Tier I Method for Evaluation of the Indirect Effects SQO

March 18, 2011

I. Introduction

This document describes the proposed approach and outcomes for a Tier I assessment in the Sediment Quality Objectives (SQO) Indirect Effects assessment framework. The approach described herein has been revised in response to comments by the SQO Scientific Steering Committee. Specific methods for performing each step in the assessment are included, in addition to provisional threshold values.

Overview of Indirect Effects Assessment Framework

The purpose of the indirect effects assessment framework is to determine whether sediment meets California's narrative SQO for human health: *Pollutants shall not be present in sediments at levels that will bioaccumulate in aquatic life to levels that are harmful to human health.* This assessment determines whether sediment contamination at a site results in an unacceptable health risk to humans who consume contaminated seafood (i.e., fish and shellfish).

Data for two types of information, referred to as indicators, are analyzed to make the assessment: risk from consuming seafood and the relative contribution of the site contamination to seafood contamination. The unit of assessment is the site, which is as an area of interest within a water body. The size and boundaries of a site are a function of the assessment's purpose and study design, which are identified by developing a conceptual site model. For some applications, a site may be equivalent to an entire bay or estuary, while other programs may require assessment within a portion of the water body.

This assessment framework is intended to provide a consistent method for interpreting monitoring data from several statewide programs. The framework's conceptual design is applicable to a variety of contaminants, while the specific tools described in this phase of the program are intended for assessing chlorinated hydrocarbon pollutants: DDTs, PCBs, chlordane, and dieldrin.

Role of Three Tiers in the Assessment Framework

The assessment framework includes three tiers, each entailing a progressively increased level of effort, site specificity, and expected accuracy of information provided (Figure 1). A tiered assessment approach focuses effort on areas where greater benefit may be achieved by greater effort (U. S. EPA and U. S. Army Corps of Engineers 1991, Cura et al. 1999, U. S. EPA 2001, Bridges and von Stackelberg 2003, SPAWAR Systems Center (SSC) San Diego and Battelle 2003, U. S. Army Corps of Engineers et al. 2006). Each tier of the assessment framework represents an increasing level of complexity and effort. This enables the assessment to match variations in data availability, site complexity, and study objectives.

Tier I is a rapid screening assessment to address the question: *Do the sediments at a site pose a potential human health hazard, warranting further evaluation?* This type of analysis is routinely performed in ecological and human health assessments (Hope 2009). In Tier I, available tissue and sediment data are examined to determine whether there appears to be sufficient human health hazard to warrant a complete site assessment (i.e., Tier II). Sediment and tissue chemical concentration data are interpreted using standardized conservative assumptions to evaluate the potential risk to human consumers of seafood. If Tier I were to indicate sufficient potential for risk, then the analysis would proceed to Tier II. Sites found to have low potential risk in Tier I would be determined to meet the SQO without a requirement for further assessment.

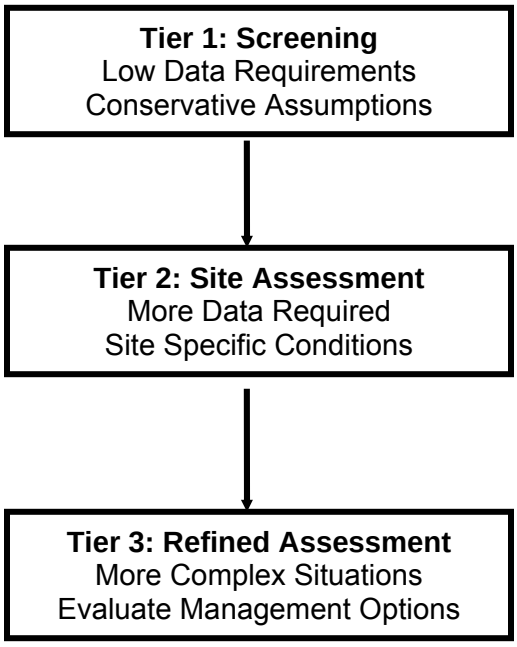

Figure 1. Tiered assessment framework.

Tier II is a complete site assessment that consists of an evaluation of both tissue data and sediment data to determine risk to human health, using available site-specific information. Tier III is an optional follow-up evaluation, entailing additional effort at data collection and modeling, to characterize in detail the conditions of the site.

Benefits and characteristics of a Tier I assessment

To be useful in practice, a Tier I screening assessment should provide the following benefits:

1. **Efficient use of technical resources by focusing on sites and contaminants that pose potential concern.** The Tier I assessment should be rapid and efficiently performed. Rapid identification of contaminants and/or water bodies that clearly meet the narrative objective for indirect effects will enable further evaluations to focus on sites and contaminants for which there is greater potential for human health impacts.

2. **Consistent assessment of multiple water bodies.** The Tier I screening assessment approach should be consistent across multiple water bodies. This will aid regional and statewide planning efforts.

To achieve the benefits of efficiency and consistency, the Tier I screening assessment should have the following characteristics:

1. **Relatively low data requirements.** Tier I assessment should be feasible using data that are typically available. Requirements for data collection should be modest and feasible for most monitoring programs.
2. **Low complexity of data analysis.** The data preparation and analysis steps should be straightforward and achievable by users having limited technical expertise in bioaccumulation modeling and risk analysis.
3. **Low rate of false negatives.** The Tier I assessment should not determine a site to be low risk when the site actually poses and unacceptable risk (based on Tier II assessment).
4. **Effective in identifying low risk sites.** The assessment should be able to discriminate between sites of varying health hazard, such that some sites are identified as having low risk.
5. **Comparable methods to those used in Tier II.** Similar data types and procedures should be used in Tier I and Tier II in order to increase the efficiency of conducting subsequent analyses in Tier II.

II. Tier I Approach Overview

To achieve the aforementioned benefits and characteristics, the Tier I assessment has a high degree of standardization, yet can accommodate different data types and study designs. A Tier I assessment may be performed using either seafood tissue or sediment contaminant concentrations, depending on what data are available for the site (Figure 2). If both sediment and tissue chemistry data are available, the Tier I assessment is performed using both data types. Either type of data are compared to thresholds to estimate whether the site poses a potential health hazard to seafood consumers. The result is classified into one of two categories based on a comparison of the concentration to standardized thresholds: 1) Meets SQO (acceptable health hazard level present) or 2) Tier II Assessment Needed (potentially unacceptable health hazard present).

The Tier I assessment can result in a determination that the site meets the SQO for indirect effects, but cannot determine that the site exceeds the SQO. If the Tier I outcome does not clearly indicate that the site meets the SQO, the analysis proceeds to the Tier II assessment (Figure 2). The site is then categorized using the Tier II approach into one of five categories, as described in a separate document (SQO Science Team 2011).

The Tier I assessment is performed in three steps:

- Step 1: Develop conceptual site model.
- Step 2: Calculate contaminant concentration.
- Step 3: Determine assessment outcome.

This process is conducted separately for each contaminant group and data type.

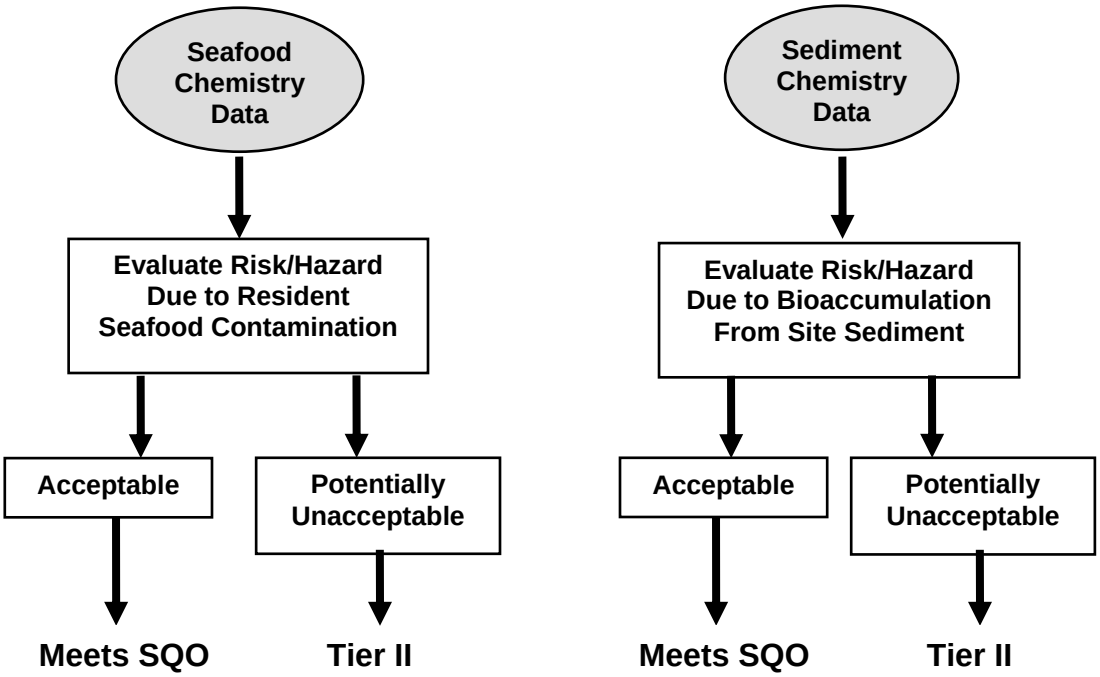

Figure 2. Tier I assessment sequence. The assessment may be performed using seafood and/or sediment chemistry data.

The procedures for each step of the assessment are similar for either tissue or sediment chemistry data. A general description of the methods is presented in the following paragraphs.

Step 1: Develop a conceptual site model

Step 1, development of a conceptual site model, is necessary for planning the assessment and formulating management decisions. Background on conceptual model development may be found in Cura et al. (1999) and Bridges et al. (2005); Davis et al. (2006) and Connor et al. (2004) provide two detailed examples. The conceptual site model should be based on local information and expertise. For Tier I assessment, the conceptual site model should contain, at a minimum, information needed to determine the following parameters:

- Site boundaries and site size
- Appropriate seafood species for Tier I analysis (if tissue data are available)

A definition of the site boundaries and site size is needed to aid in data collection and data reduction. Site boundaries may be defined based on geomorphic and hydrologic boundaries, areas of management concern, previous boundary definitions (e.g., water body segments), and other local considerations. Selection of appropriate seafood species is based on the fishing and consumption practices of local consumers, species known to reside in the site and targeted in ongoing seafood contamination monitoring programs, and inclusion of predominant dietary guilds where possible.

Step 2: Calculate contaminant concentration

For either seafood tissue or sediment data, the contaminant concentration is calculated as the 95% upper confidence limit (UCL) of the arithmetic average (i.e., Mean + 2 x Standard Error of the Mean). The estimated concentration is obtained using all appropriate data within the site boundaries (defined in Step 1). For sediment data, average TOC concentration must also be calculated.

Step 3: Determine Tier I assessment outcome

The seafood tissue or sediment concentration estimate is compared to thresholds to classify the site condition. The thresholds are calculated based on statewide values for consumption rate, acceptable cancer risk and noncancer hazard, and other risk calculation parameters. The sediment threshold is calculated from the seafood tissue threshold using a bioaccumulation model run with statewide parameter values.

A Tier I assessment results in one of two categorical outcomes, depending on how site concentrations compare to threshold values.

1. **Meets SQO:** Concentrations are below threshold values, indicating low potential risk to sport fish consumers based on the data evaluated. Results should be corroborated with both data types, if available. If only one data type is available, then no further evaluation is needed, and the analysis is complete.
2. **Tier II Needed:** Concentrations are at or above threshold values, indicating potential risk to sport fish consumers based on the tissue or sediment data evaluated. Tier II assessment is needed to confirm the results.

III. Data analysis and Evaluation

This section describes aspects of the Tier I assessment specific to three data combinations: using seafood data alone, using sediment data alone, or using both seafood and sediment data concurrently. Conceptual model development (Step 1) is similar for each data type and is not described here.

<u>Seafood Tissue Evaluation</u>

Figure 3 illustrates Steps 2 and 3 of the seafood tissue evaluation. Consistent with the intent of the Tier I assessment to have a low false negative error rate, several conservative parameter values are included in the analysis:

- A high estimate (includes most consumers) of seafood consumption rate.
- The upper confidence limit (UCL) of average tissue concentration.

For seafood tissue data, the UCL of average tissue concentration is obtained (Step 2) using all appropriate tissue chemistry samples collected within site boundaries. This calculation may include multiple fish species, provided that they are determined to be appropriate in the site conceptual model. When data for a single species are available, the Tier I concentration estimate

= 95% UCL. When data for multiple fish species are available, concentration is calculated as the average of 95% UCL across species; i.e.

concentration = $[\Sigma (\text{mean} + 2\ SE)_i]/n$

where $(\text{mean} + 2\ SE)_i$ is the 95% UCL of the average for species i, Σ is the sum across all species, and n is the number of species. In cases where the sample size is too low to calculate the UCL for a given species, the maximum concentration is used for that species.

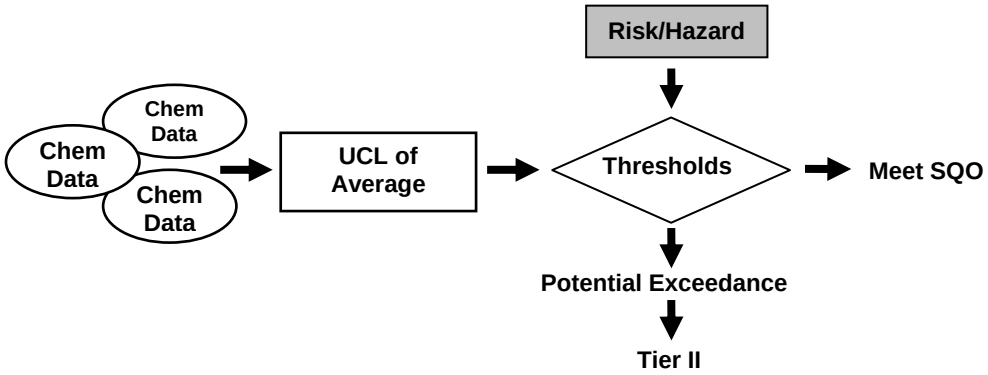

Figure 3. Seafood chemistry evaluation steps. Grey boxes are prior calculations to develop thresholds.

A brief example illustrates the calculation of the Tier I seafood contaminant concentration. In this example, the site has data available for three species (A, B, and C). For species A and B, 95% UCL of the average concentrations are 30 and 70, respectively. For species C, only a single composite sample is available with a concentration of 140. In this example, the Tier I estimated concentration for the site is (30+70+140)/3 = 80.

The seafood tissue evaluation is completed by comparing site concentrations to tissue concentration thresholds that correspond to acceptable health risk levels (Step 3). To facilitate data evaluation, the tissue thresholds are listed in Table 1. These thresholds are provisional values, pending SSC review and Water Board decisions. These thresholds correspond to the same acceptable cancer risk and noncancer hazard levels used for Tier II assessment. The equations used for threshold calculation are described in Appendix A. The proposed consumption rate (32 g/d) is a high estimate of seafood consumption rate, corresponding to the value used for OEHHA's Fish Contaminant Goals (Klasing and Brodberg 2008), U.S. EPA's (2004) national advisory for mercury, and the 95th percentile consumption rate in the San Francisco Seafood Consumption Survey (SFEI 2000).

Table 1. Tier I thresholds for tissue concentration (ng/g ww). These thresholds were developed based on parameter values in footnote a. Values shown are provisional, subject to revision by the Water Board.

Parameter [a]	Chlordanes	Dieldrin	DDTs	PCBs
Cancer Risk	39	3.2	150	26
Noncancer Hazard	168	255	2552	102

[a] Risk parameters used for threshold calculation:
consumption rate = 32 g/day (SFEI 2000, U. S. EPA 2004, Klasing and Brodberg 2008);
cooking reduction = 0.7;
exposure duration = 30 yr;
averaging time = 70 yr;
cancer risk = 1×10^{-5}
noncancer hazard quotient = 1

A separate comparison to the cancer risk and noncancer hazard thresholds is made for each contaminant type (i.e., DDTs, PCBs, chlordanes, dieldrin). If the concentration is less than both thresholds, then the site is determined to have met the SQO with respect to that contaminant type (Table 2).

Table 2. Decision matrix for tissue chemistry evaluation. A separate evaluation is made for each contaminant type.

Comparison Result	Tier I Outcome
< Threshold	Meets SQO
≥ Threshold	Tier II Needed

Sediment Evaluation

Consistent with the intent of the Tier I assessment to have a low false negative error rate, several conservative parameter values and assumptions are employed:

- A high estimate (includes most consumers) of seafood consumption rate.
- The upper confidence limit of average sediment concentration.
- A high estimate of seafood lipid concentration.
- No off-site foraging by seafood (i.e., 100% exposure of fish to the site sediment)

Figure 4 summarizes Steps 2 and 3 of the Tier I sediment evaluation. In Step 2, the upper confidence limit of the average contaminant concentration is calculated (i.e., mean + 2 SE). This calculation is based upon results from all sediment samples collected within the site. In cases where the sample size is too low to calculate the UCL, the maximum concentration is used.

In Step 3, sediment contaminant UCL concentrations are compared to sediment concentration thresholds. To facilitate data evaluation, a set of sediment thresholds has been developed (Table 3). These thresholds are provisional values, pending SSC review and Water Board decisions.

The Tier I sediment thresholds vary depending on the site total organic carbon content (TOC), in order to account for the strong influence of TOC on contaminant bioavailability. The site sediment TOC is represented as the arithmetic mean.

The Tier I sediment thresholds correspond to the Tier I tissue thresholds (Table 1). The sediment thresholds are obtained by back-calculating from the tissue thresholds using a bioaccumulation factor:

Sediment threshold = (Tissue threshold)/(BAF)

The bioaccumulation factor (BAF) is the estimated increase in concentration that occurs between sediment and seafood. The BAF is obtained using a mechanistic bioaccumulation model, which quantitatively depicts contaminant chemical partitioning, bioaccumulation, and biomagnification up the food web, based upon biota uptake and loss processes (e.g., dietary and respiratory uptake). Separate BAFs were calculated for each TOC interval. Standardized statewide estimates for other bioaccumulation model parameters were used; these included lipid content for each seafood guild, congener ratio for contaminant mixtures, and water quality measurements, such as temperature, dissolved oxygen, and dissolved and particulate organic carbon (Appendix B).

Determination of the BAF was also consistent with the dietary guild-based approach described for Tier II (SQO Science Team 2010a and 2011). A separate BAF for each of the eight dietary guilds was calculated for each TOC interval. The final BAF used for threshold calculations was the weighted average of all guild BAFs. Weighting was based on statewide estimates of human consumption rate for each guild.

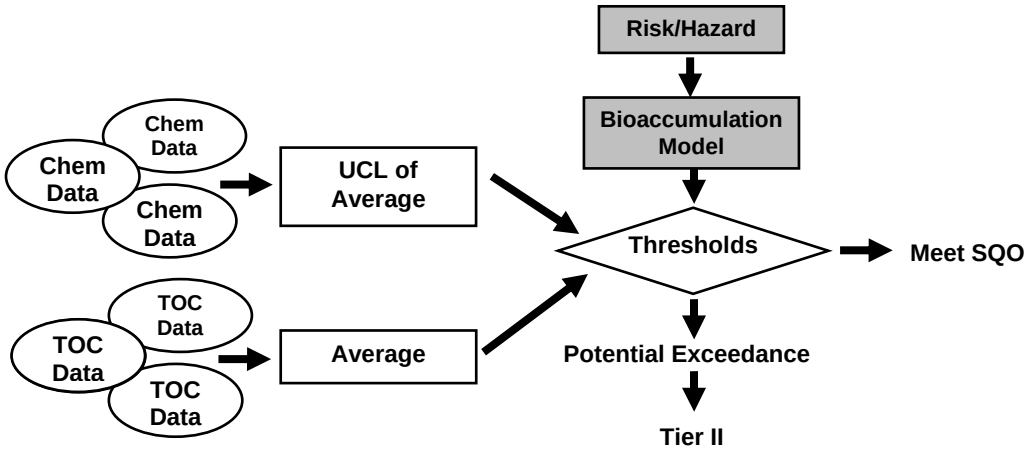

Figure 4. Sediment evaluation steps. Grey boxes are calculations performed using statewide assumptions to develop thresholds.

Table 3. Sediment threshold contaminant concentrations (ng/g dw) for Tier I assessment. CR = cancer risk threshold; H = noncancer hazard threshold.

	Chlordanes		Dieldrin		DDTs		PCBs	
TOC %	CR	H	CR	H	CR	H	CR	H
0.1	0.6	2.6	0.1	4.4	3.2	55.2	0.6	2.5
0.2	1.2	5.1	0.1	8.7	5.9	101	1.1	4.5
0.3	1.7	7.5	0.2	13.0	8.3	140	1.5	6.1
0.4	2.3	9.8	0.2	17.3	10.3	175	1.8	7.4
0.5	2.8	12.0	0.3	21.5	12.0	205	2.1	8.5
0.6	3.3	14.1	0.3	25.7	13.6	232	2.4	9.5
0.7	3.7	16.1	0.4	29.9	15.1	257	2.6	10.4
0.8	4.2	18.0	0.4	34.0	16.4	279	2.8	11.2
0.9	4.6	19.9	0.5	38.0	17.6	300	3.0	11.9
1.0	5.0	21.7	0.5	42.1	18.7	319	3.2	12.6
1.1	5.4	23.4	0.6	46.1	19.8	337	3.3	13.3
1.2	5.8	25.1	0.6	50.0	20.8	354	3.5	13.9
1.3	6.2	26.7	0.7	54.0	21.7	370	3.6	14.4
1.4	6.6	28.2	0.7	57.9	22.6	385	3.7	14.9
1.5	6.9	29.8	0.8	61.7	23.5	400	3.9	15.4
1.6	7.3	31.3	0.8	65.5	24.3	414	4.0	15.9
1.7	7.6	32.7	0.9	69.3	25.1	427	4.1	16.4
1.8	7.9	34.1	0.9	73.1	25.8	440	4.2	16.8
1.9	8.2	35.5	1.0	76.8	26.6	452	4.3	17.3
2.0	8.5	36.8	1.0	80.5	27.3	464	4.4	17.7
2.2	9.1	39.4	1.1	87.9	28.6	487	4.6	18.5
2.4	9.7	41.8	1.2	95.1	29.9	509	4.8	19.2
2.6	10.3	44.2	1.3	102	31.1	529	5.0	20.0
2.8	10.8	46.5	1.4	109	32.3	549	5.2	20.7
3.0	11.3	48.7	1.5	116	33.4	568	5.3	21.3
3.2	11.8	50.8	1.5	123	34.5	587	5.5	22.0
3.4	12.3	52.8	1.6	130	35.5	604	5.7	22.6
3.6	12.7	54.8	1.7	136	36.5	622	5.8	23.3
3.8	13.2	56.7	1.8	143	37.5	639	6.0	23.9
4.0	13.6	58.6	1.9	149	38.5	655	6.1	24.4

A separate comparison to the cancer risk and noncancer hazard sediment thresholds is made for each contaminant type (i.e., DDTs, PCBs, chlordanes, dieldrin). If the concentration is less than both thresholds, then the site is determined to have met the SQO with respect to that contaminant type (Table 2).

Evaluation Using Both Seafood and Sediment Data

If both seafood chemistry and sediment chemistry data are available, the analysis should be performed using both data types. If either evaluation (sediment or tissue) exceeds the hazard threshold, then the analysis would proceed to Tier II. Table 4 lists all possible combinations of the results and their final outcome.

Table 4. Decision matrix for all data combinations.

Sediment Category	Seafood Category	Final outcome
Meets SQO	Meets SQO	Meets SQO
Meets SQO	No data	Meets SQO
No data	Meets SQO	Meets SQO
Potential Exceedance	No data	Tier II Needed
No data	Potential Exceedance	Tier II Needed
Meets SQO	Potential Exceedance	Tier II Needed
Potential Exceedance	Meets SQO	Tier II Needed
Potential Exceedance	Potential Exceedance	Tier II Needed

IV. Comparison of Tier I and II Attributes

Tiers I and II are similar in basic elements and methodology, but differ in many specific aspects of study design and data handling (Table 5). The basic data types used for both tiers include seafood tissue contaminant concentrations or sediment contaminant concentrations. The basic methodology for determining the result is also similar, with both tiers relying on risk parameters for the tissue chemistry assessment (e.g., cancer risk, noncancer hazard, consumption rate). Also, the same mechanistic bioaccumulation model (Gobas and Arnot 2010) is employed in both tiers to aid in interpreting sediment chemistry data.

Many of the differences between Tier I and II assessments stem from the fact that Tier I is a screening assessment with a potentially less robust data set and the possible use of only one indicator (i.e., seafood or sediment chemistry alone). In Tier II, some default assumptions and parameters are replaced with parameters and assumptions based on local site measurements. For example, in Tier II evaluations, the bioaccumulation model is employed separately for each sediment assessment, whereas Tier I uses TOC-specific sediment thresholds (Table 3) that were developed using statewide calculations. Another difference between the tiers is that Tier I can be performed using a single data type (sediment or tissue chemistry), whereas Tier II requires the use of both data types. This is because Tier II compares tissue chemistry estimated from sediment to observed tissue chemistry results to determine the relative importance of bioaccumulation from the site. A third difference is that Tier I calculates a single point estimate of potential risk, whereas Tier II uses simulation methods to determine a probability distribution of risk. For example, Tier I chemistry data are represented by the UCL of the average, whereas Tier II employs the full probability distribution of the average.

Table 5. Summary of Tier I and Tier II characteristics.

Element	Attribute	Tier I	Tier II
Field Data	Sediment sample	Surface layer	Surface layer
Field Data	Sediment sample number	At least 3	At least 5
Field Data	Sediment sample location	Within site	Spatially representative
Field Data	Tissue sample location	Associated with site	Associated with site
Field Data	Tissue sample number	At least 3	At least 5
Field Data	Tissue type	Whole fish or fillet	Skin-off fillet
Field Data	Treatment of uncertainty in chemistry data	Point estimates based on 95% UCL	Probability distribution
Risk Evaluation	Treatment of uncertainty in consumption rate	Point estimate of high rate	Probability distribution
Risk Evaluation	Evaluation of sediment chemistry	Compare concentration to threshold	Compare distribution to a threshold
Bioaccumulation calculation	Model type	Mechanistic	Mechanistic
Bioaccumulation calculation	Degree of standardization	Calculation based on statewide assumptions	Site-specific calculation
Bioaccumulation calculation	Local data incorporation	Sediment TOC	TOC, site area, seafood lipid, water chemistry
Bioaccumulation calculation	Site use factor	100% site exposure assumed	Variable based on species and site dimensions
Bioaccumulation calculation	Treatment of uncertainty in bioaccumulation	Point estimate	Probability distribution based on literature range
Data Integration	Number of data types evaluated	1 or 2	2
Data Integration	Assessment outcomes	2 categories	5 categories

V. Tier I Case Study

A case study example illustrates the application of the Tier I assessment. In this example, sediment and tissue contamination data were compiled for San Francisco Bay. For the present example, Regional Monitoring Program data on contaminant concentrations in three appropriate fish species and sediment were assembled. Tissue data were collected from four sites in San Francisco Bay in 2000, 2003, 2006, and 2009. A site conceptual model was developed for San Francisco Bay (Step 1), and is described in the Tier II framework document (SQO Science Team 2011). Based on the site conceptual model, seafood chemistry data were evaluated for leopard shark, white croaker, and shiner perch. The 95%ile of the mean contaminant concentration was calculated for each species, with results for the three species averaged (Step 2). Sediment data were collected annually using a probabilistic survey design in 2002, and 2004 – 2009. The 95%ile of the mean contaminant concentration was calculated for all sediment results. Mean sediment TOC for the samples was 1.3%. Table 6 lists the chemistry data used in the assessment.

Table 6. Summary data from San Francisco Bay. Note that all contaminant results are the 95%ile of the average. Tissue are ng/g ww, sediment are ng/g dw

Parameter	DDTs	PCBs	Chlordanes	Dieldrin
Leopard shark tissue	10.5	25.3	1.4	0.7
White croaker tissue	70.4	251	12.1	2.2
Shiner perch tissue	27.4	122	6.7	1.6
95%ile average tissue	36.1	133	6.7	1.5
95%ile average sediment	2.6	7.0	0.2	0.1

Results were compared to the Tier I thresholds for each contaminant (Step 3; Tables 7 and 8). Examination of the tables illustrates consistent findings for sediment and tissue. Neither sediment nor tissue results exceed the Tier I thresholds for DDTs, chlordanes, or dieldrin. Tissue PCB results exceed both the cancer risk and noncancer hazard thresholds. Sediment PCB results exceed the cancer risk threshold, but not the noncancer hazard threshold for. In this example, both sediment and tissue data indicate that the SQO is met for DDTs, chlordanes and dieldrin, and that a Tier II evaluation should be conducted for PCBs.

Table 7. Comparison of tissue concentrations (ng/g ww, Table 6) to the Tier I screening thresholds shown in Table 2. Highlighted results exceed the Tier I tissue threshold.

Parameter	DDT	PCB	Chlordane	Dieldrin
Observed Tissue Concentration	36.1	**132.9**	6.7	1.5
Cancer Risk Threshold	<150	**>25.5**	<39	<3.2
Noncancer Hazard Threshold	<2552	**>102**	<168	<255

Table 8. Comparison of sediment concentrations (ng/g dw, Table 6) to the Tier I screening thresholds. Screening thresholds are extracted Table 4, based on a sediment TOC of 1.3 (Table Y). Highlighted results exceed the Tier I sediment threshold.

Parameter	DDT	PCB	Chlordane	Dieldrin
Observed Sediment Concentration	2.6	**7.0**	0.2	0.1
Cancer Risk Threshold	<21.7	**>3.6**	<6.2	<0.7
Noncancer Hazard Threshold	<370	<14.4	<26.7	<54.0

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Appendix A – Consumption Risk Equations

The following equations are used in the SQO assessment framework (Tier I and II) for evaluating risk to sport fish consumers. They are based on Office of Environmental Health Hazard Assessment (OEHHA) methods to establish tissue advisories and goals in California waters (Klasing and Brodberg 2008).

For carcinogenic effects
OEHHA equation:
Tissue Concentration (mg/kg) = RL x BW / [CR x CSF x (ED/AT) x CRF]

For non-carcinogenic effects
OEHHA equation:
Tissue Concentration (mg/kg) = HQ x RfD x BW / (CR x CRF)

Where:
AT = Averaging Time (yr)
BW = Body Weight (kg)
CR = Consumption Rate (kg/d)
CRF = Cooking Reduction Factor (unitless)
CSF = Cancer Slope Factor $(mg/kg/d)^{-1}$
ED = Exposure Duration (yr)
HQ =Hazard quotient for noncarcinogens (unitless)
RfD = Reference Dose (mg/kg/d)
RL = Carcinogenic Risk Level (unitless)

Appendix B – Assumptions in Tier I Bioaccumulation Factor Calculation

This section describes the assumptions and parameter values used in calculating the bioaccumulation factors (BAF) for Tier I sediment threshold development. The BAFs were used in combination with tissue thresholds (Table 1) to calculate provisional Tier I sediment thresholds (Table 3). Because these thresholds could be used in estuaries and bays throughout the state, the assumptions in their development were based on statewide average results whenever possible. These statewide parameters included the relative proportion of each seafood guild consumed by humans, lipid content of seafood species, the concentration ratio for individual contaminant compounds, and water chemistry parameters.

Dietary Proportion

The SQO Indirect Effects Assessment employs a dietary guild approach, in which species selection and the bioaccumulation model are based on the range of seafood foraging habits found in California bays and estuaries (SQO Science Team 2010a). This guild approach is intended to provide a more realistic indication of seafood exposure to contaminated sediments than using assumptions for a generic seafood organism. Consistent with this approach, the proportion of local seafood consumption represented by each guild was estimated for each of the eight dietary guilds. These values were used to calculate a weighted average BAF that reflected the different bioaccumulation properties of each guild.

Proportion of human seafood consumption was based on the total proportion of finfish harvested by mass in inland marine waters for all California coastal districts. This was obtained using an August 9, 2010 query of the Recreational Fisheries Information Network (RecFin) database on individual catch by recreational anglers (www.recfin.org). Guild membership was defined as described elsewhere (SQO Science Team 2010a). Results for all species within a guild were summed, and percent of the total mass across all included species was obtained. The three most important guilds were benthic with piscivory, benthic without piscivory, and piscivore. Each constituted greater than 20% of the total diet. The remaining five guilds each constituted less than 5% of the total diet (Table 1).

Tissue Lipid

Lipid data for Tier I threshold calculations were obtained from the SWAMP bioaccumulation database, a statewide database on tissue contamination developed and validated by SFEI (Davis et al. 2007, Hoenicke et al. 2008). The database was queried, resulting in 2606 sample records from 107 fish species. From these records, average fillet tissue lipid data were obtained for 30 of the 41 finfish species identified to be appropriate for SQO assessment (SQO Science Team 2010a). Lipid data were available for between one and ten species for each of the eight dietary guilds and represented the most common species caught by anglers. For each guild, the weighted average lipid content was obtained. Weighting was based on the total proportion of seafood caught by

mass, obtained in the RecFin database query described above. The lipid content varied substantially by guild (Table B1). The weighted average lipid content across all guilds was 1.43%. This is equivalent to the 73rd percentile of the distribution of species average lipid content for the 107 species obtained in the SWAMP database query. In other words, the lipid estimate included in the Tier I sediment threshold calculations is somewhat higher than the typical lipid concentration observed in California finfish.

Table B1. Results for percent of human seafood and lipid content across the eight SQO guilds

Guild	Portion of human seafood	Lipid (%)
1Piscivore	24.3%	0.36%
2Benthic diet with piscivory	38.2%	0.69%
3Benthic and pelagic with piscivory	4.6%	1.58%
4Benthic without piscivory	25.2%	3.29%
5Benthic and pelagic without piscivory	3.1%	1.09%
6Benthic with herbivory	0.6%	3.56%
7Benthic and pelagic with herbivory	1.7%	1.17%
8Pelagic with benthic herbivory	2.4%	4.44%

Compound ratios for bioaccumulation factor calculation

The BAF calculation is dependent on the chemical properties of individual compounds. Therefore, BAF results will be influenced by the relative ratio of different compounds in the sediment. Therefore, abundance of individual compounds must be entered into the bioaccumulation model to allow calculation of the BAF. Although it would be preferable to base the contaminant ratio on sediment data from multiple California water bodies, most data collected to date do not use detection limits sufficiently low to accurately characterize average ratios across all compounds. Data collected in San Francisco Bay by the Regional Monitoring Program (SFEI 2006) employ sufficiently low detection limits to be appropriate for this purpose, and were used to calculate individual compound abundance.

Sample selection and data reduction methods were employed based on RMP available data and metadata. The RMP collects samples at both fixed sites, and probabilistic sites selected using a spatial survey design (Lowe et al. 2004, SFEI 2006). To be more spatially representative, individual compound abundance was determined using only sediment samples collected in the probabilistic survey design (2004 – 2009).
Median concentrations were calculated for each pesticide compound (Table B2) and each PCB congener (Table B3). Results were obtained using the Kaplan-Meier procedure for estimating summary statistics in the presence of non-detects. Calculations were performed in R 2.11.1 using the NADA Package, which is based on methodologies described in Helsel (2005, 2010). Coeluting PCB congeners were reported as the lowest congener in the coelution group. Of the compounds included in the bioaccumulation model, all compounds were available for inclusion except for PCB 74 and PCB 97, each of which coeluted with other PCB congeners and were not reported. Sample size for the analysis (number of sediment samples collected and analyzed) ranged from 78 to 240

(median = 238). Percent of censored values (below detection) was low for all compounds, ranging from 0 to 26% (median = 2%). Final results used in the bioaccumulation model are presented in Tables B2 and B3.

Table B2. Median concentrations for legacy pesticide compounds measured by the RMP for Trace Substances in San Francisco Bay (2004 – 2009). These results were used to determine compound ratios for developing the provisional Tier I sediment contamination thresholds (Table 3). Sample sizes and number of censored (below detection limits) results are provided for informational purposes.

Compound	Median (ng/g dry wt.)	N	N Censored	% Censored
alpha-Chlordane	0.055	236	3	1%
gamma-Chlordane	0.057	78	0	0%
cis-Nonachlor	0.034	236	2	1%
trans-Nonachlor	0.038	238	0	0%
Oxychlordane	0.002	215	56	26%
Dieldrin	0.068	240	8	3%
o,p'-DDD	0.174	240	4	2%
o,p'-DDE	0.039	239	4	2%
o,p'-DDT	0.022	158	12	8%
p,p'-DDD	0.774	240	3	1%
p,p'-DDE	0.812	240	1	0%
p,p'-DDT	0.080	225	16	7%

Table B3. Median concentrations for PCB congeners measured by the RMP for Trace Substances in San Francisco Bay (2004 – 2009). These results were used to determine compound ratios for developing the provisional Tier I sediment contamination thresholds (Table 3). Sample sizes and number of censored (below detection limits) results are provided for informational purposes.

Compound	Median (ng/g dry wt.)	N	N Censored	% Censored
PCB 008	0.042	234	5	2%
PCB 018	0.027	223	0	0%
PCB 028	0.109	233	10	4%
PCB 031	0.058	231	4	2%
PCB 033	0.03	234	14	6%
PCB 044	0.111	237	4	2%
PCB 049	0.081	237	3	1%
PCB 052	0.128	235	0	0%
PCB 056	0.048	227	2	1%
PCB 060	0.022	236	14	6%
PCB 066	0.144	234	2	1%
PCB 070	0.206	238	4	2%
PCB 074	NA			
PCB 087	0.167	197	5	3%
PCB 095	0.161	239	6	3%
PCB 097	NA			
PCB 099	0.183	236	0	0%
PCB 101	0.306	240	5	2%
PCB 105	0.112	238	16	7%
PCB 110	0.322	240	5	2%
PCB 118	0.303	240	5	2%
PCB 128	0.094	240	9	4%
PCB 132	0.12	240	8	3%
PCB 138	0.58	240	5	2%
PCB 141	0.045	230	3	1%
PCB 149	0.352	240	5	2%
PCB 151	0.156	240	5	2%
PCB 153	0.582	240	5	2%
PCB 156	0.051	238	14	6%
PCB 158	0.047	239	23	10%
PCB 170	0.134	239	6	3%
PCB 174	0.108	239	13	5%
PCB 177	0.095	240	15	6%
PCB 180	0.302	240	5	2%
PCB 183	0.094	239	13	5%
PCB 187	0.238	240	5	2%
PCB 194	0.081	235	1	0%
PCB 195	0.028	233	14	6%
PCB 201	0.018	112	11	10%
PCB 203	0.048	227	7	3%

Water chemistry

The bioaccumulation model requires water chemistry parameters, including dissolved organic carbon (DOC), particulate organic carbon (POC), temperature, salinity, dissolved oxygen, and suspended sediment concentration (SSC). Prior sensitivity analysis indicated low sensitivity of model results for these parameters (SQO Science Team 2010b). Nevertheless, for Tier I threshold calculation, statewide estimates were obtained by compiling data from multiple water bodies. Results were obtained from technical reports (Kennison et al. 2003), theses (Condon 2007), unpublished data (LA County Sanitation District, pers. comm.; Port of Long Beach, pers. comm.; web queries to NERR, CenCOOS, and KRIS websites), and journal publications (Allen et al. 2002, Zeng et al. 2002, David et al. 2006, Greenfield et al. 2007, Gobas and Arnot 2010). Depending on data availability, water body averages were obtained from 4 to 14 estuaries or marine embayments throughout the state. All results were obtained by generating averages for each water body, and then obtaining a grand average across water bodies (Table B4).

Table B4. Summary statistics for water chemistry parameters, used in developing the provisional Tier I sediment contamination thresholds (Table 3).

Parameter	Description	N (water bodies)	Average	SD
T	Water temperature (°C)	14	17.4	4.1
Salinity	Salinity (PSU)	14	25.4	9.6
SSC	Suspended solid concentration in water column (kg L-1)	6	2.27E-05	3.20E-05
POC	Particulate organic carbon content of water (kg L-1)	4	1.57E-06	1.64E-06
DOC	Dissolved organic carbon content of water (kg L-1)	6	2.15E-06	1.48E-06