Notice of Proposed New Directive
Directive PNG045: Acknowledgement of Reclamation for Sodium Chloride-Impacted Sites

Background

The Ministry of Energy and Resources (ER) is consulting with the oil and gas industry on a new Directive known as *Directive PNG045: Acknowledgement of Reclamation for Sodium Chloride Impacted Sites* (Directive PNG045). Directive PNG045 will guide industry through the process of obtaining Acknowledgement of Reclamation status for sites with sodium chloride (NaCl) impacts exceeding the parameters established in *Directive PNG033: Phase II Environmental Site Assessment* (Directive PNG033) and in the *Saskatchewan Environmental Quality Guidelines*.

ER's existing remediation criteria under Directive PNG033 have, in some instances created uncertainty for the oil and gas industry on how to address NaCl impacts. Directive PNG045 aims to provide guidance and clarity on the mitigation of NaCl impacts to oil and gas sites with the goal of bringing NaCl-impacted sites to regulatory closure in a timelier and more cost-effective manner. This will also support the reduction of reclamation liabilities associated with such sites in the context of ER's Licensee Liability Rating (LLR) program.

The Process

ER is conducting industry consultations on Directive PNG045 from December 15, 2021 to February 11, 2022. Once this consultation period has concluded, ER will review consultation responses in preparation of a final draft of Directive PNG045 to be brought forward for approval. This new directive is expected to come into effect in the spring of 2022.

Summary of New Directive

To support a more pragmatic path for the remediation and regulatory closure of NaCl-impacted sites, Directive PNG045 aims to provide oil and gas licensees with more options to address NaCl impacts that exceed the criteria in Directive PNG033. In particular, Directive PNG045 harmonizes with the *Saskatchewan Environmental Code*, utilizing a three-tiered system for bringing sites to regulatory closure where Tier 1 follows the generic criteria of Directive PNG033 and Tiers 2 and 3 allow for the use of alternative, risk-based approaches for managing NaCl impacts where it can be demonstrated that an NaCl impact does not pose a present or future risk to human or ecological receptors. The options supplied from alternative solutions are dependent on the licensee's level of site-specific, scientific knowledge of a site obtained through ER-approved specialized environmental practitioners (i.e. "qualified persons").

Review of Draft Directive

ER is seeking written comments on Directive PNG045, a draft of which is attached to this notice as Appendix A. Please direct any comments or questions about the proposed amendments to:

ER Service Desk at er.servicedesk@gov.sk.ca
Attn: Jonas Fenn, Manager, Remediation and Reclamation
Energy Regulation Division

The deadline for submitting written comments is February 11, 2022.

APPENDIX A

Acknowledgment of Reclamation for Sodium Chloride Impacted Sites

Directive PNG045

TBA 2022

Revision 1.0

Governing Legislation:

Act:	*The Oil and Gas Conservation Act*
Regulation:	*The Oil and Gas Conservation Regulations, 2012*
Order:	N/A

saskatchewan.ca

Record of Change

Revision	Date	Description
0.0		Initial draft
1.0	Month Day, Year	Approved first version

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1. Introduction

This Directive provides options for an environmentally responsible path to obtain an Acknowledgement of Reclamation (AOR) for sites that have sodium chloride (NaCl) concentrations exceeding the criteria established in *Directive PNG033: Phase II Environmental Site Assessment* and in the *Saskatchewan Environmental Quality Standards*. Where possible, effort has been made to ensure that the methods adopted are harmonized with the *Saskatchewan Environmental Code* (Code). A risk-based approach that manages NaCl impacts, often referred to as "salinity impacts" or "produced water impacts", using site-specific criteria or Risk Assessment/Ecological Risk Assessment will be used.

Sodium and chloride in the form of NaCl salt is a contaminant of potential concern in upstream oil and gas, well, facility, and pipeline sites (sites). NaCl in soil or water becomes a contaminant of potential concern where concentrations increase soil electrical conductivity (EC, also expressed as salinity) and/or sodium increases soil's sodium adsorption ratio (SAR, also expressed as sodicity) above acceptable thresholds. The Saskatchewan Ministry of Energy and Resources (ER) recognizes that NaCl impacts are complex and generic numerical criteria may not be applicable in evaluating all sites for a variety of reasons, including the conservative nature of the criteria, naturally elevated salinity, EC, and SAR being used to indirectly represent chloride and sodium concentrations, and the variable specific risk to receptor(s) depending on site characteristics.

This Directive elaborates on the Code's risk-based approach for NaCl impacts to allow for more options for the oil and gas industry for site management of salinity and sodicity issues. An important objective of this Directive is to provide licensees with the necessary tools to support sound site management and improve provincial consistency in addressing salinity-impacted sites. This Directive is not intended to be a single solution prescriptive tool as Saskatchewan is unique with varying climate zones, crop rotations, farming practices, background soil conditions, and surface water and groundwater chemistry that all can influence the effects of NaCl on vegetation and other receptors. This Directive provides environmental practitioners with procedural guidance on the characterization and interpretation of salinity impacts with respect to the assessment of human health and ecological risk. There is an expectation that licensees and their environmental practitioners will provide the best options for NaCl-impacted sites based on a site's setting and characteristics. Before a large remediation project for an NaCl-impacted site is started, ER's expectation is that the net environmental benefit is understood and that remediation programs progress a site to closure. This Directive attempts to enable industry to better understand the balance between cost, liability and effective effort while ensuring environmental sustainability and responsibility.

This Directive has been created for regulatory closure of NaCl-impacted sites in the form of an AOR, but also is intended to cover active sites with NaCl impacts. These sites should not be left until end-of-life as the impacts could migrate, impacting a larger area and additional receptors. In instances where the licensee completes remediation on an active site where an AOR is not required, ER will supply written approval for these sites that no further investigation or remediation work is required at end-of-life unless new impacts occur. Applications will be made directly to ER for review and approval.

It is the intention of ER that NaCl impacts due to a new incident be remediated to the criteria established in Directive PNG033. ER recognizes that there will be situations where this Directive may be applicable to new incidents. However, application of this Directive to new incidents must be submitted to ER for prior approval, otherwise Directive PNG033 and the SEQG should be assumed to apply.

Questions concerning the requirements set out on this Directive should be directed to the ER Service Desk at 1-855-219-9373 or email at ER.servicedesk@gov.sk.ca.

2. Abbreviations

AEP	Alberta Environment and Parks
APEC	Area of Potential Environmental Concern
CCME	Canadian Council of Ministers of the Environment
CSA	Canadian Standards Association
CSM	Conceptual Site Model
DSA	Detailed Site Assessment
ENV	Saskatchewan Ministry of Environment
ESA	Environmental Site Assessment
ESS	Endpoint Selection Standard
NPP	Native Prairie Protocol
PWA	Potable Water Aquifer
SEQG	Saskatchewan Environmental Quality Guidelines
SPIGEC	Saskatchewan Petroleum Industry/Government Environmental Committee
SST	Subsoil Salinity Tool
QP	Qualified Person

3. Governing Legislation

The requirements in this Directive are authorized under and supplemented by:

- *The Oil and Gas Conservation Act* (OGCA)
- *The Oil and Gas Conservation Regulations, 2012* (OGCR)
- Associated Directives
  - *Directive PNG016: Acknowledgement of Reclamation Requirements* (Directive PNG016)
  - *Directive PNG018: Detailed Site Assessment Requirements* (Directive PNG018)
  - *Directive PNG025: Licensee Liability Rating (LLR) Program* (Directive PNG025)
  - *Directive PNG033: Phase II Environmental Site Assessment* (Directive PNG033)

4. Adopted Standards

Standards adopted in this Directive are:

- *Saskatchewan Environmental Code* (the Code)*
- *Saskatchewan Environmental Quality Guidelines* (SEQG)*
- *Endpoint Selection Standard**
- *Saskatchewan Administrative Control Standard**
- *Subsoil Salinity Tool***
- *Native Prairie Protocol of Reclamation Certification of Salt Affected Well Sites***

* Administered by ENV
** Administered by AEP

5. Definitions

Agricultural Land Use: As defined in the ESS.

Acceptable Solutions: Provides a pre-accepted process that licensees may follow. The chapters of the Code establish an agreed-upon acceptable level of risk that is expanded on in this Directive for use on NaCl-impacted sites. Acceptable solutions represent the minimum level of performance required for licensees to meet the acceptable risk and receives the least amount of regulatory scrutiny. Acceptable solutions fall within existing numerical criteria and utilize an industry-accepted method of remediation. Acceptable solutions are all Tier 1 and some Tier 2 that utilize existing numerical criteria.

Acknowledgement of Reclamation (AOR): as defined in Directive PNG016.

Administrative Controls: As defined in the ESS.

Alternative Solution: A plan developed by a proponent that is designed to meet the risk-based objectives and is signed off by a QP. When a person carries out an activity under this Directive that does not follow the acceptable solution or an acceptable solution is not provided, they must propose an alternative solution. It is not the duty of ER to develop an alternative solution for the proponent to comply with this Directive. Alternative solutions either exceed existing numerical criteria or utilize a non-industry accepted method of remediation. Tier 2 pathway modification and all Tier 3 options are considered alternative solutions.

Analytical Models: Mathematical models that have a closed-form solution (i.e. the solution to the equations used to describe changes in a system can be expressed as a mathematical analytic function).

Coarse-Grained Soil: Means soil having a median grain size of >75 micrometres, as defined by the ESS. When grain size is not available, fine-grained soil is considered anything that has saturation percentage of 35 per cent or higher.

Conceptual Site Model (CSM): Means a written and/or illustrative representation of the physical, chemical, and biological processes that control the transport and migration of contaminants, as well as routes of exposure to human and ecological receptors.

Commercial Land Use: as defined in the ESS.

Cumulative Effects: Are the result of multiple activities whose individual direct impacts to the environment may be relatively minor but in combination with others result in significant environmental effects. The multiple impacts of different activities may have an additive, synergistic or antagonistic effect on one another and with natural processes.

Deemed Liability: As defined in Directive PNG025.

Deeper Surface Soil: A 1 meter (m) deep buffer zone below the shallow surface soil for vegetation protection, generally from 0.5 m to 1.5 m below ground surface (bgs).

Ecological Risk Assessment (ERA): Is the process of evaluating potential adverse effects on non-human organisms, populations, or communities in response to human-induced stressors. ERA applies a formal framework, analytical process, or model to estimate the effect of human actions on natural organisms, populations, or communities and interprets the significance of those effects in light of the uncertainties identified in each study component (CCME, 2020).

Fine-Grained Soil: Means soil having a median grain size of <75 micrometres as defined by the ESS. When grain size is not available, fine-grained soil is considered anything that has saturation percentage of 60 per cent or higher.

Forest Lands: As defined in the ESS.

Industrial Land Use: As defined in the ESS.

Natural Areas: As defined in AEP, 2019b.

Numerical Models: In groundwater science, by convention, are mathematical representations of our understanding of a system (i.e. the conceptual model) that are solved by approximation methods that rely on discretizing the model domain in space and potentially discretized over time. Finite element and finite difference methods are the most commonly used models.

Receptor: as defined in the ESS.

Remedial Action Plan (RAP): A detailed summary of the environmental issues found on a property during a site characterization and outlines a plan of action that illustrates which remedies will be used to achieve remediation goals.

Residential Land Use: As defined in the ESS.

Risk Assessment: As defined in the ESS.

Risk -Based Approach: As defined in the Code.

Shallow Surface Soil: Is the interval of highest soil oxygen and primary nutrient delivery zone to vegetation, generally from 0 to 0.5 m bgs and is part of the surface soils.

Sub-Soil Salinity Tool (SST): Developed in Alberta as a part of the province's regulatory framework, can be used to define two proposed levels of site-specific subsoil salinity guidelines (Tier 2A and Tier 2B) for application at salt-impacted sites under the AEP Tier 2 guideline framework and may be accepted for sites in Saskatchewan with consultation with ER (AEP, 2020).

Subsoil: Is directly underneath the surface soil and extends past 1.5 m (bgs).

Surface Soil: Is the top 1.5 m of soil on the surface and consists of the shallow surface soil and deeper surface soil.

Wetlands: Land that is saturated with water long enough to promote wetland or aquatic processes and are indicated by poorly drained soils, hydrophytic vegetation (plants that grow partly or completely in water), and various kinds of biological activity which are adapted to a wet environment (National Wetland Working Group, 1997).

6. Risk-Based Approach

A risk-based approach is a method of identifying and assessing the risk associated with environmental impacts at a site and proposing an approach for managing these risks. If the risk at the site is characterized and addressed properly then risk-based closure can be applied to the site. This type of closure can be achieved by completing one or more of: risk assessment/ERA, applying administrative controls, or applying a site-specific background criterion. The risk assessment/ERA must be done in accordance with industry best practices. By evaluating the site on a site-specific basis, the identified risks can be properly assessed and managed or potentially ruled out.

Risk assessment is the process that evaluates the likelihood that adverse human health and/or ecological effects may occur or are occurring as a result of exposure to one or more contaminants. This definition recognizes that a risk does not exist unless the contaminant:

- has an inherent ability to cause adverse effects; and
- co-occurs with or contacts a receptor long enough and at a sufficient intensity to elicit the identified adverse effect(s) (U.S. EPA, 1998).

This allows for more options for licensees to manage NaCl-impacted sites. However, there is a cost associated with this flexibility as the licensee now must complete sufficient investigation to ensure that the impacts that remain *in situ* do not pose a present or future risk to a receptor. This may mean additional investigation work will need to be completed on site, and additional stakeholder engagement is also required to ensure that they accept the project's end points and working directly with ER and possibly other jurisdictions. Therefore, the flexibility of alternative solutions equates to an increased level of understanding of the site. Specialized environmental practitioners must be pre-approved through ER as a QP and will be required for all alternative solutions.

This Directive describes the overall outcomes, or results, that ER expects licensees to achieve. The risk-based-approach describes the required outcomes of specific activities supported by performance and enabling objectives.

ER acknowledges that this Directive cannot eliminate all adverse effects/impairment or damage once compliance with this Directive has been achieved. A more detailed explanation on the impacts of NaCL on environmental and human receptors is provided in Appendix 1.

7. The Saskatchewan Environmental Code

The Code provides options on how to achieve the expected environmental outcomes or results by following acceptable solutions (a predefined process) or proposing alternative solutions. The

Code is a risk-based approach that manages impacted sites using tiered endpoints, all of which are intended to be equally protective of human health and the environment. The licensee for each impacted site has the option to use the endpoint that it considers most appropriate for the site, provided compliance with the regulatory requirements is maintained. The Code establishes an acceptable level of risk as the Code cannot describe in detail all possible compliance options. The Code and the ESS have been prepared in a guideline format for petroleum-contaminated sites in Saskatchewan and have been expanded to apply to all types of contaminants. Where possible, the methods adopted by the Code are harmonized with those of the CCME, the CSA or other competent standards-setting agencies.

This Directive harmonizes with the Code and provides more specific guidance on solutions for the assessment and closure of NaCl-impacted sites. The Code chapters and standards that may apply to the management of NaCl-impacted sites include:

- ESS (Tiers 1 through 3);
- Reclamation Technology Standard;
- SEQG;
- CAN/CSA-Z769-00 (R2018) *Phase II Environmental Site Assessment Standard*;
- Site Assessment (Code Chapter B.1.2); and/or
- Corrective Action (Code Chapter B.1.3).

The Code distinguishes remediation solutions into acceptable and alternative solutions. An acceptable solution represents the minimum level of performance required for the licensee to meet the acceptable risk. It provides a pre-defined process that is either a step-by-step requirement that is found in the Code or is referenced as a standard. The Code uses a three-tier approach based on the level of performance required to justify the amount of contamination that may remain *in situ* and the level of regulatory scrutiny. ER is adopting the acceptable and alternative classifications and tiered system of the Code and adapting it for use in NaCl-impacted sites. The tiered endpoints will be discussed in greater detail below but sites will be identified as acceptable or alternative, where Tier 1 and **some** Tier 2 are acceptable solutions and will receive a minimal amount of regulatory scrutiny. An alternative solution is a plan developed by the licensee that is designed to meet the risk to receptor-based objectives. Sites that have site conditions exceeding the acceptable Tier 2 and Tier 3 endpoint scenario would be considered alternative solutions. Acceptable and alternative solutions are additionally categorized by remediation methodology, where industry-accepted remediation methods (like excavation) are considered an acceptable solution and non-industry accepted methods are considered alternative solutions. For example, the NaCl could meet acceptable Tier 2 criteria but utilize an alternative remediation method that would equate to an alternative solution.

Where the Code and this Directive deviate are:

- Criteria in the SEQG are to be used for comparing conditions at sites assessed under this Directive for all environmental receptors with the exception of soil salinity and sodicity. Soil remediation criteria for salinity and sodicity have been adapted from the former SPIGEC Guideline No.4: *Saskatchewan Upstream Petroleum Sites Remediation Guidelines*, as outlined in Directive PNG033.
- This Directive is solely to be used for sites to be closed and liability removed through the AOR process as outlined in Directive PNG016, whereas the Code is intended for discovery

and disclosure of incidents and options for sites still having remediation work completed on them.

8. Land Use

In order to select an endpoint, it is necessary to classify the land. This Directive adopts six definitions for land use as cited in the following sources:

1. **Residential Land Use/Parkland**: as defined in the ESS;
2. **Agricultural Land Use:** as defined in the ESS;
3. **Commercial Land Use:** as defined in the ESS;
4. **Industrial Land Use:** as defined in the ESS;
5. **Forest Land:** as defined in *The Forest Resources Management Act*;
6. **Natural Areas:** as defined in the *Alberta Tier 1 Soil and Groundwater Remediation Guidelines.*

8.1 Saskatchewan Natural Sub-Regions

Climate is an important parameter influencing vertical salt transport and drainage rate and is evaluated in terms of Natural Sub-Region for both the SST and various tables in this document. The SST-equivalent Natural Sub-Region is determined from Table 1 based on the location of the site in relation to the Saskatchewan Terrestrial Ecoregions shown in Figure 1. If the site falls near the boundary of two Natural Sub-Regions, the selection can be made using professional judgment and observations of native vegetation in the vicinity of the site, compared against reported vegetation types that occur within different Natural Sub-Regions. The drainage rate parameters for both surface soil and PWA pathways are calculated from SST protocols (Table 1) based on the equivalent SST Natural Sub-Region and overall soil texture (fine or coarse).

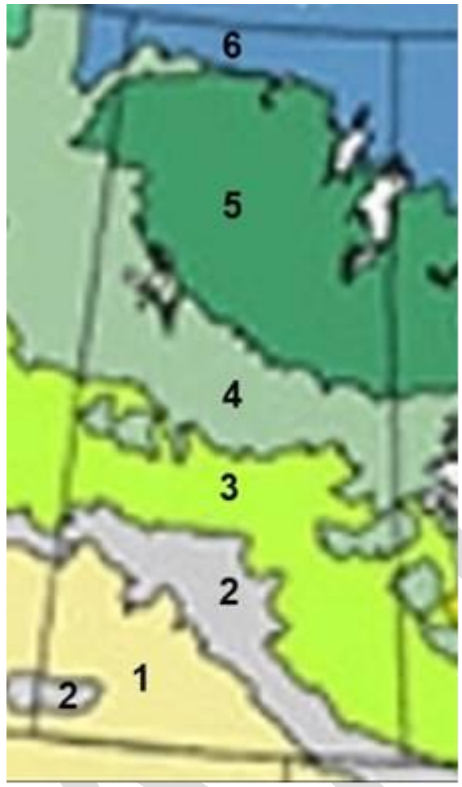


Figure 1: Saskatchewan Terrestrial Ecoregions and Natural Sub-Regions (from Ricketts et al, 2003)

Table 1: Drainage Rate Parameters

Index	Terrestrial Ecoregion	Equivalent Natural Subregion in SST	Drainage rates: Fine		Drainage rates: Coarse	
			Surface soil	PWA	Surface soil	PWA
1	Northwestern Mixed Grasslands	Dry Mixedgrass	1 up	1 down	1 up	2 down
2	Northern Mixed Grasslands	Northern Fescue/ Mixedgrass	1 up	3 down	1 up	7 down
3	Canadian Aspen Forest and Parklands	Central Parkland / Dry Mixedwood	1 up	6 down	1 up	15 down
4	Mid-Continental Canadian Forests	Central Mixedwood	1 down	9 down	2 down	30 down
5	Midwestern Canadian Shield Forests	Athabasca Plain	1 up	6 down	1 up	15 down
6	Northern Canadian Shield Taiga	Kazan Uplands	1 up	6 down	1 up	15 down

8.2 Soil Type

In order to select an endpoint, it is necessary to characterize the soil as either coarse-grained or fine-grained via sieve analysis. Fine-grained soil means soil having a median grain size of <75 micrometres. Coarse-grained soil means soil having a median grain size of >75 micrometres, as defined in the ESS. For additional information regarding soil type, refer to the ESS.

Sufficient data needs to be gathered to support the characterization of soil type. For example, a relatively thin layer of coarse-grained soils may govern lateral transport toward down gradient receptors, although it may not be the dominant soil type or be relevant for vertical transport.

If the soils have not been characterized on site as fine- or coarse-grained then the lowest Tier 1 value for NaCl shall apply.

For use of the guideline charts in section 14, the fine-grained soils are applicable for anything 60 per cent saturation percentage or higher, and 35 per cent or higher for coarse-grained soils (SST Helpfile).

9. Conceptual Site Model

All alternative solutions must have the environmental drivers and regional conditions understood to ensure a site has a path to closure. This is represented as a conceptual site model (CSM), which is a written and/or illustrative representation of the physical, chemical, and biological processes that control the transport and migration of the contamination, as well as the routes of exposure to human and ecological receptors. A preliminary CSM will guide site investigation activities to ensure all receptors and pathways have been investigated (groundwater, surface water, PWA, surface soil, etc.). Following the investigations, an updated CSM can be completed identifying the site-specific receptors of concern and applicable exposure pathways while identifying potential data gaps. It is important to understand the regulatory drivers and local and regional conditions to ensure that all environmental receptors and pathways are addressed at the end of an investigation. In all alternative solutions, a CSM section must be completed for submissions for an AOR for NaCl-impacted sites.

In some circumstances, the low severity of NaCl impacts may not justify investigations outside of soil analysis. In these situations, it may be difficult to quantify all of the receptors and pathways as the cost of the investigation may exceed the cost of physically removing the contaminant. In these circumstances, a CSM will be combined with the weight of evidence based on regionally-supplied data to ensure that all environmental receptors are protected. ER recognizes that the level of investigation should be scalable to the volume of the impacts or mass of contaminant. Additionally, the level of detail required regarding the CSM for a site is scalable based on the volume of impact, contaminant mass, and location of environmental receptors. Examples of justification for carrying out a scaled-down investigation are:

- Low concentration of NaCl in deeper soils;
- Fine-grained soils with no immediate receptors and a small contaminant mass;
- High naturally saline soils with a contaminant mass contributing little relative amounts of salt;
- Migration to the receptors of concern can be ruled out through contaminant mass considerations and equivalent soil quality can be demonstrated.

For sites utilizing the alternative solutions, a written CSM section must be included in the application indicating what environmental receptors and environmental pathways exist on site and provide justification on why impacts can be left in place. Appendix 4 illustrates ER's minimum expectations for CSM content including discussion of all appropriate environmental receptors.

10. Minimum Site Investigation Requirements

If applying for regulatory closure of NaCl-impacted sites, the minimum standard of investigation is that the impacts must be delineated both vertically and laterally. All APECs need to be identified and the associated area delineated, and where the CSM indicates that a receptor may be impacted, there must be sufficient information supplied to verify that the receptor is not at risk, such as pathway elimination. The severity of the NaCl impacts will dictate the level of investigation efforts required. However, regardless of the size of impacts, delineation is imperative. A written section must be included describing the vertical and lateral delineation established for the areas of APECs.

ER recognizes that the SST has established typical background soil chemistry to be <100 milligrams per kilogram (mg/kg) chloride (AEP, 2020) and that this value is being utilized to establish delineation of NaCl impacts. ER accepts this benchmark and considers chloride values of <100 mg/kg to represent typical background chemistry for both chloride and sodium by using chloride as an indicator for NaCl impacts. It may not be possible to achieve complete delineation due to site-specific conditions. In these cases, ER expects the majority of the impacted area to be delineated so total mass of NaCl impacts can accurately be calculated and all contaminant transport pathways identified. A written justification must be provided where vertical and horizontal delineation cannot be established and/or where chloride values are >100 mg/kg. The justification must provide scientifically defensible explanation on why the supplied information is an equal substitute for full delineation. Some justifications include but are not limited to:

- Natural conditions indicate chloride values >100 mg/kg. This needs to be verified through a thorough background assessment as indicated in section 11.
- The CSM indicates NaCl-sensitive receptors are not present on the site and the QP can identify an alternative chloride delineation value.
- The EC/SAR values are within Tier 2 acceptable values, where:
  - The vertical chloride profile has been decreasing with depth and the QP can justify that the mass of chloride has been vertically delineated,
  - Ending on a fine-grained soil,
  - Not within groundwater, and
  - A minimum depth of investigation of 3 m bgs to ensure that the mass of NaCl has been identified.

Sufficient information must be provided to indicate that delineation has been completed. This does not solely need to be soil or groundwater data but can include multiple factors, such as non-intrusive methods like electromagnetic surveys that are calibrated and referenced against soil chemistry data.

11. Background Assessment

Assessment of background conditions is a compulsory component of most investigations. Background concentrations determine the natural range of salinity concentrations in the soil, sediment, groundwater, or surface water associated with the site's geographic area. Selecting representative background sample locations should be based upon the CSM and the regional knowledge of environmental factors controlling the rate of soil formation and the type of horizons that result, such as: climate; vegetation; the parent material the soil forms in; topographical position of the soil; presence or absence of groundwater in the soil; and the soil-altering effects of human use of the soil. The location is not suitable for background sampling if there are other third-party point sources of contamination, or if there is evidence of ecosystem impairment caused by contamination. Background samples should be collected:

- Away from any human development influences, with the exception of agricultural activities in areas with an agricultural land use designation;
- Sufficiently outside of surveyed lease boundaries, lease roads, and flowline/pipeline easements so that lease operation will not affect the samples; and
- Sufficiently outside of EM anomalies that are within or directly adjacent to surveyed lease boundaries.

If samples are collected within these areas, they can be accepted as background samples if appropriate justification is provided. However, these background samples cannot be used to justify soil or water chemistry that exceeds chloride values of 100 mg/kg or 100 milligrams per liter (mg/L), respectively.

The background assessment areas should represent the environmental variables (the physical, chemical, and biological conditions) that exist within the site. These include:

- Soil type and grain size;
- Chemical composition (excluding the contaminant);
- Habitat type;
- Slope position;
- Hydrogeology;
- Wetland classification (see section 14.3);
- Proximity to the NaCl-impacted site;
- Depth;

The properties of the background samples selected should closely match that of the site. For example, if the site consists of agricultural lands on a high slope migrating to a lower slope and into a Class II wetland, the background samples should represent similar variables such as high, mid, and low slopes and Class II wetland areas having similar soil types. Other wetland types, such as Class III or Class IV may have different physical processes and biological communities and may not represent the background conditions of the site. An estimate of contamination depth should be made and background samples taken at comparable depths. Diligent background sample selection will optimize the ability to make meaningful sample comparisons. It is important that background locations that are selected do not artificially bias the result. The environmental practitioner should select background sample locations as similar as possible to the site that represent the variability of natural salinity conditions in the area.

The background assessment needs to achieve the listed attributes within reason, and it is not ER's expectation for background assessments to be competed in an area that is drastically outside of the investigation area.

ER is not prescribing a minimal amount of background data to be collected but recommends a background assessment similar to that listed in section 14.1 be used. Refer to section 14.2.4 if utilizing naturally-occurring sulphate as a pedogenic tracer to determine groundwater movement. A section of the written reporting shall be dedicated to background sample collection, chemistry, and justification.

11.1 Off-Site Sampling for Background Not Required

When the salinity concentrations at the site do not exceed Tier 1 guidelines, off-site background samples are not necessary. In these situations, there is no risk to ecological receptors regardless of the background conditions and no further details regarding background concentrations are required.

Other scenarios that would allow for potential relaxation on background sampling requirements include sites with existing historical information on the impacted site prior to impacts, or from a reference site that would be considered suitable to provide background conditions. In such circumstances, it is important to validate that the data obtained is appropriate for the intended background comparisons.

12. Third-Party Professional Qualifications

The level of investigation will be determined by the magnitude (area impacted and concentration of contaminants) of NaCl impacts and risk to human and ecological receptors. The third-party qualifications, as listed in Directive PNG033 establish the minimum standard for third-party professional qualifications signing AORs that meet the acceptable solutions criteria.

Due to the added complexity of alternative solutions site assessments, an increased level of understanding is required. Therefore, a specialized environmental practitioner with the appropriate qualifications is required to undertake an alternative solutions approach. This specialized environmental qualification is referred to as a QP and must be designated by ER through an application process.

The QP's designation is not intended to limit the type of environmental practitioners completing work in Saskatchewan but to ensure the appropriate investigations and justification are in place to allow for NaCl impacts to remain *in situ* without future risk to environmental receptors. Since QPs designated by ER are only a requirement for alternative solutions, the QP designation is solely intended to supply additional regulatory confidence that NaCl contamination remaining *in situ* that exceeds criteria supplied in Directive PNG033 and the SEQG does not represent a future risk to a receptor.

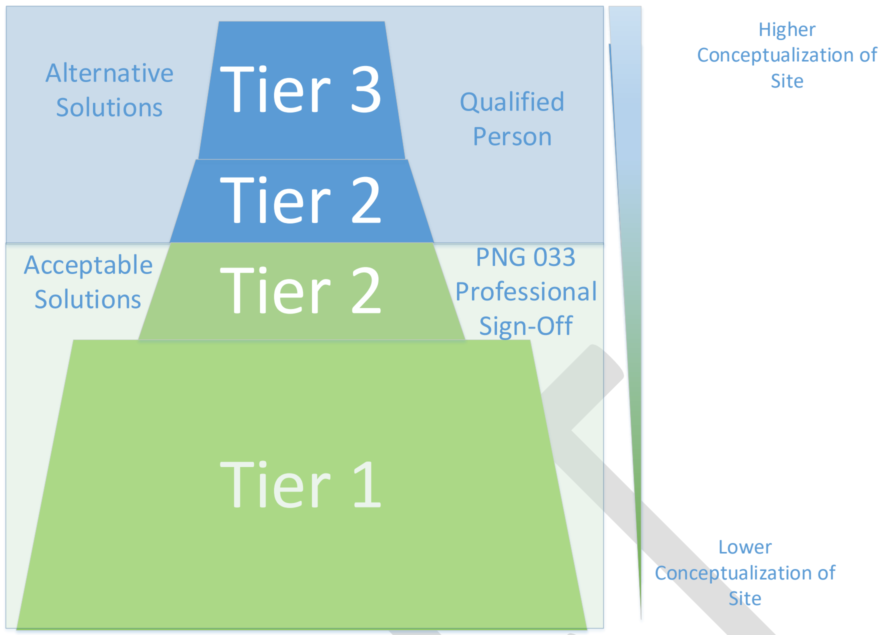


Figure 2: Tiers

12.1 Qualified Person

Requirements of a QP include being associated with a profession/professional body of practice and specialized knowledge or training. ER does not set limitations on the type of environmental practitioner completing work in Saskatchewan. Since all alternative solutions are to be presented to ER prior to submission, ER will approve environmental practitioners on individual projects if they are deemed suitable for the type of work being completed. Pre-approval for a QP can be obtained by emailing a resume including education, work history and two references from industry to lmb@gov.sk.ca. QPs approved under the Code or other jurisdictions will be grandfathered into ER's administered QP program and given ER credentials upon submission of ENV credentials. The area(s) of expertise for all QP submissions must be declared in the application process. ER will approve QP designations.

Areas of expertise that QPs may apply for include, but are not limited to:

- Hydrogeology
- Soil Science
- Aquatic Biologist
- Range Assessment
- Wetland Classification
- Wetland Assessment
- Transport Modeling (Including SST, numerical, analytical, etc.)
- Risk Assessment
- NPP
- Senior Project Manager

Site assessments have the possibility of encompassing multiple disciplines. Thus, an alternative AOR application may require numerous individuals with various competencies. A senior QP will be needed to assume overall responsibility and sign the AOR package.

Once a QP is accepted by ER, no further review of the designation will be completed unless it is determined by ER that the QP designation should be revoked due to the unacceptable work being completed. It is incumbent upon the QP to disclose to ER if a professional designation is no longer valid. If ER determines that an AOR has been submitted under false pretenses, the AOR could be revoked, and past applications submitted by that environmental practitioner will be audited and may subsequently be revoked.

13. Tiered Endpoints

The purpose of developing tiered endpoints is to distinguish sites that exceed acceptable conditions and are considered alternative solutions. Tiered endpoints are a means to allow site-specific criteria to be applied during the site assessment and remediation process in place of generic criteria, based on site-specific conditions rather than conservative assumptions. This may include receptor/pathway modification, site-specific guideline calculations, and/or interpretation of background or natural conditions. A tiered assessment consists of a site-specific review which establishes the standards, constraints, and processes to be followed according to the site-specific scenario and policy provided by the applicable regulatory agency. This Directive uses the SEQG as guidance for its tiered endpoints but supplies additional details specifically for NaCl, as described below:

- **Tier 1** endpoints are achieved when established criteria based on end use and basic site characteristics are satisfied. Tier 1 endpoints require the lowest level of understanding of the site and associated impacts. Tier 1 values are the most protective values based on end use, exposure scenarios, and basic properties of the effected (media) within the non-vegetation monitoring requirements in Directive PNG033 and the Tier 1 tables of the SEQG. All Tier 1 endpoints are considered acceptable solutions.
- **Tier 2** endpoints are specific to identified exposure scenarios and pathways as set out in this Directive. Tier 2 endpoints require detailed understanding of the receptors, pathways, source characteristics, and how to rationalize control of the exposure scenario or pathways. Tier 2 endpoints represent a calculated numerical criterion combined with vegetation monitoring or a receptor pathway modification that is as protective as Tier 1 criteria. Tier 2 endpoints that have a three- or five-year vegetation monitoring requirement are considered acceptable solutions. Tier 2 endpoints that require long term vegetation monitoring or the use of Tier 2 solutions supplied later in this Directive are considered alternative solutions.
- **Tier 3** endpoints are developed through a risk assessment that may include, but are not limited to:
  - Human health risk assessments;
  - Ecological risk assessments;
  - Site-specific objectives are developed; and/or
  - Any defensible approach used that ensures that present and future human and environmental receptors are not adversely impacted by existing contamination.

The Tier 2 alternative solutions are to provide options to forego a complete risk assessment by following predetermined pathway modifications supplied in this Directive. This is beneficial for sites that have a small footprint and lower concentrations of NaCl as the investigation cost for a risk assessment may outweigh the cost of removal of the contaminant. Tier 3 allows for site-specific end-points to be determined, which is beneficial for sites where detailed investigation can be used to justify leaving impacts *in situ*.

Investigations may see a small percentage of samples that exceed acceptable solutions but are not representative of the site. In instances where a licensee believes that a small number of exceedances should not preclude a site from an acceptable solution it must be demonstrated:

- The results are due to elevated statistical outliers present in the data set that do not represent site conditions. The presence of outliers in a data set should not exclude the use of a particular criteria, which needs to be represented statistically; or
- The exceedances have been delineated vertically and laterally and the impacts are quantified, represent a small volume, and do not represent a future risk to receptors; or
- The exceedances are variable and random and do not represent a significant NaCl mass. It must be demonstrated that the data does not represent a source that has yet to be identified.

Directive PNG016 defines the types of AORs that can be submitted, which include routine submissions which are automatically approved and non-routine which receive a full technical review from ER. The process above describes how a small percentage of exceedances may not limit a site from being an acceptable solution. However, this would not be considered a routine submission. All NaCl exceedances, even if a small percentage must be submitted as a non-routine AOR application.

Soil

Directive PNG033 soil remediation criteria are derived from the former SPIGEC Guideline No.4, *Saskatchewan Upstream Petroleum Sites Remediation Guidelines*. As such, there is no formal distinction of tiered end points. Instead, vegetation monitoring requirements are used based on the EC, SAR and the depth of impact. This Directive elaborates on the Directive PNG033 criteria, which are based on conditional and unconditional land use to now be organized into tiers. ER will accept Tier 1 and some Tier 2 approaches as acceptable solutions based on the soil EC/SAR and depth of impact.

Other Environmental Receptors

Tier 1 endpoint selection for receptors (other than soil) references the SEQG, which specifies numerical values as endpoint goals. The SEQG are based on allowable environmental concentrations of contaminants developed considering the pathways, receptors, and resources to be protected. The SEQG Tier 2 environmental endpoints have been used extensively for petroleum hydrocarbon-impacted sites and there are no Tier 2 criteria for NaCl impacts for environmental receptors. Since the Code does not have Tier 2 endpoints established, this Directive has established Tier 2 pathway modification for environmental receptors other than soil. All tier pathway modifications are considered alternative solutions.

13.1 Tier 1 Endpoints

13.1.1 Soil

Directive PNG033's unconditional land use criteria are the most conservative remediation criteria for salinity and sodicity and do not include any requirements for site monitoring and will be used as the Tier 1 endpoint for soils. These values require a basic understanding of the site and the impacts and are the most protective based on unconditional soil use. Soils that meet the Tier 1 endpoint are considered an acceptable solution.

13.1.1.1 Electrical Conductivity

Naturally occurring salts (such as sulphate) can influence EC and potentially elevating them above Tier 1 endpoints. Sites that exceed Tier 1 EC endpoints and have chlorides <100 mg/kg (AEP, 2020) are considered to be due to natural conditions and no monitoring requirement will be required. The site will be considered within the Tier 1 endpoint and can be submitted as a routine AOR application. The Tier 1 endpoint value for surface soil EC is <2 dS/m and for subsoil is <8 dS/m.

13.1.1.2 Sodium Absorption Ratio

Natural variability in ion concentrations (lack of calcium and magnesium) within the soil can cause elevated SAR. This is largely because the SAR formula is a mathematical construct and can be misleading depending on the ion concentrations that are causing an elevated SAR. As such, justification can be supplied indicating SAR values exceeding Tier 1 endpoints are due to natural conditions. Justifications can include chloride values <100 mg/kg or SAR values within background conditions (see section 11). The Tier 1 endpoint value for surface soil SAR is <5 and for subsoil is <8.

This is not intended to dismiss SAR problems since soil structure issues can occur regardless of whether the elevated SAR is due mainly to elevated sodium (from produced water impacts) or from low calcium and magnesium. Low calcium and magnesium may be due to natural background conditions, or in some cases it may be caused by historical NaCl impacts where sodium has removed the native calcium and magnesium off the cation exchange complex and left the soils depleted of those ions once they leached away. Thus, when justifying elevated SAR values as natural, reasonable justification must be supplied indicating that it is not due to produced water impacts.

$$SAR = \frac{Na^{+}}{\sqrt{\frac{(Ca^{++} + Mg^{++})}{2}}}$$

13.1.2 Other Environmental Receptors

For all other environmental media, including surface and groundwater, see the Tier 1 tables in the SEQG. Other environmental receptors that meet the Tier 1 endpoints is considered an acceptable solution.

13.1.3 Work Flow for Tier 1 Endpoints

Sites that fall within the Tier 1 endpoints can apply for an AOR submission when:

- All APECs noted in the Phase I ESA have been investigated;
- Phase II ESA has indicated that all NaCl impacts are within Tier 1 endpoints and have been delineated as per section 7 and there are no other contaminants of concern;
- A successful DSA has been completed;
- The landowner has been contacted and they have no issues with the site, and;
- Submit the AOR application as routine if it fits routine parameters or non-routine if it does not.

13.2 Tier 2 Endpoints

A high-level description of concepts related to Tier 2 endpoints are provided in this section, with a more detailed description of various Tier 2 techniques relevant to these endpoints described in section 14.

13.2.1 Soil

Those sites that are unable to achieve the unconditional soil objectives (Tier 1) may meet the conditional soil criteria (Tier 2). Conditional soil endpoints allow for less stringent remediation objectives but require additional management measures to ensure adequate environmental protection and that the objectives for the site are still achieved. Sites that fail to meet the unconditional use soil salinity and sodicity remediation criteria (Tier 1 endpoints) will require conditions such as vegetation monitoring (refer to Appendix 3). Based on the EC, SAR, and depth of impacts there are three or five-year vegetation monitoring requirements that apply to conditional soil endpoints. Tier 2 endpoints are organized into acceptable solutions and alternative solutions.

13.2.1.1 Acceptable Solutions

Surface soil (0 to 1.5 m bgs) with EC and SAR >2 dS/m and 5 and <8 dS/m and 12, respectively, are considered acceptable Tier 2 endpoints.

Subsoil EC and SAR >8 dS/m and 8 and <12 dS/m and 13, respectively, are considered acceptable Tier 2 endpoints as long as the following are demonstrated:

- The bottom of impacts is 1.5 m above the water table with 0.6 m of fine-grained material immediately below the impacted material and a minimum of 0.6 m fine-grained material between the surface soil and subsoil;
- The groundwater table can be ascertained via:
    - groundwater monitoring; or

- measured as per the NPP (AEP, 2019) (section 14.2.5); or
- inferred as per the NPP (section 14.2.2.1).

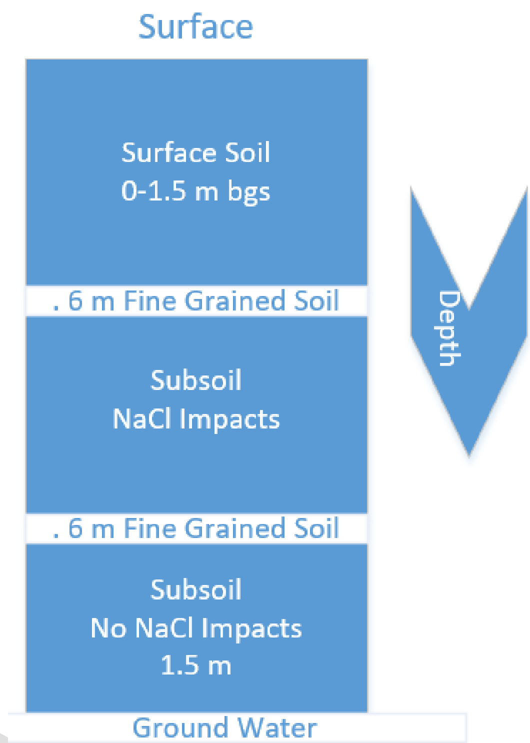


Figure 3: Sub-Soil Tier 2 Acceptable Electrical Conductivity >8 dS/m and <12 dS/m

Acceptable Tier 2 endpoints do not receive additional regulatory scrutiny and an AOR can be applied for upon a passing DSA and the vegetation monitoring requirement has been fulfilled. Refer to Appendix 3 for management considerations and monitoring requirements.

Work Flow for Acceptable Soil Tier 2 Endpoints

Sites that fall within acceptable Tier 2 endpoints can apply for an AOR submission when:

- Areas of potential concern noted in the Phase I ESA have been investigated;
- The Phase II ESA has indicated that all NaCl impacts are within Acceptable Tier 2 endpoints and have been delineated as per section 10 and there are no other contaminant of concern;
- The minimal vegetation assessment/monitoring has been completed;
- A successful DSA has been completed;
- The landowner has been contacted and they have no issues with the site; and
- Submit the AOR application as routine if it fits routine parameters or non-routine if it does not.

13.2.1.2 Alternative Solutions

In cases where the alternative Tier 2 endpoints exceed the EC and SAR values of acceptable solutions, licensees must ensure that additional environmental receptors are not negatively influenced and can utilize other jurisdiction criteria or can choose to use receptor pathway modification scenarios developed for this Directive (section 10). To ensure that all environmental receptors have been investigated, a CSM will have to be created. Sites that meet the alternative Tier 2 endpoints must have QP(s) signing RAPs and all reporting and be submitted to ER for prior approval before submitting an AOR application. Once approved, the AOR can be submitted as a routine application. If a site is unable to meet the alternative Tier 2 endpoints it will have to meet a Tier 3 endpoint selection. Refer to the flowchart in Appendix 3 for management considerations and monitoring requirements.

Work Flow for Alternative Tier 2 Endpoints

Sites that fall within alternative Tier 2 endpoints can apply for an AOR submission upon consultation with ER and a passing DSA when:

- Areas of potential concern noted in the Phase I ESA have been investigated;
- The Phase II ESA has indicated that all NaCl impacts are within alternative Tier 2 endpoints and have been delineated as per section 10 and there are no other contaminants of concern;
- The minimal vegetation assessment/monitoring has been completed;
- The licensee has engaged ER, and ER has approved the alternative Tier 2 endpoint;
- A successful DSA has been completed; and
- The landowner has been contacted and they have no issues with the site.

If ER has already reviewed the site, it can be submitted as a routine application and with ER's approval attached to the cover letter. If ER has not pre-authorized the Tier 2 endpoint it must be submitted as a non-routine application.

13.2.1.3 Vegetation Monitoring

Tier 2 soil endpoints have a mandatory vegetation requirement for agricultural lands to ensure that vegetation establishment is not negatively influenced by *in situ* NaCl impacts during different moisture conditions and crop rotations. Acceptable vegetation establishment is 80 per cent comparable to similar background conditions and would pass a DSA as stated in Directive PNG018.

ER recognizes that there are situations where vegetation establishment can be obtained prior to vegetation monitoring requirement being completed. In these circumstances, if a licensee wants to forego the remainder of the monitoring requirement the site must have a passing DSA and justification on why the remainder of the monitoring requirement can be excluded. An example of excluding vegetation monitoring is if NaCl depths are sufficient where it can be demonstrated that impacts will not migrate to the surface soil through the methods described in section 14. It is important to note that pursuant to subsection 56(7) of the OGCR, if the surface soil is negatively impacted by oil and gas operations in the future the licensee is still responsible to ensure that the site is the same as background conditions and the AOR could be revoked and liability reinstated. The licensee needs to be confident that once the vegetation is established it will not be negatively influenced due to changes in weather or land use as an AOR can be revoked and liability reinstated if future vegetation establishment is impacted from historical oil and gas activity.

There are situations where the vegetation has already been established prior to the investigations being completed. The monitoring requirement does not need to be competed if the following can be demonstrated:

- Vegetation is 80 per cent comparable to similar background conditions and would pass a DSA as stated in Directive PNG018; and,
- Vegetation has been on the landscape exceeding the three- or five-year monitoring requirement prior to the investigation work being completed.

Sites that are located within residential, forested, or industrial areas will have different vegetation establishment requirements and monitoring or DSA may not be applicable. These sites can forego the monitoring or DSA requirements if adequate justification is supplied.

13.2.2 Other Environmental Receptors

Tier 2 environmental endpoints in the SEQG have been used extensively for petroleum hydrocarbon-impacted sites and there are no Tier 2 criteria for salinity-impacted environmental receptors. As such, ER will accept other jurisdictions' criteria or licensees can choose to use pathway elimination scenarios developed for this Directive. To ensure that all environmental receptors have been investigated, a conceptual site model must be created. Environmental receptors that meet the alternative Tier 2 endpoint must be submitted to ER for approval prior to submitting an AOR application.

In some circumstances, the assessment of exposure pathways does not require a full risk assessment as the severity of NaCl impacts may not justify investigations outside of soil analysis. In these situations, it may be difficult to quantify all receptors and pathways as the cost of the investigation may exceed the cost of physically removing the contaminant. ER recognizes that the level and type of investigation should be scalable to the volume of the impacts. In these circumstances, a CSM will need to be combined with evidence based on regionally-supplied data to ensure that all environmental receptors are protected.

13.3 Tier 3 Endpoints

Tier 3 endpoints move away from the numerical criteria as outlined in the acceptable endpoints and is based on characterizing risk to receptors. The Tier 3 approach offers the flexibility for licensees to develop their own path to receive an AOR without ER being overly prescriptive. For projects that meet the Tier 3 endpoints, a QP must sign RAPs and all reporting. These projects are considered an alternative solution and must be submitted to ER for prior approval before submitting an AOR application. Some examples of when a Tier 3 approach can be used are:

- the site does not fit into any of the six generic land use categories referenced in section 8;
- the assumptions used to develop a Tier 1 or Tier 2 criteria are not applicable to the site;
- unique natural controls exist at the site, such as impermeable soils;

- site-specific conditions that warrant consideration, such as natural salinity; and/or other approaches to remediation are highly impractical by virtue of the quantity, the characteristics or location of the contaminant, and impacted media.

Tier 3 approaches will either develop a site-specific standard or complete a risk assessment. Sites that are eligible for Tier 3 endpoints will need to have an appropriate level of environmental investigation indicating that there is a low probability of impact to an environmental receptor. The risk assessment rationale must be defensible to allow ER to approve site closure. The technical activities of Tier 3 must be conducted by professionals competent in the field of risk assessment. ER expects that if site-specific criteria or the completion of an ERA is chosen for a site, either method must provide an equivalent level of environmental protection as if acceptable solutions endpoints were applied.

ER wants to allow industry options for obtaining site closure rather than endorsing a specific method. All approaches may be considered provided they include adequate rationale and documentation and are scientifically defensible or show strong peer-accepted rationale for the chosen approach. Some common methods being utilized are:

- Numerical modelling
- Predictive Contaminant Trend Analysis
- Species Sensitivity Distribution within wetlands, as per CCME
- Weight of evidence involving consideration of multiple sources of information and lines of evidence
- Toxicity assessments
- Modified SST

In addition to the above methods, some of the Tier 2 techniques described in section 14 may also be applicable on a Tier 3 basis, either as-is or in modified form.

Since Tier 3 assessments develop site-specific end points, the DSA standard to determine if a site is suitable for an AOR application may no longer be a valid mechanism to establish a site's health. As such, the end points that are established in the CSM and stakeholder engagement will be used to determine if a site is ready for an AOR application to be submitted.

13.3.1 Administrative Controls

The use of administrative controls is adopted from the Code and modified for the use of this Directive. In some circumstances, the risk assessment will indicate that the NaCl impacts do not represent a threat to environmental receptors if the contaminant is not remobilized. Administrative controls are legal or administrative tools to safeguard against unacceptable exposures to NaCl for specific pathways and receptors. To help ensure that the exposure pathway and environmental receptors can remain protected, some form of land-use controls could be required. These will take the form of administrative controls that may use any of the following:

- Title instruments;
- Land use restrictions;
- Engineered controls

Title instruments are a prohibited locked statement of interest. This ensures that anyone who is interested in the site is made aware of the environmental status.

Land use restrictions are a type of development restriction that can be applied by the authority that has jurisdiction over the land use of an impacted site (i.e. ground disturbance policy). Often land use restrictions will be combined with title instruments to ensure the restrictions remain in place.

Engineered Controls are manufactured and introduced into the natural environment to eliminate or reduce exposure of NaCl to environmental receptors. An example includes an engineered barrier to prevent NaCl to migrate vertically through the soil column. Often engineering controls will be combined with title instruments and land use restrictions to ensure the controls remain in place.

The AOR for NaCl-impacted sites will use a combination of title instruments, land use restrictions and engineering controls to ensure that environmental receptors will continue to function at the same capacity as background conditions and that the public is aware that NaCl impacts remain on site. A title instrument will be registered on the parcel of land associated with the site. The title instrument will have land use restrictions with it to ensure that impacts are not remobilized.

In order to apply an administrative control, a one-time monetary payment may be necessary to compensate landowners due to land use constraints. Some examples of administrative controls with land use restrictions include:

- Restricting the development of a water source such as a water well or dugout;
- Restricting the movement of soil;
- Limiting the depth of soil disturbance;
- Restricting the installation of a linear feature; and
- Restricting the type of vegetation that can be utilized on the site.

Administrative controls are only applied on lands where the stakeholders are agreeable to its use.

ER will not endorse a program that will allow for the loss of use of an environmental receptor such as surface or groundwater or surface soil. However, there will be scenarios where receptors will be negatively impacted and cannot be remediated to their original conditions.

Directive PNG016 provides further details on applications for an administrative controls AOR.

13.3.2 Land Use (Zoning)

A zoning control is a restriction made on the development of a site. It should be tied to municipal building permits and may require a zoning bylaw change. An example of a zoning control would be restricting the site to only industrial land use. These controls must remain in place on site in perpetuity unless the site’s environmental status is reevaluated.

Since the end land use has been altered, some environmental pathways may be excluded. More restrictive values shall apply to a 30 m buffer at the impacted site where any adjacent or adjoining land use is more restrictive. Regardless of zoning, it still needs to be demonstrated that impacts will not migrate from the site and that the remaining environmental receptors will not be impacted.

13.3.3 Environmental Compensation

Environmental compensation is a measure to correct, balance, or otherwise make up for the loss of environmental resources where an environmental receptor cannot be restored to its original condition. The loss of natural values is remedied or offset by a corresponding compensatory action on the same site or elsewhere; for example, providing compensation for removing an impacted wetland as well as creation of a new wetland as part of the remediation.

Environmental compensation can be considered as a Tier 3 solution as long as the following is completed:

- Counterbalancing the ecological impacts of the development in question by undertaking a project that has positive conservation benefits such as wildlife habitat creation;
- Having the appropriate level of scientific rationale to support wildlife habitat creation;
- sufficient time for new wildlife habitat to establish; and
- Having the appropriate QPs in place to determine proper environmental compensation.

14. Tier 2 Techniques

This section describes various techniques and tools that can be used to assess NaCl-impacted sites on a Tier 2 basis. The list is not exhaustive and some of the techniques described herein may also have relevance on a Tier 3 basis either as-is or in modified form.

Assumptions made unless otherwise noted:

- Surface soil remediated to an ‘Acceptable’ solution for EC and SAR;
- Subsoil NaCl impacts between 1.5 to 6 m bgs;
- Source length up to 25 m (match dimension);
    - Source length for the entire site is measured linearly across the longest impacted length of the site regardless of groundwater flow direction;
    - Lateral closure must be obtained around the perimeter of the chloride impact (in all cardinal directions from the approximate centre of an impact, or north, south, east, and west) as per section 10;
- Saturation percentage = 60 per cent (fine), 35 per cent (coarse);
- Background shallow groundwater TDS = 1,000 mg/L

14.1 Developing a Site-Specific Standard Based on Background Data

In some situations, the background concentration of naturally occurring cations and anions can exceed Tier 1 or Tier 2 criteria. If the remediation criteria are lower than the background levels (i.e. levels in similar media such as soil, groundwater and surface water that have not been impacted by anthropogenic effects such as upstream petroleum activities), then the background levels shall be considered as the primary remediation criteria. If the investigation leads to the development of site-specific remediation standards it is not appropriate to remediate contaminated sites to a level below relevant background concentrations.

Where the surficial geology and landscape is reasonably uniform and the site is small (<4 hectares), background soil samples must be obtained from a minimum of four locations. Soil samples should be taken in such a manner that changes in concentrations with depth for chemicals of potential environmental concern are sufficiently delineated. Default depth-increments should be:

- 0 to 15 cm;
- 15 to 30 cm;
- 30 to 60 cm;
- 60 to 100 cm; and
- In 50 cm increments thereafter to the depth of investigation.

Where there are apparent changes in soil lithology or presence of visible contamination in the soils, it may be necessary to alter the default soil sampling depths to reflect site conditions. Analytical parameters for each soil sample should include:

- Chloride, calcium, magnesium, potassium, sodium, sulphur (as SO_4) in mg/kg;
- pH using the 1:2 Soil:CaCl2 extraction method;
- Electrical conductivity (EC) using the saturated paste method;
- Texture (percent sand, silt and clay);
- Median of particle size above 75 µm;
- SAR; and
- Saturated paste per cent saturation.

It is incumbent upon the environmental practitioners when deciding to develop site-specific standards to choose the appropriate statistical metric. If a statistical standard is not chosen to be used, the minimum standard of assessment is utilizing the upper tolerance limit, where the site-specific background standard cannot exceed 95 per cent of the possible background concentrations.

Elevated statistical outliers present in a background data set may represent potentially contaminated locations belonging to an impacted site area and/or possibly from other sources, which means that these elevated outliers may not be coming from the background population under evaluation. The presence of outliers in a data set should not be included in background data sets unless a reasonable justification can be supplied. If it is deemed that outliers exist in the data by excluding the upper 2.5 per cent of the distribution, most potential outliers should be excluded. By adopting the upper end of the distribution as the background estimate, sites with soil concentrations within this natural range should be represented.

Developing a site-specific standard based on background data is considered an alternative solution and as such will need to be presented to ER prior to an AOR submission. It is important to describe the background sampling in detail including the statistical analysis used to generate the site-specific criteria. There is a strong possibility that the number of background samples will be small, so an upper tolerance limit will need to be applied and justification will be required to defend the site-specific criteria.

14.2 Pathway Modification

An appropriate Tier 2 criteria evaluation step for any site is to consider pathway exclusion or modification. This can be as simple as discounting a set of criteria when a receptor, such as a surface water body, does not exist at the site or as complex as developing a CSM for demonstrating contaminant migration. The below-presented considerations and conditions must be met to exclude or modify a pathway under a Tier 2 alternative conditions approach. Depending on the site's particular CSM elements and potential contaminant migration outcomes, multiple pathway exclusions may be considered for justification in leaving residual NaCl impacts in place. Regardless of Tier 2 criteria or pathway adjustment options, ER has adopted management limits that are to be applied to all sites as a Tier 2 upper limit. A management limit is to be applied to Tier 2 criteria whereby Tier 2 chloride guidelines have upper limits ("management limits") of 10,000 mg/kg in fine-grained soil or 7,000 mg/kg in coarse-grained soil, regardless of various pathways being excluded or modified. Concentrations above these management limits thus generally need to be remediated (i.e. removed) or Tier 3 criteria must be applied to the site.

14.2.1 Transport Calculations and Modelling

Pathway exclusion is primarily based on the site characteristics in moving salt (primarily chloride since sodium transport risk is far less than chloride) from the impact area to a distant receptor. In presenting the risk of impacted sites in moving chloride to a receptor, it is expected that a CSM will be developed as part of the evaluation of pathway exclusion using simple contaminant transport calculations. Contaminant transport predictions using complex analytical and/or numerical models would require more sophisticated CSMs. Presenting calculated predictive outcomes of contaminant transport outcomes will require an associated discussion of the groundwater flow regime, including areas of potential recharge and discharge and relevant boundary conditions. The site hydraulic conductivity and hydraulic gradient must be discussed, as well as receptors that might be affected. If using a complex model, methodology, assumptions, and outcome confidence levels as they apply to the model domain must be presented. Reliability of the data used to predict the rate and direction of contaminant movement with groundwater flow is critical in ascertaining if an environmental receptor is at risk.

For exclusion of any given pathway, using transport calculations or more complex modelling will be required to demonstrate that a receptor would not be at risk of impact over a 1,000-year timeframe. If it is shown through the model that contaminants will not adversely impact a receptor within 1,000 years, the pathway can be excluded. Some form of an uncertainty analysis should be explored and quantified, where possible, using sensitivity analysis to verify the finding of the model through consideration of the site's most sensitive parameters used in the model. Selected examples of simple transport calculations or considerations for potential pathway exclusion are provided below.

More complex analytical models, such as the SST can also be used as an alternative Tier 2 solution and may include a combination of pathway exclusion and/or pathway modification. The SST is discussed further in section 14.5 Numerical models will be considered a Tier 3 solution and may also include a combination of pathway exclusion and/or modification.

14.2.2 Surface Soils

In principle, if vegetation can be permanently established then the surface soil (top 1.5 m bgs) receptor is no longer at risk. Evaluation of risks to other receptor pathways, including groundwater receptors would still be required. If considering surface soil zone exclusion, the proponent would be required to demonstrate that the shallow surface soil (the top 0.5 m within the surface soils) would not be negatively impacted in the future from upwelling or discharge of any remaining NaCl from the deeper surface soil zone (0.5 m to 1.5 m) into the shallow surface soil (0 m to 0.5 m). ER considers:

- Shallow surface soils are the interval of highest soil oxygen and primary nutrient delivery zone to vegetation, generally from 0 to 0.5 m bgs;
- Deeper surface soils are a 1 m deep buffer zone below the shallow surface soil for vegetation protection, generally from 0.5 m to 1.5 m bgs;
- The surface soil zone includes the shallow surface soil, and the deeper surface soil (i.e. surface to 1.5 m bgs);
- The subsoil zone is defined as soil deeper than 1.5 m bgs.

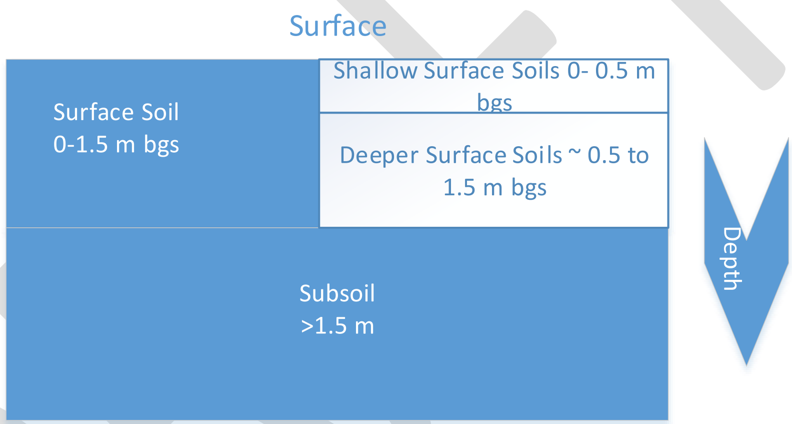


Figure 4: Surface Soil Definition

Although it is understood that the majority of vegetation in a prairie setting would be protected if the surface soil zone is adequately protected, the following needs to be considered:

- Roots may penetrate deeper than 1.5 m for some vegetation; and
- Depth of the groundwater table is within the surface soil zone and particularly within the shallow surface soil.

The onus is on the proponent to address this on a site-by-site basis for more sensitive vegetation and/or a high groundwater table.

ER regulations specifies that if in the future the surface soil is, or may be negatively impacted, the licensee is still responsible to ensure that the receptor is functioning the same as background conditions. If it is found that the surface soil has become impacted the AOR may be revoked, and a facility or site liability reinstated. When utilizing surface soil exclusion, the licensee needs to be confident that once the vegetation is established (or reestablished) it will not be negatively impacted compared to background soils from remaining residual contamination coupled with changes in weather patterns or land use.

In certain site settings, such as fine-grained soil in arid conditions, soil pore water can move upwards through capillary action when seasons transition from wet to dry. This process may draw salt upwards through the soil, thereby concentrating it in the shallow surface soil over time. A significant buildup of salts in a shallow surface soil may decrease vegetation performance and yield. Even if vegetation is successfully established as described above in the short term, upward-moving salt due to capillary action and evapotranspiration must be considered. In order to eliminate the surface soil and shallow surface soil as a receptor, demonstration that there is low risk of future vegetation impacts due to salt capillary action must be addressed. Approaches to demonstrate that vegetation will not be impacted in the future may include:

- Demonstration of a soil barrier (section 14.2.2);
- Use of Subsoil Chloride Guideline Charts (section 14.2.3);
- Using naturally occurring sulphate as a pedogenic tracer (NPP; section 14.2.4);
- Demonstration of a sufficiently deep-water table and net downward movement of salts (section 14.2.5)
- Use of the SST (section 14.5)
- Transport modelling (section 14.2.1)
- NPPI (section 14.2.4)

In order to apply any approach for surface soil zone elimination the site must be:

- Adequately delineated both laterally and vertically (section 10);
- Chloride concentrations must be less than the management limits;
- A CSM must be presented and have sufficient detail to support the complexity of the proposed elimination approach;
- There must be sufficient chemical, geological and hydrogeological data to support the proposed elimination approach; and
- The approach must adequately consider long-term site characteristics in regard to contaminant movement.

14.2.2.1 Impacts Within Native Prairie

The protection of native prairie is highly important, and the disturbance of a visibly-functioning native-prairie ecosystem would ideally be avoided even in the presence of EC and SAR exceedances in the root-zone. This, combined with the land use not changing, the presence of healthy native-prairie vegetation can be a sufficient justification (as long as there is no risk to other environmental receptors) on leaving NaCl impacts *in situ*. If proper justification can be supplied regarding no future risk of upward migration of NaCl impacts to the surface soil receptor, then potential risk to the surface soil can be eliminated. The NPP (AEP, 2019) can be utilized in its entirety for native prairie sites in Saskatchewan, including presenting sulphate soil concentration profiles as evidence of net downward movement of salinity.

14.2.2.2 Soil Barriers

A soil barrier thickness of 3 m of fine-grained soil between the base of the surface soil (1.5 m bgs) and the top of salt impacts exceeding Tier 2 acceptable criteria is considered sufficient to demonstrate protection of the surface soil. Beyond this 4.5 m depth, impacts are not likely to impact the roots (capillary rise will not be sufficient). The figure below illustrates where in the surface soils guidelines must be met. Soils deeper than 4.5 m must be less than the management limits.

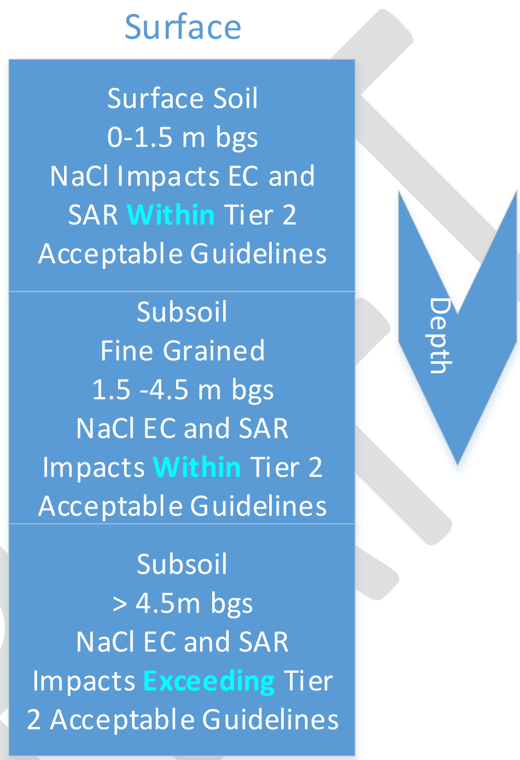


Figure 5: Soil Barriers

Capillary rise in the zone of non-impacted soil between the base of the surface soil (1.5 m bgs) and the top of the impacted soil is dependent on:

- Grain size;
- Void ratio; and
- Pore size.

If the zone of non-impacted soil is saturated and coarse-grained material, the proponent can request ER to consider a variance to the 3 m thickness as NaCl would likely travel laterally than be prone to move upward in the soil profile. Considerations for extended drier periods must be given.

14.2.3 Subsoil Chloride Guidelines

An acceptable approach to determine if subsoil chlorides can remain *in situ* is by using subsoil chloride concentration thresholds developed for this Directive generated from the SST. The subsoil chloride guidelines calculate the allowable chloride in the zone of root protection or deeper subsoil based on an EC buffer in the surface soil that calculates what the allowable chloride can be based on the buffer. The larger the buffer (i.e. the larger the difference in the upper EC threshold for vegetation effects or background soil EC) the greater the allowable chloride concentration can be in the subsoil. The buffer is calculated based on the difference in the desired Tier 2 Acceptable upper threshold criteria of <8 dS/m in the surface soil and the current day EC within the surface soil zone. The chloride criteria charts (Charts 1 and 2) are based on the surface soil recharge and depth of water table which can be established using site-specific groundwater information or the NPP (sulphate profile) information, which is explained in greater detail below. Even though the charts have been extrapolated from the SST, this Directive has some differing assumptions so the chloride output from the charts supplied in this Directive may differ from the SST. The allowable chloride concentration that can remain *in situ* in the subsoil at a site is dependent on the site-specific data. The subsoil chloride guidelines are also based on the soil type (fine or coarse) and the depth to the top of impacts. The chloride criteria charts allow for substantial chloride concentrations to remain *in situ*. However, these values are for the protection of surface soils only and do not apply to other environmental receptors. Other environmental receptors must be investigated as well and must also be protected. Additional conditions that must be applied are as follows:

- The top of the chloride impacts (TOI); if chloride impacts extend higher than 1.5 m bgs then 1.5 m bgs will be used as a default;
- The TOI will be rounded down to the next lowest number, where a TOI of 3.6 m bgs, a TOI value of 3 m bgs would be applicable for the tables below;
- The maximum surface soil EC must be <8 dS/m or within background ranges;
- Background ranges are calculated via section 14.1;
- Soil drainage will affect criteria outcomes, a list of conditions is listed below to determine the surface soil drainage rate (SSDR) that can be applied to the site based on site data;
- For sites without appropriate site data relevant to SSDR, 1 millimeter per year (mm/yr) up is used;
- The minimum vegetation monitoring requirement is based on the Tier 2 Acceptable EC value being met with at least three of the five years' monitoring time frame being met;
- A management limit of 10,000 mg/kg chlorides for fine-grained soil and 7,000 mg/kg for coarse-grained soil will be the maximum allowable concentrations;
- The surface soil EC is calculated as the average from surface to 1.5 m bgs;
- For situations where the shallow surface soil EC is greater than the deeper surface soil, the highest chloride value in the shallow surface soil will be used;
- The buffer capacity of the surface soil where:

Buffer = Tier 2 Acceptable EC – surface soil EC

- The buffer will be rounded down to the next lowest number on the table. Where a buffer of 3.6 is calculated, a buffer value of 3 would be applicable for the tables below;
- The saturation percentage must be 60 per cent for fine-grained and 35 per cent for coarse-grained soils;

- If the saturation percentage is higher, a less conservative criterion may be achieved by recalculating using the SST.

The guidelines calculated in Charts 1 and 2 are derived from the SST assuming the shallow surface soil (the primary area of oxygen and nutrient delivery surrounding the roots of a plant ~0.5 m bgs) is un-impacted, so the current-day EC is assumed to be due to naturally occurring cations and anions. The same guideline table can be used for cases where current-day chloride impacts are in the surface soil but EC remains below 8 dS/m. The greater of the two chloride concentrations can be used, between the current shallow surface soil chloride concentration where the EC is <8 dS/m or the concentration generated from the subsoil chloride guidelines would be allowable.

If NaCl impacts do exist within the surface soil and as a result the EC is >8 dS/m, it must be demonstrated that:

- Vegetation is well established for 5 years and all different applicable crop rotations and moisture levels are accounted for (e.g. dry, wet, flooding, etc.); or vegetation is newly established, and 5 years of vegetation monitoring indicate successful establishment; and
- Chloride concentrations in the surface soil or the subsoil are less than concentrations demonstrated in the shallow surface soil and are not increasing over the monitoring period.

If current-day shallow surface soil is not meeting the Tier 2 acceptable criteria then this section does not equate to regulatory acceptance of current-day exceedances. It excludes the risk of subsoil chloride rising into the shallow surface soil in the future.

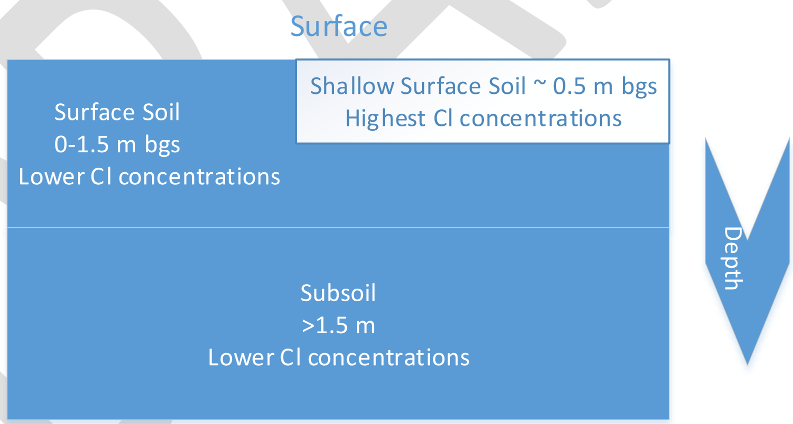


Figure 6: Highest Chlorides in Shallow Surface Soils

In situations where the surface soil is exceeding 8 dS/m and subsoil chloride concentrations are higher than surface soil this section is not applicable.

In applying the SSDR approach to a site, one of the scenarios listed below must be used. Proponents have the option to relax guidelines with more site-specific information that is relevant to the surface soil as per the NPP (section 14.2.4) and a sufficiently deep water table is present (section 14.2.5). Example calculations can be found in Appendix 6.

Selection of soil drainage scenarios:

A) No additional favorable site data relevant to surface soil risk (most conservative):

Data Description:	Soil Type:	Outcome:
No suitable NPP sulphate profiles or vertical gradient data.	Fine	Use 1 up (mm/yr)
	Coarse	Use 1 up (mm/yr)

B) Slight additional favorable site data relevant to surface soil risk (slightly less conservative):

Data Description:	Soil Type:	Outcome:
No suitable NPP sulphate profiles, but have nested wells indicating downward drainage. QP to indicate downward movement.	Fine	Use 1 down (mm/yr)
	Coarse	Use 2 down (mm/yr)

C) Moderate additional favorable site data relevant to surface soil risk:

Data Description:	Soil Type:	Outcome:
'Pass' NPP protocols [using sulphate profiles, including water table depth as a tiebreaker if needed in ambiguous cases as per NPP protocols (>2 m water table measured, or >3 m water table inferred)]	Fine	Use 3 down (mm/yr)
	Coarse	Use 7 down (mm/yr)

D) Strong additional favorable site data relevant to surface soil risk (pathway excluded):

Data Description:	Soil Type:	Outcome:
'Pass' on NPP protocols, along with a deeper water table (>3 m water table measured or >4 m inferred), and impacts start at 3 m bgs or deeper	Fine	Pathway Exclusion
	Coarse	

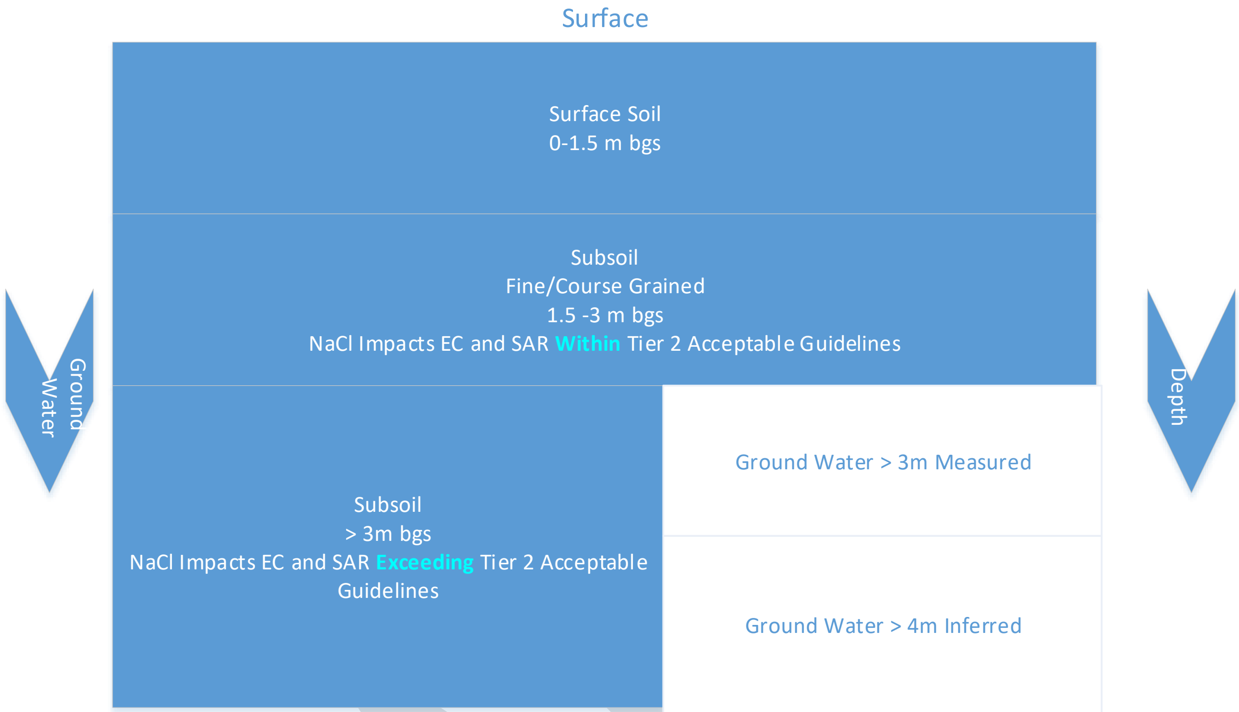


Figure 7: Strong Additional Favourable Site Data

Chart 1: Fine-Grained Soil: Protection of Surface Soil-Subsoil Guideline

FINE		Surface Soil Guideline (mg/kg chloride)			
Surface soil drainage rate (mm/yr)	Top of impact (m)	Surface soil EC buffer (dS/m)			
		1	2	4	6
1↑	1.5	410	830	1700	2500
	2	490	980	2000	2900
	3	720	1400	2900	4300
	4	1200	2300	4700	7000
1↓	1.5	540	1100	2200	3300
	2	680	1400	2700	4100
	3	1100	2200	4400	6600
	4	1900	3900	7700	10000
3↓	1.5	680	1400	2700	4100
	2	900	1800	3600	5400
	3	1600	3200	6400	9700
	4	3100	6200	10000	10000

Chart 2: Coarse-Grained Soil: Protection of Surface Soil-Subsoil Guideline

COARSE		Surface Soil Guideline (mg/kg chloride)			
Surface soil drainage rate	Top of impact	Surface soil EC buffer (dS/m)			
(mm/yr)	(m)	1	2	4	6
1↑	1.5	290	580	1200	1700
	2	360	720	1400	2200
	3	500	990	2000	3000
	4	800	1600	3200	4800
2↓	1.5	490	900	1800	2700
	2	630	1300	2500	3800
	3	1200	2300	4700	7000
	4	2300	4600	7000	7000
7↓	1.5	780	1600	3100	4700
	2	1700	3300	6600	7000
	3	5300	7000	7000	7000
	4	7000	7000	7000	7000

14.2.4 Naturally-Occurring Sulphate as Pedogenic Tracers

If there is a net downward movement of salt over the course of a year, then upward capillary movement of salt may not be an issue. An accepted approach to determine if there is net downward movement of salts is by using the distribution of naturally-occurring sulphates as a pedogenic tracer. This method can be utilized to develop a sub-soil chloride threshold (see section 14.2.3).

The current distribution of naturally-occurring sulphate has been developed over an extended period of time and can be used as an indicator of net long-term moisture flux, particularly in regions with higher natural sulphate concentrations. An accumulation of sulphate at the soil surface would indicate a long-term net upward movement of salts due to the moisture deficit in dry months. Anthropogenic NaCl would of course follow this same pattern. Conversely, a lack of sulphate accumulation in the shallow surface soil while sulphates have accumulated in the deeper surface soil or zone of root protection suggests no likely net long-term upwards migration of NaCl through moisture extreme extended differences. Under this scenario future upward migration of anthropogenic salts is unlikely. The distribution of salts in the subsurface soils can be complex and controlled by subtle micro-topographic features (local highs and lows). It is possible for one part of a site to have the potential for net upward movement of salts and another part to exhibit net downward movement. For this reason, it is important to investigate the natural sulphate profile at a range of locations across a site.

The following process has been adopted from the NPP and has been adapted for use in this Directive. The process involves an evaluation of the vertical profile of sulphate concentrations

at several locations on a site as a way of understanding potential long-term future movement trends of salts within the soil profile for the site. Three outcomes are possible:
1. No likely future net upward movement/migration of salt within the soil profile; or
2. The future net movement/migration of salt within the soil profile will likely be downward but requires confirmation; or
3. The sulphate trend indicates a potential for future net upward movement/migration; the surface soil receptor cannot be excluded.

Profile Locations of the Site: A minimum of one soil profile is required just outside of the salinity-impacted area (site), in an undisturbed fringe impact location. This profile must be located in the same topographic position as the site and in close enough proximity that the salt distribution will provide an indication of the direction of net salt movement in the site. If there is more than one salt-impacted area being managed at a site, then a minimum of one soil profile is required in close proximity to each such area. Where natural salt distribution is variable, (e.g. solonetzic landscapes) the practitioner may need to sample more than one soil profile in order to represent the soil within the impact area with similar background soils.

Profile Locations (Background): A minimum of three soil profiles are required in background areas of the site. These should be located away from areas where anthropogenic impacts are expected, and at topographic locations that are similar to the site (refer to section 11).

Profile Requirements: Each profile location must be in an undisturbed location that has not been affected by anthropogenic impacts. Sufficient samples must be collected at each profile location to enable analysis of the resulting sulphate profile as shown in Appendix 7. Typically, at each location a total of eight samples should be collected between the surface and 4.5 m, with closer sample spacing at shallow depths and larger intervals with increasing depth. In most cases, this will generate a sulphate profile that can be interpreted successfully under the guidance in Appendix 7. However, other datasets may be adequate depending on the circumstances of the site, so long as the data are sufficient for the analysis indicated in Appendix 7. An example of an appropriate sampling regime is included in section 11.

Analytical Requirements: Each sample must be analyzed for sulphate and chloride. Chloride concentrations must be within the background range for the site.

Interpretation of Each Profile: Each soil profile is interpreted to determine the long-term direction of moisture and salt movement. Analytical data for each profile must be accompanied by a graphical presentation to assist in data interpretation. Information on how to interpret the vertical sulphate distribution within the soil profile is provided in Appendix 7. Possible outcomes for each profile in relation to the direction of long-term salt migration are:
- Definitive downward;
- Probable downward;
- Upward; or
- Ambiguous.

If all profiles show a definitive downward movement, then it can be concluded that salt movement is downward across the site and there is no significant risk of salt migration upwards into the shallow surface soil. For any other outcome, additional lines of evidence (e.g. a sufficiently deep water table level, section 14.2.5) are required.

14.2.5 Sufficiently Deep Water Table

The following standard was adopted from the NPP. At sites with a sufficiently deep water table, the net movement of moisture (with associated migration of salts) back up into the shallow surface soil is unlikely (AEP, 2019). For the purposes of this Directive, it must be demonstrated that the water table is at least 2 m deep if based on monitoring well observations, or 3 m deep if based on field soil observations.

- If monitoring wells have been installed at the site, then all measured water table depths must be 2 m or greater below ground surface and the wells must be screened in the shallowest groundwater zone. There must be at least three monitoring wells installed at topographically similar locations that surround the impact so that they are not all up gradient. The water levels must be measured at least once in the spring when groundwater levels are typically shallowest.
- In the absence of sufficient monitoring well data, the long-term water table level can be inferred from careful borehole log observations. Borehole log observations of the moisture content of soils, and how it changes with depth, can be helpful in supporting an inference of water table depth. Gleying and mottling occurs when soils are saturated for extended periods of time, and observations of the evidence of these processes can also be helpful in supporting an inference of water table depth. The requirements are met if the inferred water table depth is at 3 m or deeper in all boreholes. Note that high-quality borehole log observations will be required to build a defensible case for inferred water table depth in the absence of monitoring well data, and it may not always be possible to support an inferred water table depth if the appropriate observations were not made on the borehole logs.

A sufficiently deep water table combined with probable downward salt movement (as demonstrated by sulphate profiles, section 14.2.4) can be presented to support that future migration of salt into the shallow surface soil is unlikely.

14.3 Freshwater Aquatic Life

Remediation of NaCl-impacted sites involving wetlands requires special consideration. Wetlands represent a wide range of habitat features on the landscape, can potentially support wildlife for brief or extended periods, and have widely varying hydrological relationships with other wetland features. This section provides specific guidance on how to evaluate remediation requirements of sites involving prairie wetlands.

14.3.1 Wetland Definition and Surface Hydrology Concepts

For the purpose of this Directive, ER has utilized the Canadian Wetland Classification System (as defined by the National Wetland Working Group, 1997) definition of wetlands as "*land that is saturated with water long enough to promote wetland or aquatic process and are indicated by poorly drained soils, hydrophytic vegetation (plants that grow partly or completely in water), and various kinds of biological activity which are adapted to a wet environment.*" This means that a wide range of habitat types are considered wetlands including pothole wetlands, creeks, areas adjacent to lakes, and peatlands (bogs and fens). This wetland definition recognizes that consideration must be given for remediation decision making where wetland habitats exist and may only have water present for a portion of the year. This definition encompasses wetlands that are:

- Ephemeral: only hold water for a few days (Class I);
- Temporary: only hold water for a few weeks (Class II);
- Seasonal: only hold water for a few months (Class III);
- Semi-permanent: almost always have water present (Class IV); and
- Permanent: always have water present except in extreme droughts (Class V and higher)

This wetland permanence classification is derived from the pothole wetland classification (Stewart and Kantrud, 1971) but can be broadly applied to:

- **Riverine:** Relating to or situated on a river or riverbank;
- **Lacustrine:** Wetlands that are generally larger than 20 acres and having less than 30 per cent cover of vegetation such as trees, shrubs, or persistent emergent plants. Lacustrine sediments are generally made up of fine-grained particles deposited in lakes; and
- **Peatland Wetlands:** Areas of buildup of layers of peat. This peat creates the unique conditions found in these wetlands. The first 30 to 50 centimetres of the surface of a peatland is mostly formed by living mosses and plants**.**

Applying the Canadian Wetland Classification System wetland definition in the Prairie Ecozone of Saskatchewan requires identification of those ecosites which meet this definition. Thorpe (2014) provides a detailed guide for the identification of those ecosites which meet this definition. The following ecosites should be considered wetland habitat and subject to the provisions of this Directive

- **Wet Meadow** Wet low-lying sites that are normally flooded for 3 to 4 weeks in the spring. Poorly drained soils show signs of prolonged saturation, such as dull colours or prominent mottles (Gleysolic soils). Potential vegetation includes diverse communities of fine-textured grasses, sedges, and forbs, sometimes with tall willows.
- **Shallow Marsh** Wetlands that are normally flooded until July or early August (Gleysolic or Organic soils). Potential vegetation includes simpler communities of intermediate-sized grasses and sedges.
- **Deep Marsh** Wetlands that are normally flooded throughout the growing season (nonuse areas). Potential vegetation consists of a few species of tall, coarse graminoids (e.g., cattails, bulrushes).
- **Fen-peat** Wetlands with peat accumulation (Organic soils). Potential vegetation can consist of sedge stands or swamp birch and willow shrublands.
- **Saline Wet Meadow** Wet low-lying sites that are normally flooded for 3 to 4 weeks in the spring (Saline soils). Potential vegetation is dominated by salt-tolerant plants.
- **Saline Shallow Marsh** Wetlands that are normally flooded until July or early August (Saline soils). Potential vegetation is dominated by salt-tolerant plants.
- **Saline Deep Marsh** Wetlands that are normally flooded throughout the growing season (nonuse areas; Saline soils). Potential vegetation consists of a few species of salt-tolerant plants.

The distinction between permanent and semi-permanent wetlands and less permanent types is an important distinction when considering the impacts of NaCl on affected sites. The ESS provides guidance on how to consider impacts on the permanent and semi-permanent waterbodies:

- Surface water bodies' role as recharge/discharge zones form a complex conceptual model with many factors to consider. At the impact source, connectivity with the groundwater is the primary consideration. After that, the hydrogeological properties of the site determine the ease of transport along the contaminant pathway, followed by the groundwater flow characteristics at a specific location that determine the propensity for the groundwater to discharge into the surface water body;
- Permanent water bodies which sustain aquatic life must always be considered in application of this pathway. Seasonal water bodies may be excluded from consideration except in cases where they flow directly to permanent water bodies or are otherwise hydrologically connected.

Distinguishing whether wetlands are to be considered permanent is a key distinction when applying this Directive as is determining whether wetlands are hydrologically connected. The following sections provide technical direction on these determinations.

14.3.2 Wetland Permanence

Wetland permanence is most commonly associated with pothole type wetlands (palustrine marsh). However, many wetland types (e.g. riverine, palustrine) may have seasonal types. An important distinction is that most permanent waterbodies will have zones which are less permanent (e.g. wet meadow zone adjacent to a lake). If these less permanent ecosites are spatially contiguous to the permanent wetland they are considered a part of the permanent wetland. The following wetlands should be considered permanent waterbodies:

- All peatlands (fens and bogs);
- All lacustrine wetlands;
- Palustrine (pothole wetlands) which have deep marsh or deep-water zones where rooted vegetation is absent. This includes all permanent and semi-permanent wetlands Class IV and higher (Stewart and Kantrud, 1971); and
- Riverine wetlands which have deep marsh or deep-water zone where rooted vegetation is absent.

14.3.3 Surface Water Hydrological Connection

When determining if a wetland is hydrologically connected to a permanent waterbody by surface water the following steps should be undertaken:

1. Identify the possible downstream receiving waterbody;
2. Determine if a hydrological connection is present. The previous section provides guidance on identification of permanent waterbodies. However, identifying a hydrological connection requires a more detailed consideration of hydrology especially in the Prairie Ecozone. Hydrological connection changes on prairie landscapes depending on the size of the runoff event. For the purposes of this Directive, sites should be considered hydrologically connected if they are expected to contribute runoff in 50 per cent or more of the years. The area of a watershed which contributes runoff 50 per cent or more of the years is also referred to as the 1:2 contributing area (1:2 CA). To be considered within the 1:2 CA of a waterbody, a site should be connected to the permanent waterbody by a continuous series

of linear stream features or constructed drainage works and can often be identified through vegetation differences. Topographic maps or digital elevation models can be used to confirm the direction of flow of drainage works or streams.

Figure 8: Continuous liner stream features indicate a hydrological connection from a potentially impacted site to a permanent waterbody

Figure 9: Constructed surface ditches provide a hydrological connection from a potentially impacted site to a permanent waterbody

Figure 10: Enhanced vegetation provides a hydrological connection from a potentially impacted site to other waterbodies

Tier 1
When a site meets Tier 1 criteria it is considered to meet contaminant of concern concentration criteria that deems the site free from expected impact for all land uses and all receptor pathways. This is the lowest level of criteria acceptance which requires the least amount of scientific rationale in evaluating a site for potential receptor impacts. However, a suitable sampling regime must be considered.

Under this Directive, ER defines the point of compliance for a wetland as the point where shallow groundwater interacts with the wetland, the hyporheic zone. The point of compliance for freshwater aquatic life (FAL) is not the beginning of the hyporheic zone (the zone of mixing between groundwater and a water body); that is, not within the groundwater itself. Therefore, consideration can be given to the groundwater-wetland interaction or dilution in assessing risk to the in-wetland community. The point of compliance is within the wetland water itself or within the sediment habitat or benthic zone. As shallow groundwater moves through the hyporheic zone it may commingle to some degree with water within the wetland. Therefore, regulatory criteria is applied to the wetland habitat.

Tier 2 Alternative
A Tier 2 level of criteria can be used when the site characteristics are not necessarily the same as those considered under Tier 1 and the site receptor conditions may not be as sensitive as the numerical based set of criteria. For instance, if a receptor or pathway is absent or there are extraordinary conditions preventing contaminant migration, Tier 2 scientific rationale can be used to justify a higher level of contaminants exceeding criteria. The absence of salt-sensitive species or vegetation in a wetland could provide rationale for applying higher values above

criteria. More assessment data are typically required for Tier 2 criteria adjustments or elimination.

A wetland in the direct vicinity of a contaminated site can be eliminated as a receptor if it meets one or more of the following criteria:

- The wetland is not a permanent waterbody;
- The wetland has been completely drained or infilled. Partially drained wetlands are considered a receptor;
- The wetland has been annually cropped for seven of the previous ten years;
- A wetland is up gradient or cross gradient of an impact source;
- Analytical modelling can demonstrate that current management practices will sufficiently protect the receptor;

All contaminated sites must be examined to determine if they are hydrologically connected by surface water to a permanent waterbody. Downstream permanent waterbodies can be eliminated as a receptor if:

- There is no hydrological connection to the permanent water body that is expected to result in a surface water connection in 50 per cent of years (1:2 CA) or greater;
- The hydrological connection is over 300 m of linear distance from the permanent waterbody unless the size of the impact (the impact mass) indicates a long-term potential for measurable effects to the wetland.

An acceptable approach to determine if chlorides can remain *in situ* is by using chloride concentration thresholds developed in this Directive generated from the SST. The chloride guidelines calculate the allowable chloride in the soil for protection of a FAL. The chloride criteria charts (Chart 3 and 4) are based on the groundwater velocity, depth to PWA, the source length of the chloride-impacted soils, and distance to a FAL receptor, and the soil type (fine or coarse).

- A management limit of 10,000 mg/kg chlorides for fine-grained soil and 7,000 mg/kg for coarse-grained soil will be the maximum allowable concentrations.
- The saturation percentage must be 60 per cent for fine and 35 per cent for coarse grain soils.
  - If the saturation percentage is higher, a less conservative criterion may be achieved by recalculating using the SST.
- The source length is the appropriate source dimensions, which is based on the length of chloride-impacted soil and groundwater for any vector across the impact area or in the direction of groundwater flow.
  - Source length for the entire site is measured linearly across the longest impacted length of the site regardless of groundwater flow direction.
  - Lateral closure must be obtained around the perimeter of the chloride impact (in all cardinal directions from the approximate centre of an impact, or north, south, east, and west) as per section 10.
  - Source lengths larger than 15 m will use values obtained from the 25 m source length.
  - Source lengths larger than 25 m are not valid to use the FAL charts
- The velocity of groundwater flow is calculated by hydraulic gradient and conductivity divided by effective porosity.
  - **Groundwater Velocity** = (Hydraulic Conductivity x Hydraulic Gradient) / Total Porosity

- The table below was generated from SST Help File 3.0 and indicates default values for the different parameters to calculate groundwater velocity if there is no groundwater data available.
- If none of the parameters are know for the site a default value of 1.9 m/yr for fine-grained soils or 5 m/yr for coarse-grained soils is to be used.
- The groundwater velocity will be rounded down to the next highest number on the table, where a groundwater velocity of 0.6 m/yr is calculated, a groundwater velocity of 1 m/yr would be applicable for the charts below.

Table 2: Groundwater Velocity Parameters

Parameter	Default Values	Measured Values
Hydraulic Conductivity	Fine Soils= 1E-06 m/s	maximum of measured values if 3 wells, or arithmetic mean of measured values if > 4 wells
	Coarse Soils = 1E-05 m/s	
Total Porosity	Fine Soils = .47	laboratory measurements of Core Samples brought to the surface during drilling. Measurement of porosity in the laboratory
	Coarse Soils = .36	
Hydraulic Gradient	.028 m/m	average of measured values from > 3 wells on two or more distinct sampling events (e.g., July, November)

- The receptor distance is calculated from the leading edge of chloride impacts to the hyporheic zone. The distance will be rounded down to the next lowest number on the table. The distance will be calculated to the closest FAL receptor in any direction. If groundwater flow in known, then the distance to the closest FAL receptor in the direction of flow.
- An example calculation for the FAL receptor is included in Appendix 8.

Chart 3: Fine-Grained Soil: Protection of FAL - Subsoil Guideline

FINE		Aquatic Life Guideline (mg/kg chloride)				
Source length (m)	Groundwater velocity (m/yr)	Receptor Distance (m)				
		50	125	250	500	1000
25	1.9[D]	110	490	2100	10000	10000
	1	140	630	2800	10000	10000
	0.5	180	860	3900	10000	10000
	0.25	240	1200	5500	10000	10000
15	1.9[D]	200	1200	5500	10000	10000
	1	250	1500	7400	10000	10000
	0.5	320	2100	10000	10000	10000
	0.25	440	2800	10000	10000	10000

[0] represents the 1.9 m/yr default GW velocity for fine soils in the SST ($1x10^{-6}$ HC and .0028 gradient)

Chart 4: Coarse-Grained Soil: Protection of FAL - Subsoil Guideline

Coarse	Aquatic Life Guideline (mg/kg chloride)					
Source length (m)	Groundwater velocity (m/yr)	Receptor Distance (m) 50	125	250	500	1000
25	5[D]	41	160	610	2800	7000
	2.5	46	190	780	3800	7000
	1	58	260	1200	5800	7000
	0.5	74	350	1600	7000	7000
15	5[D]	77	370	1600	7000	7000
	2.5	82	440	2000	7000	7000
	1	100	620	3000	7000	7000
	0.5	130	870	4100	7000	7000

[0] represents the 5 m/yr default GW velocity for coarse soils in the SST ($1x10^{-5}$ HC and .0028 gradient)

Tier 3
Wetland in Direct Vicinity of NaCl Impacts
For a wetland, a Tier 3 criteria level allows for the development of a site-specific set of criteria that fully incorporates the site setting and site ecological, geological, hydrogeological, and hydrological characteristics. In developing a site-specific set of criteria, such as in completing a risk assessment and a fully developed CSM along with its associated measured contaminant transport parameters would be required in consideration of receptor salt tolerances.

If a wetland in the direct vicinity of a contaminated site cannot be declassified as a receptor, the standard wetland mitigation sequence of avoid, minimize, offset should be employed. See Tier 1 for the points of compliance. In most cases with an existing NaCl-impacted site, avoidance is not possible because the contamination has already occurred.

As a minimization measure, the site may be mitigated through some form of remediation to protect the receptors or a Tier 2 ERA could be completed. When a high-value wetland is lost ER requires wetland replacement to the same local benefit. When conducting such an assessment, consideration must also be given to potential future effects on the wetland. For evaluations that would involve outcome predictions of potential effects such as simple modelling, the timeframe required to assess future in-wetland contaminant concentrations would be 1,000 years. A 500-year timeframe can be used for predicting the effects, such as determining the break-through contaminant concentrations, when using complex modelling where a fully developed conceptual site model is the basis of calculations.

In many cases, the modelling/assessment/remediation for a minimization approach may be far too expensive compared to the magnitude of the impact to the wetland. Likewise in many cases, the necessary remediation will cause excessive disturbance to a wetland and may create more impact than the spill site itself. In these cases, it is appropriate to consider an offset approach. Responsibility to develop and propose an appropriate offset approach for ER to consider is the responsibility of the licensee.

Contaminated Site is Hydrologically Connected to a Downstream Permanent Waterbody
When a large, impacted wetland is not hydrologically connected to a downstream, permanent wetland, but could be drained and is within 1,000 m of a permanent waterbody, an interest should be registered on title to prevent drainage of the wetland in the future.

If a contaminated site is hydrologically connected to and can potentially impact a downstream, permanent waterbody through surface water flow, a detailed study could be conducted to determine the impact or mitigation actions which could be put in place (e.g. ditch blocks which hydrologically separate the site from the downstream water body). An interest should be registered on title to ensure mitigation measures stay in place.

14.4 Groundwater

14.4.1 Potable Water Aquifer or Domestic Use Aquifer

The following methods can be utilized to potentially remove a PWA as a receptor of concern. Sufficient information must be supplied by a QP to justify the options below. If chloride concentrations are sufficiently elevated these options may not be available and Tier 3 solutions will have to be utilized.

- If the groundwater contains chemical constituents naturally that make the water unsafe for human consumption or contain constituents that render the water undesirable aesthetically, the PWA can be excluded (SST Help file 3.0).
- NaCl does not exceed 10 per cent of background TDS.
- The PWA can also be excluded via SST or if analytical models indicate that NaCl impacts will not impact the PWA for 1,000 years.
- PWA Guideline Charts (listed below)

14.4.2 Potable Water Aquifer Guideline Charts

An acceptable approach to determine if chlorides can remain *in situ* is by using chloride concentration thresholds developed for this Directive generated from the SST. The chloride guidelines calculate the allowable chloride in the soil for protection of a PWA. The chloride criteria charts (Charts 5 and 6) are based on the groundwater velocity, depth to PWA, the source length of the chloride-impacted soils, and the soil type (fine or coarse).

- A management limit of 10,000 mg/kg chlorides for fine-grained soil and 7,000 mg/kg for coarse-grained soil will be the maximum allowable concentrations.
- The saturation percentage must be 60 per cent for fine-grained and 35 per cent for coarse-grained soils.
- If the saturation percentage is much higher, a less conservative criterion may be achieved by recalculating using the SST.
- The source length is the appropriate source dimensions, which is based on the length of chloride-impacted soil and groundwater for any vector across the impact area or in the direction of groundwater flow (SST Help File).
- Source length for the entire site is measured linearly across the longest impacted length of the site regardless of groundwater flow direction.

- Lateral closure must be obtained around the perimeter of the chloride impact (in all cardinal directions from the approximate centre of an impact, or north, south, east, and west) as per section 10.
- Source lengths larger than 15 m will use values obtained from the 25 m source length.
- Source lengths larger than 25 m are not valid to use the PWA charts.
- Subsoil chloride impacts are confined between 1.5 to 6 m bgs.
- Drainage rates are based on the site location and sub-region information or from supplementary data such as vertical hydraulic gradient from nested wells
- The PWA depth is based on the measured depth of the PWA based on soil logs or groundwater measurements. The PWA depth will be rounded down to the next lowest number on the table.

Examples are included in Appendix 9.

Chart 5: Fine-Grained Soil: Protection of Potable Water Aquifer-Subsoil Guideline

FINE	PWA Guideline (mg/kg chloride)					
Source length	PWA drainage rate	PWA depth (m)				
(m)	(mm/yr)	6	10	15	20	25
25	9↓	970	1600	2100	2600	2900
	6↓	1500	2600	3500	4400	7500
	3↓	3300	6000	8700	10000	10000
	1↓	10000	10000	10000	10000	10000
15	9↓	1500	2500	3400	4100	4700
	6↓	2500	4200	5700	7200	10000
	3↓	5400	10000	10000	10000	10000
	1↓	10000	10000	10000	10000	10000

Chart 6: Coarse-Grained Soil: Protection of Potable Water Aquifer-Subsoil Guideline

Coarse	PWA Guideline (mg/kg chloride)					
Source length	PWA drainage rate	PWA depth (m)				
(m)	(mm/yr)	6	10	15	20	25
25	30↓	180	230	310	410	460
	15↓	330	500	710	1100	1500
	7↓	740	1400	2400	3400	5900
	2↓	3300	7000	7000	7000	7000
15	30↓	260	350	470	690	780
	15↓	520	810	1200	2100	3100
	7↓	1200	2600	5100	7000	7000
	2↓	6100	7000	7000	7000	7000

14.4.3 Livestock Dugout

If it can be demonstrated that a dugout cannot be installed due to the location of historical infrastructure then the exposure pathways can be eliminated. For example, if a wellbore exists within the contaminant plume, the dugout receptor can be eliminated because a dugout should not be installed. A buffer zone of 50 m surrounding oil and gas infrastructure that remains buried under the surface should not have a dugout installed in that area. Natural conditions can exclude a dugout if background TDS is sufficiently elevated that groundwater would be a poor resource for livestock watering (>7,000 mg/L). A maximum dugout depth is assumed to be 4 m. Situations where the seasonal average groundwater table is >4 m will result in elimination of the dugout pathway for both livestock watering and irrigation water (SST version 2.5.3). If the natural TDS is <7,000 mg/L then current versions of the SST can be utilized to remove this pathway as a receptor.

Grain size/hydraulic conductivity can be used to exclude the livestock dugout pathway. Where a heavy (>36 per cent clay content [SST]) as the contribution of groundwater compared to surface will not be sufficient.

An acceptable approach to determine if subsoil chlorides can remain in situ is by using chloride concentration thresholds developed for this Directive generated from AEP's SST. The chloride guidelines calculate the allowable chloride in the soil for protection of a dugout. The chloride criteria charts (Charts 7 and 8) are based on the groundwater velocity, depth to water table, and the soil type (fine or coarse, section 14.3.3).

14.4.4 Irrigation

There are upper bound salinity (TDS) limits that result in pathway elimination, for example when background TDS is sufficiently elevated that groundwater would be a poor resource for irrigation (>1,280 mg/L).

An acceptable approach to determine if subsoil chlorides can remain *in situ* is by using chloride concentration thresholds developed for this Directive generated from the SST. The chloride guidelines calculate the allowable chloride in the soil for protection of irrigation. The chloride criteria charts (Charts 7 and 8) are based on the groundwater velocity, depth to water table, and the soil type (fine or coarse; section 14.3.3).

14.4.4.1 Chloride Guideline Charts Livestock Dugout and Irrigation

- A management limit of 10,000 mg/kg chlorides for fine-grained soil and 7,000 mg/kg chlorides for coarse-grained soil will be the maximum allowable concentrations.
- The saturation percentage must be 60 per cent for fine-grained and 35 per cent for coarse-grained soils.
- If the saturation percentage is higher, a less conservative criterion may be achieved by recalculating using the SST.
- The water table is based on the measured depth of the PWA based on soil logs or groundwater measurements. The PWA depth will be rounded down to the next lowest number on the table.
- The groundwater velocity is calculated as indicated in section 14.3.3.
- Examples are included in Appendix 10.

Chart 7: Fine-Grained Soil: Protection of Dugout-Subsoil Guideline

FINE	Dugout Guidelines (mg/kg chloride)		
Water table (m)	Groundwater velocity (m/yr)	Livestock water	Irrigation
2	1.9[D]	7900	1800
	1	10000	3200
	0.5	10000	6300
	0.25	10000	10000
4	1.9[D]	10000	3800
	1	10000	7000
	0.5	10000	10000
	0.25	10000	10000

[0] represents the 1.9 m/yr default groundwater velocity for fine-grained soils in the SST (1x10^{-6} HC and 0.0028 gradient). Dugout guideline based on assumed 3,000 mg/l background TDS for fine-grained

Chart 8: Coarse-Grained Soil: Protection of Dugout-Subsoil Guideline

Coarse	Dugout Guidelines (mg/kg chloride)		
Water table (m)	Groundwater velocity (m/yr)	Livestock water	Irrigation
2	5[D]	2300	510
	2.5	4400	940
	1	7000	2200
	0.5	7000	4400
4	5[D]	5200	1100
	2.5	7000	2100
	1	7000	5200
	0.5	7000	7000

[0] represents the 5 m/yr default groundwater velocity for coarse-grained soils in the SST ($1x10^{-5}$ HC and 0.0028 gradient). Dugout guidelines based on 1,000 mg/l background TDS for coarse.

14.5 Subsoil Salinity Tool

Within Alberta's regulatory framework, the SST provides Tier 2 options for remediation of chloride-based salinity below the surface soil (nominally >1.5 m bgs). The SST is a software program that uses site-specific information to estimate transport of chloride to a domestic use aquifer/PWA, surface water bodies, and upward transport into the surface soil. The software and accompanying information are available on the AEP website. The SST calculates the drainage rate via climate, soil lithology, and vegetation establishment. However, the tool was developed for Alberta, and as such, does not have any specific Saskatchewan-related aspects. The user will have to correlate locations in Saskatchewan with natural subregions/climates correlating to those used in the SST (section 8.1). Figure 1 (section 8.1) can be an initial starting point for users to look up sites and assign a relevant natural sub-region that could be entered directly into the SST (and bypassing the legal subdivision entry). For ER to accept the SST outcome the user must be accredited for its use in Alberta and provide additional explanation for its use in Saskatchewan.

ER recognizes that multiple Tier 2 approaches can be used to determine if environmental receptors could be at risk of in situ NaCl. Therefore, a combination of SST and environmental receptor exclusion can be used. The receptors that are considered in SST are surface soil, livestock watering (dugout), aquatic life (fresh-water aquatic), irrigation and domestic use aquifer (PWA). Reasonable explanation must be provided along with the SST output indicating why a receptor can be eliminated from the SST calculation. ER recognizes that the SST may not apply for all sites. For smaller footprints, the SST is a valuable tool but other options may need to be considered for sites with a larger footprint. The SST can be a valuable field screening tool to indicate if it could be beneficial to a site. Utilizing the SST as a field screening tool for use in Saskatchewan does not require the individual to be accredited for its use in Alberta.

15. Stakeholder Engagement

It is the responsibility of the licensee to engage an obtain approval on remediation and reclamation plans with the relevant stakeholders. All Tier 3 solutions will need stakeholder acceptance prior to implementation. ER may engage with stakeholders if an agreement cannot be completed. ER recognizes that in some circumstances the stakeholder may not be supportive of the RAP/reclamation plan that has been presented by industry and will work to help obtain a mutually agreeable solution.

Appendix 1: Ecological and Human Health Effects of NaCl

Freshwater Aquatic Life

In general, freshwater aquatic organism are hyperosmotic, meaning they contain a higher internal salt concentration than the surrounding water. In a freshwater environment, a change in salinity affects aquatic organisms by affecting the ability of organisms to effectively osmoregulate, which in turn could affect endocrine balance, oxygen consumption, and cause changes in overall physiological processes (Nielsen et al, 2003).

The toxicity of NaCl to freshwater aquatic life is primarily attributed to the chloride ion, rather than the sodium ion (CCME, 2011). The toxicity of chloride to freshwater aquatic life varies by species; in general, invertebrate species are more sensitive to chloride than fish and amphibian species (CCME, 2011). The Tier 1 SEQG for chloride for protection of freshwater aquatic life is 120 mg/L and is based on the CCME Canadian Water Quality Guideline (CWQG) long-term exposure (CCME, 2011). The CWQG long-term exposure guideline is intended to protect against negative effects to aquatic ecosystem structure and function during indefinite exposures.

Water hardness has been shown to ameliorate chloride toxicity to freshwater aquatic life. The CCME has recognized water hardness as a modifying factor to chloride toxicity (CCME, 2011). However, this factor was not incorporated into the CWQG for protection of freshwater aquatic life due to limitations in the long-term data set.

Plants

Soil salinity (i.e. elevated NaCl) affects plants both directly and indirectly through the following mechanisms:

- toxicity to plants;
- reducing water availability; and
- changes to soil structure.

Plant toxicity from NaCl is observed when the ions accumulate in the leaves to the extent that results in damage to the plant (FAO, 1994). Typically, ions are taken up from the soil-water by the plant roots and accumulate in the leaves during transpiration. Under certain environmental conditions (i.e., high temperature and low humidity), sodium and chloride ions can also be adsorbed directly into the plants through leaves moistened during sprinkler irrigation (FAO, 1994).

Normally, it is the chloride ion that is associated with the toxicity to plants (FAO, 1994). Chloride, which is not adsorbed or held back by soil particles, is readily taken up by the plant, moves in the transpiration stream, and accumulates in the leaves. When chloride concentrations exceed the tolerance of the plant, damage to the plant occurs, which is often observed as leaf burn or drying of the leaf tissue.

Sensitivity to chloride varies among plant species. Agricultural crops that are chloride tolerant include cereals (barley, wheat, durum, oats), canola, and soybean; partly chloride tolerant crops include sunflowers, flax, potatoes, peas, and forages (brome grass, clover, fescue, alfalfa); and crops that are sensitive to chloride are mainly fruit and vegetable crops including raspberries, strawberries, blueberries, stone fruits (cherries), beans, onion, lettuce, and early vegetables

(FAO, 1994). The Tier 1 SEQG for chloride for the irrigation exposure pathway is 100 mg/L and is based on the value provided by Federal Contaminated Sites Action Plan (2016) and AEP (2016a). The chloride values for irrigation are detailed in AEP, 2018, which provides a range of 100 mg/L to 700 mg/L, where 100 mg/L is recommended for chloride-sensitive plants, and up to 700 mg/L for chloride-tolerant plants.

The sodium ion can also be toxic to plants. Sodium toxicity is associated with leaf burn along the outside edges of the leaves, in contrast to chloride toxicity which normally results in leave damage at the leaf tip (FAO, 1994). Crops sensitive to sodium include legumes such as peas, lentils, and beans; semi-tolerant crops include cereals (oats, rye, wheat) as well as canola and flax; tolerant crops include forages (alfalfa, crested wheatgrass, and tall wheatgrass) and some field crops such as barley and fall rye (FAO, 1994; Manitoba Agriculture, 2008). However, apparent toxic effects associated with sodium may be due to or complicated by poor water infiltration, as described below.

Accumulation of sodium in the soil can also affect the physical and hydraulic properties of the soil. Elevated sodium can cause the clay colloids to disperse to much smaller particles which clog soil pores. This dispersion often reduces water infiltration and promotes surface crust formation (i.e. “hard pan” soil), making it difficult for roots to penetrate and shoots to emerge (University of California, 2021).

In addition, an increase in soil salinity can also inhibit plants’ access to water by increasing the osmotic strength of the soil pore water (Manitoba Agriculture, 2008). In other words, water in the soil is held more tightly than the plants can extract it. As a result, many plants will exhibit symptoms of drought, even though the soil is relatively moist.

The SEQG does not provide a value for Total Dissolved Solids (TDS) for irrigation. Guidance on surface water quality for irrigation is available in AEP, 2018, with guidelines for irrigation water provided in units of conductivity; <1 dS/m is considered “safe”, 1.0 to 2.0 dS/m is considered “marginal or possibly safe”, and >2.0 dS/m is considered “hazardous.” A conversion factor of 1 dS/m = 640 mg/L TDS (from Tanji, 1990) was used to convert conductivity to TDS. Irrigation water with a TDS concentration of 1,280 mg/L would be considered “hazardous;” as such, this value was adapted as the toxicity reference value (TRV) for irrigation.

Livestock

For the protection of livestock watering, thresholds are based on Canadian livestock watering guidelines information. The SEQG for TDS in groundwater for livestock watering is 3,000 mg/L (ENV, 2021). The Government of Saskatchewan provides the range of TDS concentrations that are suitable for livestock watering; water with TDS concentrations <3,000 mg/L is “acceptable,” 3,000 to 5,000 mg/L is “generally acceptable,” 5,000 to 7,000 mg/L is “poor,” 7,000 to 10,000 mg/L is “potentially unsuitable,” and >10,000 mg/L is considered “unsuitable.” The value adopted as the TRV for livestock/wildlife watering is 7,000 mg/L, as this is the lower range of the “potentially unsuitable” category. The above information is available at https://www.saskatchewan.ca/business/agriculture-natural-resources-and-industry/agribusiness-farmers-and-ranchers/livestock/livestock-and-water-quality/livestock-water-quality.

Human Health Effects
Sodium (Na) and Chloride (Cl) salts are non-volatile, and human intake comes primarily through food and water. For NaCl-impacted oil and gas sites the risk for human consumption is from the ingestion of groundwater being utilized as a potable water source and salts that are most likely to have an impact on human health are those that are ingested through food sources.

The Tier 2 SEQG for sodium for potable groundwater of 200 mg/L is based on Health Canada drinking water quality guidelines (Health Canada, 1979). An excessive level of sodium is easily detected by taste; taste thresholds for salt are typically 130 mg/L to 140 mg/L. Generally, the taste of drinking water is offensive at sodium concentrations ≥200 mg/L; thus, the aesthetic objective of sodium is ≤200 mg/L (Health Canada, 1979). Sodium is not considered a toxic element; up to 5 g/day of sodium is consumed by normal adults (Health Canada, 1979).

The aesthetic objective for chloride in drinking water is 250 mg/L (Health Canada, 2020). When chloride concentrations exceed 250 mg/L water tastes objectionable. A helpful comparison of 250 mg/L chloride corresponds to approximately 180 mg/L of sodium (based on atomic weights assuming NaCl); as such, protecting human drinking water to 250 mg/L chloride is also protective of the sodium guidelines.

Sodium and chloride are not considered toxic to human health. However, individuals suffering from hypertension or congestive heart failure may require a sodium restricted diet (Health Canada, 1979). If it can be demonstrated that a potable water source will not be impacted by NaCl, or controls are put in place to restrict its use human toxicology can be removed as an environmental receptor for NaCl impacted sites.

Appendix 2: Additional Resources

AEP (2020). *Subsoil Salinity Tool Version 3.0 User Manual*. Effective as of November 2020. Developed by Equilibrium Environmental Inc. on behalf of AEP. URL https://open.alberta.ca/dataset/contaminated-sites-management-subsoil-salinity-tool#summary

AEP (2019). *Native Prairie Protocol of Reclamation Certification of Salt-Affected Well Sites*. Land Policy Branch, Policy and Planning Division. ISBN 978-1-4601-4583-8 . URL https://open.alberta.ca/publications/9781460145838

AEP (2019b). *Alberta Tier 1 Soil and Groundwater Remediation Guidelines*.

AEP (2018). *Environmental Quality Guidelines for Alberta Surface Waters*. Updated March 2018. URL https://open.alberta.ca/publications/9781460138731

AEP (2016). *Alberta Environmental Site Assessment Standard*. March 2016. Edmonton, Alberta. URL https://open.alberta.ca/publications/alberta-environmental-site-assessment-standard

CSA (2000). *(CAN/CSA-Z769-00 (R2018) Phase II Environmental Site Assessment*. Reaffirmed 2018. Toronto, Ontario.

CCME (2020). *A Framework for Ecological Risk Assessment: General Guidance (PN 1195)*. The National Contaminated Sites Remediation Program, Winnipeg, Manitoba. March 1996. ISBN 0-662-24346-3.

CCME (2011). Scientific Criteria Document for the Development of the Canadian Water Quality Guidelines for the Protection of Aquatic Life: Chloride Ion. Winnipeg, Manitoba. PN 1460 ISBN 978-1-896997- 77-3 PDF https://www.ccme.ca/fr/res/2011-chloride-ceqg-scd-1460-en.pdf

Federal Contaminated Sites Action Plan (2016). Guidance Document on Federal Interim Groundwater Quality Guidelines for Federal Contaminated Sites. Version 4.0. June 2016.

Food and Agriculture Organization of the United Nations (1994). *Water Quality for Agriculture*. R.S. Ayers, D.W. Westcot; Rural Infrastructure and Agro-Industries Division. Irrigation and Drainage Paper 29. 0254-5284. https://www.fao.org/publications/card/en/c/d5ded352-1815-5718-9797-58e42860a896

Health Canada (2020). *Guidelines for Canadian Drinking Water Quality Summary Table*. Prepared by the Federal-Provincial-Territorial Committee on Drinking Water of the Federal-Provincial-Territorial Committee on Health and the Environment. Water and Air Quality Bureau, Healthy Environments and Consumer Safety Branch. Ottawa, Ontario. September 2020. URL https://www.canada.ca/content/dam/hc-sc/migration/hc-sc/ewh-semt/alt_formats/pdf/pubs/water-eau/sum_guide-res_recom/summary-table-EN-2020-02-11.pdf

Health Canada (1979). *Guidelines for Canadian Drinking Water Quality: Guideline Technical Document - Sodium*. Ottawa, Ontario. Updated December 1992.

Manitoba Agriculture, Food and Rural Initiatives. 2008. *Soil Management Guide*. URL https://www.gov.mb.ca/agriculture/environment/soil-management/soil-management-guide/

National Wetlands Working Group (1997). *The Canadian Wetland Classification System, 2nd Edition*. Warner, B.G. and C.D.A. Rubec (eds.), Wetlands Research Centre, University of Waterloo, Waterloo, Ontario, Canada.

Nielsen, D.L, M.A. Brock, G.N. Rees, and D.S. Baldwin (2003). *Effects of Increasing Salinity on Freshwater Ecosystems in Australia*. Australian Journal of Botany.

ENV (2015). *Guidance Document: Impacted Sites*. http://www.environment.gov.sk.ca/Default.aspx?DN=125d335b-34c4-4072-8e1e-fb9408498231

Stewart, R.E. and H.A. Kantrud (1971). *Classification of Natural Ponds and Lakes in the Glaciated Prairie Region.* Bureau of Sport Fisheries and Wildlife, U.S. Fish and Wildlife Service, Washington, D.C., USA.

Tanji, J.L. (1990). *Hypertension, The Physician and Sports Medicine*. 18:8, 87-91, DOI: 10.1080/00913847.1990.11710117

Taylor H. Ricketts, Eric Dinerstein, David M. Olson, Colby J. Loucks et al. (2003). *Terrestrial Ecoregions of North America. A Conservation Assessment.* World Wildlife Fund – United States and Canada, Washington, D.C., USA

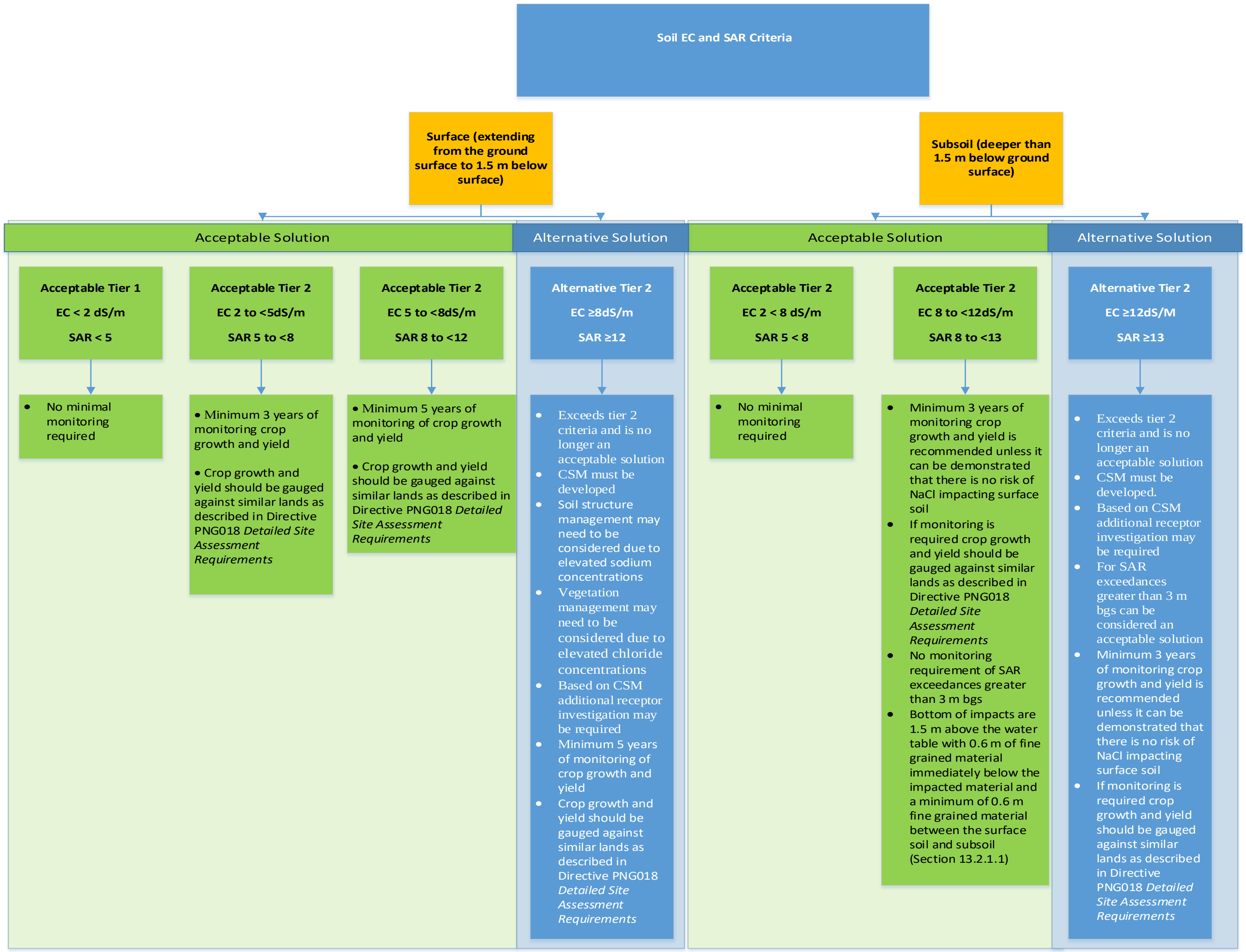
Thorpe, J. (2014). *Saskatchewan Rangeland Ecosystems, Publication 1: Ecoregions and Ecosites*. Version 2. Saskatchewan Prairie Conservation Action Plan. Saskatchewan Research Council.

United States Environmental Protection Agency (1998). *Guidelines for Ecological Risk Assessment*. EPA-600-R-93-187.

University of California, Division of Agriculture and Natural Resources (2021). *Salinity Management*. URL https://ucanr.edu/sites/Salinity/

Woods, S.A., M.F. Dyck and R.G. Kachanoski (2013). Spatial and Temporal Variability of Soil Horizons and Long Term Solute Transport under Semi-arid Conditions. *Canadian Journal of Soil Science* 93: 173-191.

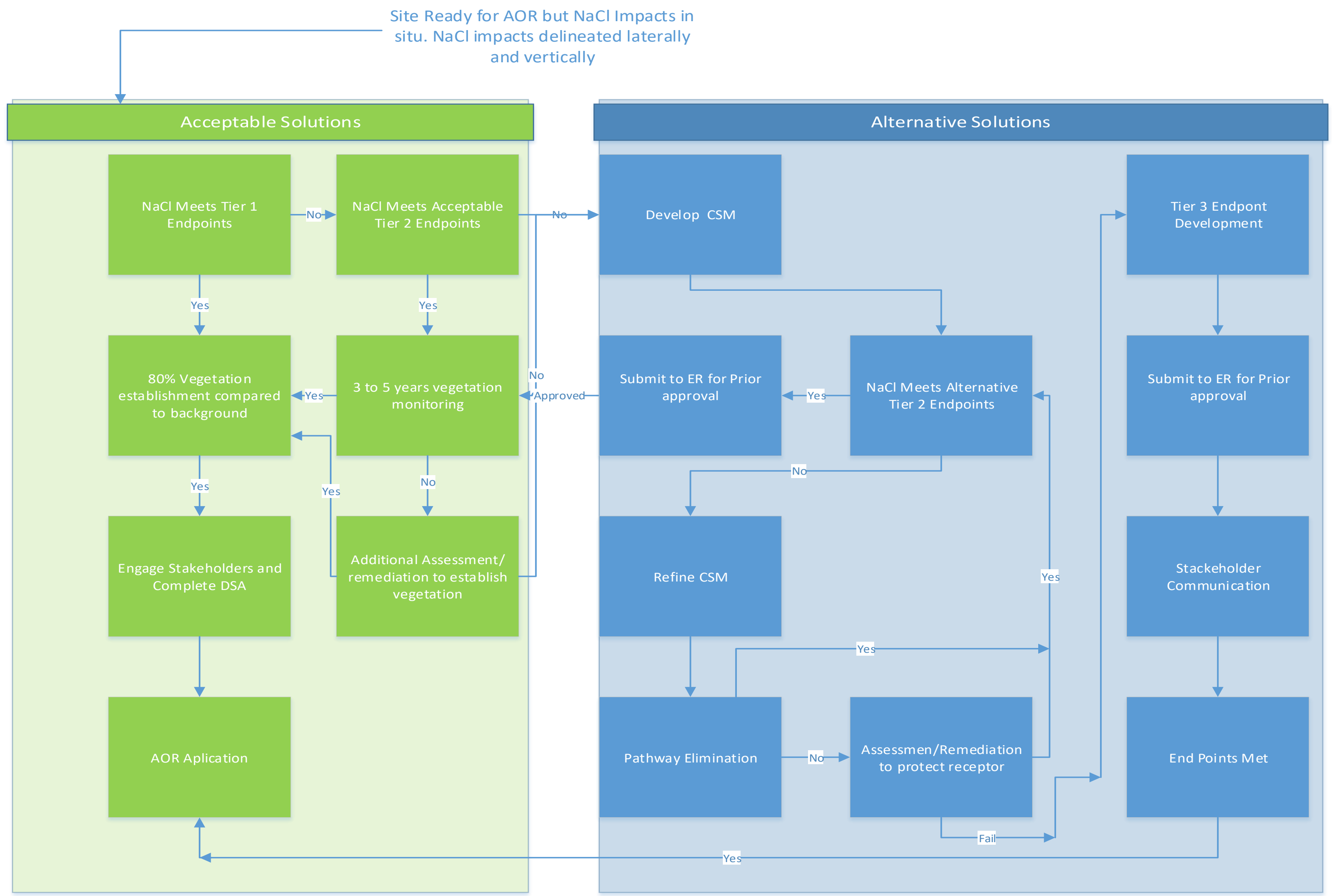
Appendix 3: Salinity and Sodicity Remediation Criteria For Soil



Appendix 4: Conceptual Site Model

Conceptual Site Model				
Tier____________________		Land Use ________	Grain Size ____________	
Receptors of Concern	**Impacts**	**Future Risk To Receptor/Pathway Indentification**	**Justification on why the pathway can be excluded**	**Remediation To Be Completed to Protect Receptor If Required**
Soil	Has the surface soil been Impacted. Have you achieved vertical and lateral closure	Is there future risk to surface soils. Have all pathways been indentifeid? Is there a posiblity of NaCl migrating upwards to impact shallow surface soils	Justification on why the pathway can be exlcuded as per the directive or by weight of evidence by regional data	
	Has the subsoil been Impacted. Have you achieved vertical and lateral closure	Is there future risk to surface soils. Have all pathways been indentifeid? Is there a posiblity of NaCl migrating upwards to impact surface soils	Justification on why the pathway can be exlcuded as per the directive or by weight of evidence by regional data	
Fresh Water Aquatic Life (FAL)	Has the FAL been impacted	Is there future risk to the FAL. Have all pathways been identified?	Justification on why the receptor can be exlcuded as per the directive or by weight of evidence by regional data	
Potable Water Aquife (PWA)	Has the PWA/DUA been Impacted	Is there future risk to the PWA? Have all pathways been indentified?	Justification on why the pathway can be exlcuded as per the directive or by weight of evidence by regional data	
Dugout	Has the Dugout been Impacted	Is there future risk to a Dugout? Have all pathways been indentified?	Justification on why the pathway can be exlcuded as per the directive or by weight of evidence by regional data	
Irrigation	Has water than can be utilized for irigation been impacted	Is there future risk for irigationt? Have all pathways been indentified?	Justification on why the pathway can be exlcuded as per the directive or by weight of evidence by regional data	
Additional Receptors				

Appendix 5: Flow Chart of Tier Endpoints



Appendix 6: Buffer Calculations for Surface Soils

Example A: No additional favourable site data relevant to Surface Soil Risk (most conservative)
A surface soil excavation (surface to 1.5 m bgs) was completed and the backfill has an average electrical conductivity (EC) of 2 dS/m. The licensee has decided to use a Tier 2 acceptable EC of 8 dS/m as their remediation goal. There will be an associated five years of vegetation monitoring to ensure vegetation is established with NaCl remaining *in situ*. There is no additional information regarding groundwater or suitable sulphate profiles.

- the targeted remediation goal is Tier 2 acceptable EC is 8 dS/m
- surface soil EC is 2 dS/m
- fine-grained soil
- Top of Impact (TOI) is 1.5 m bgs
- No additional favorable site data relevant to Surface Soil Risk, so a SSDR of 1 mm/yr up is used. The corresponding subsoil chloride would be:

Buffer= 8 dS/m -2 dS/m
Buffer = 6 dS/m, with
Fine-Grained Soil
TOI = 1.5 m bgs
RRZR 1 mm/year up
Subsoil chloride guideline = 2,500 mg/kg

Example B: Slight additional favorable site data relevant to Surface Soil Risk (slightly less conservative):
This is a non-impacted surface soil scenario where natural salinity has an average EC of 5.5 dS/m from surface to 1.5 m bgs. The licensee has decided to use a Tier 2 acceptable EC of 8 dS/m as their remediation goal. There will be an associated five years of vegetation monitoring to ensure vegetation is established with NaCl remaining in situ. The TOI is 3.6 which equates to 3 m bgs as the next conservative value on the table is used. A QP has completed a groundwater assessment on a groundwater monitoring well network indicating downward drainage and no suitable NPP sulphate profiles.

- the targeted Tier 2 acceptable EC is 8 dS/m
- surface soil EC is 5.5 dS/m
- Coarse grained soil
- TOI is 3.6 m bgs
- Nested wells indicating downward drainage, QP to indicate downward movement
- No suitable NPP sulphate profiles

Buffer= 8 dS/m -5.5 dS/m
Buffer = 2.4 dS/m, which equals 2 as you chose the next conservative value on the table
Coarse Grained Soil
TOI = 3.6 m bgs, which equates to 3 as you choose the next conservative value on the table
RRZR 2 mm/year down as the monitoring well network indicates downward groundwater movement
Subsoil chloride guideline = 2,300 mg/kg

Example C: Moderate additional favorable site data relevant to Surface Soil Risk:
In this example there is an average EC of 3.2 dS/m from surface to 1.5 m bgs. The licensee has decided to use a Tier 2 acceptable EC of 8 dS/m as their remediation goal. There will be an associated five years of vegetation monitoring to ensure vegetation is established with NaCl remaining in situ. The TOI is 1.8 which equates to 1.5 m bgs as values are rounded down to the next conservative value on the table. A QP has indicated a > 3 m water table and the site has suitable NPP sulphate profiles.

- If the targeted Tier 2 acceptable EC is 8 dS/m
- surface soil EC is 3.2 dS/m
- Fine-grained soil
- TOI is 1.8 m bgs
- >2 m water table measured, or >3 m water table inferred
- 'Pass' NPP protocols

Buffer= 8 dS/m -3.2 dS/m
Buffer = 4.8 dS/m, which equals 4 as you choose the next conservative value on the table
Fine Grained Soil
TOI = 1.8 m bgs, which equates to 1.5 as you choose the next conservative value on the table
RRZR 3 mm/year down
Subsoil chloride guideline = 2,700 mg/kg

Example D: Strong additional favorable site data relevant to Surface Soil risk (pathway excluded):
In this example the current day shallow surface soil has no NaCl impacts. A QP has indicated a > 3 m water table and the site has suitable NPP sulphate profiles. Impacted subsoil is deeper than 3m bgs.

- Pass on NPP
- Deeper water table (> 3 m water table measured or > 4 m inferred)
- Impacts > 3 m bgs

= Pathway Exclusion

Example E: Shallow surface soil has higher chloride values than the deeper surface soil and subsoil. No
In this example the shallow surface soil (0.5 m bgs) has the highest concentrations of NaCl compared to the deeper surface soils (.5 to 1.5 m bgs) and the subsoils. There is no additional information regarding groundwater or suitable sulphate profiles.

- Shallow Surface Soil = 1,200 mg/kg
- Surface soil EC of 7 dS/m
- Buffer = 8dS/m – 7dS/m = 1 dS/m
- TOI = 1.5 m
- Soil type = Fine-Grained
- Surface soil drainage rate (SSDR) minimum of 1 mm/yr up
  Subsoil chloride guideline = 410 mg/kg

Since there is elevated chloride in the shallow surface soil (1,200 mg/kg) higher than the guideline from the table of (410 mg/kg) the allowable subsoil guideline is based on shallow surface soil chloride concentration. The chloride guideline for the site is 1,200 mg/kg. For the subsoil to elevate the shallow surface soil chloride, it has to be at a higher concentration than the shallow surface soil. However, vegetation has to be previously established for a minimum of five years or there has to be a minimum of five years of vegetation monitoring with vegetation established after the monitoring period. If vegetation has not been established, 1,200 mg/kg chloride is not a suitable surface or subsoil guideline.

Appendix 7: Interpreting Sulphate Vertical Distribution

The profile of sulphate concentration with depth in prairie soils is a function of a range of processes that have occurred over extended periods of time. One of those processes is the movement of salts, including sulphate, as a result of long-term moisture movement in the top few meters of soil. A typical sulphate profile for a prairie soil is provided in Figure A-1 below.

This profile has three main regions:

- From ground surface to approximately 1.4 m bgs, the sulphate concentration increases steadily with depth. This is an indication that sulphate has been flushed out of the upper part of the soil profile by a long-term net downward moisture flux in this region.
    - At approximately 1.4 m bgs, there is a maximum sulphate concentration (referred to, for convenience, in this Appendix as the "sulphate maximum"). This represents a zone where sulphate has accumulated as a result of sulphate salts being flushed downward from the shallower soils and possibly also other processes. This zone of sulphate accumulation is a typical feature of prairie soils as indicated by Woods et al. (2013) and other authors.
    - The deeper samples in this profile (approximately 3 to 4.5 m bgs) provide an estimate of the baseline concentration of sulphate in soils that have not been strongly affected by near-surface moisture movement (~1,000 mg/kg in this example).

This profile is a good example of a soil that clearly indicates downward movement of salts from the upper part of the profile.

Analysis of Sulphate Profile Data

For each sulphate profile location, the depth and sulphate concentration data must be tabulated and a concentration-depth graph generated in a similar format to Figures A-1 to A-4.

The profile must then be analyzed for the following three tests:

- **Test A:** A decrease in sulphate concentration from surface to 1.0 m bgs, without any increase in that trend, within 0.3 m of the surface.
- **Test B:** The depth of the sulphate maximum is >1 m bgs.
- **Test C:** The concentration close to surface is less than the "baseline" sulphate concentration from deeper samples below the sulphate maximum.

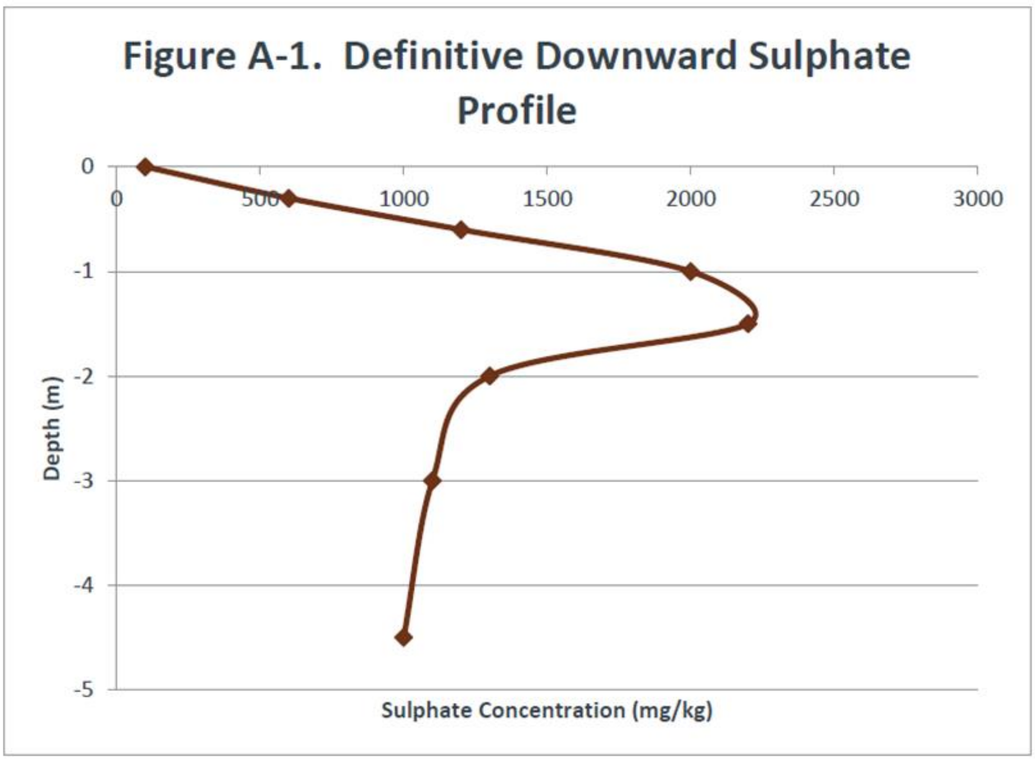
Possible outcomes from the analysis of each sulphate profile identify the direction of long-term salt movement implied by the profile and are as follows:

- Definitive Downward (Figure A-1): Profile passes Tests A, B, and C.
- Probable Downward (Figure A-2): Profile passes Test A.
- Upward (Figure A-3): Profile fails Test A due to an increase in sulphate concentration at or close to surface.
- Ambiguous Result (Figure A-4): any other outcome.

These outcomes are summarized in Table 1-1 below. Refer to the main text for instructions on how to determine the appropriate site scenario based on the outcome of the sulphate profile interpretation.

Test A	Test B	Test C	Outcome – Salt Movement Direction
Pass	Pass	Pass	Definitive Downward
Pass	Any	Any	Probable Downward
Fail	Any	Any	Upwards
Any Other Outcome			Ambiguous

Table 1-1: Profile Interpretation



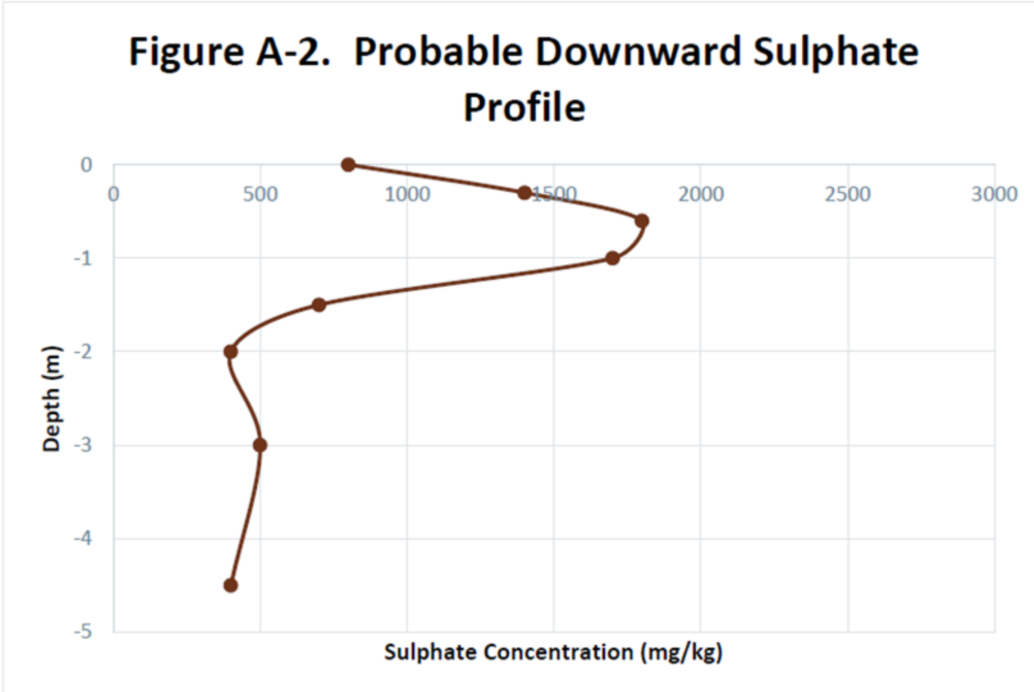


Figure A-2. Probable Downward Sulphate Profile
0
-1
-2
-3
-4
-5
Depth (m)
0
500
1000
1500
2000
2500
3000
Sulphate Concentration (mg/kg)

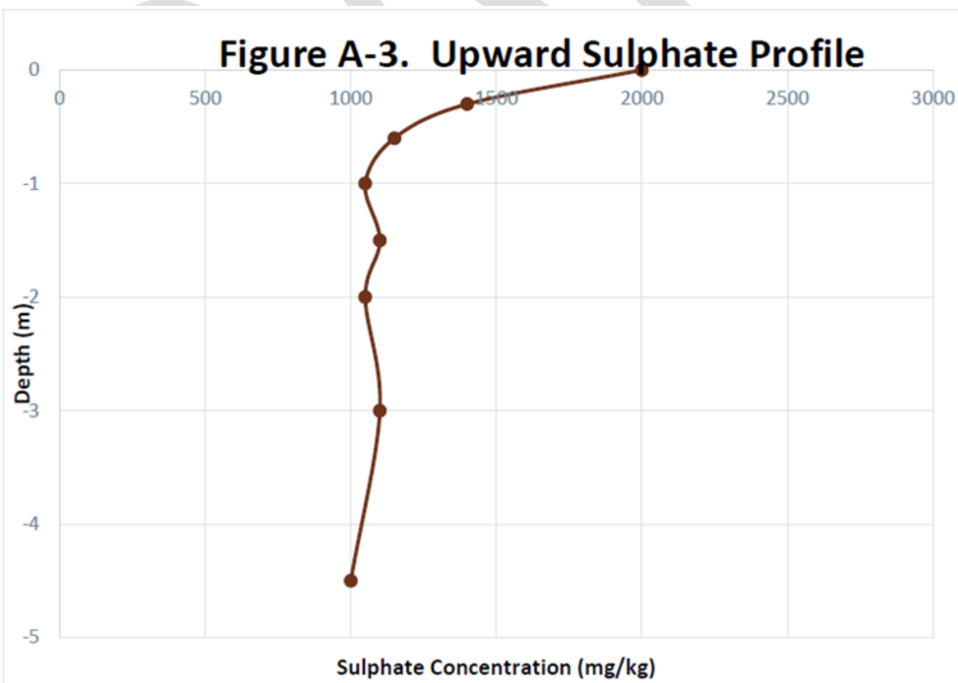


Figure A-3. Upward Sulphate Profile
0
-1
-2
-3
-4
-5
Depth (m)
0
500
1000
1500
2000
2500
3000
Sulphate Concentration (mg/kg)

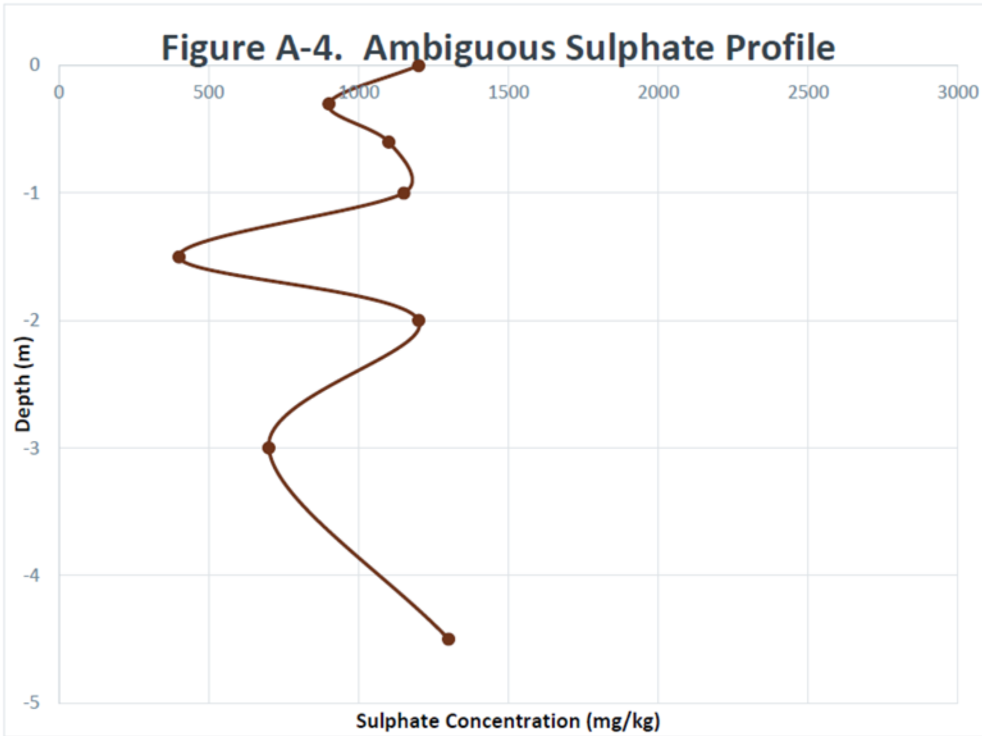


Figure A-4. Ambiguous Sulphate Profile
0
500
1000
1500
2000
2500
3000
0
-1
-2
-3
-4
-5
Depth (m)
Sulphate Concentration (mg/kg)

Appendix 8: Protection of FAL – Examples Utilizing Subsoil Guideline Charts

Example A: No groundwater data in fine-grained soil with a Class V wetland being the closest
An 18 m in length of chloride impacts are found within fine-grained soil based on delineation vertically and laterally of <100 mg/kg chloride. The closest wetland is 130 m to the west and there are no groundwater wells on site and the porosity is unknown. The wetland is classified as a Class V. The licensee has decided on a Tier 2 solution for the FAL receptor remediation goal.

- **Fine-grained soil**, use Chart 3
- Groundwater velocity = **2.5 m/yr** as there is no groundwater or porosity data
- A source length of **25 m** will be used as 18 m defaults to the next highest number
- Distance to nearest wetland will be **125 m** as 130 m defaults to the next lowest number
- **450 mg/kg** chloride can remain on site to protect the FAL

Example B: Groundwater data but no porosity in fine-grained soil with a Class IV wetland being the closest
A 14 m in length of chloride impacts are found within fine-grained soil. A chloride concentration of <100 mg/kg was not achieved vertically but was laterally based on EM data. The closest wetland is 350 m to the west and based on a groundwater monitoring well network, the hydraulic conductivity is $1\ 10^{-7}$ m/s and the hydraulic gradient is 0.03 m/m. There is no porosity data for the site. The wetland is classified as Class IV. The licensee has decided on a Tier 2 solution for the FAL receptor remediation goal.

- Hydraulic conductivity is **$1x10^{-7}$ m/**s
- Hydraulic gradient is **.03 m/m**
- Porosity is **0.47** from the default values supplied
- **Fine-grained soil**, use Chart 3
- A source length of 15 m will be used
- Based on the calculation the groundwater velocity is **0.22 m/yr**
- **0.25 m/yr** will be used in the charts as it is the most conservative value that can be used
- Distance to nearest wetland is **250 m**, as 350 m defaults to the next lowest number
- 10,000 mg/kg chloride can remain on site to protect the FAL

Example C: No groundwater data in fine-grained soil near a Class II wetland.
An 18 m length of chloride impacts are found within fine-grained soil based on delineation vertically and laterally of <100 mg/kg chloride. The closest wetland is 80 m to the west and there are no groundwater wells on site and the porosity is unknown. The wetland is classified as a Class II. The licensee has decided on a Tier 2 solution for the FAL receptor remediation goal.

- **Fine-grained soil**, use Chart 3
- Groundwater velocity = **2.5 m/yr** as there is no groundwater or porosity data
- A source length of **25 m** will be used as 18 m defaults to the next highest number
- Distance to nearest wetland will be **50 m** as 80 m defaults to the next lowest number
- **110 mg/kg** chloride can remain on site to protect the FAL

The Class II wetland does not have wetland permanence based on a review of aerial imagery of the surface water, a hydrological connection the wetland is not expected to contribute to 50 per cent of runoff. Based on the lack of wetland permanence and less than 50 per cent hydrological connection, the wetland can be removed as a receptor. The next closest wetland will be used as a receptor.

Appendix 9: Protection of a PWA – Examples Utilizing Subsoil Guideline Charts

Example A: Find-grained PWA example, known PWA depth
An 18 m length of chloride impacts are found within fine-grained soil based on delineation vertically and laterally of <100 mg/kg chloride. The PWA was found at 17 m bgs based on soil lithology during the Phase II investigation. The site is located in southeast Saskatchewan. The licensee has decided on a Tier 2 solution for the PWA receptor remediation goal.

- A source length of **25 m** will be used as 18 m will be rounded to the next highest number
- Depth to PWA will be **15 m** as you choose the next shallower depth on the chart
- **Fine-grained soil**
- The drainage rate will be **3 mm/yr down** as the site is located in the Northern Fescue/Mixed Grass sub-region
- **8,700 mg/kg** chloride can remain on site to protect the PWA

Example B: Coarse-grained PWA example, PWA not encountered in boreholes
A 14 m length of chloride impacts are found within coarse-grained soil. As chloride concentrations of <100 mg/kg were not achieved vertically but were achieved laterally based on EM data. The PWA was not encountered and deepest borehole is 6 m bgs based on soil lithology during the Phase II investigation. The site is located within southwest Saskatchewan. The licensee has decided on a Tier 2 solution for the FAL receptor remediation goal.

- A source length of **15 m** will be used
- Depth to PWA will be **6 m** as this was the deepest depth of the investigation
- **Coarse-grained soil**
- The drainage rate will be **2 down** as the site is located in the Dry Mixed Grass Sub-Region.
- **6,100 mg/kg** chloride can remain on site to protect the PWA

Appendix 10: Protection of Dugout/Irrigation – Examples Utilizing Subsoil Guideline Charts

Example A: No groundwater data in fine-grained soil
Chloride impacts are found within fine-grained soil based on delineation vertically and laterally of <100 mg/kg chloride. There are no groundwater wells on site and the porosity is unknown. The Phase II has indicated that the water table is 2.4 m bgs, based on soil lithology. The licensee has decided on a Tier 2 solution for the dugout/irrigation receptor remediation goal.

- Groundwater velocity = **2.5 m/yr** as there is no groundwater or porosity data
- The water table is **2 m,** rounding the 2.4 m measured water table to 2 m
- **Fine-grained soil**
- **5,900mg/kg** chloride can remain on site to protect the dugout
- **1,400 mg/kg** chloride can remain on site to protect irrigation

Example B: Groundwater data, but no porosity in fine-grained soil
Chloride impacts are found within fine-grained soil. As chloride concentrations of <100 mg/kg were not achieved vertically but achieved laterally based on EM data. Based on a groundwater monitoring well network, the hydraulic conductivity is $1\ 10^{-7}$ m/s, the hydraulic gradient is 0.03 m/m, and the depth of groundwater is 4.8 m. There is no porosity data for the site. The licensee has decided on a Tier 2 solution for the dugout/irrigation receptor remediation goal.

- Hydraulic conductivity is **1×10^{-7} m/s**
- Hydraulic gradient is **0.03 m/m**
- Porosity is **0.47** from the default values supplied
- **Fine-grained soil**
- Based on the calculation the groundwater velocity is 0**.22 m/yr**
- **0.25 m/yr** will be used in the charts
- The water table is **4 m**, rounding the 4.8 m measured water table to 4 m
- **10,000 mg/kg** chloride can remain on site to protect the dugout
- **10,000 mg/kg** can remain on site to protect irrigation