Stormwater Runoff Water Quality Science/Engineering Newsletter Devoted to Urban/Rural Stormwater Runoff Water Quality Management Issues

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Volume 7 Number 10
December 20, 2004,

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This issue of the Stormwater Runoff Water Quality Science/Engineering Newsletter is devoted to several aspects of the US EPA's **National Sediment Quality Survey** Second Edition. On December 8, 2004 the US EPA announced on its website, www.epa.gov Sediments section, the release of a November 2004 report, "**The Incidence and Severity of Sediment Contamination in Surface Waters of the United States**." This report is a US Congress-mandated report that addresses the current degree of chemical contamination of US river, lake, ocean, and estuary sediments. It is based on a screening-level assessment of the potential for sediment-associated adverse effects on human health and/or environmental quality. The assessment of sediment contamination was based on a National Sediment Inventory (NSI) developed by the US EPA. The NSI database includes approximately 4.6 million records of chemical characteristics, organism tissue residue, and toxicity data for more than 50,000 sediment monitoring stations across the country. The US EPA's 280 page sediment survey report contains a wealth of information on the characteristics of US aquatic sediments, and is available online at, http://www.epa.gov/OST/cs/.

The focus of this Newsletter is on how the US EPA developed its sediment quality evaluation approach for the National Sediment Quality Inventory. This topic is important to stormwater runoff water quality managers and regulatory agencies, as well as those involved in other aspects of water quality because there are several sediment quality evaluation procedures that are unreliable.

The US EPA's approach for evaluation of aquatic life impacts of sediment-associated chemical contaminants was based on

- chemical concentration data that was used with equilibrium partitioning sediment (ESG) guidelines,
- comparison of the molar concentration of acid-volatile sulfides ([AVS]) in sediment to the molar concentration of simultaneously extracted metals ([SEM]) in sediment,
- estimation of the predicted proportion toxic from sediment chemistry observations using a logistic regression model,
- comparison of the total ESG toxic unit for polycyclic aromatic hydrocarbons (PAHs) to final chronic or acute values and
- toxicity based on acute or chronic solid-phase sediment toxicity data.

The potential human health impact evaluation was based on,

- comparison of theoretical bioaccumulation potential (TBP) values derived from sediment chemical characteristic to – EPA cancer and noncancer risk levels or – Food and Drug Administration (FDA) tolerance, action and
- comparison of fish tissue contaminant levels to – EPA cancer and noncancer risk levels or – FDA tolerance, action, or guidance values.

In discussing its approach the US EPA stated,

> *"The sediment chemistry screening values used as the basis for comparison in this report are not regulatory criteria, site-specific cleanup standards, or remediation goals. Sediment chemistry screening values are reference values above which a sediment ecotoxicological assessment* ***might*** *indicate a potential threat to aquatic life."* [emphasis added]
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> *"The empirically derived or correlative approaches (e.g., predicted proportion toxic) rely on paired field and laboratory data to relate incidence of observed biological effects to the dry-weight sediment concentrations. Correlative screening values can relate measured concentration to a probability of association with adverse effects, but they do not definitively establish cause and effect for a specific chemical*."

The latter quotation had reference to the US EPA's incorporation of co-occurrence-based sediment quality evaluation through the use of a logistic regression model into its evaluation process. Based on the author's over 30 years of experience in sediment quality evaluation, the US EPA's use of co-occurrence-based sediment quality guidelines (such as Long and Morgan ERLs or ERMs, or MacDonald PEL, or TEL values) and the logistic regression model used by the Agency in its sediment quality evaluation is a significant deficiency in the Agency's national sediment quality evaluation. In a recently completed updated review, Jones-Lee and Lee (2004) discussed why the technical foundation of these values and approaches render them unreliable for any evaluation or comparative purpose, including screening. Dr. T. O'Connor of NOAA has repeatedly pointed out the unreliability of a Long and Morgan sediment quality "guideline" as an indicator of sediment toxicity. In his paper entitled, "The Sediment Quality Guideline, ERL, Is Not a Chemical Concentration at the Threshold of Sediment Toxicity," O'Connor (2004) provided additional information on the unreliability of using co-occurrence-based approaches for assessing sediment toxicity. He stated in his abstract,

> *"While it is being used as such, the sediment quality guideline ERL (effects range low) is not a threshold of any chemical concentration in sediment at which the probability of toxicity shows an abrupt increase. Similarly, while it has been done, there is no basis for assuming that multiple concentrations above an ERL increase the probability of toxicity."*

Long (2004) recently commented that it is possible to predict the broad scope of relationships between sediment chemical concentrations and toxicity. However, the error

bars are very large, making such predictions worthless for site- or area-specific assessments. He concluded,

> "*The presumption that you can predict benthic impacts with sediment chemistry data alone is very weak*."

Jones-Lee and Lee (2004) stated in their recent review,

> "*Many Superfund/hazardous chemical sites include waterbodies whose sediments contain hazardous chemicals. With the need to assess, rank, and remediate contaminated sediments at such sites, as well as in other waterways, regulators seek a simple, quantitative assessment approach that feeds easily into a decision-making scheme. Numeric, co-occurrence-based "sediment quality guidelines" have emerged with the appearance of administrative simplicity. However, the very foundation of the co-occurrence approach, based on the total concentrations of a chemical(s) in sediment, is technically invalid; its application relies on additional technically invalid presumptions. Use of technically invalid evaluation approaches renders any assessment of the significance of sediment contamination, unreliable. This paper reviews the technical roots and assumptions of the co-occurrence-based SQGs, the fundamental flaws in the rationale behind their development and application, and their mis-application for sediment quality evaluation. It also reviews concepts and approaches for the more reliable evaluation, ranking, and clean-up assessment of contaminated sediments at Superfund sites and elsewhere."*

A proper biological effects-based approach should have been employed by the US EPA for screening and assessing sediment potential for sediment-associated adverse effects on human health and/or environmental quality. Since the total concentration of a chemical in a sediment is not related to impact, its use in conjunction with effects assessment is misleading at best. If, however, concentration data were to be presented in association with the National Sediment Inventory of sediment contamination, it should have been done in the context of describing areas in which the total concentration is greater than area "background" levels; this could expose areas that may have been altered by the activities of man, i.e., contaminated. It must be made clear, however, that such a concentration-based identification does not address potential impact, or need for remediation action, and is limited in its scope to those contaminants that are measured. This approach could have identified that a sediment may be "contaminated" with elevated concentrations of certain chemicals, without invoking the technically invalid co-occurrence-based ERM or ERL PEL or TEL or the logistic regression model values that provide no reliable indication of potential impact of a chemical in a sediment on aquatic life. To the extent that the co-occurrence-based sediment quality guidelines were used to classify a sediment site in the development of the National Sediment Inventory, the inventory could contain unreliable information on the site.

Through out the report, the US EPA stressed the need to use the information in the report with caution. The USEPA stated,

"*The reader should exercise caution in evaluating the data in this report for a number of reasons. Uncertainty is associated with site-specific measures, assessment techniques, exposure scenarios, and default parameter selections. Many mitigating biological, chemical, hydrological, and habitat factors can affect whether sediment poses a threat to aquatic life or human health. Because of the limitations of the available sediment quality measures and assessment methods, EPA characterizes this evaluation as a screening-level analysis.*

The US EPA also stated,

"The definition of "area of probable concern" was developed for this report to identify watersheds for which further study of the effects and sources of sediment contamination, and possible risk reduction needs, would be warranted."

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"A screening-level assessment typically identifies many potential problems that subsequently prove not to be significant upon further analysis (i.e., more conservative)."

The effects based parameters of sediment quality used by the US EPA in its National Sediment Inventory have some validity in a sediment screening assessment for evaluating potential water quality problems, toxicity to aquatic life, and/or impacts on human health through food web bioaccumulation. Based on the author's experience in sediment water quality evaluation, the US EPA's approach for evaluating potential impacts of chemicals, with the exception of using cooccurrence values, has validity in identifying sediments that need further study to determine whether a sediment contains a chemical (s) that are adverse to water quality/beneficial uses of the waterbody in which the sediments are located.

Following the references cited in this newsletter, the Executive Summary of the US EPA's report is presented.

References

Jones-Lee, A. and Lee, G. F., "Unreliability of Co-Occurrence-Based Sediment Quality Guidelines for Contaminated Sediment Quality Evaluation at Superfund/Hazardous Chemical Sites," In Press (2004).
http://www.members.aol.com/annejlee/SQGSuperfund2.pdf

Long, E. (2004). Comments as reported in the Minutes from the CA Sediment Quality Objectives Advisory Committee 6th Meeting, October 27, 2004 State of California Water Resources Control Board, Water Quality Program Sacramento, CA.

O'Connor, T. P. (2004). The Sediment Quality Guideline, ERL, Is Not a Chemical Concentration at the Threshold of Sediment Toxicity." Mar. Poll. Bull. 49:383-385 (2004).

EPA-823-R-04-007

The Incidence and Severity of Sediment Contamination in Surface Waters of the United States

National Sediment Quality Survey
Second Edition

November 2004

United States Environmental Protection Agency
Office of Science and Technology
Standards and Health Protection Division
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EXECUTIVE SUMMARY[1]

This report, *The Incidence and Severity of Sediment Contamination in Surface Waters of the United States: National Sediment Quality Survey*, Second Edition, describes the accumulation of chemical contaminants in river, lake, ocean, and estuary bottoms and includes a screening-level assessment of the potential for associated adverse effects on human and/or environmental health. The United States Environmental Protection Agency (EPA) prepared this report to Congress in response to requirements set forth in the Water Resources Development Act (WRDA) of 1992. WRDA directed EPA, in consultation with the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Army Corps of Engineers (USACE), to conduct a comprehensive national survey of data regarding the quality of aquatic sediments in the United States. Section 503(a) of WRDA required EPA to "compile all existing information on the quantity, chemical and physical composition, and geographic location of pollutants in aquatic sediment, including the probable source of such pollutants and identification of those sediments which are contaminated." It further required EPA to "report to the Congress the findings, conclusions, and recommendations of such survey, including recommendations for actions necessary to prevent contamination of aquatic sediments and to control sources of contamination." In addition, Section 503(b) of WRDA requires EPA to conduct a comprehensive and continuing program to assess aquatic sediment quality. This program must establish methods and protocols for monitoring the physical, chemical, and biological effects of pollutants in aquatic sediment and of contaminated sediment. EPA submitted the first Report to Congress (EPA-823-R-97-006) on January 7, 1997. To comply with Section 503(b), EPA's Office of Science and Technology (OST) (1)

[1] See the online report for the figures and tables that are in the Executive Summary

initiated the National Sediment Inventory (NSI), which is designed to compile sediment quality information from available electronic databases into one centralized, easily accessible location, and (2) developed the *National Sediment Quality Survey* report.

Description of the NSI

The NSI database includes approximately 4.6 million records of sediment chemistry, tissue residue, and toxicity data for more than 50,000 monitoring stations across the country. To efficiently collect usable information for inclusion in the NSI database, EPA sought data that were available in electronic format, represented broad geographic coverage, and represented specific sampling locations identified by latitude and longitude coordinates. Although EPA elected to evaluate in this report only data collected since 1990 (i.e., 1990 through 1999), data from before 1990 are maintained in the NSI database for comparison purposes. The initial *National Sediment Quality Survey* evaluated data from 1980 through 1993. At a minimum, EPA required that electronically available data include monitoring program, sampling date, latitude and longitude coordinates, and measured units for inclusion in the data evaluation. The NSI database includes data from the following data storage systems and monitoring programs:

- Selected data sets from EPA's Storage and Retrieval System (STORET)
- NOAA's Query Manager Data System
- State of Washington Department of Ecology's Sediment Quality Information System (SEDQUAL)
- Selected data sets from the U.S. Geological Survey's (USGS's) WATSTORE
- EPA's Environmental Monitoring and Assessment Program (EMAP)
- Data compiled for the previous report to Congress, 1990 through 1993
- Chesapeake Bay Program
- Upper Mississippi River System data compilation prepared by USGS
- Indiana Department of Environmental Management Sediment Sampling Program
- Oklahoma Reservoir Fish Tissue Monitoring Program, 1990 through 1998
- Houston Ship Channel Toxicity Study

National Sediment Quality Survey Report Objective

The objective of the *National Sediment Quality Survey* report is to develop screening-level assessment protocols to allow the identification of potentially contaminated sediment. The report is to be produced biennially for Congress, as well as the regions, states, and tribes, on the incidence and severity of sediment contamination nationwide. One objective of the original report, as well as this first update to that report, is to depict and characterize the incidence and severity of sediment contamination based on the *probability* of adverse effects to human health and/or the environment. As used in this report, the probability or potential for adverse effects reflects a range of situations where the analysis of a station's data might indicate adverse effects on aquatic life and/or human health. To accomplish this objective, EPA applied assessment protocols to existing available data in a uniform fashion. EPA intended to accurately depict and characterize the incidence and severity of sediment contamination based on the probability of adverse effects to human health and/or the environment. This was done through the use of a number of different measures of sediment quality (i.e., multiple lines of evidence). Information contained in this report may be used to further investigate sediment

contamination on a national, regional, or site-specific scale. Further studies might involve toxicological investigations, risk assessment, analyses of temporal and spatial trends, feasibility of natural recovery, and source control.

The initial report presented a national baseline screening-level assessment of contaminated sediments from sediment quality data collected from 1980 through 1993 using a weight-of-evidence approach. This report presents the results of the screening-level assessment of the NSI data from 1990 through 1999. One major advantage of screening out older data (data collected prior to January 1, 1990) for this report is that it prevents the results from being unduly influenced by historical data when more recent data are available. However, this would not account for any decrease in sediment contaminant levels due to scouring, re-burial, natural attenuation, or active sediment remediation that have occurred since that sample was collected.

This report identifies locations where available data indicate that direct or indirect exposure to the sediment could be associated with adverse effects to aquatic life and/or human health. Further, even though this report focuses on data collected from 1990 through 1999, conditions might have improved or worsened since the sediment was sampled. This report does not and cannot provide a definitive assessment of the national condition or relative health of sediments across the country because the data were generally not collected in a randomized sampling approach. While this report does not provide an assessment of the "national condition" of contaminated sediments, it does evaluate data collected from 1980 through 1999 in the NSI database to assess changes in the extent and severity of sediment contamination over time for specific areas in the United States where sufficient data exist.

As mentioned above, this report provides a screening-level assessment outlining stations throughout the United States where the *probability* of adverse effects to human health and/or the environment exist. Because the data compiled for this report consist largely of non-random sampling events and do not provide complete national coverage, EPA has not developed a "national estimate" of the areal extent of contaminated sediments. Because the limitations of the data do not allow for a national estimate of the percentage of contaminated sediments, the report should not be used to estimate the national cost of potential sediment remediation or to prioritize sites for sediment remediation or risk management decisions based solely on the results of this report. Such decisions should be based on all available information, including the data reported in this report. A screening-level assessment typically identifies many potential problems that subsequently prove not to be significant upon further analysis (i.e., more conservative).

Evaluation Approach

Section 503 of WRDA 1992 defines *contaminated sediment* as "aquatic sediment which contains chemical substances in excess of appropriate geochemical, toxicological, or sediment quality criteria or measures; or is otherwise considered by the Administrator [of EPA] to pose a threat to human health or the environment...." The approach used to evaluate the NSI data focuses on the risk to benthic organisms exposed directly to contaminated sediments and the risk to human consumers of organisms exposed to

sediment contaminants. EPA evaluated sediment chemistry data, chemical residue levels in edible tissue of aquatic organisms, and sediment toxicity data taken at the same sampling station (where available) using a variety of assessment methods.

The following measurement parameters and techniques were used alone or in combination to perform a screening-level assessment of the probability of adverse effects.

Aquatic Life

• Comparison of sediment chemistry measurements to draft equilibrium partitioning sediment guidelines (ESGs) derived from final or secondary acute values and final or secondary chronic values.

• Comparison of the molar concentration of acid-volatile sulfides ([AVS]) in sediment to the molar concentration of simultaneously extracted metals ([SEM]) in sediment. (Under equilibrium conditions, sediment with [AVS] greater than [SEM] does not demonstrate toxicity from metals.)

• Estimation of the predicted proportion toxic from sediment chemistry observations using a logistic regression model.

• Comparison of the total ESG toxic unit for polycyclic aromatic hydrocarbons (PAHs) to final chronic or acute values.

• Toxicity based on acute or chronic solid-phase sediment toxicity data.

Human Health

• Comparison of theoretical bioaccumulation potential (TBP) values derived from sediment chemistry to – EPA cancer and noncancer risk levels or – Food and Drug Administration (FDA) tolerance, action, or guidance values in the absence of, or if more stringent than, EPA levels.

• Comparison of fish tissue contaminant levels to – EPA cancer and noncancer risk levels or – FDA tolerance, action, or guidance values in the absence of, or if more stringent than, EPA levels.

The sediment chemistry screening values used as the basis for comparison in this report are not regulatory criteria, site-specific cleanup standards, or remediation goals. Sediment chemistry screening values are reference values above which a sediment ecotoxicological assessment might indicate a potential threat to aquatic life. The sediment chemistry screening values include both theoretically and empirically derived values. The theoretically derived screening values (e.g., ESG, [SEM]![AVS]) rely on the physical/chemical properties of sediment and chemicals derived to protect aquatic benthic organisms from direct toxicity due to that chemical or chemicals in the case of metals mixtures and PAH mixtures. The empirically derived or correlative approaches (e.g., predicted proportion toxic) rely on paired field and laboratory data to relate incidence of observed biological effects to the dry-weight sediment concentrations. Correlative screening values can relate measured concentration to a probability of association with adverse effects, but they do not definitively establish cause and effect for a specific chemical. Toxicity data were used to classify sediment sampling stations based on their demonstrated toxicity to aquatic life in laboratory bioassays.

Under an assumed exposure scenario, TBP and tissue residue data can indicate potential adverse effects on humans from the consumption of fish that become contaminated

through exposure to contaminated sediment. TBP is an estimate of the equilibrium concentration (concentration that does not change with time) of a contaminant in tissues of aquatic organisms if the sediment in question were the only source of contamination to the organism. At present, the TBP calculation can be performed only for nonpolar organic chemicals. The TBP is estimated from the concentration of contaminant in the sediment, the organic carbon content of the sediment, the lipid content of the organism, and the relative affinity of the chemical for sediment organic carbon and animal lipid content. This relative affinity is measured in the field and is called a biota-sediment accumulation factor (BSAF, as discussed in detail in Appendix B). In practice, field-measured BSAFs can vary by an order of magnitude or greater for individual compounds depending on location and time of measurement. For this evaluation, EPA selected BSAFs that represent the central tendency, suggesting an approximate 50 percent chance that an associated tissue residue level would exceed a screening risk value.

The reader should exercise caution in evaluating the data in this report for a number of reasons. Uncertainty is associated with site-specific measures, assessment techniques, exposure scenarios, and default parameter selections. Many mitigating biological, chemical, hydrological, and habitat factors can affect whether sediment poses a threat to aquatic life or human health. Because of the limitations of the available sediment quality measures and assessment methods, EPA characterizes this evaluation as a screening-level analysis. A screening-level analysis typically identifies many potential problems that prove not to be significant upon further analysis. Thus, classification of sampling stations in this analysis is not meant to be definitive, but is intended to be inclusive of potential problems arising from persistent metal and/or organic chemical contaminants. For this reason, EPA elected to evaluate data collected from 1990 through 1999 and to evaluate each chemical or biological measurement taken at a given sampling station individually. The reader should keep in mind that a single measurement of a chemical at a sampling station, taken at any point in time over the past 10 years, might have been sufficient to categorize the sampling station as having an increased probability of association with adverse effects on aquatic life or human health.

In this report, EPA associates sampling stations with their "probability of adverse effects." Each sampling station falls into one of three categories, or tiers:
Tier 1: Associated adverse effects on aquatic life or human health are probable.
Tier 2: Associated adverse effects on aquatic life or human health are possible.
Tier 3: No indication of associated adverse effects (any sampling station not classified as Tier 1 or Tier 2; includes sampling stations for which substantial data were available, as well as sampling stations for which limited data were available).

The potential risk of adverse effects on aquatic life and/or human health is greatest in areas with a multitude of contaminated locations. The assessment of individual sampling stations is useful for estimating the number and distribution of contaminated spots and the overall magnitude of sediment contamination in monitored waterbodies of the United States. However, a "hot spot" might not pose a significant threat to either the benthic community at large or consumers of resident fish because the spatial extent of exposure could be small. On the other hand, if many contaminated spots are located in close

proximity, the spatial extent and probability of exposure are much greater. EPA examined sampling station classifications within watersheds to identify areas of probable concern (APCs) for sediment contamination, where the exposure of benthic organisms and resident fish to contaminated sediment might be more frequent. In this report, EPA defines watersheds by 8-digit USGS hydrologic unit codes, which are roughly the size of a county. Watersheds containing APCs are those in which 10 or more sampling stations were classified as Tier 1 and in which at least 75 percent of all sampling stations were categorized as either Tier 1 or Tier 2.

The definition of "area of probable concern" was developed for this report to identify watersheds for which further study of the effects and sources of sediment contamination, and possible risk reduction needs, would be warranted. Where data have been generated through intensive sampling in areas of known or suspected contamination within a watershed, the APC definition should identify watersheds that contain even relatively small areas that are considerably contaminated. This designation does not imply, however, that sediment throughout the entire watershed, which is typically very large compared to the extent of available sampling data, is contaminated. On the other hand, where data have been generated through comprehensive sampling, or where sampling stations were selected randomly or evenly distributed throughout a sampling grid, the APC definition might not identify watersheds that contain small or sporadically contaminated areas. A comprehensively surveyed watershed of the size typically delineated by a USGS cataloging unit might contain small but significant areas that are considerably contaminated, but the watershed might be too large in total area for 75 percent of all sampling stations to be classified as Tier 1 or Tier 2. Limited random or evenly distributed sampling within such a watershed also might not yield 10 Tier 1 sampling stations. Thus, the process used to identify watersheds containing APCs might both include some watersheds with limited areas of contamination and omit some watersheds with significant contamination. However, given the available data, EPA has concluded that the process represents a reasonable screening analysis to identify watersheds where further study is warranted.

Because the Tier 1, Tier 2, and Tier 3 evaluation benchmarks established in this report represent recent advances in sediment assessment techniques, they have been used in this report as a way to relate all the different data from all the different sources around the United States using common benchmarks. These benchmarks and interpretations used in this report, however, are not currently appropriate for use in EPA regulatory programs that have developed their own frameworks and regulatory requirements. They were not designed to be a substitute for the various EPA program regulatory frameworks and/or authorities. EPA's regulatory programs (e.g., Office of Solid Waste and Emergency Response, OSWER) have developed their own scientifically defensible approaches to sediment evaluation based on the needs of their programs, and they will continue to use their current regulatory frameworks when making decisions regarding potentially contaminated sediments (e.g., sediment remediation, sediment disposal).

Strengths and Limitations

For this report to Congress, EPA has compiled the most extensive database of sediment quality information currently available in electronic format. To evaluate these data, EPA has applied sediment assessment techniques using a multiple-lines-of-evidence approach recommended by national experts (Ingersoll et al., 1997). The evaluation approach uses sediment chemistry, tissue residue, and toxicity test results. The assessment tools employed in this analysis have been applied in North America, and results of these applications have been published in peer-reviewed literature. Toxicity test data were generated using established standard methods employed by multiple federal agencies. The evaluation approach addresses potential impacts on both aquatic life and human health. Some chemicals pose a greater risk to human health than to aquatic life; for others, the reverse is true. By evaluating both potential human health and aquatic life impacts, EPA has ensured that the most sensitive endpoint is used to assess environmental impacts.

There are two general types of limitations the reader should keep in mind in interpreting the results in this report to Congress—limitations of the compiled data and limitations of the evaluation approach. Limitations of the compiled data include the mixture of data sets derived from different sampling strategies, incomplete sampling coverage, the age and quality of data, and the lack of measurements of important assessment parameters. Limitations of the evaluation approach include uncertainties in the interpretive tools used to assess sediment quality (e.g., the propensity of certain chemicals to bioaccumulate and move through the aquatic food chain), use of assumed exposure potential in screening level quantitative risk assessment (e.g., fish consumption rates for human health risk), and the subsequent difficulties in interpreting assessment results. These limitations and uncertainties are discussed in detail in Chapter 2 of this report under "Limitations of the NSI Data Evaluation."

Data compiled for this report were generated using a number of different sampling strategies. Component sources contain data derived from different spatial sampling plans, sampling methods, and analytical methods. Most of the NSI data were compiled from nonrandom monitoring programs. Such monitoring programs focus their sampling efforts on areas where contamination is known or suspected to occur. Reliance on these data is consistent with the stated objective of this survey: to identify those sediments which are contaminated. However, one cannot accurately make inferences regarding the overall condition of the Nation's sediment, or characterize the "percent contamination," using the data in the NSI database because of the incomplete national sampling coverage and because, in EPA's view, uncontaminated areas are most likely substantially underrepresented.

Because this analysis is based only on readily available electronically formatted data, contamination problems exist at some locations where data are lacking. Conversely, older data might not accurately represent current sediment contamination conditions. The reliance on readily available electronic data has undoubtedly excluded a vast amount of information available from sources such as local and state governments and published

academic studies. In addition, some data in the NSI database were not evaluated because of questions concerning data quality or because no locational information (latitude and longitude) was available. NSI data do not evenly represent all geographic regions in the United States, nor do the data represent a consistent set of monitored chemicals. More than two-thirds of all stations evaluated in the NSI database are in Washington, Virginia, California, Illinois, Florida, Wisconsin, New York, Texas, Oregon, and South Carolina. Each of these states has more than 500 monitoring stations. Other states of similar or larger size (e.g., Georgia, Pennsylvania) have far fewer sampling stations with data for evaluation. Individual stations may vary considerably in terms of the number of chemicals monitored. Some stations have data that represent a large number of organic and inorganic contaminants, whereas others have measured values for only a few chemicals. Thus, the inventory should not be construed as comprehensive even for locations with sampling data.

EPA recognizes that sediment is dynamic and that great temporal and spatial variability in sediment quality exists. Movement of sediment is highly temporal and dependent upon the physical and biological processes at work in the watershed. Some deposits redistribute, whereas others remain static unless disturbed by extreme events. Because the data analyzed in this report were collected over a relatively long period of time, conditions might have improved or worsened since the sediment was sampled. Consequently, this report does not provide a definitive assessment of the current condition of sediments but serves as a baseline for future assessments.

The lack of data required to apply some important assessment parameters hampered EPA's efforts to determine the incidence and severity of sediment contamination. For example, the component databases contain a dearth of total organic carbon (TOC) and acid-volatile sulfide (AVS) measurements relative to the abundance of contaminant concentration measurements in bulk sediment. TOC and AVS are essential pieces of information for interpreting the bioavailability, and subsequent toxicity, of nonpolar organic and metal contaminants, respectively. In addition, matched sediment chemistry with toxicity tests and matched sediment chemistry with tissue residue data, were typically lacking. Also, because the evaluation approach outlined in this report needs to be applicable across the entire United States, various assumptions were made (e.g., assuming 1 percent organic carbon when none was reported, assuming the average individual consumes on average 17.5 grams of fish per day). Generally, the exposure assumptions and safety factors incorporated into toxicity assessments are intended to be protective of the majority of the general population associated with sediment contamination. However, these assumptions and factors might underestimate risks to populations of subsistence fishers and sensitive subpopulations (such as pregnant women, nursing mothers, and children).

It is important to understand both the strengths and limitations of this analysis to appropriately interpret and use the information in this report. The limitations do not prevent intended uses, and future reports to Congress on sediment quality will contain less uncertainty. To ensure that future reports to Congress accurately reflect current knowledge concerning the conditions of the Nation's sediment as our knowledge and

application of science evolve, the NSI will develop into a periodically updated, centralized assemblage of sediment quality measurements and state-of-the-art assessment techniques.

Findings

EPA evaluated 19,398 sampling stations nationwide as part of the NSI data evaluation Of the sampling stations evaluated, EPA classified 8,348 stations (43.0 percent) as Tier 1, 5,846 (30.1 percent) as Tier 2, and 5,204 (26.8 percent) as Tier 3. EPA has concluded that these results in all likelihood are not representative of the overall condition of sediment across the country. It could be that the overall extent of contaminated sediments and the corresponding adverse effects are much less. This is the case primarily because most of the NSI data were obtained from monitoring programs targeted toward areas of known or suspected contamination (i.e., sampling stations were not randomly selected).

The NSI sampling stations were located in 5,695 individual river reaches (or waterbody segments) across the contiguous United States, or approximately 8.8 percent of all river reaches in the country (based on EPA's River Reach File 1). A river reach can be part of a coastal shoreline, a lake, or a length of stream between two major tributaries ranging from approximately 1 to 10 miles long. Approximately 3.6 percent of all river reaches in the contiguous United States had at least one station categorized as Tier 1, almost 3 percent (2.9 percent) of reaches had at least one station categorized as Tier 2 (but none as Tier 1), and all of the sampling stations were classified as Tier 3 in about 2.3 percent of reaches. Looking at only the river reaches where sampling stations were evaluated, approximately 40 percent of the 5,695 river reaches evaluated had at least one sampling station categorized as Tier 1, approximately 33 percent of the river reaches evaluated had at least one station categorized as Tier 2 (but none as Tier 1), and all of the sampling stations in river reaches evaluated as Tier 3 in about 26 percent of the reaches had all sampling stations categorized as Tier 3.

Watersheds containing areas of probable concern for sediment contamination (APCs) are those that include at least 10 Tier 1 sampling stations and in which at least 75 percent of all sampling stations were classified as Tier 1 or Tier 2. The NSI data evaluation identified 96 watersheds throughout the United States as containing APCs. About 26 percent of the 370 eligible watersheds (96) contained an APC, or 4.2 percent of all the 2,264 watersheds in the United States. APC designation could result from expansive sampling throughout a watershed or from intensive sampling at a single contaminated location or a few contaminated locations. In comparison to the overall results, 23.9 percent of reaches in watersheds containing APCs have at least one Tier 1 sampling station and 18.3 percent have no Tier 1 sampling station but at least one Tier 2 sampling station. In many of these watersheds, contaminated areas may be concentrated in specific river reaches in a watershed.

Within the 96 watersheds containing APCs across the country, 97 individual river reaches or waterbody segments have 10 or more Tier 1 sampling stations. The evaluation results indicate that sediment contamination associated with probable or possible adverse effects on both aquatic life and human health exists. Overall, fewer stations were classified as

Tier 1 using aquatic life evaluation parameters (5,006 stations) than were classified using human health evaluation parameters (6,385 stations). Of the stations classified as Tier 2, 4,439 stations were so classified using aquatic life evaluation parameters and 3,131 stations were so classified using human health evaluation parameters.

Recognizing the imprecise nature of some assessment parameters used in this report, Tier 1 sampling stations are distinguished from Tier 2 sampling stations based on the magnitude of a contaminant concentration in sediment or the degree of corroboration among the different types of sediment quality measures. In response to uncertainty in both biological and chemical measures of sediment contamination, environmental managers must balance Type I errors (false positives, i.e., sediment classified as posing a threat when in fact it does not) with Type II errors (false negatives, i.e., sediment that poses a threat but was not so classified). In screening analyses, the environmentally protective approach is to minimize Type II errors, which leave toxic sediment unidentified. To achieve a balance and to direct attention to areas most likely to be associated with adverse effects, Tier 1 sampling stations are intended to have a higher probability of posing an adverse effect (e.g., sediment posing a threat) and a balance between Type I and Type II errors. On the other hand, to retain a sufficient degree of environmental conservatism in screening, Tier 2 sampling stations are intended to have a very low number of false negatives in exchange for a large number of false positives.

Section 503 of the WRDA of 1992 required EPA, as part of its program to assess sediment quality, to provide an assessment of aquatic sediment quality trends. The first Report to Congress suggested EPA "consider whether to design future evaluations of NSI data to determine the temporal trends of contamination." In response, EPA evaluated surficial sediment data from the entire NSI database (data from 1980 through 1999). The evaluation of historical surficial sediment data is limited because of the heterogeneous nature of monitoring programs and available data. Nevertheless, the evaluation tended to show decreased or no change in sediment contamination in most regions where data were available.

The USGS National Water-Quality Assessment (NAWQA) program also examined trends in sediment contamination for a number of contaminants by reconstructing water-quality histories using lake and reservoir sediment cores from 22 locations nationally. Statistically significant increasing trends in total PAH concentrations occur at nine lakes, and significant decreasing trends were detected at two lakes. The analysis of the organochlorine compounds (pesticides and PCBs) showed that only a few locations had significant trends since 1975. Since 1965, however, significant decreasing trends in total DDT have occurred at 12 of the 22 lakes. Among the organochlorine compounds, dieldrin and chlordane have increased in almost as many lakes as they have decreased since 1975. The most consistent trend since the mid-1970s for any of the constituents tested is that all 22 lakes had statistically significant decreasing trends in lead concentrations. Two other trace elements had somewhat consistent trends; chromium and nickel each increased in only one lake and decreased in nine and eight lakes, respectively. Three other elements, arsenic, copper, and mercury, had significant trends in 10 or more lakes, all with more decreasing trends than increasing. The only trace element with more

increasing trends than decreasing trends was zinc. Nine of the 19 urban lakes had increasing trends in zinc, and 4 lakes had decreasing trends.

Conclusions

The characteristics of the NSI data, as well as the degree of certainty afforded by available assessment tools, allow neither an absolute determination of adverse effects on human health or the environment at any location nor a definitive determination of the areal extent of contamination on a national scale. However, the evaluation results suggest that sediment contamination may be significant enough to pose potential risks to aquatic life and/or human health in some locations. EPA designed its evaluation methodology for this effort to develop a screening-level assessment of sediment quality. Further evaluation will be required to confirm that sediment contamination poses actual risks to aquatic life or human health for any given sampling station or watershed.

The results of the NSI data evaluation must be interpreted in the context of data availability. Many states and EPA regions appear to have a much greater incidence of sediment contamination than others. To some degree, this appearance reflects the relative abundance of readily available electronic data, not necessarily the relative incidence of sediment contamination. Although the APCs were selected by means of a screening exercise, it is EPA's view that they represent the highest priority for further ecotoxicological assessments, risk analysis, temporal and spatial trend assessment, and contaminant source evaluation because of the preponderance of evidence in these areas.

Although the procedure for classifying APCs using multiple sampling stations was intended to minimize the probability of making an erroneous classification, further evaluation of conditions in watersheds containing APCs is necessary because the same mitigating factors that might reduce the probability of associated adverse effects at one sampling station might also affect neighboring sampling stations. EPA chose the watershed as the unit of spatial analysis because many states and federal water and sediment quality management programs, as well as data acquisition efforts, are centered on this unit. This choice reflects the growing recognition that activities taking place in one part of a watershed can greatly affect other parts of the watershed, and that management efficiencies are achieved when viewing the **National Sediment Quality Survey** watershed holistically. At the same time, EPA recognizes that contamination in some reaches in a watershed does not necessarily indicate that the entire watershed is affected. Further analysis should be conducted within APC watersheds to delineate sediment contamination. This will allow sediment management activities determined to be necessary be performed in the most cost effective and environmentally sound manner.

Watershed management is a critical component of community-based environmental protection using watershed or hydrologic boundaries to define the problem area. Many public and private organizations are joining forces and creating multidisciplinary and multijurisdictional partnerships to focus on water quality problems community by community and watershed by watershed. These watershed approaches are likely to result in significant restoration, maintenance, and protection of water resources throughout the United States. As was reported in the initial *National Sediment Quality Survey* in 1997,

various programs across the United States as part of the National Estuary Program have used a watershed approach that has led to specific actions to address contaminated sediment problems. These include the Chesapeake Bay, Narragansett (RI) Bay, Long Island Sound, Puget Sound, New York/New Jersey Harbor, and San Francisco Bay Estuary programs. These specific programs have all recommended actions to reduce sources of toxic contaminants to sediment.

Continuing Challenges

The following are observations on continuing challenges to improve sediment quality assessment and management in the United States.

• ***Further Assessment of the Extent and Severity of Sediment Contamination in the 96 Targeted Watersheds Would Improve Contaminated Sediment Management Decisions.*** States and tribes, in cooperation with EPA and other federal agencies, should further evaluate the 96 watersheds containing APCs. In many cases, it is likely that much additional investigation and assessment has already occurred, especially in well-known areas at risk for contamination, and that some areas have been remediated. If active watershed management programs are in place, states and tribes may coordinate these evaluations within the context of current or planned actions. Future assessment efforts should focus on areas such as the waterbody segments located in the 96 watersheds containing APCs that had 10 or more sampling stations classified as Tier 1. The purpose of these efforts should be to gather additional sediment chemistry and related biological data, and to conduct further evaluation of data to determine human health and/or ecological risk, to determine temporal and spatial trends, to identify potential sources of sediment contamination and determine whether the appropriate source controls are being applied. Any future policies and/or actions to address contaminated sediments will have to be considered in the context of the budget process and competing demands for funding.

• ***Watershed Management Activities Would Create Multidisciplinary and Multijurisdictional Partnerships Focusing on Sediment Contamination.*** Addressing water issues within a given watershed or hydrologic boundaries—known as watershed management—is a critical component of community-based environmental protection. A watershed management framework requires a high level of inter-program coordination to consider all factors contributing to water and sediment quality problems and to develop integrated, science-based, cost-effective solutions that involve all the stakeholders. It is within the watershed framework, therefore, that federal, state, tribal, and local government agencies and industrial and citizens' groups can pool their common resources and coordinate their efforts to address their common sediment contamination issues. These watershed activities will support efforts such as monitoring and regulatory actions.

• ***Better Coordination of Contaminated Sediment Management and Research Activities Would Promote Application of Sound Science in Managing Contaminated Sediments.*** EPA developed **National Sediment Quality Survey** the *Contaminated Sediment Management Strategy* (USEPA, 1998a). Building on the *Strategy*, EPA's Contaminated

Sediment Management Committee (CSMC) has developed the *Contaminated Sediment Action Plan*. This plan outlines the next steps for the Agency in the management of contaminated sediments. The multimedia, cross-program plan describes the commitments from the EPA program offices to develop and apply sound science in managing contaminated sediments. A key component of future coordination within EPA in addressing sediment contamination is the contaminated sediment assessment pilots. The Office of Solid Waste and Emergency Response (OSWER), the Office of Water (OW), and EPA's regional offices will initiate pilot projects to facilitate cross-program coordination on contaminated sediments. The pilot projects will bring a cross-Agency focus to identifying and assessing waters that are impaired by sediment contamination. The pilots will use the legal authorities and techniques available to satisfy the needs of both the Remedial Investigation/Feasibility Study (RI/FS) evaluations and Total Maximum Daily Load (TMDL) modeling. EPA is also developing an Agency-wide Contaminated Sediment Science Plan to identify and prioritize the Agency's contaminated sediment science needs.

• ***Better Monitoring and Assessment Tools Would Improve Contaminated Sediment Management.*** The sediment quality evaluation tools used and outlined in this report should be used as the basis for future contaminated sediment assessment methods. As sediment quality data become more available and the state of the science for sediment assessment continues to evolve, better assessment methods will also evolve. As new and better sediment screening values and biological assessment techniques become available and are proven to be reliable, EPA will incorporate these techniques into future NSI data evaluations.

• ***A Weight-of-Evidence Approach and Measures of Chemical Bioavailability in Sediment Monitoring Programs Would Improve the Assessment of Contaminated Sediment.*** The ideal assessment methodology would be based on matched data sets of multiple types of sediment quality measures to take advantage of the strengths of each measurement type and to minimize their collective weaknesses. As the state of science is constantly evolving, future sediment monitoring programs should collect tissue residue, biological effects (i.e., toxicity, histopathology), and biological community (e.g., benthic abundance and diversity) measurements whenever possible along with sediment chemistry data. Collection of data to measure chemical bioavailability is critical to the success of weight-of-evidence assessments. Where metals are expected to be a concern, sediment monitoring programs should collect AVS and SEM measurements. More accurate assessments will be possible if future monitoring programs include TOC measurements wherever organic chemicals are a concern.

• ***Increased Geographic Coverage in the NSI Database Would Refine a National Assessment of the Extent and Severity of Contaminated Sediment.*** The NSI database is currently limited in terms of the number of data sets it includes and the national coverage it provides. The focus of additional data additions will be (1) to obtain a greater breadth of coverage across the United States and (2) to increase the number of waterbodies evaluated. These types of data will be extremely useful in future analyses to assess changes in the extent and severity of sediment contamination over time. Upon

completion of this report, EPA will make a concerted effort to accumulate more data for inclusion in the NSI database and for future *National Sediment Quality Survey* reports to Congress. This effort will begin its focus on areas (river reaches and watersheds) with minimal or no coverage outlined in this report. As part of this effort, EPA will broadly advertise its need for information on contaminated sediments. EPA also encourages third parties to send their information to STORET (www.epa.gov/STORET) so that it can be reflected in the next *National Sediment Quality Survey*. As part of the initial *National Sediment Quality Survey*, EPA included the data used for that report in its comprehensive GIS/modeling system, Better Assessment Science Integrating Point and Nonpoint Sources (BASINS). EPA is working on getting the additional data in the NSI database into BASINS. In addition to this effort, EPA is also working with NOAA to incorporate the NSI **National Sediment Quality Survey** database into Query Manager, which is a database program that can be used to access sediment data (chemistry, toxicity, and tissue residue data) for individual watersheds and allow the data to be queried and analyzed.

• ***Assessment of Atmospheric Deposition of Sediment Contaminants Would Improve Contaminated Sediment Management.*** The relative contribution of contaminants to the sediment from air deposition has been virtually unknown on a national scale, but could be significant. Under Section 112(m) of the Clean Air Act, the EPA in cooperation with NOAA has been conducting a program to assess the contributions and effects of hazardous air pollutants on the Great Lakes, Lake Champlain, the Chesapeake Bay, and near-coastal waters. The findings and conclusions from this program and others described in the third *Great Waters Report to Congress* will be incorporated into future iterations of the *National Sediment Quality Survey*.

• ***Prevention of Continuing Sources of Sediment Contamination is Important in Contaminated Sediment Management.*** Although sediment contamination is frequently the result of historical discharges of pollutants before the National Pollutant Discharge Elimination System (NPDES) regulatory program was established, there are still continuing sources of sediment contamination. Therefore, source control and pollution prevention are crucial items in preventing contaminated sediments. As outlined in EPA's *Contaminated Sediment Management Strategy*, EPA OW and other EPA program offices are working with non-governmental organizations and the States to prevent point and nonpoint source contamination from accumulating in sediments. Pollution prevention is a key element in reducing the sources of contaminants that can end up in the sediments, potentially resulting in adverse effects to aquatic life or human health. Pollution prevention has been shown to reduce costs, as well as pollution risks, through source reduction and recycling/reuse techniques. Additionally, EPA has developed and is implementing a national multimedia strategy (under the cross-agency PBT Program) for the reduction of persistent, bioaccumulative, toxic chemicals (PBTs), which generally accumulate in sediments. EPA is forging a new approach to reducing risks from and exposures to priority PBT pollutants. This approach, focused on increased coordination among EPA and regional programs also requires the significant involvement of stakeholders, including international, state, local, and tribal organizations, the regulated community, environmental groups, and private citizens.

• ***Better Coordination and Communication with External Stakeholders and Other Federal Agencies Would Improve the Contaminated Sediment Management Process.*** Sediment contamination is a concern to stakeholders throughout the United States. EPA will work closely with other Federal Agencies (e.g., USACE, NOAA, USGS) to compile and evaluate data in the NSI database as well as the development of future reports. Additionally, EPA will reach out to the public as we compile additional sediment quality data in the NSI database and develops the next report to Congress. During the next year, EPA anticipates setting up "listening sessions" to gather information that can be used for future reports to Congress. During these sessions, EPA will be searching for additional data for the NSI database and subsequent reports, taking recommendations on how to improve the report, and establishing better and more effective ways to keep the public and interested stakeholders informed. This report and future *National Sediment Quality Survey* reports will provide environmental managers at the federal, state, tribal, and local levels with valuable information. The NSI database and this report can assist local watershed managers by providing data and by demonstrating the application of a multiplelines- of-evidence approach for identifying and screening contaminated sediment locations. It also allows researchers to draw on a large data set of sediment information to conduct new analyses that will continue to advance the science of contaminated sediment assessments, which ultimately can be applied at the local level to assist environmental managers in making sediment management decisions.