Final Report

UTILIZING GAMMA ISOTOPE TRACERS TO DETERMINE SEDIMENT SOURCE AT REEF SITES NEAR THE CHARLESTON OCEAN DREDGED MATERIAL DISPOSAL SITE

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1.0 INTRODUCTION

In the early 1990's, the South Carolina Department of Natural Resources (SCDNR) initiated a monitoring program of the physical and biological conditions in and around the Charleston Ocean Dredged Material Disposal Site (ODMDS, Figure 1, Van Dolah *et al*, 1996). This monitoring program has documented increased sedimentation rates and elevated levels of silt/clay in surficial sediments in areas to the west and northwest of the ODMDS (Noakes, 2003; Gayes *et al*, 2003; Zimmerman *et al*, 2003). Possible sources of this material include the migration of dredged materials from the Charleston ODMDS, unauthorized disposal activity in the area, and trailings from barges as they enter or exit the ODMDS (Jutte *et al.*, 2001). Approximately 22 million cubic yards (mcy) of material was placed at the site as part of the 1999-2002 Charleston Harbor Deepening project. In addition, the ODMDS is continually utilized for dredged material disposal from channel maintenance activities, but considerably less material has been placed at the site since completion of the deepening project. The most recent activity included the placement of 1.6 mcy of entrance channel material (typically sediments high in sand and $CaCO_3$) from December 2003 through March 2004 (USACE, pers. comm.).

A companion monitoring program was initiated by the SCDNR in 2000 to study possible impacts to natural hard bottom reef communities in the vicinity of the Charleston ODMDS. Six hard bottom reef sites in the area surrounding the Charleston ODMDS (Figure 1) were established, and have been assessed during spring and fall field seasons to document changes in sedimentation rates, condition of biological communities, and areal extent of hard bottom reef habitats.

Higher sedimentation rates have been documented at the inshore reef sites, which may be due to their proximity to the ODMDS (Jutte *et al*, 2003). However, another potential source of sedimentation at the inshore reef sites is density driven or tidal transport of estuarine sediments. An analysis of the isotopic signature of sediments collected by divers and sediment traps at reef sites, in addition to samples collected by a vessel-deployed sediment-grab sampler in Charleston Harbor and various tributaries was conducted as part of the Year 4 monitoring efforts of the hard bottom reef communities in the vicinity of the Charleston ODMDS. The goal of this study was to determine the

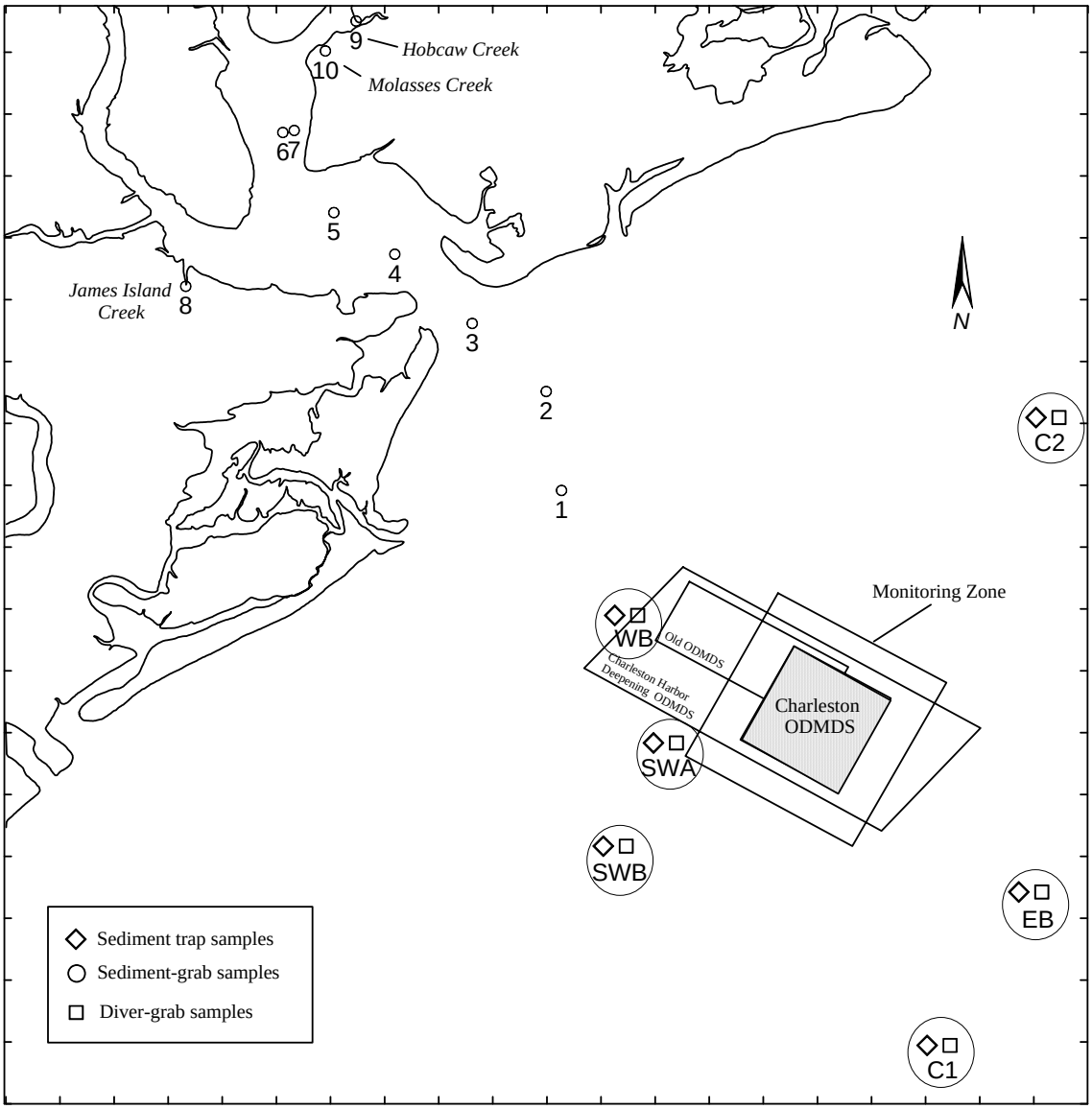

Figure 1. Charleston ODMDS, sediment sampling stations, and hard bottom reef monitoring stations (WB, SWA, SWB, EB, C1, and C2.

relative contribution of disposal materials from the Charleston ODMDS versus tidally transported or density driven sediment from Charleston Harbor.

Coastal marine sediments have many commonly found isotopes associated with them, as well as occurrences of rarer isotopes such as beryllium-7 (^{7}Be) and cesium-137 (^{137}Cs; IAEA, 2000). The isotopic signature of sediments has been successfully used by the Center for Applied Isotope Studies (CAIS) at The University of Georgia, to trace the placement and subsequent migration of dredged material placed at the Charleston ODMDS (Noakes, 2003). Evaluating isotopic signatures to identify the relative contribution of sediments deposited at natural reef sites is a novel use of this technique and could prove to be an important tool in future assessments.

Several isotopes were evaluated in the current study. The occurrence of ^{137}Cs is directly related to the atomic bomb testing era when this isotope was distributed throughout the world by atmospheric fallout. As a result of the cessation of atomic bomb testing, there is very little ^{137}Cs present in the atmosphere today. ^{7}Be has a cosmogenic origin and is uniquely associated with atmospheric fallout. What makes ^{7}Be a particularly good tracer is that it has a relatively short half life of only 53 days. Therefore, ^{7}Be tends to disappear quickly from the marine sediment if there is not a constant source. The presence of ^{7}Be and ^{137}Cs isotopes in the marine environment would be expected at low levels, with higher levels typically found in estuarine sediments due to erosion of terrestrial sediments. When estuarine sediments are dredged and placed in offshore disposal areas, ^{137}Cs would be expected to persist, but due to its short half-life, very little ^{7}Be would be present for extended periods of time.

In addition to ^{7}Be and ^{137}Cs, uranium (^{238}U), thorium (^{232}Th), and potassium (^{40}K) were also analyzed as part of this study. These isotopes are considered pathfinder isotopes and are generally indicative of the nature of the seafloor (Jones *et al*, 1988). ^{238}U reflects the uranium content of phosphatic deposits often found in the coastal regions, ^{232}Th is associated with heavy mineral deposits, and ^{40}K is often found in fine-grained clay sediments.

For this study, sediment samples were collected in the Charleston Harbor and various tributaries and along a transect leading towards the ODMDS to measure the gamma activity of various isotopes (1) in estuarine sediments, (2) in areas where tidal

deposition was expected, and (3) at the hard bottom reef sites in the vicinity of the ODMDS. The isotopic signature of sediments at the hard bottom reef sites in the vicinity of the ODMDS could then be used to identify the contribution of tidal and density driven transport to the sediment budget at these sites.

2.0 TECHNICAL APPROACH

A total of ten sediment-grab samples were collected in April 2004 from Charleston Harbor, the Cooper River, several small tributaries and near shore sites along a transect leading towards the disposal area (Figure 1). These samples were collected using a stainless steel sediment-grab sampler deployed from a surface vessel. Only the surficial sediment (~ 2 cm) was removed from the sampler to best represent recent deposition. Diver collected sediment-core samples were also collected in May 2004 from the surficial sediment at each of the six hard bottom reef monitoring stations (Figure 1). These sediment samples were dried according to standard operating procedures, and submitted for gamma analyses. Additionally, replicate sediment traps were deployed at the six hard bottom reef monitoring stations to collect a representative sediment sample from material settling on each monitoring site. Upon collection, SCDNR analyzed the trap sediments for composition and total dry weight and then shipped the samples to CAIS for gamma analysis.

The sediment samples (sediment-grab, diver collected, and sediment-trap) were analyzed in the CAIS laboratory using a High Purity Germanium (HPGe) gamma radiation detector and pulse height-analyzer. Once dried, the sample was packed into a tared 0.5-L Marinelli beaker and weighed. Preliminary gamma analysis was completed on all the samples immediately after drying to obtain results for ^{7}Be, which has a relatively short half-life of only 53 days. The samples were then reanalyzed approximately two weeks later to obtain results for the ^{238}U, ^{232}Th, and ^{40}K which require a holding time for the ingrowth of the gamma-emitting U and Th daughter products. The sample was placed in an HPGe radiation detector for a counting time of 12,000 s. In addition to ^{7}Be and ^{137}Cs, the results for ^{238}U, ^{232}Th, and ^{40}K were recorded and converted to picocuries per kilogram (pCi/kg).

3.0 RESULTS

The results for the gamma analyses were plotted in bar graph format to aid comparison of the data. The ratios for the U, Th, and K were very similar for the sediment samples collected making it difficult to use these isotopes as definitive indicators for sediment transport. The data from these gamma analyses is presented in Appendix A.

Gamma analyses of the three samples that were collected in small tributaries associated with the Cooper River and Charleston Harbor (Figure 1) were conducted to demonstrate the presence of both ^{7}Be and ^{137}Cs in recently deposited terrestrial sediment, which would have been eroded from the surrounding marshes. As anticipated, all three of the tributary samples had ^{7}Be and ^{137}Cs present due to the uniform distribution of atmospheric fallout over the marshes.

Samples were also collected along a transect from the entrance channel inward to the Cooper River (Figure 1). No ^{7}Be or ^{137}Cs were detected in Sample 1 (nearshore) indicating that terrestrial sediment either was not transported or at least was not deposited that far from the mouth of the harbor (Figure 2). Absence of ^{7}Be or ^{137}Cs does not rule out the possibility that fine-grained sediment containing either isotope could remain suspended in the water column and be deposited further offshore. Detectable levels of ^{7}Be were shown starting in the nearshore at Sample 2 and increased considerably in Samples 3 and 4 at the harbor entrance and inside the harbor, clearly indicating a major deposition zone. No ^{7}Be was detected in Samples 5 through 7, located at the inner harbor and Cooper River. However, these samples were considerably sandier than expected, indicating a higher energy zone allowing less fine-grained sediment to be deposited. ^{137}Cs was detected in Samples 3, 4, and 6 (harbor entrance, inside harbor, and Cooper River) indicating past terrestrial sediment deposition at these locations. As expected, ^{238}U, ^{232}Th, and ^{40}K activities were similar across all sampling stations.

All of the sediment trap samples not only showed detectable levels of ^{7}Be (Figure 3), but the ^{7}Be activities in the sediment traps were considerably higher than the activity detected in the grab samples. The only sediment trap sample that had detectable ^{137}Cs levels was site WB. WB is the closest monitoring station to land and the presence of ^{137}Cs at this site suggests that sediment transport from the Charleston Harbor may reach

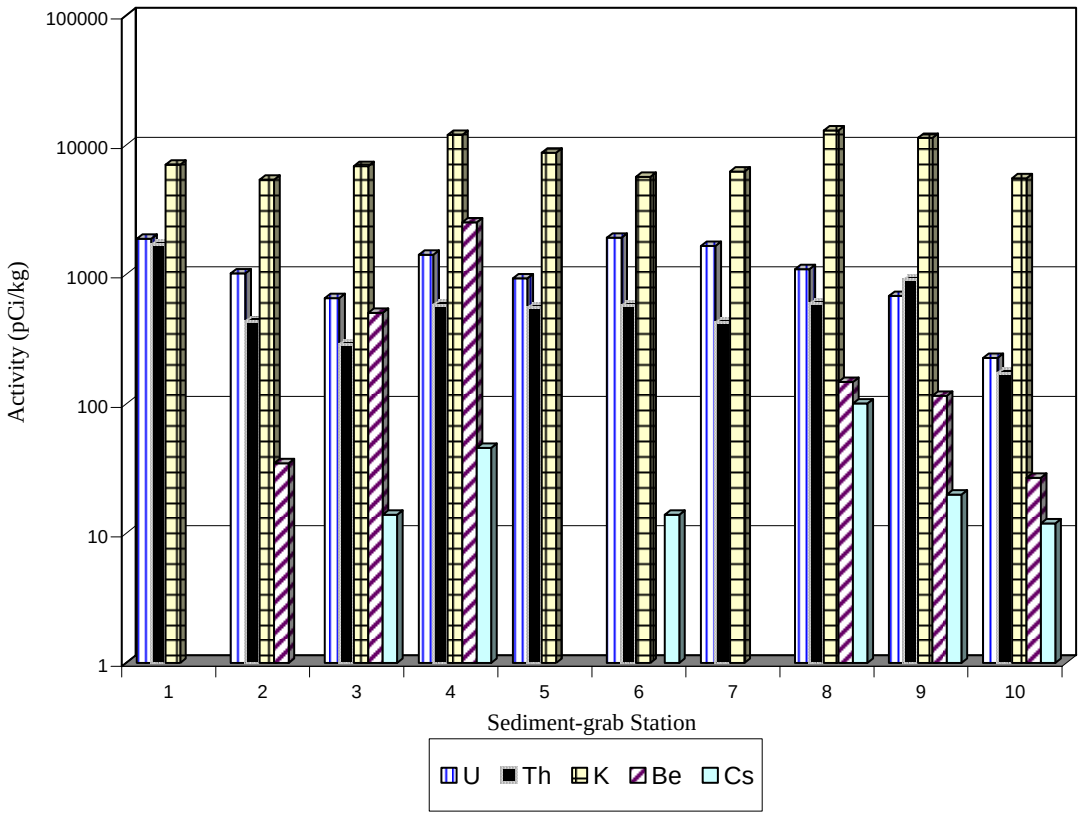

Figure 2. Sediment-grab stations in Charleston Harbor, Cooper River and tributaries.

this site and contribute to the sediment budget. Since ^{137}Cs is no longer present in atmospheric fallout, it was not expected to find ^{137}Cs uniformly distributed offshore. Any ^{137}Cs detected offshore would have originated from eroded terrestrial sediment and transported either by tidal action, density driven transport or dredged material deposition. Levels of U, Th and K were similar across all hard bottom reef sites (Figure 3), and were similar to levels observed in sediment grab samples.

The diver core sediment samples collected at each of the hard bottom reef monitoring stations indicated that SWA, SWB, WB, and reference area C1 all had detectable levels of ^{7}Be present (Figure 4), while site EB and reference area C2 had no detectable levels of ^{7}Be. The levels of ^{7}Be found at sites SWA, SWB, WB, and C1 were similar to levels found at sediment-grab Stations 2, 8, 9, and 10, but approximately an order of magnitude less than ^{7}Be levels at sediment-grab Stations 3 and 4 (the major deposition zone in the harbor mouth). The sediment-trap stations also had ^{7}Be levels at least an order of magnitude higher that the sediment-grab samples with the exception of Stations 3 and 4. No ^{137}Cs was detected at any of the reef sites for the diver collected core samples. Levels of U, Th, and K were similar across all the stations, and similar to values collected by both sediment grabs and sediment traps. This indicates that the suspended sediment in the water column coming from the Charleston Harbor and resuspended bottom sediment have very similar radionuclide content.

4.0 DISCUSSION

The sediment collected from the sediment-traps deployed at each of the hard bottom reef sites represents material settling onto the seafloor. In addition to vertical sediment deposition, redistribution of bottom sediments may make some contribution to the total volume within a sediment trap. Sediment traps are very selective in collection in that only very fine-grained sediment suspended in the water column is collected. Coarser grained sediment rarely becomes suspended due to size and weight. As previously mentioned, the ^{7}Be activities in the sediment traps were considerably higher than the activity detected in the grab samples. The presence of ^{7}Be was expected due to its cosmogenic origin and the higher levels relative to grab samples is likely due to the

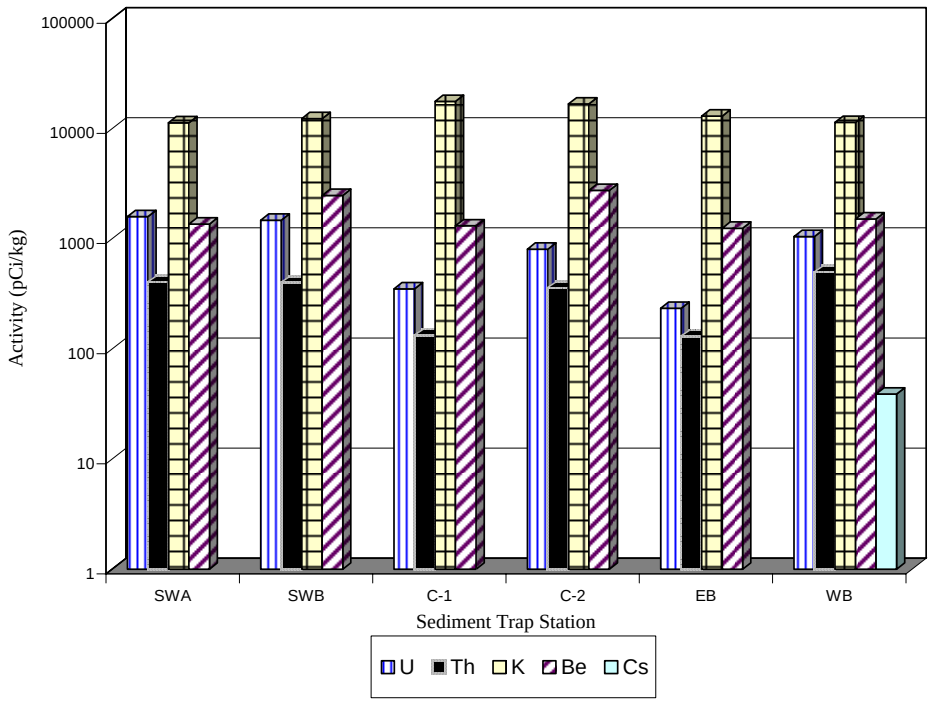

Figure 3. Sediment trap stations at the Charleston ODMDS.

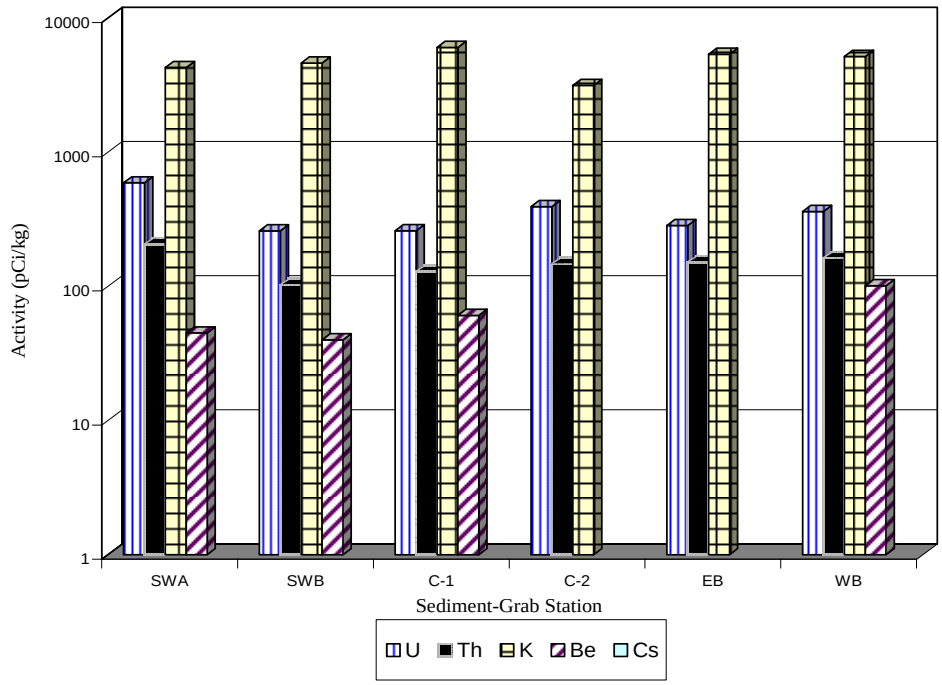

Figure 4. Diver-collected sediment core samples at the Charleston ODMDS.

sediment traps selective sampling process collecting the very fine-grained sediment from the water column. Coarser grained sediment would act to dilute the ^{7}Be gamma activity. The sediment traps effectively act as a gauge to determine the ^{7}Be activity settling to the seafloor. However, the ^{7}Be activity from the sediment traps cannot be directly compared to the ^{7}Be on the seafloor due to natural ocean forces acting on the seafloor. Unlike the material in the sediment traps, erosional forces can sweep much of the ^{7}Be-rich sediment away from the seafloor or mix it with existing seafloor sediment effectively lowering the ^{7}Be activity in surficial sediment.

However, what is not clear is the background ^{7}Be activity for the marine environment offshore Charleston. Hard bottom reef sites SWA, EB, WB, and reference area C1 all had very similar activity levels, which may be considered as normal fallout or background activity, particularly since sites EB and C1 are approximately 4-5 miles seaward of the disposal site. Grass and leaf matter analyzed as part of the Georgia Department of Natural Resources Environmental Radiation Program has revealed similar ^{7}Be levels (GADNR, 2004). Marine organic matter and suspended sediment may take up ^{7}Be similar to terrestrial matter and sediment therefore suggesting that the values in the current study and the GADNR study represent comparable background levels. SWB and reference area C2 had the highest levels of ^{7}Be present (~100% higher than the average of the other four reef sites) which could be from natural variation or may indicate a potential additional source such as tidal or density driven transport.

To achieve a better concept of the distribution of both ^{7}Be and ^{137}Cs in the Charleston study area, the isotopes were plotted by stations in relation to relative activities (Figures 5 and 6). All three of the tributaries associated with the Charleston Harbor were shown to have ^{7}Be present. As previously mentioned, the ^{7}Be activity was highest near the mouth of the harbor and continued to decrease further offshore. However, it was readily shown that four of the ODMDS monitoring stations also had ^{7}Be present in the surficial sediment. Two of the stations, SWB and C2 had considerably higher activities indicating an additional source of ^{7}Be laden sediment other than atmospheric fallout. All of the sediment-trap samples had ^{7}Be present, which was anticipated due to the atmospheric fallout.

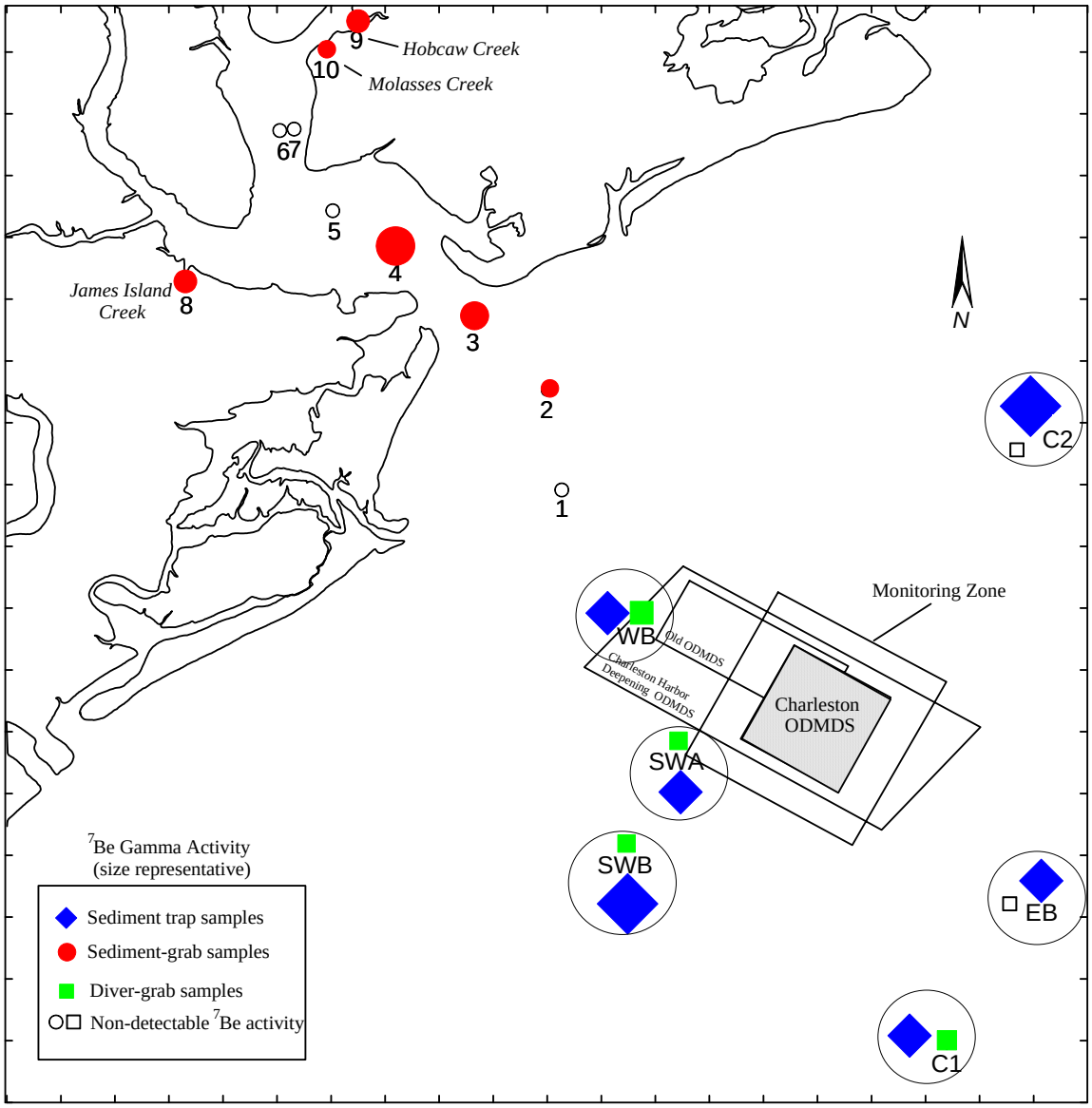

Figure 5. ^{7}Be gamma activity (size representative).

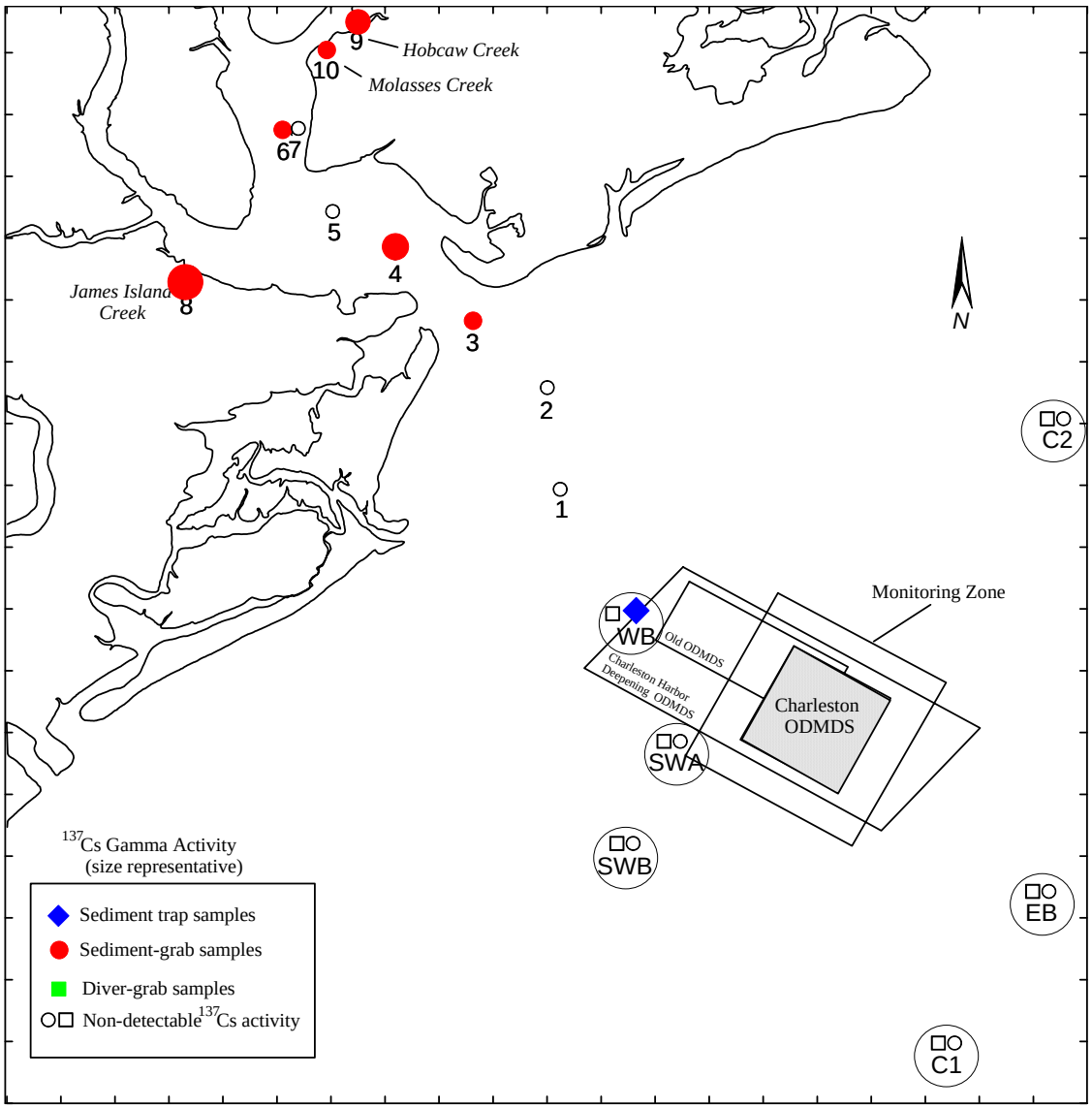

Figure 6. ^{137}Cs gamma activity (size representative).

Similar results were demonstrated for ^{137}Cs, in that it was readily shown to be present in the harbor and tributaries. However, unlike ^{7}Be, ^{137}Cs was not readily detected in the sediment-trap or diver collected samples. ^{137}Cs was detected at WB in the sediment-trap station located nearest to the coast. Tidal currents at the ODMDS are generally oriented on a northwest-southeast axis. However, past studies have indicated that tidal transport at the ODMDS is minimal compared to density driven and offshore currents (Voulgaris, 2002). Due to the location of the WB site with respect to the disposal site, and the fact that no other samples contained ^{137}Cs, it is unlikely that the ^{137}Cs at the WB site could be from deposited dredged material.

Density driven and offshore currents are predominantly responsible for the sediment disbursement in the coastal marine environment. The offshore currents around the ODMDS are typically oriented along a southwest-northeast axis with the predominant sediment transport to the southwest (Voulgaris, 2002). In addition, the Coriolis Effect typically turns coastal associated, density driven flows southward along the eastern United States. The Charleston ODMDS and hard bottom reef monitoring stations are located approximately ten miles offshore. However, sediment plumes from the Charleston Harbor can readily reach the disposal site. Figure 7 shows an example of a sediment plume extending outward towards the ODMDS and monitoring stations (NASA, 2003). From the satellite photo, it is evident that the plumes from Charleston Harbor and other discharges turn southward upon entering the Atlantic Ocean.

The role of tidal, density driven, and offshore currents, and the general orientation of the Charleston Harbor to the ODMDS, explains why ^{7}Be was not detected at hard bottom reef sites C2 and EB. Due to the southwestern sediment migration and the turning of density driven plumes, hard bottom reef sites C2 and EB may not normally be reached by sediment plumes from Charleston Harbor. Both C2 and EB did have ^{7}Be present in the sediment-trap samples, but the total volume of sediment in these samples was only a fraction of that collected in the other sediment-trap samples. Considerably less terrestrial sediment was transported to C2 and EB, most likely from sources further up the coast from Charleston.

Figure 7. Satellite view of the Charleston including the ODMDS and sampling stations.
*Image courtesy of Earth Sciences and Image Analysis Laboratory (NASA, 2003).

5.0 CONCLUSION

Analyses of the tributary and harbor sediments have clearly shown that ^{7}Be and ^{137}Cs are associated with terrestrial sediment. The presence of ^{7}Be and ^{137}Cs in the offshore diver collected and sediment-trap samples indicate that this sediment is also of terrestrial origin. The novel approach of utilizing ^{7}Be and ^{137}Cs as tracers in this study to identify the relative contribution of density driven sediment from the harbor versus disposal material migration suggests that some terrestrial sediment has been transported to a subset of the hard bottom reef monitoring stations through natural processes. Since the diver and sediment trap samples were collected approximately two months after the end of the most recent dredged material disposal, it is doubtful that the ^{7}Be present in the offshore samples is related to the disposal operation. Any ^{7}Be from the disposal activities would have had at least one complete half-life to degrade prior to the current sampling effort. Additionally, the entrance channel material deposited at the site does not typically contain either ^{7}Be or ^{137}Cs. This material is generally sandy and contains little fine-grained sediment.

A comparison of the levels of ^{7}Be between inshore and nearshore sediment-grab samples and diver collected sediment core samples at the reef sites suggests density driven transported sediments, with tidal and/or disposal site origins, may influence the sediment budgets at reef sites WB, SWA, SWB, and C1, and to a much lesser extent at sites EB and C2. The comparison of ^{137}Cs levels between inshore/nearshore sites and sediment cores collected at reef sites suggests the presence of tidally transported sediments only at the hard-bottom reef site in closest proximity to land, site WB.

Further sampling and analyses of sediment samples would allow a better understanding of the role that tidal and density driven transported sediments play in the sediment budgets at hard bottom reef sites. Based on the findings from the current study, the continuation of this study is recommended for another year. The collection of additional samples at all the sampling stations visited during this study is warranted, in addition to the collection of samples collected within the most recently deposited dredged material at the Charleston ODMDS for comparative purposes with diver and sediment-trap sediment samples collected offshore.

6.0 REFERENCES

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Appendix A. HPGe Gamma Analyses on collected sediment.

Sediment-grab Samples

Station	Isotope (pCi/kg)				
	^{238}U	^{232}Th	^{40}K	^{7}Be	^{137}Cs
1	1890	1696	7068		
2	1023	434	5396	35	
3	659	288	6884	507	14
4	1419	580	11980	2531	46
5	936	553	8730		
6	1930	573	5687		14
7	1662	424	6249		
8	1102	595	13000	148	101
9	684	912	11350	116	20
10	228	173	5535	27	12

Sediment-trap Samples

Station	Isotope (pCi/kg)				
	^{238}U	^{232}Th	^{40}K	^{7}Be	^{137}Cs
SWA	1591	406	11300	1364	
SWB	1477	402	12370	2482	
C1	351	133	17720	1313	
C2	805	360	16790	2755	
EB	234	130	13040	1248	
WB	1052	499	11400	1515	39

Diver-collected Samples

Station	Isotope (pCi/kg)				
	^{238}U	^{232}Th	^{40}K	^{7}Be	^{137}Cs
SWA	591	206	4270	45	
SWB	259	103	4619	40	
C1	260	129	6042	61	
C2	394	147	3147		
EB	284	151	5376		
WB	362	162	5170	101	