University Lands

THE UNIVERSITY OF TEXAS SYSTEM

Soil Remediation Guidance for Crude Oil, Condensate, and Produced Water Releases

A. Crude Oil

1) Report all spills by email or phone to the University Lands representative.
2) For RRC-reportable releases to soil (>5 bbls) submit copy of RRC Form H-8 to the UL representative.
3) Generally, UL references the methods and requirements in the attached RRC "Field Guide for Reportable Surface Releases of Crude Oil in Non-Sensitive Areas."
4) Soil remediation will be completed within one month of the release date.
5) Provide the UL representative a site sketch illustrating aerial extent of affected soil, location of initial soil characterization sample locations, and location of excavation confirmation sample locations.
6) Annotate the site sketch with TPH lab analyses and square feet of damaged pasture as measured after remediation is completed.
7) If clean soil is obtained from a UL caliche pit, provide UL representative the pit location and volume of soil.
8) **Do Not** obtain clean soil for blending, or any other purpose, from the Pasture.

B. Condensate

1) Report all spills by email or phone to the University Lands representative.
2) For RRC-reportable releases to soil (>5 bbls) submit copy of RRC Form H-8 to the UL representative.
3) Generally, UL references the methods and requirements in the attached RRC "Field Guide for the Assessment and Cleanup of Soil and Groundwater Contaminated with Condensate from a Spill Incident."
4) Soil remediation will be completed within one month of the release date.
5) Provide the UL representative a site sketch illustrating aerial extent of affected soil, location of initial soil characterization sample locations, and location of excavation confirmation sample locations.
6) Annotate the site sketch with TPH and benzene lab analyses and square feet of damaged pasture as measured after remediation is completed.

7) If clean soil is obtained from UL caliche pit, provide UL representative the pit location and volume of soil.
8) **Do Not** Obtain clean soil for blending, or any other purpose, from the Pasture.

C. Produced Water Releases

University Lands requires removal of affected soil containing chloride concentrations >3,000 ppm

The University does not authorize remediation either by blending or the application of soil amendments.

UL will consider alternate remedial measures at locations that present unique circumstances.

1) Report all spills by email or phone to the University Lands representative.
2) Generally, UL references the methods and requirements in the attached RRC "Draft Version of the Field Guide for the Assessment and Cleanup of Produced Water Releases."
3) Soil remediation will be completed within one month of the release date.
4) Provide the UL representative a site sketch illustrating aerial extent of affected soil, location of initial soil characterization sample locations, and location of excavation confirmation sample locations.
5) Annotate the site sketch with chloride lab analyses and square feet of damaged pasture as measured after remediation is completed.
6) If clean soil is obtained from a UL caliche pit, provide UL representative the pit location and volume of soil.
7) **Do Not** obtain clean soil for blending, or any other purpose, from the Pasture.

Retrieved from http://www.rrc.state.tx.us/environmental/spills/spillincident.php

RAILROAD COMMISSION of TEXAS

Field Guide For Reportable Surface Releases of Crude Oil in Non-Sensitive Areas SWR 8, 20, 91

To assure persons meet the goals established by Statewide Rules 8, 20, and 91, all spill responses should include:

1. Notice to the RRC as described in Statewide Rule 20(a)(1) and (b)

2. Removal of all free liquids immediately as described in SWR 91(c)(1)

3. Horizontal and vertical delineation of all areas with more than one percent by weight of total petroleum hydrocarbons (TPH). If analytical testing for TPH is used, available methods include but are not limited to 418.1, modified TNRCC 1005 (to include carbon fractions up to C-35), TNRCC 1006, Massachusetts VPH/EPH. Additional methods may be used provided that the interested party demonstrates that the method is appropriate to characterize the specific crude oil.

4. Proper reporting as described in Statewide Rule 91(e)

5. One confirmation sample at the base of an excavation to verify that all soil containing over one percent by weight TPH is brought to the surface for disposal or remediation, if spill excavation is concurrent with delineation.

Delineation and reporting of spills over 5 barrels but less than 25 barrels

1. If spill excavation is not performed, delineation horizontally and vertically will be required to verify that all soil containing over 1% by weight TPH is brought to the surface for disposal or remediation. In most cases horizontal delineation will require a minimum of four samples.

2. For spills in this category, all delineation sampling may be performed with TPH field test kits. These TPH results should be submitted with the H-8 and the signature of the operator will verify that the sampling was performed in accordance with the proper procedures of the specific test kit.

3. Final closure (compliance of RRC regulations) of the spill will require at least one laboratory TPH analysis to confirm that the impacted soil is less than 1% by weight TPH.

Delineation and reporting of spills over 25 barrels

1. If spill excavation is not performed, delineation horizontally and vertically will be required to verify that all soil containing over 1% by weight TPH is brought to the surface for disposal or remediation. In most cases horizontal delineation will require a minimum of four grab samples (not composite samples).

2. For spills in this category, horizontal delineation sampling may be performed with TPH field test kits. These TPH results should be submitted with the H-8 and the signature of the operator will verify that the sampling was performed in accordance with the proper procedures of the specific test kit.

3. Any sample used for vertical delineation of the spill must be analyzed by a laboratory using an appropriate TPH methodology.

4. Final closure (compliance of RRC regulations) of the spill will require at least one laboratory TPH analysis to confirm that the impacted soil is less than 1% by weight TPH.

All reportable spills

1. If spill delineation indicates that the spill site may be in a sensitive area, additional delineation with site-specific criteria will likely be required once the operator consults with the appropriate District Office about proper cleanup standards and methods, reporting requirements and other special procedures.

2. A topographic map of the spill or GPS coordinates of the area may be requested to assist in locating the spill site, determining the location relative to streams, residences, wetlands etc. and determining the potential for off-site migration.

3. Site-specific information may result in additional sampling requirements on a case-by-case basis.

Remediation of soil

1. If on-site bioremediation is chosen to meet Commission compliance goals, soil mixing with ambient or clean soil must achieve a uniform mixture that is no more than 18 inches in depth and contains no more than 5.0% by weight TPH.

2. A final level of 1.0% by weight TPH should be achieved for all spills in non-sensitive areas as soon as it is technically feasible but no later than on year after the spill.

3. For larger spills compliance sampling may require one sample for each 50 cubic yards.

Preventative Measures

1. If a spill is within a properly bermed area and the operator has preventatively lined the area of the spill with an impermeable material and no spilled fluids breach the liner, then soil sampling will not be required.

Retrieved from http://www.rrc.state.tx.us/environmental/spills/spillcleanup.php

RAILROAD COMMISSION of TEXAS

Field Guide for the Assessment and Cleanup of Soil and Groundwater Contaminated with Condensate From a Spill Incident

(Statewide Rules 8, 20 and 91)

Introduction

This Field Guide will help the District Offices and responsible parties clean up condensate spills in a manner that assures the goals established by Statewide Rules 8, 20, and 91 are met.

Statewide Rule 8 provides that no person conducting activities subject to regulation by the Commission may cause or allow pollution of surface or subsurface water in the state. Rule 20 provides that operators shall give immediate notice of a fire, leak, spill or break, followed by a letter giving the full description of the event including the volume of products lost. Rule 91 provides that cleanup requirements for hydrocarbon condensate spills and crude oil spills in sensitive areas will be determined on a case-by-case basis.

Statewide Rule 91 distinguishes two categories of spills: (a) crude oil spills into non- sensitive areas; and, (b) (i) hydrocarbon condensate spills and (ii) crude oil spills in sensitive areas. Rule 91 establishes clear goals for cleanup of crude oil spills in non-sensitive areas: immediate removal of all free oil; immediate vertical and horizontal delineation; specifying the "area of contamination" that must be delineated and disposed of or remediated, and specification of a final cleanup level of "1.0% by weight total petroleum hydrocarbon." Rule 91 is less clear about the second category of spills.

It stands to reason that hydrocarbon condensate spills and crude oil spills in sensitive areas, which pose greater risks, should at least follow standards established for the equally important but less threatening spills. Over time, the Commission has come to believe the lack of enumerated standards for condensate spills hamstrings field personnel and perpetuates unacceptable risk to the water and subsurface water of the state. Commission staff therefore implements the following field guide to establish bench marks and protocols that, when met and followed, will demonstrate that condensate spills have been addressed in a manner that complies with Statewide Rules 8, 20 and 91.

This Guide provides notice of criteria field personnel may employ in judging whether a hydrocarbon condensate spill response is adequate or inadequate. This guidance is intended to make operators and responsible persons aware of the Commission staffs' position and afford an opportunity for voluntary compliance.

The sampling described in this guide is specific to delineation sampling. In addition to the samples obtained for delineation, an appropriate number of samples should also be obtained and analyzed to characterize the impacted area.

Approved Criteria

It is recommended that field personnel use the following criteria to evaluate compliance with Statewide Rules 8, 20 and 91 after a condensate release. The operator/responsible person response actions should include the following activities:

A. Notification:

1. Provide notice of the release to the RRC.

(Note: condensate spills exceeding five barrels shall be immediately reported to the Commission. All spills of condensate into water must be immediately reported to the Commission).

2. Remove all free liquids immediately.

B. Delineation:

1. Horizontal and vertical delineation is required of all reportable condensate spills.

2. Grab samples (not composite samples) are to be collected and analyzed at a laboratory for Total Petroleum Hydrocarbons (TPH) and benzene, toluene, ethyl benzene and xylenes (BTEX) to verify that delineation has been achieved.

(Note: knowledge about product composition is helpful in determining appropriate analytical methods. TPH analyses should use standard industry methods, which include but are not limited to, 418.1, modified TNRCC 1005 (to include carbon fractions up to C-35), TNRCC 1006, or Massachusetts VPH/EPH. BTEX analyses should be conducted using EPA-approved methods, which include 8260 or 8021B. Any of these methods or any additional method may be used provided that the operator/responsible party demonstrates that the method is appropriate to characterize the specific condensate).

3. Soil delineation is to be conducted to soil to groundwater protection limits illustrated in the appropriate table of section C of this guidance.

C. Remediation:

1) All condensates spills of any volume are to be remediated.

2) If reportable releases are immediately excavated and properly disposed of the operator/responsible person may limit grab samples and laboratory analytical results to one confirmation sample of TPH and BTEX at the base of the excavation where deepest spill penetration has occurred.

3) When reportable releases are not immediately excavated, the operator/responsible person shall collect multiple grab samples (not composite samples) and analyze for TPH and BTEX to provide adequate soil delineation that determines the lateral and vertical extent of impact.

4) Soil remediation is to be conducted to soil to groundwater protection limits illustrated in the appropriate table of section C of this guidance.

5) If soil concentrations are above the soil to groundwater protection limits an evaluation should be performed to determine if a Risk Assessment is the appropriate remedial option.

6) If on-site bioremediation is chosen to meet Commission compliance goals, soil mixing with ambient or clean soil must achieve a uniform mixture that is no more than 18 inches in depth and contains no more than 5.0% by weight TPH. In the absence of a Risk assessment, closure of the land-farm will require that soil to groundwater protection limits are achieved for all compounds of concern.

D. Protection of subsurface water (groundwater):

When data indicate that subsurface water may be impacted, soil and groundwater delineation should be based on site-specific criteria that will protect the potentially impacted groundwater resource. The operator/responsible person should conduct the following activities:

1. Collect sufficient information and data to determine the classification of the first groundwater zone as Class 1, Class 2, or Class 3.

(Note: see Attachment A of this document for groundwater classification definitions)

2. For delineation of Class 3 groundwater zones a minimum of 5 soil sample locations (to delineate the lateral and vertical extent) shall be analyzed for TPH and BTEX. Lateral and vertical soil delineation should be conducted to the following soil-to-groundwater protection limits:

Table 1: Class 3 Soil-to-Groundwater Protection Limits for Delineation and Remediation

Compound	Residential Limits (mg/kg)	Industrial Limits (mg/kg)
TPH	10,000	10,000
Benzene	2.6	2.6
Toluene	820	820
Ethylbenzene	760	760
Xylenes	12000	12000

For delineation of Class 1 or Class 2 groundwater zones, a minimum of 5 soil sample locations (to delineate the lateral and vertical extent) shall be analyzed for TPH and BTEX. Special consideration should be given by Commission staff to determine whether there is a need for a groundwater investigation, and if so, whether the operator/responsible person installed monitor well(s) and conducted groundwater sampling. Lateral and vertical soil delineation should be conducted to the following soil-to-groundwater protection limits:

Table 2: Class 1 and Class 2 Soil-to-Groundwater Protection Limits for Delineation and Remediation

Compound	Residential Limits (mg/kg)	Industrial Limits (mg/kg)
TPH	10,000	10,000
Benzene	0.026	0.026
Toluene	8.2	8.2
Ethylbenzene	7.6	7.6
Xylenes	120	120

E. Confirmed groundwater impacts

1. Where impacts to Class1 and 2 groundwater have been confirmed, the operator/responsible person should use permanent monitor wells to delineate groundwater impacts to the following limits:
Table 3: Class 1 and Class 2 Impacted Groundwater Delineation and Remediation Limits

Compound	Maximum Contaminant Level (MCL) mg/L
TPH	1.1*
Benzene	0.005
Toluene	1.0
Ethylbenzene	0.7
Xylenes	10.0

***Not a maximum contaminant level**

2. Where impact to Class 3 groundwater resources have been confirmed the operator/responsible person is to delineate to limits that are 100 times the Class 1 and 2 limits listed above.

F. Documentation of condensate releases

The operator/responsible person should provide the following documentation regarding condensate releases:

1. A summary of the events related to the immediate or emergency activities that took place following discovery of the release, including the total volume of condensate released and recovered.

2. A description of the released condensate, including the API gravity (if available) and any additional condensate properties. Gas chromatographs may be useful for this purpose.

3. A topographic map showing the release location and the proximity of all domestic and irrigation water supply wells within a ½ mile radius of the delineated edge of the release. GPS coordinates should also be provided if they are available.

In appropriate cases, consider requesting the following additional documentation:
1. Analytical data in support of delineation.

2. A remedial investigation report, including total volumes of impacted media recovered and disposed, soil investigation and verification results and groundwater investigation results.

3. An annotated map of the free-phase and dissolved-phase of any groundwater contaminant plume.

4. Subsurface soil characterization and/or geologic cross-sections, including stratigraphy and lithology of the subsurface.

ATTACHMENT A **Groundwater Classification Definitions**

Class 1 Groundwater Resource
(A) A groundwater-bearing unit which is the only reliable source of water (i.e., a connection to a public water system is not currently available) not more than 800 feet below the land surface that is capable of producing groundwater

with a naturally occurring total dissolved solids content of less than 1,000 milligrams per liter (mg/l) and at a sustainable rate greater than 5,000 gallons per day to a well with a four inch diameter casing or an equivalent sustainable rate in gallons per day to a well with a smaller or larger diameter casing;

or

(B) Groundwater-bearing unit capable of yielding groundwater with less than or equal to a naturally occurring total dissolved solids content of 3,000 mg/l and at a sustainable rate greater than or equal to 144,000 gallons per day to a well with a 12 inch diameter casing or an equivalent sustainable rate in gallons per day to a well with a smaller or larger diameter casing, and the natural quality of that groundwater meets all primary drinking water standards as defined in 40 Code of Federal Regulations Part 141, as amended.

Class 2 Groundwater Resource
(A) Any groundwater-bearing unit which is a groundwater production zone for an existing well located within 1/2 mile of the affected property and which is used to supply groundwater for human consumption, agricultural purposes or any purpose which could result in exposure to human or ecological receptors;
or

(B) Any groundwater-bearing unit which is capable of producing waters with a naturally occurring total dissolved solids content of less than 10,000 mg/l and at a sustainable rate greater than 150 gallons per day to a well with a four inch diameter casing or an equivalent sustainable rate in gallons per day to a well with a smaller or larger diameter casing.

Class 3 Groundwater Resource
Any groundwater-bearing unit which produces water with a naturally occurring total dissolved solids content of greater than 10,000 mg/l or at a sustainable rate less than 150 gallons per day to a well with a four inch diameter casing or an equivalent sustainable rate in gallons per day to a well with a smaller or larger diameter casing.

Documentation Courtesy of:
RAILROAD COMMISSION OF TEXAS
OIL AND GAS DIVISION

Field Guide for the Assessment and Cleanup of Produced Water Releases (DRAFT VERSION 1/19/2005)

A. Introduction and Purpose

This Field Guide will help the District Offices and responsible parties investigate and remediate produced water (saltwater) spills in a manner that assures the goals established by Statewide Rule 3.8(b) are met. SWR 3.8(b) provides that no person conducting activities subject to regulation by the Commission may cause or allow pollution of surface or subsurface water in the state.

RRC staff has used the following template to respond to saltwater spills that impact groundwater and/or surface water: 1) identify and remove the source, 2) delineate impacts, 3) identify sensitive receptors (such as freshwater supply intakes or water supply wells), and 4) evaluate remediation options and necessity. This updated field guide is intended to complement the existing template with additional considerations for investigation and remedy development in soil, groundwater, and surface water.

The major concerns with saltwater spills are 1) potential pollution of surface water and groundwater, and 2) adverse effects on plant growth, soil structure and agricultural use. Accordingly, these guidelines are intended to provide criteria RRC field personnel may employ in judging whether a saltwater spill response is adequate to protect groundwater and surface water. This guide also contains information to assist field personnel in identifying potential adverse impacts to soil productivity and structure, which could eventually contribute to degradation of surface water and shallow groundwater quality.

B. Spill Notification

SWR 3.20(a) does not specifically address produced water spill notification to the Commission; therefore, all produced water spill notifications are voluntary. However, any groundwater or surface water pollution resulting from produced water spills of any size must be cleaned up in accordance with SWR 3.8(b).

To facilitate reporting of produced water spills, operators or responsible persons are encouraged to immediately notify the RRC of significant produced water spills. Significant produced water spills are spills that exceed 25 barrels or a spill of produced water or any volume that enters groundwater or surface waters of the State.

C. Initial Response

Initial response should focus on source identification and removal of recoverable fluids. Prompt fluid recovery is valuable to minimize migration and spread of saltwater. If saltwater penetrates soils, flushing soils potentially can remove salinity before soil damage occurs; however, flushing should not be performed without consideration of groundwater protection. In some cases, it may be better to retain saltwater in shallow soils to protect a valuable water supply.

Identify potential affected receptors (e.g., surface water supply intakes, shallow water supply wells, stock ponds, agricultural areas, orchards). Things to look for and, if possible, describe in spill response field-notes:

- Source
- Rate and/or duration of release
- Does saltwater flow overland (run-off)?
- Does saltwater pool in limited area(s) instead of run-off?
- Is surface soil porous, clayey, hard, fractured, previously wet or dry?
    - ✓ High rate of release, over sandy soil, with saltwater pooling in limited area suggests that produced water is penetrating soil to potentially affect groundwater table.
    - ✓ Slow rate of release, over clayey soils, where saltwater is spreading out on top of soil may suggest limited initial vertical migration.
- Identify use of affected media (soil, surface water, groundwater) and determine if imminent threat to natural resource (e.g. fresh water supply or agriculture) exists.
- Initiate necessary notifications and identify notified parties.

D. Soil Assessment

A fresh or recent spill of produced water may not be readily apparent in soil, unless the soil was initially dry, and the wetted area can be observed. However, over time a "kill area" may become apparent in areas where plants, shrubs, and trees have been affected. As such, for historic spills, visual evidence of produced water contamination (e.g., salt scar, stressed or killed vegetation) may be helpful in identifying the extent of affected soil. In addition to visual description, discrete soil sampling is also recommended for the following reasons:

- For recent spills to soil (i.e., where potential long-term effects have not yet become apparent), soil sampling and analysis for chloride and/or electrical conductivity (EC) is recommended for the purpose of identifying the lateral and vertical extent of produced water spill impacts.

- For all spills to soil, soil sampling and analysis of affected soils for chloride, EC, sodium absorption ration (SAR) and exchangeable sodium percentage (ESP) is recommended for evaluating soil restoration options.

- Produced water may contain other regulated continents such as benzene, toluene, ethyl benzene, xylenes (BTEX) and metals. As such, laboratory analyses for additional constituents of concern (COCs) may be appropriate, (e.g., sensitive areas).

- Information about the natural salinity of unaffected soils (background) may be useful in determining if a remedy is necessary and, if necessary, site-specific remediation goals. Therefore, staff recommends collecting samples from the surrounding unaffected areas in order to measure background salinity (chloride and EC), SAR and ESP.

Field test kits may be used to measure EC and chloride levels in soil. Delineations sampling objectives should include one or more of the following:

- Determine the lateral and vertical extent of soils affected above background levels

- If background is not known, characterize the vertical and lateral extent of soil that contains chloride above 3,000 mg/kg (note: EC equal to or below 8 mmhos/cm is expected to not exceed 3,000 mg/kg chloride).

- If background is not known and EC is measured instead of chloride, the following EC values may be used as delineation criteria, depending on site-specific vegetative cover
    - 0-2 mmhos/cm- no affect on plant life
    - 2-4 mmhos/cm- slight affect on plant life (consistent with Rule 8 guidelines)
    - 4-8 mmhos/cm- moderate affect on plant life
    - 8-16 mmhos/com- only very tolerant plants yield well
    - >16 mmhos/cm- only very tolerant plants yield well

If saline soils are detected below the soil root zone, deeper samples may be needed to evaluate the depth of saltwater infiltration, or, in the case of a historical impact, the depth of salt-leaching impacts. However, if a spill occurs within a bermed area that has been preventatively lined with an impermeable material, and no fluid breached the liner, then soil sampling is unnecessary.

E. Soil Remediation Considerations

Remediation of saltwater affected soil can be complex and involve a number of variables and options. Operators/responsible parties are responsible for selecting and successfully implementing a remediation procedure.

In all cases, the source of a produced water spill is to be identified and eliminated, and all free liquids should be immediately removed. Subsequent remediation of saltwater affected soil should be evaluated based on the consideration of groundwater protection (through leaching from soil to groundwater) or potential damage to soil productivity (i.e., the ability of the soil to sustain vegetative growth) for the intended use of the affected property.

If soil assessment is sufficient to demonstrate that soil conditions (i.e., salinity and sodicity) are appropriate for intended site use following initial saltwater spill abatement, then no additional remedy would be required provided that the affected surface soils are protective of groundwater (through future leaching), and surface water (through runoff).

Soils with maximum concentration of 3,000 mg/kg chloride or 8 mmhos/cm EC are generally expected to be protective of groundwater based on the assumption of a complete soil leaching or runoff pathway with a 10 fold dilution of leachate in the receiving water body. However, site-

specific conditions may warrant different remediation goals for affected soils for sites in sensitive or non-sensitive areas.

Additional remedial options for affected saline soil include:

- Amendments- Amendments (e.g., gypsum, organic matter) may be added to soil to restore productivity and structure, based on intended vegetative cover and agricultural use. Improved soil structure allows for natural remediation of soils through increased drainage. Improved structure and plant productivity also reduces potential for erosion. Laboratory analyses for pH, major cations and anions, and EC and delineation of the contaminated area will be necessary to determine the appropriate mix of amendments based on intended soil use. Please refer to the following webpage for an example of remedy development using soil amendments (http://www.kcc.state.ks.us/conservation/scar/).

- Flushing- Soil flushing with fresh water (sometimes referred to as leaching) may be an acceptable remedy for saline contaminated soils provided that groundwater is not threatened by the resulting saline leachate. Flushing affected soils can reduce salinity and remove salts to below the soil root zone so that the soil can return to its natural productivity. Flushing may be of best use where soil structure is not severely damaged, and where groundwater is not potentially threatened by increased infiltration and transfer of salt to underlying water-bearing zones. Where groundwater is threatened, a leachate recovery system could be installed to collect and remove applied water before it reaches groundwater.

- Removal- Removal of saline soils and replacement with clean soils may be acceptable or desirable where:
    - Soil salinity is too extreme such that in-situ amendments and/or flushing are not viable treatment options
    - The landowner approves of removal/replacement procedure

F. Groundwater Assessment

When data shows that subsurface water may be impacted, or in areas where repeated spills or leaks have occurred, special consideration should be given by Commission staff to determine whether this is a need for the operator/responsible person to install monitor well(s) and conduct groundwater sampling.

Groundwater impacts are likely to occur where produced water spills penetrate permeable soils and groundwater occurs as an unconfined water table. Produced water can penetrate sandy soils or fractured clay or rock and, due to relatively high density of produced water compared with freshwater, saltwater contamination can sink in freshwater to collect at the base of a water table aquifer.

Given time, however, groundwater can become contaminated after a produced water spill in a variety of environments, depending on the source and occurrence of migration pathways. Therefore, the need to investigate groundwater contamination should be considered at every produced water spill and eliminated only when site-specific information demonstrates that migration pathways to groundwater (either through direct penetration of produced water to groundwater or from future leaching of salts from soil) are incomplete.

In order to evaluate and remedy groundwater contamination, the following actions should be taken:

- Where contamination pathways to groundwater have been *confirmed* through either soil assessment activities or based on other site-specific information, the operator/responsible person should use permanent monitor wells to delineate groundwater impacts. As an alternative, direct push technology may be proposed and will be considered by staff on a case-by-case basis.

- The operator/responsible person should delineate the vertical and horizontal extent of the groundwater contamination or plume.

- Delineation should be to background (i.e., naturally occurring levels) or to 300mg/L Cl concentration in the affected aquifer

- Produced water may contain other regulated constituents such as benzene, toluene, ethylbenzene, xylenes (BTEX) and metals. As such, laboratory analyses for additional constituents of concern (COCs) may be appropriate. Analyzing the sample with the highest chloride may be a sufficient screen for the presence of additional COCs.

- Geophysical tools such as borehole electric logs or surface resistivity surveys may be used on a site-specific basis, provided that the operator/responsible party demonstrates that the selected method is appropriate to characterize the nature and extent of salinity in groundwater.

G. <u>Groundwater Remediation Considerations</u>

Sensitive environmental receptors, such as water wells or down gradient surface water should be identified. Analysis of groundwater samples for BTEX (in addition to CL and other parameters) to evaluate the possible risk to these receptors may be necessary. Possible remedies include:

- <u>Hydraulic Control/Removal</u>- If the saltwater plume is growing, or has the potential to grow outside of a controlled area, groundwater extraction (using either recovery wells or an interceptor trench) may be necessary to ensure that the migrating saltwater plume does not cause adverse effect at sensitive receptors in the area. Where density stratification of saltwater and freshwater has occurred in an aquifer, direct removal of produced water from the aquifer may be possible.

- <u>Closure in Place w/Institutional Controls</u>- In all cases, the feasibility of groundwater extraction should be evaluated. If recovery of saltwater is technically or economically infeasible, saltwater contamination in groundwater may be left in place provided that potential exposure to sensitive receptors within the plume is controlled or eliminated and the plume does not grow outside of the controlled area. Other considerations include 1) demonstration that plume will not migrate to deeper freshwater aquifers and 2) requires

landowner concurrence. Long term monitoring may be needed to determine if offsite migration has occurred or if any active source remains.

H. Surface Water Sampling

Where impacts to surface water have occurred, the operator/responsible person should collect surface water samples up gradient from the point of entry to the water body to determine background levels for chloride and, if necessary, BTEX. Also, if a significant spill migrates across ground surface to impact a surface water body, soil and groundwater between the release location and the surface water body may also be impacted. As such, the assessment and cleanup of surface water contamination may occur in tandem with a soil and groundwater investigation/cleanup.

Additional considerations for spills to surface water include:

- Sensitive environmental receptors, such as downstream water supply intakes, aquatic parks, recreational areas, fish hatcheries, etc., should be identified within a one-mile length downstream.

- Surface water samples should be collected from several locations near and downstream of the release area (between the source and sensitive receptors) and analyzed for chloride and BTEX (if applicable) to determine the potential risk to downstream receptors.

- If the receiving water body is a pond or lake where surface water flow direction is not apparent, then samples may be collected at locations radial to the point of entry

- Saltwater will tend to sink when it enters fresh water due to density differences. Consequently, if the water column is sufficiently deep to accommodate multiple discrete samples, surface water samples should be collected form near surface, mid-column, and the base of the water column.

- Delineation should be to background (i.e., naturally occurring levels for the impacted water body) or 300 mg/L chloride between the source area and downstream receptors.

I. Surface Water Remediation Conideration

- Eliminate the source, separate surface water from the source of overland runoff with berms or trenches, and remove all free-standing fluids.
- If subsurface flow (i.e., affected groundwater) is contributing to elevated salinity in surface water, hydraulic control of groundwater may be achieved with trenches. Recovery water wells may be needed.

- If saline soils adjacent to a surface water body are contributing salinity to surface water, the affected soils should be removed.

- Once the contributing sources of salinity to a surface water body have been removed, remediation options may be evaluated based on the water body's natural (pre-impacted) condition and also the intended use the affected water body. In some cases where natural inflow and outflow are of sufficient quantity and the ratio of impacted resource to

unaffected resources is small, removal of the source and contributing secondary sources may be a sufficient remedy.

- If the receiving body is standing water, such as a natural pond situated over low permeability native material (e.g., clay), then removal of standing water may be feasible, provided that the volume of water contained in the pond is not too large. Because of density differences, saline water will tend to collect at the bottom of a pond. Consequently, confirmation sampling should target multiple depths, including the base of the water column.

- In general, the cleanup objective should be to restore the affected water to background water quality, or at a minimum maintain biological productivity and restore the surface water resource to a quality appropriate for the intended use of the water.

- In the absence of site-specific water quality data or other pertinent information about resource management, a value of 300 mg/L Cl may be used as a default cleanup goal. Additionally, the Texas Surface Water Quality Standards [30TAC307] contain general water quality criteria for classified stream segments, including criteria for chloride, sulfate and total dissolved solids (TDS). Consequently, these criteria may be used as guidelines for the cleanup of a saltwater spill that has affected surface water associated with a classified stream segment. Accordingly, surface water samples would be analyzed for chloride, sulfate and TDS.

ATTACHMENT 1

Technical Backup for Chloride and EC Assessment Criteria

The following information is taken from "Abrol, I.P., J.S.P. Yaday anad F.I. Massoud, 1988, *Salt-Affected Soils and their Management* in FAO SOILS BULLETIN 39 FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS Rome, 1988"

Salinity and plant growth

Excess soil salinity causes poor and spotty stand of crops, uneven and stunted growth and poor yields, the extent depending on the degree of salinity. The primary effect of excess salinity is that it renders less water available to plants although some is still present in the root zone. This is because the osmotic pressure of the soil solution increases as the salt concentration increases. Apart from the osmotic effect of salts in the soil solution, excessive concentration and absorption of individual ions may prove toxic to the plants and/or may retard the absorption of other essential plant nutrients.

Table 1 SOME USEFUL CONVERSION FACTORS

Note: the SI unit of conductivity is "Siemens" symbol "S" per metre. The equivalent non-SI unit is "mho" and 1 mho=I Siemens. Thus for those unused to the SI system mmhos/cm can be read for dS/m without any numerical change.

Conductivity 1 S cm^{-1} (1 mho/cm)= 1000 mS/cm (1000 mmhos/cm)

1 mS/cm^{-1} (1mmho/cm) = 1 dS/m = 1000 mS/cm (1000 micromhos/cm)

Conductivity to mmol (+) per litre:

Mmol (+)/1 = 10 * EC (EC in dS/m)

For irrigation water and soil extracts in the range 0.1-5 dS/m.
Conductivity to osmotic pressure in bars:

OP= 0.36 * EC (EC in dS/m)

For soil extracts in the range of 3-30 dS/m.

Conductivity to mg/l:

Mg/l = 0.64 * EC * 10^3, or (EC in dS/m)

Mg/l= 640 * EC

For waters and soil extracts having conductivity up to 5 dS/m.

Mmol/l (chemical analysis) to mg/l:

Multiply mmol/l for each ion by its molar weight and obtain the sum.

There is no critical point of salinity where plants fail to grow. As the salinity increases growth decreases until plants become chlorotic and die. Plants differ widely in their ability to tolerate salts in the soil. Salt tolerance ratings of plants are based on yield reduction on salt-affected soils when compared with yields on similar non-saline soils. Soil salinity classes generally recognized are given in Table 2.

Table 2 SOIL SALINITY CLASSES AND CROP GROWTH

Soil Salinity Class	Conductivity of the Saturation Extract (dS/m)	Effect on Crop Plants
Non saline	0-2	Salinity effects negligible
Slightly saline	2-4	Yields of sensitive crops may be restricted

Moderately saline	4-8	Yields of many crops are restricted
Strongly saline	8-16	Only tolerant crops yield satisfactorily
Very strongly saline	>16	Only a few very tolerant crops yield satisfactorily

RRC staff note: The relationship between 3,000 mg/kg chloride and 8 mmhos/cm EC, discussed in Section D is based on the following conversion factor mg/l = 640 * EC (shown in Table 1 above).

Assuming that TDS is approximately 60% chloride (a reasonable assumption based on measured TDS and chloride in produced waters in Texas). The following relationships exist:

8mmhos/cm * 640 mg/L = 5,100 mg/l TDS

5,100 mg/l TDS * 0.60 = 3,000 mg/L chloride

Assuming a 1/1 ration of chloride in soil to chloride in pore water, 3,000 mg/L chloride in pore water is approximately equal to 3,000 mg/kg chloride in soil.