TCEQ Regulatory Guidance

Remediation Division

RG-366/TRRP-24 December 2007

SUBJECT: **DETERMINING PCLS FOR SURFACE WATER AND SEDIMENT**

Objectives:

- To provide direction for determining the surface water and sediment Protective Concentration Levels (PCLs) for human and ecological receptors.
- To provide direction for determining the surface water Risk-Based Exposure Limit (RBEL).
- To provide direction for determining the source media PCLs for groundwater and soil.

Audience: TCEQ Project Managers, Regulated Community and Environmental Professionals

References:

- The regulatory citation for the Texas Risk Reduction Program (TRRP) rule is 30 TAC § 350. The TRRP Rule and Preamble are found on-line at http://www.tceq.state.tx.us/rules/indxpdf.html#350.

- The TRRP rule, together with conforming changes to related rules, is contained in 30 Texas Administrative Code Chapter 350, and was initially published in the September 17, 1999 Texas Register (24 TexReg 7413-7944). The rule was amended in 2007 (effective March 19, 2007; 32 TexReg 1526-1579).

- The surface water discussion within the TRRP rule relies heavily on the Texas Surface Water Quality Standards (TSWQS), as amended. The TSWQS are contained in 30 Texas Administrative Code Chapter 307, and were most recently published in the August 11, 2000 Texas Register (25 TexReg 7722-7774). The TSWQS are available on-line at http://www.tceq.state.tx.us/assets/public/legal/rules/rules/pdflib/307%60.pdf. The preamble is available on-line at http://www.tceq.state.tx.us/assets/public/permitting/waterquality/attachments/standards/preamble.pdf.

- Implementation Procedures: TCEQ, 2003. Procedures to Implement the Texas Surface Water Quality Standards. Water Quality Division. (January 2003 or most recent approved version). This document is available on-line at http://www.tceq.state.tx.us/files/rg-194.pdf_4005964.pdf.

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- Ecological Risk Assessment Guidance: TNRCC, 2001. Guidance for Conducting Ecological Risk Assessments at Remediation Sites in Texas. RG-263 (revised). Toxicology and Risk Assessment Section. December 2001. This document is available on-line at http://www.tceq.state.tx.us/files/rg-263.pdf_4006056.pdf.

- 2006 Guidance Update: TCEQ, 2006. Update to Guidance for Conducting Ecological Risk Assessments at Remediation Sites In Texas RG-263 (Revised). Remediation Division. January. This document is available on-line at http://www.tceq.state.tx.us/assets/public/remediation/eco/0106eragupdate.pdf.

- 303(d) List: TCEQ, 2005. 2004 Texas 303(d) List (May 13, 2005). This document was approved by U.S. EPA Region 6 on May 8, 2006 and is available on-line at http://www.tceq.state.tx.us/compliance/monitoring/water/quality/data/04twqi/04_303d.html.

- SWQM Procedures Manual: TCEQ, 2003. Surface Water Quality Monitoring Procedures, Volume 1: Physical and Chemical Monitoring Methods for Water, Sediment, and Tissue. Monitoring Operations Division. RG-415. (December 2003 or most recent version). This document is available on-line at http://www.tceq.state.tx.us/comm_exec/forms_pubs/pubs/rg/rg-415/rg-415.html.

Contacts: TCEQ Remediation Division Technical Support Section 512/239-2200

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7Q2 – seven-day, two-year low-flow
APAR – affected property assessment report
AQUIRE – Aquatic Toxicity Information Retrieval System
AVS – acid volatile sulfide
BAF – bioaccumulation factor
BCF – bioconcentration factor
BOD_5 – five-day biochemical oxygen demand
BSAF – biota sediment accumulation factor
BTEX – total of benzene, toluene, ethyl benzene, and xylene
$CaCO_3$ – calcium carbonate
CASRN – Chemical Abstracts Service Registry Number
CFR – Code of Federal Regulations
cfs – cubic feet per second
COC – chemical of concern
CSF – cancer slope factor
DF – dilution factor
DQO – data quality objectives
ERA – ecological risk assessment
F – flow through (exposure)
FW – freshwater
FR – Federal Register
HMF – harmonic mean flow
IBWC– International Boundary Water Commission
LC_{50} – lethal concentration (50%)
ln – natural log
MCL – maximum contaminant level
ug/L – microgram per liter
umhos/cm – micromhos per centimeter
mf/L – million fibers per liter
mg/kg – milligram per kilogram
mg/L – milligram per liter
MOR – mortality (effect)
MQL – method quantitation level
NAPL – non-aqueous phase liquids
NPDES – National Pollutant Discharge Elimination System
PAHs – polycylic aromatic hydrocarbons
PCL – protective concentration level
PCLE – protective concentration level exceedance
PMZ – plume management zone
POE – point of exposure
PS – public water supply
RBEL – risk-based exposure limit
RfD – reference dose
S – static (exposure)
Sed_{Eco} – sediment PCL protective of ecological receptors
^{Sed}GW – PCL for groundwater discharge to sediment
$^{Sed}Soil$ – PCL for soil runoff to sediment
SEM – simultaneously extracted metal

SW – saltwater
^{SW}GW – PCL for groundwater discharge to surface water
SWMU – solid waste management unit
SW_{Eco} – surface water PCL protective of ecological receptors
^{SW}RBEL – surface water RBEL
^{SW}Soil – PCL for soil runoff to surface water
^{SW}SW – surface water PCL
TAC – Texas Administrative Code
TARA – TCEQ Toxicology and Risk Assessment Section
TCDD – tetrachlorodibenzo-p-dioxin
TCEQ – Texas Commission on Environmental Quality
TDH – Texas Department of Health
TDS – total dissolved solids
TEF – toxicity equivalency factor
TEQ – toxicity equivalence
TMDL – total maximum daily load
TNRCC - Texas Natural Resource Conservation Commission
TPDES – Texas Pollutant Discharge Elimination System
TRRP – Texas Risk Reduction Program
TSS – total suspended solid(s)
TSWQS – Texas Surface Water Quality Standards
TTHM – total trihalomethanes
U.S. ACOE – United States Army Corps of Engineers
USDA – United States Department of Agriculture
U.S. EPA – United States Environmental Protection Agency
USGS – United States Geological Survey
USLE – Universal Soil Loss Equation
UST – underground storage tank

1.0 INTRODUCTION

This guidance describes a process for developing protective concentration levels (PCLs) for human and ecological receptors that may be exposed to surface water and sediment affected by chemicals of concern (COCs). The guidance also provides information for developing source media PCLs for soil and groundwater that may release COCs to surface water and sediment. The Texas Risk Reduction Program (TRRP) requires persons to develop PCLs for each COC for complete and reasonably anticipated to be completed ecological and human health exposure pathways (§350.71). Figure 1-1 illustrates the overall process for determining the surface water and sediment PCLs, and identifies where each topic is discussed in the guidance or other TCEQ guidance documents. Additionally, miniature versions of Figure 1-1 are displayed throughout the document so the reader can identify where they are in the overall process. The subject topic will be indicated by a heavy weight outline in each miniature figure.

1.1 Organization of Guidance

The overall organization of the guidance is reflected in Figure 1-1. The following list details the concepts discussed in each section of the guidance:

Section 1.0	General overview of concepts as well as surface water and sediment protective concentration levels (PCLs) and points of exposure (POEs).
Section 2.0	Surface water and sediment sampling methods and background considerations.
Section 3.0	Discusses the surface water risk-based exposure level (RBEL). More specifically: • Section 3.1 - Basic surface water concepts, application of criteria for various surface water uses, and the concept of the surface water RBEL (^{SW}RBEL) and its relationship to the surface water PCL. • Section 3.2 - ^{SW}RBEL for aquatic life protection. • Section 3.3 - ^{SW}RBEL for human health protection. • Section 3.4 - ^{SW}RBEL for releases of petroleum fuel-impacted waters. • Section 3.5 - ^{SW}RBEL for conventional parameters other than COCs such as metals and organics that are normally evaluated at affected properties. Includes consideration of aesthetics, nutrients, salinity, chloride, sulfate, pH, total dissolved solids (TDS), and dissolved oxygen. • Section 3.6 - General provisions for the preclusion of toxicity as it relates to the ^{SW}RBEL.
Section 4.0	Surface water and sediment PCLs protective of ecological receptors as determined in an ecological risk assessment (ERA).
Section 5.0	Surface water and sediment PCLs for human health pathways not addressed by the ^{SW}RBEL. Includes pathways such as incidental ingestion and dermal contact with surface water or sediment while swimming or wading, and indirect ingestion of sediment COCs via food chain transfer from sediment to fish or shellfish.
Section 6.0	Determination of the critical sediment and surface water PCLs.

Section 7.0	Source media PCLs for groundwater and soil. More specifically: • Section 7.1 - Groundwater-to-surface water pathway and the default and property-specific dilution factor (DF) allowances for this pathway. Also discusses sampling and modeling approaches for determining a property-specific DF. • Section 7.2 – Groundwater-to-sediment pathway and approaches for development of a groundwater PCL protective of sediment (^{Sed}GW). • Section 7.3 - Scenario where groundwater COCs in excess of the ^{SW}RBEL or SW_{Eco} discharge across a significant area within a surface water body. Addresses the determination of "significant" and resulting actions where this is the case. • Section 7.4 - Soil PCLs for soil releases to surface water and sediment.
Section 8.0	Critical source media (soil and groundwater) PCLs for sediment and surface water.
Section 9.0	References.

1.2 General Concepts

Which Water Bodies Should be Considered?

Surface water and sediment PCLs should only be determined for water bodies that meet the definition of surface water in the state as defined in §307.3 of the Texas Surface Water Quality Standards (TSWQS). Surface water in the state generally includes any natural or man-made water body and the beds and banks of all watercourses and bodies of surface water. Consider the following:

- Waters in treatment systems (authorized by state or federal law, regulation, or permit) that are created for the purpose of waste treatment are not considered to be water in the state.
- Consult the agency's Ecological Risk Assessment Guidance (and updates) for direction regarding conveyances, decorative ponds, and portions of un-permitted process facilities. These may be surface waters in the state by definition, but they may be excluded from consideration for the development of a PCL protective of ecological receptors as long as they are <u>not</u> ultimately in contact with other surface waters in the state <u>and</u> are not used as valuable habitat for wildlife.
- A surface water and sediment PCL may be appropriate for a man-made drainage ditch with intermittent flow that <u>is</u> in communication with other waters in the state.
- Acute aquatic life criteria apply to all waters in the state, including man-made drainage ditches and intermittent streams.

It would <u>not</u> be appropriate to develop a surface water or sediment PCL for an active on-site waste impoundment that has affected sediments. However, if the impoundment has had a release to the underlying groundwater that is in communication with adjacent surface water, it would be appropriate to develop a groundwater PCL protective of the surface water and sediment. Some pathways may be excluded for certain exposure scenarios. See Sections 4.2.1, 4.2.2, 5.1, and 5.2.

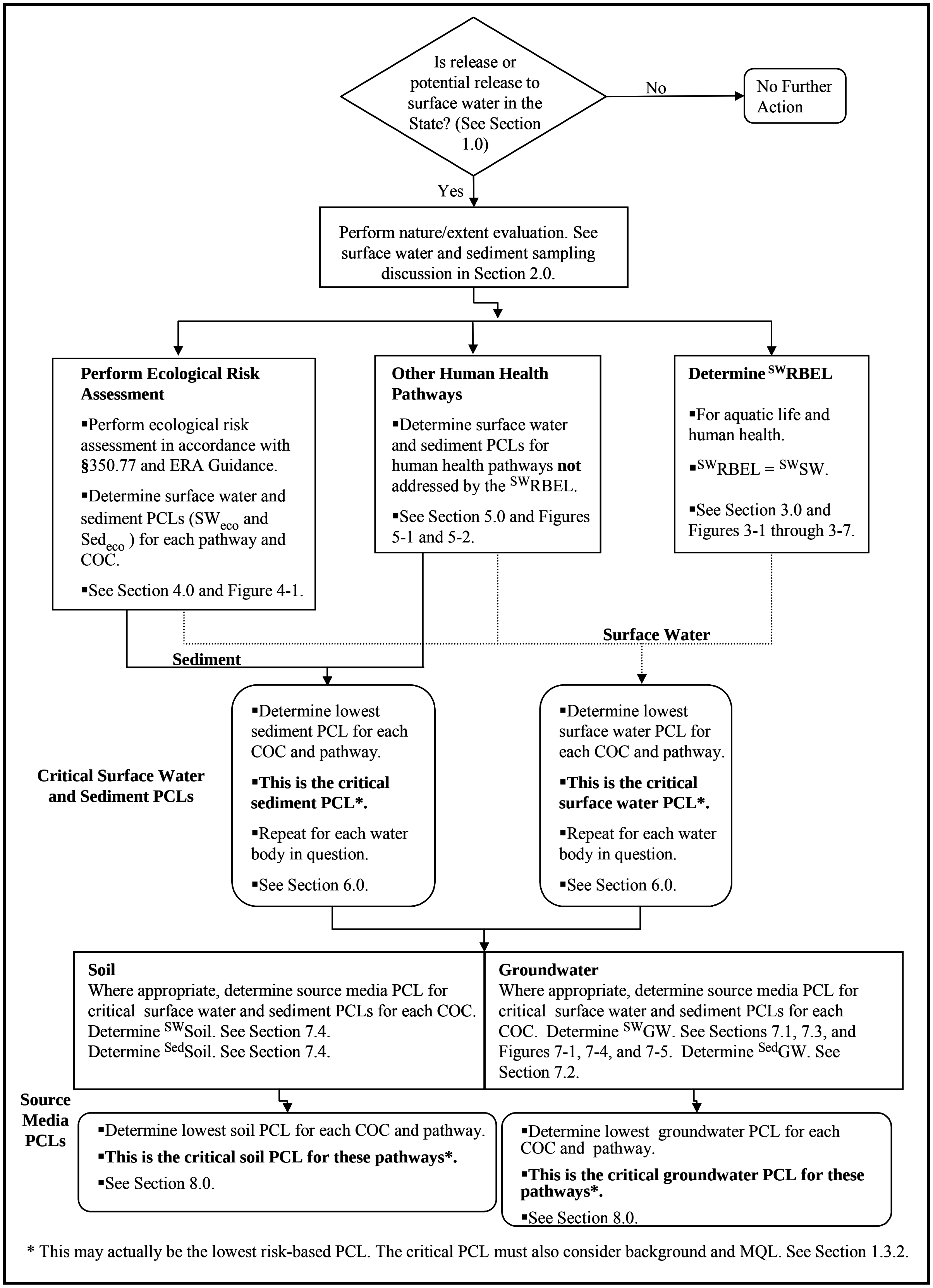

Figure 1-1. Overview of the Process for Deriving Surface Water and Sediment PCLs

Overall Considerations

The discussions in this guidance will largely categorize different types of releases to surface water and sediments. For example, Section 7.1 discusses groundwater releases to surface water, and Section 7.4 discusses soil releases to surface water. Similarly, the evaluations will be somewhat separated since PCLs are determined for each pathway and each source media where appropriate. Although the rule and the guidance are somewhat categorized by pathway, it is important to remember that surface water systems are dynamic. Persons should evaluate the impact of releases to surface water in conjunction with the releases to sediment. Additionally, multiple impacts to a surface water body should be evaluated where appropriate. For instance, a surface water could receive releases from contaminated storm water runoff, groundwater discharges, and seeps throughout an affected property. Further, multiple units or Solid Waste Management Units (SWMUs) within an affected property could have combined impacts, such as multiple protective concentration level exceedance (PCLE) zones, to a surface water body and its sediments. In all cases, the PCLs that are developed for surface water and sediment should be protective of aquatic life, wildlife receptors, livestock (where appropriate), and human health.

Exposure Pathways

Figure 1-2 illustrates the various exposure pathways and corresponding PCLs and RBELs that may be appropriate for an affected property. Since multiple receptors (both human and ecological) may come in contact with affected sediment and surface water, the lowest of the applicable human health and ecological PCLs determined for each COC in surface water and sediment (and source media such as groundwater and soil), becomes the critical PCL (see Section 1.3.2) as it applies to the surface water or sediment exposure pathways.

Human exposure to surface water is principally evaluated by comparison with the TSWQS or federal water quality criteria. Where there are no human health standards for a particular COC, the guidance provides default values (see TRRP web site) along with a process for deriving appropriate values protective of humans that may consume potentially affected fish, shellfish, or drinking water. Human exposure to sediments or other surface water pathways (not addressed by the TSWQS) should be evaluated when there is a complete pathway (see discussion in Section 5.0), and the associated surface water and sediment PCLs should be used/developed.

Potential impacts to aquatic life (water column) that may be exposed to affected surface water are principally evaluated by comparison with the TSWQS or federal criteria. Where there are no standards for a particular COC, the guidance provides a select number of default values (see TRRP web site) along with a process for deriving appropriate values protective of aquatic life. In both cases, a surface water risk-based exposure level (^{SW}RBEL) is determined for each COC depending on the nature of the receiving water (e.g., intermittent, perennial, freshwater, saltwater). Additionally, potential impacts to aquatic life that may be exposed to sediment affected by COCs are primarily evaluated, where appropriate, as part of an ERA in accordance with the requirements of §350.77. Here a sediment PCL (denoted as Sed_{Eco}) is developed where appropriate for each COC and pathway.

Potential impacts to other more mobile or wide-ranging ecological receptors and threatened or endangered species that may be exposed directly to affected surface water or sediment or indirectly from food consumption are also evaluated as part of an ERA in accordance with the requirements of §350.77, and surface water and sediment PCLs (denoted as SW_{Eco} and Sed_{Eco}) are developed for each COC and pathway where appropriate. In some cases, PCLs for ecological receptors should be developed that consider exposure to <u>both</u> surface water and sediment. The Ecological Risk Assessment Guidance (and updates) should be consulted for further details on determining PCLs for multiple media.

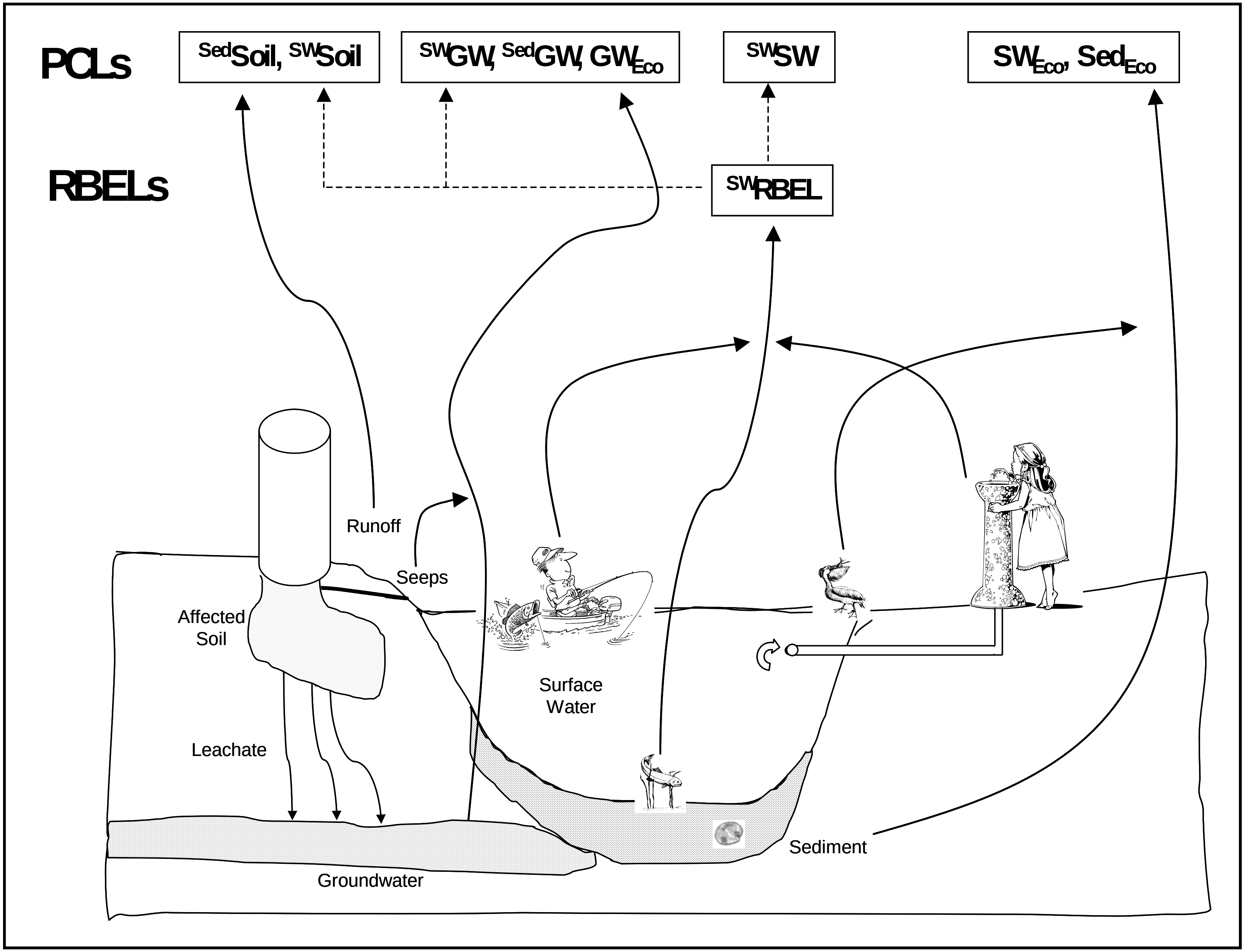

Figure 1-2. Surface Water and Sediment PCLs and RBELs

Groundwater as a Source Medium

Groundwater releases to surface water are evaluated using the dilution factor (DF) approach after the surface water PCL has been determined. Where a DF is allowed, the DF is applied to the surface water PCL to derive a groundwater PCL protective of surface water (^{SW}GW). The surface water PCL (^{SW}SW) is the lesser of the $^{SW}RBEL$ established in accordance with 350.74 (h), and the $^{SW}SW_{Eco}$ that is protective of ecological receptors. The surface water exposure concentrations that are entered into the ecological risk calculations should be adjusted to account for the default or property-specific dilution. More details are provided in Section 7.1.

Where groundwater is released to surface water, there is usually a release to sediment as well. Sediment exposure pathways will need to be evaluated to determine appropriate PCLs protective of human and ecological receptors. Once a sediment PCL is developed (where appropriate), this value should be compared with affected property sediment concentrations or modeled concentrations to determine if response actions are necessary. If it is determined that response actions are necessary, a groundwater PCL should be developed that is protective of sediment. Section 7.2 and Figure 7-5 provide a Tier 2 model for determining the groundwater PCL protective of sediment (^{Sed}GW).

Soil as a Source Medium

COCs in surface soil can be transported to a downstream water body in surface water runoff to the water body. A soil PCL ($^{Sed}Soil$ and $^{SW}Soil$) should be developed where this pathway is reasonably complete and significant. Section 7.4 describes a general approach to characterizing surface soil COC releases to surface water and sediment, and development of PCLs for this pathway. Using the Universal Soil Loss Equation and partitioning theory, the text provides a Tier 2 approach for developing PCLs for releases to streams and rivers. The text also provides recommendations for developing Tier 3 PCLs for this pathway.

1.3 Surface Water and Sediment Points of Exposure and Protective Concentration Levels

1.3.1 Points of Exposure and Exposure Routes

COCs may migrate to surface water or sediment by groundwater transport, surface runoff, or as a result of an unauthorized release or spill. Within the surface water and sediment, exposure to humans is possible while swimming or wading, and as a result of ingestion of potentially affected drinking water, fish, and shellfish. Within the surface water and sediment, COC exposure to aquatic and benthic organisms, birds, amphibians, reptiles, mammals, and livestock is possible due to direct ingestion of water or sediment, direct exposure to the body surface, and/or indirect exposure as a result of food ingestion. Examples of potential ecological exposure pathways in aquatic habitats include:

(a) Direct or indirect exposure of aquatic (including benthic) and terrestrial organisms to **sediment** impacted by:

- affected groundwater discharging to surface water and sediment
- erosion of affected surface soil
- runoff of affected surface water
- surface seepage or unauthorized release of COCs

(b) Direct or indirect exposure of aquatic or terrestrial organisms to **surface water** impacted by:

- affected groundwater discharging to surface water
- erosion of affected surface soil
- runoff of affected surface water
- surface seepage or unauthorized release of COCs
- re-suspension or dissolution of affected sediments

The points of exposure (POEs) for surface water and sediment will vary depending on the receptor in question. Table 1-1 summarizes the appropriate POEs with various media and receptors.

Table 1-1. Points of Exposure for Surface Water and Sediment

Release/Receptor	POE	Rule Citation
Releases to surface water.	Point of entry of COCs into and throughout the extent of any surface water body meeting the definition of surface water in the state.	§350.37 (j)
Surface water runoff.	At the point of surface water runoff into and throughout the extent of any surface water body meeting the definition of surface water in the state; includes the surface water body at the initial point of entry and other water bodies that may be impacted.	§350.37 (i)
Groundwater discharges to surface water.	Within the groundwater-bearing unit at the point of discharge into and throughout the extent of any surface water body meeting the definition of surface water in the state; includes the surface water body at the initial point of entry and other water bodies that may be impacted. The monitoring point, however, will normally be a groundwater monitoring well placed immediately upgradient of the zone of groundwater discharge to surface water. See §350.51 (f).	§350.37 (i)
Sediment/humans.	Within the upper one-foot of sediment. For intermittent water bodies, both sediment and surface soil POEs may apply (see discussion in Section 5.2.3). For the contact recreation pathway (where appropriate), this applies to the portion of the water body that is less than 2 meters deep.	§350.37 (k)
Surface water/ecological receptor.	Property-specific. See Ecological Risk Assessment Guidance and updates.	§350.77
Sediment/ecological receptor.	Property-specific. See Section 2.2.4.1, the sediment discussion in Section 4.2, and the Ecological Risk Assessment Guidance and updates.	§350.77

More information regarding POEs is provided in the TRRP guidance titled *Human Health Points of Exposure* (RG-366/TRRP-21).

1.3.2 Protective Concentration Levels

Subchapter D of the TRRP rule specifies the methodology for determining PCLs for COCs at affected properties for both humans and ecological receptors. In effect, the PCLs are the cleanup levels for the affected property. The PCL is the concentration of a COC which can remain within the source medium and not result in levels that exceed the applicable human health RBEL or ecological PCL at the POE for that exposure pathway. The rule requires (§350.71 (b)(1)) that persons ensure that PCLs are protective of human health and the environment. The rule further requires (§350.71 (c)(7)) that persons develop PCLs protective of human health where contact with surface water or sediment containing COCs originating from the source area is a complete or reasonably anticipated to be completed exposure pathway.

The surface water exposure pathway PCL (^{SW}SW) is provided in Figure 30 TAC §350.75 (b)(1):

$$^{SW}SW = \textit{the lesser of } {}^{SW}RBEL \textit{ and } {}^{SW}SW_{ECO}$$

The source medium and the exposure medium is the surface water, and the receptors are aquatic life and humans ($^{SW}RBEL$) and ecological receptors ($^{SW}SW_{Eco}$) that are directly or indirectly exposed to surface water COCs.

For a given medium, a number of PCLs may be determined for a particular COC for a variety of receptors and exposure pathways. In these cases, persons must develop a critical PCL (§350.78 (a)(19)), which is the lowest PCL for a particular environmental medium considering all the exposure pathways for which a PCL is developed in accordance with §350.75 (i) (relating to Tiered Human Health PCL Evaluation) and/or §350.77 (relating to ERA and Development of Ecological PCLs)[1, 2].

2.0 SAMPLING SEDIMENT AND SURFACE WATER

Sediment and surface water may be sampled for a number of reasons. These include:

- to determine the nature and extent of COCs and to identify the areas of highest impact
- to support an ERA or to evaluate potential human health risks
- to confirm or support modeling and dilution factor assumptions
- to target depositional areas
- to assess the potential for resuspension of affected sediments during floods or other current-based scouring events, dredging operations, or other disturbances
- to support remediation decisions
- to evaluate the effectiveness of remediation efforts

However, under any circumstance, efforts to characterize affected property contributions to surface water or sediment contamination can be complex. There may be many sources of COC loading to surface water

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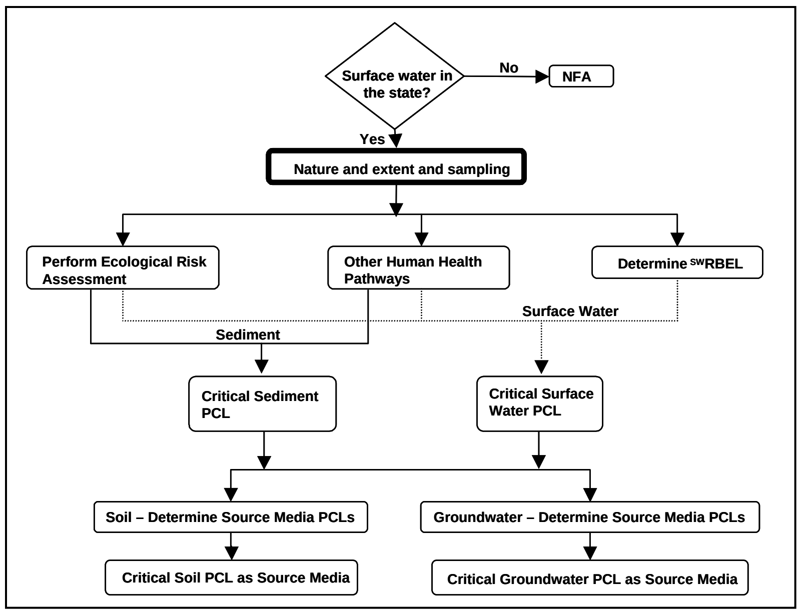
[1] For example, consider copper in surface water. Based on the criteria in the TSWQS, persons may develop a PCL that is protective of aquatic life, and a PCL that is protective of humans that may consume fish from the water body in question. As part of the ERA, PCLs may have also been developed for a heron and a raccoon that may be exposed to copper in the surface water directly by ingestion or indirectly through food consumption. The lowest PCL for these four scenarios will be the critical PCL for copper in surface water unless the method quantitation limit (MQL) or background concentration for that COC is higher (§350.78 (c)).

[2] Where the term critical PCL is used throughout this document, the context may actually mean the lowest risk-based PCL to refer to the lowest pathway-specific PCL when background and MQL have not been considered (as indicated in footnote 1). Persons should be mindful that the critical PCL is always the higher of the risk-based value for a particular medium, background, or the MQL. The TRRP guidance titled *Determination of the Critical PCL* (RG-366/TRRP-25) should offer more information on this subject.

bodies and their sediment systems, both historical and current. Furthermore, it is often difficult to distinguish impacts from local properties undergoing remedial investigations from impacts to surface water and sediments from other sources, past and present. Evaluating the ecological significance of any local affected property contributions to surface water and sediment contamination is equally complex, as there can be many stressors affecting ecological receptor populations, including man-made and natural media quality, temperature, salinity, and sediment type. Therefore, considerable thought and planning should occur before efforts to sample surface water and sediment are initiated.

It is suggested that potential impacts of discharges on surface water bodies (and their sediments) follow a tiered weight-of-evidence approach that includes methods to:

- evaluate existing and readily available data
- determine whether sampling is appropriate and to guide sampling approaches
- evaluate any sampling data



A weight-of-evidence approach acknowledges that although no single factor is likely to be a determinant, a preponderance of evidence can establish the significance (or lack thereof) of impacts on surface water and sediment quality. Such an approach is useful in this context for evaluating existing data. The quantity and quality of available data will aid in determining the weight that this "evidence" provides when making a determination about sampling needs, and will help focus and guide sampling and data evaluation efforts where needed. Persons are encouraged to identify data needs, develop data quality objectives and establish data evaluation procedures prior to any sampling. See §350.54 and the TRRP guidance documents titled *Assessment Planning* (RG-366/TRRP-6) and *Review and Reporting of COC Concentration Data* (RG-366/TRRP-13).

Sections 4.2, 5.2, and 6.2 address conditions under which sediment sampling may or may not be required (i.e., exclusions) for some pathways. This section focuses on the technical considerations for sampling surface water and sediments including the impact of natural and anthropogenic background (Section 2.1) and sampling and analysis (Section 2.2) including the appropriate sampling depth.

mg/L vs. ug/L

As indicated in Section 1.0, much of the information regarding the surface water pathways keys off the TSWQS and the Implementation Procedures. Persons should be aware that those programs generally use the units of micrograms per liter (ug/L) when referring to COCs in surface water whereas TRRP uses milligrams per liter (mg/L).

2.1 Background Determination for Surface Water and Sediment

The TCEQ is aware that many of the State's water bodies, especially in urban/industrial settings, have ambient levels of diffuse, anthropogenic pollution of surface water and sediments (in particular) at concentrations greater than natural background. This is the result of historic point and non-point releases to these water bodies over many years. Where ambient levels are elevated compared to other areas that may not have received the discharges, it may be very difficult to distinguish between site- and non-site-related COCs and, further, to make meaningful remedial action decisions. "Background" determinations should be made to assess whether property-specific COCs can be distinguished from area-wide presence of COCs. This section provides some pragmatic (i.e., "do what makes sense") guidance on how to make background determinations that are consistent with TRRP to address elevated ambient levels. It is important to remember that response actions are not necessary unless affected property concentrations exceed the PCLs. In particular, decisions regarding risk management for sediment involve more complex scientific and policy concerns than the traditional soil-based exposure scenario. Section 6.2 provides some risk management considerations for addressing this issue.

The background definition in TRRP (§350.4 (a)(6)) specifically defines natural background and anthropogenic background, both of which are considered to be part of background under TRRP. Natural background (i.e., the concentration is not due to a release of COCs from human activities) differs from anthropogenic background (i.e., the presence of a COC in the environment which is due to human activities but is not the result of site-specific use or release of waste or products, or industrial activity). Persons should consult the TRRP guidance titled *Determining Representative Concentrations* (RG-366/TRRP-15) for policy distinguishing between anthropogenic and natural background.

> The TRRP rule discusses statistical methods and minimum sample numbers for determining background at §350.51 (l), and statistical comparisons of COC concentrations to background at §350.79 (1) and (2). Like groundwater and soil, the critical PCL for surface water and sediment defaults to the greater of the method quantitation limit (MQL) or background concentration, if the appropriate lowest PCL is less than either of these values for a particular COC (§350.78 (c)). Persons should consult the TRRP guidance titled *Determining Representative Concentrations* (RG-366/TRRP-15) for guidance related to the statistical procedures for determining property-specific background concentrations and for the comparison of investigative and remediation data to background.

A major difficulty in determining background concentrations relates to the variability of water and sediment quality over time and space. Sampling programs to establish background conditions should be designed to characterize this variability or should be designed to represent critical conditions. In some instances, extensive sampling efforts may be necessary to accurately define surface water and sediment background concentrations. Persons involved in designing and implementing the sampling program should take into consideration the potential spatial boundaries of the investigation area – small areas may not require a substantive sampling program whereas other areas may. In other words, there is likely to be a high degree of site specificity in each sampling program that may require the person to consult frequently with TCEQ staff during the design process. In addition, it may be difficult to identify suitable reference sites in areas that have been affected by property-specific anthropogenic activities for extended periods. In such cases, it may be necessary to identify nearby reference areas with similar features to define background levels of naturally occurring substances. In some cases there will be a single reference area that will provide the necessary conditions, in other situations more than one reference area may be needed.

Are other point sources or non-point sources of COCs considered to be part of the anthropogenic background?

Under TRRP, anthropogenic background includes only COCs present at generally low levels over large areas. As a result, most point sources of COCs, such as TPDES permitted discharges, and some non-point sources including releases from other affected properties regulated under TRRP, would not be considered anthropogenic background. However, any impacts associated with these other sources (which may originate from the on-site property or an adjacent properties) are not considered to be part of the affected property. The TCEQ recognizes that, at some affected properties, remediation to the critical PCL may not be possible due to COC concentrations associated with these alternate sources. At these affected properties, the appropriate response action and delineation requirements should be determined on a case-by-case basis in coordination with the TCEQ.

Before this background question is addressed, persons should also be mindful that they might not be required to establish a PCL where it is sufficiently demonstrated that the release of COCs did not result from an activity at the on-site property (§350.71 (k)(2)(E)).

Background sediment or surface water samples should be collected from an appropriate reference location that is an unimpacted area otherwise comparable to the affected property. Ideally, background samples should be collected from locations outside the affected property's potential influence. Where possible, background samples should not be collected from locations directly influenced by or in close proximity to other obvious sources of COCs (e.g., other waste affected properties with known releases, sewer/storm water outfalls, point source discharges). Samples should also be collected from the same depth as those surface water and sediment samples collected at the affected property, depending on the pathway in question. For sediment sampling, recent weather-related scouring events and channel dredging should be considered.

Persons should consider the questions that follow when locating background samples in surface water bodies. Since these characteristics collectively represent ideal scenarios, absolute conformance is not expected in the real world application.

- Is the background sample location susceptible to non-point source runoff that differs from runoff affecting the surface water at the affected property?

- Have there been any recent spills or documented releases in the area that might influence the current conditions?

- Does the background sample location for surface water demonstrate, within reason, the same general morphology, hydrology, and water chemistry (alkalinity, hardness, pH, temperature, biochemical oxygen demand, dissolved oxygen, total dissolved solids, salinity, total organic carbon, nitrogen, and phosphorus may be considered) as the water body being assessed?

- Does the background sample location for sediment demonstrate, within reason, similar current velocity, depositional features, and physical properties (such as grain size (texture) mineralogy, organic carbon content, gradation, redox status, moisture content, bulk density, humic content, pH, sulfide, redox characteristics, and cation exchange capacity) as the water body being assessed?

- Are the water bodies similar in terms of size, depth, tidal influence, and trophic status?

Where streams and rivers are potentially affected, background samples should be collected during moderate or low stream flow conditions. For lakes and ponds, sample locations within the same water body may be appropriate although this requires careful consideration since impacts may be distributed throughout the water body over time. As an alternative, background samples may be collected from a nearby lake or pond in the same river basin where physical, chemical and biological conditions are known to be similar. For background determinations at marine or tidally influenced water bodies, surface water samples must be collected during low freshwater inflow conditions. Such flow conditions should prevail for at least one week prior to data collection. In tidal waters, upstream/upgradient sediments may be impacted by the affected property because of tidal influences.

Since the TSWQS for metals in surface water are particularly low, samples for background metals in surface water should be collected and preserved using clean techniques (as discussed in the Implementation Procedures) or equivalent. For freshwater locations, TSS and hardness analyses should accompany the metals analysis. For silver, chloride measurements should be made for each sample location (see Implementation Procedures).

A more detailed discussion of reference area selection, including surface water and sediment sample locations, is provided in U.S. EPA, 1994b and U.S. EPA, 1997a.

2.2 Sampling and Analysis

TRRP provides minimal direction regarding the sampling methodology for sediments and surface waters. When determining concentrations of COCs in surface water and sediment, the rule states (§350.51 (k)) that the person shall collect and handle samples in accordance with the requirements in the agency's *Surface Water Quality Monitoring (SWQM) Procedures, Volume I*, as amended, or shall use an alternative methodology approved by the executive director. The SWQM Procedures Manual is intended to provide guidance to TCEQ staff and contractors that are routinely collecting ambient data for general screening purposes. As such, alternate property-specific methodologies may be appropriate depending on the specific data quality objectives, and will be evaluated on a case-by-case basis. A recent guidance document developed by the U.S. Army Corps of Engineers may be useful (U.S. ACOE, 2001). Additionally, the U.S. EPA has recently released a technical manual (U.S. EPA, 2001) that should be very useful for persons developing a sampling strategy for sediment. This manual addresses the collection, storage, and manipulation of sediments and includes information specific to sediment pore water (interstitial water) sample collection.

2.2.1 General Analytical Issues

As an initial rule of thumb, persons should endeavor to select an MQL for a particular surface water or sediment COC that is below the values specified for ecological screening benchmarks as provided in the Ecological Risk Assessment Guidance (and updates) and/or the surface water values provided in the Aquatic Life ^{SW}RBEL and Human Health ^{SW}RBEL tables that are available on the TRRP web site (http://www.tceq.state.tx.us/remediation/trrp/trrp.html)[3]. For COCs without benchmarks or values in these tables, persons may choose to develop preliminary PCLs to target an appropriate MQL, or persons may opt to use Tier 1 human health residential PCLs for groundwater and soil (total soil combined ($^{Tot}Soil_{Comb}$); lower of values for 0.5 or 30-acre source area) as initial targets for surface water and sediment. In either case, persons run the risk that additional sampling and analyses may be necessary if the MQLs are higher than the PCLs determined for human and ecological exposure to surface water and sediment. For any COCs where the final PCL has not been established, the person may elect to analyze samples using the standard available method with the lowest MQL in order to ensure that reanalysis of the samples using a more sensitive method is not required at a later date (see box).

[3] For brevity and convenience when referencing these tables, they will be denoted throughout the document as the AL ^{SW}RBEL Table, and the HH ^{SW}RBEL Table, and can be found on the TRRP web site.

2.2.2 General Sampling Issues

> The TRRP rule (§350.54 (e)(3)) requires that persons select a standard available analytical method that provides a MQL below the necessary level of required performance for purposes of assessment as well as demonstration of conformance with critical PCLs. If it is not possible to achieve an MQL below the necessary level of required performance, and the COC does not meet the conditions of §350.71(k), then the person should select the standard available analytical method that provides the lowest possible MQL for that COC.

Determining the spatial extent (and nature) of contaminated media is a principal goal for conducting remedial investigations. The Data Quality Objectives (DQO) Process published by the U.S. EPA (U.S. EPA, 2000a), offers a logical, step-wise framework for accomplishing such an end goal. Specifically, the DQO Process "…provides a systematic approach for defining the criteria that a data collection design should satisfy, including: when, where, and how to collect samples or measurements; determination of tolerable decision error rates; and the number of samples or measurements that should be collected" (U.S. EPA, 2000a). The DQO Process considers a variety of impacted media potentially occurring at hazardous waste sites (including surface and subsurface soils, groundwater, surface water, and air), but does not consider sediments directly. Nevertheless, the process should also be applicable to sediment-related issues, particularly when considered in concert with a previously published (and sediment-specific) document titled *Sediment Sampling Quality Assurance User's Guide* (U.S. EPA, 1985a) and the more recent sediment collection guidance (U.S. EPA, 2001).

The number of samples that are collected will typically be based on several factors including:

- study objectives
- properties of the surface water or sediment
- degree of confidence required
- statistical power and hypotheses
- access to sampling points
- resource constraints

Through design optimization, the sampling effort can be distributed spatially and temporally in such a way as to maximize the amount of information obtained within the area sampled. Temporally, longer term surface water and sediment monitoring over several seasons is usually the best means for capturing COC variation due to changes in weather patterns and biological cycles. Resource and timing constraints usually limit the amount and duration of sampling. In planning the frequency, duration, and timing of sampling, persons should consider:

- weather patterns and tidal activities that may influence COC concentrations (monitoring that reflects near worst case conditions is preferred)
- recent dredging events
- induced changes in flow patterns due to flood gate and dam operations
- sample size necessary to satisfy statistical assumptions
- need to characterize daily, seasonal, or annual variability
- life history or life cycle of sensitive receptors that may be impacted by affected property COCs
- other appropriate factors

2.2.3 Sampling Surface Water

The TSWQS state (§307.9) that details concerning the laboratory analysis of water quality samples are provided in the latest version of the SWQM Procedures Manual, the most recently published edition of the book titled *Standard Methods for the Examination of Water and Wastewater*, 40 CFR 136, or other reliable sources acceptable to the executive director.

> **Groundwater Releases to Surface Water**
>
> It is not appropriate to sample surface water for groundwater releases to surface water except where sampling is needed to confirm a property-specific dilution factor or where the PCLE zone discharges across significant areas of a surface water body. Normally the groundwater-to-surface water pathway is evaluated using groundwater sample data. Refer to the discussions in Sections 7.1 and 7.3 for more information.

For toxic COCs such as metals and organics, §307.9(c)(4) of the TSWQS specifies that numerical aquatic life criteria apply to water samples collected at any depth. Numerical human health criteria apply to the average concentration from the surface to the bottom. For the purposes of standards attainment for aquatic life protection and human health protection, samples which are collected at approximately one foot below the water surface will also be acceptable for comparison to numerical criteria. Persons should refer to the discussion in Section 7.1.5.2 for sampling guidance regarding the groundwater-to-surface water pathway.

In all cases, sampling and analytical methods should be documented in the affected property assessment report (APAR), including a discussion of the sample locations, sample timing, and sample number.

2.2.4 Sampling Sediments

2.2.4.1 Sampling Depth. The prescribed POE for sediment for human exposure is within the upper one-foot of sediment beneath any surface water body meeting the definition of surface waters in the state. TRRP provides for a site-specific determination of the POE for ecological receptors exposed to sediment. The depth of the sediment sample should target the aerobic layer since this represents more recent deposition, and is where most benthic infauna will occur. Although this biologically active layer is frequently considered to be the upper 4 inches (10 centimeters) of sediment, it may be considerably shallower in some environments. In any case, the POE should be evaluated on a property-specific basis since some receptors are known to burrow deeper.

The person will need to justify the sample depth used in the ERA based on sediment characteristics observed during sampling. Observations of differing color intervals, texture and consistency, and biological inclusions (worm tubes, evidence of movement) may help distinguish between the biologically active layer and deeper layers. These types of observations should be noted in the ERA to justify the depth interval sampled. Typically the sediment will exhibit a light brown silt layer on top, followed by a gray colored aerobic zone overlying a typically black anaerobic layer (SWQM Procedures Manual). The key is to sample a depth interval that will best represent expected exposure, including exposure to predators that feed on burrowing or tube-dwelling biota. For example, freshwater oligochaetes may burrow 4 to 15 centimeters into sediment (U.S. EPA, 1994a). Alternatively, Whitlatch (1982) as cited in Armstrong (1987) found that most polychaetes, amphipods and bivalves were in the top 2 to 4 centimeters in estuarine mudflats. However polychaetes have been observed as deep as 20 centimeters in some waters after the sediments were colonized by deep-burrowing species (enteropneust) (Armstrong, 1987). Similarly, the angel wing clam burrows 30 centimeters or more beneath the surface depending on its size (Fotheringham, 1980). Deeper sediments should also be evaluated on a site-specific basis when COCs present in sediment below the biologically active layer are likely to be exposed at some future date from either natural causes (e.g., hurricanes) or anthropogenic events (e.g., dredging).[4]

Other sampling depths may be relevant depending on the circumstances in question. For example, samples collected for Acid Volatile Sulfide/Simultaneously Extracted Metal (AVS/SEM) analyses should be collected specifically in the oxic interval. Thus where sediment samples are collected at deeper depths to account for organisms that may have burrows in the anaerobic, black, sulfide-rich sediment, separate samples should be collected for AVS/SEM analyses in the more shallow oxic zone where the greatest density of benthic organisms are found. Alternatively, if the purpose of the sampling effort is to evaluate COC uptake through methylation, it is reasonable to limit sampling to the upper few centimeters down to the anoxic/oxic interface.

2.2.4.2 Statistical Designs for Sediment Sampling. As described in a number of regulatory documents (U.S. EPA, 1985a, 1991c, 2000a), a variety of statistical designs and procedures may be employed to determine the array, number, and locations for sediment data collection at an affected property, including: simple random sampling; systematic sampling; stratification; or composite sampling. Another sampling approach, referred to as judgmental sampling, may also be used and is generally based on historical information for the affected property (including knowledge of historical source locations), visual inspection, and professional judgment (U.S. EPA, 1991c). Although judgmental sampling is not a statistically based approach, a well-designed judgmental sampling program typically can provide good information about affected property conditions particularly where the representative concentrations are not biased low by the judgmental sampling. The TRRP rule states (§350.51 (1)) that judgmental samples may be used, as long as it can be demonstrated that the resulting estimated representative concentration is not biased low.

There are pros and cons associated with the use of any one of the above approaches to sampling design (e.g., U.S. EPA, 2000a), as related to variability in:

- the confidence with which the assumption of a normal distribution for affected property data can be justified (which is required when using statistically based, randomized sampling approaches but is not often true);
- the level of knowledge of property-specific conditions and characteristics;
- the relative ease of design implementation;
- the ability to focus sampling efforts in more critical areas of the affected property;
- the range in COC concentrations that may occur across the affected property; and
- relative cost effectiveness.

Some of these drawbacks may be overcome by collecting a large amount of data, but this may not be cost effective. In contrast, fewer samples or less data may be needed to adequately characterize spatial extent of COC-affected sediment if a field-validated sediment transport and deposition model has been developed for the affected property (U.S. EPA, 1985a). Consult the TRRP guidance titled *Determining Representative Concentrations* (RG-366/TRRP-15) for further information regarding statistical methods and assumptions.

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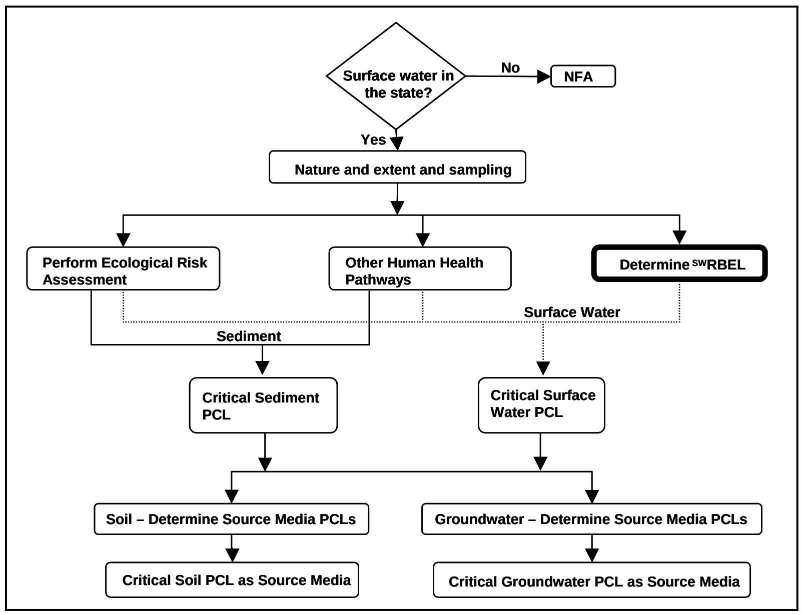
[4] Where property-specific circumstances warrant that sampling be performed in both the biologically-active layer and in the deeper sediments below, vertical compositing of samples should be avoided. Compositing of localized sediments is fine on a horizontal basis. However vertical composites can dilute or otherwise affect the analytical results such that the data are not reflective of the true conditions in either the biologically-active zone or the sediments at depth.

3.0 SURFACE WATER RBEL

The surface water RBEL (^{SW}RBEL) is the protective concentration of a COC at the POE in surface water. The process for determining the ^{SW}RBEL is detailed at §350.74 (h) of the TRRP rule. To establish the ^{SW}RBEL for a COC, persons should determine the lowest value for a COC as set out in paragraphs (1) through (5) of §350.74 (h), unless there is sufficient information to support an adjustment to the RBEL as allowed in paragraph (6) of this subsection (e.g., using property specific hardness and total suspended solids information). In establishing the ^{SW}RBEL, TRRP relies heavily on the criteria for aquatic life and human health protection defined in the TSWQS, as amended. The TSWQS are set out in 30 TAC §307. A number of concepts related to the types of criteria, types of water bodies, and water body uses are important to understand before the ^{SW}RBEL can be appropriately applied. These are discussed in the following section. Figure 3-1 illustrates the overall process for determining the ^{SW}RBEL.

3.1 Basic Surface Water Concepts



The TSWQS set out both narrative and numerical criteria. In determining the ^{SW}RBEL, the TRRP rule relies on the numerical criteria for toxic pollutants as defined at §307.6 of the TSWQS (see §350.74 (h), (1) and (2)). These criteria are divided into those for the protection of aquatic life (§307.6 (c)), and those for the protection of human health (§307.6 (d)). Application of these criteria depends on the type and use of the water body that may be potentially affected by COCs. The aquatic life criteria are divided into acute and chronic criteria for both freshwater and saltwater. The human health criteria apply to surface waters with a sustainable or incidental fishery, and to waters in the state with a public drinking water supply use. More information on water body types and use determinations will be discussed in Section 3.1.1.

The TSWQS also specify numerical criteria for chloride, sulfate, total dissolved solids (TDS), and pH. These criteria should be applied as ^{SW}RBEL values, as appropriate, in accordance with §350.74 (h)(5). The rule also requires an adjustment of the ^{SW}RBEL in cases where the release has the potential to lower the surface water dissolved oxygen (see §350.74 (h)(8)). These types of criteria are seldom applicable to most releases addressed by the TRRP rule. More details regarding the appropriateness and application of these criteria will be provided in Section 3.5.

The TSWQS also set out narrative criteria, which are non-quantitative statements that describe the desired water quality goal. The TRRP rule references selected narrative criteria in §350.74 (h)(7)(A) and (B). Here the ^{SW}RBEL may be modified to address general state criteria related to aesthetic parameters, nutrients, salinity, and general provisions precluding adverse toxic effects on aquatic and terrestrial wildlife, livestock, or domestic animals. Application of these narrative criteria is discussed in Sections 3.5.1 and 3.6.

3.1.1 Determining Water Body Type and Applicable Surface Water Criteria

The rule requires that the ^{SW}RBEL for a given COC is protective of relevant downgradient water bodies in consideration of the water body use, the water body type, the standards applicable to the type of water body/use, and the fate and transport characteristics of the COC in question (§350.74 (h)). Thus, for a given COC in surface water (or groundwater), multiple ^{SW}RBELs may be applicable at multiple locations within the potentially affected surface waters, depending on the water body use and the fate and transport of the COC in question as a release moves down a watershed. Figure 3-2 illustrates this concept. Consider the top left box in that figure. Assume the release is to one of the upper intermittent streams. Also assume that, due to the fate and transport characteristics of the release or COCs within the release, some COCs are expected or known to be present as far downstream as the lake. In this case it would be necessary to determine a ^{SW}RBEL for all of the following scenarios:

Water Body	Applicable Criteria
First order intermittent stream	Acute aquatic life criteria.
Second order perennial stream	Acute and chronic aquatic life criteria, and fish only human health criteria x 10 (incidental fishery).
Third order perennial stream	Acute and chronic aquatic life criteria, and fish only human health criteria (sustainable fishery).
Lake	Acute and chronic aquatic life criteria, water and freshwater fish human health criteria (since in the example, the lake is a drinking water source).

For this example, the person would possibly need to determine ten ^{SW}RBELs (some are repeated) for a given COC, for the various water body types downstream of the release.

The following information suggests ways of determining water body type and summarizes the applicable toxic criteria according to water body type (Table 3-1). Figure 3-3 tracks the decisions necessary to match the water body type with the applicable criteria (^{SW}RBEL). It will be helpful to have a copy of the TSWQS on hand while determining the water body type.

> **What is Stream Order?**
>
> As shown in Figure 3-2, stream order is a classification of stream size, where the smallest, unbranched tributaries of a drainage basin are designated first order streams. Where two first order streams join, a second order stream is formed; and where two second order streams join, a third order stream is formed, and so on (see §307.3). Stream order should be determined from USGS topographic maps with a scale of 1:24,000.

1. ***Check 30 TAC §307.10, Appendix C***, to determine if the water body is a classified segment. The segment descriptions in Appendix C of the TSWQS include the upstream and downstream boundaries for stream and river segments and the normal pool elevation for lake and reservoir segments. Also see the classified segment maps discussed in the text box in Section 3.1.3. Tidal water bodies include those that have the word "tidal," but not "above tidal," as part of the segment name, plus all bays, estuaries, and the Gulf of Mexico. If the water body is a nontidal classified segment, check 30 TAC §307.10, Appendix A, to determine if the segment has a domestic water supply use. Segments with a designated domestic water supply have the letters "PS" in the Domestic Water Supply column. Additionally, all designated segments in Appendix A of the TSWQS are presumed to have sustainable fisheries unless specifically exempted. Chronic (and acute) water quality standards apply to all designated segments in Appendix A with an aquatic life use category of limited, intermediate, high, or exceptional. If the water body is not a classified segment, go to step 2.

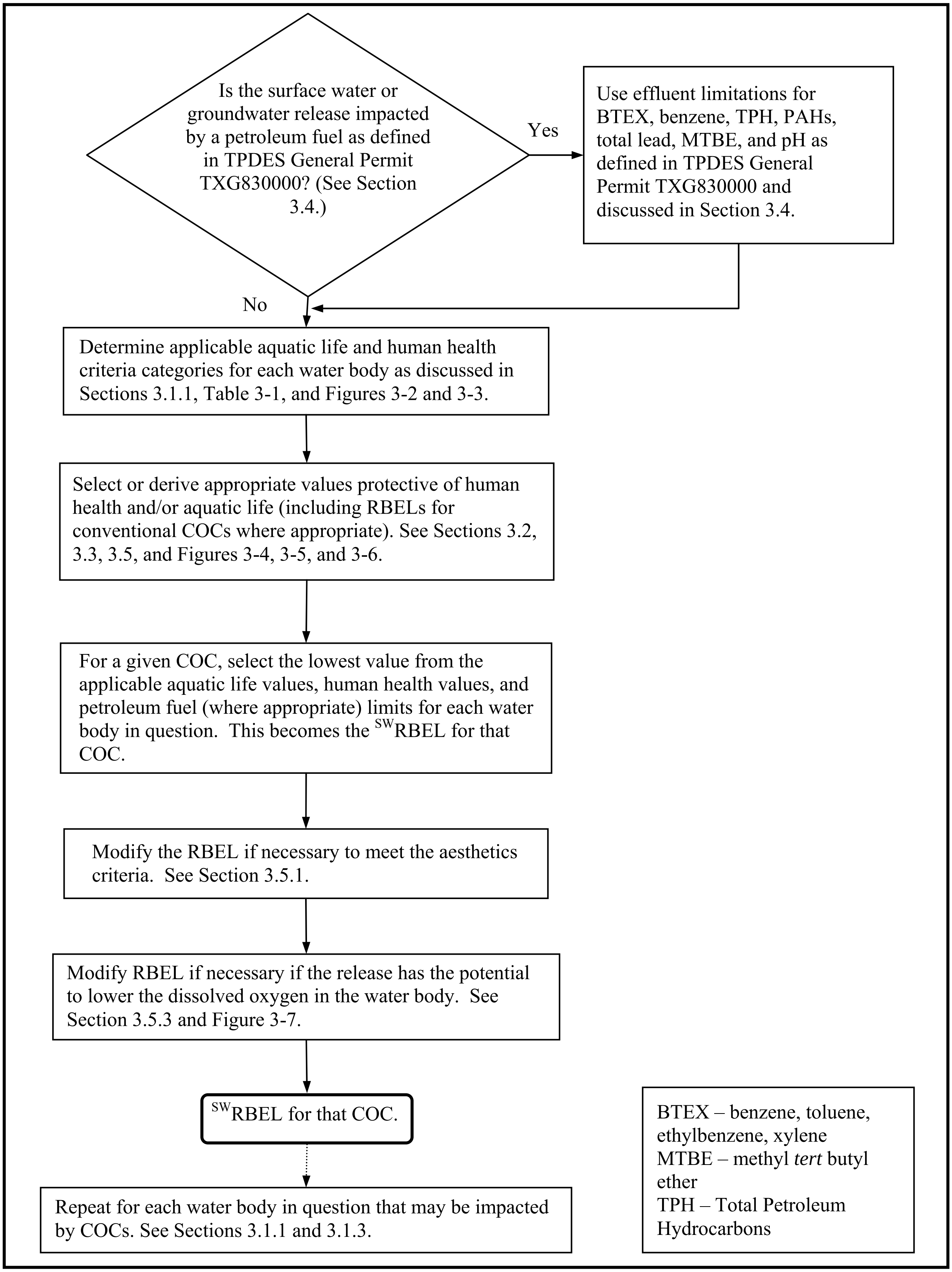


Figure 3-1. Determination of the Surface Water RBEL

2. ***Check 30 TAC §307.10, Appendix D***, to determine if the water body is partially classified. Water bodies in Appendix D of the TSWQS are listed in order by segment, county, and water body name. The water body type is included in the description, which also specifies the upstream and downstream boundaries or normal pool elevation delineating the portion of the water body that has been partially classified. Chronic (and acute) water quality standards apply to all partially classified water bodies in Appendix D with an aquatic life use category of limited, intermediate, high, or exceptional.

3. If the receiving water is not listed in either Appendix C or Appendix D of 30 TAC §307.10, first determine if the water body is tidal, a lake, or a stream.

> **What is a Wetland?**
>
> A wetland is an area (including a swamp, marsh, bog, prairie pothole, or similar area) having a predominance of hydric soils that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support and that under normal circumstances supports the growth and regeneration of hydrophytic vegetation.
>
> - Hydric soil - soil that, in its undrained condition, is saturated, flooded, or ponded long enough during a growing season to develop an anaerobic condition that supports the growth and regeneration of hydrophytic vegetation.
> - Hydrophytic vegetation - a plant growing in: water or a substrate that is at least periodically deficient in oxygen during a growing season as a result of excessive water content.
>
> The term "wetland" does not include irrigated acreage used as farmland; a man-made wetland of less than one acre; or a man-made wetland for which construction or creation commenced on or after August 28, 1989, and which was not constructed with wetland creation as a stated objective, including but not limited to an impoundment made for the purpose of soil and water conservation which has been approved or requested by soil and water conservation districts.
>
> If this definition of wetland conflicts with the federal definition in any manner, the federal definition prevails.
>
> (From the TSWQS)

- ***Tidal*** – A water body is considered tidally influenced when there is observed tidal activity, TDS is greater than or equal to 2,000 mg/L, salinity is greater than or equal to two parts per thousand, or specific conductance is greater than or equal to 3,077 umhos/cm (TCEQ, 2007).

- ***Lakes and reservoirs*** **-** Distinguish between playa lakes and other lakes and reservoirs.

> **What is a Playa Lake?**
>
> Playa lakes in Texas are shallow (generally less than 1 meter deep), isolated, naturally ephemeral circular lakes located in an enclosed basin in the High Plains and West Central Plains areas of the state.

- ***Streams and rivers*** **-** Streams and rivers may be perennial, intermittent, or intermittent with perennial pools. The distinction between perennial and intermittent water bodies is based on the seven-day, two-year low-flow (7Q2), which is defined in 30 TAC §307.3 as the lowest average stream flow for seven consecutive days with a recurrence interval of two years, as statistically determined from historical data. Based on this definition:

    - A perennial stream has a 7Q2 of greater than or equal to 0.1 cfs or does not go dry for at least one week during most years.

    - An intermittent stream has a 7Q2 of less than 0.1 cfs or goes dry for at least one week during most years.

- An intermittent stream with perennial pools maintains persistent pools even when flow in the stream is less than 0.1 cfs.

  Sources of information on stream flow characteristics include: USGS gage records, personal observations (observations that the creek goes dry for at least a week every two years, observations that it stops flowing but maintains pools, or observations that the creek never goes dry), and historical observations of adjacent landowners. Since historical trends are most relevant, any short term observations or measurements should be tempered with an awareness of extreme climatic conditions. For information on how to calculate the 7Q2, see the section of the agency's Implementation Procedures document titled "Determining the 7Q2" and the discussion later in this guidance (Section 7.1.3.2, Determination of Q_{stream}).

- ***Wetlands*** – Wetlands may be associated with either freshwater or saltwater bodies. They may or may not be permanently inundated.

Table 3-1. Determination of Appropriate Water Quality Toxic Criteria

Water Body Type	Freshwater/ Saltwater	Acute/Chronic Aquatic Life	Human Health
Tidal	Saltwater	Acute & Chronic	Saltwater Fish Tissue[1]
Lake or Reservoir			
area < 50 surface acres or volume < 150 acre-feet	Freshwater	Acute & Chronic	Water and Fish[2] or Freshwater Fish Tissue × 10
area ≥ 50 surface acres or volume ≥ 150 acre-feet	Freshwater	Acute & Chronic	Water and Fish[2] or Freshwater Fish Tissue
playa lake	Freshwater	Acute	N/A
Stream or River			
Perennial			
1st or 2nd order	Freshwater	Acute & Chronic	Water and Fish[2] or Freshwater Fish Tissue × 10
3rd order or greater	Freshwater	Acute & Chronic	Water and Fish[2] or Freshwater Fish Tissue
Intermittent with perennial pools	Freshwater	Acute & Chronic	Water and Fish[2] or Freshwater Fish Tissue × 10
Intermittent[3]	Freshwater	Acute	N/A
Wetland			
Permanently inundated	Freshwater	Acute & Chronic	Freshwater Fish Tissue
	Saltwater	Acute & Chronic	Saltwater Fish Tissue

Table 3-1. Determination of Appropriate Water Quality Toxic Criteria			
Water Body Type	**Freshwater/ Saltwater**	**Acute/Chronic Aquatic Life**	**Human Health**
Not permanently inundated	Freshwater	Acute	N/A[4]
	Saltwater	Acute & Chronic	Saltwater Fish Tissue

1 Releases to Segments 1006 and 1007 of the Houston Ship Channel (and tidal tributaries) should be evaluated for human health saltwater fish tissue criteria (pursuant to the Implementation Procedures).

2 If the water body is designated or used as a public drinking water supply, then the criteria for Water and Fish apply.

3 Includes intermittent channelized or man-made ditches that are waters in the State.

4 Chronic aquatic life criteria and human health criteria to protect an incidental freshwater fishery (Freshwater Fish Tissue x 10) apply whenever a freshwater aquatic life use occurs. Human health criteria to protect a sustainable fishery (Freshwater Fish Tissue) apply whenever a sustainable fishery occurs.

3.1.2 Dissolved Metal Concentrations versus Total Metal Concentrations

With the exception of mercury and selenium, specific aquatic life and human health criteria for metals and metalloids in the TSWQS apply to dissolved concentrations rather than total recoverable concentrations since the dissolved form of the metal represents the bioavailable form. Dissolved concentrations can be estimated by filtration of samples prior to analysis, or by converting from total recoverable measurements in accordance with the procedures in the Implementation Procedures, as amended. The aquatic life number for silver is a special case that will be addressed later.

Where a water quality standard is specified for a dissolved metal, the agency prefers that surface water be filtered for dissolved metals analyses[5] using a 0.45-micron filter (SWQM Procedures Manual) rather than use of the mathematical translator. The agency recognizes that in the case of groundwater releases to surface water, unfiltered groundwater data are frequently compared to surface water quality standards adjusted to a total metals basis since unfiltered groundwater data are also used for comparison to applicable groundwater criteria. If the conversion method is used, the agency uses a partition coefficient calculation to determine in-stream compliance with the numerical standards for dissolved concentrations. The partition coefficients used in

Example Dissolved to Total Conversion for Copper:

Segment 0806; West Fork of the Trinity River
Hardness = 140 mg/L
TSS = 9 mg/L
Freshwater Chronic Standard for Dissolved Copper:

$$0.960\ e^{(0.8545(\ln(\text{hardness}))-1.386)} = 16.4\ \text{ug/L}$$

Determination of the Total Copper Number*:
Partition Coefficient, $K_d = 10^b \times TSS^m$

$$K_d = 10^{(6.02)} \times (9)^{-0.74}$$
$$K_d = 2.06 \times 10^5$$

Fraction of Metal Dissolved = C/C_T

$$\frac{C}{C_T} = \frac{1}{1 + \left(K_d \times TSS \times 10^{-6}\right)}$$

$$= \frac{1}{1 + \left((2.06 \times 10^5)(9) \times 10^{-6}\right)}$$

$$= 0.350$$

Total Chronic Standard = 16.4 ug/L ÷ 0.350 ≈ 46.9 ug/L

*See Implementation Procedures for formulas and variables.

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[5] Keep in mind that a total metal number is usually applied to ERA calculations for metal uptake through the food chain. Where surface water data will be used in an ERA, both total and dissolved metal analyses are preferred. See Section 4.1.2.

the conversion are obtained from the Implementation Procedures. For this application, the Kd values in the Implementation Procedures should be used rather than those provided in Figure 30 TAC §350.73 (e). For convenience, the partition coefficients provided in Table 7 in the Implementation Procedures have been repeated in Appendix B of this guidance.

Where no partition coefficient is available for a particular metal in saltwater or freshwater, the agency assumes that the dissolved concentration equals the total recoverable concentration unless sufficient additional information and data are presented which justify a different fraction of dissolved metal. A calculation example is provided in the previous box. The amount of metal that partitions out is a function of the total suspended solids (TSS) in the receiving water. Persons should use the TSS concentration for the nearest classified downstream or downgradient segment, as provided in the Implementation Procedures (§350.74 (h)(1)), or the person may use property-specific TSS data from affected property sample results in accordance with the latest revision of the Implementation Procedures (§350.74 (h)(6)(B)).

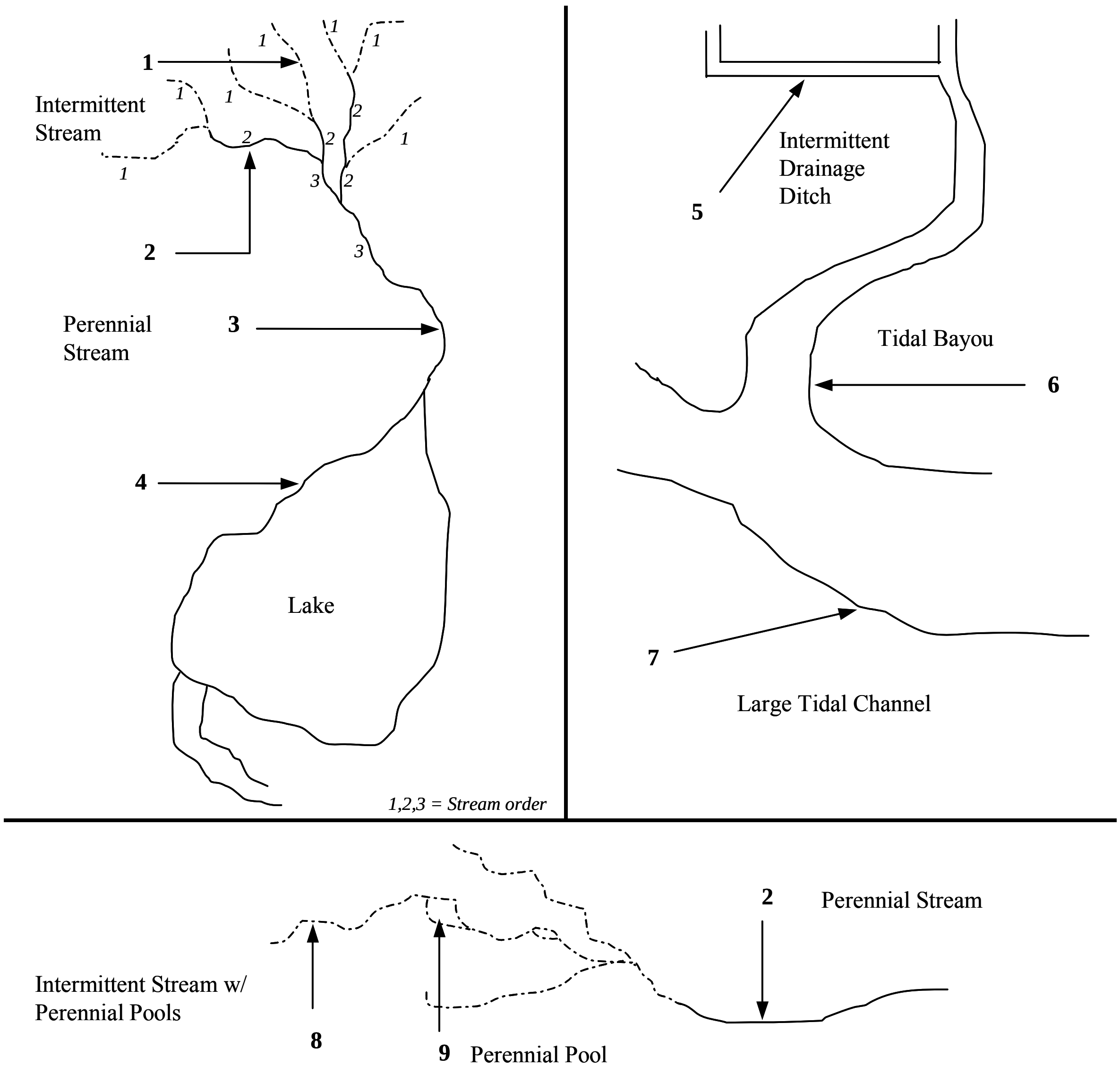
3.1.3 Impact of Downstream Water Bodies With More Conservative Water Quality Standards

The language in the TRRP rule and the TSWQS is silent regarding the distance downstream or downgradient to apply a surface water criterion (or the ^{SW}SW for that matter). The TRRP rule requires that the person conduct an affected property assessment (§350.51 (a)) in a manner appropriate for the affected property considering the hydrogeology, physical and chemical properties of the COCs, location of human and ecological receptors, and the complete or reasonably anticipated to be completed exposure pathways. Clearly, for a release to surface waters (storm water runoff, direct discharge, impacted groundwater release), compliance with the water quality standards applicable to the immediate receiving water should be evaluated. Beyond this, the concept that it is appropriate to evaluate potential impacts beyond the initial point of release within a watershed is emphasized at §350.37 (i) (related to the human health POE for surface water runoff or groundwater discharges to surface water) and §350.74 (h) (the surface water RBEL). The human health POEs include the surface water body at the initial point of entry, and other water bodies that may be impacted by COCs. Further, the ^{SW}RBEL should be protective of relevant downgradient water bodies, in consideration of the water body use, the water body type, the standards applicable to the type of water body/use, and the fate and transport characteristics of the COC in question.

Determining the Closest Downstream Classified Surface Water Segment

It is important to know the closest downstream classified surface water segment that a release could eventually enter. This information is relevant even where releases are not expected to reach the nearest downstream classified segment. First, classified segments have assigned uses and associated water quality standards. For instance, all classified segments are defined as sustainable fisheries, so the "fish only" human health criteria apply. Secondly, segment specific information is also used to assign TSS and hardness concentrations for the determination of metals criteria protective of aquatic life. A text description of the classified segments is provided in Appendix C of the TSWQS (Figure 30 TAC §307.10(3)). Segment maps for each watershed are available on-line at http://www.tceq.state.tx.us/comm_exec/forms_pubs/pubs/gi/gi-316/index.html. These maps are also available as a bound publication (*Atlas of Texas Surface Water*, GI-316) though the agency's publication office.

For instance, if the release is not limited to a confined water body such as a small lake or pond, the surface water or groundwater PCL that is based on a RBEL for the immediate receiving water may not always be protective of a downstream water body with a more conservative water quality standard (or derived number), depending on the water body use designation and the particular COC. If a more conservative water quality standard is appropriate for downstream water bodies, then the person must determine a PCL (applied at the point of release to the first water body) that is protective for the more restrictive RBEL, applied to the downstream water bodies.



1. Intermittent Stream - Acute freshwater aquatic life criteria apply.
2. Perennial Stream (not third order or greater) - Acute and chronic freshwater aquatic life criteria apply. Incidental fishery so fish only (x 10) human health criteria apply.
3. Perennial Stream (third order or greater) - Acute and chronic freshwater aquatic life criteria apply. Sustainable fishery so fish only human health criteria apply.
4. Lake (greater than 50 surface acres and drinking water source) - Acute and chronic freshwater aquatic life criteria apply. Sustainable fishery so fish <u>and</u> water human health criteria apply.
5. Intermittent Drainage Ditch - Acute freshwater aquatic life criteria apply since it is not tidally influenced.
6. Tidal Bayou - Acute and chronic aquatic life criteria apply. Sustainable fishery so saltwater fish only human health criteria apply.
7. Large Tidal Channel - Same as 6.
8. (and 9) Intermittent Stream w/ Perennial Pools - Acute and chronic freshwater aquatic life criteria apply to the pools and the stream. Incidental fishery so fish only (x 10) human health criteria apply.

Figure 3-2. Determination of Appropriate Water Quality Criteria

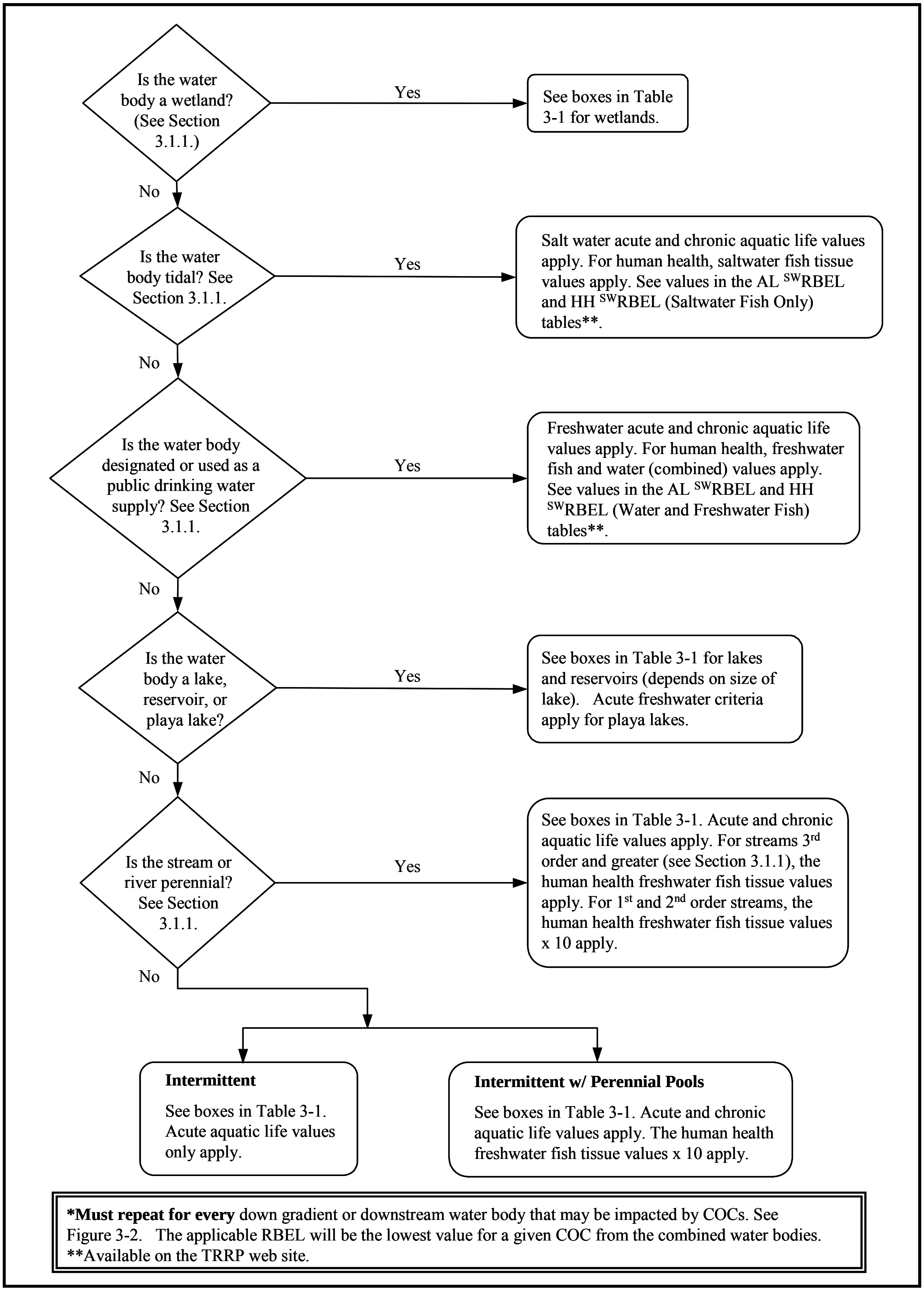


Figure 3-3. Determining the Applicable Water Quality Values Based on Water Body Type

In determining the appropriateness of a PCL, the person may account for dilution and degradation that occurs in the surface water between the point of release and the downstream water body. Appropriate justification may include information related to:

- persistence
- half-life
- biodegradation
- adsorption
- volatility
- transformation
- photolysis
- hydrolysis
- stream flow/release rate
- other data necessary to characterize the COC's movement and reaction in the environment

The lowest PCL for all of the water bodies will be the risk driver for this pathway.

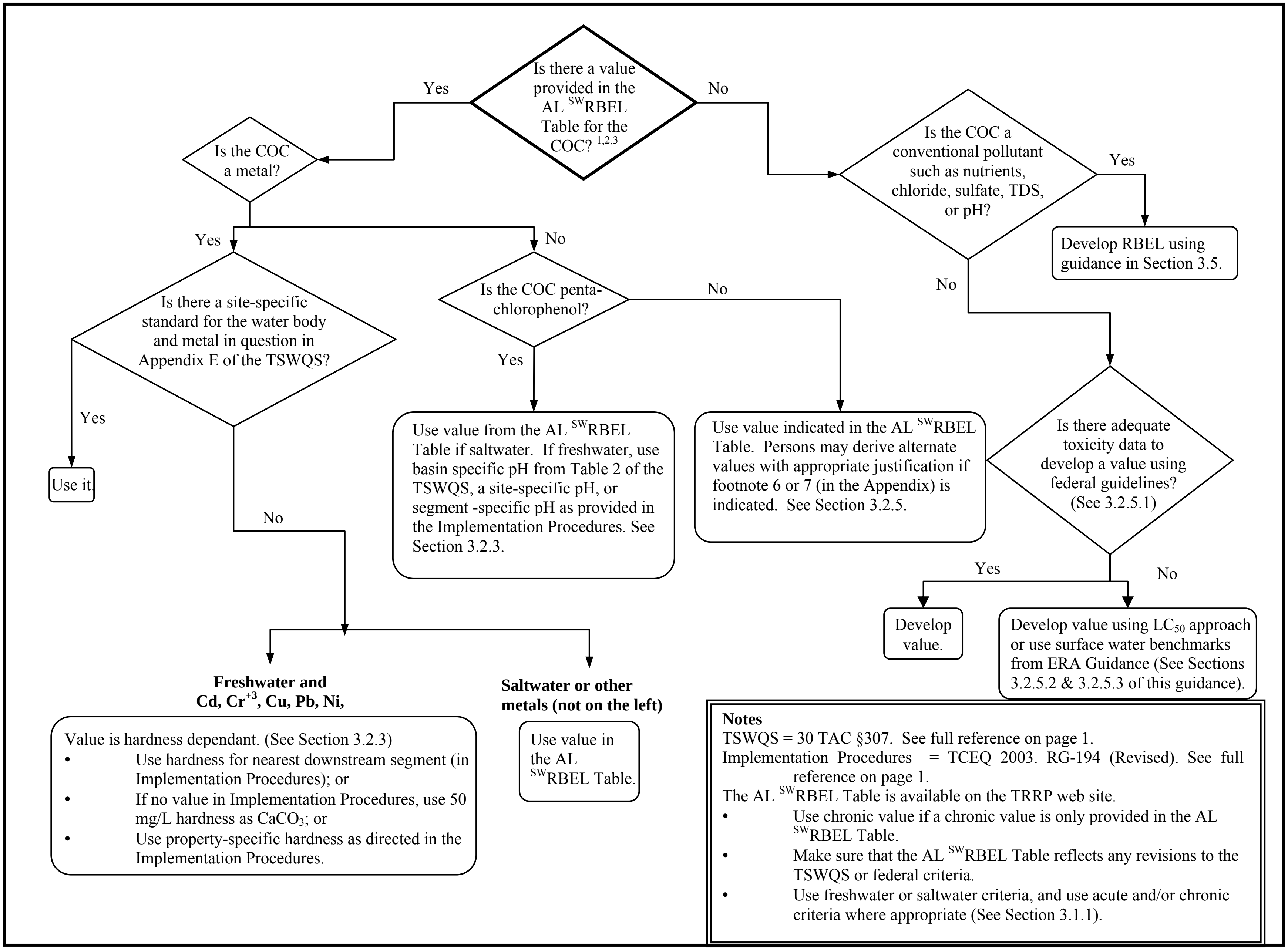


Figure 3-4. Determination of Aquatic Life RBELs

3.2 Surface Water RBEL for Aquatic Life Protection

Figure 3-4 details the process for deriving the ^{SW}RBEL protective of aquatic life.

3.2.1 Types of Criteria and Application of Criteria

The TSWQS specify freshwater and saltwater criteria protective of aquatic life to address both acute (short-term) and chronic (long-term) effects of toxic COCs. For convenience, the most recent aquatic life criteria in Table 1 (Figure 30 TAC §307.6 (c)(1)) of the TSWQS are presented in the AL ^{SW}RBEL Table. Persons should ensure that the table reflects the latest TSWQS and the latest federal criteria. Section 3.1.1, Figure 3-3, and Table 3-1 provide information for determining the applicability of the aquatic life criteria for the surface water in question.

3.2.2 Site – Specific Aquatic Life Criteria

The TSWQS define (Appendix E, Figure 30 TAC §307.10(5)) site-specific criteria for aquatic life protection for <u>selected water bodies</u>. These criteria are less conservative than those defined in Table 1 of the TSWQS. Persons should verify whether the surface water in question (and COC) is identified in this Appendix.

A number of water bodies have a site-specific criterion for copper. Notably, these include, but are not limited to:

- Sabine River Tidal in Orange County (Segment 0501)
- Houston Ship Channel (Segments 1005, 1006, and 1007)
- San Jacinto Bay (Segment 2427)
- Tucker Bayou in Harris County (Segment 1006)
- Greens Bayou Tidal in Harris County (Segment 1006)
- Brazos River Tidal in Brazoria County (Segment 1201)

Other than adjustments using property-specific hardness, TSS, and pH, the TRRP rule does not authorize persons to pursue a property-specific standard for COCs that have defined values in the TSWQS.

3.2.3 Hardness and pH Dependant Criteria

The acute and chronic freshwater criteria for pentachlorophenol are a function of pH in that the standard is actually a formula that includes pH as the independent variable. Although the value in the AL ^{SW}RBEL Table reflects an assumed pH of 7, §350.74 (h)(1) requires persons to use the basin-specific pH values provided in §307.6, Table 2, of the TSWQS. Alternatively, the person may use the actual pH of the particular surface water body at the affected property in accordance with §350.74 (h)(6)(C), or the segment-specific lower fifteenth percentile pH values provided in Table 5 of the Implementation Procedures, as amended. If the surface water body at the affected property is freshwater, but the nearest downstream classified segment is saltwater, the person may use a pH value from either an upstream freshwater segment (if available) or a nearby freshwater segment.

The freshwater aquatic life criteria for cadmium, trivalent chromium, copper, lead, nickel, and zinc are functions of hardness. Generally, these metals are less bioavailable with increasing hardness. Although the value in the AL ^{SW}RBEL Table reflects an assumed hardness concentration of 50 mg/L, the rule (at §350.74 (h)(1)) requires persons to use the hardness value for the nearest downstream classified segment, as listed in the agency's Implementation Procedures, as amended. The Implementation Procedures specify lower fifteenth percentile hardness values for each segment (see Table 5 in that document, as amended). If the surface water body at the affected property is freshwater, but the nearest downstream classified segment is saltwater, the person should use a hardness value from either an upstream freshwater segment (if available) or a nearby freshwater segment. Where no value is provided in the Implementation Procedures, the rule directs persons to use a hardness value of 50 mg/L as $CaCO_3$. Alternatively, the person may use property-specific hardness data, based on sample requirements specified in the Implementation Procedures (§350.74 (h)(6)(A)).

3.2.4 Chromium and Silver

The TSWQS express the freshwater aquatic life criterion for silver in the free ionic form. Additionally, the aquatic life criteria for chromium are specified for both hexavalent and trivalent chromium. Appendix A provides guidance for determining compliance with these criteria.

3.2.5 Surface Water RBEL for Aquatic Life Protection for COCs Without Standards

Frequently, the affected property COCs may include those that do not have defined aquatic life or human health criteria in the TSWQS. Although there may not be criteria available for the COCs in question, they should still be evaluated for potential impacts to aquatic life. The TRRP rule requires (§350.74 (h)(4)) that persons apply U.S. EPA guidelines (first choice) or alternate provisions (second choice) in accordance with §307.6 (c)(7) of the TSWQS, as amended where there is no state standard. This provision of the TSWQS referenced in TRRP provides a mechanism for deriving numerical criteria where there are no state standards and there is insufficient data available to use EPA guidelines. The following two sections discuss these approaches.

3.2.5.1 Use of Federal Guidelines for Aquatic Life Protection. As a first choice, a federal aquatic life criterion should be used where available. For purposes of this guidance, current federal criteria are set out in U.S. EPA, 2006 (or the most recent update), and are indicated as such in the AL ^{SW}RBEL Table. Alternatively, specific numeric criteria should be calculated using the method outlined in the following *Federal Register* publications if toxicity data requirements outlined in these documents are met (as discussed in the Implementation Procedures, as amended):

Guidelines for Deriving Water Quality Criteria for the Protection of Aquatic Life and Its Uses	45 FR 79341-79347, November 28, 1980
Summary of Revisions to Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses	50 FR 30792-30793, July 29, 1985

The federal guidance provided in the *Federal Register* specifies a rigorous procedure for developing criteria that requires toxicity data for at least one aquatic species in at least eight different taxonomic families. The guidance further requires toxicity tests for specific types of organisms within the eight families (e.g., salmonid fish, planktonic crustacean). The federal guidance also specifies parameters for selection of toxicity test data that were generated using specific test protocols and endpoints. The TCEQ expects that the federal guidelines will rarely be used to generate values to evaluate COCs at affected properties for the same reason that there are no readily available state or federal criteria - lack of appropriate toxicity data. Nevertheless, this remains an option.

3.2.5.2 Deriving Aquatic Life Numbers Using LC_{50} Data. Depending on the persistence and bioaccumulative nature of the COC in question, the TSWQS specify that the LC_{50} for the most sensitive aquatic organism may be used to derive a value protective of aquatic life. An LC_{50} is the concentration of a COC that is lethal (fatal) to 50% of the organisms tested in a specified time period. The provisions of the TSWQS (§307.6 (c)(7)) are as follows:

- acute criteria = LC_{50} x (0.3)
- chronic criteria for non-persistent COCs = LC_{50} x (0.1)
- chronic criteria for persistent COCs that do not bioaccumulate = LC_{50} x (0.05)
- chronic criteria for bioaccumulative COCs = LC_{50} x (0.01)

A COC is considered to be ***persistent*** if it has a soil, sediment, or water half-life of 4 days or greater. It is ***highly persistent*** if it has a soil, sediment, or water half-life of 6 months or greater.

A COC is considered ***bioaccumulative*** if its bioaccumulation factor (BAF) or bioconcentration factor (BCF) is 1,000 or greater. It is ***highly bioaccumulative*** if either its BAF or BCF is 5,000 or greater.

(from the Implementation Procedures, as amended)

Using this procedure, aquatic life protection values have been derived for 13 COCs. These are denoted by footnote 6 in the AL ^{SW}RBEL Table. As an example, a detailed discussion of the process for deriving aquatic life values for chloroform is provided in Appendix C. Persons may contact the TCEQ Technical Support Section for copies of the rationale used for deriving the values for the remaining 12 COCs. Persons may use these values or they may derive their own for these COCs <u>and others</u> that do not have defined criteria in the TSWQS. The agency's Ecological Risk Assessment Guidance (and updates) should be consulted for direction on the process for deriving aquatic life numbers using LC_{50} data. If a state or federal aquatic life criterion is developed in the future for any of the COCs in the AL ^{SW}RBEL Table, persons should use the new criteria. The values in the AL ^{SW}RBEL Table will be updated as soon as practical whenever the TCEQ or the U.S. EPA develops new criteria, or whenever the TCEQ adds a COC or updates its LC_{50}-based values for COCs without standards.

3.2.5.3 Use of Surface Water Benchmarks from the Ecological Risk Assessment Guidance. The Ecological Risk Assessment Guidance (and updates) provides benchmark screening values for COCs in surface water that do not have state or federal water quality criteria for the protection of aquatic life. These benchmark values are provided in the AL ^{SW}RBEL Table and are denoted by footnote 7. Persons may use these values for the surface water chronic RBEL or the LC_{50} approach discussed above. Refer to Table 3-2 and Section 3.5.3 in the Ecological Risk Assessment Guidance (and updates) to determine the source for the benchmark and the rationale for selection. In the event that the TCEQ or the U.S. EPA develops any new aquatic life criteria, persons should use these values rather than the benchmarks provided in the AL ^{SW}RBEL Table.

3.3 Surface Water RBEL for Human Health Protection

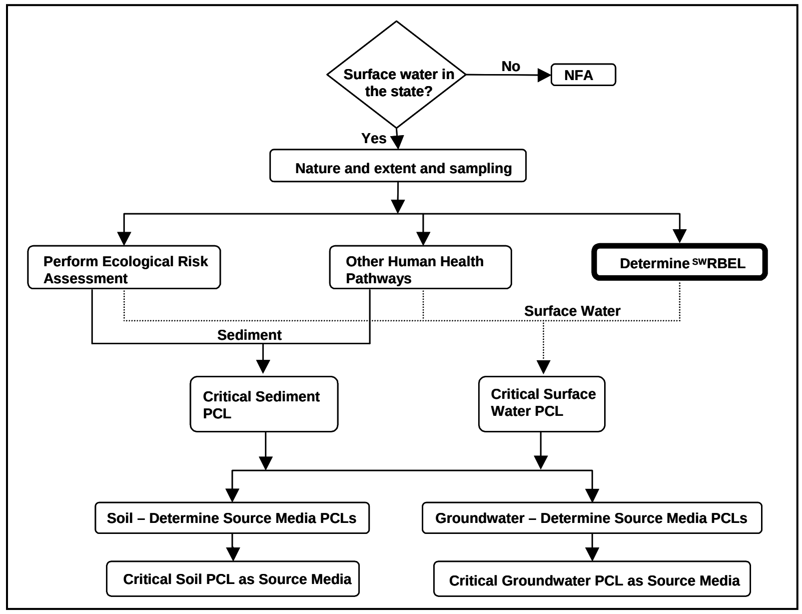


Figure 3-5 illustrates the overall process for determining the ^{SW}RBEL for the protection of human health.

3.3.1 Types of Criteria and Application of Criteria

The TSWQS specify three categories of criteria for human health protection. The three categories are as follows:

- freshwater criteria to prevent contamination of drinking water, fish and other aquatic life to ensure that they are safe for human consumption. These criteria apply to freshwaters that are designated or used for public drinking water supplies (column A in Table 3 of the TSWQS and the Water and Freshwater Fish Column in the HH ^{SW}RBEL Table);

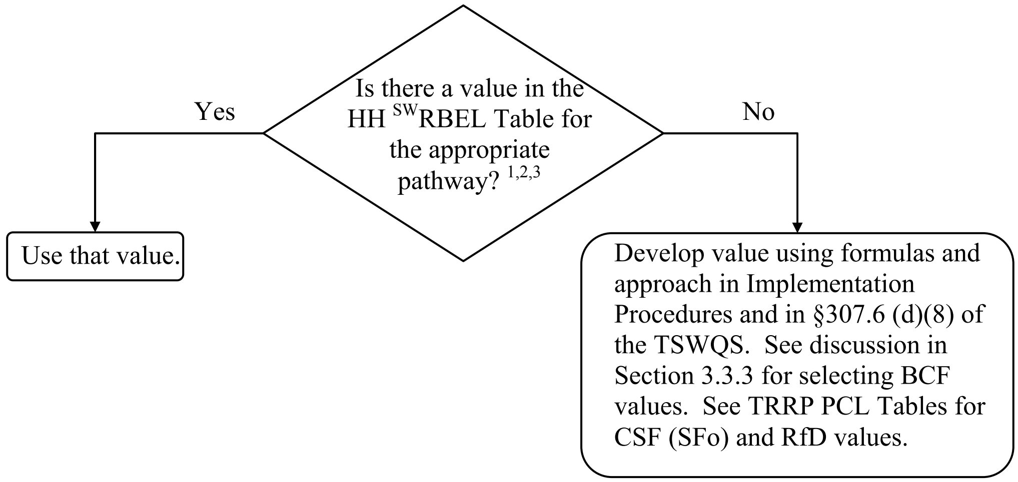
- freshwater criteria to prevent contamination of fish and other aquatic life to ensure that they are safe for human consumption. These criteria apply to freshwater which have sustainable fisheries (discussed below), and which are **not** designated or used for public water supply (column B in Table 3 of the TSWQS and the Freshwater Fish Column in the HH ^{SW}RBEL Table);

- saltwater criteria to prevent contamination of fish and other aquatic life to ensure that they are safe for human consumption. The TCEQ generally considers all saltwaters to have a sustainable fishery (Column C in Table 3 of the TSWQS and the Saltwater Fish Column in the HH ^{SW}RBEL Table).

For convenience, the most recent human health criteria in Table 3 (Figure 30 TAC §307.6(d)(1)) of the TSWQS are presented in the HH ^{SW}RBEL Table. A general discussion and flow chart for determining the applicability of the human health criteria for the surface water in question were provided in Section 3.1.1, Figure 3-3, and Table 3-1. The human health surface water RBEL table noted above incorporates only the pathways used in the development of TSWQS (i.e., fish ingestion, drinking water). Other human health pathways for surface water and sediment are discussed in Sections 5.1 and 5.2.

As provided in the TSWQS (§307.6 (d)(5)), sustainable fisheries include:

- all designated segments listed in Appendix A of §307.10
- perennial streams with a stream order of three or greater
- lakes and reservoirs having a volume equal to or greater than 150 acre-feet and/or a surface area equal to or greater than 50 acres
- all bays, estuaries and tidal rivers
- all other waters that potentially have sufficient fish production or fishing activity to create significant long-term (sustainable) human consumption of fish



Notes

BCF = Bioconcentration Factor.
CSF = Cancer Slope Factor; denoted as SFo in TRRP PCL Table.
RfD = Reference Dose
Implementation Procedures = TCEQ 2003. RG-194 (Revised). See full reference on page 1.

1. See Figures 3-2 & 3-3, Table 3-1, and Section 3.1.1 for a description of the types of human health values that are appropriate for various types of water bodies. See box to right that pairs the criteria and water body type.
2. Make sure that the HH ^{SW}RBEL Table (see TRRP web site) reflects any revisions to the TSWQS or federal criteria.
3. This chart only addresses human health RBELs for surface water and the pathways addressed by the TSWQS. Other human health pathways for surface water (e.g., incidental ingestion of surface water and dermal contact while swimming or wading) and sediment (dermal, incidental ingestion, fish ingestion) should be evaluated as indicated in Section 5.0 and Figures 5-1 and 5-2.

HH ^{SW}RBEL Table Nomenclature

- Water & FW Fish = Water body used/designated as a drinking water supply. Do not use fish only if water body is a designated drinking water source.
- FW Fish Only = 3rd order or greater streams, FW wetlands, and lakes greater than or equal to 50 surface acres.
- SW Fish Only = All tidal water bodies and saltwater wetlands.
- FW Fish Only x 10 = Lake smaller than 50 surface acres, 1st and 2nd order streams, and intermittent streams with perennial pools

FW = Freshwater
SW = Saltwater

Figure 3-5. Determining Surface Water RBELs for the Protection of Human Health

Additionally, waters with an aquatic life use but no sustainable fishery are considered to have an incidental fishery (§307.6 (d)(6)). Numerical criteria applicable to incidental fishery waters are ten times the human health water quality standards because the TSWQS specify fish consumption rates of 1.0 and 1.5 grams per person per day for incidental fisheries, compared to 10 and 15 grams per person per day for sustainable fisheries. First and second order perennial streams and intermittent streams with perennial pools are assumed to be incidental fisheries (see Table 3-1).

Fishing Advisories and Closures

The Texas Department of State Health Services has posted fishing advisories or fishing closures for a number of water bodies in Texas due to elevated levels of COCs in fish and shellfish. These advisories and closures are lifted as concentrations of COCs drop with improving water quality.

As such, these advisories should not be considered when evaluating the applicability of human health criteria (whether it is appropriate to dismiss a pathway) for a particular surface water body. Rather, only the definition of sustainable or incidental fisheries as provided in the TSWQS should be used.

(See http://www.dshs.state.tx.us/seafood/survey.shtm for lists and maps of advisories and closures).

3.3.2 Human Health Criteria for Dioxins/Furans

The TSWQS address the differences in the relative toxicity of dioxin/furan congeners in comparison to 2,3,7,8 TCDD (the most toxic dioxin/furan congener) with the use of toxic equivalency factors (TEFs). Table 3 of the TSWQS and the HH ^{SW}RBEL Table specify TEFs for seven congeners. The concentration of each dioxin/furan compound in a surface water or groundwater sample is multiplied by the COC's TEF. The sum of these products is the toxicity equivalence (TEQ) of the mixture, expressed as if the toxicity were due entirely to 2,3,7,8 TCDD. The agency evaluates compliance with the surface water RBEL for dioxins/furans using the TEQ method. Although the TRRP rule specifies a TEQ approach (§350.76 (e)) for polychlorinated dibenzo-p-dioxins and dibenzofurans, the TEQs specified in the TSWQS should be used for this application since TRRP refers to the TSWQS for the determination of the ^{SW}RBEL.

3.3.3 Surface Water RBEL for Human Health Protection for COCs Without Standards

In determining human health PCLs for COCs in surface water, including groundwater discharge to surface water, TRRP refers the user to Table 3 of 30 TAC §307.6, or the TSWQS, which lists approximately 70 COCs. For COCs not listed in the TSWQS, a ^{SW}RBEL should be determined where exposure pathways are complete.

For the sake of convenience, the TCEQ has developed a table of human health surface water values that are "preapproved" by the TCEQ (see all three columns in the HH ^{SW}RBEL Table). The table is a compilation of the TSWQS (August 17, 2000 effective date), and the U.S. EPA's recommended criteria (U.S. EPA, 2006, or more recent update). The U.S. EPA's criteria for carcinogenic chemicals have been adjusted to reflect a $1{\times}10^{-5}$-risk level in order to be consistent with the TSWQS and TRRP. If an MCL or equivalent agency guideline (e.g., 30 TAC §290) for the protection of drinking water sources was less than the federal water quality standard, then the MCL was used for drinking water supplies (Water and Freshwater Fish column in the HH ^{SW}RBEL Table) in accordance §307.6 (d)(8)(A and B). Persons should ensure that the table reflects the latest TSWQS and the latest federal water quality criteria.

Human health surface water RBELs/PCLs for COCs not listed in the table may be derived using the methodology described in TCEQ's Implementation Procedures (as amended) and in the TSWQS (§307.6 (d)(8)) (as amended). The formulas in the Implementation Procedures currently use a lipid-normalized bioconcentration factor (BCF). The text box provides information regarding the selection of the BCF. Persons should consult the Tier 1 PCL Tables on the TRRP website (http://www.tceq.state.tx.us/remediation/trrp/trrp.html) to obtain a reference dose or cancer slope factor, as appropriate. If no value is available on the website, persons should consult the TRRP guidance titled *Toxicity Factors and Chemical/Physical Parameters* (RG-366/TRRP-19) for information on the process for requesting toxicity factors from the TCEQ.

Selection of BCFs for Human Health Calculations

Persons may use measured BCFs from the literature or estimated BCFs based on the linear relationship between the logarithm of the BCF and the logarithm of the octanol-water partition coefficient (K_{ow}). In development of the current TSWQS, the agency generally used the following equation from Veith and Kosian, 1982 as referenced in U.S. EPA, 1991a:

$$\log BCF = (0.79 \log K_{ow} - 0.40)$$

BCF values estimated for organics using this equation and the log K_{ow} value provided in Figure 30 TAC §350.73(e) will be considered acceptable by the TCEQ.

This equation predicts BCFs for fish with a 7.6% lipid content. When this regression equation is used, the lipid conversion factor of (3% ÷ 7.6%) should be used as provided in the formulas in the Implementation Procedures (see section titled "Establishing Permit Limits for Toxic Pollutants without Criteria").

If the BCF is already based on 3% lipids, this conversion is not necessary. Persons may also elect to use more recent U.S. EPA recommendations for BCF as indicated in U.S. EPA, 1998 and U.S. EPA, 2000b.

If BCF values from the literature are used:

- laboratory studies based on commonly consumed fish are preferred
- BCF values recommended in U.S. EPA guidance criteria (where there is a substantial data base of measured BCFs for a given COC) are preferred
- an aggregate BCF value may be calculated as the geometric mean of the available values, when multiple literature values for a COC are deemed acceptable, provided the values are for similar taxa
- BCF data for surrogate compounds may also be used if appropriately justified.

Overall, persons should provide a brief justification regarding the selection of the BCF, and the reference source should be indicated.

3.4 Surface Water RBEL for Releases of Petroleum Fuel Impacted Waters

To establish the ^{SW}RBEL for a COC, the TRRP rule directs persons to use the lowest value from paragraphs 1-5 of §350.74 (h). The process for determining the ^{SW}RBEL pursuant to paragraphs 1, 2, and 4 was discussed in Sections 3.1, 3.2, and 3.3. For releases of petroleum fuel impacted groundwater or stormwater, TRRP directs (§350.74 (h)(3)) persons to apply the effluent limitations specified in the Texas Pollutant Discharge Elimination System (TPDES) Permit Number TXG830000, as amended. The permit is available on the agency web site at:
http://www.tceq.state.tx.us/permitting/water_quality/wastewater/general/TXG83_steps.html.

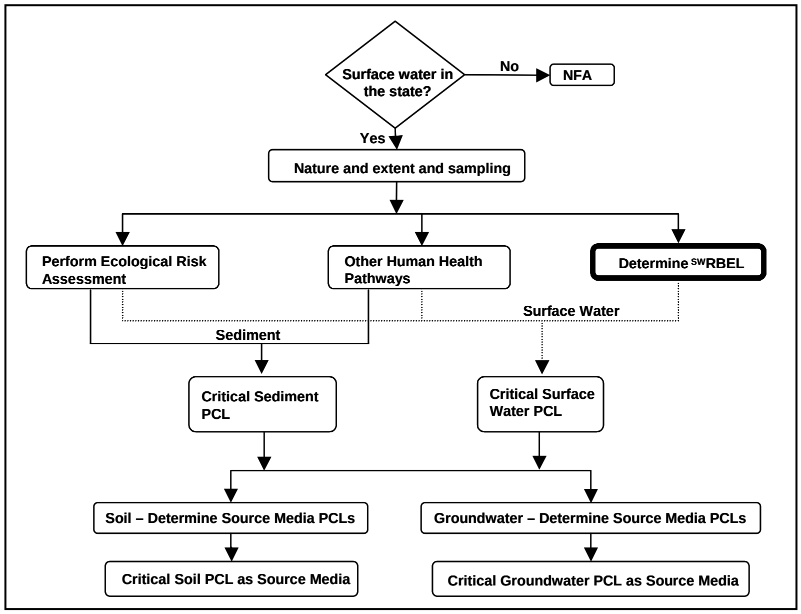
This general permit regulates the surface discharge of water contaminated by petroleum fuel or petroleum substances resulting from a variety of activities (e.g., groundwater pump tests, remediation activities, spill cleanups, impacted water removal from underground and aboveground storage tank systems previously containing petroleum fuel or petroleum substances, removal of accumulated groundwater from excavation sites, and removal of accumulated water from utility vaults). From a TRRP standpoint, this is irrelevant. The pertinent aspect is that the effluent limits in the general permit should be used (along with paragraphs 1, 2 and 4 of §350.74 (h)), to establish the ^{SW}RBEL for releases of petroleum fuel as defined in the general permit. The lowest value for a particular COC would determine the final ^{SW}RBEL. This would apply to groundwater or stormwater that has been impacted by petroleum fuel that is released to surface water. Petroleum fuel is defined in the general permit as gasoline, diesel fuel, fuel oil, kerosene, and jet fuel.

The permit limitations are as follows:

COC	Daily Maximum/Average Limit
Total Petroleum Hydrocarbons (mg/L) (using TNRCC Method 1005)	15
Total Lead (mg/L)	0.10 or 0.02, depending on county
Benzene (mg/L)	0.005
Total BTEX (mg/L)	0.10
PAHs (mg/L)	0.01
pH (Std. Units)	6.0 – 9.0
MTBE (mg/L)	0.24

Persons should consult the general permit to determine the counties where the lower lead limit would apply, and to identify the 16 PAH compounds that should be summed to evaluate compliance with the PAH limit. Where the limit reflects the sum of multiple COCs (such as TPH, total BTEX and PAHs), the RBELs should be applied in addition to any appropriate RBELs for the individual COCs derived pursuant to paragraphs 1, 2 and 4 of §350.74 (h). The TCEQ expects that the benzene and MTBE limits defined in the general permit will usually drive the ^{SW}RBEL, where appropriate.

3.5 Surface Water RBEL for Conventional Parameters



To meet the requirements of §350.74 (h)(5), (7), and (8), the following sections discuss the surface water RBEL (or modification of a surface water RBEL) for conventional parameters such as aesthetics, nutrients, salinity, chloride, sulfate, TDS, pH, and dissolved oxygen. Although the TCEQ anticipates that surface water RBELs developed for most types of releases addressed under TRRP will seldom require consideration of these parameters, the criteria associated with these parameters apply to all surface waters in the state and specifically apply to substances attributed to waste discharges or human activities.

Specific nutrients (e.g., nitrate nitrogen, total phosphate), salinity, chloride, sulfate, TDS, and pH must be evaluated at an affected property only if they are COCs (or daughter products of COCs) for the affected property. Specific COCs are not defined by TRRP, but are determined based on the nature of the release and the requirements of the program area that triggered the need for a response action under TRRP. In general, knowledge of process or affected property history should be evaluated and discussed to determine the necessity of including these conventional parameters as COCs. TCEQ project managers may be consulted for additional input.

The text of the following sections provides some examples of activities that may alter groundwater and/or surface water levels for these conventional parameters. This does not mean that these parameters should always be evaluated at these types of affected properties. Nor does it mean that other types of activities that are not listed should be excluded from evaluation. For some affected properties such as Superfund sites or properties with a variety of historical operations, a decision by type of activity or affected property history may be difficult, so evaluation of these parameters could be appropriate. Narrative criteria to preclude toxicity are discussed in Section 3.6.

3.5.1 Surface Water RBEL for Aesthetics, Nutrients, and Salinity

A surface water RBEL for affected property COCs may need to be developed or require modification in accordance with §350.74 (h)(7)(A) of the rule which cites the general criteria in the TSWQS related to aesthetic parameters, nutrient parameters, and salinity (§307.4 (b), (e), and (g), as amended). In addition to the information provided below, further discussion of various methodologies for screening and assessing narrative criteria are provided in the SWQM Procedures Manual.

3.5.1.1 Aesthetics. Generally, the provisions of the TSWQS related to aesthetics preclude:

- concentrations of taste and odor producing substances
- floating debris and suspended solids
- settleable solids (that may change flow characteristics of stream channels or cause filling of surface water in the state)
- persistent foaming and frothing, and oil, grease, or related residue in such amounts that will produce a visible film of oil or globules of grease on the surface or coat the banks or bottoms of a watercourse

Additionally, the TSWQS provide that surface waters be maintained in an aesthetically attractive condition, and that waste discharges will not cause substantial and persistent changes from ambient conditions of turbidity or color.

A decision whether or not a surface water body meets these aesthetic criteria is inherently less objective than that for the numerical toxic criteria. Therefore, persons should determine if the aesthetic criteria are met relative to a release to surface water based on the results of water quality studies, occurrence of fish kills, obvious sheens on the surface water and sediments, photographic evidence, local knowledge, and best professional judgment. Best professional judgment should also be used to modify the RBEL for a given COC to meet the aesthetics provision. Also see the box titled "Solubility Considerations" for a discussion of solubility and non-aqueous phase liquids (NAPL).

> **Solubility Considerations**
>
> Depending on its relative toxicity and the dilution factor used (see Section 7.1), the ^{SW}RBEL and ^{SW}GW for a particular COC may be very large. In these cases, the value should be no greater than the aqueous solubility limit for that COC as specified in Figure 30 TAC §350.73(e) since levels above the solubility limit are predicted to occur as NAPL. When the NAPL is a mixture, the mixture's effective solubility should be considered.
>
> To comply with the aesthetics criteria in the TSWQS relating to the preclusion of oil, grease, or related residue in such amounts to cause a visible film on the surface, banks, or bottom of the watercourse, releases of NAPL to surface water will not be permitted.
>
> Similarly, a surface water sheen or NAPL can be interpreted to adversely impact environmental quality, present objectionable characteristics, or render a natural resource unfit for use in accordance with the aesthetics provisions at §350.74 (i).

3.5.1.2 Nutrients. Although nutrients such as nitrogen and phosphorus are needed for basic metabolism, excess amounts can result in eutrophication of surface waters, overgrowth of plants, low dissolved oxygen, decline in the biological community, and increased risks to human health due to blooms of pathogenic microorganisms. The TSWQS states that nutrients shall not cause excessive growth of aquatic vegetation which impairs the use of the surface water body. Assuming they are affected property COCs, nitrogen compounds (ammonia, nitrate nitrogen, nitrite nitrogen) and phosphorus compounds (phosphate, etc.) in runoff and groundwater above background should be evaluated relative to a surface water RBEL developed for that COC. Examples of activities that may alter nutrient levels include:

- manufacturing, processing, formulating, packaging, distribution or related disposal of fertilizers, pesticides, explosives, nitrogen or phosphorus compounds (such as acids) for coatings, catalysts, oxidizing agents, metals passivation, and coal coking processes

- nutrient additions to stimulate in-situ bioremediation, land farming, or similar processes

- meat processing and/or rendering activities

Numerical water quality criteria for nutrients and chlorophyll *a* in surface water have not been developed by the TCEQ. However, the agency has developed screening levels for ammonia (NH_3-N), nitrate nitrogen (NO_3-N), nitrite nitrogen (NO_2-N), orthophosphate, total phosphorus, and chlorophyll *a* based on the 85th percentile values for each parameter from long term monitoring data. These screening values, provided in Table 3-10 of TCEQ, 2007, can be used as default RBELs for nutrients. Where nutrients are COCs, the person should compare surface water or groundwater concentrations for each COC, to the screening values in this document (and future updates to the document) as an initial indication of whether response actions are necessary. The screening levels do not represent adopted state criteria and should not be considered as such. Alternate RBELs may be proposed with appropriate justification or required by the TCEQ based on property-specific considerations.

3.5.1.3 Salinity. The TSWQS states that the concentrations and the relative ratios of dissolved minerals such as chloride, sulfate, and total dissolved solids (TDS) will be maintained such that surface water uses will not be impaired. Furthermore, the TSWQS provide criteria for chloride, sulfate, and TDS for classified freshwater segments (see Appendix A of §307.10). Thus, persons will not need to derive a RBEL for salinity. Rather, a RBEL for chloride, sulfate, or TDS should be used when necessary depending on the COCs present. See Section 3.5.2 for a discussion of these parameters.

3.5.2 Surface Water RBEL for Chloride, Sulfate, Total Dissolved Solids, and pH

Although chloride (Cl^{-1}), sulfate (SO_4^{-2}), and TDS are not expected to be problematic in most releases being evaluated for compliance with the surface water RBEL, some industrial processes and waste materials may result in elevated levels in runoff and groundwater above background. As affected property COCs, chloride, sulfate, TDS, and pH in groundwater and runoff should be evaluated relative to a surface water RBEL (§350.74 (h)(5)). Examples of activities that may alter levels of these parameters include:

- aluminum processing such as secondary refining
- galvanizing processes
- pulp and paper processes
- metal recovery processes, ore-processing, and metal plating
- fertilizer manufacturing, formulating, packaging, and distribution locations
- water treatment facilities or process facilities incorporating large pH neutralization processes
- co-generation facilities or facilities that employ significant water recycling (TDS)
- desalination processes
- processes using acids or bases in extractions such as alumina extraction from bauxite
- processes using acids or bases in petroleum/petrochemical processes such as alkylations
- cement processing (pH)
- battery recycling (pH)

3.5.2.1 Chloride, Sulfate, and TDS. The process for determining a ^{SW}RBEL for chloride, sulfate, or TDS is depicted in Figure 3-6. When chloride, sulfate, or TDS are affected property COCs, the person should compare the surface water or groundwater concentrations to the criterion provided in Appendix A of §307.10(1) for the nearest downstream or downgradient classified segment. These Appendix A numbers will serve as default RBELs. If the surface water or groundwater (with the application of any applicable dilution factor) COC concentrations exceed the segment criterion in Appendix A, persons should further evaluate the potential for impacts using the Implementation Procedures, as amended to determine whether any response action is necessary.

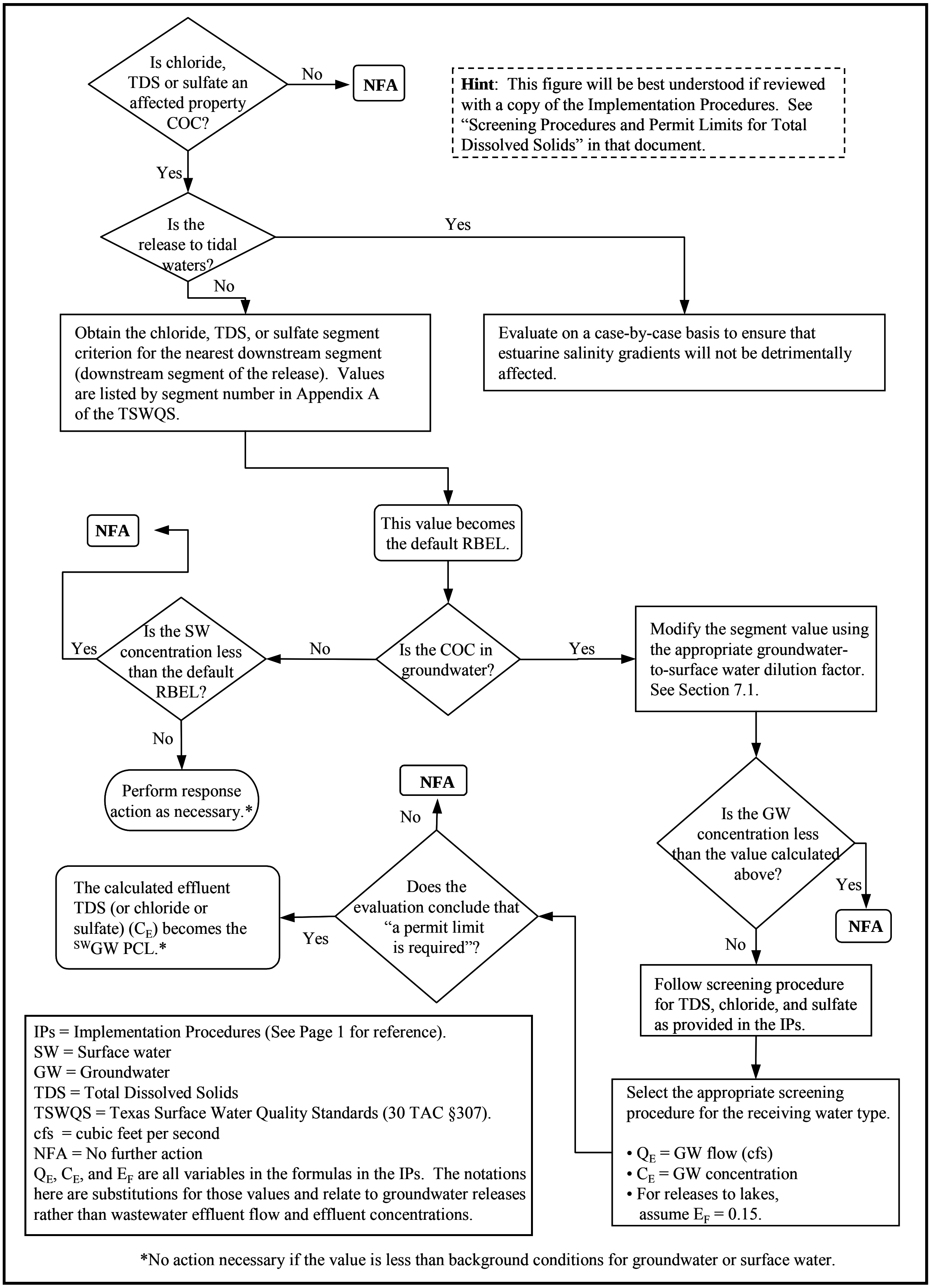


Figure 3-6. Determining the ^{SW}RBEL and ^{SW}GW for TDS, Chloride, and Sulfate

The Implementation Procedures provide a detailed methodology for evaluating TDS in wastewater effluents (see section titled "Screening Procedures and Permit Limits for Total Dissolved Solids"). Although the text language refers to TDS screening, the same methodology is used for screening sulfate and chloride concentrations. Since that document is crafted for the evaluation of point source discharges, groundwater or storm water runoff release rates and COC data should be used wherever effluent flow rates or effluent concentrations are mentioned. For groundwater releases, persons may use the DF approach provided in §350.75 (i)(4) to establish a ^{SW}GW PCL based on the surface water RBEL. See Figure 3-6 for more explanation. Following the rationale in the Implementation Procedures, a response action would be necessary for chloride, sulfate, and TDS whenever the "wastewater evaluation" would conclude that there is a need for a permit limit.

Normally, a surface water RBEL for chloride, sulfate, and TDS will not be necessary for releases to tidal waters. As provided in the TSWQS, surface water uses should not be impaired, and careful consideration should be given to any releases that may detrimentally affect salinity gradients in estuaries. Therefore persons should evaluate releases to tidal waters on a case-by-case basis to ensure that estuarine salinity gradients will not be detrimentally impaired. Be aware that the ionic make-up of "salt" in a release could be detrimental to aquatic life if it is substantially different from that of seawater. Mysid shrimp, for example, are particularly sensitive to high concentrations of calcium (Ca^{2+}) (Kline and Stekoll, 2000).

3.5.2.2 pH. The TSWQS (Appendix A of §307.10) also provide criteria for pH (as a range) for each classified segment. Given the normal buffering capacity of surface waters, persons should also use best professional judgment to determine if a release could potentially raise or lower the ambient pH of the receiving water outside the prescribed range for the nearest downstream or downgradient classified segment. This downstream segment value becomes the RBEL for pH if pH is a COC. Releases of contaminated groundwater or runoff with abnormally high or low pH to small perennial or intermittent streams are of particular concern.

3.5.3 Surface Water RBEL for Dissolved Oxygen

According to 30 TAC §350.74 (h)(8), the TCEQ may determine that a release has the potential to lower dissolved oxygen in the surface water. Thus COCs in groundwater and runoff should be evaluated relative to a surface water RBEL if the receiving water dissolved oxygen is expected to be lowered significantly based on prior analyses, history of the affected property, or process knowledge. Although the dissolved oxygen of the groundwater or runoff may be useful information for this determination, the presence of elevated organic levels in runoff or groundwater may be a more important factor in this decision, since oxygen in the receiving water may be decreased as these organics are broken down chemically and biologically.

Where persons suspect that the dissolved oxygen level in the receiving water will be decreased as a result of a groundwater release, persons should perform a five-day biochemical oxygen demand (BOD_5) test on a sample of the groundwater. The groundwater concentration (well-by-well) should be determined in the same manner as that for toxic COCs (see, Section 7.1.2.2). Evaluate as provided in Figure 3-7.

Releases of affected runoff to surface water are not usually expected to decrease the dissolved oxygen in the receiving water. However, if dissolved oxygen impact is a concern (for example, runoff contains nutrients), it may be necessary to monitor dissolved oxygen levels in the receiving water during a runoff event to determine the extent, if any, of the impact. Thus, the evaluation of the ^{SW}RBEL for dissolved oxygen will normally only be required for releases of groundwater-to-surface water. In some cases, persons may also need to evaluate historically affected sediments that may present a significant oxygen demand on the water column due to affected property COCs in the sediment.

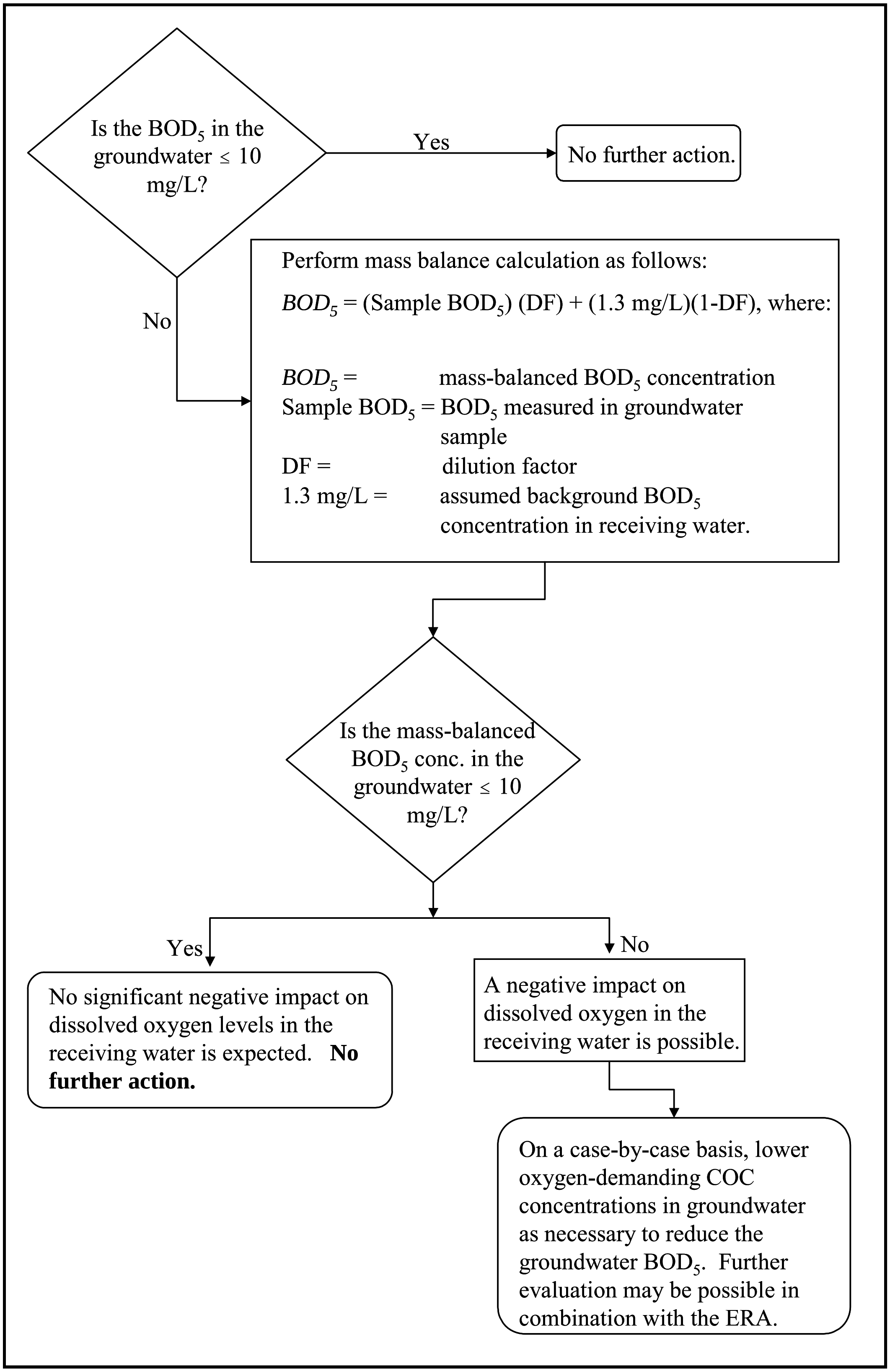


Figure 3-7. Evaluating BOD_5 in Groundwater

3.6 Surface Water RBEL Related to General Provisions for Toxicity Exclusion

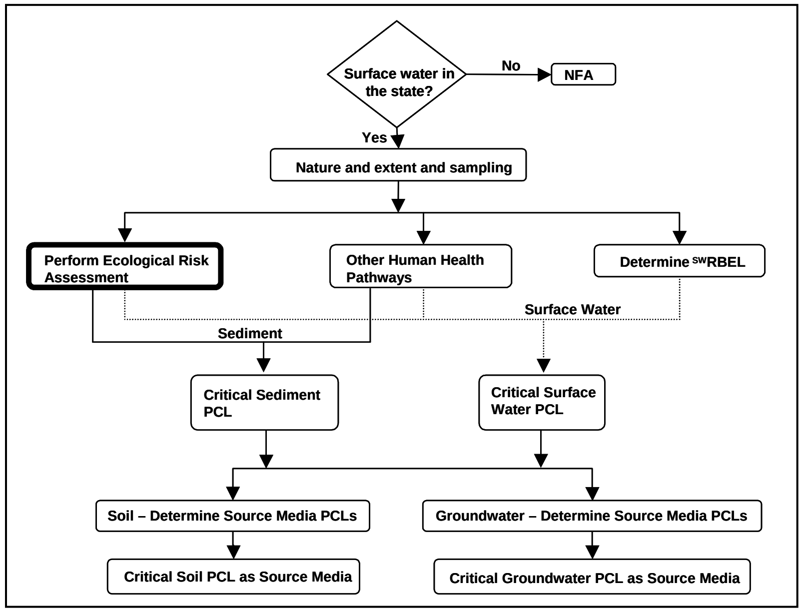
As provided in §350.74 (h)(7)(B), the surface water RBEL may require modification to comply with the general provisions related to the preclusion of adverse toxic effects on aquatic and terrestrial life, livestock, or domestic animals in accordance with §307.6 (b) of the TSWQS, as amended. Compliance with the provisions at §307.6 (b) will be evaluated as provided in the following table:

Table 3-2. TRRP Implementation of the General Provisions for Toxicity Exclusion in the TSWQS §307.6 (b)

TSWQS Provision	Evaluation
Water in the state shall not be acutely toxic to aquatic life, or chronically toxic to aquatic life in waters with designated or existing aquatic life uses.	• Determine surface water RBEL as specified in §350.74 (h). Compare groundwater concentrations (with DF where appropriate) and contaminated runoff with these values. • Evaluate potentially affected sediment as part of the ERA (§350.77). Evaluate impacts to benthic organisms, where appropriate, and impacts to aquatic organisms that feed on benthic biota as provided in the Ecological Risk Assessment Guidance, and updates.
Water in the state shall be maintained to preclude adverse toxic effects on human health resulting from contact recreation, consumption of aquatic organisms, consumption of drinking water or any combination of the three.	• Determine surface water RBEL as specified in §350.74 (h). Compare groundwater concentrations (with DF where appropriate) and contaminated runoff with these values. • Evaluate other potentially complete human exposure pathways as directed by the TCEQ as discussed in Section 5.0.
Water in the state with sustainable fisheries and/or public drinking water supply uses will not exceed applicable human health toxic criteria.	• Determine surface water RBEL as specified in §350.74 (h). • Compare groundwater concentrations (with DF where appropriate) and contaminated runoff with these values.
Water in the state shall be maintained to preclude adverse toxic effects on aquatic life, terrestrial wildlife, livestock, or domestic animals, resulting from contact, consumption of aquatic organisms, consumption of water, or any combination of the three.	• Evaluate potential risks to mobile or wide-ranging ecological receptors (birds, mammals, reptiles, and amphibians), threatened/ endangered species, and livestock and domestic animals as part of the ERA (§350.77). • Indirect and direct exposure to surface water and sediment should be evaluated. • See Ecological Risk Assessment Guidance, and updates.

Looking at this table, the general message is that the toxicity preclusion at §307.6 (b) will usually not require the person to perform any additional evaluations other than those already detailed in this guidance. The three main pathways exhibited in Figure 1-1 (ecological risk assessment, RBEL determination, and other human health pathways not addressed by the RBEL) are all represented in this table. The table is presented so that the reader is aware of the general toxicity preclusions in the TSWQS that are referenced in TRRP.

4.0 ECOLOGICAL RISK ASSESSMENT



As indicated in the introduction, persons will need to perform an ERA whenever COCs have migrated and resulted in a release or imminent threat of release to either surface waters or to their associated sediments via surface water runoff, air deposition, groundwater discharge, or other pathway. This process should not be confused with the development of the ^{SW}RBEL which is discussed in Section 3.0. The ERA process for TRRP is described in great detail in the agency's Ecological Risk Assessment Guidance (and updates). As indicated in that guidance, the primary functions of an ERA are to:

- determine whether actual or potential ecological risk exists at an affected property
- screen the COCs present to identify those that might pose an ecological risk, thereby focusing further efforts
- if necessary, generate ecological PCLs (surface water, SW_{Eco} and sediment, Sed_{Eco}) to be used in evaluating response actions

Persons should consult the Ecological Risk Assessment Guidance (and updates) for more details concerning the ERA. To avoid unnecessary repetition, this process will not be discussed in great detail here. Thus, the ERA should be performed to determine the applicable surface water and sediment PCLs that are protective of ecological receptors. The Ecological Risk Assessment Guidance also provides a discussion regarding the evaluation of risks to livestock. This text should be consulted if COCs in surface water or sediment present potential risks to livestock associated with the affected property.

4.1 Determining the Surface Water PCL Protective of Ecological Receptors (SW_{Eco})

TRRP defers to the TSWQS (in §307.3) for the definition of surface water in the state. This definition was previously discussed in Section 1.2. Surface water PCLs may be necessary as a result of releases of COCs to surface water from groundwater, releases in storm water runoff, and releases of COCs from COC-affected sediments.

4.1.1 Surface Water PCLs for Aquatic Life Protection

In general, the ^{SW}RBEL (equivalent to the surface water PCL) should be protective of fish and water column invertebrates. The process for determining the ^{SW}RBEL, which relies on the TSWQS, is discussed in Section 3.2. This will be the primary way in which surface water PCLs are determined for aquatic life protection. In some cases, surface water COCs may accumulate in the tissues of fish and water column invertebrates. This may also be an appropriate pathway to evaluate (in the context of an ERA), particularly where body burden concentrations are correlated with effects on the aquatic biota.

4.1.2 Surface Water PCLs for Wildlife Receptor Protection

Wildlife (i.e., upper trophic level receptors such as waterfowl, reptiles, amphibians, and mammals) may be exposed to surface water COCs directly by ingestion of surface water or exposure to the body surfaces, or indirectly via COC transport through the food chain. The agency's Ecological Risk Assessment Guidance (and updates) should be consulted to determine surface water PCLs protective of wildlife receptors. These PCLs will be derived as part of a Tier 2 (or optional Tier 3) ERA. Keep in mind that wildlife receptors may also be exposed to COCs in groundwater that is released to surface water. This exposure pathway should also be evaluated within the context of the ERA (see text box in Section 7.1.2).

TRRP requires persons to perform a Tier 2 (or optional Tier 3) ERA if the affected property has had a release to surface water or sediment. For some water bodies meeting specific conditions, an expedited stream evaluation may be used (as provided at §350.77 (a)) to address releases to surface water in lieu of conducting a full Tier 2 ERA. The primary criterion is that the water body is an intermittent stream without perennial pools. The other conditions, related to habitat and property setting, are detailed in the Ecological Risk Assessment Guidance (and updates). If the stream meets all of these conditions, the stream does not need any further evaluation for ecological receptors unless downstream analyses reveal impacts. In this case, the stream may need to be evaluated as a potential secondary source of COCs. Details regarding the downstream evaluation are provided in the Ecological Risk Assessment Guidance (and updates). Where the water body does not meet the conditions for the expedited stream evaluation, persons will need to perform a full Tier 2 (or optional Tier 3) ERA.

4.2 Determining the Sediment PCL Protective of Ecological Receptors (Sed_{Eco})

Sediment is defined in the rule (§350.4 (79)) as non-suspended particulate material lying below surface waters such as bays, the ocean, rivers, streams, lakes, ponds, or other similar surface water body (including intermittent streams). Sediment PCLs may be necessary as a result of releases of COCs in groundwater to sediment, releases to sediment from storm water runoff, and historical releases to sediment. Although the surface water quality criteria play an important role in assuring a healthy aquatic community, alone they are not always sufficient to

Is it soil or sediment?

Persons may ask whether the medium in the bottom of a dry watercourse should be evaluated as soil or sediment. The rule defines the material lying below surface waters, including intermittent streams, as sediment. Consider the following suggestions:

- Evaluate exposure from both the dry stream bottom, and from sediment associated with intermittent streams.
- Evaluate exposure to land-based ecological receptors when the stream bottom is dry (consider the media to be soil), and perform normal sediment evaluations (develop a sediment PCL where necessary) for times when the stream bottom is wet.
- The exposure duration for a particular receptor can be adjusted to reflect the usual dry/wet cycles for the water body in question.
- If the water body meets the criteria for an expedited stream evaluation (see Ecological Risk Assessment Guidance (and updates)), neither evaluation is necessary for the intermittent stream.
- One scenario or the other may be evaluated based on property-specific considerations. Discuss the rationale for not quantitatively evaluating the remaining scenario in the uncertainty analysis of the ERA.

ensure appropriate levels of environmental protection for ecological and human receptors. Even where the water column aquatic life criteria are satisfied, the surface water may not meet designated uses due to sediment impacts which may impair the benthic community, impact water column concentrations, result in fishing advisories/closures, and impact wildlife receptors directly through sediment ingestion or indirectly due to ingestion of contaminated food. Further, the aquatic life criteria are not designed to address the exposure to COCs in sediments. The following text discusses the applicability of a sediment PCL and the procedures for its derivation for ecological receptors. Figure 4-1 outlines the process for developing a sediment PCL (including human health pathways), where applicable. Human health sediment exposure pathways are discussed in Section 5.2.

4.2.1 Sediment PCLs for Aquatic Life Protection

Although research to identify sediment concentrations protective of aquatic life has been ongoing for years, there are no federal or state promulgated sediment criteria that can automatically serve as a PCL. Therefore, sediment PCLs protective of aquatic life should be determined within the context of the ERA. Exposure to <u>both</u> bulk sediment and sediment pore water should be evaluated where appropriate.

4.2.1.1 Benthic Invertebrates. TCEQ recognizes that the benthic (bottom-dwelling) community in some water bodies may be diminished for reasons unrelated to the release of COCs from property subject to the TRRP regulation. Persons should review the agency's Ecological Risk Assessment Guidance (and updates) and Section 7.2.1 to identify particular exposure scenarios where it is unnecessary to develop a sediment PCL protective of the benthic community. As provided in that guidance, this <u>does not necessarily preclude</u> an evaluation of risks to higher trophic level receptors (see text that follows) that may forage in the subject water body or water bodies downstream. Nor does it preclude the TCEQ from requiring additional evaluations for these particular types of water bodies on a case-by-case basis. Where it <u>is</u> appropriate to derive a sediment PCL protective of benthic invertebrates, there are a variety of ways to do this within the context of an ERA. The agency's Ecological Risk Assessment Guidance (and updates) should be consulted for guidance on this process.

Persons should be mindful that the benthic PCL preclusion, where appropriate, does not also signify a surface water PCL preclusion. Surface water PCLs apply to all surface water in the state (see discussion in Section 1.0 for more details).

4.2.1.2 Fish and Water Column Invertebrates. It is important to understand that fish and water column invertebrates may be affected by COCs in sediment just as they may be affected by COCs in surface water. Persons should consider the possibility that elevated COCs in sediment may result in surface water concentrations above designated state and federal aquatic life criteria (or values derived if there is no applicable state or federal criterion for a specific COC). Thus the sediment acts as a secondary source of COCs in surface water. Where this is the case, sediment remediation may be necessary to meet the surface water PCL.

Similar to the discussion in Section 4.1.1 for surface water, sediment COCs may also accumulate in the tissues of fish and water column invertebrates. For some sediment COCs, this may be an appropriate pathway to evaluate in the context of an ERA, particularly where body burden concentrations are correlated with an effect.

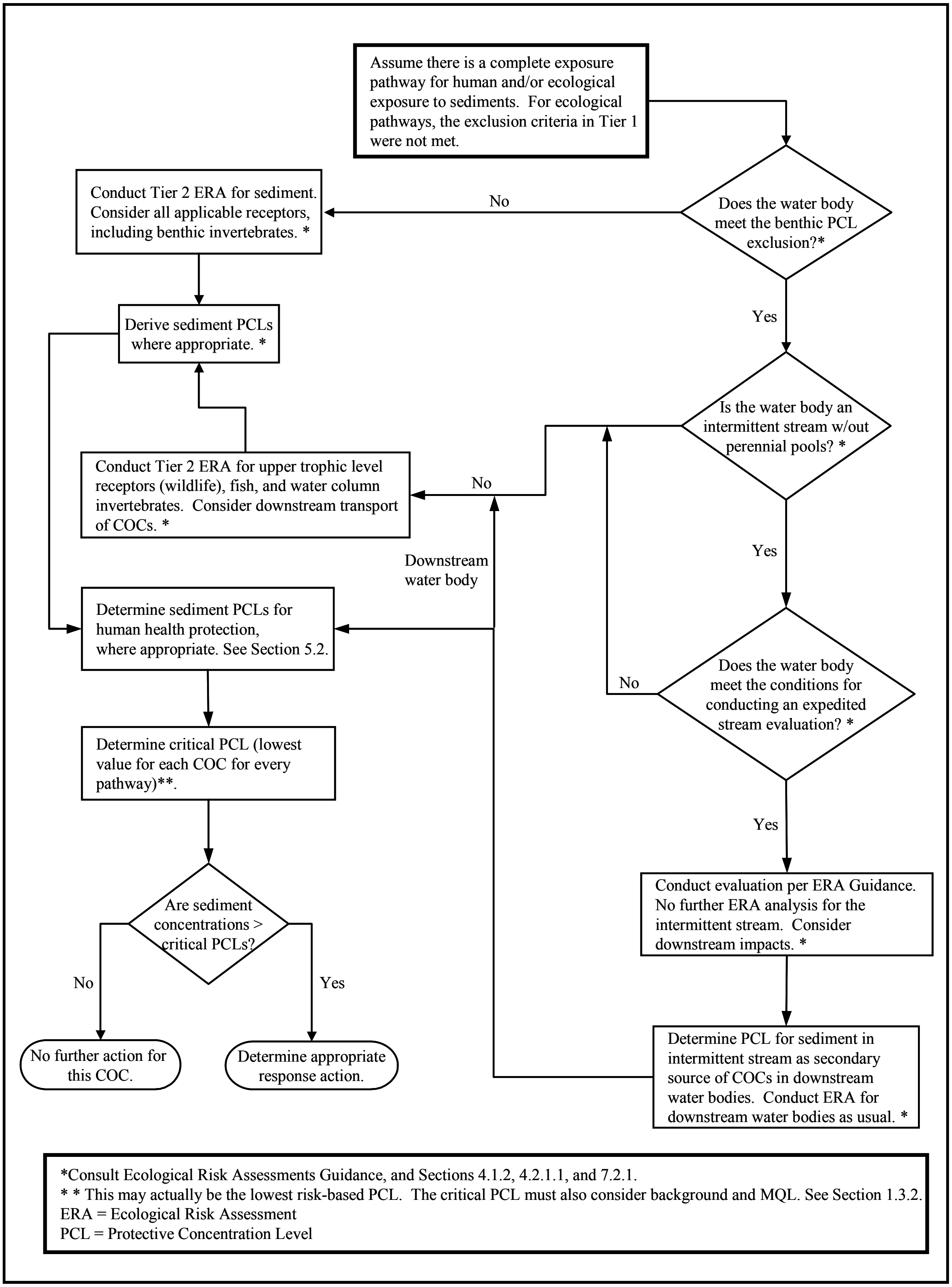


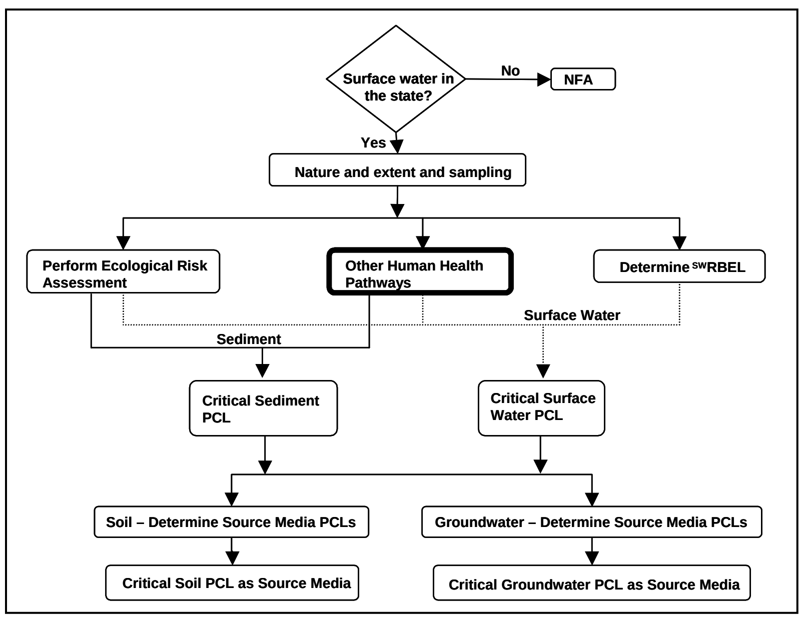
Figure 4-1. Determination of the Sediment PCL

4.2.2 Sediment PCLs for Wildlife Receptor Protection

Wildlife may be exposed to sediment COCs directly by ingestion of sediment or exposure to the body surfaces, or indirectly via COC transport through the food chain. The agency's Ecological Risk Assessment Guidance (and updates) should be consulted to determine sediment PCLs protective of wildlife receptors. These PCLs will be derived as part of a Tier 2 (or optional Tier 3) ERA. Again, releases of COCs in groundwater to sediment that are transferred up the food chain to wildlife receptors should also be evaluated within the context of the ERA.

TRRP requires persons to perform a Tier 2 (or optional Tier 3) ERA if the affected property has had a release to surface water or sediment. For some water bodies meeting specific conditions, an expedited stream evaluation (see §350.77 (a)) may be used to address releases to sediment in lieu of conducting a full Tier 2 ERA. The primary criterion is that the water body is an intermittent stream without perennial pools. The other conditions, related to habitat and property setting, are detailed in the Ecological Risk Assessment Guidance (and updates). If the stream meets all of these conditions, the stream does not need any further evaluation for ecological receptors unless downstream analyses reveal impacts. In this case, the stream may need to be evaluated as a potential secondary source of COCs. Details regarding the downstream evaluation are provided in the Ecological Risk Assessment Guidance (and updates). Where the water body does not meet the conditions for the expedited stream evaluation, persons will need to perform a full Tier 2 (or optional Tier 3) ERA.

5.0 HUMAN HEALTH PATHWAYS NOT ADDRESSED BY THE SURFACE WATER RBEL



Section 3.3 discussed the process for determining a surface water RBEL protective of human health. Recall that the RBELs (or surface water PCLs, ^{SW}SW) are intended to be protective of:

- humans that may consume fish and shellfish harvested from potentially affected surface water (saltwater)
- humans that may consume fish harvested from potentially affected surface water (freshwater)
- humans that may consume fish harvested from potentially affected surface water (freshwater) and also may consume drinking water where the drinking water source is the same water body (freshwater)

These three pathways do not address human exposure to sediments, or human exposure to surface water while swimming or wading. The following sections offer guidance for determining surface water and sediment PCLs for these exposure pathways. Figures 5-1 and 5-2 also summarize the pathways discussed in the following text.

5.1 Determining Surface Water PCLs Protective of Human Health

TRRP requires that surface water PCLs be established when the TCEQ determines that relevant exposure pathways are complete or are reasonably complete for a particular COC (§350.71 (c)(7) and §350.75 (i)(13)). Pathways likely to be relevant to surface water include ingestion of surface water, dermal contact with surface water, and ingestion of contaminated fish/shellfish. In most cases, human exposure to surface water via fish/shellfish ingestion and/or drinking water ingestion is already considered in the ^{SW}RBEL (i.e., available TSWQS incorporate considerations for human ingestion of fish and consumption of surface water as a drinking water source). When the TSWQS values provided in column "A" of Table 3 in Chapter 307 (the first column in the HH ^{SW}RBEL Table) are used as the ^{SW}RBELs, it is generally not necessary to evaluate other possible exposure pathways, as it is reasonable to assume that concentrations that are protective of drinking water consumption and transfers to fish, will also be protective of skin contact and other routes of exposures.

When a water body is not classified as a drinking water source, however, the TSWQS allow surface water quality standards to be set based solely on consideration of uptake of COCs into fish/shellfish and aquatic life criteria. As described in §307.6 (b)(3) of the TSWQS, water quality should preclude any adverse toxic effects on human health resulting from contact recreation and consumption of drinking water. When a water body is not being evaluated as a drinking water source under the TSWQS, TRRP requires (§350.74 (h)(2)) that persons determine the necessity of evaluating pathways associated with contact recreation such as incidental ingestion of surface water and dermal contact with surface water. The TCEQ will consider the following in determining whether it is necessary to evaluate these contact recreation pathways for a given COC (when a water body is not being considered as a drinking water source):

- contact recreation status of the water body (see Appendix A- Site-specific Uses and Criteria for Classified Segments, Figure 30 TAC §307.10 (1))
- observed recreational use patterns
- documentation in the APAR of factors likely to preclude contact recreation on a regular basis (e.g., intermittent nature of the water body, substrate, salinity, shipping traffic, access)
- COC-specific factors that influence long-term exposure potential (e.g., volatility, environmental persistence, likelihood of dermal uptake)
- other relevant water body-specific considerations
- TCEQ staff judgment that the contact recreation pathways would be of limited significance when compared to other pathways included in the evaluation (i.e., aquatic life criteria, transfers of contaminants into fish)

The TCEQ has developed Tier 1 surface water PCLs for the contact recreation pathway. These PCLs are available on the TRRP web site at: http://www.tceq.state.tx.us/assets/public/remediation/trrp/contactrecpcls.pdf. The pathway-specific exposure parameters (e.g., exposure frequency, incidental surface water ingestion rates) are not specified in the TRRP rule. The residential RBEL-4 equations (see Figure 30 TAC §350.74 (a)) were adapted to evaluate surface water incidental ingestion during contact recreation by changing the exposure frequency and ingestion rates. The PCL equations for evaluating the incidental ingestion of surface water due to contact recreation and pathway-specific exposure assumptions are provided in Table 5-1. When a Tier 1 surface water PCL is not available for a given COC, the TCEQ will determine an appropriate value. The person should contact the TCEQ and provide some specific information about the COC and the site as specified in the procedure detailed in the TRRP guidance titled *Toxicity Factors and Chemical/Physical Parameters* (RG-366/TRRP-19).

Unlike the surface water ingestion pathway, appropriate evaluation of the surface water dermal exposure scenario requires equations and inputs that are very different from those described for dermal exposure to soil. Complete guidance on evaluating this pathway, including the appropriate equations and inputs (i.e., those not specified in Table 5-2) to use in estimating exposures, is provided in *Risk Assessment Guidance for Superfund (RAGS) Part E* (U.S. EPA, 2004). While a number of COC-specific factors must also be calculated to evaluate dermal exposures to COCs in surface water, key exposure parameters are detailed in Table 5-2. This TRRP guidance and RAGS Part E differ slightly with regards to the age-adjusted evaluation. RAGS Part E gives exposure parameters (e.g., body weight, skin surface area) based on the young child and adult for the age-adjusted evaluation, whereas parameter values recommended in Table 5-2 for input as "adult" parameters in RAGS Part E equations (i.e., BW_{adult}, SA_a) incorporate the adolescent as well. As a result, age-adjusted evaluations using exposure factors recommended in this TRRP guidance (with the age-adjusted equations in RAGS Part E) incorporate the young child, adolescent, and adult. This is consistent with age-adjusted evaluations under TRRP for other exposure pathways (i.e., residential dermal contact with and incidental ingestion of soil).

Table 5-1. Exposure Assumptions and Tier 1 PCL Equations for the Incidental Ingestion of Surface Water (Contact Recreation Surface Water Pathway)

PCL Equation for the Incidental Ingestion of Carcinogenic COCs in Surface Water:

$$^{SW}SW_{Ing-c}\ PCL\ (mg/L) = \frac{(RL)(ATc)(365\ days/yr)}{(SF_o)(MF)(IRsw.AgeAdj.rec)(EF.sw.rec)}$$

PCL Equation for the Incidental Ingestion of Noncarcinogenic COCs in Surface Water:

$$^{SW}SW_{Ing-nc}\ PCL\ (mg/L) = \frac{(RfD_o)(HQ)(BW.C)(AT.C.res)(365\ days/yr)}{(IRsw.rec)(EF.sw.rec)(ED.C.res)}$$

Inputs for Incidental Ingestion of Surface Water

Term	Exposure Factor	Default Value
ATc	Averaging Time – carcinogens (yr)	70
AT.C.res	Averaging Time – noncarcinogens – child (yr)	6
BW.C	Body Weight – child (kg)	15
ED.C.res	Exposure duration – child (yr)	6
EF.sw.rec	Exposure frequency (days/yr)	39 (1) (13 weeks/yr, 3 days/week)
HQ	Hazard Quotient (unitless)	1
IR.sw.rec	Incidental Surface Water Ingestion Rate (L/day)	0.15 (2)
IR.sw.AgeAdj.rec	Incidental Surface Water Ingestion Rate – Age adjusted by body weight (L-yr/kg-day)	0.126 (3)
SF_o	Oral Slope Factor $(mg/kg\text{-}day)^{-1}$	Chem-spec.
MF	Modifying Factor for SF_o (unitless)	1 (0.1 for arsenic)
RfD_o	Oral Reference Dose (mg/kg-day)	Chem-spec.
RL	Risk Level (unitless)	10^{-5}

[1] Upper percentile, TCEQ professional judgment and need to use high-end exposure frequency consistent with TRRP.
[2] 50 ml/hr mean estimate U.S. EPA, 1989b; 3 hr/day upper percentile U. S. EPA, 1997b; 0.05 L/hr x 3 hr/day = 0.15 L/day.
[3] ((0.15 L/day * 6 yr) / 15kg) + ((0.15 L/day * 12 yr) / 45 kg) + ((0.15 L/day * 12 yr) / 70 kg) = 0.126 L-yr/kg-day.

Table 5-2. Exposure Assumptions for the Dermal Contact Surface Water Pathway		
Parameter	**RAGS Part E Acronym [9]**	**Value [(reference)]**
Exposure Frequency	EF_c, EF_a	39 days/yr [1] (13 weeks/yr, 3 days/week)
Length of Dermal Contact	$T_{event\text{-}RME}$	3 hours/event [2] (1 event/day)
Swimming Skin Surface Area (Young Child)	SA_c	6,600 cm^2 [3, 4]
Swimming Skin Surface Area (Older Child)	N/A	13,100 cm^2 [3]
Swimming Skin Surface Area (Adult)	N/A	18,000 cm^2 [3]
Swimming Skin Surface Area (Age-Adjusted Adolescent/Adult)	SA_a	15,550 cm^2 [5, 6]
BW (Young Child)	BW_{child}	15 kg
BW (Age-Adjusted Adolescent/Adult)	BW_{adult}	57.5 kg [7, 8]
Fraction Absorbed	FA	1

[1] Upper percentile, TCEQ professional judgment and need to use high-end exposure frequency consistent with TRRP.
[2] Upper percentile, U. S. EPA, 1997b.
[3] Median skin surface areas for swimming from Tables 6.2 and 6.3 of U.S. EPA, 1997b.
[4] For use in the noncarcinogenic evaluation.
[5] For use as the adult skin surface area along with the young child skin surface area in the age-adjusted carcinogenic evaluation (see page D-5 of RAGS Part E).
[6] ((18,000 cm^2 x 12 yr) + (13,100 cm^2 x 12 yr)) / 24 yr = 15,550 cm^2
[7] For use as the adult body weight (BW) along with the young child BW in the age-adjusted carcinogenic evaluation (see page D-5 of RAGS Part E).
[8] ((70 kg x 12 yr) + (45 kg x 12 yr)) / 24 yr = 57.5 kg
9 See list of parameters on page D-3 of RAGS Part E, U.S. EPA, 2004.

The total surface water combined PCL (as provided in the Tier 1 PCL Table on the TRRP web site) protective of the contact recreation pathway is calculated as follows:

$$^{Tot}SW_{Comb}\ \ PCL\ (mg/L) = \frac{1}{(1/\,^{SW}SW_{Ing}\ \ PCL) + (1/\,^{SW}SW_{Derm}\ \ PCL)}$$

The young child exposure scenario is most conservative (i.e., results in a lower $^{Tot}SW_{Comb}$ PCL) for noncarcinogenic hazard, and the age-adjusted scenario is most conservative for carcinogenic risk. Therefore, total surface water combined PCLs ($^{Tot}SW_{Comb}$ PCLs) for carcinogenic and noncarinogenic effects are determined based on the age-adjusted and young child exposure scenarios, respectively. The lowest value is then presented as the total surface water combined ($^{Tot}SW_{Comb}$) PCL on the TRRP website.

For water bodies where this level of contact is unlikely (e.g., industrial activity, shipping traffic, dry periods, accessibility) alternative exposure assumptions may be warranted. For Tier 2 or 3, the Tier 1 exposure assumptions should only be adjusted when the underlying assumptions are clearly not appropriate for a given water body, subject to TCEQ concurrence.

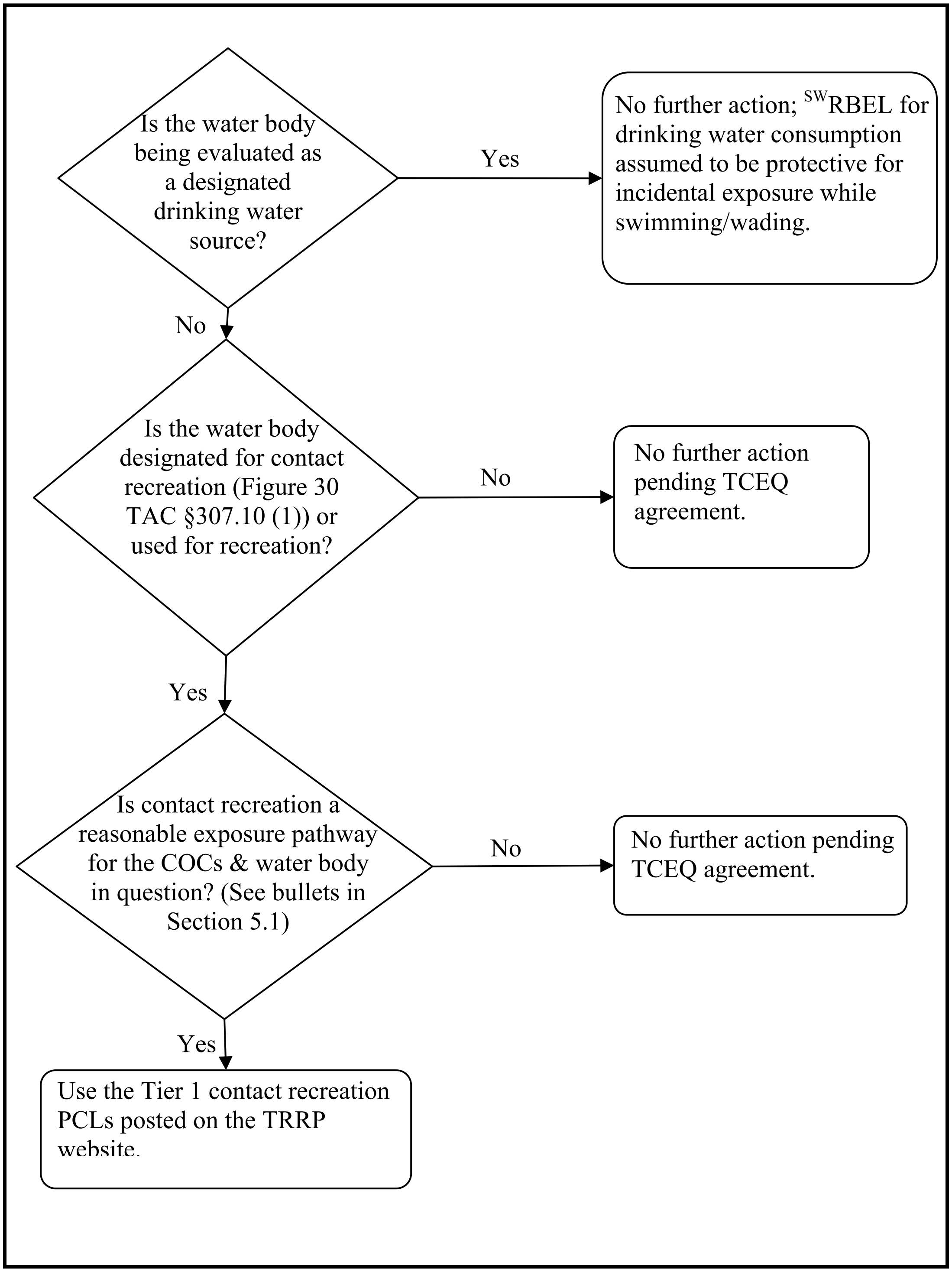


Figure 5-1. Determining Surface Water PCLs Protective of Human Health (Contact Recreation)

5.2 Determining Sediment PCLs Protective of Human Health

The rule (§350.71 (c)(7) and §350.75 (i)(15)) requires that sediment PCLs be established when the TCEQ determines that relevant exposure pathways are complete or are reasonably anticipated to be complete for a particular COC. With sediment contamination, the following human health exposure pathways are assumed to be potentially relevant:

- incidental ingestion of sediment
- dermal contact with sediment
- transfer of COCs from sediment to the tissue of finfish/shellfish within a water body

Except for rare situations, inhalation of COCs that may volatilize from sediment is not considered to be a pathway of concern. The approach recommended for addressing each of these human health pathways is discussed in more detail in the following sections.

5.2.1 Incidental Ingestion/Dermal Contact with Sediment

Individuals may potentially be exposed to COCs in sediment through incidental ingestion of and dermal contact with sediment while wading/recreating in a water body. The TCEQ has developed Tier 1 PCLs (see text that follows) that may be used to evaluate affected property sediments for these exposure pathways. Persons may propose Tier 2 or Tier 3 PCLs at their discretion, subject to TCEQ concurrence, to account for property-specific circumstances.

5.2.1.1 Affected Property Considerations. The TCEQ recommends that persons normally evaluate the affected property sediments for these pathways to determine if a response action is necessary. With appropriate justification for some locations, persons may argue that it is unreasonable to assume that these pathways are complete. Examples include industrial water bodies or water bodies with a large volume of shipping traffic. Certainly these pathways should be evaluated where the:

- water body in question is designated for a contact recreation use (See 30 TAC §307.10, Appendix A - Site-specific Uses and Criteria for Classified Segments); or
- water body is known to be used for recreation (swimming, wade fishing, water skiing, etc.).

Since persons are not expected to wade in deep water, the TCEQ assumes that the consideration of the sediment dermal/ingestion pathways is not relevant for areas where the water column depth is greater than 2 meters. In these instances, it may not be appropriate to evaluate the entire affected property sediments for this pathway. Obviously water depth will vary throughout the year for a variety of reasons. Persons should base the water depth decision (determination of the sediment exposure area) on the expected depth of the water body during a normal year during a period when persons are expected to recreate in the surface water body.

5.2.1.2 Exposure Assumptions for Tier 1 PCLs. The sediment PCL equations for evaluating incidental ingestion and dermal contact with sediment, and the pathway specific exposure assumptions used in the development of the TRRP Tier 1 PCL values, are provided in Table 5-3. Although exposure conditions can undoubtedly vary across water bodies, the values are intended to represent a reasonable high-end estimate of exposure, consistent with the approach used in the development of other Tier 1 PCLs. Childhood exposure to sediment was evaluated for non-carcinogenic compounds. For carcinogens, an age-adjusted scenario (where exposure begins in childhood and continues through to adulthood) was evaluated. This approach is conservative and allows for the development of a single sediment PCL for each COC that is protective of both carcinogenic and non-carcinogenic (systemic) health endpoints. The residential contact equations (RBEL-2, dermal contact with COCs in soil; and RBEL-3, ingestion of COCs in soil) in TRRP (Figure 30 TAC §350.74 (a)) were used to calculate risks/hazards for the sediment exposure pathway. While TRRP soil exposure assumptions were generally applied in calculating the sediment PCLs, several of the exposure assumptions applied for sediment differ from those assumed for soil (e.g., exposure frequency, adherence factors). These sediment-specific assumptions are also detailed in Table 5-3.

Table 5-3. Exposure Assumptions and Tier 1 PCL Equations for Incidental Ingestion and Dermal Contact with Sediment (Contact Recreation Sediment Pathway)

PCL Equation for the Incidental Ingestion of Carcinogenic COCs in Sediment:

$$^{Sed}SED_{Ing-c}\ PCL\ (mg/kg) = \frac{(RL)(ATc)(365\ days/yr)}{(SF_o)(MF)(10^{-6}\ kg/mg)(IRsed.AgeAdj.rec)(EF.sed.rec)(RBAF)}$$

PCL Equation for the Incidental Ingestion of Noncarcinogenic COCs in Sediment:

$$^{Sed}SED_{Ing-nc}\ PCL\ (mg/kg) = \frac{(HQ)(RfD_o)(BW.C)(AT.C.res)(365\ days/yr)}{(10^{-6}\ kg/mg)(IRsed.C.rec)(EF.sed.rec)(ED.C.rec)(RBAF)}$$

PCL Equation for Dermal Contact with Carcinogenic COCs in Sediment:

$$^{Sed}SED_{Derm-c}\ PCL\ (mg/kg) = \frac{(RL)(ATc)(365\ days/yr)}{(SF_d)(MF)(10^{-6}\ kg/mg)(DF.adj.sed)(EF.sed.rec)(ABS.d)}$$

PCL Equation for Dermal Contact with Noncarcinogenic COCs in Sediment:

$$^{Sed}SED_{Derm-nc}\ PCL\ (mg/kg) = \frac{(HQ)(RfD_d)(BW.C)(AT.c.res)(365\ days/yr)}{(10^{-6}\ kg/mg)(SA.C.sed.rec)(AF.C.sed.rec)(EF.sed.rec)(ED.C.res)(ABS.d)}$$

Exposure Assumptions for Sediment Contact Exposure Pathway

Term	Exposure Factor	Default Values
EF.sed.rec	Exposure Frequency (days/yr)	39 (1) (13 weeks/yr, 3 days/week)
IRsed.AgeAdj.rec	Incidental Sediment Ingestion Rate – Age adjusted by body weight (mg-yr/kg-day)	120
IRsed.C.rec	Incidental Sediment Ingestion Rate – child (mg/day)	191
RBAF	Relative Bioavailability Factor (unitless)	1 (0.78 for arsenic)
SA.C.sed.rec	Skin Surface Area – child (forearms, hands, lower legs, feet, face) (cm^2)	2,200
AF.C.sed.rec	Child soil-to-skin adherence factor (0-6 years) (mg/cm^2-event)	3.3
RL	Risk Level (unitless)	10^{-5}
HQ	Hazard Quotient (unitless)	1
BW.C	Body Weight – child (kg)	15
AT.C.res	Averaging Time – noncarcinogens – child (yr)	6
ED.C.res	Exposure duration – child (yr)	6
RfD_o	Oral Reference Dose (mg/kg-day)	Chem-spec.
RfD_d	Dermal Reference Dose (mg/kg-day)	Chem-spec.
ATc	Averaging Time – carcinogens (yr)	70

Table 5-3. Exposure Assumptions and Tier 1 PCL Equations for Incidental Ingestion and Dermal Contact with Sediment (Contact Recreation Sediment Pathway)		
DF.adj.sed	Dermal adjustment factor – incorporates age-specific skin surface area, soil-to-skin adherence factors, and BW (mg-yr/kg-event)	3,410 [(2)]
SF_o	Oral Slope Factor $(mg/kg\text{-}day)^{-1}$	Chem-spec.
SF_d	Dermal Slope Factor $(mg/kg\text{-}day)^{-1}$	Chem-spec.
ABS.d	Dermal Absorption Fraction (unitless)	Chem-spec.
MF	Modifying Factor for SF_o (unitless)	1 (0.1 for arsenic)

[1] Upper percentile, TCEQ professional judgment and need to use high-end exposure frequency consistent with TRRP.
[2] $((SA_{0<6} \times AF_{0<6} \times ED_{0<6}) / BW_{0<6}) + ((SA_{6<18} \times AF_{6<18} \times ED_{6<18}) / BW_{6<18}) + ((SA_{18<30} \times AF_{18<30} \times ED_{18<30}) / BW_{18<30})$ = ((2,200 cm^2 x 3.3 mg/cm^2-event x 6 yr) / 15 kg) + ((3,500 cm^2 x 0.3 mg/cm^2-event x 12 yr) / 45 kg) + ((4,400 cm^2 x 0.3 mg/cm^2-event x 12 yr) / 70 kg) = 3,410 mg-yr/kg-event

The Tier 1 PCLs for sediment are intended to represent a fairly intensive level of contact, consistent with a reasonable maximum exposure scenario. For water bodies where this level of contact is unlikely (e.g., lack of suitable substrate, depth of the water body) alternative exposure assumptions may be warranted. For Tier 2 or 3, the Tier 1 exposure assumptions should only be adjusted when the underlying assumptions are clearly not appropriate for a given water body (e.g., documented observations of the actual frequency of recreational contact with sediment, or less intensive sediment exposure). As indicated previously, subject to TCEQ concurrence, persons may propose Tier 2 or Tier 3 PCLs to account for property-specific circumstances.

5.2.1.3 Tier 1 PCLs. The Tier 1 PCLs for sediment exposure (sediment ingestion and dermal contact) are available on the TRRP web page (http://www.tceq.state.tx.us/remediation/trrp/trrppcls.html). In development of these PCLs, some COC-specific considerations were used similar to the soil exposure pathways. For example, dermal exposure to sediment is not evaluated for those COCs which are defined as volatile organic compounds (vapor pressure ≥ 1 mm Hg). Also, certain sediment PCLs (e.g., lead, cadmium, dioxins/furans) are based on alternative chemical-specific technical approaches that are described more fully in TRRP (§350.76). When a Tier 1 sediment exposure PCL is not available for a given COC, the TCEQ will determine an appropriate value. The person should contact the TCEQ and provide some specific information about the COC and the site as specified in the procedure detailed in the TRRP guidance titled *Toxicity Factors and Chemical/Physical Parameters* (RG-366/TRRP-19).

The total combined sediment PCL protective of the contact recreation pathway is calculated as follows:

$$^{Tot}Sed_{Comb}\ PCL\,(mg/kg) = \frac{1}{(1/\ ^{Sed}Sed_{Ing}\ PCL) + (1/\ ^{Sed}Sed_{Derm}\ PCL)}$$

Values for both carcinogenic and noncarinogenic effects are determined, and the lowest value is presented as the total combined sediment ($^{Tot}Sed_{Comb}$) PCL on the TRRP website.

5.2.2 Fish and Shellfish Uptake from Sediment

Although the TSWQS consider the bioconcentration of a COC from water into fish or shellfish, in many instances affected sediments may also act as a continuing source of COCs to the water column, or more likely, may contribute to the accumulation of COCs in fish or shellfish tissue through direct or indirect (food chain transfer) contact with COC-affected sediment. Hence, human exposure through the consumption of affected fish or shellfish may also be a pathway of concern when addressing sediment

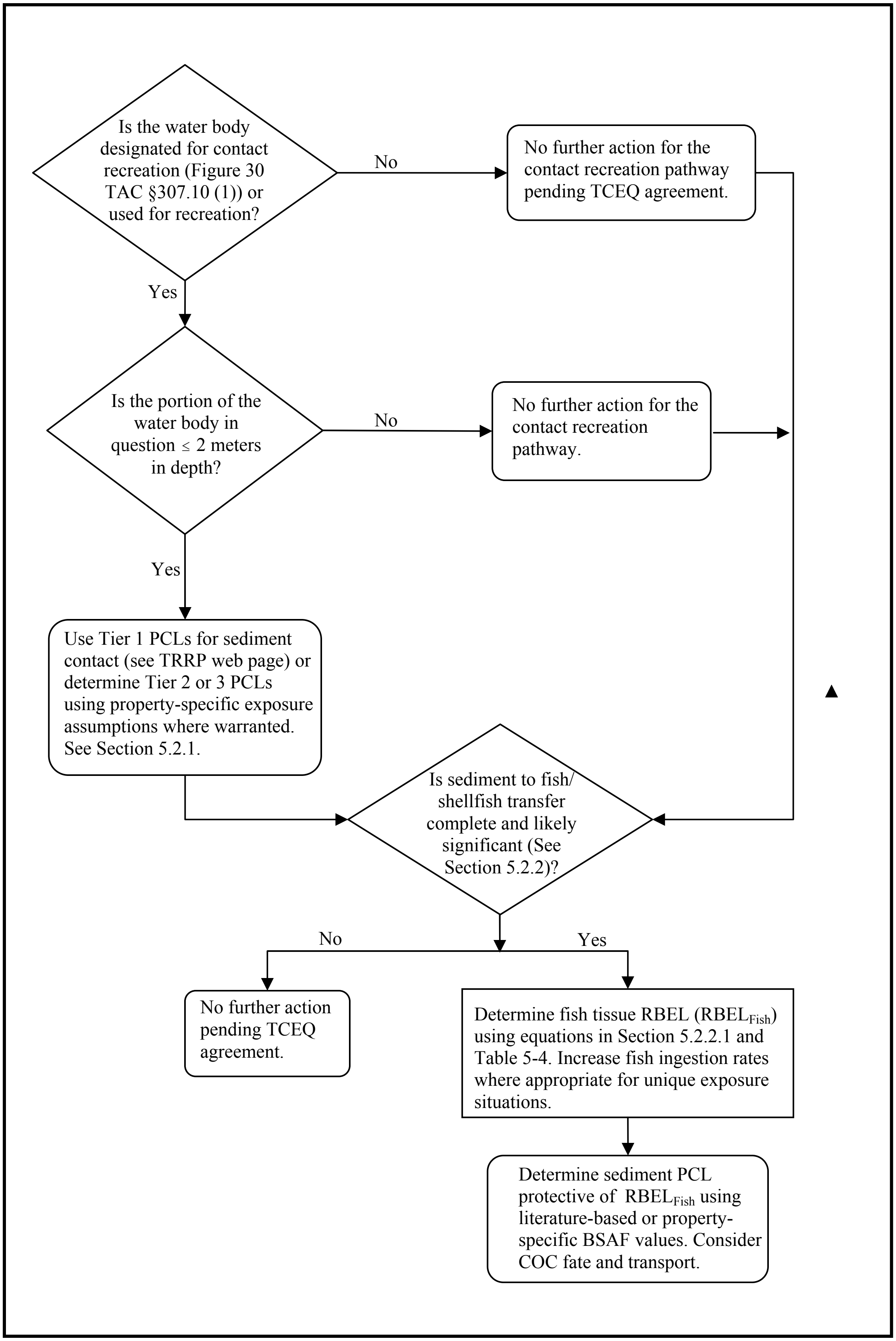


Figure 5-2. Determining Sediment PCLs Protective of Human Health

impacts. A property-specific assessment is needed to determine if this pathway is complete and likely to be significant. Persons should consider:

- fate and transport of the sediment COCs (COCs should be bioaccumulative and moderately to highly hydrophobic)
- depth of COCs within the sediment
- source and time of COC release to sediments (e.g., historical or ongoing release)
- trophic structure of the water body
- if the water body is a sustainable fishery or incidental fishery (has an aquatic life use, see Section 3.3.1)
- available tissue concentration information
- other property-specific factors

5.2.2.1 Determining the Fish Tissue RBEL. Where the pathway is determined to be complete and likely significant for a given COC, the person should determine a sediment PCL that is appropriate for that COC. The first step in addressing the pathway is to establish a fish tissue RBEL ($RBEL_{Fish}$). Equations (taken from U.S. EPA, 1989a, 1991d) and exposure assumptions that are specific to the TSWQS are adapted to TRRP and are used in calculating this RBEL, as presented in Table 5-4. Note that the fish tissue RBEL equation based on carcinogenic effects ($RBEL_{Fish\text{-}c}$) does not contain an averaging time adjustment (e.g., exposure duration of 30 years / averaging time of 70 years), and one should not be included in $RBEL_{Fish\text{-}c}$ calculations.

Table 5-4. Risk-Based Exposure Limit Equations for Human Ingestion of Fish Tissue

$RBEL_{Fish}$ (mg/kg):

Ingestion of carcinogenic COCs in fish tissue:

$$RBEL_{Fish\text{-}c} = \frac{RL \times BW_{(18\text{-}30)}}{SF_o \times IR_{Fish}}$$

Ingestion of non-carcinogenic COCs in fish tissue:

$$RBEL_{Fish\text{-}nc} = \frac{HQ \times BW_{(18\text{-}30)} \times RfD_o}{IR_{Fish}}$$

Where:

RL	Risk Level, 1×10^{-5}
$BW_{(18\text{-}30)}$	Adult body weight (kg), 70 kg
SF_o	Oral Slope Factor $(mg/kg\text{-}day)^{-1}$, chemical-specific
IR_{Fish}	Fish ingestion rate (kg/day), see discussion
HQ	Hazard Quotient, 1.0
RfD_o	Oral Reference Dose (mg/kg-day), chemical specific

*Note: For COCs with both carcinogenic and non-carcinogenic effects, it is necessary to determine $RBEL_{Fish}$ values for both endpoints, and to select the more conservative value to calculate the sediment PCL.

With the exception of IR_{Fish}, all exposure factors referenced in these equations are found in Figure 30 TAC §350.74 (a) of TRRP. The default fish ingestion rate (expressed in 0.010 kg/day for freshwater and 0.015 kg/day for marine waters) is specified in §307.6 (d)(3)(C) of the TSWQS. While these daily ingestion rates are appropriate defaults, §307.6 (d)(11)(H) describes how local differences in fish consumption rates may warrant the use of consumption amounts that differ from the default levels listed above. For example, the default fish ingestion rates roughly correspond with two fish meals per month; a rate that may significantly underestimate typical fish consumption for a given high-end recreational or subsistence population.

Another consideration is that the Texas Department of State Health Services (DSHS) uses 0.030 kg/day (about one 8-ounce meal per week) as their assumed fish consumption rate in determining if a water body should be placed under a fish consumption closure/advisory. Because a water body that is subject to a DSHS fishing advisory would not meet the narrative criteria of the TSWQS, it would be prudent to use a fish ingestion rate greater than the TCEQ default values in these situations where warranted. If the TSWQS default fish ingestion rates are used in evaluating the fish ingestion pathway under TRRP, they should not be combined with a "fraction ingested" term which would serve the purpose of lowering the assumed fish ingestion rate to account for the possibility that less than 100% of the 0.010 kg/day or 0.015 kg/day is provided by fish from a given water body. Thus, unless the water body does not meet the definition of a sustainable fishery under the TSWQS, assumed fish ingestion rates for a given water body should not be below the default TSWQS ingestion rates.

5.2.2.2 Determining a Sediment PCL Protective of the $RBEL_{Fish}$. After calculating an appropriate $RBEL_{Fish}$, it is necessary to consider the fate and transport processes that result in COC transfer from sediment to fish/shellfish in setting the sediment PCL. For many COCs, literature-derived or measured water body-specific biota-sediment accumulation factors (BSAFs) may be used to set the sediment PCL. In other cases, the sediment may be evaluated as a contributing source of COCs to the water column rather than as a direct source of uptake into aquatic organisms. There are a number of property-specific considerations that must be made in evaluating transfers from sediment to fish, and it is important to minimize uncertainty by incorporating water body-specific data wherever feasible. Various guidance documents are available in the scientific literature, which can serve as resources to evaluate the transfer of COCs from sediment to fish.

Using a site-specific or literature-derived BSAF, the general formula for deriving the sediment (fish ingestion) PCL is:

$$^{Sed}Sed_{Fish}\ PCL\,(mg/kg) = \frac{RBEL_{Fish}}{BSAF}$$

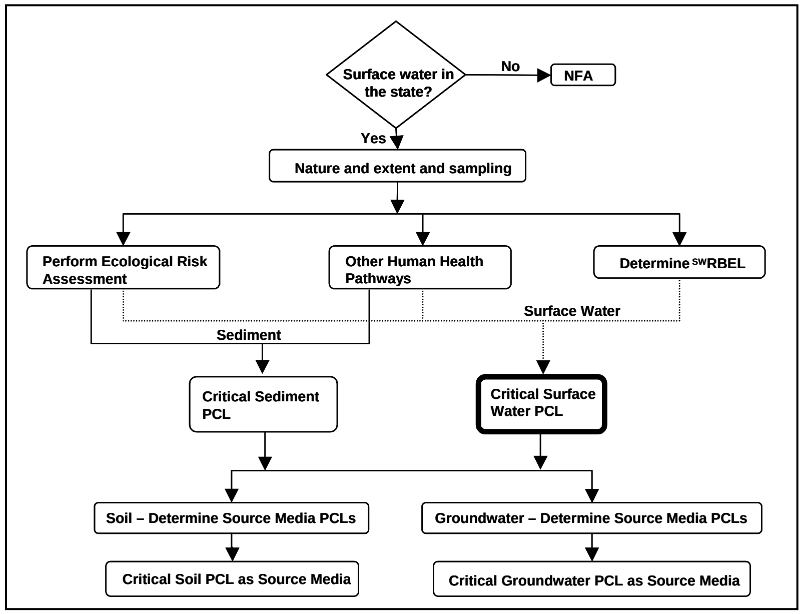
5.2.3 POEs in Intermittent Water Bodies; Is it Soil or Sediment?

For human health exposure pathways, the prescribed POE for sediment is within the upper one-foot of sediment beneath any surface water body meeting the definition of surface water in the state. However, for intermittent water bodies that may dry up from time to time, TRRP states that both sediment and soil POEs may apply (§350.37 (k)).

Where a water body is dry most of the year, persons should evaluate the media as soil and incorporate the data into the exposure point concentration determination and PCL comparison for soil. The decision to apply residential or commercial/industrial soil PCLs should be based primarily on the land use adjacent to the water body. Where an intermittent water body contains water most of the year, persons should consider the media as sediment and evaluate the contact recreation exposure pathway as appropriate. Since an intermittent stream does not meet the definition of a sustainable fishery, it would generally not be necessary to evaluate the transfer of sediment COCs to fish that could be consumed by humans. An exception to this rule is a classified segment since all classified segments are considered sustainable fisheries by definition.

6.0 DETERMINING CRITICAL SURFACE WATER AND SEDIMENT PCLS

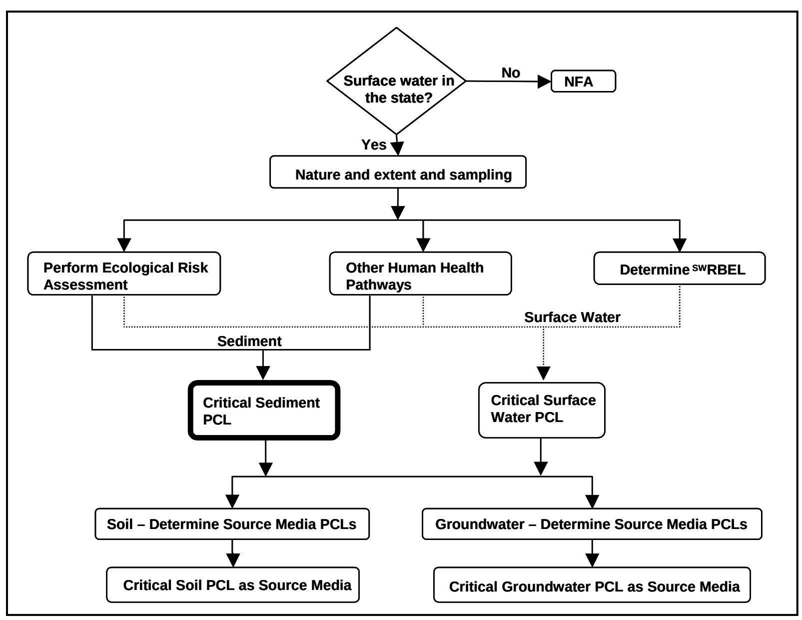
6.1 Critical PCLs for Surface Water



Up to this point, this guidance has presented text for determining surface water PCLs in the Ecological Risk Assessment process (Section 4.0), surface water RBEL protective of aquatic life (Section 3.0), surface water RBELs protective of humans that may consume fish or drinking water from a surface water source (Section 4.0), and where appropriate, surface water PCLs protective of humans that may be wading or swimming in surface water (Section 5.0). Remember that the surface water PCL (^{SW}SW) is the lesser of the ^{SW}RBEL and the surface water ecological PCL ($^{SW}SW_{Eco}$) for a given COC.

For a given COC, the lowest PCL from the analysis of all of these pathways is the critical surface water PCL (also consider background and MQL). If several surface water bodies have been affected by COCs, the critical PCLs for each water body may differ depending on the water body use (perennial, fishery, drinking water source, ecological receptors expected to be present, etc.). The lowest value for each affected surface water body will be the critical PCL for that particular surface water body.

6.2 Critical PCLs for Sediment and Sediment Risk Management Considerations



So far this guidance has presented text for determining sediment PCLs in the Ecological Risk Assessment process (Section 4.0), and where appropriate, sediment PCLs protective of humans that may be wading or swimming in surface water, or humans that may be indirectly exposed to sediment from the ingestion of fish and shellfish affected by COCs (Section 5.0).

For a given COC, the lowest PCL from the analysis of all of these pathways is the critical sediment PCL (also consider background and MQL).

There is no need to develop a sediment PCL if all of the following conditions are met:

- water body meets the exclusion for developing a PCL protective of benthic receptors as detailed in the Ecological Risk Assessment Guidance (and updates);

- sediment concentrations do not result in exceedances of the surface water PCL;

- sediment concentrations are not harmful to water column biota as detailed in the Ecological Risk Assessment Guidance (and updates);

- water body is an intermittent stream without perennial pools, meets habitat requirements for an expedited stream evaluation (detailed in the Ecological Risk Assessment Guidance, and updates), and does not have downstream impacts; and

- the TCEQ does not require an evaluation of this pathway for human health protection for the affected property in question.

If any one of these statements is not true, a PCL could be required depending on the results of the ERA, human health concerns, and the affected property sediment concentrations. Arguably, few water bodies will meet all of these conditions. More than likely, sediment PCLs will need to be derived for one or more particular pathways where sediment exposure pathways are complete or reasonably anticipated to be completed (§350.75 (i)(15)). It is important to remember that response actions are not necessary unless affected property concentrations exceed the sediment PCLs. Decisions regarding risk management for sediment involve more complex scientific and policy concerns than the traditional soil-based exposure scenario. Persons may consider the following when suggesting risk management decisions for sediment (SMWG, 1999, in part with TCEQ adaptations):

- decisions should be based on sound science taking into account site-specific characteristics;

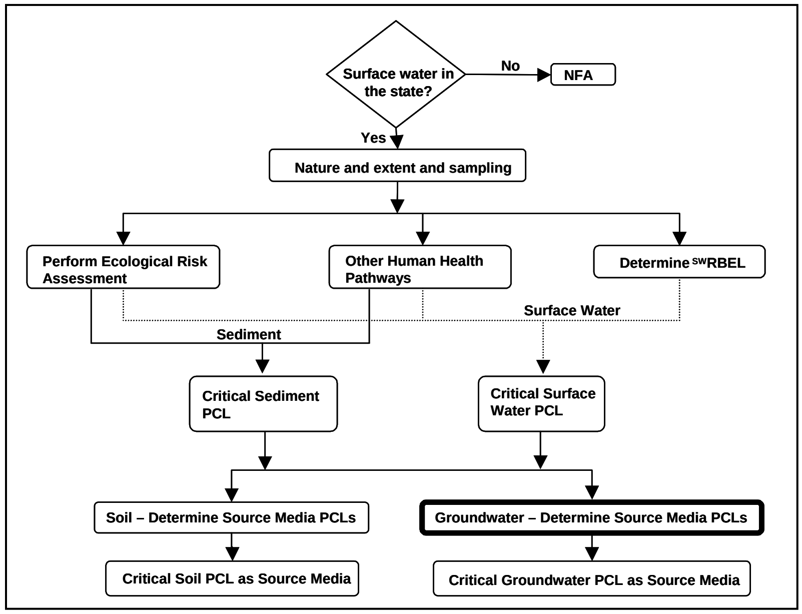
- response actions should be based on an understanding of COC movement and uptake and exposure pathways leading to potentially unacceptable risk for human and ecological receptors;

- based on site-specific information, sediment remediation options can include source control, removal, capping, natural recovery (attenuation), monitoring, Ecological Services Analysis (see Ecological Risk Assessment Guidance (and updates), §350.33 (a)(3)(B), and §350.77 (f)(2)), or some combination of these alternatives; and

- remediation decisions should consider hot spots, external COC sources, natural recovery rates, long-term effectiveness and permanence, recontamination potential, ease of implementation, depth of sediment above applicable PCLs, risks as a result of the implementation of a remedy, risks due to storm events, and TCEQ and Natural Resource Trustee acceptance.

7.0 DETERMINING SOURCE MEDIA PCLs

7.1 Groundwater Releases to Surface Water



This section of the guidance principally discusses the application of a dilution factor (DF) when comparing groundwater COC data to the ^{SW}SW. There will be little mention of the relationship of this pathway (groundwater-to-surface water) to sediments (see Section 7.2) and the ecological relevance of upwelling groundwater within a surface water body. Perhaps this is because environmental regulatory programs and academia have historically tended to isolate groundwater and surface water into separate areas of policy and regulation. However, persons should not overlook the connectedness of these systems. The location within the bed of the water body where surface water, sediments, biota, and subsurface interstitial water (either groundwater or advective surface water) interact is termed the transition zone (Greenberg et al., 2000). The transition zone provides a number of ecologically important functions including thermal, temporal, chemical buffering and degradation, food service, habitat, flow augmentation, and refugia (Gardner, 2000). Biological and physicochemical conditions within the groundwater, surface water, and transition zone are different. This will impact the mobility, bioavailability, and partitioning of COCs as they move from the groundwater through the sediments, and into the surface water column. Consideration of the groundwater/surface water transition zone from an ecological, hydrogeological, chemical process, and investigative perspective are all areas of rapidly developing science and policy (U.S. EPA, 2000c). Any future editions of this guidance (check the TRRP web site) may reflect these advances.

7.1.1 Reliance on the Surface Water RBEL and Use of a Dilution Factor

In accordance with §350.75 (i)(4), persons are required to establish protective concentration levels (PCLs) for COCs in groundwater that discharge to surface water (^{SW}GW). The groundwater-to-surface water PCL (^{SW}GW) is simply the surface water PCL (^{SW}SW) divided by the surface water dilution factor. In accordance with §350.75 (i)(4), the ^{SW}SW PCL is the lesser of the ^{SW}RBEL (established in accordance with §350.74 (h) and the surface water PCL protective of ecological receptors SW_{Eco} (established in accordance with §350.77). The rule also provides the following equation to establish the ^{SW}GW (Figure 30 TAC §350.75 (b)(1)):

$$^{SW}GW = \frac{^{SW}SW}{DF}$$

Here the exposure pathway description is discharge of Class 1, 2, or 3 groundwater to surface water. The source medium is Class 1, 2, or 3 groundwater, and the exposure medium is surface water. When affected groundwater discharges into a surface water body, the mixing of groundwater with surface water results in lower COC concentration in the surface water relative to the groundwater (i.e., dilution). The ratio of groundwater flow to total flow (surface water and groundwater) is defined as the DF. Hence the ^{SW}GW is equivalent to the appropriate water quality standard as specified at §307.6 of the TSWQS (or an appropriately justified derived value where there is no criterion for the particular COC), contact recreation human health PCL, or ecological surface water PCL, modified by a DF. Where the groundwater COC is chloride, sulfate, or TDS, persons should use Figure 3-6 to determine the ^{SW}GW. Selection and use of a DF will be discussed in the following sections.

What About Seeps?

Groundwater COCs may enter surface water and sediments at seeps or springs. Certainly, these releases should be evaluated for their potential impacts to human and ecological receptors that may be exposed to COCs associated with the seep. When evaluating these scenarios, we suggest the following considerations:

- Discharges from seeps and springs should be considered when evaluating the cumulative impact (e.g., runoff, groundwater discharges, and seep discharge) of COC releases to surface water and sediment.
- Persons may need to sample the seep directly if the groundwater flow is minimal such that well installation does not produce adequate groundwater. In this case, the seep or spring water data could be evaluated in the same manner as groundwater data from wells (with the application of a dilution factor where appropriate).
- Although the seep or spring discharge may be diluted in the receiving water, persons should consider that some ecological receptors may be directly exposed to the seep water and/or sediments (thus no dilution should be assumed). In some locations, ecological receptors could be attracted to these discharges where other water sources are not readily available.
- A case-by-case evaluation should be appropriate for most scenarios to account for property-specific variability.

Figure 7-1 displays the process for determining a DF for various surface water scenarios. If dilution is not allowed, the DF is set at one and the ^{SW}GW equals the ^{SW}SW. Mathematically, as the DF decreases, the quotient becomes larger and ^{SW}GW increases. As previously discussed, the appropriate ^{SW}RBEL will vary depending on the nature of the receiving water (freshwater or marine water) and the uses of the receiving water (aquatic life uses, drinking water, sustainable fishery). Therefore the ^{SW}GW for a particular COC will be based on the lowest ^{SW}RBEL value (depending on the various uses of the downstream receiving water(s), and the distance downstream or downgradient that surface water may be affected by the COC (based on fate and transport information)), or the lowest surface water ecological PCL.

7.1.2 Groundwater Releases to Surface Water – Determining When a Groundwater-to-Surface Water Dilution Factor May Be Used

The dilution factor should be set at one (no dilution) unless the provisions that would allow dilution are met. The discussions that follow detail the DFs allowed for various surface water types as provided in subparagraphs (C), (D), or (E) of §350.75 (i)(4). Generally, the person may establish a surface water DF when the concentration of a COC in groundwater at the zone of discharge to surface water exceeds the ^{SW}SW for any COC at the time the affected property assessment is conducted. For COCs which are listed as impairing adjacent or downstream surface water in the current 303(d) List, however, a DF other than one will <u>not</u> be allowed, as provided in §350.75 (i)(4)(A) (see Section 7.1.2.3). Typically the intention of the rule is that the person be allowed to use a DF when the eligibility conditions (see Sections 7.1.2.2 and

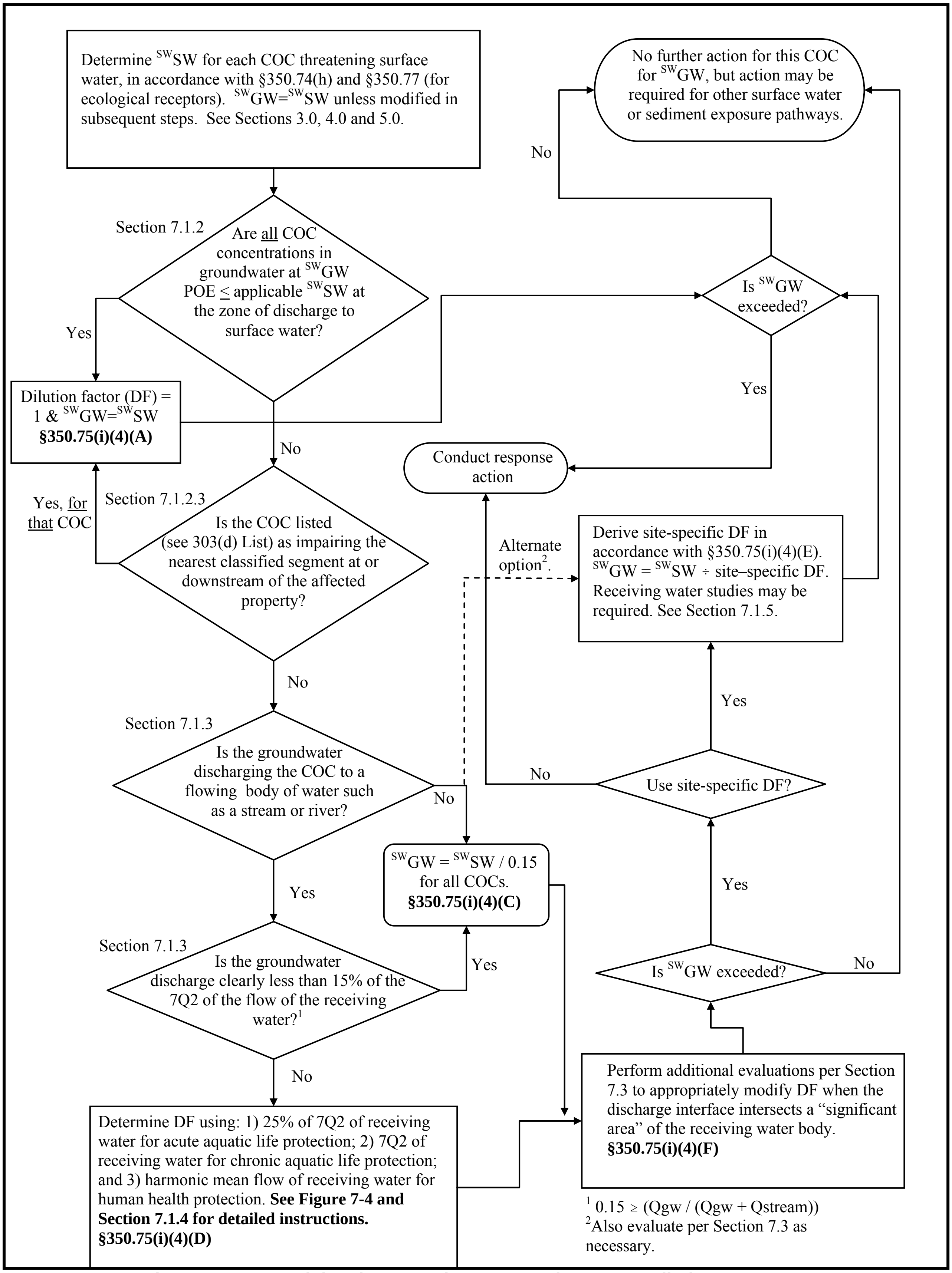


Figure 7-1. Determining the Groundwater-to-Surface Water Dilution Factor

Consideration of Surface Water PCLs Protective of Ecological Receptors
Where Groundwater is the Source Media

The text in Section 7.1 provides considerable detail regarding the use of a dilution factor in the determination of the ^{SW}GW PCL. With this approach, the dilution factor is applied to the $^{SW}RBEL$ protective of surface waters. The text also states that the compliance with the ^{SW}GW will be determined in a groundwater monitoring well placed immediately upgradient of the zone of groundwater discharge to surface water (Section 7.1.2).

What if the critical surface water PCL is an ecological PCL rather than a $^{SW}RBEL$?

In this case, the ecological PCL should be used with the application of the appropriate dilution factor to derive the ^{SW}GW PCL:

$$^{SW}GW = \frac{SW_{\mathrm{Eco}}}{DF}$$

What surface water data should be used for the ERA calculations for an ecological receptor?

If the source of COCs in surface water is groundwater, ambient surface water data <u>should not</u> be used for this pathway. Rather, groundwater monitoring well data should be used with the application of a DF (default or property specific). For example, assume that selenium is a COC in groundwater being discharged to surface water:

1. Start with the selenium concentration in groundwater at the point of discharge to surface water (generally in the monitoring well being used as the groundwater-to-surface water POE). For example, assume this value is 0.030 mg/L.
2. Estimate the surface water concentration (Groundwater concentration x DF). For example: 0.030 mg/L x 0.15 = 0.0045 mg/L. (Note: Because of dilution, the estimated surface water concentration will always be less than or equal to the measured groundwater concentration.)
3. Use the estimated concentration (from Step 2) in the ERA as the <u>surface water</u> exposure point concentration for the ecological receptor.
4. Determine the surface water ecological PCL (SW_{Eco}), where appropriate by conducting an ERA in accordance with §350.77 and the Ecological Risk Assessment Guidance. If the value in Step 2 is less than the SW_{Eco}, no further action is necessary for this pathway. For example, if the SW_{Eco} is greater than 0.0045 mg/L, then no further action is required. However, if the SW_{Eco} (assume a PCL of 0.0021 mg/L is determined for this example) is less than the estimated surface water concentration from Step 2, then a ^{SW}GW PCL must be calculated as described in Step 5.
5. If needed, determine the ^{SW}GW PCL using the formula indicated above. Continuing the example:

$$^{SW}GW = \frac{SW_{Eco}}{DF} = \frac{0.0021}{0.15} = 0.014 \ \ mg/L$$

6. Compare the ^{SW}GW PCL protective of ecological receptors with the selenium groundwater concentration (in the monitoring well where ^{SW}GW must be met since it is the ^{SW}GW POE) to determine if the ^{SW}GW PCL is exceeded, which indicates that a response action is necessary.

When should ambient surface water samples be collected and evaluated in an ERA?

Certainly, ambient surface water data can be and should be evaluated in the ERA wherever surface water impacts result from multiple pathways (spills, runoff) and/or historical contamination is present. The use of the well data and the application of a dilution factor only applies for the groundwater-to-surface water scenario.

7.1.2.3) of §350.75 (i)(4) are met. However, in certain instances, ^{SW}GW PCLs adjusted to account for dilution may not ensure human health and the environment are protected. In such a situation, the TCEQ will disallow the use of a DF. It is anticipated that such a TCEQ response will generally be a result of a specific concern regarding the level of uncertainty surrounding the toxicity and environmental behavior of a COC, or the presence of a receptor that is particularly susceptible to the COC. The regulatory authority for this is §350.71 (b)(1) where the person is required to ensure PCLs are protective of human health and the environment.

Figure 7-2 illustrates the relationship between the ^{SW}GW PCLE zone and other PCLE zones, plume growth, and the DF allowances depending on circumstances at the time the APAR is submitted.

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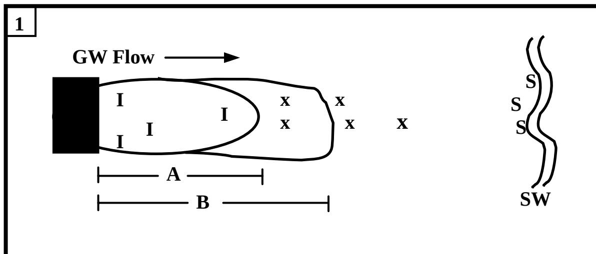
<tr><td>
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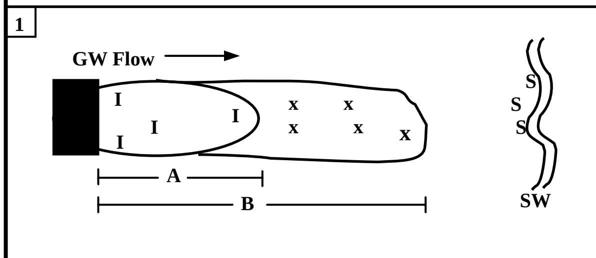
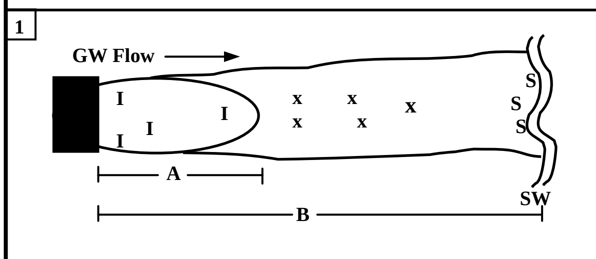
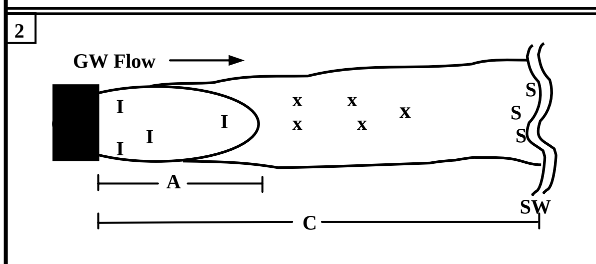
•Assume $^{GW}GW_{Ing}$ > ^{SW}SW.
•COC concentration in gw at S < ^{SW}SW.
•PCLE zone based on $^{GW}GW_{Ing}$ PCL at POE, I. POE for human health gw ingestion (I) is not equal to POE for ^{SW}GW (S).
•COC concentration at S < ^{SW}SW, therefore DF = 1, and ^{SW}GW = ^{SW}SW ÷ 1.</td></tr>
<tr><td>
</td><td>T_2 = After APAR submittal

•PCLE zone for gw ingestion can not expand (§350.32 (f) and §350.33 (f)(B)) unless a PMZ is allowed.
•COC concentration < $^{GW}GW_{Ing}$ can expand up to ^{SW}GW POE, S, if COC concentration in gw ≤ ^{SW}GW at S.</td></tr>
<tr><td>
</td><td>T_3 = Much after APAR submittal

•COC concentration in gw is now > ^{SW}GW at ^{SW}GW POE, S. This situation is <u>not allowed</u> under TRRP since the gw concentration > ^{SW}GW at ^{SW}GW POE (§350.33 (f) (D and E).
•Expansion of COCs < $^{GW}GW_{Ing}$ is allowed, but not above the ^{SW}GW PCL at S.</td></tr>
<tr><td>
</td><td>T_1 = APAR submittal

•Assume $^{GW}GW_{Ing}$ > ^{SW}SW.
•COC concentration in gw > ^{SW}SW at ^{SW}GW POE, S, therefore use of a DF is allowed.
•Be aware that DF allowed for all COCs (assuming no COC is on the 303 (d) list of impaired water bodies).</td></tr>
<tr><td>GW = groundwater
SW = surface water
x = groundwater monitoring well
A = COC concentration > $^{GW}GW_{Ing}$
B = COC concentration > ^{SW}GW
C = COC concentration > ^{SW}SW</td><td>I = POE for gw ingestion.
S = POE for ^{SW}GW
PMZ = Plume management zone
T = Time</td></tr>
</table>

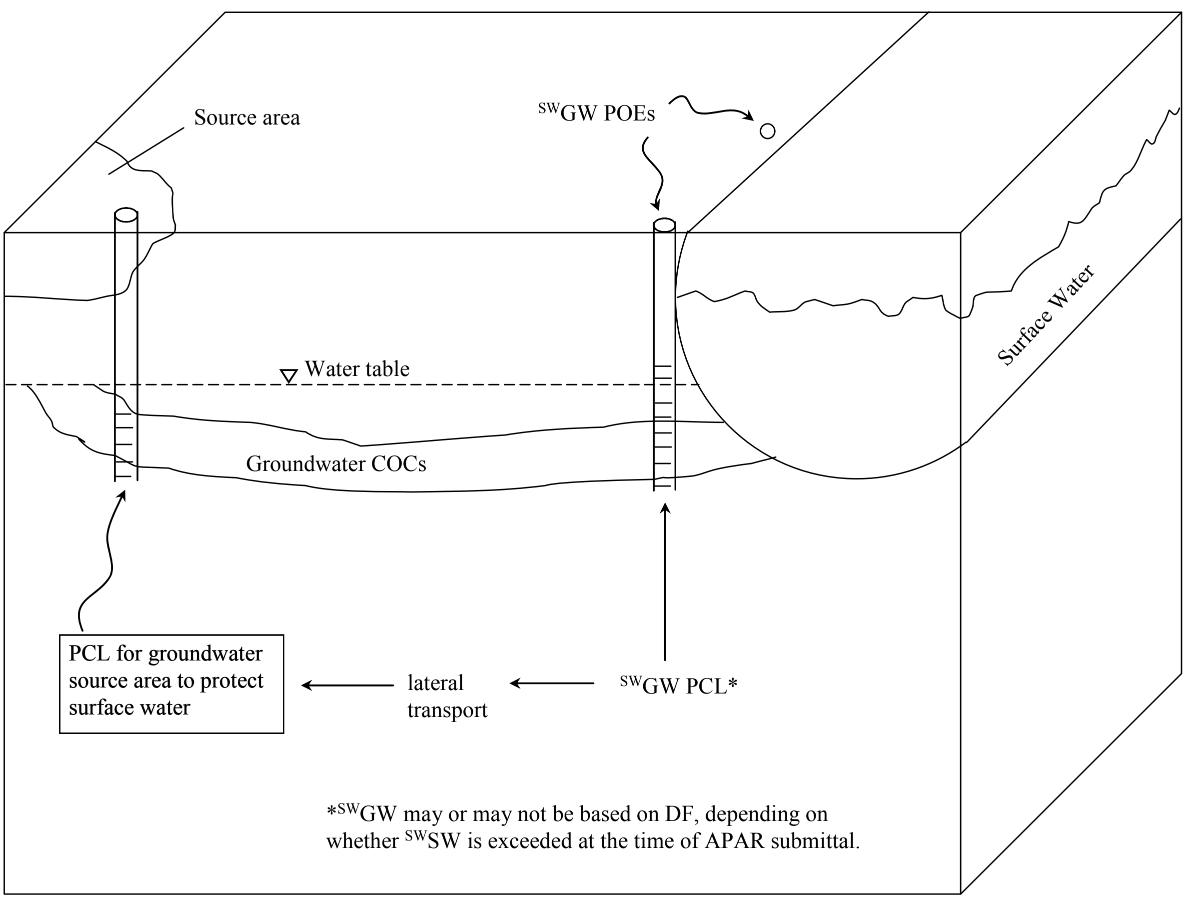
Figure 7-2. Application of the ^{SW}GW PCL

In Figure 7-2 there are two scenarios depicted: 1 and 2. Three different time events are depicted in Scenario 1 whereas just one time event is depicted in Scenario 2. Scenario 1 illustrates the situation where the surface water has not been affected at the time of APAR submittal (T_1). Subsequent to the APAR submittal, if the COC concentrations extend downgradient (COC concentrations < $^{GW}GW_{Ing}$ or via a plume management zone), the concentration at the ^{SW}GW POE cannot be allowed to exceed the ^{SW}RBEL (or ^{SW}SW). Two points are important. The first is that ^{SW}GW PCLs are only applicable at the ^{SW}GW POE, "S", and not at the upgradient monitoring location. Second, because the ^{SW}RBEL (or ^{SW}SW) was not already exceeded at the ^{SW}GW POE at the time of APAR submittal, no dilution can be considered.

In Scenario 2 of Figure 7-2, the situation is different. The ^{SW}RBEL (or ^{SW}SW) is already exceeded at the ^{SW}GW POE at the time of APAR submittal; therefore dilution can be used in setting ^{SW}GW, barring other property-specific factors to the contrary.

Figure 7-2 addresses the question of when can a DF potentially be used. In the first example, though illustrated, it is not acceptable for the person to allow COCs to discharge to surface water in excess of ^{SW}SW when the surface water had not already been impacted by the groundwater COCs. When it is unclear if such an impact will occur, appropriate groundwater monitoring should be initiated to evaluate the potential for impact to the surface water. An appropriate response action should be implemented in accordance with TRRP requirements where it becomes evident an impact will occur.

When the ^{SW}GW PCL is exceeded at the ^{SW}GW POE, it is appropriate to consider lateral groundwater transport under Tier 2 or 3 to back calculate a PCL to be applied to the groundwater source area (see Figure). Under Tier 2, the lateral groundwater transport consideration is referred to as a dilution attenuation factor (DAF) (See Tier 2 PCL equations, or the TCEQ guidance document titled *Application of Tier 1 and 2 NAF Models* (RG 366/TRRP-26). The process is analogous to establishing an attenuation action level at an attenuation monitoring point for a PMZ (see the TCEQ guidance document titled *Tiered Development of Human Health PCLs* (RG-366/TRRP-22).



7.1.2.1 Designing a Monitoring Well Network. The rule (§350.51 (f) and §350.37 (i)) requires that persons use concentrations measured in groundwater at or immediately upgradient of the zone of groundwater discharge to surface water to determine if COCs in groundwater have discharged to surface waters. This determination is performed using a network of monitoring wells located adjacent to (as close as feasible) and upgradient of the surface water body. To provide justification for using a particular monitoring well to evaluate the groundwater-to-surface water pathway, persons must demonstrate that the monitoring well is located upgradient of the surface water body by measuring the static water levels in the surface water and groundwater prior to each sampling event. The construction and placement of monitoring wells and the scheduling of sampling events should be adequate to identify any seasonal variations in hydrogeologic/ hydrologic conditions, and migration or other variations in the behavior or characteristics of COCs in groundwater within the PCLE zone, especially in situations where results may be greatly influenced by a gaining or losing stream.

7.1.2.2 Comparing Groundwater Data to ^{SW}SWs. The concentration of <u>each</u> COC detected in the ^{SW}GW POE wells(s) should be directly compared to the respective ^{SW}SW to determine if the concentration of the COC exceeds the ^{SW}SW. For comparison of COC concentrations in a well when there are multiple sampling events, the COC concentrations should be averaged by calculating an arithmetic mean. The mean concentration for the specific COC would then be directly compared to the respective ^{SW}SW. To account for "false positives" that may result from sampling or laboratory errors, persons should demonstrate that the concentrations in groundwater have exceeded the ^{SW}SW during two consecutive sampling events. For example, two consecutive events could be based on two consecutive monthly events, quarterly events, semiannual events, annual events, or historical data from consecutive monitoring events. Sampling events conducted during the affected property assessment may be considered for this demonstration to allow for adequate characterization of varying subsurface conditions.

> This text is only meant to provide direction when comparing groundwater data to the ^{SW}RBEL to determine if a DF is appropriate. It is not intended to provide guidance on determining a representative concentration for groundwater for comparison of groundwater data with the critical groundwater PCL. Persons should consult the TRRP guidance titled *Determining Representative Concentrations* (RG-366/TRRP-15) for guidance related to the procedures for determining the groundwater representative concentration.

If no COC concentrations measured at any ^{SW}GW POE wells(s) have exceeded their respective ^{SW}SW, then a DF is not allowed and the ^{SW}GW is equal to the ^{SW}SW (e.g., DF = 1; Figure 7-2, Scenario 1). If the concentration of any COC detected in a ^{SW}GW POE well exceeds the respective ^{SW}SW, a DF may be allowed for <u>all</u> COCs (Figure 7-2, Scenario 2) within that particular plume, except those listed on the current 303(d) List as impairing the nearest classified segment at or downstream of the affected property (as discussed below). When a DF is allowed, the COC-specific ^{SW}GW equals the respective ^{SW}SW divided by the DF. Refer to Section 7.1.1 of this guidance document for details on ^{SW}GW PCL calculations, and to the box in Section 3.5.1 regarding the consideration of solubility limits.

7.1.2.3 Groundwater Releases to Impaired Surface Waters. The rule specifies (§350.75 (i)(4)(A)) that persons assume the surface water DF = 1 for those specific COCs which are listed as impairing the nearest classified segment at or downstream of the affected property. Impaired water bodies are provided in the current 303(d) List. The 303(d) List is an inventory of impaired and threatened water bodies in the state which do not meet or are not expected to meet applicable provisions of the TSWQS. The list, which is updated periodically, is available at the following website: http://www.tceq.state.tx.us/compliance/monitoring/water/quality/data/wqm/305_303.html or by contacting the TCEQ Surface Water Quality Monitoring program. Persons should use the most recent 303(d) List that has been approved by U.S. EPA as indicated on the agency's web site at the time the APAR is submitted. Typically, the timing is that the most recent version of the list reflected on the agency's web site has not been approved by U.S. EPA, but the next most recent version has. Water bodies are listed by segment and segment name (or name of an unclassified water body within the watershed of a classified segment). Hence, it is critical to identify the first classified segment adjacent to or immediately downstream or downgradient of the groundwater release or potential release to surface water. Unless specified in the 303(d) List, segment descriptions are provided in Appendix C of the TSWQS and classified segment maps are available at: http://www.tceq.state.tx.us/comm_exec/forms_pubs/pubs/gi/gi-316/index.html.

The segment summary column in the 303(d) List describes the portion of the segment or water body that is listed and the reason for the listing. Water bodies are listed for a variety of water quality problems including elevated bacteria, low dissolved oxygen, elevated temperature, elevated metals and organics, elevated chloride, sulfate, and TDS, fish and shellfish consumption advisories and closures, ambient toxicity, and sediment toxicity. For application of a DF = 1, specific listings for metals (dissolved or total), other inorganics (such as chloride, sulfate, and TDS), and organics (including listings due to fish advisories and closures and sediment toxicity) are applicable.

A DF = 1 should be applied whenever the listed water body is the first designated segment that may receive the groundwater release. For example, consider segment 0610 (Sam Rayburn Reservoir) which was listed in 2004 for mercury in fish tissue. A DF = 1 would apply to groundwater COCs (where the mercury concentration is above the concentration of mercury in groundwater background) that directly discharge to Sam Rayburn. It would also be applicable where groundwater COCs are released to any creek that flows directly into the reservoir, but would not apply to releases to an upstream segment (segment 0611, Angelina River above Sam Rayburn) that then flows into segment 0610.

7.1.3 Groundwater Releases to Surface Water – Justification and Use of the Surface Water Dilution Factor of 0.15

If it has already been determined that any COC in a particular groundwater plume exceeds the respective ^{SW}SW, the rule specifies (§350.75 (i)(4)(C)) that a DF of 0.15 may be used for groundwater releases to non-flowing surface waters such as lakes, estuaries, tidal rivers; and fresh water streams and rivers where the groundwater discharge is <u>clearly less than 15%</u> of the 7Q2 stream flow. Thus, the default DF of 0.15 may automatically be applied to lentic surface waters such as lakes, estuaries, and tidal rivers, but requires some justification for releases to lotic surface waters such as rivers and streams. To apply the default DF of 0.15, the following condition must be satisfied:

$$0.15 \geq \frac{Q_{gw}}{\left(Q_{gw} + Q_{stream}\right)}$$

Where:

Q_{gw} = Groundwater PCLE zone-to-surface water discharge rate
Q_{stream} = Seven-day, two-year low flow (7Q2) of the receiving stream

As a conservative measure, at this point the rule makes no provision for the use of a harmonic mean flow (HMF) value (which is usually applied in the case of human health criteria) even where the ^{SW}RBEL is a human health surface water criterion. The HMF can be used in the case where the DF derived using a 7Q2 is clearly greater than 0.15 (see later discussion related to §350.75 (i)(4)(D) in Section 7.1.4 and Figure 7-4).

7.1.3.1 Determining Q_{gw}. To determine a dilution factor, first determine the influent flow of the PCLE zone discharging to the receiving surface water body. The influent flow of the PCLE zone (Q_{gw}) is based on the groundwater Darcy velocity (U_{gw}), the plume thickness (δ_{pi}), and the influent width (L_m) of groundwater COCs in excess of the ^{SW}SW at the point of discharge to the surface water body. The influent flow should be reported in cubic centimeters per second (cm^3/s). These parameters are described in Table 7-3 and Figure 7-5.

The groundwater Darcy velocity (U_{gw}) is equal to the hydraulic conductivity (K) of the affected groundwater-bearing unit multiplied by the lateral hydraulic gradient (i) of the affected groundwater-bearing unit. The hydraulic conductivity and the lateral hydraulic gradient should be for the affected groundwater-bearing unit near the point of discharge to the surface water body, unless the person demonstrates that use of data from another location is more representative. The hydraulic conductivity should be determined in accordance with *Groundwater Classification* (RG-366/TRRP-8).

The lateral hydraulic gradient of the affected groundwater-bearing unit is the change in hydraulic head over horizontal distance. Lateral hydraulic gradient is typically determined from a potentiometric surface elevation contour map, constructed from water level measurements in three or more monitoring wells screened across the affected groundwater-bearing unit. Groundwater flows perpendicular to the potentiometric surface contours, and the gradient is the decrease in head between two points, divided by the distance between the two points along the flow path. In groundwater-bearing units where the flow is significantly affected by tidal fluctuations, mean hydraulic gradients can be determined using data filtering methods presented by Serfes (1991).

The thickness (δ_p) is equal to the vertical extent of concentrations in groundwater that exceed the ^{SW}SW. The thickness (δ_p) should be measured using nested monitoring wells or estimated as the total thickness of the affected groundwater-bearing unit. If δ_p is estimated, the total thickness of the affected groundwater-bearing unit should be determined in the same area used to determine Darcy velocity. The thickness of the area in excess of the ^{SW}SW discharging to the surface water body (δ_{pi}) should be the lesser of δ_p or 1.5 times the depth of the surface water body (see Figure 7-5 for examples). A cross-section of the affected groundwater-bearing unit and the surface water body should be provided with the APAR in order to verify the thickness of the plume area in excess of the ^{SW}SW discharging to the surface water body.

L_m is equal to the lateral extent of concentrations in groundwater, at or near the point of discharge to the surface water body, that exceed the ^{SW}SW. See Figure 7-3. This width may be determined by direct measurement or by reasonable interpolation of groundwater concentrations between wells. An isoconcentration map should be constructed and submitted with the APAR in order to verify L_m at the point of discharge.

Two questions should be considered when determining L_m:

> *Should the L_m be based on the largest L_m for all COCs or should a separate L_m be determined for each COC (and hence a separate Q_{gw} for each COC)?*

Out of simplicity, a single Q_{gw} should be determined based on the COC with the widest L_m (see Figure 7-3, example A). However, persons may determine a COC-specific L_m (and Q_{gw}) particularly where the width for one COC is significantly less compared to other COCs. Obviously this will increase the complexity of the ^{SW}GW determination.

> *Groundwater plumes vary in shape based on a variety of factors and may be narrower at their leading edge with a wider portion within a short travel time from the surface water body. Should we use the widest portion of the area of the plume in excess of the ^{SW}SW, or the width closest to the surface water body to determine the L_m?*

The answers to this question will vary depending on whether a plume management zone (PMZ) is approved (§350.33 (f)(4)) under Remedy Standard B. First let's assume there is no PMZ. In this case, remember that:

- COC concentrations above the critical groundwater PCLs ($^{GW}GW_{Ing}$ in Figure 7-2) may not migrate (vertically <u>or</u> horizontally) beyond the existing boundary of the PCLE zone (in this instance, ^{SW}GW is not the critical PCL in Figure 7-2). See §350.32 (f) and §350.33 (f)(B).
- COCs may not migrate to surface water at concentration levels above the ^{SW}GW.
- COCs must already exceed the ^{SW}SW at the ^{SW}GW POE in order to use a DF.

As shown in Figure 7-3, example A, it would be more conservative to measure the L_m at the widest point perpendicular to the groundwater flow, rather than that at the tip of the plume. Certainly if the plume will be constricted closer to the surface water body (e.g., groundwater enters a buried stream channel as shown in Figure 7-3, example B), a smaller L_m is appropriate. If the $^{GW}GW_{Ing}$ PCLE zone is wider than the area of the plume in excess of the ^{SW}SW, persons may use the width of the $^{GW}GW_{Ing}$ PCLE zone if this is easier (see Figure 7-3, example C). If it is evident that the width of COCs exceeding the ^{SW}SW will be wider than the $^{GW}GW_{Ing}$ PCLE zone by the time the surface water is reached (e.g. lateral wells become affected), it is not appropriate to use a narrower width (see Figure 7-3, example D).

Conversely, let's assume that a PMZ has been proposed and approved. The PMZ includes the existing groundwater PCLE zone plus an additional allowable distance since the POE is moved to the downgradient boundary of the PMZ. As long as the PMZ size is not limited by other factors specified at §350.37, the PCLE zone could expand downgradient up to the surface water POE as long as the ^{SW}GW PCL is <u>not</u> exceeded at the ^{SW}GW POE (see Figure 7-2). TCEQ suggests using the greater of the PMZ width or the $^{GW}GW_{Ing}$ PCLE zone width as the value for L_m (see Figure 7-3, examples C and E regarding the determination of L_m).

7.1.3.2 Determining Q_{stream} (Non-Tidal). The 7Q2 is defined (see 30 TAC §307.3) as the lowest average stream flow for seven consecutive days with a recurrence interval of two years, as statistically determined from historical data. The TCEQ has calculated 7Q2 flows (and harmonic mean flows) for USGS and IBWC gages in the State of Texas and has posted the information in a Paradox table on the agency's TRRP web site (link listed with this guidance document). This table will be updated periodically. Persons may find this table a useful source of flow data for both classified and unclassified water bodies.

Releases to classified segments. As specified in the rule (§350.75(i)(4)(C)), the person should use the 7Q2 flows as listed in Appendix B of the TSWQS for groundwater discharges directly to a classified segment as listed in Appendix C of §307.10 of the TSWQS, as amended. In Appendix B, if multiple gages are listed for a segment, the gages are sequenced from a downstream to upstream order. The person should use the 7Q2 value for the nearest gage upstream of the affected property.

The introductory paragraph to Appendix B (of the TSWQS) explains that the flow values presented in the table are intended as guidelines and may be recalculated as additional data become available. The table mentioned above (on the agency's web site) contains such updated flows. If the affected property is downstream of one of these gages, the 7Q2 flow for the nearest upstream gage may be used. In this situation, no additional review of the flows by the TCEQ will be necessary. Note that if the 7Q2 in the table is less than 0.1 cfs, a 7Q2 of 0.1 cfs should be used because the receiving water is a classified segment. If there is no USGS gage upstream of the affected property, flow data from a downstream gage or other source may be used, but additional review by TCEQ staff will be necessary.

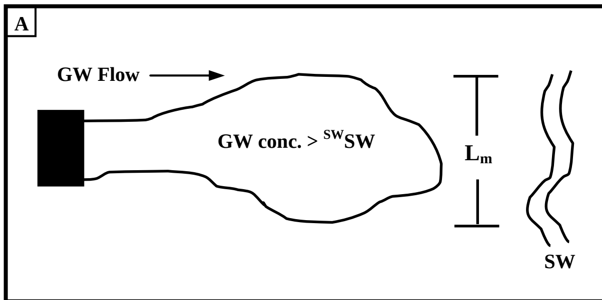
Releases to unclassified water bodies. For groundwater discharges which are not directly to a classified segment, property-specific 7Q2 values must be determined for the water body directly receiving the groundwater discharge. The Paradox table posted on the agency's TRRP web site (link listed with this guidance document) is a good place to start in determining the property-specific 7Q2. If the affected property is downstream of one of the gages in the table, the 7Q2 flow for the nearest upstream gage may be used. In this situation, no additional review of the flow by the TCEQ will be necessary. In the case of an unclassified water body, if the 7Q2 in the table is less than 0.1 cfs, the stream is not considered to be perennial. If there is no USGS gage upstream of the site, flow data from a downstream gage or other source may be used, but additional review by TCEQ staff will be necessary. For more information on how to calculate the 7Q2, see the section of the agency's Implementation Procedures document titled "Determining the 7Q2". Documentation related to the value determined should be included with the APAR (such as gage data, flow measurements, historical data, and calculation methodology).

Releases to Intermittent Streams. By definition (see §307.3), an intermittent stream has a 7Q2 of less than 0.1 cfs or goes dry for at least one week during most years. Hence, a 7Q2 of 0.1 should be assumed in the calculation of the Q_{stream} in most cases. An exception would be the case where groundwater is released to the headwaters of a creek. In this case, the person should attempt to derive a property-specific 7Q2 or assume a value of zero.

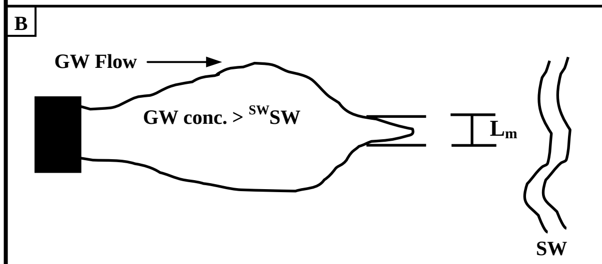
7.1.4 Groundwater Releases to Surface Water – Determining the DF Where Groundwater Flow is Clearly More Than 15%

Where the DF derived using the stream 7Q2 is clearly more than 0.15, the rule requires (§350.75 (i)(4)(D)) a more specific determination of the DF, depending on the type of water quality criteria being evaluated to determine the ^{SW}GW. The idea here is to identify the stream flow event and water quality standards combination that is most limiting for a given COC. In previous evaluations, the 7Q2 flow event was used regardless of the type of water quality standard in question. In any case, the default DF of 0.15 remains the minimum DF except as provided in §350.75 (i)(4)(E) as discussed in Section 7.1.5. The following sections detail the three possible options. Using these three approaches, the ^{SW}GW will be the lowest value calculated for a particular COC in groundwater. In all cases, documentation related to the flow value used or derived should be included in the APAR. Figure 7-4 displays the process for deriving the ^{SW}GW using these approaches. As an example, Tables 7-1 and 7-2 compare the ^{SW}GW PCL calculations where the DF (using the stream 7Q2) is clearly less than, and clearly more than, 0.15.

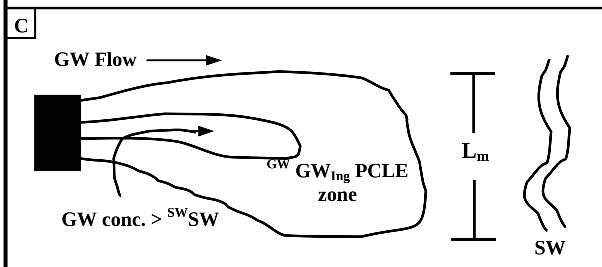
7.1.4.1 Determining the ^{SW}GW for an Acute Criterion. As stated in §350.75 (i)(4)(D), if the ^{SW}SW is based on an acute aquatic life standard or derived number (in the case where there is no TSWQS), the DF should be calculated using one-fourth (0.25 times) the 7Q2 using the 7Q2 for the classified segment (if the release is directly to a classified segment), or a property-specific 7Q2 in the case of a release to an unclassified water body.



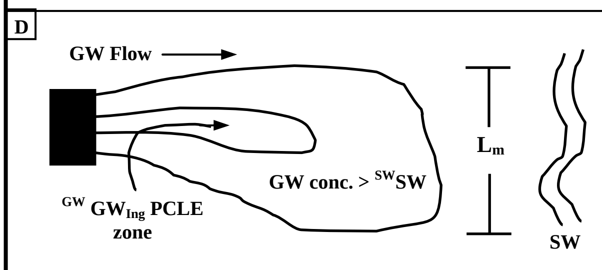
•Set L_m as the greatest width of COCs in excess of the ${}^{SW}SW$ even if the COC width is narrower closer to the surface water body.



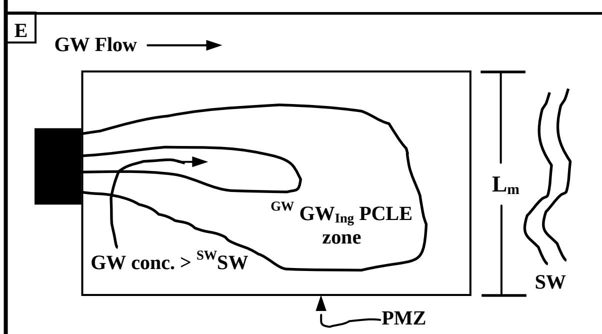
•Assume COC width > the ${}^{SW}SW$ is constricted down gradient due to a buried stream channel.
•Set L_m at the width of the stream channel.



•Assume width of COCs in excess of the ${}^{SW}SW$ is narrower than the ${}^{GW}GW_{Ing}$ PCLE zone.
•Although the width is smaller, set L_m as the greatest width of the ${}^{GW}GW_{Ing}$ PCLE zone where this is easier.
•This is not a mandatory requirement but is suggested since the ${}^{GW}GW_{Ing}$ PCLE zone is often better delineated than the width of COCs in excess of the ${}^{SW}SW$.



•Assume width of COCs in excess of the ${}^{SW}SW$ is wider than the ${}^{GW}GW_{Ing}$ PCLE zone.
.Must set L_m as the greatest width of COCs in excess of the ${}^{SW}SW$.



•Assume a PMZ has been approved.
•Set L_m as the widest expanse of the PMZ, unless the width of the ${}^{SW}SW$ is greater than the PMZ width.
•This is not a mandatory requirement but is suggested since the ${}^{GW}GW_{Ing}$ PCLE zone is often better delineated than the width of COCs in excess of the ${}^{SW}SW$.

GW = groundwater SW = surface water PMZ = Plume management zone
L_m = influent width of groundwater COCs in excess of the ${}^{SW}SW$ at the point of discharge to SW.

Figure 7-3. Suggested Distances to Set L_m

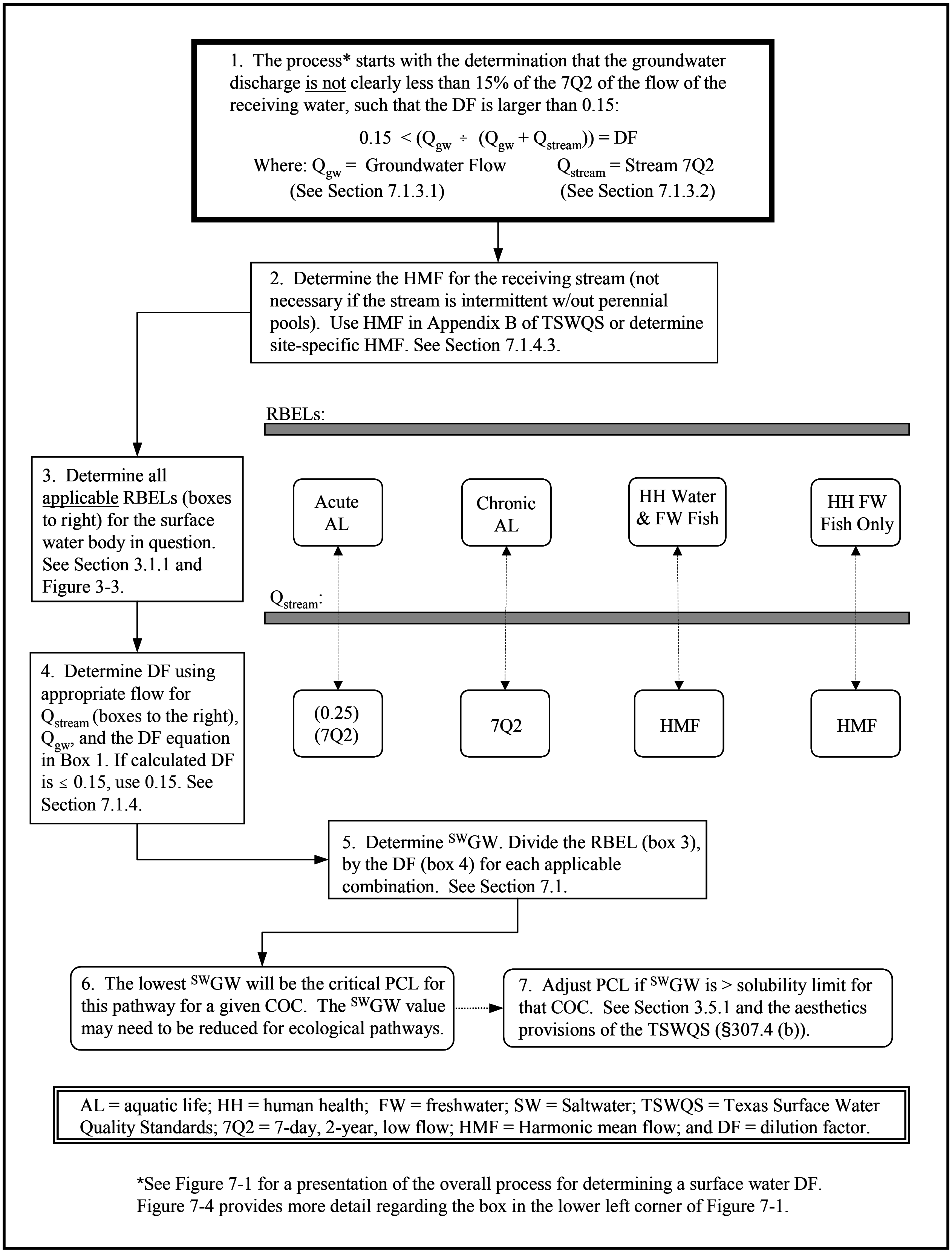


Figure 7-4. Determining the ^{SW}GW per 30 TAC §350.75 (i)(4)(D)

Table 7-1. Example PCL Determination Where the Groundwater Discharge ≤ 15% of Receiving Water 7Q2

Consider the following scenario. The receiving water is a perennial third order stream. It is not a drinking water source. Thus to determine the ^{SW}RBEL, the acute and chronic aquatic life criteria apply (or other values where there is no standard), and the human health criteria for freshwater fish only apply (or other values where there is no standard). Assume the Q_{gw} is 0.08 cfs. Assume the receiving stream 7Q2 flow is 1.6 cfs.

1. Verify that DF used should be 0.15.	Calculate $Q_{gw} \div (Q_{gw} + Q_{stream})$: $0.08 \div (0.08 + 1.6) = 0.05$. By rule, the default DF will be 0.15.[g]

Determination of the ^{SW}GW

		COC					
		Nickel	Selenium	Mercury	Anthracene	Benzene	Toluene
2. Determine the ^{SW}RBEL (mg/L) for each pathway.	Acute AL[a]	0.7874[d]	0.020	0.0024	6×10^{-4}[e]	1.3[e]	8.7
	Chronic AL[a]	0.0874[d]	0.005	0.0013	6×10^{-5}	0.130	2.9
	FW Fish only HH[b]	4.6	11	1.22×10^{-5}	110	0.106	200
3. Select the lowest RBEL and divide by the DF to determine the ^{SW}GW (mg/L)[f]. (Lowest RBEL ÷ 0.15)		0.583	0.033	8.13×10^{-5}	4×10^{-4}	0.707	19.3
4. Compare to the Solubility Limit (mg/L)[c].		---	---	0.030	0.0434	1.77×10^{3}	530
5. Set ^{SW}GW (mg/L) as the lowest value between the solubility limit and the values in step 3.		0.583	0.033	8.13×10^{-5}	4×10^{-4}	0.707	19.3

Footnotes
a - See the AL ^{SW}RBEL Table.
b - See the HH ^{SW}RBEL Table.
c - See Figure 30 TAC §350.73 (e). Solubility limit controls if ^{SW}GW is greater.
d - Based on an assumed hardness of 50 mg/L.
e - No value in the AL ^{SW}RBEL Table. For purposes of exercise, used chronic value x 10.
f - May also need to calculate a SW_{Eco} based on surface water values protective of ecological receptors (e.g., mink, heron). The surface water PCL protective of ecological receptors would then be modified by the 0.15 DF to determine the ^{SW}GW.
g - Persons could use a property - specific DF of 0.05 if adequately justified pursuant to §350.75 (i)(4)(E).

Abbreviations
7Q2 - 7-day 2-year low flow
AL - Aquatic life
cfs - cubic feet per second
DF - Dilution Factor
FW - Freshwater
GW_{Eco} - Groundwater PCL protective of ecological receptors.
HH - Human health
Q_{gw} - Groundwater flow
Q_{stream} - Stream flow
^{SW}GW - PCL for groundwater discharge to surface water

<table>
<tr><th colspan="8">Table 7-2. Example PCL Determination Where the Groundwater Discharge > 15% of Receiving Water 7Q2</th></tr>
<tr><td colspan="8">Consider the same scenario as provided in Table 7-1, except for the flow values. Assume the Q_{gw} is 0.08 cfs. Assume the receiving stream 7Q2 flow is 0.18 cfs and the receiving stream HMF is 0.4 cfs.</td></tr>
<tr><td colspan="2">1. Verify that the DF used should not be 0.15.</td><td colspan="6">Calculate $Q_{gw} \div (Q_{gw} + Q_{stream})$: 0.08 ÷ (0.08 + 0.18) = 0.31.
Thus the default DF of 0.15 <u>should not</u> be used. Three dilution factors should be determined that pair the acute AL value with 25% of the 7Q2, the chronic AL value with the 7Q2, and the HH value with the HMF. Each of these values will be used to calculate the ^{SW}GW for each type of water quality value.</td></tr>
<tr><td colspan="2" rowspan="3">2. Calculate a DF for each applicable standard type.</td><td colspan="6">DF for Acute AL: 0.08 ÷ (0.08 + 0.045) = 0.64.</td></tr>
<tr><td colspan="6">DF for Chronic AL: 0.08 ÷ (0.08 + 0.18) = 0.31.</td></tr>
<tr><td colspan="6">DF for HH value: 0.08 ÷ (0.08 + 0.4) = 0.17.</td></tr>
<tr><td colspan="8">Determination of the ^{SW}GW</td></tr>
<tr><td colspan="2" rowspan="2"></td><td colspan="6">COC</td></tr>
<tr><td>Nickel</td><td>Selenium</td><td>Mercury</td><td>Anthracene</td><td>Benzene</td><td>Toluene</td></tr>
<tr><td rowspan="3">3. Determine all applicable ^{SW}RBELs (mg/L).</td><td>Acute AL[a]</td><td>0.7874[d]</td><td>0.020</td><td>0.0024</td><td>6×10^{-4}[e]</td><td>1.3[e]</td><td>8.7</td></tr>
<tr><td>Chronic AL[a]</td><td>0.0874[d]</td><td>0.005</td><td>0.0013</td><td>6×10^{-5}</td><td>0.130</td><td>2.9</td></tr>
<tr><td>FW Fish only HH[b]</td><td>4.6</td><td>11</td><td>1.22×10^{-5}</td><td>110</td><td>0.106</td><td>200</td></tr>
<tr><td rowspan="3">4. Divide RBEL by the applicable DF (step 2) to determine the ^{SW}GW (mg/L).</td><td>Acute AL</td><td>1.23</td><td>0.03125</td><td>0.00375</td><td>9.4×10^{-4}</td><td>2.031</td><td>13.594</td></tr>
<tr><td>Chronic AL</td><td>0.282</td><td>0.016</td><td>0.0042</td><td>1.9×10^{-4}</td><td>0.419</td><td>9.355</td></tr>
<tr><td>FW Fish only HH</td><td>27.059</td><td>64.706</td><td>7×10^{-5}</td><td>647</td><td>0.624</td><td>1.17×10^{3}</td></tr>
<tr><td colspan="2">5. Compare to the Solubility Limit (mg/L)[c].</td><td>---</td><td>---</td><td>0.030</td><td>0.0434</td><td>1.77×10^{3}</td><td>530</td></tr>
<tr><td colspan="2">6. Set ^{SW}GW (mg/L)[f] as the lowest value between the solubility limit and the values in step 4.</td><td>0.282</td><td>0.016</td><td>7×10^{-5}</td><td>1.9×10^{-4}</td><td>0.419</td><td>9.355</td></tr>
<tr><td colspan="2">Basis</td><td>Chronic AL/ 7Q2</td><td>Chronic AL/ 7Q2</td><td>FW Fish HH/HMF</td><td>Chronic AL/ 7Q2</td><td>Chronic AL/ 7Q2</td><td>Chronic AL/ 7Q2</td></tr>
<tr><td colspan="8">Footnotes
a - See the AL ^{SW}RBEL Table.
b - See the HH ^{SW}RBEL Table.
c - See Figure 30 TAC §350.73 (e). Solubility limit controls if ^{SW}GW is greater.
d - Based on an assumed hardness of 50 mg/L.
e - No value in the AL ^{SW}RBEL Table. For purposes of exercise, used chronic value x 10.
f - May also need to calculate a SW_{Eco} based on surface water values protective of ecological receptors (e.g., mink, heron). The surface water PCL protective of ecological receptors would then be modified by the DF for chronic aquatic life to determine the ^{SW}GW.</td></tr>
</table>

Table 7-2. Example PCL Determination Where the Groundwater Discharge > 15% of Receiving Water 7Q2	
Abbreviations 7Q2 - 7-day 2-year low flow AL - Aquatic life cfs - cubic feet per second DF - Dilution Factor FW - Freshwater GW_{Eco} - Groundwater PCL protective of ecological receptors.	HMF - Harmonic Mean Flow HH - Human health Q_{gw} - Groundwater flow Q_{stream} - Stream flow ^{SW}GW - PCL for groundwater discharge to surface water

7.1.4.2 Determining the ^{SW}GW for a Chronic Criterion. As stated in §350.75 (i)(4)(D), if the ^{SW}SW is based on a chronic aquatic life standard or derived number (in the case where there is no TSWQS), the DF should be calculated using the 7Q2 for the classified segment (if the release is directly to a classified segment), or a property-specific 7Q2 in the case of a release to an unclassified water body. In essence, this is no different from the initial calculation as discussed in Section 7.1.3 as it relies on the 7Q2 flow.

7.1.4.3 Determining the ^{SW}GW for a Human Health Protective Criterion. As stated in §350.75 (i)(4)(D), if the ^{SW}SW is based on a standard for the protection of human health (fish only or fish and drinking water) or derived number (in the case where there is no TSWQS), the DF should be calculated using the HMF value for the classified segment, if the release is directly to a classified segment (see Appendix B of §307.10 of the TSWQS), or a property-specific HMF value in the case of a release to an unclassified water body. The HMF is defined in the TSWQS (see §307.3) as a measure of the mean flow in a water course which is calculated by summing the reciprocals of the individual flow measurements, dividing this sum by the number of measurements, and then calculating the reciprocal of the resulting number. As with the 7Q2, persons may consult the agency's Implementation Procedures for guidance on deriving the HMF. Also, TCEQ has calculated HMFs for USGS and IBWC gages and posted the information on the agency's TRRP web site at (link listed with this guidance document).

7.1.5 Groundwater Releases to Surface Water – Use of a Property-Specific Dilution Factor Less Than 0.15

If persons do not believe that the default DF of 0.15, as specified at §350.75 (i)(4)(C), is appropriate for the release in question, the rule does allow for the derivation of an alternate DF with appropriate documentation (§350.75 (i)(4)(E)). Possible methods suggested in the rule include, but are not limited to:

- analytical calculations
- numerical models
- receiving water and sediment sample analyses
- tracer studies
- other techniques upon the TCEQ's approval

TCEQ expects that analytical calculations or numerical models will be the methods typically employed for estimating groundwater dilution in receiving waters. A tiered process for determining a property-specific DF is described below.

7.1.5.1 Methods to Derive Tier 2 and Tier 3 Dilution Factors. The rule does not clearly state (in §350.75 (i)(4)) that the option to use the default (0.15 or one, if on 303(d) List) or property-specific dilution factors (§350.75 (i)(4)(E)) can be evaluated with a tiered concept. There is nothing restricting this approach as is indicated in the rule (per Figure 30 TAC §350.75 (b)(1)). The following text will present approaches for deriving alternate dilution factors using analytical calculations (Tier 2 models) or numerical models (Tier 3 models).

Tier 1 Dilution Factor. The Tier 1 (default) DF of 0.15 (§350.75 (i)(4)(C)) has already been described. This DF is intended to be conservative (i.e., underestimate true dilution) at the majority of affected properties. This Tier 1 DF may be used at any affected property where the true DF is less than or equal to 0.15 (except as indicated in Sections 7.1.2.3 and 7.1.4). As an alternative, a property-specific Tier 2 or Tier 3 DF may be used. As with any Tier 1 default, if the default DF is not protective (i.e., the true DF is greater than 0.15), then a Tier 2 or 3 DF must be used.

Tier 2 Dilution Factor. A property-specific DF can be calculated using a simple Tier 2 analytical model. The Tier 2 models for calculating a property-specific DF for flowing water bodies (i.e., streams and rivers), lakes, and tidal water bodies are shown in Figure 7-5. Conservative default values are provided for some model input parameters in Table 7-3, which also contains methods for estimating property-specific parameter values.

> Flowing water bodies with 7Q2 flow ≤ 100 cfs: For streams or rivers that have a 7Q2 ≤ 100 cfs, the groundwater flow is divided by the sum of the groundwater flow plus the 7Q2 to calculate the DF. See Figure 7-5 and Table 7-3 for more information on the parameters and their values.
>
> Lakes, tidal water bodies, and flowing water bodies with 7Q2 > 100 cfs: For these types of water bodies, a ratio of flows is still used, but the method for calculating the surface water flow is different. The flow of the entire surface water body is not used; instead, a portion of the surface water is considered to be in the mixing area of the discharge from the PCLE zone. That mixing area is bounded by the width of the affected groundwater discharge (perpendicular to the shoreline) and a thickness of 30 centimeters or the actual water body average depth, whichever is smaller. The remaining parameter, surface water velocity, may be measured within that mixing area or default values may be used as follows:
>
> - lake: 0.5 cm/s
> - tidal water body: 1 cm/s
> - large flowing water body (7Q2 > 100 cfs): $0.0035(7Q2)^{0.5}$ cm/s, where 7Q2 is in cm^3/s

Tier 3 Dilution Factor. For sites where the Tier 2 models yield overly conservative dilution factors or where the Tier 2 models are inappropriate for other reasons, Tier 3 DFs may be determined using alternate analytical models, numerical models, or direct property measurements. Persons using a Tier 3 model are encouraged to use an appropriate off-the-shelf model (when available) that includes a user's manual with an explanation of the model theory and numerical procedures, data needs, etc. U.S. EPA (2000c) discusses a variety of techniques for direct property measurements, including the use of seepage meters, mini-piezometers, natural tracer studies, and heat-flow meters.

7.1.5.2 Use of Surface Water Data to Determine a Property-Specific Dilution Factor. The rule language states that groundwater dilution in surface water may be estimated or measured using receiving water and sediment sample analyses. Since compliance with the surface water PCL is determined at the groundwater monitoring well, receiving water and sediment sampling cannot be used alone to derive an alternate DF. Determination of an alternate DF using property-specific measurements of COC concentrations requires concentration data for both surface water and groundwater. Samples should be collected in the area of the receiving water (and sediment) that is most likely to be impacted by the PCLE zone.

Although mixing with surface water is assumed by application of a default DF, there is no regulatory mixing zone defined (e.g., with set horizontal and vertical extent) for unauthorized releases of affected groundwater (compared to point source permitted releases to surface water). For the groundwater-to-surface water pathway in particular, surface water samples should be collected 1 to 2 feet off the bank or bottom for releases to lakes, tidal water bodies, and flowing water bodies with a 7Q2 greater than 100 cfs.

For flowing water bodies with a 7Q2 less than or equal to 100 cfs, composite samples of the entire water column may be collected in the area of the PCLE zone interface. More discussion of sampling in general, including sediment sampling, is provided in Section 2.0.

Using a variety of possible techniques, §350.75 (i)(4)(E) states that the person may measure or estimate the groundwater dilution in surface water using property-specific base flow conditions for groundwater, 7Q2 conditions for receiving streams, and critical mixing conditions for lakes, estuaries, and tidal streams. The idea is to simulate or evaluate groundwater dilution during or near worst-case conditions when the impact of groundwater on the receiving water is more evident due to local flow and tidal conditions. Because of the inherent variability in the flow regime and mixing characteristics for any given water body, persons are encouraged to conduct multiple monitoring events to best represent critical conditions.

Level of Effort for Stream Flow Determinations

TRRP (§350.75 (i)(4)(C)) states that a person may use a dilution factor (DF) of 0.15 for groundwater releases to freshwater streams and rivers where the groundwater discharge is clearly less than 15% of the 7Q2 stream flow. Here persons must demonstrate that the groundwater flow is less than 15% of the total flow (groundwater flow plus 7Q2 stream flow) - see formula in Section 7.1.3. Alternatively, TRRP states that a person may use a property-specific DF (§350.75 (i)(4)(E)) for releases to any type of water body.

Is there a difference in the level of effort needed to demonstrate that the assumed DF of 0.15 is appropriate compared to that needed to justify a property-specific dilution factor?

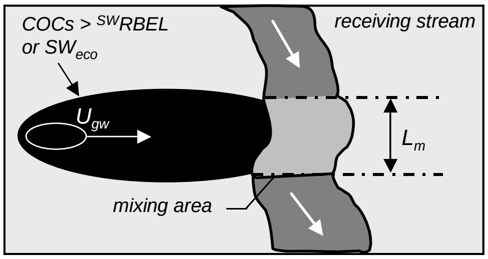
In reality, the level of certainty and conservatism may vary.

For instance, if the groundwater is released to the headwaters of a creek, we need to be very certain that the assumed DF of 0.15 is appropriate since potential groundwater impacts may be more pronounced in these small systems. Unless a property-specific 7Q2 can be derived with certainty, <u>a value of zero should be assumed</u>. Alternatively, where a property-specific DF is proposed, persons should be appropriately conservative in determining the 7Q2 (or HMF), Q_{gw}, and L_m. The more uncertainty there is for any one of these variables, the more conservative the particular value should be.

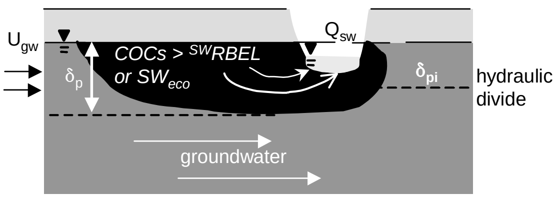
Regarding flow conditions for streams and run-of-river reservoirs, it is not absolutely necessary to monitor or model for a 7Q2 event. In fact, the chronic aquatic life criteria do not apply below a 7Q2 event, and the acute aquatic life criteria do not apply below a (0.25)7Q2 event. Additionally, the surface water human health criteria do not apply below the HMF. Sampling during such conditions may not be possible. Therefore, sampling should be conducted at times most likely to approach these conditions. In any event, the preferred approach is to obtain historical flow data for the stream being sampled. If this information cannot be obtained, sampling and/or flow measurements should not be performed if there has been a rainfall event in the previous week exceeding a trace (0.01 inches) of precipitation anywhere in the watershed above the sampling location. Otherwise, clear justification should be provided that elevated flow conditions have not occurred at the time of sampling. Where flow in a water body is artificially regulated to some extent by upstream dams or irrigation return waters, persons should ensure that sampling is not conducted during periods of high release rates. For monitoring in lakes and reservoirs with a water flow through residence time greater than 20 days during critical conditions, persons should consider seasonal variations in water level, wind speed, and direction that would impact groundwater dilution in surface water.

^{SW}GW: Groundwater-Surface Water Protection PCL: Flowing water bodies w/ 7Q2 flow rate <100 cfs

Plan View



Cross-section



^{SW}GW:

$$^{SW}GW = \frac{\left(^{SW}RBEL\right)}{DF}$$

Dilution factor:

$$DF = \left[\frac{Q_{igw}}{Q_{sw} + Q_{igw}}\right]$$

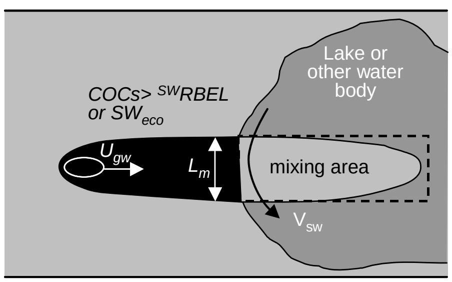
Surface water flow rate:

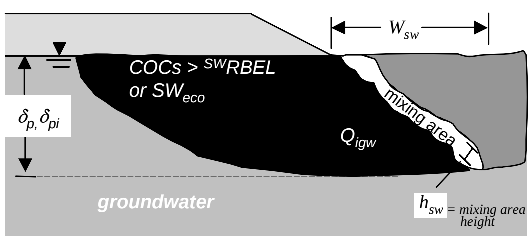
$$Q_{sw} = 7Q2 \text{ flow rate}$$

Groundwater flow rate:

$$Q_{igw} = \mathrm{U}_{\mathrm{gw}} \bullet \delta_{\mathrm{pi}} \bullet L_m \left[\frac{yr}{3.15\,x\,10^7\ s}\right]$$

^{SW}GW: Groundwater-Surface Water Protection PCL: Lakes, tidal water bodies, and large rivers (7Q2 flow rate $\geq$ 100 cfs)





^{sw}GW:

$$^{sw}GW = \frac{\left(^{sw}RBEL\right)}{DF}$$

Dilution Factor:

$$DF = \left[\frac{Q_{igw}}{Q_{sw} + Q_{igw}}\right]$$

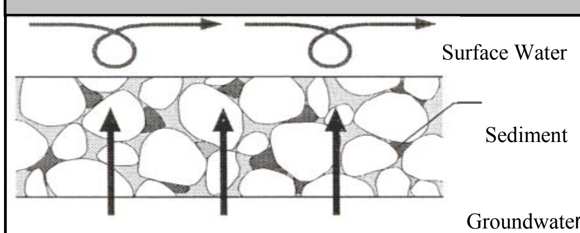
Surface water flow rate:

$$Q_{sw} = V_{sw} \bullet W_{sw} \bullet h_{sw}$$

Groundwater flow rate:

$$Q_{igw} = \mathrm{U}_{\mathrm{gw}} \bullet \delta_{\mathrm{pi}} \bullet L_m \left[\frac{yr}{3.15\,x\,10^7\ s}\right]$$

^{Sed}GW: Groundwater – Sediment Protection PCL



^{sed}GW:

$$^{sed}GW = {}^{sed}RBEL\ x\ K_{sed-w}\ x\ SWMF$$

$$K_{sed-w}\left[\frac{mg/L - GW}{mg/kg - sed}\right] = \frac{\rho_{sed}}{\theta + K_d\,\rho_{sed}}$$

Figure 7-5. Tier 2 Models for Surface Water and Sediment PCLs

Table 7-3. Parameter Selection Guidelines For Tier 2 Dilution Factor Models			
Input Parameter		**Typical Range**	
Symbol	**Description**		**Parameter Measurement or Estimation Guidelines**
PCLS AND RBELS			
^{SW}GW	Groundwater-surface water protection PCL (mg COC/L groundwater)	Calculated Value	Calculate as shown in Figure 7-5.
^{Sed}GW	Groundwater-sediment protection PCL (mg COC/L groundwater)	Calculated Value	Calculate as shown in Figure 7-5.
$^{SW}RBEL$	Risk-based exposure limit for surface water (mg COC/L surface water)	COC-specific	See Section 3.0 of this guidance.
$^{Sed}RBEL$	Risk-based exposure limit for sediment (mg COC/kg sediment)	COC-specific	See Sections 4.2 and 5.2 of this guidance.
DF	Groundwater/surface water dilution factor (mg/L in GW per mg/L in SW)	Calculated Value	Calculate as shown in Figure 7-5.
GROUNDWATER FLOW RATE (Q_{igw})			
Q_{igw}	Average influent flow of affected groundwater to receiving surface water body (cm^3/s)	Calculated Value	Calculate as shown in Figure 7-5.
U_{gw}	Groundwater Darcy velocity (cm/yr)	Site-specific	Calculate site-specific value based on the following equation: $U_{gw} = K \times i \ (3.15 \times 10^7 \ s/yr)$, where K and i are determined as specified below in this Table.
K	Hydraulic conductivity of affected groundwater-bearing unit (cm/s)	Site-specific	Measure values based upon either i) rising-head slug tests or ii) constant-rate aquifer pumping tests conducted on wells properly installed and developed in water-bearing unit. Re-evaluate test results if measured values fall outside typical range for the predominant soil type, as provided in the TRRP guidance titled *Procedures for Determination of Groundwater Resource Classification* (RG-366/TRRP-8).
i	Lateral hydraulic flow gradient of affected groundwater-bearing unit (cm/cm)	0.001 - 0.1	Measure lateral flow gradient in area beneath soil source zone based on triangulation among three or more monitoring wells or piezometers screened within affected groundwater-bearing unit.
δ_p	Thickness of affected groundwater (cm) in excess of the $^{SW}RBEL$ or the SW_{Eco}.	Site-specific	Measure using nesting monitoring wells or estimate as total thickness of affected groundwater bearing unit.
δ_{pi}	Thickness of affected groundwater (in excess of the $^{SW}RBEL$ or the SW_{Eco}) discharging to surface water stream (cm).	Site-specific	Estimate portion discharging to surface water as **minimum** of i) Total thickness (δ_p) (in excess of the $^{SW}RBEL$ or the SW_{Eco}) or ii) 1.5 x depth of surface water body.

Table 7-3. Parameter Selection Guidelines For Tier 2 Dilution Factor Models			
Input Parameter		**Typical Range**	
Symbol	**Description**		**Parameter Measurement or Estimation Guidelines**
L_m	Influent width of groundwater (in excess of the ^{SW}RBEL or the SW_{Eco}) at the point of discharge to surface water (cm).	Site-specific	Calculate site-specific value based on area of groundwater containing COCs at concentrations exceeding ^{SW}RBEL. Extrapolate between affected and "clean" wells to estimate width of affected groundwater. May be done on a COC-by-COC basis. See other suggestions in Section 7.1.3.1 and Figure 7-3.
SURFACE WATER FLOWRATE (Q_{sw})			
Q_{sw}	Flow of surface water through the surface water mixing area (7Q2 flow for a flowing stream with 7Q2 ≤ 100 cfs or mixing area flow for other water body, cm^3/s)	Calculated Value	Calculate as shown in Figure 7-5.
7Q2	Seven-day low-flow occurring on average every two years (cm^3/s)	Site-specific	Determine using Implementation Procedures. Also see discussion in Section 7.1.3.2.
V_{sw}	Average surface water velocity in groundwater discharge mixing area (cm/s)	≥ 0.5	Recommended default values: Lake: 0.5 cm/s Tidal Water: 1 cm/s Large River (≥100 cfs): 3.5 x $(7Q2)^{0.5}$ cm/s, where 7Q2 is in cm^3/s
W_{sw}	Distance from the shore extending into the surface water body through which affected groundwater discharges through sediment into surface water (cm)	Site-specific	Estimate as distance from shore to point where water depth is equal to estimated groundwater thickness (in excess of the ^{SW}RBEL or the SW_{Eco}). Use minimum of 5 feet and maximum of 50 feet.
h_{sw}	Depth of surface water mixing area above the affected groundwater discharge to surface water (cm)	Site-specific	Estimate depth as **minimum** of i) Average surface water depth in area of affected groundwater discharge, or ii) Default value of 30 cm.
GROUNDWATER – SEDIMENT PROTECTION PCL (^{Sed}GW)			
$K_{sed\text{-}w}$	Sediment-groundwater partition coefficient (mg/L-groundwater/mg/kg-sediment)	Calculated	Calculate as shown in Figure 7-5.
ρ_{sed}	Sediment bulk density (g-soil/cm^3-sediment) as dry weight		Measure or use TRRP default for soil of 1.67.
θ	Total sediment porosity (cm^3-pore space/cm^3-sediment)		Measure or use TRRP default for soil of 0.37.
K_d	Sediment-water sorption coefficient (g-H_2O/g-sediment)	Chemical-specific	For organics, estimate as: $K_d = K_{oc} \times f_{oc}$. For ionizing organics (e.g., chlorophenols), use K_d based on pH dependent partitioning coefficients for ionized and neutral forms (see Figure 30 TAC §350.73 (e)(1)(B)). For inorganics, use K_d as pH-dependent isotherms, based on measured groundwater pH (see Figure 30 TAC §350.73 (e)(1)(C)).

Table 7-3. Parameter Selection Guidelines For Tier 2 Dilution Factor Models			
Input Parameter		**Typical Range**	
Symbol	**Description**		**Parameter Measurement or Estimation Guidelines**
f_{oc}	Fraction of organic carbon in sediment (g-carbon/g-sediment)	0.001 - 0.03	Use default value of 0.01 or measure using ASTM D 2974-87 "Organic Matter of Peat and Other Organic Soils". If measured, convert % organic matter to f_{oc} as follows: f_{oc} = (% organic matter/100) x 0.58 Note: Organic matter assumed to be 58% carbon. Other appropriate methods may be proposed.
K_{oc}	Sediment organic carbon-water partition coefficient (g-H_2O/g-carbon)	Chemical-specific	Use K_{oc} from TRPP rule (see Figure 30 TAC §350.73 (e)).
SWMF	Surface water mixing factor (unitless)	Site-specific	Use default value of 1 or use alternate values based on literature or site-specific measurement.

In tidal bays and estuaries and large tidal rivers, differences in tides, river flow, wind intensity and direction, and thermal and saline stratification will impact groundwater dilution in surface water (U.S. EPA, 1991b). If the tidal water body is not stratified, critical conditions are generally a combination of low water slack at spring tide, and low flows for river input. With stratification, persons should consider periods of maximum and minimum stratification to determine which results in the lowest dilution at low water slack tide.

> **Tides**
>
> Ebb and flood tides - The incoming or rising tide is traditionally referred to as the flood tide because it floods the channel. The outgoing tide is referred to as the ebb tide.
>
> Spring tides - Tides of increased range or tidal currents of increased speed occurring semimonthly as the result of the moon being new or full. The average height of the corresponding low waters is called spring low water or mean low water springs.
>
> Slack water - The period of quiet water when its speed is near zero when the tide reverses from flood to ebb or vice versa. The term also is applied to the entire period of low speed near the time of turning of the current when it is too weak to be of any practical importance in navigation. Low water slack refers to the tide change from ebb to flood.

7.1.5.3 Consideration of Benthic Communities. See Section 7.2.1.

7.1.5.4 Bioaccumulative COCs. A bioaccumulative COC is defined (see §350.4 (8)) as a COC that has the tendency to accumulate in the tissues of an organism as a result of food consumption or dietary exposure and/or direct exposure (e.g., gills and epithelial tissue) to an environmental medium. The concern with bioaccumulative COCs in groundwater is that these groundwaters may discharge to surface water and, as a result, may present a problem to wildlife receptors and humans due to accumulation within the food chain. There are many examples within Texas and around the country where particular COCs are not detected in the water column, but are present at harmful levels in the sediment, as well as tissues of aquatic and terrestrial receptors.

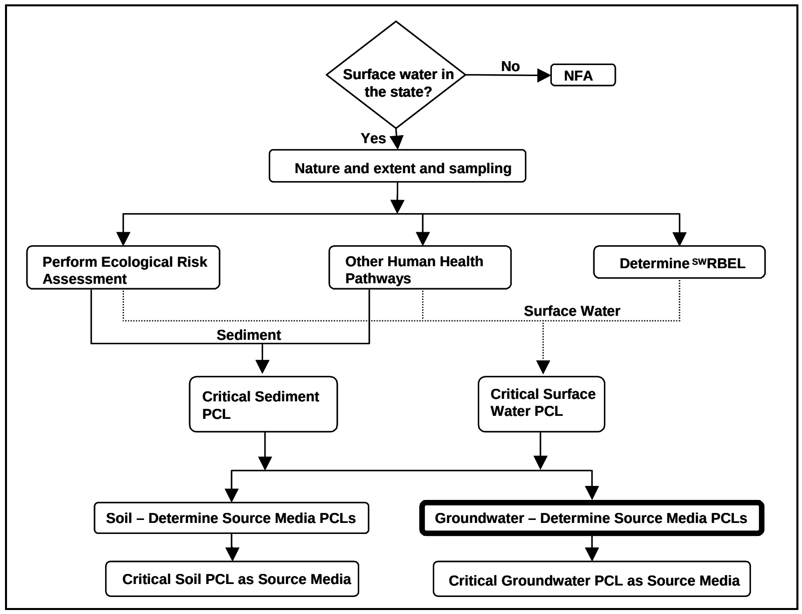
Thus, bioaccumulative COCs may need to be evaluated for this potential regardless of the appropriate property-specific DF that is determined. The first step in the evaluation is determining relevant complete pathways. For example, toxic criteria to protect human health for consumption of fish and shellfish apply only to waters with a sustainable or incidental fishery. If the water body in question has a fishing advisory or closure in effect due to potentially harmful levels of bioaccumulative COCs in fish and shellfish, a DF of 1 or the default DF of 0.15 (in the case where the segment is <u>not</u> listed in the 303(d) List for this reason) should be applied. Regardless of the DF, wildlife effects, in addition to potential human health concerns, may need to be evaluated. If after applying the appropriate DF, the estimated surface water concentrations are below the relevant surface water PCLs, further evaluation is not needed <u>except where</u> the COCs are expected to partition to the sediment and bioaccumulate in the food chain. The Ecological Risk Assessment Guidance (and updates) provides direction for evaluating COCs in surface water and sediment, including a list of bioaccumulative COCs and exceptions to when surface water evaluations are needed even though the COCs meet the relevant criteria (see Sections 3.4 and 3.5 of the Ecological Risk Assessment Guidance, and updates).

In cases where groundwater COCs include bioaccumulative COCs, the rule states (§350.75 (i)(4)(E)) that the executive director may require a receiving water study or empirical analysis to ensure that the release of that particular COC is not causing, or will not result in, harmful levels in the tissue of aquatic and terrestrial organisms that feed in the water body. Methods for determining tissue levels include both direct measurements in the field or lab (suited for evaluating current conditions but “causal link” may be difficult), and predictive modeling (appropriate for future potential and has uncertainties). Where sediment partitioning is of concern, sediment data will be required.

7.2 Groundwater Releases to Sediment

In many cases, it is suspected that groundwater releases to surface water will quickly dissipate to *de minimus* levels in the water column depending on local hydrology, tidal action, groundwater release rates, and degradation processes. For an active groundwater release, some COCs may persist at acutely toxic concentrations at the groundwater/surface water interface and in sediment pore water, and/or may accumulate in the sediments. A groundwater to sediment PCL (^{Sed}GW) should be developed that is protective of humans and ecological receptors depending on the critical sediment PCL for all pathways for a given COC.

7.2.1 Potential Impact to Benthic Communities



To address these concerns, the rule states (§350.75 (i)(4)(E)) that the TCEQ may require a receiving water study to ensure that benthic communities in the sediment are not adversely impacted. Benthic community studies and/or sediment studies should be performed in the context of a Tier 2 or Tier 3 ERA as required by §350.77. By definition, ecological PCLs (see §350.4 (27)) are primarily intended to be protective of more mobile or wide-ranging ecological receptors and, where appropriate, benthic invertebrate communities within waters in the state. The Ecological Risk Assessment Guidance (and updates) identifies the water body types that would not require the derivation of a sediment PCL and groundwater PCL (^{Sed}GW) that is protective of benthic communities. This does not preclude an evaluation of risks to higher trophic level organisms that may forage in these types of water bodies or nearby water bodies (that could become affected as a result of sediment COC transport). These types of water bodies that would not require a sediment PCL protective of benthic communities are described in the following bullets:

- Routinely dredged water bodies. This includes the portion of the channel that is actually dredged at a frequency of every three years or less. Risks to benthic communities that are potentially exposed to COCs in the sediments that are not routinely dredged (such as significant areas of shallow waters near the banks that are not used for shipping traffic) should be evaluated where the exposure pathway is complete.

- Intermittent streams (dry up completely at least one week a year) without perennial pools. (Intermittent streams with perennial pools are defined at §307.3 (a), as amended and discussed in the Implementation Procedures, as amended.)

- Water bodies with concrete-lined channels (bottom and sides).

- Segments 1006 and 1007 of the Houston Ship Channel as defined at §307.10, Appendix C, as amended, excluding tidal tributaries to these segments

- Classified and unclassified water bodies with a designation of no aquatic life use, as indicated in §307.10, Appendices A and D, as amended.

The person should consult the Ecological Risk Assessment Guidance (and updates) for more details. As this evaluation concerns potential sediment impacts in addition to potential surface water impacts, it should be performed regardless of the DF used (§350.75 (i)(4)(E)), since a Tier 2 or 3 ERA is required whenever there is a complete exposure pathway to surface water or sediment. Within the uncertainty analysis discussion of the ERA, persons may discuss the appropriateness of a sediment or surface water PCL (and a corresponding ^{Sed}GW or ^{SW}GW PCL) protective of benthic organisms given property-specific considerations such as bioavailability, fate and transport, sediment partitioning, dredging activities, and water body use.

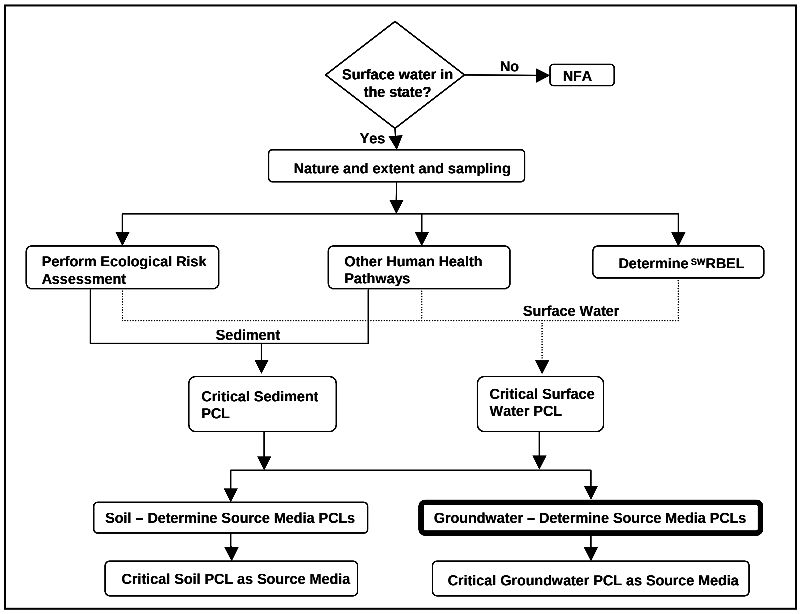
7.2.2 Potential Impact to Wildlife Receptors

Releases of COCs in groundwater to sediment that are transferred up the food chain to wildlife receptors should also be evaluated within the context of the ERA. Again, the agency's Ecological Risk Assessment Guidance (and updates) should be consulted to determine sediment PCLs protective of wildlife receptors. Here these PCLs will be derived as part of a Tier 2 (or optional Tier 3) ERA.

7.2.3 Conversion from a Sediment PCL to a Groundwater PCL

Once the critical sediment PCL has been established for a given COC (where appropriate), a source media PCL (for groundwater) should be derived if affected property sediment concentrations are in excess of the critical PCL. The formulas and variables presented in Table 7-3 and Figure 7-5 provide a Tier 2 model for the development of a ^{Sed}GW. Persons may propose a Tier 3 approach using alternate analytical models, numerical models, or direct measurements at appropriate locations. As with the DF approach for surface water, persons using a Tier 3 model are encouraged to use an appropriate off-the-shelf model (when available) that includes a user's manual with an explanation of the model theory and numerical procedures, data needs, etc.

7.3 Groundwater COC Discharges Across Significant Areas of a Surface Water Body



TRRP stipulates that the person may be required "to take appropriate action to ensure that discharging groundwater COCs do not result in exceedances of surface water quality standards in significant areas of the potentially affected surface water body" (§350.75 (i)(4)(F)).

Why is this a separate requirement in the rule? The person is allowed to account for dilution of groundwater with surface water when calculating a ^{SW}GW PCL based on a ^{SW}SW. Because the mixing of groundwater with surface water is not instantaneous, exceedances of the TSWQS may occur in surface water or sediment in the area of affected groundwater discharge where the full mixing has not yet occurred. This provision of the rule is designed to ensure these exceedances do not occur in significant areas of the surface water body.

When does this provision require explicit consideration? Larger areas of groundwater COC discharges may have the potential to cause surface water quality standards to be exceeded in significant areas of the potentially affected surface water body. The area that is significant depends on the type of water body:

Tidal water bodies	Discharge interface[6] extends more than 400 feet along the bank or shoreline; or area of the interface in the receiving water exceeds 30,000 square feet.
Lakes	Discharge interface extends more than 200 feet along the shoreline; or area of the interface exceeds 7,500 square feet.
Streams and rivers	Discharge interface extends more than 400 feet along the bank; or area of the interface exceeds a) 16,000 square feet or b) 0.25 x stream width x 400 feet.

The distance the interface extends into the water body (W_{sw} in Figure 7-5) may be estimated using the vertical thickness of the groundwater containing COCs in excess of the ^{SW}SW (δ_p in Figure 7-5). Any discharge interface meeting at least one of these criteria should be evaluated to ensure that exceedances of the TSWQS do not occur in significant areas of the surface water body. The text box that follows provides some examples of discharge interfaces that are considered to cover a significant area.

[6] Discharge interface – Area where groundwater COCs at concentrations greater than the ^{SW}SW PCL are released to surface water.

What action is required to address this provision? For larger discharge interfaces, three approaches may be used to ensure that exceedances of the TSWQS do not occur in significant areas of the surface water body:

1. *Direct Measurement of Surface Water Concentrations*: After ^{SW}GW PCLs have been achieved, measure COC concentrations in the surface water body to ensure that ^{SW}SWs are not exceeded. The locations for sample collection should be consistent with the guidance provided in Section 7.1.5.2. If ^{SW}SWs are exceeded, then the ^{SW}GW PCLs should be lowered sufficiently to eliminate these exceedances. Because the ^{SW}RBELs are developed based on both the numeric and narrative TSWQS, COC concentrations below the ^{SW}RBEL indicate no exceedance of the TSWQS.

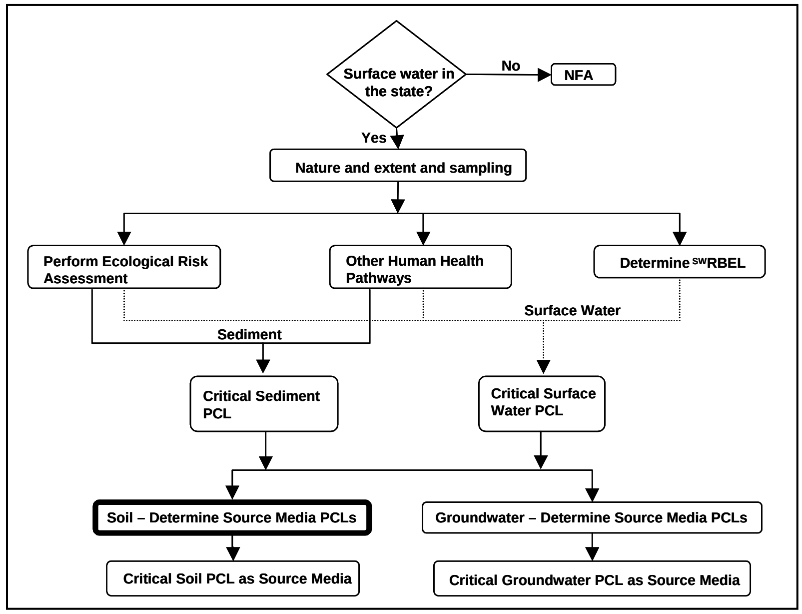
2. *More Conservative Dilution Factor*: As an alternative to direct measurement of surface water concentrations, the person may elect to determine ^{SW}GW PCLs based on a dilution factor which is more conservative than would be appropriate otherwise. The person should calculate the ^{SW}GW PCLs based on a dilution factor which is four times higher than the default DF or the value determined in accordance with Section 7.1.4 or 7.1.5. If this is done, then it will be assumed that exceedances of the TSWQS will not occur over significant areas and sampling of surface water will not be required. For example, if a property-specific dilution factor of 0.1 is determined in accordance with Section 7.1.5, then the person would use a dilution factor of 0.4 to calculate the ^{SW}GW PCLs.

3. *Direct Measurement of Sediment Concentrations and Evaluation of Impacts to Ecological Receptors*: In addition to approaches 1 or 2, persons should evaluate potential impacts to ecological receptors, particularly the benthic community, pursuant to the requirements of §350.77 and the Ecological Risk Assessment Guidance (and updates) to ensure compliance with the TSWQS that preclude adverse toxic effects on aquatic life (§307.6 (4)). Also see previous discussion in Section 7.2.

Examples of Groundwater Discharge Interfaces Across Significant Areas of a Surface Water Body

- A discharge interface that extends only 350 feet along the shore of a bay but has an interface area of 35,000 square feet.
- A discharge interface that extends 250 feet along the shore of a lake with an interface area of 6,000 square feet.
- A discharge interface that has an area of 15,000 square feet discharging to an 100 foot wide river along 300 feet of the bank; it exceeds 0.25 x stream width x 400 feet (≈10,000 square feet).
- A discharge interface that has an area of 20,000 square feet discharging to a 500 foot wide river along 250 feet of the bank; it exceeds the 16,000 foot criterion.
- A discharge interface that has an area of 2,500 square feet discharging to a 20 foot wide stream along 170 feet of the bank; it exceeds 0.25 x stream width x 400 feet (≈2,000 square feet).

7.4 Soil Releases to Surface Water and Sediment via Runoff



COCs in surface soil can reach water and sediment in an adjacent water body in surface water runoff and through transport via leaching and groundwater release to the water body. COC transport to adjacent water bodies via leaching and groundwater release, and development of PCLs for this pathway are described in Section 7.1. This section describes the general approach for characterizing dissolved and particulate COC releases to surface water and sediment from erodable soils, and development of PCLs for this pathway.

The TSWQS state (§307.8 (e)) that pollution in storm water shall not impair existing or designated uses of the receiving water. However, numerical criteria do not exist for evaluating the specific potential aquatic life or human health impacts of contaminated soil runoff on surface waters and sediment. Nevertheless, a soil PCL protective of surface waters and sediment (^{Sed}Soil, ^{SW}Soil) should be derived whenever there is potential release to surface waters and sediment due to runoff carrying contaminants in dissolved or particulate forms. Persons should consider the following factors to determine whether the transport of affected soil and COCs dissolved in runoff to surface water is a relevant pathway:

- proximity to surface waters
- extent of exposed and/or erodable soils
- extent of erodable impacts
- transport or erosion potential based on soil types, compaction, vegetation density, and slope
- presence of metals and/or persistent bioaccumulative organic COCs in soil
- PCLs for soil erosion are only applicable to the area and thickness of soils likely to be eroded based on property-specific evaluation

For purposes of the following discussion, COCs in soil are assumed to occur in a dissolved or particulate form when they enter a surface water body. Based on their chemical properties and many other environmental factors, COCs in soil particles released during a storm event might remain attached to soil particles, go into solution, or enter a colloidal form. Evaluation of chemicals in the colloidal form is beyond the scope of this guidance.

Storm water runoff releases are usually intermittent and occur during wet weather conditions. Therefore, it would be inappropriate to evaluate the potential impacts of an estimated or measured COC concentration in undiluted storm water in the same manner as other releases (i.e., continuous point source and groundwater releases). These other releases are normally frequent to continuous instead of episodic, and are evaluated using chronic aquatic life criteria and surface water concentrations measured during low flow or critical mixing conditions, or are modeled to represent those same conditions. Although it is unlikely that a single runoff event will present chronic risks to water column biota, continued runoff events can result in an accumulation of COCs in the sediment and the water column for some systems and some COCs. Over time these COCs may become a chronic risk to water column and sediment biota (and ecological receptors) principally due to accumulation in the sediment, but also as a result of COC build-up in smaller systems (e.g., small lakes and ponds) or sediment-to-surface water releases.

This section focuses on evaluating sediment and in-stream surface water concentrations of COCs released to streams and rivers from affected erodable soil in a Tier 2 evaluation. A general approach to developing screening-level (Tier 2) ^{Sed}Soil and ^{SW}Soil PCLs and recommendations for developing Tier 3 PCLs for this pathway is discussed.

7.4.1 Affected Property Soil Screening Equations

The Tier 2 calculation methods provided in this section provide one acceptable approach for the evaluation of soil releases to surface water and sediment. However, alternative qualitative or quantitative approaches for evaluation of these pathways will be considered acceptable by the TCEQ.

7.4.1.1 Screening Calculation for a Tier 2 ^{Sed}Soil PCL. A screening calculation may be appropriate in order to evaluate whether storm water runoff from an affected property has the potential to pose a risk to human or ecological receptors in an adjacent receiving water body. This approach to deriving a PCL does not require sediment samples from the water body. It does provide a calculated ^{Sed}Soil PCL for the surface water runoff pathway that can be used to evaluate the concentration of the COC in erodable soil at the affected property. The following text provides step-by-step instructions to calculate the ^{Sed}Soil PCL.

A. *Universal Soil Loss Equation*

The Universal Soil Loss Equation (USLE) is a Tier 2 model based upon research originally performed by the U.S. Soil Conservation Service for agricultural land. Note that this section is simply intended to be a general discussion of the USLE method and, if used, more definitive guidance should be consulted. This guidance can be found in numerous hydrology textbooks and on the World Wide Web. There are several readily available web pages that provide more information regarding the USLE and its individual components. Some of these are listed here:

- http://www.fao.org/docrep/T1765E/t1765e0e.htm
- http://topsoil.nserl.purdue.edu/nserlweb/weppmain/jhtml/usle.html
- http://abe.www.ecn.purdue.edu/~engelb/agen526/erosiondocs/usleapp.html

This empirical model describes representative annual soil erosion magnitudes as a function of:

- a rainfall parameter characteristic of rainfall's potential to erode soil
- a soil erosivity factor
- a factor characterizing the area of erosion
- a land slope parameter
- two land use factors

The USLE is conservative because it was developed based on studies and measurements performed on agricultural soils. Since agricultural soils have regular disturbances to the soil surface and soil cover (i.e., cultivation) which has a radical effect on soil erodibility, the model may over-predict COC releases due to sheet runoff.

The USLE was the first developed to estimate soil loss over a wide range of situations, usually in the United States, east of the Rocky Mountains. The USLE is empirical and is based on statistical relationships that support its universal applicability. The USLE specifically offers the opportunity to evaluate the effect on erosion using one parameter, namely, soil erodibility. This soil composite characteristic summarizes the medium term effect of the soil profile on soil erosion. Erodibility varies with basic soil characteristics such as clay, organic matter and geometric mean diameter. The USLE was recently revised (RUSLE) and is defined by:

$$A = R * K * LS * C * P$$

where:

A	=	estimated average annual soil loss in tons per acre
R	=	rainfall-runoff erosivity factor
K	=	soil-erodibility factor
LS	=	topographic factor
C	=	cover-management factor
P	=	support practice factor

These factors are discussed in more detail below.

Rainfall-Runoff Erosivity Factor (R). The R factor is an empirical value derived from several different sources. The literature indicates that when factors other than rainfall are held constant, soil losses from cultivated fields are directly proportional to a rainstorm parameter: total storm energy (E) multiplied by the maximum thirty-minute intensity (I). This parameter incorporates both raindrop impact and overland flow.

Isoderent maps covering the entire United States with R factor “contours” are available from the United States Department of Agriculture (USDA) and the Environmental Protection Agency (U.S. EPA). These maps must be visually interpolated to assign an R factor to the area of interest. There are several web pages that provide this information, or specific R factors can be obtained from the local county extension service.

Soil-Erodibility Factor (K). The K factor is, in simple terms, the ease with which soil is detached by splash during rainfall or by surface flow or by a combination of both. Technically speaking, K is the rate of soil loss per rainfall erosion index unit as measured on a unit plot, which is 72.6 feet long with a 9% slope. It can also be thought of as the average long-term soil and soil-profile response to the erosive processes of rainstorms. These processes include soil detachment and transport by raindrop impact and surface flow, localized deposition due to topography and tillage-induced roughness, and rainwater infiltration into the soil profile. Using soil types and their associated textures (clay and silty clay), a K factor can be found in USDA literature.

Topographic Factor (LS). The effect of topography on erosion is accounted for in the LS factor. A value is calculated using the rill susceptibility, slope length, and slope incline, providing a representation of the ratio of soil loss on a given slope length and steepness to soil loss from a slope that has a length of 72.6 feet and a steepness of 9%, all other conditions being the same. The topographic factor is calculated by multiplying L, the slope length factor, by S, the slope steepness factor.

Slope Length Factor (L). Erosion increases as slope length increases, and this is taken into account using the L factor. Slope length is defined as the horizontal distance from the origin of overland flow to the point where either (1) the slope gradient decreases enough that deposition begins, or (2) runoff becomes concentrated in a defined channel (Wischmeier and Smith, 1978). Slope lengths, as well as steepnesses, are typically estimated from contour maps. The slope length is the horizontal projection of plot length, not the length measured along the slope. In other words, this length is measured from each edge of the slope, but the length is completely horizontal, as opposed to parallel to the slope.

An important factor to consider in the calculation of L is the ratio of rill erosion, caused by flow, to interrill erosion, caused mainly by raindrop impact (Foster et al., 1977). Land use is the main issue affecting the rill to interrill ratio. Because the pervious areas within the study sites were considered to have rangeland- or agriculture-type land uses, it was assumed the rill to interrill ratio is moderate in the area of interest. This is the ratio used for lands associated with cropland and is higher than the ratio used for lands associated with rangeland and pasture, producing a worst-case scenario for those areas.

Slope Steepness Factor (S). Slope steepness plays an even greater role in erosion than slope length. The slope steepness factor, S, can be obtained from McCool et al., 1987. There are separate equations for slopes longer than 15 feet in length and slopes shorter than 15 feet in length. Slopes with steepness values of 9% or less are also calculated differently from those slopes having steepness values greater than 9%.

Cover Management Factor (C). The C factor is the ratio of soil loss with specific cropping and management practices to the corresponding loss with up-slope and down-slope tillage and continuously fallow conditions. This factor includes the effects of cover, crop sequence, productivity level, length of growing season, tillage practices, residue management, and the expected time distribution of erosive rainstorms. The Natural Resources Conservation Service (NRCS) provides charts of C factor values for various land uses.

Support Practice Factor (P). The P factor is the ratio of soil loss with a specific support practice to the corresponding loss with up slope and down slope tillage and continually fallow conditions. These practices mainly affect erosion by modifying the flow pattern, grade, or direction of surface runoff and by reducing the amount and rate of runoff (Renard and Foster, 1983). For cultivated land, the support practices considered include contouring, strip cropping, terracing, and sub-surface drainage. On dry land or rangeland areas, soil-disturbing practices oriented on or near the contour that result in storage of moisture and reduction of runoff are also used as support practices.

The reduction in soil loss at a given slope is about 50 percent for the next more intensive practice. An overall P factor value is computed as a product of P sub factors for individual support practices (those mentioned above), which are typically used in combination. Factor values can be found on charts provided by the USDA, among other entities.

B. *Delivery Ratio and Sediment Load*

Once the Estimated Average Annual Soil Loss (A) has been calculated using the method in A (A. *Universal Soil Loss Equation*), a delivery ratio must be used to localize this number for an affected property. This results in an estimated sediment load. The edge of stream load is not always equal to the edge of field load because not all of the sediment created by upland erosion reaches the watershed outlet. Several processes occur within an affected property that prohibit the eroded material from reaching the watershed outlet. These processes include redeposition in surface water storage, trapping by vegetation and plant residues, and local scour and redeposition in rills and channels. Also, many factors inhibit the eroded material's delivery to the watershed outlet, including climate, soil particle size and texture, size and proximity of the upland erosion source, the ratio of rill versus sheet erosion, total watershed area, watershed length and relief, and drainage density (the ratio of total stream length within the system divided by the area).

To determine the delivery ratio, a calculation can be performed using the area, relief, length and bifurcation ratio of the stream of interest, or it can be found on graphs provided by the USDA. The delivery ratio will be between 0, which represents 0% delivery, and 1, which represents 100% delivery. Therefore, the USDA graphs will show that as drainage area increases, the delivery ratio decreases. The following equation should be used to calculate the sediment load for the area of interest:

$$SL = A * DR$$

where:

SL = Sediment Load
A = Estimated Average Annual Soil Loss in tons per acre (from A. *Universal Soil Loss Equation*)
DR = Delivery Ratio

C. *Calculating the Tier 2 ^{Sed}Soil PCL*

The following algebraic equation is the basis for the calculation of the Tier 2 ^{Sed}Soil PCL for an affected property (AP):

$$(SL_{AP} * C_{AP}) + (SL_{OA} * C_{OA}) = SL_{TOT} * C_{TOT}$$

where:

SL_{AP}	=	Sediment load from the affected property (kg/year) estimated using the method presented in B (B. *Delivery Ratio and Sediment Load*).
C_{AP}	=	The ^{Sed}Soil PCL (mg/kg) for the surface water runoff pathway from the affected property.
SL_{OA}	=	Sediment load (kg/year) estimated for other areas of the watershed using the method presented in B (B. *Delivery Ratio and Sediment Load*).
C_{OA}	=	Texas-specific median background soil concentration (mg/kg) for inorganic COCs (if available) or affected property "background" (if available). This term is zero for organic compounds.
SL_{TOT}	=	Total Sediment load (kg/year) estimated for the entire contributing watershed using the method presented in B (B. *Delivery Ratio and Sediment Load*).
C_{TOT}	=	COC Sediment PCL (mg/kg)
OA	=	Other Area. This is the area of the contributing watershed other than the AP.

Solving for C_{AP} (the ^{Sed}Soil PCL) gives:

$$C_{AP} = \frac{(SL_{TOT} * C_{TOT}) - (SL_{OA} * C_{OA})}{SL_{AP}}$$

This equation is used for inorganic COCs. For organic COCs, there are no Texas-specific median background soil concentrations (C_{OA} = 0), and the equation simplifies to:

$$C_{AP} = \frac{(SL_{TOT} * C_{TOT})}{SL_{AP}}$$

These calculations provide a conservative value for the ^{Sed}Soil PCL and account for watershed contributions of inorganic COCs. These values may be modified to incorporate more appropriate property-specific data as described in the following section. The equation is simple to set up in a spreadsheet for the COCs at an affected property, but does require some knowledge of land use in the entire watershed. If the watershed contains significant sources of a COC, then the simplifying assumption that it contributes only median background levels of the COC for inorganics and no contribution of organic COCs is likely to make the ^{Sed}Soil PCL under-protective relative to impacts from other sources. A discussion of uncertainties in the application of this approach, especially those about the background only contributing the median background level of a COC, should accompany presentation of the C_{AP} value and its application to decision-making for a specific affected property.

Once the C_{AP} value has been calculated, it must be compared with the affected property surface soil exposure concentration to determine if the erodable soil concentrations exceed the soil PCL for this pathway.

7.4.1.2. Screening Calculation for a Tier 2 ^{SW}Soil PCL.

Bays, Lakes and Estuaries

Unfortunately, there is no relatively simple method available to calculate COC contributions in runoff when the water body of interest is a bay, lake, estuary, or similar. If the water body classified as such, and the available field data are above the ^{Sed}Soil PCL developed in C in Section 7.4.1.1, a Tier 3 investigation should be the next step in the analysis.

Water Courses

Tier 2 screening for this pathway may be conducted using conservative screening equations that account for some affected property and watershed characteristics. The sediment load to the surface water body calculated using the USLE and Delivery Ratio approaches (Section 7.4.1.1, A and B) can be used to estimate the load on surface water during average (harmonic mean) flow conditions to estimate the greatest potential effect on the water body using an equilibrium partitioning approach. This assumption is necessary to account for the maximum release from the affected property. It is assumed that storm events during periods when 7Q2 conditions prevail are less frequent and less likely to pose a chronic threat to aquatic organisms in receiving waters.

The mass balance for the watercourse may be represented as:

$$Q_D C_D = Q_{AP} C_{AP} + Q_{OA} C_{OA}$$

where:

Q_D	=	flow downstream of the affected property watershed (ft^3/sec)
C_D	=	concentration of COC downstream of the affected property (mg/L)
Q_{AP}	=	runoff from the affected property (ft^3/sec)
C_{AP}	=	concentration of the COC in runoff from the affected property (mg/L)

Q_{OA} = runoff from other areas of the affected property watershed (ft^3/sec)
C_{OA} = concentration of the COC in runoff from other areas of the affected property watershed (mg/L)

The equation can be rearranged as shown below. Setting the concentration downstream of the affected property (C_D) equal to the surface water PCL (^{SW}SW), and solving for the concentration in the affected property runoff yields:

$$C_{AP} = \frac{Q_D\,^{SW}SW - Q_{OA}C_{OA}}{Q_{AP}}$$

Assuming that all of the liquid-phase COC in the affected property runoff is in equilibrium with the solid phase (C_{SOIL}), then the concentration in the liquid phase is:

$$C_{AP} = \frac{C_{SOIL}}{K_d}$$

Substituting the right side of the equation above into the mass balance equation, and solving for the affected property soil concentration yields:

$$C_{SOIL} = \frac{K_d\ (Q_D\,^{SW}SW - Q_{OA}C_{OA})}{Q_{AP}} = {}^{SW}SOIL$$

Many methods are available for calculation of runoff rates and volumes. The Simple or Schueler Method is described to provide one method. Two equations are required to calculate runoff flow volumes by the Schueler Method (Schueler, 1987). First, the runoff coefficient for each land use type must be derived with the following equation:

$$R_{VU} = 0.05 + (0.009 * I_U)$$

where:

R_{VU} = runoff coefficient (unit less) for land use type u ($inches_{run}/inches_{rain}$),
I_U = percent imperviousness (unit less) characteristic of land use type u

The runoff flow rates are then calculated using the following equation (Schueler, 1987):

$$Q = P * P_J * R_{VU} * A_U$$

where:

P = precipitation rate (inches/year)
P_J = ratio of storms producing runoff (unit less), with a default value of 0.9
R_{VU} = runoff coefficient (unit less) for land use type u ($inches_{run}/inches_{rain}$)
A_U = area of land use type u (acres)

If the COC concentration in the soil at the affected property is greater than more than one of the applicable PCLs, then the soil critical PCL should determined. If the critical soil PCL is either of the calculated screening ^{Sed}Soil or ^{SW}Soil PCLs for surface water runoff, then a Tier 3 evaluation should be considered to refine the screening ^{Sed}Soil or ^{SW}Soil PCL. Possible considerations in deriving a Tier 3 ^{Sed}Soil or ^{SW}Soil PCL are discussed in the following section.

7.4.2 Tier 3 Evaluation and PCLs for the Storm Water Runoff Pathway

The Tier 3 effort would require a data collection program for the affected property, its watershed, and the water body (and possibly its watershed) that would focus on characterizing risks to human and ecological receptors for those COCs that exceeded the critical PCL.

While a weight-of-evidence approach can be used to infer that a source of this type is the cause of an impaired ecological community, it would still require a more sophisticated modeling approach to develop a quantitative PCL for the storm water release pathway. In addition, releases to the sediments via leaching and groundwater release to the surface water body would also have to be considered, which would support a decision to move to a Tier 3 assessment.

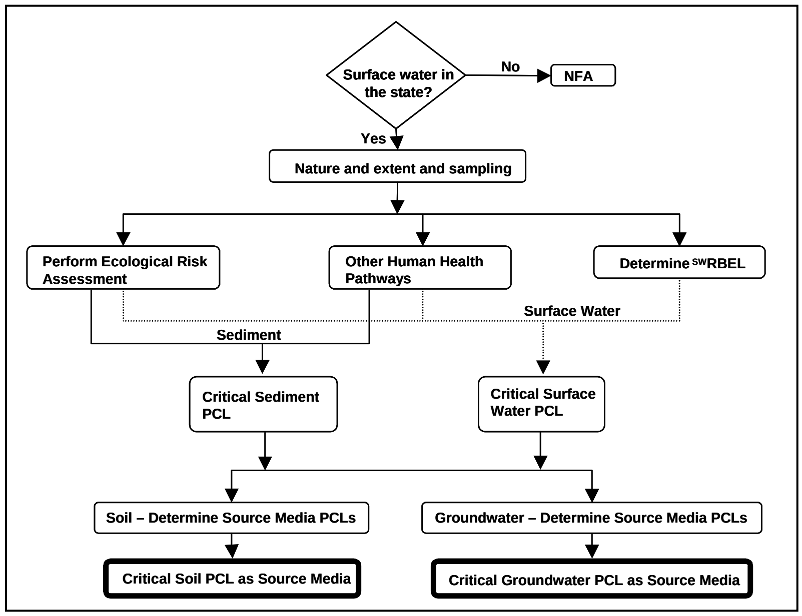
Storm water runoff usually carries a dissolved COC and particulate load. The impacted soil particles can remain suspended in the water column for some distance during a storm, and either remain in the water column after the storm ends, or settle to the bottom and become mixed with sediment. The portion of the sediment load that remains suspended in the water column contributes to the total surface water concentration of the COC and can be evaluated according to existing TCEQ guidance (Implementation Procedures). Because a portion of the total sediment load can settle to the bottom of the water body, impacts to the sediment in potentially affected surface waters should also be considered. A portion of the dissolved COC load from storm events might also enter the sediments of a water body via chemical partitioning and adsorption. Once part of the sediment of the water body, the COCs released from an affected property via storm water runoff contribute to the total sediment COC concentration that is usually evaluated on the basis of a comparison to the sediment PCL.

The suspended particulates in a storm water release are likely to initially form a thin layer of deposited particles on the surface of the existing sediment in the water body. Unless the COC concentrations are extremely high, or the COC is extremely toxic, the particulates added from a single storm event are unlikely to cause measurable adverse impacts to the biota in the affected area related to the COC's inherent toxicity. There is the possibility of a smothering effect in extreme cases, but this type of stress is not addressed here. Therefore, it is inappropriate to develop a ^{Sed}Soil PCL for evaluating COC releases from single storm events. It is possible that sediment loads from storm water releases during multiple storm events could cause adverse impacts to the sediment biota.

Unfortunately, many environmental factors and site characteristics affect the gradual accumulation and scouring of sediment in water bodies, and with the exception of very simple cases, sediment dynamics must be considered in modeling accumulation of COCs in sediments. For instance, sediments at a given location downstream of the release from an affected property will receive particulate loads from all areas of the watershed above that point. That was the basic assumption for the screening calculation in Section 7.4.1. Over time that sediment is subject to scouring and accretion, two processes with opposite effects. In addition to these physical processes, COC concentrations in sediment are subject to fate and transport processes that are highly dependent on site conditions and the chemical properties of individual COCs. Therefore, evaluation of the accumulation of COCs in sediment from storm water releases from a single affected property with contaminated soils is appropriate only at the Tier 3 level of evaluation.

For a Tier 3 evaluation, models are available that can represent the concentration of a COC in surface water and sediment from many storm water releases, and the resulting surface water and sediment concentration can be used to evaluate compliance with a surface water or sediment PCL over multiple storm events, i.e., an annual average COC release from storm water runoff. Models that take these factors into consideration are available in the literature (Schnoor, 1996; U.S. EPA, 1985b, 1985c, 1987, 1996a, 1996b) and from the U.S. EPA's Center for Exposure Assessment Modeling (http://www.epa.gov/ceampubl/). For instance, off-the-shelf models are available that address both rural and urban non-point source pollution. These readily available models need to be evaluated for their applicability to the affected property evaluation and, if applicable, adjusted to match the scale of the Tier 3 investigation.

8.0 DETERMINING CRITICAL PCLs FOR SOURCE MEDIA



The guidance has presented text for determining groundwater PCLs protective of surface water and sediment (Sections 7.1 and 7.2) where COCs in groundwater are released to those media at levels above the critical PCL. Persons should compare these groundwater PCLs with those for other pathways (e.g. ingestion of groundwater) to determine the most limiting PCL for a given COC. That will be the critical PCL (also consider background and MQL) for that COC in groundwater. Similarly, the guidance has also discussed the development of soil PCLs protective of sediment (Section 7.4.1.1) and surface water (Section 7.4.1.2) when soil COCs are released to these media during a storm water runoff event that would result in concentrations for those media above their critical PCL. Persons should compare these soil PCLs with those for other pathways (e.g. total soil combined PCL or the groundwater protective soil PCL) to determine the most limiting PCL for a given COC. That will be the critical PCL (also consider background and MQL) for that COC in soil.

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Appendix A - Surface Water RBELs for Chromium and Silver

Silver

Based on the process defined in the Implementation Procedures, the percent dissolved silver in freshwater that is in the free ionic form is estimated from the following regression equation:

$$Y = \exp\left[\exp\left(\frac{1}{0.6559 + 0.0044(Cl)}\right)\right]$$

where Y = % of dissolved silver that is in free ionic form, and Cl = dissolved chloride concentration (mg/l). Persons should use the 50^{th} percentile chloride value from the Implementation Procedures for the nearest downstream segment unless site-specific data is available. Because there is no readily available means to predict the percent free ion in marine waters, silver should be evaluated as dissolved silver.

Persons should perform the dissolved to total calculation in addition to the chloride-dependant estimation of the percent silver that is in the free ionic form in accordance with the explanation in the Implementation Procedures. An example calculation is provided in the box to the right.

Example Converting Dissolved Free Ion to Total Silver for Freshwater (Aquatic Life Protection):

Segment 0604; Neches River below Lake Palestine
Hardness = 36 mg/L
TSS = 7 mg/L
Chloride = 24 mg/L
Freshwater acute standard for the free ion form of silver = 0.8 ug/L.

Determination of the % dissolved silver*:

Y = exp [exp (1/ 0.6559 + 0.0044 (Cl)))] = 41.18% dissolved silver.

Determination of the total silver number*:

Partition Coefficient, $K_d = 10^b \times TSS^m$

$$K_d = 10^{(6.38)} \times (7)^{(-1.03)}$$
$$K_d = 3.233 \times 10^5$$

Fraction of metal dissolved = C/C_T

$$\frac{C}{C_T} = \frac{1}{1 + \left(K_d \times TSS \times 10^{-6}\right)}$$
$$= \frac{1}{1 + \left(\left(3.233 \times 10^5\right)(7)\left(10^{-6}\right)\right)}$$

$= 0.31$

Total Acute Standard = 0.81 ug/L ÷ ((0.31)(0.41)) = 6.37 ug/L

*See Implementation Procedures for formulas and variables.

Chromium

The TSWQS for the protection of aquatic life are expressed as dissolved concentrations for hexavalent chromium (Cr^{+6}) and trivalent chromium (Cr^{+3}). In accordance with the methodology in the Implementation Procedures, surface water or groundwater samples should be analyzed for dissolved Cr^{+6} and total recoverable chromium to determine compliance with the applicable surface water RBEL. Total recoverable chromium is the sum of dissolved Cr^{+6}, adsorbed Cr^{+6}, dissolved Cr^{+3}, and adsorbed Cr^{+3}:

$$Total\ recoverable\ Cr = dissolved\ Cr^{+6} + adsorbed\ Cr^{+6} + dissolved\ Cr^{+3} + adsorbed\ Cr^{+3}$$

The analytical method for Cr^{+6} measures only for the dissolved form. The TCEQ assumes that the amount of adsorbed Cr^{+6} is negligible so total Cr^{+3} in a surface water or groundwater sample is calculated by subtracting dissolved Cr^{+6} from the total recoverable chromium:

$$Total\ Cr^{+3} = total\ recoverable\ Cr - dissolved\ Cr^{+6}$$

The dissolved Cr^{+3} criterion can be converted to total using the partition coefficient conversion detailed in the Implementation Procedures. The dissolved Cr^{+6} result should be compared directly with the hexavalent criterion.

Appendix B – Partition Coefficients for Metals in Streams, Lakes, and Estuarine Systems

METAL	Streams [1]		Lakes [1]		Estuarine Systems [2]	
	Intercept (b)	Slope (m)	Intercept (b)	Slope (m)	Intercept (b)	Slope (m)
Arsenic	5.68	-0.73	Assumed equal to streams		—	—
Cadmium	6.60	-1.13	6.55	-0.92	—	—
Chromium	6.52	-0.93	6.34	-0.27	—	—
Copper	6.02	-0.74	6.45	-0.90	4.85	-0.72
Lead	6.45	-0.80	6.31	-0.53	6.06	-0.85
Mercury	6.46	-1.14	6.29	-1.17	—	—
Nickel	5.69	-0.57	6.34	-0.76	—	—
Silver [3]	6.38	-1.03	Assumed equal to streams		5.86	-0.74
Zinc	6.10	-0.70	6.52	-0.68	5.36	-0.52

$$Kd = 10^b \times TSS^m \qquad \frac{C_d}{C_T} = \frac{1}{1+\left(Kd \times TSS \times 10^{-6}\right)}$$

where:

Kd	=	partition coefficient[4] (L/kg)
TSS	=	total suspended solids (mg/L)
b	=	intercept (from table)
m	=	slope (from table)
C_d/C_T	=	fraction of metal dissolved

Example: Assume TSS = 15 mg/L in a river. Find Kd and C_d/C_T for Nickel.

$$\mathrm{Kd} = 10^{5.69} \times 15^{-0.57} = 0.49 \times 10^6 \times 15^{-0.57} = 0.10467 \times 10^6$$

$$\frac{C_d}{C_T} = \frac{1}{1+\left(0.10467 \times 10^6 \times 15 \times 10^{-6}\right)} = 0.389$$

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4 ----These partition coefficients are used to express the partitioning of metals in surface water between the total and dissolved phases as provided in the Implementation Procedures. They should be used for this application rather than the Kd values in Figure 30 TAC §350.73 (e).

Appendix C – Example Aquatic Life Calculation Using the LC_{50} Approach

Chloroform: CAS: 67-66-3

Fate and Transport in Water

When released into water, chloroform will be primarily lost by evaporation into the atmosphere due to its high Henry's Law constant of 3.68 x 10^{-3} atm-m^3/mole (TNRCC, 1999). Modeling studies suggest that the volatilization half-life is 36 hours in a river, 40 hours in a pond, and 9-10 days in a lake (U.S. EPA, 1984). Field monitoring data indicate the half-life of chloroform to be 1.2 days in the Rhine River and 31 days in a lake in the Rhine Basin (Zoeteman et al., 1980). Mackay et al. (1999) suggests a semi-quantitative classification of half-lives using nine different classes based on average environmental conditions. These half-life classes (i.e., referred to as reactivity classes) integrate reaction rates of the chemical for all relevant processes, including biodegradation, volatility, and photolysis. Chloroform is classified as Class 6 with a mean half-life of 1700 hours and a range of 1000 – 3000 hours. Howard et al. (1991) indicates a half-life of 672 - 4320 hours in surface water, based on aqueous aerobic biodegradation. The reported fate and transport data for chloroform suggest that it is likely to persist in water environments for greater than 4 days (see Implementation Procedures for a discussion of persistence). Based on these data, chloroform is considered to be persistent for the purposes of deriving the water quality value.

Bioaccumulation Potential

Chloroform has little or low potential to bioconcentrate. The log bioconcentration factor is less than one for four species of fish (Anderson and Lusty, 1980). A BCF for chloroform was estimated using a log K_{ow} value of 1.52 provided in the Texas Risk Reduction Program (TRRP) Rule (TCEQ, 2007) and the BCF equation referenced in U.S. EPA, (1999) for water-to-aquatic invertebrates BCFs.

$$\text{Log BCF} = 0.819 * \text{Log } K_{ow} - 1.146$$
$$\text{BCF} = 1.26$$

The estimated BCF value for chloroform suggests that it has a very low potential to accumulate in the food chain.

Toxicity to Aquatic Organisms

Freshwater: Chloroform is moderately toxic to aquatic organisms; several toxicity values are in the range of greater than 13 mg/L to 353 mg/L (see Table C-1). The 96-hr LC_{50} values for freshwater species are 70.7 – 171 mg/L for *Pimephales promelas* (fathead minnow), 13.3 - 115 mg/L for *Lepomis macrochirus* (bluegill), 15.1 – 66.8 mg/L for the *Oncorhynchus mykiss* (rainbow trout), and 45.4 - 55.8 mg/L for *Micropterus salmoides* (large mouth bass) (AQUIRE, http://cfpub.epa.gov/ecotox/). For freshwater invertebrates, the 48-hr LC_{50} values for water fleas (*Daphnia magna* and *Ceriodaphnia dubia*) ranged from 29 - 353 mg/L (AQUIRE).

Marine: Only one marine species study was referenced in AQUIRE. The 48- and 72-hr LC_{50} value for *Penaecus duorarum* (northern pink shrimp) is 81.5 mg/L (AQUIRE). See Table C-1 for a summary of the results of aquatic toxicity studies.

Water Quality Criteria

Freshwater: As indicated above, several acute toxicity studies have been conducted in a number of freshwater species for chloroform. Two separate flow-through studies were referenced in AQUIRE, and these were by Geiger et al. (1990) and Anderson and Lusty (1980). In one study, Geiger et al. (1990) evaluated the acute toxicity of chloroform in the fathead minnow and reported a 96-hr LC_{50} of 70.7 mg/L.

In the other study, Anderson and Lusty (1980) evaluated the acute toxicity of chloroform in four freshwater species (i.e., channel catfish, large mouth bass, bluegill, and rainbow trout). Statistical analyses of the toxicity test results were analyzed using a computer program, which computes LC_{50}s by probit, moving average, and binomial computational procedures. The 96-hr LC_{50} values reported in this study ranged from 13.3 to 75 mg/L. The channel catfish and the large mouth bass were not very sensitive to the toxicity of chloroform. The reported 96-hr LC_{50} for the channel catfish is 75 mg/L. Three 96-hr LC_{50} values were reported for the large mouth bass, and the values ranged from 45.4 to 55.8 mg/L. The geometric mean of the three 96-hr LC_{50} values is 51 mg/L.

The LC_{50} results for the rainbow trout and bluegill indicated that these species were more sensitive to chloroform. Acute toxicity tests with juvenile rainbow trout indicated 96-hr LC_{50} values between 15 and 22 mg/L, with a geometric mean of 18 mg/L. Acute toxicity tests conducted in the bluegill indicated 96-hr LC_{50} values ranging from 13.3 - 22.3 mg/L, with a geometric mean of 17.8 mg/L. In the bluegill toxicity test, the authors reported that during the study there was an outbreak of columnaris disease in the control and tested groups, but to a lesser extent in the test groups. However, testing in the bluegill study was suspended until the columnaris infection was controlled.

The LC_{50} results for the channel catfish, the large mouth bass, and the fathead minnow were eliminated from further consideration on the basis that chloroform was moderately toxic to these species in comparison to the bluegill and rainbow trout. The studies for the bluegill and rainbow trout indicated similar 96-hr LC_{50} values (i.e., a geometric mean of 17.8 and 18 mg/L for the bluegill and rainbow trout, respectively). Since the rainbow trout is not a native species of Texas, the LC_{50} data for the trout were not given further consideration. Even though the authors indicated initial problems with the bluegill study, it appears that the final test results were based on data collected after the columnaris problem was resolved. Therefore, the LC_{50} data for the bluegill were considered appropriate for use in the derivation of the water quality values for chloroform.

The geometric mean of the flow-through exposure 96-hr LC_{50} values (17.8 mg/L) for the bluegill was used in the derivation of freshwater acute and chronic criteria for chloroform. The following calculation of the freshwater acute and chronic criteria for chloroform assumes persistence and non-bioaccumulative potential for the chronic criterion:

*Freshwater acute criterion (mg/L) = 0.3 * 17.8*
= 5.34 mg/L

*Freshwater chronic criterion (mg/L) = 0.05 * 17.8*
= 0.89 mg/L

Marine: Only one marine species study was referenced in AQUIRE. Bentley et al. (1979) evaluated the toxicity of chloroform in the *Penaecus duorarum* (pink shrimp) using static methods. The reported 48- and 72-hr LC_{50} value for the pink shrimp is 81.5 mg/L. The 48-hr LC_{50} value of 81.5 mg/L for the northern pink shrimp was used in the derivation of marine acute and chronic criteria for chloroform. The following calculation of the marine acute and chronic criteria for chloroform assumes persistence and non-bioaccumulative potential for the chronic criterion:

Marine acute criterion (mg/L) $= 0.3 * 81.5$
$= 24.5$ *mg/L*

Marine chronic criterion (mg/L) $= 0.05 * 81.5$
$= 4.1$ *mg/L*

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Table C-1. Summary of Aquatic Toxicity Data for Chloroform								
Common Name	**LATIN NAME**	**Water Type**	**Duration**	**Exposure Type**	**Endpoint**	**Effect**	**Conc. (ug/L)**	**AQUIRE Reference**
Channel catfish	*Ictalurus punctatus*	FW	96	F	LC_{50}	MOR	75,000	5267
Water flea	*Ceriodaphnia dubia*	FW	48	S	LC_{50}	MOR	290,000	212
Water flea	*Daphnia magna*	FW	48	S	LC_{50}	MOR	29,000	5184
Water flea	*Daphnia magna*	FW	48	S	LC_{50}	MOR	353,000	212
Water flea	*Daphnia magna*	FW	48	S	LC_{50}	MOR	66,500	12055
Water flea	*Daphnia magna*	FW	48	S	LC_{50}	MOR	63,800	12055
Bluegill	*Lepomis macrochirus*	FW	96	F	LC_{50}	MOR	16,200	5267
Bluegill	*Lepomis macrochirus*	FW	96	F	LC_{50}	MOR	22,300	5267
Bluegill	*Lepomis macrochirus*	FW	96	F	LC_{50}	MOR	13,300	5267
Bluegill	*Lepomis macrochirus*	FW	96	F	LC_{50}	MOR	18,300	5267
Bluegill	*Lepomis macrochirus*	FW	96	F	LC_{50}	MOR	20,800	5267
Bluegill	*Lepomis macrochirus*	FW	96	S	LC_{50}	MOR	100,000	2644
Bluegill	*Lepomis macrochirus*	FW	96	S	LC_{50}	MOR	115,000	2644
Large mouth bass	*Micropterus salmoides*	FW	96	F	LC_{50}	MOR	55,800	5267
Large mouth bass	*Micropterus salmoides*	FW	96	F	LC_{50}	MOR	52,500	5267
Large mouth bass	*Micropterus salmoides*	FW	96	F	LC_{50}	MOR	45,400	5267
Rainbow trout	*Oncorhynchus mykiss*	FW	96	F	LC_{50}	MOR	18,200	5267
Rainbow trout	*Oncorhynchus mykiss*	FW	96	F	LC_{50}	MOR	18,400	5267
Rainbow trout	*Oncorhynchus mykiss*	FW	96	F	LC_{50}	MOR	22,100	5267
Rainbow trout	*Oncorhynchus mykiss*	FW	96	F	LC_{50}	MOR	15,100	5267
Rainbow trout	*Oncorhynchus mykiss*	FW	96	F	LC_{50}	MOR	17,100	5267
Rainbow trout	*Oncorhynchus mykiss*	FW	96	F	LC_{50}	MOR	43,800	2644
Rainbow trout	*Oncorhynchus mykiss*	FW	96	F	LC_{50}	MOR	66,800	2644
Fathead minnow	*Pimephales promelas*	FW	96	F	LC_{50}	MOR	70,700	3217
Fathead minnow	*Pimephales promelas*	FW	96	F	LC_{50}	MOR	129,000	10432
Fathead minnow	*Pimephales promelas*	FW	96	S	LC_{50}	MOR	171,000	10432
Fathead minnow	*Pimephales promelas*	FW	96	S	LC_{50}	MOR	103,000	10432
Northern pink shrimp	*Penaecus duorarum*	SW	48	S	LC_{50}	MOR	81,500	2644
Northern pink shrimp	*Penaecus duorarum*	SW	72	S	LC_{50}	MOR	81,500	2644