Presenter's Manual for: Remediation of Contaminated Sediments

Acknowledgements

This manual was prepared to guide EPA staff during public presentations of the 28-minute videotape "Contaminated Sediments: Impacts and Solutions." The developers of the videotape (Pat Carey, Steve Ells, Bruce Englebert, Katrin Kral, Ernie Watkins, and Suzanne Wells of EPA) are grateful to Ashwaubenon, Wisconsin resident Mary Deckert; United Tribe Nation of Wisconsin, Tom Nelson and Laura Manthe; Wisconsin Department of Natural Resources Bill Fitzpatrick and Greg Swanson; EPA reviewers and participants who include Alice Kaufman, Richard Stapleton, Jim Hannenberg, Michelle Jaster, Mick Hans, T. Stuart Hill, Bri Bill, Craig Zeller, Leah Evison, Bonnie Eleder, Kymberlee Keckler, Beverly Negri, Chris Long, and Judy Smith; and to Tom Heim the project work assignment manager with Environmental Management Support, Inc.

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TAB 1. INTRODUCTION

Purpose of the Videotape

EPA developed the videotape "Contaminated Sediments: Impacts and Solutions" to help explain in plain terms how:

- sediment becomes contaminated,
- what this contamination means to an ecosystem,
- its potential impact on both human health and a community's economy, and
- different approaches that can be used to cleanup or reduce these impacts.

The videotape lays the groundwork in simple terms for in-depth discussions on these topics. The information provided in the videotape will help the public evaluate the contaminated sediment problem in their community and potential cleanup strategies.

Generally it is best to show the videotape after the remedial investigation (RI) and baseline risk assessment have been completed, which is when the extent of contamination and its risks are known, and before the feasibility study (FS) is completed (i.e., when potential remedies are first discussed). Holding a public meeting centered around the videotape during FS development will allow informed community participation in remedy selection.

The 28-minute videotape cannot replace discussions with technical experts, such as a risk assessor, remedial engineer, or project manager. Although the videotape helps explain issues related to contaminated sediment and its cleanup, it is intended to be used with technical staff present to answer questions. Your efforts to communicate with the public may be hindered if you do not have the resources to answer questions during the session. Commit to responding to any unanswered questions quickly, preferably within a day.

You should schedule about one hour to show the 28-minute videotape and answer questions. Before starting the videotape, discuss what you expect the video tape to accomplish and take a few minutes to explain that you will be stopping the tape at specific points to tell them about how the video information relates specifically to this site. The presence of technical staff, such as the remedial project manager, risk assessor, and/or other technical assistance staff, is important to be able to explain how the video relates to the specific site. If you are soliciting informal public input on the RI or FS plans, be upfront about how community input will be used and identify any limitations on that input.

One way to show the 28-minute videotape is in segments, particularly if the audience is new to the contaminated sediments issue. Because the videotape covers a number of different issues, plan to stop the tape periodically to reinforce key messages and give people a chance to ask questions. The pauses also offer an

Essential Ingredients
- Risk Assessor
- Engineer
- Community Involvement Coordinator
- Knowing your audience
- Good preparation for site-specific issues
- Time to pause and discuss
- Follow up plans

Schedule about one hour to show the 28-minute videotape

Pause the Tape to
- Discuss technical concepts
- Answer questions
- Reinforce messages

opportunity to talk about the ways community members can be involved. The best places to pause are after the impacts discussion (6 minutes), after the solutions introduction section and two of the technologies (8 minutes), and after the excavation section (12 minutes).

The end of the tape is another time to reinforce main messages, answer questions, discuss site-specific concerns, and talk about how and when follow up will occur. This also is an appropriate time to give viewers additional information, handouts, and a list of regional contacts.

Purpose of this Manual

This Manual Will Help You
- Reinforce key concepts
- Prepare for questions
- Generate discussion
- Plan for follow up

This manual highlights the key messages described in the videotape and other issues that audiences might raise. The information is intended as background for presenters to use in explaining contaminated sediment issues and remedial strategies. These materials are not intended to be read verbatim to audiences.

(Tab 2) Video Segments: Notes for the Presenter contains key messages and additional information on topics that could not be addressed in the videotape. References are provided at the end of Tab 2. **(Tab 3) Handouts** includes a glossary of technical terms used in the videotape and manual. You should provide viewers with additional information about Superfund, assistance programs, and people to contact.

The materials in this manual are not intended to be read verbatim to audiences

Unfortunately most of the available references on contaminated sediment and remedial strategies are written for environmental professionals. Almost no easy-to-read information is available for citizens, many of whom read at basic grade-school levels (see below).

Facts About Literacy*

About 47 percent of the U.S. adult population (16 years old and older) reads only at a fifth to eighth grade level (26 percent at a maximum of fifth grade and 21 percent at a maximum of eighth grade).

Among adult welfare recipients, reading skills are generally worse. In this group, 75 percent read at the fifth to eighth grade level (50 percent at about fifth grade and 25 percent at about eighth grade).

Also, many people who live and fish near contaminated sediment sites are foreign born or speak English as a second language.

*The National Center for Educational Statistics' 1992 National Adult Literacy Survey (http//nces.ed.gov/naal).

Tips

This section contains the following:

- Presenter's Checklist
- Getting the Most Out of the Videotape

PRESENTER'S CHECKLIST

When presenting this videotape, be well prepared. Preparation is essential if you and the audience are to get the most from the videotape. The audience should have some familiarity with Superfund and ideally should know something about the site from previous meetings that have covered the site investigation and risk findings. The videotape covers several very technical concepts that are an integral part of a sediment cleanup. People are likely to ask tough questions, especially about remedies that leave contamination in place and how dangerous the cleanup process will be to their own health and well being. This Presenter's Manual will help you prepare for them.

Here are some tips:

- ❒ Schedule about an hour to show the videotape and answer questions.
- ❒ Set up the room to facilitate viewing and discussion (U-shape arrangement is good for small groups; offset-row arrangement is better for large groups).
- ❒ Make sure the room temperature and accommodations are comfortable.
- ❒ Have a flip chart(s), markers, and tape on hand to record notes and to list questions to answer later.
- ❒ Make sure you have a working TV, VCR, and any other necessary equipment.
- ❒ Make copies of handouts appropriate to the audience
- ❒ Before showing the videotape, you should familiarize yourself with it and this Presenter's Manual.
- ❒ We recommend that you pause the videotape after the following sections for audience questions and site-specific discussions:

Sediment and how it becomes contaminated	3 minutes
Biological impacts of contaminated sediment	1.5 minutes
Economic and cultural impacts of contaminated sediment	1 minute
(Pause)	
Solutions	1 minute
Monitored natural recovery	4.5 minutes
Capping in place	2.5 minutes
(Pause)	
Environmental dredging	10 minutes
Excavation	2 minutes
(Pause)	
What the community can do	1.5 minutes

- ❒ Because it is critical to have knowledgeable staff on hand to respond to questions, we recommend showing this videotape only when a remedial engineer and a risk assessor or other appropriate technical staff are present.
- ❒ Encourage discussion.

Show the videotape at a time when the audience can focus on cleanup alternatives, not before they know they have a contaminated sediment problem or after the FS has recommended a cleanup method

Getting the Most Out of the Videotape

Before showing the videotape

- Discuss expectations
- Explain what the RI findings and baseline risk assessment for the sediment means
- Be up front about how community input will be used and any limitations
- Explain that you intend to pause the tape after each major topic for questions and discussion

During the videotape

- Pause the tape for questions and answers
- Reinforce key messages
- Talk about ways community members can be involved

After

- Take any additional questions
- Reinforce main messages
- Discuss how and when follow up will occur
- Give viewers additional information, handouts, and lists of contacts

TAB 2. VIDEO SEGMENTS: NOTES FOR THE PRESENTER

What is Sediment and How it Becomes Contaminated

The videotape begins with an overview, description of sediment, and how sediment becomes contaminated. The video explains that sediment occurs naturally as particles at the bottom of surface water bodies. Human activities, such as industrial waste discharges, wastewater treatment plants, storm sewers, runoff from agricultural areas, mining operations, and air pollution, which are mentioned in the videotape, can contaminate sediment.

KEY MESSAGES

- Community involvement is important. EPA and state regulatory agencies rely on community input to help guide their decision making.

EPA and state regulatory agencies rely on community input to help guide their decision making

- Many contaminated sediment sites are the result of former industrial practices.

- Controlling the source of contamination is the key to preventing the sediment from becoming re-contaminated in the future. State and federal regulations now control the release of many contaminants into the environment at their sources, but cleanup of source areas on land remains a major challenge at most Superfund sediment sites.

Sediment Types and Conditions

Sediment, which is matter that settles to the bottom of water bodies, frequently is classified by the grain size of its minerals and the amount of organic material mixed with those minerals. Sand particles, which consist mostly of silicon dioxide (quartz), can range in size from coarse (2 mm) to very fine (0.06 mm). Silt, which is structurally similar to sand, ranges in size from 0.06 mm to 0.002 mm. Clay consists of the smallest particles (less than 0.002 mm) and typically contains alumino-silcate minerals. Clay also can contain calcium carbonates, iron oxides, and other matter.

Sand and silt are generally chemically inert unless they are coated with active materials, such as ferric oxides, and they do not provide any mechanism for binding contaminants. Clay, on the other hand, is chemically active and can provide surfaces to which many different types of contaminants will bond. Therefore, clayey sediment, or the clayey fraction of sediment, is often where contaminants are found.

Contaminants usually are found in the clayey fraction of sediment

Sediment also can contain naturally occurring organic matter, such as leaves and organic debris washed into the water body or organic matter created by plants and animals living in the water body. These compounds can interact with contaminants and may concentrate them. The amount of organic matter in sediment varies tremendously, depending on the environment.

The sediment of waterways also can contain larger rocks and debris. These may be anthropogenic (man made) materials, such as tires and construction debris, as well as natural materials, such as tree limbs or large rock cobbles or boulders. The contaminated sediment may be underlain by clean sediment, hard bedrock, or glacial deposits, such as clayey till. The presence of debris or hard deposits under the contaminated sediment may affect the choice of remedy because it may be difficult to remove contaminated sediment under these conditions.

Surface Waters

If surface water intercepts the groundwater table, contaminants in the groundwater may move up into the sediment

Surface water can be broadly divided into those bodies of water that intercept the groundwater table (gaining) and those that do not (losing). Both may have implications for the remedy selection. Gaining bodies of water are characterized by an upward flow of groundwater into the waterway. If the groundwater is contaminated, the upward flow can bring contamination with it or cause some sediment contaminants to slowly dissolve into the surface water. If the groundwater is contaminated and likely to affect the sediment remedy, the sediment remedy usually occurs after the contaminated groundwater problem is resolved or contained. Losing bodies of water are characterized by a downward flow of surface water to an underlying water table. Significant dissolution of contaminants from the sediment may become a source of groundwater contamination.

Contaminated sediment is more likely to be found in low energy areas than in high energy areas where the currents or wave action are stronger and discourage particle settlement

The energy of the water body also plays an important role in the movement of contaminated sediment. Energy is generally expressed in terms of strength of current or wave action. High energy systems have the ability to move sediment more readily than low energy systems. In rivers and streams, the river bed often consists of scour and settling areas with the scour area water having high energy and the settling area lower energy. Contaminated sediment is more likely to be found in the latter than the former. The energy of the system also has an affect on remedy selection. Some remedies cannot be applied in high energy areas. How energy affects the remedies will be discussed later in the solution section.

Contaminant Sources

Many of the serious contaminated sediment problems of today are the result of past industrial practices

Many of the most serious contaminated sediment problems of today are the result of past industrial practices. Contaminants were either dumped directly into water bodies or escaped into the environment during product and waste handling procedures and subsequently found their way to surface waters.

Mining. While many currently operating mine sites are careful about controlling runoff from their waste rock areas, this was not always the case. Mine tailing piles at abandoned mine sites and old piles at currently operating sites can be the source of sediment and surface water contamination. The contamination can be caused directly by the runoff of metals bearing materials washed into the surface water or indirectly through acid mine drainage.

Acid mine drainage occurs when rock minerals that were previously unexposed to oxygen because they were buried underground become exposed to oxygen-rich precipitation that percolates through them. The oxygen reacts with some of the rock minerals (generally pyrites) to form sulfuric acid. The sulfuric-acid rich water in turn mobilizes heavy metals contained in the tailings and washes them into a nearby surface water or the groundwater. If the groundwater intersects a surface water body it will contaminate it too. Another form of acid mine drainage occurs when the same process takes place within an abandoned mine shaft. Infiltrating, oxygen-rich water reacts with minerals on the walls and in fractures of the shaft causing the water to become acidic. The acidic water leaches metals from the wall materials and carries them to the groundwater or to surface water.

Oxygen-rich precipitation can cause the release of heavy metals from rock minerals

Storm sewers. Storm water sewers that channel runoff from streets, parking lots, and homes to receiving bodies of water represent point sources of pollution that are generally not controlled by government regulations. Runoff often contains oil and fuel from motor vehicles, heavy metals from tire wear, and polynuclear aromatics from air deposition of motor vehicle exhaust (especially from diesel engines) as well as eroded soil and anthropogenic cast-offs (cigarette butts, soda cans, cups, etc.).

An example of a point source of pollution is a storm sewer

Non-point sources. Sediment can become contaminated from non-point sources that represent runoff from open areas, such as forested watersheds and agricultural fields. Runoff from agricultural land often contains high levels of nitrates from fertilizer applications and can contain persistent pesticides. Most modern agricultural pesticides are designed to biodegrade in a relatively short time, but some still do not. An example of a persistent pesticide is DDT, which was banned many years ago, but is still in the environment.

An example of a non-point source of pollution is runoff from agricultural land

Contaminated groundwater and NAPLs. Although not covered in the video, depending on site-specific circumstances, the presenter should also be prepared to address questions on contamination caused by contaminated groundwater and non-aqueous phase liquids (NAPLs) entering sediment from below. Examples of the latter are the Eagle Wyckoff site in Washington state where coal tars moving through the subsurface have appeared in the bay sediment and the General Electric Housatonic Massachusetts site where polychlorinated biphenyl (PCB) contaminated oil has appeared in an adjacent stream bed.

Several mechanisms can cause this. If the NAPLs are lighter than water, they can move along the top of the water table and enter the surface water where the groundwater intersects it. If there is a layer of soil or rock with a low hydraulic conductivity (typically bedrock or clay) that intersects the surface water, NAPL can move across that layer and enter the sediment.

Government Regulations for Controlling Sources

Clean Water Act. A provision of the Clean Water Act (CWA) establishes a National Pollutant Discharge Elimination System for point source industrial discharges and discharges from publically owned wastewater treatment plants. This system limits the amount of pollution that a given facility can discharge to a surface water body. The lower the pollutant load allowed into a water body, the less likely contaminants will settle in sediment.

To minimize releases RCRA provides for cradle to grave regulation of hazardous waste

Resource Recovery and Conservation Act. The Resource Recovery and Conservation Act (RCRA) provides for stringent handling, storage, and disposal regulations of hazardous chemicals, waste, and municipal garbage. These regulations are aimed at preventing the accidental or deliberate release of chemicals into the environment by requiring engineered storage and disposal areas, monitoring of these areas, and a system to track waste shipments. RCRA also includes provisions in its corrective action program that require cleanup of RCRA-regulated wastes.

Superfund helps to address problems associated with past practices as well as to mitigate impacts from accidental releases

Comprehensive Environmental Response, Compensation and Liability Act. The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), better known as Superfund, was created to address problems caused by past practices and to create a mechanism whereby the government could rapidly respond to accidental releases of hazardous materials, such as those that might occur during a train or truck wreck. The federal government's response to accidental releases of chemicals to surface waters is addressed by provisions in the CWA. The methodology for responding is laid out in the National Oil and Hazardous Substances Pollution Contingency Plan, which implements both CERCLA and the release response action provisions of the CWA.

For designated industries, the Clean Air Act seeks to minimize emissions of hazardous chemicals into the air

Clean Air Act. The Clean Air Act regulates the amount of pollution that can be discharged to the air by certain industrial activities. Air pollutants have the ability to travel many miles and settle on land or water bodies. Some of them end up in sediment. For example, air deposition from former ore smelters have contributed to lead, zinc, and arsenic contamination in wetlands. It is estimated that coal fired electrical power plants are the largest contributors of mercury pollution in the Chesapeake Bay.

Biological Impacts of Contaminated Sediment

This portion of the videotape discusses the impacts that contaminated sediment may have on wildlife and human health. It explains that some contaminants produce an affect only by direct contact with humans in shallow water or wetlands, or to the benthic organisms (flora and fauna) living in or on the contaminated sediment. A second category of contaminant, called persistent bioaccumulators affect humans and other organisms (e.g., fish, shellfish) that feed on bottom flora and fauna. These chemicals also have the ability to concentrate (i.e., biomagnify) in animals. For example, humans that eat fish containing bioaccumulating chemicals accumulate those chemicals in their bodies. Some chemicals can cause health problems, such as genetic defects, tumors, and cancer. Most bioaccumulating chemicals are stored in fat and are not excreted to any significant degree. Methyl mercury and PCBs are examples of bioaccumulating chemicals that pose health concerns for humans.

Benthic organisms include the flora (plants) and fauna (animal) that live in or on the sediment

KEY MESSAGES

- If exposure to contaminated sediment is not addressed, it may continue to pose risk to ecological and/or human receptors for a long time.
- Bioaccumulating chemicals do not have to be present at high concentrations in sediment and water to be a risk to ecological and human receptors.
- The amount of a chemical that is bioavailable to a given receptor is generally, though not always, less than its total concentration in the sediment.

Most bioaccumulating chemicals, such as methyl mercury and PCBs, are stored in fat tissue and are not significantly excreted from the body

Contaminant Properties

Many factors affect the transport and fate of contaminants in sediment. Most of these factors have to do with the physical and chemical properties of the sediment and whether the contaminant is organic or inorganic.

As mentioned in the previous section, sand and silt are usually inert chemically while mineral clay is not. Some clays provide a relatively large negatively charged surface area that can attract many organic and inorganic chemicals. Under stable (i.e., equilibrium) conditions chemicals attracted to clay can be "sequestered" from the environment and therefore biologically inavailable. The properties of clay, including its structure and small particle size, means clay has many "dead end" pathways from which contaminants can escape only by diffusion, which is a very slow process.

Clayey sediment often attracts contaminants

In addition to containing chemically active clay, sediment also may contain varying amounts of organic matter. Hydrophobic organic chemicals, like PCBs and DDT, prefer to associate with organic matter rather than with water. Hence,

PCBs and DDT generally remain immobile in organic-rich sediment

PCBs entering surface water from the air are likely to remain in the water column rather than settle in the sediment

they generally remain biologically unavailable in an organic-rich sediment. However, for PCBs to associate more with organic matter than with water, they need to have entered the water body directly, which was usually the case when they were manufactured and used in commercial applications. Although PCBs are no longer manufactured in the United States, PCBs often enter water bodies through runoff from old land sources and through sewage outfalls. They may also enter water bodies through air deposition where they are likely to remain suspended in the water column. Organic materials also can sequester some metals.

The presence or absence of oxygen in sediment (the redox condition) has an influence on the mobility of contaminants, and can influence the rate at which organic chemicals biodegrade.

The Benthic Community

The benthic community, which is made up of organisms that live in and on the sediment, may contain a wide variety of plants, animals, and bacteria from all levels of the food chain. There are three distinct types:

- Infauna—plants, animals, and bacteria of any size that live in the sediment.
- Epifauna—plants, animals, and bacteria that are attached to the hard bottom or substrate (for example to rocks or debris), or live on the sediment surface.
- Demersal—bottom-feeding or bottom-dwelling fish that feed on the benthic infauna and epifauna.
  (See Chesapeake Bay Program— http://www.chesapeakebay.net/info/benthos.cfm)

Benthic animals can be further sub-divided into filter feeders and deposit feeders. Filter feeders, such as clams and quahogs, filter their food by siphoning particles out of the water. Deposit feeders, such as snails and shrimp, ingest or sift through the sediment and consume organic matter within it. (See University of Rhode Island Office of Marine Programs— http://omp.gso.uri.edu/doee/science/biology/benth1.htm).

Bioavailability

Bioavailability is defined in different ways across scientific disciplines, and hence there is a great deal of room for misunderstanding and confusion. A National Research Council (NRC, 2003) study on bioavailability offered the following definitions among the many available:

- The ability of a chemical to be absorbed by an organism
- The individual chemical's physical and biological interactions that determine the exposure of plants and animals to chemicals in the sediment

- The fraction of a chemical accessible to an organism for absorption
- The rate at which a chemical is absorbed into a living system
- A measure of the potential to cause a toxic affect

Sediment conditions that might have a very negative affect on one species might not affect another species

It is important to remember that very complex mechanisms are involved in bioavailability that depend upon the state of the chemical (e.g., compound and valence for metals), the type of sediment (e.g., sand versus clay), redox condition, amount of naturally occurring organic matter in the sediment (e.g., humic acids, peat, rotting leaf matter), and route of exposure (e.g., dermal adsorption, root uptake, ingestion, gills). However, the chemical state and environmental setting that might have a very negative affect on one species might not affect another in the same setting. Also, when sediment conditions vary greatly across a contaminated area, any given contaminant may be more bioavailable in some areas than in others. As a rule of thumb, most contaminants are more bioavailable when they are in solution than when they are not.

For bottom feeders, such as certain fish and ducks, the actual chemical mobility of a contaminant into and out of the sediment may not be as important in estimating its bioavailability as is whether the bottom feeder forages for food and consequently ingests the sediment directly. The classic example of this is a duck that ingests lead shot from feeding in a wetland. Elemental lead is not very soluble in water or available to flora, but when subjected to a duck's digestive acids, it quickly becomes bioavailable and poisons the duck. However, not all contaminants that are ingested become bioavailable and the degree of bioavailability varies significantly among species living in any given area.

Why Bioaccumulation And Biomagnification Are Important

The toxicity of a bioaccumulating chemical is not necessarily related to ambient concentrations

In many cases the concentration of a chemical in sediment and water can be very low (much lower than is required to cause a toxic effect) or the amount that is bioavailable is very low. If the chemical does not bioaccumulate, exposures up to the concentration where an observed affect occurs usually are not a concern. However, with bioaccumulating chemicals, toxicity is not necessarily related to ambient or available concentrations but rather to the time the organism is exposed to the chemical and also whether the exposure is passive (direct contact with water and sediment) or active (ingestion of food). Because bioaccumulating chemicals also vary in the amount that they are metabolized or excreted by animals, exposure to low concentrations over a long time may cause the contaminant to accumulate in the organism until it reaches toxic levels.

Biomagnification occurs when a bioaccumulating chemical transfers up the food chain from one trophic level to another through feeding. Therefore, a chemical

Exposure to low concentrations of a bioaccumulating chemical over a long time may eventually reach toxic levels

that is not directly bioavailable to a fish but is available to the zooplankton that the fish eats, gets into the fish by ingestion and will begin to accumulate in the fish. By removing the contaminated food source, the accumulation will stop; however, the current chemical concentration in the body will remain or possibly decrease slowly. Humans, who might not have any physical exposure to the contaminated sediment or water containing the bioaccumulating chemicals, can still accumulate the contaminants in their bodies if they consume the contaminated fish.

Economic and Cultural Impacts of Contaminated Sediment

Contaminated sediment can lead to restricted uses of a water for recreational activities; commercial fishing/shell fishing; and traditional cultural uses, such as tribal fishing. The presence of contaminated sediment can potentially prevent navigational dredging, which may prevent the use of the waterway by commercial shipping.

Contaminants that partition into the water at low but unsafe levels may lead to restrictions on recreational uses. Other contaminants, if present at sufficient concentrations in the sediment, may pose a hazard to swimmers if resuspension of the sediment into the surface water occurs.

Contaminated sediment has the potential to lower real estate values of nearby land, especially when people use the water body. The presence of potentially toxic chemicals near or on a property tends to stigmatize the property in the eyes of potential buyers.

Due in part to the presence of contaminated sediment, 28 percent of the lakes in the United States and 14 percent of the river miles have fishing bans or fish consumption advisories that restrict commercial fishing or recommend limiting eating fish and/or shellfish. Fishing bans and consumption advisories impact the commercial fishing economy and some Native American and other ethnic and minority communities that depend on fishing for their livelihoods and food supply. Also inhabitants of poor communities often catch local fish that may represent a substantial portion of their protein intake. If the fish are contaminated, these populations may be at risk.

28 Percent of lakes and 14 percent of river miles in the United States have fish advisories, which can affect real estate value, commercial fishing, recreational uses, and subsistence fishers

KEY MESSAGES

- Because bioaccumulating chemicals are not significantly metabolized or excreted, the body's burden of them increases with consumption of contaminated fish/shellfish.

- Subsistence fishers are in greater danger of health affects from eating contaminated fish than the general population because they tend to eat more fish.

Water Body and Beach Use Restrictions

Contaminated sediment can lead to restrictions on wading and swimming. Humans may be exposed to contaminated sediment through skin contact (dermal absorption) while wading at beaches, streams, or wetlands, or by ingestion of water and sediment particles while swimming. The ingestion of resuspended sediment is of special concern since many contaminants that generally are not

Humans may be exposed to contaminated sediment through skin contact and ingestion of water or sediment while swimming

directly bioavailable under ambient conditions become so in the acidic conditions of the human digestive system.

Fish Consumption Advisories

The states, U.S. Territories, and Native American tribes have primary responsibility for protecting their residents from the health risks of consuming contaminated noncommercially caught fish. They do this by issuing consumption advisories for the general population as well as for specific vulnerable subpopulations (e.g., children and nursing mothers). These advisories tell the public when high concentrations of chemical contaminants have been found in local fish. They also include recommendations to limit or avoid eating certain fish species from specific water bodies or water body types (http://www.epa.gov/ost/fish/). There is an excellent source of fish advisories and outreach material on the EPA website at http://www.epa.gov/waterscience/fish/forum/pdfs/indexsub.pdf

Common Community Concerns About Contaminated Sediment

- Human health impacts from eating fish and shellfish, wading, and swimming
- Ecological impacts on wildlife and aquatic species
- Loss of recreational and subsistence fishing opportunities
- Loss of recreational swimming and boating opportunities
- Loss of traditional cultural practices by tribes and others
- Economic affects of the loss of fisheries
- Economic affects on development, reduction in property values, or property transferability
- Economic affects on tourism
- Concern whether all contamination sources have been identified
- Increased costs of drinking water treatment, other affects on drinking water, and other water uses
- Loss or increased cost of commercial navigation

Solutions to Contaminated Sediment

The videotape makes the point that the first step in managing contaminated sediment is pollution prevention through laws and regulations, such as those that control point-source releases. Because contaminated sediment problems differ from site to site and often within one site, more than one management technique may be needed even at one site. The videotape covers several management strategies, including monitored natural recovery, capping, dredging, and excavation.

KEY MESSAGES

- The first step in remediation is to ensure that the source(s) of the contamination has been addressed.

- Contaminated sediment sites can be complex, requiring more than one remediation technology to clean them up.

Contaminated sediment sites can be complex, often requiring more than one cleanup technology

Monitored Natural Recovery (MNR)

MNR is most effective in water bodies that are relatively deep and slow moving

Monitored natural recovery (MNR) is a risk reduction approach for contaminated sediment that uses ongoing, naturally occurring processes to contain, destroy, or reduce the bioavailability or toxicity of contaminants in sediment. Not all natural processes result in risk reduction; some may increase or shift risk to other areas. Therefore, to use MNR successfully, it is necessary to identify and evaluate the natural processes that reduce risk. MNR usually requires assessment, modeling, and monitoring to demonstrate that risk is actually being reduced.

Natural processes that can reduce risk include the following, in order of preference:

A. Processes that convert contaminants to less toxic forms (e.g., biodegradation)
B. Processes that bind contaminants more tightly to the sediment (e.g., sorption)
C. Processes that bury contaminated sediment beneath clean sediment (e.g., sedimentation)
D. Processes that disburse or dilute contaminated sediment

Relying on dispersion or dilution of the contaminants is a last resort for EPA and should only be considered when all other alternatives are impractical. When this is considered, the affect of the dispersed contaminants on downstream areas should be carefully considered.

MNR uses natural physical, biological, or chemical processes to reduce risk

The videotape explains that MNR relies on naturally occurring processes, such as biodegradation or burial by clean sediment, to reduce mobility or toxicity of contaminants in sediment, and that MNR should not be confused with no action since monitoring is required to ensure that MNR is working. The tape also explains that MNR is most effective in bodies of water that are relatively deep and slow moving. It is not recommended for use where local cultures subsist on fish or shellfish because it is generally a slow process. MNR may be recommended for some sensitive environments depending on the type of contaminant in the sediment. For instance, MNR may be suitable for certain wetlands when disturbing the sediment could cause irreversible damage to the ecosystem.

Monitoring of the ecosystem during MNR ensures that the conditions needed for MNR to take place haven't changed and that progress is being made towards cleanup goals. Testing may include water and sediment sampling, and tissue sampling of birds, fish, shellfish, and other bottom dwelling organisms.

The **advantages** of MNR are:
- No disturbances to the existing biological community
- No disturbances to the surrounding human community
- Relatively low cost (monitoring)
- No property needed for handling of removed sediment
- No offsite disposal or treatment sites are required

The **limitations** of MNR are:
- Recovery may be slower than that for active cleanup methods
- Long-term fish advisories may be needed
- Effectiveness is still unproven
- Long-term monitoring is needed
- Natural events, such as storms, may cause resuspension of contaminated sediment
- Human activities, such as boating or wading, may cause resuspension

KEY MESSAGES

Community input into the decision process is important and does make a difference

- Source control generally should be implemented to prevent recontamination.

- MNR is not a no action option; it requires careful monitoring to ensure that the conditions needed for effective MNR remain unchanged.

- Community input is important in a decision to use MNR, and EPA listens. At Lake Hartwell, for instance, EPA altered its cleanup plan in response to the community's preferences.

- MNR frequently includes multiple physical, biological, and chemical mechanisms that act together to reduce risk.

- Evaluation of MNR usually should be based on site-specific data collected over a number of years.

- Contingency measures should be included as part of an MNR remedy when there is significant uncertainty that the remedial action objectives will be achieved within the predicted time frame.

- Generally MNR should be used as one component of an overall site remedy, and cautiously as the sole risk reduction approach.

Institutional controls may be needed for a long time

General Site Conditions Especially Conducive to MNR

- Risk is low to moderate
- Anticipated land uses or new structures are not incompatible with natural recovery
- Natural recovery processes have a reasonable degree of certainty to continue at rates that will contain, destroy, or reduce the bioavailability or toxicity of contaminants within an acceptable time frame
- Expected human exposure is low and/or reasonably controlled by institutional controls
- Site includes sensitive, unique environments that could be irreversibly damaged by capping or dredging
- Sediment bed is reasonably stable and likely to remain so
- Sediment is resistant to resuspension, e.g., cohesive or well-armored sediment
- Contaminant concentrations in biota and in the biologically active zone of sediment are moving towards risk-based goals
- Contaminants readily biodegrade or transform to lower toxicity forms
- Contaminant concentrations are low and cover diffuse areas
- Contaminants have low ability to bioaccumulate

Case Study

The videotape describes a case involving Lake Hartwell, South Carolina. EPA initially proposed a relatively aggressive cleanup approach for the lake's 700 acres of PCB contaminated sediment. However, the local community and others heavily favored MNR, and EPA took this into account in the final choice of an MNR remedy. In this case, MNR depends on the natural burial of the contamination with some biodegradation of the heavier PCBs to less toxic lighter PCBs. Biosampling is performed once a year to determine if PCBs in the fauna are falling at an acceptable rate. Biosampling involves gill netting migratory fish, electroshocking shallow water fish, and harvesting shellfish in the lake's tributaries. Monitoring of both sediment and fish are on-going at this site. Results to date show improvement in surface sediment but eating fish remains a risk.

MNR by Burial or "Natural" Capping

When the contaminant of interest is essentially immobile (not soluble or subject to becoming soluble), and the main danger is direct contact or ingestion, then sequestering the sediment by burial is an acceptable remedy provided there is little chance of resuspension. The burial layer also has to be sufficiently thick that burrowing worms and other creatures will not contact the underlying contaminated layer.

Natural burial occurs when faster-flowing or more turbulent water that is carrying sediment slows down or becomes more quiet, causing the sediment to fall out. A good example of this phenomenon are river deltas, which are formed when the faster moving sediment laden river water encounters a lake or ocean. The Lake Hartwell example given in the videotape is interesting in that the same river that delivered the PCB contamination to the lake is the one now covering it with clean sediment. Burial generally occurs much more rapidly near the mouth of a river than downstream of the mouth where thinning can occur for some distance.

The burial layer must be sufficiently thick to prevent benthic organisms from reaching the underlying contaminated sediment

Biodegradation

Wiedemeier et al., explains that biodegradation of organic compounds occurs via three mechanisms:

Biodegradation of organic compounds can occur when microbes feed on the contaminants and convert them to less or non-toxic substances

- Use of the organic compound as the primary growth substrate
- Use of the organic compound as an electron acceptor
- Cometabolism

The first two biodegradation mechanisms involve the microbial transfer of electrons from electron donors (primary growth substrate) to electron acceptors. This process can occur under aerobic or anaerobic conditions.

The third biodegradation mechanism is cometabolism. During cometabolism the compound being degraded does not benefit the organism. Instead, degradation is brought about by a fortuitous reaction wherein an enzyme produced during an unrelated reaction degrades the organic compound.

Several issues need to be addressed when proposing an MNR remedy that relies primarily on bioremediation to reduce risk at a site. The first involves determining the rate of the biodegradation process. Biodegradation occurs very slowly if at all in the presence of pure chemicals, such as a pool of PCB contaminated oil. Generally the larger the molecule of a family of chemicals of concern, the slower the degradation rate. For instance, a 6-ring polynuclear aromatic hydrocarbon (PAH) degrades more slowly than a 2-ring PAH.

Biodegradation of organic compounds also can occur due to processes unrelated to a food source

A second concern is end point. Native bacteria may not be able to transform a contaminant to an innocuous end point. An example of this is the degradation of PCBs in the Lake Hartwell case history. More highly chlorinated biphenyls were degraded to less toxic, less chlorinated biphenyls, but these biphenyls were still toxic, and it is unlikely that they will degrade completely except over a very long time (biodegradation stopped with compounds containing 2-4 chlorine atoms). Hence in the case history, bioremediation alone would not have been acceptable. PCE and TCE are other examples of compounds that generally do not fully degrade. While a few bacteria can transform these compounds to non-toxic

Generally, the larger the molecule in a family of chemicals, the slower the degradation rate

ethene, they don't exist in all sediment environments. When they are not present, the likely outcome will be an accumulation of dichloroethene and very toxic vinyl chloride.

Some contaminants, such as PCBs, TCE, and PCE, generally do not fully biodegrade

Although most organic chemicals degrade, some do so under aerobic conditions while others are better suited to anaerobic conditions. For example, when the appropriate microbes are present to degrade TCE to ethene, they generally do so under reducing conditions. If the sediment suddenly becomes aerobic through resuspension, the biodegradation process for TCE largely stops. However, it will continue to degrade the degradation product, vinyl chloride, which is readily degraded under aerobic conditions.

Metals Sequestering

Metals cannot be degraded, they can only be made less bioavailable, and there are a number of ways this can happen. The least protective is the electrostatic attraction of metal cations to the negatively charged surfaces of mineral clays. Although attraction reduces the amount of the metals in solution, the metals may still be bioavailable to some flora and to fauna that inadvertently ingest sediment while foraging. The mix of available cations determines which metals preferentially attract to charged surfaces and which stay in solution. Hence a change in the mix of cations could release more hazardous metals than were originally predicted.

Metals do not degrade but can be made less bioavailable

Although the pH and redox condition of sediment can strongly influence precipitation of metal ions into compounds that are not soluble or generally bioavailable to flora, ingestion can still be a problem for fauna. Metal-specific, carbonate and phosphate compounds have relatively low solubilities. Also, metals bonded to iron or manganese oxides have very low solubilities. However, a change in pH or redox conditions within the sediment can make some metals more mobile and others less.

Charged surfaces can attract metals, rendering the metals less bioavailable

Metal ions can be complexed to organic or inorganic materials found in the sediment and in solution. Complexation involves surrounding a metal ion with one or more organic or inorganic compounds. Some of the more common materials that can complex with metals are hydroxides and humic and fulvic acids. Metals also can form bonds directly with humic substances found in sediment. The hydroxides and acids are soluble and are generally found both in the water column and soil pore water. The metals affiliate with humic acids in a variety of different ways that make them more or less bioavailable.

Organic and inorganic compounds can surround a metal ion, making it less bioavailable

It should be remembered that the fate and transport of metals in sediment is highly site specific and depends upon a multitude of factors, many of which may not be stable.

Common Community Concerns

- Long time required for recovery leading to extended loss of resources and uses
- Spreading of contamination due to resuspension caused by flooding or other disturbance
- Perception of a "do nothing" approach with doubts about its effectiveness
- On-going human and ecological exposure during recovery period
- Extended loss of resources and uses
- Environmental justice and other community concerns with leaving contaminants in place
- Diminished property values and real estate sales due to concerns with leaving contaminants in place

CAPPING

Caps reduce risk by isolating and stabilizing contaminated sediment

Capping

Another remediation option in some situations involves placing clean material over the contaminated sediment, which remains in place, in a process called capping. Caps are generally constructed of clean sediment, sand, or gravel. A more complex cap can include geotextiles, liners, and other permeable or impermeable materials in multiple layers. Caps may also include additions of organic carbon or other material to slow the movement of contaminants through the cap.

Depending on the contaminants and the environment, a cap may reduce risk in the following ways:

- By physically isolating the contaminated sediment from the overlying water
- By stabilizing the contaminated sediment and protecting it from erosion and transport to other areas
- By chemically isolating the contaminants or reducing their movement into the water body

Several capping techniques:

Typical capping techniques include conventional capping, armored capping, and composite capping

- Conventional capping places sand or other natural materials directly over the contaminated sediment area. The cap has to be at least as thick as the large populations of burrowing benthic organisms to keep them from becoming contaminated. Also, current velocity, availability of capping materials, and the type of contamination present determine cap thickness and the materials used. Typically, sand caps are used in low velocity waterways to protect them from scouring by strong (high energy) currents.
- Armored capping places an additional layer of stone or rip rap over a conventional cap to provide additional protection from high velocity currents.
- Composite capping places several layers of sand, rock, and geomembrane/textile over the contaminated sediment to further isolate it. Geomembranes can be employed when there is a concern that advection by upward groundwater gradients or diffusion will carry contamination up into the clean cap area. Geomembranes are, however, problematic if anaerobic gas is generated from the underlying sediment.

KEY MESSAGES

- Source control generally should be implemented to prevent recontamination.

- In-situ caps generally reduce risk primary through physical isolation, stabilization, and reduction of contaminant transport.

- Caps may be most suitable where water depth is adequate, slopes are moderate, groundwater flow gradients are low or contaminants are not mobile, substrates are capable of supporting a cap, and an adequate source of cap material is available.

- Evaluation of capping alternatives and the design of caps will consider buried infrastructure, such as water, sewer, electric and phone lines, and fuel pipelines.

- Substrate and depth alteration from capping will be evaluated for effects on aquatic biota.

- Evaluation of capping alternatives will include consideration of cap disruption from human and natural sources (e.g., 100-year flood, earthquake).

- Cap placement methods will be selected to minimize the resuspension of contaminated sediment and releases of dissolved contaminants from underlined sediment.

- Experienced contractors skilled in marine construction techniques will be used as they are very important to the placement of an effective cap.

- In-situ caps will be monitored during and after placement to evaluate long-term integrity of the cap, recovery of biota, evidence of recontamination, and maintenance needs.

General Site Conditions Appropriate for In-Situ Capping

- Suitable types and quantities of cap material are readily available
- Anticipated infrastructure needs (e.g., piers, pilings, buried cables) are compatible with the cap
- Water depth is adequate to accommodate the cap with anticipated uses (e.g., navigation, flood control)
- Incidence of cap-disrupting human behavior, such as large boat anchoring, is low or controllable
- Weight of the cap can be supported by the underlying sediment without slope failure
- Expected human exposure is substantial and not well-controlled by institutional controls
- Long-term risk reduction outweighs habitat disruption, and/or habitat improvements are provided by the cap
- Hydrodynamic conditions (e.g., floods, ice scour) are not likely to compromise the cap or can be accommodated in the cap design
- Rates of groundwater flow in the cap area are low and not likely to create unacceptable contaminant releases

- Sediment has sufficient strength to support the cap (e.g., has high density/low water content)
- Risk is moderate to high
- Contaminants have low rates of flux through the cap
- Contamination covers contiguous areas

Capping quickly lowers exposures to contaminants in sediment

The **advantages** of capping are:
- Capping quickly reduces exposure to contaminants with little disturbance to them (the process itself generally does not induce significant resuspension)
- Compared to sediment removal, less land and equipment are needed for material handling
- Compared to sediment removal, land is not needed for dewatering, water treatment, and sediment disposal
- Changes in bottom elevation caused by capping may create desirable habitat or improve bottom conditions for desirable species
- Implementation generally is quicker than for sediment removal and generally is less costly
- Cleanup goals (exposure reduction) are quickly reached

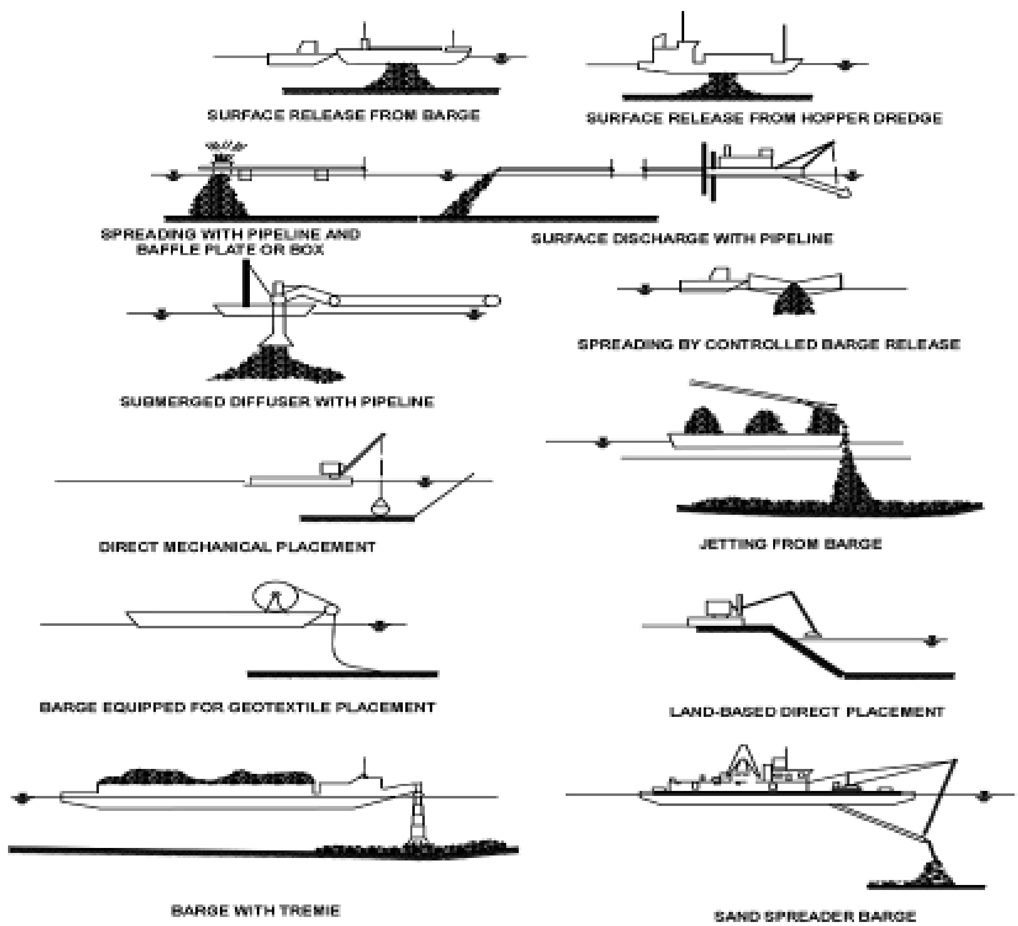
Caps may be disturbed by waves, ice, or large boat traffic

The **limitations** of capping are:
- Contaminants remain in place where they may be subject to disturbance if the cap is eroded by water or ice, or if contaminants move through the cap in significant amounts
- In some environments, it can be difficult to place caps without disturbing contaminants
- Caps cannot prevent exposure to contaminants already in the food chain, and fish consumption advisories may still be needed for a period of time
- In some environments, a preferred habitat may not be provided by the cap materials, especially when it is necessary to use erosion control materials on the cap surface
- Anchoring or draft restrictions may be necessary for commercial boat traffic
- Existing piers, bridges, and pipelines can limit cap placement

How Capping is Accomplished

When installing a granular cap, the major consideration is the accurate placement, density, and rate of application of the capping material. In general, the capping material should be placed so that it accumulates in a layer covering the contaminated material. Equipment and placement rates that cause the capping material to displace or mix with the contaminated sediment should be avoided. Exhibit 1 shows different placement techniques.

Exhibit 1. Sediment Capping Technologies



Source: U.S. EPA 1998d

Direct mechanical placement. If the area to be capped is nearshore and appropriate access is available, direct mechanical placement of capping material with land-based equipment may be considered. The reach of the equipment is the major limitation. The capping material would likely be trucked to the site with this method, so access for the trucks and traffic needs to be considered.

Caps can be installed using land-based equipment or from barges

Surface discharge from barges. The surface release of clean, mechanically-dredged capping material from barges results in a faster descent, tighter mound, and less water column dispersion than surface discharge of clean, hydraulically-dredged capping material from a pipeline. Surface release of hydraulically-dredged capping material from a hopper dredge has characteristics somewhat between barge and pipeline discharges. Surface discharge of material from barges or hopper dredges is not normally considered for in-situ capping unless special provisions are made for gradual release and spreading of the material over a large area. Point discharges from hopper dredges or barges normally are not applicable for in-situ capping of soft, fine-grained contaminated sediment.

Granular capping materials, such as sand, can be transported to a site in flat-topped barges and washed overboard with high-pressure hoses to form a cap layer of uniform thickness. This technique produces a gradual buildup of cap material, prevents any sudden discharge of a large volume of sand, and may be suitable for water depths as shallow as 10 feet or less.

When granular cap material is excavated by a hydraulic dredge or transported in a slurry form through a pipeline, spreading can be accomplished easily from the surface by an energy dissipating device, such as a baffle plate or sand box, attached to the end of the pipeline, similar to the effect of directing a low energy stream of hose water (to prevent splashing) against a building. Hydraulic placement is well-suited to distribute thin layers over large surface areas.

Spreading capping material from barges is difficult to control

Underwater spreading from barges. A layer of capping material can be spread or gradually increased in depth using bottom-dump barges if provisions are made for controlling the opening and movement of the barges. This can be accomplished by slowly opening a conventional split-hull barge over a 30- to 60-minute interval, depending on the size of the barge. Such techniques have been successfully used for controlled placement of predominantly coarse-grained, sandy capping material.

Submerged diffuser. A submerged diffuser can be used to provide additional control for submerged pipeline discharge. The diffuser consists of conical and radial sections joined to form the diffuser assembly, which is mounted to the end of the discharge pipeline. A small discharge barge is required to position the diffuser and pipeline vertically in the water column. By positioning the diffuser several feet above the bottom, the discharge is isolated from the upper water column. The diffuser design allows material to be radially discharged parallel to the bottom and at a reduced velocity. Movement of the discharge barge serves to spread the discharge to larger cap areas.

(Source USEPA, 1998a, http://www.epa.gov/glnpo/sediment/iscmain/four.html#General%20Considerationspp)

Recontamination Issues

Recontamination of previously-remediated sediment is an issue with any sediment remedy. The most common causes of recontamination are additional deposition of contaminated sediment from source areas either on land or upstream of the remediated area, and re-distributuion of low level contaminated sediment that was outside of actively remediated areas. Additional, potential causes of recontamination of in-situ caps include the release of contaminants during cap placement due to compression, movement of contaminants through the cap due to ground water advection or long-term diffusion, and physical failure of the cap due to erosion or ice scour.

Caps can fail if they are too heavy for the underlying sediment, groundwater contaminants seep up into the cap, contaminants migrate through the cap, or the cap is physically damaged

During the initial placement of the cap materials, the weight of the material will cause some compression of the underlying contaminated sediment. Clayey sediment compresses more than sandy sediment because wet, clayey sediment has a much lower shear strength than wet sandy sediment. Compression squeezes contaminated pore water out of the underlying sediment and into the clean cap material, which increases the potential, or decreases the time, when contaminant breakthrough of the cap surface will occur.

A second recontamination mechanism is groundwater advection. In gaining water bodies, groundwater advection rates to the surface water can range from negligible to very high. Advection creates a flushing effect for the soluble fraction of contaminants in the sediment pore water, carrying them up through the clean cap materials and potentially into the surface water. Cap designers can partially address this issue by including fines and organic matter in the capping materials or by using a semi-impermeable geomembrane material. The geomembrane material may not be an option if the underlying sediment is strongly anaerobic and is producing hydrogen sulfide or methane gases.

A more long-term issue is diffusion. Chemicals dissolved in the contaminated pore water, which has relatively high concentrations of contaminants, will tend to move to an area of relatively low concentrations of contaminants, such as those in the cap pore water. How important this mechanism is depends on the toxicity of the contaminant, its solubility, and its affinity for clays and naturally occurring soil organic matter. While diffusion does occur, the thing to remember is that it does not necessarily transfer at rates that pose a risk to biota in the cap bioturbation area.

A final cause of recontamination is physical disturbance of the cap. This can occur by erosional scouring if the cap is subjected to high energy water currents, such as those that occur during large storms, or by turbulence created by ships and other vessels (propeller action and bow wave). Other human actions, such as shellfish harvesting, can disturb the cap if institutional controls are not observed.

Common Community Concerns

- Increased truck or rail traffic
- Cap material source area issues (it has to come from some place)
- Loss of privacy during construction
- Loss of resource and harvesting rights (no disturbance of the cap even after flora and fauna reclaim the area)

- Navigational limitations (shallower water and capped area cannot be dredged)
- Loss of access to boat anchoring areas
- Access to buried utilities
- Increased flooding potential
- Recreation and tourism impacts
- Concern about diminished property values and real estate sales potential when contaminants are left in place
- Disturbance of aquatic habitat (with exception of MNR this will be true of all the remedies)
- Cap erosion or disruption
- Contaminant migration through the cap
- Environmental justice and other community concerns associated with leaving contaminants in place

Environmental Dredging

Environmental dredging removes contaminated sediment from a water body without draining or diverting the water. Dredges remove a certain amount of water with the sediment. The sediments are usually dewatered on land, and the water is usually treated before discharge back to the water body or public treatment works. The contaminated sediment is then disposed of in a landfill or a confined disposal facility. Highly contaminated sediment may be treated, most often by stabilization, before disposal. Unlike navigational dredging, which stresses the quick removal of relatively clean sediment, environmental dredging is more precise with greater emphasis on controlling the resuspension of contaminated sediment. The tape discusses mechanical, hydraulic, and hybrid dredges, which are addressed in separate sections below.

Contaminated sediment may be removed by mechanical, hydraulic, or hybrid dredging

To protect against resuspension during dredging, the contaminated sediment area can be enclosed with silt curtains that extend to the bottom. These curtains have floatation devices at the surface and anchors at the bottom to ensure they hug the sediment floor. They are best deployed in low current environments. Real time monitoring for increased turbidity is used as an early warning sign that sediment may be resuspending.

For both mechanical and hydraulic dredging, a dewatering step is necessary to reduce the volume of material that needs to be taken to a treatment or disposal site. The water that is removed from the sediment generally requires treatment before it is returned to the surface water body. Because hydraulic dredging operates on the principle of transporting the contaminated sediment to the shore as a slurry, it produces a much larger volume of water requiring treatment. For quality control and safety, the water outside the working area is monitored and analyzed to ensure that contaminated sediment is not escaping.

Hydraulic dredging produces more water that has to be treated than mechanical or hybrid dredging procedures

KEY MESSAGES

- Source control generally should be implemented to prevent recontamination.
- Dredging or excavation alternatives have many phases, including sediment removal, staging, de-watering, water treatment, sediment transport, and sediment treatment, reuse, or disposal, that need to be discussed with stakeholders.
- Transport and disposal options can be complex and controversial; investigate options early and discuss them with stakeholders.
- In predicting the risk reduction affects of dredging or excavation of deeply buried contaminants, remember that current risk, and therefore current biota exposure, is only related to contaminants that are bioaccessible.

Dredging is often more costly than MNR or capping

- Environmental dredging should minimize resuspension of sediment and transport of contaminants.

- Monitoring will occur during dredging or excavation implementation to assess resuspension and transport of contaminants, immediately after implementation to assess residuals, and after implementation to measure long-term recovery of biota and to test for recontamination.

General Site Conditions Especially Conducive to Dredging or Excavation

- Risk is high
- Suitable disposal sites are available and nearby
- Suitable area is available for staging and handling of dredged material
- Existing shoreline areas and infrastructure (e.g., piers, pilings, buried cables) can accommodate dredging or excavation needs
- Water depth is adequate to accommodate a dredge but not so great as to be infeasible
- Expected human exposure is substantial and not well-controlled by institutional controls
- Long-term risk reduction of sediment removal outweighs sediment disturbance and habitat disruption
- Water diversion is practical, or current velocity is low or can be minimized, to reduce resuspension and downstream transport during dredging
- Contaminated sediment is underlain by clean sediment (so that over-dredging is feasible)
- Sediment contains a low incidence of debris (e.g., logs, boulders, scrap material) or is amenable to effective debris removal prior to dredging
- High contaminant concentrations cover discrete areas

Residual and Recontamination Issues

Regardless of the efficiency of the dredging process, some residual contamination will remain in the dredged area. The extent of that residual contamination is dependent both on the physical environment and the dredging operation itself. Some of the most important factors include:

- Type and size of dredging equipment
- Extent of controls on dispersion of resuspended sediment (e.g., silt curtains, sheet piling)
- Contaminant concentrations inside and outside the area to be dredged
- Characteristics of the underlying clean sediment or bedrock (e.g., whether over-dredging is feasible)

- Extent of debris, obstructions, or confined operating area, which may limit effectiveness of dredge operation
- Skill of operators

Residual contamination is likely to be greater in the presence of boulders, cobbles, or buried debris and when the contaminated sediment lies directly over bedrock.

Recontamination of previously-remediated sediment is an issue with any sediment remedy. The most common causes of recontamination are additional deposition of contaminated sediment from source areas either on land or upstream of the remediated area, and re-distributuion of low level contaminated sediment that was outside of actively remediated areas.

The biggest advantage of dredging is the removal of the bulk of the contamination

The **advantages** of environmental dredging are:
- If it achieves cleanup levels, dredging may result in the least uncertainty about long-term effectiveness of the cleanup
- Dredging can be used in relatively high energy environments
- Dredging removes the bulk of the contaminated sediment
- Following cleanup, use of the waterway (recreational and other) is generally less restricted than with other methods
- If residual contamination is low, dredging may result in faster achievement of cleanup goals than MNR

The **limitations** of environmental dredging are:
- Dredging is generally more complex and costly than other remedies
- More land is needed for staging, treatment, and disposal
- Some contaminant resuspension and short-term impact on the ecosystem is inevitable
- Disposal sites for the contaminated sediment may be difficult or expensive to locate
- Extent of residual contamination is often highly uncertain

Dredging is often more costly than MNR or capping

Key Components to Consider when Implementing a Dredging Cleanup

Sediment removal. The depth of the water, type of sediment, and presence of shallow bedrock or debris need to be determined to select the best equipment for the conditions.

Sediment transport. Getting the contaminated sediment to the shore usually depends on the type of dredge chosen and may involve a hopper barge or slurry pipe. Once onshore, the sediment has to be transported to a treatment or disposal area.

Contaminated water and sometimes sediment may be treated onsite

Staging (temporary storage). Because treatment or disposal capacity rarely matches the sediment volume generated by dredging, temporary storage or staging areas are usually needed. These areas can be controversial because of the potential for runoff during precipitation events; loss of sediment into the air (called particulate air entrainment), which occurs when the surface dries out before the sediment is treated; and volatilization of organic contaminants into the air. You should be prepared to explain the actions you would take to prevent these from happening.

Treatment. Regardless of whether the sediment is treated to reduce or eliminate the contaminants or disposed of in an appropriate landfill, it probably will require some form of dewatering, especially when hydraulic dredges are used. The pore water that is drained from the sediment will likely be contaminated and require treatment, which can sometimes be done onsite. Depending upon the contaminants present, treating contaminated sediment may require several processes or a treatment train.

Disposal. Water from dredging operations can be treated onsite and returned to the water body, pumped into the sewer for treatment at a local sewage plant (POTW), or shipped offsite for treatment and disposal depending on the type and concentration of contaminants in the water. Contaminated sediment that has been dewatered is often separated by grain size to isolate the most contaminated sediment and then disposed of in an appropriate landfill (i.e., for hazardous or non-hazardous waste). It may also be disposed of in a near-shore confined disposal facility constructed specially for the cleanup project. If the sediment can be treated to a sufficiently low level of contamination, it may be reused.

COMMON COMMUNITY CONCERNS

- Increased truck or rail traffic
- Noise, emissions, and lights at treatment and disposal facilities
- Siting of new disposal facilities
- Property values near dredging, treatment, and disposal facilities
- Infrastructure needs on adjacent land
- Loss of capacity at existing disposal facilities
- Loss of privacy during construction
- Access to private property
- Recreation and tourism impacts
- Environmental justice and other community concerns with disruption
- Disturbance of aquatic habitat
- Resuspension and spreading of contamination
- Concerns about how much contamination will be left
- Cost and impact on local employment when local industries are paying for the remediation

Mechanical Dredging

Mechanical dredging works well in hard packed sediment, in areas with limited access, and in areas where the sediment is mixed with debris, such as tree limbs, used tires, and building rubble. In environments where resuspension is a problem, a bucket designed specifically for environmental dredging may be helpful. These buckets have an overlapping sealed clam shell to scoop up the contaminated sediment and trap it during the ascent. The bucket boom can be fitted with video cameras, sonar, and a global positioning system to enhance precision and provide sediment resuspension monitoring capability. The open bucket can be positioned by computer to provide precision for the cut. These specially designed buckets can make a precise horizontal cut. A venting system that usually flaps open to water pressure allows water to pass through the bucket during the descent, thus minimizing the bow wave and disturbance to the sediment prior to collection. The bucket is paused just at the surface to allow water that is trapped over the sediment to drain. The sediment generally is delivered to a hopper barge. The empty bucket, which has contaminated sediment attached to it, is rinsed in a hopper of clean water after which it is ready for lowering to the next target area.

Where resuspension is a problem, mechanical dredging with specially designed buckets may be useful

KEY MESSAGES

- Mechanical dredging itself and constant monitoring of the operation can result in very little contaminated sediment resuspension.

- Mechanical dredging minimizes the amount of water that requires treatment.

Technical Issues Involving Mechanical Dredging

Mechanical dredges remove sediment with nearly the same solids content as they have in-situ (in place at the bottom of the water body). By not adding water to the sediment as part the removal process, less treatment costs are incurred because the only water that requires treatment is the pore water.

Unlike conventional dredging, environmental dredging allows more control

Bucket dredges penetrate the sediment bed by being dropped on it. The depth of penetration depends on the weight of the bucket and the stiffness of the bottom. Hence, it is not easy to control the depth of the grab. Conventional bucket dredges take "bites" out of the sediment, while the environmental clamshell bucket, as shown in the videotape, produces a horizontal cut that is less prone to over dredging (collecting clean sediment with the contaminated sediment, which occurs by "biting" the area in question too deeply), thus saving the cost of removing sediment that does not need to be removed. However, a certain amount of over-dredging is usually desirable and is an important part of minimizing residual contamination.

High currents, choppy water, and deep water affect the precision of the dredging operation

The videotape shows the mechanical dredge operating in relatively quiet water. The ability to control precisely where the sediment is grabbed decreases in high currents, choppy water, and increased water depth. There are several reasons why precision of grab is stressed in the video:

- To ensure that all of the known contaminated area is retrieved both laterally and vertically; and
- To avoid an excessive amount of over dredging, which results in an increased volume of sediment that needs to be handled and treated.

Hydraulic Dredging

Hydraulic dredging has the ability to deliver contaminated sediment directly to an onshore disposal or treatment area. However, its use is limited in open, rough waters, and the delivery pipeline, which is generally on the surface of the water, can be an obstruction to ships and recreational boats.

Hydraulic dredging can deliver sediment directly to an onshore dewatering and disposal or treatment area

A hydraulic cutter head has been described as a large vacuum cleaner. The cutter loosens the sediment and a pump sucks it into a delivery pipe. The swing and cut angles are monitored at all times. Sonar, GPS, and video cameras can be attached to the cutter head to monitor progress and identify problems.

The sediment is pumped to an onshore area for dewatering and disposal or treatment. The water is treated and/or tested before being returned to the waterbody.

KEY MESSAGES

- Dredging can be accomplished in a safe manner and can be designed to minimize disturbance to local community activities.
- Hydraulic dredging is generally more expensive than mechanical dredging because it produces more contaminated material that must be handled and treated.

Hydraulic dredging is generally more expensive than mechanical dredging

Case Study

A demonstration project using a hydraulic dredge took place on three acres (Deposit N Site) of a 39-mile long region of PCB contaminated sediment in the Fox River of Wisconsin. The demonstration was successful even though the sediment particle size was fine, the water velocity relatively high, and the bedrock shallow, all of which can present problems. For instance, fine sediment can easily resuspend. High water velocity can make capturing the sediment difficult, and shallow bedrock affects the ability of the cutter head to disturb the sediment sufficiently to capture it.

The stated goal of the Fox River project was to determine whether this type of dredge can be applied successfully in an urban environment while protecting the air, water, land, and neighborhoods. Air and water samples were taken to demonstrate that only very low levels were escaping from the site during the cleanup.

Note: Although the resuspension and air data were good and significant buried contaminants were removed, the project only reduced surface sediment concentrations by 12%. As a result, the fish won't improve much, which was the main risk to people and wildlife at the Fox.

Several different dredgehead designs are available for loosening the sediment

Sediment shields, gas collection systems, underwater cameras, and bottom sensors can be used to reduce resuspension and volatilization of the sediment during dredging

Technical Issues Involving Hydraulic Dredging

Several hydraulic dredgehead designs exist. The basket cutterhead, which was shown in the videotape, is one of the most common. Other designs include the horizontal auger and suction, which generally employs high pressure water jets to loosen the sediment. Like mechanical dredges some specialty designs have been built specifically for the environmental market with an emphasis on minimizing resuspension of sediment. Examples include the modified dust pan, horizontal profiling grab, Eddy pump, and matchbox.

A conventional cutterhead dredge is operated by swinging the head in a zig-zag pattern of arcs across the bottom. If care is not taken, this can leave windrows of contaminated sediment. Cutterhead dredges can be operated to reduce resuspension or losses of volatile contaminants using additional equipment, such as sediment shields and gas collection systems accompanied by water cameras and bottom sensors.

Most, but not all, hydraulic dredges have limited applicability in debris laden bottoms, near piers and other man-made structures, and when thin sediment overlays bedrock.

Hybrid Dredging

Hybrid systems use a sealed clam shell dredge to collect sediment, which is placed in an on-board container equipped with a pump that moves the sediment through a pipeline to an onshore treatment station. Like the other two dredging technologies hybrids can be equipped with sonar, GPS, and videocameras to enhance placement and safety.

Hybrid dredging combines a clam shell dredge and a pump to move the sediment to shore in a pipeline

The use of a clamshell or bucket to excavate the sediment preserves the sediment's natural water content. This preservation greatly reduces the volume of materials needing treatment as compared with hydraulic dredging. The use of pumps to directly transport the contaminated sediment to the shore is more efficient than traditional clamshell operations that generally use hopper barges.

KEY MESSAGES

- Hybrid dredges can deliver contaminated sediment directly to a treatment station on shore while preserving a high solids content, which minimizes the cost of treating the materials.

Unlike hydraulic dredging, hybrid dredges can preserve the sediment's natural water content while minimizing the volume of materials that need treatment

Case Study

The case study presented in the videotape took place in a section of the New Bedford, Massachusetts, harbor where PCBs had contaminated the sediment. The purpose was to clear an area for the construction of dewatering cells. After the cells are built, a hybrid dredge will be used to remediate the approximately 450,000 yd^3 of contaminated sediment. Although the project deployed a silt curtain, it was found to be ineffective because of wave action and tidal affects.

Technical Issues Involving Hybrid Dredging

The delivery pipeline, which is generally on the surface of the water, can be an obstruction to shipping and recreational boating.

The pipeline used to deliver the sediment to the shore may be a hazard for shipping

Fugitive emissions (contaminants released into the air from the sediment) generally are less than those encountered in pure mechanical dredging operations, but are more than those released during hydraulic dredging.

EXCAVATION

EXCAVATION

Excavation usually involves removing or diverting water to allow excavation equipment direct access to the sediment

Excavation of contaminated sediment involves pumping or diverting water from the area, and using traditional earth moving equipment (e.g., backhoe, front shovel) to remove sediment. Similar to dredging, the removed sediment is then dewatered and transported to a treatment or disposal area. In some environments, excavation may be possible without water diversion, such as from wetlands during dry seasons or while the sediment and water are frozen. Typically, excavation is used in streams, shallow rivers and ponds, or near shorelines. The contaminated sediment can be isolated by a cofferdam constructed of sheet pile wall or by some form of diversion. Temporarily removing the water over the contaminated sediment area allows direct access by excavation equipment and transport trucks to the sediment.

KEY MESSAGES

- Excavation allows for direct visual observation of the sediment removal process and in some cases can achieve lower cleanup levels than dredging.

CASE STUDY

The case study in the videotape shows the removal of a hotspot of 25,000 yd^3 of DDT-contaminated sediment from the Pine River in Michigan. For nearly 25 years, the state has had a "no fish consumption" advisory on over 33 miles of the river. During removal of the hotspot, a temporary cofferdam made of sheet piling was constructed to allow dewatering of the sediment. A drying agent was added to improve the handling qualities of the sediment. The extracted sediment was trucked to a staging area for subsequent transport to a disposal facility. Because of the proximity to housing, an irrigation system was installed at the perimeter of the contaminated area to control dust. As a further precaution, air and water monitoring was conducted to ensure that the community was protected and the cleanup criteria were met. Additional work in other areas of the Pine River are on-going.

TECHNICAL ISSUES INVOLVING EXCAVATION

The ability and cost of hydraulically isolating the contaminated area are key factors in choosing excavation

Excavation of contaminated sediment generally involves isolating the sediment from the overlying water. Isolation can be accomplished by permanently relocating the waterbody or temporarily re-routing the waterbody using pipes, dams, or sheet piling.

Permanent relocation. This is generally performed only on small streams and creeks and involves physically diverting the water so that it preferentially flows through a prepared channel. After remediation is complete, the stream or creek will continue to flow in the new channel.

Temporary re-routing of the waterbody using dams or pipes. The use of dams is similar to permanent relocation since the dam diverts the water flow through a different channel. However, unlike the permanent solution, when the dam is removed the water is allowed to resume flowing in its old channel. For small streams and creeks, it is possible to divert their entire flow into a large diameter pipe that by-passes the contaminated area. When the area is cleaned up, the pipe is removed and the water returns to its natural channel.

Earthen dams. Earthen dams can be employed in very shallow water to temporarily divert water away from the area to be remediated.

Sheet piling. Sheet piling involves driving interlocking metal sheets into the sediment using percussion or vibration methods. While this method can have some depth limitations, it is applicable beyond just very shallow waters. Depending on the waterbody, the wall can temporarily divert the water from the remediation area (e.g., to allow excavation of one side of a river at a time) or completely surround the contaminated area. Sheet piling is generally not an option if the bedrock is shallow or the subsurface contains gravel or cobbles.

If groundwater or surface water from surrounding areas flows into the excavation area, some form of on-going dewatering system is needed to allow equipment access.

The cost and ability to hydraulically isolate the contaminated area are key factors in choosing this technology.

WHAT THE COMMUNITY CAN DO

What the Community Can Do

One of EPA's eleven principles for managing risk of contaminated sediment is to involve the community early and often. This is an important principle in relation to other stakeholders as well, including local governments, port authorities, and potentially responsible parties. The mission of the Superfund and RCRA community involvement programs is to advocate and strengthen early and meaningful community participation during cleanups.

Communication and outreach with the Agency and other stakeholders can pose unique challenges at sediment sites, especially at large sites on publically-used water bodies. Stakeholders should be aware that sediment sites that span large areas may present barriers to effective communication among different communities, local governments, and the private sector along the water body. People who live, work, and play adjacent to water bodies that contain contaminated sediment should seek accurate information about the safety of their activities, and opportunities for involvement in EPA's decision-making process for sediment cleanup.

EPA encourages communities to get involved and express their cleanup technology preferences

Encourage community stakeholders to ask questions so that they understand what the issues are and what cleanup options are available to address them. Evaluate whether several cleanup methods might be better than one. For example, MNR may be good for one part of the waterway, while hydraulic dredging of a hotspot may be better for another part.

Through the Technical Assistance Grant (TAG) Program, EPA will fund independent technical assistance for the community. The Superfund statute provides for only one TAG per site. At very large sites with diverse community interests, communities may choose to form a coalition and apply for grant funding as one entity. The coalition would need to function as a nonprofit corporation for the purpose of participating in decision making at the site. Individual organizations may choose to appoint representatives to a steering committee that decides how TAG funds should be allocated, and defines the statement of work for the grant. The coalition group may hire a grant administrator to process reimbursement requests to the EPA and to ensure consistent management of the grant. In some cases, EPA regional office award officials may waive the $50,000 per-site grant limit if site characteristics indicate additional funds are necessary due to the nature or volume of site-related information.

Information on the EPA community relations programs can be found at http://www.epa.gov/superfund/action/community/index.htm for Superfund and at http://www.epa.gov/epaoswer/hazwaste/ca/guidance.htm for RCRA.

KEY MESSAGES

- Get involved.
- EPA and state regulatory agencies need public input to make the right decision for the community.
- Results often don't appear overnight.
- In many cases, more than one cleanup method will be needed.
- What may work in one situation may not work in another.

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Glossary of Technical Terms in EPA's Contaminated Sediments: Impacts and Solutions Videotape

Advection	The horizontal or vertical flow of groundwater. Advection is the principal transport mechanism of contaminants through sediment.
Anthropogenic	Having to do with human activities.
Aerobic	The state of being oxygen rich.
Anaerobic	The state of being oxygen depleted.
Baseline risk assessment	An analysis of the potential adverse affects (current or future) caused by hazardous substances at a site in the absence of any actions to control or mitigate these releases (under the assumption of no action). The results of the baseline risk assessment are used to: • help determine whether additional response action is needed, • modify preliminary cleanup goals, and • document the magnitude of risk at a site and the primary causes of risk.
Benthic Organism	Any animal, plant, or bacteria that lives in or on the bottom of a surface water body.
Biomagnification	The increased accumulation and concentration of a contaminant at higher levels of the food chain; organisms higher on the food chain will have larger amounts of contaminants than those lower on the food chain because the contaminants are not eliminated or broken down into other chemicals within the organisms.
Bioturbation	The disturbance of sediment layers by biological activity, such as burrowing worms.

Bow wave

Water that is displaced as a mechanical dredge moves downward. In environmental dredging, an effort is made to minimize the wave strength to avoid resuspending contaminated sediment before it can be captured by the dredge.

Calcium carbonate

A natural occurring mineral ($CaCO_3$) that is also known as calcite or limestone. Carbonates can play a role in metal mobility since many of the metal carbonates are sparingly soluble.

Cofferdam

A water tight enclosure from which water is pumped to allow excavation or construction within its confines.

Cation

An atom or molecule that has lost one or more electrons and is left with a positive charge.

Cometabolism

A bioremediation process during which the bacteria use a primary chemical to obtain energy (feeding) while an adjacent, secondary contaminant chemical is transformed. The bacteria do not derive energy from the transformation of the secondary contaminant, which was not the deliberate target of the bacteria.

Complexation

With metals, complexation involves a centrally located metal ion in solution surrounded by one or more organic or inorganic compounds.

Congener

A member of the same kind, class, or group of chemicals. PCBs have 209 congeners that consist of the same biphenyl core that gives them similar characteristics but have 209 different ways to place chlorine atoms on it.

DDT

Dichlorodiphenyltrichloroethane. A persistent, bioaccumulating insecticide, the use of which is banned in the United States. DDT is a suspect carcinogen and exposure to it may cause tremors, excitability, and seizures (http://www.atsdr.cdc.gov/tfacts35.html).

Diffusion The process by which chemicals in a matrix (water, soil, air) move from a higher concentration area to a lower concentration area.

Effective porosity The percentage of pore volume that contributes to percolation.

Electroshocking In ecology, the practice of applying an electric current to a body of water that stuns fish and makes them float on the surface where they can be counted, examined, or caught.

Food chain The scheme of feeding relationships between plants and animals in a biological community.

Fulvic acid The colorless fraction of humic matter that is soluble across all pH ranges (acid through base). It has a lower molecular weight than humic acid and more hydrophyllic functional groups.

Geomembrane A plastic like material (like disposable plastic garbage bags only thicker) that is sold in large sheets that can be glued together to form a low permeability barrier against contaminant movement.

Hardpan A hard layer of soil or sediment often just below the surface that is produced by cementation of the sediment particles by relatively insoluble materials.

Humic acid A complex group of organic acids derived from the decay of organic (plant and animal) matter. They are the materials that make some surface waters look brownish.

Hydraulic conductivity The rate with which water can move through a permeable medium, such as sand or sediment.

Hydrogen bonding A weak electrostatic bond formed between a hydrogen atom on one molecule and a strongly negatively charged surface or atom of another molecule.

Iron oxide	Ferric oxide (Fe_2O_3) is important in sediment water chemistry as it can provide a substrate for the adsorption of metal from the water.
Methanogenesis	The creation by anaerobic bacteria of methane (CH_4) from organic debris and other organic compounds.
PCB	Polychlorinated biphenyl. Two benzene rings joined by a carbon bond with varying amounts of substituted chlorine atoms ranging from 1 to 10. Exposure to PCBs include acne-like skin conditions in adults and neurobehavioral and immunological changes in children. PCBs are known to cause cancer in animals.
Persistent pesticide	A pesticide that does not or only slowly degrades through biological or abiotic action.
Point source	Any discernible, confined, and discrete conveyance, including but not limited to, any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, landfill, leachate collection system, vessel or other floating craft from which pollutants are or may be discharged.
Polynuclear aromatics	Organic compounds that contain two or more fused benzene rings.
Pore water	Water contained in the void spaces (pores) of soil or sediment, also known as interstitial water.
Pyrites	Any of various metallic looking sulfides of which iron sulfide (FeS_2) is the most common.
Receptor	A living organism that is in a position to be exposed to a contaminant.

Redox	The redox potential is a measure (in volts) of the affinity of a substance for electrons – its electronegativity – compared with hydrogen (which is set at 0). In sediment it is used to estimate how aerobic or anaerobic the sediment is.
Reducing conditions	In ecology, chemical conditions favoring the acceptance of electrons by atoms or molecules. Soil or water that are depleted of oxygen have reducing conditions.
Rip rap	Stones ranging in size from 4 inches to 24 inches in diameter that are used for erosion control.
Runoff	Sheet flow water that moves under force of gravity from higher to lower areas. Runoff can come from hillsides or fields after a rainfall or snow melt. Urban areas collect their pollutant laden runoff into storm drains that are often channeled to surface water bodies.
Shear strength	The maximum stress a material can withstand before rupture.
Superfund	This is the common term for the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980 and its subsequent amendments. It is the law that can compel the cleanup of uncontrolled hazardous waste sites.
Trophic level	In ecology, the trophic level is the position that an organism occupies in a food chain – what it eats, and what eats it.
Van der Waals bonding	A relatively weak attractive force between two atoms or nonpolar molecules.