Guidance For Sediment Quality Evaluations

New Jersey Department of Environmental Protection

November 1998

New Jersey Department of Environmental Protection
Mission Statement

To assist the residents of New Jersey in preserving, sustaining, protecting and enhancing the environment to ensure the integration of high environmental quality, public health and economic vitality.

- Developing and integrating an environmental master plan to assist the Department and our partners in decision-making through increased availability of resource data on the Geographic Information System.
- Defining and publishing reasonable, clear and predictable scientifically-based standards.
- Achieving the Department's goals in a manner that encourages compliance and innovation.
- Employing a decision-making process that is open, comprehensive, timely, predictable and efficient.
- Providing residents and visitors with affordable access to safe and clean open space, historic and natural resources.
- Assuring that pollution is prevented in the most efficient and practical way possible.
- Assuring that the best technology is planned and applied to achieve long-term goals.
- Assuring that non-treatable wastes are isolated, managed and controlled.
- Enhancing environmental awareness and stewardship through education and communication.
- Fostering a work environment that attracts and retains dedicated and talented people.
- Committing to an ongoing evaluation of the Department's progress toward achieving our mission.

Guidance For
Sediment Quality Evaluations

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SITE REMEDIATION PROGRAM
GUIDANCE FOR SEDIMENT QUALITY EVALUATIONS

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1.0 INTRODUCTION

The purpose of this document is to establish practical guidance for the evaluation of sediment quality to be used in the ecological risk assessment process associated with contaminated sites under the jurisdiction of the Site Remediation Program (SRP) in the New Jersey Department of Environmental Protection. Presented are procedures and references that form a framework for qualitative and quantitative determinations of actual or potential adverse ecological effects and provide the basis for remedial decision-making and evaluation of injury to natural resources in sediment media. The information presented in this document is based on State and Federal regulations and guidances, in particular *Ecological Risk Assessment Guidance for Superfund, Process for Designing and Conducting Ecological Risk Assessments* (EPA 540-R-97-006) and *Risk Assessment Guidance for Superfund, Volume II, Environmental Evaluation Manual* (EPA/540/1-89/001). It is intended to be consistent with, and supplementary to, the *Technical Requirements for Site Remediation, N.J.A.C. 7:26E*. References are presented at the end of each major section for ease of use.

In accordance with *N.J.A.C. 7:26E-3.8 (b)*, the collection of sediment samples is required when it is evident that a discharge to a surface water body has occurred pursuant to *N.J.A.C. 7:26E-3.8 (a)*. Successful evaluation and risk management of contaminated sediments requires knowledge of the nature, concentration and areal extent of contamination, as well as site-specific variables that affect the expression of environmental impacts. There are three components of a complete assessment of sediment quality:

(1) measurement of contaminant concentration, via standard or special analytical laboratory procedures;

(2) measurement of toxicity and bioavailability, via tissue analysis, sediment toxicity testing, etc.; and

(3) assessment of resident biota, via community bioassessment/survey procedures.

These three components, measured at potentially site-impacted and reference locations, provide complementary data, because no single component can be used to predict the measurement of the other components. For example, sediment chemistry provides information on the identification and extent of contamination but not on biological effects. Sediment toxicity testing provides direct evidence of sediment toxicity but cannot discriminate among contaminants nor predict actual in-situ responses. In-situ responses of resident biota, measured by in-fauna community surveys can provide direct evidence of contaminant-related effects, but only if confounding effects unrelated to contamination can be excluded, such as differences in habitat quality. Thus, a sediment evaluation program must be based on this “triad” approach to provide a weight of evidence for determining if adverse effects are occurring, and if so, whether they are due to the site in question.

For sediment quality evaluations at SRP sites, this "triad" investigation is accomplished pursuant to the tiered approach described in *N.J.A.C. 7:26E-3.11 and 4.7.* In the Baseline Ecological Evaluation (BEE), the site is examined for the co-occurrence of chemicals of potential ecological concern, environmentally sensitive areas, and complete chemical migration pathways, to assess the potential for ecological risk. If this initial evaluation indicates the potential for adverse ecological effects, a subsequent, more rigorous evaluation will be required for the full Ecological Risk Assessment (ERA) to further characterize risk.

REFERENCES

N.J.A.C. 7:26E. Technical Requirements for Site Remediation.

U.S. Environmental Protection Agency. March, 1989. *Risk assessment guidance for Superfund, volume II, environmental evaluation manual.* EPA/540/1-89/001. Office of Emergency and Remedial Response. Washington.

U.S. Environmental Protection Agency. June, 1997. *Ecological risk assessment guidance for Superfund, process for designing and conducting ecological risk assessments.* EPA 540-R-97-006. Office of Solid Waste and Emergency Response. Washington.

2.0 SAMPLING PLAN DESIGN

2.1 SEDIMENT SAMPLING PLAN

Generally, the goals of a sediment sampling program include preliminary and definitive determination of the nature and areal extent of contamination, and identification of areas of highest contamination. Data may also be gathered in support of ecological risk assessments, long-term monitoring, or for sediment transport and deposition modeling. The sediment sampling plan shall be a component of the Site Investigation or Remedial Investigation Work Plan, and shall be prepared pursuant to *N.J.A.C. 7:26E* and *the NJDEP Field Sampling Procedures Manual* (*FSPM, May 1992* or most recent version). Department approval may be required, pursuant to the oversight document (for privately funded projects) or contract in effect. Site-specific details regarding the study objectives, data quality objectives, sampling methodology, location, and depth of samples must be specified, as well as field and laboratory quality control/quality assurance procedures. Guidance and special considerations for designing a sediment sampling scheme are provided herein to supplement and highlight the regulatory requirements and FSPM guidance; the reader is referred to these documents for a comprehensive treatment of the subject.

1. Number of Samples

The reader is referred to USEPA's *Sediment Sampling Quality Assurance User's Guide* (USEPA, 1985) and the NJDEP FSPM for guidance on statistically determining the appropriate number of sediment samples.

2. Location

In aquatic systems, the areas of greatest contamination will generally occur in depositional areas, thus these must be specifically targeted by the sampling plan. Such depositional areas are generally characterized by slow moving water where fine sediments tend to accumulate (e.g., pool areas, river bends, etc.). Sediment samples collected for chemical analysis, toxicity testing and benthic community surveys must be spatially and temporally co-located.

a. Stream/River/Tidal Creeks Systems

An idealized approach to locating sediments samples is as follows: The stream location adjacent to the contaminated site most likely to receive contaminant input via the chemical migration pathway is considered the initial sample point. The study region is divided into linear segments and sample transects located systematically within each segment; the length of the segments and distance between transects increases with increasing distance downstream. This is depicted in Figure 1, a diagram of a sampling plan indicating 15 sediment samples per segment region. In

this example, the first segment is from 0 to 1 km, the second from 1 to 3 km, and third from 3 to 7 km. The sampling transects are located at ¼, ½, and ¾ the distance along each segment. Sample points are located along the transects at 1/6, 1/3, 1/2, 2/3, and 5/6 the distance bank to bank (USEPA, 1985). In tidal creeks, the distance from bank to bank is measured from the high water mark. **Note that upgradient sediment samples must be collected (refer to Section 2.3), thus similar sampling transects should be located upstream of the initial sampling point.**

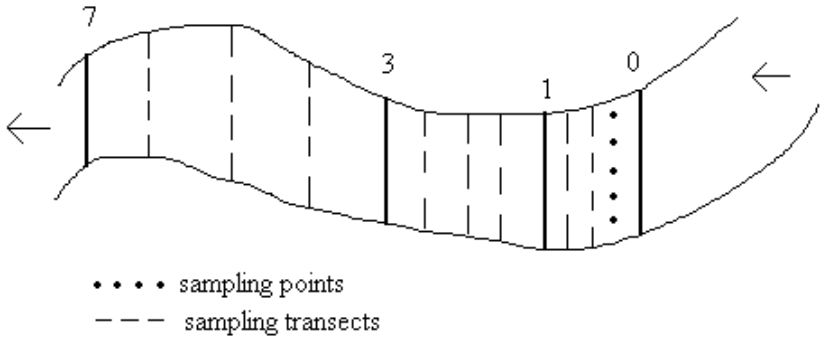

Figure 1. Sketch map of river showing stratified regions and sampling points.

The actual number and location of sample points will be decided on a case-by-case basis, based on the study objectives, water body dimensions, flow conditions, substrate conditions, availability of previous data, etc.

b. Lakes/Lagoons/Pond Areas

Sediment samples must be biased toward inflow/outflow areas and topographically low/deep areas where sediments may be expected to accumulate. If there is no basis for biasing, then random sampling of these areas is required, pursuant to *N.J.A.C. 7:26E-3.9(f).*

3. Sample Depth

Pursuant to N.J.A.C. 7:26E-4.1, surface and subsurface sediment samples are required for contaminant delineation and to assess the potential for resuspension of contaminated sediments during flood/current-based scouring events, dredging operations, or other disturbances. Surface sediment samples must be taken at the 0-6" interval, generally considered the biotic zone in sediments. Subsurface core samples, 6-12" or deeper (actual depth based on site-specific conditions), are appropriate in areas of known discharge of contaminated groundwater to surface water (refer to 2.1.5. below) or where known historic discharges have become overlain with newer sediment.

4. Analytical Protocol and Additional Measurements

In addition to bulk chemistry analysis pursuant to *N.J.A.C. 7:26E-2*, a sediment quality evaluation may include additional physical measurements, including but not limited to river depth, flow rate, suspended solids, bed load, pH, and temperature. Total organic carbon (TOC) and particle grain size must be included as indicators of contaminant bioavailability and the depositional nature of the sediments. TOC is necessary for the determination of certain sample-specific sediment quality guidelines (refer to Section 3.0).

5. Volatile Organic Contamination

The most prevalent scenario requiring the collection of sediment samples when volatile organics are of potential concern is when contaminated groundwater is known/suspected to discharge to a surface water body. When this pathway is being investigated, the sediment samples shall be collected from the 6-12" interval. It should be noted that non-aqueous samples to be analyzed for volatile organics shall be sampled using a methanol extraction/preservation method acceptable to the NJDEP pursuant to *N.J.A.C. 7:26E-2.1 (a)4.*

2.2 SPECIAL CONSIDERATION FOR SAMPLING IN TIDALLY-INFLUENCED AREAS

Salinity and tides can be strong factors in the distribution of contaminants. The delineation of the point at which these effects are most pronounced, and the distribution of the highly contaminated sediments, might be confounded by these factors. For example, as contaminated water moves downstream, an abrupt increase in salinity can cause a sudden change in contaminant solubility. When less soluble, a contaminant may precipitate and appear in the sediment at substantially higher concentrations than the previous (i.e., upstream) location. These factors should be taken into consideration and assessed when making decisions regarding the selection of sample locations and relation of contaminants to the site.

Sediment sampling must be conducted during consistent tidal conditions. Either an ebb tide or flood tide interval is appropriate and shall be decided on a case-by-case basis. The tidal stage must be recorded. Samples must be collected from depositional areas (e.g., intertidal areas along the shoreline, which are often marked by emergent vegetation and muddy or organic bottoms, as well as mudflats, etc.).

2.3 CHEMICAL CHARACTERIZATION OF UPGRADIENT AND/OR OFFSITE REFERENCE CONDITIONS

When investigating sediment contamination in order to determine if it is linked to site operations, it is important to establish the chemical composition of upgradient sediments. These data also aid in the assessment of the site's contamination relative to the regional quality of the water body being investigated and in the development of remedial goals. The SRP recognizes that many of the State's water bodies, especially in urban/industrial settings, have become contaminated by historic point and non-point discharges, resulting in the diffuse, anthropogenic contamination of sediments at concentrations greater than natural background. Additionally, upgradient sediments

can be contaminated by the site because of tidal influences. While it is difficult to distinguish between site and non site-related contamination at these settings, it is the policy of NJDEP as well as USEPA Region II to make a reasonable attempt to do so. If potential sources of contamination are present upstream of the site, and it is believed that these sources have contributed to the contamination detected on-site, these upgradient areas should be sampled, and professional judgment should dictate how these data are to be interpreted/utilized (refer to Section 3.0). Note that these results will not be considered representative of true reference (i.e., natural background) conditions.

Certain site-specific conditions or study objectives may warrant the sampling of an offsite local reference location. The need for such data shall be determined on a case-by-case basis in consultation with BEERA/ETRA.

For upgradient and offsite reference locations, SRP recommends the collection of a minimum of three (3) to five (5) samples to establish a range of reference location contaminant concentrations (the larger number of samples is recommended due to sediment heterogeneity). Samples shall be collected from areas outside the site's potential influence. The samples must not be collected from locations directly influenced by or in close proximity to other obvious sources of contamination (i.e., other hazardous waste sites, sewer/storm water outfalls, tributaries, other point and non-point source discharges, etc.). If a local reference site is included in the sampling plan, it must be of comparable habitat to the study area. Upstream areas influenced by tides shall be sampled at locations determined to be within the mixing zone to delineate upstream migration of contaminants as well as upstream of any mixing zone in order to assess local ambient conditions. At a minimum, upgradient and local reference samples shall receive the same chemical analyses as site-related samples. Additional determinations, such as benthic community structure, may be required on a case-by-case basis.

2.4 SURFACE WATER QUALITY INVESTIGATIONS AND CRITERIA

Pursuant to *N.J.A.C. 7:26E-3.8 and 4.5*, a surface water investigation is required when there is evidence that surface water may have been impacted by site-related contamination. Additionally, since the release of contaminants from sediments may play a substantial role in surface water contamination, especially in quiescent aquatic systems such as lakes, wetlands, ponds and intermittent or slow moving streams, it is appropriate to include surface water samples in the overall assessment of sediment quality. Surface water quality data also serve as a tool for the interpretation of related biological test data.

Details for surface water sampling plan design, field sampling methodology, and analytical requirements are found in *N.J.A.C. 7:26E* and the *NJDEP FSPM*. As a general guide, surface water samples should be collected near banks/depositional areas where water current is slower and there is greater retention time for the surface water to accumulate contaminants from sediment. Since contaminated groundwater and surface water can serve as sources of sediment contamination, obvious surface-runoff channels, leachate seeps, groundwater discharge areas,

etc., should be targeted. Determination of the number and location of samples should be made after all surface water migration pathways and discharge points have been identified; the potential for upstream contaminant migration in tidal water bodies must be addressed.

Surface water samples must be collocated spatially and temporally with sediment samples. In addition to bulk chemical analysis, measurements for salinity (in estuarine systems), pH, dissolved oxygen, and total hardness (as mg/1 $CaCO_3$) are required.

Surface water risks to aquatic receptors are evaluated based on comparison of measured concentrations with acute and chronic *Surface Water Quality Standards* (*N.J.A.C. 7:9B*). The most recent version of the list entitled *Surface Water Quality Criteria Applicable to New Jersey* can be obtained from the Standards Assessment and Modeling Unit, Office of Environmental Planning, at 609-633-7020. Those criteria that require a hardness value to derive the applicable criterion must employ a station-specific hardness value, not an average value.

For inorganic contaminants, it is recommended by the USEPA Region II Biological Technical Assistance Group (BTAG) and the SRP that both dissolved and total recoverable metals be measured. Most aquatic water quality criteria are based on the dissolved (filtered) form of the metal; however, the total recoverable (unfiltered) inorganic value is more indicative of total contaminant exposure and should be used for risk-management decision-making. Additionally, USEPA Office of Water recommends that Superfund ecological risk assessments consider inorganics on a total recoverable basis to conservatively avoid underestimation of bioavailable metals. (USEPA, 1993). Together, the two sets of measurements are used to judge regulatory compliance as well as potential adverse ecological impact.

REFERENCES

N.J.A.C. 7:9B. Surface Water Quality Standards

N.J.A.C. 7:26E. Technical Requirements for Site Remediation

N. J. Department of Environmental Protection. 1992. *Field sampling procedures manual.* Trenton, NJ.

U. S. Environmental Protection Agency. July, 1985. *Sediment sampling quality assurance user's guide.* EPA/600/4-85/048. PB85-233542. Environmental Monitoring Systems Laboratory. Las Vegas, NV.

U.S. Environmental Protection Agency. October 1, 1993. *Office of water policy and technical guidance on interpretation and implementation of aquatic life metals criteria.* Office of Water. Washington.

3.0 SEDIMENT SCREENING VALUES FOR USE IN THE BASELINE ECOLOGICAL EVALUATION

To aid in the identification of contaminants of potential ecological concern, site-related sediment data are compared to established screening level criteria in the Baseline Ecological Evaluation (BEE). SRP's Bureau of Environmental Evaluation and Risk Assessment, Environmental Toxicology and Risk Assessment Unit (BEERA/ETRA) recommends the use of the sediment screening values on the three (3) attached tables for the purpose of identifying sediment contaminants of concern for a BEE. These values supersede those provided in *Guidance for Sediment Quality Evaluations, Final Draft for Internal Use Only, March 1991* and are applicable to traditional sediments and to wetland sediments if a benthic community is supported.

3.1 INORGANICS, SEMIVOLATILE ORGANICS, PESTICIDES/PCBs

The values presented in Tables 1 and 2 are extracted from references cited *in N.J.A.C. 7:26E-3.11* and are used by USEPA Region II BTAG for EPA Screening Level Ecological Risk Assessments. Freshwater sediment screening values used for the BEE are the Ontario Lowest Effects Levels (LEL) (Persaud et al., 1993), and marine/estuarine sediment screening values used for the BEE are the Effects Range-Low (ER-L) values (Long et al., 1995).

3.2 VOLATILE ORGANICS

The values indicated in Table 3 are to be used as sediment screening criteria. The values were obtained from Environment Canada's *The Development of Canadian Marine Environmental Quality Guidelines* (MacDonald et al., 1992).

3.3 TOTAL PETROLEUM HYDROCARBONS (TPHC)

There is currently no sediment screening value for TPHC, therefore TPHC-contaminated sediment should be analyzed for volatile and semivolatile organics and resultant data evaluated on a chemical-specific basis. If chemical analyses produce low or nondetectable levels of the expected organic compounds, but petroleum product is observable, the product is likely to cause adverse ecological effects (physical impairment of biota, loss of available substrate, etc.). A

benthic macroinvertebrate survey (Section 4.2) in the affected area and in an appropriate reference location can be conducted to guide remedial decision-making. In general, sediments with TPHC contamination are managed on a case-by-case basis in consultation with BEERA/ETRA.

3.4 COMPARISON OF SITE-RELATED DATA TO SEDIMENT SCREENING VALUES

The following should be considered when comparing data from potentially impacted samples to sediment screening values:

1. In the BEE, maximum and mean concentrations of site-related and reference sample data are compared to the sediment screening values. No contaminants can be excluded from the evaluation without adequate justification. Contaminants may not be excluded from consideration based on comparison with background/reference location data until completion of the BEE because an evaluation of total site risk is appropriate at this stage.

2. The Long et al. marine/estuarine **ER-L** (Effects Range-Low) screens represent a concentration at which adverse benthic impacts are found in approximately 10% of studies. A level greater than the **ER-M** (Effects Range-Median) indicates a greater than 50% incidence of adverse effects to sensitive species and/or life stages. A concentration between the ER-L and ER-M therefore indicates an expected impact frequency between 10% and 50%.

   Ontario s freshwater **LEL** (Lowest Effects Level) screen is generally comparable to Long et al., ER-Ls. Ontario has no ER-M, but does provide an **SEL** (Severe Effect Level) indicating **severe benthic impacts** in 95% of studies. For non-polar organics, the SEL is calculated via site-specific total organic carbon (TOC). See Table 1 footnotes for details on SEL calculation.

   The ER-L and LEL screens were developed based on benthic community studies and do not directly address **biomagnification (food chain toxicity)** to water column species (fishes), birds, and mammals. However, values found to be protective of the food chain are generally similar (within an order of magnitude) to ER-L/LEL values. When **PCBs, organochlorine pesticides and mercury (Hg)** are found in sediments at or above these screens, potential wildlife risks exist and case-by-case evaluation is warranted. Other known biomagnifiers without Ontario or Long et al. screening numbers that warrant case-by-case evaluation are **dioxins, furans, other chlorinated organics, and selenium (Se).**

3. The attached **ER-L** and **LEL** values are not cleanup standards but screening guidelines for use in the BEE. An exceedence indicates a **potential** risk (adverse impact) to the benthic community and need for further investigations, which would reduce uncertainty and better characterize risk and natural resource injury. Such investigations include toxicity testing, macroinvertebrate community surveys, and tissue bioassays. The determination for more rigorous studies should be made on a case-by-case basis in consultation with BEERA/ETRA.

Further remedial investigations/actions need not be triggered by BEE screening exceedences if sediments proximal to the site display contaminant concentration ranges similar to upgradient sediments, which may be impacted by other sources, diffuse anthropogenic contamination, etc. However, upgradient sediment data must not be used to eliminate contaminants of concern until the BEE has been completed. At that point, the determination of chemicals of concern retained for further evaluation will be addressed through the risk management process in consultation with the case team. Justification for no further action must be provided in the BEE for Department review and must contain site-specific upgradient data (refer to Section 2.3).

Risk assessment and **risk management** should be clearly distinguished. Local reference contaminant levels comparable to site levels do not indicate absence of site risk, but do indicate reference area and site risks that are similar. A risk management decision to forego further action is based on no observable additional site-generated risk.

4. A number of screening values for Polynuclear Aromatic Hydrocarbons (PAHs) are below Practical Quantitation Limits (PQLs) and Contract Required Detection Limits (CRQLs). To screen site data that are below the CRQL, the estimated values (indicated by a "J" data qualifier) are to be compared with the screening criteria.

5. Generally, sediments containing ppb-levels of non-persistent ($\log_{10} K_{OW} < 3$), photodegradable, non-polar **volatile organics** are not of ecological concern and further remedial investigation or remediation would not be warranted. However, this approach is conditioned upon no observable acute or chronic toxicity in the sediments, source removal, and compliance with associated Surface Water Quality Standards.

6. Where analytical detection limits are higher than screening criteria, contaminants must be retained as contaminants of concern. For this reason, detection limits for all analytes, including undetected contaminants, must be provided with all data summaries.

7. **Particle/grain size, pH,** and **TOC** analyses are required for all sediment investigations. These data confirm whether samples were collected in depositional zones, as indicated by relatively higher TOC values and a higher percentage of fine-grained particles, and provide a qualitative indication of bioavailability. Depositional zones are areas of highest potential contamination and must be targeted during sampling events.

   TOC results may be used to interpret borderline screening exceedences in a weight of evidence /professional judgement decision, or to generate site specific screening values via an Equilibrium Partitioning (EP) approach (non-polar organics only, e.g., PCBs, PAHs, organochlorine pesticides). Some EPA sediment screening numbers, and some Ontario SELs, are generated via this approach; however, BEERA/ETRA and the USEPA Region II BTAG no longer use the EP approach for general screening purposes due to uncertainties regarding some of the assumptions used. Please consult **BEERA/ETRA (609-633-1348)** if a

No Further Action (NFA) remedial decision is based on an EP approach or an EP approach is considered to have site-specific utility.

References for TOC (Kahn, 1988) and particle/grain size (ASTM, 1992) analyses are provided below. At a minimum, particle size analysis results must provide the percent clay, silt, sand and gravel.

8. If contaminant levels are marginally higher than screens or background, consult BEERA/ETRA prior to requiring additional studies, as a weight of evidence"/professional judgment approach may preclude the need for the studies.

9. If a screening value is not provided for a specific contaminant, it must be retained as a contaminant of concern. It is also recommended that BEERA/ETRA be contacted prior to conducting a literature search, since ETRA may be able to determine if a screening value is presently available. Published sediment screening values other than those cited in this guidance may be used on a case-by-case basis following consultation with ETRA .

REFERENCES

American Society for Testing and Materials (ASTM). 1992. *Standard guide for selection of methods of particle size analysis of fluvial sediments (manual methods).* Method D4822-88. American Society for Testing and Materials. 1916 Race Street, Philadelphia, PA. Volume 11.02, pg. 622-624.

Kahn, L. 1988. *Determination of total organic carbon in sediment.* U.S. Environmental Protection Agency, Region II. Environmental Services Division, Monitoring Management Branch, Edison, NJ.

Long, E.R., MacDonald, D.D., Smith, S.L., and Calder, F.D. 1995. *Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments.* Environmental Management Vol.19, No.1. pp. 81-97.

MacDonald, D.D., Smith, S.L., Wong, M.P. and Murdroch, P. Environment Canada. 1992. *The development of Canadian marine environmental quality guidelines. Marine environmental quality series no. 1.* Ecosystem Sciences and Evaluation Directorate. Eco-Health Branch. Ottawa, Ontario. 121 pp.

Persaud, D., Jaagumagi, R., and Hayton, A. 1993. *Guidelines for the protection and management of aquatic sediment quality in Ontario*. ISBN 0-7729-9248-7. Ontario Ministry of the Environment, Ottawa, Ontario. 23p.

TABLE 1.

FRESHWATER SEDIMENT SCREENING GUIDELINES

Ontario (Persaud et al., 1993)

BOLD TYPE IN TABLE INDICATES ECOLOGICAL SCREENING VALUES TO BE USED IN THE BASELINE ECOLOGICAL EVALUATION (BEE).

Metals	**Lowest Effects Level (LEL) [1] (mg/kg, dry weight)**	Severe Effects Level (SEL) [2] (mg/kg, dry weight)
Arsenic	**6**	33
Cadmium	**0.6**	10
Chromium	**26**	110
Copper	**16**	110
Lead	**31**	250
Mercury	**0.2**	2
Nickel	**16**	75

Silver	**(see Table 2.)**[3]	--
Zinc	**120**	820

Table 1. (con t)

Organics

Polynuclear Aromatic Hydrocarbons (PAHs)	**Lowest Effects Level** (LEL)[1] (mg/kg, dry weight)	Severe Effects Level (SEL)[2] (mg/kg organic carbon, dry weight)
Acenaphthene	**(see Table 2)**[3]	--
Acenaphthylene	**(see Table 2)**[3]	--
Anthracene	**0.220**	370
Benzo (a) anthracene	**0.320**	1480
Benzo (k) fluoranthene	**0.240**	1340
Benzo (g,h,i) perylene	**0.170**	320
Benzo (a) pyrene	**0.370**	1440
Chrysene	**0.340**	460
Dibenzo (a,h) anthracene	**0.060**	130

Fluoranthene	**0.750**	1020
Fluorene	**0.190**	160
Indeno (1,2,3-cd) pyrene	**0.200**	320
2-methylnaphthalene	**(see Table 2)[3]**	--
Naphthalene	**(see Table 2)[3]**	--
Phenanthrene	**0.560**	950
Pyrene	**0.490**	850
Total PAH	**4.0**	10000

Table 1. (con t)

Pesticides	**Lowest Effects Level (LEL)[1] (mg/kg, dry weight)**	Severe Effects Level (SEL)[2] (mg/kg organic carbon, dry weight)
Aldrin	**0.002**	8
Benzohexachloride (BHC)	**0.003**	12
a-BHC	**0.006**	10
b-BHC	**0.005**	21
y-BHC (Lindane)	**0.003**	1
Chlordane	**0.007**	6
DDT (Total)	**0.007**	12
op+pp-DDT	**0.008**	71
pp-DDD	**0.008**	6

pp-DDE	**0.005**	19
Dieldrin	**0.002**	91
Endrin	**0.003**	130
Hexachlorobenzene (HCB)	**0.020**	24
Heptachlor epoxide	**0.005**	5
Mirex	**0.007**	130

Table 1. (con t)

Polychlorinated Biphenyls (PCBs)	**Lowest Effects Level (LEL)[1] (mg/kg, dry weight)**	Severe Effects Level (SEL)[2] (mg/kg organic carbon, dry weight)
PCB Aroclor 1016	**0.007**	53
PCB Aroclor 1248	**0.030**	150
PCB Aroclor 1254	**0.060**	34
PCB Aroclor 1260	**0.005**	24
PCB (total)	**0.070**	530

FOOTNOTES:

1**. Lowest Effects Levels** (**LELs)** indicate concentrations at which adverse benthic impact may begin to occur (level tolerated by most benthic organisms). Water column species and wildlife are at potential risk via biomagnification (food chain toxicity) if site-related sediment concentrations of PCBs, organochlorine pesticides, or mercury are at or above the LEL.

Other known biomagnifiers without Ontario screening numbers (dioxins, furans, other chlorinated organics, and selenium) warrant case-by-case evaluation.

2. Severe Effects Levels (SELs) are also provided, but the SEL is not a BEE screening value. Contamination at this level indicates severe impacts to the benthic community in most cases studied. For non-polar organics (PAHs, organochlorine pesticides, PCBs), the SEL is calculated from a site-specific TOC level**.** Since the table SEL is based on 100% organic carbon, the calculated site-specific number is lower.

To calculate a site-specific SEL, TOC is multiplied by the table SEL. For TOC at 1% (10,000 ppm) the SEL is multiplied by 0.01. If the table SEL is 360 ppm, 360 x 0.01 = a 3.6 ppm SEL. A default value of 1% is used when a TOC value is not available. 10% TOC is upper limit for SEL calculation. 1% and 10% TOC represents the average range over which this approach has been examined (USEPA, 1988).

3. Refer to Table 2 (Estuarine/Marine Screening Criteria) when a Table 1 parameter has no corresponding value. Since the biological activity of non-polar organics is not expected to differ greatly in the estuarine/marine environment, Table 2 screens can be used as surrogates. While uncertainty associated with the use of estuarine/marine metal screens as freshwater surrogates is greater than with non-polar organics, one Table 2 surrogate metal (silver) is provided.

REFERENCES

Persaud, D., Jaagumagi, R., and Hayton, A. 1993. *Guidelines for the protection and management of aquatic sediment quality in Ontario.* ISBN 0-7729-9248-7. Ontario Ministry of the Environment, Ottawa, Ontario. 23p.

U.S. Environmental Protection Agency. 1988. *Interim sediment criteria values for nonpolar hydrophobic organic contaminants.* Office of Water Regulations and Standards, Criteria and Standards Division. SCD #17.

TABLE 2

MARINE/ESTUARINE SEDIMENT SCREENING GUIDELINES

(Long et al., 1995)

BOLD TYPE IN TABLE INDICATES ECOLOGICAL SCREENING VALUES TO BE USED IN THE BASELINE ECOLOGICAL EVALUATION (BEE).

Metals	**Effects Range – Low (ER-L)[1]**	Effects Range – Medium (ER-M)[2]
	(mg/kg, dry weight)	(mg/kg, dry weight)
Arsenic	**8.2**	70
Cadmium	**1.2**	9.6

Chromium	**81**	370
Copper	**34**	270
Lead	**47**	218
Mercury	**0.15**	0.71
Nickel	**21**	52
Silver	**1.0**	3.7
Zinc	**150**	410

Table 2 (con't)

Organics

Polynuclear Aromatic Hydrocarbons (PAHs)	**Effects Range–Low (ER-L)[1] (mg/kg, dry weight)**	Effects Range–Medium (ER-M)[2] (mg/kg, dry weight)
Acenaphthene	**0.016**	0.500
Acenaphthylene	**0.044**	0.640
Anthracene	**0.085**	1.1
Benzo (a) anthracene	**0.261**	1.6

Benzo (k) fluoranthene	**(see Table 1.)**[3]	--
Benzo (g,h,i) perylene	**(see Table 1.)**[3]	--
Benzo (a) pyrene	**0.430**	1.6
Chrysene	**0.384**	2.8
Dibenzo (a,h) anthracene	**0.063**	0.26
Fluoranthene	**0.600**	5.1
Fluorene	**0.019**	0.54
Indeno (1,2,3-cd) pyrene	**(see Table 1.)**[3]	--
2-methylnaphthalene	**0.070**	0.67
Naphthalene	**0.16**	2.1
Phenanthrene	**0.240**	1.5
Pyrene	**0.665**	2.6
Total PAH	**4.0**	45.0

Table 2 (con't)

Pesticides	**Effects Range-Low (ER-L)**[1] **(mg/kg, dry weight)**	Effects Range-Medium (ER-M)[2] (mg/kg, dry weight)
Aldrin	**(see Table 1.)**[3]	--
Benzohexachloride (BHC)	**(see Table 1.)**[3]	--
Chlordane	**(see Table 1.)**[3]	--

DDT (total)	**0.0016**	0.046
pp -DDE	**0.0022**	0.027
Dieldrin	**(see Table 1.)[3]**	--
Endrin	**(see Table 1.)[3]**	--
Hexachlorobenzene (HCB)	**(see Table 1.)[3]**	--
Heptachlor epoxide	**(see Table 1.)[3]**	--
Mirex	**(see Table 1.)[3]**	--

Polychlorinated Biphenyls (PCBs)	**Effects Range – Low (ER-L)[1] (mg/kg, dry weight)**	Effects Range – Medium (ER-M)[2] (mg/kg, dry weight)
PCB (total)(see Table 1.)[3]	**0.023**	0.180

FOOTNOTES:

1. **Effects Range-Low (ER-L)** represents a concentration at which adverse benthic impacts are found in approximately 10% of studies. Water column species and wildlife are at potential risk via biomagnification (food chain toxicity) if site-related sediment concentrations of PCBs, organochlorine pesticides, or mercury are at or above the ER-L. Other known biomagnifers without NOAA screening numbers (dioxins, furans, other chlorinated organics, and selenium) warrant case-by-case evaluation.

2. The Effects Range-Median (ER-M) is also provided. The ER-M is not a BEE screening value. Contamination greater than the ER-M value indicates adverse benthic impacts in more than 50% of cases studied.

3. Refer to Table 1 (Freshwater Sediment Screening Criteria) when a Table 2 parameter has no corresponding value and for individual Aroclor values. Since the biological activity of non-

polar organics is not expected to differ greatly in the fresh water environment, Table 1 screens can be used as surrogates.

REFERENCES

Long, E.R., MacDonald, D.D., Smith, S.L., and Calder, F.D. 1995. *Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments.* Environmental Management Vol. 19, No.1. pp. 81-97.

TABLE 3.

VOLATILE ORGANIC SEDIMENT SCREENING GUIDELINES

FRESHWATER AND ESTUARINE/MARINE SYSTEMS[1]

(MacDonald et al., 1992)

BOLD TYPE IN TABLE INDICATES ECOLOGICAL SCREENING VALUES TO BE USED IN THE BASELINE ECOLOGICAL EVALUATION (BEE)

Volatile Organics	**Chronic Value (mg/kg, dry weight @1% TOC)**	$Log_{10}K_{OW}$ (Montgomery and Welkom, 1990)
Benzene	**0.34**[2]	1.69 – 2.12
Ethylbenzene	**1.4**[2]	3.05 – 3.15
Tetrachloroethylene	**0.45**[2]	2.1 – 2.9
Toluene	**2.5**[2]	2.11 – 2.80
Trichloroethylene	**1.6**[2]	2.29 – 3.3
Xylene	**>0.12**[3]	2.77 – 3.2 (o,m,p)

FOOTNOTES:

1. All screening values were developed for the protection of marine receptors; however, for the purpose of this document they are considered surrogates for freshwater systems.

2. Bolton, S.H., R.J. Breteler, B.W. Vigon, J.A. Scanlon and S.L. Clark. 1985. *National perspective on sediment quality.* Prepared for the U.S. Environmental Protection Agency. Washington, D.C. 194 pp. Contained in MacDonald et al., 1992.

3. Barrick, R., S. Becker, L. Brown, H. Beller and R. Pastorok. 1988. *Sediment quality values refinement: 1988 update and evaluation of Puget Sound AET. Vol. I.* Prepared for the Puget Sound Estuary Program. PTI Environmental Services, Bellevue, Wa. 74 pp. + appendices. Contained in MacDonald et al., 1992.

REFERENCES

MacDonald, D. D., Smith, S.L., Wong, M.P. and Mudroch, P. Environment Canada. 1992. *The development of Canadian marine environmental quality guidelines. Marine environmental quality series no. 1.* Ecosystem Sciences and Evaluation Directorate. Eco-Health Branch. Ottawa, Ontario. 121 pp.

Montgomery, J.H. and Welkom, L.M. 1990. *Groundwater chemicals desk reference.* Lewis Publishers, Inc., Chelsea, MI. 640p.

4.0 BIOLOGICAL EVALUATIONS FOR USE IN ECOLOGICAL RISK ASSESSMENT

4.1 SEDIMENT TOXICITY TESTING

Toxicity tests are used to expose test organisms to a medium (i.e., sediment) and to evaluate the effects of contamination on the survival, growth, reproduction, behavior and/or other attributes of these organisms. They provide important information that cannot be derived solely from chemical analysis nor from community surveys. The data assimilated by sediment toxicity tests can be used to: a) demonstrate the bioavailability of sediments contaminants, b) evaluate the

aggregate toxic effects of all contaminants in a medium, c) evaluate the toxicity of substances whose biological effects may not have been well characterized, d) characterize the nature of a toxic effect, e) characterize the distribution of toxicity at a site, f) develop remedial goals, g) monitor the effectiveness of remedial actions, and h) determine a site's post-remedial potential to support a viable ecological community (USEPA, 1994).

When designing a toxicity assessment, one must consider the study objective, test site, reference site, medium analyzed, test organisms, test methodology, and quality assurance/quality control requirements. All of the above elements must be tailored to meet the site specific needs/goals of the investigation. The specific type and technique of sediment toxicity test appropriate in a particular situation will be determined by a variety of site- specific factors. These include, but are not limited to, type and salinity of water body present, nature and extent of contamination, local biota, and site-specific informational needs. Numerous studies have shown that different testing regimes with the same sediment and organism can result in different bioassay responses. Additionally, bioassays with different organisms conducted on the same sediment do not always give similar results. For these reasons, it is imperative that a sediment bioassay program not rely on a single species endpoint. No single test is adequate to allow a detection of an impact among the various toxicants or stresses present at hazardous waste sites.

At a minimum, a sediment toxicity test shall incorporate the following:

1. Both **acute** (i.e., survival) and **sub-chronic** (i.e., growth, reproductive capacity) endpoint measurements.

2. The use of two (2) test organisms, preferably representing two different ecological niches (e.g., one infaunal and one epifaunal species).

3. Each sediment sample collected and slated for sediment toxicity testing shall also be analyzed for the chemical contaminants of concern associated with the site. The sample shall be obtained directly from the bulk sediment intended to be used for the sediment toxicity test.

4. Sediment samples must be maintained in the dark at $4^{o}C$ prior to beginning toxicity testing.

5. A control sediment sample should be tested in addition to the reference sample, and is usually supplied along with the cultured organisms.

6. Five (5) test replicates per sample.

7. Two (2) weeks is the maximum allowable holding time for sediments used in toxicity tests.

8. For work conducted under SRP oversight, the source of the reference sediments and overlay water, intended procedures for endpoint measurement, and statistical analyses for results, etc., should be provided to the SRP via a work plan prior to commencement.

As previously stated, the particular tests that are selected will be determined by site-specific characteristics and needs. The following list of references can serve as a starting point in the selection of appropriate tests but should not be considered as all inclusive. It is highly recommended that BEERA/ETRA is consulted prior to the selection and implementation of a sediment toxicity test.

REFERENCES

American Society for Testing and Materials (ASTM). 1992. *Standard guide for conducting sediment toxicity tests with freshwater invertebrates.* American Society for Testing and Materials, Philadelphia, PA. 23 pp.

American Society for Testing and Materials (ASTM). 1992. *Standard guide for conducting 10-day static sediment toxicity tests with marine and estuarine amphipods.* American Society for Testing and Materials, Philadelphia, PA. 24 pp.

U.S. Environmental Protection Agency. June 1994. *Methods for assessing the toxicity of sediment-associated contaminants with estuarine and marine amphipods*. EPA/600/R-94/025. Office of Research and Development, Narragansett, RI.

U.S. Environmental Protection Agency. June 1994. *Methods for assessing the toxicity of and bioaccumulation of sediment-associated contaminants with freshwater invertebrates.* EPA/600/R-94/024. Office of Research and Development, Narragansett, RI.

U.S. Environmental Protection Agency. September 1994. *Using toxicity tests in ecological risk assessment*. ECO Update. Publication 9345.0-051. EPA 540-F-94-012. PB94-963303. Intermittent Bulletin, Volume 2, Number 1.

U.S. Environmental Protection Agency. September 1994. *Catalogue of standard toxicity tests in ecological risk assessment.* Publication 9345.0-051. EPA 540- F-94-013. PB94-963304. Intermittent Bulletin, Volume 2, Number 2.

4.2 BENTHIC MACROINVERTEBRATE SURVEYS

Benthic macroinvertebrate surveys have been performed historically by USEPA and state regulatory agencies to evaluate the ecological integrity of aquatic systems as mandated by specific sections of the Clean Water Act. Recently, such evaluations have been used, in conjunction with other methodologies (i.e. sediment toxicity tests, sediment chemistry data), to assess the health of aquatic systems associated with the investigation of hazardous waste sites.

Assessments of benthic macroinvertebrate community structure and function are used extensively to provide direct evidence of contaminant-related effects in the environment. Benthic macroinvertebrates are relatively sedentary organisms that inhabit or depend upon the sediment environment for their various life functions. They are sensitive to both long term and short-term changes in sediment and water quality. Benthic macroinvertebrates are frequently used as environmental indicators of biological integrity because they are found in most aquatic habitats, are of a size permitting ease of collection, and can be used to describe water quality conditions or health of ecosystem components, and to identify causes of impaired conditions (USEPA, 1990). A wide variety of procedures have been developed to evaluate how changes in environmental quality affect benthic communities. A complete description of these methods is beyond the scope of this document. However, these procedures can be divided into those that measure community structure and those that measure community function. Community structure is the measurement of biotic characteristics (i.e., species abundance, diversity, and composition) at a point in time, whereas community function is the measurement of rate processes (i.e., species colonization rates) of the ecosystem. The use of biological communities in environmental monitoring is normally done from a structural perspective because structural studies usually take less time, are more conventional, and facilitate comparisons with data from other studies. It must be kept in mind, however, that contamination is not the only factor capable of changing community structure. Changes in salinity, temperature, dissolved oxygen, pH, Eh, sediment texture, and shading can all effect community structure.

The specifics on sampling strategy, collection, identification, data reduction, and interpretation of results will depend upon site-specific conditions and requirements. It is important that benthic macroinvertebrate studies be carefully designed as confounding effects not related to pollution (e.g., natural temporal and spatial variability, competition, predation, sediment type, salinity, sample depth, season of sampling, sediment pH) can profoundly influence study results. At a minimum, it is essential that all locations selected for macroinvertebrate surveys also undergo sediment chemistry analyses. The sediment used for the chemical analyses shall be obtained at the same location and time of the macroinvertebrate survey.

It is recommended that the guidance documents listed below be consulted for work plan development. As previously stated, the particular type of survey selected will be determined by site-specific characteristics and data needs. As the decisions regarding the selection of procedures and methodologies to be used in the macroinvertebrate survey are often complex, it is recommended that the macroinvertebrate survey work plan be discussed with BEERA/ETRA prior to implementation.

REFERENCES

U.S. Environmental Protection Agency. May 1989. *Rapid bioassessment protocols for use in streams and rivers - benthic macroinvertebrates and fish.* EPA/440/4-89/001. Assessment and Watershed Protection Division, Washington.

U.S. Environmental Protection Agency. November 1990. *Macroinvertebrate field and laboratory methods for evaluating the biological integrity of surface waters.* EPA/600/4-90/030. Environmental Monitoring Systems Laboratory, Cincinnati, OH.

U.S. Environmental Protection Agency. 1997. *Field and laboratory methods for macroinvertebrates and habitat assessment of low gradient nontidal streams.* Mid-Atlantic Coastal Streams Workgroup, Environmental Services Division, Region 3, Wheeling, WV.

4.3 TISSUE RESIDUE ANALYSIS

Many contaminants found at hazardous waste sites are capable of being transferred from the sediment, water, and diet to biota. These contaminants can accumulate within tissues of organisms to levels that greatly exceed ambient concentrations. Bioaccumulation can result in acute and chronic effects (including adverse effects on reproduction) on individual organisms and also expose predators to toxic doses of contaminants. Biomagnification is the total process by which tissue concentrations of bioaccumulated compounds increase as compounds are transferred up the food chain.

During ecological/sediment quality investigations, the purpose of tissue residue analysis is to measure whole body contaminant concentrations in prey species consumed by a predatory species of concern. This will provide a usable estimate of the exposure dose to the species of concern and allow comparison with literature-based No Observed Adverse Effect Levels (NOAEL) and/or Lowest Observed Adverse Effect Levels (LOAEL) for the purpose of estimating risk. Also, a protective sediment clean-up number based on the NOAEL/LOAEL can be estimated knowing (1) the concentration of a given contaminant in fish tissue corresponding to the LOAEL/NOAEL for adverse effects to a species of concern and (2) the relationship between the contaminant levels in sediments and in the forage species (site-specific bioaccumulation factor).

Considerations for a tissue analysis study include, but are not limited to, the following:

1. Species Selection - the aquatic species selected for sampling will depend on site-specific data requirements and ecologic characteristics. The organisms should ideally have a small home range and forage within the study area, overlapping areas of maximum contamination. The species selected must be sufficiently abundant that adequate numbers of individuals can be collected to achieve the necessary sample mass required for analysis. Predatory species of concern, feeding guilds of interest, lipid content, etc. should all be considered. "Back-up" species should be selected in the event that the recommended target species are not able to fulfill the study's objectives.

a. Fish

Fish are useful tools in monitoring biological uptake and have proven to be good indicators of both inorganic and organic contamination. Fish species are used in various environmental monitoring capacities creating an extensive database for background levels of many compounds. Care must be

taken in choosing among fish species to be sampled, as many fish species have a large home range and/or are migratory, thus would not be entirely indicative of local conditions. When appropriate, fish species should be selected that are present year round. If measurement of maximum accumulation is desired, the species should be high in lipid content, long-lived, and closely associated with the sediment. Two fresh water species that meet these criteria and are commonly used in sediment monitoring programs are the common carp (Cyprinus carpio) and brown bullhead catfish (Ictalurus nebulosos). Mummichogs (Fundulus heteroclitus) are a marine/estuarine specie that has been used successfully at several SRP sites. If only fin fish species are to be collected for tissue residue analysis, two different trophic levels should be represented.

b. Mollusks/Crustaceans

Mollusks and crustaceans have been successfully used to monitor biological uptake of sediment contaminants. The behavior of these species, which places them in direct contact with sediment, make them particularly useful in measuring the potential for biological uptake of sediment contaminants. Species that have been used in biological sampling programs in the SRP include blue claw crab (Callinectes sapidus), grass shrimp (Palaemonetes spp.), soft shell clam (Mya arenaria), fiddler crab (Uca minax), and bent-nose macoma clam (Macoma nasuta).

2. Seasonality

The season during which biological samples are collected for tissue analysis is an important consideration . The spawning and breeding season should be avoided whenever possible because aquatic species are often stressed at this time, having different feeding habits, fat content, and respiration rates, which can influence pollution uptake and clearance. Generally, the most appropriate sampling period is from late summer to early fall (i.e., August through October), when the lipid content of many species is generally highest after a full, active season of consumption and contaminant accumulation. Also, fresh water levels are typically lower during this time, facilitating sample collection.

3. Sample Compositing

Because a sample mass of 20g to 50g is typically required for analysis, individuals are routinely composited. Individual organisms used in composite samples must be of the same species because bioaccumulation potential is species-specific. Accurate taxonomic identification is essential to prevent the compositing of closely related species. The sample must be a whole-body, soft tissue composite, assuming the whole organism is consumed.

Sample composites must be segregated based on age and sex. BEERA/ETRA generally recommends sampling adults, which will have had a greater opportunity for contaminant accumulation. The sampler should be aware of situations which could introduce bias into results. For example, samples containing high ratios of gravid females could dramatically increase concentrations of contaminants known to biomagnify. As another example, the large claw and muscle tissue of the mature male fiddler crab generally have lower levels of contaminants than more lipid-rich digestive and reproductive organs; results from a composite sample containing a

greater proportion of mature males would likely be biased low due to sex differences rather than from site conditions.

BEERA/ETRA generally recommends three (3) to five (5) replicate composite tissue samples of each target species at each sample location.

It is highly recommended that the references cited below be consulted for further information on tissue sample collection, sample preparation, and analytical methods.

REFERENCES

U.S. Department of Commerce. 1993. *Sampling and analytical methods of the National Status and Trends Program, National Benthic Surveillance and Mussel Watch Projects, 1984 - 1992. Volume IV. Comprehensive descriptions of trace organic analytical methods.* NOAA Technical Memorandum NOS ORCA 71. National Oceanic and Atmospheric Administration, Coastal Monitoring and Bioeffects Assessment Division, Ocean Resources Conservation and Assessment, National Ocean Service, Silver Spring, MD.

U.S. Environmental Protection Agency. 1993. *Guidance for assessing chemical contaminant data for use in fish advisories. Volume 1: Fish sampling and analysis*. EPA 823-R-93-0 Office of Science and Technology, Office of Water, Washington.

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