Step 2 – Strip topsoil, and stockpile for eventual restoration.

Step 3 – Perform construction (i.e., pipeline).

Step 4 – Grade site to original slopes, and replace topsoil.

Step 5 – Prepare seedbed, and seed with appropriate seed mix at recommended depth.

Step 6 – Control weeds and erosion to allow seeding to become established.

Step 7 – Monitor reclamation area for up to 5 years, and take corrective action if necessary.

Step 8 – Obtain concurrence from regulatory agency and landowner that reclamation is complete and monitoring can stop.

Spill-Impacted Areas (as part of in situ remediation process)

Step 1 – Perform a thorough inventory of native soil and vegetative conditions to document site-specific information and ecosystem function.

Step 2 – Perform remediation as described earlier.

Step 3 – Control weeds and erosion to allow seeding to become established.

Step 4 – Monitor reclamation area for up to 5 years, and take corrective action if necessary.

Step 5 – Obtain concurrence from regulatory agency and landowner that reclamation is complete and monitoring can stop.

Landowner Contacts

The North Dakota Industrial Commission Department of Natural Resources Division of Oil and Gas hosts an informational Web page related to gathering lines (www.dmr.nd.gov/oilgas/mvc/ndgathering/) which also includes an electronic form for submitting gathering line incidents (www.dmr.nd.gov/oilgas/mvc/NDGathering/GatheringIncident/CreateIncident).

The North Dakota Petroleum Council hosts an informational Web page at (www.ndoil.org/oil_can_2/easementinfocenter/).

The North Dakota Department of Agriculture provided mediation services to assist landowners in resolving reclamation nonperformance issues.


SPILLS
CLEANUP
PROJECTS DONE RIGHT

Case Studies

Project Summary

Location: North Dakota

Land Use: Cropland

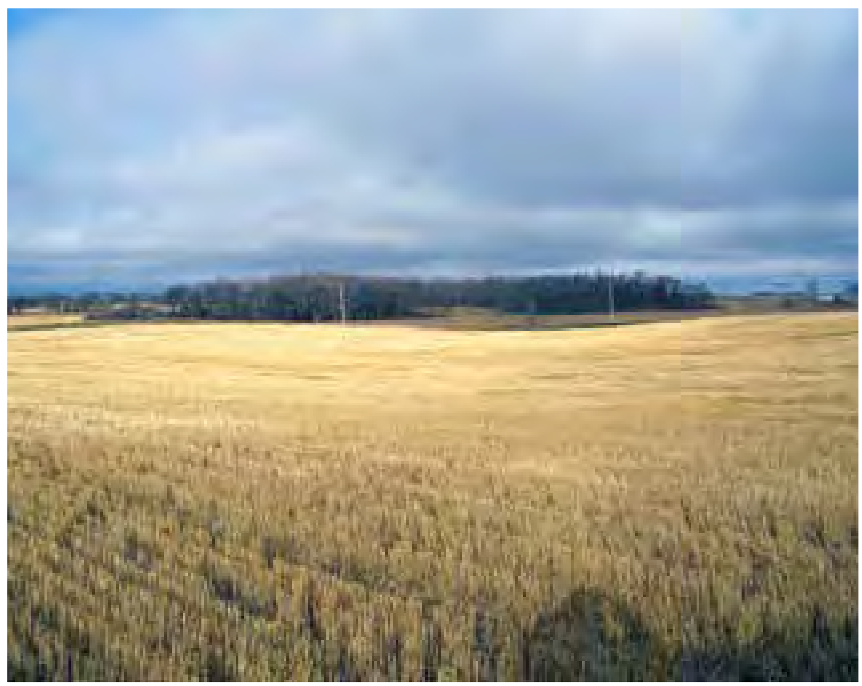
Spill Type: Pipeline release of brine

Native Soil Analysis: EC = 0.05 mS/cm, pH = 7.2

Initial Soil Analysis: EC = 17.9 mS/cm, pH = 6.2

Final Soil Analysis: EC < 1.5 mS/cm, pH = 6.9

Brine-impacted landscape (March 2000)



Remediation and reclamation complete (November 2007)

Project Summary

Location: Keene, North Dakota, area

Land Use: Rangeland

Spill Type: Pipeline release of brine

Native Soil Analysis: EC = 0.8 mS/cm, pH = 7.2

Initial Soil Analysis: EC = 24.5–27.0 mS/cm, pH = 7.1–7.2

Final Soil Analysis: EC < 1.0 mS/cm

Brine-impacted landscape (August 1997)

Application of amendments (November 1997)

Remediation and reclamation complete (September 2001)

Case Studies (continued)

Project Summary

Location: North Dakota

Land Use: Rangeland – natural drainage

Spill Type: Illegal discharge of brine

Native Soil Analysis: EC = 0.5 mS/cm

Initial Soil Analysis: EC = 37.9 mS/cm

Final Soil Analysis: EC = 1.9 mS/cm

Brine-impacted landscape (November 2011)

Remediation and reclamation complete (2014)

FOR MORE INFORMATION

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