SEDIMENT IN BALTIMORE HARBOR

Quality and Suitability for Innovative Reuse

An Independent Technical Review

October 2009

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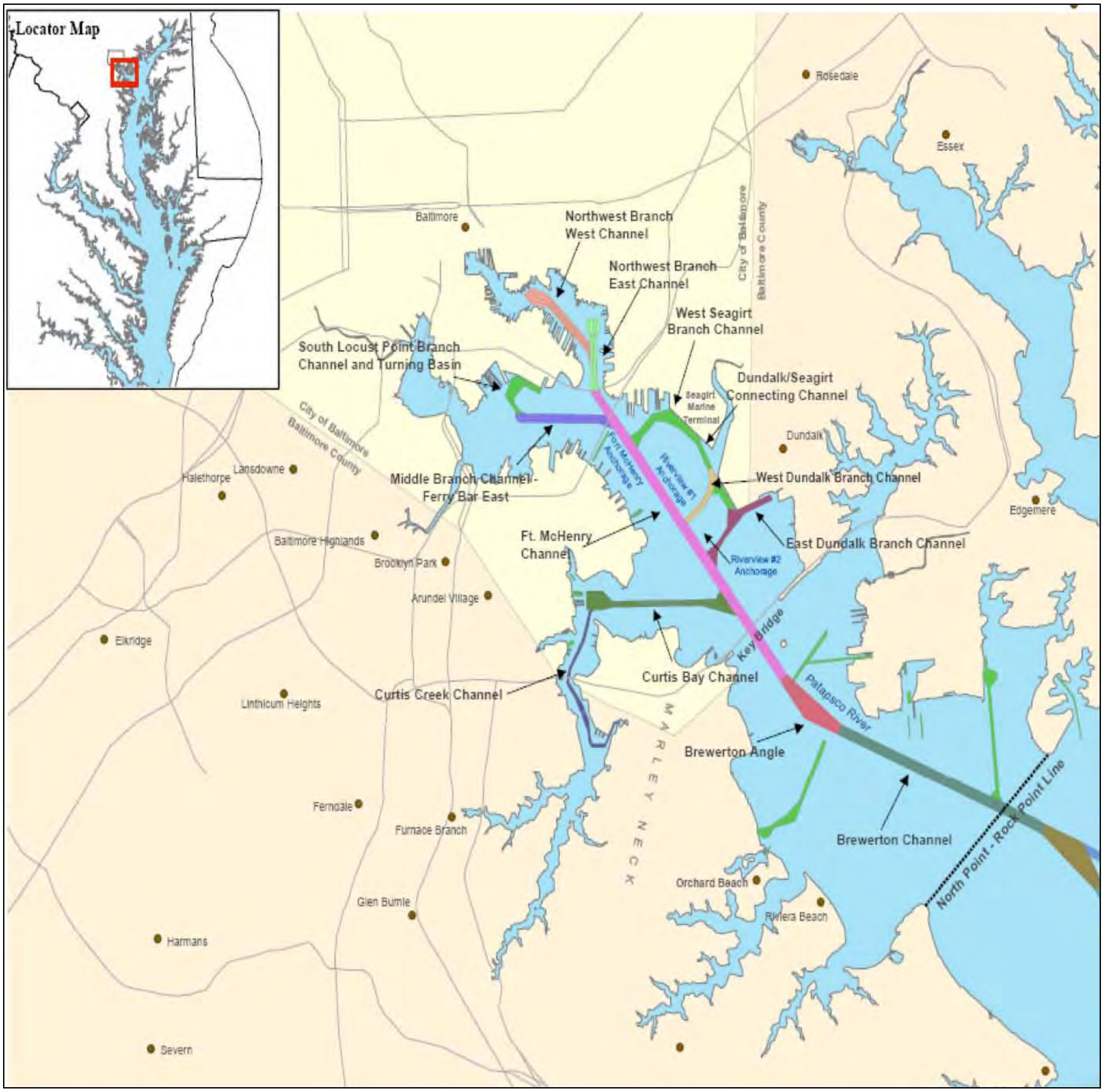
Report Highlights

A national team of independent experts examined historical data for levels of metals and organic contamination in sediments that may be dredged from Baltimore Harbor shipping channels, including off-channel sites and harbor approach channels in the Chesapeake Bay. To help authorities as they manage large amounts of sediment taken from these channels — over three million cubic yards a year — the team evaluated the suitability of dredged sediments for innovative reuse. These potential uses include a range of applications, from manufactured topsoil to cement filler and building materials. To provide managers with a scientifically sound basis for determining potential innovative reuse options, the team assembled data and information to construct a frame for risk analysis and decision-making. Among the team's significant conclusions are:

- In most cases, soil criteria currently applied in Maryland are sufficient to assess sediment quality. Based on these criteria, the team felt that some sediments in the harbor are contaminated to the point that consideration should be given to leaving them in place. For much of the remaining sediment taken from currently dredged channels, a variety of options do exist for innovative reuse.
- The team noted that in some cases — arsenic is an example — background levels in the environment are often higher than the state's regulatory limits. These limits therefore make it difficult to meet the criteria, thus restricting reuse options. Addressing this regulatory issue will require consultations between the Innovative Reuse Committee and the Maryland Department of the Environment.
- A screening protocol developed by the team based on available datasets revealed varying suitability for three types of innovative reuse: unrestricted land amendment (e.g., agricultural), residential (e.g., manufactured topsoil), and non-residential (e.g., industrial).
- The team determined that no sites met the most stringent criteria for unrestricted upland reuse options (e.g., agricultural land amendment). The review team therefore did not consider land amendment a viable option, both because of contaminants and because of inherent characteristics of estuarine sediments that can impact the integrity and productivity of soils.
- A limited number of sites meet Maryland criteria for residential reuse (e.g., manufactured topsoil, not meant for cropland).
- A greater number of sites meet Maryland criteria for non-residential reuse criteria. These uses include, for example, fill for mines and for sand and gravel pits, and as components in cement filler and lightweight aggregate materials.
- Acceptable uses in the residential and non-residential categories cover ten of the options under consideration by the Innovative Reuse Committee. Further feasibility assessments for innovative reuse are therefore clearly warranted.
- Numbers of sites, however, exceeded both residential and non-residential reuse criteria. This was especially true in off-channel sites. Managers must carefully consider specific conditions before undertaking channel widening or other activities in these areas.
- Before decisions are made regarding dredging and innovative reuse, any selected sites will require case-by-case, site-by-site testing, risk assessment, and monitoring.



Inner Harbor Channels. Figure from the Dredged Material Management Plan (USACE 2006).

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Executive Summary

The Port of Baltimore serves as a vital economic resource for the city of Baltimore, the state of Maryland, and the entire region. On average, more than 3 million cubic yards of dredged materials must be removed annually from Baltimore Harbor's shipping and approach channels to maintain operations. Maryland law stipulates that harbor sediments (defined as those inside a line drawn between North Point and Rock Point at the harbor entrance) may not be placed outside the harbor and that the unconfined placement of *any* dredged materials (including those from approach channels), even at sites used for several decades, will cease by December 31, 2010 (Maryland Environmental Code 5-1102). This action initiated a thorough analysis of a variety of options to maintain the long-term sustainability of the port and its approaches. As part of this process, the Maryland Ports Administration (MPA), through its Dredged Materials Management Program (DMMP), instituted the Innovative Reuse Committee (IRC) to examine the potential for innovative reuses of these dredged materials. The IRC developed a list of priority technologies, with a focus on upland uses and reclamation projects as well as the production of engineering fill and specific building materials. The viability of these options depends in great part on the quality of the sediments to be dredged — in particular, levels of metal and organic contaminants and other chemical characteristics of the sediments in question.

In 2008, the DMMP sought a scientific and technical review of sediment quality in Baltimore Harbor, with emphasis on the associated shipping and approach channels. In addition, the DMMP sought guidance on state and federal criteria for sediment quality assessment. Central to this effort was a strong commitment on the part of the DMMP and the Ports Administration to an independent assessment — one that would yield a better understanding of the characteristics of harbor sediments and the development of effective guidance for stakeholders and policy makers focused on decision making for innovative reuse options.

With these general goals in mind, the Ports Administration engaged Maryland Sea Grant and the Chesapeake Research Consortium to organize and facilitate a scientific review of issues related to sediment quality in Baltimore Harbor. The review was conducted by an Independent Technical Review Team composed of seven individuals (scientists and engineers) from across the region and the country. This expert panel has extensive experience in such fields as sediment biogeochemistry, metal and organic contaminants, toxicology, risk assessment, human health issues, dredging operations, and sediment management. The team focused on completing six main tasks:

1. A summary of the status of sediment quality guidelines and criteria that may be in use regionally or nationally.

2. Recommendations for scientific protocols to evaluate dredged material for its suitability for use in various innovative reuse applications.

3. A characterization of the sediment quality (physical, chemical, and biological) in the port's shipping channels and the adequacy of information available for that purpose.

4. A comparison of sediment quality (physical, chemical, and biological) in harbor channels and the main Bay channels, including the potential for beneficial uses of these sediments.

5. An assessment of trends in the quality of sediments deposited in and dredged from harbor channels over time and of differences between the contamination found in legacy sediments and sediments recently dredged from maintenance channels.

6. A list of considerations regarding the value of formal chemical-specific limits or guidance versus the use of a case-by-case, site-specific process for assessment of sediment quality.

Assessing Risk and Criteria for Reuse

The team conducted a thorough analysis of sediment quality guidelines and criteria, as well as an assessment of relevant risk factors for innovative reuse options. There are risks associated with all dredging activities. Therefore, it is important to understand the resources at risk for a given reuse option. Risk, defined as the likelihood that a situation (or substance) will produce harm under a specified set of conditions, is a combination of two factors: (1) the probability that an adverse event or exposure will occur and (2) the consequences of that adverse event or exposure (i.e., hazard or, in this case, toxicity). There is no risk if exposure to a harmful substance or situation does not or will not occur. An important early step during the problem formulation phase of a risk assessment is to determine potential pathways for exposure, both to humans and the ecosystem. Accordingly, the team detailed potential pathways for exposure to contaminants in dredged materials to various receptors for each of the innovative reuses identified by the IRC. In addition, because the DMMP charged the team with assessing sediments in the main Bay channels, aquatic restoration was included in this analysis. These exposure pathways were defined for a range of management alternatives, and the team developed a tiered classification scheme that requires that dredged material meet increasingly stringent criteria as the risk increases for a given reuse.

Sediment Screening Guidelines

The team focused on guidelines used locally, but also consulted guidelines from beyond the region to verify the validity of local criteria. These analyses were instrumental in the development of both the screening level assessment protocol used by the team and the guidance for future management decisions. The team adopted a practical approach to develop its screening protocol and used a process consistent with one currently employed by the State of New Jersey, using Maryland soil standards when possible. The exception to this was a subset of metal contaminants. The natural (geological) background levels of those metals are higher than the Maryland soil standards.

The team’s analysis resulted in screening criteria based on four general classes of reuse. These are:

- Unrestricted upland reuse
- Residential reuse
- Non-residential reuse
- Material that must be confined, or material that should not be dredged at all

This screening protocol was adequate to assess potential sediment quality for the suite of reuse options under consideration by the Port’s Innovative Reuse Committee.

Analysis of Sediment Quality Data

The team’s evaluation of harbor and approach channel sediment quality was based on a large number of studies used for testing of sediment quality for individual dredging projects. All datasets were provided to the team — new sampling was not a part of this assessment. These data were originally collected to meet differing goals of projects conducted over a relatively wide spatial and temporal range. Use of secondary data of this type can sometimes result in significant uncertainties. Accordingly, the team first screened all the provided datasets to assess their suitability for inclusion in the team’s analysis. Although much of the data were collected using rigorous and reliable protocols that satisfied data quality objectives specific to the original goal, many datasets did not meet the needs of the present assessment. Further, many of the datasets were not available in raw format, at least electronically. The team used studies that met minimum criteria with respect to analytical methodology, quality assurance/ quality control, and, importantly, sampling that was representative of what would be dredged in a given project. The team concluded that there were a number of datasets that sufficiently met these criteria to provide an adequate scoping assessment of sediment suitability.

These datasets represented a reasonable distribution in time and space to enable baseline screening of contamination of sediments and suitability for potential reuse. The compiled data were used in a geographic information system to generate a series of maps detailing sediment characteristics in various areas of the harbor and approach channels. These maps demonstrate general findings for a given area based on the team’s screening protocol. The maps do have important limitations imposed by the spatial and temporal nature of the datasets, as well as the underlying variability (heterogeneity) of harbor sediments. The team emphasizes that these analyses are based on a compilation of historical data collected across approximately ten years of sampling. While a synthesis of this type is extremely useful, the maps are best used as a means to highlight sites that could be examined with respect to the potential innovative reuses of sediments found there.

The Quality of Harbor Sediments

The team concluded that none of the sites for which there was available data met the standard for the most stringent reuse options (i.e., unrestricted upland use) and, therefore, harbor sediments have some limitations regarding reuse options with the highest risk factors. Land amendment was not considered a viable reuse option by the team due to concerns regarding contaminant levels and the biogeochemical characteristics of estuarine sediments (i.e., pH, sodium, chloride, and sulfate), which can have highly adverse impacts and lead to soil infertility.

Many of the sites in the datasets analyzed meet criteria for residential (e.g., manufactured topsoil) or non-residential reuse options. By far the majority of these met the latter criteria. The team notes that most innovative reuse options under consideration should be regulated using the non-residential criteria. The data also suggest that the channels dredged currently are most suitable for innovative reuse.

The scoping assessment also revealed that numerous sites exceeded both the residential and non-residential reuse criteria. The distribution of these sites was complex, with locations across most of the harbor. The screening assessment used by the team was designed to identify sites that exceed the non-residential (e.g., industrial) reuse criteria. With that in mind, exceeding the non-residential criteria does not preclude certain other innovative reuses. This is especially true where engineering and institutional controls — as well as existing site conditions and proposed final end use — make using them appropriate.

Comparing Harbor and Main Bay Sediments

The team found limited data to make comparisons between harbor and main Bay channels — those that were found were restricted to information on organic contaminants. Examination of the maps revealed that no sites, neither inside nor outside the harbor, had organic contaminant levels that met criteria for the most stringent reuse options. A comparison of the maps does show that a greater percentage of the sites outside the North Point-Rock Point line met the criteria for residential applications and a smaller percentage exceeded the criteria for non-residential reuse. Should this finding remain consistent when re-sampled, it may indicate that the sediments outside the harbor will have a greater potential for innovative reuse than those inside the harbor.

Trends in Sediment Quality

While very useful, the studies analyzed by the team did not lend themselves to a coherent trend analysis. This is due in part to variations in study intent/design, analytical technique, and location of sediments. A cursory examination of Federal Channel data for metal contaminants suggests some improvement in sediment quality since 1998. However, the team recommends that managers work closely with the scientific community to consider how best to implement trend studies.

Guidance for Future Decision Making

The team did not find data in the applicable data sets that indicated that any of the sediments in currently dredged areas are too hazardous to be dredged. However, given some of the data available in off-channel areas, the team recommends that sediment in areas proposed for new channels, or for channel deepening or widening, should be carefully examined during the design process to ensure that the sediments that will either be removed or exposed will have an appropriate management option and will not result in undue environmental harm during dredging. It is possible that some of these sediments would require special management or techniques during either dredging or disposal. The team did not specifically identify or evaluate these sediments.

While the independent team process was suitable for screening the large dataset provided, it would not be appropriate to use this process for decision making on actual projects. Accordingly, the team developed a decision-support matrix that provides guidance for sediment characterization for projects inside and outside the harbor. The first step in determining appropriate management options for a particular dredging project would be to evaluate the historical database. If data exist that show that the material has either always been clean, or always been contaminated, this information can be used to decide what the ultimate management goal might be. For example, a site that has been historically clean might be targeted for evaluation for use in habitat restoration, or unrestricted innovative reuse or beneficial use. It would not be a wise use of time or resources, however, to evaluate a historically contaminated site for these uses. Rather, one should proceed toward the goal of a more restrictive use or confined disposal. This screening step is analogous to what the team performed to produce this report.

The team has proposed four categories for the management of Chesapeake Bay sediments. Three of these categories would divide the material for upland or aquatic use and innovative reuse ranging in quality from upland industrial sites to land amendment. Each successive category requires that the sediment meet more stringent criteria. For material that does not meet the lowest upland innovative reuse criteria, the only options are confined disposal or sediment decontamination. It logically follows that if disposal options are not available, or if the material exceeds criteria for all options, then the sediment should remain in place until appropriate management options have been developed. The team emphasizes that project decision making must be made on a case-by-case, site-specific basis.

Introduction

In 2008 approximately 33 million tons of foreign cargo moved through the Port of Baltimore's public and private marine terminals (MPA 2009a). The value of this cargo totaled over $45 billion (MPA 2009b). With direct access to major markets, the Port ranks first in the nation for roll on/roll off (farm and construction equipment), trucks, imported forest products, imported gypsum, and imported iron ore and sugar (MPA 2009b). Overall, the Port of Baltimore ranks 12th nationally for total dollar value of cargo and 14th nationally for total foreign cargo handled. Recent analyses reported that the Port provides 16,500 direct jobs — and those generated by overall Port activity exceed 100,000 across Maryland, accounting for $3.6 billion in personal wages and salary. Annually, the Port has generated $1.9 billion in business revenues and $400 million in state, county, and municipal tax revenues (MPA 2009b). These statistics highlight the Port's role as a vital economic resource for the city of Baltimore, the state of Maryland, and the entire region. In this context, maintaining safe and efficient shipping is an essential part of the Maryland Port Administration's (MPA) mission. On average, over 3 million cubic yards of dredged materials must be removed annually from Baltimore Harbor's shipping channels to maintain operations. Constraints on the placement for this material require that decision makers explore a variety of options to ensure the long-term sustainability of the port and its approaches. Recognizing this fact, the Maryland Ports Administration, through its Dredged Materials Management Program, instituted the Innovative Reuse Committee (IRC) to examine the potential for innovative reuse of dredged materials.

The Maryland Legislature has specific definitions regarding uses of dredged materials from Chesapeake Bay and Baltimore Harbor. Specifically:

> **"Beneficial use of dredged material"** means any of the following uses of dredged material from the Chesapeake Bay and its tributary waters placed into waters or onto bottomland of the Chesapeake Bay or its tidal tributaries, including Baltimore Harbor:
>
> (i) the restoration of underwater grasses;
> (ii) the restoration of islands;
> (iii) the stabilization of eroding shorelines;
> (iv) the creation or restoration of wetlands; and
> (v) the creation, restoration, or enhancement of fish or shellfish habitats.
>
> **"Innovative Reuse"** includes the use of dredged material in the development or manufacturing of commercial, industrial, horticultural, agricultural, or other products." (Maryland Senate Bill 830)

In their analyses the IRC (2007) noted that several potential options exist and a selected subset should be pursued in pilot studies. The IRC, however, also emphasized that implementation of any methods will depend in great part on whether the sediments in question are sufficiently free of contaminants to be deemed suitable for processing and the projected end uses. Specifically:

> MDE and MPA should use the best scientific expertise available to examine the issue of sediment quality in the port's shipping channels and conduct a comparison of sediment quality in the harbor and sediment quality in the main Bay channels. This review should include historic and recent monitoring data and sampling protocols, comparison of sediment quality to EPA and MDE criteria and standards, and analysis of the impacts of current legal restrictions on the management of dredged materials. The review should recommend a scientific protocol to identify and categorize dredged material to be either processed so it can be reused innovatively or handled in a confined facility if it were deemed unsuitable for innovative reuse. (Recommendation 3 [IRC 2007])

In 2008 the Dredged Materials Management Program sought an independent scientific review of sediment quality in the target area as well as further guidance on state and federal criteria for sediment quality assessment. Their intent was to help inform stakeholders and policy makers as they engage in the decision-making process on reuse of dredged sediments. With this general goal in mind, the MPA engaged Maryland Sea Grant and the Chesapeake Research Consortium to organize and facilitate a scientific review of issues related to sediment quality of the entire Baltimore Harbor, with an emphasis on the associated shipping channels. This report is the result of that effort, which compared the characteristics of harbor channels and the main Bay channels and considered the potential for beneficial uses of these sediments. The review was conducted by an Independent Technical Review Team comprised of experts able to address the tasks outlined. The review team was composed of seven individuals (scientists and engineers) from across the region and the country. They conducted a thorough review of sediment data from Baltimore Harbor and the Port of Baltimore's Bay shipping channels. The team analyzed and synthesized a variety of data relevant to completing the following tasks as defined by the IRC:

- A summary of the status of sediment quality guidelines and criteria that may be in use regionally or nationally.
- Recommendations for scientific protocols to evaluate dredged material for its suitability for use in various innovative reuse applications.
- A characterization of the sediment quality (physical, chemical, and biological) in the port's shipping channels and the adequacy of information available for that purpose.
- A comparison of sediment quality (physical, chemical, and biological) in harbor channels and the main Bay channels including the potential for innovative uses of these sediments.
- An assessment of trends in the quality of sediments deposited in and dredged from harbor channels over time and of any differences between the contamination found in legacy sediments and sediments recently dredged from maintenance channels.
- A list of considerations regarding the value of formal chemical-specific limits or guidance versus the use of a case-by-case, site-specific process for assessment of sediment quality.

Data

To address these questions, the team examined data provided to them by Maryland Environmental Services as well as other data sources. They did not collect additional data from the field.

Because these datasets spanned a wide timeframe, the team considered the sampling and analytical methodologies used in the collection and analysis and their overall utility for the comparison of data sets — an especially important task when attempting to assess differences over time. For those datasets deemed useful, the team considered technical information such as physical and chemical characteristics of sediment and the implications of any sediment bioassay information available. While both environmental and human health components and criteria were considered in analysis of risk levels, a complete ecological and human health-based risk assessment was beyond the scope of the study.

Project Structure

The team used a variety of means to complete their study, including face-to-face meetings, conference calls, and email exchanges. Each team member was responsible for analyzing data relevant to their area of expertise and for providing summary text for the final report. The team findings presented in this report represent a strong consensus of the team members.

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Dredging in Baltimore Harbor

To evaluate the potential for innovative reuse of dredged materials, it is important to have a basic understanding of current dredging operations in the Port of Baltimore and its approach channels. In this background section we describe:

- Current dredging needs
- Regulatory considerations
- Current placement of dredged materials
- Potential environmental issues associated with current dredging and placement activities
- Future placement options and innovative reuse

Current Dredging Needs

Maintenance dredging is essential for the operation of the Port of Baltimore. Maintaining the authorized depth of the channels is tasked to the U.S. Army Corps of Engineers (USACE), with a substantial State of Maryland responsibility for placement of dredged materials. Continual dredging is required because of ongoing inputs of fluvial sediment inputs from the Susquehanna River and substantial rates of shoreline erosion (Hobbs et al. 1992). These two sources of sediment are key to the infilling of Baltimore Harbor, with the multi-layer circulation resulting in inputs of “Bay” sediment (Chao et al. 1996). Indeed, studies by the Maryland Geological Survey (MGS) and University of Maryland Center for Environmental Science (J. Cornwell, personal communication) suggest that the dominant source of sediment into the harbor is from the Chesapeake Bay, with lesser contributions from the Patapsco River and other drainages, low shoreline erosion because of shoreline structures, urban runoff from streets, and modest inputs of dust.

The dredged material management plan for Baltimore Harbor (USACE 2006) details current dredging for maintenance of shipping channels. Table 1 summarizes average dredging needs with channel locations indicated in Figures 1 to 3. The average annual need for placement of dredged materials is ~ 3.4 million cubic yards, with ~ 0.5 million cubic yards derived from Baltimore Harbor. For current dredging purposes Baltimore Harbor is defined as the area inside the North Point-Rock Point line at the mouth of the Patapsco River (Figure 3).

Regulatory Considerations

Two key actions by the State of Maryland have large consequences for placement alternatives:

1. **State law (MD Senate Bill 830; Maryland Environmental Code (5), Subtitle 11) prohibits the placement of dredged material from Baltimore Harbor in an unconfined manner in the Bay or its tributaries (**Maryland Senate 2001). Baltimore Harbor is defined by the North Point-Rock Point Line and there are no provisions for detailed characterization of dredged materials to enable their use outside the harbor. Even

clean materials from inside the line face a strong regulatory constraint, and are defined as suitable only for a containment facility such as Hart-Miller Island (HMI) Dredged Material Containment Facility (DMCF).

2. The future use of open water placement has been removed, a consequence of the heated debate over the proposed use of the Site 104 open water site. By the end of 2010, open water disposal of any dredged materials within Maryland is prohibited (Blankenship 2000, Maryland House of Delegates 2001)**.**

In addition, and as noted earlier, the Maryland legislature has developed strict definitions of innovative reuse and beneficial use of dredged materials.

Table 1. Average maintenance dredging in federally authorized channels/anchorages in the northern Chesapeake Bay. Data are from the Dredged Material Management Plan (USACE 2006).

Channel Section	Length (nm)	Constructed Width (ft)	Authorized Depth (ft)	Maintenance Dredging Average Annual Pay Quantity (1996-2004) (cubic yards)
Baltimore Harbor Channels				
Curtis Bay Channel	2.2	400	50	96,431
Curtis Creek Channel	2.2	150 (Upper)		12,132
		290 (Middle)		
		200 (Lower)		
East Dundalk Branch	1	400	42	0
West Dundalk Branch	1.2	500	42	484
Dundalk/Seagirt connecting	1	500	42	2,814
South Locust Point Branch	0.7	400	36	0
Middle Br. Channel - Ferry Bar East	1.4	600	42	11727
NW Branch East	1.3	600	49	0
NW Branch West	1.3	600	40	10187
Brewerton Channel	3	700	50	111364
Brewerton Angle	0.8	1075	50	107648
Ft. McHenry Channel	3.8	700	50	101392
				Total 454,179
C&D Approach Channel (Lower Approach)	15	450		**Total 1,200,000**
Anchorages				
Ft. Mc Henry	0.3	Deauthorized		0
Riverview #1 3A	0.4	2200		16667
Riverview #1 3B	0.3	1800		0
Riverview #2	0.4	1800		4441
				Total 21,108
Chesapeake Bay Approach				
Craighill Entrance	3.1	700	50	193983
Craighill	2.8	700	50	100668
Craighill Angle	1.6	1258	50	396742
Craighill Upper Range	2.1	700	50	56889
Cutoff Angle	0.9	1220	50	188855
Brewerton Eastern Extension	5	600	35	439906
Swan Point	1.7	600	35	103465
Tolchester	6.5	600	35	208787
				Total 1,689,295
			Cumulative Total	**3,364,582**

Figure 1. Northern Approach Channels. Copied from the Dredged Material Management Plan (USACE 2006).

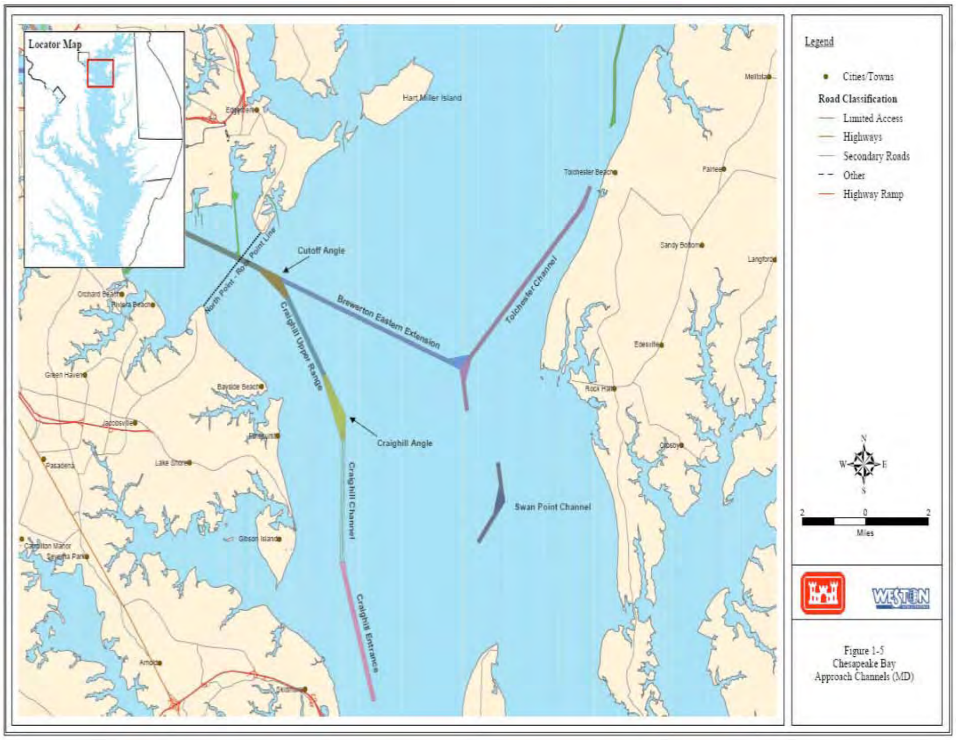

Figure 2. Outer Harbor Approach Channels. Copied from the Dredged Material Management Plan (USACE 2006).

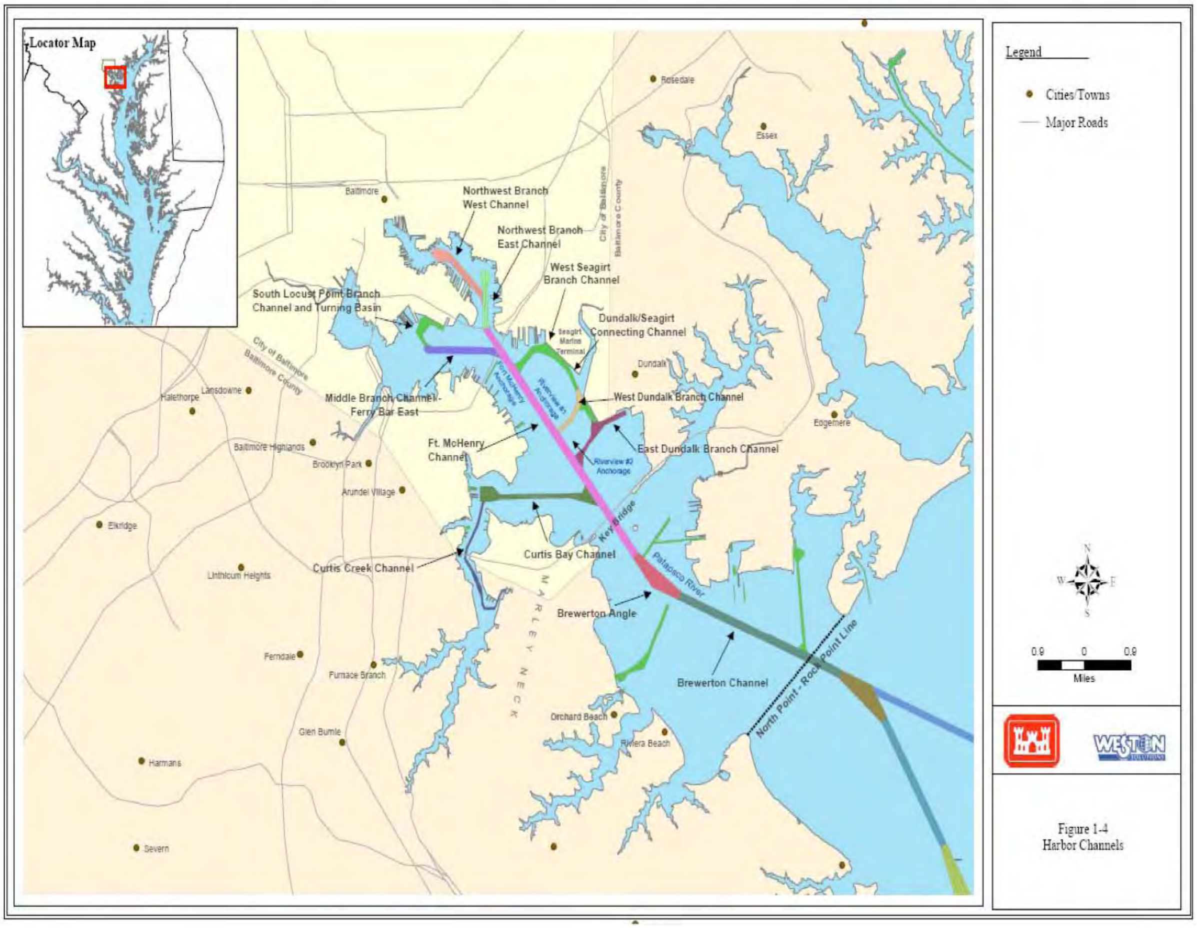

Figure 3. Inner Harbor Channels. Copied from the Dredged Material Management Plan (USACE 2006).

Current Placement of Dredged Materials

Current placement options are summarized in the dredged material management plan (USACE 2006). These include:

- C&D Approach Channels. The Pooles Island Open Water Site consists of a series of open water placement sites near Pooles Island. This open water dumping site has a mandatory closure by the end of 2010.

- Harbor Channels and Anchorages. Through the end of 2009, the Hart-Miller site can accept material from Baltimore Harbor and the approach channels. This 1,200-acre facility was designed to contain contaminated materials and appears to have been effective in retaining contaminants on-site; because of the unexpected failure of approval of an open water site (Site 104), large quantities of approach channel materials were deposited at Hart-Miller. Capacity of the 102-acre Cox Creek Confined Disposal Facility is currently being expanded to accommodate harbor materials. This facility can provide only about half the capacity needed for the next 21 years of harbor dredging.

- Chesapeake Bay Approach Channels in Maryland. The Paul Sarbanes Poplar Island Environment Restoration Project is a beneficial use project offshore of Talbot County, Maryland. This large facility is being used for the development of 570 acres of tidal wetlands and 570 acres of upland, using uncontaminated dredged material from the Baltimore Harbor and Channels Federal navigation projects (USACE 2009). The upland component of this facility has by far the largest capacity to accommodate dredged materials. The current island configuration will reach capacity in 2017, with expansion options on the north end of the island adding capacity through 2025.

Two new alternatives for dredged material from Baltimore Harbor placement are currently being developed by the Port, and sites in the middle Bay area (Dorchester County, see below) are being evaluated for large island and wetland restoration or dredged material placement.

- Current plans for Cox Creek suggest that this relatively new facility will reach capacity by 2017, with a new facility (Masonville DCMF) coming online in 2012 and reaching capacity in 2025. These two facilities cannot supply all the capacity needed for the 21-year planning window for dredged material placement.

- For Chesapeake Bay Approach Channel sediments, a new Mid-Bay Island Project is being evaluated, with a combination of: (1) large island (~2,000 acres) creation at the remnants of James Island (Dorchester County) and (2) island/wetland restoration at Barren Island and other eroding islands in southern Dorchester County.

Other alternatives such as wetland restoration at the Blackwater National Wildlife Reserve may be evaluated in the future (IAN 2007).

Potential Environmental Issues Associated with Current Dredging and Placement Activities

Both USACE and MPA have considerable environmental data on their dredging and placement practices. In this section, we discuss the process of dredging and potential issues associated with the collection, handling, and final disposition of this material.

Dredging in the northern Chesapeake Bay is most often carried out using clamshell dredges. This approach minimizes the mixing of dredged materials with the water column during the dredging process, with sediment deposited onto barges. One important environmental effect is the exposure of deep, nutrient-rich sediments to overlying water (Cornwell 1999) and some resuspension of sediment.

There are generally minimal losses during transport (with the possible exception of volatile organic materials) and the next major step of handling is offloading. Bay or harbor water is added to the sediment to facilitate hydraulic movement of the material through pipelines. The resultant mixture is mostly water.

Dewatering of the offloaded material is a major issue in the handling of dredged material and all discharges require permits from the regulatory agencies to ensure that they meet water quality standards prior to being discharged into receiving waters. In confined facilities or at beneficial use sites, the material is pumped to areas where the slurried sediment is deposited. Over many months, the sediment compacts and the water is generally pumped offsite. Cornwell et al. (2009) have summarized the major constraints for removing the water. These include non-compliant pH values, excessive trace metal concentrations (most often zinc and nickel), and high turbidity (both suspended sediments and algae). The pH values can be too high (> 8.5) from high primary production of algae, or too low from pyrite oxidation ($\text{pH} < 6.5$; see below). High concentrations of ammonium are also common in the water pumped offsite. The sediment is often reworked to repeatedly expose wet sediment to drying conditions — a process referred to as “crust management.” This process is critical for maximum capacity at the facility; wet sediment takes up more volume, and ineffective drying reduces the ability to receive more dredged materials. Keeping each year’s sediment addition (“lift”) relatively thin enhances the longevity of the facility.

Estuarine sediments such as those in Chesapeake Bay have sulfate reduction as the major anaerobic metabolism. A consequence of this is the formation of pyrite in deposited sediment. Upon exposure to oxygen in air, pyrite oxidizes, releasing sulfuric acid: $4FeS_2 + 15O_2 + 8H_2O \rightarrow 2Fe_2O_3 + 8\ H_2SO_4$. This release of acid can mobilize some trace metals, with soil solutions having low pHs (< 4). Low pH causes problems when using dredged materials as upland soils, with substantially reduced soil fertility until pyrite is exhausted and pH adjusted.

Containment facilities are designed to effectively retain metals, trace organics, and particulate material. The multi-decade experience at the Hart-Miller site suggests that these facilities are effective. Studies conducted by UMCES, MGS, and the Maryland Department of the Environment (MDE) suggest that no discernable impacts on living resources occurred in the waters near the facility; and ground water studies suggest that metals are effectively retained at the facility (Hill 2005). The most recent external monitoring report (MDE 2009) shows some external chemical enrichment, but no long-term biological impacts:

> - The South Cell discharge operations did appear to have an effect on the exterior sedimentary environment, which is evident in the enrichment of Pb and Zn around the South Cell Spillway 003.
>
> - Although monitoring detected both a Zn and a Pb signature in sediments surrounding Hart-Miller Island over the long-term record, construction and operation at the HMI-DMCF have produced no long-term biological impacts to surrounding aquatic communities.

Restoration sites such as the wetlands at Poplar Island have shown little apparent toxicological effects from metals (EA Engineering, Science, and Technology, Inc. 2007) — sediments deposited at this site derived from approach channels, which made contaminant issues less anticipated. Upland restoration presents a great challenge because of pH (see above), but the successful establishment of upland grasses in the south cell of Hart-Miller Island shows that, over time, the soil becomes suitable for grassland (Cornwell et al. 2009).

Future Placement Options for Beneficial Use and Innovative Reuse

Island creation, wetland/island restoration, and containment facilities represent the immediate future for placement of dredged materials (i.e., defined as beneficial use). The current Dredged Materials Management Program (DMMP) clearly identifies the volumetric limitations of the status quo, with placement of harbor materials of particular concern. The accepted suitability of non-harbor dredged materials for environmental restoration enhances the likelihood that sites will be supported by the public and approved by regulators. Indeed, with wetland/island/shoreline losses in the mesohaline Chesapeake Bay likely to increase with increasing sea levels, there is a *bona fide* prospect of competition for “clean” dredged materials by a number of interests (IAN 2007).

A list of options is shown in Table 2. Some options such as open water placement are included in this federal list, but are not viable under current Maryland state law. They are included here to provide a comprehensive listing of placement options that have been discussed. Options shown here encompass both beneficial use and innovative reuse as specified by the Maryland legislature and include: agricultural placement, island creation/restoration, capping projects at landfills and brownfields, mine placement, building products, and confined disposal.

The Port’s Innovative Reuse Committee (IRC) recognized that the most urgent need is for placement of Baltimore Harbor channel sediments and articulated the importance of considering other options for these sediments. Indeed, they have noted that this material should be considered a “recyclable resource” that can be reused for purposes beyond those previously described.

A number of different options were evaluated by the IRC (2007). Different technologies were prioritized and suggestions were made for pilot projects to start the evaluation (Table 3).

Table 2. List of Maryland Placement options considered in the Dredged Material Management Plan. Data in table are derived from USACE (2006).

Dredged Material Management Placement Options	**Harbor Channels**	**C&D Approach Channels**	**Ches. Bay Approach (MD)**
Agricultural Placement	■	■	■
Artificial Island Creation —Upper Bay	■	■	■
Building Products	■	■	■
C&D Canal Upland Sites Expansion	■	■	■
Capping Brownfields	■	■	■
Capping Landfill	■	■	■
Capping Patapsco River		■	■
Confined Aquatic Disposal Area Patapsco River	■		
Confined Disposal Area Patapsco River	■		
Cox Creek Expansion	■		
Hart-Miller Expansion	■	■	■
Large Island Restoration — Mid-Bay		■	■
Mine Placement — Cecil County	■	■	■
Mine Placement — Western Maryland	■	■	■
Pooles Island Open Water Site Expansion		■	■
PIERP Expansion		■	■
Shoreline Restoration — Mid-Bay	■	■	■
Shoreline Restoration — Upper Bay	■	■	■
Small Island Restoration — Mid-Bay	■	■	■
Wetlands Restoration — Dorchester County		■	■
Dam Neck Open Water Placement (Existing)			
Hart-Miller Island (Existing)	**BASE**	■	■
New Open Water Placement — Mid-Bay (Deep Trough)		■	**BASE**
Pooles Island Open Water Site (Existing)		**BASE**	
Wolf Trap Alternate Open Water Placement (Existing)		■	■

Table 3. Technologies recommended for evaluation by the Innovative Reuse Committee (IRC 2007).

High Priority Technology	**Medium Priority Technology**	**Low Priority Technology**
Land Amendment	Lightweight Aggregate	Brownfields
Sand & Gravel Pits	Cement Filler	Compressed Blocks
Flowable Fill	Base Material	Manufactured Topsoil
Mines		Daily Cover
		Bricks

The Context for Risk Assessment

To assess the potential suitability for reuse of dredged sediments from Baltimore Harbor, one must consider the state of contamination of the sediments, their end use, and the resources at risk. Risk is defined as the likelihood that a situation (or substance) will produce harm under a specified set of conditions. Risk is a combination of two factors: (1) the probability that an adverse event or exposure will occur and (2) the consequences of that adverse event or exposure (i.e., hazard or, in this case, toxicity). There is no risk if exposure to a harmful substance or situation does not or will not occur. Therefore, an important early step during the problem formulation phase of a risk assessment is to determine potential pathways for exposure, both to humans and to ecologic receptors. Accordingly, potential pathways for exposure to contaminants in dredged materials to various receptors were assessed for each of the beneficial uses identified by the IRC (Table 3). In addition, because the Dredged Materials Management Program charged the team with assessing sediments in the main Bay channels, aquatic restoration was included also in this analysis. Table 4 describes potential exposure pathways for each management alternative; it also identifies, where available, sediment criteria for evaluating risk.

Risk Factors for Harbor and Approach Channel Sediments

There are risks associated with all dredging activities (Table 4), especially involving “new dredging” of relatively deeper and older sediments, which may be more highly contaminated than areas where repeated maintenance dredging has previously removed more contaminated sediments. The team developed a tiered classification scheme that requires that dredged material meet increasingly more stringent criteria as the risk increases for a given innovative or beneficial use (Table 5). The team defined Class K sediment where data suggest that the best option may be to leave sediments in place, if buried under clean, more recently deposited sediments. The criteria used in designating dredged material Class B through I and specified beneficial uses (Table 5) are consistent with the approach taken by the Great Lakes Commission (2004) in their report on evaluating dredged material for upland beneficial uses. As documented in that report, the approach for setting criteria for those uses was similar among a number of states. Driscoll et al. (2002) provide an excellent case study showing that manufacturing construction materials can often have the largest number of complete exposure pathways (e.g., inhalation, dermal, ocular, ingestion) to humans because there is much more manipulation of the sediment.

The team was also charged with assessing sediments in the main Bay channels. Here, aquatic restoration (e.g., habitat restoration in areas such as the Blackwater National Wildlife Refuge) was included as a possible beneficial use. In this case (Class A), the risk of adverse ecological effects was deemed high and, accordingly, the potential hazard must be minimized through use of more stringent criteria.

Table 4. Potential pathways for human and ecological receptors to be exposed to contaminants under various beneficial use scenarios of dredged materials (DM). For humans, routes of exposure are explicitly identified: (1) vaporized chemicals can be inhaled leading to lung and systemic exposure; can also lead to ocular exposure and eye irritation; (2) airborne dusts and particles can be inhaled leading to lung and systemic exposure, ocular exposure; deposition on skin can lead to dermal exposure; and they can be ingested (e.g., as much as half of inhaled dusts and particles are swallowed following deposition in mouth, nose, esophagus and lung); (3) DM and soils can lead to dermal exposure but can also be ingested inadvertently via contaminated hands; (4) fishery exposure leads to ingestion by humans; (5) groundwater and surface water contamination can lead to ingestion via drinking water, wash water, and irrigation or plant watering activities, as well as dermal exposure, ocular exposure, and inhalation exposure of mists and droplets (e.g., in shower or with watering activities). Also shown are various potential sediment quality guidelines to assess risk (cancer and non-cancer) from the specified pathway-receptor combination. It is important to recognize that under most of these scenarios dredged materials will become oxidized for some period of time, thus altering the bioavailability of contaminants currently buried deep in anaerobic sediments.

Management Alternative	Exposure Pathway and Final Receptor	Comments	Sediment Quality Assessment Criterion
Dredge Operation (common to all alternatives)	Sediment Resuspension → Aquatic Toxicity	Increased turbidity, decreased dissolved oxygen levels, and release of sediment-bound contaminants	Elutriate Test: State water quality criteria
	Sediment Resuspension → Surface Water → Fishery → Human Toxicity	Ingestion, contaminants bioaccumulated in recreational or commercially important finfish or shellfish	Elutriate Test: BCF and FDA action level; Sediment Bioaccumulation Screening Level Values (ODEQ 2007)
	Exposed Sediment → Sediment Biota Toxicity Exposed Sediment → Water Column → Pelagic Biota Toxicity Exposed Sediment → Sediment Biota → Predator Toxicity Exposed Sediment → Sediment Biota/Water Column → Fishery → Human Toxicity	Through removal of sediment, expose contaminated sediments that had been buried. Dermal, ingestion	Must have chemistry on sediments exposed following dredging. Threshold or Probable Effects Levels (MacDonald 1994, MacDonald et al. 2003); USEPA 2002; Sediment Bioaccumulation Screening Level Values (ODEQ 2007)
	DM → Atmosphere Vaporization → Human Toxicity	Inhalation, ocular (e.g., barge operators, on-site workers)	Industrial Use Soil Cleanup Requirements (MDE 2008b)
	DM → Airborne Particulates → Human Toxicity	Inhalation, ocular, dermal, ingestion (e.g., barge operators, on-site workers)	Industrial Use Soil Cleanup Requirements (MDE 2008b)
	DM → Human Toxicity	Dermal, ingestion (e.g., barge operators, on-site workers)	Industrial Use Soil Cleanup Requirements (MDE 2008b)

Table 4, continued.

Management Alternative	Exposure Pathway and Final Receptor	Comments	Sediment Quality Assessment Criterion
Confined Disposal Area	DM → Sediment/Soil Biota → Scavenger Toxicity	Confined Disposal Area as an attractive nuisance	Sediment Bioaccumulation Screening Level Values (ODEQ 2007); EcoSSL (USEPA 2003, Friday 2005); Site specific risk assessment
	DM → Runoff → Surface Water → Aquatic Toxicity		Elutriate test: State water quality criteria
	DM → Runoff → Surface Water → Fishery → Human Toxicity	Ingestion	Elutriate test: State water quality criteria BCF/FDA action level; Sediment Bioaccumulation Screening Level Values (ODEQ 2007)
	DM → Groundwater → Human Toxicity	Ingestion, dermal, ocular, inhalation	Synthetic Precipitation Leaching Procedure: State water quality criteria; Groundwater Assessment/Remedial Action Requirements (MDE 2008b)
Industrial Uses: flowable fill, aggregate, base material, compressed blocks, cement filler, bricks	DM → Human Toxicity	Dermal, ingestion	Industrial Use Soil Cleanup Requirements (MDE 2008b)
	DM → Atmosphere Vaporization → Human Toxicity	Inhalation, ocular (e.g., on-site workers, off-site excavation workers, nearby residents)	Industrial Use Soil Cleanup Requirements (MDE 2008b)
	DM → Airborne Particulates → Human Toxicity	Inhalation, dermal, ocular, ingestion (e.g., on-site workers, off-site excavation workers, nearby residents)	Industrial Use Soil Cleanup Requirements (MDE 2008b)
Landfill Daily Cover or Closure ---------------------------- *If Landfill does not have liner and leachate collection*	DM → Atmosphere Vaporization → Human Toxicity	Inhalation, ocular (e.g., on-site workers, off-site excavation workers, nearby residents)	Industrial Use Soil Cleanup Requirements (MDE 2008b)
	DM → Airborne Particulates → Human Toxicity	Inhalation, dermal, ocular, ingestion (e.g., on-site workers, off-site excavation workers, nearby residents)	Industrial Use Soil Cleanup Requirements (MDE 2008b)
	DM → Runoff → Surface water → Wildlife toxicity		Synthetic Precipitation Leaching Procedure: Surface water criteria
	DM → Runoff → Surface Water→ Fishery → Human Toxicity	Ingestion	Synthetic Precipitation Leaching Procedure: BCF and FDA action level; Sediment Bioaccumulation Screening Level Values (ODEQ 2007)
	DM → Leachate → Groundwater → Human Toxicity	Ingestion, dermal, ocular, inhalation	Synthetic Precipitation Leaching Procedure: State Water Quality Standard; Groundwater Assessment/Remedial Action Requirements (MDE 2008b)

Table 4, continued.

Management Alternative	Exposure Pathway and Final Receptor	Comments	Sediment Quality Assessment Criterion
Brownfields	DM → Atmosphere Vaporization → Human Toxicity	Inhalation, ocular (e.g., on-site workers, off-site excavation workers, nearby residents)	Industrial Use Soil Cleanup Requirements (MDE 2008b)
	DM → Airborne Particulates → Human Toxicity	Inhalation, dermal, ocular, ingestion (e.g., on-site workers, off-site excavation workers, nearby residents)	Industrial Use Soil Cleanup Requirements (MDE 2008b)
	DM → Human Toxicity	Dermal, ingestion	Industrial Use Soil Cleanup Requirements (MDE 2008b)
	DM → Groundwater → Human Toxicity	Ingestion, dermal, ocular, inhalation	Synthetic Precipitation Leaching Procedure: State Water Quality Standard; Groundwater Assessment/Remedial Action Requirements (MDE 2008b)
Upland Beneficial Uses: sand & gravel pits/ mined lands restoration	DM → Soil Biota Toxicity		EcoSSL (USEPA 2003, Friday 2005)
	DM → Plant Toxicity	Consider pH, excess Na, SO_4, Chlorides, soil physical properties	EcoSSL (USEPA 2003, Friday 2005)
	DM → Soil Biota → Predator Toxicity		EcoSSL (USEPA 2003, Friday 2005)
	DM → Plant → Wildlife Toxicity		EcoSSL (USEPA 2003, Friday 2005)
	DM → Human Toxicity	Dermal, ingestion	Residential/Recreational Use Soil Cleanup Requirements (MDE 2008b)
	DM → Airborne Particulates → Human Toxicity	Inhalation, dermal, ocular, ingestion (e.g., on-site workers, off-site excavation workers, nearby residents)	Residential/Recreational Use Soil Cleanup Requirements (MDE 2008b)
	DM → Atmosphere Vaporization → Human Toxicity	Inhalation, ocular (e.g., on-site workers, off-site excavation workers, nearby residents)	Residential/Recreational Use Soil Cleanup Requirements (MDE 2008b)
	DM → Surface Runoff → Surface Water → Aquatic Toxicity		Synthetic Precipitation Leaching Procedure or Leachate toxicity test: Surface water quality criteria
	DM → Surface Runoff → Surface Water →Wildlife Toxicity		Synthetic Precipitation Leaching Procedure or Leachate toxicity test: Surface water quality criteria
	DM → Surface Runoff → Surface Water → Human Toxicity	Ingestion, dermal, ocular, inhalation	Synthetic Precipitation Leaching Procedure or Leachate toxicity test: Surface water quality criteria

Table 4, continued.

Management Alternative	Exposure Pathway and Final Receptor	Comments	Sediment Quality Assessment Criterion
Upland Beneficial Uses, continued: sand & gravel pits/mined lands restoration	DM → Surface Runoff → Surface Water → Fishery → Human Toxicity	Ingestion	Synthetic Precipitation Leaching Procedure or Leachate toxicity test: Surface water quality criteria
	DM → Groundwater → Human Toxicity	Ingestion, dermal, ocular, inhalation	Synthetic Precipitation Leaching Procedure: Surface water quality criteria; Groundwater Assessment/Remedial Action Requirements (MDE 2008b)
Upland Beneficial Uses: land amendment, manufactured topsoil (MS)	DM/MS → Soil Biota Toxicity (including microbes responsible for biogeochemical cycling of nutrients)		EcoSSL (USEPA 2003, Friday 2005)
	DM/MS → Plant Toxicity	Consider pH, excess Na, SO4, Chlorides, soil physical properties	EcoSSL (USEPA 2003, Friday 2005, USEPA 2007)
	DM/MS → Soil Biota → Predator Toxicity		EcoSSL (USEPA 2003, Friday 2005)
	DM/MS → Human Toxicity	Dermal, ingestion	Residential Use Soil Cleanup Requirements (MDE 2008b)
	DM/MS → Airborne Particulates → Human Toxicity	Inhalation, dermal, ocular, ingestion	Residential Use Soil Cleanup Requirements (MDE 2008b)
	DM/MS → Atmosphere Vaporization → Human Toxicity	Inhalation, ocular (e.g., on-site workers, off-site excavation workers, nearby residents)	Residential Use Soil Cleanup Requirements (MDE 2008b)
	DM/MS → Surface Runoff → Surface Water → Aquatic Toxicity		Synthetic Precipitation Leaching Procedure: Surface water quality criteria; leachate toxicity test
	DM/MS → Surface Runoff → Surface Water → Free Range Animal/Wildlife Toxicity		Synthetic Precipitation Leaching Procedure: Surface water quality criteria
	DM/MS → Surface Runoff → Surface Water → Human Toxicity	Ingestion, dermal, ocular, inhalation	Synthetic Precipitation Leaching Procedure: Surface water quality criteria
	DM/MS → Surface Runoff → Surface Water → Fishery → Human Toxicity	Ingestion	Synthetic Precipitation Leaching Procedure: Surface water quality criteria
	DM/MS → Groundwater → Human Toxicity	Ingestion, dermal, ocular, inhalation	Synthetic Precipitation Leaching Procedure: Surface water quality criteria; Groundwater Assessment/Remedial Action Requirements (MDE 2008b)
	DM/MS → Farm Animal/Wildlife Toxicity	Dermal, ingestion	Residential Use Soil Cleanup Requirements (MDE 2008b)

Table 4, continued.

Management Alternative	Exposure Pathway and Final Receptor	Comments	Sediment Quality Assessment Criterion
Upland Beneficial Uses, continued: land amendment, manufactured topsoil (MS)	DM/MS → Plant → Feedlot/Free Range Animal/Wildlife Toxicity		Residential Use Soil Cleanup Requirements (MDE 2008b)
	DM/MS → Plant → Feedlot/Free Range Animal/Wildlife → Human Toxicity	Ingestion	Residential Use Soil Cleanup Requirements (MDE 2008b); Site specific risk assessment
	DM/MS→ Plant → Human Toxicity	Ingestion	40 CFR Part 503 Land Application Pollutant Limits; Site-specific risk assessment
Aquatic Beneficial Uses (e.g., creation of wetlands)	DM → Sediment Biota Toxicity		Threshold or Probable Effects Levels (MacDonald 1994, MacDonald et al. 2003); NY state sediment guidance (NYSDEC 2004); Porewater toxicity test, Chronic whole sediment toxicity test and/or sediment-water interface toxicity test.
	DM → Water Column → Pelagic Biota Toxicity		USEPA 2002; or Sediment-water interface toxicity test; Surface water quality criteria
	DM → Sediment Biota → Predator Toxicity	From ingestion of contaminants bioaccumulated in living sediment biota	Sediment Bioaccumulation Screening Level Values (ODEQ 2007) BSAF/BMF/CBR (Moore et al. 2005)
	DM → Sediment Biota→ Pelagic Biota → Wildlife Toxicity	Same as above	Sediment Bioaccumulation Screening Level Values (ODEQ 2007); BSAF / BMF / CBR (Moore et al. 2005); Leachate/BCF/ BCR = equilibrium partitioning and trophic transfer (Word et al. 2005)
	DM → Sediment Biota/Water Column → Fishery → Human Toxicity	Ingestion	Sediment Bioaccumulation Screening Level Values (ODEQ 2007); See California Phase II Sediment Quality Objectives Proposal (Beegan 2008); BSAF/BMF/FDA action level (Moore et al. 2005)

Exposure routes modified from Canadian Council of Ministers of the Environment (CCME) 2006, Chang et al. 2002, Driscoll et al. 2002, Great Lakes Commission 2004.

Synthetic Precipitation Leaching Procedure (SPLP)
Effluent Elutriate Test (EET)
Critical body residue (CBR)
Biota-sediment accumulation factors (BSAF)
Bioconcentration factor (BCF)
Biomagnification factor (BMF)

Table 5. Screening criteria for innovative reuse and beneficial use of dredged material.

Dredged Material Classification	**Uses**	**Criteria**
AA	Land amendment for agricultural use	Must meet the most stringent criteria, i.e., use a two-phased approach — physiochemical/bioassay screening for plant toxicity followed by a case-by-case assessment of risk of bioaccumulation and human exposure to relic (e.g., metals, PCB, pesticide) and emerging contaminants
A	Aquatic habitat restoration — i.e., salt marsh	Must meet sediment quality assessment guidelines — Threshold Effect Level (TEL); Sediment Bioaccumulation Screening Level values
B	Upland habitat restoration	Must meet ecological soil screening levels
C	Upland reclamation — i.e., fill or soil cover for residential sites	Must meet residential soil cleanup criteria
D	Manufactured topsoil for landscaping	Must not exceed residential soil cleanup requirements for concentrations in blended soil product
E	Building materials, e.g., aggregate, blocks	Must have satisfactory results from air concentration modeling of volatiles and respirable suspended particulates to protect on-site workers; in addition, must test to confirm the strength of binding and the lack of leaching
F	Upland reclamation — cover for industrial, sites e.g., mines, gravel pits, brownfields	Must meet non-residential soil cleanup criteria; groundwater protection criteria; Synthetic Precipitation Leaching Procedure Test and state's water quality standards
G	Engineering fill, e.g., base material	Must meet non-residential soil cleanup criteria; groundwater protection criteria; Synthetic Precipitation Leaching Procedure Test — and state's water quality standards
H	Fill for landfill closure cap	Must meet non-residential soil cleanup criteria
I	Fill for landfill daily cover or upland use with containment, e.g., liners and leachate collection, and cap	Must be non-toxic or hazardous as defined by Code of Maryland Regulations 26.13.02.15-19; Toxic Substances Control Act (i.e., < 50 mg/kg PCB)
J	Confined disposal facility	Data indicates dredged material does not meet criteria for higher tier classification or data are absent
K	Leave undisturbed	Case-by-case assessment shows risk of mobilization (i.e., through chemical and physical processes) is such that buried sediments should be left undisturbed if more recently deposited material is cleaner and acts as a barrier

The beneficial use with the greatest risk was dredged material used as land amendment for agricultural use (Class AA). The team raised a number of concerns with regard to this use. The first focused on the fact that the physical structure of the sediment, its pH, sodium, chloride and sulfate contents could cause soil infertility. The greater risk was associated with the completed exposure pathways to humans (Table 4). The team was unable to offer generic screening values for this classification. It recommends a two-phased approach: (1) initially assessing physiochemical/bioassay screening for plant toxicity followed by (2) a case-by-case assessment of risk of bioaccumulation and human exposure (Table 5). USEPA/USACE (2004) suggested the use of criteria contained in U.S. EPA 503 regulations (40 CFR Part 503) for the application of biosolids to agricultural areas but did not elaborate on its use nor offer other alternative criteria. As suggested in regards to applications of biosolids (Chang et al. 2002), a guiding principle here should be to prevent pollutants from accumulating in the soil and limiting potential uses over the long term. There has been considerable controversy over the 503 rules and biosolids applications (Snyder 2005). Recently, a U.S. court has strongly criticized American biosolids policy, and awarded compensation to a farmer whose land was contaminated, thus limiting its use, following biosolids amendment (McElmurray v. USDA 2008). The team was concerned not only with relic, commonly measured contaminants (e.g., metals, PCB, pesticides) but also emerging contaminants (e.g., brominated, fluorinated compounds) that are not currently routinely measured. Therefore, much more analysis would be required before dredged materials could be classified as suitable for agricultural use. It is very likely this would also involve a number of pilot tests.

As evident from Table 4, a number of potentially completed exposure pathways exist if contaminated dredged materials were to be used for aquatic restoration. All things being equal (e.g., contaminants of potential concern and their concentrations), the risk associated with aquatic restoration was deemed higher than with upland restoration, due to the intimate contact of sediment with water. The likelihood that an exposure pathway could be completed to humans (i.e., DM→Sediment→biota/water column→fishery→human) was deemed higher for aquatic than for upland uses. An issue specific to Blackwater was completed pathways to valued ecological receptors in a national wildlife refuge. Although many differences exist between Blackwater Refuge and Lake Apopka, Florida, the bird mortalities that occurred following the ecological restoration efforts at Lake Apopka should always be considered as a cautionary note in risk assessments of potential use of contaminated sediments in shallow-water aquatic restoration. Accordingly, screening criteria should factor in both biota-sediment accumulation factors and biomagnification factors to be protective of fisheries and wildlife, and one should not simply rely on threshold effects levels that are derived to assess potential toxicity to benthic infauna.

Uncertainty and Risk Management Goals

Decision making in the face of uncertainty is inescapable. Some authors distinguish “variability,” which is inherent in natural systems (i.e., statistical variance that derives from random or heterogeneous factors) from “incertitude.” The latter stems from incomplete knowledge and is a byproduct of random error (measurement error), systematic error and subjective judgment, linguistic imprecision (vagueness) and, of course, model uncertainty (Morgan and Henrion 1990). Collection of additional data and refinement of models can reduce incertitude. Alternatively, although we can establish bounds for the inherent variability, there is no way to rid the process of it completely.

Depending on the hazard (e.g., incidence of cancers in humans versus acute toxicity to sediment biota), risk managers may tolerate greater incertitude. Ultimately, the question reduces to how much uncertainty managers are willing to tolerate for a given hazard (consequences of making the wrong decision, see Bridges et al. 2006) and, as a corollary, how many resources they are willing to devote to reduce uncertainty.

In human health assessments, the risk management goal is to protect the individual — even the high end or what is known as the reasonable maximal exposure (RME) individual (often taken to be the 90th or 95th percentile). By comparison, in most ecological assessments, the risk management goal is to guard against population-level effects by protecting some hypothetical "average" individual or what is called the central tendency exposure individual (i.e., the 50th percentile). However, where the ecological receptor is a threatened or endangered species, it may be more appropriate to protect the RME individual. Nonetheless, there remains no established default decision threshold for identifying what level of risk is either clearly acceptable or clearly unacceptable for a reasonable maximum exposure (Suter 1993; USEPA 1999); nor should there be for several reasons. First, use of "bright lines" (i.e., single value thresholds or decision criteria such as screening values above which the risk is considered unacceptable by definition) presumes a level of accuracy in both exposure models and effects measures that does not exist in practice (NRC 1994; Presidential/Congressional Commission on Risk Assessment and Risk Management 1997). Risk estimates must be interpreted relative to the assumptions on which the assessment was based. Clearly, the more conservative the exposure and effects assumptions, the greater the upper boundary for tolerable risk. Under certain circumstances, it may also be necessary to differentiate and accept some level of background risk and assess only the excess risk due to some new action (e.g., arsenic levels above the risk-based criteria but below background levels).

It must be understood that this assessment was completed to support, not direct, decision making. Decision makers have the ultimate responsibility — which must not be "abrogated" (Hope 2007) — of reaching a decision not only based on science but also balanced against a variety of potentially competing issues (e.g., social, political, legal, etc.).

Data Evaluated to Assess Sediment Quality

This evaluation of Baltimore Harbor and approach channel sediment quality has at its core a large number (46) of studies for individual dredging projects. Included are considerable data on contaminant levels in sediments collected in and around Baltimore Harbor that have been provided to the team by Maryland Environmental Services and other sources. These data were originally collected to meet differing goals for projects conducted over a relatively wide spatial and temporal range. Use of secondary data (sometimes referred to as "found data") can sometimes result in significant uncertainties. Although much of the data were collected using rigorous and reliable protocols that satisfied data quality objectives specific to the original program goal, many datasets did not meet the needs of the present assessment. Further, many of the datasets were not available in raw form, at least electronically, or the associated metadata were insufficient to allow analysis. Because of this, all datasets were first screened to assess their suitability for the purposes of the team.

Dataset Utility Criteria

The team employed a series of criteria to assess the utility of data provided, including:

- **Age of Dataset.** The available datasets represent samples taken to meet a variety of objectives over several decades. Datasets for samples collected prior to 1985 were rejected because results would not be representative of the present pollution climate of the sediments (which should be improving over time through circulation/ transport processes and biogeochemical activity). In addition, analytical techniques employed prior to 1985 were inferior to those used more recently. Older data may be used to make some judgments regarding temporal trends in sediment contamination for given sites in and around Baltimore Harbor, but this must be done with caution because the data were not likely collected with that purpose in mind. This makes inter-comparability of data using diverse analytical procedures among the various studies problematic.

- **Methodology.** Datasets were also rejected from further consideration if the analytical methodology was deemed inadequate (partial digestion, poor detection limits, etc.) and if there were insufficient analytes to allow for a reasonable assessment of the validity of the data. For example, in the case of metals, elements such as iron and aluminum should reflect natural abundances and not be affected by significant human artifacts. For organic contaminants, ancillary data on total organic carbon was considered useful.

- **Quality Assurance/Quality Control.** To be useful, datasets needed sufficient information on quality assurance and quality control. This includes measures used in acquiring data to support its validity, such as blanks, matrix spike recoveries, and duplicates.

- **Representative Sediment Samples.** The team considered it essential that the sediment sample be representative of the material potentially removed during dredging; in practice, it is often recommended that sediment cores extend at least one foot below maximum proposed dredge depth (NYSDEC 2004). Those not meeting this condition were rejected from further consideration.[1]

Once the suitability of the dataset was established, results, where appropriate, were compared to environmental quality standards to enable a prediction of the potential risk associated with reuse of sediments with given levels of contaminants. Appendix Table A1 details the data sources and the assessment the team made with respect to their utility for examining the levels of metals and organic contaminants in sediments.

Analyzing Trends in Data

The team considered the data with respect to discerning trends in contaminant loading to harbor sediments. They concluded that the data were not usable for trend analysis. Contaminated areas such as Baltimore Harbor tend to have very heterogeneous contaminant concentrations that can vary by orders of magnitude over short distances. Therefore, it is impossible to compare sediment data collected at a specific site in the late 1990s to data supposedly collected at the same site years later. In actuality, the sediments are not collected from the same location, but within meters of each other. Consequently, one may be looking at spatial heterogeneity rather than a true trend. We could ignore the problem of heterogeneity noted above and interpret data from the same area to indicate that levels of a particular contaminant have changed. However, these changes could be simply due to dredging and removal of previously contaminated sediments rather than a change in inputs of a particular contaminant. Finally, the team noted that great care needs to be exercised in using any trend data to indicate that a decline in legacy pollutants could be interpreted to mean that the contaminant status of Baltimore Harbor is getting better. Without data for emerging contaminants, we would not be able to say whether the opposite case is true for these chemicals.

The preferred approach to collect appropriate trend analysis information is to obtain sediment cores in areas of accumulation and then date the cores using lead-210 and cesium-137. To the best of the team’s knowledge, there has not been a sampling plan that addresses the need for trend analysis using these appropriate methodologies. With this in mind, the team recommends that managers consider how best to implement trend studies in sampling sites slated for maintenance dredging. With a 21-year forecast for placement options, sampling every 3-4 years on a selected grid would generate that information for longer-term placement issues.

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[1] Sampling for one foot over dredged depth is typical and ensures that the potential overdredge is included in the sample. For example, in the NY/NJ harbor, the sampling is typically done to project depth, plus 2-foot overdredge, followed by separating out the bottom six inches as a separate sample. This is done because contamination is often greater at depth, and there is more concern about the sediment that remains than the sediment that is removed. Excluding the potential overdredge from typical maintenance dredging would most likely bias the sample to the high or low side since the material is typically dredged to depth at each location, rather than moving down by increments over the project footprint. If contamination increases with depth, then the sample would be biased low; if the converse were true then the sample would be biased high.

Evaluation of Existing Criteria, Standards, and Guidelines for Applicability to Dredged Material Management Decision Making

There are numerous soil and sediment quality assessment frameworks in use throughout the world. Typically, soil/sediment quality is assessed for one of the following reasons:

1. To assess need for corrective action and/or remediation (i.e., use *in situ* evaluation to locate areas of ecological or human health risk).
2. To assess risk associated with a change in land use (e.g., use of a former industrial site for residential development or an agricultural area for ecological restoration).
3. To assess risk associated with various alternatives for managing the disposal/beneficial uses of sediments dredged for navigational purposes (i.e., *ex situ* management).

The team focused on the third option while benefitting from tools developed for the other two.

A number of literature reviews and compilations have been completed recently on media specific screening values, (i.e., chemical concentration in environmental media that are used as benchmarks to predict frequency or intensity of negative biological effects (Friday 2005, Apitz et al. 2007, Buchman 2008). These screening values were developed based on a number of simplifying assumptions about the interactions between the receptor (i.e., organism) and the specific media (e.g., freshwater, marine water, freshwater sediment, marine sediments, soil) and about the presumptive pathway (e.g., direct exposure, inhalation, ingestion, biomagnification) leading to exposure (Bartley et al. 2004). Because they are highly specific, screening values should only be used with an understanding of how they were derived, the exposure pathway and receptors for which they were designed to protect, and their predictive ability (Word et al. 2005).

Compilation of Currently Available Screening Values

The team compiled criteria, standards, and guidelines from a number of sources (Appendix Tables B1-B4). Where available, the team utilized screening values that were already adopted by the State of Maryland. For example, to protect aquatic life from leaching of materials and contamination of surface water (e.g., fresh, estuarine, and salt water) the team relied on COMAR26.08.02.03-2 - Numerical Criteria for Toxic Substances in Surface Waters (MDE 2008a). For the protection of human health from potentially contaminated dredged materials used as soils, the team relied on soil standards that were developed for residential clean-up, non-residential clean-up and protection of groundwater (MDE 2008b). Where a specific criterion had not been codified by the state of Maryland, the team compiled multiple criteria from different sources and, as appropriate for a scoping-level study, used the most conservative value. For the protection of ecological health in scenarios where dredged material would be used as upland soil, we compiled U.S. EPA's Ecological Soil Screening Levels (Eco-SSL) for 17 metals and 4 organics, including metabolites and degradates (USEPA 2003, updated in 2005). Eco-SSLs were derived separately for four groups of ecological receptors: plants, soil invertebrates, birds, and mammals. These criteria were developed through a collaborative effort by a multi-stakeholder group consisting of federal, state, consulting, industry, and academic participants led by the U.S. EPA Office of Solid Waste and Emergency Response (USEPA 2003, updated in 2005). Where appropriate, the Eco-SSL explicitly consider and model the potential for bioaccumulation and subsequent biomagnification through trophic transfer. Soil screening values for the protection of plants, invertebrates, birds, and mammals were also compiled from the Oregon's Department of Environmental Quality (ODEQ 1998 and updated in 2001), the New Jersey's Department of Environmental Protection (NJDEP 2009) and from Friday (2005). The latter two were compilations from other sources including, but not limited to, the U.S. EPA, U.S. Fish and Wildlife Service, Oak Ridge National Laboratory (http://www.hsrd.ornl.gov/ecorisk/reports.html), the Canadian Council of Ministers of the Environment, and the Dutch Ministry of the Environment.

It is difficult to adequately evaluate the scientific underpinnings of a screening value that is derived from a compilation of previous compilations (see below). To screen scenarios where dredged materials might be used for aquatic habitat restoration, three sets of sediment screening values of marine sediments for the protection of benthic infauna (Long et al. 1995, MacDonald et al. 1996, Barrick et al. 1989) were compiled and evaluated. As discussed in greater detail below, these three sets of screening values were derived using different approaches resulting in different degrees of protection. To screen for possible negative impacts to ecological (e.g., fish, birds, mammals) and human receptors (e.g., general/recreational fishers and subsistence fishers) from bioaccumulation and subsequent biomagnification through trophic transfer of contaminants in dredged materials, Sediment Bioaccumulation Screening Level Values were compiled from Oregon's Department of Environmental Quality (ODEQ 2007). The derivation of those screening values is described in Appendix D of that document and involved using chemical-specific biota-sediment accumulation factors, the fraction of total organic carbon in the sediment, and the fraction of lipid in the receptor to model the sediment concentration that would not be expected to exceed acceptable tissue levels in diet for the specific receptors (either no observable adverse effect level (NOAEL) for individuals or lowest observable adverse effect level (LOAEL) for populations).

Application of Screening Values

The application of screening values must be consistent with the underlying assumptions in their derivation. Caution must also be exercised because screening values are developed using different methods, especially across different media, each with varying degrees of embedded conservatism. A recent review found screening values were not always correctly applied and often were derived from other previously published compilations that were based on outdated values (Barron and Wharton 2005).

For the purposes of this scoping-level assessment, the team compiled and applied criteria specific for the receptor in each of the exposure pathway scenarios (Table 4). However, these screening values are not offered as final criteria; development of final criteria was beyond the scope of this assessment. Several guidance documents are available for developing criteria (Chang et al. 2002, Cura et al. 2004, CCME 2006, ODEQ 2007), including criteria for *ex situ* management of contaminated dredged materials (Driscoll et al. 2002, Munns et al. 2002, USEPA/USACE 2004). Before adopting final criteria, the state of Maryland must carefully evaluate the technical basis, predictive ability, embedded conservatism, and uncertainty surrounding each screening value. As an illustration of this process, the ensuing section provides details on the development of different sediment screening values and the team selection rationale.

The Effects Range-Low/Effects Range-Median (ER-L/ER-M) sediment screening value (Long et al. 1995), the Threshold Effects Level/Probable Effects Level (TEL/PEL) sediment screening value (MacDonald et al. 1996) and the Apparent Effects Threshold (AET) sediment screening value (Barrick et al. 1989) were all derived from compilations of toxicity test results and benthic infauna analyses for marine and estuarine sediments, but each through a different approach. ER-L and ER-M values were derived from effects data sets of toxicity tests and benthic community surveys, representing the 10th and 50th percentile of effective concentrations of each chemical in the dataset, respectively (Long et al. 1995). The derivation of TEL and PEL values included both effects and no-effects datasets of toxicity tests and benthic community analyses. The TEL represents the geometric mean of the 15th percentile concentration of the effects dataset and the 50th percentile concentration of the no-effects dataset for each given chemical, and the PEL represents the geometric mean of the 50th percentile concentration of the effects dataset and the 85th percentile concentration of the no-effects dataset (MacDonald et al. 1996). AET values have been determined using effects and no-effects datasets, with the AET being the highest detected concentration of a chemical in sediments at which no statistical effect is observed for a given biological indicator. Confirmation was done by verifying if statistically significant effects occurred at concentrations higher than the AET (Barrick et al. 1989).

The ER-L and TEL values represent concentrations of chemicals below which adverse biological effects are not expected (i.e., are rarely observed). The ER-M and PEL values represent concentrations of chemicals above which adverse biological effects are likely (i.e., frequently occur). Values between the ER-L and ER-M, or the TEL and PEL, represent concentrations at which adverse biological effects are expected to occasionally occur (Long et al. 1995; MacDonald et al. 1996). The AET is the concentration of a chemical in the sediment above which adverse effects to the biota are always expected for a particular biological indicator (Barrick et al. 1989).

ER-L and ER-M values, including those originally derived by Long et al. (1995) and some additional values added to the NOAA SQuiRT tables (Buchman 2008), are available for a total of 32 chemicals or groups of chemicals, including nine trace metals, total PCBs, DDT and its derivatives, and two additional organochlorine pesticides, 13 polynuclear aromatic hydrocarbons (PAHs), and three classes of PAHs (low molecular weight, high molecular weight, and total PAHs). TEL and PEL values are available for the same chemicals, with some additional pesticides, metals, a phthalate, a PCB, and a dioxin, including original values from MacDonald et al. (1996) and additional values from Buchman (2008). AET values are available for 70 compounds or groups of compounds, including a broader variety of metals and organics than the other two guidelines (Buchman 2008).

Given the method by which the TEL and PEL were derived, including effects and no-effects datasets, they represent a more robust set of SQGs and tend to be more conservative (i.e., more protective of the aquatic environment). Therefore, we recommend the use of the TEL to establish acceptability of dredged material from Baltimore Harbor for aquatic restoration uses. For chemicals for which TEL values are not available, the use of the next most conservative sediment quality guideline shown in Appendix Tables B1-B4 is recommended for screening purposes. However, it is important to note that while numerical sediment quality guidelines are useful tools for environmental management, they do not preclude the need for site-specific considerations (Nipper 1998).

Mixtures of Different Contaminants

An often-ignored source of uncertainty occurs when environmental media contain a mixture of contaminants. In most cases, screening values are developed for individual contaminants as if they occurred in isolation in the environment. More often than not, however, contaminants occur as mixtures. The effects of chemical interactions on the toxicity of mixtures are not well understood. In assessing potential impacts, the mode of action (MOA) of each potential toxicant should be considered when assessing the potential for chemical interactions such as additivity, antagonism, synergism, and potentiation. The often-invoked simplifying assumption that the toxicity of a combination of toxicants will be additive may have some degree of validity only where those toxicants share a common MOA and interact with the same site of action. Assessing the interactive effects of mixtures of toxicants that do not share a similar MOA or site of action remains a source of considerable uncertainty (for other sources of uncertainty, see Vorhees et al. 2002).

Assessing Dredged Material for Reuse

Regardless of the end reuse, assessing the potential suitability of dredged sediments involves two steps: (1) an evaluation of the level of contamination of the sediment to be dredged and (2) an evaluation of how the material will be reused and the levels of contaminants which likely pose a risk to relevant resources or environmental receptors (see "The Context for Risk Assessment," p. 15).

The first step requires data on levels of contaminants in the sediments to be dredged and an evaluation relative to defined criteria. With these considerations, the team conducted a screening level assessment based on criteria detailed earlier for metal and organic contaminants (see "Evaluation of Existing Criteria, Standards, and Guidelines for Applicability to Dredged Material Management Decision Making," p. 27). The team criteria are useful as a screening tool for the purposes of this assessment and may be appropriate in cases where the hazard is not "unacceptable" (even where the probability of occurrence or exposure is not "low"). One example might be use of dredged material as daily cover in a lined landfill. In many cases, however, decision making must be made on a case-by-case, site-specific basis.

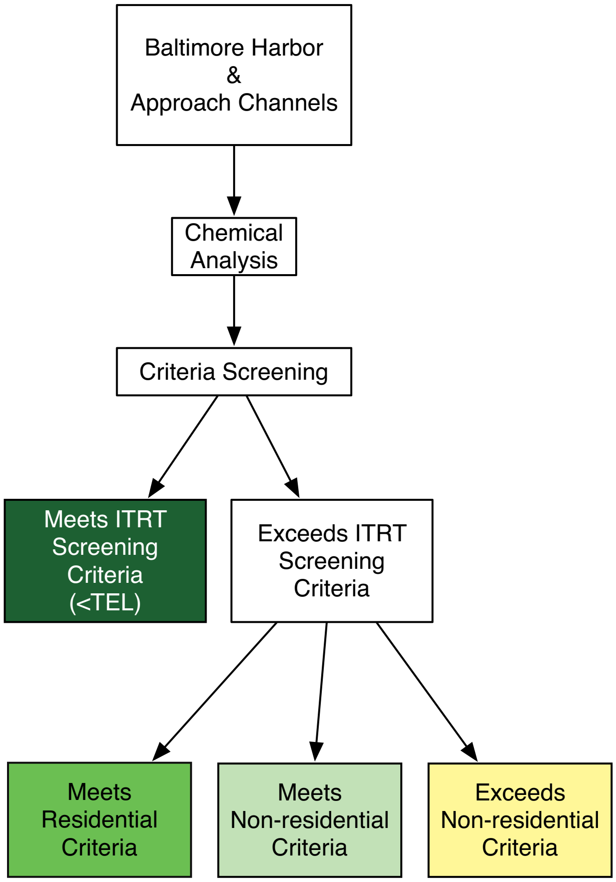

Figure 4. Independent Technical Review Team Screening Level Assessment Process.

The team sediment suitability screening process (Figure 4) recognizes that the contaminant concentration threshold to be applied depends on the risk associated with a particular reuse. The most straightforward innovative reuses, for which there may be an applicable set of standards for contaminant concentrations, are those described by the Innovative Reuse Committee (see Table 3).

NOTE: Tables 6 and 7 and Figures 5-22 are located in a separate section beginning on p. 57.

Maryland's existing soil clean-up criteria list acceptable levels for contaminants (both inorganic and organic) in residential and non-residential soils. The team focused on end reuses for fill material in remedial activities on landfills and brownfields where state standards for residential and industrial soil cleanup are applicable and contaminant concentrations in the sediments can be used as the main criteria for assessing their potential suitability. It was clear that assessing the suitability for other reuses, such as land amendment for agricultural use and habitat restoration, would require additional steps that address specific transfer pathways to environmental receptors (see "Evaluation of Existing Criteria, Standards and Guidelines for Applicability to Dredged Material Management Decision Making," p. 27).

If these criteria are to be applied specifically to dredged material reuse, there are, however, several issues that must first be addressed. These issues may differ among the categories of contaminants and will be discussed below for metals and organic contaminants.

Metals

The team employed a "weight of evidence" approach to using existing criteria to arrive at reasonable screening levels for potential dredged material upland reuse with regard to metal contamination. This provides a set of screening criteria used to assess Baltimore Harbor sediments for potential innovative reuse in non-agricultural upland applications.

Regarding metal contaminants, Table 6 lists relevant environmental criteria along with data on the natural abundances of those contaminants of most concern. Metals such as aluminum, manganese, and iron are so naturally enriched in soils that they were not considered, since they are unlikely to influence decision making. Table 6 lists the Maryland criteria for residential and non-residential cleanup along with those for New Jersey; an EPA standard for industrial use is also provided. The process for establishing these criteria provides a starting point for evaluating the potential reuse of dredged material.

Sediments in harbors and navigation channels are primarily naturally occurring materials in which contaminants, typically from land-based activities, have accumulated. There is a rich literature on the natural abundance of the elements in natural solids. Early papers (Turekian and Wederpohl, 1961;Taylor, 1964; Taylor and McLennan, 1981) quantified average concentrations in natural crustal materials that provide the source material of metals in all natural sedimentary deposits. These values have fundamentally not changed. The literature also demonstrates that surface geochemical processes that lead to the formation of natural aquatic sediments do not fractionate metals significantly, so that elemental ratios remain similar to those of crustal abundances. This fact has facilitated the ability to discriminate natural from metal-contaminated sediments (Windom, et al., 1989; Loring, 1990; Weisberg et al., 2000). The weathering process does, however, lead to natural enrichment of metals in suspended sediments, which ultimately supply bottom sediments; and average concentrations of metals in this material, as well as in oceanic sediments, is also well documented (Martin and Whitfield, 1983). Metals are generally more concentrated as the mean grain size of the material decreases, the result of naturally occurring metals being associated primarily with clay minerals. The metal concentrations given in Table 6 for average continental rocks, natural soils, and suspended sediments should be reasonably representative of the expected range of metal concentrations in the sediments if no contaminants were added.

With this considered, it is apparent that the Maryland criteria for some of the metals (e.g., arsenic, chromium, and vanadium) for residential and non-residential soil clean-up are lower than the concentrations characteristic of natural materials, such as average soils. This may be overly restrictive in the context of innovative reuse of certain dredged sediments.

Using the natural abundances, along with soil criteria for New Jersey and EPA Region 3 that are similar to those in Maryland, a modified set of criteria was prepared by the team for dredged material upland reuse. This is shown in two rows, residential and non-residential, at the bottom of Table 6. By using naturally observed soils metals concentrations as the minimum, the team selected reuse concentrations from New Jersey, EPA, or those already in place in Maryland as reasonable values over naturally occurring concentrations. This rationalization only affected criteria for arsenic, chromium, cobalt, and vanadium.

A criterion based on threshold effects levels (TELs), discussed elsewhere in this report, allows for the assessment of the suitability of harbor sediments for aquatic habitat restoration and the most restrictive upland reuses. These criteria are noted at the bottom of Table 6. For chromium, copper, and nickel, the TEL criteria are unreasonably low (52.3, 18.7, and 15.9 mg/kg, respectively) compared to soil abundances (70, 30, and 50 mg/kg, respectively) and natural coastal marine sediments. Therefore the value for natural soils was used for these metals in the screening presented below. For reuses where biological receptors become the focus of risk, the team employed criteria based on biological effects (hence TELs).

Organic Contaminants

The team screened subsets of existing sediment organic contaminant data relative to several criteria. These included the State of Maryland criteria for residential and non-residential soil clean-up standards, and aquatic sediment threshold effects levels (TELs) to determine potential suitability of sediments for habitat restoration.

In a limited number of cases where no Maryland soil cleanup criteria or TEL data existed for a particular group of contaminants, the data were assessed relative to the State of Oregon standards for bioaccumulation in humans that subsistence feed on fish exposed to contaminated sediments (ODEQ 2007). This third assessment provides additional information regarding the suitability of sediments for habitat restoration.

Classes of organic contaminants examined included polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), polychlorinated dibenzo-p-dioxins (PCDDs) and furans (PCDFs), volatile organic contaminants (VOCs), semivolatile organic contaminants (SVOCs), and pesticides. Table 7 lists the relevant environmental criteria for various components of these classes of organic contaminants.

Sediment Screening for Potential Reuse

Using the criteria developed above, the team evaluated existing data for metal concentrations in sediments from channels in and around Baltimore Harbor to assess the potential suitability for various types of reuse. (These data were previously screened for relevance.) The team used color-coding for contaminants in sediments to indicate four levels of potential reuse: *dark green* indicates that the contaminant level is below the TEL or natural abundance (whichever is higher) and is potentially suitable for the most stringent reuse applications; *medium green* indicates that the material exceeds the TEL or natural abundance (whichever is higher), but is suitable for residential reuse applications; *light green* indicates that the material exceeds the residential reuse application criteria, but is below the team screening criteria for non-residential (industrial) reuse criteria; and *yellow* indicates that the material exceeds the team screening criteria for industrial reuse.

The team used an approach that weights the number of criteria that are met for each sample, yielding maps that allow for a comparative evaluation of potential reuse of sediments from the different locations in the harbor. The simple weighting protocol is as follows:

- Below Thresholds Effects Level (TEL) Criteria — No chemicals measured exceed the TEL or natural abundance (whichever is higher).
- Meets Residential Reuse Criteria — At least one chemical exceeds the TEL or natural abundance (whichever is higher), but all measured chemicals are suitable for residential reuse based on the team’s screening criteria.
- Meets Non-Residential Reuse (Industrial) Criteria — At least one chemical exceeds the team screening criteria for residential reuse application, but all measured chemicals are suitable for non-residential (industrial) reuse based on the team’s screening criteria.
- Exceeds Non-Residential Reuse (Industrial) Criteria — At least one chemical exceeds the team’s screening criteria for non-residential (industrial) reuse.

The team stresses that there are a variety of possible end uses for each category. For instance, a yellow determination (“material exceeds the industrial reuse criteria”) does not mean that the material could not be reused, but instead that site-specific application information is required before a determination could be made. Table 8 applies the color-coding scheme to the initial screening criteria for innovative reuse and beneficial use presented earlier in this report.

The results of these analyses are presented in tables for the data sets with demonstrable quality, derived from appropriate analytical procedures (see “Data Evaluated to Assess Sediment Quality,” p. 25). The tables found in Appendix Tables C1-C8 list contaminant levels (metals and organics contaminants) in geographically defined sediment samples collected for specific projects. Each table is color-coded according to the scheme described above. In total, they provide a reasonable distribution in time and space to enable a baseline screening of the contamination of sediments in Baltimore Harbor and the immediate vicinity and the suitability of these sediments for potential reuse.

Table 8. Screening criteria for innovative reuse and beneficial use of dredged material.

Dredged Material Classification	Uses	Criteria
AA	Land amendment for agricultural use	Must meet the most stringent criteria, i.e., use a two-phased approach — physiochemical/bioassay screening for plant toxicity followed by a case-by-case assessment of risk of bioaccumulation and human exposure to relic (e.g., metals, PCB, pesticide) and emerging contaminants
A	Aquatic habitat restoration — i.e., salt marsh	Must meet sediment quality assessment guidelines — Threshold Effect Level (TEL); Sediment Bioaccumulation Screening Level values
B	Upland habitat restoration	Must meet ecological soil screening levels
C	Upland reclamation — i.e., fill or soil cover for residential sites	Must meet residential soil cleanup criteria
D	Manufactured topsoil for landscaping	Must not exceed residential soil cleanup requirements for concentrations in blended soil product
E	Building materials, e.g., aggregate, blocks	Must have satisfactory results from air concentration modeling of volatiles and respirable suspended particulates to protect on-site workers; in addition, must test to confirm the strength of binding and the lack of leaching
F	Upland reclamation — cover for industrial, sites e.g., mines, gravel pits, brownfields	Must meet non-residential soil cleanup criteria; groundwater protection criteria; Synthetic Precipitation Leaching Procedure Test and State's water quality standards
G	Engineering fill, e.g., base material	Must meet non-residential soil cleanup criteria; groundwater protection criteria; Synthetic Precipitation Leaching Procedure Test — and state's water quality standards
H	Fill for landfill closure cap	Must meet non-residential soil cleanup criteria
I	Fill for landfill daily cover or upland use with containment, e.g., liners and leachate collection, and cap	Must be non-toxic or hazardous as defined by Code of Maryland Regulations 26.13.02.15-19; Toxic Substances Control Act (i.e., < 50 mg/kg PCB)
J	Confined disposal facility	Data indicates dredged material does not meet criteria for higher tier classification or data are absent
K	Leave undisturbed	Case-by-case assessment shows risk of mobilization (i.e., through chemical and physical processes) is such that buried sediments should be left undisturbed if more recently deposited material is cleaner and acts as a barrier

Data compiled in tables were input to a geographic information system (ESRI ArcMap 9.3 with associated data processing done in Microsoft Excel and Microsoft Access) to generate a series of maps detailing sediment characteristics in various areas of the harbor and approach channels. Here we present maps that specifically focus on contaminant levels in harbor channels. Data for off-channel locations are summarized below. Maps for off-channel sites analogous to those shown below are found in the Appendix (Figures D1-D12).

- Potential reuse options based on application of the team's screening criteria for metal contaminants criteria only (Figures 5, 6, 7, 8).
- Potential reuse options based on application of the team's screening criteria for organic contaminants (Figures 9, 10, 11, 12).
- Potential reuse options based on application of the team's screening criteria for metals and organic contaminants together. Data for these maps come from sampling locations where both metal and organic contaminant data co-occur (Figures 13, 14, 15, 16).

For clarity, sites meeting criteria for each level of possible reuse (<TEL, Meets Residential Reuse, Meets Non-Residential Reuse and >Non-Residential Reuse) are shown separately. These maps are useful to demonstrate general findings and, as such, they represent potential reuse options for a given area based on the team's screening protocol. However, they have important limitations imposed by the spatial and temporal nature of the datasets used to generate them. The scale of the maps is designed to show general spatial trends, not highly specific locations of each sample. Therefore, when comparing maps for different designations, the colored circles may appear to be at the same site. This is most likely not the case. Individual sampling stations vary on the scale of hundreds of meters — enough to be significant with respect to the mapping program, but not visible on the scale of the maps presented here. In addition, as noted earlier in this report, contaminated areas such as Baltimore Harbor tend to have very heterogeneous contaminant concentrations that can vary by orders of magnitude over short distances. The team reiterates that these analyses are based on a compilation of historical data from studies done at different times. While the data used were deemed to be of sufficient quality for the team's assessment, they extend across approximately ten years of sampling — an important context to consider.

While a synthesis of this type is extremely useful, the maps that follow have not been designed to be of sufficient scale to make detailed management decisions. Rather, they highlight areas that could be examined with respect to potential innovative reuses. For reference, we present the original list of priority innovative reuses designated by the IRC (2007) here in Table 9. The table has been color-coded consistent with the team screening protocol to show how projected end uses link to potential areas where sediments might be dredged.

The team emphasizes that a projected innovative reuse — depending upon its level of risk — would be based on new assessments of sediment quality at the specific sites where dredging would take place.

Table 9. Technologies recommended for evaluation by the Innovative Reuse Committee (IRC 2007).

High Priority Technology	Medium Priority Technology	Low Priority Technology
Land Amendment	Lightweight Aggregate	Brownfields
Sand & Gravel Pits	Cement Filler	Compressed Blocks
Flowable Fill	Base Material	Manufactured Topsoil
Mines		Daily Cover
		Bricks

Findings for the Harbor Channels

Metal Contaminants

For metal contaminants in harbor channels the following general observations are made:

- There were no samples in the datasets reviewed by the team that were lower than the threshold effects level (TEL), eliminating land amendment reuse applications or aquatic habitat restoration (Figure 5).

- A limited number of the samples analyzed met the criteria for residential reuse applications. Based solely on the limited number of samples with limited geographic distribution that were analyzed, about 9% of the samples fell into this category (Figure 6).

- Significantly more samples met the team screening criteria for non-residential (industrial) reuse applications. Based solely on the limited number of samples with limited geographic distribution that were analyzed, about 43% of the samples fell into this category (Figure 7).

- There were a number of samples that exceeded the criteria for non-residential reuse. Based solely on the limited number of samples with limited geographic distribution that were analyzed, about 48% of the samples fell into this category. In most cases, arsenic concentrations in excess of the team's screening standard resulted in this designation (Figure 8).

- The team did a general comparison of the 1998 Federal Channel data with samples taken more recently. The analysis suggested that, with regard to metal contamination, sediments from the Federal Channel in 1998 were more contaminated than those analyzed more recently. This is not surprising because there is an expectation that contamination of the harbor should decline, due to more recent rigorous environmental controls as well as natural sorting processes. Nonetheless, the only potential reuse of these sediments would be for residential and non-residential soils.

Organic Contaminants

For organic contaminants in harbor channels the team made the following general observations:

- There were no samples in the datasets reviewed by the team that were lower than the threshold effects level (TEL) criteria, eliminating land amendment reuse applications or aquatic habitat restoration (Figure 9).
- A limited number of the samples analyzed met the criteria for residential reuse applications. Based solely on the limited number of samples with limited geographic distribution that were analyzed, about 44% of the samples fell into this category (Figure 10).
- A similar number of samples met the team's screening criteria for non-residential (industrial) reuse applications. Based solely on this limited number of samples with limited geographic distribution that were analyzed, about 41% of the samples fell into this category (Figure 11).
- There were a number of samples that exceeded the criteria for non-residential reuse. Based solely on the limited number of samples with limited geographic distribution that were analyzed, about 15% of the samples fell into this category. High levels of benzo(a)-pyrene in many areas resulted in this designation (Figure 12).

Lack of TEL data for numerous organic contaminants, combined with levels of octachlorodibenzo-p-dioxin (OCDD) that exceed the standard for bioaccumulation in humans that subsistence feed on fish exposed to contaminated sediments, indicate that sediments in the harbor should be carefully evaluated prior to use if aquatic habitat restoration becomes an option for reuse. See Appendix Table C3 and C4 and Figure 21.

Aggregated Metals and Organic Contaminants

By pooling the data for both metal and organic contaminants for all stations it is possible to generate a composite or aggregate set of maps showing the suitability of sediments for reuse applications. There were fewer stations with overlap of data for both metal and organic contaminants limiting the conclusions that the team could make. The following general observations are made:

- There were no samples in the datasets reviewed by the team that were lower than the TEL, eliminating land amendment reuse applications or aquatic habitat restoration (Figure 13).
- A single sample (1%) analyzed met the criteria for residential reuse applications (Figure 14).
- Significantly more samples met the team screening criteria for non-residential (industrial) reuse applications. Based solely on this limited number of samples with limited geographic distribution that were analyzed, about 43% of the samples fell into this category (Figure 15).
- There were a number of samples that exceeded the criteria for non-residential reuse. Based solely on the limited number of samples with limited geographic distribution that were analyzed, about 56% of the samples fell into this category (Figure 16).

Findings for Off-Channel Locations

Data for off-channel locations is summarized in Appendix Tables C1-C8. Maps of off-channel sites for all four criteria are also found in the Appendices (Figures D1-D12). We summarize these findings here (Table 10).

- Metals: With respect to metal contaminants, the team found that off-channel sites grouped into a range of possible reuse options that was very similar to that found in the harbor channels (Appendix Maps D1-D4). No sites met the most stringent reuse criteria (<TEL), with a low percentage meeting residential reuse criteria. More sites either met or exceeded non-residential criteria.
- Organics: The team found that the distribution of sites that met reuse criteria for organic contaminants in off-channel locations varied from what was observed in channels (Appendix Maps D5-D8). While no sites met the most stringent reuse options (<TEL), few sites (8%) were found that met residential reuse criteria. A greater number (32%) were suitable for non-residential reuse; however, the majority of off-channel sites examined for this study (60%) exceeded the criteria for non-residential reuse option.
- Metals and Organics: Pooled data for both metal and organic contaminants for off-channel locations were examined to generate a composite picture for those sites with sufficient sample coverage (Appendix Maps D9-D12). In general terms, the pattern for these stations was similar to that observed for organic contaminants. Almost none of the sites examined met the TEL or residential reuse criteria, and a small number met non-residential reuse criteria. The large majority of sites for which there was composite data (74%) exceeded non-residential guidelines (Table 10).

Table 10. Comparison of sites in harbor channels or in off-channel locations that meet reuse criteria for each contaminant class. All values reported as the percent of the total number of sites for each contaminant class (metals, organics or metals & organics) in channels or off-channel sites respectively.

	Metals		**Organics**		**Metals & Organics**	
Location	Channel Sites (n= 96)	Off-Channel Sites (n= 80)	Channel Sites (n= 85)	Off-Channel Sites (n= 92)	Channel Sites (n= 71)	Off-Channel Sites (n= 70)
Criteria	**%**	**%**	**%**	**%**	**%**	**%**
Below TEL	0	0	0	0	0	0
Below Residential Reuse	9	5	44	8	1	1
Below Non-Residential Reuse	43	47.5	41	32	43	25
Exceeds Non-Residential Reuse	48	47.5	15	60	56	74

Findings for Approach Channels, the Main Bay and Areas Outside the Harbor

With respect to metal contaminants, the team did not find sufficiently validated metal data outside the harbor to conduct a detailed assessment. Limited data for organic contaminants outside the harbor were analyzed and a series of wide area maps produced (Figures 17-20). It should be noted that most of the samples outside the harbor were taken from the approach channels with a small percentage derived from the Back River and mid-Bay stations. With respect to organic contaminants the team found:

- Consistent with the analysis of other sites using the team screening criteria, there were no samples in the datasets from outside of the harbor (North Point to Rock Point line) that were lower than the TEL (Figure 17).

- Of the samples screened, a significant number (~58%) met the criteria for residential use (Figure 18).

- Approximately 36% of the samples met the criteria for non-residential reuse (Figure 19).

- There were very few samples that exceeded the non-residential reuse criteria (~6%), however, the sample size was very small, limiting any conclusions the team could make (Figure 20).

Similar to findings for the harbor, limited data for approach channels and a few sites in the Bay screening revealed levels of octachlorodibenzo-p-dioxin (OCDD) that exceed the standard for bioaccumulation in humans that subsistence feed on fish exposed to contaminated sediments. See Appendix Tables C3 and C4 and Figure 22.

General Conclusions

The Independent Technical Review Team was asked to undertake several specific tasks to help the Innovative Reuse Committee understand the suitability of Baltimore Harbor sediments for reuse applications. Here we summarize the team's findings and general conclusions. More detailed guidance regarding future dredging efforts appears in the next section.

1. A summary of the status of sediment quality guidelines and criteria that may be in use regionally or nationally.

The team conducted a thorough analysis of sediment quality guidelines and criteria, as well as an assessment of relevant risk factors for innovative reuse options. These analyses were instrumental in the development of the assessment protocol used by the team in shaping and in guidance for future management decisions. The team focused on guidelines and criteria that were locally derived and used, but also reached out to find guidelines and criteria that were not available locally or to verify the validity of locally derived criteria. The team did not perform an overall evaluation of the status of sediment criteria or guideline development, as this would be beyond the scope of this effort. Nor did the team perform a critical evaluation of the criteria or guidelines that were used beyond what is discussed below with regards to natural background of metals.

2. Recommendations for scientific protocols to evaluate dredged material for its suitability for use in various innovative reuse applications.

The team has summarized a broad set of scientific protocols deemed useful for the evaluation of sediment quality for innovative reuse applications. For the purposes of the current assessment, the team developed a screening criteria based on four general classes of reuse. This was adequate to assess potential sediment quality for the suite of reuse options under consideration by the Innovative Reuse Committee. The team adopted a practical approach to develop its screening protocol and used a process consistent with that currently employed by the State of New Jersey, using Maryland soil standards where possible. The exception to this was a subset of metal contaminants. In each case, the natural (geological) background levels of these metals is higher than the Maryland soil standards. In order to complete the screening and consider potential reuse options, the team felt it was necessary to develop alternate criteria derived from an analysis of what is done elsewhere and consistent with the region's geological background. The team recommends that the Innovative Reuse Committee work closely with the Maryland Department of the Environment with respect to this issue as they move forward on implementing reuse options. In the case of a number of organic contaminants where there are no threshold effects level (TEL) criteria, it is important to consider bioaccumulation criteria such as those adopted by the state of Oregon. The team notes that dioxin concentrations in some samples both inside and outside the harbor should be considered with respect to potential reuse options.

A more detailed compilation of criteria — consistent with what is employed in other parts of the United States — was developed and provides guidance for evaluation of sediment quality for additional innovative reuse and beneficial use (Table 8). The team concluded that for the purposes of the current assessment, the use of threshold effects level (TEL) criteria provided an appropriate initial screen for reuse options with higher potential risk. While no sites met the TEL criteria in the current assessment, additional sites that do could emerge with more sampling. At that point, soil criteria (as opposed to TELs specifically related to sediments) should be brought into play for screening level assessment of upland reuse. Such criteria include the U.S. EPA's ecological soil screening levels, the State of Oregon's soil screening values, and those compiled by Friday (2005) or the State of New Jersey (see also Table 4).

3. *A characterization of the sediment quality (physical, chemical, and biological) in the port's shipping channels and the adequacy of information available for that purpose.*

The team used studies that met minimum criteria with respect to analytical methodology, QA/QC, and, importantly, sampling that was representative of what would be dredged in a given project. The team concluded that there were a number of datasets that sufficiently met these criteria to provide an adequate scoping assessment of sediment suitability. The team emphasizes that there are, at present, several highly relevant and detailed syntheses that provide guidance on sampling and analytical methodologies that should be considered as a basis for planning future characterizations of sediments (Best et al. 2001, Bridges et al. 2008, Great Lakes Commission 2004, NYDEC 2004, USEPA/USACE 2004).

The team's scoping assessment and mapping protocol revealed that Baltimore Harbor contains a number of sites with a range of potential reuse options. The team concluded that none of the sites for which there was available data met the TEL standard and, therefore, harbor sediments have some limitations regarding reuse options with the highest risk factors. Land amendment (e.g., agricultural) was not considered as a viable reuse option by the team. As stated previously, a number of concerns were raised with regard to land amendment including the biogeochemical characteristics of estuarine sediments (i.e., pH, sodium, chloride and sulfate) that can have highly adverse impacts and lead to soil infertility. The greater risks were associated with the completed exposure pathways to humans (Table 4). In addition, the team notes that additional data regarding emerging contaminants (e.g., brominated and fluorinated organics) will need to be collected if land amendment is to be considered. The team also emphasizes that if sites for aquatic restoration are identified in future assessments, additional criteria (e.g., bioaccumulation) need to be considered as well.

Many of the sites in the datasets analyzed meet criteria for residential or non-residential reuse options (see Figures 6, 7, 10, 11, 14, 15). By far the majority of these met the latter criteria. The team notes that most innovative reuse options under consideration should be regulated using the non-residential criteria. The data also suggest that the currently dredged channels are most suitable for innovative reuse. It is important to note, however, that much of the data used for the team's analysis came from channel surveys. The team did not find data in the applicable datasets that indicated that channel sediments are too hazardous to be dredged.

The scoping assessment also revealed that there were numerous sites that exceeded the non-residential reuse criteria. The distribution of these sites was complex and locations were found across most of the harbor. The screening assessment used by the team was designed to identify sites that exceed the non-residential reuse criteria. With that in mind, exceeding the non-residential criteria does not preclude certain innovative reuses, especially where engineering and institutional controls, as well as existing site conditions and proposed final end use, make using them appropriate. Therefore, the extent to which sites exceed criteria is important and needs to be evaluated on a case-by-case basis. The team notes that in some cases sediments chiefly outside the currently dredged channels (see below) may not be suitable for innovative reuse. In these cases, appropriate disposal, or leaving sediments in place, may be the appropriate management decision.

4. A comparison of sediment physical, chemical, and biological quality in harbor channels and the main Bay channels including the potential for innovative reuse/ beneficial uses of these sediments.

The team found limited data to make comparisons between Baltimore Harbor and main Bay channels — those that were found were restricted to information on organic contaminants. Examination of the maps revealed that no sites, neither inside nor outside the harbor, had organic contaminant levels that were less than the threshold effects level (TEL) criteria. A comparison of the maps does show that a greater percentage of the sites outside the North Point-Rock Point line met the criteria for residential applications and that a smaller percentage exceeded the criteria for non-residential reuse. Should this finding remain consistent when re-sampled, it may indicate that the sediments outside the harbor will have a greater potential for innovative reuse than those inside the harbor. An important caveat with respect to these analyses is that most of these sites outside the harbor were associated with approach channels. A greater number of sites inside the North Point-Rock Point line were taken at locations that were not in channels. This is especially true with respect to those sites that exceeded the non-residential reuse criteria (compare Figures 12 and 20). These results emphasize the challenge with using historical data derived from studies with diverse scientific goals. Accordingly, the team must reiterate its strong endorsement of the need for project-specific, site-by-site analyses as the basis for all decisions regarding innovative reuse of dredged sediments regardless of whether projects occur inside or outside the legislatively defined boundaries for Baltimore Harbor.

5. An assessment of trends in the quality of sediments deposited in and dredged from harbor channels over time and of any differences between the contamination found in legacy sediments and sediments recently dredged from maintenance channels.

The team concluded that the data were not usable for trend analysis. While very useful, the studies analyzed by the team simply do not lend themselves to a coherent trend analysis. This is due in part to variations in study intent and design, significant changes in analytical technique, and the inherent spatial heterogeneity of sediments. A cursory examination of Federal Channel data for metal contaminants suggests some improvement in sediment quality since 1998 (data not shown). However, the team recommends that managers work closely with the scientific community to consider how best to implement trend studies.

6. A list of considerations regarding the value of formal chemical-specific limits or guidance versus the use of a case-by case, site-specific process for assessment of sediment quality.

The team concluded that the use of any sediments from a specific site must be evaluated on a case-by-case basis using appropriate guidelines and analytical procedures — and with a clear understanding of the risk factors involved with the projected reuse option. The final section of this report summarizes the team's guidance, focused on decision support that adopts this approach.

Guidance for Future Sediment Management Decision Making

The retrospective analysis conducted by the team provides a basic context for understanding the suitability of sediments for various end uses. The team stresses, however, that the use of any sediments from a specific site must be evaluated on a case-by-case basis using appropriate guidelines and analytical procedures. Here we present a decision matrix to help inform this process (see Figure 23, p. 49).

Note that at least one aspect of sediment management decision making for the harbor and its approach channels has been set legislatively: the inner/outer harbor boundary. Material dredged west of this line must be managed in a confined manner, while material dredged from the east may be evaluated for certain restrictive uses. While there may be other management options for Baltimore Harbor sediments that are scientifically defensible, the decision tree presented here is based on the assumption that this spatial criterion will continue to be used. However, the matrix could be used to evaluate material “inside” the harbor material for more restrictive uses simply by entering the matrix from the “outside” the harbor side.

This approach creates four different levels of sediment targeted for upland innovative reuse (Table 8). These include unrestricted upland use (dark green), and two levels of restricted upland use (medium and light green for residential and non-residential reuse). The remainder of the sediment inside the harbor would fall into one additional category (yellow): material that must be confined, or material that should not be dredged at all. For existing channels, only material that cannot be reused should be targeted for confined disposal. It is possible that some of the material that exceeds the upland placement criteria could be used safely if the placement site was properly constructed, managed, and restricted (e.g., sites that have sophisticated engineering controls such as leachate collection, caps and liners, slurry walls, etc. that eliminate contaminant migration pathways). Institutional controls such as deed restrictions and careful recordkeeping are also prudent in these situations to ensure that future land owners and regulators are aware of the nature of the materials placed at the site.

The team did not find data in the applicable data sets that indicated that any of the sediments in currently dredged areas are too hazardous to be dredged. However, given some of the data available in off-channel areas, the team recommends that sediment in areas proposed for new channels, or for channel deepening or widening, should be carefully examined during the design process to ensure that the sediments that will either be removed or exposed will have an appropriate management option and will not result in undue environmental harm during dredging. It is possible that some of these sediments would require special management or particular techniques during either dredging or disposal. The team did not specifically identify or evaluate these sediments.

While the team process was suitable for screening the large dataset provided, it would not be appropriate to use this process for decision making on specific projects. The first step in determining appropriate management options for a particular dredging project would be to evaluate the historical database. If data exist that show that the material has either always been clean, or always been contaminated, this information can be used to decide what the ultimate management goal might be. For example, a site that has been historically clean might be targeted for evaluation for use in habitat restoration, or unrestricted beneficial or innovative reuse. It would not be a wise use of time or resources, however, to evaluate a historically contaminated site for these uses. Rather, one should proceed toward the goal of a more restrictive use or confined disposal. This screening step is analogous to what the team performed to produce this report.

The second step would be to design a sampling program to evaluate the material proposed to be dredged. This sampling program should be designed using the historical database and any data that may be available regarding outfalls, spills, or other potential sources of contamination. Sampling equipment, frequency, depth, compositing scheme, and the target analyte list will also be informed by historical data. The type of analysis required will be determined by the proposed management option(s). Bulk sediment chemistry, elutriate, or synthetic leachate tests can all provide valuable information.

Careful evaluation of any stratification in the sediment bed is important, especially in new work dredging. This information may suggest stratified management options for different portions of a given work site. Some regulatory programs require that the bottom six inches of cores be evaluated separately in order to show what contamination might be exposed by a new dredging project (NJDEP 1997). If the sediments will be amended with pozzolans or other stabilizing agents before placement, bench scale batches should also be analyzed along with the bulk sediment. Synthetic leachate analysis should also be conducted on amended samples, if amending is anticipated in the field. The analysis of the amended sediment allows for consideration of both the sediment and the amendment at the same time, and ensures adequate evaluation of changes in contaminant mobility caused by the pozzolan-sediment interaction. In most cases, this will show that the mobility has decreased significantly due to the amendment.

The Target Analyte List (TAL) should be based on the criteria available for comparison. When MDE cleanup standards (MDE 2008b) are used for decision making, only those contaminants that have criteria need be analyzed for sediment proposed for upland placement as fill. However, for more restrictive uses, a more expansive TAL might be desirable. In some cases, site-specific historical information may make it prudent to require additional analyses. Care should be taken to avoid requiring or performing analyses against which there are no criteria to base decisions. It is also important to ensure that the analyte reporting is in a form consistent with the criteria (i.e., Total PCBs vs. PCB Aroclors vs. PCB congeners).

Chemical data would then be evaluated against the appropriate criteria, specific to the proposed end use. For material from inside the harbor, where upland innovative reuses such as land fill or capping are anticipated, the appropriate criteria are the 2008 MDE soil cleanup criteria evaluated against samples of amended dredged material. In cases where groundwater contamination is a concern, these data can be used to ensure that leachate meets groundwater quality standards. In some cases, however, engineering controls installed during the remediation will eliminate the leachate pathway. If leachate data is not available, bulk sediment or amended sediment data can be evaluated against maximum contaminant levels (MCLs) for protection of groundwater. Elutriate data is appropriate only for evaluation of in-water placement options or upland confined disposal facilities with passive dewatering and can be compared to Maryland water quality standards.

Under certain scenarios, environmental variables affecting a contaminant's bioavailability are too numerous and convolved to rely on screening values. In particular, our ability to forecast the potential for biomagnification and exposure to higher trophic level receptors is often constrained. Additional modeling and risk assessment will be required in those cases. Tools for such modeling are already available. One example is the spreadsheet tool, TrophicTrace, developed by the U.S. Army Corps of Engineers to assist managers in making informed management decisions when selecting appropriate management alternatives for dredged material where contaminants have the potential to biomagnify (http://el.erdc.usace.army.mil/trophictrace/).

Where the degree of uncertainty is too great, biological assays (e.g., sediment toxicity identification evaluation, seed germination tests, plant growth screening tests; Sturgis et al. 2001, Munns et al. 2002, USEPA 2007) and monitoring are highly recommended. As identified in Tables 4 and 8, sediment/soil quality guidelines are only one tool, Elutriate Tests, Synthetic Precipitation Leaching Procedure (SPLP) and air dispersion models are some examples of the numerous other tools that will need to be brought to bear for scientifically credible risk-based assessments.

It may be appropriate to consider the volatilization potential of bound contaminants when permitting a sediment processing or placement site. While air quality is not likely to be impacted outside of the site, exposure of the workers should be considered and appropriate protective measures taken to ensure their long-term health and safety when processing contaminated sediments. If appropriate, limits could be set for a processing or placement site on an annual weight basis, or on a sediment concentration basis.

In cases where the non-residential criteria are exceeded, the management options do not necessarily have to be limited to confined disposal. A site-specific risk assessment could be used to determine appropriate criteria to evaluate sediment. This would result in site-specific criteria, where sites with more engineering controls or less sensitive end uses would be able to take more contaminated sediments. Sediments that fail to meet the criteria for any of the available upland sites would need to be either disposed of in a confined facility, or treated using decontamination technologies. Decontamination techniques such as thermal desorption, chemical oxidation or sediment washing can be used to create artificial aggregates, manufactured soils, blended cement, or products such as brick or tile. The utility and costs of these techniques have been discussed by the IRC (2007).

For material from outer Baltimore Harbor, where contaminant levels have historically been low, certain restrictive beneficial uses are possible. However, more extensive testing and analysis will need to be conducted in order to show that the uses are protective of human health and the environment. The team used screening level criteria to evaluate the existing database for potential uses. While this screening could also be used for actual project evaluations, it is preferable to perform either a site-specific risk assessment or toxicological/bioaccumulation tests, or both. A site-specific risk assessment could be used to develop criteria for comparison of bulk sediment and elutriate data from projects proposed for either aquatic restoration or land amendment sites. The USEPA and USACE have developed batteries of toxicological tests for evaluation of sediments proposed for in water placement (U.S. EPA 1998). Data from these tests could also be used to evaluate material proposed for aquatic restoration. Note that the results from bioaccumulation tests would still need to be evaluated against site-specific tissue criteria.

Overall, we propose four categories for the management of Chesapeake Bay sediments. Three of the categories would divide the material for upland or aquatic beneficial use and innovative reuse ranging in quality from upland industrial sites to land amendment. Each successive category requires that the sediment meet more stringent criteria. For material that does not meet the lowest upland innovative reuse criteria, the only options are confined disposal or sediment decontamination. It logically follows that if disposal options are not available, or the material proposed exceeds criteria for all options, then the sediment should remain in place until appropriate management options have been developed.

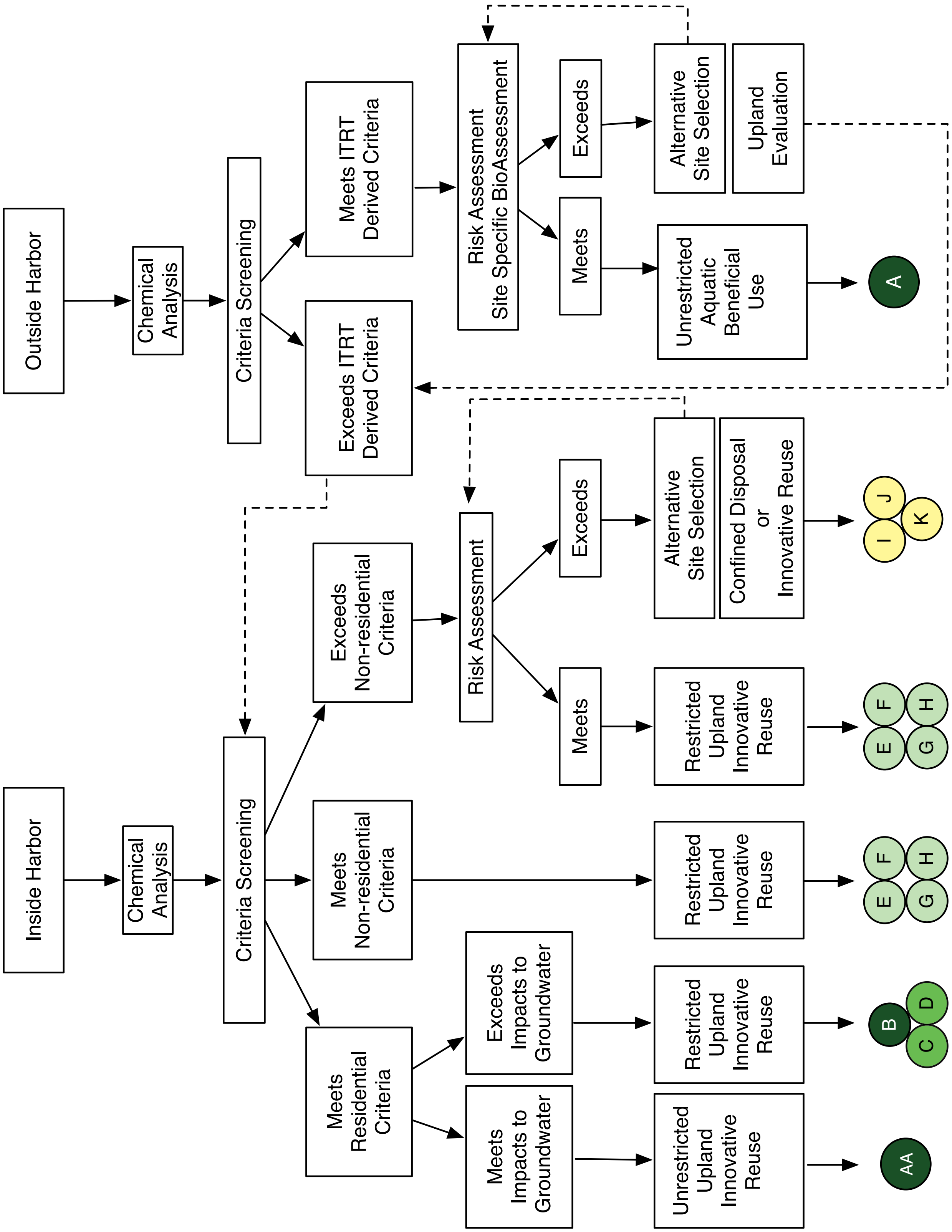

Figure 23. Decision matrix for case-by-case assessment of sediments for innovative reuse.

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Assessment and Criteria

Tables and Figures

Table 6. Comparison of Standards for Metal Concentrations and ITRT Scoping Assessment Criteria for Metals (all values mg/kg).

	Al	Sb	As	Ba	Be	Cd	Cr	Co	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Tl	Sn	V	Zn
Standards																				
MD Residential Clean up	7800	3.1	0.43	1600	16	3.9	23		310	5500	400	160	2.3	160	39	39	.55	4700	7.8	2300
MD Non-Residential Clean up	100000	41	1.9	20000	200	51	310		4100	72000	1000	2000	31	2000	510	510	7.2	61000	100	31000
NJ Residential Soil Clean up	NA	14	20	700	1	1	NA	NA	600	NA	400	NA	14	250	63	110	2		370	1500
NJ Residential Direct Contact Soil Rem.	78000	31	19	16000	16	78		1600	3100		400	11000	23	1600	390	390	5		78	23000
NJ Non-Residential Soil Clean up		340	20	47000	1	100	NA	NA	600	NA	600	NA	270	2400	3100	4100	2		7100	1500
NJ Non-Residential Direct Contact Soil Rem.	NA	450	19	59000	140	78		590	45000		800	5900	65	23000	5700	5700	79		1100	110000
EPA Region 3 Industrial Soil RBC's		40.9	1.91		204.4	51.1	306.6		4088	30600	1000	2044	30.66	2044	511	511	7.15	61320		30660
Natural Abundances																				
Continental Rocks	69300	0.96	7.9	455	1	0.2	71	13	32	35900	16	720		49	0.5	0.07	1	2	97	127
Soils	71000	1	6	500		0.35	70	8	30	40000	35	1000	.1	50		0.05			90	90
Riverine Suspended Sediments	94000	1	5	600		1	100	20	100	48000	100	1050	.1	90		0.07			170	250
Marine Sed. Quality Standards																				
TEL			7.24			.68	52.3		18.7		30.24		0.13	15.9		0.73				124
PEL			41.6			4.21	160.4		108.2		112.18		0.696	42.8		1.77				271
ITRT Criteria																				
ITRT TEL			7.24			0.68	70		30		30		0.13	50		0.73		0.048		124
Residential		3.1	20		16	3.9	70	8	310		400		2.3	160	39	39	0.55	4700	90	2300
Non Residential		41	20		200	51	310	8	4100		1000		31	2000	510	510	7.2	61000	100	31000
Exceeds Non-Residential Use		>41	>20		>200	>51	>310	>8	>4100		>1000		>31	>2000	>510	>510	>7.2	>61000	>100	>31000

Table 7. Independent Technical Review Committee Screening Criteria for Organic Compounds.

PAHs	**Units**	**<TEL**	**<MD Residential Soil Clean Up Criteria**	**<MD NonResidential Soil Clean Up Criteria**	**>MD NonResidential Soil Clean Up Criteria**	
2-methylnaphthalene	µg/kg		<31,000	<410,000	>410,000	
Acenaphthene	µg/kg	<6.7	<470,000	<6,100,000	>6,100,000	
Acenaphthylene	µg/kg	<5.9	<470,000	<6,100,000	>6,100,000	
Anthracene	µg/kg	<47	<2,300,000	<31,000,000	>31,000,000	
Benzo(a)anthracene	µg/kg	<75	<220	<3,900	>3,900	
Benzo(a)pyrene*	µg/kg	<89*	<22	<390	>390	
Benzo(b)fluoranthene	µg/kg		<220	<3,900	>3,900	
Benzo(ghi)perylene	µg/kg		<230,000	<3,100,000	>3,100,000	
Benzo(k)fluoranthene	µg/kg		<2,200	<39,000	>39,000	
Chrysene	µg/kg	<108	<22,000	<390,000	>390,000	
Dibenzo(a,h)anthracene	µg/kg	<6	<22	<390	>390	
Fluoranthene	µg/kg	<113	<310,000	<4,100,000	>4,100,000	
Fluorene	µg/kg	<21	<310,000	<4,100,000	>4,100,000	
Indeno(1,2,3-cd)pyrene	µg/kg		<220	<3,900	>3,900	
Naphthalene	µg/kg	<35	<160,000	<2,000,000	>2,000,000	
Phenanthrene	µg/kg	<87	<2,300,000	<31,000,000	>31,000,000	
Pyrene	µg/kg	<153	<230,000	<3,100,000	>3,100,000	
** Tel > MD residential soil criteria; lower value used for screening criteria*						
PCBs	**Units**					**>OR Sediment Standard for Bioaccumulation by Humans**
Bz 77*	µg/kg					>0.0064
Bz 105*	µg/kg					>0.021
Bz 118*	µg/kg					>0.026
Bz 126*	µg/kg					>0.0000062
Bz 156	µg/kg					>0.026
Bz 169*	µg/kg					>0.000021
Total PCBs (nd=0)	µg/kg	<22	<320	<1400	>1400	
Total PCBs (nd=1/2mdl)	µg/kg	<22	<320	<1400	>1400	
** MDL for individual congeners in most cases exceed the Oregon Sediment Bioaccumulation Screening Level Values for subsistence feeding by humans.*						

Table 7, continued.

PCDDs and PCDFs	**Units**					**>OR Sediment Standard for Bioaccumulation by Humans**
2,3,7,8-TCDD*	ng/kg					>0.0011
1,2,3,7,8-PECDD*	ng/kg					>0.034
1,2,3,4,7,8-HXCDD*	ng/kg					>0.34
1,2,3,6,7,8-HXCDD*	ng/kg					>0.34
1,2,3,7,8,9-HXCDD*	ng/kg					>0.34
1,2,3,4,6,7,8-HPCDD	ng/kg					>85
OCDD	ng/kg					>2800
2,3,7,8-TCDF*	ng/kg					>0.094
1,2,3,7,8-PECDF*	ng/kg					>0.31
2,3,4,7,8-PECDF*	ng/kg					>0.0037
1,2,3,4,7,8-HXCDF*	ng/kg					>0.34
1,2,3,6,7,8-HXCDF*	ng/kg					>0.34
2,3,4,6,7,8-HXCDF*	ng/kg					>0.34
1,2,3,7,8,9-HXCDF*	ng/kg					>0.34
1,2,3,4,6,7,8-HPCDF	ng/kg					>85
1,2,3,4,7,8,9-HPCDF	ng/kg					>85
OCDF	ng/kg					>2800

** MDL for individual congeners in most cases exceed the Oregon Sediment Bioaccumulation Screening Level Values for subsistence feeding by humans.*

Table 7, continued.

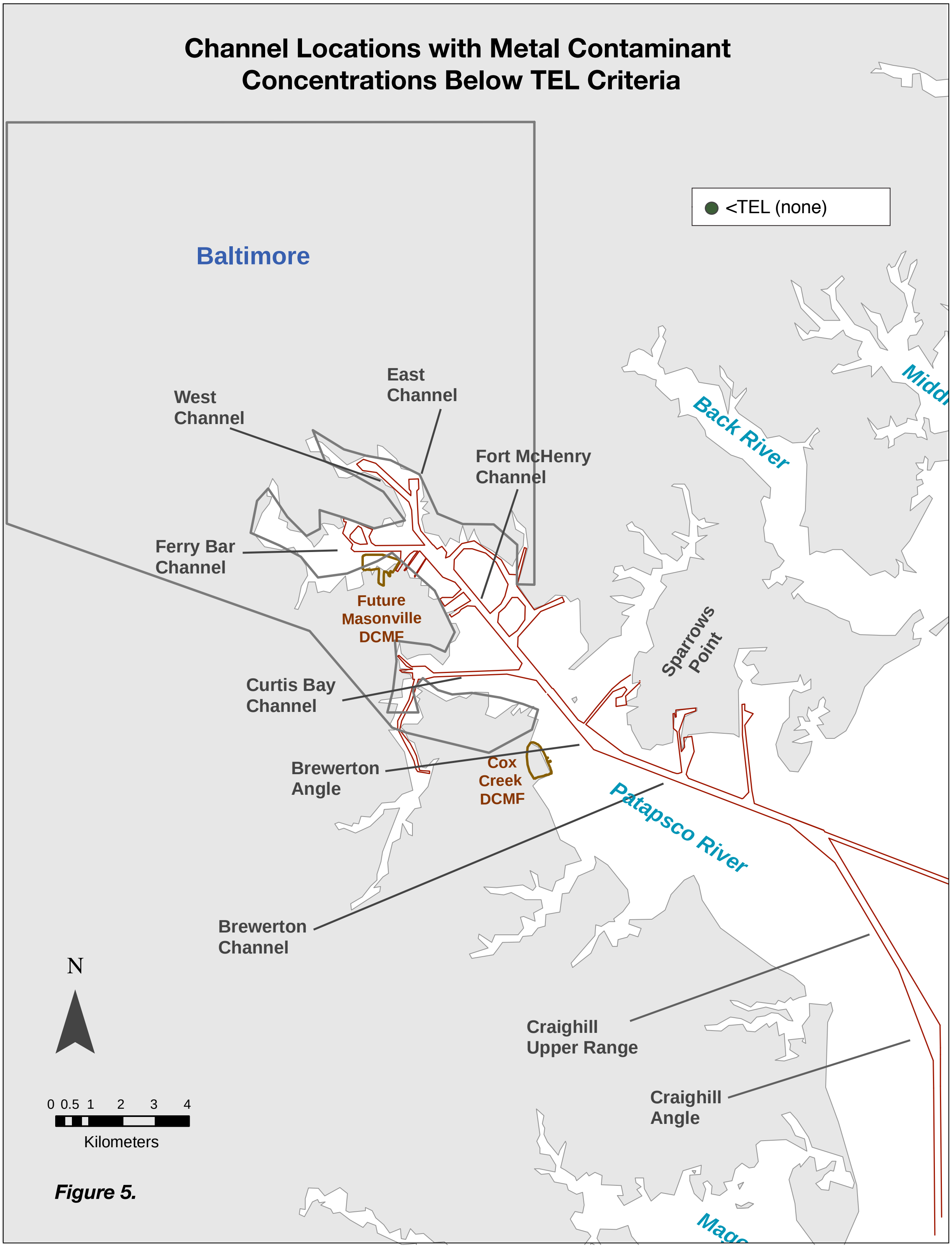
VOCs	Units	<TEL	<MD Residential Soil Clean Up Criteria	<MD NonResidential Soil Clean Up Criteria	>MD NonResidential Soil Clean Up Criteria	
1,1,1-trichloroethane	µg/kg		<16,000,000	<200,000,000	>200,000,000	
1,1,2,2-tetrachloroethane	µg/kg		<3200	<14,000	>14,000	
1,1,2-trichloroethane	µg/kg		<11,000	<50,000	>50,000	
1,1-dichloroethane	µg/kg		<16,000,000	<200,000,000	>200,000,000	
1,1-dichloroethene	µg/kg		<390,000	<51,000,000	>51,000,000	
1,2-dichlorobenzene	µg/kg		<700,000	<9,200,000	>9,200,000	
1,2-dichloroethane	µg/kg		<7000	<31,000	>31,000	
1,2-dichloropropane	µg/kg		<9400	<42,000	>42,000	
1,3-dichlorobenzene	µg/kg		<23,000	<310,000	>310,000	
1,4-dichlorobenzene	µg/kg		<27,000	<120,000	>120,000	
2-butanone (mek)	µg/kg		<4,700,000	<64,000,000	>64,000,000	
Benzene	µg/kg		<12,000	<52,000	>52,000	
Bromodichloromethane	µg/kg		<10,000	<46,000	>46,000	
Bromoform	µg/kg		<81,000	<360,000	>360,000	
Bromomethane	µg/kg		<11,000	<140,000	>140,000	
Carbon tetrachloride	µg/kg		<4900	<22,000	>22,000	
Chloroethane	µg/kg		<220,000	<990,000	>990,000	
Chloroform	µg/kg		<78,000	<1,000,000	>1,000,000	
Cis-1,3-dichloropropene	µg/kg		<6400	<29,000	>29,000	
Dibromochloromethane	µg/kg		<7600	<34,000	>34,000	
Ethylbenzene	µg/kg		<780,000	<10,000,000	>10,000,000	
Methylene chloride	µg/kg		<85,000	<380,000	>380,000	
Tetrachloroethene	µg/kg		<1200	<5300	>5300	
Toluene	µg/kg		<630,000	<8,200,000	>8,200,000	
Trans-1,2-dichloroethene	µg/kg		<160,000	<2,000,000	>2,000,000	
Trans-1,3-dichloropropene	µg/kg		<6400	<29,000	>29,000	
Trichloroethene	µg/kg		<1600	<7200	>7200	
Vinyl chloride	µg/kg		<90	<4000	>4000	

Table 7, continued.

SVOCs	**Units**	**<TEL**	**<MD Residential Soil Clean Up Criteria**	**<MD NonResidential Soil Clean Up Criteria**	**>MD NonResidential Soil Clean Up Criteria**	
1,2,4-trichlorobenzene	µg/kg		<78,000	<1,000,000	>1,000,000	
2,4,6-trichlorophenol	µg/kg		<58,000	<260,000	>260,000	
2,4-dichlorophenol	µg/kg		<23,000	<310,000	>310,000	
2,4-dimethylphenol	µg/kg		<160,000	<2,000,000	>2,000,000	
2,4-dinitrophenol	µg/kg		<16,000	<200,000	>200,000	
2,4-dinitrotoluene	µg/kg		<16,000	<200,000	>200,000	
2,6-dinitrotoluene	µg/kg		<7800	<100,000	>100,000	
2-chloronaphthalene	µg/kg		<630,000	<8,200,000	>8,200,000	
2-chlorophenol	µg/kg		<39,000	<510,000	>510,000	
2-methylphenol	µg/kg		<390,000	<5,100,000	>5,100,000	
4-methylphenol	µg/kg		<39,000	<510,000	>510,000	
Bis(2-chloroethyl) ether	µg/kg		<580	<2600	>2600	
Bis(2-chloroisopropyl) ether	µg/kg		<9100	<41,000	>41,000	
Bis(2-ethylhexyl) phthalate	µg/kg	<182	<4600	<200,000	>200,000	
Dibenzofuran	µg/kg		<7800	<100,000	>100,000	
Diethyl phthalate	µg/kg		<6,300,000	<83,000,000	>83,000,000	
Di-n-butyl phthalate	µg/kg		<780,000	<1,000,000	>1,000,000	
Hexachlorobenzene	µg/kg		<400	<1800	>1800	
Hexachlorobutadiene	µg/kg		<8200	<37,000	>37,000	
Hexachlorocyclopentadiene	µg/kg		<47,000	<610,000	>610,000	
Hexachloroethane	µg/kg		<46,000	<200,000	>200,000	
Isophorone	µg/kg		<670,000	<3,000,000	>3,000,000	
Nitrobenzene	µg/kg		<3900	<51,000	>51,000	
N-nitrosodi-n-propylamine	µg/kg		<91	<410	>410	
N-nitrosodiphenylamine	µg/kg		<130,000	<580,000	>580,000	
Pentachlorophenol	µg/kg		<5300	<24,000	>24,000	
Phenol	µg/kg		<2,300,000	<31,000,000	>31,000,000	

Table 7, continued.

Pesticides	**Units**	**<TEL**	**<MD Residential Soil Clean Up Criteria**	**<MD NonResidential Soil Clean Up Criteria**	**>MD NonResidential Soil Clean Up Criteria**	
4,4'-ddd	µg/kg	<1.2	<2700	<12,000	>12,000	
4,4'-dde	µg/kg	<2.1	<1900	<8400	>8400	
4,4'-ddt	µg/kg	<1.2	<1900	<8400	>8400	
Aldrin	µg/kg		<38	<170	>170	
Alpha-BHC	µg/kg		<100	<450	>450	
Beta-BHC	µg/kg		<350	<1600	>1600	
Chlordane	µg/kg	<2.26	<1800	<8200	>8200	
Delta-BHC	µg/kg		<490	<2200	>2200	
Dieldrin	µg/kg	<0.72	<40	<180	>180	
Endosulfan I	µg/kg		<4700	<610,000	>610,000	
Endosulfan II	µg/kg		<4700	<610,000	>610,000	
Endosulfan sulfate	µg/kg		<4700	<610,000	>610,000	
Endrin	µg/kg		<2300	<31,000	>31,000	
Endrin aldehyde	µg/kg		<2300	<31,000	>31,000	
Gamma-BHC	µg/kg	<0.32	<490	<2200	>2200	
Heptachlor	µg/kg		<140	<640	>640	
Heptachlor epoxide	µg/kg		<70	<310	>310	
Methoxychlor	µg/kg		<39,000	<510,000	>510,000	
Toxaphene	µg/kg	<0.1	<580	<2600	>2600	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West Channel
East Channel
Fort McHenry Channel
Ferry Bar Channel
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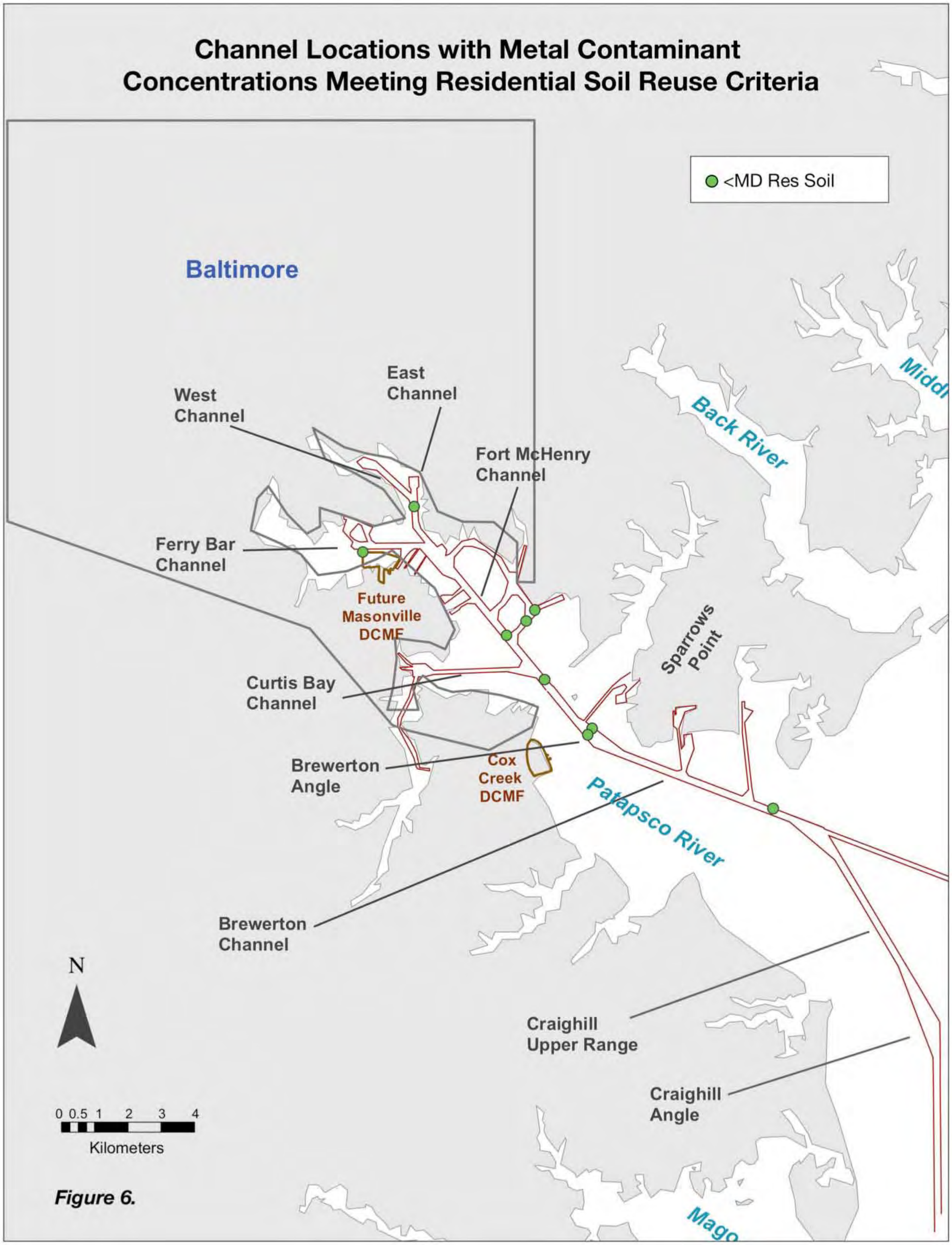
Curtis Bay Channel
Brewerton Angle
Cox Creek DCMF
Brewerton Channel
Back River
Middl
Sparrows Point
Patapsco River
Craighill Upper Range
Craighill Angle
Mag
N
0 0.5 1 2 3 4
Kilometers

Figure 5.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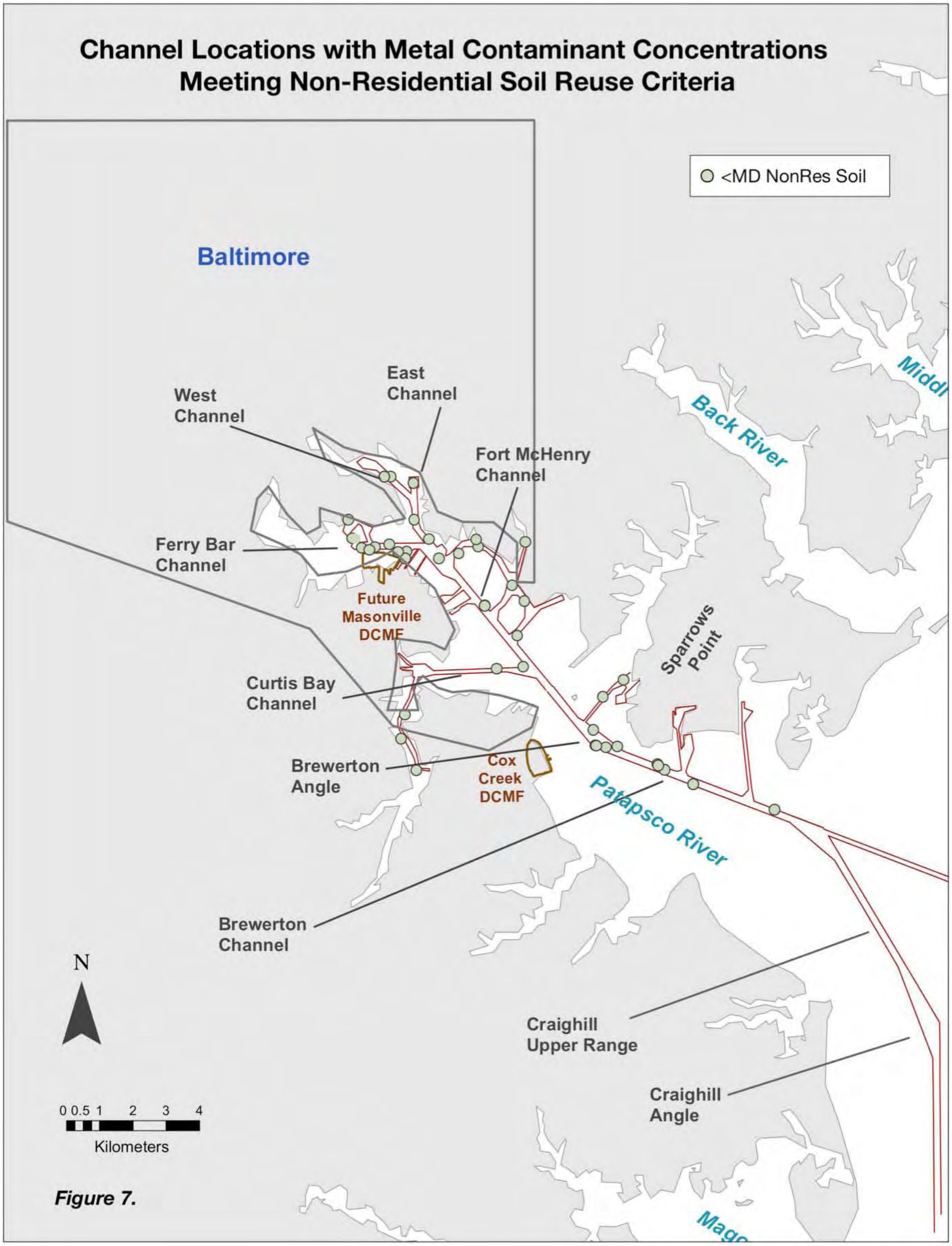
Back River
Midd
Sparrows Point
Curtis Bay Channel
Brewerton Angle
Cox Creek DCMF
Patapsco River
Brewerton Channel
N
Craighill Upper Range
Craighill Angle
0 0.5 1 2 3 4
Kilometers
Mago

Figure 6.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Meeting Non-Residential Soil Reuse Criteria
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Curtis Bay Channel
Brewerton Angle
Cox Creek DCMF
Brewerton Channel
Back River
Middl
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Craighill Upper Range
Craighill Angle
Mago
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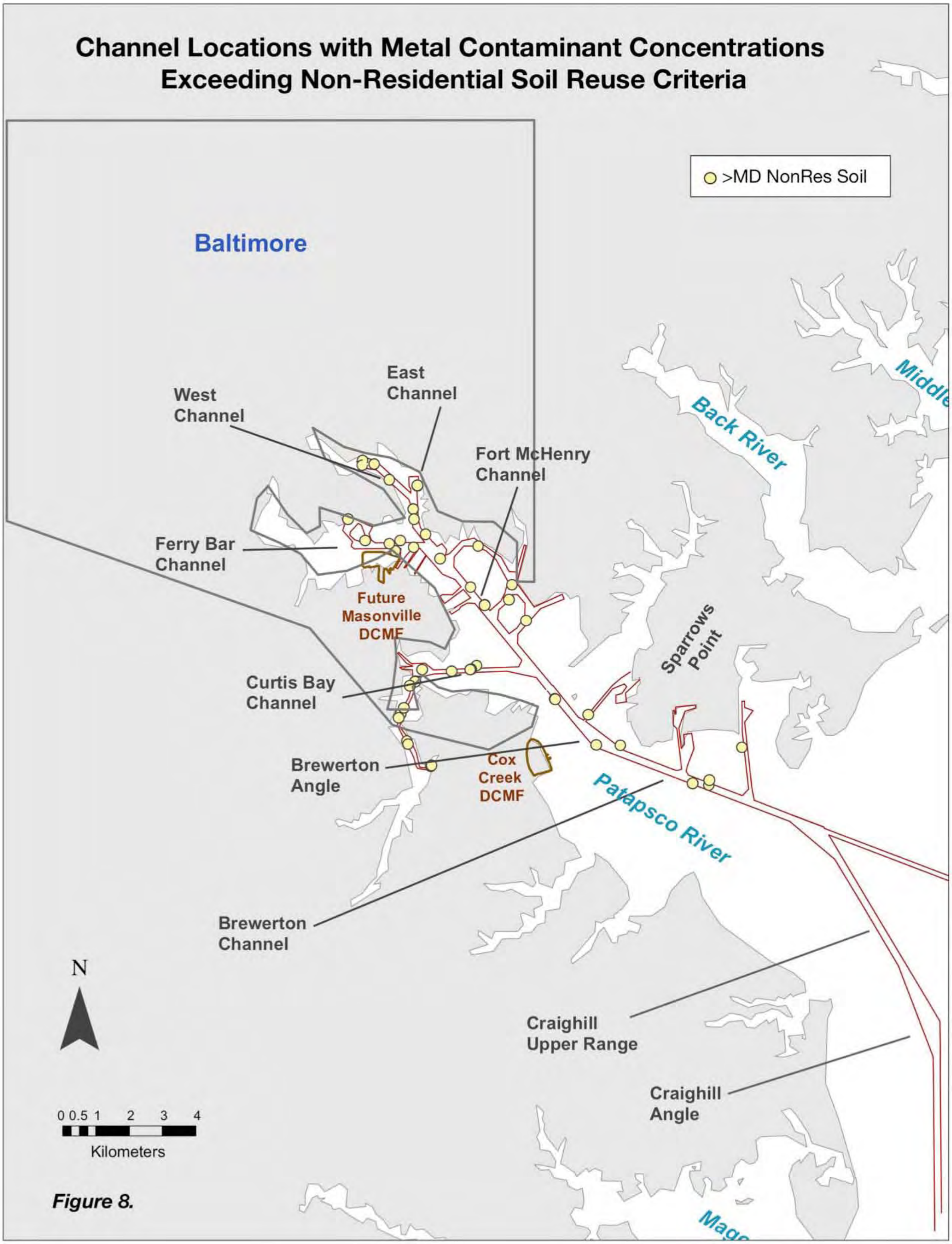
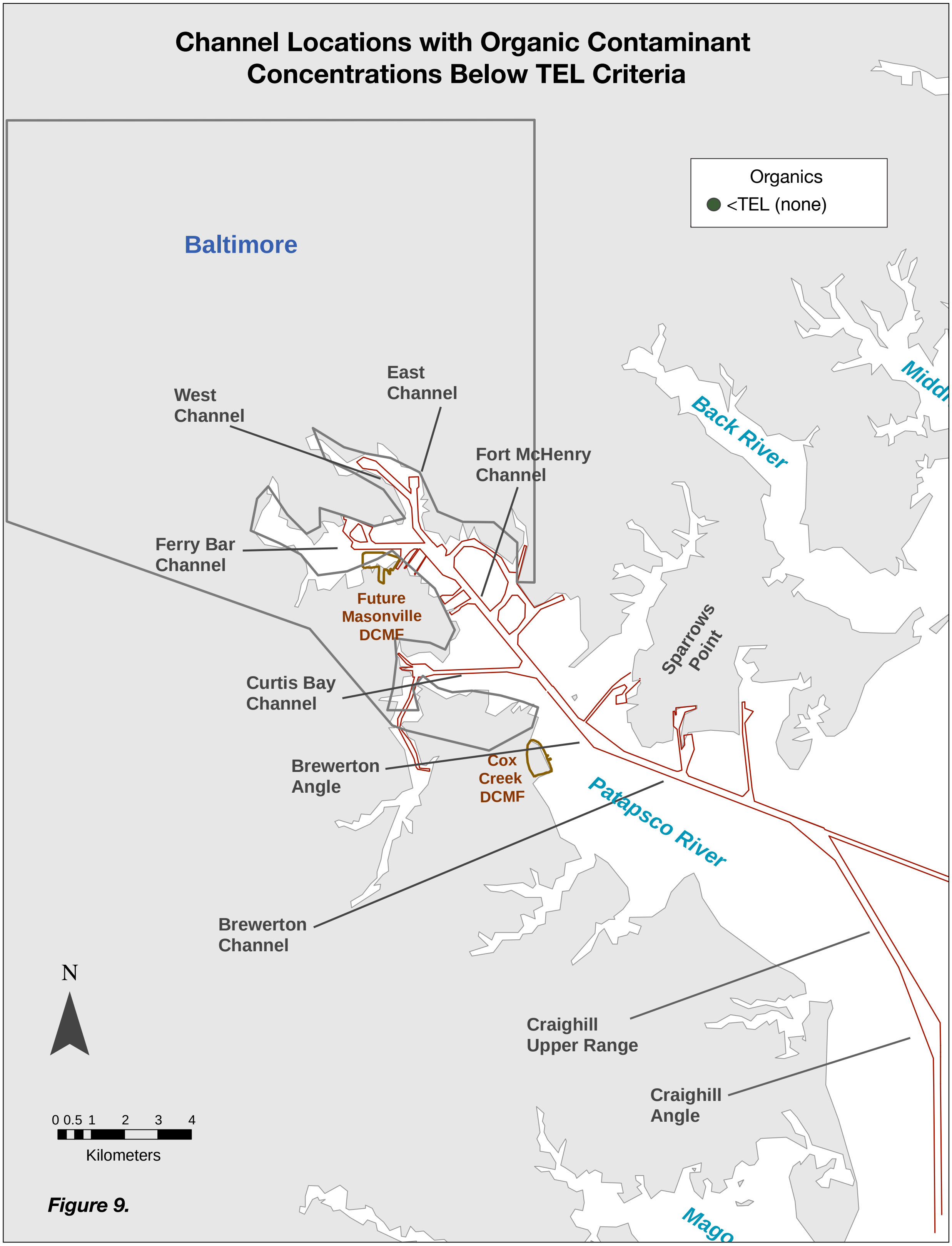
0 0.5 1 2 3 4
Kilometers

Figure 7.



Channel Locations with Metal Contaminant Concentrations Exceeding Non-Residential Soil Reuse Criteria

Figure 8.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Organics
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East Channel
Fort McHenry Channel
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Curtis Bay Channel
Brewerton Angle
Cox Creek DCMF
Brewerton Channel
Back River
Middl
Sparrows Point
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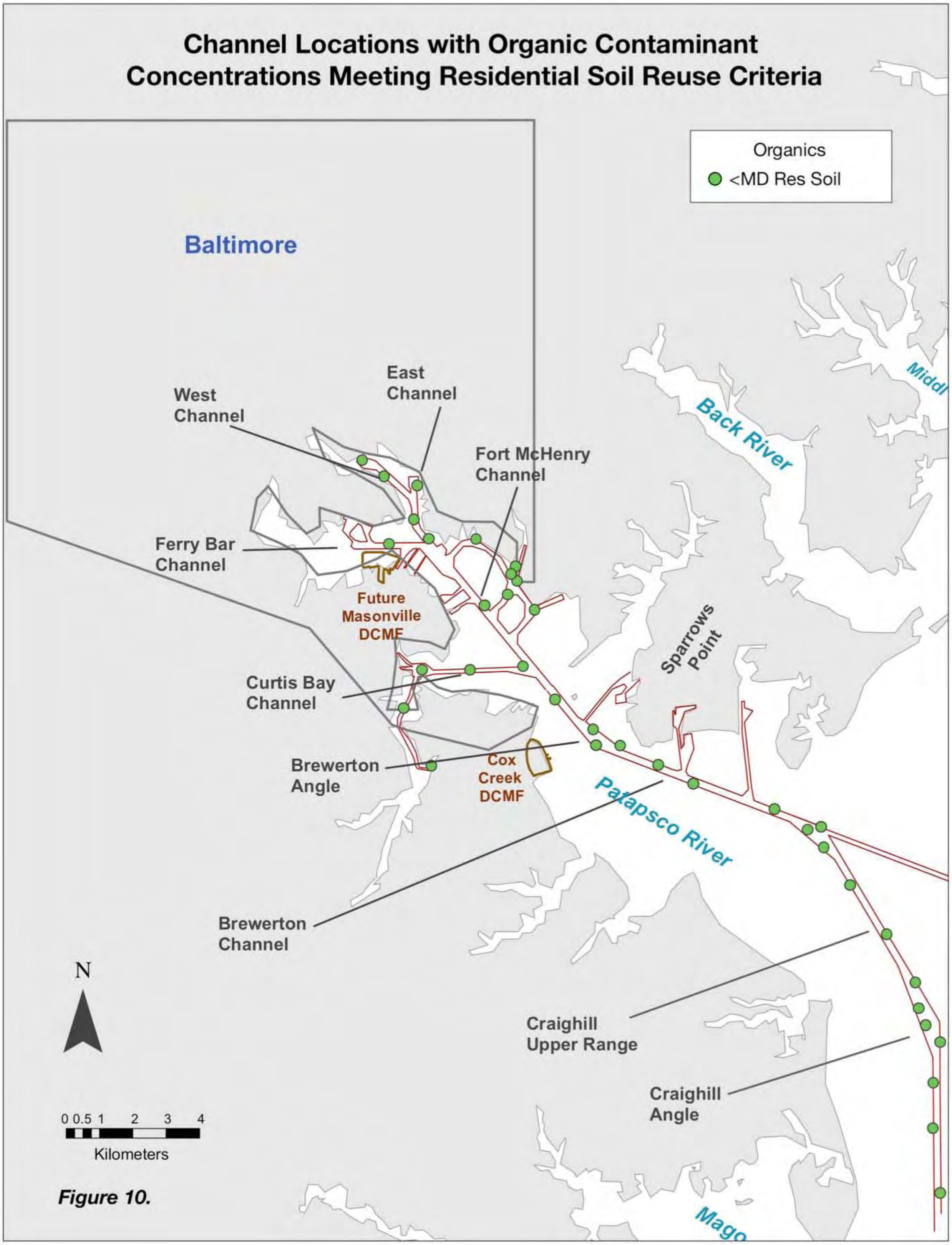
Craighill Upper Range
Craighill Angle
Mago
N
0 0.5 1 2 3 4
Kilometers

Figure 9.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Organics
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East Channel
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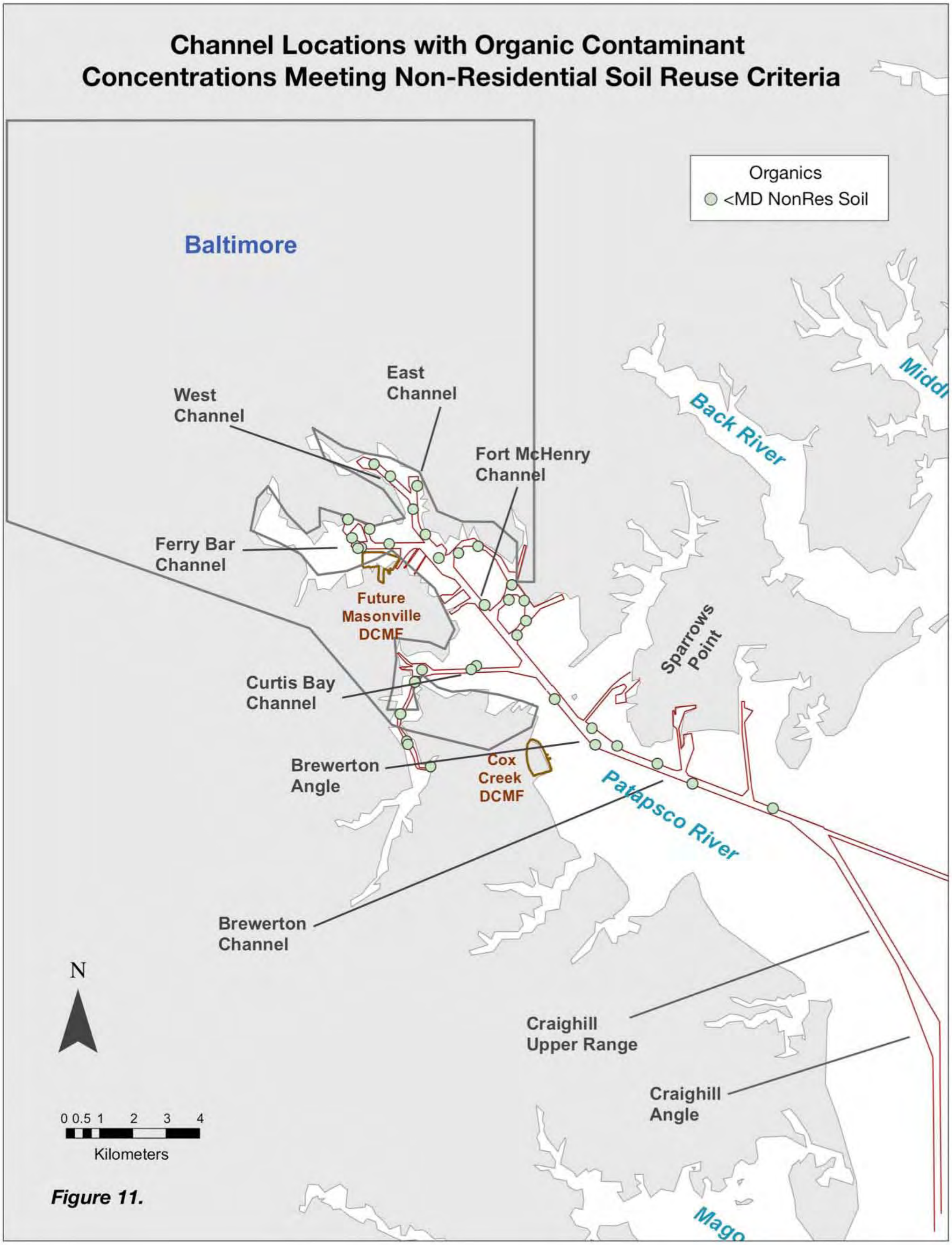
Cox Creek DCMF
Brewerton Channel
Craighill Upper Range
Craighill Angle
Back River
Middl
Sparrows Point
Patapsco River
Mago
N
0 0.5 1 2 3 4
Kilometers

Figure 10.


Channel Locations with Organic Contaminant Concentrations Meeting Non-Residential Soil Reuse Criteria
Organics
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East Channel
Fort McHenry Channel
Ferry Bar Channel
Future Masonville DCMF
Curtis Bay Channel
Brewerton Angle
Cox Creek DCMF
Brewerton Channel
Back River
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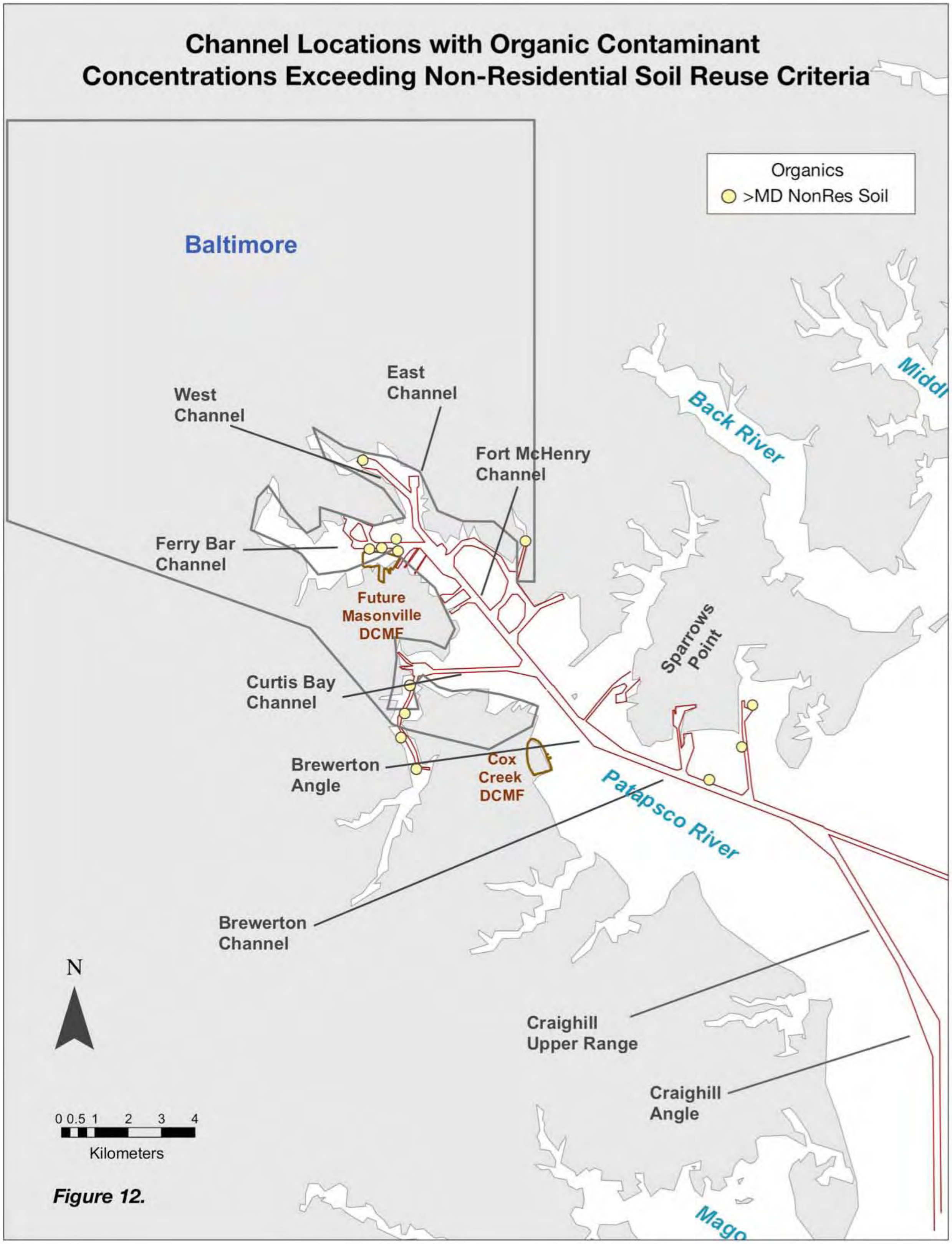
Sparrows Point
Patapsco River
Craighill Upper Range
Craighill Angle
Mago
N
0 0.5 1 2 3 4
Kilometers

Figure 11.


Channel Locations with Organic Contaminant
Concentrations Exceeding Non-Residential Soil Reuse Criteria
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Baltimore
West Channel
East Channel
Fort McHenry Channel
Ferry Bar Channel
Future Masonville DCMF
Back River
Middl
Sparrows Point
Curtis Bay Channel
Brewerton Angle
Cox Creek DCMF
Patapsco River
Brewerton Channel
N
Craighill Upper Range
Craighill Angle
0 0.5 1 2 3 4
Kilometers
Mago

Figure 12.

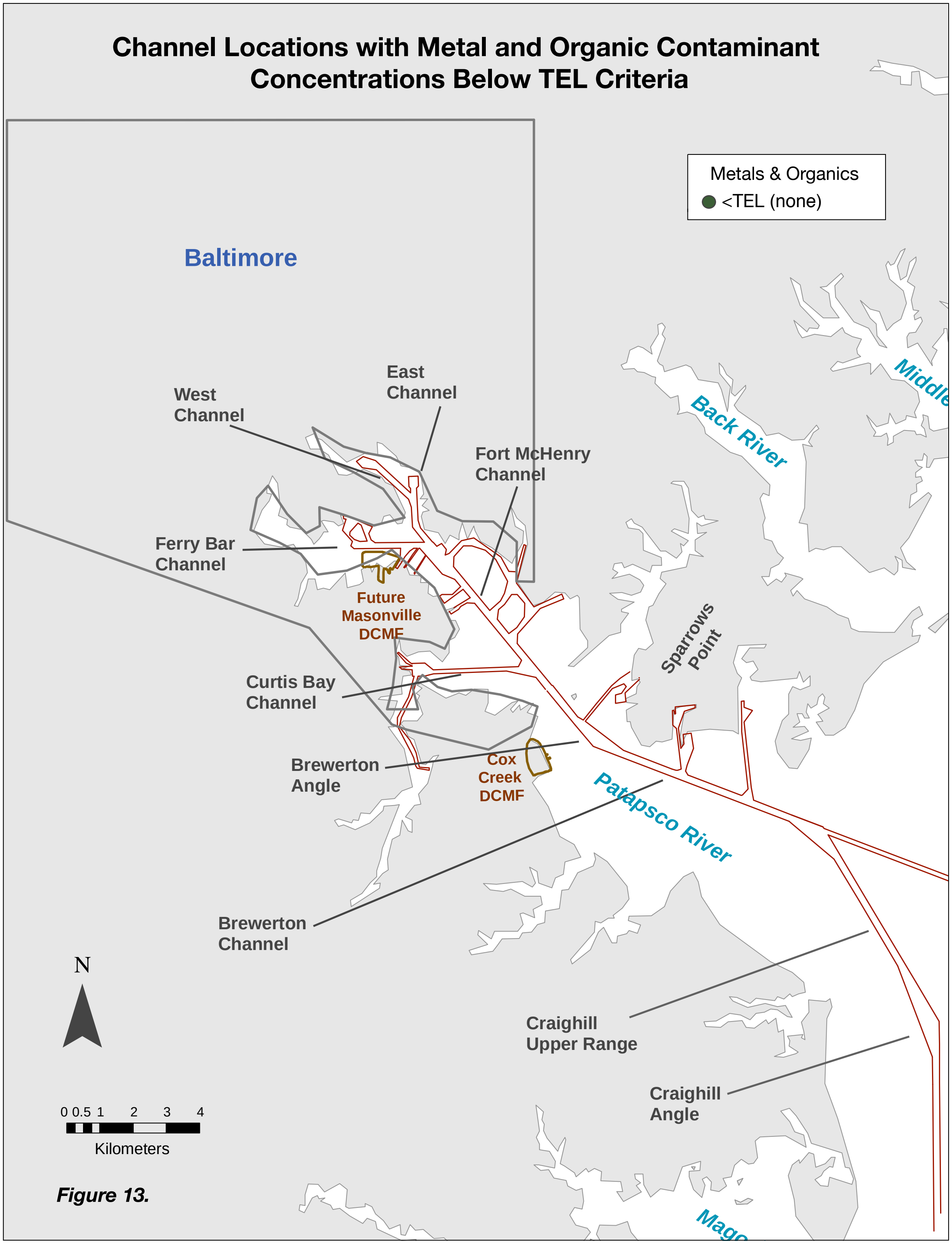
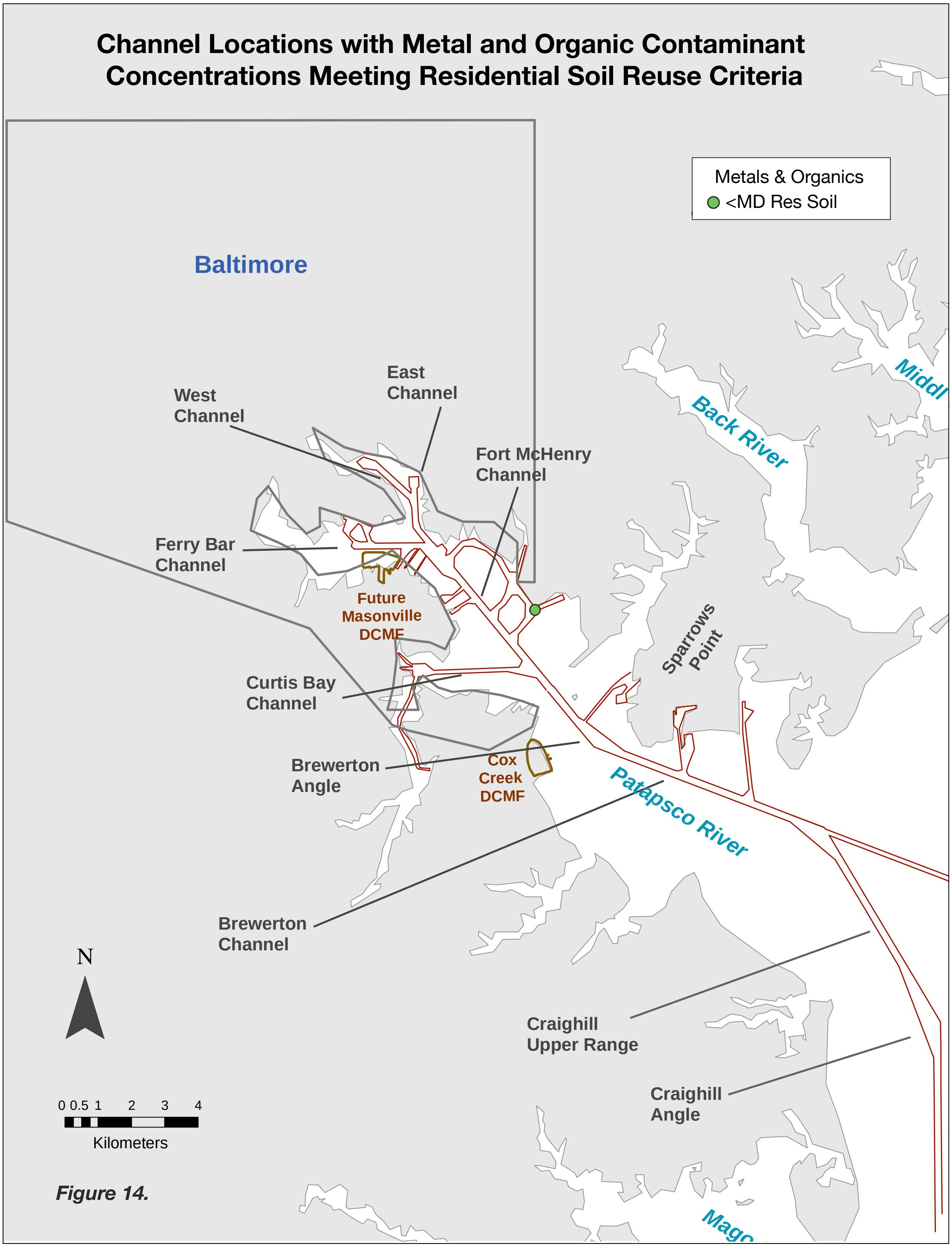

Channel Locations with Metal and Organic Contaminant Concentrations Below TEL Criteria
Metals & Organics
● <TEL (none)
Baltimore
West Channel
East Channel
Fort McHenry Channel
Ferry Bar Channel
Future Masonville DCMF
Curtis Bay Channel
Brewerton Angle
Cox Creek DCMF
Brewerton Channel
Back River
Middle
Sparrows Point
Patapsco River
Craighill Upper Range
Craighill Angle
Mago
N
0 0.5 1 2 3 4
Kilometers

Figure 13.



Channel Locations with Metal and Organic Contaminant Concentrations Meeting Residential Soil Reuse Criteria

Figure 14.

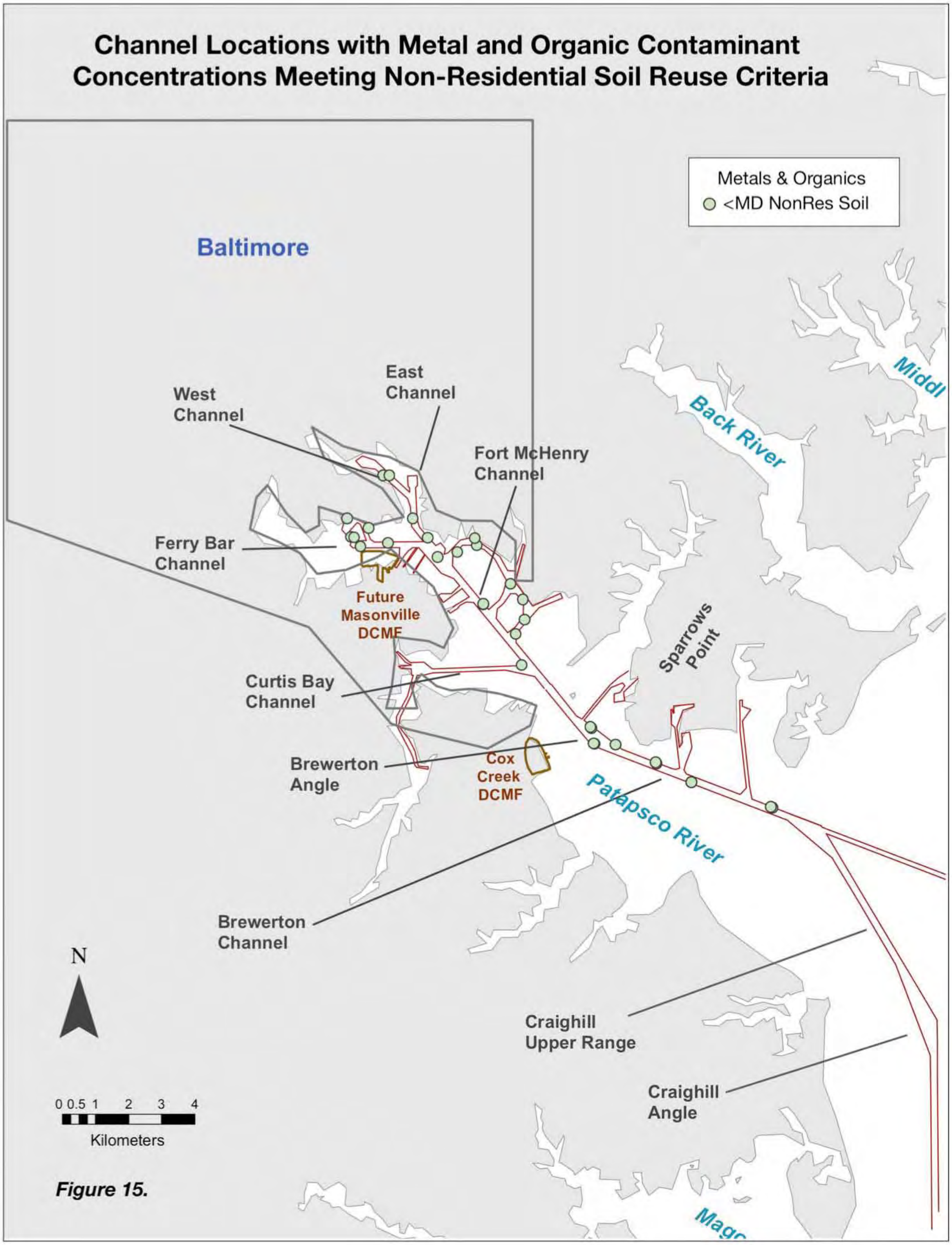

Channel Locations with Metal and Organic Contaminant Concentrations Meeting Non-Residential Soil Reuse Criteria
Metals & Organics
○ <MD NonRes Soil
Baltimore
West Channel
East Channel
Fort McHenry Channel
Ferry Bar Channel
Future Masonville DCMF
Curtis Bay Channel
Brewerton Angle
Cox Creek DCMF
Brewerton Channel
Craighill Upper Range
Craighill Angle
Back River
Middl
Sparrows Point
Patapsco River
Mag
N
0 0.5 1 2 3 4
Kilometers

Figure 15.

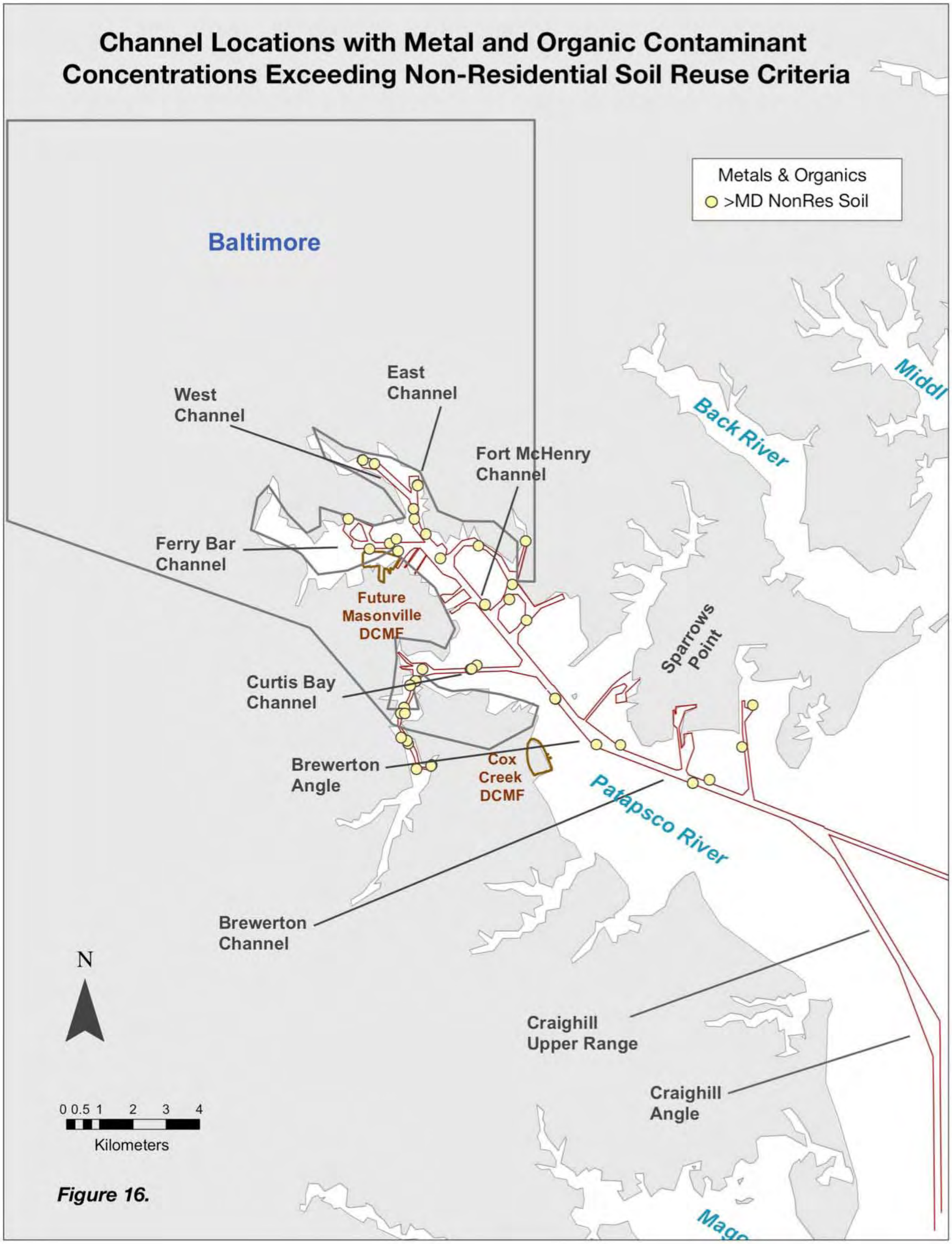
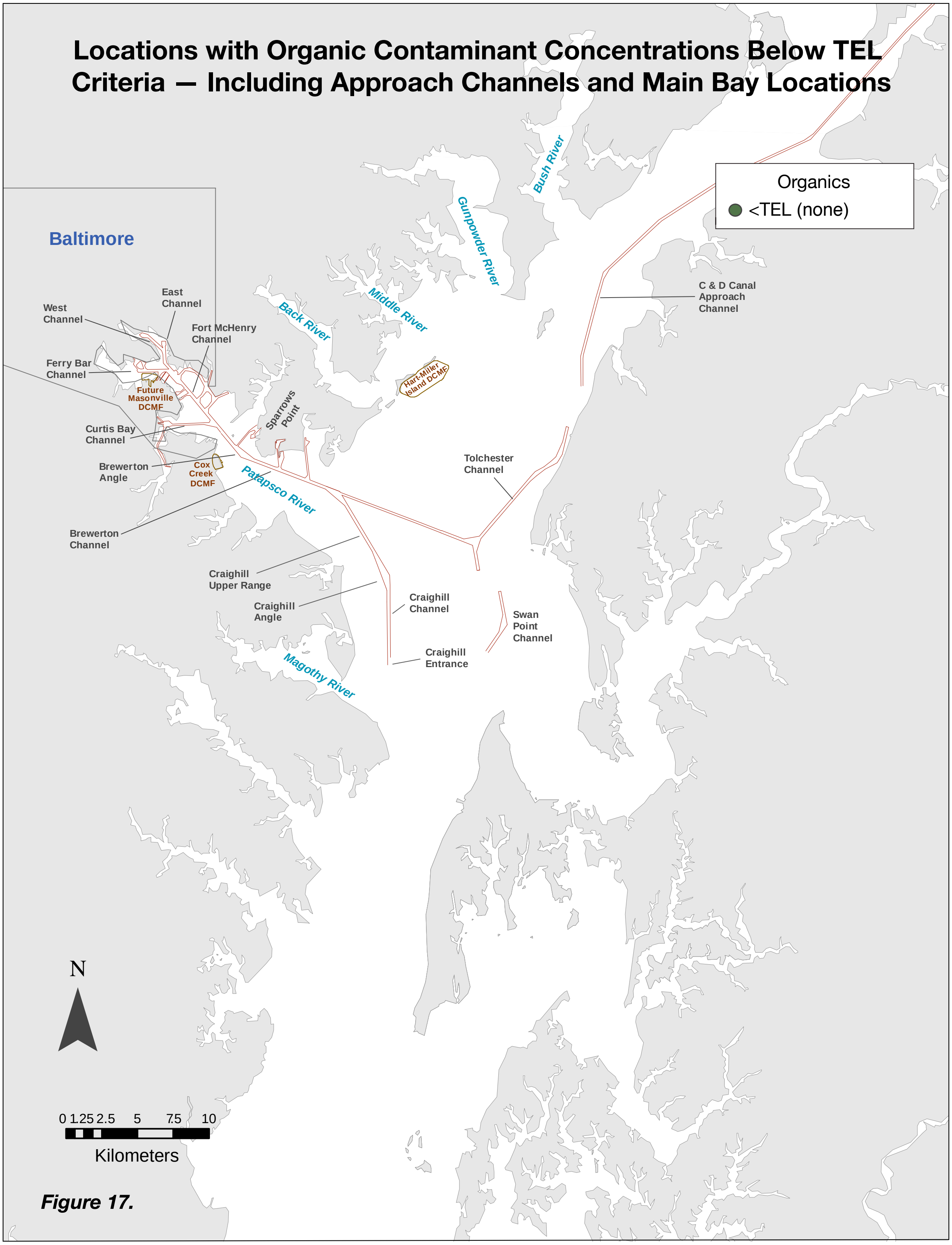
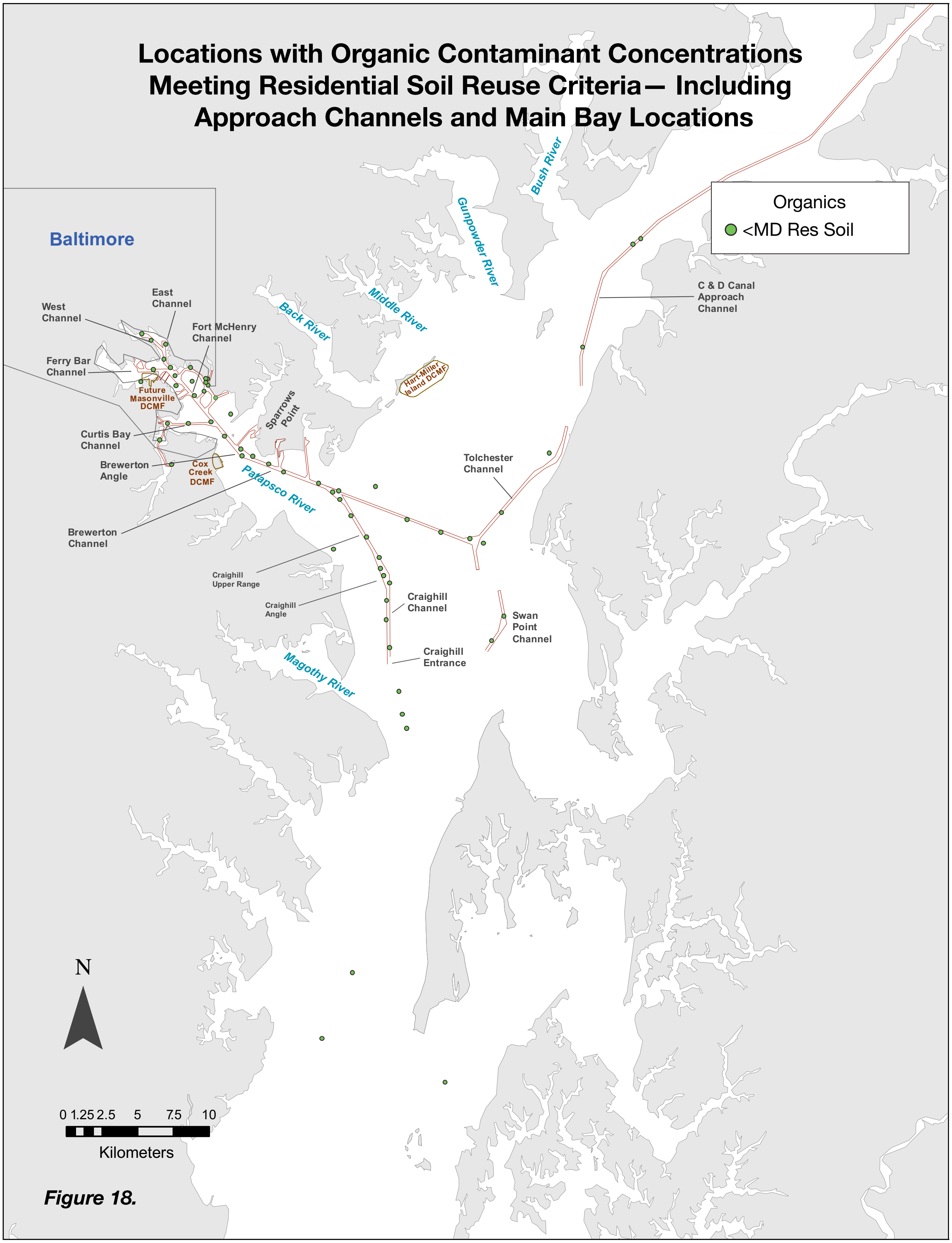

Channel Locations with Metal and Organic Contaminant Concentrations Exceeding Non-Residential Soil Reuse Criteria

Figure 16.



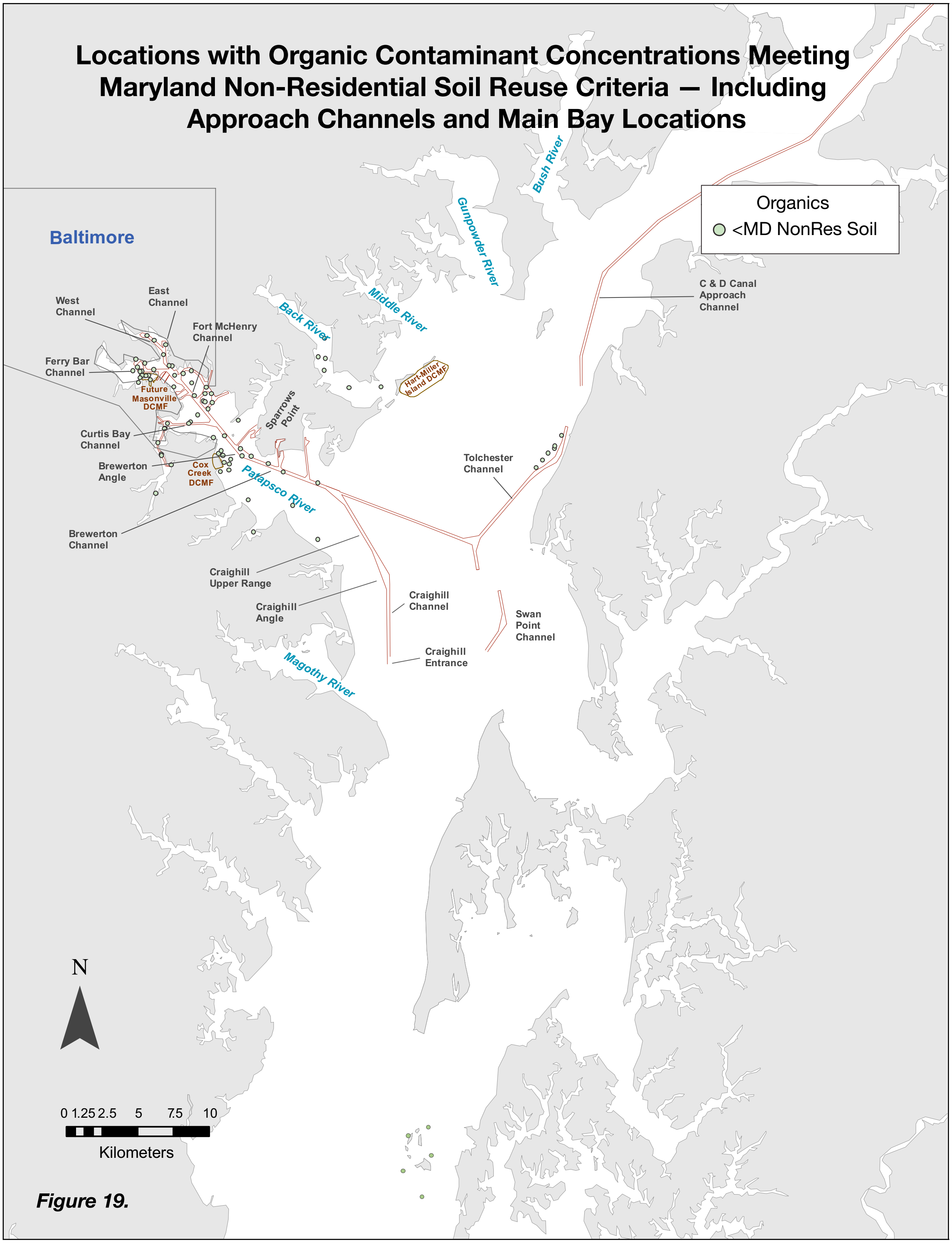
Locations with Organic Contaminant Concentrations Below TEL Criteria — Including Approach Channels and Main Bay Locations

Figure 17.



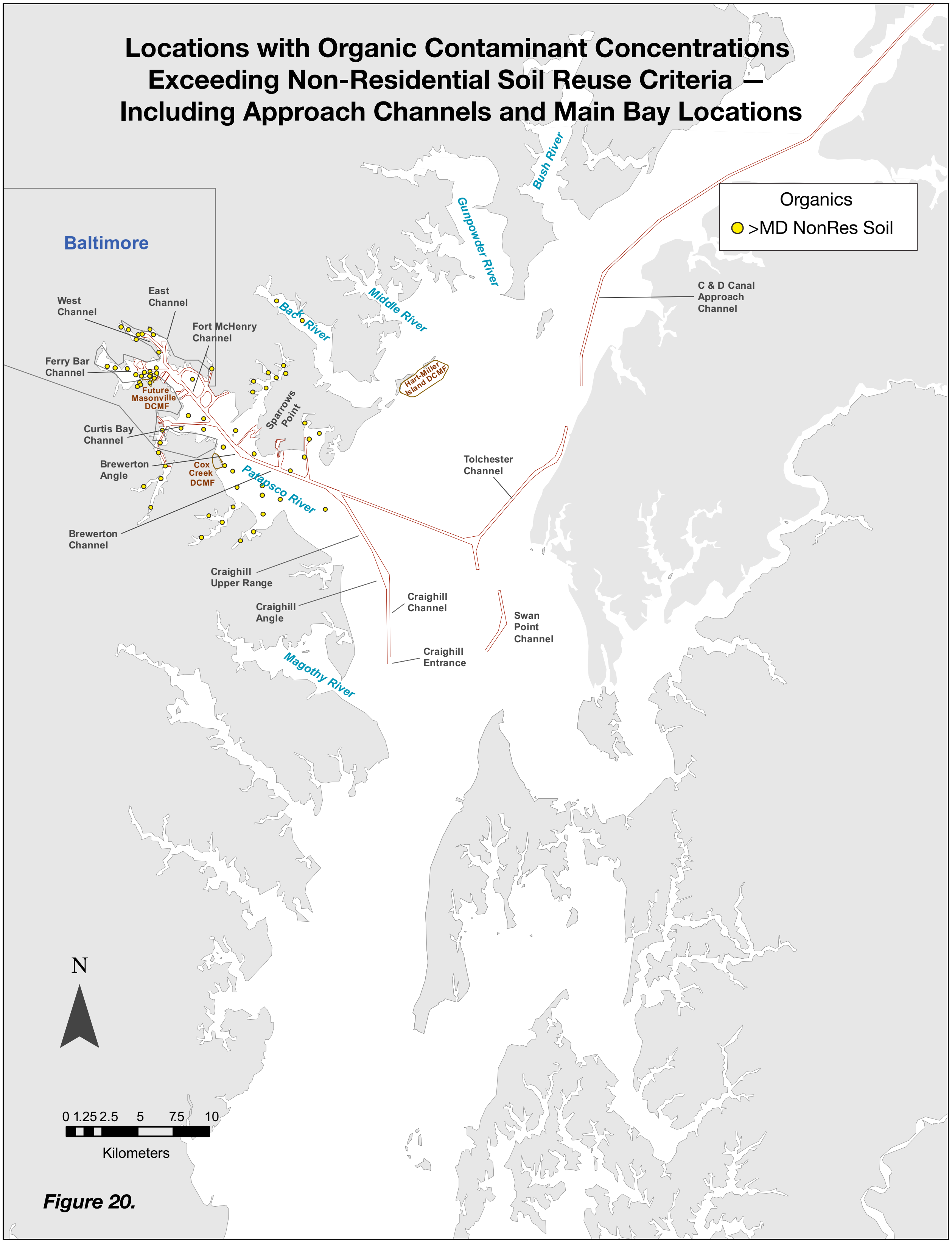
Locations with Organic Contaminant Concentrations Meeting Residential Soil Reuse Criteria— Including Approach Channels and Main Bay Locations

Figure 18.



Locations with Organic Contaminant Concentrations Meeting Maryland Non-Residential Soil Reuse Criteria — Including Approach Channels and Main Bay Locations

Figure 19.



Locations with Organic Contaminant Concentrations Exceeding Non-Residential Soil Reuse Criteria — Including Approach Channels and Main Bay Locations

Figure 20.

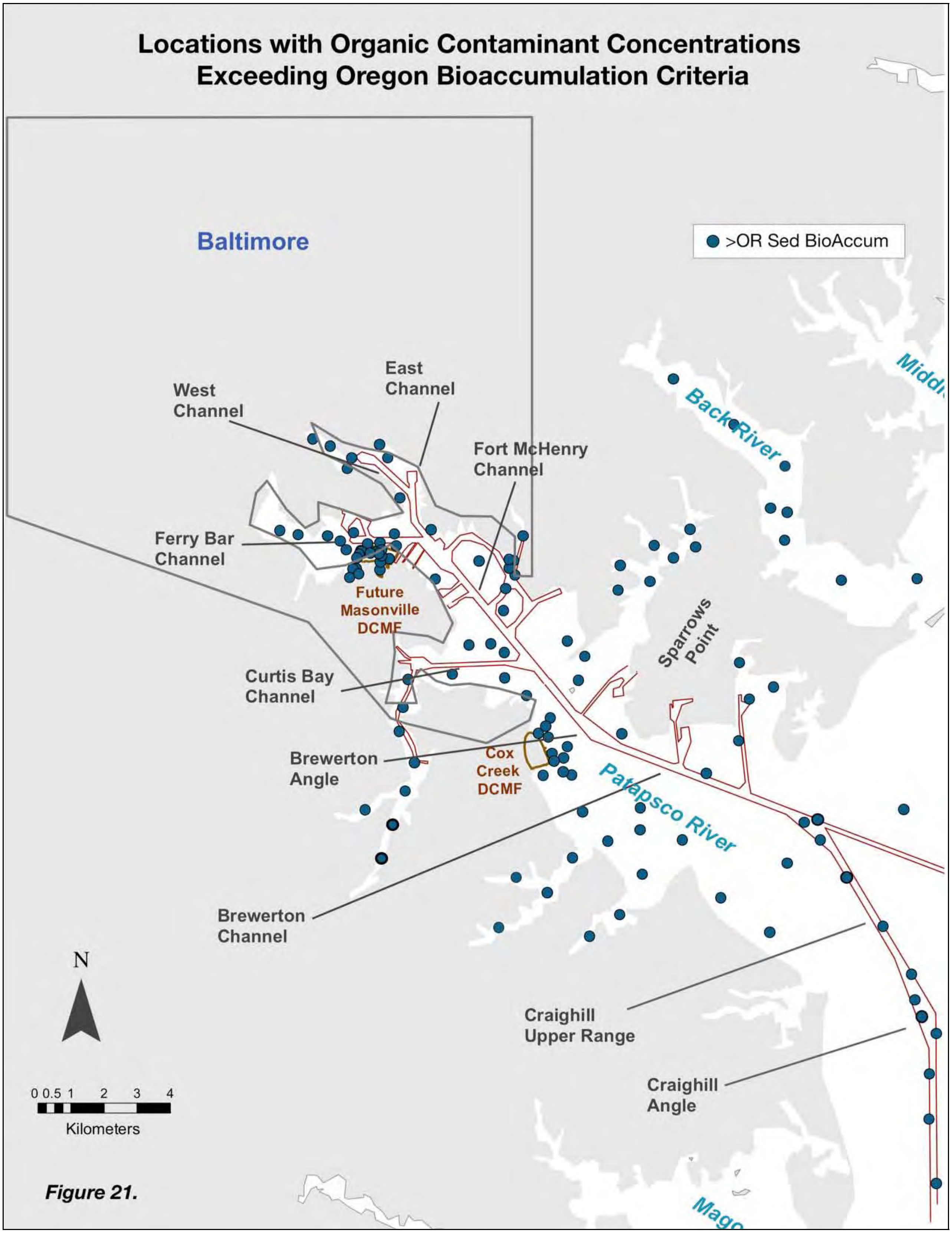
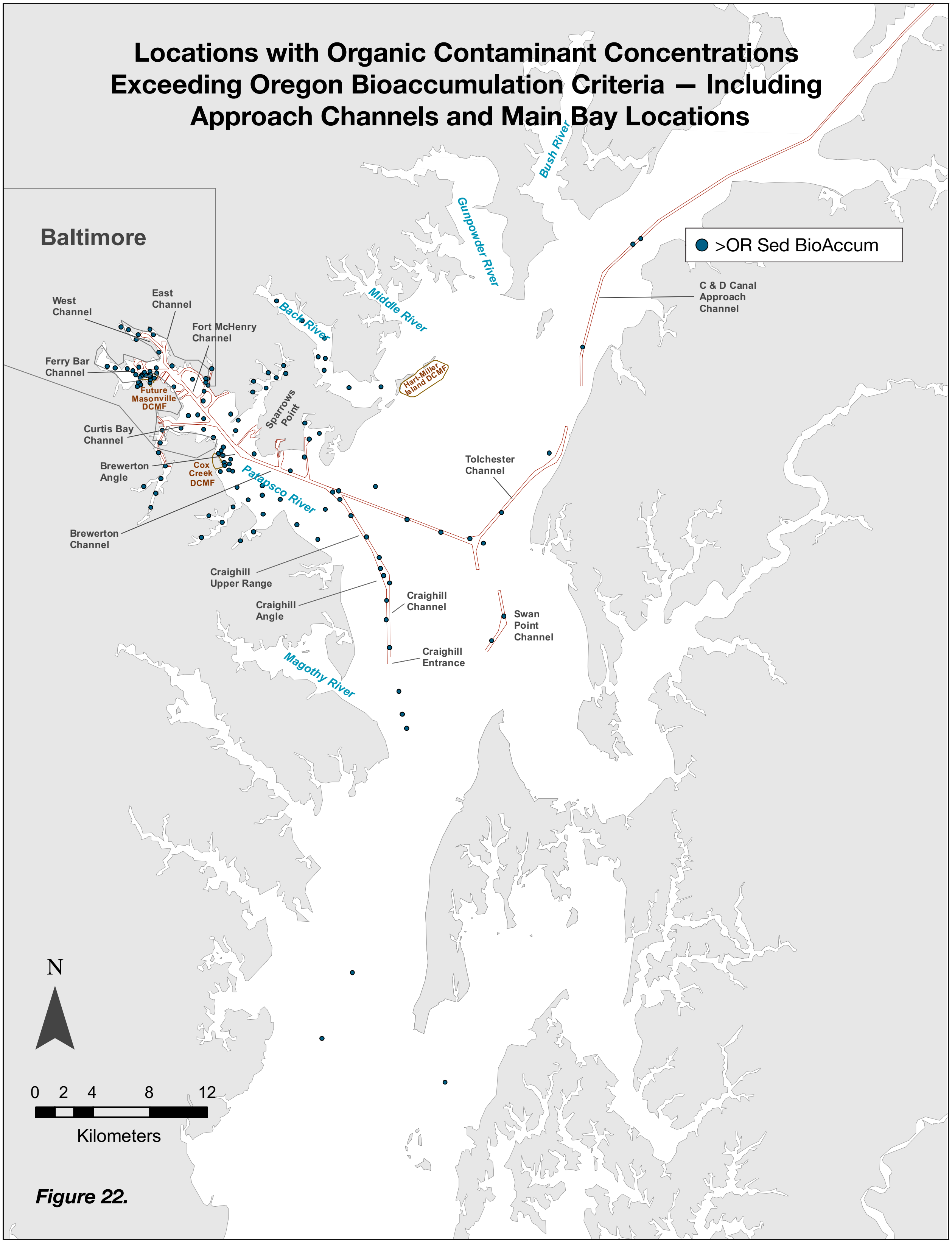

Locations with Organic Contaminant Concentrations Exceeding Oregon Bioaccumulation Criteria
Baltimore
● >OR Sed BioAccum
West Channel
East Channel
Fort McHenry Channel
Ferry Bar Channel
Future Masonville DCMF
Curtis Bay Channel
Brewerton Angle
Cox Creek DCMF
Brewerton Channel
Sparrows Point
Back River
Middl
Patapsco River
Craighill Upper Range
Craighill Angle
Mago
N
0 0.5 1 2 3 4
Kilometers

Figure 21.



Locations with Organic Contaminant Concentrations Exceeding Oregon Bioaccumulation Criteria — Including Approach Channels and Main Bay Locations

Figure 22.

Appendices

List of Tables Included in Appendices

Dataset Files

File	Contents
Table A1.pdf	Datasets Included and Excluded

Criteria Tables

File	Contents
Table B1.pdf	Compilation of Screening Criteria
Table B2.pdf	OR Bioaccumulation Screening Levels
Table B3.pdf	Maryland soil and groundwater standards
Table B4.pdf	NJDEP Ecological Screening Criteria

Data Files Used to Create Maps

(Use the "zoom" function in your pdf viewer to enhance visualization of the files)

File	Contaminants	Screening Criteria
Table C1.pdf	Metals	Independent Technical Review Team Screening
Table C2.pdf	PAHs	Independent Technical Review Team Screening
Table C3.pdf	Pesticides	Independent Technical Review Team Screening
Table C4.pdf	VOCs	Independent Technical Review Team Screening
Table C5.pdf	sVOCs	Independent Technical Review Team Screening
Table C6.pdf	PCBs	OR Bioaccumulation
Table C7.pdf	PCDDs	OR Bioaccumulation
Table C8.pdf	Combined Metals and Organics	Independent Technical Review Team Screening

Tables C1-C5 & C8 are color-coded following the scheme detailed in the text applying the Independent Technical Review Team Screening Criteria to assess sediment quality at each site.

See next page for abbreviations used to designate studies.

Abbreviations for Studies Used for Mapping

Abbreviation	Dataset Utilized
FED 98 FED 02 FED 05	US Army Corps of Engineers Federal Channel Testing: 1998 (metals), 2002 and 2005 (organics)
HMI	Final White Paper – Development of Potential Closure Options – North Cell HMI DMCF: Appendix A Comprehensive Report: South Cell Soil and Vegetation Survey for the HMI DMCF: 2005 (metals)
HMI	HMI DMCF Bulk Sediment: 1984-present (metals)
COX CREEK	Cox Creek DMCF South Cell Soil Sampling - (Post-Placement): 1999, 2005, 2007 (metals)
COX CREEK	Cox Creek Dredged Material Containment Facility Exterior Monitoring Study: Baseline 2006. (EA Engineering, Science, and Technology, Inc. 2007b) (metals and organics)
MASONVILLE	Masonville and Masonville Cove Exterior Monitoring Study: Baseline 2006 (EA Engineering, Science, and Technology Inc. 2007c) (metals)
MASONVILLE	Tiered Final Environmental Impact Statement for the Proposed (Masonville) Dredged Material Containment Facility: 2005 (metals and organics)
SEAGIRT	Seagirt Dredging Area Proposed Borrow Material Sediment and Water Quality Report (EA Engineering, Science, and Technology, Inc. 2007d) (metals and organics)
VARIOUS SITES*	Sample and Testing for Dredged Materials: Baltimore Harbor, Baltimore, Maryland (Law Engineering and Environmental Services, Inc. 1996) (metals)
NEW WORK	Proposed New Work Dredging Baltimore Harbor and Channels, Maryland and Virginia. Straightening of the Tolchester Channel S-turn, Maryland: Draft Environmental Assessment and Draft Finding of No Significant Impact. (Department of the Army, Baltimore District, Corps of Engineers 2000) (organics)
SPARROWS POINT	Final Report Sparrows Point Confirmatory Sampling (Dredged Material Characterization) Sparrows Point Shipyard, Baltimore Harbor, Maryland: October 2006 (metals)
BALT CONT	Spatial Mapping of Contaminants in the Baltimore arbor/Patapsco River/Back River System (Baker et al. 1997) (metals and organics)
BALT CONT	Hydrophobic Organic Contaminants in Surficial Sediments of Baltimore Harbor: Inventories and Sources (Ashley and Baker 1999) (organics)

** A limited number of sites from this study (Dundalk, Seagirt, S. Locust Point, N. Locust Point) were mapped but are not listed separately on the data tables.*