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Economic assessment of dredging operations in Mobile Bay, USA and some additional notes on sustainable management of dredged material

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Abstract This paper describes a study that was performed to determine the cost-effective method of dredging in Mobile Bay in the United States and to explore the possibility of utilizing the dredged materials in an environmentally sustainable way. An analysis of the historical cost and working time data for hopper dredging and pipeline dredging for Mobile Bay showed that there was not a substantial difference in unit costs between the two methods. However, while the disposal methods for dredged materials were taken into consideration, the pipeline dredging seemed to be a more desirable and environmentally friendly option for dredging in Mobile Bay. In addition to cost analysis, the paper discusses several possible ways of sustainable management of dredged materials. The paper also indicates that if the sediment in Mobile Bay is found to be contaminated by the Deepwater Horizon oil spill, the pipeline dredging will become a more desirable dredging alternative.

Keywords Cost effective · Coastal restoration · Dredging · Hopper dredge · Maritime transport · Pipeline dredge · Sustainable material management

Introduction

Marine transportation is the backbone of international trade. It is an economic and efficient mode of transport for transporting mass quantities of commodities and containerized cargo (Boile et al. 2005; Grigalunas et al. 2005). Maritime transportation handles around 80 % of global trade by volume and over 70 % by value (UNCTAD 2012). In the United States, it carries around 78 % by weight and 44.5 % by value of all international trade (BTS 2011). The role of maritime transport in the global economy is increasing and to meet the growing demand for an increase in shipping activities, larger and more efficient ships are introduced. The introduction of larger ships has resulted in the needs of deepening and/or widening the navigation channels to provide safe and adequate access to the ports and harbors (Sulaiman et al. 2011). Maintenance activities of navigation channels through dredging can pose a major threat to the environment due to the environmental degradation it might cause and the disturbances it might create to marine life. Therefore, the disposal methods or use of the dredge material in a beneficial way is a major issue that should be addressed while selecting a particular method for dredging operations.

Background

Mobile Bay is an inlet of the Gulf of Mexico. It extends 56 km north to the mouth of the Mobile River in the southwestern part of Alabama in the United States. Mobile bay is Alabama's only port for ocean going ships that transport approximately 25 million tons of cargo to and from the Alabama State Port (ASPA 2012). As of 2010, Mobile, Alabama was ranked 8th among U.S. ports for dry bulk vessel calls, 7th for general and 4th for combo vessel calls (Ray and Matsuda 2011). Year round maintenance dredging of Mobile Bay is required to keep the bay accessible to

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the ships to maintain the regular port activities. Currently, hopper dredging is the most common method of dredging in Mobile Bay and its shipping channel. A self-propelled hopper dredge is a large ship which is capable of dredging sediment from the floor of a body of water through a large mechanical drag arm, storing it into a hopper within the ship's body, transporting it to the disposal area, and discharging the slurry (sediment mixed with water) using large doors on the underside of its body. The removed sediment from Mobile Bay by hopper dredging is disposed of in deepwater disposal sites in the Gulf of Mexico as mandated by the Water Resources Development Act (WRDA) of 1986 (WRDA 1986).

In the WRDA of 1996 (WRDA 1996), the Congress modified the protocol for the disposal of dredged material from the Mobile Harbor to allow the United States Army Corps of Engineers (USACE) to consider other alternatives for disposing dredge material in the Gulf of Mexico. According to the WRDA of 1996, the possible alternatives for conducting the dredging operations must use the dredged material in an environmentally conscious and beneficial way and/or provide protection against shore erosion. One common method of using suitable dredged material in a beneficial way is to perform the dredging process with a pipeline dredge and discharge the sediment onto a shoreline for erosion control or to build up coastal areas that are subject to damage by hurricanes. A pipeline dredge is a semi-stationary vessel that removes sediment from an area by drawing it through a pipeline and discharging it onto a barge, a shoreline or an open water disposal site.

A hopper dredge is able to collect large quantities of material in a relatively short amount of time but must travel to and from its approved discharge locations. A pipeline dredge does not immediately remove the same cubic meterage as a hopper dredge but it is able to maintain continuous operations since it does not have to break work to dispose of the dredged material. The extended distance that a hopper dredge travels may result in higher fuel cost. Also, it may result in higher emissions that negatively affect air quality. The U.S. Army Corps of Engineers (USACE) and U.S. Environmental Protection Agency (USEPA) have developed documents that address the aquatic and terrestrial impacts from dredging and placement operations (USEPA 2004). However, air emission from the dredging equipment is not considered as a criterion in their guidelines for selecting dredging equipment for a site. The USEPA has generated the transportation and general conformity rules that require project sponsors to include air quality analysis in their planning process, but the rules do not focus on dredging equipment selection process based on air emissions from marine engines. It should be noted that with comparable costs and equipment availability, environmental impacts can be minimized by choosing the dredging equipment with the lowest air emissions, thereby making the dredging project more sustainable (Anderson and Barkdoll 2009). The goal of this paper is to compare the costs associated with pipeline and hopper dredging in Mobile Bay, and to weigh the benefits of sediment disposal methods associated with each type of dredging. This paper also discusses possible sustainable ways of utilizing the dredged material.

Methodology

The following sections describe the process that was followed in collecting and analyzing the cost data for hopper and pipeline dredging in Mobile Bay.

Data collection

The data in the form of dredging contract history cards from 1991 to present for Mobile Bay were obtained from the Mobile District USACE via the Freedom of Information Act (FOIA). There were 56 history cards containing information on hopper dredging and six containing information on pipeline dredging.

There were not sufficient data on pipeline dredging for Mobile Bay. Therefore, additional dredging data in the form of history cards for Bayou Casotte, Mississippi were obtained from the Mobile District USACE. The reason for including Bayou Casotte data in the analysis was that the two areas have similar geographical features as far as dredging factors are concerned with the exception of the distance from their open ocean disposal areas. Pipeline dredging is primarily used for channel maintenance in Bayou Casotte, while hopper dredging is typically used in Mobile Bay. Eleven history cards were obtained for Bayou Casotte with seven of them being for pipeline dredging and four for hopper dredging. Mobile District USACE was contacted for background information and assistance in properly reading the cards and interpreting these results.

Data analysis

The data consisted of history cards and operational logs for contracted hopper and pipeline work as well as dredge rental work done in Mobile Bay, Alabama and Bayou Casotte, Mississippi. These cards and logs were records of completed dredging operations. They included the contractor's name, type of dredge, its capacity, the cubic meterage of dredging and an itemized cost breakdown of the work performed to include mobilization fees, turtle observers etc. The data obtained from these records were reduced and compiled into a spreadsheet that included the working times, cubic meterage and costs for dredging operations performed from 1991 to present day for each location and for each year the data were available.

All the cost data from 1991 to present were adjusted to 2011 US Dollars using the yearly average Consumer Price Index (CPI) values as compiled by the Bureau of Labor and Statistics (BLS 2012). The following formula was used to inflate the cost data to 2011 US dollar values:

$$Cost\ \ in\ \ 2011\ \ US\ \ Dollars = Cost\ \ in\ \ US\ \ Dollars\ \ in\ \ year\ \ x * \frac{\text{CPI for year 2011}}{\text{CPI for year x}}$$

For each year, the total cost of dredging operation was tabulated in a spreadsheet and adjusted to 2011 US Dollars. The unit cost of dredging for each year was determined by dividing the total amount paid for a dredging operation by the total cubic meters of sediment dredged by the same dredging operation.

The dredging rate was calculated as the arithmetic mean of cubic meters of dredged material extracted per hour from each dredging operation obtained from the data cards. Similarly, average working hours per day were calculated as the arithmetic mean of the working hours per day for each dredging operation obtained from the data cards. Emergency dredging, atypical contracts and erratic data were not included in any of these calculations.

Results and discussions

The annual volume of dredged material and corresponding annual expenses for hopper and pipeline dredging from 1993 to 2010 for Mobile Bay are presented in Figs. 1 and 2. As seen in Fig. 1, the Mobile District USACE spent annually between $3.0 million and $14.0 million to dredge 1.4 to 4.0 million cubic meters of sediment from Mobile Bay between 1993 and 2010 using hopper dredging. On the other hand, they spent between $1.4 million and $9.8 million to dredge 0.4 to 2.6 million cubic meters of sediment using pipeline dredging between 1991 and 2010. Hopper dredging was primarily used because the U.S. Congress mandated in the WRDA of 1986 that dredged material from Mobile Bay should be disposed of in the deep waters of the Gulf of Mexico. Pipeline dredging was performed in Mobile Bay only for special instances when a hopper dredger could not be brought in at the location due to space constraints.

To better understand the cost associated with each type of dredging, unit costs were calculated as the total cost of dredging in a year divided by the total volume of dredged material produced in that year. Table 1 shows the annual expenditure and the volume of dredging performed using hopper dredging and the corresponding average unit cost per cubic meter from 1993 to 2010 for Mobile Bay. The total cost and the average unit cost adjusted to 2011 dollar values are also shown in Table 1. In Mobile Bay, the unit cost to extract a cubic meter of dredged material using a hoper dredging varied from $1.79 to $5.90 (in 2011 US dollars). Table 2 shows the annual expenditure and the volume of dredging performed using pipeline dredging and the corresponding average unit cost for Mobile

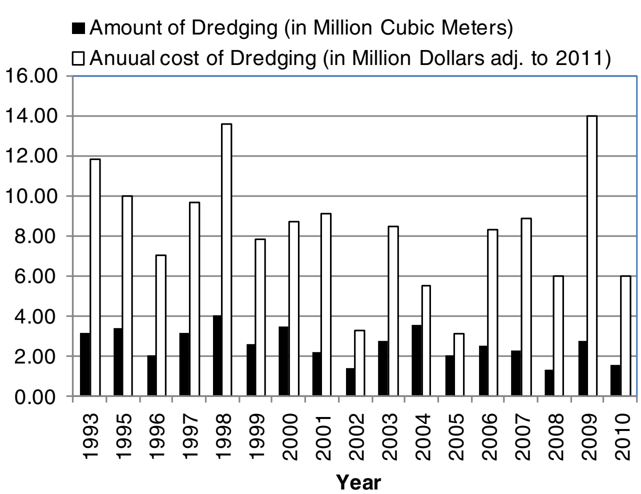

Fig. 1 Annual cost and volume of dredged material produced using a hopper dredge in Mobile Bay

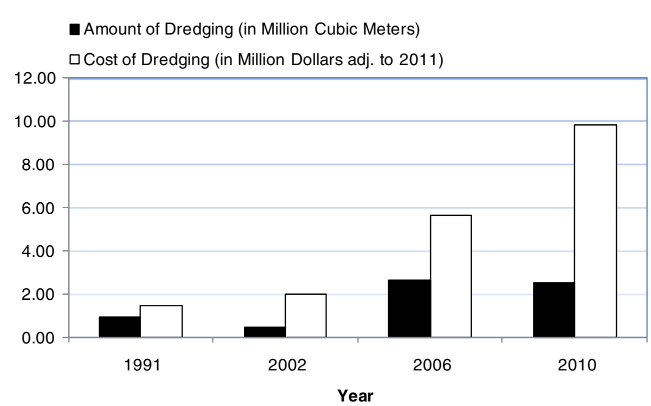

Fig. 2 Annual cost and volume of dredged material produced using a pipeline dredge in Mobile Bay

Table 1 Cost data for hopper dredging in Mobile Bay

Year	Volume in cubic meters	Total cost	Total cost adjusted in 2011 dollars	Unit cost	Unit cost adjusted in 2011 dollars
1993	3,108,947	$ 11,781,935	$ 18,340,599	$ 3.79	$ 5.90
1995	3,353,754	$ 9,967,770	$ 14,712,207	$ 2.97	$ 4.39
1996	2,061,885	$ 7,046,096	$ 10,101,605	$ 3.42	$ 4.90
1997	3,116,964	$ 9,697,830	$ 13,591,403	$ 3.11	$ 4.36
1998	4,050,606	$ 13,544,004	$ 18,690,643	$ 3.34	$ 4.61
1999	2,580,121	$ 7,808,398	$ 10,542,697	$ 3.03	$ 4.09
2000	3,479,754	$ 8,733,788	$ 11,408,650	$ 2.51	$ 3.28
2001	2,201,960	$ 9,074,631	$ 11,525,908	$ 4.12	$ 5.23
2002	1,393,910	$ 3,296,527	$ 4,122,290	$ 2.36	$ 2.96
2003	3,593,649	$ 10,632,430	$ 13,000,914	$ 2.96	$ 3.62
2004	3,519,866	$ 5,473,573	$ 6,517,840	$ 1.56	$ 1.85
2005	1,988,104	$ 3,090,241	$ 3,559,220	$ 1.55	$ 1.79
2006	2,488,920	$ 8,268,103	$ 9,225,292	$ 3.32	$ 3.71
2007	2,247,534	$ 8,889,181	$ 9,643,601	$ 3.96	$ 4.29
2008	1,299,025	$ 6,005,000	$ 6,273,757	$ 4.62	$ 4.83
2009	2,782,146	$ 13,994,991	$ 14,673,549	$ 5.03	$ 5.27
2010	1,508,937	$ 5,999,980	$ 6,189,371	$ 3.98	$ 4.10

Bay. In Mobile Bay, the unit cost to extract a cubic meter of dredged material using pipeline dredging varied from $2.38 to $5.78 (in 2011 US dollars). Since there were not sufficient data on pipeline dredging for Mobile Bay, cost data for pipeline dredging in Bayou Casotte, Mississippi were also tabulated in Table 2 to investigate the possible trend in cost for pipeline dredging. In Bayou Casotte, the unit cost to extract a cubic meter of dredged material through a pipeline dredger varied from $1.70 to $8.17 (in 2011 US dollars).

To explore possible trends in the unit cost per cubic meters of dredged material produced by hopper and pipeline dredging, the unit costs are plotted in Fig. 3. Figure 3a shows the unit costs of hopper dredging in Mobile Bay from 1993 to 2010. The unit costs in general demonstrated a non-linear decrease until 2005 and then demonstrated a non-linear increase until 2009. Figure 3b shows the unit costs of pipeline dredging in Mobile Bay from 1991 to 2010. As mentioned earlier, pipeline dredging is not typically used in Mobile Bay and consequently there is a shortage of data for pipeline dredging as demonstrated in Fig. 3b. As seen in Fig. 3b, there was a general increase in unit cost of pipeline dredging from 1991 to 2010. However, the figure shows that there was a jump in the unit cost of pipeline dredging in 2002. This jump occurred immediately after the change in WRDA legislation

Table 2 Cost data for pipeline dredging in Mobile Bay and Bayou Casotte

Year	Volume in cubic meters	Total cost	Total cost adjusted in 2011	Unit cost	Unit cost adjusted in 2011 dollars
Mobile Bay					
1991	939,688	$ 1,444,691	$ 2,385,957	$ 1.54	$ 2.54
2002	428,643	$ 1,980,371	$ 2,476,444	$ 4.62	$ 5.78
2006	2,644,205	$ 5,639,387	$ 6,292,252	$ 2.13	$ 2.38
2010	2,534,807	$ 9,862,183	$ 10,173,485	$ 3.89	$ 4.01
Bayou Casotte					
2005	1,251,667	$ 1,603,584	$ 1,846,946	$ 1.48	$ 1.70
2006	1,032,632	$ 2,671,935	$ 2,981,262	$ 2.89	$ 3.22
2007	807,321	$ 3,080,650	$ 3,342,103	$ 4.14	$ 4.49
2008	821,388	$ 6,147,659	$ 6,422,801	$ 7.82	$ 8.17
2009	1,490,678	$ 6,924,150	$ 7,259,873	$ 4.87	$ 5.11
2011	1,462,067	$ 6,259,680	$ 6,259,680	$ 4.28	$ 4.28

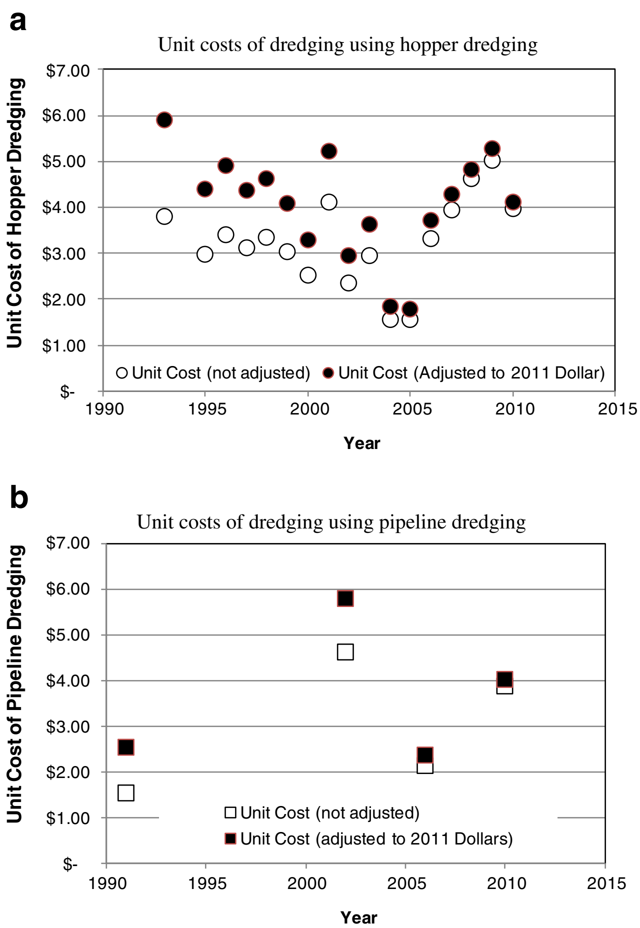

Fig. 3 Unit costs of dredging using hopper dredging and pipeline dredging in Mobile Bay, Alabama

in 1996. As per the changed legislation, the hopper dredging was not the only dredging option for Mobile Bay anymore.

To further compare the unit cost of pipeline and hopper dredging, the unit cost data adjusted to 2011 values for both dredging methods are plotted in Fig. 4. Since there is a shortage of pipeline dreding data for Mobile bay, the unit cost of pipeline dredging in Bayou Casotte is also plotted in Fig. 4. As it appears in Fig. 4, there was not a substantial difference in unit cost between pipeline and hopper dredging except for the exceptional instance of pipeline dredging in Bayou Casotte in 2008. Though the trends in unit costs look similar, there was a 151.5 % increase in unit cost of pipeline dredging in Bayou Casotte from 2005 to 2011. This rapid increase in unit cost might be due to the reason that pipeline contractors inflated their price as they were in demand for maintenance dredging in Bayou Casotte.

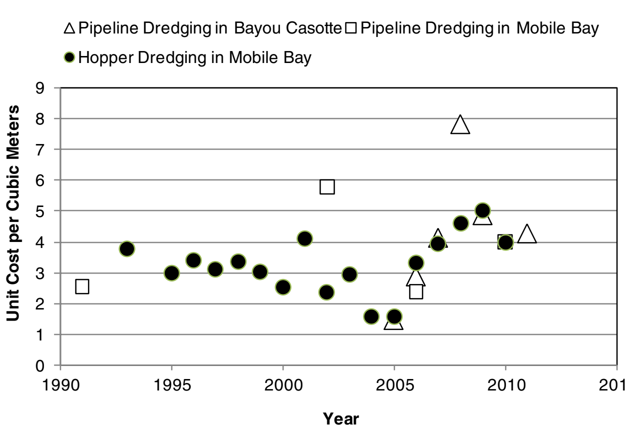

Fig. 4 Unit costs of dredging using hopper and pipeline dredging in Mobile Bay, Alabama and Bayou Casotte, Mississippi

Dredging rate and work output

The dredging rates and dredging outputs for both dredging methods for Mobile Bay and Bayou Casotte are presented in Table 3 and Fig. 5. The table shows that for hopper dredging in Mobile Bay, the dredging rate was 698 cubic meters per hour for approximately 20 working hours per day. For pipeline dredging in Mobile Bay, the dredging rate was 1,230 cubic meters per hour for approximately 12 working hours per day. For Bayou Casotte, the dredging rate for hopper dredging was approximately 749 cubic meters per hour for 18 working hours per day. The dredging rate for pipeline dredging was approximately 1,476 cubic meters per hour for 14 working hours per day. The comparison of dredging rate between pipeline and hopper dredging in cubic meters per hour for Mobile Bay and Bayou Casotte is shown in Fig. 5a. It is evident from the figure that the dredging rates were comparable between Mobile Bay and Bayou Casotte for both hopper and pipeline dredging. The daily work output achieved from each dredging method in terms of cubic meters of dredged material per day was calculated by multiplying the dredging rate (in cubic meters per hour) by the working hours per day. Figure 5b shows the daily work output using pipeline and hopper dredging for Mobile Bay and Bayou Casotte. As shown in Fig. 5b, pipeline dredging produced more dredged material per day than hopper dredging. The data from Bayou Casotte, where pipeline dredging was most commonly used, provide the strongest evidence in favor of pipeline dredging.

Dredging contracts and cost issues

There are two types of contracts that are used to perform dredging operations, namely a rental contract and a unit price contract. In a rental agreement the contractor works on an hourly basis; this allows the USACE to direct their work until their budget for that project is exhausted. In unit price contracts, in order for a contract to be established for dredging work, the required funds have to be allocated in full for the amount of the contract. Instances of cost fluctuations have influenced the Mobile District USACE to enter into more rental contracts in lieu of unit price contracts as rental contracts offer more flexibility in terms of funds allocation issues.

Table 3 Dredging and work output from hopper and pipeline dredging

Dredging type	Location	Dredging rate (cubic meters per hour)	Average working hours per day	Dredging output (cubic meters per day)
Hopper	Mobile	698	20	13,976
Pipeline	Mobile	1,231	12	14,771
Hopper	Bayou Casotte	749	18	13,486
Pipeline	Bayou Casotte	1,476	14	20,668

Disposal of dredged material

Historically, the dredged material is discharged into deep waters of oceans, rivers, wetlands or into confined disposal facilities depending on the properties of dredged material, operational costs and availability of disposal sites (Thomas and Hutton Engineering 2005). The dredge material disposal sites in the offshore area are approved by the US Environmental Protection Agency and only uncontaminated materials can be disposed at these sites. Typically, these sites are deep enough and far from site of dredging operation. The fine-grained sediment (also referred to as mud) dredged from Mobile Bay with a hopper is disposed of in deep offshore waters. On the other hand, much of the fine-grained sediment that is pipeline dredged from Mobile Bay is discharged onto Gaillard Island or other disposal sites which is beneficial for their maintenance. An aspect of the disposal process that warrants some attention is the impact that the Deepwater Horizon oil spill may have on the sediment quality of the dredged material. Prior to the oil spill, as shown in Fig. 6, the sediment in Mobile Bay was rated fair by the Environmental Protection Agency (EPA) with only 9 % of the monitored areas of the estuary containing poor sediment quality (EPA 2007). This relative cleanliness allowed the sediment from Mobile Bay to be suitable for open sea disposal by hopper dredge. There are currently studies being conducted to investigate the quality of the sediment after the oil spill to determine its purity (Bandara et al. 2011; McKenna 2010; Ramsey et al. 2011). If the sediment is found to contain contaminants, it may no longer be feasible or recommended to dispose of the dredged material in the open sea thereby negating the use of a hopper dredge and making any alternative dredging and disposal method like pipeline dredging more environmentally friendly and beneficial.

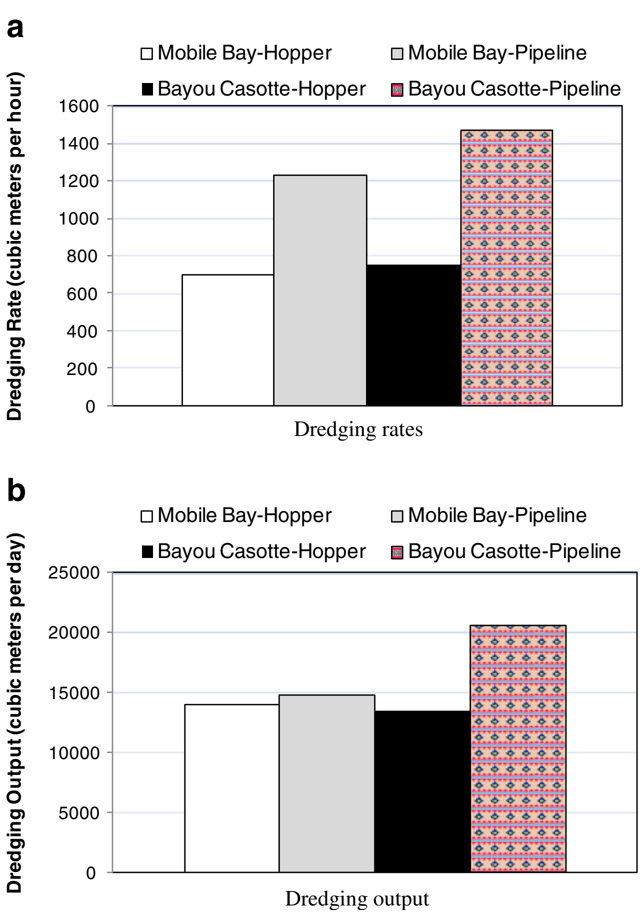

Fig. 5 Dredging rates and dredging ouputs for pipeline and hopper dredging in Mobile Bay, Alabama and Bayou Casotte, Mississippi

Sustainable use of dredged material

Literature shows that the U.S. Army Corps of Engineers (USACE) disposes approximately 65 % of its dredged material in open water, as opposed to land disposal (Kurland et al. 1994). Disposal of dredged material in the open waters is becoming less popular as the disposal of dredged material in offshore waters involves environmental effects beyond those associated with the actual dredging operations. Also, land disposal may not be a feasible alternative due to various limitations, including availability of land, transporting the material, overflow and runoff of polluted water, saltwater intrusion into groundwater etc. (Kurland et al. 1994). Therefore, determining beneficial ways to use dredged material has become extremely important.

While the difference in cost between pipeline dredging and hopper dredging is not substantial, the disposal method and use of dredged material obtained from each dredging method hold a paramount importance in deciding for a particular

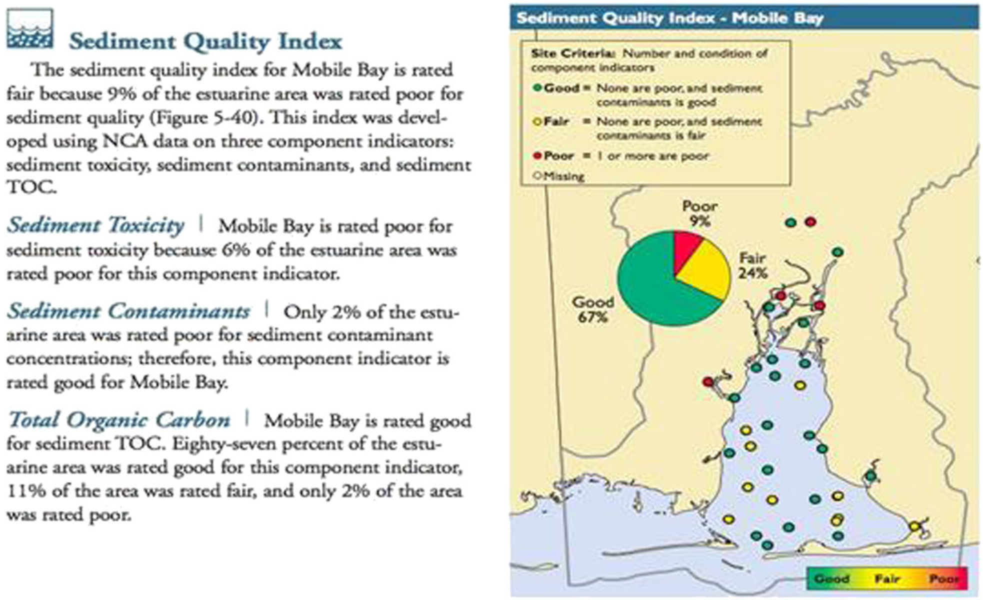

Fig. 6 Mobile Bay sediment quality (EPA 2007)

method. The sediments from Mobile Bay and adjacent channels are a great asset to our coast. They have the potential to contribute greatly to the improvement of our shoreline and, with the proper treatment, our agricultural land. The following paragraphs discuss several possible sustainable ways of utilizing dredged material obtained from Mobile Bay.

Mobile Bay has a unique environmental system and its suitably-grained sediment has the benefit of being suitable for beneficial uses such as berm establishment, barrier island build-up and non-recreational beach re-nourishment. Many States, such as Louisiana, have difficulty locating suitable material for their coastal improvement projects (Lavoie et al. 2010) and others, such as New York and New Jersey, have to decontaminate their materials through lengthy and expensive treatment procedures in order to even consider using them beneficially (Millarath et al. 2001). Material that is produced as a result of maintenance dredging the Mobile Bay can be utilized in a sustainable way if proper initiative is taken. In one such initiative, a proposal was submitted to the Congress in 2010 for using dredged material from the Mobile Bar Channel to build an oil mitigation berm at the mouth of Mobile Bay and rebuild Sand Island to its original size (USACE and USDEM 2010). Figure 7 shows the location of the Bar Channel and Sand Island beneficial use area. The proposal has been accepted and this work has recently been contracted by the Mobile District USACE. In addition to the beneficial use of dredged material, this project could reduce the cost of maintenance dredging in the Bar Channel area since there will be virtually no distance to travel to a disposal site. Another good example of sustainable use of dredged material is the initiative taken by Mississippi Coastal Improvements Program (MCIP) to utilize dredged material from the widening of the Mississippi Bar Channel and other sites in order to restore coastal barrier islands (MCIP 2009). Similarly, in the future, suitably-grained dredged material form maintenance dredging of Mobile Bay may be considered for use in the restoration and protection of Alabama's coast as well.

Another possibility of sustainable use of dredged material from Mobile Bay is using it on agricultural lands in Alabama or elsewhere. However, prior to using the dredged material on the agricultural land, it should be tested for possible contamination to avoid health risks. If the dredged material contains contaminates from oil spill or any other sources, it must be treated before adding to the fields. In 2004, the U.S. Department of Agriculture published the results of a study in which lake dredged material was used on pasture-lands in Sumter County, Florida (Sigua 2009). The study found that

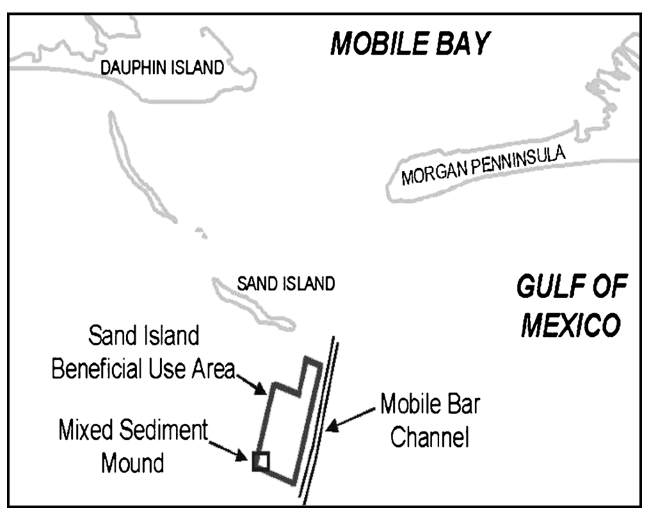

Fig. 7 Location of the Bar Channel and Sand Island beneficial use area (USACE and USDEM 2010)

the lake-dredged material acted as a fertilizer for Bahia grass grown on the pasture-lands. The plots they experimented showed increased grass production and higher crude protein content than those without lake-dredged material. The fine grained sediment that is found at the bottom of Mobile Bay is rich in nutrients and organic material that has washed down through the Mobile-Tombigbee-Alabama River system (Alabama Wildlife Federation 2012). In a way similar to the lake-dredged material used in the USDA research, dredged sediment from Mobile Bay could serve to enrich the agricultural lands in Alabama or elsewhere if it were desalinated. There is a need for research to develop a cost efficient method of desalination of dredged material. A cost efficient method of salt extraction might expand the options for its beneficial use. If it has to be decontaminated due to the Deepwater Horizon oil spill, then the desalination process may be more feasible since the material will already be undergoing some type of chemical treatment or processing.

Summary and conclusions

In this paper, an attempt has been made to compare the cost of hopper and pipeline dredging, two alternative methods for maintenance dredging in Mobile Bay. Cost data for both dredging methods were obtained from Mobile District USACE. USACE could not provide sufficient pipeline dredging data for Mobile Bay since pipeline dredging was performed in Mobile Bay only for special instances when a hopper dredge could not be brought in at the location due to space constraint. To account for this shortage, additional pipeline dredging data were obtained for Bayou Casotte in Mississippi. The reason for including Bayou Casotte data in the analysis was that the two areas have similar geographical features as far as dredging factors are concerned. Analysis of data showed that there was not a substantial difference in unit costs between pipeline and hopper dredging in Mobile Bay.

Although unit costs were similar for both methods of dredging, further analysis showed that pipeline dredging was able to produce more dredged material output (per day) than hopper dredging. This is due to the fact that a pipeline dredge can dredge continuously for longer hours than a hopper dredge since hopper dredge needs to stop dredging and travel to a disposal site to dispose of dredged sediment.

The extended distance that a hopper dredge must travel in order to dispose of dredged sediment from Mobile Bay makes pipeline dredging more desirable for Mobile Bay and its channel maintenance needs. As the cost of fuel increases the cost of hopper dredging is also expected to increase. Therefore, pipeline dredging should be made a natural choice for Mobile Bay as it is efficient and also offers sustainable alternates for utilizing the readily available dredged materials.

It is unknown at this time whether the Deepwater Horizon oil spill has contaminated the sediment in Mobile Bay area to levels exceeding the EPA regulations for deepwater ocean disposal. If Mobile Bay sediment quality is found to be negatively affected, it is expected to have vast implications on Mobile Bay dredging practices and disposal methods. In addition, if future shoreline restoration and beneficial use projects are initiated, it is possible that pipeline dredging may become the most desired maintenance dredging method to be used in Mobile Bay in order to keep up with the demand for material to supply future shoreline re-nourishment projects.

The paper provides several possibilities of sustainable utilization of dredged materials. The most innovative of them is to use the dredged materials on agricultural lands in Alabama or elsewhere since the fine grained sediment at the bottom of Mobile Bay is rich in nutrients and organic materials. However, these sediments must be desalinated before they can be used on the agricultural land. Development of a cost efficient method of salt extraction might expand the options for its beneficial use.

Dredging projects in each area are unique. The cost of a dredging operation may vary widely with type of equipment used, amount of dredging, access to the site, management and disposal of dredged material and other economic factors. For example, despite having similar geographic features (as far as dredging factors are concerned) cost per cubic meter for hopper dredging was more for Bayou Casotte, Mississippi as compared to Mobile Bay area due to their difference in distance of travel to open water disposal areas. However, the paper presents useful information about possible beneficial uses of dredged material that can be relevant for any port location where dredging operation is performed. For example, use of dredged material for shoreline protection, building berms and barrier islands and other environmental-friendly and economical alternatives have been discussed in this paper. Material movement and processing cost can be eliminated if dredged material is utilized for such purposes. Open water disposals are becoming less popular all around the world due to environmental concerns. Therefore, this paper will be a helpful reference for any port authority that is currently using open water disposal method or is considering sustainable alternatives for using dredged material.

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