# 2017 SENATE AGRICULTURE

## SB 2331

# 2017 SENATE STANDING COMMITTEE MINUTES

**Agriculture Committee**
Roosevelt Park Room, State Capitol

SB 2331
2/2/2017
Job # 27792

☐ Subcommittee
☐ Conference Committee

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| Committee Clerk Signature | Emmery Brotberg |

**Explanation or reason for introduction of bill/resolution:**

Relating to the protection of groundwater and other responsibilities of a mineral developer

**Minutes:**

Attachments: #1 - 8

**Chairman Luick:** Opened the hearing on SB 2331.

**Senator Wardner, District 37:** Introduced SB 2331. I sponsored this bill for the Northwest Landowners. This bill deals with testing for ground water while we are doing mineral development.

**Troy Coons, Northwest Landowners Association:** Testified in Support of SB 2331 (See Attachments #6 and 8).

**Chairman Luick:** In section 1, line 21-22 there are tests you are asking for and some of them can get expensive. Have you gathered any information on what the costs of doing these particular tests are?

**Troy Coons:** We did work with soil scientists and soil classifiers to come up with all the different things we are testing for in oil development instead of a broader spectrum, and yes we did. I do have some information I can give to the committee. When you look at the cost of developing a well, a lot of the numbers we see are from 6.6-million-dollars to 8-million-dollars. We have a schedule of what many of the different soil tests cost; some are 28 dollars, some are 12. The whole gamut can come up to a couple thousand dollars on that and depending on the well it can range from a few hundred to a few thousand as well.

**Chairman Luick:** Are you talking about $1,000 per core sample or per site?

**Troy Coons:** Per site. Each core sample on the different items you are testing for can range from $13 to $27 to $40 so for a full site, based on a five-acre site, it would be a couple thousand dollars. That's why we did it on a per acre basis because you have sites that may be developed from three acres to 28 acres and to get the proper demographics of what is out there the per acre basis would be the most accurate and for the soil changes and classifications.

**Chairman Luick:** What do you do if you are on a haul road?

**Troy Coons:** There we are looking at one core sample per every 300 feet with similar testing.

**Senator Klein:** You said we are going to test the soil before and someone down the line is going to test the soil to see if the soil is where it was when we started?

**Troy Coons:** Right. So even if there is a contamination issue or at end of life, we would know if the site and water wells are being returned to pre disturbed conditions.

**Senator Klein:** Do we have issues? Are there things going on now and you think this may be a way to get a handle on it?

**Troy Coons:** There are issues arising and if you don't have a background test then everything is speculation or you go to the buffer area around on it which depending on the amount of time, from the development to that period your watershed will change, there can be other things that affect the closer buffer and if you move outside of that you're into different soils and different conditions.

**Senator Klein:** Who's responsibility will it be if they find contaminates in the soil with the initial testing?

**Troy Coons:** That's why when we were working with the soils people we worked with and the attorneys we worked we have developed a list of items they are testing for.

**Senator Klein:** If they find contaminants, who will be liable?

**Troy Coons:** Again we come back to the list that we felt would be related to the oil development and not pesticides or other things that could come from farm practice. That is why we developed this list.

**Senator Klein:** So this list wouldn't find other contaminates?

**Troy Coons:** This is stuff related to this development. We have the property, there's the implied easement. If something happens that changes the property, we are looking at having a baseline so it can be restored to predevelopment conditions. A lot of this is related to brine and salts.

**Senator Myrdal:** Doesn't the ND Water Commission already do this water quality testing thoroughly throughout the state so would this be duplicative?

**Troy Coons:** They do have that but most of the time it does not apply to these situations. That is why we are putting this here in this section. This is for the cattle and farm wells; not the main aquifers.

**Senator Larsen:** The soil sample is going to be taken prior to the preparation of the pad or the site. Normally when the go down a foot to get the sample, don't they peel back a foot to get down to the clay and get all the top soil and that stuff off so that is in a pile? Is it not deep enough for leaching?

**Troy Coons:** When we are working with the soil scientists it varies and that is one of the issues with the basic reclamation we have now. It could be a lot more site specific and something that should be worked on but if you go down a foot, that usually entails your top soils. Below there are the clays so if anything was contaminated on the surface you would know it from the beginning and the soil scientists thought that would be all we would need for further down because any of the contaminates should be in the top soil.

**Senator Osland:** Could you give us an example of a problem?

**Troy Coons:** There have been instances on an access road where there has been salt water brine released. On site, you can have small spills and some go unreported, some go reported but there can be residual there over a several year period and you can find there is a buildup of these contaminants and we want to know if at this point a developer could say these were issues prior to our development. With this, we have that baseline saying there wasn't a problem. We aren't tasked with proving that there wasn't something there that is already in a baseline or background test. Otherwise we have the burden to prove it. At the amount we that we receive for these surface right agreements, the economics aren't there to do that.

**Senator Osland:** Where does the residue go with these oil spill cleanups? I have heard that if you spread some residue on a piece of soil the sun takes care of the problem. Is that what happens on a pad?

**Troy Coons:** I am not the scientific expert but my understanding of that is a person can spread things to a certain dilution ratio and if they are on the surface and they are re-disturbed, that the sunlight will kill a lot of things. But that would not be the case with salt water brine.

**Senator Piepkorn:** If in the course of investigating you did find some contaminates, who would be responsible for cleaning that up?

**Troy Coons:** That is where the soil people they come up with this parameter of testing.

**Senator Piepkorn:** But if they did find something that wasn't not on the list, someone would have to clean it up?

**Senator Larsen:** There is a discussion of testing the water wells within a mile area. Some of these locations may not have a well there so is it their responsibility to drill a test well in that area for testing purposes?

**Troy Coons:** That was not the intent of this. This would be for existing wells.

**Senator Larsen:** If there is not a well in that drill pad and there has to be testing of the water, is it up to that company to build a test well?

**Troy Coons:** That was not the intent of this; this is for existing wells.

**Senator Klein:** I hope we would not turn a blind eye if we find something extremely hazardous in the soil because we are only testing for these few things. When does the litigation start? If the company pays to run the test at the beginning and then they have to run the test at the end. If that end test determines the soil is contaminated, when does litigation begin?

**Troy Coons:** This would be third party independent testing and if the background testing showed there wasn't contaminate, the assumption is that most developers are working in good faith and they would clean up any contaminates. In the instance where they would not, it would probably end up in litigation. That is part of the reason for this because the burden Is not on the surface owner to prove that there was nothing there; we know what the baseline is already.

**Senator Klein:** Is this bill because someone did something in bad practice? I am thinking about the potential litigation because someone is going to argue that they did not cause the contamination.

**Troy Coons:** The intent of this is to protect the surface owner so if we have a background test that shows that things are ok the intent of this to protect them from mistakes and bad actors. Otherwise, we have to go in and prove that this contaminate wasn't there prior and these tests relate to oil development.

(21:00) **Kari Cutting, Vice President, ND Petroleum Council:** Testified in Opposition to SB 2331 (See Attachment #1-3). Miss Cutting provided the committee with spill cleanup manuals (See Attachments: #2-4).

(31:55) **Chairman Luick:** There is good and bad to finding contaminates in the soil. It just depends on how hazardous and detrimental it can be in the future?

**Senator Larsen:** What kind of technologies are being used today to get those salts out of the soil for remediation?

**Kari Cutting:** I cannot give specifics but I can say that based on the study of the salt water remediation taskforce, the technology has come a long way. Often times what we here in the media is discussion about how harmful the older spills from the 80s were the environment. Today there are a lot of better techniques; in fact, EERC has been working on remediating those spills now with today's technology so we are certainly aware that there is a need for technology and innovation and entrepreneurs that will fill that space. We are seeing a lot more private companies who are getting into remediation. Salt water is difficult but technology has come a long way.

(34:40) **Scott Radig, Director, Division of Waste Management, ND Department of Health:** Testified Neutral on SB 2331 (See Attachment #5).

(37:08) **Senator Larsen:** Is there more rigorous soil and water sampling in the oil and gas industry compared to the waste industry in comparison to the agriculture industry? Is there a tier effect of that and what is more heavily regulated?

**Scott Radig:** There are quite a few tests that are required for wastes that go into landfills to verify that they are not hazardous. Agronomic testing of fields is generally not regulated because each landowner is trying to control the quality for production purposes on their own fields. The state rarely collects any of that data so we do not know a lot about soil salinity on individual fields.

**Chairman Luick:** Do you have your own lab for testing these samples?

**Scott Radig:** Yes, the state does have a chemistry lab but there are many private laboratories that cover all sorts of testing.

**Chairman Luick:** In your opinion, do you think costs of the tests in this bill are going to be in that high of a range or where do you think those testing costs should be?

**Scott Radig:** I have a hard time saying specifically what those costs will be. We use our own lab for testing so I cannot say what a private lab would charge.

**Roger Kelley, Continental Resources:** Testified in Opposition to SB 2331. I have more than thirty years of experience dealing with oil spills. When we do come into a location in ND in particular we usually remove the top soil and we build a 5-acre pad. In my experience, you are not going to find significant deviation across the 5-acre pad. We are required to go back and clean it up to that ground and it has been accepted by the EPA. There is not a whole lot of benefit from the landowner. I have recommended at times to collect soil samples as insurance. In doing that, we would look for all concentration of contaminates so that if something happened, we would have evidence that it was in the soil when we arrived. On the flip side, if we do find it we are required by law to report it the Health Department and perhaps the EPA and so in general, whoever owns that land would be responsible to clean it up.

(42:50) **Chairman Luick:** Have you come into any of those places like that where you have found contamination?

**Roger Kelley:** In TX, we found buried mercury meters and we had to clean up the spill since we broke the meters. We don't find a lot of it but there is always the possibility. The samples from the aquafer and farm wells will probably not be much different so that a large number of samples wouldn't be required. If I took three soil samples off a pad, it would probably be plenty to give me background if that would need to be cleaned up. This really is a protection for the oil companies. It is not helping the landowner that much because we can find background because our footprint is very small. As far as technologies, salt water has been our nemesis in the past and it was very hard to cleanup. There have been products generated recently that would cleanup saltwater spills. Sun will not clean up a spill.

**Senator Piepkorn:** The Northwest Landowners Association and Miss Cuttings provided different estimates. Would the prices provided by Miss Cuttings be enough to shut down a project?

**Roger Kelley** I don't know pipelines but the more regulation you put on an industry, the more the expense goes up and as oil prices go down it will be an impact.

**Senator Klein:** Do you self-regulate among the industry?

**Roger Kelley:** We do. We don't abhor regulations; we welcome regulations that will keep everyone in line and it keeps us completive. We want a good oil and gas agency who are doing a good job. We don't want situations where we have solution looking for a problem. In my opinion, I don't think the estimates Miss Cuttings estimates are too high. If we go into a place that is environmentally sensitive, we will test. This bill sounds great but we can get the background without having to sample every acre.

**Senator Piepkorn:** Are you saying you agree in general with the request of the landowner association but want to limit the acres?

**Roger Kelley:** If we think we need to do it, we will do it. I would rather not have a regulation or statute requiring it because it does raise the expense and have an impact on the operation and investment. If we do have a spill, that background can be obtained at the time of our cleanup.

**Jennifer Weir, Hydrologist Water:** Provided Neutral Testimony on SB 2331 (See Attachment #7).

**Chairman Luick:** Closed the hearing on SB 2331.

# 2017 SENATE STANDING COMMITTEE MINUTES

**Agriculture Committee**
Roosevelt Park Room, State Capitol

SB 2331
2/2/2017
Job # 27809

☐ Subcommittee
☐ Conference Committee

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| Committee Clerk Signature | Emmery Brotberg |

**Explanation or reason for introduction of bill/resolution:**

Relating to the protection of groundwater and other responsibilities of a mineral developer

**Minutes:**

**Chairman Luick:** Opened the discussion on SB 2331.

**Committee Discussion:** The committee discussed how they would proceed on SB 2331. They decided to wait to take any action until the following day.

**Chairman Luick** closed the discussion on SB 2331.

# 2017 SENATE STANDING COMMITTEE MINUTES

**Agriculture Committee**
Roosevelt Park Room, State Capitol

SB 2331
2/3/2017
Job # 27897

☐ Subcommittee
☐ Conference Committee

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| Committee Clerk Signature | Emmery Grotberg |

**Explanation or reason for introduction of bill/resolution:**

Relating to the protection of groundwater and other responsibilities of a mineral developer

**Minutes:**

Attachments: #1 - 2

**Chairman Luick:** Opened the discussion on SB 2331.

**Senator Myrdal:** Invited the Northwest Landowners Association to explain proposed amendments on SB 2331.

(2:25) **Troy Coons, Chairman, NW Landowners Association:** Mr. Coons explained his amendments to the committee (See Attachments #1 – 2).

(8:40) **Harrison Weber, Intern, Legislative Council:** The amendments use "split sample." Split sample is not defined in that chapter.

**Troy Coons:** Split sample is a term from the industry.

**Harrison Weber:** I do not see the definition of a split sample core in this chapter.

**Troy Coons:** If we need to change the language, we can.

(10:32) **Chairman Luick:** We have an ombudsman's program in process today that we brought forward last session with the Agriculture Commissioner. We need to decide if you are going to allow the program to work or if we mandate more on top of the requirements.

**Senator Klein:** I understand your interest to see if the ombudsman program does what it is supposed to do. This bill tries to set a baseline but the cost would have to be incurred by someone.

**Senator Larsen:** The individual from Continental Resources testified that they already do soil sampling if they have a concern. This bill might be repetitive to what the industry is already doing and the cost is substantial.

**Chairman Luick:** I met with the Agriculture Department and I asked them how the program was working. They said the program was working very well despite a few obstacles they had come against.

**Senator Larsen:** Senator Larsen shared the positive experience his relatives had had with the ombudsman program.

**Senator Piepkorn:** Mr. Coons, you agree this ombudsman program is working?

**Troy Coons:** We were the moving force behind the ombudsman program. That is a program to help industry and property owners negotiate and come to settlements on pipeline issues. This bill is about access roads and sites. The ombudsman program is working well and it is doing what we hoped it would. There are not as many landowners signed up as we had hoped because the first person who applied for the program received a lot of media attention.

**Senator Larsen:** I thought the ombudsman was responsible for any issues between industry and landowners. I didn't think it was restricted to pipeline issues.

**Chairman Luick:** That is what I understand.

**Senator Larsen:** Moved Do Not Pass on SB 2331.

**Senator Osland:** Seconded the motion.

**Chairman Luick:** I think this bill has good intentions. I think maintaining and restoring property is a huge responsibility of the person who desecrated it but I do think there is a difference here between a pad and a pipeline site.

**Senator Myrdal:** I concur with your sentiments in regards to intent. I believe this may be duplicative and the cost is quite ambiguous.

**Senator Larsen:** I remember some bad things happening in the industry 1980s but when I went to a well site recently, a lot of those problems have been resolved. I think this bill would be too expensive.

**Chairman Luick:** We have bad actors in every industry.

**Senator Piepkorn:** I am sympathetic with the landowners drafting this legislation and perhaps there would be an opportunity to visit with the ombudsman program.

**A Roll Call Vote Was Taken: 6 yeas, 0 nays, 0 absent.**

**Motion carried.**

**Senator Klein will carry the bill.**

Date: 2/3/17
Roll Call Vote #: 1

**2017 SENATE STANDING COMMITTEE**
**ROLL CALL VOTES**
**BILL/RESOLUTION NO. 2331**

Senate Agriculture Committee

☐ Subcommittee

Amendment LC# or Description:

Recommendation:
☐ Adopt Amendment
☐ Do Pass ☑ Do Not Pass ☐ Without Committee Recommendation
☐ As Amended ☐ Rerefer to Appropriations
☐ Place on Consent Calendar

Other Actions:
☐ Reconsider ☐

Motion Made By Sen. Larsen Seconded By Sen. Osland

| Senators | Yes | No | Senators | Yes | No |
|---|---|---|---|---|---|
| Senator Luick | ✓ | | Senator Piepkorn | ✓ | |
| Senator Myrdal | ✓ | | | | |
| Senator Klein | ✓ | | | | |
| Senator Larsen | ✓ | | | | |
| Senator Osland | ✓ | | | | |
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Total Yes 6 No 0

Absent 0

Floor Assignment Sen. Klein

If the vote is on an amendment, briefly indicate intent:

## REPORT OF STANDING COMMITTEE

**SB 2331: Agriculture Committee (Sen. Luick, Chairman)** recommends **DO NOT PASS** (6 YEAS, 0 NAYS, 0 ABSENT AND NOT VOTING). SB 2331 was placed on the Eleventh order on the calendar.

# 2017 TESTIMONY

# SB 2331

#1

NORTH DAKOTA
PETROLEUM
COUNCIL
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# Senate Bill 2331
## Testimony of Kari Cutting
## Senate Agriculture Committee
## February 2, 2017

Chairman Luick and members of the Agriculture Committee, my name is Kari Cutting, vice president of the North Dakota Petroleum Council. Last year the North Dakota Petroleum Council represented more than 500 companies in all aspects of the oil and gas industry, including oil and gas production, refining, pipelines, transportation, mineral leasing, consulting, legal work, and oilfield service activities in North Dakota. I appear before you today in opposition of Senate Bill 2331.

SB 2331 disregards existing soil and water quality data and regulatory requirements, thus creating duplicative sampling and analysis requirements with a high implementation cost and very little, if any, benefit to the landowner.

The state of North Dakota has established resources available to the public with soil and water quality data. The North Dakota State Water Commission maintains a database of ground water information, with over 36,000 data points statewide, including specific water well information (lithologic logs, water levels, and water chemistry), which is searchable by specific location, county, and other parameters (http://www.swc.state.nd.us/info_edu/map_data_resources/groundsurfacewater/). The North Dakota Department of Health, Water Quality Division, Watershed Management Program, monitors surface water quality and maintains this data collected from approximately 1300 monitoring stations through North Dakota (http://www.ndhealth.gov/WQ/sw/Z8_SWData/viewer.html). The United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) has conducted soil surveys throughout the state of North Dakota. The soil data and information is part of the largest natural resource information system in the world. This data includes soil maps and data including chemical properties, erosion factors, soil health, physical properties, and suitable land use. This data is a valuable resource used by engineers and technical professionals for project planning and development. The soil survey data is available at http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm. The United States Geological Survey monitors and assesses the water quality of major river basins and principal aquifer systems (http://water.usgs.gov/owq/). These are examples of the established resources available to all of us for information regarding background and existing soil and water quality properties and conditions.

This bill creates a duplicative sampling and analysis requirement for the purposes of establishing background concentrations of certain analytes that are found in produced water from oil and gas development, as evidenced by the sample analysis analytes presented in lines 22 and 23 of the bill. As presented above, there are existing resources that provide information on soil and water quality which can be used for understanding the background conditions in the state. There are existing regulatory requirements that further the gathering of soil and water quality data.

The North Dakota Saltwater Remediation Task Force spent over two and a half years discussing, educating themselves, and drafting a guidance document on saltwater remediation. This Task Force included members of the North Dakota Department of Health (DoH), the North Dakota Department of Mineral Resources (DMR), the Governor's Office, the Commissioner of Agriculture (Dept. of Ag), soil scientists from NDSU and EERC, the Northwest Landowners Association, and the North Dakota Petroleum Council (NDPC). I submit copies of the final document to the committee, as well as the Remediation Resource Manual, written by an industry working group, and the Spill Cleanup Primer, written by EERC with input from NDSU and subject matter experts.

As another outcome of Task Force collaboration, the North Dakota DoH guidance document titled "*Guidelines for the Assessment and Cleanup of Saltwater Releases*" was developed, and the guidance provides criteria for sample collection and analysis of background and existing conditions, additionally furthering the collection of soil and water quality data. The North Dakota Department of Mineral Resources (DMR) also has a previously established guidance on soil sampling required to support cleanup and remediation efforts: "*A Guide for Remediation of Salt/Hydrocarbon Impacted Soil.*" Both departments require immediate cleanup response and cleanup; both require sampling and analysis of background and existing conditions; and both require any sample analysis data be submitted to the agency(s). These sampling and analysis requirements are established, apply regardless of the material spilled, and address all sites, present and future.

The bill specifies sampling the top twelve inches of soil prior to commencement of development. During oil and gas facility development, the topsoil and subsoils are stripped and set aside for use in future reclamation. They are preserved and will not be subject to spills or pipeline leaks. The background information collected on the top twelve inches is therefore a costly but meaningless exercise. Furthermore, requiring sampling and analysis every three hundred feet prior to development of a crude oil and natural gas pipeline doesn't make any sense either. The bill addresses only produced water background analytes. The sampling and analyses cost required by this bill for pipeline development is very significant. One of our member companies reported that if they had been required to sample every 300 feet on their newly constructed 180 mile produced water pipeline, the cost would increase capital investment by 8%. For every mile, the bill required eighteen samples at a cost of $2000 per sample according to Intertek Laboratories. That equates to a sampling and analysis bill of $6.5 million. Another company constructed an oil pipeline in the same corridor, with the same route, that company would also be subject to an additional $6.5 million in analytical costs.

The bill specifies one sample and analysis per acre of development. The typical well pad is seven to eight acres, some more, and some less. The average analysis as specified by the bill will cost $2000 per sampling according to Intertek Laboratories, Bismarck. DMR has stated they anticipate an additional 6,500 to 10,000 oil and gas facilities for the Bakken to be completely developed. If we use conservative estimates of 6,500 facilities, with seven samples per facility, at a cost of $2,000 per sample, the low-end cost to industry of this bill would be $91 million. And as I have testified today, that $91 million would be spent with very little, if any benefit to the landowner, the State of North Dakota, or the environment, and is a duplication of current regulatory requirements.

This bill also has some potential unintended consequences. Anytime you generate data, you create an opportunity for that information to be discovered. What happens if the water or soil analysis finds existing contamination? Evidence of nitrate contamination in the water, for example, caused by fertilizer runoff or soil contaminated with old farm chemical spills.

We urge a Do Not Pass on SB 2331. I would be happy to answer any questions.

SB 2331 2/2/17 #2

# Guidelines for the Assessment And Cleanup of Saltwater Releases

North Dakota Department of Health
Environmental Health Section
Division of Water Quality
Bismarck, North Dakota

September 2016

# Table of Contents

## Tables

SB 2331 2/2/17 #2

## DEFINITIONS

Background Sample – A sample collected from outside the impacted area that is representative of the impacted soils.

Compatible Soils – Soils that are similar in composition. The USDA Soil Survey can provide locations for compatible soils. USDA soil survey information is also available on USDA's Web Soil Survey.

Competent Person – A person who has a thorough understanding of the conditions and regulatory requirements associated with a remediation project.

Ecosystem - A community of living organisms in conjunction with the nonliving components of their environment. This includes all terrestrial and non-terrestrial life.

Facility – Refers to any location or structure that can be the source or recipient of a release. This includes all permanent and mobile sources.

Groundwater - The water present beneath Earth's surface in soil pore spaces and in the fractures of rock formations. Groundwater is considered a "water of the state."

Landscape Position – The landforms in and around an impact area that are likely to have similar soil series, i.e. drainage bottoms, slopes, hilltops.
Leachate - Water that has percolated through a solid and leached out some of the constituents.

NDDoH Approved Laboratory – Analytical laboratories that have been certified by the North Dakota Department of Health, Division of Laboratory Services. Other analytical laboratories may be allowed at the discretion of the Department.
Receptor – Any area where a contaminant may collect. Receptors may include, but are not limited to; groundwater, surface water, wells, utility corridors and basements.

Remediation – Reversing or stopping environmental damage. This can be accomplished by altering a contaminant or moving it to a non-sensitive area.

Responsible Party – The individual or party responsible for the remediation of a release.

Root Zone – The zone of the soil profile penetrated by plant roots.

Salt – In this document, a general term for sodium chloride.

Saltwater– In this document, any water containing sodium chloride.

SAR – Sodium Adsorption Ratio(SAR) is a ratio of sodium to calcium and magnesium.

$$\text{S.A.R.} = \frac{Na^+}{\sqrt{\frac{1}{2}(Ca^{2+} + Mg^{2+})}}$$

Waters of the State- All waters within the jurisdiction of this state, including all streams, lakes, ponds, impounding reservoirs, marshes, watercourses, waterways, and all other bodies or accumulations of water on or under the surface of the earth, natural or artificial, public or private, situated wholly or partly within or bordering upon the state, except those private waters that do not combine or effect a junction with natural surface or underground waters just defined. N.D.C.C 61-28-02 (15)

## SECTION 1. INTRODUCTION

The *Guidelines for the Assessment and Cleanup of Saltwater Releases* establish guidelines for use by the North Dakota Department of Health (NDDoH), responsible parties and their consultants in the assessment and cleanup of sites impacted by saltwater releases. It is intended that these guidelines will help return sites impacted by saltwater releases to pre-release conditions or background levels in order to adequately protect the waters of the state. Cleanup of such sites must take into account the specifics of the site and the release, but the site shall be restored to its pre-release conditions if reasonable.

Some factors to be considered include:

1. Would greater environmental damage be caused by additional work?
2. Does depth to contamination make excavation impracticable?
3. Are there culturally or environmentally sensitive areas to avoid disturbing?
4. Is there public safety or infrastructure at risk?
5. What are the wishes of the landowner?
6. What are the limits of current technology?

The NDDoH may vary application of these guidelines based on site-specific geological, hydrological or environmental conditions, but only in ways that are consistent with the requirements of law, the policies set forth in these guidelines and best professional judgment. The guidelines set forth are explanatory in nature, *and do not have the force and effect of law,* North Dakota Century Code (NDCC) § 28-32-01(11)(k). The NDDoH evaluates releases based on the specific site conditions and will follow the standards in these guidelines for all applicable sites. It is understood, however, that there may be cases where some of the standards may need to be modified to meet site-specific or contaminant-specific circumstances. The responsible party may request alternative standards for specific sites. If it is appropriate to deviate from these standards, the reasoning shall be explained and documented. In addition, the NDDoH may institute more stringent requirements to protect water quality or public health if appropriate.

The primary responsibility of all personnel involved in the assessment and cleanup of a spill site is to ensure the protection of the following:

- Public health
- Safety of personnel
- Livestock
- Aquatic life
- The ecosystem

Owners/operators of the facility are responsible for ensuring their facilities do not pollute waters of the state, and for assuring compliance with NDCC 61-28, NDCC 23-29 and the rules promulgated under that authority.

The objective of an investigation at a saltwater release site is to determine the extent and environmental impact of the release. The investigation includes:

- Mapping and photo-documenting the site.
- Identifying and evaluating receptors.
- Delineating the horizontal and vertical extent of impacts in the soil and groundwater.
- Adequately defining the site geology and hydrogeology.

The investigation, in conjunction with a site characterization, should determine the ongoing or historical source or sources of the release and must adequately identify background conditions. The investigation must provide adequate and reliable information that can be used to determine if further remedial action is required.

The facility owner or responsible party is responsible for adequately investigating the site and recommending additional investigation or corrective action as appropriate. This is best performed by a competent person who is familiar with all local, state and federal regulations, as well as NDDoH guidance documents which address technical and reporting requirements. The competent person should also be well-versed in industry-accepted remediation technologies and be aware of appropriate emerging technologies.

The responsible party must notify all landowners affected by a release and obtain permission to access the areas needed to address any impacts. The responsible party shall keep all landowners informed as to the status of all assessment and remediation activities.

This document is designed to provide guidance for performing a site investigation and cleanup of a saltwater release in North Dakota.

The primary sources of saltwater releases in North Dakota are produced water and flow-back water from oil field production and development. There are three primary constituents of concern regarding a produced or flow-back water release:

- Sodium ($Na^+$)
- Chloride ($Cl^-$)
- Total petroleum hydrocarbons (TPH)

The term "saltwater" will be used in this document to refer to water produced in association with oil production, hydraulic fracturing (flow-back) and any other brine releases. It should be noted that saltwater does contain other constituents that can cause detrimental impacts to the environment. Safety Data Sheets (SDS) shall be made available for all additives that may be present in any saltwater release. Although this document focuses on salt, these other constituents (Tables 1 and 2) also must be addressed in accordance with the *Guidelines for Investigation of Contaminant Release Sites*. This document can be found on the NDDoH website.

The term "remediation" is loosely used in this document to define the mobilization and redistribution of salt impacts. There are no known biological or chemical additives that can remove or consume salt. Salts can only be redistributed by means of excavation or mobilizing them so they can be moved.

## 1.1. Total Petroleum Hydrocarbons

Separators remove most of the petroleum hydrocarbons from saltwater; however, total petroleum hydrocarbons (TPH) may still be present. Although this document will not specifically address the remediation of petroleum hydrocarbons, TPH sampling will be initially required for all saltwater releases. If no TPH is present in initial sampling then further sampling for TPH will not be required, unless new information is provided to the contrary. If TPH impacts are present, sampling for benzene, ethyl benzene, toluene and xylenes (BETX) may be required by the NDDoH.

## 1.2. Chlorides

Due to the negative charge of the chloride ion, it is generally mobile and easily migrates below the root zone of most plant species. Although sampling for chlorides will be required on all saltwater releases, remediation generally occurs with the treatment or removal of the sodium ions. Chlorides are far more likely to impact groundwater, however. For this reason, chlorides will be used as the indicator for potential risk to groundwater and surface water.

## 1.3. Sodium

Due to the positive charge of the sodium ion, it will bond with clay particles and organic matter in soil. Sodium is a soil dispersant (particles repel each other) whereas calcium is a soil flocculant (particles are held strongly together). When sodium concentrations in the soil are high, and dispersion occurs, water movement will be slow or non-existent compared to when a soil has a high concentration of calcium. A common measure of the amount of sodium in a soil is the SAR, and is recorded as a ratio of sodium to calcium plus magnesium in the soil from a saturated-paste extract. SAR does not determine the concentration of sodium from the soils' exchange sites and only measures Na, Ca, and Mg that have dissolved from soluble salts in water. The more calcium present, the less likely it is for the sodium to bond with the clay particles and cause dispersion. Therefore, one method of remediation is to increase the level of calcium (e.g. add gypsum) in the soil solution which then promotes the flocculation of clay particles.

## SECTION 2. INITIAL RESPONSE

In the event of a saltwater release, the primary concern is the protection of human health and safety. If the release has resulted in the injury of personnel or presents a safety issue, this must be addressed first. Once safe to do so, the source of the release should be eliminated as quickly as possible and the release contained using reasonable methods. Temporary earthen berms and dikes, as well as diversion trenches, can help to control and limit the flow of water. Oil booms can collect hydrocarbons in the water, but the booms do not absorb saltwater. Every effort shall be made to prevent saltwater releases from entering waters of the state.

A sample of the released water must be collected if possible. The sample shall be collected from the source of the release (e.g., pipeline, tanker, produced water tank). If no water is available at the source, a sample may be collected from areas of pooling. It is important to collect a sufficient volume of water for an NDDoH-approved laboratory to complete the analyses for the constituents listed in Table 1.

For any disturbance below 18", North Dakota One Call must be contacted. Except in an emergency, an excavator shall contact the notification center and provide an excavation or location notice at least forty-eight hours before beginning any excavation excluding Saturdays, Sundays, and holidays. The North Dakota One Call number is 800-795-0555 or 811.

## SECTION 3. SITE ASSESSMENT

The following tasks shall be performed for all saltwater releases, as appropriate:

- Estimate the volume of saltwater released.
- Estimate the volume of saltwater not contained within a well pad.
- Estimate the area of impact.
- Document the method used to estimate volume and area.
- Estimate depth to groundwater.
- Determine if waters of the state have been impacted or threatened.
- Determine land use and vegetation impacted.
- Estimate the actual or potential exposure to livestock.
- Estimate the actual or potential impact to aquatic life.

The assessment should include (1) the lateral and vertical delineation of contaminants; (2) the date, time and location of any samples collected; (3) a site evaluation in respect to groundwater, surface water, sensitive groundwater areas, wells, wellhead protection areas, topography, etc.; and (4) an evaluation of potential receptors. The area of impact and all potential receptors shall be documented on a site map.

Background soil and groundwater samples shall be collected, as appropriate, for all saltwater release sites. Background samples shall be collected outside of the area of impact; however, the soils sampled should be representative of the impacted media (i.e. same landscape position). Background soil samples should be collected in sets and represent the soil profile at 12-inch intervals from the surface to the base of the root zone or 24 inches, whichever is deeper. The number of background samples must be sufficient to fully represent the impacted area, with a minimum of two (2) background samples per landscape position impacted. Background samples shall be sent to an NDDoH-approved laboratory and analyzed for the constituents listed in Table 2.

Laboratory Method Detection Limits (MDL) shall be of sufficient sensitivity to adequately characterize any impacts. Re-sampling may be required if the MDL is deemed to be too high for a constituent.

## SECTION 4. EVALUATION OF POTENTIAL RESPONSE ACTIONS

In addressing a saltwater release, the responsible party has two options. The first option is to begin immediate excavation of impacted soils. This is typically used for smaller, confined releases where no groundwater or surface water has been impacted. The second option, for larger releases, is to conduct a site investigation.

### 4.1. Excavation

Remove all impacted vegetation and soils. In some cases, the NDDoH may allow excavations to be limited to the base of the root zone of the impacted vegetation. Excavated vegetation and soils shall be disposed of at an NDDoH-approved special waste landfill permitted to accept oil field waste. (http://www.ndhealth.gov/wm/Publications/SpecialWasteLandfills.pdf) Depending on the release, this material may or may not be considered exploration and production (E&P) exempt waste. The responsible party should check with the landfill to determine if laboratory analysis is needed to characterize the waste prior to disposal. If waste characterization is required, the excavated material should be stored in covered, leak-proof containers or on a bermed and poly-lined revetment, and covered to prevent storm water contact and runoff. Waste characterization shall be conducted as quickly as possible to satisfy the requirements of the landfill.

Once impacted soils have been removed, confirmation samples shall be collected. Confirmation samples shall be collected from the base of the excavation at a rate of one composite sample for every 10,000 square feet. For linear impacts, the distance between composite samples shall not be greater than 250 feet. Each composite sample should consist of a minimum of five sub-samples. If excavations are in excess of 3 feet in depth, then one set of sidewall confirmation samples shall be collected for every 50 feet of sidewall. In some situations, additional samples may need to be collected to adequately characterize the site. Confirmation samples shall be sent to an NDDoH-approved laboratory and analyzed for the constituents listed in Table 2.

There are times when the excavation has extended below the root zone and it becomes impractical to continue digging. In these situations the Department may allow the site to be backfilled if an adequate monitoring plan is established. In some cases, the Department may require monitoring wells to be installed as part of the monitoring plan.

In order to prevent loss of productivity on agricultural lands and subsequent private property damage, lower constituent levels may be needed. These levels will be negotiated between the landowner and responsible party and do not require the involvement of the NDDoH.

If excavation takes place on agricultural lands, the responsible party shall reach an agreement with the landowner with regard to backfilling with compatible soil and reseeding the excavation. Reseeding may not be necessary if the land is to be put back into crop production; however, steps should be taken to prevent erosion prior to replanting crops.

On nonagricultural lands, the excavation shall be backfilled with a soil series compatible with the surrounding area. The area shall be contoured to match the grading prior to impact. The responsible party shall ensure that the backfill soils are not contaminated. The area shall then be reseeded with a seed mix compatible with existing vegetation. In some situations, the use of a cover crop prior to reseeding may be beneficial. Erosion protection shall be used to prevent soil erosion prior to re-vegetation. The area shall be monitored by the responsible party for a minimum of one full growing season to ensure that reseeding is successful and no erosion has occurred. Erosion control shall be addressed by the responsible party.

A Notice of Completion report shall then be submitted to the NDDoH detailing the nature and cause of the release and the remedial actions taken. The report shall include all laboratory data summarized in tabular form, along with the original laboratory report as well as site maps and photographs. The report also must include any recommendations for continued work and/or monitoring and the proposed work plan.

### 4.2. Site Investigation

The purpose of the site investigation is to determine whether in-situ remediation or natural attenuation/remediation processes are viable options. The goal of in-situ remediation is to permanently move the salts away from the root zone of the local vegetation and restore soil structure, allowing for healthy plant growth and environmental protection.

To determine the depth to groundwater and flow direction, topography should be observed, and geologic maps and publications or borings should be utilized. If groundwater is in close proximity to the bottom of the root zone of the local vegetation, then moving the salts below that zone may impact groundwater. In this instance, the potential impacts to groundwater should be calculated using the following process.

- Mass chloride (lbs) = [volume released (bbls) X chloride concentration (mg/L)]/2,900
- Chloride loading (g/day) = [mass chloride (lbs) X annual rainfall $(\text{in/yr})^2$]/1,000
- Adjusted chloride loading (g/day) = chloride loading (g/day)/soil type factor
- Increase in chloride concentration (mg/L) = [adjusted chloride loading (g/day)/effective width (ft)] X 13

<u>Soil Type Factor</u>
Sandy soil = 1
Silty soil = 2
Clayey soil = 10
Effective width = the width of impact area perpendicular to groundwater flow

In-situ remediation may be used if (1) the background chloride concentration of the groundwater aquifer is known and (2) the increase in chloride concentration plus the natural chloride concentration in the groundwater is less than 250 milligrams per liter (mg/L).

In-situ remediation also may be used if (1) the background chloride concentration of the groundwater is not known and (2) the increase in chloride concentration is less than or equal to 170 mg/L. If the increase in chloride concentration is greater than 170 mg/L, then excavation methods shall be used unless the NDDoH determines otherwise.

If groundwater is at risk, in-situ remediation may still be used if a collection system, such as drain tile, is used to capture the brine leachate. The collection system must be placed to adequately protect the groundwater. In some cases, the Department may require that monitoring wells be installed as part of the site investigation.

Soil samples shall be collected from the impacted area at a rate of one composite sample for every 10,000 square feet. Each composite sample should consist of a minimum of five sub-samples. Soil samples shall be sent to an NDDoH-approved laboratory and analyzed for the constituents listed in Table 2. Additional testing parameters may be required depending on the quality of the released saltwater and the presence of any additives.

If laboratory analysis reveals no exceedances in any of the constituents in Table 2, then no additional work is required, and a Notice of Completion report must be submitted to the NDDoH. If background sampling indicates a natural exceedance of any of these constituents, then the cleanup levels may be adjusted to require cleanup to the natural concentration at the discretion of the NDDoH. If soil concentrations exceed any of these values, then remediation is required.

### **4.2.1.** Limited Action Option

Natural processes can be utilized in areas that are not accessible, such as steep and narrow drainages or in areas where remedial activity is likely to disrupt the following:

- Critical habitat
- Sensitive vegetation
- Cultural resources

If limited action is proposed, a site monitoring plan shall be submitted to the NDDoH for review and approval. The plan should include methods and frequency for the following:

- Monitoring vegetation for signs of stress
- Soil sampling

Monitoring should be conducted for three years following remediation, with no adverse conditions to the local restored vegetation, or until the Department determines monitoring is no longer needed. In some situations, the length of monitoring may be adjusted based on site conditions and sampling results.

### **4.2.2.** In-Situ Remediation

Any in-situ remediation plan must be preapproved by the NDDoH and will only be allowed if it is the least damaging alternative. The in-situ remediation plan should be designed to allow salt impacts to migrate from the root zone of local vegetation and provide a sufficient nutrient base to allow for the reestablishment of vegetation. In some situations, the installation of drain tile can be utilized to collect and remove leachate from the soil. This can be used to prevent chloride impacts to groundwater. The NDDoH may require steps to be taken to monitor the fluids moving out of the root zone.

Remedial materials (e.g., gypsum, organic material) shall be placed on the impact area and tilled into the soil in such a manner as to disrupt surrounding vegetation as little as possible. Steps shall be taken to prevent erosion until vegetation in the impact area has been reestablished.

The quantity of remedial material used will be dependent on the type of material being used, sodium concentrations in the soil, type of soil and depth of the root zone. The deeper into the soil the remedial material can be tilled, the more effective will be the remediation. Depending on site conditions, additional applications of remedial materials may be necessary.

The remediation plan must also include a monitoring and soil sampling plan. Monitoring shall be conducted on surrounding vegetation for signs of stress. Soil sampling shall be conducted semi-annually until the Department determines monitoring is no longer needed. In some cases, the Department may require that monitoring wells be installed as part of the remediation plan.
The responsible party should reach an agreement with the landowner in regard to reseeding the impacted area. Reseeding may not be necessary if the land is to be put back into crop production immediately; however, steps should be taken to prevent erosion prior to replanting crops.

On non-agricultural lands, the impacted area shall be reseeded with a seed mix compatible with existing vegetation. Erosion protection shall be used to prevent soil erosion prior to re-vegetation. The area shall be monitored for a minimum of one growing season to ensure that reseeding is successful and no erosion has occurred.

## SECTION 5. MONITORING

Site monitoring shall be part of any saltwater spill remediation. Monitoring of areas that require re-vegetation can take up to four years or longer, depending on environmental factors. Quarterly and annual monitoring reports shall be presented to the NDDoH and landowner. The following summarizes the monitoring goals for each year:

Year 1 - Weed control is required. Mow weeds or use appropriate herbicide and rate prior to their reproductive stage

Year 2 - Conduct electrical conductivity (EC) and vegetative health surveys at the original sample points. A 40 to 50 percent remediation improvement should be observed. Make any adjustments if required. Weed control is required, possibly two to three times per year. In some cases, cover crop should be seeded as dormant seeding.

Year 3 - Conduct EC and vegetative health surveys at the original sample points. A 70 to 100 percent remediation improvement should be observed. Record all of the plant types and growth rates within the impact area. Make any adjustments required.

Year 4 - Remediation should be complete and all goals of the remediation process achieved. If remediation is not completed, the site requires reevaluation, and causes other than salt contamination should be considered. Additional treatments may be required.

At anytime remediation criteria have been met, monitoring may be suspended at the discretion of the Department.

- Incident factors affecting remediation
    - Concentration of salt
    - Concentration of hydrocarbons
    - Remediation not a linear relationship to contamination concentration

- Environmental factors affecting remediation
    - Precipitation (minimum requirement of 12 to 14 inches rain per year)
    - Soil series
    - Soil texture
    - Historical land usage
    - Grade/slope
    - Drainage
    - Temperature
    - pH
    - EC
    - Organic Matter
    - Compaction

## 6. REPORTING

A Notice of Completion report shall then be submitted to the NDDoH detailing the nature and cause of the release and the remedial actions taken. The report should include all laboratory data summarized in tabular form as well as site maps and photographs. The report should also include any recommendations for continued work and/or monitoring.

## 7. Analysis

**Table 1**
**Cleanup Standards for Protection of Ground and Surface Waters**

| Constituent | Analytical Method | Concentration | Basis |
|---|---|---|---|
| Chloride | EPA Method 300.0 | 250 mg/L | ND WQS |
| % Sodium | Calculated | | ND WQS |
| Sulfate | EPA Method 300.0 | | |
| Alkalinity | Standard Method 2320 B | 600 mg/L | NDDoH UST |
| TDS | Calculated or Volumetric | 500 mg/L | EPA Secondary MCL |
| Benzene | EPA Method 524.2 | 0.005 mg/L | |
| Ammonium | EPA Method 350.1 | 5 mg/L[t] | ND WQS |
| Bromide | EPA Method 300.0 | | |
| pH | Field Measured | 5-9 | ND WQS |

[t] A Guideline only, the Ammonium standard may vary based on temperature and pH.

**Table 2**
**Soil Analytes**

| Constituent | Analytical Method |
|---|---|
| Chloride | The Department will allow any analytical method, provided the Laboratory Method Detection Limits (MDL) is of sufficient sensitivity to adequately characterize any impacts and verify remediation.<br>The Responsible Party shall inform the Department of all analytical methods used. |
| SAR | |
| EC | |
| Bromide | |
| % Sodium | |
| pH | |

Where pre-release conditions differ from these guidelines, cleanup to background conditions is acceptable. The values of Table 1 are for the protection of waters of the state, including surface and groundwater. In order to prevent loss of productivity on agricultural lands and subsequent private property damage, cleanup to lower levels may be needed. This level should be negotiated between the landowner and responsible party.

The responsible party shall keep all landowners informed as to the status of all assessment and remediation activities. Copies of all documents should be shared with the landowner.

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# SPILLS CLEANUP PRIMER

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pg. 1

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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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Research Engineer
Energy & Environmental Research Center

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## Notice

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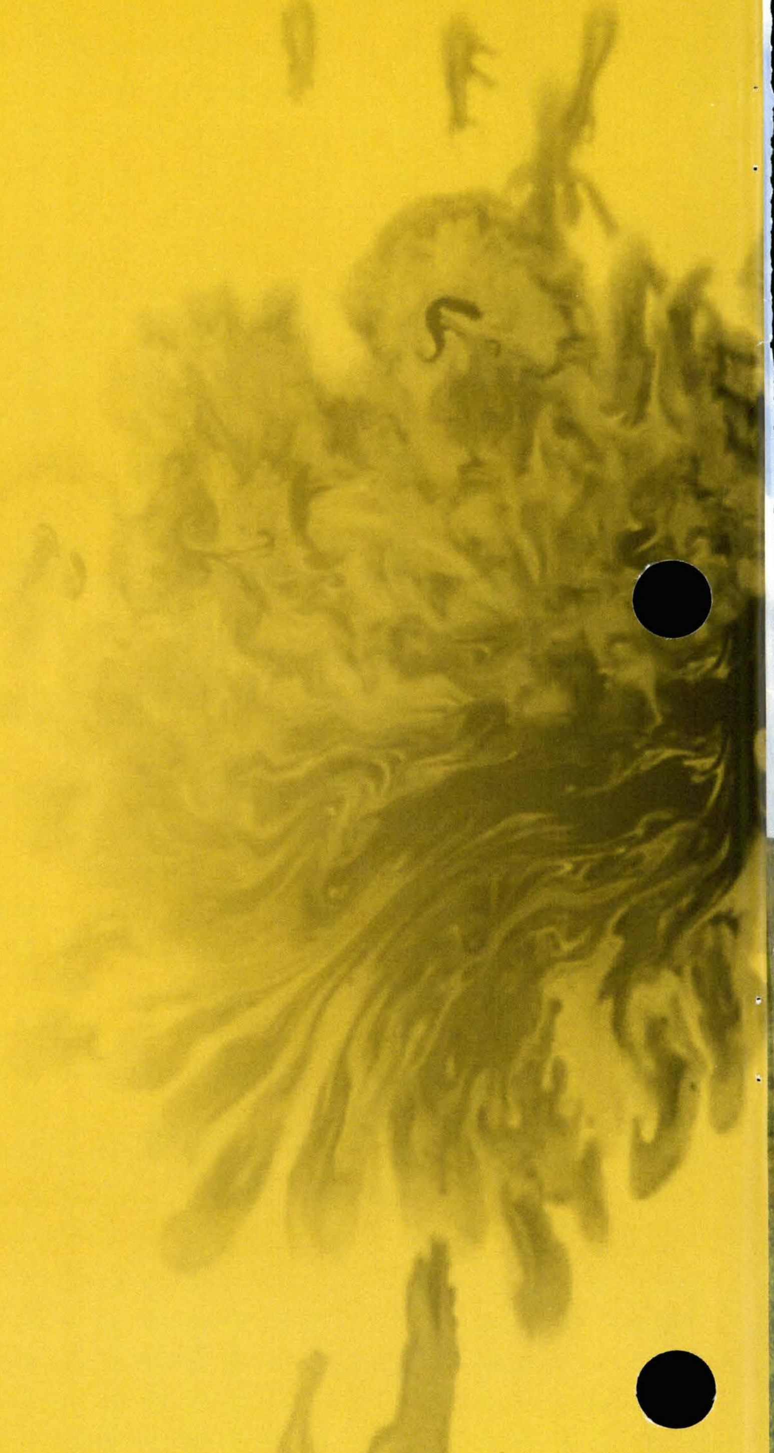

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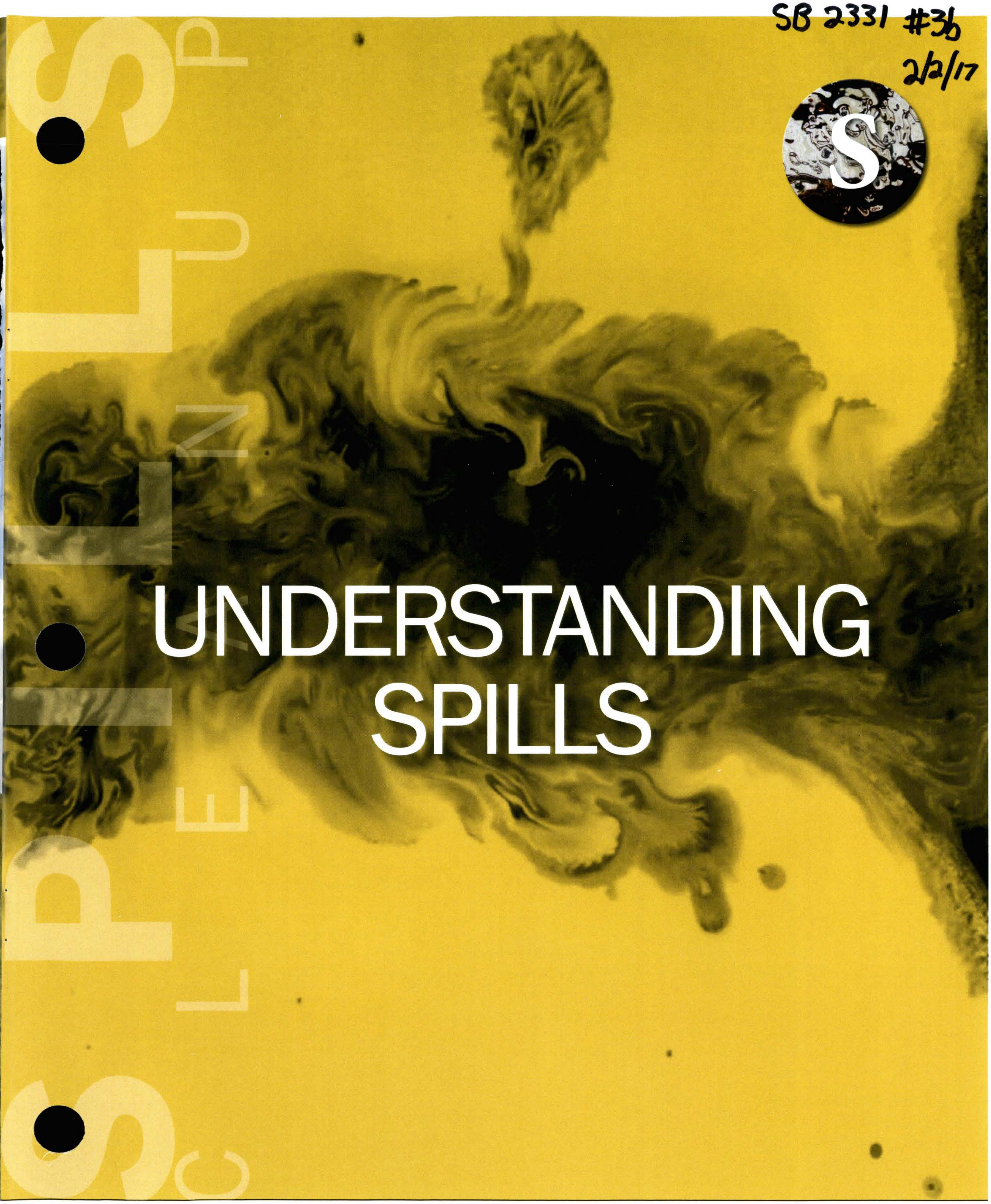
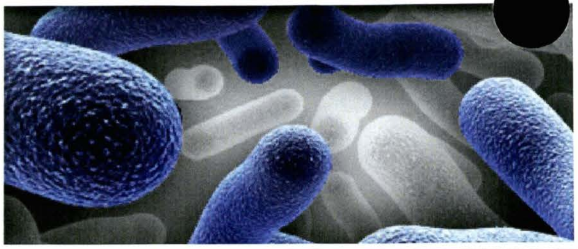


# UNDERSTANDING SPILLS

# 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.

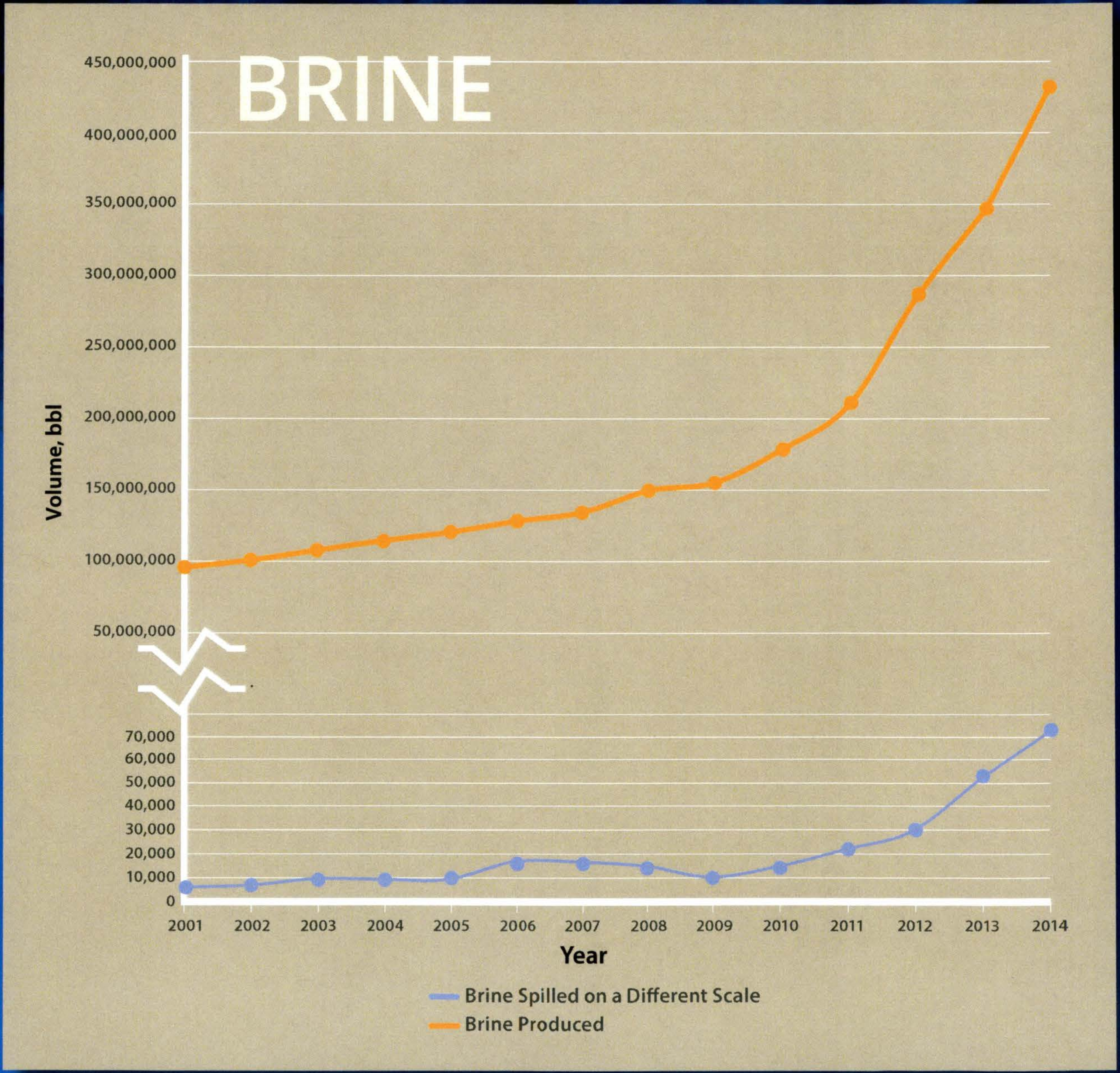
**TPH** – total petroleum hydrocarbons, a measure of the quantity of oil-related compounds in a given quantity of soil.

# 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.

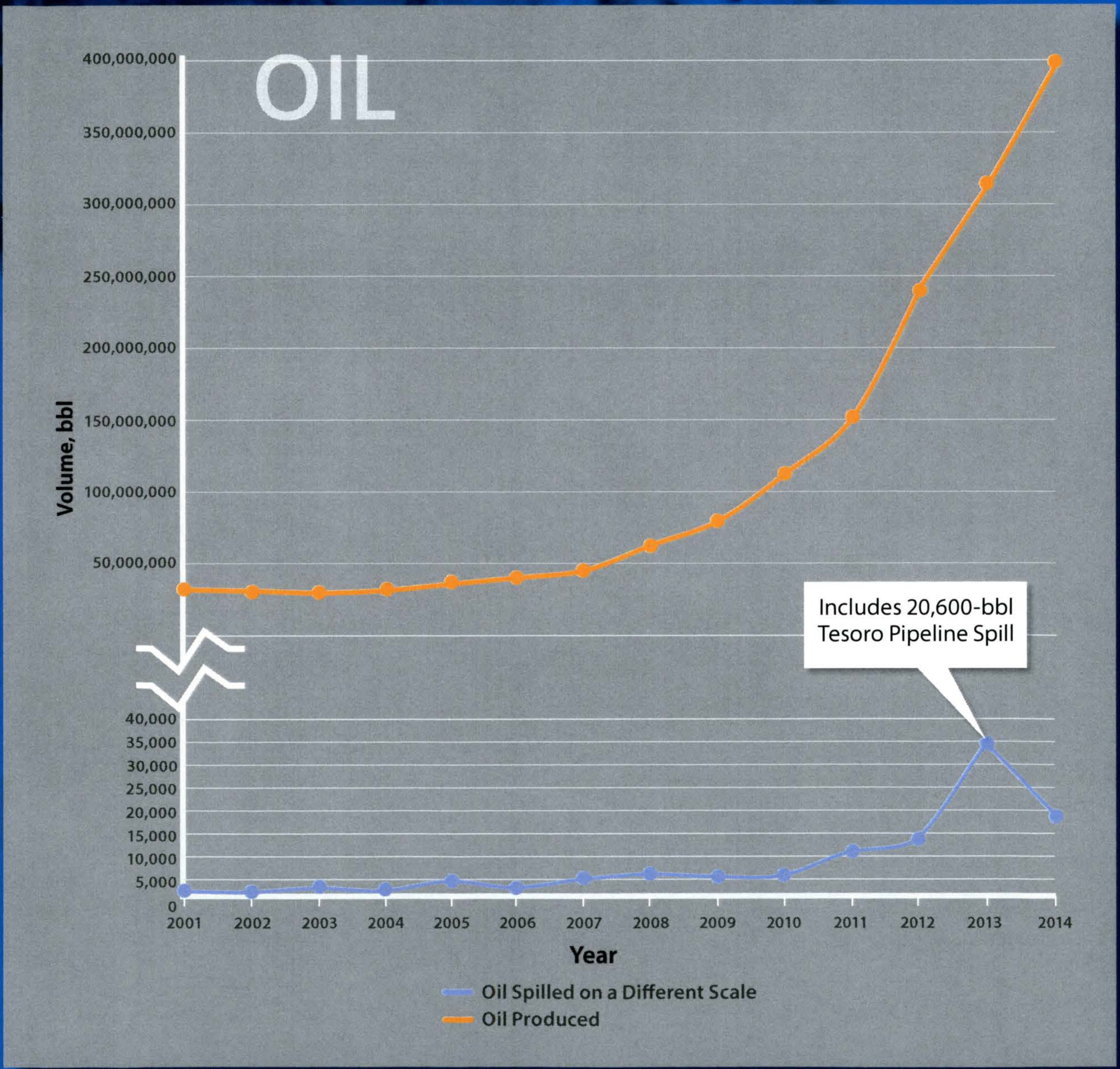
75%–80% of all spills are contained (meaning the spill does not leave the bermed production location).



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).

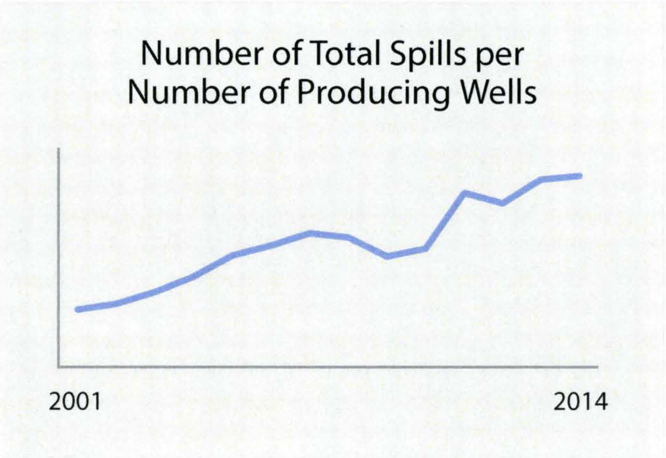


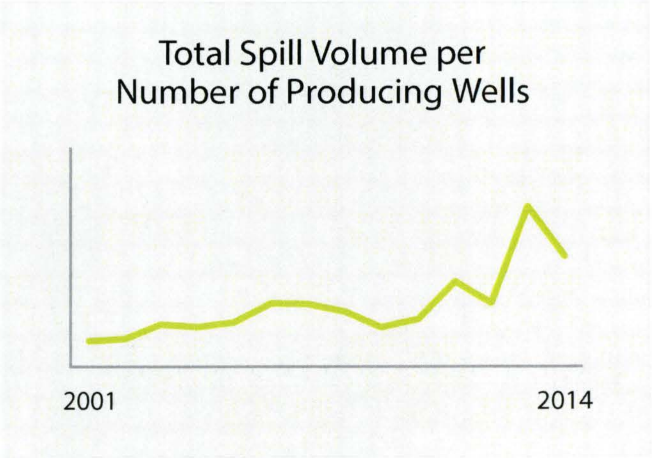
# Spill Statistics (continued)

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.

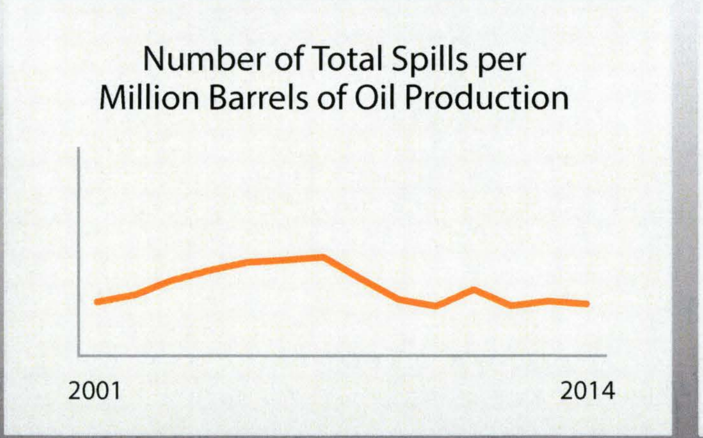
To this point, the annual spill data from 2001 through 2014 are presented two ways (note that the spike in spill volume in 2013 is largely due to the 20,600-barrel Tesoro pipeline release as well as nearly 70,000 barrels of freshwater spilled).

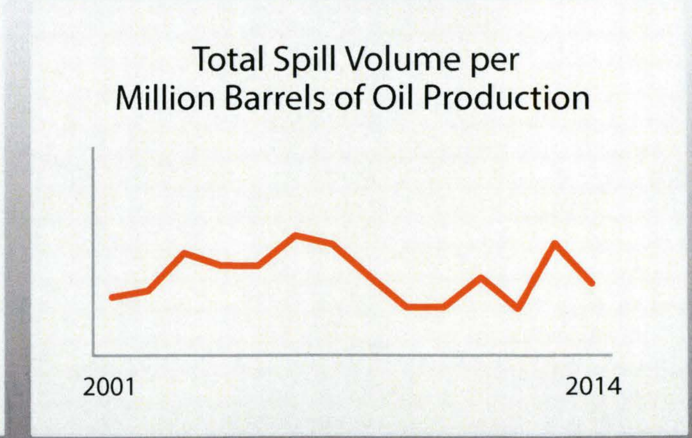
These two graphs are the annual number of spills and spill volumes as a function of the number of producing wells.


Number of Total Spills per Number of Producing Wells


Total Spill Volume per Number of Producing Wells

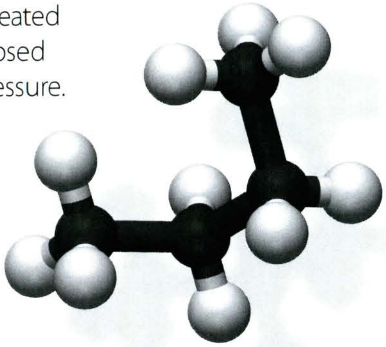
These two graphs are the annual number of spills and spill volume as a function of the annual oil production in million barrels.


Number of Total Spills per Million Barrels of Oil Production


Total Spill Volume per Million Barrels of Oil Production

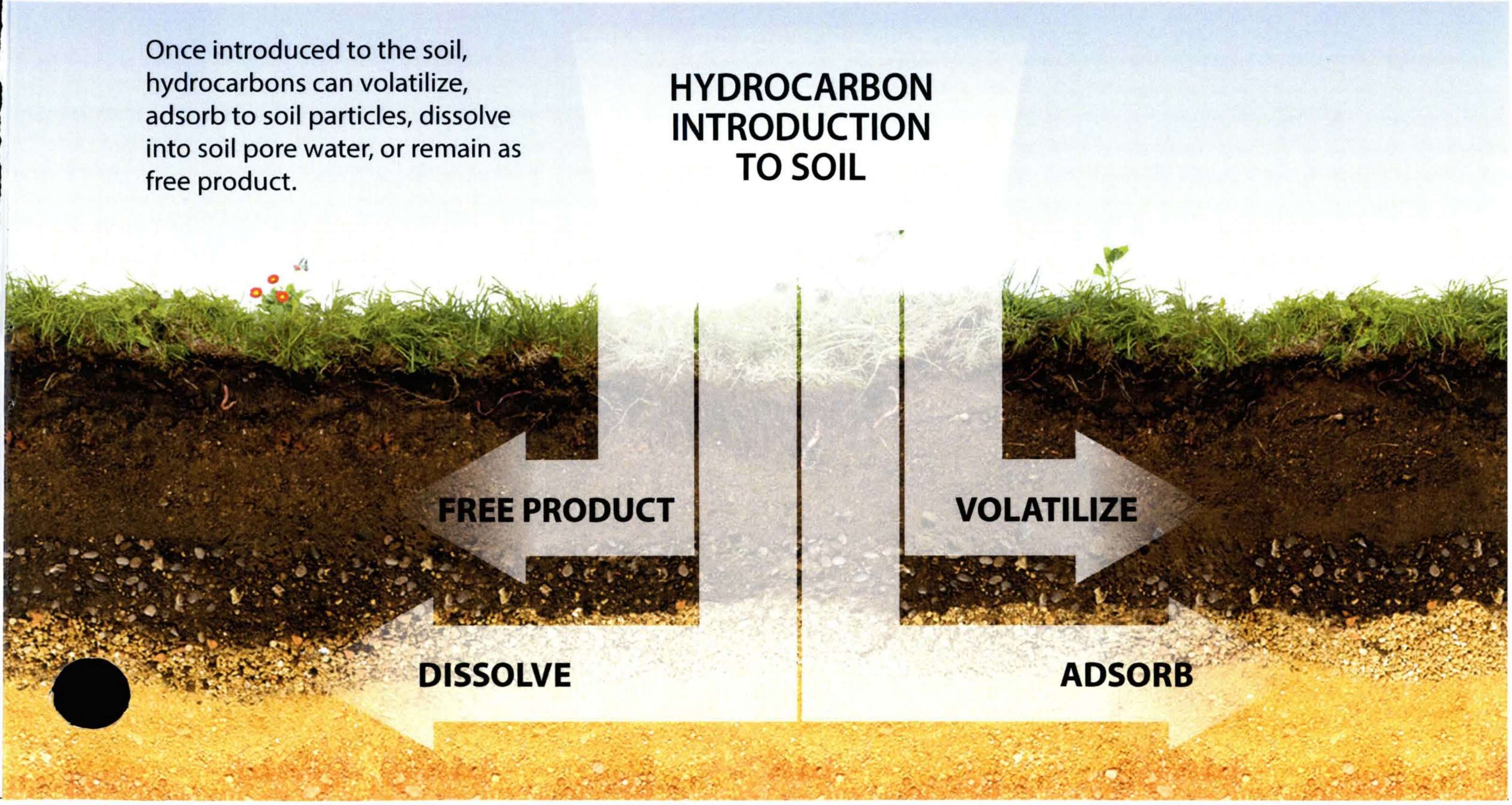
# Hydrocarbon Interaction with Soil

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.



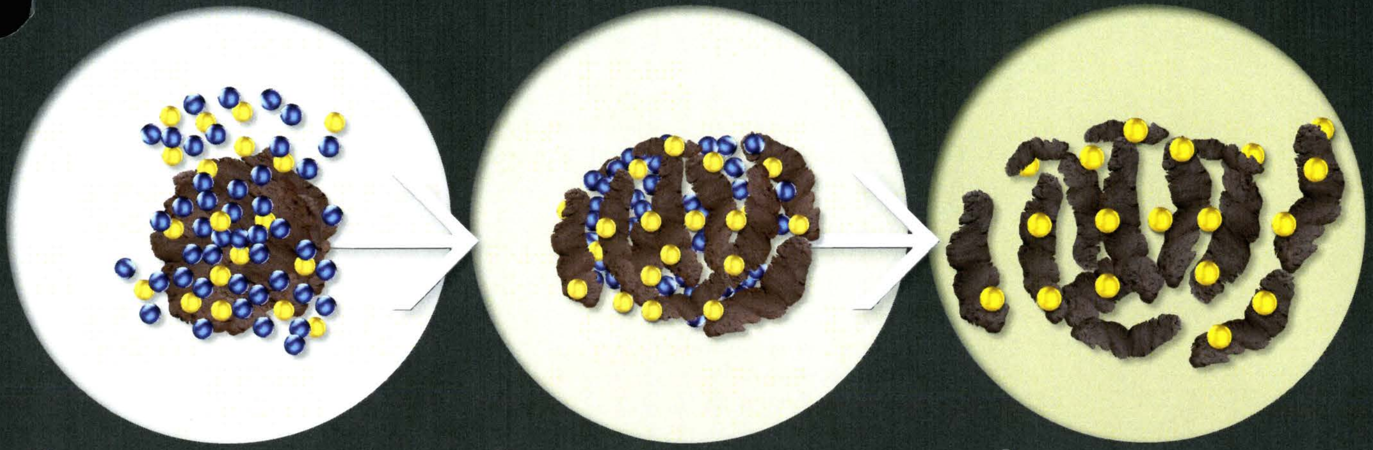
Bakken crude oil is much lighter than the "black gold" many people think of when they think of crude oil. Because of this, it is much more biodegradable.

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.



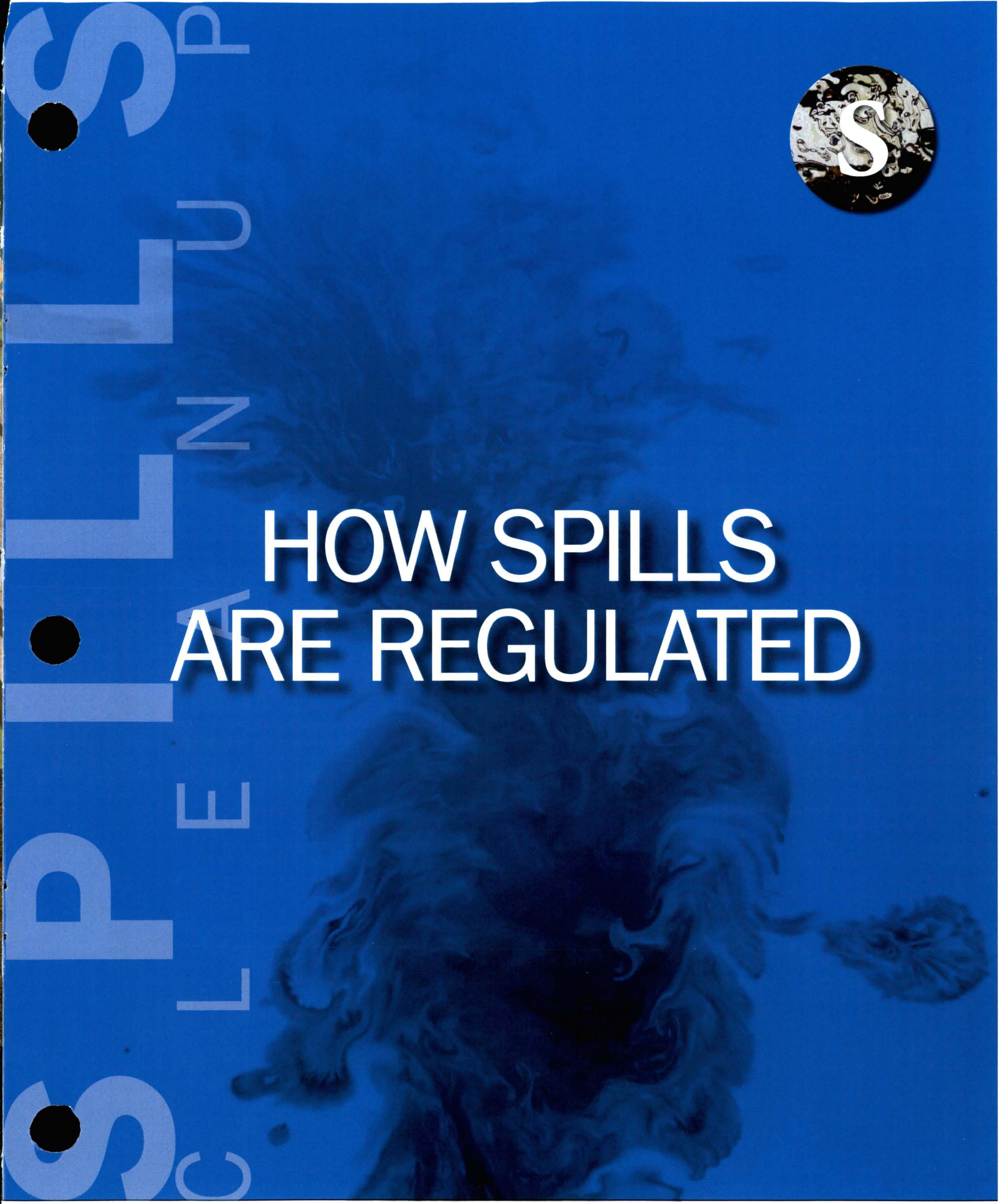
**1.** Introduction of brine (NaCl) **2.** Swelling of clay in the soil matrix **3.** Dispersion of clay particles

● **Sodium (Na)** ● **Chloride (Cl)**

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.


USGS



# 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

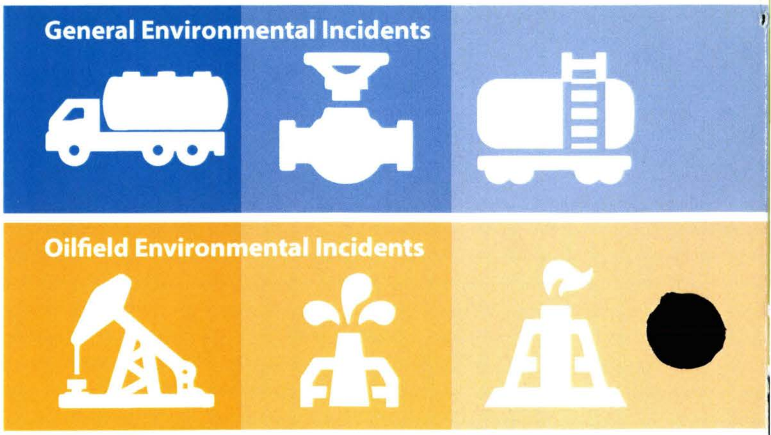
**North Dakota Industrial Commission Department of Mineral Resource Oil and Gas Division:** (701) 328-8020, www.dmr.nd.gov/oilgas/mvc/wincident/

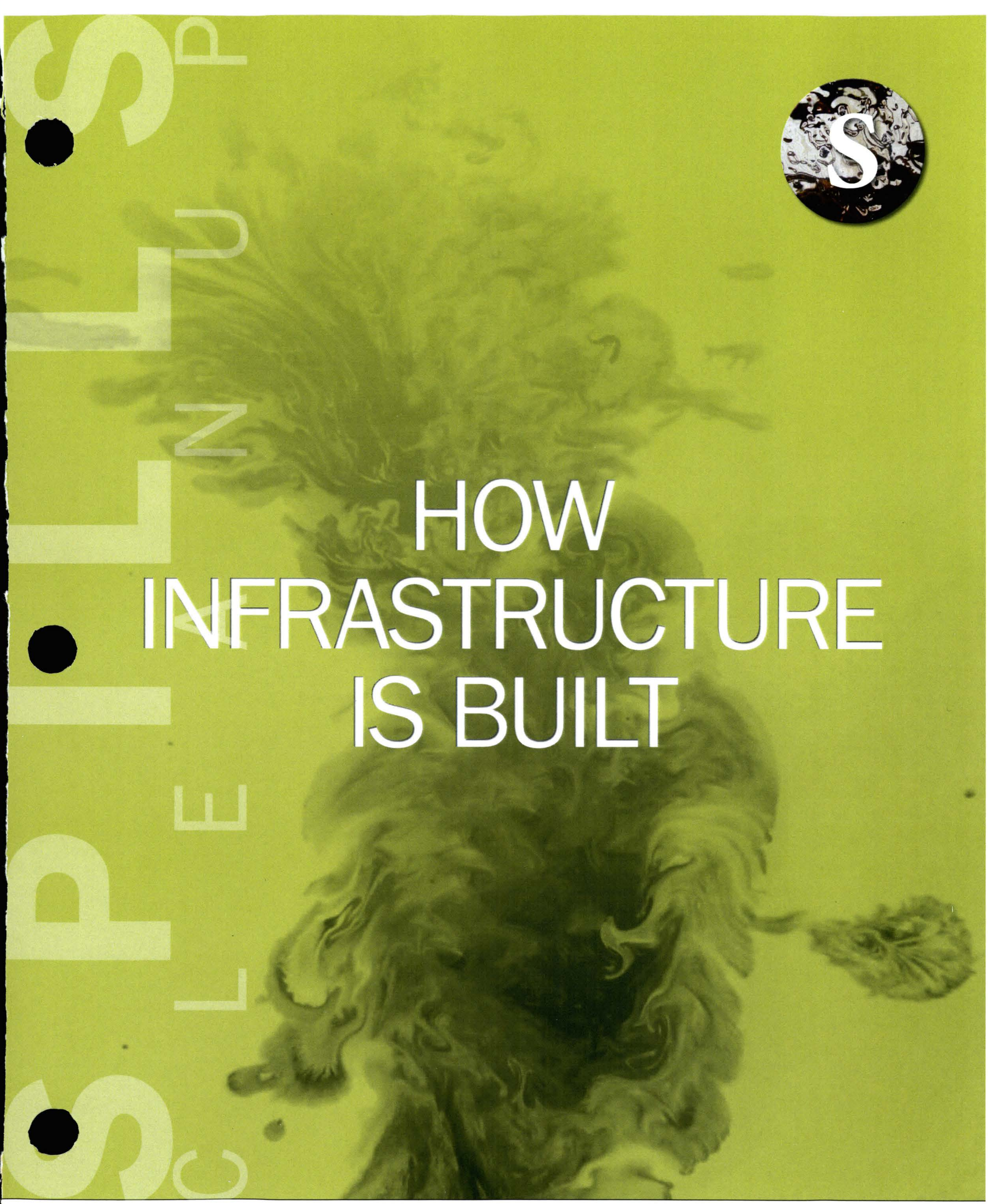
## Regulatory Jurisdiction

**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/.**





# 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.

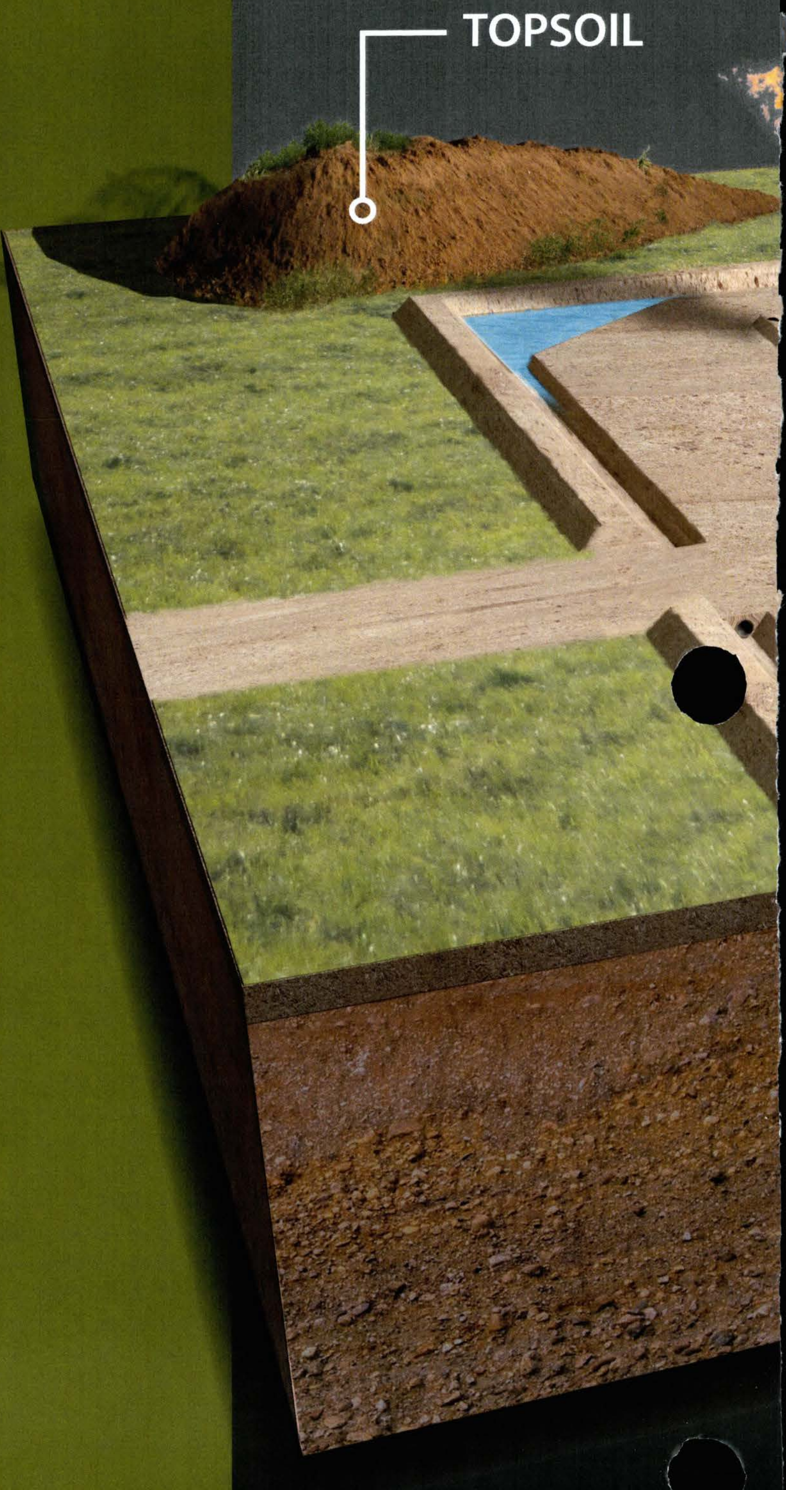
**PERIMETER BERM** – Construction of clay perimeter berms surrounding the entire location provides complete containment on-site.

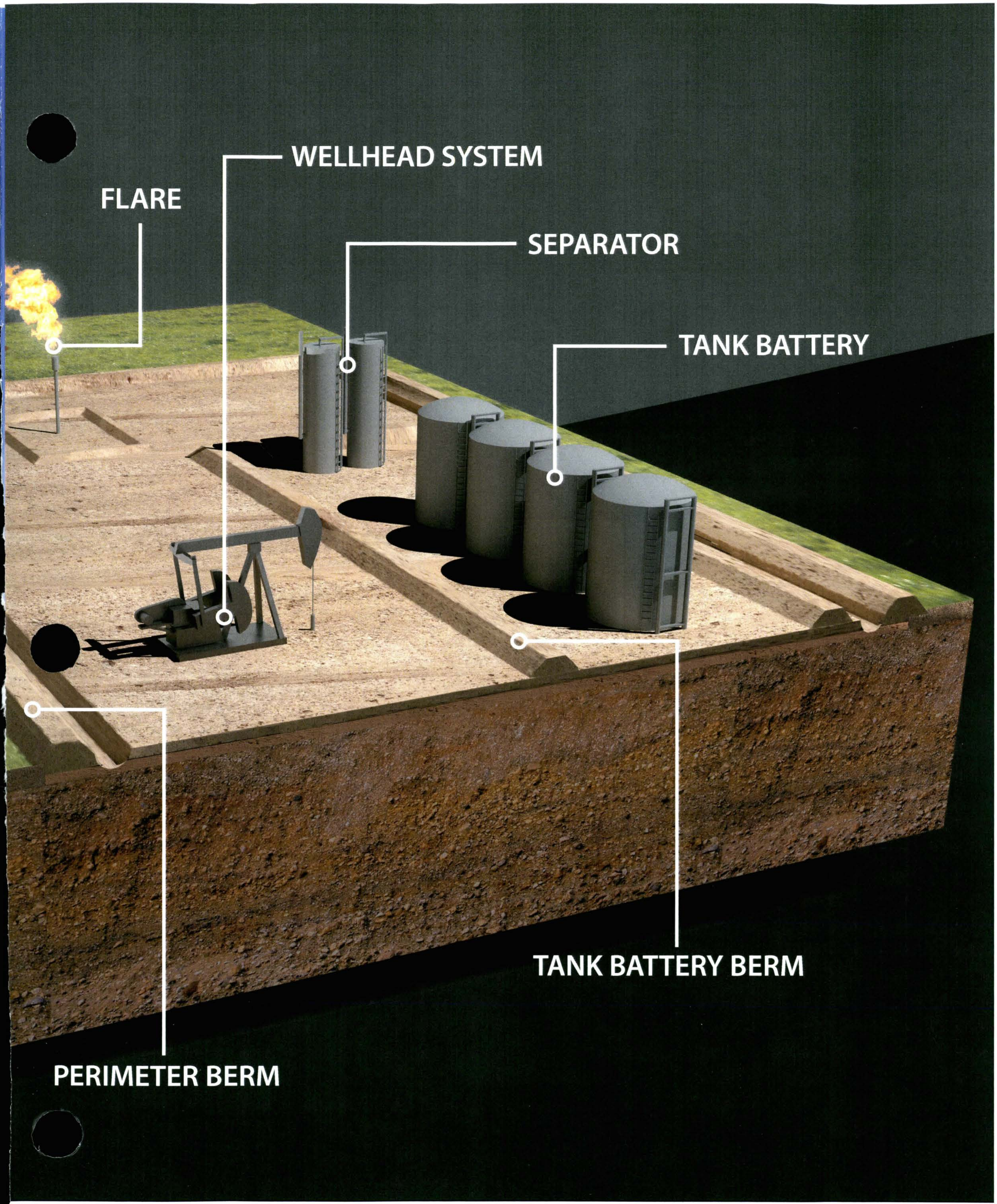
**WELLHEAD SYSTEM** – An interface is installed between the individual casing strings and the blowout preventer (BOP) stack. This interface is required for four main reasons:

- 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.

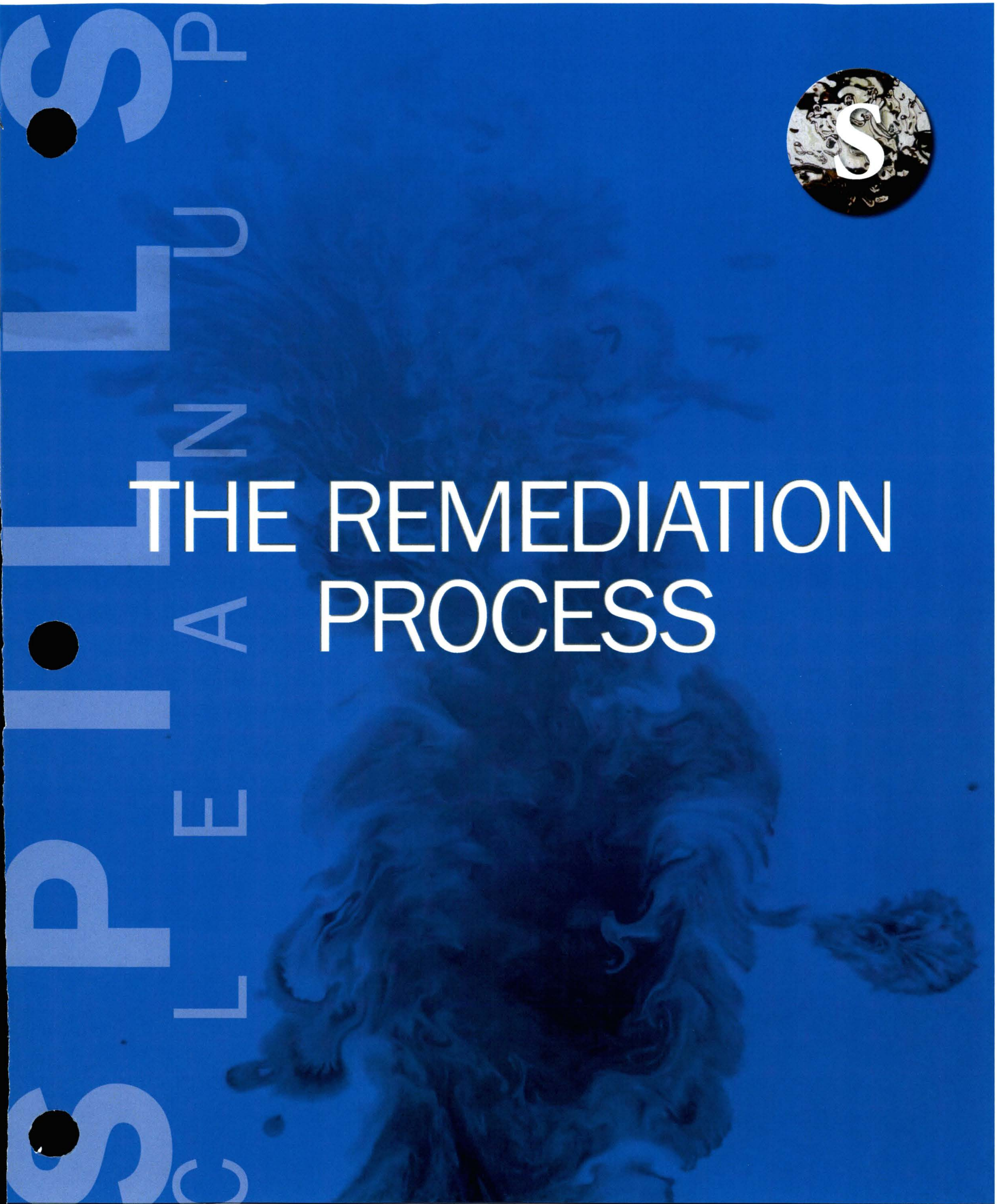
## Interim Reclamation – Production Phase

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.<br>• Less truck traffic.<br>• Preserves native topsoil and subsoil which maintains native soil structure and ecological function. |
| **Cons** | • Remediation and reclamation process can take years to complete.<br>• 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<br>• Adequate nutrients<br>• Adequate oxygen<br>• Adequate moisture<br>• Appropriate pH<br>• 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.<br>• Cost to haul and dispose of hydrocarbon-impacted soil at a special waste landfill.<br>• Potential long-term liability of impacted soil placed in a special waste landfill.<br>• Added expense of replacing the removed soil with uncontaminated topsoil of similar textural class.<br>• The potential introduction of weeds not previously observed at the site prior to the spill.<br>• 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<br>• 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).

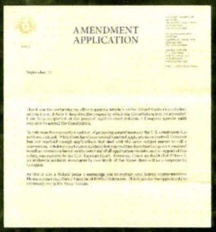
- Perform site investigation to delineate impacts and identify receptors.
- Develop remediation plan with input from regulatory agency and landowner.

**Excavation**

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

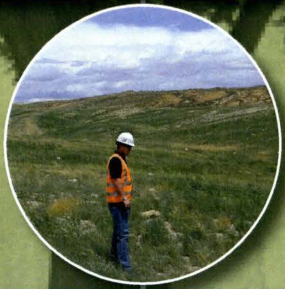
**Remediation**

- Perform remediation.
- Monitor.

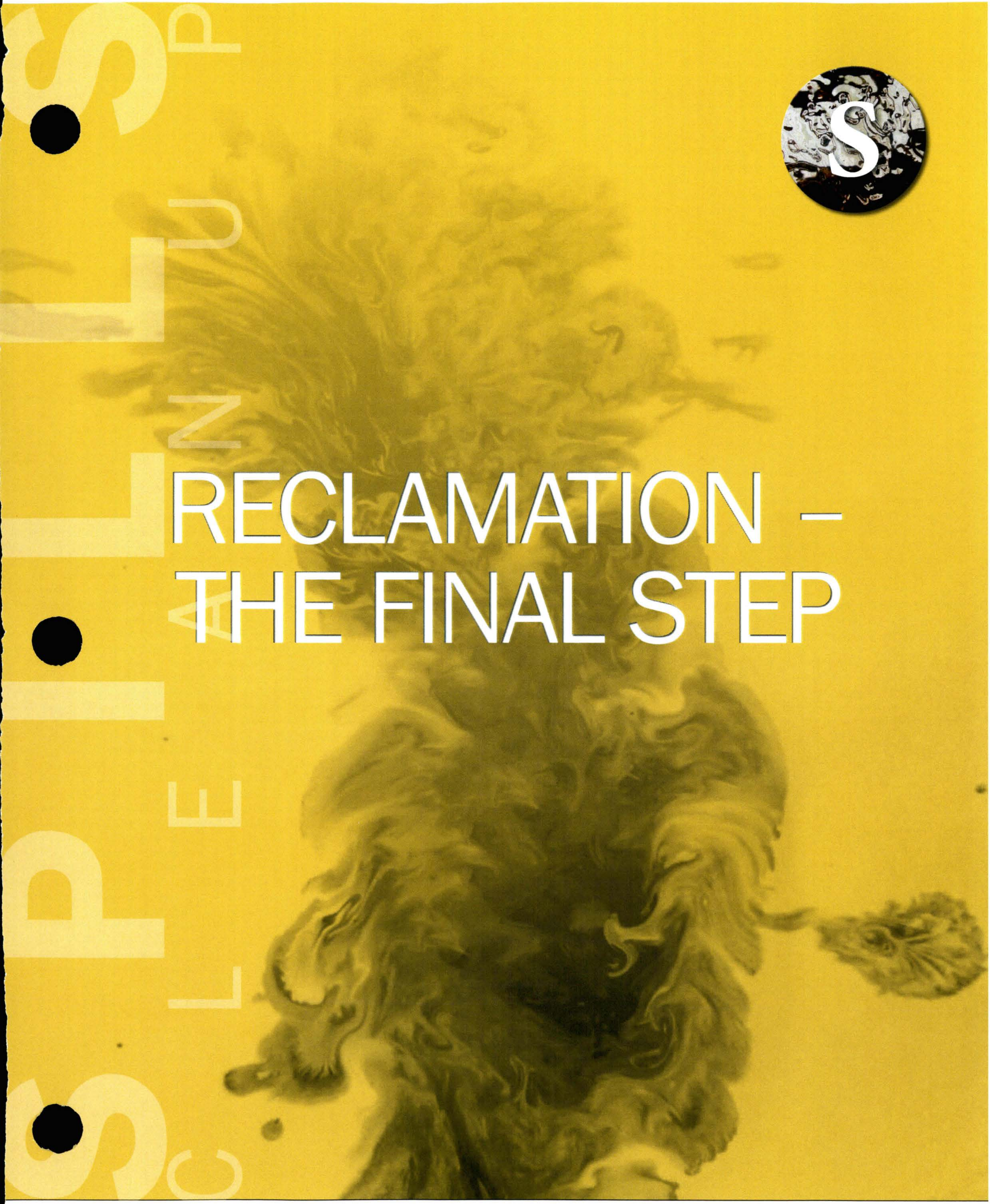


AMENDMENT
APPLICATION

Submit "notice of completion" report to regulatory agency.



"No further action" required by regulatory agency.



# 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

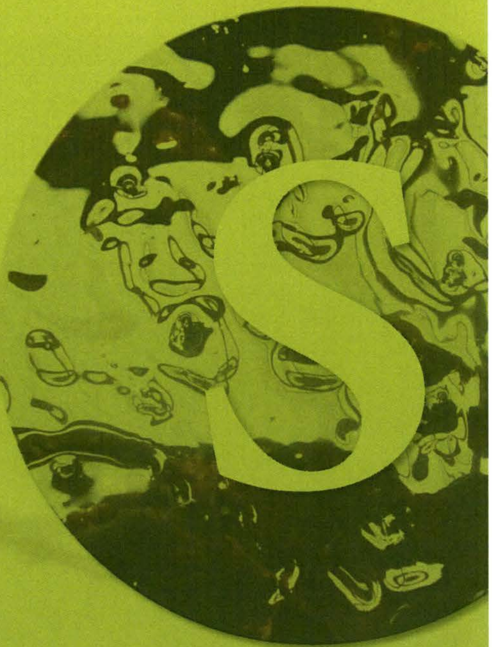
**The North Dakota Industrial Commission Department of Natural Resources Division of Oil and Gas** hosts an informational Web page related to gathering lines (www.dmr.nd.gov/oilgas/mvc/ndgathering/) which also includes an electronic form for submitting gathering line incidents (www.dmr.nd.gov/oilgas/mvc/NDGathering/GatheringIncident/CreateIncident).

**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

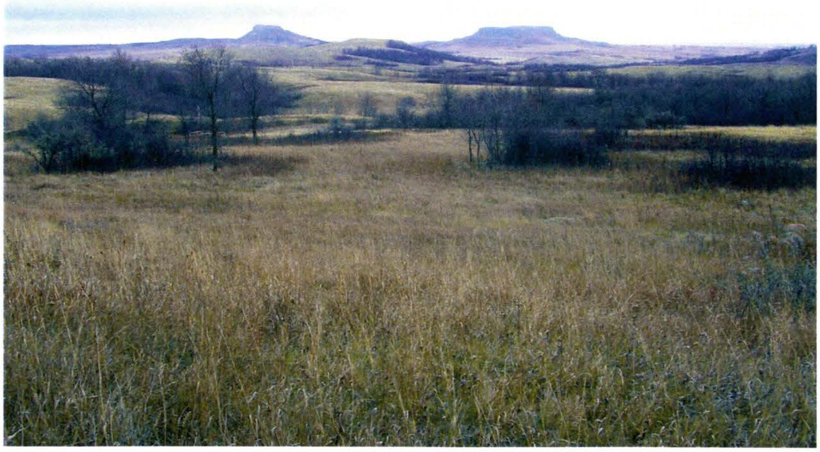
**Native Soil Analysis:** EC = 0.8 mS/cm, pH = 7.2

**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)*

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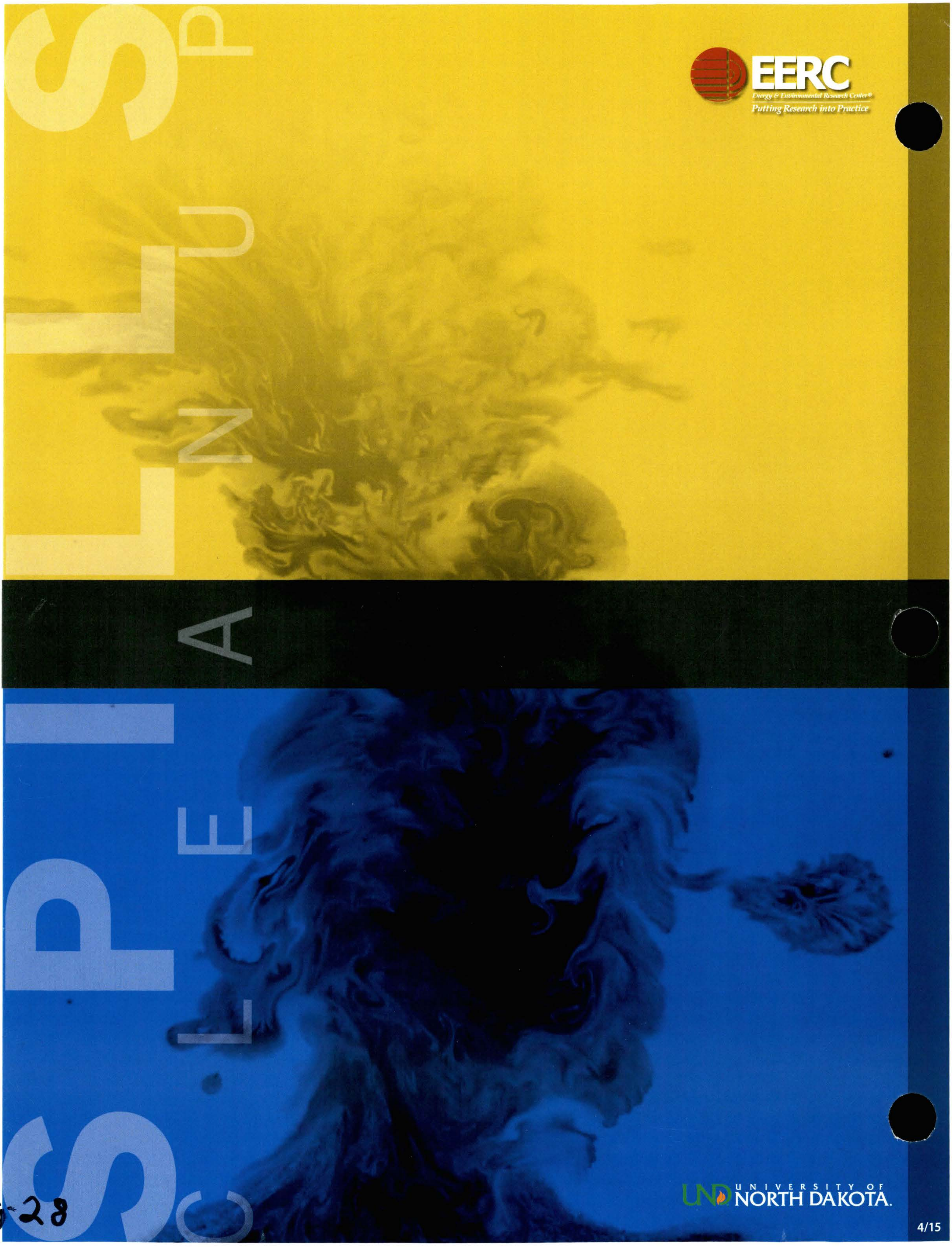

# SPILLS
## CLEANUP

UND UNIVERSITY OF NORTH DAKOTA

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# NORTH DAKOTA REMEDIATION RESOURCE MANUAL

*In Conjunction with:*

WaveLink

North Dakota Petroleum Council

instructables

TheTravelingTrio

BT

Fresh Fire

Swarm

He

*Prepared by:*

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FURTHER, EERC, and each of the contributing authors, reviewers, companies and organizations expressly acknowledge that while the North Dakota Remediation Resource Manual ("Resource Manual") identifies several options for remediation methods and procedures for various types of spills, the Resource Manual is not intended, nor should it be relied upon by any party as *requiring* a specific remediation process for any particular spill event. Recognizing each spill event may require unique or different remediation efforts, together with future technologies and advancements in remediation, any remediation plan, after consultation between the company, landowner, and appropriate state, federal and/or tribal governmental agency having regulatory jurisdiction, should consider any appropriate and relevant factors, options, methods and mitigating circumstances, whether described in the Resource Manual or not.

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## PURPOSE OF THE MANUAL

This manual was created to be a technical resource summarizing remediation techniques and the decision processes associated with selecting remediation options as well as other useful information and should not be assumed to be an all-inclusion summary. This manual is intended for a variety of audiences including but not limited to the following hypothetical users:

- The seasoned environmental professional may utilize this document as a technical resource to be referenced along with their many other resources during hydrocarbon and brine remediation.
- The entry-level environmental practitioner may use this manual as an introductory training and educational tool as they develop remediation experience in the field.
- The general public may use this manual to develop a better understanding of the process of remediating hydrocarbon and brine spills.

Regardless of the user, the content provided in this manual is in no way intended to dictate or prescribe any specific remediation decisions or standardize practices. The specific remediation approach and process can only be done with careful consideration and analysis of site-specific conditions on a case-by-case basis.

## ACKNOWLEDGMENT

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- Brad Stevens, P.E. – Energy & Environmental Research Center

## PROLOGUE

The current version of the resource manual is a product of existing successful practices currently being utilized in the oil fields of North Dakota as well as, but not limited to, the most relevant concepts from previous work by the following:

- American Petroleum Institute
- Environment Sciences Division of Alberta Environment
- U.S. Department of Agriculture
- Kerry Sublette, Ph.D.
- Len Gawel, Ph.D. (work funded by the North Dakota Industrial Commission and Hess Corporation)

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## LIST OF FIGURES

## LIST OF TABLES

# NOMENCLATURE

| | |
|---|---|
| API | American Petroleum Institute |
| BIA | Bureau of Indian Affairs |
| BLM | U.S. Bureau of Land Management |
| BTEX | benzene, toluene, ethylbenzene and xylene |
| C | carbon |
| $Ca^{2+}$ | calcium ion |
| CEC | cation exchange capacity |
| CFR | Code of Federal Regulations |
| cfs | cubic feet per second |
| $Cl^{-}$ | chloride |
| COC | chemical of concern |
| DC | direct current |
| DMR | Department of Mineral Resources |
| DRO | diesel-range organics |
| dS/m | decisiemens per meter |
| E&P | exploration and production |
| EC | electrical conductivity |
| EERC | Energy & Environmental Research Center |
| EM | electromagnetic |
| EPA | U.S. Environmental Protection Agency |
| ESP | exchangeable sodium percentage |
| FBIR | Fort Berthold Indian Reservation |
| GPS | global positioning system |
| GRO | gasoline-range organics |
| $K^{+}$ | potassium ion |
| LEPC | Local Emergency Planning Committee |
| Mcf | thousand cubic feet |
| meq | milliequivalent |
| MHA | Mandan, Hidasta, and Arikara Nation |
| mg/L | milligrams per liter |
| $Mg^{2+}$ | magnesium ion |
| N | nitrogen |
| $Na^{+}$ | sodium ion |
| NDDES | North Dakota Department of Emergency Services |
| NDDH | North Dakota Department of Health |
| NDIC | North Dakota Industrial Commission |
| NDPC | North Dakota Petroleum Council |
| NDSU | North Dakota State University |
| $NO_3^{-}$ | nitrate |
| NRC | National Response Center |

Continued. . .

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## NOMENCLATURE (continued)

| | |
|---|---|
| P | phosphorus |
| PEI | precipitation evaporation index |
| pH | potenz hydrogen |
| PID | photoionization detector |
| ppb | parts per billion |
| ppm | parts per million |
| QA | quality assurance |
| QC | quality control |
| RCRA | Resource Conservation and Recovery Act |
| SAR | sodium adsorption ratio |
| SARA | Superfund Amendments and Reauthorization Act |
| SDS | safety data sheet |
| $SO_4^{2-}$ | sulfate |
| SPCC | spill control and countermeasure |
| TDS | total dissolved solids |
| TPH | total petroleum hydrocarbons |
| UND | University of North Dakota |
| USFS | U.S. Forest Service |
| WOTUS | Waters of the United States |

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## DEFINITION OF TERMS

**active site:** A description of a site where activities are being performed in association with the investigation, assessment, and remediation of a spill.

**adsorption:** The electrostatic attraction of ions or compounds to a surface (i.e., nutrients in solution [ions] carrying a positive charge become attached to [adsorbed by] negatively charged soil particles).

**aeration:** The process by which air in the soil is replaced by air from the atmosphere. The rate of aeration depends largely on the size, volume, and continuity of pores from the surface and within the soil. Compaction, sodic-induced clay dispersion, and texture have a direct influence on aeration.

**aerobic:** Processes that occur only in the presence of molecular oxygen, i.e., aerobic decomposition.

**aggregation (as in soil):** A description of soils where the fine particles are bonded together, usually with humus, in a single mass or cluster.

**A horizon:** A mineral soil horizon formed at or near the surface in the zone of removal of materials in solution and suspension or maximum in situ accumulation of organic carbon or both.

**alkali soil:** 1) A soil with a high degree of alkalinity (pH of 8.5 or higher), a high exchangeable sodium content (15% or more of the exchange capacity), or both. 2) A soil that contains sufficient alkali (sodium) to interfere with the growth of most crop plants.

**anion:** A negatively charged ion (i.e., chloride [$Cl^-$] and sulfate [$SO_4^{2-}$]).

**B horizon:** A mineral soil horizon characterized by one or more of the following:

1. An enrichment in silicate clay, iron, aluminum, or humus.
2. A prismatic or columnar structure that exhibits pronounced coatings or staining associated with significant amounts of exchangeable sodium.
3. An alteration by hydrolysis, reduction, or oxidation to give a change in color or structure from the horizons above or below or both.

**bioremediation:** A process by which naturally occurring or deliberately introduced organisms in the soil consume and break down soil contaminants.

**brine:** Water produced in the extraction of oil and gas, typically high in sodium chloride. Commonly considered water with total dissolved solids (TDS) >30,000 mg/L. Also referred to as produced water.

**bulk density:** The mass of dry soil per unit bulk volume, expressed in grams per cubic centimeter. Soil compaction increases the bulk density of soil and can impact soil porosity, water infiltration, and root penetration.

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**cation:** A positively charged ion (i.e., sodium [$Na^+$], calcium [$Ca^{2+}$], magnesium [$Mg^{2+}$], and potassium [$K^+$]).

**cation exchange capacity:** The total amount of exchangeable cations that can be adsorbed or held by the soil, expressed in terms of milliequivalents per 100 grams of soil at pH 7.0 or at some other stated pH value.

**C horizon:** A mineral soil horizon comparatively unaffected by the soil formation processes operative in A and B horizons, except gleying and the accumulation of carbonates and soluble salts.

**colloidal material:** Organic and inorganic matter with very small particle size and a correspondingly large surface area per unit mass that does not go into solution as salts do.

**chemical of concern:** Specific chemicals, whether they be hydrocarbon, or brine compounds or both, that are identified as potentially persisting or having an impact to the environment.

**diesel-range organics:** Laboratory analysis that quantifies the hydrocarbons present in a sample with carbons ranging from C10 to C28.

**dispersion (as in soil):** The breaking down of soil aggregates into individual particles. A description of soil in which the clay has dispersed. A dispersed soil consists of discrete soil particles that are not bonded together and are highly erodible. Dispersion is the opposite of aggregation.

**electrical conductivity:** A measure of how well a substance conducts electricity. It is a measure of the amount of soluble salts (salinity) in a soil, expressed in dS/m.

**exchangeable sodium percentage:** The extent to which the adsorption complex of a soil is occupied by sodium or the amount of exchangeable sodium expressed as a percentage of total exchangeable cations (Equation 1):

$$\mathrm{ESP} = \frac{\text{Exchangeable Sodium (meq/100 g soil)}}{\text{Cation Exchange Capacity (meq/100 g soil)}} \times 100 \qquad \text{[Eq. 1]}$$

The approximate relationship between the ESP and the SAR at equilibrium can be calculated as follows (Equation 2):

$$\mathrm{ESP} = \frac{100\,(-0.0126+0.01475\ \mathrm{SAR})}{1+(-0.0126+0.01475\ \mathrm{SAR})} \qquad \text{[Eq. 2]}$$

**field capacity:** The amount of soil water remaining in a soil after the free water has been allowed to drain away (1 or 2 days) after the root zone has been previously saturated. It is the greatest amount of water that the soil will hold under conditions of free drainage and is related to the saturated paste extract.

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**gasoline-range organics:** Laboratory analysis that quantifies the hydrocarbons present in a sample that have carbons ranging from C6 to C12.

**gleyed soil:** Soil that formed under poor drainage, resulting in the reduction of iron and other elements in the profile and in gray colors and mottles.

**groundwater:** Subsurface water that fills the pore space of the soil to the extent that it is considered water-saturated.

**halophytes:** Plants that are highly tolerant of saline conditions.

**hydraulic conductivity:** The rate at which water will move through soil under a unit hydraulic gradient.

**hydraulic gradient:** The change in hydraulic head per unit distance. In groundwater this would be the slope of the groundwater table.

**illuviation:** The introduction of salts or colloids into one soil horizon from another by percolating water.

**in situ remediation:** A description of remediation that is performed on soil and/or water in place without requiring removal of the material to treat the impacted material.

**landfarming:** A bioremediation process where an environment is created to allow naturally occurring or deliberately introduced organisms in the soil to break down hydrocarbons (primarily in an aerobic environment). This is accomplished by incorporating nutrients, amendments, and oxygen in the soil with tillage while maintaining adequate moisture.

**milliequivalent (meq):** one-thousandth of the equivalent weight of an element, radical, or compound. Concentrations of electrolytes are often expressed as milliequivalents per liter, which is an expression of the chemical combining power of the electrolyte in a fluid.

**natural attenuation:** The reduction of contamination toxicity due to natural processes over time, including dispersion, dilution, sorption, and biodegradation.

**no further action:** A description of site status where sufficient remediation has been performed at the site such that the state regulatory agency deems there is no risk to receptors.

**osmotic pressure:** A term describing the pressure created when unequal salt concentration develops between two bodies. Water will move from the area of higher salt concentration to the area of lower concentration.

**percent sodium:** The percentage of the CEC occupied by sodium.

**perched groundwater:** Unconfined groundwater that is separated from an underlying body of groundwater by an unsaturated zone and a confining bed.

**permeability:** A measure of the ability for water or air to move through a soil profile. It is dependent on grain size, pore size, fracture size, and orientation but is not dependent on fluid viscosity and density like hydraulic conductivity.

**pH:** A measure of the degree of acidity or alkalinity of a soil. Expressed in terms of the pH scale ranging from 0 to 14 ($pH < 7$ being acidic, $pH = 7$ being neutral, and $pH > 7$ being basic or alkaline).

**photoionization detector:** A field instrument used to detect and measure certain petroleum hydrocarbon vapors.

**phytoremediation:** The specific use of plants and their associated microorganisms to reduce contamination in soils, surface water, and groundwater.

**pore space:** Total space not occupied by soil particles in a bulk volume of soil, commonly expressed as a percentage.

**porosity:** The volume percentage of the total bulk volume not occupied by solid particles.

**produced water:** See *brine*.

**receptor:** A term used to describe a person, plant, animal, or environment that could be adversely affected by a release of petroleum or brine.

**reclamation:** The process of returning disturbed land to a natural productive ecosystem or economically usable purpose.

**remediation:** Removal, conversion, or concentration reduction of contaminants from soil or water by physical, mechanical, or biological methods to minimize the impacts of these contaminants to the environment.

**saline:** Having elevated concentrations of salts (i.e., Ca, Mg, Na, K, Cl, $NO_3$, and $SO_4$).

**saline soil:** Nonsodic soil containing sufficient soluble salts to impair its plant growth productivity. Commonly considered to be soil that exhibits a saturated paste extract EC >4 dS/m and a pH <8.5.

**saline–sodic soil:** Soil that contains sufficient exchangeable sodium to interfere with the growth of most crop plants and also contains appreciable quantities of soluble salts. Commonly considered to be soil with a sodium adsorption ratio >13 (ESP >15%) and a saturated paste extract EC >4 dS/m.

**salinity:** A term describing water solutions containing dissolved solids.

**saturated paste:** A mixture of soil and water that occurs when all soil pores are just filled with water. At saturation, the soil paste glistens as it reflects light and flows slightly when the container is tipped. The paste slides freely and cleanly from a spatula for all soils except those with high clay content. In undersaturated soil, deionized water is added to the soil sample with minimal mixing

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until all soil pores are filled with water and there is negligible air in the pores. The saturated paste moisture content is directly related to the field percent moisture range between permanent wilting and field capacity. It is useful as a reference because it represents the actual concentration and ratios of dissolved constituents available for uptake by plant roots.

**saturated paste extract:** Soil pore water containing dissolved constituents (soluble salts) that have been removed from the saturated paste with a suction filter for analysis.

**sodicity:** Sodium concentration.

**sodium adsorption ratio:** A measure of the sodic content of soil, expressed empirically as (Equation 3):

$$\mathrm{SAR} = \frac{[\mathrm{Na}]}{\sqrt{(([\mathrm{Ca}]+[\mathrm{Mg}])/2)}} \qquad \text{[Eq. 3]}$$

**sodic soil:** Soils that contain sufficient sodium to interfere with the growth of most crop plants. Commonly considered to be soil that exhibits a SAR ≥13 (ESP ≥15%). Also referred to as alkali soil.

**soluble salts:** Determined by EC as measured in the extracts from saturated paste, 1:1 or 1:5 extracts (soil:water). The reliability of salinity estimates based on the conductivity of 1:1 and 1:5 extracts depends upon the kind of salts present. Highly soluble chloride salts will be only slightly affected by solutions with higher moisture content. In salts with lower solubilities such as sulfate or carbonate salts, the apparent amount of soluble salts (EC) will be higher in soils with higher moisture content.

**subsoil:** The B horizon of soils with distinct illuviation. Located below the A horizon and normal plowing depth, it is very important for rooting depth, soil moisture, and fertility.

**subsoiling:** The tillage of subsurface soil (subsoil) without inversion, for the purpose of breaking up dense layers that restrict water movement and root penetration.

**surface soil:** The uppermost part of the soil often mechanically affected by tillage in cultivated soils ranging in depth from 5 to 8 inches. Frequently designated as the plow layer (Ap) or the A horizon.

**tile drain:** Pipe made of perforated flexible plastic pipe to collect and carry excess water from the soil to a sump or other drainage feature. Usually laid at depths between 1 and 5 feet and spaced laterally depending on soil texture and horizonation.

**total dissolved solids:** Mineral matter suspended and dissolved in solution which passes a standard glass filter and 0.45-µm filter and does not evaporate below 180°C. Generally used as a gross indicator of the mass of dissolved salts in a solution, but the analytical method is subject to interferences from colloidal material.

**total petroleum hydrocarbons:** A measure of the quantity of oil-related compounds in a given quantity of soil.

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# NORTH DAKOTA REMEDIATION RESOURCE MANUAL

## INTRODUCTION

**Man—despite his artistic pretensions, his sophistication, and his many accomplishments—owes his existence to a six inch layer of topsoil and the fact that it rains." –** ***Author Unknown***

The "North Dakota Remediation Resource Manual" is dedicated to the North Dakota landowner. It was the landowner who asked that remediation, especially for saltwater spills, be an option for returning the topsoil back as close to original productivity as possible. The oil and gas industry of North Dakota, having been engaged in spill response efforts for decades and recognizing the value of topsoil as a nonrenewable resource, was receptive to landowner desires, recognizing the importance of landowner relationships in resource development.

**"The Nation that destroys its soils destroys itself." –** ***President Franklin D. Roosevelt, February 26, 1937***

In 2013, members of the North Dakota Petroleum Council (NDPC) created a working group to collaborate with the Energy & Environmental Research Center (EERC) to create two documents: a public education booklet entitled "Spills Cleanup Primer" and this document, the "North Dakota Remediation Resource Manual."

Media across North Dakota have done their part to shape public perception of spills. Some perceptions of spills include the idea that spills are common, produced water is laden with metals and other harmful chemicals, and once a spill occurs, the soil and surrounding land is ruined forever.

Based on data from the North Dakota Department of Mineral Resources (DMR), only 0.01% of the produced water (brine) or oil volume produced is ever involved in a spill, and 75%–80% of spills are contained on the well pad. In addition, remediation techniques have evolved to put the land back to its previous productivity in a shorter time period and more effectively than ever before, many times within one season.

**As early as 1760, George Washington used crushed limestone, manure, and gypsum fertilizers and plowed crops of grass, peas, and buckwheat back into his fields.**

The method of remediation is determined by the type of spill—hydrocarbon, brine, or other—as well as the site conditions, soil type, and risk to public and environment. Once remediation has been performed, surface reclamation is undertaken to reestablish vegetation. Although complete restoration is the goal of everyone involved in the spill remediation process, it should be recognized by all that remediating the impacted land back to its original, prespill condition may not be achievable.

This document was prepared to aid those involved in the remediation and reclamation of sites impacted by oil field-related spills. Remediation information included in this document is for spills limited to soil impacts and does not address remediation related to groundwater impacts. In addition, the information is specific to the execution of these activities in North Dakota and may not be wholly applicable to other areas of the country.

This Resource Manual is organized much like an instruction manual or reference document with distinct sections for different topics (listed below). This manual is based on practical, reproducible, and field-friendly procedures. The document is prepared so that users can reference individual sections specific to their needs without requiring them to read the entire document. The NDPC, and those whose efforts this manual represents, are assured that technology advancement in the future will create additional options for more effective remediation and this manual will be revised to incorporate those technological advances. The distinct sections are as follows:

- Introduction: page 1
- Spill Reporting: page 3
- Site and Spill Evaluation: page 6
- Risk Assessment: page 13
- Data Interpretation: page 15
- Remediation Options – Hydrocarbon Impacts: page 18
- Remediation Options – Brine Impacts: page 22
- Postremediation Monitoring and Site Closure: page 26
- References: page 30
- Appendix A – Field Forms
- Appendix B – Field Screening Methods
- Appendix C – Laboratory Methods
- Appendix D – Seed Mix Information for Disturbed and Hydrocarbon-Impacted Areas
- Appendix E – Salt-Tolerance Information of Grasses, Forbs, and Legumes
- Appendix F – Salt-Tolerance Information of Agronomic Crops
- Appendix G – Useful Information
- Appendix H – API Information and Worksheets

### Regulation Overview

Spill remediation and reclamation regulations, for the most part, are at the discretion of the various regulatory agencies. North Dakota Industrial Commission (NDIC) regulations require operators to respond with appropriate resources to contain and clean up spills. Discharged fluids must be properly and promptly removed unless otherwise approved. Remediation standards are determined on a case-by-case basis, depending on the contaminant involved and the potential for risk to human health and the environment.

Depending on the severity of the spill or accidental discharge, the North Dakota Department of Health (NDDH) may require the owner or operator to do one or all of the following:

- Take additional actions necessary to protect human health and the environment.

- Take immediate remedial measures.

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- Determine the extent of pollution to waters of the state.
- Provide alternate water sources to water users impacted by the spill or accidental discharge.

Depending on if federal lands are impacted and what agency governs the remediation efforts, reclamation requirements will vary. As indicated below in spill reporting, for tribal lands in North Dakota, the MHA (Mandan, Hidatsa, and Arikara Nation) Energy Division requires preapproval for spill remediation activities. The U.S. Forest Service (USFS) dictates activities on Forest Service lands.

## SPILL REPORTING

Spill reporting varies based on the spill volume, severity of the impacts, and site location. These variables determine when/what agencies will respond to an event. A breakdown of who needs to be contacted depending on these mentioned variables is provided in Figure 1.

### A. State Spill Reporting

In general terms, the NDIC requires verbal and online spill reporting based on specific spill volume thresholds and timelines. Spills impacting waterways must be reported to NDDH or the North Dakota hazardous materials emergency assistance and the North Dakota Department of Emergency Services (NDDES). Additional reporting requirements exist throughout the remediation/reclamation process. Additional notifications may be required depending on location and spill impact. See Figure 1 for the North Dakota Release Notification Procedure Flowchart for further information. See Appendix A for an example of a spill response notification form as well as other useful field forms. For details regarding spill reporting volume thresholds and timelines, as well as other pertinent information the user should access the Website below or contact the state agencies listed below.

**Online Initial Notification Report:**
www.dmr.nd.gov/oilgas/mvc/wincident/

**North Dakota Industrial Commission:**
Oil and Gas Division
(701) 328-8020

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

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

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### B. Federal Mineral Impact

Any well impacting federal royalties, whether on federal or private land, is subject to Bureau of Land Management (BLM) reporting regulations. For details regarding spill reporting volume thresholds and timelines, as well as other pertinent information the user should access the Website below or contact the BLM.

**Bureau of Land Management:**
(701) 227-7700
North Dakota Field Office
99 23rd Avenue West, Suite A
Dickinson, ND 58601

**Notice to Lessees and Operators of Onshore Federal and Indian Oil and Gas Leases (NTL-3A – Reporting of Undesirable Events):**
www.blm.gov/style/medialib/blm/mt/blm_programs/energy/oil_and_gas/operations/ntls.Par.36263.File.dat/ntl3a.pdf

### C. Tribal Land Impact

Spills occurring on tribal land have additional requirements from those state or federal requirements. For details regarding spill reporting volume thresholds and timelines, as well as other pertinent information the user should access the Website below or contact the MHA Energy Division.

**MHA Energy Division:**
(701) 627-5154
Compliance Department
227 West Main Street
New Town, ND 58763

**MHA Energy Division: Accidental Release or Spill Requirements:**
www.mhanation.com/main2/departments/mha_energy_division/mha_energy_website/Information%20Spill%20Response%20Requirements.pdf

### D. Federal Reportable Spills

Any operator responsible for a release or spill is required to notify the federal government when the amount reaches a federally determined limit. See chemical-specific safety data sheets (SDS) for reportable quantity. For petroleum hydrocarbons, discharges in such quantities that have been determined may be harmful to the public health or the environment must be reported to the National Response Center (NRC) if one of the following occurs:

1. Spill reaches navigable water or direct tributaries/adjoining shorelines
2. Discharge violates water quality standards
3. Discharge leaves a sludge or emulsion beneath the surface

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**EPA National Response Center:**
(800) 424-8802

**EPA Region 8:**
(303) 312-6384 or (800) 227-8917
8OC-EISC
1595 Wynkoop Street
Denver, CO 80202-1129

**EPA Reporting Requirements:**
www2.epa.gov/emergency-response/reporting-requirements-oil-spills-and-hazardous-substance-releases

### E. Other Reporting

Depending on the location and magnitude, USFS, U.S. Army Corps of Engineers if the spill impacted waters of the United States (WOTUS), affected landowners, and local community agencies must also be notified. USFS will oversee any remediation activities on USFS land. For spills occurring close to a community, the Local Emergency Planning Committee (LEPC) and fire department may need to be contacted to respond to the incident. Through annual Tier II reporting, LEPC and the fire department have already been made aware of what hazardous chemicals are located within their counties.

**USFS:**
(701) 250-4443
Supervisor's Office
240 West Century Avenue
Bismarck, ND 58503

**LEPC Contact List:**
www.nd.gov/des/uploads%5Cresources%5C815%5Cnd_em_list_9-23-2015.pdf

**Fire Department Contacts:**
www.nd.gov/des/uploads%5Cresources%5C667%5Cfiredeptlisting.pdf
As part of emergency response plans, operators should have spill or incident response notification forms. These forms can be used as a resource during an event to track who was contacted when and what response efforts are already under way.

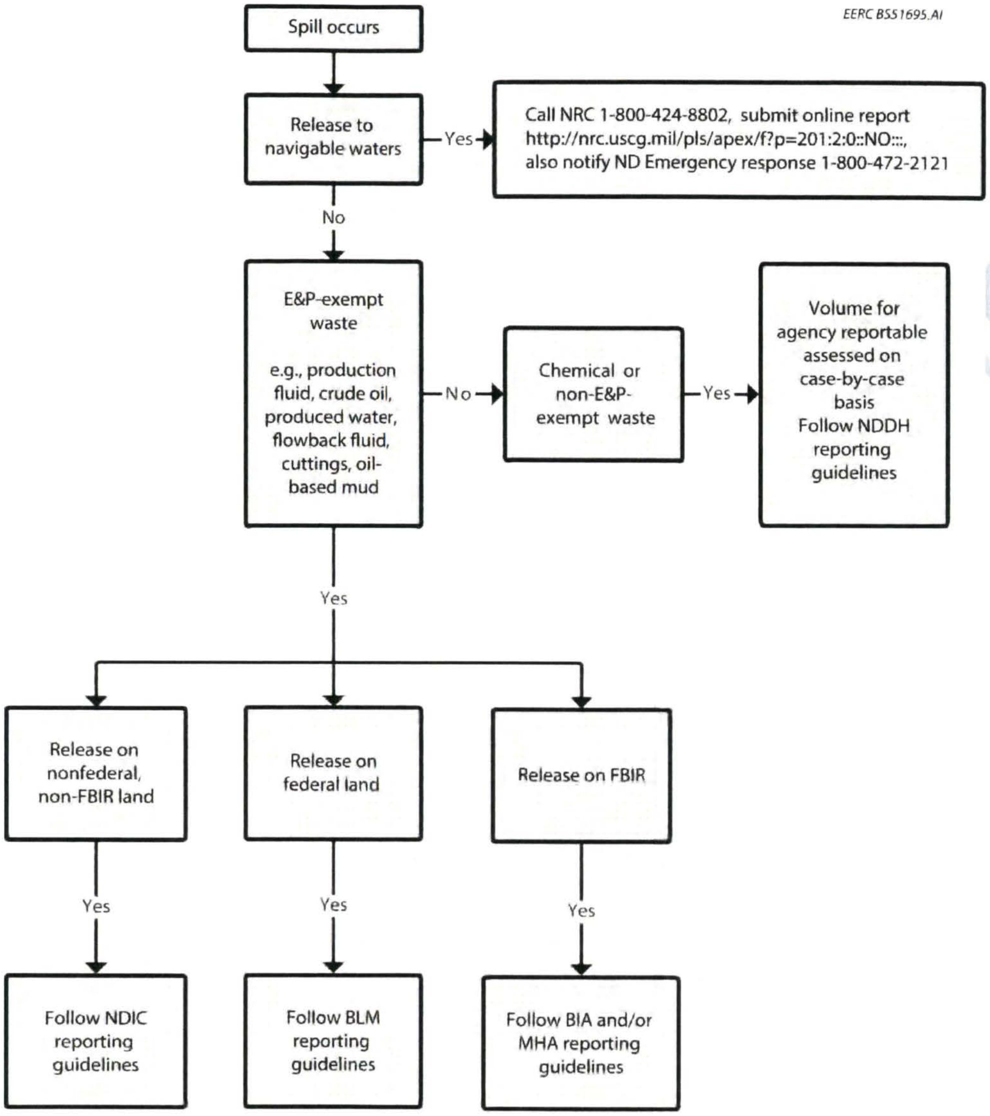

Figure 1. North Dakota release notification procedures.

## SITE AND SPILL EVALUATION

### Impact of Hydrocarbons on Soil

Crude oil is a complex mixture of organic compounds of which greater than 95% is carbon and hydrogen (Pinnella and Alstad, 2013). Crude oil from the Bakken and Three Forks Formations has an American Petroleum Institute (API) gravity of approximately 42 and is classified as a light sweet crude. McMillan and others (2002) report that crude oils with API gravity greater than 20 are readily biodegradable.

The impact of hydrocarbon spills can vary but is largely a function of the following factors (Pinnella and Alstad, 2013):

- Spill volume
- Type of crude oil (density, viscosity, and interfacial tension)
- Dispersion rate
- Surface terrain
- Soil type (porosity and permeability)
- Weather

Once introduced to the environment, hydrocarbons can volatilize, adsorb to soil particles, dissolve into soil pore water, or remain as free product (Spence and others, 2001).

### Impact of Salt on Soil

Process water brine, when released into the environment, can have a detrimental effect on soil both chemically and physically. This occurs by increasing the amount of salts in the soil (salinity) and by the total sodium concentration (sodicity). Depending on the amount of salts or sodium in the brine, saline, saline–sodic, or sodic soil conditions may result. The different classifications each have specific mitigation requirements.

Typically, saline–sodic soil conditions will be present following a brine spill; as such, saline–sodic soils will be covered in this document. Soil is classified as saline–sodic when the electrical conductivity (EC) is greater than four decisiemens per meter (dS/m), the pH greater than 8.5, and the sodium adsorption ratio (SAR) greater than 13 (unitless).

There are three major impacts on soil and plants when saline–sodic conditions are present:

1. Soil particles are dispersed reducing soil aggregation (**sodic soil**)
2. Osmotic potential inhibits the plant's ability to uptake water (**saline soil**)
3. Ionic imbalance of the soil solution reducing nutrient absorption (**saline–sodic soil**)

One of the major impacts of a brine spill is the physical destruction of the soil aggregates by dispersion and swelling. Dispersion/swelling can occur when the sodium ion occupies more than 15% of a clay particle's exchange sites and when the total EC in the soil solution is low (note dispersion and swelling are dependent on the clay mineralogy and content, organic matter, and soil moisture among other field conditions). The summations of the total number of clay exchange sites and exchange sites from organic matter are referred to as the clay's cation exchange capacity (CEC). When brine, dominated by the sodium ion ($Na^+$) of the sodium chloride molecule, is released into the environment in elevated concentrations, the $Na^+$ is more available to the clay exchange sites due to "mass action" than are the other common ions (calcium [$Ca^{2+}$] and magnesium [$Mg^{2+}$]), resulting in an ion imbalance. When these conditions are present, the $Na^+$ ion is able to exchange with a sufficient number of the $Ca^{2+}$ and $Mg^{2+}$ ions on the clay particles. The $Na^+$ is a larger ion and has a weaker valence charge than $Ca^{2+}$ and $Mg^+$; therefore, it has a weaker hydrated bonding strength. Basically, $Na^+$ prefers to be hydrated (surrounded by water), and Ca and Mg prefer to be coordinated (bound) to the clay layer, thus keeping the soil clay flocculated (held together). The general order of exchangeability of some important hydrated exchangeable cations is as follows:

$$\mathrm{Al^{3+} > Ca^{2+} > Mg^{2+} > K^{+} = NH_4^{+} > Na^{+}}$$

These conditions result in the physical destruction of the soil aggregate and clogging of soil pores. Figure 2 shows the process of dispersion/swelling. The potential dispersion of impacted soil can be determined by the exchangeable sodium percentage (ESP), SAR, or the percent of the $Na^+$ in the soil solution.

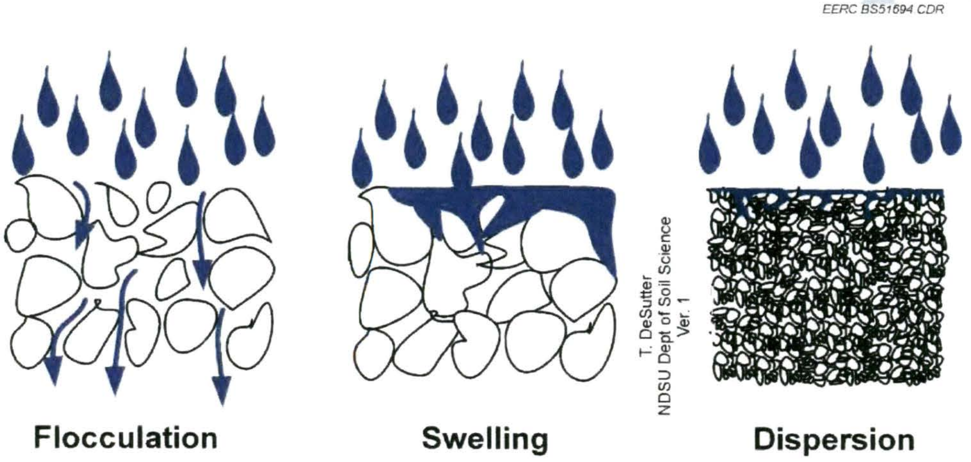

Figure 2. Example of dispersion in sodium-impacted soil.

1. Soil Dispersion

Soil dispersion/swelling results in:

- Loss of soil structure
- Loss of pore structure
- Soil compaction
- Reduced infiltration of precipitation or irrigation waters
- Reduced air and water movement
- Reduced bioactivity
- Reduced nutrient transfer
- Increased water runoff and soil erosion

2. Osmotic Potential

Salts decrease the soil's osmotic pressure and can starve plants of water if the pressure drops below the osmotic pressure of the plant roots (i.e. an osmotic gradient away from the plant root). The restoration of soil aggregation becomes very important to decrease the salinity. Because of the major impact of $Na^+$ in the soil root zone, the remediation process is focused on restoring the soil

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aggregation. When the soil aggregation is restored, soil water is able to percolate through the soil profile and carry soluble salts from the plant's root zone deeper into the soil profile or to an artificial recovery system (tile) for recovery and disposal, thus decreasing the salt concentration/EC within the rooting zone.

Also, brine contamination can negatively impact soil microbe communities by lowering the osmotic potential of soil water and preventing cell growth/division (Emerson and Breznak, 1997). Similar to plant roots, soil microbes will experience water loss of cells in high saline conditions. Soil microbe and plant root symbiosis is important for nutrient cycling.

1. Ionic Imbalance of Soil Solution

Depending on the chloride concentration among other negatively charged ions in the released brine, chloride can have a direct toxicity effect on plants. Sensitivity of different plant species to the ions in the brine solution will vary (refer to Appendices E and F for plant species tolerance levels). The chloride and other negatively charged ions are highly mobile in soil solution and, consequently, can percolate below the root zone of most perennial plants under normal annual precipitation conditions (12–14 inches of rain) in parts of North Dakota. It should be noted that to ensure that brine impacts remain below the root zone, sufficient water, either natural or introduced, must be applied to the site to translocate salts deep in the soil. Without sufficient translocation via applied waters, salts will likely move back into the root zone via capillary rise.

It is important to note that in the remediation process it is very important to treat the soil as soon as possible. Rain on the spill site before it has been amended with a calcium-based product will increase the potential for soil dispersion and clogging of soil pores, thus sealing pores and limiting water infiltration/movement.

### Spill and Site Assessment

When a sampling plan is developed, it is important to consider the unique nature of the spill and complexity of the site. Soil sampling, coupled with field and laboratory analysis, can provide accurate information on the extent and severity of the brine contamination if samples are taken, handled, and analyzed correctly. Sampling and analysis can provide information on depth and lateral extent of salt contamination, type, age, source, and concentration of salts in soil. It can also be used to confirm whether other contaminants such as hydrocarbons or metals are present in the soil. Users should consider, the following when developing a sampling plan.

### Sampling Strategy

First, conduct a paper or electronic search for the area of interest (landowner/operator interviews, historical aerial photographs, Web Soil Survey), identify all potential sensitive receptors, and then conduct a visual site assessment. This could include a geophysical survey (electromagnetic [EM] induction survey) or soil sampling which can be used to indicate variability of salt distribution and document site characteristics and distance to sensitive receptors. A more detailed discussion regarding the use of EM induction is included later in the "Geophysical Survey" section.

Once the site features have been documented, develop a systematic sampling strategy. This could include a consistent grid pattern, transects, or a stratified random sample selection. Note, the systematic sampling strategy needs to be reproducible (Form 2). Table 1 is a list of potential analytical parameters during the respective phases of remediation. The user must determine which parameters are appropriate for each situation.

**Table 1. Analytical Parameters (example)**

| Project Phase | Soil Lab Test | Hot Spots | Full Spill Area | Background Sample |
|---|---|---|---|---|
| Site Assessment | | | | |
| | EC (saturated paste, 1:1, or 1:5) | X | X | X |
| | Chloride concentration | X | X | X |
| | Bromide concentration | X | X | X |
| | SAR and/or %Na | X | X | X |
| | Total petroleum hydrocarbons DRO[1] | X | X | |
| | Total petroleum hydrocarbons GRO[2] with BTEX[3] | X | X | |
| | pH | X | X | X |
| | RCRA[4] metals | X | X | |
| Remediation/Reclamation | | | | |
| | CEC | X | X | X |
| | SAR and/or %Na | X | X | X |
| | Particle size and texture class | X | X | |
| | Exchangable sodium percent (ESP – if necessary) | X | X | X |
| | Basic soil fertility (N, P, K, Ca, Mg, Na, S, EC) | X | X | X |

[1] Diesel-range organics.

[2] Gasoline-range organics.

[3] Benzene, toluene, ethylbenzene, and xylene.

[4] Resource Conservation and Recovery Act.

### Sample Type

The two common types of sampling methods are single or composite. A single (grab) sample is where a sample is collected from a specific spot at a site (best for delineating variations in salinity, very effective when used in conjunction with the EM survey). Narrow linear sampling of wetlands or stream channels is well suited for single grab samples because of the transport of contaminants downstream.

Composite samples are derived by combining/collating portions of multiple samples (usually five subsamples). This sampling technique is best suited for monitoring previously characterized soils or larger areas of similar soils or impacts. Generally, only samples that are expected to have the same range of contaminant concentration are composited. It is best to use composite samples from the same profile depth.

Note: composite samples can be used to minimize laboratory expense.

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Representative control (background) sampling should be collected as either single or composite samples from sites adjacent to the contaminated area, unaffected by the contaminant. The use of single or composite sampling should be the same for control and salt-affected soils. EM induction surveying can be used to assist in selecting control locations. Controls are used for comparative purposes and should be taken at similar landscape setting or soil type, land use, etc., to the spill area. Controls are essential for salt characterization in areas where soils may be naturally salinized.

### Number of Sample Locations

Depending on the complexity of the spill/site, samples can be selected to represent a range of conditions in the spill area. Fewer samples may be required if an EM induction survey is conducted. Different remediation methods may be appropriate for different parts of a large spill. In such situations, the spill area can be broken into areas of low, medium, and high contamination and/or by landscape setting within the contaminated area. If the area is small and uniform, two sets of samples, one near the edge and one near the center or most impacted area, may be adequate. Refer to NDDH's *Guidelines for the Assessment and Cleanup of Saltwater Releases* for guidance on sample collection.

Note: each sampling location should be assigned a unique name, which should be recorded clearly on a diagram of the site, and its position marked using the global positioning system (GPS) (refer to Form 2).

### Depth of Sampling

Sufficient sampling is necessary to determine the extent and magnitude of the contamination. Common practice is to sample the impacted area vertically at 12-inch intervals until clean soil is reached. Since it is extremely important to understand the impacts in the upper soil profile from 0 to 12 inches, one might consider sampling the upper 12 inches of soil at 0–6-inch and 6–12-inch intervals. Appendix B presents field screening methods that can be employed to limit the amount of soil samples being submitted to the laboratory. Once clean samples have been achieved in the field, a sample can be collected from just above and below the field screened sample and submitted for laboratory analysis.

### Sample Containers and Labeling

For salinity analysis, soil samples can be collected in heavy-duty plastic bags and sealed with either a Ziplock or twist tie. Most soil testing laboratories are able to supply soil sampling bags.

For hydrocarbon analysis, soil samples should be collected in precleaned glass jars with Teflon-lined lids. Again, most laboratories will supply the necessary sample container, preservative material, and labels for the appropriate analytical parameters and matrix as well as chain-of-custody forms. Soil with organic compounds should be stored at 4°C (39°F) or colder, and the laboratory should receive samples within 24 hours of sampling, if possible.

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When sampling, record the following information:

- Project name
- Sample identification number (assigned by the sample plan)
- Date the sample was collected
- Time sample was collected
- Name or initials of the person collecting the sample
- Sample depth or interval sample was collected from

Other information that will be required by the laboratory includes chain of custody, sample site name, preservative if used, time of preservation, and any relevant sample site observations. Collect adequate samples for multiple analyses. Consult the laboratory to make sure the required amount of samples is collected for the required analytical methods. Table 1 presents recommended analytical parameters for conducting a site assessment.

Note: consider formal, laboratory-supplied bottle orders when responding to large spills.

### Sample Quality Assurance and Quality Control

Quality assurance (QA) is a systematic process for guaranteeing that collected data and decisions based on these data are technically sound, statistically valid, and properly documented. Quality control (QC) procedures are methods used to measure the degree to which QA objectives are met. Appropriate QA/QC measures are based on the data quality requirements of the project, which set the limit for overall uncertainty of results. General QA and QC measures that are employed for subsurface investigation include:

- Use of proven and appropriate methods by trained field and laboratory personnel.
- Care, cleanliness, maintenance, and calibration of field equipment and analytical instrument.
- Documentation of all field and laboratory activities.
- Use of field QC measures, including field blanks and duplicate sample analyses, to detect contamination during handling, transport, and analytical precision.
- Coordination with analyzing laboratory for preparation of sampling containers, preservation, packaging, shipping, and receipt of samples.

Note: consider developing a formal QA/QC plan when responding to larger spills.

### Geophysical Survey

A number of geophysical tools can be used to make indirect measurements of salinity. The most commonly used of these are EM induction meters. All meters detect EC differences in subsurface materials. This technology generates an EM field that passes through the soil, giving a bulk EC value. The response of the EM meter is largely influenced by soil salinity but also, to a lesser extent, by soil temperature, moisture, and texture. Pipelines, overhead wires, other metals, and electrical fields may interfere with results. Electrical resistivity surveys can be also used to delineate salt-contaminated areas. The surveyed geophysical area should extend well into the surrounding noncontaminated area to adequately characterize both spill and nonspill (background control) areas. Data quality may be impacted by infrastructure interference caused by utility lines, steel fences, or other large metallic objects.

Geophysical surveys can be used:

- For initial delineation of soil salinity, it is usually adequate to determine relative differences in EC values throughout the site, as indicated by the EM values. If required, site-specific correlation between EM and field and/or laboratory-saturated paste extract EC values can be made to ground-truth the survey results. This technology is especially useful when determining impacts on large sites.
- To determine "hot spots" or areas of highest contaminant concentration.
- To indicate variability of salt distribution (low, medium, and high areas) in soil. Groundwater impacts can be determined as well.
- To aid in selecting soil sample locations.

## RISK ASSESSMENT

Based on the analytical results, Figure 3 provides some rules of thumb associated with soil and plant impact potential. Specific $EC_e$ and SAR thresholds are intended to be rules of thumb only and the user should determine the whether these thresholds are valid for their specific project.

The use of risk-based criteria to determine potential impacts to receptors involves assessing the source, identifying the exposure pathways, and identifying potential receptors. Figure 4 provides a flowchart to assist in identifying potential receptors during the risk assessment process.

### Sources

For the purposes of this document, the primary sources discussed are hydrocarbon and brine fluids associated with the exploration and production of crude oil.

### Pathways

Pathway is a term used to describe how the source reaches the receptor, which is most often over the land surface and through the soil.

### Receptors

Receptor is a term used to describe the thing that is impacted by a release. Receptors most often include soil and plants but may include surface water and, in some cases, may also include groundwater, livestock, native animals, and humans.

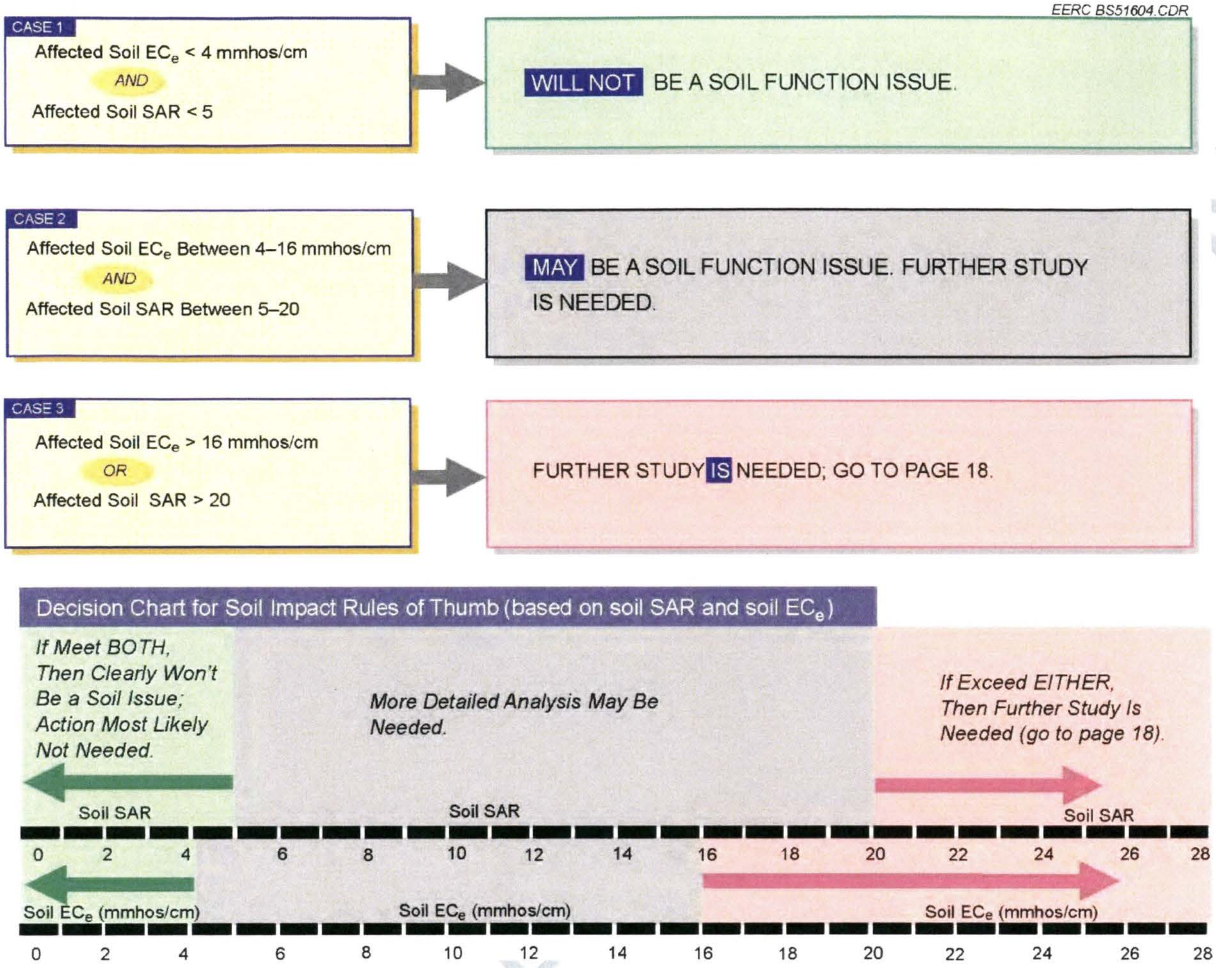
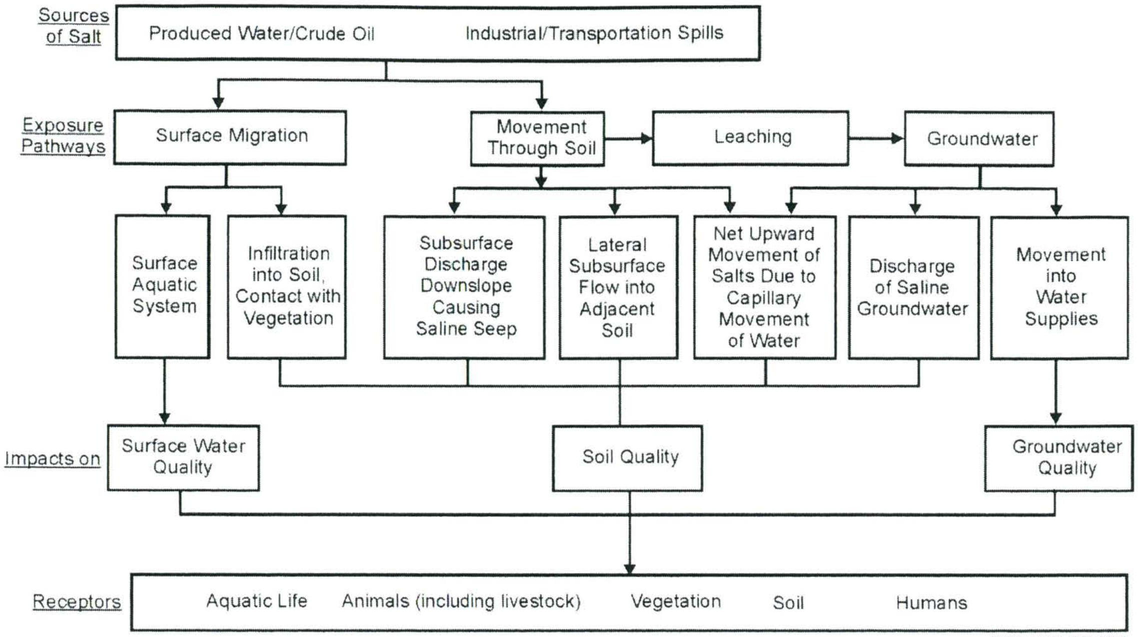


Figure 3. Soil impact rules of thumb (modified from API 4758, 2006).

Impacts to the environment from brine spills have been studied by a number of governmental agencies, scientific institutions, and trade groups, including API, EPA, and others, and these studies show that cleanup standards depend on land use, soil type, vegetation, migration potential to groundwater, groundwater use, and migration potential to surface water.

Based on these studies, Table 2 has been provided as an example of potential soil cleanup thresholds which may be used under a risk-based approach.



EERC BS51606.CDR

Figure 4. Risk assessment flowchart (modified from Alberta Environment, 2001).

**Table 2. Soil Cleanup Standards**[1]

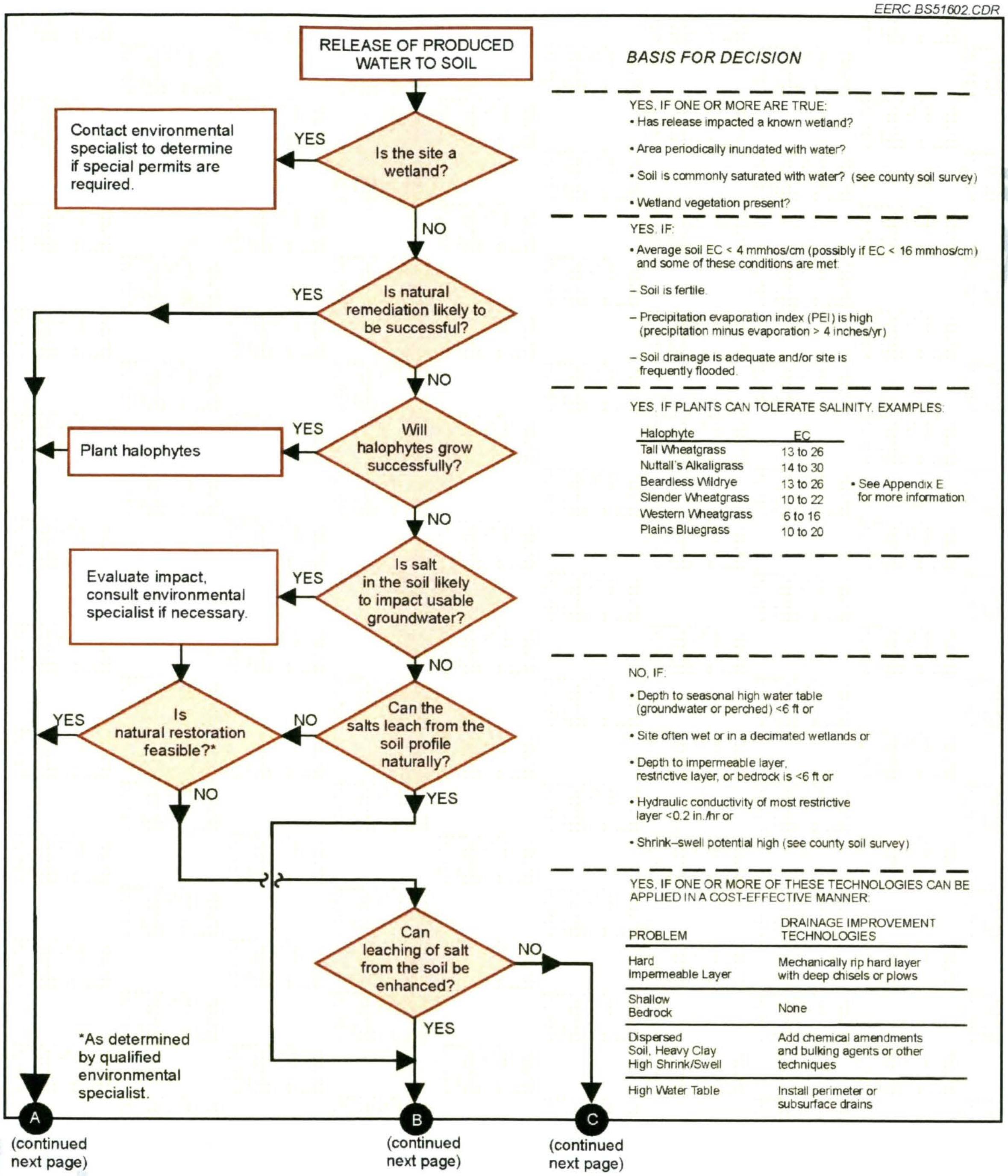
| Distance to Groundwater | <25 feet | 26–100 feet | >100 feet |
|---|---|---|---|
| Distance to Surface Water | <100 feet | 101–1000 feet | >1000 feet |
| | | | |
| EC, mmhos/cm | 4 | 6 | 12 |
| SAR, root zone only | 12 | 12 | 12 |
| Chloride, mg/kg | 250 | 650 | 1500 |
| TPH[2] | 100 | 5000 | 10,000 |

[1] On a case-by-case basis, operators and regulators can incorporate soil type, vegetation type, and water usage to propose alternate cleanup standards.

[2] Total petroleum hydrocarbon.

## DATA INTERPRETATION

Figures 5a and 5b represent a remedial options decision tree that can be used as a tool to develop remediation strategies for site cleanup. Specific numbers used in the "Basis for Decision" section are to be considered rules of thumb. The user should determine the whether these values are valid for their specific project.



*BASIS FOR DECISION*

YES, IF ONE OR MORE ARE TRUE:
- Has release impacted a known wetland?
- Area periodically inundated with water?
- Soil is commonly saturated with water? (see county soil survey)
- Wetland vegetation present?

YES, IF:
- Average soil EC < 4 mmhos/cm (possibly if EC < 16 mmhos/cm) and some of these conditions are met:
  - Soil is fertile.
  - Precipitation evaporation index (PEI) is high (precipitation minus evaporation > 4 inches/yr)
  - Soil drainage is adequate and/or site is frequently flooded.

YES, IF PLANTS CAN TOLERATE SALINITY. EXAMPLES:

| Halophyte | EC |
|---|---|
| Tall Wheatgrass | 13 to 26 |
| Nuttall's Alkaligrass | 14 to 30 |
| Beardless Wildrye | 13 to 26 |
| Slender Wheatgrass | 10 to 22 |
| Western Wheatgrass | 6 to 16 |
| Plains Bluegrass | 10 to 20 |

- See Appendix E for more information

NO, IF:
- Depth to seasonal high water table (groundwater or perched) <6 ft or
- Site often wet or in a decimated wetlands or
- Depth to impermeable layer, restrictive layer, or bedrock is <6 ft or
- Hydraulic conductivity of most restrictive layer <0.2 in./hr or
- Shrink–swell potential high (see county soil survey)

YES, IF ONE OR MORE OF THESE TECHNOLOGIES CAN BE APPLIED IN A COST-EFFECTIVE MANNER:

| PROBLEM | DRAINAGE IMPROVEMENT TECHNOLOGIES |
|---|---|
| Hard Impermeable Layer | Mechanically rip hard layer with deep chisels or plows |
| Shallow Bedrock | None |
| Dispersed Soil, Heavy Clay High Shrink/Swell | Add chemical amendments and bulking agents or other techniques |
| High Water Table | Install perimeter or subsurface drains |

Figure 5a. Remedial options decision tree (modified from API 4758, 2006).

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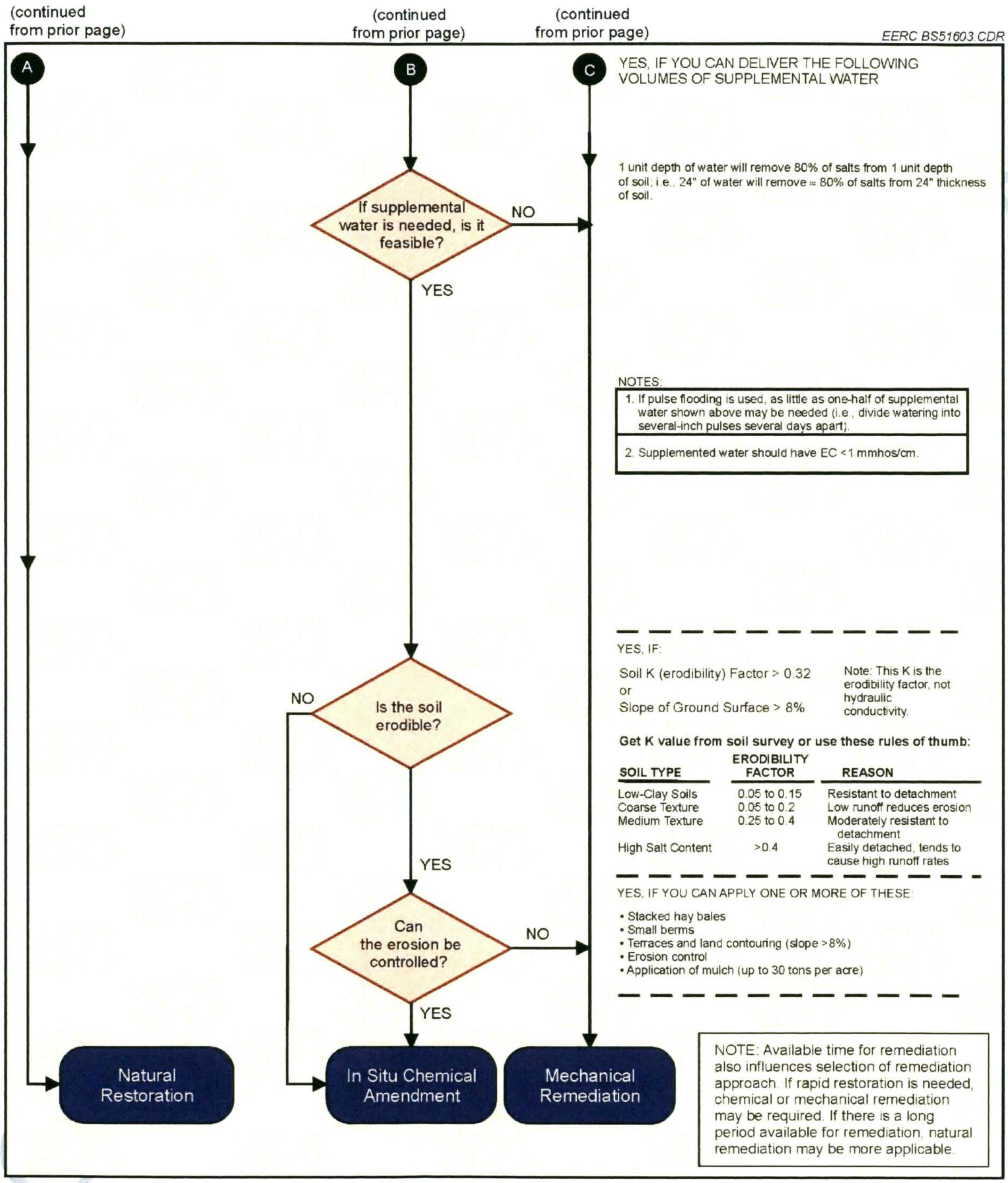

YES, IF YOU CAN DELIVER THE FOLLOWING VOLUMES OF SUPPLEMENTAL WATER

1 unit depth of water will remove 80% of salts from 1 unit depth of soil; i.e., 24" of water will remove ≈ 80% of salts from 24" thickness of soil.

NOTES:

1. If pulse flooding is used, as little as one-half of supplemental water shown above may be needed (i.e., divide watering into several-inch pulses several days apart).
2. Supplemented water should have EC <1 mmhos/cm.

YES, IF:

Soil K (erodibility) Factor > 0.32
or
Slope of Ground Surface > 8%

Note: This K is the erodibility factor, not hydraulic conductivity.

**Get K value from soil survey or use these rules of thumb:**

| SOIL TYPE | ERODIBILITY FACTOR | REASON |
|---|---|---|
| Low-Clay Soils | 0.05 to 0.15 | Resistant to detachment |
| Coarse Texture | 0.05 to 0.2 | Low runoff reduces erosion |
| Medium Texture | 0.25 to 0.4 | Moderately resistant to detachment |
| High Salt Content | >0.4 | Easily detached, tends to cause high runoff rates |

YES, IF YOU CAN APPLY ONE OR MORE OF THESE:

- Stacked hay bales
- Small berms
- Terraces and land contouring (slope >8%)
- Erosion control
- Application of mulch (up to 30 tons per acre)

NOTE: Available time for remediation also influences selection of remediation approach. If rapid restoration is needed, chemical or mechanical remediation may be required. If there is a long period available for remediation, natural remediation may be more applicable.

Figure 5b. Remedial options decision tree (modified from API 4758, 2006).

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## REMEDIATION OPTIONS – HYDROCARBON IMPACTS

This section is intended to provide a brief overview of the various remediation options available and when they might be utilized.

### In Situ Remediation Option

#### *Natural Attenuation*

Natural attenuation is the scientific term for letting the natural systems already in place remediate the spill contaminant. Natural attenuation is only applicable in hydrocarbon spills of relatively low concentration when no sensitive receptors are threatened.

#### *Bioremediation*

In situ bioremediation is only effective on hydrocarbons and, therefore, would only be a remediation option if the spill is only hydrocarbons or a mixed release with minimal brine present.

This option involves the use of microorganisms already present in the soil to remediate the impacted soil. Usually this also involves the implementation of specific enhancements to optimize the effectiveness of the natural degradation of the hydrocarbons.

In situ bioremediation is a process where naturally occurring organisms in the soil are allowed to break down the hydrocarbons (primarily in an aerobic environment). The soil is prepared and maintained to promote this process during the remediation phase.

The following factors are vital to a successful bioremediation project:

- Contact between the bacteria and the hydrocarbons
- Available nutrients
- Presence of oxygen
- Adequate moisture
- Appropriate pH
- Proper soil temperature

#### *Soil–Hydrocarbon Contact*

Contact between the bacteria and the hydrocarbons is achieved by tilling or disking the hydrocarbon-impacted soil (and amendments if needed). In addition, working the spill area also creates a more even vertical distribution of hydrocarbons and nutrients as well as eliminates any surface crusting and increases soil pore space for the transport of oxygen from the atmosphere to bacteria and removal of bacterial respiration by-products (e.g., carbon dioxide) from the soil environment which could become toxic for bacteria if aeration removal rates are not adequate.

After initial soil sampling is complete, tillage should be performed to incorporate "clean" soil (if needed) and pH amendments (if needed). A second tillage event should be performed to incorporate nutrients and organic matter. Tillage should then be performed every other week for the first 3 months and monthly thereafter to maintain proper soil aeration because of soil settling over time.

### *Nutrient Addition*

Nutrient requirements will most likely not be sufficient to maximize biodegradation rates in the native soil, and additional nutrients will be required. The primary nutrients required are nitrogen (N), phosphorus (P), and potassium (K). Application of commercial fertilizers is the most effective method for supplementing nutrients. Nitrogen requirements are typically based on suggested carbon (C) to N ratios, and C can be assumed to be 80% of the TPH concentration.

EPA suggests a C:N:P:K ratio of 100:10:1:1 (U.S. Environmental Protection Agency, 1996), while others have suggested it is more appropriate to use a C:N ratio of 150:1 to avoid excess salinity and a corresponding N:P:K ratio of 4:5:1 (Sublette, 2014; Hodges and Simmers, 2006).

Care must be exercised when the amount of N, P, and K to apply to the site is determined as the potential of adding salinity exists when commercial fertilizers are introduced (these commercially available nutrients come in the form of salts). Sandy soils and soils with low moisture tend to be susceptible to fertilizer salinity, whereas clays and soils with high organic matter tend to be less susceptible to fertilizer salinity (Sublette, 2014).

If the N requirement exceeds 150 pounds/acre, an operator should consider splitting up the applications and applying the required N in two or three applications performed 30 days apart.

### *Oxygen*

Introduction of oxygen into the bioremediation process is achieved with tillage of the site. Oxygen content does not need to be measured, as properly scheduled tillage should accomplish adequate oxygen transfer.

### *Moisture*

Most in situ bioremediation sites will only rely on natural precipitation for moisture addition. References sourced for preparation of this document indicate that optimal moisture content is 40%–80% (Hodges and Simmers, 2006) or 60%–80% (Sublette, 2014) of the soil's water-holding capacity or field capacity. This is equal to about 12%–30% on a weight basis (U.S. Environmental Protection Agency, 1996).

The use of organic matter can greatly increase the moisture-holding capacity of the soil and help prevent compaction issues. Typical organic amendments used include manure (best to use aged manure), hay, straw, cornstalks, and biosolids.

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When used as an organic matter bulking source, fully composted manure is preferred over fresh manure for several reasons but mainly because it tends to be lower in N, P, and K (thereby not affecting fertilizer calculations) and low in salts, and weed seeds have been killed.

### *pH Adjustment*

A soil pH of 6 to 8 is optimal for microbial activity. A soil sample should be taken initially to determine the soil pH, and adjustments should be made by the incorporation of amendments (lime or elemental sulfur) at the time of first tillage. An operator should consult with agriculture experts, soil testing laboratories, or North Dakota State University (NDSU) Extension to determine the appropriate type and quantity to apply.

### *Soil Temperature*

In an in situ bioremediation site, an operator can do little to control soil temperature. Being aware that soil temperature has an impact on microbial performance is the important factor. Microbes are considered to be active when the soil temperatures are between 40° and 90°F (4° and 32°C). With that said, bioremediation projects should be considered active from April through October.

## Ex Situ Remediation Options

### *Excavation and Disposal*

Although often not considered a remediation practice, the excavation of impacted soils does remove the contaminant from the environment. This practice is the most aggressive and, in North Dakota, is one of the most common practices for addressing hydrocarbon spills.

The benefits of excavation and disposal include the following:

- Immediate removal of source and impacted soils
- Satisfaction of the landowner
- Potentially less long-term liability at the spill site

The potential disadvantages of excavation and disposal include the following:

- Cost required to haul and dispose of hydrocarbon-impacted soil at a special waste landfill
- Potential liability of hauling impacted soil from the spill site
- Added expense of uncontaminated topsoil of similar textural class and quality
- The potential introduction of weeds not previously observed at the site prior to the spill

The extent of the excavation is dictated primarily by the cleanup action threshold guidance provided by the regulatory agency. In most cases, soils are excavated to a point where the vertical and horizontal extent of contamination above the action threshold is removed. This would assume that groundwater is not impacted and sensitive receptors are not present, such as groundwater wells, within a distance of concern.

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To determine the areal extent of hydrocarbon impacts/excavation limits, a photoionization detector is typically be used for surface spills. For brine spills, the extent of impacts are determined by a field EC measurement. In both cases, confirmation samples from the bottom and sides of the excavation would be collected and submitted to an approved laboratory. Appendix B contains field screening methods for collecting hydrocarbon confirmation samples.

The contaminated soils are manifested and transported to an approved special waste landfill for disposal. A current list of special waste landfills can be viewed at the NDDH Web site (www.ndhealth.gov/wm/Publications/SpecialWasteLandfills.pdf).

To replace the excavated material, "clean" subsoil and topsoil of similar mineral textural class and quality should be brought in and placed in the excavation. Care should be taken to place replacement subsoil and then replacement topsoil with minimal mixing of the two subsoil types and topsoil.

Note: consider working with the property owner when selecting a source for the borrow material.

### *Bioremediation/Landfarming*

Ex situ bioremediation or landfarming involves the removal of impacted soil and treatment of the soil either at the spill site or at a separate landfarming site. This option would only be applicable for hydrocarbon-only spills.

Ex situ bioremediation involves the same process as in situ bioremediation except impacted soils to be remediated are excavated and hauled from the spill site and taken to an approved landfarming site. Ex situ bioremediation may also be performed by composting the excavated soil. The primary difference between landfarming and composting is the soils are windrowed and often aerated (and sometimes covered), watered, and fertilized to more aggressively facilitate biological activity.

Currently, this remediation technology is not being employed in North Dakota.

### *Ex Situ Thermal Treatment*

Ex situ thermal desorption is used to treat light and heavy-end hydrocarbon contamination. The process works by heating soil in a rotating kiln to temperatures between 350°C (low-temperature thermal desorption) to 850°C (high-temperature thermal desorption). The temperature of the desorber is dependent upon what contaminants are being targeted, but the preference (fuel and capital costs) is to use the lower-temperature systems where possible.

Essentially, at elevated temperatures, contaminants that are adsorbed to or within the pores of soils are driven into the vapor phase. The vapors are subsequently drawn through a filter under vacuum prior to being combusted in a thermal oxidizer unit prior to exhaust to atmosphere. Cleaned soils are quenched for cooling and lost moisture added prior to reuse.

There are limitations with thermal desorption, specifically with the type soil. Soil that is too clayey or silty will reduce the process efficiency, as will oversaturated soil. Soil that has a high

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contaminant load will also need to be carefully considered prior to treatment. However, if the soil can be properly processed/handled through appropriate pretreatment steps, thermal desorption can be an effective treatment method, often resulting in a very high standard of cleanup.

## REMEDIATION OPTIONS – BRINE IMPACTS

### In Situ Remediation Option

#### *Natural Attenuation*

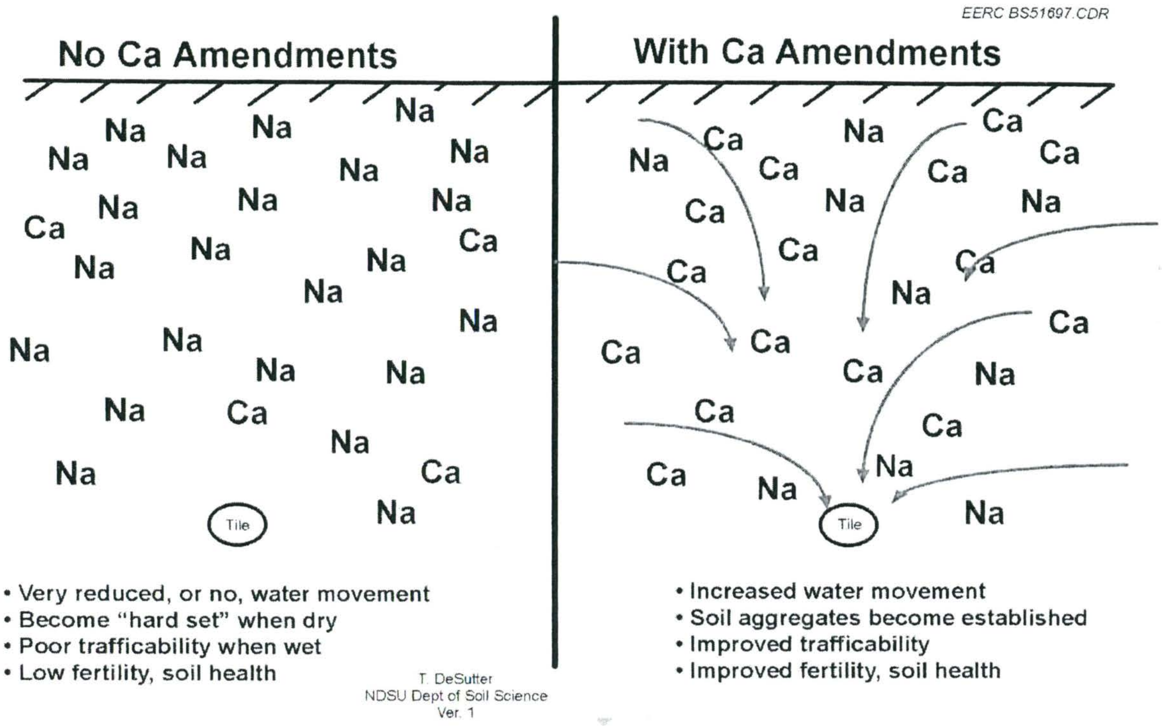
Natural attenuation, with brine-impacted soil, could be an appropriate option if the salt effects to the soil chemical and physical properties are within the tolerance of the dominant plant species or desired crop (refer to the rule of thumb flowchart [Figure 2] and Appendices E and F for more information). Natural remediation should only be considered after careful review of site-specific conditions.

Occasionally, situations occur where any attempt to enhance remediation may cause greater environmental damage than the brine released. These situations include highly erosive soils or wetland settings where any attempt to bring in equipment may cause significant and/or long-lasting habitat loss. In these situations, the operator may choose to monitor the site to verify that natural remediation is occurring at an acceptable rate and with limited risk to environmental and sensitive receptors.

#### *In Situ Chemical Amendment Remediation*

The objective of in situ chemical amendment remediation is to restore the soil's natural chemical and physical properties and decrease the salt concentration in the upper soil profile to a level that no longer impedes plant growth. This technique involves the introduction of calcium-based ($Ca^{2+}$) chemicals and water that facilitate the remobilization of $Na^+$ $Cl^-$ so they can be carried by percolating water deeper into the subsoil or to a tile system for removal and disposal (Figure 6). It is imperative that these salts are mobilized to a soil profile depth greater than the potential upward capillary movement of soil water by evaporation and transpiration forces. These forces could potentially transport the removed salts back into the plant rooting zone.

As discussed in the decision tree (Figures 5a and 5b), a net downward movement of water and salts is required in order to be successful. These conditions require sufficient precipitation and soil and groundwater conditions that allow sufficient internal soil drainage. If precipitation is limited, application of irrigation and/or improved drainage may be required. The decision tree concentrates on the process of determining when this technique is an appropriate option and on developing the data required to select specific amendments and techniques that increase the probability of success.



- Very reduced, or no, water movement
- Become "hard set" when dry
- Poor trafficability when wet
- Low fertility, soil health

- Increased water movement
- Soil aggregates become established
- Improved trafficability
- Improved fertility, soil health

T. DeSutter
NDSU Dept of Soil Science
Ver. 1

Figure 6. Comparison of soil with and without calcium amendments.

Physical replacement of soil cations such as calcium (Ca), potassium (K), and magnesium (Mg) with sodium (Na) results in the dispersion and swelling of clays resulting in the loss of soil aggregation/structure. This physical breakdown reduces aeration, water infiltration, and permeability leading to surface crusting, runoff, and erosion. As previously stated, the replacement of exchangeable Na ions can be accomplished by increasing the amount of Ca concentration in the soil solution by the addition of a Ca amendment. A variety of chemical amendments can be added to remobilize Na. These include granular gypsum ($CaSO_4$), liquid gypsum, liquid calcium nitrate ($CaNO_3$), calcium chloride ($CaCl_2$), and citric acid with calcium amendments. With the addition of calcium in the soil, the ions of the soil particles are in a dynamic equilibrium with the soil solution. Therefore, a high concentration of Ca in the soil solution will result in Ca replacing Na on the clay exchange sites. This process lowers the SAR and %Na and begins to balance the chemistry of the soil solution, which facilitates the improvement of the soil's physical properties.

On a fresh release, the ionic concentration (EC) of the soil solution should not be allowed to fall below the level at which clay swelling or dispersion (Figure 2) occurs until sufficient calcium has been applied to replace most of the sodium on the soil's exchange sites and lower the SAR to acceptable levels. Swelling and/or dispersion will occur when the SAR or %Na is 5 or greater and the EC1:1 is less than 1.5 mmhos.cm. This maintenance of high EC will promote infiltration and soil water movement. The critical level will be site-specific (different types of clay behave differently to Na and EC) but may be estimated by means of a laboratory treatability study. It may take several years and treatments to return an area to its previous productive capacity especially in areas with high clay content.

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Calcium amendments can be added to the soil in dry or liquid form. Liquid calcium amendments are faster acting and have a deeper initial penetration depth. Commercial formulations of liquid calcium are available in concentrated and finely ground forms. Liquid amendments can also be made by dissolving calcium sources in water. The most commonly used dry amendments are gypsum and calcium nitrate, although calcium chloride may be used if adequate drainage is in place and leachate is collected for disposal. Use of calcium amendments may require subsequent irrigation and leachate collection.

The amount of calcium nitrate applied is often limited by concerns about nitrate contamination of groundwater. The amount that should be applied will depend on the potential for movement of nitrates into groundwater. Sites of greater concern are those with high permeability soils (sandy), shallow groundwater, high rainfall, or applied irrigation water.

### *Phytoremediation*

Phytoremediation involves the introduction of specfic halophytic plant species that are capable of surviving (and in some cases thriving) in saline environments. The use of plants to perform remediation is usually most applicable to brine spills. It should be noted that most of the extremely salt tolerant plant species are not typically considered beneficial use plants and, in some cases, are the same plants (weeds) that the agricultural community works very hard to eliminate. Appendices E and F contain information about halophytic forages and crops as well as their respective salt tolerances.

### *Electrokinetics*

Electrokinetics technology involves the application of direct current (DC) electric fields in conjunction with relatively inexpensive direct-push wells. When soil and groundwater are subject to DC electric fields, the pore water moves toward the cathode via electroosmosis while cations also migrate toward the cathode and anions migrate toward the anode by electromigration. A series of anode and cathode wells placed in the soil can be used to separate and recover chloride (anion) and sodium (cation), respectively, from brine-impacted soil. Figure 7 provides an illustration of this process.

The advantages to this technology include moderate expense and noninvasive passive soil remediation, especially when remediating small, confined, high-value habitats such as wetlands. Disadvantages include time and equipment. Consulting with a technical expert is suggested when exploring this technology.

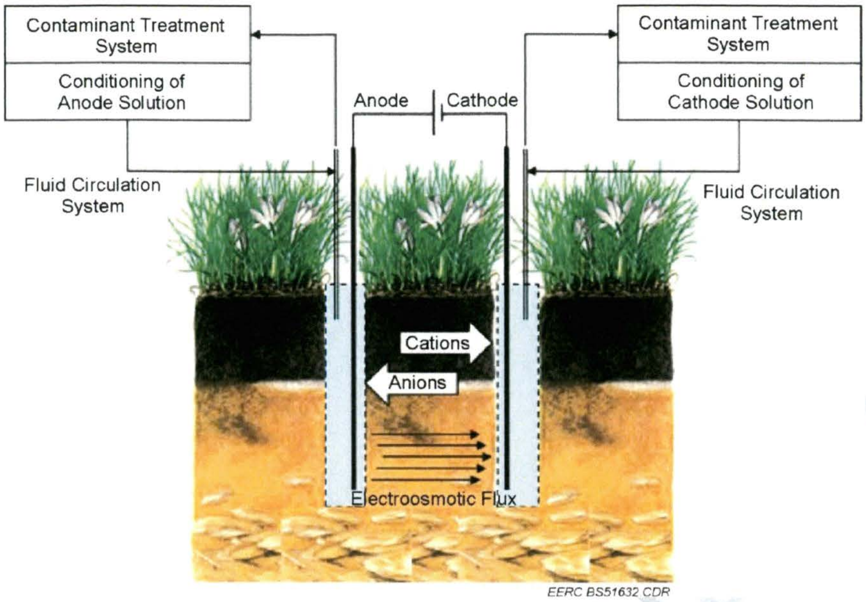

Figure 7. Example of electrokinetic process (Cameselle and others, 2013).

#### *NDSU Crystallization Inhibitor Technology*

NDSU is studying the use of crystallization inhibitors, such as the chemical hexacyanoferrate for use in reclamation of oilfield land impacted by saltwater (Daigh and Klaustermeier, 2016). The crystallization inhibitor is surface applied as a colloidal suspension with a solvent if the inhibitor's counter ion (e.g. K, Na, Fe, etc.) is not readily soluble in water. During subsequent evaporation of water in soil pores, the salts are transported to the soil surface and then inhibited from crystalizing and forming a cemented salt crust near the soil surface. Instead, soft dendritic salt growths form above the soil surface so that it can be easily removed without physical disturbance to the soil. The salt would then be disposed or injected into an approved site. Laboratory research conducted at NDSU showed that application of the ferric hexacyanoferrate, which is mixed with water and ammonia (a solvent), brought 29% to 70% of the salt on high-salt soil to the surface which varies based on the soil texture. One advantage of using crystallization inhibitors such as ferric hexacyanoferrate on salt-impacted soil is that they are available on the market and is nonproprietary. Refer to the open-access publication Daigh and Klaustermeier (2016) for more details on crystallization inhibitors for use in remediating brine spills.

### Ex Situ Remediation Options

#### *Excavation and Disposal*

Mechanical remediation may be appropriate when natural remediation and in situ chemical amendment remediation options are not advisable. When dealing with a small release, mechanical remediation could be the least complex and costly option.

Most mechanical remediation options involve the excavation and relocation of the brine-impacted soil to a suitable treatment facility or certified special waste landfill. Following excavation, clean soil is typically brought in to replace the excavated soil. Imported subsoil can be used for deeper excavations, but the uppermost 6 to 12 inches of the excavation is generally replaced with clean and productive topsoil as similar as possible in texture and quality to the impacted soil.

This option is often selected for sites with extremely high salt concentrations or sites that are located near sensitive waters, shallow soils, or when treating soil with poor drainage or permeability and where regulatory, lease, or legal considerations favor this option.

Field screening, as presented in Appendix B, could be employed to guide excavation activities to determine when the impacted soil has been removed. Refer to the NDDH's Guidance Document for directions when collecting soil closure sample.

#### *Soil Washing*

Soil washing involves the excavation of the impacted soil, putting the soil through a "washing" process to remove the contaminants, and replacing the soil in the original excavation. This process is only applicable to brine-impacted soils. Soil washing may be done at the location. This technology involves chemical remediation with intensive mechanical agitation to speed up the reaction and for better control of the leachate.

In the initial phases of soil washing, freshwater or brackish water may be mixed with the brine-affected soil to decrease salinity if the relationship between EC and SAR is monitored closely to avoid clay dispersion. When EC and SAR relationships begin to approach dispersion (i.e., low EC and high SAR or high in %Na), then the salty washwater can be removed for disposal. Additional chemical amendments and freshwater can then be reapplied to further displace sodium from the cation exchange sites. When the sodium has been displaced sufficiently to meet the remediation goal, the soil water containing the displaced sodium and chloride may be removed for disposal. The soil may require fertilization and organic amendments postwashing to replace the nutrient balance following treatment.

In addition to rapid and complete remediation, the advantage of soil washing includes close control of soil chemistry through chemical additions and water. This can result in material cost savings. Disadvantages are the expense that is required for specialized equipment.

## POSTREMEDIATION MONITORING AND SITE CLOSURE

### Site Monitoring and Maintenance

After reclamation activities are completed, ongoing monitoring is necessary to ensure adequate vegetation establishment. Necessary site visits should be performed to assure establishment (a minimum of two visits per year is suggested, one in mid to late spring and one in early fall). The spring visit provides a preview of plant emergence and is the first indication of long-term growth. Monitoring during the initial growing season(s) can consist of simple visual observations to ensure that germination has occurred and seedlings are beginning to establish. Any areas of poor seedling emergence should be noted for further evaluation. Inspections should also include checking for noxious weeds, erosion problems, and grazing impacts. Grazing should be excluded from reclaimed sites until they are well established.

Fall and spring visits should also be used to plan weed management efforts. Appropriate herbicides should be spot-applied to prevent the establishment and spread of noxious weeds on the reclaimed area. Note that many broadleaf-selective herbicides can still have impacts on emerging grass seedlings and should be applied with care. Noxious weed management efforts should be conducted a minimum of twice a year, as needed. Noxious weeds, by law, must be controlled by mowing or spraying before they spread or produce seed. If annual weed competition is inhibiting establishment of the desired plant species, annual weeds can be mowed in initial growing seasons. However, it is important that mowing height be (at a minimum) about 6 inches to avoid impacting establishing grasses.

During monitoring, any areas of instability or erosion should be identified. Uncontrolled wind and water erosion can rapidly degrade a reclamation project, destroying the integrity of the land and the quality of water downgradient. If areas of erosion are found, incorporate control measures that slow and divert runoff. Erosion control best management practices include successful stands of vegetation, erosion control fabric, wattles, silt fences, straw bales, and trenches. Wind erosion is more difficult to evaluate than water erosion; however, if best management practices are implemented for water erosion control, wind erosion control is highly likely.

Any persistent bare spots should be tested for remaining salt or hydrocarbons. If they are determined to be impacted, soil amendments or suitable alternative treatments previously discussed should be considered.

After establishment, quantitative vegetation monitoring may be required to demonstrate revegetation success. If vegetation monitoring is performed, the user may want to consider the following guidelines.

Monitoring should be conducted by a qualified professional who is well versed in the native flora, pasture grasses, or crops that are being reestablished on the site. Monitoring should occur at the peak of seasonal growth as determined by the qualified professional.

In addition to monitoring the reclaimed area, a nearby unimpacted area should be monitored at the same time for comparison purposes. Using a reference area instead of a fixed vegetation standard to determine revegetation success allows for annual and seasonal environmental variations (i.e., precipitation) and a direct comparison with a target vegetation community. The reference area should be a nearby existing pasture, native grassland, or crop with similar species composition and soil type. For pasture or cropland, it may be appropriate to seed a nearby similar area at the same time as the reclamation with the same seed mix and use this area for comparison.

Revegetation success standards should be based on the reference area. Depending on the vegetation type (cropland, native grassland, or pasture), various measures of vegetation cover and/or production should be taken. Recommended revegetation success standards are described in Table 3.

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**Table 3. Suggested Revegetation Success Standards**

| Revegetation Standard | Cropland | Native Grassland | Pasture |
|---|---|---|---|
| Cover | None | Native perennial vegetation cover greater or equal to 90% of reference for two consecutive growing seasons | Desired* perennial vegetation cover greater or equal to 90% of reference |
| Production | Yields greater or equal to 90% of reference | Productivity greater or equal to 90% reference for two consecutive growing seasons | Productivity greater or equal to 90% reference |

* In pasture areas, introduced perennial grasses may be included as appropriate vegetation cover depending on the specific land use of the area.

### Monitoring Methods

Vegetation cover (if appropriate) should be measured using the point intercept method with a minimum of ten points per sample unit (frame or transect). Production should be measured using crop-harvesting techniques or standard plot clipping with a minimum plot size of 0.25 $m^2$, Table 4.

Samples should be located arbitrarily on the reclaimed and reference areas. Best practices include plotting the sample locations in advance of monitoring using mapping software to eliminate bias.

It is important to collect an adequate number of cover samples to ensure the data are representative of the vegetation on the entire site. Table 5 provides recommended sample sizes and adequacy calculations. Statistically adequate samples should be collected on both the reclaimed and reference areas.

**Table 4. Recommended Sampling Methods**

| Sampling Methods | Cropland | Native Grassland | Pasture |
|---|---|---|---|
| Cover | None | Basal or first hit by species + litter + rock + bare<br>Minimum of ten points per sample unit | Basal or first hit by species + litter + rock + bare<br>Minimum of ten points per sample unit |
| Production | Whole field harvest, representative strips with equipment, or hand harvest | Plot clipping by life form<br>0.25-$m^2$ frames | Whole field harvest, representative strips with equipment, or plot clipping by life form<br>0.25-$m^2$ frames |

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**Table 5. Recommended Sample Size and Adequacy Calculations**

| Sample Size and Adequacy | Cropland | Native Grassland | Pasture | Adequacy Calculation* |
|---|---|---|---|---|
| Cover | None | Minimum 15 Sample to adequacy on sites larger than 5 acres | Minimum 15 Sample to adequacy on sites larger than 5 acres | $n = \frac{t^2 pq}{d^2}$<br>Poisson or binomial distribution<br>$n = \frac{t^2 s^2}{d^2}$<br>Normal distribution |
| Production | Minimum 15 if hand harvest is used | Minimum 15 | Minimum 15 if plot clipping is used | None |

* n = number of samples required.
t = t-distribution value for a given level of confidence.
p = cover percentage.
q = 100-p.
d = level of accuracy desired for the estimate of the mean.
s = the estimate of the variance from sampling.

### Site Closure

After the site is seeded, monitored, and maintained for vegetation success and site stability, the final step in spill remediation is the process of site closure. Site closure documentation shows how effective your remediation efforts are as discussed above in the monitoring methods section. Depending on the impact of the spill, various agencies may be involved in the spill closure process. Landowners should also be consulted as part of the spill closure process.

### Stakeholder Consideration

Stakeholder satisfaction is key when determining when site closure is final. Multiple stakeholders should be considered throughout the reclamation and site closure process. Landowners, particularly, should be consulted throughout the entire remediation process and sign off on the site closure, whenever possible.

### Documentation

Documentation provides written proof of proper reclamation activities. Seed tags should be collected and stored with site files to provide proof that the proper seed mix and quantities have been used. Written inspections should occur during site monitoring and should include dated pictures. The inspections and pictures provide a dated record of site conditions. This is especially important during remediation and reclamation activities to show how the site has improved from the original spill conditions. Any chemicals or herbicides used during reclamation should also be documented, including what was applied, area applied to, and quantities used. A final inspection should occur once the site is fully reclaimed. As part of this final inspection, site conditions should be documented with dated pictures and comments.

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# APPENDIX A

# FIELD FORMS

**DRAFT**

## SPILL RESPONSE NOTIFICATION FORM (EXAMPLE)

Reporter's Name:__________ Reporter's Position:__________

**INCIDENT DETAILS:**

Date of Incident:__________ Approximate time incident occurred:__________

Material Discharged:__________ Estimated Quantity (with units):__________

Incident Description:__________

Material Released in Water? If so, estimate quantity (include units):__________

Media Affected: Soil_____ Water_____ Other (list)__________

Spill Location:__________ Nearest City:__________

**IMPACT:**

Description of Injuries (quantity/type):__________

How many people were evacuated?__________

Was there any damage:__________ (Y/N)? If yes, describe damage including the medium affected and the approximate dollar amount of damage. (Be complete):__________

**RESPONSE ACTION:**

Actions Taken to Correct, Control, or Mitigate Incident:__________

**EXTERNAL NOTIFICATIONS:**

Agency:__________ Contact Name:__________ Date/Time:__________
Agency:__________ Contact Name:__________ Date/Time:__________
Agency:__________ Contact Name:__________ Date/Time:__________
Agency:__________ Contact Name:__________ Date/Time:__________
Landowner:__________ Contact Name:__________ Date/Time:__________

(Based on severity of the incident, consider calling the following: National Response Center, US EPA, State Agencies, Local Fire Department, LEPCs, Hospitals, etc.)

**RESPONSE CONTRACTORS:**

Company:__________ Contact Name:__________ Date/Time:__________
Company:__________ Contact Name:__________ Date/Time:__________
Company:__________ Contact Name:__________ Date/Time:__________

**ADDITIONAL COMMENTS:**__________

**NOTE: DO NOT DELAY NOTIFICATION (INTERNAL OR EXTERNAL) PENDING COLLECTION OF ALL INFORMATION.**

| | | | | | |
|---|---|---|---|---|---|
| **PARAMETER:** Plant Production | | | **METHOD:** meter (0.5m x 2m rectangle) | | |
| **LOCATION:** | | | **EXAMINER:** | | |
| **AREA:** | | | **DATE:** | | |
| **TRANSECT NUMBER:** | | | **TRANSECT NUMBER:** | | |
| **SPECIES/ LIFE FORM** | **WET WEIGHT** | **DRY WEIGHT** | **SPECIES/ LIFE FORM** | **WET WEIGHT** | **DRY WEIGHT** |
| Cool Perennial Grass | | | Cool Perennial Grass | | |
| Warm Perennial Grass | | | Warm Perennial Grass | | |
| Annual Grass | | | Annual Grass | | |
| Grass-Like | | | Grass-Like | | |
| Perennial/Biennial Forb | | | Perennial/Biennial Forb | | |
| Noxious Weeds | | | Noxious Weeds | | |
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| COMMENTS: | | | COMMENTS: | | |

Point Intercept Ground Cover (50 m at 1 m spacing); Shrub Density (50 m x 2 m belt)

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|---|---|---|
| **Sampling Area:** | **Date:** | **Observer:** |

| **Sample No.-->** | Species Total | | Secondary Hits | Species Total | | Secondary Hits |
|---|---|---|---|---|---|---|
| **Graminoids** | | Photo: | | | Photo: | |
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| **Total Plant Cover** | | | | | | |
| **Rock** | | | | | | |
| **Litter** | | | | | | |
| **Bare Ground** | | | | | | |
| 100% | | | | | | |

**NOTES:**

## SOIL SURVEY FORM

| | | | | |
|---|---|---|---|---|
| Soil type | | | | Additional Notes: |
| Area | | Date | Photo #: | File #: |
| Classification | | | | Stop #: |
| Location | | | | |
| Native Vegetation | | Climate | | run#1 |
| Parent Material | | | | run#2 |
| Physiography | | | | run#3 |
| Relief | Drainage | Salt or alkali | | run#4 |
| Elevation | Ground Water | Stoniness | | run#5 |
| Slope | Moisture | Redoximorphic | | run#6 |
| Aspect | Root Distribution | % Clay* | | |
| Erosion | % Coarse fragments* | % Coarser than V.F.S.* | | |
| Permeability | | | | |
| | | | | |

| Sample Number | Depth Upper Lower | Horizon Designation | Thickness Avg (a) Max (b) Min (c) | Dry Color | Moist Color | Texture | Structure | Consistence | Mottles | Surface Features | Boundary | Effervescence | Roots | Pores | Concentrations | Rock Fragments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | GR SBK<br>SGR MA | N W M S<br>L S SH H EH | | | V A C G D<br>S W I B | NE VS SL<br>ST VE | F C M<br>vf f m co vc | vf f m co vc | F M N Co Cr<br>C D I P R S T | |
| | | | | | | | GR SBK<br>SGR MA | N W M S<br>L S SH H EH | | | V A C G D<br>S W I B | NE VS SL<br>ST VE | F C M<br>vf f m co vc | vf f m co vc | F M N Co Cr<br>C D I P R S T | |
| | | | | | | | GR SBK<br>SGR MA | N W M S<br>L S SH H EH | | | V A C G D<br>S W I B | NE VS SL<br>ST VE | F C M<br>vf f m co vc | vf f m co vc | F M N Co Cr<br>C D I P R S T | |
| | | | | | | | GR SBK<br>SGR MA | N W M S<br>L S SH H EH | | | V A C G D<br>S W I B | NE VS SL<br>ST VE | F C M<br>vf f m co vc | vf f m co vc | F M N Co Cr<br>C D I P R S T | |
| | | | | | | | GR SBK<br>SGR MA | N W M S<br>L S SH H EH | | | V A C G D<br>S W I B | NE VS SL<br>ST VE | F C M<br>vf f m co vc | vf f m co vc | F M N Co Cr<br>C D I P R S T | |
| | | | | | | | GR SBK<br>SGR MA | N W M S<br>L S SH H EH | | | V A C G D<br>S W I B | NE VS SL<br>ST VE | F C M<br>vf f m co vc | vf f m co vc | F M N Co Cr<br>C D I P R S T | |
| | | | | | | | GR SBK<br>SGR MA | N W M S<br>L S SH H EH | | | V A C G D<br>S W I B | NE VS SL<br>ST VE | F C M<br>vf f m co vc | vf f m co vc | F M N Co Cr<br>C D I P R S T | |
| | | | | | | | GR SBK<br>SGR MA | N W M S<br>L S SH H EH | | | V A C G D<br>S W I B | NE VS SL<br>ST VE | F C M<br>vf f m co vc | vf f m co vc | F M N Co Cr<br>C D I P R S T | |

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**REPORT OF:**________________________

Time: ________ AM PM to ________ AM PM ________ Total Hours Mileage: ________ Total Round Trip

To: ______________________________

Job No.:________________ Date: ____________

Daily Report No.: __________Sheet _______of ____

Invoice No.: ________________________

Project:

Copies: ____________________________

Field Observer: ________________________

Approved By: ________________________

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## INCIDENT BRIEFING (ICS 201)

| | | |
|---|---|---|
| **1. Incident Name:** | **2. Incident Number:** | **3. Date/Time Initiated:**<br>Date: Time: |

**4. Map/Sketch:**

**5. Situation Summary and Health and Safety Briefing** (for briefings or transfer of command)**:** Recognize potential incident Health and Safety Hazards and develop necessary measures (remove hazard, provide personal protective equipment, warn people of the hazard) to protect responders from those hazards.

**6. Prepared by:** Name: ________________ Position/Title: ________________ Signature: ________________

**ICS 201, Page 1** Date/Time: ____________________________

# INCIDENT BRIEFING (ICS 201)

**1. Incident Name:**

**2. Incident Number:**

**3. Date/Time Initiated:**
Date: Time:

**7. Current and Planned Objectives:**

**8. Current and Planned Actions, Strategies, and Tactics:**

| Time: | Actions: |
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**6. Prepared by:** Name: ________ Position/Title: ________ Signature: ________

**ICS 201, Page 2**

Date/Time: ________

# INCIDENT BRIEFING (ICS 201)

**1. Incident Name:**

| Sample ID | EC (mS/cm) | Chloride (ppm) | Notes (location/assignment/status) |
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## FORM 3 - ONSITE SURFACE EVALUATION

**Site Name (C):** ____________________ **Date (C):** ____________
**Form Prepared By (C):** ____________ **Spill ID No. (C):** ____________
**Landscape (E):** ____________________ **Land Use (E):** ____________
**Slope of Affected Area (E):** ______ **Typical Vegetation (E):** ____________
**Physical Hazards and Equipment Limitations (E):** ____________________
**Other Issues (E):** ________________________________________
**Observable Spill Area (E):** ______ (sq ft) **Observable Spill Depth (I):** ______ (ft)
**Scale (I):** ______________
**Site Sketch (E):**

| | A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
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**Notes:**

(E) = Essential information
(I) = Important information
(H) = Helpful information
(C) = Convenient information

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## FORM 5 - CONDENSED ESSENTIAL DATA

### ADMINISTRATIVE

Site Name ____________ Date Spill Reported __________ Spill ID No. ________

Regulatory Jurisdiction ______________________________________

Regulatory Constraints ______________________________________

Locally Acceptable Remediation Options ____________________________

### CHARACTERISTICS FROM SOIL SURVEY OR OTHER AVAILABLE SOURCES

Aerial Photo Sheet No. ______________ Soil Series (name) ______________

Map Unit Designation ______________ Drainage ________________ (class)

Impermeable Layer/Bedrock ___________ (depth)

Seasonal High Water Table Depth __________ (ft) Season(s) ____________ (months)

Groundwater Quality (good/poor/unusable) Migration Rate _____ (ft/yr) Flood Prone Site (Y/N)

Organic Soil (Y/N) Any Portion of Affected Site Delineated as Wetland (Y/N)

**Typical Soil Horizon Data to 6 ft as Follows:**

| Depth (ft) | Texture (C, M, F) | pH (s.u.) | CEC (meq/100g) | Permeability (in/hr) | Shrink-Swell (H, M, L) | Erodibility (K) | Carbonates (%) |
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**SITE OBSERVATIONS AND ANALYTICAL DATA** (site sketch recommended - note the following)

Affected Onsite Area ______ (sq ft) Onsite Open Water Affected (Y/N, describe) ______

______________________________________________

______________________________________________

Affected Offsite Area _______ (sq ft) Offsite Open Water Affected (Y/N, describe) ______

______________________________________________

______________________________________________

Landscape Position (top, side, bottom, depression)

Potential Groundwater Impact (Y/N) Depth _________ (ft)

Slope Type (H, M, L, basin)_________________ Direction (down toward N,S,E,W)

Potential Open Water Impact (Y/N) Distance ____________ (ft from affected area)

Vegetation Remaining (type) _________________ Remaining Coverage ________ (%)

Erosion Visible (H, M, L) Remaining Topsoil Thickness ______________________ (ft)

Surface Impediments to Equipment _________ Buried Impediments (e.g., pipes) (Y/N)

Sample Collection (draw locations with sample numbers on Form 4)

**Typical Soil Horizon Data to 2 ft as Follows:**

| Samp. No. | Depth (ft) | Texture (C, M, F) | pH (s.u.) | EC (mmhos/cm) | SAR (ratio) | CEC (meq/100g) | ESP (%) | Titratables (meq/100g) |
|---|---|---|---|---|---|---|---|---|
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## IMPORTANT INTERPRETATIONS

Groundwater Accessible by Migrating Salts (Y/N) Interception Feasible (Y/N)

Internal Soil Drainage Enhancement Required (Worksheet 2) (Y/N) Feasible (Y/N)

Supplemental Water Indicated (Worksheet 3) (Y/N) Feasible (Y/N)

Chemical Amendments Required (Worksheet 4) (Y/N) Feasible (Y/N)

Chemical Amendments to Depth ________ (ft) Type(s) __________________________

Chemical Amendments Application Rate ____________ (lb/1,000 sq ft) Feasible (Y/N)

Erosion Control Enhancements Recommended (Y/N) Feasible (Y/N)

Remediation Equipment Limitations ___________________ Land reshaping required (Y/N)

Revegetation Planting Recommended (Y/N) Feasible (Y/N)

Halophytic Revegetation Planting Recommended (Worksheet 1) (Y/N) Feasible (Y/N)

Other Considerations _______________________________________________________

___________________________________________________________________________

___________________________________________________________________________

___________________________________________________________________________

___________________________________________________________________________

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# APPENDIX B

# FIELD SCREENING METHODS

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## FIELD SCREENING METHODS

### SPECIFIC CONDUCTIVITY AND CHLORIDE CONCENTRATION FIELD TEST

**Materials Needed:**

Distilled water
Scale
Plastic soil tray for scale
Shaker Bottle
Shot glass
Liquid Measuring Cup (mL)
Filters
Funnel
Conductivity Meter
Chloride Quantab Titration Strips
Data sheets

**Method:**

**Step 1:** Gather supplies

**Step 2:** Decontaminate items, wash out any residual material with potable water and rinse with distilled water. Remove any excess distilled water by snap shaking. DO NOT USE TOWELS TO DRY.

**Step 3:** Calibrate electrical conductivity (EC) meter with appropriate calibration solution range that you expect to encounter in the field. If EC readings occur outside the range of the calibration solution, rerun the calibration to the appropriate calibration solution.

**Step 4:** Thoroughly homogenize field sample making sure the sample is not separated into chunks.

**Step 5:** Turn on scale and set plastic soil tray on scale and reset to zero, measure 25 g of soil and add to shaker bottle.

**Step 6:** Measure 100 mL of distilled water and add to shaker bottle for a 1:5 dilution. Record the dilution factor. A 1:1 dilution factor can also be used and may be more representative of a saturated paste extract conducted in the laboratory.

**Step 7:** Mix by shaking bottle for 60 seconds until the sample is sufficiently liquefied. Heavy clay soils will not generally mix in 60 seconds and you may have to stir with a porcelain spatula to break up the clods.

**Step 8:** Set funnel with filter on shot glass and pour liquefied mixture into the funnel so it will drain through the funnel into the glass.

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**Step 9:** Once drained remove funnel, measure and record conductivity of the sample using the conductivity meter. Multiply the recorded value by five to compensate for the 5:1 dilution. Record dilution factor and the EC value in either µS/cm or mS/cm.

**Steps 9 and 10:** Place a Quantab in the shot glass and wait for the yellow band near top to turn black. It should be noted, where the tip of the white chloride peak falls on the numbered Quantab scale, this represents the Quantab unit value. Refer to the table on the back of the Quantab bottle and multiply the recorded value by five to compensate for the 5:1 dilution.

**Step 11:** Quantab test strip scales are available in low range (30 to 600 mg/L) and high range (300 to 6000 mg/L). If the low range scale is exceed, either perform a carefully measured dilutions with distilled water of 5:1 or 10:1 (distilled water:aliquot) or use the high range tab. Record the dilution factor.

**Step 12:** Record this value as the sample chloride concentration as mg/L.

**Step 13:** Decontaminate all equipment used by method explained in Step 2.

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## HEATED HEADSPACE

Two commonly used field instruments for detecting organic vapors at petroleum sites are photoionization detectors (PIDs) and flame ionization detectors (FIDs).

Heated headspace organic vapor monitoring involves the measurement of volatile organics emitted from soil samples in a sealed container. The container is typically warmed and then tested for volatile organic vapors using photo- or flame-ionization techniques. The results generated by this method are qualitative to semi-quantitative and are limited to compounds that readily volatilize.

Conduct headspace analysis in glass jars or re-sealable polyethylene bags. If using re-sealable polyethylene bags, a blank sample should be tested prior to field screening to account for potential interferences caused by the bags themselves. In addition, the presence of moisture may interfere with instrument readings. Results should be presented in the report.

The following heated headspace field screening procedure must be used:

- Calibrate PID and FID field instruments according to the manufacturer's specifications and requirements.
- Partially fill (one-third to one-half) a glass jar or re-sealable polyethylene bag with the sample to be analyzed. Total capacity of the jar or bag may not be less than eight ounces (approximately 250 ml), but the container should not be so large as to allow vapor diffusion and stratification effects to significantly affect the sample.
- If the sample is collected from a split spoon, transfer it to the jar or re-sealable polyethylene bag for headspace analysis immediately after opening the splitspoon.
- Collect the sample from freshly uncovered soil if is collected from an excavation or soil stockpile.
- If a jar is used, quickly cover the top with clean aluminum foil or a jar lid. Use screw tops, strong rubber bands, or other methods that will tightly seal the jar. If a re-sealable polyethylene bag is used it must be quickly sealed shut.
- From the time of collection, allow headspace vapors to develop in the container for at least 10 minutes but no longer than one hour.
  - Shake or agitate containers for 15 seconds at the beginning and end of the headspace development period to assist volatilization. Temperatures of the headspace must be warmed to at least 40°F (approximately 5°C).
- After headspace development, insert the instrument sampling probe to a point about one-half the headspace depth. The container opening must be minimized and care must be taken to avoid uptake of water droplets and soil particulates.

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- After probe insertion, record the highest meter reading. This normally will occur between two and five seconds after probe insertion.
- Complete headspace field screening within one hour from the time of sample collection.
- Document all field screening results in the field record or log book.

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# Department of Environmental Protection
# Bureau of Remediation & Waste Management
# RCRA Program
# Standard Operating Procedure Change Record

**Title:** FIELD SCREENING OF SOIL SAMPLES UTILIZING PHOTOIONIZATION AND FLAME-IONIZATION DETECTORS

**Identification #:** **RWM-DR 011**

**SOP Originator:** Brian Beneski

| Author | Revision Number | Description of Change | Date |
|---|---|---|---|
| Deb Stahler | RCRA 01 | Substitute MEDEP/RCRA in the place of MEDEP/DR, and Division of Oil and Hazardous Waste Facilities Regulation in the place of Division of Remediation.<br>Section 2.0: Change first sentence to "MEDEP/RCRA is responsible for the investigation and subsequent corrective actions for RCRA facilities throughout Maine."<br>Section 7.0 Procedure: Include the updated PID/FID calibration set-points guidance. For key project decisions and site closure, use all procedures listed in Appendix Q of Chapter 691 as attached.<br>Section 8.0 Additional Considerations with Use of PID/FID: Add sentence "When using the PID/FID to determine clean-up standards for petroleum use the attached set-points."<br>Section 10.0 Documentation: All sampling events must be documented in a field notebook or field note forms. Chain of custody forms must be completed, and a completed, signed copy retained in the project file. | 8/1/2009 |
| | | New Set Points | |
| | RCRA 02 | New Set Points | 8/19/04 |
| | RCRA 03 | New Set Points | 9/13/06 |
| | RCRA 04 | | 11/24/08 |

Approved by:

Scott Whittier, RCRA Program Manager　　　　Date:

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## Appendix Q: Field Determination of Soil Hydrocarbon Content by Jar/Poly Bag Headspace Technique

1. **Introduction.** The following is a procedure acceptable to the commissioner for determination of the hydrocarbon content of soils contaminated only by oil and petroleum products. A soil sample is placed in a sealed jar or polyethylene bag and the volatile hydrocarbons are allowed to come to equilibrium with the jar headspace. The headspace hydrocarbon concentration is then measured with a calibrated photo- or flame-ionization (PID or FID) instrument, approved by the commissioner.

2. **Applicability.** This procedure is intended for estimating gasoline, No. 2 heating oil, diesel fuel, kerosene, and other chemically and physically similar oil contamination in mineral soils, having water contents between bone-dry and saturation. The procedure is not intended for estimating concentrations of heavy oils, lubricating oils, waste oil, and other low volatility hydrocarbon products. Soil grain size distribution and organic carbon content may effect the partitioning of hydrocarbon between soil, liquid, and vapor phases. Weathering of the hydrocarbon product also will decrease the proportion of volatile and soluble constituents, thereby decreasing instrument response. None of these limitations invalidate the method as a technique for approximation of low-level petroleum hydrocarbon concentrations.

3. **Equipment Required.**

   A. Shovel; trowel

   B. Lab containers (VOA or SVOA) of type and quantity for hydrocarbon to be sampled at expected concentrations

NOTE: Laboratory should be consulted in advance to determine their needs.

   C. Metal dial-type thermometer, –10°C to 50°C

   D. (Jar headspace method only) Glass, wide-mouthed, metal screw-top, 16 oz. jars, with cardboard lid liner removed, and ¼ inch hole drilled through center of lid

   E. (Jar headspace method only) Roll of heavy duty aluminum foil

   F. (Poly bag method only) 1-quart, Zip-Lock® type polyethylene bags

   G. Means of measuring 250 gm soil sample, plus or minus 10 gms. (e.g., a "calibrated" container, a "Weight Watchers" spring balance)

   H. Photoionization (PID), or flame ionization (FID) instrument approved by the commissioner

NOTE: A list of approved instruments and their calibration set points is available from the commissioner. The department also has developed a protocol whereby manufacturers of other instruments may generate calibration data for commissioner evaluation and approval. Copies are available from the Bureau of Remediation and Waste Management.

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I. Calibration equipment for instrument chosen

J. Decontamination equipment including soapy water and clean distilled water in squirt bottles or pressurized canisters

## 4. Analytical Procedure.

A. Determine the location at which the sample is to be taken. If possible, identify an uncontaminated location at the same site from which soil of similar texture and moisture content can be obtained, to serve as a field "blank".

B. Measure a 250 gm. sample of the soil into a wide-mouthed jar or polyethylene bag. In so far possible, samples should be mineral soil free of vegetation and stones larger than ½ inch in diameter. Seal the samples immediately in the jars by placing a square of foil over the mouth and screwing on the lid, and the bag by zipping the closure. Sufficient air should be left in the bag so that the instrument can withdraw an adequate headspace sample.

C. Repeat this procedure for three (3) more samples, all gathered within a 2 ft. × 2 ft. area.

D. Shake the jars for 30 seconds to thoroughly mix the contents. If bags are used, they may be kneaded until the contents are uniform.

E. Measure the samples' temperature by sacrificing one jar or bag. If necessary, adjust all sample temperatures to between 15°C and 25°C by bringing sample containers into a warm vehicle or immersing in a water bath. In warm weather, samples should be kept in a shaded, ventilated area during headspace development and analysis.

F. Allow at least 15 minutes but not more than 1 hour for soil hydrocarbons to reach equilibrium with the headspace.

G. If samples are to be taken for laboratory analysis, they should be collected and preserved per laboratory protocols at this time. Preferably, these samples should bracket a wide range of hydrocarbon concentrations including the highest and lowest concentration at the site.

H. Warm up and calibrate the PID or FID instrument to be used to the calibration set point determined by the commissioner for the make of instrument in use and the product(s) present at the facility.

NOTES: 1. These calibration set points have been established by testing the instruments against weathered petroleum headspace surrogates. Therefore, no conversion of the readings to their benzene equivalent is necessary.

2. The UV source in PID instruments should be cleaned at least weekly per the manufacturer's recommended procedure. Both PID and FID instruments must be recalibrated after four hours of continuous use, as well as at the beginning of field use, since their calibration may drift with battery condition.

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I. Shake the jars or knead the bags again for thirty (30) seconds.

J. Measure the samples' headspace concentration. If the jar headspace technique is used, break the foil seal through the drilled hole in the jar lid using a pencil or nail. Insert the instrument's probe about ½ inch into the jar. If using the poly-bag technique, insert the probe through the bag opening while squeezing the bag tight around the probe. Record the highest reading that remains steady for 1 to 2 seconds (i.e., that is not due to instrument needle inertia). Repeat this step until all jars have been measured.

NOTE: Both PID and FID instruments withdraw a headspace sample from the jar. In the jar headspace technique, air replaces this sample, diluting the headspace as it is being measured. In the poly bag technique, the bag collapses as its headspace is used by the instrument. In either case it is important to obtain an instrument reading immediately after the seal is broken – preferably within 10 seconds. Once a jar or bag has been used, it may not be used again, even if sufficient time is allowed to re-establish headspace equilibrium.

K. Repeat all steps at each other location of interest at the site. Finally, repeat all steps for the "field blank" obtained from the uncontaminated location.

L. Average the three readings obtained from each soil sample within each 2 ft. × 2 ft. area. Blank results must be reported but must not be used to adjust the readings obtained on other samples.

NOTE: Because calibration set points have been established by testing the instruments against weathered petroleum headspace surrogates, no conversion of the readings to their benzene equivalent is necessary.

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# CALIBRATION SET POINTS
## November 2008 Update

**DATE:** November 24, 2008

**TO:** All Persons Performing Site Assessments Pursuant To "Regulations for Registration, Installation, Operation & Closure of Underground Oil Storage Facilities (Appendix P of CMR, Chapter 691)"

**FROM:** George Seel, Director Division of Technical Services, Bureau of Remediation & Waste Management

**SUBJ:** Calibration Set Points For Photoionization- (PID) and Flame Ionization- (FID) Detectors Used in Field Headspace Determinations at Maine Petroleum Remediation Sites

******************************************************************************

The following table gives the set points for various PIDs and FIDs when calibrated with manufacturer-recommended span gas. The listed set points were determined for each make and model of PID using the lamp normally supplied by the manufacturer for petroleum investigations, usually in the 10.2 – 10.6 eV range. The set points are not valid for lamps of other energies.

**Please note that the set points previously established for several instruments have changed (new or changed values are shown in red).** This was necessary due to a recent change in the test gas formulation. Set points are intended only to normalize response of various PID and FID models to complex petroleum mixtures, not to evaluate the cleanup level achieved at most sites. DEP's guidance for determining cleanup standards, *DEP Procedural Guidance For Establishing Standards For The Remediation Of Oil-Contaminated Soil And Groundwater In Maine* ("Decision Tree") requires laboratory analysis of soil or groundwater for the closure of any Stringent (ST) or Intermediate (IN) site. These changes, therefore, should seldom affect the extent of a remediation or produce outcomes inconsistent with past practices.

**Only the makes and models of instrument listed below may be used in Maine site assessments pursuant to Chapter 691 closure requirements**. The notification level using instruments adjusted to these set points is 100 ppm for motor vehicle fuels, aviation fuel, marine diesel fuel, and middle distillate heating products. The headspace method is not appropriate and should not be used for evaluating heavy oil or waste oil sites.

Instruments calibrated to the listed set points **may** be used to determine compliance with the cleanup standards at Baseline (BL) sites, where a petroleum discharge poses minimal risk to human and ecological health or environmental resources.

Instruments may be made to read directly by entering the appropriate set point when the calibration routine requests the span gas concentration. Alternatively, the instrument may be calibrated to the actual span gas concentration and its readings later multiplied by the set point divided by 100. Concentrations obtained by either method should not be corrected to "benzene equivalents," as suggested by some instrument manufacturers.

This list is periodically updated as set points are established for additional instruments. For the most current listing, please contact the Division of Technical Services, Bureau of Remediation & Waste Management (BRWM) at (207) 287-2651.

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**Photoionization Instruments (PIDs)**

| Make | Model | Gasoline Set Point | Fuel Oil Set Point |
|---|---|---|---|
| GasAlert | Micro 5 PID | 260 | 385 |
| Hnu Systems | HNu 101 Series | 320 | 400 |
| | HNu 102 Series | 210 | 290 |
| Ion Science | PhoCheck Series | 140 | 130 |
| MSA | Photon Gas Detector | 225 | 225 |
| | Passport PID II OVM | 200 | 220 |
| | Sirius Multigas Detector | 285 | 385 |
| Photovac | MicroTIP Series | 225 | 225 |
| | 2020 ProPLUS | 120 | 130 |
| RAE Systems | MiniRAE 2000 | 130 | 140 |
| | MiniRAE 3000 | 220 | 260 |
| Thermo Environmental | OVM 580 Series | 210 | 240 |
| Foxboro | TVA-1000 (PID mode) | 210 | 250 |

**Flame Ionization Instruments (FIDs)**

| Make | Model | Gasoline Set Point | Fuel Oil Set Point |
|---|---|---|---|
| Photovac | MicroFID | 100 | 90 |
| Thermo Environmental | OVM 680 | 80 | 45 |
| Foxboro | TVA-1000 (FID mode) | 100 | 90 |

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# COVERSHEET
# STANDARD OPERATING PROCEDURE

**OPERATION TITLE:** **FIELD SCREENING OF SOIL SAMPLES UTILIZING PHOTOIONIZATION AND FLAME-IONIZATION DETECTORS**

**Originator:**
**Brian Beneski**
**Quality Assurance Coordinator**
**Division of Remediation**
**Bureau of Remediation and Waste Management**

***Standard Operating Procedure:*** *DR#011*

REVISION: **02**
DATE: **March 16, 2009**
Written/Revised by: **Nick Hodgkins**
Reviewed by: **Troy Smith**

Five Year Review No Changes Needed:

Print Name:______________ Signature:______________ Date:________

Print Name:______________ Signature:______________ Date:________

Print Name:______________ Signature:______________ Date:________

Print Name:______________ Signature:______________ Date:________

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## 1.0 PURPOSE

The purpose of this document is to describe the Maine Department of Environmental Protection, Bureau of Remediation and Waste Management, Division of Remediation's (MEDEP/DR) procedure for field screening volatile organic content of soils using a closed container and a photoionization detector (PID) or a flame ionization detector (FID).

## 2.0 APPLICABILITY

MEDEP/DR is responsible for the investigation and remediation of uncontrolled hazardous substance sites throughout Maine. The procedure described herein will provide a screening tool for determining relative levels of volatile organic compounds (VOCs) present in soil with a field PID or FID instrument.

## 3.0 RESPONSIBILITES

This procedure applies to all staff in the MEDEP/DR who are involved with performing field activities in the investigation of uncontrolled hazardous substance sites. Generally, it is the field personnel of MEDEP/DR and MEDEP/Technical Services (MEDEP/TS) (the Oil and Hazardous Materials Specialist and Geologist positions) who will be responsible for performing this task. Project managers of MEDEP/DR can assist and/or perform this task with field personnel present, or after receiving specific training in this activity.

All managers and supervisors are responsible for ensuring that staff who are responsible for performing this procedure understand and adhere to it for all events.

## 4.0 INTRODUCTION

In conducting this procedure, a soil sample is placed in an approved container and the volatile constituents are allowed to come to equilibrium. The headspace is then measured with a calibrated PID or FID, with a result expressed in parts per million (ppm). Due to the different ionization potentials of various compounds, actual levels of contamination cannot be determined. However, this technique provides an effective means of screening soil to determine "hot spots", extent of contamination, and as a means of screening samples for submittal for laboratory analysis.

This methodology is not a substitute for actual laboratory analysis; it is a screening tool in the field for determining "hot spots" and other areas of high or low concentrations of VOCs present in soil, or for when choosing samples from a site to submit for laboratory analysis.

## 5.0 PLANNING

As with any sampling event, a sampling and analysis plan (SAP) and a health and safety plan (HASP) must be developed. Protocol for the development of a Sampling and Analysis Plan can be found in DSR's SOP #014 – Development of a Sampling and Analysis Plan.

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## 6.0 EQUIPMENT

The following equipment is required for conducting the procedure:

- Soil sampling equipment (shovel, bucket auger, soil borer)
- Approved containers (one quart freezer zip lock bags are most commonly used, see section 6.1)
- A PID or FID
- Calibration equipment, including user's manual, for particular PID or FID to be used.

### 6.1 SPECIAL CONSIDERATIONS REGARDING CONTAINERS

Currently, the most commonly used (and recommended) containers are one quart sized polyethylene zip lock freezer bags (various manufacturers make these types of bags). Freezer bags are recommended as they are usually constructed from thicker material, and have better quality zip locks. Also used are wide mouthed, metal screw top 16 oz jars, with a ¼ inch hole drilled through center, with foil over the top to provide the seal.

## 7.0 PROCEDURE

1) Collect the soil sample, as outlined in the site specific Sampling and Analysis Plan (SAP) (See SOP DR#014 - Development of a Sampling and Analysis Plan) with appropriate soil sampling equipment.

2) Place approximately 250 grams of the soil sample into a approved container as stated in the SAP. The same type of container should be consistently used at the site for comparison purposes; do not mix or reuse headspace containers (unless the approved container is reusable and cleaned appropriately between uses). In so far as possible, samples should be mineral soil free of vegetation and stones larger than ½ inches in diameter. If soil samples are of different type (loam, sand, silt), this should be identified in the field log book. If a duplicate sample is to be submitted to the laboratory for analysis, this sample should be containerized and preserved as appropriate **immediately**. Soil that has been screened with this procedure should not be submitted for laboratory analysis, unless so documented. If using jars, the jars should be sealed now by placing a square of foil over the mouth and screwing on the lid. If using a bag, the bag should be zipped closed leaving sufficient air in the bag so that the instrument can withdraw an adequate headspace sample.

3) Shake the container for 30 seconds to thoroughly mix the contents. If bags are used, they may be kneaded until the contents are uniform.

4) Let Sample equilibrate. Allow at least fifteen minutes but not more than two hours for VOCs to reach headspace equilibrium with the headspace. An attempt should be made to allow the same amount of equilibration time for each sample.

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5) Warm up and calibrate the PID and FID instrument to be used according to the manufacturers recommended procedure (See Section 8 - Additional Considerations With Use of PID/FID). The PID and/or FID should be ready for use prior to collection of the first sample.

6) Shake containers/knead bags again for thirty seconds.

7) Measure and record the samples headspace concentration with the instrument. Collect a sample of the headspace by inserting the PID/FID probe into the appropriate opening for the container you are using. Record the highest reading on the instrument after allowing the probe to "sniff" the container for 10 – 15 seconds. It is important to obtain insert the probe as quickly as possible after the seal to the container has been broken. Documentation of headspace results should be outlined in the SAP.

## 8.0 ADDITIONAL CONSIDERATIONS WITH USE OF A PID/FID

Use of a PID/FID can be found in SOP DR#019 – Protocol for Use of a PID/FID.

There are limitations of PIDs and FIDs. A PID or FID cannot detect all VOCs, nor do they detect all VOCs equally. Factors that influence the response of the particular compound include ionization potential of compound, particular energy rating of lamp, calibration standard used, response factor, response curve, etc. In some instances, such as when the contaminant of concern is a single known compound, it is possible to calibrate the instrument so that a relatively accurate measurement, when compared to laboratory analysis, can be obtained. Because of this, it is recommended that the operator of the particular instrument that will be conducting this procedure take the time before the sampling event to familiarize themselves with the particular instrument that will be used, if they are not already familiar with that instrument. This includes reviewing the specific user manual, and calibration and practice with the instrument prior to the sampling event.

## 9.0 QUALITY ASSURANCE/QUALITY CONTROL

Data quality objectives (DQOs) should be stated in the SAP (See SOP DR#014). QA/QC samples may be collected if needed to meet your data quality objectives. The following are typical QA/QC samples or tasks conducted for PID/FID field screening. Additional sampling or tasks may be added based on the DQO requirements of the project.

### 9.1 RECALIBRATION DURING USE

During the course of the work day, the PID/FID should be recalibrated after all long work stoppages (such as lunch break). Additionally, the TVA's response should be periodically tested by challenging it with calibration gas. If the TVA does not read within 15% of the calibration gas, it should be recalibrated. All recalibration and meter challenges must be documented in the field notebook.

### 9.2 DUPLICATE SAMPLES

Duplicate samples may be collected at a rate of 5% to assess sample location variability.

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## 10.0 DOCUMENTATION

Field notes should be collected following the standard procedures outlined in SOP DR#013 - Documentation of Field Activities and Development of a SETR. It is important that documentation include the specific lamp energy rating, calibration standard, and special response factors or curves that may be employed for the particular sampling event. When documenting such a sampling event, one should include enough information so that a person at a later date can easily duplicate the sampling and be able to compare the results.

As this type of screening is done in the field by the sampling team conducting the sampling, no chain of custody is required.

Specialized forms may be developed for recording field screening data. Additionally, some PID/FIDs have software which can record data. Any special method of recording and documenting results must be outlined in the SAP.

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# APPENDIX C

# LABORATORY METHODS

## Guidelines for the Assessment and Cleanup of Saltwater Releases - NDDH
## Recommended Alternative Methods

| | North Dakota Cleanup Standards | | | Recommended Alternative Methods | |
|---|---|---|---|---|---|
| **Constituent** | **Analytical Method** | **Soil Concentration** | **GW Concentration** | **Soil Analytical Method** | **Water Analytical Method** |
| Chloride | EPA[1] 300.0 | 250 mg/kg | 250 mg/L | Saturated Paste Prep | |
| Sodium, % | Calc | | | Saturated Paste Prep | EPA 200.8, 200.7, 6010C, 6020A |
| Sulfate | EPA 300.0 | NA[2] | 250 mg/L | NA | |
| Alkalinity | SM 2320B | NA | 600 mg/L | NA | |
| Conductivity/EC[3] | SM 2510B | 2 mmohs/cm | 1.5 mmohs/cm | Saturated Paste Prep | |
| TDS[4] | Calc | NA | 500 mg/L | NA | SM 2540C |
| Benzene | 5035/8021 | NA | 5 μg/L | 5035/8260B/8021B | 5035/8260B/8021B |
| TPH[5]-GRO[6] | 8015C | 100 mg/kg | 10 μg/L | 8260B | 8260B |
| TPH-DRO[7] | 8015D | 100 mg/kg | 40 μg/L | 8015D | 8015D |
| Bromide | EPA 300.0 | NA | | NA | |
| Lead | 7421* | 250 μg/kg | 15 μg/L | EPA 200.8, 200.7, 6010C, 6020A | EPA 200.8, 200.7, 6010C, 6020A |
| Mercury | 7471A | 10 μg/kg | 2 μg/L | 7471B | 245.1 |
| Arsenic | 7060A* | 250 μg/kg | 10 μg/L | EPA 200.8, 200.7, 6010C, 6020A | EPA 200.8, 200.7, 6010C, 6020A |
| Barium | 6010B | 2500 μg/kg | 2000 μg/L | EPA 200.8, 200.7, 6010C, 6020A | EPA 200.8, 200.7, 6010C, 6020A |
| Cadmium | 7191A* | 500 μg/kg | 5 μg/L | EPA 200.8, 200.7, 6010C, 6020A | EPA 200.8, 200.7, 6010C, 6020A |
| Chromium | 7191* | 250 μg/kg | 100 μg/L | EPA 200.8, 200.7, 6010C, 6020A | EPA 200.8, 200.7, 6010C, 6020A |
| Selenium | 7740* | 250 μg/kg | 50 μg/L | EPA 200.8, 200.7, 6010C, 6020A | EPA 200.8, 200.7, 6010C, 6020A |
| Silver | 7761* | 250 μg/kg | 100 μg/L | EPA 200.8, 200.7, 6010C, 6020A | EPA 200.8, 200.7, 6010C, 6020A |
| SAR[8] | EPA 200.7 | 12 | NA | Saturated paste prep | NA |

[1] U.S. Environmental Protection Agency.
[2] Not applicable.
[3] Electrical conductivity.
[4] Total dissolved solids.
[5] Total petroleum hydrocarbons.
[6] Gasoline-range organics.
[7] Diesel-range organics.
[8] Sodium adsorption ratio.
* No longer EPA promulgated

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# APPENDIX D

# SEED MIX INFORMATION FOR DISTURBED AND HYDROCARBON-IMPACTED AREAS

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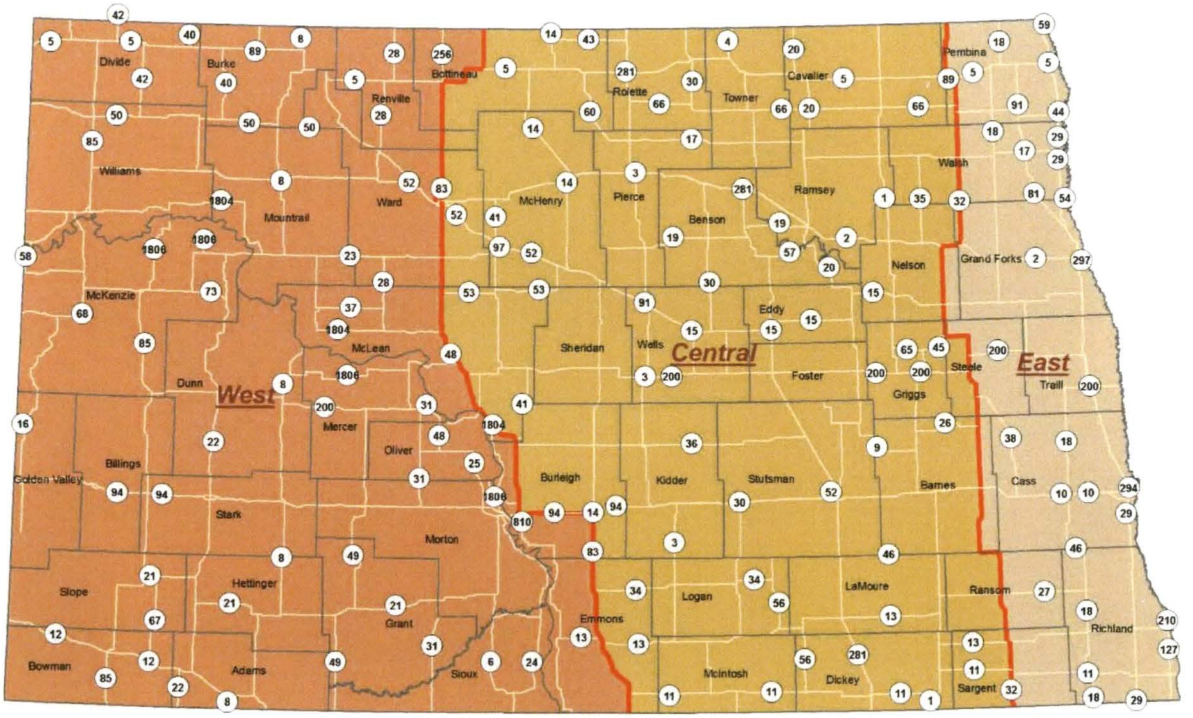
# SEED MIXTURES AND RATES FOR RANGELAND, CONSERVATION RESERVE PROGRAM LANDS, HAY LAND, TAME PASTURE AND RIGHT OF WAY FOR DISTURBED AND HYDROCARBON-IMPACTED AREAS

We divided the state into three major areas for seed mixtures and separated them by major roadways (Figure F-1). Major highways were used to simplify the decision making of remediation and reclamation. The boundaries were delineated on general rangeland types and precipitation relative to a region. Each section will have a recommended native rangeland seed mixture for *loamy/clayey sites, thin loamy/shallow loamy/limy sites, sandy/sands sites, and wet meadow, saline, and/or sodic sites.*

For the *upland rangeland sites,* select a minimum of three forbs/legumes from the recommended species list to complement the recommended grass-seeding mixtures. For the *wet meadow, saline, and/or sodic rangeland sites,* select at least one forb species from the list that best fits the site.



EERC BS50447.CDR

Figure D-1. Location of west, central and east zones, with the boundary, to be used for recommended seeding mixtures and rates in North Dakota. The *West* is an area from the Montana border east to U.S. Highway 83, *Central* stretches from U.S. Highway 83 to North Dakota Highway 32 and the *East* lies east of North Dakota Highway 32 to the Minnesota border.

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***Government agencies may have more rigorous restrictions on seed cultivars, origins, seeding dates, or other specifications than those listed here. Consult with the corresponding agency before designing and purchasing a seed mixture.***

*It is **NOT** recommended to apply fertilizer to native plant seeding. Fertilizers enhance exotic grasses and annual weeds, reducing the success of the establishment.*

**Upland Grass Seed Mixture Option for Rangeland Reclamation**

| Loamy and Clayey Sites | | | |
|---|---|---|---|
| Grass Species | West | Central | East |
| PLS lb/ac[1] | | | |
| Western Wheatgrass | 5.0 | 3.0 | 2.0 |
| Green Needlegrass | 2.5 | 2.0 | 2.0 |
| Slender Wheatgrass | 1.0 | 1.0 | 1.0 |
| Sideoats Grama | 2.0 | 2.0 | 2.0 |
| Blue Grama | 0.5 | 0.25 | 0.25 |
| Big Bluestem | – | 1.0 | 1.5 |
| Switchgrass | – | 0.25 | 0.5 |
| Canada Wildrye | – | 1.0 | 1.0 |
| Indiangrass | – | – | 1.0 |
| Total Seed Mixture | 11.0 | 10.5 | 11.25 |
| Thin Loamy, Shallow Loamy, and Limy Sites | | | |
| PLS lb/ac[1] | | | |
| Western Wheatgrass | 2.5 | 3.0 | 2.0 |
| Green Needlegrass | 1.5 | 1.5 | 1.5 |
| Slender Wheatgrass | 1.5 | 1.0 | 1.0 |
| Little Bluestem | 1.0 | 1.0 | 1.0 |
| Prairie Sandreed | 1.0 | 1.0 | 1.0 |
| Sideoats Grama | 2.0 | 2.0 | 2.0 |
| Blue Grama | 0.5 | 0.5 | 0.25 |
| Big Bluestem | – | 1.0 | 1.5 |
| Total Seed Mixture | 10.0 | 11.0 | 10.25 |
| Sandy and Sands Sites | | | |
| PLS lb/ac[1] | | | |
| Western Wheatgrass | 2.5 | 2.5 | 2.0 |
| Needle-and-Thread | 2.0 | 2.0 | 1.0 |
| Canada Wildrye | 1.0 | 1.0 | 1.0 |
| Little Bluestem | 1.0 | 1.0 | 1.0 |
| Prairie Sandreed | 1.5 | 1.5 | 1.0 |
| Sideoats Grama | 2.0 | 2.0 | 2.0 |
| Blue Grama | 0.5 | 0.5 | 0.25 |
| Sand/Big Bluestem | – | 1.5 | 2.0 |
| Total Seed Mixture | 10.5 | 12.0 | 10.25 |

[1] PLS = pure live seed: Seeding rates are 1.5 times the normal seeding rate based on 30 seeds/ft$^2$.

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### Upland Forb Seed Options (select 3) to Seed with the Grass Seed Mixture for Rangeland Reclamation

| Forb and Legume Mixture (loamy, clayey, sandy, sands, shallow loamy, thin loamy, limy) | |
|---|---|
| Forb and Legume Species[2] | North Dakota |
| PLS lb/ac[1,3] | |
| Purple Prairieclover | 0.1 |
| White Prairieclover | 0.1 |
| Purple Coneflower | 0.1 |
| Maximilian Sunflower | 0.1 |
| Blanket Flower | 0.2 |
| Black-Eyed Susan | 0.05 |
| Stiff Sunflower | 0.1 |
| Goldenrod | 0.05 |
| Lewis Flax | 0.1 |
| Scarlet Globemallow | 0.05 |
| Prairie Coneflower | 0.1 |

[1] PLS = pure live seed: Seeding rates are 1.5 times the normal seeding rate based on 30 seeds/ft².

[2] Select a minimum of three forb/legume species from the list. The seeding rate of three selected forbs/legumes at the prescribed rate will equal approximately 5% of the total mixture.

[3] Drill calibration is critical when seeding low rates because seed may be expensive.

### Wet Meadow and Saline/Sodic Site Grass and Forb Species Seed Mixture Options for Rangeland Reclamation

| Wet Meadow, Saline and/or Sodic Sites | | | |
|---|---|---|---|
| Plant Species[2,3] | West | Central | East |
| PLS lb/ac[1] | | | |
| Western Wheatgrass | 8.0 | 5.0 | 5.0 |
| Slender Wheatgrass | 2.0 | 2.0 | 2.0 |
| Prairie Cordgrass | 2.0 | 2.0 | 2.0 |
| Inland Saltgrass | 1.0 | 1.0 | 1.0 |
| Switchgrass | – | 1.0 | 1.0 |
| Total Grass Seed Mixture | 13.0 | 11.0 | 11.0 |
| Western Yarrow | 0.05 | 0.05 | 0.05 |
| Gardner Saltbush[4] | 0.3 | 0.3 | 0.3 |
| Fourwing Saltbush[4] | 0.45 | 0.45 | 0.45 |
| Lewis Flax | 0.1 | 0.1 | 0.1 |

[1] PLS = pure live seed: Seeding rates are 1.5 times the normal seeding rate based on 30 seeds/ft².

[2] Select a minimum of one forb/legume species from the list.

[3] Drill calibration is critical when seeding low rates because seed may be expensive.

[4] Gardner and fourwing saltbush should be used only on the saline/sodic sites.

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### Varieties/Cultivars/Ecovars

| Approved Named Varieties | | |
|---|---|---|
| Species | | Recommended Varieties for North Dakota |
| | | Origin of nonvarietal (common) native and introduced grass seed is limited to North Dakota, South Dakota, Nebraska, Montana, Wyoming, Minnesota and Canada. |
| Introduced Cool-Season Grasses | | |
| Meadow Bromegrass | | Fleet, Paddock, Regar, Montana, MacBeth, Cache |
| Crested Wheatgrass | Type: Standard | Nordan, RoadCrest, Summit |
| | Fairway | Ephraim, Ruff, Parkway, Fairway, Douglas |
| | Hybrid | HyCrest II, HyCrest, NU-ARS AC2 |
| Intermediate Wheatgrass | | Reliant, Clarke, Slate, Chief, Oahe, Haymaker, Beefmaker, Manifest |
| Pubescent Wheatgrass | | Manska, Greenleaf |
| Native Warm- and Cool-Season Grasses | | |
| Green Needlegrass | | Lodorm, AC Mallard, Fowler |
| Needle-and-Thread | | Common, AC Sharptail |
| Nutall Alkaligrass | | Common |
| Porcupine Grass | | Common |
| Prairie Junegrass | | Common |
| Slender Wheatgrass | | Adanac, Pryor, Revenue, Primar, Firststrike |
| Western Wheatgrass | | Rodan, Walsh, Flintlock, Rosana, W.R. Poole, Recovery |
| Canada Wildrye | | Mandan |
| Big Bluestem | | Sunnyview, Bison, Bonilla, Bounty |
| Little Bluestem | | Badlands, Itasca |
| Blue Grama | | Bad River |
| Sideoats Grama | | Killdeer, Pierre, Butte |
| Indiangrass | | Tomahawk |
| Prairie Cordgrass | | Red River |
| Prairie Sandreed | | Goshen, Bowman, Koch |
| Switchgrass | | Dacotah, Forestburg, Sunburst, Summer |
| | | Nonvarietal (common) native forbs and legumes will originate or be grown in North Dakota, South Dakota, Nebraska, Montana, Wyoming, Idaho, Washington, Oregon, Minnesota, Wisconsin, Iowa, Colorado and Canada. |
| Native Legumes/Forbs | | |
| Black-Eyed Susan | | Common |
| Blanket Flower | | Common |
| Grayhead Coneflower | | Common |
| Narrow-Leaved Purple Coneflower | | Bismarck |
| Prairie (yellow) Coneflower | | Stillwater |
| Purple Coneflower | | Common |
| Canada Goldenrod | | Common |
| Missouri Goldenrod | | Common |
| Stiff Goldenrod | | Common |
| Lewis Flax | | Appar, Maple Grove |
| Maximilian Sunflower | | Medicine Creek |

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| Approved Named Varieties | | |
|---|---|---|
| Species | | Recommended Varieties for North Dakota |
| Purple Prairieclover | | Bismarck |
| Scarlet Globemallow | | Common |
| Stiff Sunflower | | Bismarck |
| Western Yarrow | | Great Northern |
| White Prairieclover | | Antelope |
| **Introduced Legumes** | | |
| Alfalfa [1] | | Fall dormancy rating or winter survival index (WSI) of 3 or less [2] |
| Native Shrubs | | |
| Fourwing Saltbush | Dewinged | Wytana, Snake River |
| Gardner Saltbush | | |
| Winterfat | | Open Range |
| WY Big Sagebrush | | Common |

[1] A partial list of grazable-type alfalfas can be found in "Developing Alfalfa Adapted to Grazing in the Northern Great Plains," available at www.ag.ndsu.edu/archive/streeter/99report/berdahl99.htm.

[2] The following Web sites are approved for use in determining approved alfalfa varieties: www.alfalfa.org/ and www.maes.umn.edu/. Varieties should have a fall dormancy rating or WSI of 3 or less. Note: Alfalfa varieties with a WSI of 2 or 3 may experience some winter kill. The origin of nonvarietal (common) alfalfa types is limited to North Dakota, South Dakota, Minnesota, Montana and Canada.

**NOTE**: Approved alfalfa varieties that may not be shown on these Web sites include Alogonquin, Anik, Blazer, Champ, Drylander, Grim, Ladak, Ladak 65, Prowler, Rambler, Rangelander, Ramsey, Ranger, Spredor 2, Teton, Travois, Vernal, and Wrangler. Alfalfa varieties not listed here or shown on these Web sites will require documentation from the distributor or developer to determine suitability.

### Conservation Reserve Program (CRP)

Seed CRP fields back to the predominant species found within the stand. Contact the local NRCS office for help with seed mixtures in your construction area. Some CRP is seeded to native species. Take care to seed all areas to appropriate species.

### Hay Land Reclamation

| Hay Land Sites | | | |
|---|---|---|---|
| Plant Species[3] | West | Central | East |
| | PLS lb/ac[1] | | |
| Crested Wheatgrass | 3.0 | – | – |
| Pubescent/Intermediate Wheatgrass | 4.0 | 3.0 | – |
| Meadow Bromegrass | – | 7.0 | 10.0 |
| Alfalfa[2] | 4.0 | 3.0 | 5.0 |
| Total Seed Mixture | 11.0 | 13.0 | 15.0 |

[1] PLS = pure live seed: Seeding rates are 1.5 times the normal seeding rate based on 30 seeds/ft$^2$.

[2] Use alfalfa varieties with a fall dormancy rating of 3 to 4 and a winter hardiness rating of 2 to 2.5 when reseeding pure stands of alfalfa. Recommended seeding rates are 8 pounds/acre of PLS in the west, 9 pounds/acre of PLS in the central, and 10 pounds/acre of PLS in the eastern portions of North Dakota.

[3] These hay land recommendations are to be used as examples. Always consult with the landowner/manager, and plant what he or she prefers or needs for future use.

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**Tame Pasture Reclamation**

| Hay Land Sites | | | |
|---|---|---|---|
| Plant Species[3] | West | Central | East |
| PLS lb/ac[1] | | | |
| Crested Wheatgrass | 4.0 | – | – |
| Pubescent/Intermediate Wheatgrass | 5.0 | 6.0 | 6.0 |
| Western Wheatgrass | 5.0 | – | – |
| Meadow Bromegrass | – | 15.0 | 15.0 |
| Alfalfa[2] | – | – | – |
| Total Seed Mixture | 14.0 | 21.0 | 21.0 |

[1] PLS = pure live seed: Seeding rates are 1.5 times the normal seeding rate based on 30 seeds/ft$^2$.

[2] Use alfalfa varieties with a fall dormancy rating of 3 to 4 and a winter hardiness rating of 2 to 2.5 when reseeding pure stands of alfalfa. Recommended seeding rates are 8 pounds/acre of PLS in the west, 9 pounds/acre of PLS in the central, and 10 pounds/acre of PLS in the eastern portions of North Dakota.

[3] These tame pasture recommendations are to be used as examples. Always consult with the landowner/manager, and plant what he or she prefers or needs for future use.

**Rights of Way**

Use specifications for Class II seed specifications in North Dakota Department of Transportation Manual Section 708.02B.

**Seeding Dates**

| **Recommended Seeding Dates** | |
|---|---|
| **Species Type and Season of Planting** | **North Dakota** |
| **Cool-Season Species** | |
| Spring | Prior to June 1[2] |
| Late Summer [1] | Aug. 1 to Sept. 1 |
| Late Fall (dormant) | See footnote[3] |
| **Warm/Cool-Season Mix** | |
| Spring | April 20 to June 15[2] |
| Late Summer[1] | Not recommended |
| Late Fall (dormant) | See footnote[3] |

[1] Weather and soil moisture conditions permitting. If soil moisture levels and forecasted precipitation amounts are not favorable, this time period of seeding is not recommended.

[2] Seeding may be extended with adequate soil moisture and when favorable precipitation and temperatures are forecast.

[3] Seed after Oct. 10 when ground temperatures at a depth of 4 inches are 45°F or lower, and cooler air temperatures are forecast.

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# APPENDIX E

# SALT-TOLERANCE INFORMATION OF GRASSES, FORBS, AND LEGUMES

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**Table E-1. Relative Saline Tolerance Levels (EC) of Selected Grass, Forb, and Legume Species[1]**

| | EC (mmhos/cm) Production Affected | Upper Limit | Tolerance Rating | Palatability |
|---|---|---|---|---|
| **Grass** | | | | |
| Nuttall's Alkaligrass | 14 | 30 | Very High | Medium |
| Alkali Sacaton | 14 | 26 | Very High | Medium |
| Beardless Wildrye | 13 | 26 | Very High | Medium |
| Tall Wheatgrass | 13 | 26 | Very High | Low |
| Green Wheatgrass (Newhy) | 13 | 26 | Very High | High |
| Russian Wildrye | 13 | 24 | Very High | Medium |
| Alkali Cordgrass | 12 | 24 | Very High | – |
| Alkali Bluegrass | 12 | 24 | Very High | – |
| Slender Wheatgrass | 10 | 22 | Very High | Medium |
| Altai Wildrye | 10 | 20 | Very High | Medium |
| Plains Bluegrass | 10 | 20 | Very High | Medium |
| Tall Fescue | 8 | 18 | High | Medium |
| Western Wheatgrass | 6 | 16 | High | High |
| Thickspike/Streambank Wheatgrass | 6 | 14 | Moderate | Medium |
| Crested Wheatgrass | 6 | 14 | Moderate | High |
| Siberian Wheatgrass | 6 | 14 | Moderate | Medium |
| Pubescent Wheatgrass | 6 | 12 | Moderate | Medium |
| Intermediate Wheatgrass | 6 | 12 | Moderate | High |
| Creeping Foxtail | 5 | 12 | Moderate | High |
| Smooth Brome | 5 | 10 | Moderate | Highest |
| Meadow Brome | 4 | 10 | Moderate | Highest |
| Orchardgrass | 3 | 8 | Low | Highest |
| Switchgrass | – | 6 | Low | Medium |
| Reed Canarygrass | 3 | 5 | Low | Highest |
| Blue Grama | – | 5 | Low | Highest |
| Buffalograss | – | 3 | Low | Highest |
| **Forbs and Shrubs** | | | | |
| Forage Kochia | 10 | 18+ | High | Medium |
| Fourwing Saltbush | 10 | 18+ | High | Medium |
| Winterfat | 10 | 18+ | High | High |
| Strawberry Clover | 6 | 16 | High | Highest |
| Yellow Sweetclover | 5 | 10 | Moderate | High |
| Cicer Milkvetch | 4 | 10 | Moderate | Highest |
| Birdsfoot Trefoil | 5 | 8 | Low | High |
| Alfalfa | 4 | 8 | Low | Highest |
| Clovers (red, alsike, ladino) | 3 | 4 | Low | Highest |
| Small Burnet | 2 | 3 | Low | Highest |

[1] Source: Ogle, D., and St. John, L., 2009, Plants for saline to sodic soil conditions: TN Plant Materials No. 9A (Rev.). USDA, NRCS, October 2009.

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# APPENDIX F

# SALT-TOLERANCE INFORMATION OF AGRONOMIC CROPS

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**Table F-1. Relative Saline Tolerance Levels (EC) of Agronomic Crops[1,2]**

| Crop | EC (mmhos/cm) Production Affected | Upper Limit | Tolerance Rating |
|---|---|---|---|
| Canola | 10 | 14 | High |
| Barley | 8 | 16 | High |
| Wheat (durum) | 7 | 14 | Moderate |
| Wheat (semidwarf) | 7 | 14 | Moderate |
| Sugar Beets | 7 | 14 | Moderate |
| Sunflower | 6 | 14 | Moderate |
| Safflower | 6 | 10 | Moderate |
| Oats | 4 | 8 | Low |
| Soybean | 4 | 8 | Low |
| Alfalfa | 4 | 8 | Low |
| Corn | 3 | 6 | Low |
| Flax | 2 | 4 | Low |
| Edible Beans | 1 | 2 | Low |

[1] Source: Ogle, D., and St. John, L., 2009, Plants for saline to sodic soil conditions: TN Plant Materials No. 9A (Rev.). USDA, NRCS, October 2009.

[2] Source: Franzen, D., 2013, Managing saline soils in North Dakota: Circ. SF1087 (Rev), NDSU Extension Service.

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# APPENDIX G

# USEFUL INFORMATION

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## CONVERSIONS AND STANDARDS

### Electrical Conductivity

| | |
|---|---|
| decisiemen per meter (dS/m) | mmhos/cm |
| | |
| | |
| | |
| | |
| | |
| | |
| | |

### Chemical Concentration

| | |
|---|---|
| parts per million (ppm) | mg/kg (in soil)<br>mg/L (in liquids) |
| parts per billion (ppb) | µg/kg (in soils)<br>µg/L (in liquids) |
| | |
| | |
| | |
| | |
| | |
| | |

### Area

| | |
|---|---|
| Acre | 43,560 square feet |
| 1 ha | 2.471 acres |
| | |
| | |
| | |
| | |

### Volume

| | |
|---|---|
| barrel | 42 gallons |
| acre-foot | 325,851 gallons |
| 1 cfs/day | 1.98 acre feet |
| | |
| | |

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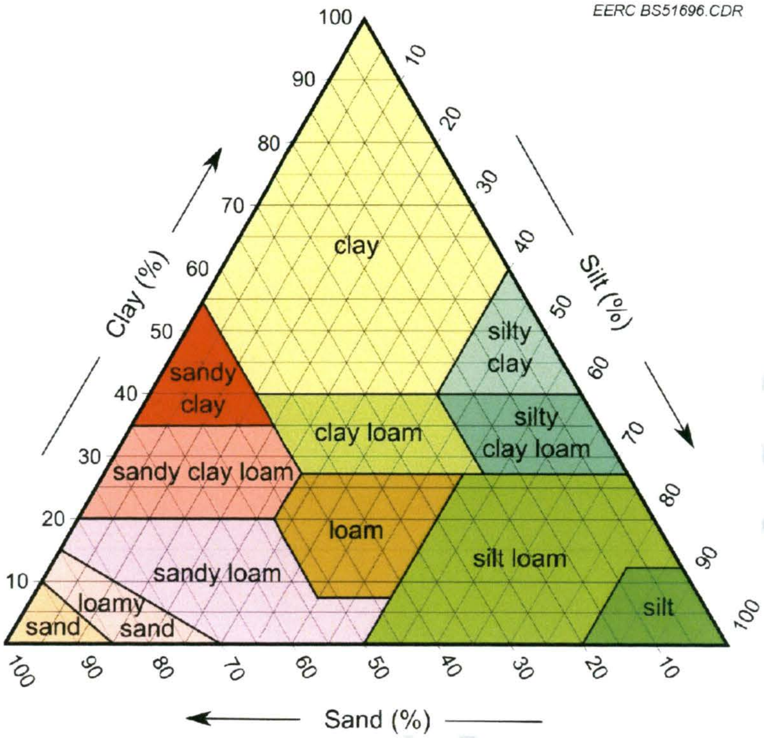

Figure G-1. Soil texture triangle. (source: U.S. Department of Agriculture).

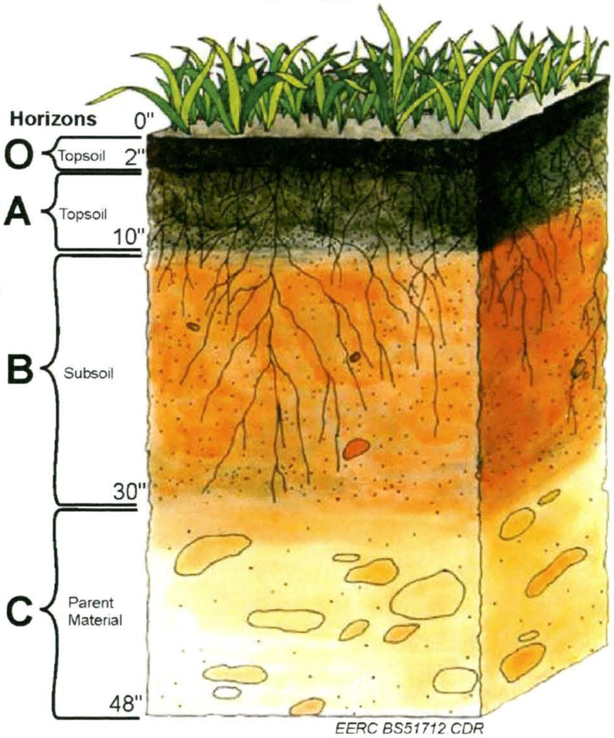

Figure G-2. Soil profile image (figure source: U.S. Department of Agriculture).

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# APPENDIX H

# API INFORMATION AND WORKSHEETS

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## INSTRUCTIONS FOR TABLE A-1—RECLAMATION PRACTICES

For relatively uncomplicated saltwater release sites, Table A-1 may be used to estimate the amounts of amendments to be applied if chemical remediation is found to be a viable remedial option.

### HOW TO USE TABLE A-1

1. Determine Moisture Deficit (Sections A, B, or C)
Find the section of Table A-1 that matches the rainfall characteristics for the site [select either adequate rainfall (Section A), marginal rainfall (Section B), or inadequate rainfall (Section C)]. To select the appropriate section, estimate the net annual moisture condition [i.e., precipitation evaporation index (PEI)]. Appendix I contains the information needed to calculate the net annual moisture condition. For the site of interest, obtain the normal annual precipitation and mean annual class A pan evaporation rate from the maps in Appendix I. Calculate the net annual moisture condition as follows:

Annual Precipitation (inches) Minus Annual Evaporation (inches) = Net Annual Moisture Condition

| If the Net Annual Moisture Condition is: | Select Table A-1 Section: |
|---|---|
| Less negative or more positive than -12 inches (e.g., -4 inches or +7 inches) | A, Adequate Rainfall |
| Between -12 and -28 inches (e.g., -19 inches) | B, Marginal Rainfall |
| More negative than -28 inches (e.g., -33 inches) | C, Inadequate Rainfall |

2. Locate Soil EC (Column 1)
Within the appropriate section of Table A-1, find the EC value in Column 1 that matches the site conditions. If EC levels are <4 mmhos/cm and there is evidence that the salt-affected soil will not support natural vegetation, chemical amendments may be needed to alleviate dispersed soil conditions. At low soil EC values, soil dispersion may occur if ESP >5% in soils with smectite clays or ESP > 15% in soils containing clays other than smectites (e.g., illites).

3. Calculate Chemical Amendment (Gypsum) Requirement
To calculate the amount of chemical amendment (expressed as gypsum) required, use the equation provided in Column 2:

a. Use the values for CEC and ESP from the 0–1 ft depth interval to calculate the gypsum requirement for the 0–1 ft depth interval. (Figure A-1 may be used to convert SAR to ESP.)

b. Repeat the calculation using the CEC and ESP for the 1–2 ft depth interval.

c. Add the results from the two calculations to get the amount of gypsum to treat the upper 2 ft of soil. An additional topdressing of gypsum will help prevent soil crusts from forming at the ground surface.

d. If the pH is <5.5 or >8.5, or chemical amendments other than gypsum are to be applied, consult manual.

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EXAMPLE GYPSUM CALCULATION:

A site characterization found that the 0–1 ft depth interval had a CEC = 14 meq/100 g and an SAR = 32. The 1–2 ft depth interval was found to have a CEC = 17 meq/100 g and an SAR = 20. Using Figure A-1, the SAR values of 32 and 20 convert to ESP values of 37% and 26%, respectively. Using the equation in Column 2 (and ignoring the CEC denominator), calculate the pounds of gypsum per 100 sq ft of soil as follows:

0–1 ft depth interval: (14 meq)(37-5)(0.078) = 35 lb gypsum/100 sq ft

1–2 ft depth interval: (17 meq)(20-5)(0.078) = 20 lb gypsum/100 sq ft

To find Total Gypsum Requirement:

(35 lb gypsum/100 sq ft) + (20 lb gypsum/100 sq ft) = 55 lb gypsum/100 sq ft

If a chemical amendment other than gypsum is to be used, consult manual.

About 1 vertical ft of water will be required to dissolve 50 pounds of gypsum per 100 sq ft of salt-affected soil. Therefore, slightly over 1 vertical ft of water will be required to dissolve 55 pounds of gypsum per 100 sq ft of soil in this example.

4. Note Mulch and Fertilizer Application Rates (Columns 3 and 4)
Mulch and fertilizer improve drainage and fertility of soil. Mulch (Column 3) and fertilizer (Column 4) may be applied at the rates indicated.

5. Note Remedial Actions (Column 5)
Remedial actions noted in Column 5 provide additional information and cautions applicable to the spill site circumstances within the same row. The steps provided are in approximate chronological order (there may be some site-specific exceptions).

Table A-1. Reclamation Practices for Adequate, Marginal, and Inadequate Rainfall Areas

| Column 1 | Column 2 | Column 3 | Column 4 | Column 5 |
|---|---|---|---|---|
| EC (mmhos/cm) | Calculate Gypsum Application Rate* (lb/100 sq ft) | Mulch Rate** (depth in inches before incorporation***) | N-P-K Fertilizer Rate** (lb/100 sq ft) | Remedial Actions |
| **Section A, Adequate Rainfall** (net annual moisture condition less negative or more positive than -12 inches) | | | | |
| 0–4**** | (CEC)(ESP-5)(0.078)= then, 0-1 + 1-2 ft = total | 2c, 3m, 4f | 3 lb of 13-13-13 | Incorporate gypsum (to displace sodium and prevent dispersion) and mulch. Surface apply fertilizer. Plant. |
| 4–8 | (CEC)(ESP-5)(0.078)= then, 0-1 + 1-2 ft = total | 2c, 3m, 4f | 3 lb of 13-13-13 | Incorporate gypsum and mulch. Surface apply fertilizer. Plant with semi-salt-tolerant vegetation. |
| 8–16 | (CEC)(ESP-5)(0.078)= then, 0-1 + 1-2 ft = total | 2c, 3m, 4f | 3 lb of 13-13-13 | Incorporate gypsum and mulch. Surface apply fertilizer. Plant with salt-tolerant vegetation. |
| >16 | => | => | => | Consult Environmental Specialist. |
| **Section B, Marginal Rainfall** (net annual moisture condition between -12 and -28 inches) | | | | |
| 0–4 | (CEC)(ESP-5)(0.078)= then, 0-1 + 1-2 ft = total | 2c, 3m, 4f | 3 lb of 13-13-13 | Incorporate gypsum (to displace sodium and prevent dispersion) and mulch. Surface apply fertilizer. Plant. Irrigate, if required. |
| 4–8 | (CEC)(ESP-5)(0.078)= then, 0-1 + 1-2 ft = total | 2c, 3m, 4f | 3 lb of 13-13-13 | Incorporate gypsum and mulch. Surface apply fertilizer. Plant with semi-salt-tolerant vegetation. Irrigate, if required. |
| 8–16 | (CEC)(ESP-5)(0.078)= then, 0-1 + 1-2 ft = total | 2c, 3m, 4f | 3 lb of 13-13-13 | Incorporate gypsum and mulch. Irrigate, if required. Surface apply fertilizer. Plant with salt-tolerant vegetation. Irrigate again, if required. |
| >16 | => | => | => | Consult Environmental Specialist. |
| **Section C, Inadequate Rainfall** (net annual moisture condition more negative than -28 inches) | | | | |
| 0–4 | (CEC)(ESP-5)(0.078)= then, 0–1 + 1–2 ft = total | 2c, 3m, 4f | 2 lb of 13-13-13 | Incorporate gypsum (to displace sodium and prevent dispersion) and mulch. Surface apply fertilizer. Plant. Irrigate. |
| 4–8 | (CEC)(ESP-5)(0.078)= then, 0–1 + 1–2 ft = total | 2c, 3m, 4f | 2 lb of 13-13-13 | Incorporate gypsum and mulch. Surface apply fertilizer. Plant with semi-salt-tolerant vegetation. Irrigate. |
| 8–16 | (CEC)(ESP-5)(0.078)= then, 0–1 + 1–2 ft = total | 2c, 3m, 4f | 2 lb of 13-13-13 | Incorporate gypsum and mulch. Irrigate. Surface apply fertilizer. Plant with salt-tolerant vegetation. Irrigate again. |
| >16 | => | => | => | Consult Environmental Specialist. |

* Example Gypsum Calculation: A site characterization found that the 0–1 ft depth interval had a CEC = 14 meq/100 g and an SAR = 32. The 1–2 ft depth interval was found to have a CEC = 17 meq/100 g and an SAR = 20. Using Figure A-1, the SAR values of 32 and 20 convert to ESP values of 37% and 26%, respectively. Using the equation in Column 2 (and ignoring the CEC denominator), calculate the pounds of gypsum per 100 sq ft of soil as follows:
  0–1 ft depth interval: (14 meq)(37-5)(0.078) = 35 lb gypsum/100 sq ft
  1–2 ft depth interval: (17 meq)(20-5)(0.078) = 20 lb gypsum/100 sq ft
  To find Total Gypsum Requirement:
  (35 lb gypsum/100 sq ft) + (20 lb gypsum/100 sq ft) = 55 lb gypsum/100 sq ft
  If a chemical amendment other than gypsum is to be used, consult manual.
  About 1 vertical ft of water will be required to dissolve 50 pounds of gypsum per 100 sq ft of salt-affected soil. Therefore, slightly over 1 vertical ft of water will be required to dissolve 55 pounds of gypsum per 100 sq ft of soil in this example.

** Mulch and fertilizer improve soil drainage and fertility and may speed the remediation process. Consult your company policy or Environmental Specialist regarding the use of these amendments.

*** c = coarse-textured soil, m = medium-textured soil, f = fine-textured soil.

**** See instructions on the use of Table A-1 regarding gypsum application to soils with EC <4 mmhos/cm.

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# Infiltration Rates of Various Soils

| Soil Type | Steady Infiltration Rate |
|---|---|
| | (inch/hour) |
| Sands | >0.79 |
| Sandy and silty soils | 0.39-0.79 |
| Loams | 0.20-0.39 |
| Clayey soils | 0.04-0.20 |
| Sodium clayey soils | <0.04 |

Adapted from Hillel, D. 1998. Environmental soil physics. Pg. 403. Academic Press, San Diego, Calif.

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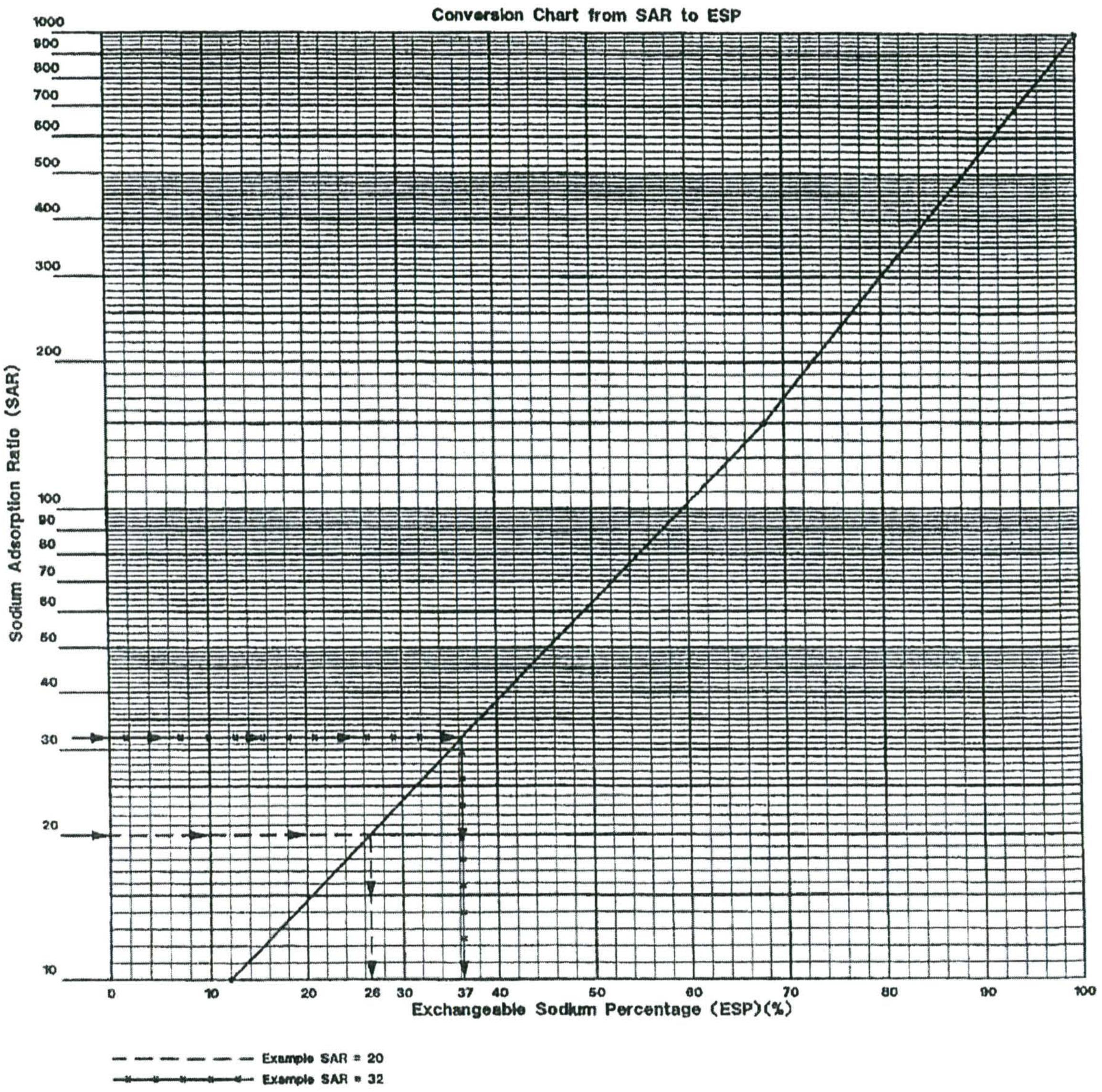

Figure A-1. Correlation of ESP and SAR.

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## WORKSHEET 2 - DRAINAGE (INSTRUCTIONS)

### SUMMARY

The potential need for enhanced soil drainage is evaluated in this worksheet. One of the most critical aspects of remediating salt-affected soil is assuring that the subsoil provides a sufficiently permeable route to allow salts to move out of the upper 6 ft of soil. Most failures of *in situ* chemical amendment remediation efforts in areas of adequate and possibly marginal rainfall are due to omission of this one consideration from remediation planning. This worksheet may be modified to be consistent with operator policy.

**Data:** Worksheet 2 has been prepared to provide a determination about whether the spill-affected soil is capable of allowing salts to move beyond 6 ft via leaching. Data required include depth to the high water table, determination of wetlands classification, landscape position, depth to an impermeable layer, hydraulic conductivity, and shrink-swell potential.

The Soil Survey and local community knowledge will provide most of the data for a "generic" soil of this type. However, influences by humans can alter many of these properties, and the precision of large-scale mapping sometimes misrepresents soil conditions at a specific location. For best results, determine these characteristics first-hand by examining the soil to be remediated.

**Criteria:** Data gathered in previous steps are interpreted as follows. If any of the following are true, then this soil is at great risk of not being able to allow the salts to move out of the upper 6 ft of soil:

- If the depth to the top of the seasonal high water table or perched water is less than 6 ft from the soil surface
- If the site is in a wet or delineated wetlands area (or at low elevation and close to one)
- If the landscape position is basin (or sometimes toe-slope)
- If the saturated hydraulic conductivity (or permeability) of ANY layer (no matter how thin) is <0.2 in/hr
- If the shrink-swell potential is high

**Interpretation:** A determination based on all of this information is then made. If the soil is determined to have a drainage problem, then chemical remediation alone (without appropriate drainage enhancement) does not have a high probability of success.

**Determination:** A determination is then made regarding whether drainage improvement efforts will be made. If drainage improvement efforts will be made, continue with the next step in the Decision Tree (Section 5) leading to *in situ* chemical remediation efforts. If drainage will not be improved, then consider the natural remediation or mechanical remediation section of the Decision Tree.

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## WORKSHEET 2 - DRAINAGE

| | Decision-Making Parameter | Data: Site Condition (record) | Criteria: Potential Drainage Problem If: | Interpretation: Drainage Problem? (Y/N) |
|---|---|---|---|---|
| 1 | Depth to seasonal high water table (groundwater or perched) (ft) | ______ | <6 ft | ______ |
| 2 | Site often wet or in a delineated wetlands (Y/N) | ______ | Y | ______ |
| 3 | Depth to impermeable layer, restrictive layer, or bedrock from 0–6 ft (ft) | ______ | <6 ft | ______ |
| 4 | Hydraulic conductivity of most restrictive layer from 0–6 ft (in/hr) | ______ | <0.2 in/hr | ______ |
| 5 | Shrink-swell potential (low/moderate/high) | ______ | High | ______ |
| 6 | Cumulative determination based on all evidence | NA | Any of above | ______ |

**Determination:** If cumulative evaluation is that the site has a drainage problem, then *in situ* chemical remediation will probably result in long-term failure without concurrent improvement of drainage.

**Notes:** Determine responses for lines 1–5 from field, Soil Survey, USDA-NRCS, or community knowledge.

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## WORKSHEET 3 - SUPPLEMENTAL WATER (INSTRUCTIONS)

### SUMMARY

The potential need for supplemental water (irrigation) is evaluated in this worksheet. When *in situ* chemical amendment remediation will be used, sufficient leaching water is required to move salts permanently below the root zone. Worksheet 3 is provided to determine if sufficient water is naturally available in the form of rainfall to remediate the soil chemically, and if not, the amount of supplemental water indicated. This worksheet may be modified to be consistent with operator policy.

**Data:** The important data to be collected are soil texture group, annual PEI, and the percent of salts in the soil which must be removed to reach a target level.

Soil texture group should be determined in the field, but the Soil Survey and local community knowledge may provide information. The soil texture group to enter in this table is the finest texture which occurs in a cumulative 2 ft of soil in the upper 6 ft. The response will be coarse (sandy), medium (loamy), or fine (clayey).

The PEI, or net annual moisture condition, is determined from weather maps in Appendix I. The location of the spill is found on each map. By interpolation, note the annual normal precipitation in inches and the annual pan evaporation in inches. Subtract the annual pan evaporation in inches from the annual normal precipitation in inches. The mathematical result is the PEI, and it is recorded in Worksheet 3. In general, a north-south line which follows the eastern edge of Oklahoma separates a positive PEI to the east, from a negative PEI to the west. PEI values more or less become more negative until near the Pacific Coast. The more negative the PEI, the more supplemental water may be required to provide enough water to move the salts below 6 ft. Where the PEI is positive, rainfall alone is usually enough to provide this amount of water. Depending on soil texture, a slightly negative PEI may not indicate the need for supplemental water.

**Determination of Quantity of Supplemental Water Indicated:** Approximately 1 ft of water is required to remove 80% of salts from 1 ft of soil (Abrol, *et al.*, 1988). This and a number of other factors have been combined to provide a supplemental water indication matrix in Worksheet 3. Diligent application of supplemental water using pulse flooding (flooding with several inches of water followed by several days of drying, and repeating this process until all supplemental water has been applied) may reduce the total quantity of supplemental water required for leaching by as much as 50% of the volume shown in the Worksheet 3 matrix.

Use of this matrix requires calculation of the amount of salt which must be removed from the soil. This value is calculated from the following information:

- The highest soil EC in mmhos/cm in either the 0–1 or 1–2 ft soil layer; this is measured in a saturated paste extract
- The target EC in mmhos/cm; for most agricultural crops this will be 4 mmhos/cm; higher ECs (based on background soil or the tolerance level of halophytic plants) can be used in many cases

The desired percent decrease in EC = [1-(Target EC/Current EC)][100].

**Example:** The following example shows how to determine the amount of water that is indicated.

Assume the finest soil texture is medium, the annual precipitation is 16 inches, the annual pan evaporation is 38 inches, the target EC is 4 mmhos/cm, and the highest soil EC is 28 mmhos/cm.

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The PEI is then 16 inches precipitation - 38 inches evaporation = -22 inches.

The desired percent decrease in EC = [1-(4/28][100] = 85.7%. This percent decrease falls within a percent decrease range of 80% to 96% EC.

The above information is converted into inches of supplemental water using the matrix in Worksheet 3. In a medium-textured soil where the EC should be decreased between 80% and 96%, and having a PEI of -22 inches, the amount of supplemental water indicated to remove this much salt beyond 6 ft is about 42 inches. In this example, if supplemental water is diligently applied in successional pulse flooding events, then as little as one-half this much water (21 inches) may be sufficient to leach salts.

**Interpretation:** Based on this information, the cost and potential problems associated with supplying this much water are considered. A decision is then made whether this amount of water will be supplied. If this much water WILL NOT be supplied, consider natural remediation or mechanical remediation. If this much water WILL be supplied, the supplemental water problem is solved, and the next step is to consider the potential for soil erosion.

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## WORKSHEET 3 - SUPPLEMENTAL WATER

**Data:**

Soil texture group* (finest texture in any layer >2 ft thick) (coarse, medium, fine) ____________

Annual PEI** (rainfall less evaporation) ______________________________ (inches)

Percent EC decrease required to reach target EC*** ______________________________ (%)

**Determination of Quantity of Supplemental Water Indicated:**

| **If Annual PEI is** | **To Decrease EC by 0%–64%**<br>**>-12** | <br>**-12 to -28** | <br>**<-28** |
|---|---|---|---|
| **Texture Group:** | **Supplemental Water Indication (in)** | | |
| Coarse | 0 | 8 | 18 |
| Medium | 0 | 10 | 21 |
| Fine | 0 | 12 | 24 |

| **If Annual PEI is** | **To Decrease EC by 64%–80%**<br>**>-12** | <br>**-12 to -28** | <br>**<-28** |
|---|---|---|---|
| **Texture Group:** | **Supplemental Water Indication (in)** | | |
| Coarse | 0 | 18 | 36 |
| Medium | 0 | 21 | 42 |
| Fine | 0 | 24 | 48 |

| **If Annual PEI is** | **To Decrease EC by 80%–96%**<br>**<-4** | <br>**-4 to -12** | <br>**-12 to -28** | <br>**<-28** |
|---|---|---|---|---|
| **Texture Group:** | **Supplemental Water Indication (in)** | | | |
| Coarse | 0 | 18 | 36 | 72 |
| Medium | 0 | 21 | 42 | 84 |
| Fine | 0 | 24 | 48 | 96 |

If supplemental water indicated is >0 inches, the application of supplemental water should be considered.

As little as one-half the supplemental water indication shown may suffice with diligent pulse flooding.

**Interpretation:** If the cumulative determination is that supplemental water is indicated, then *in situ* chemical remediation will probably exhibit long-term failure without application of the quantity of supplemental water indicated.

**Notes:**

* Obtain information from field, Soil Survey, or community knowledge.
** Obtain precipitation and evaporation data from Appendix I.
*** Percent EC decrease required = [1 - (target EC/current EC)][100].
Calculate for either 0–1 or 1–2 ft layer (whichever has highest current EC)
Example: Current EC in 0–1 ft = 18 mmhos/cm
Current EC in 1–2 ft = 28 mmhos/cm
Target EC = 4 mmhos/cm
Percent EC decrease required = [1 - (4/28)][100] = 85.7%

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## WORKSHEET 4 - CHEMICAL AMENDMENTS (INSTRUCTIONS)

### SUMMARY

Chemical amendments can be used to displace sodium from soil cation exchange sites. Worksheet 4 provides a step-by-step process whereby soil or spilled produced water analytical data are used to calculate the quantity and type of chemical amendment required to remediate the spill-affected soil. This worksheet may be modified to be consistent with operator policy.

**Step 1:** The quantity of chemical amendment to apply may be calculated based on soil measurements (Step 2A) or measurements from the spilled material (Step 2B). The first step is to decide which of these two methods will be used. Using the calculations based on spilled material (Step 2B) has the following inherent disadvantages:

- Assumes the entire spill is contained in the upper 2 ft of soil
- Assumes all sodium is retained on clay cation exchange sites
- Assumes uniform distribution of spilled material over the entire spill-affected area
- Does not address soil responses to salt over time

As a result, this option should be used only when soil data cannot be obtained and only if the spill occurred within the previous 6 months. Use of the calculations based on soil measurements (Step 2A) is always acceptable, regardless of the age of the spill. Therefore, Step 1 guides the user into either Step 2A for calculations based on soil measurement or into Step 2B for calculations based on spilled material.

**Step 2A:** Following the soil measurement option, Step 2A involves collection of the data shown. Soil pH, CEC, and ESP are determined separately at the analytical laboratory for the 0–1 and 1–2 ft depth increments. The 0–1 and 1–2 ft depth intervals can be substantially different in physical and chemical properties which are important to chemical amendment selection. The spill area is also determined.

**Step 3A:** In Step 3A, the comprehensive gypsum requirement is calculated. Gypsum is used as a reference material to determine how much calcium should be applied to displace sodium to an endpoint ESP of 5%. An ESP of 5% accounts for smectite, which is especially sensitive to exchangeable sodium, and sampling and analytical inefficiencies.[1] The final calculation in this step is the total calculated pounds of pure gypsum required to displace sodium in the affected area. However, due to sodium displacement inefficiencies with gypsum, it is generally recommended to apply about 1.25 times the amount of gypsum calculated in Step 3A. Thus, if gypsum is the material selected for application, then 1.25 times that amount should be applied and incorporated into the spill area. If the pH is between 5.5 and 8.5, and neither calcium nitrate nor calcium chloride are to be applied, then this is the actual amount of gypsum to apply. The principal disadvantage of gypsum is that 1 ft of water is required to dissolve gypsum applied at a rate of 10 tons/acre under optimal dissolution conditions (high EC and high ESP).

**Step 4A (neutral pH soil):** The corresponding alternative amount of calcium chloride or calcium nitrate to apply when the pH is between 5.5 and 8.5 is given in Step 4A (neutral pH soil). Although the equivalent weight of calcium chloride and calcium nitrate is less than that of gypsum, these two materials are usually much more expensive than gypsum. They also have potential disadvantages associated with the addition of nitrates or yet more chlorides. However, with these disadvantages understood, both of these amendments are fast acting and require less water to dissolve compared to gypsum.

---

[1] Higher ESP endpoints (ESP = 6 – 15%) may be appropriate if smectite clays are known to be absent and there is a high degree of confidence in the characterization and analysis of ESP of the affected soil.

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**High or Low pH Amendments:** If the pH is less than 5.5, as an option, it may be advisable to apply lime as a chemical amendment unless plant pH preference is lower than 5.5. Calcium and magnesium from lime dissolving in acid soil will displace sodium in acid soils, and it will raise the pH to a level more suitable to the growth of many plants. If the pH is more than 8.5, an acidifying amendment may be used to displace sodium in soils with carbonates. Acidifying amendments can decrease the soil pH to a level more suitable to the growth of most plants, but over time, gypsum will also tend to lower pH. The acidifying amendments usually work best in topsoil and when the soil contains carbonates because calcium and magnesium are released when the carbonates dissolve in the acid. However, it may be better to use gypsum, calcium chloride, or calcium nitrate if the pH is above 8.5 or if the soil has insufficient carbonates to buffer the pH change. Any adjustments made in soil pH should be consistent with the pH preference or tolerance range of the vegetation present.

**Step 4A (acid soil):** Data required to calculate the amount of lime to apply for an acid soil are calculated in Step 4A (acid soil). If the soil analytical results show that the soil pH is less than 5.5 and the deliberate liming option is chosen, the analytical laboratory should be asked to provide a lime requirement to raise the pH to 7.0 as indicated in Appendix J. The laboratory should perform a titration procedure and report the results in pounds of calcium carbonate ($CaCO_3$) required to raise the pH of the soil to 7.0 in 1,000 pounds of soil. This should be done separately for the 0–1 and 1–2 ft depth intervals. The total amount of calcium carbonate to apply is calculated at the bottom of Step 4A (acid soil).

**Step 5A (acid soil):** The lime requirement to raise the pH to 7.0 may not supply enough calcium to displace the amount of sodium necessary. Lime applied in excess of the pH 7.0 endpoint does not dissolve and therefore, supplies little calcium or magnesium at a pH level above 7.0. Therefore, in Step 5A (acid soil), the lime requirement value is converted into a gypsum equivalent value. In Step 6A (acid soil), the remaining sodium displacement required is calculated so that it can be supplied by gypsum.

**Step 6A (acid soil):** In Step 6A (acid soil), the gypsum equivalent value of lime from Step 5A (acid soil) is subtracted from the total comprehensive gypsum value required to displace sodium calculated in Step 3A. The result is the amount of gypsum which should be co-applied with the calcium carbonate to provide the total amount of calcium required to displace sodium. For more rapid response, strong and very soluble liming agents, such as calcium oxide (CaO) and calcium hydroxide [$Ca(OH)_2$], can be used but they are both dangerous to handle and they could have a cementing effect on the soil. In contrast, it is always acceptable to apply limestone or dolomite to raise pH. Unlike calcium oxide and calcium hydroxide, limestone and dolomite will not cause chemical burns or raise the soil pH above 8.5. In addition, limestone and dolomite are usually readily available, inexpensive, and relatively easy to handle. Their reaction rate in soil can be accelerated by applying in small grain sizes.

**Step 4A (alkali soil):** Data required to determine the amount of acidifying amendment to apply to an alkali soil are shown in Step 4A (alkali soil). If this option is chosen, the laboratory is asked to provide a sulfur (S) requirement in pounds of sulfur per 1,000 pounds of soil to decrease the pH to 8.3. The total amount of sulfur to apply is calculated at the bottom of Step 4A (alkali soil).

**Step 5A (alkali soil):** In Step 5A (alkali soil), the gypsum equivalent of the sulfur is calculated.

**Step 6A (alkali soil):** The amount of gypsum to co-apply with sulfur to supply the total amount of calcium required is calculated in Step 6A (alkali soil).

**Step 7A (alkali soil):** Acidifying alternatives to sulfur are given in Step 7A (alkali soil). These include aluminum sulfate [$Al_2(SO_4)_3$]:$18H_2O$; iron (II or ferrous) sulfate ($FeSO_4$:$7H_2O$); and sulfuric acid ($H_2SO_4$). Sulfuric acid is dangerous to handle and is applied as a liquid. Use of elemental sulfur should be restricted to sites which have topsoil remaining because the oxidation of sulfur to sulfate requires the presence of a soil-borne bacterium which will usually be

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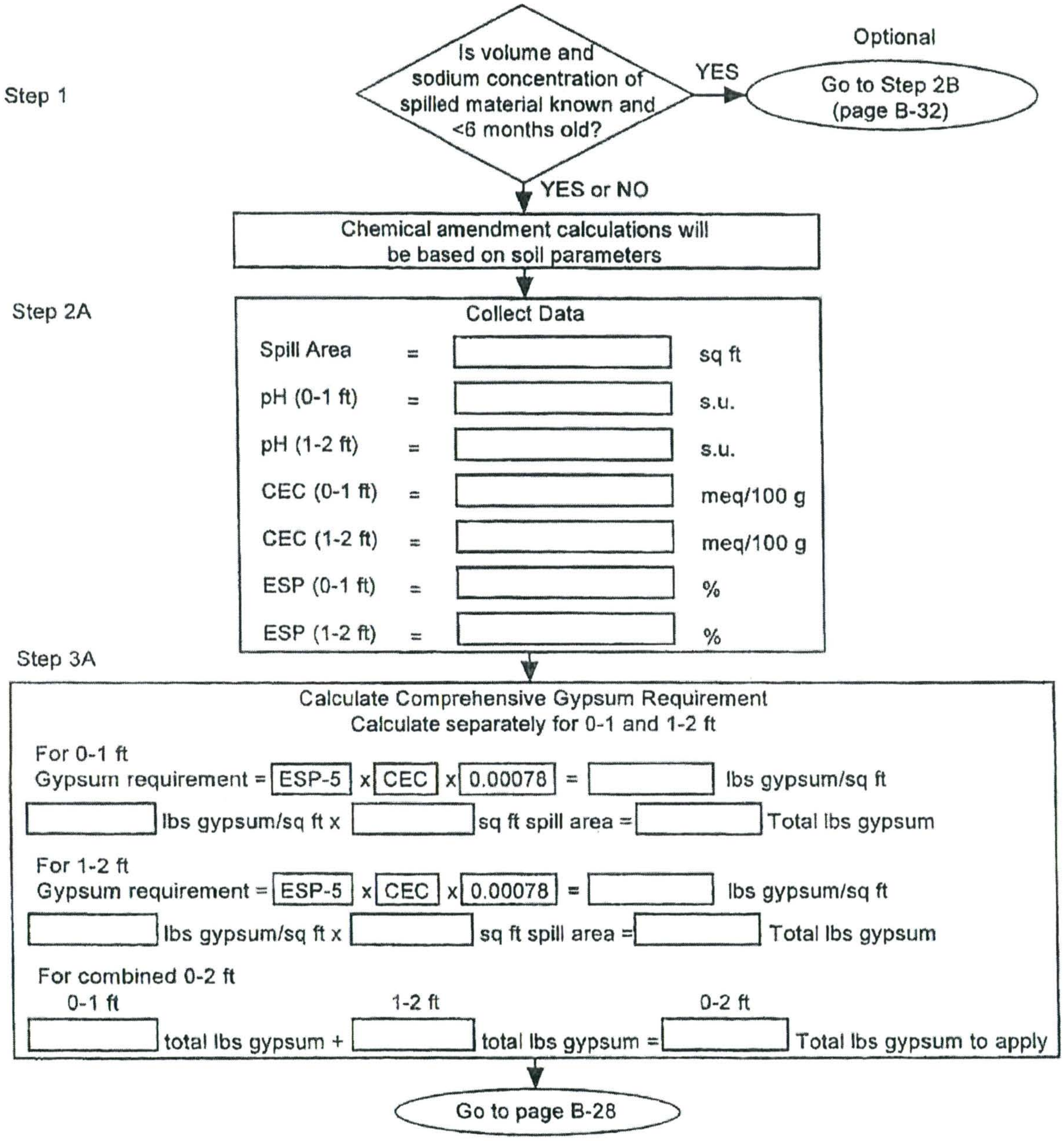
more abundant and amid more growth support factors in topsoil in contrast to surface exposed subsoil. To avoid undesired results, it is important to apply no more of these acidifying chemicals than is calculated here.

**Step 2B:** Data required to calculate the chemical amendment equivalent and requirement based entirely on the concentration and quantity of spilled material are listed in Step 2B. These data include the volume spilled (in barrels) and the sodium concentration (in mg/L) in the spilled material. The sodium concentration is typically between 20% to 35% of the TDS (in mg/L) in produced waters, and the TDS data are requested as a check function. The spill area is also recorded here as a matter of convenience.

**Step 3B:** The gypsum equivalent and requirement based on the concentration and quantity of spilled material are calculated in Step 3B. The amount of gypsum to apply to the spill area is the last calculation in Step 3B. Calculating the gypsum requirement in this manner does not address potentially high or low soil pH conditions. For reasons listed in Step 1 of this worksheet, calculation of the chemical amendment requirement based on soil data is preferred over calculations based on the concentration and quantity of spilled material.

## Worksheet 4
## Chemical Amendments Worksheet

Chemical amendment for displacing sodium and adjusting pH is calculated for upper 2 ft of spill-affected soil*



Step 1

Is volume and sodium concentration of spilled material known and <6 months old?

YES → Optional: Go to Step 2B (page B-32)

YES or NO ↓

Chemical amendment calculations will be based on soil parameters

Step 2A

Collect Data

|  |  |  |  |
|---|---|---|---|
| Spill Area | = |  | sq ft |
| pH (0-1 ft) | = |  | s.u. |
| pH (1-2 ft) | = |  | s.u. |
| CEC (0-1 ft) | = |  | meq/100 g |
| CEC (1-2 ft) | = |  | meq/100 g |
| ESP (0-1 ft) | = |  | % |
| ESP (1-2 ft) | = |  | % |

Step 3A

Calculate Comprehensive Gypsum Requirement
Calculate separately for 0-1 and 1-2 ft

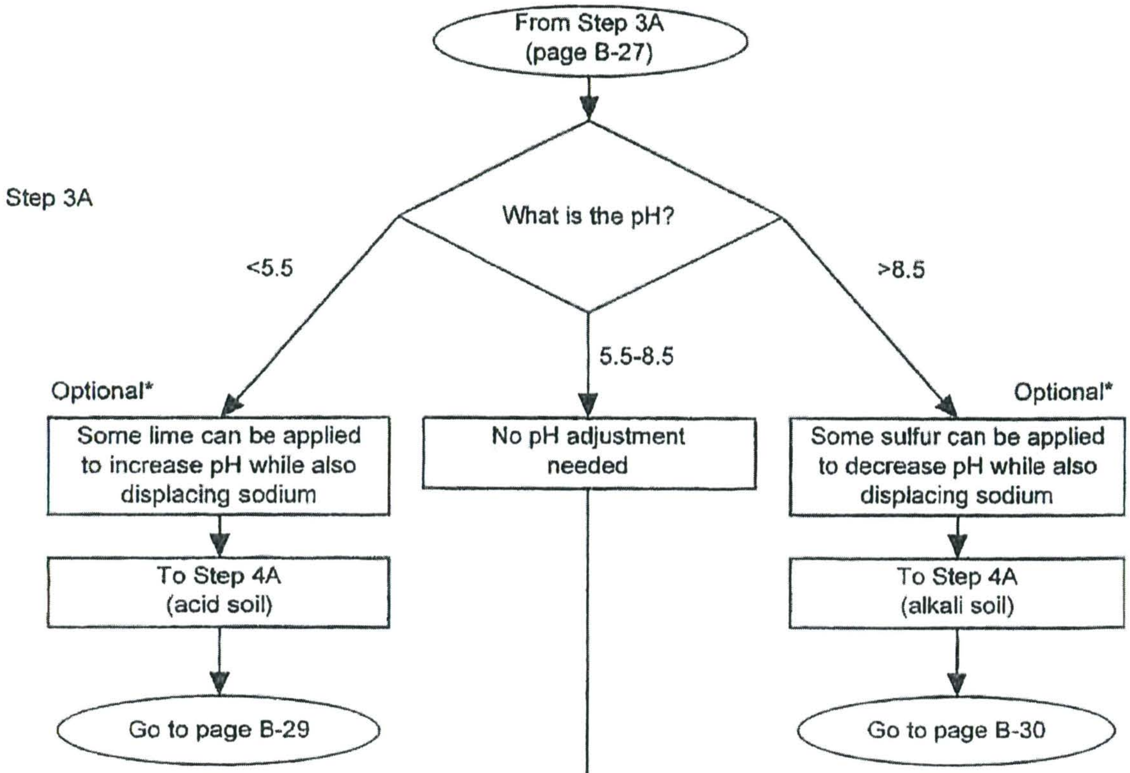
For 0-1 ft
Gypsum requirement = ESP-5 x CEC x 0.00078 = lbs gypsum/sq ft
lbs gypsum/sq ft x sq ft spill area = Total lbs gypsum

For 1-2 ft
Gypsum requirement = ESP-5 x CEC x 0.00078 = lbs gypsum/sq ft
lbs gypsum/sq ft x sq ft spill area = Total lbs gypsum

For combined 0-2 ft
0-1 ft total lbs gypsum + 1-2 ft total lbs gypsum = 0-2 ft Total lbs gypsum to apply

Go to page B-28

* Calculations are performed using only numbers in boxes [i.e., numbers in denominators (e.g., per 100 g in CEC expression) are for identification only and have already been considered in the constants provided (e.g., for 0-1 ft of a soil with ESP = $\boxed{45}$ % and CEC = $\boxed{13}$ meq/100 g, the first line calculation would be: $\boxed{45-5} \times \boxed{13} \times \boxed{0.00078} = \boxed{0.4056}$ lbs gypsum/sq ft)].



Step 4A (neutral pH soil)

Alternative Chemical Amendments to Gypsum
Where Soil pH is Between 5.5 and 8.5

| Alternatives are: | Lbs equivalent to 1 lb gypsum |
|---|---|
| Calcium chloride, $CaCl_2 : 2H_2O$ | 0.85 |
| Calcium nitrate, $Ca(NO_3)_2$ | 0.95 |

Caution - Neither calcium chloride nor calcium nitrate should be used if chloride or nitrate can migrate to surface water or usable groundwater.

Note - Gypsum is slower to react with soil, but lasts longer than calcium chloride or calcium nitrate. At least 25% of the total gypsum requirement should be satisfied by use of gypsum, and a final topdressing of gypsum should also be applied to protect the soil surface from dispersion.

Stop

* Most plants prefer pH 5.5-8.5. pH should be adjusted to within 5.5 to 8.5 as part of salt remediation of most soils, but there may be exceptions in certain locations and agricultural situations. Applications of pH-neutral amendments will usually improve yields in both strongly acid and strongly alkaline soils.

From Step 3A
(page B-28)

(To increase pH while displacing sodium)

Step 4A (acid soil)

**Collect Data**

Have laboratory titrate acidity up to pH 7.0 and provide a lime requirement in lbs $CaCO_3$ /1,000 lbs soil

Determine 0-1 and 1-2 ft separately

From 0-1 ft ____ lbs $CaCO_3$ /1,000 lbs soil
+
From 1-2 ft ____ lbs $CaCO_3$ /1,000 lbs soil
=
Total 0-2 ft ____ lbs $CaCO_3$ /2,000 lbs soil

0-2 ft
( ____ lbs $CaCO_3$ /2,000 lbs soil) x 0.092 x ( ____ sq ft soil) = ____ Total lbs $CaCO_3$ to apply

Step 5A (acid soil)

**Calculate Gypsum Equivalent**

For 0-1 ft

( ____ lbs $CaCO_3$ /1,000 lbs soil) x 0.158 x ( ____ sq ft soil) = ____ Total lbs gypsum equivalent

For 1-2 ft

( ____ lbs $CaCO_3$ /1,000 lbs soil) x 0.158 x ( ____ sq ft soil) = ____ Total lbs gypsum equivalent

For combined 0-2 ft

0-1 ft ____ lbs gypsum equivalent + 1-2 ft ____ lbs gypsum equivalent = 0-2 ft ____ Total lbs gypsum equivalent

Step 6A (acid soil)

**Calculate Gypsum to Co-Apply with Calcium Carbonate ($CaCO_3$)**

From Step 3A: ( 0-2 ft ____ total lbs comprehensive gypsum required ) - From Step 5A (acid soil): ( 0-2 ft ____ total lbs gypsum equivalent ) = ____ Total lbs gypsum to co-apply

Stop

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From Step 3A
(page B-28)

(To decrease pH while displacing sodium)

Step 4A (alkali soil)

**Collect Data**

Have laboratory titrate alkalinity to pH 8.3 and provide
an acid requirement in lbs S/1,000 lbs soil

Determine 0-1 and 1-2 ft separately

From 0-1 ft ☐ lbs S/1,000 lbs soil

\+

From 1-2 ft ☐ lbs S/1,000 lbs soil

=

Total 0-2 ft ☐ lbs S/2,000 lbs soil

0-2 ft
( ☐ lbs S/2,000 lbs soil) x 0.092 x ( ☐ sq ft soil) = ☐ Total lbs S to apply

Step 5A (alkali soil)

**Calculate Gypsum Equivalent**

For 0-1 ft
( ☐ lbs S/1,000 lbs soil) x 0.495 x ( ☐ sq ft soil) = ☐ Total lbs gypsum equivalent

For 1-2 ft
( ☐ lbs S/1,000 lbs soil) x 0.495 x ( ☐ sq ft soil) = ☐ Total lbs gypsum equivalent

For combined 0-2 ft
0-1 ft ☐ lbs gypsum equivalent + 1-2 ft ☐ lbs gypsum equivalent = 0-2 ft ☐ Total lbs gypsum equivalent

Step 6A (alkali soil)

**Calculate Gypsum to Co-Apply with Sulfur (S)**

From Step 3A: ( 0-2 ft ☐ total lbs comprehensive gypsum required ) - From Step 5A (alkali soil): ( 0-2 ft ☐ total lbs gypsum equivalent ) = ☐ Total lbs gypsum to co-apply

Go to page B-31

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## DRAINAGE

Many spill circumstances will require some amount of attention to internal soil drainage. Unattended poor internal soil drainage may be the most common reason for failure of remediation projects. Soil drainage factors can be combined into hydrologic soil groups, as shown in Table E-1.

Table E-1. Hydrologic Soil Groups.

| Hydrologic Soil Groups | Definition |
|---|---|
| A | Soils having a high infiltration rate even when thoroughly wetted and consisting chiefly of deep, well to excessively drained sands or gravels (low runoff potential). These soils have a high rate of water transmission. |
| B | Soils having a moderate infiltration rate when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse texture. These soils have a moderate rate of water transmission. |
| C | Soils having a slow infiltration rate when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water or soils with moderately fine to fine texture. These soils have a slow rate of water transmission. |
| D | Soils having a very slow infiltration rate when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission. |

Source: USDA, Soil Survey Division Staff, 1993; USDA-SCS, 1979.

In order to remediate a salt-affected soil chemically, salts must have a pathway through which they can migrate out of the root zone during leaching. Impediments to salt migration out of the root zone include bedrock, an impermeable layer, a water table, or a very slowly permeable soil within 6 ft of the soil surface. Unless these conditions are altered, chemically displaced salts will be unable to migrate out of the root zone.

There are six basic ways to create a path for soil-pore water to migrate below the root zone. They are:

- Chemical amendment
- Plant growth
- Mulching
- Deep plowing
- Installing subsurface drains
- Establishment of intensive-water-demand plants around the spill-affected area to lower the water table

In most spill circumstances which require attention to improved drainage, several or all of these methods may be utilized simultaneously.

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## CHEMICAL AMENDMENT

Application of appropriate chemical amendments causes the soil to aggregate. A period of years may be required for slowly soluble amendments, such as gypsum, to aggregate soil sufficiently to create macropores, whereas typically a few weeks or months may be required for very soluble amendments, such as calcium nitrate or calcium chloride. These reactions are dependent on soil moisture conditions.

In order to aggregate the soil, the chemical amendment must come into contact with the salt-affected soil. If the soil has already dispersed, the chemical amendment requires a mechanical method to place it in the salt-affected areas. This can be done with plowing to shallow depths, or by hydraulic injection as a slurry or solution for deeper depths.

All forms of chemical amendment should be incorporated into the soil. A final topdressing of gypsum may protect the surface from dispersion. Various chemical amendments and their application are discussed in Appendix K.

## PLANT GROWTH

During remediation, the roots of any vegetation present will help physically to move soil particles. If the soil chemistry has been adjusted with an effective chemical amendment, the soil particles will aggregate. If the salt concentration is high (EC >8–12 mmhos/cm) at the outset of remediation, establishment of interim, salt-tolerant vegetation will help generate macropores. If the water table is also high, then wetlands plants may be advisable. Vegetation also occurs in conjunction with other soil biota, such as invertebrate animals, fungi, and microbes, all of which will help aggregate soil. If required, addition of fertilizer will stimulate these organisms, and the soil will be remediated more quickly. Attributes of various types of vegetation are given in Appendix F.

## MULCHING

The use of mulch greatly assists the soil in aggregation, improves aeration, and minimizes evaporation and erosion. Mulch should be incorporated into the soil as deeply as possible. Chemical amendments (previously discussed) should be applied at least as deep as the mulch is placed. Mulch and chemical amendments can be incorporated with a variety of plows and rototillers. Mulch has been shown to accelerate the rate of remediation substantially, and improve the effectiveness of chemical amendments.

The interface between the mulch and the soil usually acts as a water channel or macropore. Then, as the mulch decomposes, larger macropores are left where the mulch had been. If the chemical amendment has had time to promote soil aggregation, these pores will remain open for some time. If the chemical amendment has not reacted by the time the mulch decomposes, then the clay particles may disperse again and refill the macropores. Mulch with high C:N ratios will decompose slowly, and mulch with low C:N ratios will decompose quickly. Mulches are discussed in more detail in Appendix L.

## DEEP PLOWING

Impermeable layers can be broken up by heavy-duty deep plows, or by hydraulic fracturing. Breaking up this layer will promote internal soil drainage and removal of soluble salts. Deep plows are mechanical implements pulled by a tractor or tracked vehicle and are functional to a

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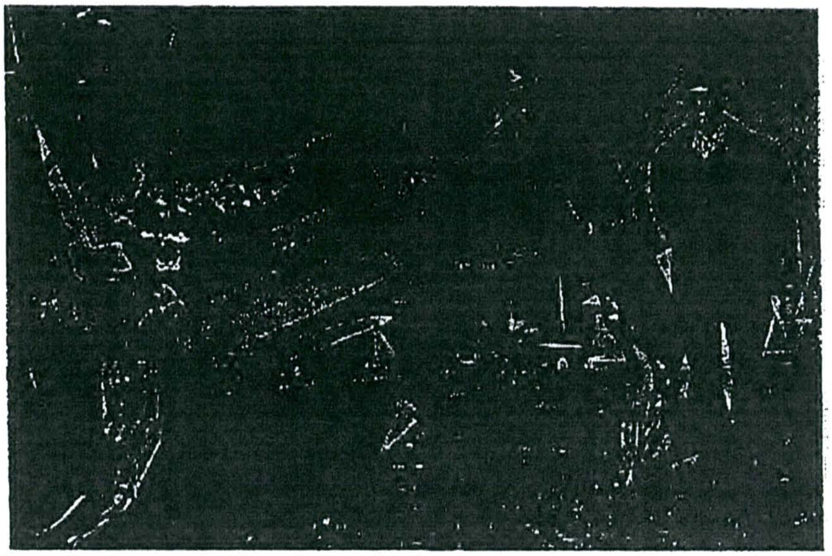
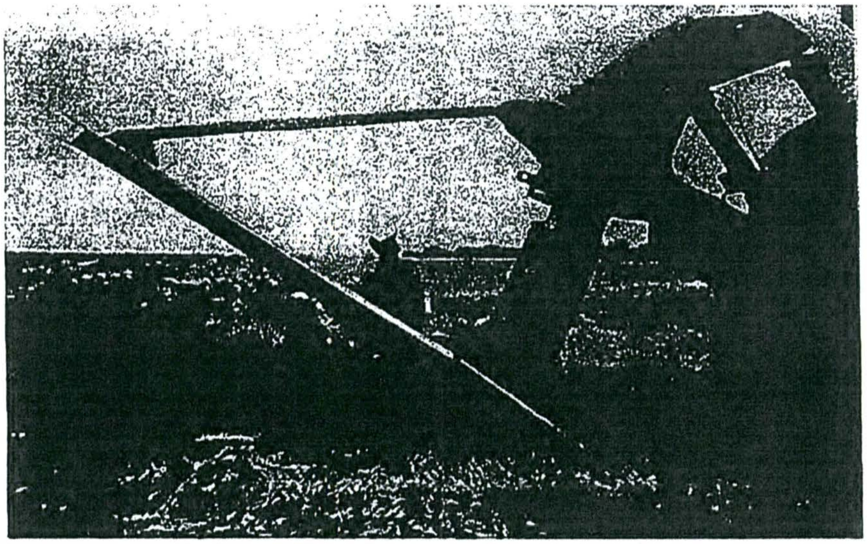
depth of about 3 ft. Pictures of two types of deep plows are shown in Figures E-1 and E-2. Deep plows are usually pulled in a cross pattern.



These ripper shanks are pulled through the soil to break cemented pans. The person is about 2m tall.

Figure E-1. Ripper Shanks (Singer/Munns, 1992).
(SOILS, AN INTRODUCTION by Singer/Munns, © 1992. Reprinted by permission of Prentice-Hall, Inc., Upper Saddle River, NJ)



This giant slip-plow mixes soil horizons as it is pulled through the soil. Soil is lifted up the inclined blade to the top where it falls back into the slit made by the plow. This is an effective tool for destroying stratification.

Figure E-2. Giant Slip-Plow (Singer/Munns, 1992).
(SOILS, AN INTRODUCTION by Singer/Munns, © 1992. Reprinted by permission of Prentice-Hall, Inc., Upper Saddle River, NJ)

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Impermeable layers can be fractured (but not mixed) by high pressure hydraulic injection. As noted above, chemical amendments can be the material injected during this process. Hydraulic injection can go to a depth of 10 ft or more.

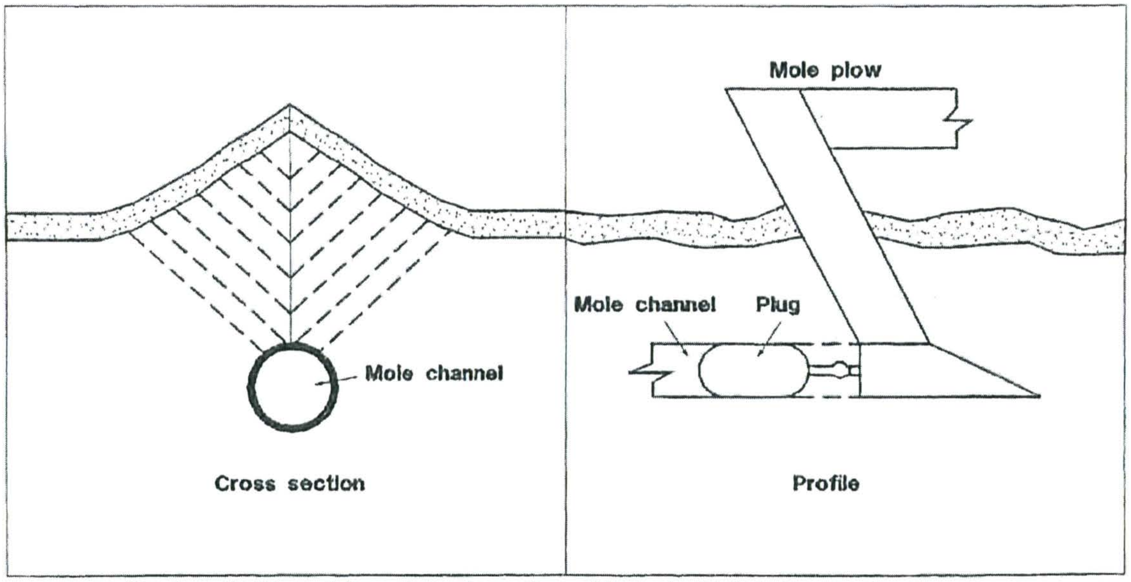
## SUBSURFACE DRAINS

Subsurface drains can be used to lower the water table and/or intercept downward-migrating salts if the receiving groundwater is sensitive to salts. Consultation with a drainage expert is recommended if subsurface drains are contemplated.

For very small plots, one or two open trenches may suffice. Trench drains may be most effective for a coarse soil over a finer-textured subsoil where the water table is higher than the finer-textured subsoil. The trench is dug slightly lower than the top of the fine-textured subsoil, and "perched" water runs into it. The salty water is collected in the trench for transfer to a processing or disposal unit. The trench drain would not be appropriate for intercepting salts to prevent migration into groundwater if there is no barrier layer between the topsoil and the groundwater.

In larger areas, or if a greater intensity of drain spacing is required, a temporary mole drain, or more permanent drain tubing can be installed. These subsurface drains can be used both to lower the water table and intercept salts. Both mole drains and subsurface tubing drains terminate in a sump. Saltwater collected in the sump is disposed in an approved manner.

Mole drains involve pulling a 4-inch-diameter, bullet-shaped implement through the subsoil. This drain is temporary and will usually close and seal off within a couple of years as the soil settles. Figure E-3 portrays a mole drainage system.



Plug is pulled through the soil, leaving a channel through which drainage water can move.

Figure E-3. Diagrams Showing How an Underground Mole Drainage System is Put in Place (Hughes, H. A. 1980).
(Reproduced by permission of Deere & Company, © 1980. Deere & Company. All rights reserved).

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To install subsurface drain tubing, a trench approximately 8 inches wide is dug. Sand may be placed in the bottom of the trench in addition to 4-inch-diameter perforated plastic drain tubing. The drain tube should be surrounded with a filter sock to minimize clogging the drain interior with soil particles. The lengths of 4-inch lateral tubing snap together, and also snap into the main, which can be 4 or 6 inches in diameter. A diagram depicting lateral and main configurations is shown in Figure E-4.

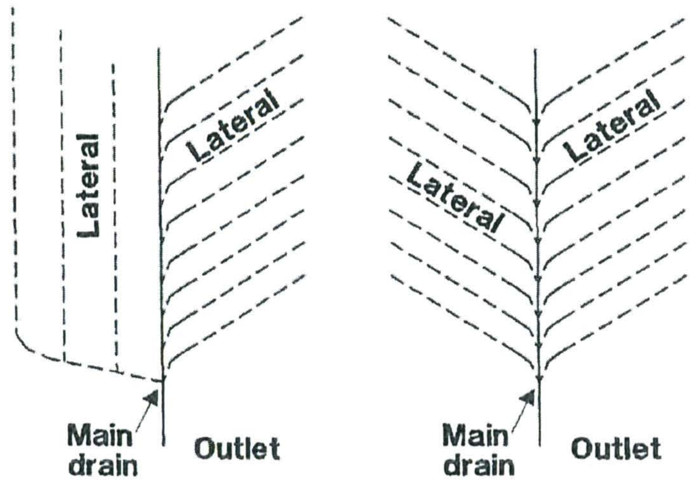

Figure E-4. Example Layer of Subsurface Laterals and Main (adapted from Brady, 1984).

Subsurface drain tubing is placed at the depths and lateral spacings shown in Table E-2. However, laterals should not be placed more than twice as deep as the surface layer of a stratified soil. Drains should also be placed above a transmissive subsoil layer if this layer is within the saturated zone and underlies a finer texture. The reason is to avoid collecting water primarily from the surrounding area instead of from the salt-affected soil above.

Table E-2. Approximate Depth and Spacing of Subsurface Drain Lines.

| Soil Texture (group) | Drain Depth (ft) | Lateral Spacing (ft) |
|---|---|---|
| Coarse | 3 | 30 |
| Coarse | 6 | 60 |
| Medium | 3 | 20 |
| Medium | 6 | 40 |
| Fine | 3 | 10 |
| Fine | 6 | 20 |

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Extreme caution should be used in working with trenches associated with soil drainage. Shoring should be used to stabilize trench walls if workers will be in them. Check OSHA requirements for working in confined spaces or trenches.

## INTENSIVE-WATER-DEMAND PLANTS

Where circumstances permit, high-water-demand plants adjacent to the spill area can be used to lower the water table beneath the salt-affected area. As an example, alfalfa, a deep-rooted, high-water-demand plant can lower a water table in the surrounding area by several feet.

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# CHEMICAL AMENDMENTS AND APPLICATION PROCEDURES

Chemical amendments are used to displace sodium from soil clays. In a dilute electrolyte solution, [low electrical conductivity (EC)] soil clays with more than 10% to 15% sodium on cation exchange sites will cause soil dispersion. In smectitic soils, the critical exchangeable sodium percentage (ESP) is as low as 5%. The dispersion of soil particles results in structural disintegration and a reduction of drainage which greatly impedes remedial efforts. Dispersion can be avoided by applying a chemical amendment before leaching begins. Chemical amendments will prevent the soil from dispersing until the sodium has been displaced from cation exchange sites. As the ESP decreases, the need for soil electrolytes (e.g., total soluble anions and cations) also decreases. After the ESP has decreased to less than 10% to 15%, the leaching in most soils can be completed without concern for additional dispersion.

The chemical amendments discussed below include materials to be used at relatively neutral pH (5.5 to 8.5), and in more acid (pH <5.5) and more alkaline (pH >8.5) solutions. A variety of chemical of amendments typically applied as both solids and liquids are discussed below (see also Table K-1).

Concentrated amendment solutions (e.g., liquid chemical amendments and fertilizers), may shorten the remediation time and require less water compared to solid amendments like gypsum. However, they are typically more expensive, thus making them less practical in most situations than solid amendments. Concentrated amendments can often be applied with irrigation water, but it is important that the irrigation process equally distribute the chemical amendment over the affected area.

With the exception of the acidifying amendments and calcium nitrate, an efficiency correction factor should be used for increasing the amount of the chemical amendment applied. Often, unrepresentative sampling and inaccurate analytical results cause chemical amendment calculations to underestimate the amount of amendment actually needed. Practice has shown that about 1.25 times the amount calculated using the laboratory analyses will provide sufficient chemical amendment to accomplish remediation objectives. As noted below, regardless of other chemical amendments used, a final top dressing of gypsum will provide long-lasting protection of the soil surface while the soil recuperates.

## CHEMICAL AMENDMENTS FOR RELATIVELY NEUTRAL SOILS

### GYPSUM ($CaSO_4{:}2H_2O$)

Gypsum is the most commonly used amendment. It dissolves slowly to provide low but adequate electrolyte (as expressed by EC) and a slow release of calcium. Various particle sizes of gypsum physically keep pore sizes open while soil chemistry is slowly converted from the dispersive to aggregative condition. The solubility of gypsum increases as salt concentration increases—gypsum is twice as soluble when EC is 15 mmhos/cm compared to when EC is 3.5 mmhos/cm, and is about four times more soluble when ESP is 100% compared to when ESP is near 0%. Because of low solubility, gypsum must be mechanically mixed into the soil to be effective. For various reasons the solubility of industrial-grade gypsum is several times more than mined gypsum. One ft of water is required to dissolve each 10 ton/acre application of gypsum under optimal dissolving conditions (e.g., high EC, high ESP, and gypsum in powdered form).

Gypsum is normally applied by broadcasting, followed by incorporation via discing. Gypsum should be mixed throughout the upper 2 ft of soil (when possible) if salts occur throughout that

Table K-1. Chemical Amendments Used to Remediate Salt-Affected Soils.

| Amendment | Chemical Formula | Commercial Availability | Purpose | Positive Attributes | Application Method | Follow-up Procedures | Warnings or Cautions |
|---|---|---|---|---|---|---|---|
| Bulk or sack gypsum/calcium sulfate | $CaSO_4{:}2H_2O$ | Bulk or sack | Sodium displacement | Slow release; residual benefits | Surface spread, then till | Light surface application | Poor solubility; about 1 vertical ft water required to dissolve about 50 pounds of gypsum/100 sq ft of very salt-affected soil |
| Calcium chloride | $CaCl_2{:}2H_2O$ | Bulk, sack, or liquid | Sodium displacement; supplies Ca | Quick acting; faster results | Slurry or dissolved in water | Surface apply gypsum for residual benefit | Increases chlorides; protect shallow groundwater |
| Calcium nitrate | $Ca(NO_3)_2$ | Bulk, sack, or liquid | Fertilizer; sodium displacement; supplies Ca and N | Quick acting; enhances biodegradation and vegetation growth | Broadcast on surface and incorporate, or apply as liquid | Surface apply gypsum for residual benefit | Protect drinking water, nitrate toxic to some animals |
| Calcium carbonate | $CaCO_3$ | Bulk or sack | Soil alkalizer; sodium displacement; supplies Ca | Good for use in acidic soils | Broadcast on surface | Surface apply gypsum for residual benefit | Will not work in alkaline soils |
| Dolomite | $CaCO_3{:}MgCO_3$ | Bulk or sack | Soil alkalizer; sodium displacement; supplies Ca and Mg | Good for use in acidic soils | Broadcast on surface | Surface apply gypsum for residual benefit | Will not work in alkaline soils |
| Calcium oxide | $CaO$ | Sack | Soil alkalizer; sodium displacement | Quick acting; good for use in acidic soils | Broadcast on surface, then incorporate; co-apply with gypsum | Surface apply gypsum for residual benefit | Will not work in alkaline soils; can burn skin and eyes, reactive with water; overuse can cement soil; determine quantity by titration |
| Calcium hydroxide | $Ca(OH)_2$ | Bulk or sack | Soil alkalizer; sodium displacement | Quick acting; good for use in acidic soils | Broadcast on surface, then incorporate; co-apply with gypsum | Surface apply gypsum for residual benefit | Will not work in alkaline soils; can burn skin and eyes, reactive with water; overuse can cement soil; determine quantity by titration |
| Sulfur | $S$ | Bulk or sack | Soil acidifier; sodium displacement | Slow release | Apply as slurry or powder, then incorporate; co-apply with gypsum | Surface apply gypsum for residual benefit | Corrosive to metals after oxidation; requires water and thiobacillus; determine quantity by titration |
| Sulfuric acid | $H_2SO_4$ | Bulk, drum, or liquid | Soil acidifier; sodium displacement | Rapid response | Apply liquid to surface, then incorporate; co-apply with gypsum | Surface apply gypsum for residual benefit | Corrosive to metals; use with caution; determine quantity by titration |
| Aluminum sulfate | $Al_2(SO_4)_3{:}18H_2O$ | Bulk or sack | Soil acidifier; enhanced drainage; sodium displacement | Rapid response in developing soil macropores | Broadcast on surface, then incorporate; co-apply with gypsum | Surface apply gypsum for residual benefit | Can become toxic to plants at pH <5; determine quantity by titration; |
| Iron sulfate | $FeSO_4{:}7H_2O$ | Sack | Soil acidifier; drainage enhancement; sodium displacement | Provides iron and sulfate to vegetation | Broadcast on surface, then incorporate; co-apply with gypsum | Surface apply gypsum for residual benefit | Determine quantity by titration |
| Diammonium phosphate | $(NH_4)_2(HPO_4)$ | Bulk or sack | Fertilizer; sodium displacement; soil binder | Provides nitrogen and phosphate to vegetation | Broadcast on surface, then incorporate; co-apply with gypsum | Surface apply gypsum for residual benefit | Very water soluble; protect shallow groundwater |
| Displacer polymers | Various chemicals | Bucket or drum | Drainage enhancement; aggregate stabilizer | Fast acting | Apply sodium displacer first, then broadcast or spray on surface, incorporate, allow to dry | Surface apply gypsum for residual benefit | Soil must be allowed to dry after wetting for polymers to bind soil |

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depth. In most reclamation circumstances, at least 50% of the gypsum applied should be placed within the upper 1 ft.

A final top dressing of gypsum is suggested to protect the soil surface from dispersion, regardless of the principal type of chemical amendment used. A top dressing of gypsum provides the slow release of calcium to the uppermost clay particles which incorporated chemical amendments may have bypassed. The following top dressing rates are suggested in pounds per acre: coarse, 250; medium 500; fine 1,500. Some practitioners recommend that the maximum single application of gypsum not exceed 5 ton/acre for each 6-inch depth into which it will be incorporated. If additional gypsum is required, it can be applied at 6-month intervals until all required gypsum has been applied.

Gypsum can also be applied as a slurry. Gypsum rocks placed along the irrigation water route line will slowly dissolve, supplying calcium to the irrigation water.

CALCIUM CHLORIDE ($CaCl_2{:}2H_2O$) AND CALCIUM NITRATE [$Ca(NO_3)_2$]
Calcium chloride and calcium nitrate are very soluble and provide solutions of high electrolyte concentration. The reaction time of these chemicals is very rapid, and they penetrate the soil at approximately the same rate as water, except for the fraction that becomes adsorbed onto clay. For this reason, they provide for rapid remediation as long as the solution they are in can penetrate the soil.

These chemicals are typically applied as a slurry or as dissolved ions in water. They are preferred by remediation contractors because they show rapid results. Gypsum may be co-applied to provide more residual benefits, especially at the soil surface.

Because the anions of calcium nitrate ($NO_3^-$) and calcium chloride ($Cl^-$) are very mobile and move at the same rate as water, it is very important to have an understanding of where application and subsequent leaching water will go. If the receiving groundwater is to be sacrificed (because it is already too salty to reclaim), this may be an acceptable location for additional chloride (and sodium). However, it is not usually an acceptable location for nitrate, as noted below.

Calcium nitrate supplies nitrogen in a plant-available form and also improves the biodegradation rate of petroleum hydrocarbons. However, the amount applied may exceed the ability of the plants or microbes to consume it before it leaches into groundwater. Only 10 mg/L nitrate is allowed in drinking water due to its extreme toxic effects on animals. Therefore, nitrate must be contained to the extent possible and not allowed to migrate overland into surface water or leach into groundwater. This is difficult because nitrate is one of the most mobile ions in soil. As a general rule, use of calcium nitrate is not advised in coarse-textured soils, and only with caution in medium- and fine-textured soils. It should never be used close to surface water, or where nitrate can migrate into usable groundwater.

Calcium chloride and calcium nitrate are expensive, except that sometimes calcium chloride can be obtained as a waste byproduct. Both are also corrosive, and consideration should be given to the type of application equipment to be used. The amount of calcium chloride and calcium nitrate equivalent to 1 pound of gypsum is 0.85 and 0.95 pounds, respectively. This means that 0.85 pounds of calcium chloride and 0.95 pounds of calcium nitrate can displace the same amount of sodium as 1 pound of gypsum in a soil if the entire amount of each chemical is dissolved and used appropriately.

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## CHEMICAL AMENDMENTS FOR ACID SOILS (PH <5.5)

### LIMESTONE ($CaCO_3$) AND DOLOMITE ($CaCO_3$:$MgCO_3$)

Limestone (calcium carbonate) and dolomite are only effective in acid soils because these amendments are not very soluble at alkaline pH levels. The soil pH should be less than 6.0 if limestone is to be used. These liming agents are usually applied as a powder or in crushed form, but can also be applied as a slurry. Dolomite (also known as dolomitic limestone) is slightly less soluble than calcite and also supplies magnesium ($Mg^{++}$), which is a divalent cation capable of displacing sodium, and is an important plant nutrient. In general, soils west of a line running due north from Houston, Texas, are not suitable for lime applications due to their alkalinity, whereas many soils east of that line are acidic and respond very well to lime.

Both lime and dolomite are relatively inexpensive. They are easy to apply and not corrosive. In addition, they constitute excellent pH buffers in the soil, and overapplication is not as much of a concern as it is for calcium oxide, calcium hydroxide, and the acidifying amendments.

### CALCIUM OXIDE (CaO) AND CALCIUM HYDROXIDE [$Ca(OH)_2$]

Calcium oxide (burned lime, quick lime, oxide, or burned oyster-shell lime) and calcium hydroxide (hydrated lime or slaked lime) are concentrated liming agents. Their use is not recommended in a general sense because they may cause some soil cementation. However, they are very fast-acting and can be used to raise the pH of acid soils. Both present handling problems and cause a burning sensation when they come into contact with water (or perspiration). They are also serious hazards to the eye and have a high heat of reaction. When calcium oxide first comes into contact with water, it can actually raise the temperature of nearby paper and wood to ignition temperature. Calcium oxide and calcium hydroxide are, respectively, 1.6 and 1.25 times as effective by weight as calcium carbonate for neutralizing soil acidity.

## CHEMICAL AMENDMENTS FOR ALKALINE SOILS (PH >8.5)

### SULFUR (S)

Elemental sulfur must be oxidized in the soil to be effective. In the presence of certain types of bacteria which occur in most soils, the sulfur oxidizes and combines with soil-pore water to become sulfuric acid. The soil must contain sufficient water to assist in the microbial oxidation of the sulfur. The acid dissolves calcium carbonate in the soil and releases calcium for exchange with sodium on exchange sites. The soil pH is simultaneously decreased as the hydrogen ions are released from the sulfuric acid. Remediation time usually requires several months.

Sulfur can be applied at the soil surface as a dry powder, then mechanically incorporated into the soil. However, the dust may be problematic. Sulfur can also be applied as a slurry, typically as a solution of about 55% to 60% sulfur. Typically, sulfur should not be applied to a soil which does not contain calcium carbonate.

It is important to not overapply the acidifying amendments, and generally, they should be applied only when calcium carbonate is present in the soil layers being treated. Incorporation of manure with acidifying amendments has been especially efficient at improving the soil for plant growth and improving drainage of salt-affected soils.

### SULFURIC ACID ($H_2SO_4$)

Sulfuric acid also reacts with calcium carbonate to produce a soluble source of calcium and sulfate. Water intake and percolation rates are increased due to increased electrolyte concentration and dissolution of aluminum and iron compounds which promote aggregation.

As a liquid, sulfuric acid can move at a rate in the soil similar to the rate of water percolation. Because downward movement in soil may be slow if the soil is dispersed, incorporation of elemental sulfur to greater depths may be more rapid. However, elemental sulfur must be in oxidizing conditions to form sulfuric acid.

Sulfuric acid is generally inexpensive because it can be obtained as an industrial byproduct. Approximately 3.06 pounds of sulfuric acid is equivalent to 1 pound of elemental sulfur. However, special handling and equipment may be required. Caution should be exercised when working with sulfuric acid and because it is corrosive, selection of application equipment should be appropriate.

Sulfuric acid is less damaging to the soil when applied in concentrated form directly to the soil, instead of as a diluted solution. It can also be applied by spray equipment, or in irrigation water.

### ALUMINUM SULFATE [$Al_2(SO_4)_3$:$18H_2O$] AND IRON SULFATE ($FeSO_4$:$7H_2O$)

Aluminum sulfate and iron sulfate act like dilute sulfuric acid in the soil, and they supply a trivalent cation ($Al^{+++}$) or divalent cation ($Fe^{++}$). Both aluminum and iron are very strong aggregating agents and can rapidly create macropores in a soil. Although iron is an important plant nutrient, especially at high pH where it is not very soluble, aluminum has no fertility value, and in fact, can be toxic when the pH is less than 5.0.

These chemicals would be expected to work faster than elemental sulfur, and at about the same rate as sulfuric acid, calcium nitrate, or calcium chloride. Approximately 6.94 and 8.69 pounds of aluminum sulfate and iron sulfate, respectively, are equivalent to 1 pound of elemental sulfur. In other words, 6.94 pounds of aluminum sulfate and 8.69 pounds of iron sulfate can displace the same amount of sodium in soil as 1 pound of elemental sulfur if the entire amount of each chemical reacts or is dissolved and used appropriately.

## OTHER CHEMICAL AMENDMENTS

### POLYMERS

Several organizations manufacture and distribute or use their own staff to apply salt-remediation materials which contain polymers. There are several different types of polymers (such as polyvinyl alcohols, polyacrylamides, and natural plant polymers) currently on the market. Initial studies indicate that polymers may aid in remediation of salt-affected soils by rapidly aggregating soil particles. These polymers are usually applied in a mix of other salt-remediating chemical amendments, most often being calcium nitrate.

### PROPRIETARY CHEMICALS

A number of organizations are working on proprietary chemical amendments for salt remediation. These materials should not be given widespread use without prior performance demonstrations.

### DIAMMONIUM PHOSPHATE [$(NH_4)_2(HPO_4)$]

Although technically a fertilizer, diammonium phosphate provides a unique opportunity to speed remediation of a salt-affected soil. The ammonium ion ($NH_4^+$) will behave similarly to potassium ($K^+$) as a mild displacing agent for sodium. However, the ammonium is also a plant-available

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form of nitrogen. The phosphorus supplied with diammonium phosphate is also an important plant nutrient and has been demonstrated to help plants withstand stress due to excessive salts and sodium. Rapid growth of plant seedlings is especially stimulated. Diammonium phosphate is also completely water soluble and can move quickly into the soil.

Diammonium phosphate should be applied only at a rate indicated by fertility testing. When fertilizer results are to be reported, the analytical laboratory should be asked to recommend a rate which will utilize diammonium phosphate.

Diammonium phosphate is usually provided in the fertilizer grade 18-46-0. This means that the fertilizer contains 18% nitrogen, 46% phosphate as $P_2O_5$, and no potassium. Fertilization application rates are site-specific depending on soil type and can be readily identified by the analytical laboratory conducting the soil analysis.

## MIXING CHEMICAL AMENDMENTS

Often the best remediation results are obtained when more than one chemical amendment is used at a given site. Examples are gypsum and sulfuric acid, and calcium nitrate or calcium chloride and gypsum. Studies indicate combining calcium chloride or sulfuric acid with gypsum appreciably reduces the time and leaching needed to achieve reclamation as compared to gypsum alone. This process, while more costly, may be applicable in situations where expediency is deemed necessary. Use of substantial mulch is almost always advisable, and use of manure is highly recommended when nitrate and phosphorus migration into surface water or groundwater are not concerns. Manure is especially effective for soil redevelopment.

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# Testimony
# Senate Bill 2331
# Senate Agriculture Committee
# February 2, 2017, 9:00 a.m.
# North Dakota Department of Health

Good morning Chairman Luick and members of the Agriculture Committee. My name is Scott Radig, and I am the director of the Division of Waste Management within the North Dakota Department of Health's Environmental Health Section.

The Department supports the collection of verifiable background soil and water quality data. I am here to suggest some clarifications to SB 2331.

- The term "certified" (Page 2, line 31) is not defined. The Department would suggest that instead of "certified water quality … test," a statement be included requiring a test be collected according to methods prescribed by the Department of Health and analyzed by a state-certified laboratory.
- Soil sampling generally is conducted to depths greater than 12 inches. One sample taken at a 0- to 6-inch depth and another at a 6- to 24-inch depth would be typical for agronomic soil sampling and would provide more representative data.
- Water quality testing is already required in N.D.C.C section 38-11.2-07. That section is the subject of HB 1409, which would require reporting of water quality testing results to the Department to be recorded in a database. It may be beneficial to ensure the language about water quality testing is consistent in both bills.

This concludes my testimony. I am happy to answer any questions you may have.

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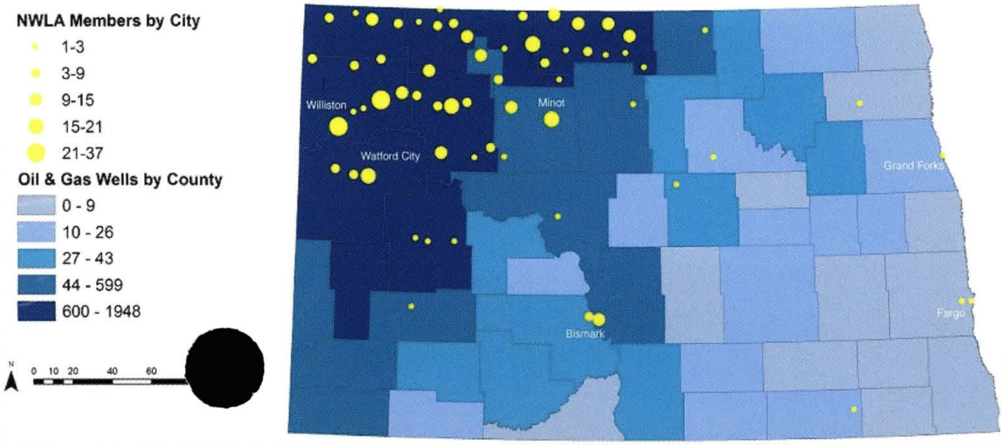
*Bringing landowners and energy providers together.*

*Supporting responsible development and stewardship of North Dakota's resources for a bright future for all.*

**Northwest Landowners Association: Members Living in the Bakken**



#6

# Impact Report

Northwest Landowners Association
www.nwlandowners.com
701-721-4258

NW Land Owners
NORTHWEST LANDOWNERS ASSOCIATION

# Legislative Impact Since Inception

Northwest Landowners Association has had a tremendous impact on landowners in the state by advancing private property rights. Since beginning operations, members of Northwest Landowners Association have advocated on behalf of landowners in North Dakota at three legislative bienniums: 2011, 2013, and 2015.

## Successful Legislation

### 2011

**HB1241:** Required that annual loss of production payments be made to landowners.
**HB1382:** Required new gathering lines to be mapped and filed with statewide ND One Call.

### 2013

**HB1333:** Allocated more dollars into an abandoned well fund and abandoned pipeline reclamation. Required gathering lines to be entered into a GIS database. Allowed for mediation for pipeline easements.
**HB1348:** Required tanks and other equipment to be located further away from residence than the well bore.
**HB1350:** Gave landowner more time to claim damages with the statute of limitations.
**HB1352:** Provided for mediation for surface use disputes.

### 2015

**SB2347:** Allowed for marking flag removal on property.
**SB2356:** Provided for a study of gravel pit reclamation.
**HB1358:** Provided for the regulation of gathering pipelines.
**SB2271:** Provided for the creation of a pipeline reclamation program (Ombudsman Program).

## Additional Legislation Contributed To or Followed

**HB1259:** Providing for performance audits of the Oil & Gas Division and the ND Dept. of Health.
**HB1266:** Relating to the reclamation, landowner inspection, and bond release for well sites.
**HB1267:** Relating to an exception to confidentiality of pipeline information and well data.
**HB1270:** Relating to when land that has undergone reclamation may be returned to agricultural assessment status.
**HB1271:** Relating to the environmental quality restoration fund for continued appropriation.
**HB1440:** Relating to temporarily abandoned status.
**HB1468:** Relating to injury to property not from contract.
**HB1180:** Relating to the confidentiality of mediation.
**HB1032:** Relating to the abandoned oil and gas well plugging and site reclamation fund; and to provide a contingent effective date.
**HB1054:** Relating to assessment of agricultural property.
**HB1113:** Relating to custody of land used for disposal of radioactive material.
**HB1114:** Relating to solid waste management correspondence and environmental protection; and to provide a penalty.
**HB1145:** Relating to tracking of water used for oil and gas development.
**HB1409:** Relating to the funding and purposes of the Outdoor Heritage Fund.
**HB1197:** Providing for a prohibition on the purchase of real property and easements for wildlife or conservation purposes with public funds.
**HB1382:** Relating to the construction of electric transmission lines by cooperatives and municipal power agencies.
**HB1390:** Relating to licensing of commercial oilfield special waste from oil and gas drilling and production operations.
**SB2147:** Relating to the one-call excavation notice system.
**SB2190:** Relating to the abandoned oil and gas well plugging and site reclamation.
**SB2374:** Relating to regulation of gathering pipelines, abandoned oil and gas well plugging and site reclamation fund, and to provide for a legislative management study.
**SB2167:** To provide for a legislative management study of the one-call system.
**SB2251:** Relating to the enforcement of laws relating to the conservation of oil and gas.
**SB2287:** Relating to flaring restrictions.
**SB2338:** Relating to county emergency management access to well sites pipelines and waste disposal sites.
**SB2341:** Relating to loss of production payments for surface owners.
**SB2361:** Relating to the use of eminent domain by WAWSA.
**SB2370:** Relating to setbacks for oil and gas wells.

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# Northwest Landowners Association

Formed in Berthold, ND

## Organization History

Since its formal establishment in 2010, Northwest Landowners Association has worked to bring together landowners and stewards of North Dakota's resources for responsible resource development. Now numbering nearly 500 members, Northwest Landowners Association is striving to work with elected officials to develop comprehensive legislation to protect North Dakota's resources well into the future and ensure a more harmonious coexistence among landowners, residents, and industry. Additionally, Northwest Landowners Association strives to provide unbiased education regarding current and past resource development processes.

## North Dakota Landowner Fact

90% of North Dakota's acreage is comprised of farm and ranch land

RURAL COMMUNITY GRANT FUND

Farm Credit Services' Rural Community Grant Fund is a great partner of farmers and ranchers in North Dakota. In 2015, Northwest Landowners Association was awarded a $50,000 grant from the Rural Community Grant Fund to hire an executive director.

**Become a member today! Head to www.nwlandowners.com for more information!**

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## North Dakota State Water Commission
## Water Appropriations Division

Testimony on Senate Bill No. 2331
Jennifer Weier, Hydrologist Manager
February 2, 2017

Dear Chairman Luick and Members of the Senate Agriculture Committee:

Please accept the following written testimony to supplement the oral comments I provided to you this morning. I apologize for not having written testimony prepared for the hearing.

The Water Appropriations Division provides the following comments with respect to the language of Senate Bill No. 2331:

- Relating to the word "route" on page 2, lines 21 and 30.

The word "route" is unclear as used in these two lines. For example, the first sentence of section 6, which begins on page 2, line 29, states:

> *The mineral developer shall conduct or have conducted an inventory of water wells located within one mile [1.61 kilometers] of a proposed route or site for oil and gas drilling operations.*

Without further clarification, the route for oil and gas drilling operations might be interpreted to mean paths of ingress to or egress from the site, pipelines carrying oil and gas or produced water, paths of well horizontal legs below ground, etc. This should be clarified before the bill is passed, so that mineral developers are able to conduct a proper inventory of wells.

- Relating to the phrase "certified water quality and quantity test" on pages 2 and 3, lines 31 and 1.

The second sentence in section 6, which begins on page 2, line 31 states:

> *The mineral developer shall conduct or have conducted a certified water quality and quantity test within one year before the commencement of drilling operations on each water well or water supply located on the involved real property and as identified by the surface owner of that real property.*

The certification of water quality or water quantity tests is not clear. Particularly with respect to water quantity tests, certification might require the test be completed by a water well driller certified by the North Dakota Board of Water Well Contractors, or the test itself might need to be conducted and documented in such a manner as to be certified. There are a number of ways that such a test could be performed and documented, and our division is unaware of a particular method that would constitute a certified test or what this portion of the bill is intended to mean.

- Relating to the term "sodium adsorption rate" on page 2, line 23.

*Sodium adsorption rate* is listed as one of the constituents for which the mineral developer should have soil samples analyzed. The correct term is *sodium adsorption ratio*. This is the ratio of sodium ions to calcium and magnesium ions in the soil or an aqueous extract from the soil. The sodium adsorption ratio characterizes the soil sodicity and has implications for water infiltration, aeration, and plant growth.

Thank you for your time,

Jennifer Weier

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**NORTH WEST LANDOWNERS ASSOCIATION**
6050 Old Highway 2, Berthold, ND 58781
contactus@nwlandowners.com

# Senate Bill 2331
## Testimony of Troy Coons
## Senate Agriculture Committee
## February 2, 2017

Good morning Mr. Chairman and Committee Members. My name is Troy Coons and I am here as Chairman of the Northwest Landowners Association representing our membership of about 500 farmers, ranchers, and property owners. We are a nonprofit volunteer board. Northwest Landowners Association is in favor of Bill SB 2331. This bill is important, especially for property owners that have only surface ownership.

In North Dakota, minerals can be severed from the surface ownership. In other words, one person can own the minerals, while a different person can own the surface of the land. When this is the case, there is an implied easement allowing surface access to the mineral owner due to the mineral owner's rights to develop the minerals below. Because of this implied easement, the surface owner does not have the normal ability to negotiate surface use as a willing seller would have if there were no implied easement. Without any consent of the landowner, a mineral developer with the right to the minerals can do "whatever is reasonable" to the surface. There is a rule that requires that a developer pay for any damages to the surface and restore the land to as close as reasonably practicable to its original condition, however often it costs the land owner more in attorney fees to prove the actual damage to the surface and what the original condition is than the amount the landowner would receive in damages.

What this law does is require sampling be done prior to the construction of a well pad in order to establish a baseline of the quality of the land prior to any damages. We find it should be the duty of the mineral developer to take these samples to ensure the landowner is protected and everyone knows the original condition of the land and both the developer and the landowner do not have to spend money litigating the issue at the end of the project. The cost of this requirement is small, not only in relation to the cost of building a well pad and drilling a well, but also in relation to the court costs, litigation fees, and burden on the courts if we do not have this baseline beforehand. When there is factual proof there is nothing to argue about.

Northwest Landowners Association asks that the Senate Agriculture Committee votes do pass on SB 2331. Thank you. I will stand for any questions.

SB 2331 2/3/17 #1

NW Land Owners

*For responsible development of*
*North Dakota's resources*

6050 Old Highway 2
Berthold, ND 58718
www.nwlandowners.com

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To the Senate Agriculture Committee:

I am writing you to supplement my testimony from yesterday on SB 2331. During the hearing I realized that some who spoke in opposition to the bill raised some reasonable concerns. I am attaching a proposed amendment that addresses those concerns. The attached proposed amendment adds the option for the landowner to waive the sampling requirement, removes the requirement for sampling along pipelines, changes the depth requirements for soil sampling for one at 0-6" and another at 6-24", changes the testing frequency so that it requires a 1-5 acre site to have one test per acre, a 6-10 acre site to have one test per two acres, and a site 11 acres or more to have 1 test per three acres.

I would also like to respond to some things the opposition said that I did not agree with. A speaker opposed to the bill claimed that SB 2331 disregards existing soil and water quality data. Some of the water samples she is referring to may be from decades ago. The soil surveys throughout the state are not specific, and give only a general idea of what soil is like in a large area. Any soil scientist would agree that they are not a replacement for actual soil testing.

SB 2331 does not create duplicative regulations. This bill is about decommissioning and *reclamation*, not remediation. The opposition is confused. The intent of this bill is to address reclamation of well sites after a well is abandoned. All of the sampling requirements, training, and manuals people opposed to the bill cited as "duplicative" only apply to finding out the extent of a spill for remediation purposes. These tests only happen if there is a spill, and are used to figure out what needs to be done to clean up the spill. The remediation sampling has nothing to do with decommissioning and reclamation of well pads decades from now.

The sampling SB 2331 requires would establish a baseline for when a well pad is in the decommissioning and reclamation phase so that everyone can agree and avoid lawsuits about what the "original condition" of the land was before the well pad, and the farmer can regain the same crop yields that were enjoyed prior to the well.

While I believe that the costs of the sampling cited by the opposition were on the higher end of the spectrum, I believe that our proposed amendment addresses and alleviates most of those concerns.

Finally, the opposition attempted to scare you with "the unknown unknowns" that could come about with this testing. The only substances required to be tested for are listed in statute. If the operator does not have to test for it, the operator will not test for it. If the operator is concerned with expense, it is unreasonable to claim that it will pay for a more expensive test.

Northwest Landowners Association asks that you consider our proposed amendment to SB 2331 and vote due pass as amended. Thank you for taking the time to read my concerns.

Sincerely,

Troy Coons,
President, Northwest Landowners Association

2/3/17 #2

# PROPOSED AMENDMENTS TO SENATE BILL NO 2331

Page 2, line 20, after "obtain" remove "samples from the top twelve inches [30.48 centimeters] of topsoil from a proposed route or" and insert "a split sample from a soil bore consisting of one sample of the topsoil from the top zero to six inches [0–15.24 centimeters] and a sample of soil from six to twenty-four inches [15.24–60.96 centimeters] below the surface from a"

Page 2, line 24, after "battery sites" insert "that are one to five acres"

Page 2, line 24, after "one" insert "split"

Page 2, line 25, after the period remove "For access roads and pipeline rights of way, the mineral developer shall take at least one sample every three hundred feet [91.44 meters] and at both terminus." and insert "For wells sites and tank battery sites that are six to ten acres, the mineral developer shall take at least one split sample per two acres of land that will be disturbed. For well sites and tank battery sites that are eleven acres or more, the mineral developer shall take at least one split sample for every three acres of land that will be disturbed."

Page 3, line 3, after the period, on the next line insert "7. The surface owner shall have the right to waive the requirements of subsections 5 and 6.

Renumber accordingly