D-106, in: A.K. Bullard, D.T. Dahlen (Chairs), *Remediation and Management of Contaminated Sediments—2015.* Eighth International Conference on Remediation and Management of Contaminated Sediments (New Orleans, LA; Jan 12–15, 2015). ISBN 978-0-9819730-9-8, ©2015 Battelle Memorial Institute, Columbus, OH. **www.battelle.org/sedimentscon**

Analysis of Recontamination Following Completion of Sediment Remediation Projects: An Update

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ABSTRACT: Numerous sediment remediation projects completed over the past 10 to 20 years have become recontaminated after remedial construction. These findings underscore the importance of the strong directive in U.S. EPA's contaminated sediment strategy and guidance to confirm that sources have been controlled prior to embarking on dredging or other sediment management alternatives.

The 2007 survey by Mel Skaggs and Steven Nadeau identified approximately 20 remediated contaminated sediment sites in which the sediment became recontaminated. Six additional remediated contaminated sediment sites have now been identified, and this paper updates the status of these sites. The identified sediment recontamination sites occurred in widely varying geomorphic and geographical settings. The sites included freshwater as well as estuarine locations, and did not appear to exhibit geographical centralization. The initial remedial responses at these sites included dredging, subaqueous capping, and combined remedies employing both of these remedial responses.

The factors behind the sites' respective recontamination were site-specific, but some common features appear to exist. Among these sites, the most frequent cause of recontamination was found to be uncontrolled point sources. Runoff sources, sediment sources, and other processes were also identified as having contributed to the recontamination at these sites. Understanding the controls needed for these potential recontamination pathways continue to present challenges in building the sediment site's conceptual site model (CSM). Watershed approaches are often necessary to get these sources integrated into the CSM. This need underscores the critical importance of integrating the authorities of CERCLA, WRDA, CWA, state authorities, etc.

INTRODUCTION

In its Contaminated Sediment Management Strategy (1998), the U.S. EPA stated that "before initiating any remediation, active or natural, it is important that point and non-point sources of contamination be identified and controlled." Likewise, the Principles for Managing Contaminated Sediment Risks at Hazardous Waste Sites (U.S. EPA 2002) restated this concern but with more specificity. First among these principles was "Control Sources Early." Finally, U.S. EPA's once again reiterated the importance of evaluating and avoiding sediment site recontamination in its Contaminated Sediment Remediation Guidance for Hazardous Waste Sites (U.S. EPA 2005). Site managers were advised to factor the potential for recontamination into the remedy selection process through steps such as the inclusion of source control measures.

Nadeau (2007) reported the results of a survey of completed contaminated sediment remedial actions. Nineteen sites were identified at that time as having become recontaminated since completion of the remedial action. Point Sources were identified as the source of the recontamination at 50% of the twenty sites reviewed. Runoff Sources and Sediment Sources each contributed recontamination at about 40% of the sites.

Since 2007, most of these sites have undergone additional study to better understand the source(s) of recontamination. Additionally, a number of these sites have implemented additional source controls and/or have undergone additional remediation. These additional studies allow some of the 2007 analyses of these recontamination sources to be recategorized.

In the current study, the status of the sites originally reported in 2007 has been updated. An additional six sediment recontamination sites have been identified and are added to the analyses performed on the earlier reported sites. These six sites included five freshwater and one estuarine locations. Five of the six sites involved sediment removal actions, and one employed the placement of a sand cap.

Thinking has advanced considerably since 2007 on the challenges involved in avoiding recontamination of the sites being proposed for sediment remediation. Recent practice reflects a deepened conviction to avoid the recontamination problem by constructing better conceptual site models (CSMs) and incorporating necessary source controls. The CSM informs the project team of the data needed for later remedial decision making. This means the data needed to incorporate source controls will be available before the remedy is selected and certainly before it is implemented.

This deepened conviction to avoid the recontamination problem has given rise to several useful guidance documents and papers. Some of these recent references providing helpful information on avoiding sediment site recontamination are discussed below.

ASTSWMO (2013). In 2013, the Association of State and Territorial Solid Waste Management Officials (ASTSWMO) produced a study entitled "Sediment Remedy Effectiveness and Recontamination: Selected Case Studies." (2013) ASTSWMO found the reasons for the various sites' recontamination to have been site-specific and variable. More than one type of source contributed to the recontamination of some sites reviewed. The reasons for recontamination reportedly included surface runoff, seepage of site contaminants through the capping material, bank storage of contaminants, resuspension or disturbance of contaminated sediment during capping or dredging, slumping/erosion of contaminated sediment in undredged areas beneath docks and pilings, dredge residuals, and contaminated storm sewers.

ASTSWMO concluded that every effort should be made early in the sediment remedial process to identify other potential sources, and that "a coordinated or regionalized remedial strategy across governmental and private entities may be worthwhile to ensure the overall success of the sediment remedy."

ITRC (2014). The Interstate Technology Regulatory Council (ITRC) recently issued a guidance document entitled "Contaminated Sediments Remediation – Remedy Selection for Contaminated Sediments." (2014) ITRC's Guidance enumerated twelve contaminant sources with the potential to cause recontamination after remediation:

- Discharge from point sources such as industrial facility outfalls

- Discharge from a POTW and CSOs
- Private and public stormwater discharges (including sheet flow runoff)
- Discharge of nonaqueous phase liquid (NAPL) from sediment
- Overland flow from an upland (upgradient) source
- Soil erosion where contaminants are present in the stream bank, riverbank or floodplain soils
- Sediment transport from other sediment sources in the watershed
- Contaminated groundwater discharge (such as dissolved phase and NAPL release)
- Air deposition of contaminants (such as mercury from fossil fuel power plants and PAHs from particulate matter from heavily burdened traffic areas such as highways, airports, or ports)
- Nonpoint source and watershed-wide sources of contamination
- Over-water activities (such as fuel and product spills and ship maintenance and repair) or other incidents which release contaminants to the water body
- Naturally occurring sources (such as inputs of metals or other inorganics from natural watershed sources)

The ITRC guidance emphasizes the iterative development of a complete CSM that identifies "all current sources of contamination, especially in large urban waterways and large watersheds with multiple point and nonpoint sources."

Two Case Studies on Integrating Recontamination Potential into CSMs. Strecker (2010) and Fitzpatrick (2009) presented papers on integrating the evaluations of recontamination potential into contaminated sediment site CSMs. Presenting a simplified CSM graphic, Fitzpatrick noted that "[t]he CSM also highlights the gaps in our understanding, especially regarding recontamination potential. The RI/FS should address the two primary mechanisms for recontamination – sediment exposure and source control."

Strecker provided considerable information on the factors causing urban stormwater to become contaminated and thereby become a potential pathway to recontaminate sediment. He reported that copper, zinc, lead, pesticides, and dioxin are all present from current sources in urban runoff. He further noted that legacy pollutants present in stormwater may include PCBs, mercury, pesticides, and lead. His paper presented a method to consider these discharges in the CSM, as well as how Best Management Practices might be used to avoid post-remediation recontamination.

UNIVERSE OF SITES IDENTIFIED

Recent information was researched on the sediment recontamination sites in the original 2007 paper to update the information reported. Additional information was particularly sought on whether additional source information had been reported, as well as what action might have been taken since 2007 to address the recontamination.

USEPA's 2005 Sediment Remediation Guidance emphasized the need to perform post-remedial sampling. The sites reported in 2007 could only have been identified as being recontaminated if such post-remedial sampling was performed and reported. It was expected that additional recontamination sites might be identified as more projects were implemented under the auspices of the 2005 Guidance. In the course of preparing this update, six additional sediment recontamination sites were found.

In the 2007 analyses, four types or groups of sediment site recontamination sources were established based on USEPA guidance and other sources. These generalized groups of sources are summarized in the following manner:

- Point Sources – public sources such as combined sewer overflows (CSOs), storm sewer overflows (SSOs), and municipal sewage treatment plants, and industrial discharges.
- Sediment Sources – including upstream sources, unremediated nearby sediment.
- Runoff Sources – runoff from industrial manufacturing and storage sites, erosion of stream bank and/or adjacent upland soils, mining sites runoff, agricultural run-off.
- Other Sources – atmospheric deposition, contaminated groundwater advection, spills

A total of 25 sites were identified in the original study and this update. These 25 sites are listed in Table 1. These sites included 14 estuarine and 11 freshwater sites. Ten of these sites were originally remediated by sediment removal, another ten of the sites underwent dominantly capping remediation, and five sites were both dredged and capped.

The available information was reviewed to attempt to characterize the source(s) of recontamination at each site. Differing levels of information were available on these sites, but in all cases, at least some indication existed of the type(s) of source that led to the recontamination. In some cases, more than one type of source contributed to the recontamination of the site. Additionally, for the nineteen sites first identified in 2007, Table 1 summarizes the response actions, if any, taken in the past eight years in response to the recontamination.

Point sources were identified as a source of recontamination at 64% of the sediment sites (16 of 25). This is somewhat greater than the 50% of sites found in the 2007 information. CSO and public SSO storm sewer discharge sources continued to dominate within the Point Sources category. No industrial point source discharges were identified in the 2007 study, but in 2014, industrial discharges were suggested to be at least partially responsible for the recontamination at 7 sites. This is consistent with the 2007 observation that unidentified industrial sources may have been unidentified upstream contributors to the CSO and SSO storm drain sources.

Approximately 40% of the 25 identified sites had some portion of their recontamination attributed to sediment sources – the relocation of unremediated nearby sediment into the response area that defined the specific site. The sediment source group includes sites where the response action addressed only a portion of the affected sediment, and then the unremediated sediment subsequently moved into the area previously addressed. This corresponds well to the 40% of the sites identified in 2007.

The other aources group was identified as a source of recontamination at 32% percent of the current 25 sites analysis, much greater than the 17% of sites reported in 2007. In the 2007 sites group, none of the sites reported groundwater advection or mining site impact. The newly added sites list included three sites where the migration of upland NAPLs to the waterbody recontaminated the sediment, and another site where mining sources impacted the sediment.

Runoff sources was the most difficult group to characterize both in 2007 and again in 2014. Erosion of contaminated bank materials clearly belonged in this group, but general sources such as “upland sources,” “recent sediment deposition,” “from the surrounding harbor,” etc. could be placed here or in either the point sources or sediment sources category if more information were available.

CASE EXAMPLES

Examples are presented for the purpose of demonstrating the recontamination mechanism concepts described above, as well as the actions taken at sites after recontamination was discovered.

Bloomington, IN. PCB-contaminated materials were disposed at Neal’s Landfill. Sediment in Conard’s Branch became contaminated by these PCBs, and this sediment was removed from 1370 meters of the stream in 1987. Groundwater collection and treatment was also initiated at that time. In 2012 improvements were constructed to capture additional PCB contaminated groundwater. Recontaminated sediment, bank soils, and floodplain soils were also excavated. (USEPA, 2010)

Convair Lagoon, CA. Convair Lagoon is a 4-hectare embayment in North San Diego Bay. A 2.3-hectare area within the lagoon, contaminated with PCBs, was remediated in 1998 through the application of a robust subaqueous cap. By 2002, PCBs had been detected in newly deposited sediment present on top of the cap. PCBs were identified in adjacent public storm drain systems (Carlisle 2002), and surrounding industry was found to be significant contributors. Extensive work was performed to clean sewer connectors and laterals, line sewers, and plug connectors in these industrial facilities (Hitchens 2009). In 2010, the City of San Diego undertook studies of PCBs prevalence and sources in its 1.52 meter storm drain pipe upstream of the industrial area. (City of San Diego, 2010)

River Raisin, MI. In 1997, Ford completed a sediment remediation project adjacent to an industrial outfall was completed. Approximately 20,600 cubic meters of PCB Aroclor 1248-contaminated sediment was dredged from a depositional area of the Raisin River. Dredging removed sediment to the bedrock in most locations and post-dredging residual sampling confirmed that the cleanup level had been achieved. Sampling in 2001 found that that 33 cm of PCB contaminated sediment had redeposited and was impacted almost exclusively by a different Aroclor – 1242. 57,300 cubic meters of contaminated sediment was removed in 2012 and a sand cover was placed. (Tuchman, 2012)

Lauritzen Canal, CA. The Lauritzen Canal is a tidally influenced marine site located off San Francisco Bay. The sediment at this tidally influenced marine site is contaminated by DDT, dieldrin, and other substances from the United Heckathorn site. Site releases impacted sediment in the adjacent waterway. In 1996-1997, approximately 82,000 cubic meters of contaminated sediment was removed by dredging, and then an average 30-cm thick sand cap was applied across the site. Capping alone was performed in portions of the site beneath docks and around pile structures where dredging access was poor. Initial post-construction testing indicated a high degree of remedial success (Weston 2002).

Additional testing conducted in 1998 and 1999 indicated that the site had become recontaminated with DDT (USEPA 2001). The source of the recontamination materials was initially thought to be from slumping and erosion from undredged areas beneath docks and around pilings. In late 2001, a source identification study found very high levels of DDT to be present in waters being discharged from an embankment outfall which had been believed to have been sealed off (USEPA, 2004a). Thus, this site is one in which two sources of recontamination are reported — the movement of unremediated sediment and the outfall point source.

USEPA has conducted a series of studies to better understand the recontamination sources and to develop remedial alternatives. The current publicly available schedule suggests that cleanup will begin during 2015. (USEPA, 2014)

Pine River, MI. The Pine River lies adjacent to the former Velsicol Chemical DDT plant, and sediment in the river was substantially contaminated by DDT and other substances. An estimated 489,300 cubic meters of sediment was successfully removed from the Pine River by "in the dry" excavation in 2007. DDT contaminated NAPL was found to be flowing from beneath the former plant into the sediment. A NAPL collection system was constructed to intercept the NAPL prior to entering the sediment bed, along with a containment cap. (ITRC, 2014)

St. Clair Shores, MI. The St. Clair Shores site involves sediment in two fairly small canals in a residential neighborhood, the Lange and Revere canals, which connect to Lake St. Clair in the Detroit metropolitan area. PCB contaminated sediment was removed from these canals by dredging during 2002-2003. Subsequent testing in 2004-06 found a recurrence of elevated concentrations of PCBs in canal sediment. These PCBs were attributed to an adjacent public storm water drain. Even though the storm sewers had been cleaned, the lack of integrity of the old sewer pipe joints was allowing PCB impacted materials to re-infiltrate the sewer liner. Source controls were implemented on this sewer, and approximately 500 meters of the waterways were then redredged to remove the recontaminated sediment (Scotta, 2003). Additional source controls were constructed in 2007 and contaminated sediment was removed from portions of the drain. USEPA conducted additional PCB removal actions in and near the storm sewers between 2009 and 2012. In 2011, sediment sampling found that the Lange and Revere canal sediment was again recontaminated by PCBs discharged from the storm drain. This time, the recontamination was caused by PCB contaminated backfill surrounding the sewer pipes in the vicinities of two manhole vaults. In 2014, USEPA selected interim measures that "to reduce the volume of PCBs discharged into the canals until a final remedy addressing all site risk is implemented." (USEPA, 2014a)

TABLE 1. Sediment sites with reported recontamination.

Site	Response Measure(s)	2007 Recontamination Information	2014 Update Information
Anacostia River, DC	2004 Cap	Urban sources, upstream sources (USEPA 2006)	Focus has expanded greatly to address basin-wide urban CSO issues. River accepted into USEPA's Urban Rivers Initiative. Four year basin-wide RI study undertaken July 2014. 75 to 90 % of Anacostia's pollution caused by CSO discharges. (Pipkin 2014, Reible 2013, NRCD 2014)
Ashtabula River, OH	2006-07 Dredge	Site added since 2007	Sediment recontaminated by PCBs from Strong Brook and (lesser) Fields Brook. (Durell 2013)
Bloomington, IN (3 creeks)	1987 Sediment Removal	All sources unclear – point source discharge included (ATSDR 1992)	Remedy selected to remove sediment from Conard's Branch (one of the recontaminated creeks) and to collect/treat PCB contaminated spring waters flowing to it. (USEPA 2010, Monroe County 2014)
Convair Lagoon, CA	1998 Cap	Public storm drain discharges (Zeng 2002, Carlisle 2002)	Storm water sewer system cleaned to reduce PCBs in discharges. Storm sewer laterals in industrial properties were filled with concrete. (Hutchens 2009)
Denny Way Site, WA	1990 Cap	CSO point source discharges (Palermo 2002, NRC 2001, Romberg 2005, WDNR 2002)	Source was resuspension of nearby sediment by wave action and CSO discharges. Additional dredging was performed and cap placed, along implementing storm water controls and constructing a 1,890-meters-long, 4.47-meter-diameter tunnel relocating the CSO discharge. (ASTSWMO 2013, King County website)
Duwamish Norfolk CSO, WA	1999 Dredge-Cap	CSO point source discharges; unremediated adjacent contaminated sediment (WDE 2003, USEPA 2003a)	Sediment removed near CSO discharge. Program undertaken to divert or reduce CSO discharges. Further sediment remediation postponed until site-wide remedial design phase. (Trim 2004, USEPA 2013a)
Duwamish River Diagonal, WA	2004 Dredge	Sewage system discharges (SPI 2005)	Many CSO and SSO sources identified. Various pipe cleaning and flow revisions have been completed or are planned (out to 2026). Prop wash and resuspension of river sediment also postulated as pathways (Trim 2004, USEPA 2013a)
Eagle Harbor Site, WA	1994 Cap	"Surface sources", "offsite sources" (USEPA 1999, Palermo 2002)	Urban signature identified as source of increasing PAH recontamination. Reported surface concentrations remain an order of magnitude lower than pre-remediation. (Wakeman 2004, ASTSWMO 2013, Thompson 2013)
Fox River SMU 56/57, WI	2000 Dredge-Cap	1.2-1.5 m of new impacted sediment deposited in five years (Anchor 2006)	Area now is incorporated into a much larger basin-wide dredging remedial action. (USEPA 2003b)
Housatonic River, MA	2002 Dredge-Cap	Upstream sediment, CSO and SSO point source discharges (Daley 2005)	Pittsfield facility discharge monitoring and treatment increased. "Most problematic" erodible banks to be excavated in "Rest of River" remedy. (Boughton 2014)
Lauritzen Canal, CA	1996 Dredge-Cap	Undetected point source(s); incomplete remediation near margins of site (USEPA 2001, Weston 2002, USEPA 2004a)	Recontamination appears to have continued. DDT concentrations in Lauritzen Channel anchovies have increased by a factor of 30 since before remediation. Source and fate studies continue with 2015 remedy selection projected. (USEPA 2014b)
Long Beach North Energy Island Borrow Pit (NEIBP), CA	2001 Cap	"Deposition from the surrounding harbor" (USACE 2005)	After recontamination by metals was reported in years 1-3 monitoring results, no further reports were identified. City has proposed to use NEIBP as a CAD for navigational dredging. (ASTSMWO 2013, SC-DMMT 2009)
Pier 51 Ferry Terminal, WA	1989 Cap	PAHs due to pile pulling; metals from "new sediment deposition" (HSRC)	State reported discharges from stormwater outfalls and combined sewer overflow structures do not contain enough pollutants to result in recontamination of remediated sediment at levels higher than the applicable CSL. However, numerous outfalls in the vicinity may be sources of pollutants. Recontamination may also occur from nonpoint sources such as spills, creosote pilings, and bulkheads. (Parametrix 2011)

Site	Response Measure(s)	2007 Recontamination Information	2014 Update Information
Pier 53-55, WA	1992 Cap	Prop wash resuspension near edges; PAHs due to pile removal (Romberg 2005)	State reported discharges from stormwater outfalls and CSOs do not contain enough pollutants to result in recontamination of remediated sediment at levels higher than the applicable CSL. However, recontamination may also occur from ongoing pollutant sources and nonpoint sources. Prop wash and creosote pile pulling contributed to recontamination from nearby sediment. BEHP concentrations continued to increase and after ten years exceeded SQS levels. BEPH recontamination came from wastewater, stormwater, and atmospheric deposition. (Parametrix 2011, ASTSWMO 2013)
Pier 64-65, WA	1994 Cap	2002 Piling repair work released creosote (Romberg 2005)	No new information identified.
Pine River, MI	2007 Sediment Removal	Site added since 2007	Uncontrolled upland DDT-contaminated NAPL. NAPL collection system with containment cap. (ITRC 2014)
Pine Street Canal, VT	2003-04 Cap	Site added since 2007	PAHs migrating upwards by ebullition. Organoclay reactive matting and NAPL recovery system installed. (ITRC 2014)
Port of Olympia, WA	2009 Dredge	Site added since 2007	Dioxin contaminated sediment sloughed from adjacent pier. (Olympian 2010)
Puget Sound Naval Shipyard Pier D, WA	1994 Dredge	Suspected resuspension of sediment from outside response area (RETEC 2002)	Onshore improvements implemented including stormwater upgrades and covering shoreline soils with the potential to erode. (USEPA 2004b)
River Raisin, MI	1997 Dredge	Unremediated upstream sediment and/or upland sources; sediments sloughed from adjacent navigational channel (Cieniewski 2003, Bergeron 2000, Cleland 2000, Cleland 2001)	57,300 m3 PCB contaminated sediments removed in 2012, and sand and organoclay cover was placed. (Tuchman 2013)
Silver Bow Creek, MT	Dredging	Added since 2007	Being recontaminated by runoff from Butte hill and waste piles. (Klemz 2008)
Sitcum Waterway/ Nearshore Tideflats, WA	1993 Dredge	"Continued source input from recent sediment deposition or off-loading activities" (RETEC 2002)	Site was delisted with no further monitoring required. (Fitzpatrick 2009, NRC 2007)
St. Clair Shores, MI	2002 Dredge	Sewer pipe discharges (Scotta 2006)	Sediment redredged. Sewer pipe lined and traps installed but PCB contamination continued to appear. Additional interim remedy being constructed to manage PCBs entering the sewer manholes. (USEPA 2013b, USEPA 2014a)
Thea Foss Waterway, WA	2002 Dredge-Cap	2006 City storm drain discharges (Gordon 2006a, Gordon 2006b)	Recontamination linked to discharges from two 2.44-meter storm sewers. Sediment below the entry of these pipes was covered to prevent washout. City is evaluating what Best Management Practices (sewer cleaning, street sweeping, in-line filtration vaults, and development standards) to implement to improve discharge quality. (Dalton 2013, Thornburg 2013)
Town Branch, KY	2000 Dredged/Excavated	Site added since 2007	Recontamination caused by uncontrolled NAPL source. NAPL recovery system installed. (ITRC 2014)

DISCUSSION

Both the Table 1 sites and the related contaminant sources that caused sediment recontamination were remarkably diverse. These recontaminated sites were located in fresh and brackish waters; in flowing, tidally influenced, and lacustrine settings; and at dredged, capped, and combination-remedied sites; etc. Similarly, the uncontrolled sources that gave rise to the recontamination included urban public storm drain and CSO discharges; relocation of unremediated contaminated sediment by several means; releases from creosote pile maintenance; uncontrolled NAPL advection; etc. The recontamination sites in Table 1 included eight of the twelve potential contaminant sources enumerated by ITRC (2014) above.

USEPA's 2005 Contaminated Sediment Remediation Guidance emphasized that identifying and controlling sources prior to conducting remediation is critical to the effectiveness of any sediment cleanup. "In most cases, before any sediment action is taken, project managers should consider the potential for recontamination and factor that potential into the remedy selection process."

This guidance also describes that the "[e]ssential elements of a CSM generally include information about contaminant sources, transport pathways, exposure pathways, and receptors." ITRC (2014), Strecker (2010), and Fitzpatrick (2009) (above) all provide details that demonstrate how site CSMs should treat potentially uncontrolled sources that might cause recontamination.

The recontamination that occurred at some of the sites in Table 1 appears to have been relatively easily managed. The Ashtabula River project appears to have been one such site. The recontamination events at many more sites have been adversely consequential. Some of these examples are the St. Clair Shores, Convair Lagoon, and Lauritzen Canal sites. At these sites, bringing all of the sources under control and addressing the recontamination is requiring several phases and multiple years at significant expense.

Urban CSO and SSO storm water discharges were reported to be important at seven of the sites. Gaining the understanding and financial commitment needed to resolve public storm water discharge problems can be very time consuming. Further, these discharges are normally controlled under authorities outside of CERCLA. ITRC (2014) emphasized the need to incorporate such sources into the Conceptual Site Model, especially in large urban waterways and large watersheds with multiple point and nonpoint sources.

Watershed approaches are often necessary to get these sources integrated into the CSM. This need brings about questions of how to best integrate the authorities of CERCLA, WRDA, CWA, state programs, etc. Per USEPA (2005), "A critical question often is whether an action in one part of the watershed is likely to result in significant and lasting risk reduction, given the probable timetable for other actions in the watershed."

CONCLUSIONS

Recontamination experience continues to show the importance of controlling sources before implementing expensive sediment remedies. This survey identified twenty-five sites at which recontamination have been reported. USEPA's sediment remediation guidance and policies have consistently directed remedial managers to take steps to avoid this problem. The new ITRC guidance emphasizes the iterative development of a complete conceptual site model (CSM) that identifies "all current sources of contamination, especially in large urban waterways and large watersheds with multiple point and nonpoint sources."

This group of sites suggests that recontamination is most likely to arise from uncontrolled Point Sources and/or the movement of unremediated contaminated sediment from adjacent or upstream areas of the water body. In addition to these two dominant recontamination pathways, several sites became recontaminated due to groundwater (and NAPL) advection and also due to creosote piling repairs.

The factors behind the sites' respective recontamination were site-specific, but some common features appear to exist. Among these sites, the most frequent cause of recontamination was found to be uncontrolled point sources. Runoff sources, sediment sources, and other processes were also identified as having contributed to the recontamination at these sites. Understanding the controls needed for these potential recontamination pathways continue to present challenges in building the sediment site's CSM. Watershed approaches are often necessary to get these sources integrated into the CSM. This need brings about questions of how to best integrate the authorities of CERCLA, WRDA, CWA, state authorities, etc.

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Analysis of Recontamination of Completed Sediment Remedial Projects – An Update

Battelle Eighth International Conference on Remediation and Management of Contaminated Sediments
New Orleans, LA
January 2015

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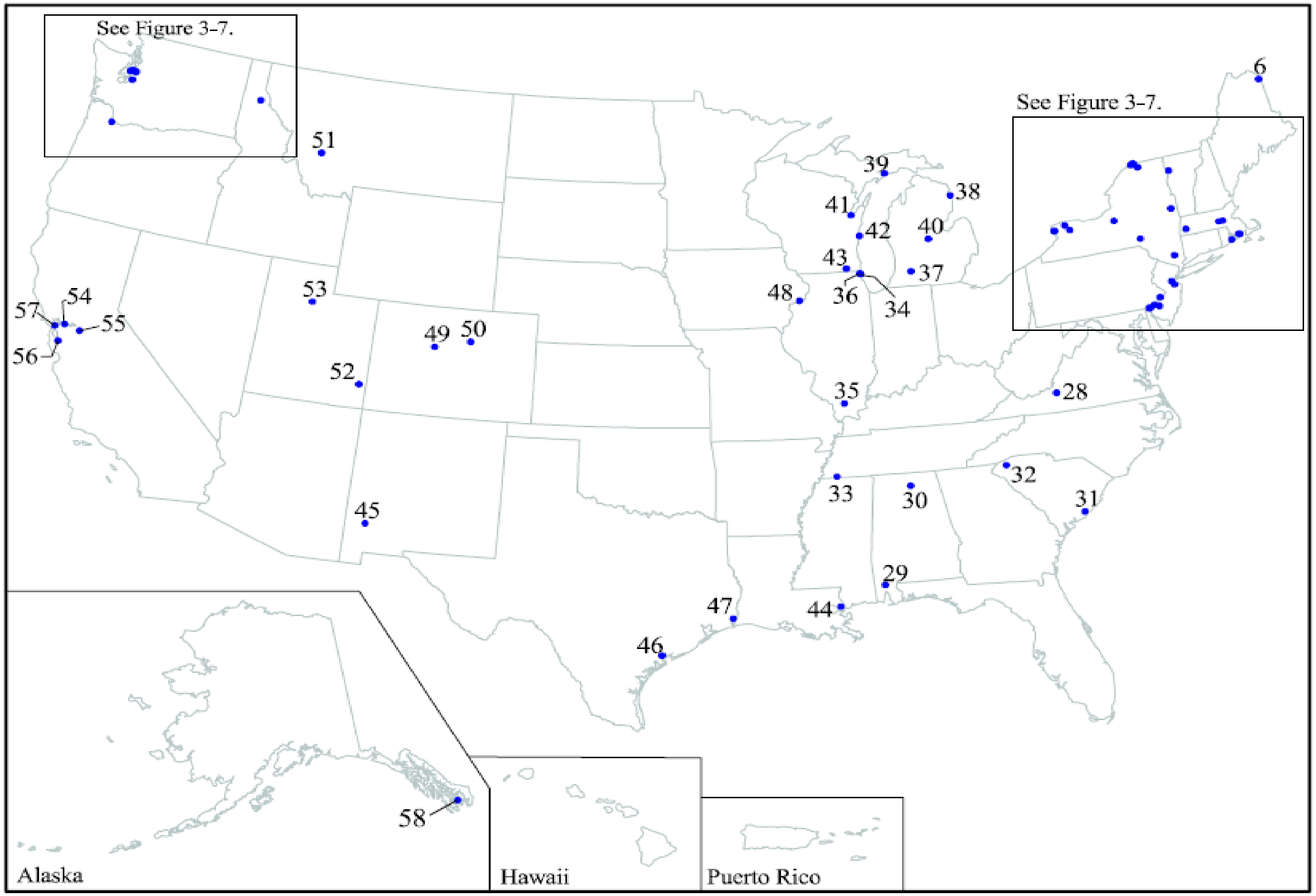
Magnitude of the Contaminated Sediment Problem

- In its 1998 Contaminated Sediment Management Strategy document, U.S. EPA estimated that 1.2 billion cubic yards of sediment is contaminated, using only the top 5 cm of the areas identified.
- Assuming an average sediment thickness of 2 to 3 feet, an estimated 20 billion cubic yards of sediment is likely to require some form of management.

CURRENT STATISTICS

- The 2004 U.S. EPA *Updated Report on the Incidence and Severity of Sediment Contamination in Surface Waters of the United States* notes that in the 2800 waterbodies with fish advisories include:
  - 33% of the nation’s total lake acreage
  - 15% of the total river miles
  - 100% of the Great Lakes
- The Superfund Program has decided to address sediment issues at over 150 sites
- Over 65 of these sites are large enough that they are being tracked at the national level
- 96 watersheds were identified as being areas of probable concern for sediment contamination

Nationally Tracked CERCLA Sites



From U.S. Environmental Protection Agency. 2004. The Incidence and Severity of Sediment Contamination in Surface Waters of the United States.

Urban Waterways of Particular Concern for Recontamination

For Example:

- Gowanus Canal
- Newtown Creek
- Lower Passaic River

EPA’s Emphasis on Source Control

- *Contaminated Sediment Management Strategy* (1998):
  - “Before initiating any remediation, active or natural, it is important that point and nonpoint sources of contamination be identified and controlled.” (p. 55)

EPA's Emphasis on Source Control

- *Principles for Managing Contaminated Sediment Risks at Hazardous Waste Sites* (2002):
  - Principle #1: CONTROL SOURCES EARLY

EPA’s Emphasis on Source Control

- *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (2005):
  - “Identifying and controlling contaminant sources typically is critical to the effectiveness of any Superfund sediment cleanup.” (p. 2-20)
  - “In most cases, before any sediment action is taken, project managers should consider the potential for recontamination and factor that potential into the remedy selection process.” (p. 2-21)

Interstate Technology Regulatory Council Guidance

- ITRC's "Contaminated Sediments Remediation – Remedy Selection for Contaminated Sediments" (2014) identifies potential sources of recontamination and emphasizes the iterative development of a complete Conceptual Site Model (CSM) to identify all current sources of contamination.

ITRC Identified 12 Sources of Recontamination

- discharge from point sources such as industrial facility outfalls
- discharge from a POTW and CSOs
- private and public stormwater discharges (including sheet flow runoff)
- discharge of nonaqueous phase liquid (NAPL) from sediment
- overland flow from an upland (upgradient) source
- soil erosion where contaminants are present in the stream bank, riverbank or floodplain soils

ITRC Identified 12 Sources of Recontamination

- sediment transport from other sediment sources in the watershed
- contaminated groundwater discharge (such as dissolved phase and NAPL release)
- air deposition of contaminants (such as mercury from fossil fuel power plants and PAHs from particulate matter from heavily burdened traffic areas such as highways, airports, or ports)
- nonpoint source and watershed-wide sources of contamination
- over-water activities (such as fuel and product spills and ship maintenance and repair) or other incidents which release contaminants to the water body
- naturally occurring sources (such as inputs of metals or other inorganics from natural watershed sources).

Recontamination Following Remediation

- Initial survey of completed projects in 2007 identified 19 sites where recontamination occurred.
- Most sites have undergone additional study since 2007 and some have implemented source control and/or additional remediation.

Recontamination Following Remediation

- Current study updates the status of the 19 original sites.
- An additional 6 recontamination sites have been identified.
- Sites varied widely in geomorphic and geographic settings.
- Included 14 freshwater and 11 estuarine locations.

Recontamination Following Remediation

- Initial remedial actions included dredging, capping, and combinations of dredging and capping.
  - 10 capping sites
  - 10 dredging sites
  - 5 combination capping & dredging sites

Recontaminated Sites

Site	Response Measure(s)	2007 Recontamination Information	2014 Update Information
Anacostia River, DC	2004 Cap	Urban sources, upstream sources	**Four year basin-wide RI study undertaken July 2014. 75 to 90 % of Anacostia's pollution caused by CSO discharges.**
Ashtabula River, OH	2006-07 Dredge	Site added since 2007	**Sediment recontaminated by PCBs from Strong Brook and (lesser) Fields Brook.**
Bloomington, IN (3 creeks)	1987 Sediment Removal	All sources unclear – point source discharge included	**Remedy selected to remove sediment from Conard's Branch (one of the recontaminated creeks) and to collect/treat PCB contaminated spring waters flowing to it.**
Convair Lagoon, CA	1998 Cap	Public storm drain discharges	**Storm water sewer system cleaned to reduce PCBs in discharges. Storm sewer laterals in industrial properties were filled with concrete.**
Denny Way Site, WA	1990 Cap	CSO point source discharges	**Source was resuspension of nearby sediment by wave action and CSO discharges. Additional dredging was performed and cap placed, along with implementing storm water controls and constructing a 1,890-meters-long, 4.47-meter-diameter tunnel relocating the CSO discharge.**
Duwamish Norfolk CSO, WA	1999 Dredge-Cap	CSO point source discharges; unremediated adjacent contaminated sediment	**Sediment removed near CSO discharge. Further sediment remediation postponed until site-wide remedial design phase.**
Duwamish River Diagonal, WA	2004 Dredge	Sewage system discharges	**Many CSO and SSO sources identified. Prop wash and resuspension of river sediment also postulated as pathways.**

Recontaminated Sites

Site	Response Measure(s)	2007 Recontamination Information	2014 Update Information
Eagle Harbor Site, WA	1994 Cap	“Surface sources”, “offsite sources”	**Urban signature identified as source of increasing PAH recontamination. Reported surface concentrations remain an order of magnitude lower than pre-remediation.**
Fox River SMU 56/57, WI	2000 Dredge-Cap	1.2-1.5 m of new impacted sediment deposited in five years	**Area now is incorporated into a much larger basin-wide dredging remedial action.**
Housatonic River, MA	2002 Dredge-Cap	Upstream sediment, CSO and SSO point source discharges	**Pittsfield facility discharge monitoring and treatment increased. "Most problematic" erodible banks to be excavated in "Rest of River" remedy.**
Lauritzen Canal, CA	1996 Dredge-Cap	Undetected point source(s); incomplete remediation near margins of site	**Recontamination appears to have continued. DDT concentrations in Lauritzen Channel anchovies have increased by a factor of 30 since before remediation. Source and fate studies continue with 2015 remedy selection projected.**
Long Beach North Energy Island Borrow Pit (NEIBP), CA	2001 Cap	“Deposition from the surrounding harbor”	**After recontamination by metals was reported in years 1-3 monitoring results, no further reports were identified. City has proposed to use NEIBP as a CAD for navigational dredging.**

Recontaminated Sites

Site	Response Measure(s)	2007 Recontamination Information	2014 Update Information
Pier 51 Ferry Terminal, WA	1989 Cap	PAHs due to pile pulling; metals from "new sediment deposition"	**Numerous outfalls in the vicinity may be sources of pollutants. Recontamination may also occur from nonpoint sources such as spills, creosote pilings, and bulkheads.**
Pier 53-55, WA	1992 Cap	Prop wash resuspension near edges; PAHs due to pile removal	**Recontamination may occur from ongoing pollutant sources and nonpoint sources. Prop wash and creosote pile pulling contributed to recontamination from nearby sediment.**
Pier 64-65, WA	1994 Cap	2002 Piling repair work released creosote	**No new information identified.**
Pine River, MI	2007 Sediment Removal	Site added since 2007	**Uncontrolled upland DDT-contaminated NAPL. NAPL collection system with containment cap.**
Pine Street Canal, VT	2003-04 Cap	Site added since 2007	**PAHs migrating upwards by ebullition. Organoclay reactive matting and NAPL recovery system installed.**
Port of Olympia, WA	2009 Dredge	Site added since 2007	**Dioxin contaminated sediment sloughed from adjacent pier.**

Recontaminated Sites

Site	Response Measure(s)	2007 Recontamination Information	2014 Update Information
Puget Sound Naval Shipyard Pier D, WA	1994 Dredge	Suspected resuspension of sediment from outside response area	**Onshore improvements implemented including stormwater upgrades and covering shoreline soils with the potential to erode.**
River Raisin, MI	1997 Dredge	Unremediated upstream sediment and/or upland sources; sediments sloughed from adjacent navigational channel	**57,300 m3 PCB contaminated sediments removed in 2012, and sand cover was placed.**
Sitcum Waterway/ Nearshore Tideflats, WA	1993 Dredge	"Continued source input from recent sediment deposition or off-loading activities"	**Site was delisted with no further monitoring required.**
St. Clair Shores, MI	2002 Dredge	Sewer pipe discharges	**Sediment in canals redredged. Sewer pipe lined and traps installed but PCB contamination continued to appear. Additional interim source control remedy will be constructed to manage PCBs entering the sewer manholes. The final remedy is yet to be determined.**
Thea Foss Waterway, WA	2002 Dredge-Cap	2006 City storm drain discharges	**Recontamination linked to discharges from two 2.44-meter storm sewers.**
Town Branch, KY	2000 Dredged/Excavated	Site added since 2007	**Recontamination caused by uncontrolled NAPL source. NAPL recovery system installed.**

Common Sources of Recontamination

- Point sources:
  - combined sewer overflows (CSOs)
  - storm sewer outfalls (SSOs)
  - municipal sewage treatment plants
- Sediment sources:
  - upstream sources
  - unremediated nearby sediments

Common Sources of Recontamination

- Runoff sources:
  - industrial manufacturing and storage sites
  - erosion of streambank and/or adjacent upland soils
  - agricultural runoff
- Other sources:
  - atmospheric deposition
  - contaminated groundwater advection
  - mining sites
  - spills

Sources of Recontamination for the 25 Sites

- Point sources (16 of 25 sites - 64%):
  - Up from 50% in 2007
  - Most frequent source: CSO and other public storm water discharges
  - Industrial sources potentially at least partially responsible at 7 sites (28%)

Sources of Recontamination for the 25 Sites

- Sediment sources (10 of 25 sites - 40%):
  - Relocation of unremediated nearby sediments into the response area
  - Corresponds to 40% of sites identified in 2007
- Runoff sources
  - Recent sediment deposition
  - From surrounding harbor
  - Upland/upstream sources
  - Most difficult category to characterize as many could be placed in the Point Source or Sediment Source categories if more information was available

Sources of Recontamination for the 20 Sites

- Other sources (8 of 25 - 32%):
  - Significant increase from 17% observed in 2007
  - New sites include 3 with upland NAPL migration and 1 with mining site impact
  - Category includes sites with recontamination due to creosote piling repairs and atmospheric deposition, as two examples

Case Study: Bloomington, IN

- Site characteristics:
  - Three creeks
- COCs:
  - PCBs
- Remedy:
  - Sediment removal (1987)
  - Groundwater collection and treatment (1987)
- Recontamination:
  - PCB-contaminated groundwater from a landfill exceeded the installed groundwater collection capacity. Recontaminated sediment, bank soils and floodplain soils were excavated (2014). Additional groundwater collection and treatment installed.

Case Study: River Raisin

- Site characteristics:
  - River
- COCs:
  - PCB Aroclor 1248
- Remedy:
  - Dredged 20,600 m^3 (1997)
  - Post-dredging sampling confirmed that cleanup level was achieved
- Recontamination:
  - Deposition of sediment contaminated with a different PCB Aroclor -- 1242 -- likely from unremediated sediment and land soil sources upstream of the dredged area.
  - An additional 75,000 cubic yards was removed in 2012 and a sand cover was placed

Case Study: Convair Lagoon

- Site characteristics:
  - 4 hectare embayment in North San Diego Bay
- COCs:
  - PCBs
- Remedy:
  - 2.3 hectare area remediated by placement of a cap (1998)
- Recontamination:
  - Deposition of contaminated sediments on top of the cap from an adjacent public storm drain systems (2002).
  - Extensive work cleaning storm drain and plugging connectors (2009).
  - Additional studies of potential storm drain sources upland of industrial area initiated in 2010.

Case Study: St. Clair Shores

- Site characteristics:
  - Lange and Revere Canals, located in a residential area and which connect to Lake St. Clair
- COCs:
  - PCBs
- Remedy:
  - Dredging (2002-2003, 2006)

Case Study: St. Clair Shores

- Recontamination:
  - Recurrence of elevated concentrations of PCBs due to discharges from an adjacent public storm water sewer. After source controls were implemented, waterways were redredged (2006).
  - Additional source controls (2007) and removal actions in and near the storm sewers were undertaken (2009-2012).
  - Sampling in 2011 revealed that both canals were again recontaminated with PCBs from the storm drain; interim source control measures were selected in 2014, which will be implemented until a final remedy can be determined and implemented.

Case Study: Lauritzen Canal

- Site characteristics:
  - Tidally influenced marine site off San Francisco Bay
- COCs:
  - DDT and dieldrin
- Remedy:
  - 82,000 m^3 dredged, followed by placement of 30 cm thick cap (1996-1997)
- Recontamination:
  - Sampling in 1998 & 1999 showed recontamination with DDT. One source thought to be from slumping and erosion from undredged areas but capped beneath docks and around pilings.
  - Second source later discovered to be waters discharged from embankment outfall.
  - Additional remedial measures to be selected during 2015.

Case Study: Pine River, MI

- Site characteristics:
  - River
- COCs:
  - DDT
- Remedy:
  - 640,000 yd^3 excavated using “in the dry” method (2007)
- Recontamination:
  - DDT contaminated NAPL discovered to be flowing into the sediments. A NAPL collection system and a containment cap were installed.

Rapid Recontamination

- All 25 sites became recontaminated relatively quickly following remediation.
- Not a failure of the initial remedial action.
- Reasons for recontamination:
  - No assessment of source control made prior to remedy selection
  - Incomplete assessment of source control made prior to remedy selection
  - Remediation conducted at locations where source control known to be incomplete

Conclusions

- Survey identified 25 sites that were recontaminated.

- U.S. EPA’s sediment strategy, policies, and guidance have consistently focused on avoiding this problem.

Conclusions

- Recontamination most likely to arise from uncontrolled Point Sources and/or incomplete remediation in adjacent/upstream areas.
- Careful study of potential Point Sources is necessary.
- Control of Point Sources must be as great or greater a priority as the sediment response action.

Conclusions

- Urban CSO and SSO discharges were important contributors at 11 sites.
- These sources present special financial challenges and are normally controlled under authorities outside of CERCLA.
- Watershed approaches are often necessary to get these sources integrated into the CSM.

Conclusions

- Several sites recontaminated due to incomplete remediation – contaminated sediment from outside the response area entered via resuspension, etc.
- Lesson: Avoid remediating single or discrete locations (especially downstream) out of a larger area until a thorough understanding is developed of how the unremediated area may affect the long-term effectiveness of the remediation.

Bottom Line

CONTROL SOURCES EARLY

<u>But</u>, source control is challenging because sources of sediment and contaminants are watershed issues

For Further Info ...

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