Delaware Estuary
Regional Sediment Management Plan
White Paper

RESTORATION AND BENEFICIAL USE

August 2013

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Acronyms and Abbreviations

BU	Beneficial Use
CDF	Confined Disposal Facility
DNREC	Delaware Department of Natural Resources and Environmental Conservation
MACWA	Mid-Atlantic Coastal Wetlands Assessment
PADEP	Pennsylvania Department of Environmental Protection
PDE	Partnership for the Delaware Estuary
PDM	processed dredged material
RSMP	Regional Sediment Management Plan
TMDL	Total Maximum Daily Load
TNC	The Nature Conservancy

Introduction

Delaware River Estuary Regional Sediment Management Plan (RSMP) Restoration and Beneficial Use Objective: Support ecological restoration and optimize environmental benefits through the incorporation of an enhanced understanding of sediment-related processes; and to promote the beneficial use of sediment (including dredged material) for a variety of purposes.

The RSMP Team is exploring ways to improve the management of sediments in the Delaware Estuary. This white paper is intended to identify restoration actions that would help natural systems cope with current sediment regimes, outline a broader range of placement and use alternatives for dredged material, and identify specific ways to combine restoration and port maintenance activities to achieve dual purposes.

From an ecological perspective, sediment is a resource and a vital component of estuarine systems. Anthropogenic actions can alter sediment processes on variety of scales, from local to watershed, leading to changes in the quantity or quality of sediment in the environment. Too much or too little sediment in any given location can create problems for the estuary's natural systems. Changes in grain size or contaminant concentration can also create ecological problems. Increased understanding of sediment processes, allow resource agencies to take appropriate action to correct or mitigate problems.

From an economic perspective, the estuary’s function as an international port leads to the traditional view that sediment is a problem for navigation. It accumulates continuously in channels and harbors, and needs to be removed regularly, usually by dredging. In theory, there are a wide variety of options for the placement of dredged material (sediment), but considerations of cost and other practical constraints limit the viability of many of these options. For many years, dredgers in the Delaware Estuary have placed most of the dredged sediment into upland Confined Disposal Facilities (CDFs) located along the shores of the estuary.

This paper describes ecological and economic concerns related to sediment in the Delaware River Estuary and how these concerns are inter-related. The paper is organized into sections entitled Restoration and Beneficial Use. The Restoration section includes a broad discussion of restoration topics that affect sediment-related processes and suggests ways in which dredged materials may be beneficially used as part of restoration. The Beneficial Use section discusses issues related to the use of dredged sediment for a variety of purposes. Figure 1 shows areas of separation and overlap between the sections: Sediment-associated activities considered in this white paper are encompassed within the two large circles.

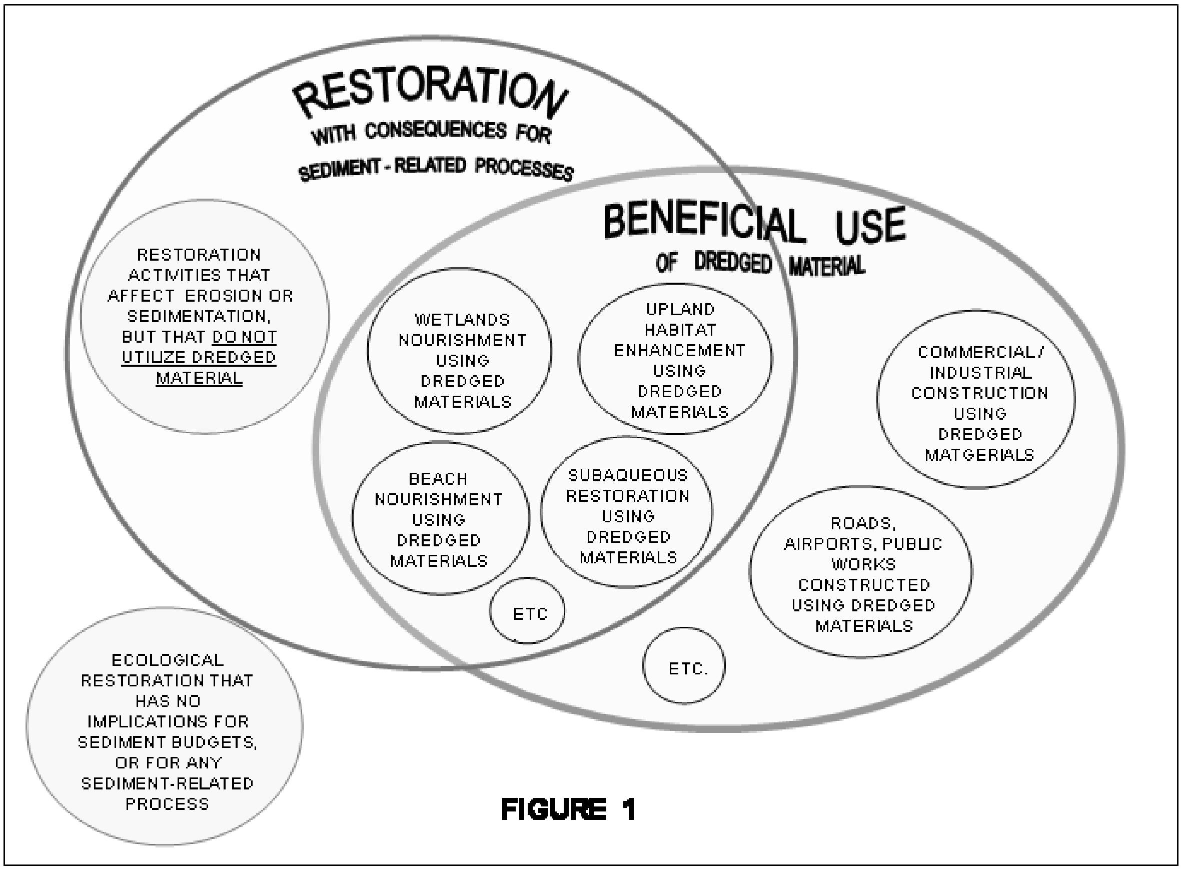

Figure 1: Relationship between Restoration and Beneficial Use

Restoration

Introduction

Restoration, in an ecological context, refers to activities that are designed to undo, or correct for, losses or adverse impacts to natural resources. Because this paper has been prepared as part of a Sediment Management Plan, the discussion of restoration topics will be limited to those that have a bearing on sediments or sediment-related processes.

This paper will consider both active and passive ways of using sediments in restoration. Active use of sediments is the importation and placement of sediment as part of the restoration activity, and represents a kind of beneficial use. Passive use of sediment is an action that causes a change in the sediment dynamics at a restoration site, usually to improve the site's retention of sediment. Passive restoration may slow erosion, enhance natural deposition, or both. It is possible to conceive of restoration actions that are at once both active and passive.

The following natural resource topics have been selected for consideration: sub-aqueous lands, tidal wetlands, shorelines, upland areas, and watersheds.

Subaqueous Lands

Recent efforts by the Delaware Department of Natural Resources and Environmental Conservation (DNREC), the Partnership for the Delaware Estuary (PDE), and others to assess the estuary bottom have shed new light on its tremendous diversity and spatial heterogeneity. Two broad categories of habitat have been described: soft bottom and hard bottom. Soft bottom is composed of loose sediments ranging from fluid mud to sand and gravel. Soft bottom areas are subject to regular deposition and re-suspension of sediments according to fluctuations in the current. Hard bottom areas cover a smaller total area than soft bottoms and include rock or cobble, and reefs formed by the colonial habits of certain aquatic invertebrates, including oysters and tube worms such as *Sabellaria*. The estuary's hard bottoms are considered to have a high ecological value and are used extensively by fish. They also provide additional water quality benefits through filter-feeding by reef-forming organisms.

A hard bottom species of particular interest is the American oyster (*Crassostrea virginica*), which has had an important place in the estuary's natural and human histories. The area covered by healthy oyster colonies was once very large, but is now significantly reduced. Resource managers in New Jersey and Delaware are involved in various activities aimed at restoration of oysters, including the physical importation of material (shell) for the purpose of providing suitable substrate for oyster larvae to attach and grow. In spite of the ecological and economic significance of oysters, the long-term prospects of the Delaware Estuary oyster reefs are uncertain, particularly in light of the changes that may come with rising sea level, salinity, and temperature. Assuming that oyster restoration is an activity that can and should continue, it could be combined with other sub-aqueous or shoreline restoration projects in ways that are discussed below.

Human activities have altered the estuary bottom at places such as borrow pits and abandoned navigation and berthing areas. Such areas often (but not always) have a low ecological value, having been affected by changes in water depth, water chemistry, circulation patterns, and sediment type. In some cases, restoration of such sites may be desirable. This would be accomplished by filling the hole with sediment to bring the bottom back to a more natural grade. The material used in such restoration would need to meet a high standard of quality in order to be approved by regulatory agencies. The restored estuary bottom would need to be comprised of material with an appropriate grain size distribution and low contaminant concentrations.

If the hole to be filled is deep enough, and if dredged material of varying quality is available, it may be possible to place unsuitable (i.e. moderately contaminated, or inappropriate grain size) material into the deepest part of the hole, and then cover it with a layer of clean material. In order for such a layered project to be successful, there would need to be a sufficient thickness of the uncontaminated top layer to ensure that the deeper material is not available to the benthic ecosystem, and also to ensure that erosion will not expose the deeper material over time. Another variant of this kind of restoration is to cover the filled area with coarse material and promote the formation of a hard bottom community.

It is possible that such restoration opportunities exist in the Delaware Estuary, but they are not well known. It would be useful to survey State and Federal agencies that maintain navigation and beach nourishment projects, to prepare an inventory of sites. It should be recognized that conditions at former dredging and borrow sites may change over time due to deposition and side slumping.

All underwater restoration proposals would require the review and approval of State agencies, who will consider the advisability of filling the area and the suitability of the material proposed for the fill. Minimizing environmental damage from the restoration activity may require the use of sediment dispersal prevention techniques such a silt curtains, tremie tubes, or diffusers. Seasonal restrictions to protect aquatic wildlife would need to be observed.

Note: Seasonal restrictions on underwater placement of fill are an example of how construction activities in subaqueous and littoral habitats are regulated to protect aquatic life. Seasonal restrictions are commonly referred to as windows (or dredging windows), and there are several of them that apply in the

Delaware Estuary, corresponding to the life cycles of different species. The windows close on certain dates to protect wildlife during spawning, migration, or other sensitive life stages; and then open again later in the year to allow dredging and other construction activities to take place. Dredging windows in the Delaware Estuary are established through a cooperative process involving several State and Federal agencies, known as the Delaware River Basin Fish and Wildlife Management Cooperative. Additional information about seasonal restrictions appears in the Dredging and Dredged Material Management White Paper.

Tidal Wetlands

Tidal wetlands are some of the most productive natural ecosystems in the world, and are widely recognized for their important ecological functions. The services they provide include flood protection for coastal communities, maintenance of water quality, habitat for hundreds of species of fish and wildlife, and carbon sequestration. Tidal wetlands are a hallmark feature of the Delaware Estuary. They are found in a nearly complete and contiguous band along both shores of the Bay from the capes to the central portion of the estuary near the C&D Canal, and above that point more sporadically to the head of tide at Trenton.

While much of the Estuary's original wetlands have been destroyed by draining or filling, fringing wetlands today encompass more than 150,000 hectares (370,000 acres) (Kreeger at al 2010). Of the areas that remain, many have been altered by human activities such as diking and ditching. Dikes were built beginning in the 1800s to control tidal flows and create salt-hay farms and impoundments for waterfowl. Ditches were built on a huge scale starting in the 1930s to control mosquitoes. These historic activities have had major effects on the exchange of water and waterborne sediment between the Estuary and its wetlands.

Large-scale wetland restoration has been undertaken in the Delaware Estuary, primarily consisting of two kinds of activities: 1) conversion of tidal marsh vegetation from invasive types to more desirable native types, and 2) restoration of tidal flows to sites that were formerly diked for salt hay farming (PSEG). More recently, there has been a growing interest in other kinds of restoration activities, specifically activities that could help wetlands adjust their surface elevation and keep from being drowned as sea level rises.

Many of the Delaware Estuary's wetlands are overrun with non-native vegetation, especially *Phragmites australis*, known as the common reed. The restoration of native wetland vegetation is done primarily to improve ecological conditions for the production of fish and other wildlife. Such projects generally do not involve importation or removal of sediment, but they may have a passive impact on erosion and sedimentation processes in the marsh. The type of vegetation that is dominant in a marsh can affect tidal flows, surface elevation, and topography in the marshes. The re-establishment of native plant cover should restore a more natural exchange of tidal flows and sediment between the marsh and the adjacent waterways. Beginning in the 1990s, thousands of acres in Delaware and New Jersey have been restored in this manner.

Restoration of tidal flows to formerly diked wetlands has been carried out at several large sites in southern New Jersey. Almost 10,000 hectares (24,700 acres) of tidal wetlands was restored using this approach in the 1990s. Sediment was not imported for these projects, although excavated material from the dike breaches and from channel construction was redistributed across the site to create topographic diversity.

Although the large-scale diking and draining of wetlands ended years ago, there have been progressive declines of tidal wetlands documented in recent years across the Delaware Estuary region. Several causal factors have been implicated in this phenomenon including rising sea level and inadequate importation of suspended sediment (Kearney et al 2002; Stedman and Dahl 2008, Cahoon et al 2009). Normally, tidal wetlands can build vertically (accrete) in order to compensate for subsidence and/or sea level rise. This accretion occurs through the accumulation of organic matter (peat) from autochthonous production as well as the importation and trapping of suspended sediments washing in with tidal or storm flows. The importation and deposition of new sediments is essential to the long-term sustainability of coastal wetlands. Marshes that are not keeping pace with sea level rise and sit too low in the tidal prism cannot maintain their vegetation. Once the vegetation is lost, erosion can cause irreversible changes, which often results in the conversion of marsh to shallow open water or unvegetated mud flats.

To enhance a threatened marsh's chances of survival, active restoration could be implemented through importation and placement of sediment. The primary method for this type of restoration is called thin-layer application, which involves spraying sediment slurry under high pressure (Ray, 2007). Developed in Louisiana in the early 1990s, this method has been used at sites in other States, including Maryland and New York, but not in the Delaware Estuary. The practice is not common and should be considered an innovative method. An important limitation of the thin-layer method is the barge-mounted spraying equipment must be within about 90 meters (295 feet) of the restoration site, which limits the area that can be treated by spraying. In most of the thin-layer spray projects undertaken to date, nearby channel bottoms have been used as the source of sediment. However, it is possible that sediment supplies (i.e. dredged material) could be transported to a restoration site by hopper barge or pipeline.

A possible alternative to spraying would be to apply a thin layer of sediment slurry by pipeline. Slocum et al. (2005) studied a marsh site where an accidental spill of dredged material had occurred, and used their observations to speculate on the viability of nourishing tidal wetlands using deliberate applications of dilute sediment slurry. They believe that this method may be used to distribute sediment across a large area. Unlike the spray method, sites deep within the marsh interior could be reached by using standard movable pipes, and by ensuring high water content in the slurry, which should be capable of transporting sediment up to 1,000 meters from the pipe.

The method of application depends on the thickness of material to be applied and the desired final elevation of the wetland surface.. In an early experiment, applying more than 23 cm of material smothered the existing vegetation; but with a thickness of 23 cm or less, native grasses re-established by growing up through the new layer (Reimold 1997). If a project design calls for placement of a thicker layer of new sediment, vegetation could be established in other ways such as from seed if there is a seed source adjacent to the restoration area or transplant (Mendelssohn and Kuhn, 2003). Ongoing scientific research and monitoring of recent restorations around the country are likely to produce additional information that could be used to optimize restoration outcomes. General recommendations for research are outlined in the Recommendations section below.

There is currently no broad consensus in the Delaware Estuary region about the need for, or the appropriateness of, performing wetland nourishment by thin-layer placement. The conditions that govern wetland resilience vary from place to place across the region. Some sites may accrete at a rate sufficient to maintain the marsh as sea level rises, and other sites may not. Any kind of restoration proposal for wetlands would need to be approved by both the landowner and State and Federal permitting agencies. Early engagement with these parties is recommended, particularly since the idea of placing sediment in wetlands is contrary to the traditional ideas of wetland protection and stewardship that are held by the regulatory agencies.

Several efforts are currently under way to gather site-specific information about wetland condition across the Delaware estuary region. The USACE is producing a report this year describing conditions at wetlands around the region (see *Sediment Quantity and Dynamics White Paper*). PDE recently launched a collaborative effort to examine the health and function of tidal wetlands. The Mid-Atlantic Coastal Wetlands Assessment (MACWA) includes probabilistic rapid assessments of wetland condition as well as ongoing monitoring at a network of fixed stations. The study may help identify sites where active restoration efforts could help maintain ecological viability. The Nature Conservancy (TNC) is currently undertaking a project to identify priority conservation areas throughout the Delaware River Basin, including the tidal marsh complexes and shoreline of the bay. As part of the project scheduled to be completed June 30, 2011, TNC staff are assessing the ecological condition of the basin. TNC and its partners, including Federal and State governments and conservation non-profits, will identify priority areas for protection, restoration, and/or other conservation actions. Ultimately, TNC will use the results to recommend tidal marsh restoration, shoreline restoration, and shellfish restoration projects.

Shorelines

The Delaware Bay shore is characterized by a variety of shoreline types. The upper portions of the tidal river are highly developed with much of the shoreline altered by structures such as bulkheads and revetments. The middle section of the Estuary has a mix of developed shorelines, marsh edges, and narrow sandy beaches. The central and southern section of the Delaware Bay, where wave energy increases, has long stretches of narrow sandy beach, often backed by low lying dunes.

Developed shorelines: Where the shoreline is bulkheaded or otherwise hardened with man-made structures, the ecological value of the shore and nearshore environment is generally poor. In some places, these structures are no longer in use and may be degraded. Advocates of environmental restoration would like to see such areas converted where possible, with unused structures removed and replaced with natural habitat. An ideal restoration project would involve removing the structural shore treatment and changing the topography along the entire slope, starting above the high tide elevation and grading down to the sub-tidal. Often, one of the specific goals of this kind of project is to create a fringe of tidal marsh at the water's edge. Although such restoration sites are intended to function like natural systems, they often require some kind of engineered solution to provide stability. Projects of this kind may affect local erosion and sedimentation processes, but they are not likely to require the active importation of large quantities of sediment.

Shoreline restoration can sometimes involve trade-offs between different kinds of habitats. Some shoreline conversion projects propose changing existing areas of shallow open water to intertidal wetland, or to a gradually sloping shoreline. Such conversion of habitat may not be viewed as beneficial by all environmental resource agencies. The lead agencies for permitting (State environmental agency and USACE Regulatory branch) have the primary responsibility for weighing the environmental costs and benefits of restoration designs, and these agencies customarily consider comments from other State and Federal resource agencies when making permitting decisions.

Wetland edges: Wetland edges comprise much of the shoreline in the central part of the Delaware Estuary. Examining maps and satellite images shows large stretches of shoreline where wetland edges are retreating through erosion with loss of wetland acreage. In some places, the shoreline has retreated as much as 1000 meters between 1880 and the present. When wetland edges retreat, wetlands are converted to open water and sediment is deposited in subtidal areas. In the interest of slowing or reversing shoreline recession, PDE and Rutgers University are undertaking a project to test various methods of protecting and restoring marsh edges along the shores of the Maurice River in southern New Jersey. The project, "Delaware Estuary Living Shorelines," is specifically designed to slow shoreline erosion at wetland edges, and facilitate passive sediment trapping and accretion in the wetland. The project uses a soft-armoring tactic as an alternative to hard approaches such as bulkheads or riprap. Logs made of natural fibers are anchored along the eroding wetland edge and augmented with shell bags and live plants and mussels. The living shoreline is intended to promote the stability of both the wetland behind the shoreline and the subtidal areas in front of it. Field work began in 2007 and a practitioner's guide is being prepared for release in 2011. An estuary-wide planning project is soon to be launched, which will involve a survey of shoreline condition over a large area to assess restoration needs.

For high-energy areas along the open bay, more aggressive tactics may be needed to provide protection from waves. In such places, structures such as breakwaters or nearshore reefs could be placed a short distance offshore to deflect wave energy. This would facilitate the passive trapping of sediments and provide wave protection for the wetland edges. Breakwaters, sills, or reefs could be built using dredged material. Combining active restoration (using sediment to build sills or reefs) with passive restoration (design to facilitate trapping of sediment) would create a "hybrid approach to shoreline restoration.

Beaches: In the lower bay, there are long stretches of narrow sandy beach backed by low-lying dunes. Often there are broad tidal wetlands behind the dunes. The bay beaches are important habitat for a variety of animals, including migratory birds, horseshoe crabs, and terrapins. Small residential communities, typically consisting of one or two rows of homes behind the beach and dune, occur on both sides of the Bay. Beach erosion is an ongoing problem in the developed areas, in part because the natural tendency of the sand to migrate is hindered by the presence of homes and shore protection structures.

Both New Jersey and Delaware use sand for beach nourishment projects along the bayshore. DNREC has estimated the long term and perpetual need for roughly 94,000 cubic yards of sand per year to counteract the effects of coastal erosion at seven bayfront communities in the southern part of the State. Potential sources of sand include offshore borrow areas and navigation channel dredging. Beach nourishment needs in New Jersey are given here not in terms of annual maintenance needs, but in terms of major projects for one-time placement. A number of such projects have been in planning for several years, and they include both developed areas and environmental restoration areas. The cumulative total of sand needs for several projects in three different counties is more than 1.5 million cubic yards.

Appropriate methods need to be used in all beach nourishment projects to ensure that the project does not cause ecological damage, and that the restored sandy beach meets the habitat needs of wildlife. Critical issues include sediment grain size, beach slope, and location of borrow areas. The sediment in most parts of the lower Delaware Bay tends to be coarse-grained (i.e. sand), and low in contaminants. Every proposed beach nourishment project would require site-specific testing of source materials to ensure the material placed on the beach is appropriate for that use. Offshore borrow areas should be selected so as not to disturb important underwater habitats. Seasonal restrictions apply to beach nourishment projects, which are generally not permitted between April 15 and September 15. State environmental agencies have the responsibility of reviewing nourishment projects to ensure that these issues are properly addressed.

From the perspective of Regional Sediment Management, dredged material should be used in beach nourishment whenever possible. There have been several examples of this kind of beneficial use in the Delaware Bay. The beaches of Bowers and South Bowers Beach in Delaware have been nourished through the direct placement of sand dredged from the nearby Murderkill River navigation channel. Likewise, sand dredged from the Mispillion Inlet has been placed on the eroded shoreline north of the Mispillion jetty to repair a breach. These projects demonstrate successful collaboration between the USACE and DNREC.

Uplands

Restoration of upland areas is usually associated with a past disturbance that has interfered with the ability of the land to regenerate a productive natural plant community. Disturbed uplands areas may be poorly vegetated and subject to high rates of erosion. Such sites can be significant sources of sediment and contaminants.

While the means for restoring degraded uplands vary with the nature of the disturbance and the setting, it is common for such projects to involve soil imports or soil amendments to fill depressions, grade the surface topography, and improve the growing conditions for plants. Dredged material can be used for this purpose, either by itself or as a component of a blended material. The Harbison-Walker site (Northwest Magnesite Plant) is a former industrial site located in Cape May, New Jersey. In the 1990s, before restoration, the site's soil was too alkaline to support healthy and diverse vegetation. The desired end use of the property was open space and wildlife habitat. Dredged material was incorporated into the soil to add organic matter and decrease the pH. Native vegetation was planted and established. While this project is a successful example of restoration, it also illustrates a challenge that should be considered when taking dried dredged material from a CDF. Depending on how long it has been in the CDF, dredged material may contain roots and rhizomes of plants that were growing at the CDF site. These plants, including invasive types, may establish opportunistically at the restoration site and should be considered.

Dredged material has been used to reclaim abandoned mine lands in Pennsylvania. Across the State there are hundreds of thousands of acres of land that are impacted by coal mining. The mining activity removed forests and topsoil, leaving many sites physically unstable, or with insufficient soil to support healthy plant cover. The Pennsylvania Department of Environmental Protection (PADEP) has worked for years to carry out restoration activities at former mining lands, and yet much remains to be done. A pilot project to demonstrate the use of dredged material for mine reclamation was carried out at Bark Camp in Clearfield County between the late 1990s and 2002. Over 400,000 cubic yards of dredged material from the New York/New Jersey Harbor was transported to Bark Camp, mixed with coal ash and lime kiln dust, and used to grade and contour the site. The surface of the regraded site was covered with 18 to 20 inches of manufactured topsoil (not containing dredged material), and the site was planted with grasses. Despite the abundance of mine sites needing reclamation, there have been only a small number of other projects completed to date. Some material from USACE's Fort Mifflin CDF in Philadelphia has been transported to former mining sites in northeast Pennsylvania, but the scale of this has been limited. The sheer magnitude of the abandoned mine problem in Pennsylvania makes this beneficial use concept appealing. The challenges, however, include high costs for material transportation and handling, and public concerns regarding the safety of dredged material. Pennsylvania's experience in the mine reclamation projects shows that beneficial use projects may require public education and outreach to help people understand the ways in which the environmental risks can be managed.

Watersheds

This section provides a general overview of the 12,000 square mile Delaware Estuary watershed and sediment issues in its non-tidal areas. It would be beyond the scope of this paper to attempt a comprehensive explanation of the role that sediments play in physical and ecological processes in watersheds. Instead, we will provide a broad discussion of watershed conditions and restoration. There is a discussion of related issues in the *Sediment Quantity and Dynamics White Paper*. None of the restoration concepts discussed in this section are likely to require the active use of dredged material.

Accelerated stream erosion is one of the most common water quality problems reported in streams of the Delaware watershed. Stream channel instability is widespread. While this problem is not new, a detailed understanding of its causes is still emerging. It is appropriate to consider this on a multi-decadal time scale, and to recognize that the ultimate cause of stream channel instability is often land use change. While streams in undisturbed forested landscapes tend to be reasonably stable, streams in landscapes where forests have been removed tend to be unstable. Development on the land surface generally has the effect of increasing sediment loads in waterways. There are a number of large-scale, long-term efforts under way that address various aspects of this problem.

The earliest efforts to reduce watershed sediment loading were directed at agricultural lands. Beginning in the 1930s, the loss of soil from agricultural areas across the U.S. was the impetus for establishing programs to assist farmers with the implementation of conservation practices. The Natural Resources Conservation Service (formerly the Soil Conservation Service) is the primary organization responsible for this effort. Conservation work in agricultural lands has been under way for many decades now, and it has almost certainly reduced the flux of eroded sediment from farmlands to waterways.

Beginning in the 1970s, as urban and suburban sprawl advanced across the landscape, awareness has grown of the ways in which developed landscapes influence the streams that flow through them. Streams in urban areas tend to suffer from a common set of problems; when land development takes place, construction activities can produce a large temporary flux of sediment to local waterways. As development progresses, increasing the amount of impervious surfaces in a landscape causes erosive flood flows in urban streams, streambank erosion, and downstream transport of sediment. It is generally believed that much of the sediment load in urban areas is derived from the stream channels themselves, as the streams erode and the channels enlarge. In recent decades, there have been increasing regulatory efforts to address these problems using erosion and sediment control practices at construction sites, low-impact development practices, and stormwater management retrofits. A considerable amount of work remains to be done in these areas.

The growing field of stream restoration is a response to the stream channel problems caused by land use changes. Using various techniques (and with varying degrees of success) stream restoration is generally aimed at stabilizing waterways that are actively eroding. Taken altogether, stream restoration efforts in the basin have probably had the effect of reducing the export of sediment to downstream areas. However, compared to the scale of the problem, the amount of restoration that has been completed to date is very small. It may be expected that these efforts will continue for the foreseeable future, but at a rate that will vary according to the availability of funding. Federal and State governments generally support such efforts with modest funding through grant programs. Assessment of restoration needs and prioritization of projects has not been carried out on a basin-wide scale in the Delaware River basin.

Total Maximum Daily Load (TMDL) is a regulatory tool that could play a role in the control of sediment from developed areas. Where streams have been determined to be impaired from sediment-related causes, a TMDL implementation plan must be prepared. These plans may force local governments or landowners to implement projects to reduce sediment discharges. Philadelphia's work to reduce sediment in the Wissahickon watershed through stream restoration projects is an example of this effort (Philadelphia Water Department, 2010). The program for addressing sediment impacts using TMDLs is fairly new and not well established. In the future, as more entities undertake TMDL implementation, it may eventually result in further reductions in sediment loading from watersheds across the region.

Historic dams and their legacy represent a special concern within this subsection. From the watershed perspective, dams trap sediment that would otherwise make its way downriver to the estuary. Although the mainstem Delaware River is famously dam-free, tributaries in the Delaware basin have hundreds of dams that were built between 150 and 300 years ago. Some historic dams are still in place, others have been breached, and some have been deliberately removed as a restoration measure. Behind these historic dam sites, the stream channels and floodplains are filled with large volumes of sediment. The volume of material represented by these legacy sediments may be quite significant. When old dams become partially or completely breached, it leads to erosion and downstream transport of the stored sediment. Sites with breached dams and eroding legacy sediments are often very unstable, and can represent significant sediment sources in their watersheds (Walter and Merritts, 2008). Gellis et al. (2009) and Merritts et al. (2010) note the following regarding removal (through streambank erosion) of sediment from storage behind mill dams and on flood plains: 1) occurring today, 2) major source of sediment in the basin, and 3) expected to be a significant source for decades to come. Because of the similarity between the Chesapeake and the Delaware basins in terms of geology, landforms, and history, these conclusions should be of interest for the Delaware basin. However, there has been no large-scale attempt to inventory Delaware basin streams to assess the number of dam sites or the volume of legacy sediments still present in former impoundments behind old dam sites.

The planned removal of historic dams and the restoration of formerly dammed sites are activities that can have important consequences for sediment flows in watersheds. Dam removal has been undertaken for a variety of reasons, the most common one being the desire to re-establish fish passage between stream segments. One of the most significant results of removing a dam is that it allows watershed-derived sediment to move naturally downriver and releases the legacy sediments that have been stored behind the dam for decades (sometimes centuries). Regulatory oversight is typically provided for dam removal projects to ensure that the release of legacy sediments will not severely impact downstream reaches, and that the stream channel remains stable following the demolition of the dam. Even so, some sites where dams have been removed may represent significant ongoing sediment sources despite the best efforts of the parties carrying out the restoration.

Beneficial Use

Introduction

Sediment dredged from underwater areas is called dredged material. Dredged material can be a nuisance, hazard, or valuable commodity, depending on its characteristics and intended use. Dredged material is often simply disposed of in deep water or in a disposal facility. The practice of putting dredged material to a good use is called beneficial use.

In the Delaware Estuary, it has long been common practice to dispose of dredged material by placing it into a Confined Disposal Facility (CDF). Dredged material is pumped into a CDF as liquid slurry, and water is removed by draining and evaporation, while the sediment is retained in the facility. Most large CDFs are used repeatedly, which results in dredged materials from recent projects being placed on top of layers of dredged materials from past projects. Eventually, every CDF will reach capacity and need to be closed. Beneficial use of dredged material is the most effective means of conserving CDF capacity. Beneficial use may involve alternative methods of placement during dredging (that is, bypassing the CDF altogether), or it may involve the removal of dried dredged material from a CDF.

Beneficial use is not new to the Delaware River basin. In the past two decades, over 3.5 million cubic yards of Delaware River dredged material has been used for projects such as land redevelopment, highway construction, and landfill cover. Below is a table showing some examples of beneficial use projects in the Delaware Estuary region, compiled from information provided by USACE, New Jersey Department of Environmental Protection, and Pennsylvania Department of Environmental Protection.

Examples of Beneficial Use in the Delaware Estuary

Project	Location	Year completed	Amount of dredged material used, cubic yards
NJ Turnpike, Exit 1	Deepwater, NJ		180,000
Landfill cap	Burlington Co. RRC, Bordentown, NJ		15,000
Route 29 overpass	Trenton, NJ		2,900
Tweeter Center	Camden, NJ	1995	220,000
Philadelphia International Airport, Runway 8-26 construction	Philadelphia, PA	1997	1,900,000
River Winds Golf Course	West Deptford, NJ	2001	160,000
Strip mine reclamation	Tamaqua, PA	2003	60,000
Landfill closure	Hazleton, PA	2009	800,000
Mispillion Inlet shoreline restoration	Sussex County, DE	2009	25,000 +
Landfill daily cover	Waste Management, Inc, Falls Township, PA	ongoing	150,000 / year
Dream Park Equestrian Center	Gloucester County, NJ	ongoing	150,000 through end 2010
Landfill cap	Harrison Ave Landfill, Camden, NJ	pending	180,000

The amount of material beneficially used to date in the Delaware River region is small in proportion to the total amount of material produced by dredging. There is considerable potential for increasing the quantity of material used beneficially in this region. In the sections to follow, we discuss four categories of beneficial use: landfill uses, site remediation, general construction, and ecological restoration.

There are three fundamental factors related to beneficial use: grain size, chemical composition, and location. Each of these three factors has an important bearing on the viability of a potential beneficial use project.

Grain size: Dredged material is typically a combination of gravel, sand, silt, and/or clay in varying proportions that is mixed with organic matter from decomposed plant and animal material. Understanding potential uses of dredged material requires that the material be characterized by particle size distribution, and organic content. Particle size is mainly what drives the engineering properties of the sediment.

Chemical composition: Sediments tend to bind and hold chemical contaminants. Smaller particle sizes (clay and silt) tend to have higher affinities for contaminants than larger particles such as sand. Higher quantities of organic material also correlate with a higher potential to bind contaminants. Understanding potential uses of a dredged material requires that the material be characterized by contaminant concentrations. Regulatory requirements, usually administered at the State level, set limits on the uses of materials that contain contaminants. The presence of chemical contamination does not necessarily preclude all uses of a material, but knowing the contaminant concentrations is critical to determining which uses are appropriate. The higher the level of contamination, the more restrictive the beneficial use options. Some material may be so contaminated that no beneficial uses are permissible. Such materials should be handled properly to eliminate human health or environmental risks. For a more detailed discussion of sediment contamination, see the *Sediment Quality White Paper*.

Location: Material transportation and handling costs have a major influence on the feasibility of beneficial use project proposals. In general, increasing the distance between the source of the dredged material and the beneficial use location increases the cost of the project. Transportation cost can be sufficient by itself to prevent implementation of an otherwise viable project.

Good planning requires that resource managers have a number of beneficial use tools available. Those considered below are the options that the white paper workgroup members believe are applicable in the Delaware Estuary. This discussion will attend to the simplest applications first, considering both engineering and regulatory perspectives, and progress to more complicated applications.

Landfill Uses

There is a constant need for daily cover on solid waste landfills throughout the greater Delaware River region. Dredged material has the engineering properties appropriate for this use. This use is relatively unrestrictive in terms of contamination, because modern landfills are constructed with controls that make it possible to safely use dredged material that has some degree of contamination.

There is a continuous demand for material to be used at landfills. Waste Management of Pennsylvania has been successfully using dredged material on its landfills in Falls Township, Bucks County, for a number of years. These facilities have the advantage of being located close to a CDF where the USACE and others routinely dispose dredged material. The RSM Workgroup recommends that other landfill operators should consider using dredged material. Naturally, they will need to take into account the distance to a reliable source of material, and the cost of transportation.

Construction Aggregate

The value of sand and gravel for construction is well known. These materials are usually obtained by mining natural deposits, but dried dredged material from a CDF may be used as well. Dredged material can be readily used for infrastructure construction or private development, as long as the material meets the engineering requirements of the user, and does not exceed the State's chemical criteria for the proposed use.

Since CDFs are traditionally managed for disposal, and not for beneficial use, the valuable aggregate (sand and gravel) they contain is sometimes mixed with less desirable fine grained material, and/or with contaminated material. In such cases, the materials in the CDF may need to be sorted or blended prior to use. Such material handling processes will drive up the cost of the project, but depending on the circumstances, the extra cost still may not preclude beneficial use.

If a CDF owner determines that his facility contains valuable aggregates, and that the value of the material exceeds the cost of excavation, processing, and transportation, then it may be possible for him to sell the material to a construction contractor, developer, or broker. In the case of Federally-owned CDFs, USACE can put out a bid if there is known interest in material, and the market would determine the cost of removing the material. In some cases, it may be worthwhile for a CDF operator to subsidize the cost of removing sediment in order to create disposal capacity. This idea of a renewable CDF may, in some locations, be an important management tool where new land is either unavailable or too valuable to use for a new CDF. One specific way that a CDF owner could facilitate the marketing of dredged materials for beneficial use would be to conduct sampling and analysis of the materials in his facility. Providing information about the regulatory characteristics of the material would reduce uncertainty for prospective purchasers, and allow a larger number of bidders to consider using it.

The types of projects that can use dredged material are as numerous as there are needs for aggregate. Dredged material has been used as general fill, for airport construction, in highway projects, for construction or repair of berms and levees, for beach replenishment, and for general landscaping. At least one regional company in New Jersey uses dredged material in their concrete formulations, and actually seeks permits to dredge in Federal channels to obtain it. While it is possible to discuss these various proven uses, the fact remains that these projects still account for a small percentage of the total production of dredged material in the Delaware Estuary region. Relatively few contractors and developers understand the value of dredged material, or know where such materials can be easily and consistently obtained. Therefore, developing beneficial use opportunities in the construction field will require aggressive marketing. The RSM Workgroup suggests that CDF owners should be responsible for developing marketing plans, with assistance from any stakeholders who have an interest in increasing the rate of beneficial use.

Site Remediation

The long history of industrial activity in the Delaware River region has left a large number of former industrial sites that require some remediation in order to be used. Dredged material has been used in the remediation or redevelopment of several contaminated industrial sites, closed solid waste landfills, and abandoned mines. A wide range of types of dredged material have been used for this purpose, ranging from clean sand to contaminated silt and clay. This kind of project offers multiple benefits, including the opportunity to eliminate an existing source of contaminated sediment by capping or stabilizing the site. Despite the record of successful projects, and despite the multiple benefits that can be achieved, this is a complicated and still somewhat controversial beneficial use strategy.

Dredged material is a soil-like product whose characteristics may be less environmentally harmful than the contaminated soils currently exposed at a remediation site. Dredged material can be used to fill and grade the site to prepare it for redevelopment, and/or to create an impermeable cap over contaminated soils. There is a wide range of conditions at former industrial sites and possible combinations of use of dredged material and engineering controls. State environmental agencies play a significant role by reviewing the proposed remedy and determining if the dredged material ought to be used in such a way. Environmental consultants and contractors should consider using dredged material whenever imported fill is required for a remediation site, or when an impervious cap is needed to sequester contaminated soils.

Dredged material can be blended or otherwise processed to improve its characteristics. The need for processing of dredged material prior to beneficial use depends on the nature of the material and its intended use. Sometimes dredged material requires blending with another aggregate in order to give it the desired engineering properties. Fine grained dredged material (silts and clays) can be blended with pozzolanic additives (such as cement kiln dust or coal ash) for dewatering and providing structure and strength. Dredged material that has been modified in this way is usually referred to as processed dredged material (PDM). Because of its low permeability when compacted in place, PDM can be useful as an impermeable cap or hydraulic barrier. The properties of this engineered product are not identical to those of other fill materials, and its use requires special care. It may be necessary to add a layer of surface soil on top of PDM for use as a growing medium if the site is intended to support plants. The creation and use of PDM is amenable to dredged material that has modest levels of contamination. In some situations, the addition of pozzolans to form PDM can actually reduce the potential for leaching of contaminants from the product after it is placed (Douglas et al, 2005).

Using dredged material at contaminated sites often raises concerns from the public, particularly from people who live near the remediation site. Many people are concerned about the use of dredged materials and uncertain about the implications on the quality of life. Therefore, these projects will often need to involve some public education or outreach component in order to be successful.

Ecological Restoration

Dredged material could be used in a variety of ways to help restore natural habitats in the Delaware Estuary region. Some general issues are addressed below.

On a national level, more dredged material has been used for habitat creation and restoration than for any other beneficial use. This is mostly due to the enormous amounts of clean material dredged annually in remote locations, much of which can be placed in such a way as to create aquatic or avian habitat near the dredging site. In the Delaware Estuary, there have been relatively few projects to date. In this region, the principal challenges of using dredged material for habitat come from chemical composition and location.

In order to use dredged material for habitat projects, contaminant concentrations in the material must be very small. But how small? There is no clear answer to that question. The environmental agencies who oversee aquatic resource permitting programs may seek to apply different sediment quality criteria than the ones used in other beneficial use projects. Instead of using human health-based criteria, as is usually done in construction projects, the permitting agencies may consider applying ecologically-based criteria. Important factors include fate and transport, bioavailability, and bioaccumulation of the particular contaminants present in the material. This issue is technically complex, and is further complicated by the fact that there are few, if any, ecological criteria that are universally applied by all Federal and State regulators. Attitudes and approaches toward this subject vary from State to State. Successful implementation of any project will require early and close coordination between the agencies that have relevant expertise and legal jurisdiction.

In the Delaware Estuary, matching up restoration sites with conveniently-located sources of dredged material is a challenge. Creative solutions may be necessary to overcome the technical challenges of transport as well as the problem of cost. In selecting the means of transport, consideration will have to be given to the end use, and whether it is advantageous to deliver the material as water slurry or as dewatered material. In the interest of demonstrating the feasibility of such projects in the near term, it may be wise to keep transportation costs low by matching dredged material sources with restoration locations that happen to be located close by.

Additional Considerations

This white paper is intended to highlight restoration and beneficial use opportunities that may be available in the Delaware Estuary region. We have tried to indicate some of the advantages, and also some of the challenges. We have not attempted to give a cost/benefit profile of each concept. Ultimately the viability of any concept or project depends on a complex set of circumstances, costs, and benefits. Some of these circumstances depend on market conditions, and some depend on regulatory requirements and agency attitudes. Much depends on available funding.

Although restoration is an idea with many proponents, a myriad of challenges often stand in the way of implementation. Opportunities for restoration are sometimes limited, especially in urban areas, so it may take extra effort to find them and to make them work. On the other hand, the value that our society places on natural habitats is increasing, and will likely continue to rise. Our intent with this paper has been to identify restoration opportunities and look to the future and think outside the box as we consider project feasibility.

Traditionally, at the USACE and other agencies, policies and goals for ecological restoration are considered separately from policies and goals for dredged material disposal. For those projects whose purpose is strictly related to the maintenance of navigation channels, the USACE is constrained to choose the least cost method for dredged material disposal, provided that method is environmentally acceptable. (USACE, 2007) As long as this rule, which is informally called the Federal Standard, governs the placement of dredged material, it will be rare to have projects that combine dredging operations with restoration. Usually, dredging disposal needs are linked with restoration only when the added costs of incorporating a restoration element into a navigation project are relatively small; when a non-Federal sponsor assumes the incremental cost of placement at a restoration site; or when particular projects are authorized to have multiple purposes, as in some USACE Civil Works projects. For USACE, multi-purpose projects are those that cross-cut multiple business lines, such as Navigation and Ecosystem Restoration. For multi-purpose projects that include ecosystem restoration, cost-benefit analyses would be required, and would include calculation of both the National Economic Development and National Ecosystem Restoration values of various alternative plans. It is hoped that USACE's implementation of multi-purpose projects will increase in future years, to help address the complex challenges described in this paper. The members of the Delaware Estuary Regional Sediment Management team also hope that our efforts can help bring about a new paradigm, where the environmental and economic benefits of the restoration component of a project are considered to offset the (presumably) higher costs of moving dredged material to a restoration site instead of to the nearest CDF.

Restoration and Beneficial Use - Recommendations

Next Steps: Project Framework and Goals

The diverse options for incorporating restoration and beneficial use into sediment management can be categorized and simplified into an implementation strategy. This strategy should establish clear short-term and long-term goals for restoration and beneficial use of sediments, and categorize projects according to those goals within a conceptual framework developed by consensus. A starting point for this conceptual framework is suggested below. The next step should be to convene a working group to develop and implement a restoration and beneficial use sediment strategy.

Project Framework

Project Category	Objective	Example Projects	Example Goals*	
			Short-Term	Long-Term
Non-Tidal Passive	Control sediment loading to estuary	Riparian and in-stream habitat improvements to trap sediments	By 2020: 1) Increase acreage of floodplain wetlands by 10% 2) Replace 10% of dams with natural stream habitat	By 2040: 1) Restore riparian land cover to 1990 acreage; 2) Remove all non-purposed dams and stabilize legacy sediments
Non-Tidal Active	Enhance uplands and stabilize sediment sources	Placement of dredged materials to remediate or cap brownfields, mine lands, etc	By 2020: Re-use 5% of dredged material produced in the estuary for upland enhancement	By 2030: Maximize the re-use of appropriate quality dredged material for uplands restoration
Tidal Passive	Capture sediment along shorelines	Install "Living Shorelines" to prevent shoreline recession, expand intertidal wetlands, and improve nearshore subaqueous habitat	By 2020: Install pilot Living Shoreline projects of at least 500 m at 2 sites in the upper estuary and 2 sites along Delaware Bay (for at least 2 km total)	By 2030: Integrate living shorelines into routine management of sediments and for sea level rise adaptation
Tidal Active	Enhance tidal wetlands and beaches with sediment	Placement of dredged materials to build elevation of tidal wetlands; and nourish eroding bay beaches	By 2020: 1) Protect at least 1,000 acres of tidal wetland from drowning using nourishment 2) Enhance at least 2 km of beaches	By 2030: Maximize the re-use of appropriate quality dredged material for tidal wetlands and beaches

* Example goals in the table are suggested for discussion purposes only and do not represent the viewpoint of any individuals or organizations. Goals to be proposed in the Regional Sediment Management Plan should be science-based and developed by consensus of the participating organizations.

Additional Recommendations

1. <u>Research and planning are needed to advance the concept of **subaqueous restoration**</u>

   a) Inventory Delaware Estuary borrow pits, unused channels, and other areas that were previously dredged that may represent subaqueous restoration opportunities.

   b) Evaluate the feasibility (costs, logistics) and benefits of using dredged material to restore subaqueous habitats.

2. <u>Research, planning, and action are needed to advance the concept and implementation of **tidal wetland restoration** by the active method of thin-layer placement of sediment.</u>

   a) Assess Delaware Estuary tidal wetlands for restoration needs.

      i. Collect and maintain detailed elevation data for Delaware Estuary tidal wetlands.

      ii. Assess the need for intervention, and prioritize on a regional scale.

         (1) Integrate results of assessment projects completed or currently under way (including USACE, The Nature Conservancy, and PDE).

(2) Assess, rank, and map the tidal wetlands of the Delaware Estuary for elevation capital.

(3) Assess possible future conditions in Delaware Estuary tidal wetlands in the absence of restoration.

(4) Identify wetland sites that have sediment sources located nearby, since these may be considered for early implementation.

b) Engage landowners and regulatory agencies to identify and address barriers to implementation of thin-layer placement, including regulatory impediments.

c) Evaluate methods of thin-layer placement to understand how to optimize restoration outcomes.

d) Evaluate where and how sediment (including dredged material) could be obtained for thin-layer placement in wetlands.

e) Engage stakeholders to develop implementation opportunities, beginning with demonstration-scale project.

3. Research, planning, and action are needed to advance the concept and implementation of **shoreline restoration**.

a) Assess, prioritize, and map Delaware Estuary shorelines for restoration needs. This includes areas where shoreline restoration would protect or restore adjacent tidal wetlands.

b) Evaluate living shorelines demonstration projects, and use the results to improve the method.

c) Continue research on living shoreline techniques, including hybrid techniques that involve construction of subaqueous sills or reefs.

d) Engage stakeholders to develop additional implementation projects for living shorelines and hybrid projects.

e) Promote engagement between USACE and States to implement the placement of dredged sand for beach nourishment, to meet the sand needs that have been identified by the States.

4. Understanding and controlling the **watershed sediment** load. [Also see Project Framework above.]

a) Advocates of reducing watershed sediment loads should become familiar with the existing sediment reduction programs that are operating in particular watersheds. These may include regulatory or outreach programs in agriculture, land development, stormwater management, stream restoration, or dam removal.

b) To follow on recent findings reported for the Chesapeake basin (Gellis et.al. 2008, Merritts et.al. 2010), detailed research about sediment storage behind historic dam sites in the Delaware basin may be warranted.

c) Watershed planning should engage all stakeholders. Multiple purposes can often be achieved through cooperation between partners.

5. Beneficial Use (BU) of dredged materials for all categories of activity

a) **Dredgers** may facilitate BU by:

i. Evaluating each dredging project for its potential to support the implementation of beneficial use by direct placement.

b) **CDF owners** may facilitate BU by:

i. Managing placement operations so as to keep high-value dredged material segregated from other materials, and prevent dissimilar materials from being mixed together.

ii. Collecting and maintaining information about sediment characteristics (e.g. grain size, contaminant concentrations) for material in the CDFs. Identifying areas where usable material exists, and providing this information to prospective users of material.

iii. Consider ways to allow access to usable material currently in the CDFs.

iv. Develop a marketing plan to increase awareness of the availability of usable materials.

c) **States** may facilitate BU by:

i. Implementing regulatory incentives.

ii. Clarifying regulatory requirements for beneficial use, to reduce uncertainty for project sponsors.

iii. Coordinating between States to simplify project planning by project sponsors.

iv. Being open to early engagement by sponsors of beneficial use projects.

v. Considering the use of dredged material at State-sponsored restoration or remediation projects.

d) **Developers, construction contractors**, and other project sponsors may facilitate BU by:

i. Considering dredged material as an alternative to other sources of aggregate for all kinds of construction, restoration, and remediation projects.

ii. Understanding the special issues that come with using dredged material and being willing to work with the dredger or CDF owner to address implementation challenges.

e) **All stakeholders** should assist in public outreach activities to address the negative perception that many in the public have about dredged material being used for various beneficial uses in their communities.

6. Beneficial Use of dredged material for ecological restoration [also see Project Framework above.]

a) **All stakeholders** may facilitate beneficial use for ecological restoration by:

i. Supporting regional restoration planning and related research.

ii. Collaborating on the development of reasonable, region-specific technical criteria for the use of dredged material in habitat restoration.

b) **USACE** may facilitate beneficial use for ecological restoration by:

i. Actively developing multiple-purpose projects that involve an ecosystem restoration component.

ii. Engaging the USACE Regulatory branch to facilitate the permitting of beneficial use applications that require Federal permits.

c) **States** may facilitate beneficial use for ecological restoration by:

i. Being open to the use of dredged material for habitat restoration in projects that require State permits.

ii. Developing projects on State-owned lands.

d) **Other resource agencies** may facilitate beneficial use for ecological restoration by:

i. Developing projects on agency-owned lands.

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