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National Air and Radiation
Environmental Laboratory
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Montgomery, AL 36115-2601

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EPA

Radiological Survey at the Kings Bay Naval Submarine Base

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EXECUTIVE SUMMARY

This report presents results of a radiological survey conducted in May 1999 by the National Air and Radiation Environmental Laboratory (NAREL) to assess levels of environmental radioactivity in and around the Kings Bay Submarine Base (KBSB) located approximately 10 miles east of Kingsland, GA. The purpose of the survey was to assess whether the maintenance, overhaul, refueling or operation of nuclear-powered warships have created elevated levels of radioactivity in the environment that could expose nearby populations or contaminate the environment.

During this survey 81 samples were collected: 69 at the KBSB study site; 9 from background locations; and 3 near the outfall of the Navy water treatment plant. Samples included drinking water, surface water, sediment, sediment cores, and biota. All samples were analyzed for gross alpha and beta activities and gamma emitting radionuclides. Water samples were analyzed for tritium. In addition to sample collection and analysis, radiation surveys were performed using portable survey instruments to detect gamma radiation.

No radioactivity attributable to nuclear-powered warship operations was detected. All radioactivity detected in the 81 samples taken during the survey is attributed to naturally occurring radionuclides or fallout from atmospheric nuclear tests and the Chernobyl reactor accident in 1986. External radiation measurements did not detect any increased radiation above natural background levels. Based on this radiological survey, practices regarding nuclear-powered warship operations at KBSB have resulted in no increases in radioactivity causing population exposure or contamination of the environment.

ACKNOWLEDGMENTS

Many staff participated in this study and helped prepare this report. The detailed planning, support, and assistance of the Kings Bay Submarine Base personnel was much appreciated. The EPA survey team consisted of Sam Poppell, Jim Moore, Ed Mantiply, and Bob Trefethen from NAREL; Jon Richards and Lloyd Generette from EPA Region 4 in Atlanta, GA. Ed Mantiply and Bob Trefethen provided the computer technical expertise in the preparation of figures for the sample locations. Chuck Petko edited the report. Finally, thanks go to the EPA staff who served as technical peer reviewers of the manuscript.

DISCLAIMER

Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

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ABBREVIATIONS

cm ..... Centimeter

GPS ..... Global Positioning System

IAG ..... Inter-Agency Agreement

KBSB ..... Kings Bay Submarine Base

L ..... Liter

m ..... Meter

μR ..... Microroentgen (10^{-6} roentgen of γ–ray exposure)

μR/hr ..... Microroentgen per hour

MDC ..... Minimum Detectable Concentration

NAREL ..... National Air and Radiation Environmental Laboratory

NAVSEA ..... Naval Sea Systems Command

ND ..... Not Detected

pCi ..... Picocurie (10^{-12} curies of radioactivity)

pCi/g-dry ..... Picocuries per gram-dry-weight

pCi/g-ash ..... Picocuries per gram-ashed-weight

pCi/g-wet ..... Picocuries per gram-wet-weight

pCi/L ..... Picocuries per liter

PIC ..... Pressurized Ionization Chamber

USEPA ..... United States Environmental Protection Agency

1.0 INTRODUCTION

The National Air and Radiation Environmental Laboratory (NAREL) of the United States Environmental Protection Agency (EPA) in cooperation with the United States Naval Sea Systems Command (NAVSEA) has previously surveyed facilities serving nuclear-powered warships. These surveys began in 1963 and have been conducted on the Atlantic and Pacific coasts, on the Gulf of Mexico within the Continental United States and at Pearl Harbor, Hawaii. In 1996, an interagency agreement (IAG) was signed with NAVSEA for NAREL to perform radiological surveys over five years at active facilities serving nuclear-powered warships. These surveys assess whether the construction, maintenance, overhaul, refueling or operations of nuclear-powered warships have created elevated levels of radioactivity that could expose nearby populations or contaminate the environment.

The first five environmental surveys performed under the interagency agreement were: Puget Sound Naval Shipyard (PSNS) at Bremerton, WA, and the Naval Submarine Base (NSBB) near Bangor, WA during 1996 (Fo98); San Diego Bay, CA (Go99) and Portsmouth Naval Shipyard at Kittery, ME during 1997 (Sm01); Pearl Harbor Naval Complex (PHNC), HI during 1998 (Po01); and the Navy Nuclear Power Training Unit (NPTU), North Charleston, SC in 1999 (Fo03). The sixth environmental survey under the IAG was performed May 7 13, 1999, at the Kings Bay Submarine Base (KBSB) at Kings Bay, GA.

A pre-survey trip to KBSB was made March 23 25, 1999 to develop a sampling and survey work plan with the assistance of knowledgeable site personnel and EPA radiation program representatives from EPA-NAREL and EPA Region 4. Staff from NAVSEA and KBSB provided NAREL with information on past and present KBSB radiological operations and procedures. All requested information was freely provided verbally and/or in writing. Based on the information received and that derived from previous EPA studies, a work plan (EPA99) was developed to describe the approach for assessing the radiological condition of the KBSB and nearby aquatic environments.

1.1 Site Description and History (Ma99)

The Kings Bay Submarine Base (KBSB) is located in southeast Georgia, adjacent to St. Marys, approximately 10 miles east of Kingsland and about 30 miles north of Jacksonville, Florida. The facility is on Kings Bay just off Cumberland Sound which is created by Cumberland Island, a barrier island on Georgia's Atlantic coast. KBSB consists of five primary work areas; a drydock located at the northwest end of Kings Bay; a central pier, which is the center of most activity, located to the northwest into Kings Bay; two covered explosives handling wharves located at approximately the center of Kings Bay; a second pier located to the southeast near the entrance of Kings Bay; and a magnetic silencing facility located further south of Kings Bay extending in an easterly direction into Cumberland Sound.

Most of the Kings Bay area consists of shallow water and tidal marshes, except for the area of the

ship channels which have been deepened by dredging. Fishing and boating were noted in the local area, particularly on Cumberland Sound which is part of the intercoastal waterway. Submerged aquatic vegetation is rare at KBSB due to excessive water current. Marine life available to be sampled includes marsh grass, oysters, and crabs.

1.2 Survey History

KBSB was surveyed previously by the EPA in 1985 (Wi87). During the 1985 survey, no radionuclides associated with nuclear-powered warship operations were detected in any of the samples and the only shoreline gamma radiation levels which were elevated above the local natural background resulted from stone which had been brought in to stabilize the shoreline. The stone, which appeared to be large pieces of granite, contained levels of natural radioactivity slightly greater than the local terrain. A number of new facilities have been constructed at KBSB since the 1985 EPA survey. This was the initial EPA survey of the areas constructed since 1985 which included the drydock located at the northwest end of Kings Bay, Refit Wharves Numbers 1, 2 and 3 and Explosive Handling Wharves Numbers 1 and 2.

1.3 Contaminants of Concern

The results of previous harbor surveys indicate that cobalt-60 is the predominant radionuclide one would find in environmental media if radioactivity were present as a result of naval nuclear propulsion plant operations (Ca77, Ca87). Therefore, environmental sampling during this study emphasized detection of cobalt-60. Other radionuclides of concern in liquid effluents or encountered during maintenance work include tungsten-187, chromium-51, iron-59, iron-55, nickel-63, niobium-95, zirconium-95, manganese-54, and cobalt-58 (ANS99). Water samples were also analyzed for tritium since this radionuclide is known to be produced in the coolant of light-water nuclear reactors.

1.4 Study Objectives

The objectives of the study were to determine if radioactive material related to US Navy nuclear-powered warship operations, repair and maintenance is present at measurable levels in the harbor samples collected, to make comparisons of current study results with past study results, and, as deemed appropriate, to estimate potential doses to the public.

2.0 SAMPLING, MEASUREMENT AND ANALYSIS

The following terms will be used in the discussion of the collection of samples and measurements:

Study Site:	The geographical area in and around KBSB that was studied.
Measurement Location:	A location in or near the study site where gamma exposure rates were measured.
Sampling Location:	A location in or near the study site from which samples were collected.
Background Location:	A selected sampling location where representative levels of naturally occurring or existing radionuclides, not likely to be related to KBSB, were measured.

2.1 Sampling and Measurement Strategy

This study was intended to determine the concentrations of cobalt-60 and other selected radionuclides that could be present due to the operations performed at KBSB and other selected radionuclides that may be present at or near the study site but originating from off-site locations. The sampling locations selected were those where the Navy presently conducts environmental monitoring, locations where the USEPA-NAREL sampled in 1985 and locations selected by NAREL to more comprehensively characterize the study site.

Background sampling locations were selected to obtain baseline radionuclide levels that are characteristic of the area. The data from the study site were compared directly to the background concentrations when background data were available or to appropriate standards, such as those in the national drinking water regulations (FR00).

Field duplicate samples were either co-located (adjacent) with the original samples or the original samples were split. Biota, bottom sediment and water samples were typically composited at the sampling location upon collection and then split into duplicate samples. However, the duplicate shoreline samples were collected as adjacent samples at the same sampling location. Duplicates of different media (e.g., biota, sediment, etc.) were taken at 3 sampling locations resulting in 10 samples (5 duplicate pairs).

2.1.1 Background Sampling Locations

There are three background locations for KBSB: in the middle of the Crooked River just off Crooked River State Park (location KBSB055); on the shoreline at Crooked River State Park

(location KBSB056) (see Fig. 1 and Table 1); and, for drinking water, at a motel in Kingsland, GA (location KBSB058) (see Table 1). These background locations were selected during the March 1999 pre-survey visit to the KBSB study site. Operations at KBSB would not have impacted the background locations since they are far away from the study site.

2.1.2 Kings Bay Submarine Base (KBSB) Survey Site

The KBSB survey site is on Kings Bay off of Cumberland Sound and the surrounding environs including the Crab Island dredging spoils area. Sampling locations presently used by the Navy and sampling locations added by NAREL were used during this survey. Approximate sample locations are shown in Figures 1 and 2. The type of sample and a description of the sample location are presented in Table 1. A total of 81 samples were collected during this survey. Repeated efforts to obtain sediment samples at locations 4 (east side of channel Marker R-80) and 51 (southeast of Crab Island at Marker R-76) were unsuccessful.

2.1.3 Instrumentation

At selected locations, primarily public access areas, radiation measurements were made using portable survey instruments to detect gamma radiation. External radiation measurement locations are given in Table 2 and Figures 1 and 2. Three types of gamma measuring instruments were used: a Ludlum Model-19 Micro-R radiation survey instrument, a GENITRON GM survey instrument and a Reuter-Stokes pressurized ionization chamber (PIC). Instrument serial numbers and calibration dates are available on the field data sheets.

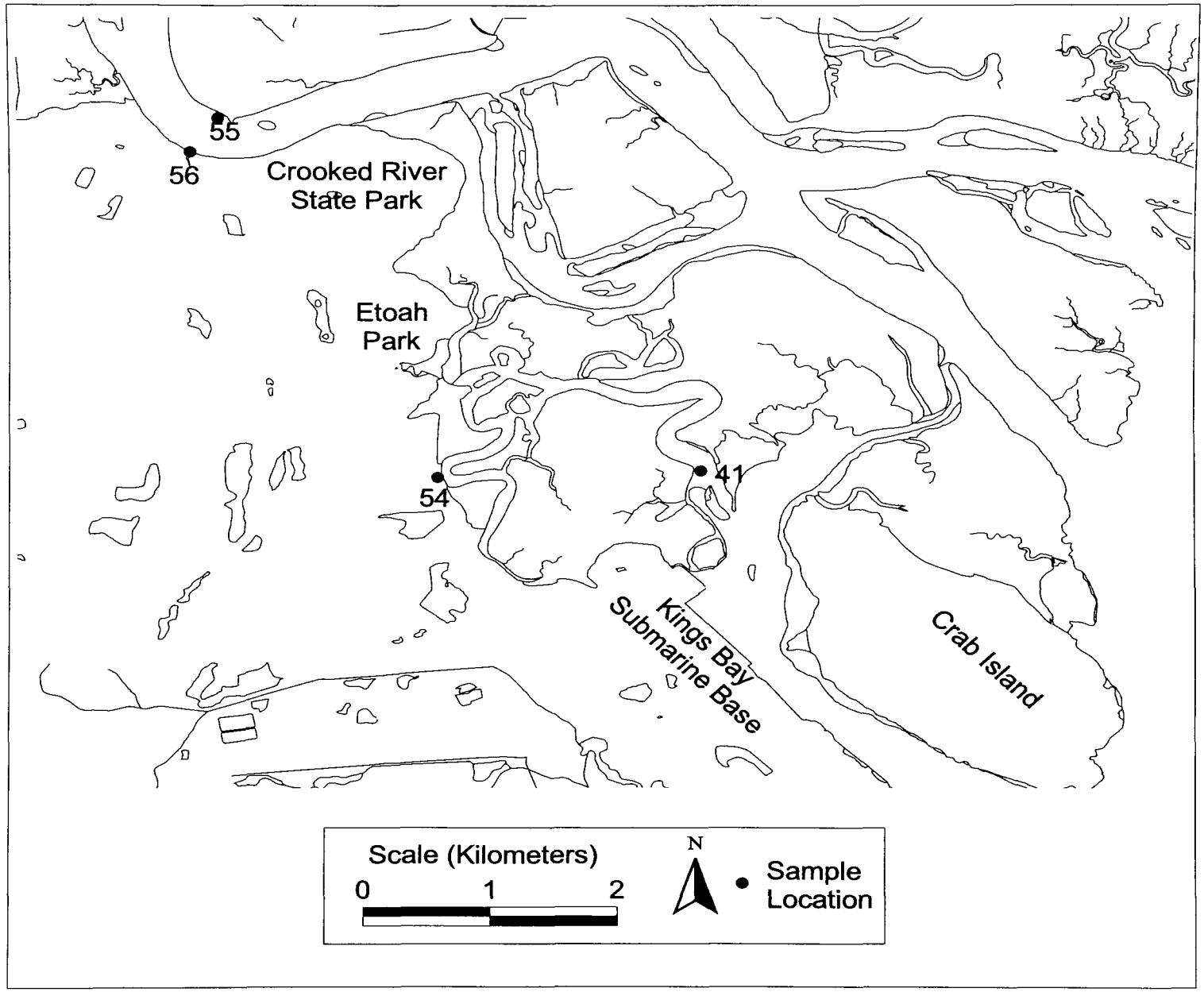

Fig. 1. Kings Bay Submarine Base Area Map

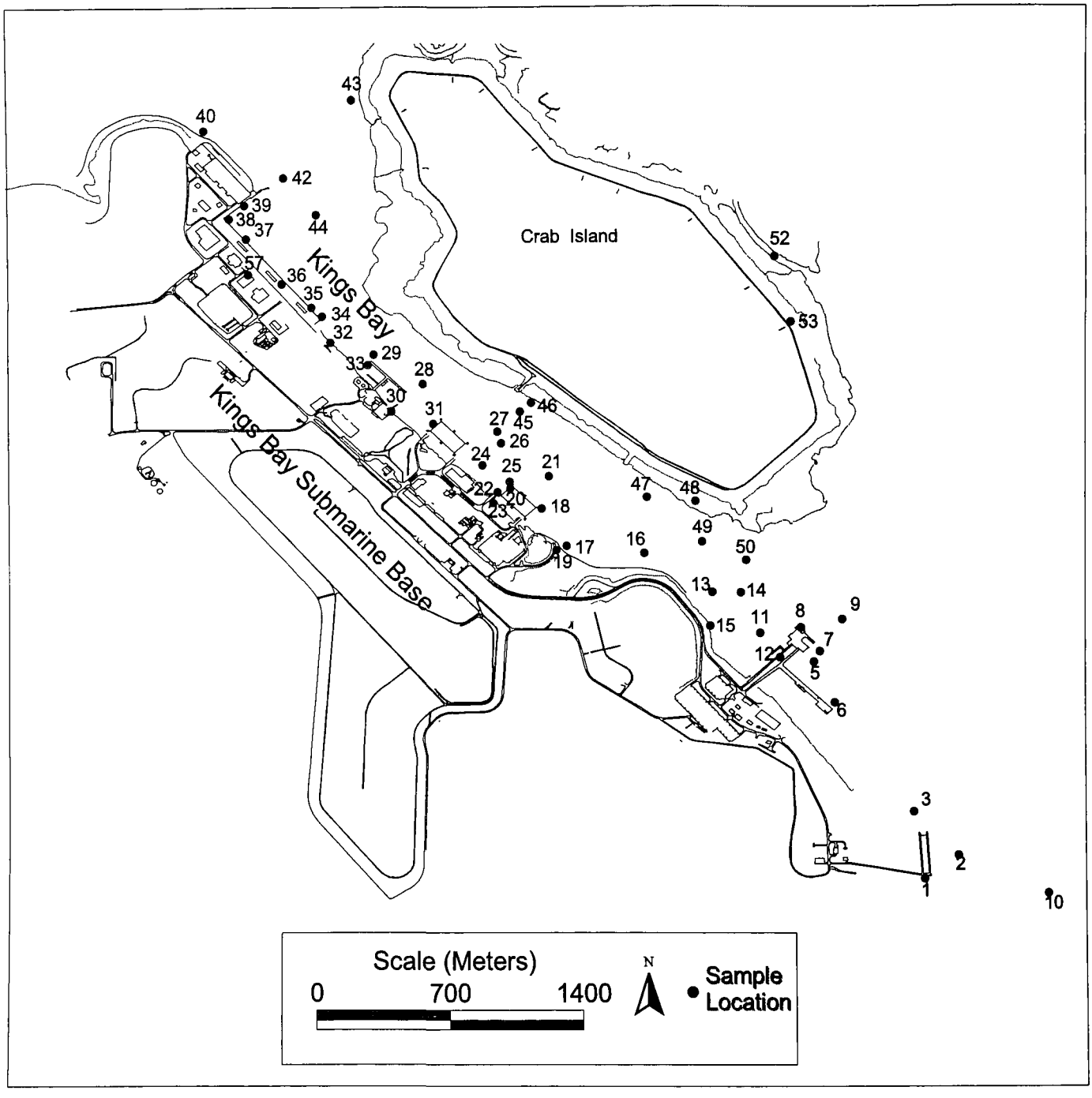

Fig. 2. Kings Bay Submarine Base Sample and External Measurement Locations

TABLE 1
Sample and Measurement Locations

Location ID	Navy ID[a]	EPA 1985 ID[b]	Position[c]		Background	Duplicate	Samples and Measurements[d,e,f]							Location Description
			Latitude	Longitude			Sediment	Core	Biota	S-Water	D-Water	Shoreline	Exposure	
001	S29/ W8		N 30° 46.681'	W 81° 29.511'			S			W				Approximately 30 m south of the Magnetic Silencing Facility.
002			N 30° 46.749'	W 81° 29.413'									E	Approximately 152 m east of the Magnetic Silencing Facility
003	S19	19	N 30° 46.872'	W 81° 29.543'			S							Approximately 60 m north of the Magnetic Silencing Facility.
005	S26		N 30° 47.300'	W 81° 29.829'			S							Approximately 15 m south of the Southern end of the Warrior Wharf.
006	S25		N 30° 47.183'	W 81° 29.770'			S							Approximately 30 m off the Northeast of the Southern end of Lay Berth #2.
007		3	N 30° 47.330'	W 81° 29.812'			S							Approximately 1 m off east side of pier on the south side of the Warrior Wharf. (This is the location of the floating dry dock during the 1985 EPA survey).
008		1	N 30° 47.398'	W 81°29.866'			S	C		W				Approximately 1 m off Warrior Wharf, 143 m east of Lay Berth. (This is the location of the floating dry dock during the 1985 EPA survey.)
009			N 30° 47.421'	W 81° 29.748'									E	On the water, approximately 152 m east of the Warrior Wharf.
010	S30		N 30° 46.640'	W 81° 29.147'			S							Approximately 15 m west and 30 m north from the southern tip of Drum Island.
011	S24		N 30° 47.382'	W 81° 29.984'			S							North of the Warrior Wharf mid-way between the wooden Pylons on Site VI beach and tender mooring site.
012	B1		N 30° 47.313'	W 81° 29.927'					B					Warrior Wharf, approximately 36 m north of Lay Berth.
013	S15		N 30° 47.500'	W 81° 30.122'			S							Approximately 60 m east of the middle of the south end pier beach.
014	S18/ W3		N 30° 47.499'	W 81° 30.040'			S			W				Approximately 122 m east of the middle of the south end of pier beach.
015	BG		N 30° 47.281'	W 81° 30.088'								L	E	North of Warrior Wharf at KBSB Environmental Data Point #BG.
016	S6		N 30° 47.612'	W 81° 30.320'			S							Approximately 30 m east of the point where the shoreline stops running north from the Warrior Wharf and starts running northwest to Explosive Handling Wharf #2.
017		35	N 30° 47.663'	W 81°30.545'			S	C						Approximately 30 m east of the shore and 220 m south of the southeast tower of Explosive Handling Wharf #2. (This is the location of the Tender during the 1985 EPA survey.)
018	S4		N 30° 47.741'	W 81° 30.618'			S							Approximately 15 m south of the southeast corner of Explosive Handling Wharf #2.

TABLE 1 –*Continued*

ID	Navy	EPA	Latitude	Longitude	BK	DU	Samples & Measurements	Location Description
019			N 30° 47.620'	W 81° 30.575'			B L E	Shore near former Tender mooring at south end of Explosive Handling Wharf #2, east side of road at shoreline.
020	B4		N 30° 47.800'	W 81° 30.710'			B	South end of Explosive Handling Wharf #2 at center.
021			N 30° 47.835'	W 81° 30.596'			S C	Approximately 158 m center of due east side of Explosive Handling Wharf #2.
022			N 30° 47.789'	W 81° 30.747'			S W	Near the sewer outfall north of Explosive Handling Wharf #2.
022-2			N 30° 47.789'	W 81° 30.747'			W	The sewer outfall north of Explosive Handling Wharf #2 at approximate depth of the discharge pipe outflow (Pipe not located).
023			N 30° 47.758'	W 81° 30.759'			B	On the shoreline at the sewer outfall location north of Explosive Handling Wharf #2.
024	S1		N 30° 47.868'	W 81° 30.791'			S	Approximately midway between the entrance to Explosive Handling Wharf #1 and Explosive Handling Wharf #2 and 15 m east of the pier.
025	B3		N 30° 47.820'	W 81° 30.711'			B	North end of Explosive Handling Wharf #2.
026			N 30° 47.930'	W 81° 30.735'			S C	Explosive Handling Wharf #1 centerline on the east side.
027	S2/ W1		N 30° 47.964'	W 81° 30.747'			S W	Mid channel between site 24 (midway between the entrance to Explosive Handling Wharf #1 and Explosive Handling Wharf #2 and 15 m east of the pier) and Navigation Marker 56.
028	S7		N 30° 48.101'	W 81° 30.969'			S	Mid channel between the south end of the Port Services Pier and Navigation Marker 58.
029	S8		N 30° 48.186'	W 81° 31.107'			S	Mid channel parallel with the north end of the Port Services Pier.
030			N 30° 48.023'	W 81° 31.056'			E	South end of boat dock over granite rocks on the shoreline of Port Services Pier.
031	B2		N 30° 47.987'	W 81° 30.934'			B	North end of Port Services Pier (KBSB Map B).
032			N 30° 48.219'	W 81° 31.234'			L E	North end of shoreline of submarine base, on Defense Mapping Agency marker #4086, near Environmental Data Point #9.
033	S10		N 30° 48.155'	W 81° 31.124'			S	Approximatelyb15 m north of the north end of Port Services Pier.
034	S27/ W6		N 30° 48.295'	W 81°31.257'			S W	Southeast corner, approximately 15 m from Refit Wharf #3.
035			N 30° 48.320'	W 81° 31.290'			S C	Refit Wharf #3 centerline on east side, about 240 m from EHW-2, approximately 21 m from southeast corner of BSB #3.
036			N 30° 48.388'	W 81° 31.376'			S C	Refit Wharf #2 centerline on east side, approximately 33 m from southeast corner of BSB #2, about 93 m from north end of CCSB #3.

TABLE 1 -*Continued*

ID	Navy	EPA	Latitude	Longitude	BK	DU	Samples & Measurements	Location Description
037			N 30° 48.320'	W 81° 31.290'			S C	BSB #1 centerline on east side, approximately 21 m from center, about 192 m from north end of CCSB #2.
038	S12		N 30° 48.574'	W 81° 31.529'			S	Approximately 15 m from the north corner of pier and base.
039			N 30° 48.614'	W 81° 31.484'			S C	South end of dry dock at the north end of the submarine base, about 160 m from NE corner of CCSB #1.
040			N 30° 48.826'	W 81° 31.601'			B	Shore near northeast corner of dry dock discharge at north end of submarine base.
041			N 30° 49.211'	W 81° 31.476'			E	North end of Kings Bay at nearest point of public access on the water between two warning signs.
042	S13/ W7		N 30° 48.692'	W 81° 31.370'			S W	At the north end of Kings Bay, approximately 15 m south of navigation marker #68.
043	S14		N 30° 48.962'	W 81° 31.170'			S	Approximately 18 m west of the Kings Bay Military Installation sign at the north end of Crab Island.
044	S11		N 30° 48.586'	W 81° 31.274'			S	Approximately 15 m west of navigation marker #64 in the bay on the northwest side of Crab Island.
045	S3		N 30° 48.021'	W 81° 30.680'			S	West of Crab Island, approximately 15 m west of navigation marker #56.
046			N 30° 48.047'	W 81° 30.647'			B L E	Crab Island west shoreline, due NE of Explosive Handling Wharf #2 at Crab Island pier.
047	S5		N 30° 47.774'	W 81° 30.311'			S	West of Crab Island, about 15 m West of navigation marker #54.
048			N 30° 47.762'	W 81° 30.170'			B L E	South end of Crab Island shoreline, due SW of KBSB survey marker #10.
049	S16		N 30° 47.645'	W 81° 30.152'			S	Approximately 30 m from the southeast corner of Crab Island dredge spoil area.
050	S17		N 30° 47.591'	W 81° 30.024'			S	Approximately 12 m southwest of Kings Bay Military Installation sign at the south end of Crab Island.
052	S21/ W5		N 30° 48.459'	W 81° 29.940'			S W	Middle of the mouth of the creek on the eastern side of Crab Island dredge spoils area.
053			N 30° 48.273'	W 81° 29.893'			C L	Near south spillover tower at Crab Island dredge spoils area.
054			N 30° 49.179'	W 81° 32.594'			B L E	South of boat ramp and pier, Etowah Park located near the northeast boundary of KBSB and Crooked River State Park.
055			N 30° 50.898'	W 81° 33.518'	BK	DU	S W	At mid-river on Crooked River at Crooked River State Park.
056			N 30° 50.738'	W 81° 33.638'	BK	DU	B L E	Shoreline at Crooked River State Park, NNW of boat ramp, take small trail to opening at a small concrete marker "R/W."

TABLE 1 -*Continued*

ID	Navy	EPA	Latitude	Longitude	BK	DU	Samples & Measurements	Location Description
057			N 30° 48.433'	W 81° 31.466'		DU	D	Drinking water at Building 5104, Refit Support, KBSB.
058			N 30° 47.441'	W 81° 39.208'	BK		D	Drinking water at Best Western Motel, Kingsland, GA.

[a] Navy symbols used in the tables are explained on page 12.
[b] "EPA 1985" location ID's are from the EPA/NAREL 1985 Kings Bay survey. Locations were determined from text descriptions or maps from Wi87.
[c] Latitude and longitude are given in degrees and decimal minutes.
[d] Sample and measurement codes are explained on page 11.
[e] Sites which have Navy ID's are located exactly at the Navy location. Corresponding EPA 1985 ID's indicate sampling locations which approximately correspond to the Navy location (within about 30 m). Sites which have EPA 1985 ID's but not Navy ID's are located at the EPA 1985 location.
[f] Water samples were collected at a depth of 1 m unless otherwise specified.

2.1.4 Table Notes

2.1.4.1 General

Samples were taken as close to piers as situations permitted when a distance was not specified. Sometimes barges, ships and other equipment prevented collecting a sample close to the pier, therefore, an alternate location was selected. Geographic positions (latitude and longitude) were determined by commercially available Global Positioning System (GPS) units. These units had a typical accuracy ranging from 30 to 100 meters.

2.1.4.2 Sample Identification

Each sample collected or measurement taken during the survey was marked with a unique code which denoted:

1. Location
2. Matrix or Measurement type
3. Sample type detail (e.g., field duplicate, background, sewer outfall)

The sample identification (ID) code has the form KBSBxxx-yyyy[-zz], where 'xxx' indicates the sampling site ID number, 'yyyy' identifies the measurement type or matrix (and species for biota samples), and (zz) provides additional descriptive information: 'DU' if the sample was a duplicate or 'BK' if the sample was a background location. Not all samples required the use of all characters. The following table explains the codes used for the different sample types.

Sample and Measurement Codes

Code	Sample or Measurement Type	Code	Sample or Measurement Type
S	Harbor Sediment	B?	Unidentified Type of Marsh Grass
L	Shoreline Sediment	W	Harbor Surface Water
C	Sediment Core	D	Drinking Water
BO	Oysters	E	External Exposure Rate
BMG	Marsh Grass		

Coding for a typical sample might be as follows: a KBSB harbor-bottom sediment sample taken at location 11 is coded 'KBSB011-S'. If the sample were a duplicate at KBSB location 24, it would be 'KBSB024-S-DU'. A duplicate water sample taken at KBSB location 55 (a background location) is labeled 'KBSB055-W-DU-BK'. A non-duplicate marsh grass sample taken at KBSB location 48 is labeled 'KBSB048-BMG'. A second water sample taken at the depth of the sewer outfall has an additional identifier of "02" after the location number to indicate that this is the second water sample collected at this location, but at a different depth

than the first water sample, e.g. 'KBSB022-02-W'. "Navy" location ID's with "S" prefixes are sediment sample location ID's, "W" prefixes are water sample location ID's, and "B" prefixes are biota sample ID's.

2.2 Sample Collection and Analysis

2.2.1 Sample Collection

Shoreline (intertidal) sediment, harbor bottom sediment (grab and core), water (harbor surface, sewage outfall, and drinking waters), and biota were collected. By previous agreement between USEPA-NAREL and the Navy, most samples were split for routine independent comparisons by the Navy. The samples collected are listed in Table 1. The locations where duplicate samples were taken are noted in Table 1. All samples were analyzed for gross alpha and beta activities and gamma emitting radionuclides. Water samples were analyzed for tritium.

A total of eleven surface water samples were collected. This included one sample and a duplicate taken at a background location and two samples taken at the water treatment outfall. Sample KBSB022-2-W was taken before the sewer outfall pipe was located. Surface water samples were collected by lowering a Wildco horizontal water sampling bottle (alpha bottle) to a depth of 1 m (two samples at the Navy sewer outfall north of Explosive Handling Wharf #2 were collected at the depth of the outfall pipe) and then closing the bottle by releasing a "messenger" that activated a tripping mechanism. This process was repeated until 5 L of water were obtained. About 4 L of water were poured into a plastic sample container and acidified to a pH of < 2 with nitric acid. The acidified water sample was analyzed for gross alpha and beta activities and gamma emitting radionuclides. One fourth liter of the water sample was poured into a glass container and, without being acidified, was analyzed for tritium.

Three drinking water samples were collected from 2 taps representing the water supplies of Kingsland, GA, and KBSB. A duplicate sample was collected at KBSB. The 5 L drinking water sample collected at each location was divided into 2 sample containers and analyzed in the same manner as were the surface water samples.

Thirty-seven harbor bottom sediment samples were obtained during this study. Sediment sampling from boats was performed using a Peterson dredge to sample approximately the top 10 cm of sediment. Each sample consisted of approximately 4 liters. Samples collected included one background location and one duplicate background sample.

A total of 9 shoreline sediment samples were collected, of which one was a background and one was a duplicate background sample. Shoreline sediment samples were collected with a small trowel or scoop and consisted of approximately 4 liters of surface soil collected from the intertidal shoreline near the low tide line. Stones and organic debris were excluded as much as possible. Any remaining debris was removed by sieving with a 16-mesh sieve during sample preparation at the laboratory.

Nine sediment core samples were collected. Except for the single core collected by the EPA

sampling team at the dredging spoils area, core samples were collected by Navy divers. Each sediment core sample consisted of a 5 cm diameter cylinder of sediment up to 51 cm in length. Sediment core samples were obtained to evaluate the vertical distribution of radioactivity in sediment. Samples were collected by pushing the plastic tube vertically into the harbor bottom or dredging spoils as far as possible, then capping the ends. Excess water was decanted from the top of each core. The cores were frozen prior to shipping and remained frozen during shipping. Before analysis, the frozen cores were cut into a maximum of 5 segments per core with each segment having a minimum length of 5 cm. Each section was oven dried.

Twelve biota samples were collected, each consisting of approximately 4 liters of one species of marine life. One sample and a duplicate were collected for quality assurance purposes at a background location. Samples were collected from as small a region as possible. Marsh grass was collected on the shoreline by the EPA sampling team and oysters were collected by divers. Biota samples were homogenized in the field, frozen for shipping and thawed for radioanalysis. Because of the interest in iodine-131, all biota samples were counted wet by gamma spectroscopy within 7 days after collection.

2.2.2 Sample Analysis

Samples for each location were analyzed for gamma emitting radionuclides and for gross alpha/beta activities. It was of particular interest to determine if cobalt-60 could be found in the sediment samples and if iodine-131 could be found in the water samples. All water samples were analyzed for tritium.

Gamma Spectrometry. This procedure allows for characterization of the gamma-emitting radionuclides present in the sample without separating them from the sample matrix. The limit of detectability of this method is a function of the sample size, counting geometry, detector efficiency, background, counting time, gamma photon energy of the nuclide, and branching ratio (percent abundance). Liquid samples are acidified and soil or sediment samples are ground and sieved to ensure the homogeneity of the samples. Biota samples are homogenized prior to analysis to ensure uniformity of the sample.

Gross Alpha/Beta. This procedure, which provides a rapid screening measurement, was used as a gross approximation of the alpha and beta activity present in the sample. Low energy and volatile radionuclides such as tritium, carbon-14, and iodine will not be detected by this method. In addition, polonium and cesium may be lost if the procedure requires flaming of the sample. For water samples, a known amount of the sample is evaporated to a small volume then transferred to a small container and further evaporated for measurement. For solid samples, a known amount of the sample is placed on the planchet. Water is added and the sample is dried to provide even distribution. The sample is weighed and counted on a gas proportional counter. These analyses are not nuclide specific and are not as accurate as other types of analyses.

Tritium Analysis. Water samples are distilled and are incorporated into a counting mixture consisting of a primary solvent, emulsifier, and fluors. The tritium is assayed in a liquid scintillation spectrometer.

3.0 RESULTS AND DISCUSSION

The radioanalytical results for the KBSB samples collected during this survey are reported in the Appendix. The tables were generated from Data Quality Packages (DQPs) produced from radioanalytical results. The quality assurance/quality control (QA/QC) results for the laboratory analyses and field sample QA/QC were presented in the DQPs for the sample analyses, and the results were within acceptable limits as specified in the Quality Assurance Project Plan (EPA97) for this survey. Some of the reported radionuclide activity results are negative. Negative results occur when a previously determined counting instrument background value is subtracted from a sample value that is less than the background value. Negative values represent a portion of the statistical distribution of negative and positive values around zero for samples containing very little or no detectable radioactivity.

3.1 Water Samples

Gamma analysis results for the 11 surface water samples are shown in Table A.1. Only naturally occurring radionuclides were detected in surface water samples.

Three drinking water samples, which included a background and a site sample with duplicate sample, were collected. The gamma analysis results are shown in Table A.4. Only naturally occurring radionuclides were detected in drinking water samples.

Tritium analyses were performed on all water samples and results are presented in Tables A.2 and A.5. Tritium concentrations in the water samples collected at KBSB were similar to those collected at the background location (KBSB055). The minimum detectable concentration (MDC) of tritium was about 140 pCi/L for the water samples.

Results of the gross alpha and beta analyses of water samples are presented in Tables A.3 and A.6. Samples collected from KBSB have concentrations similar to those found in the background sample and samples at the Navy water treatment outfall. The KBSB drinking water samples had a gross alpha concentration of -0.03±0.34 pCi/L and -0.8±1.3 pCi/L, respectively (Table A.6), which indicates that these samples had little or no radioactivity. The National Primary Drinking Water Regulations (FR00) state that the maximum allowed gross alpha particle radioactivity in community water systems is 15 pCi/L (including radium-226, but excluding radon and uranium).

3.2 Sediment and Sediment Core Samples

A total of 46 sediment samples were collected. Of the 37 harbor bottom sediment samples collected: 34 were collected at KBSB locations; one was collected at the Navy water treatment outfall; and 2, including one duplicate, were collected at the background location. Nine shoreline sediment samples were collected: 7 at KBSB locations and 2 background samples, which included one duplicate sample. The gamma analysis results are shown in Tables A.7 and A.8. Gamma emitting radionuclides measured in the sediment samples were naturally occurring

radionuclides or fallout from atmospheric nuclear tests (EPA04). No cobalt-60 was detected in any of the sediment samples collected at KBSB. The cobalt-60 MDCs for the dredged sediment samples were in the range of 0.01 to 0.03 pCi/g-dry due to the detector used and the sample size. All samples were counted on a Ge detector for 1000 minutes.

Results of the gross alpha and beta analyses of sediment samples are presented in Table A.9. The maximum total gross alpha and beta concentrations were 12.5±4.5 pCi/g-dry and 22.5±4.1 pCi/g-dry, respectively, in samples collected from KBSB; 8.5±3.9 pCi/g-dry and 16.6±3.7 pCi/g-dry in samples collected at the Navy water treatment outfall; and 12.5±4.4 pCi/g-dry and 18.5±3.8 pCi/g-dry, respectively, in samples from background locations. In summary, sediment samples from KBSB have concentrations similar to the background and Navy water treatment outfall samples.

Sediment core samples were taken at 9 sites. Gamma analysis results for the sediment core samples are shown in Tables A.10 and A.11. The cobalt-60 MDCs for the sediment core samples were in the range of 0.01 to 0.45 pCi/g-dry due to the detector used and the sample size. All samples were counted on a Ge detector for 1000 minutes. No cobalt-60 was detected in any of the sediment core samples collected at KBSB. All radionuclides identified were attributed to naturally occurring radionuclides or fallout. The radionuclide content of the core samples showed no significant differences with depth or with the dredge samples taken in the same general area.

Results of the gross beta and alpha analyses of sediment core samples are shown in Table A.12 for KBSB.

3.3 Biota Samples

Gamma analysis results for the 12 biota samples are shown in Table A.13. Only naturally occurring radionuclides were detected, with the exception of trace amounts of Cs-137, which are most likely present due to fallout.

Results of the gross alpha and beta analyses of biota samples are presented in Table A.14. Samples collected from KBSB showed concentrations of alpha emitting radionuclides similar to those found in the background samples.

3.4 External Radiation Measurements

External radiation measurements were made along the shoreline and on the water at KBSB with emphasis on areas accessible to the public. Measurements were recorded every 10 minutes during the survey with a Genitron Instruments Gamma TRACER GM type survey instrument, and readings were downloaded at each external monitoring location. External exposure readings were also taken for 5 to 10 minutes at each location with a Reuter-Stokes pressurized ion chamber (PIC). A Ludlum Model-19 was also used to measure variation in exposure rates along

the shoreline at each location. The Ludlum Model-19 does not respond linearly in response to gamma rays of different energies as do the other instruments. Due to this difference in response, the Ludlum Model-19 may provide what appears to be inconsistent results, and will frequently indicate higher radiation readings than the other detectors due to this nonlinear response. Results of the external radiation measurements are shown in Table 2. Radiation levels measured were similar to background and due to naturally occurring radionuclides. The highest external radiation reading was at a stone-stabilized shoreline location (KBSB030) and was attributed to higher levels of naturally occurring radioactivity in the stone than in the surrounding terrain.

TABLE 2
External Gamma Radiation Measurements

Location ID	PIC Exposure Rates µR/hr	GENITRON Exposure Rates µR/hr	Ludlum Model-19 Exposure Rates µR/hr
KBSB002-E	3.2 - 4.5	5 ± 1	1
KBSB009-E	3.5 - 4.4	4 ± 1	1
KBSB015-E	4.0 - 10.9	8 ± 1	7
KBSB019-E	7.9 - 9.2	11 ± 1	7
KBSB030-E	5.4 - 16.4	11 ± 1	15
KBSB032-E	6.0 - 8.3	9 ± 1	6
KBSB041-E	3.3 - 4.4	5 ± 1	2
KBSB046-E	7.9 - 9.4	9 ± 1	8
KBSB048-E	3.7 - 5.5	6 ± 1	4
KBSB054-E	5.4 - 7.0	9 ± 1	7
KBSB056-E-BK	4.1 - 8.8	7 ± 1	6
KBSB056-E-DU-BK	1.2 - 15.3	7 ± 1	6

4.0 QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

4.1 Quality Assurance Program

The NAREL Quality Assurance (QA) Plan applies to all work performed at NAREL. The purpose of the quality assurance program is to ensure that all measurements performed at NAREL are valid, scientifically defensible, and of known precision and accuracy. The NAREL Quality Assurance Project Plan (QAPP) for the U.S. Navy Environmental Studies (EPA 97) was prepared in accordance with the requirements described in "EPA Requirements for Quality Assurance Project Plans for Environmental Data Operations" (EPA94).

Quality Assurance/Quality Control (QA/QC) for the laboratory analyses performed for this survey is detailed in the QAPP (EPA97). Quality control (QC) samples are analyzed in conjunction with routine samples to ensure the quality of the analytical results. Corrective actions must be taken when it is shown by the results of QC samples that the radioanalytical procedure is beyond predetermined control limits. Quality assurance is equally important in the sample collection process. All documentation, including chain-of-custody forms, was properly completed. Sampling equipment was in good working order and field measurement equipment was calibrated and properly maintained.

4.2 Quality Control Samples

Field and laboratory quality control samples were included with site samples to help evaluate the entire sampling and analysis process. Evaluation of QC samples allows assessment of the accuracy and precision of the analytical procedures. The field duplicate results assess the consistency of the sampling process and the representativeness of the samples collected.

In the laboratory, samples were grouped in batches for quality control purposes, with a maximum of 20 samples per matrix per analysis type. For each batch, the laboratory analyzed a reagent blank, a matrix spike, a matrix spike duplicate, and a laboratory replicate sample. However, for gamma spectrometry and gross alpha and beta analyses, only a recount (duplicate) or split was performed for batch QC. Results of these QC samples were reviewed with sample results as part of the data verification and review process. Specific criteria for acceptance are included in the QAPP (EPA97). All blank sample results were maintained on control charts by analyst, matrix, and analyte. Warning and rejection limits were used to assess acceptance of the blank results. No substantial corrective actions were required during the processing and analysis of the samples for this survey. Radioanalytical sample results complied with the terms and conditions of the QAPP as certified by the NAREL Quality Assurance Coordinator and the Chief of the Monitoring and Analytical Services Branch.

4.3 Performance Evaluation Programs

It is NAREL policy to participate in many inter laboratory comparisons of radioactivity

measurements and cross-check programs. NAREL participates in intercomparison QA studies with the National Institute of Science and Technology (NIST) in Gaithersburg, MD; the World Health Organization (WHO) in Le Vesinet, France; the International Atomic Energy Agency (IAEA), Vienna, Austria; the U.S. Department of Energy (DOE) Radiological Environmental Science Laboratory in Idaho Falls, ID; the DOE Environmental Measurements Laboratory (EML) in New York, NY and Analytics, a commercial company in Atlanta, Georgia.

5.0 CONCLUSIONS

The radiological survey at the KBSB provides the basis for the following conclusions:

1. All radioactivity detected in the 81 samples taken during the survey is attributed to naturally occurring radionuclides or fallout from atmospheric nuclear tests and the Chernobyl reactor accident in 1986. Water samples from KBSB contained no detectable levels of radioactivity other than those occurring naturally. No cobalt-60 was detected in any of the sediment or sediment core samples collected at KBSB.

2. External radiation measurements did not detect any increased radiation exposure above natural background levels.

3. Based on the results presented in this study, practices regarding nuclear-powered warship operations at KBSB have resulted in no increases in radioactivity causing population exposure or contamination of the environment.

6.0 REFERENCES

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APPENDIX

Radioanalytical Results for

May 1999

KBSB Samples

General Information for NAREL Analytical Methods

as Reported in the NAREL Data Quality Packages

Gamma Spectrometry

Gamma analysis was done on all collected samples. The activity and 2-sigma uncertainty for radionuclides measured by gamma spectroscopy are reported only if the nuclide is detected. Nuclides that are not detected do not appear in the report, with the exception of barium-140, cobalt-60, cesium-137, iodine-131, potassium-40, radium-226, and radium-228. If one of these seven nuclides is undetected, NAREL reports it as "Not Detected" or "ND".

Due to potential spectral interferences and other possible problems associated with the determination of the activity for certain radionuclides, the activities for thorium-234, protactinium-234m, radium-226, and uranium-235 are subject to greater possible error than other commonly reported radionuclides. Note that this potential error is not included in the 2-sigma counting error reported with each activity. Although in this report we do provide the calculated activities for these radionuclides, we recommend that the results be used only as a qualitative means of indicating the presence of these radionuclides and not as a quantitative measure of their concentration. The results for these nuclides are not used in the evaluation of quality control samples. Furthermore, because of mutual interference between radium-226 and uranium-235, NAREL's gamma analysis software tends to overestimate the amounts of these nuclides whenever both are present in a sample. Lower estimates for radium-226 activities can be obtained from the reported activities of its decay products, lead-214 and bismuth-214, which could be somewhat less than the radium-226 activity because of the potential escape of radon gas.

NAREL's gamma spectroscopy software corrects activities and MDCs for decay between collection and analysis, but only up to a limit of ten half-lives. So, if the decay time for a sample is more than ten half-lives of a radionuclide, that nuclide will almost for certain be undetected, and the reported MDC will be meaningless. This is usually a problem only for short-lived radionuclides, such as iodine-131 and barium-140, when there is a long delay between collection and analysis.

Gross Alpha and Beta Analysis

In comparison to the methods employed to determine radionuclide-specific activities, the method employed by NAREL to determine gross alpha and beta activity has the potential for greater analytical bias. This is especially true for soils. Note that this potential analytical error is not included in the 2-sigma counting error term. Therefore, gross alpha and beta results should be used as gross approximations of the alpha and beta activity present.

TABLE A.1
Gamma Spectrometry Results for Surface Water Samples

Sample ID	NAREL ID	Activity (pCi/L ± 2σ counting error)				
		^{226}Ra	^{214}Bi	^{212}Pb	^{60}Co	^{40}K
STUDY SAMPLES						
KBSB 001-W	99.02539	ND	ND	ND	< 2.8	301 ± 29
KBSB 008-W	99.02537	ND	ND	ND	< 3.1	315 ± 29
KBSB 014-W	99.02541	ND	ND	ND	< 2.8	316 ± 29
KBSB 022-W	99.02535	ND	10.4 ± 3.0	ND	< 3.2	314 ± 29
KBSB 022-W-2	99.02536	ND	ND	ND	< 3.3	324 ± 29
KBSB 027-W	99.02540	ND	ND	ND	< 3.1	321 ± 29
KBSB 034-W	99.02581	ND	ND	ND	< 2.9	307 ± 29
KBSB 042-W	99.02610	ND	ND	ND	< 3.2	318 ± 30
KBSB 052-W	99.02579	ND	ND	ND	< 3.1	303 ± 29
BACKGROUND SAMPLES						
KBSB 055-W-BK	99.02609	ND	ND	3.6 ± 3.6	< 2.8	299 ± 29
KBSB 055-W-BK-DU	99.02613	38 ± 46	ND	ND	< 2.8	308 ± 29

Note: ND indicates the radionuclide was not detected by gamma spectrometry.

"< X" indicates the radionuclide was not detected and "X" was the minimum detectable concentration for the nuclide in this sample.

No other gamma-emitting radionuclides were detected in these samples.

TABLE A.2
Tritium Results for Surface Water Samples

Sample ID	NAREL ID	Tritium Activity (pCi/L ± 2σ counting error)
STUDY SAMPLES		
KBSB 001-W	99.02539	25 ± 79
KBSB 008-W	99.02537	6 ± 78
KBSB 014-W	99.02541	-13 ± 78
KBSB 022-W	99.02535	16 ± 79
KBSB 022-W-2	99.02536	11 ± 79
KBSB 027-W	99.02540	44 ± 80
KBSB 034-W	99.02581	25 ± 79
KBSB 042-W	99.02610	-3 ± 78
KBSB 052-W	99.02579	40 ± 80
BACKGROUND SAMPLES		
KBSB 055-W-BK	99.02609	-57 ± 76
KBSB 055-W-BK-DU	99.02613	19 ± 79

TABLE A.3
Gross Alpha and Gross Beta Activity Results for Surface Water Samples

Sample ID	NAREL ID	Activity (pCi/L ± 2σ counting error)	
		Gross Alpha	Gross Beta
STUDY SAMPLES			
KBSB 001-W	99.02539	25 ± 52	400 ± 110
KBSB 008-W	99.02537	-37 ± 97	390 ± 110
KBSB 014-W	99.02541	-12 ± 37	430 ± 110
KBSB 022-W	99.02535	-3 ± 29	300 ± 140
KBSB 022-W-2	99.02536	-36 ± 44	470 ± 150
KBSB 027-W	99.02540	-27 ± 11	335 ± 98
KBSB 034-W	99.02581	-16 ± 26	326 ± 98
KBSB 042-W	99.02610	-12 ± 36	320 ± 100
KBSB 052-W	99.02579	-26 ± 32	420 ± 150
BACKGROUND SAMPLES			
KBSB 055-W-BK	99.02609	-1 ± 33	320 ± 100
KBSB 055-W-BK-DU	99.02613	-9 ± 34	380 ± 110

TABLE A.4
Gamma Spectrometry Results for Drinking Water Samples

Sample ID	NAREL ID	Activity (pCi/L ± 2σ counting error)		
		^{212}Pb	^{208}Tl	^{60}Co
STUDY SAMPLES				
KBSB 057-D	99.02554	ND	ND	< 2.8
KBSB 057-D-DU	99.02569	7.3 ± 7.7	ND	< 7.2
BACKGROUND SAMPLES				
KBSB 058-D-BK	99.02568	ND	1.7 ± 1.5	< 2.5

Note: ND indicates the radionuclide was not detected by gamma spectrometry.

"< X" indicates the radionuclide was not detected and X was the minimum detectable concentration for the nuclide in this sample.

No other gamma-emitting radionuclides were detected in these samples.

TABLE A.5
Tritium Results for Drinking Water Samples

Sample ID	NAREL ID	Tritium Activity (pCi/L ± 2σ counting error)
STUDY SAMPLES		
KBSB 057-D	99.02554	2 ± 78
KBSB 057-D-DU	99.02569	-11 ± 78
BACKGROUND SAMPLES		
KBSB 058-D-BK	99.02568	19 ± 79

TABLE A.6
Gross Alpha and Gross Beta Activity Results for Drinking Water Samples

Sample ID	NAREL ID	Activity (pCi/L ± 2σ counting error)	
		Gross Alpha	Gross Beta
STUDY SAMPLES			
KBSB 057-D	99.02554	-0.03 ± 0.34	1.5 ± 1.1
KBSB 057-D-DU	99.02569	-0.8 ± 1.3	2.4 ± 1.2
BACKGROUND SAMPLES			
KBSB 058-D-BK	99.02568	0.06 ± 0.70	2.6 ± 1.2

TABLE A.7
Gamma Spectrometry Results for Harbor and Shoreline Sediment Samples
Uranium and Actinium Decay Chains

Sample ID	NAREL ID	Activity ($pCi/g_{dry} \pm 2\sigma$ counting error)								
		^{234}Th	^{234m}Pa	^{226}Ra	^{214}Pb	^{214}Bi	^{235}U	^{227}Th	^{223}Ra	^{219}Rn
HARBOR SEDIMENT - STUDY SAMPLES										
KBSB 001-S	99.02545	1.41 ± 0.28	1.5 ± 1.2	1.67 ± 0.33	0.816 ± 0.055	0.719 ± 0.051	ND	ND	ND	ND
KBSB 003-S	99.02538	0.65 ± 0.19	0.65 ± 0.85	1.39 ± 0.21	0.613 ± 0.040	0.542 ± 0.037	ND	ND	ND	ND
KBSB 005-S	99.02547	0.87 ± 0.21	1.4 ± 1.3	1.96 ± 0.30	0.737 ± 0.051	0.688 ± 0.049	ND	ND	ND	ND
KBSB 006-S	99.02551	0.60 ± 0.16	1.6 ± 1.0	1.96 ± 0.24	0.881 ± 0.056	0.793 ± 0.052	0.120 ± 0.015	ND	0.108 ± 0.047	ND
KBSB 007-S	99.02548	ND	ND	1.90 ± 0.33	0.715 ± 0.050	0.648 ± 0.048	0.117 ± 0.020	ND	ND	ND
KBSB 008-S	99.02534	0.74 ± 0.20	1.7 ± 1.3	1.86 ± 0.28	0.612 ± 0.044	0.552 ± 0.041	0.113 ± 0.017	ND	ND	ND
KBSB 010-S	99.02544	0.89 ± 0.22	ND	1.99 ± 0.29	0.857 ± 0.056	0.765 ± 0.052	ND	ND	ND	ND
KBSB 011-S	99.02542	1.41 ± 0.25	2.7 ± 1.3	1.76 ± 0.27	0.645 ± 0.047	0.607 ± 0.045	0.108 ± 0.017	ND	ND	ND
KBSB 013-S	99.02553	1.09 ± 0.30	1.7 ± 1.4	1.61 ± 0.32	0.753 ± 0.053	0.664 ± 0.049	ND	ND	ND	ND
KBSB 014-S	99.02552	1.26 ± 0.22	2.2 ± 1.3	1.90 ± 0.32	0.722 ± 0.050	0.663 ± 0.048	0.115 ± 0.019	ND	ND	ND
KBSB 016-S	99.02550	1.21 ± 0.22	1.8 ± 1.3	1.93 ± 0.29	0.667 ± 0.047	0.599 ± 0.044	0.115 ± 0.017	ND	ND	ND
KBSB 017-S	99.02533	ND	0.8 ± 1.0	1.33 ± 0.26	0.572 ± 0.041	0.495 ± 0.038	0.082 ± 0.016	ND	ND	ND
KBSB 018-S	99.02543	2.06 ± 0.21	2.4 ± 1.2	1.75 ± 0.25	0.598 ± 0.040	0.536 ± 0.038	0.108 ± 0.015	0.129 ± 0.059	ND	ND
KBSB 021-S	99.02603	1.11 ± 0.26	1.6 ± 1.6	1.85 ± 0.32	0.652 ± 0.050	0.609 ± 0.049	0.111 ± 0.019	ND	ND	ND
KBSB 022-S	99.02532	0.65 ± 0.18	ND	1.46 ± 0.32	0.596 ± 0.046	0.563 ± 0.047	0.092 ± 0.020	ND	ND	ND

TABLE A.7--*Continued*

Sample ID	NAREL ID	Activity ($pCi/g_{dry} \pm 2\sigma$ counting error)								
		^{234}Th	^{234m}Pa	^{226}Ra	^{214}Pb	^{214}Bi	^{235}U	^{227}Th	^{223}Ra	^{219}Rn
KBSB 024-S	99.02549	1.40 ± 0.25	3.1 ± 1.6	1.73 ± 0.38	0.769 ± 0.057	0.693 ± 0.053	0.109 ± 0.023	ND	ND	ND
KBSB 026-S	99.02604	1.39 ± 0.22	ND	1.86 ± 0.29	0.698 ± 0.033	0.655 ± 0.036	ND	ND	ND	ND
KBSB 027-S	99.02546	1.36 ± 0.21	0.9 ± 1.2	1.80 ± 0.31	0.644 ± 0.046	0.571 ± 0.043	0.110 ± 0.019	ND	ND	ND
KBSB 028-S	99.02578	ND	1.1 ± 1.2	1.55 ± 0.29	0.760 ± 0.051	0.696 ± 0.049	0.098 ± 0.017	ND	0.099 ± 0.063	ND
KBSB 029-S	99.02580	ND	0.74 ± 0.89	1.16 ± 0.24	0.545 ± 0.038	0.490 ± 0.036	ND	ND	ND	ND
KBSB 033-S	99.02556	ND	1.9 ± 1.3	1.66 ± 0.28	0.736 ± 0.050	0.631 ± 0.045	ND	ND	ND	ND
KBSB 034-S	99.02614	ND	ND	1.75 ± 0.33	0.800 ± 0.054	0.708 ± 0.050	ND	ND	ND	ND
KBSB 035-S	99.02562	0.46 ± 0.17	0.98 ± 0.98	1.54 ± 0.25	0.618 ± 0.043	0.520 ± 0.039	ND	ND	ND	ND
KBSB 036-S	99.02563	0.49 ± 0.16	1.39 ± 0.84	1.64 ± 0.20	0.606 ± 0.040	0.557 ± 0.038	0.100 ± 0.012	ND	ND	ND
KBSB 037-S	99.02564	0.74 ± 0.17	1.5 ± 1.3	1.60 ± 0.31	0.598 ± 0.044	0.530 ± 0.042	0.099 ± 0.019	ND	ND	ND
KBSB 038-S	99.02555	0.98 ± 0.18	2.3 ± 1.5	1.54 ± 0.28	0.532 ± 0.040	0.471 ± 0.039	0.094 ± 0.017	ND	ND	ND
KBSB 039-S	99.02565	ND	1.6 ± 1.2	2.23 ± 0.26	0.901 ± 0.059	0.851 ± 0.059	0.137 ± 0.016	ND	ND	ND
KBSB 042-S	99.02557	0.98 ± 0.23	ND	1.41 ± 0.28	0.611 ± 0.044	0.591 ± 0.044	0.088 ± 0.017	ND	ND	ND
KBSB 043-S	99.02573	0.26 ± 0.11	0.65 ± 0.67	0.56 ± 0.19	0.346 ± 0.026	0.311 ± 0.025	0.035 ± 0.012	ND	ND	ND
KBSB 044-S	99.02576	ND	0.86 ± 0.83	ND	0.677 ± 0.045	0.618 ± 0.043	0.123 ± 0.015	ND	ND	ND
KBSB 045-S	99.02572	1.62 ± 0.19	2.8 ± 1.0	1.87 ± 0.24	0.674 ± 0.044	0.609 ± 0.041	ND	ND	ND	ND
KBSB 047-S	99.02575	0.73 ± 0.19	1.4 ± 1.1	2.01 ± 0.29	0.771 ± 0.052	0.686 ± 0.048	ND	ND	0.067 ± 0.045	ND
KBSB 049-S	99.02577	0.92 ± 0.18	0.97 ± 0.93	1.94 ± 0.25	0.906 ± 0.057	0.827 ± 0.053	ND	ND	ND	0.066 ± 0.051
KBSB 050-S	99.02574	0.59 ± 0.25	1.9 ± 1.1	1.63 ± 0.27	0.846 ± 0.056	0.778 ± 0.053	0.098 ± 0.016	ND	ND	ND
KBSB 052-S	99.02612	ND	ND	1.06 ± 0.23	0.462 ± 0.033	0.414 ± 0.032	0.066 ± 0.014	ND	ND	ND

TABLE A.7--*Continued*

Sample ID	NAREL ID	Activity ($pCi/g_{dry} \pm 2\sigma$ counting error)								
		^{234}Th	^{234m}Pa	^{226}Ra	^{214}Pb	^{214}Bi	^{235}U	^{227}Th	^{223}Ra	^{219}Rn
HARBOR SEDIMENT - BACKGROUND SAMPLES										
KBSB 055-S-BK	99.02607	ND	0.80 ± 0.45	0.69 ± 0.11	0.224 ± 0.017	0.211 ± 0.017	0.0407 ± 0.0063	ND	ND	ND
KBSB 055-S-BK-DU	99.02608	0.67 ± 0.11	1.15 ± 0.55	1.30 ± 0.15	0.715 ± 0.043	0.694 ± 0.042	0.0770 ± 0.0088	ND	ND	ND
SHORELINE SEDIMENT - STUDY SAMPLES										
KBSB 015-L	99.02616	0.35 ± 0.17	1.0 ± 1.2	1.32 ± 0.28	0.733 ± 0.027	0.661 ± 0.028	0.083 ± 0.017	ND	ND	ND
KBSB 019-L	99.02615	ND	0.75 ± 0.81	1.03 ± 0.22	0.497 ± 0.036	0.469 ± 0.035	ND	ND	ND	ND
KBSB 032-L	99.02605	ND	0.55 ± 0.64	1.46 ± 0.19	0.713 ± 0.045	0.653 ± 0.042	0.089 ± 0.012	ND	ND	ND
KBSB 046-L	99.02611	0.43 ± 0.14	ND	1.02 ± 0.22	0.547 ± 0.038	0.520 ± 0.038	ND	ND	ND	ND
KBSB 048-L	99.02571	0.75 ± 0.17	ND	1.54 ± 0.27	0.564 ± 0.040	0.534 ± 0.040	0.094 ± 0.016	ND	ND	ND
KBSB 053-L	99.02570	0.98 ± 0.22	1.5 ± 1.2	2.01 ± 0.30	0.690 ± 0.048	0.630 ± 0.046	ND	ND	ND	ND
KBSB 054-L	99.02606	ND	ND	0.63 ± 0.23	0.266 ± 0.024	0.230 ± 0.024	ND	ND	ND	ND
SHORELINE SEDIMENT - BACKGROUND SAMPLES										
KBSB 056-L-BK	99.02566	ND	ND	1.31 ± 0.24	0.680 ± 0.045	0.632 ± 0.043	ND	ND	ND	ND
KBSB 056-L-BK-DU	99.02567	0.61 ± 0.24	ND	1.38 ± 0.27	0.764 ± 0.050	0.686 ± 0.047	0.081 ± 0.016	ND	ND	ND

Note: ND indicates the radionuclide was not detected by gamma spectrometry.

"< X" indicates the radionuclide was not detected and X was the minimum detectable concentration for the nuclide in this sample.

No other gamma-emitting radionuclides were detected in these samples.

TABLE A.8
Gamma Spectrometry Results for Harbor and Shoreline Sediment Samples
Thorium Decay Chain and Other Gamma-Emitting Radionuclides

Sample ID	NAREL ID	Activity ($pCi/g_{dry} \pm 2\sigma$ counting error)								
		^{228}Ra	^{224}Ra	^{212}Pb	^{212}Bi	^{208}Tl	^{7}Be	^{60}Co	^{137}Cs	^{40}K
HARBOR SEDIMENT - STUDY SAMPLES										
KBSB 001-S	99.02545	0.829 ± 0.062	0.55 ± 0.31	1.040 ± 0.068	0.99 ± 0.15	0.328 ± 0.025	0.59 ± 0.10	< 0.02	0.068 ± 0.013	8.49 ± 0.55
KBSB 003-S	99.02538	0.602 ± 0.043	0.50 ± 0.19	0.720 ± 0.046	0.70 ± 0.13	0.223 ± 0.017	0.388 ± 0.072	< 0.01	0.0331 ± 0.0080	6.70 ± 0.43
KBSB 005-S	99.02547	0.746 ± 0.056	0.94 ± 0.27	1.050 ± 0.068	1.16 ± 0.16	0.334 ± 0.025	1.33 ± 0.15	< 0.02	0.132 ± 0.015	9.63 ± 0.61
KBSB 006-S	99.02551	0.931 ± 0.062	0.81 ± 0.21	1.110 ± 0.069	1.01 ± 0.15	0.372 ± 0.025	0.075 ± 0.058	< 0.02	0.084 ± 0.011	9.69 ± 0.60
KBSB 007-S	99.02548	0.732 ± 0.058	0.78 ± 0.33	1.010 ± 0.066	1.09 ± 0.15	0.338 ± 0.026	1.01 ± 0.12	< 0.02	0.124 ± 0.015	9.36 ± 0.61
KBSB 008-S	99.02534	0.764 ± 0.056	0.78 ± 0.30	0.935 ± 0.062	0.92 ± 0.15	0.294 ± 0.023	0.414 ± 0.088	< 0.02	0.116 ± 0.014	8.75 ± 0.56
KBSB 010-S	99.02544	0.902 ± 0.064	0.81 ± 0.28	1.130 ± 0.072	1.12 ± 0.15	0.351 ± 0.026	0.276 ± 0.080	< 0.02	0.050 ± 0.012	5.72 ± 0.39
KBSB 011-S	99.02542	0.756 ± 0.057	0.73 ± 0.29	1.040 ± 0.068	0.97 ± 0.14	0.337 ± 0.025	1.93 ± 0.17	< 0.02	0.150 ± 0.016	9.86 ± 0.63
KBSB 013-S	99.02553	0.756 ± 0.060	0.73 ± 0.33	1.020 ± 0.067	0.93 ± 0.19	0.329 ± 0.026	1.46 ± 0.15	< 0.02	0.157 ± 0.016	9.46 ± 0.62
KBSB 014-S	99.02552	0.712 ± 0.054	0.59 ± 0.31	1.030 ± 0.067	0.95 ± 0.16	0.334 ± 0.025	1.63 ± 0.16	< 0.02	0.146 ± 0.015	9.17 ± 0.59
KBSB 016-S	99.02550	0.789 ± 0.060	0.90 ± 0.30	1.060 ± 0.068	1.01 ± 0.15	0.326 ± 0.024	1.34 ± 0.14	< 0.02	0.154 ± 0.015	9.60 ± 0.61
KBSB 017-S	99.02533	0.602 ± 0.049	0.54 ± 0.26	0.727 ± 0.050	0.83 ± 0.13	0.246 ± 0.020	0.145 ± 0.073	< 0.02	0.0310 ± 0.0087	3.62 ± 0.28
KBSB 018-S	99.02543	0.707 ± 0.050	0.94 ± 0.22	0.986 ± 0.062	0.85 ± 0.14	0.310 ± 0.022	2.05 ± 0.16	< 0.02	0.164 ± 0.014	9.49 ± 0.59
KBSB 021-S	99.02603	0.700 ± 0.061	0.57 ± 0.32	0.900 ± 0.061	0.82 ± 0.17	0.315 ± 0.027	1.62 ± 0.20	< 0.03	0.144 ± 0.018	9.02 ± 0.61
KBSB 022-S	99.02532	0.572 ± 0.053	0.52 ± 0.29	0.816 ± 0.057	0.89 ± 0.16	0.265 ± 0.023	0.94 ± 0.14	< 0.03	0.124 ± 0.016	9.07 ± 0.62
KBSB 024-S	99.02549	0.719 ± 0.060	0.80 ± 0.38	1.050 ± 0.071	0.99 ± 0.18	0.310 ± 0.026	1.86 ± 0.19	< 0.03	0.162 ± 0.018	9.86 ± 0.65
KBSB 026-S	99.02604	0.684 ± 0.046	0.82 ± 0.35	0.928 ± 0.032	1.00 ± 0.17	0.310 ± 0.021	1.12 ± 0.21	< 0.03	0.131 ± 0.016	8.60 ± 0.33
KBSB 027-S	99.02546	0.726 ± 0.056	0.91 ± 0.29	1.040 ± 0.066	0.98 ± 0.16	0.337 ± 0.025	1.21 ± 0.13	< 0.02	0.160 ± 0.017	9.28 ± 0.60
KBSB 028-S	99.02578	0.756 ± 0.056	0.71 ± 0.28	1.010 ± 0.065	0.81 ± 0.14	0.315 ± 0.024	0.185 ± 0.095	< 0.02	0.043 ± 0.010	5.31 ± 0.37

TABLE A.8--*Continued*

Sample ID	NAREL ID	Activity ($pCi/g_{dry} \pm 2\sigma$ counting error)								
		^{228}Ra	^{224}Ra	^{212}Pb	^{212}Bi	^{208}Tl	^{7}Be	^{60}Co	^{137}Cs	^{40}K
KBSB 029-S	99.02580	0.536 ± 0.041	0.47 ± 0.26	0.646 ± 0.044	0.64 ± 0.11	0.209 ± 0.017	ND	< 0.02	0.0087 ± 0.0066	3.81 ± 0.27
KBSB 033-S	99.02556	0.768 ± 0.056	0.66 ± 0.31	0.920 ± 0.060	0.84 ± 0.14	0.298 ± 0.022	0.077 ± 0.081	< 0.02	0.0341 ± 0.0090	5.00 ± 0.35
KBSB 034-S	99.02614	0.755 ± 0.058	0.54 ± 0.31	0.956 ± 0.064	0.92 ± 0.17	0.310 ± 0.025	0.14 ± 0.11	< 0.02	0.067 ± 0.012	6.68 ± 0.45
KBSB 035-S	99.02562	0.636 ± 0.050	0.49 ± 0.25	0.771 ± 0.051	0.79 ± 0.12	0.252 ± 0.020	ND	< 0.02	0.060 ± 0.011	6.37 ± 0.43
KBSB 036-S	99.02563	0.681 ± 0.048	0.58 ± 0.19	0.814 ± 0.051	0.78 ± 0.10	0.273 ± 0.019	0.145 ± 0.065	< 0.02	0.0909 ± 0.0098	7.96 ± 0.50
KBSB 037-S	99.02564	0.651 ± 0.053	0.69 ± 0.28	0.872 ± 0.058	0.94 ± 0.15	0.283 ± 0.023	0.75 ± 0.13	< 0.02	0.129 ± 0.016	9.14 ± 0.60
KBSB 038-S	99.02555	0.618 ± 0.052	0.68 ± 0.27	0.845 ± 0.056	0.83 ± 0.15	0.282 ± 0.022	0.70 ± 0.10	< 0.02	0.127 ± 0.014	8.84 ± 0.58
KBSB 039-S	99.02565	0.511 ± 0.048	0.31 ± 0.25	0.543 ± 0.040	0.59 ± 0.18	0.189 ± 0.018	0.40 ± 0.13	< 0.03	0.021 ± 0.011	5.04 ± 0.38
KBSB 042-S	99.02557	0.688 ± 0.053	0.60 ± 0.27	0.810 ± 0.054	0.74 ± 0.15	0.270 ± 0.022	0.070 ± 0.077	< 0.02	0.083 ± 0.012	7.14 ± 0.47
KBSB 043-S	99.02573	0.243 ± 0.025	0.17 ± 0.16	0.302 ± 0.024	0.345 ± 0.083	0.093 ± 0.011	ND	< 0.01	ND	1.18 ± 0.13
KBSB 044-S	99.02576	0.713 ± 0.052	0.72 ± 0.24	0.868 ± 0.056	0.73 ± 0.13	0.273 ± 0.020	0.255 ± 0.098	< 0.02	0.0486 ± 0.0099	6.03 ± 0.40
KBSB 045-S	99.02572	0.754 ± 0.052	0.55 ± 0.20	0.935 ± 0.059	0.94 ± 0.12	0.304 ± 0.021	1.33 ± 0.12	< 0.02	0.139 ± 0.013	9.30 ± 0.58
KBSB 047-S	99.02575	0.735 ± 0.054	0.66 ± 0.29	0.943 ± 0.061	0.96 ± 0.14	0.301 ± 0.023	0.190 ± 0.094	< 0.03	0.128 ± 0.014	8.87 ± 0.56
KBSB 049-S	99.02577	0.971 ± 0.064	0.75 ± 0.22	1.080 ± 0.067	1.03 ± 0.12	0.352 ± 0.024	0.255 ± 0.080	< 0.02	0.0631 ± 0.0096	8.62 ± 0.54
KBSB 050-S	99.02574	0.794 ± 0.056	0.66 ± 0.31	0.933 ± 0.061	0.80 ± 0.13	0.293 ± 0.022	ND	< 0.02	0.0346 ± 0.0090	7.49 ± 0.48
KBSB 052-S	99.02612	0.444 ± 0.036	0.22 ± 0.23	0.485 ± 0.035	0.461 ± 0.095	0.154 ± 0.014	ND	< 0.02	0.0104 ± 0.0065	3.04 ± 0.23
HARBOR SEDIMENT - BACKGROUND SAMPLES										
KBSB 055-S-BK	99.02607	0.089 ± 0.013	ND	0.104 ± 0.011	0.078 ± 0.054	0.0380 ± 0.0055	ND	< 0.01	ND	1.20 ± 0.10
KBSB 055-S-BK-DU	99.02608	0.971 ± 0.059	0.60 ± 0.13	0.952 ± 0.057	1.040 ± 0.092	0.330 ± 0.021	ND	< 0.01	0.0085 ± 0.0043	3.40 ± 0.22

TABLE A.8--*Continued*

Sample ID	NAREL ID	Activity ($pCi/g_{dry} \pm 2\sigma$ counting error)								
		^{228}Ra	^{224}Ra	^{212}Pb	^{212}Bi	^{208}Tl	^{7}Be	^{60}Co	^{137}Cs	^{40}K
SHORELINE SEDIMENT - STUDY SAMPLES										
KBSB 015-L	99.02616	0.328 ± 0.029	0.25 ± 0.24	0.406 ± 0.024	0.36 ± 0.11	0.127 ± 0.013	0.21 ± 0.10	< 0.02	0.0165 ± 0.0078	4.09 ± 0.20
KBSB 019-L	99.02615	0.550 ± 0.044	0.52 ± 0.22	0.633 ± 0.043	0.476 ± 0.096	0.204 ± 0.017	ND	< 0.01	0.0363 ± 0.0076	1.74 ± 0.16
KBSB 032-L	99.02605	0.771 ± 0.051	0.79 ± 0.18	0.887 ± 0.055	0.85 ± 0.10	0.283 ± 0.019	ND	< 0.01	ND	0.99 ± 0.10
KBSB 046-L	99.02611	0.331 ± 0.031	0.31 ± 0.19	0.370 ± 0.029	0.321 ± 0.094	0.118 ± 0.013	0.069 ± 0.068	< 0.01	ND	2.04 ± 0.18
KBSB 048-L	99.02571	0.615 ± 0.047	0.44 ± 0.22	0.681 ± 0.046	0.67 ± 0.13	0.225 ± 0.018	ND	< 0.02	0.067 ± 0.011	5.88 ± 0.40
KBSB 053-L	99.02570	0.665 ± 0.053	0.66 ± 0.27	0.746 ± 0.051	0.76 ± 0.14	0.251 ± 0.021	0.10 ± 0.11	< 0.02	0.153 ± 0.016	8.06 ± 0.53
KBSB 054-L	99.02606	0.262 ± 0.028	0.20 ± 0.19	0.327 ± 0.027	0.43 ± 0.10	0.107 ± 0.013	0.073 ± 0.071	< 0.01	0.0072 ± 0.0072	1.62 ± 0.16
SHORELINE SEDIMENT - BACKGROUND SAMPLES										
KBSB 056-L-BK	99.02566	0.753 ± 0.052	0.49 ± 0.24	0.846 ± 0.055	0.89 ± 0.12	0.271 ± 0.020	ND	< 0.02	ND	1.52 ± 0.14
KBSB 056-L-BK-DU	99.02567	0.884 ± 0.061	0.78 ± 0.26	1.010 ± 0.064	0.90 ± 0.15	0.308 ± 0.023	ND	< 0.02	ND	1.90 ± 0.17

Note: ND indicates the radionuclide was not detected by gamma spectrometry.

"< X" indicates the radionuclide was not detected and X was the minimum detectable concentration for the nuclide in this sample.

No other gamma-emitting radionuclides were detected in these samples.

TABLE A.9
Gross Alpha and Gross Beta Activity Results for Harbor and Shoreline Sediment Samples

Sample ID	NAREL ID	Activity ($pCi/g_{dry} \pm 2\sigma$ counting error)	
		Gross Alpha	Gross Beta
HARBOR SEDIMENT - STUDY SAMPLES			
KBSB 001-S	99.02545	5.2 ± 3.2	14.8 ± 3.5
KBSB 003-S	99.02538	5.8 ± 3.3	11.3 ± 3.3
KBSB 005-S	99.02547	10.0 ± 4.0	20.3 ± 3.9
KBSB 006-S	99.02551	11.3 ± 4.3	19.1 ± 3.8
KBSB 007-S	99.02548	12.5 ± 4.5	17.4 ± 3.6
KBSB 008-S	99.02534	12.2 ± 4.5	18.5 ± 4.0
KBSB 010-S	99.02544	6.1 ± 3.7	12.5 ± 3.5
KBSB 011-S	99.02542	4.7 ± 3.3	22.5 ± 4.1
KBSB 013-S	99.02553	7.9 ± 3.6	21.8 ± 4.0
KBSB 014-S	99.02552	9.1 ± 4.0	14.5 ± 3.5
KBSB 016-S	99.02550	7.6 ± 3.7	15.1 ± 3.5
KBSB 017-S	99.02533	3.9 ± 2.9	6.4 ± 2.9
KBSB 018-S	99.02543	8.1 ± 3.8	21.1 ± 4.0
KBSB 021-S	99.02603	7.2 ± 3.4	17.5 ± 3.6
KBSB 022-S	99.02532	8.5 ± 3.9	16.6 ± 3.7
KBSB 024-S	99.02549	8.6 ± 4.1	17.9 ± 4.1
KBSB 026-S	99.02604	4.9 ± 3.5	18.8 ± 3.8
KBSB 027-S	99.02546	8.47 ± 3.9	18.0 ± 3.8
KBSB 028-S	99.02578	5.61 ± 3.3	10.2 ± 3.3
KBSB 029-S	99.02580	3.62 ± 2.6	5.28 ± 2.8
KBSB 033-S	99.02556	3.67 ± 3.0	14.8 ± 3.5
KBSB 034-S	99.02614	4.56 ± 3.4	9.52 ± 3.2
KBSB 035-S	99.02562	6.65 ± 3.8	13.1 ± 3.5
KBSB 036-S	99.02563	8.1 ± 3.7	14.1 ± 3.5
KBSB 037-S	99.02564	8.4 ± 3.7	12.9 ± 3.4
KBSB 038-S	99.02555	6.2 ± 3.3	17.5 ± 3.7
KBSB 039-S	99.02565	2.7 ± 2.5	10.3 ± 3.2
KBSB 042-S	99.02557	8.3 ± 3.7	14.1 ± 3.5

TABLE A.9--*Continued*

Sample ID	NAREL ID	Activity ($pCi/g_{dry} \pm 2\sigma$ counting error)	
		Gross Alpha	Gross Beta
KBSB 043-S	99.02573	2.7 ± 2.5	5.9 ± 2.9
KBSB 044-S	99.02576	5.8 ± 3.5	11.2 ± 3.4
KBSB 045-S	99.02572	8.8 ± 3.8	18.4 ± 3.7
KBSB 047-S	99.02575	6.7 ± 3.9	13.8 ± 3.6
KBSB 049-S	99.02577	9.2 ± 4.1	16.5 ± 3.7
KBSB 050-S	99.02574	7.1 ± 3.4	14.9 ± 3.5
KBSB 052-S	99.02612	5.1 ± 2.9	7.4 ± 3.0
HARBOR SEDIMENT - BACKGROUND SAMPLES			
KBSB 055-S-BK	99.02607	0.8 ± 1.9	0.2 ± 2.3
KBSB 055-S-BK-DU	99.02608	12.5 ± 4.4	18.5 ± 3.8
SHORELINE SEDIMENT - STUDY SAMPLES			
KBSB 015-L	99.02616	7.3 ± 3.7	12.3 ± 3.4
KBSB 019-L	99.02615	4.62 ± 3.2	4.77 ± 2.8
KBSB 032-L	99.02605	3.2 ± 2.8	7.25 ± 3.0
KBSB 046-L	99.02611	2.45 ± 2.4	3.23 ± 2.7
KBSB 048-L	99.02571	7.33 ± 3.6	16.1 ± 3.6
KBSB 053-L	99.02570	7.87 ± 3.7	14.2 ± 3.5
KBSB 054-L	99.02606	3.42 ± 2.8	6.78 ± 2.9
SHORELINE SEDIMENT - BACKGROUND SAMPLES			
KBSB 056-L-BK	99.02566	4.3 ± 2.8	5.1 ± 2.8
KBSB 056-L-BK-DU	99.02567	6.5 ± 3.6	13.5 ± 3.5

TABLE A.10
Gamma Spectrometry Results for Sediment Core Samples
Uranium and Actinium Decay Chains

Sample ID	Core Slice (cm)	NAREL ID	Activity ($pCi/g_{dry} \pm 2\sigma$ counting error)						
			^{234}Th	^{234m}Pa	^{226}Ra	^{214}Pb	^{214}Bi	^{235}U	^{223}Ra
STUDY SAMPLES									
KBSB 008-C	00-05	99.02679	1.2 ± 1.2	ND	3.1 ± 1.7	0.76 ± 0.16	0.75 ± 0.19	ND	ND
KBSB 008-C	05-10	99.02680	ND	ND	4.61 ± 0.89	0.88 ± 0.12	0.91 ± 0.12	0.276 ± 0.053	ND
KBSB 008-C	10-15	99.02681	ND	ND	1.6 ± 1.3	0.70 ± 0.13	0.60 ± 0.14	0.132 ± 0.074	ND
KBSB 008-C	15-32	99.02682	ND	ND	1.65 ± 0.67	0.744 ± 0.073	0.658 ± 0.080	ND	ND
KBSB 008-C	32-49	99.02683	ND	ND	1.69 ± 0.45	0.700 ± 0.062	0.574 ± 0.060	ND	ND
KBSB 017-C	00-05	99.02674	ND	ND	ND	0.733 ± 0.065	0.673 ± 0.065	0.089 ± 0.027	ND
KBSB 017-C	05-10	99.02675	0.56 ± 0.23	2.5 ± 2.0	1.21 ± 0.34	0.544 ± 0.045	0.517 ± 0.049	0.075 ± 0.020	ND
KBSB 017-C	10-15	99.02676	0.79 ± 0.27	ND	0.74 ± 0.34	0.271 ± 0.033	0.218 ± 0.033	ND	ND
KBSB 017-C	15-28	99.02677	0.44 ± 0.16	0.79 ± 0.92	0.83 ± 0.22	0.334 ± 0.027	0.322 ± 0.028	ND	ND
KBSB 017-C	28-41	99.02678	ND	ND	1.21 ± 0.21	0.421 ± 0.032	0.381 ± 0.031	0.075 ± 0.013	ND
KBSB 021-C	00-05	99.02706	2.5 ± 3.1	ND	8.2 ± 4.6	2.09 ± 0.47	1.85 ± 0.46	ND	ND
KBSB 021-C	05-10	99.02707	ND	ND	ND	0.26 ± 0.14	0.18 ± 0.16	ND	ND
KBSB 021-C	10-15	99.02708	ND	ND	ND	0.81 ± 0.13	0.63 ± 0.14	ND	ND
KBSB 021-C	15-32	99.02709	ND	ND	1.72 ± 0.50	0.697 ± 0.053	0.678 ± 0.054	ND	ND
KBSB 021-C	32-49	99.02710	1.08 ± 0.30	ND	1.80 ± 0.43	0.698 ± 0.039	0.641 ± 0.044	0.107 ± 0.026	ND

TABLE A.10–*Continued*

Sample ID	Core Slice (cm)	NAREL ID	Activity (pCi/g_{dry} ± 2σ counting error)						
			^{234}Th	^{234m}Pa	^{226}Ra	^{214}Pb	^{214}Bi	^{235}U	^{223}Ra
KBSB 026-C	00-05	99.02711	ND	ND	2.3 ± 2.4	0.65 ± 0.26	0.65 ± 0.27	ND	ND
KBSB 026-C	05-10	99.02712	ND	ND	2.6 ± 1.5	0.53 ± 0.16	0.59 ± 0.15	0.169 ± 0.088	ND
KBSB 026-C	10-15	99.02713	ND	ND	1.3 ± 1.9	0.70 ± 0.17	0.57 ± 0.18	ND	ND
KBSB 026-C	15-32	99.02714	0.89 ± 0.38	3.1 ± 3.0	1.99 ± 0.53	0.660 ± 0.052	0.616 ± 0.055	ND	ND
KBSB 026-C	32-49	99.02715	0.74 ± 0.35	2.8 ± 2.4	2.22 ± 0.48	0.778 ± 0.042	0.650 ± 0.048	0.134 ± 0.028	ND
KBSB 035-C	00-05	99.02692	ND	ND	ND	0.71 ± 0.12	0.61 ± 0.15	ND	ND
KBSB 035-C	05-10	99.02693	0.72 ± 0.66	ND	1.78 ± 0.93	0.78 ± 0.10	0.66 ± 0.11	ND	ND
KBSB 035-C	10-15	99.02694	ND	ND	4.19 ± 0.83	0.923 ± 0.099	0.92 ± 0.12	0.267 ± 0.051	ND
KBSB 035-C	15-33	99.02695	1.11 ± 0.29	ND	1.47 ± 0.32	0.679 ± 0.050	0.591 ± 0.049	0.087 ± 0.019	0.137 ± 0.066
KBSB 035-C	33-51	99.02696	0.72 ± 0.35	ND	1.69 ± 0.48	0.679 ± 0.059	0.622 ± 0.065	ND	ND
KBSB 036-C	00-05	99.02688	ND	ND	1.0 ± 1.7	0.80 ± 0.14	0.53 ± 0.17	ND	ND
KBSB 036-C	05-10	99.02689	ND	ND	1.3 ± 1.4	0.60 ± 0.15	0.52 ± 0.16	ND	ND
KBSB 036-C	10-15	99.02690	0.92 ± 0.81	ND	1.7 ± 1.6	0.67 ± 0.13	0.46 ± 0.17	ND	ND
KBSB 036-C	15-30	99.02691	ND	ND	1.71 ± 0.49	0.716 ± 0.066	0.597 ± 0.066	ND	ND
KBSB 037-C	00-05	99.02697	ND	ND	1.6 ± 1.8	0.59 ± 0.19	0.42 ± 0.20	ND	ND
KBSB 037-C	05-10	99.02698	ND	ND	ND	0.58 ± 0.16	0.63 ± 0.19	ND	ND
KBSB 037-C	10-15	99.02699	ND	ND	1.1 ± 1.6	0.66 ± 0.15	0.48 ± 0.16	ND	ND
KBSB 037-C	15-27	99.02700	ND	ND	3.00 ± 0.50	0.705 ± 0.066	0.637 ± 0.067	0.183 ± 0.030	ND
KBSB 037-C	27-39	99.02701	ND	ND	1.60 ± 0.70	0.601 ± 0.066	0.537 ± 0.077	0.099 ± 0.041	0.29 ± 0.13

TABLE A.10–*Continued*

Sample ID	Core Slice (cm)	NAREL ID	Activity (pCi/g_{dry} ± 2σ counting error)						
			^{234}Th	^{234m}Pa	^{226}Ra	^{214}Pb	^{214}Bi	^{235}U	^{223}Ra
KBSB 039-C	00-05	99.02684	ND	ND	4.35 ± 0.76	1.07 ± 0.10	1.00 ± 0.11	ND	ND
KBSB 039-C	05-10	99.02685	1.05 ± 0.43	ND	ND	1.160 ± 0.086	0.996 ± 0.085	0.161 ± 0.032	ND
KBSB 039-C	10-15	99.02686	ND	ND	ND	0.955 ± 0.092	0.80 ± 0.10	0.107 ± 0.049	ND
KBSB 039-C	15-30	99.02687	ND	1.6 ± 1.9	2.20 ± 0.41	0.833 ± 0.062	0.735 ± 0.061	0.131 ± 0.024	ND
KBSB 053-C	00-05	99.02702	ND	ND	1.9 ± 1.2	0.62 ± 0.11	0.51 ± 0.13	ND	ND
KBSB 053-C	05-10	99.02703	ND	ND	ND	0.60 ± 0.14	0.56 ± 0.17	ND	ND
KBSB 053-C	10-15	99.02704	ND	ND	1.7 ± 1.2	0.57 ± 0.12	0.45 ± 0.13	ND	ND
KBSB 053-C	15-31	99.02705	ND	3.3 ± 2.1	2.49 ± 0.34	0.695 ± 0.037	0.626 ± 0.041	ND	ND

Note: ND indicates the radionuclide was not detected by gamma spectrometry.

"< X" indicates the radionuclide was not detected and X was the minimum detectable concentration for the nuclide in this sample.

No other gamma-emitting radionuclides were detected in these samples.

TABLE A.11
Gamma Spectrometry Results for Sediment Core Samples
Thorium Decay Chain and Other Gamma Emitting Radionuclides

Sample ID	Core Slice (cm)	NAREL ID	Activity ($pCi/g_{dry} \pm 2\sigma$ counting error)								
			^{228}Ra	^{224}Ra	^{212}Pb	^{212}Bi	^{208}Tl	^{7}Be	^{60}Co	^{137}Cs	^{40}K
STUDY SAMPLES											
KBSB 008-C	00-05	99.02679	0.65 ± 0.20	2.2 ± 1.6	0.86 ± 0.16	1.90 ± 0.92	0.32 ± 0.10	ND	< 0.19	0.123 ± 0.061	10.4 ± 1.4
KBSB 008-C	05-10	99.02680	0.73 ± 0.16	ND	0.97 ± 0.11	0.68 ± 0.64	0.425 ± 0.067	ND	< 0.15	0.113 ± 0.055	8.4 ± 1.1
KBSB 008-C	10-15	99.02681	0.74 ± 0.16	ND	0.95 ± 0.13	0.55 ± 0.61	0.277 ± 0.070	1.81 ± 0.55	< 0.12	0.125 ± 0.053	9.3 ± 1.1
KBSB 008-C	15-32	99.02682	0.82 ± 0.10	1.09 ± 0.70	0.955 ± 0.083	0.76 ± 0.42	0.299 ± 0.042	0.80 ± 0.25	< 0.05	0.120 ± 0.025	9.65 ± 0.80
KBSB 008-C	32-49	99.02683	0.731 ± 0.083	0.77 ± 0.49	0.840 ± 0.067	0.75 ± 0.26	0.266 ± 0.031	ND	< 0.05	0.128 ± 0.022	8.39 ± 0.65
KBSB 017-C	00-05	99.02674	0.748 ± 0.086	0.60 ± 0.47	0.813 ± 0.065	0.74 ± 0.26	0.262 ± 0.031	ND	< 0.04	ND	2.86 ± 0.37
KBSB 017-C	05-10	99.02675	0.573 ± 0.057	0.46 ± 0.30	0.599 ± 0.048	0.64 ± 0.18	0.212 ± 0.024	ND	< 0.03	ND	2.18 ± 0.27
KBSB 017-C	10-15	99.02676	0.176 ± 0.037	ND	0.188 ± 0.028	0.15 ± 0.16	0.079 ± 0.016	ND	< 0.02	ND	1.89 ± 0.23
KBSB 017-C	15-28	99.02677	0.238 ± 0.029	ND	0.262 ± 0.024	0.25 ± 0.12	0.086 ± 0.012	ND	< 0.01	ND	2.38 ± 0.20
KBSB 017-C	28-41	99.02678	0.260 ± 0.031	0.22 ± 0.20	0.317 ± 0.027	0.303 ± 0.087	0.102 ± 0.012	ND	< 0.02	ND	2.48 ± 0.21
KBSB 021-C	00-05	99.02706	1.93 ± 0.58	ND	2.81 ± 0.42	ND	1.02 ± 0.24	5.2 ± 2.7	< 0.45	0.47 ± 0.17	33.4 ± 3.6
KBSB 021-C	05-10	99.02707	ND	ND	0.30 ± 0.13	0.90 ± 0.67	0.084 ± 0.091	ND	< 0.13	0.059 ± 0.043	3.5 ± 1.0
KBSB 021-C	10-15	99.02708	0.72 ± 0.20	ND	0.93 ± 0.13	0.88 ± 0.57	0.286 ± 0.077	1.18 ± 0.68	< 0.14	0.198 ± 0.068	10.7 ± 1.1
KBSB 021-C	15-32	99.02709	0.761 ± 0.077	0.56 ± 0.58	0.856 ± 0.049	0.78 ± 0.27	0.297 ± 0.031	0.93 ± 0.33	< 0.05	0.145 ± 0.022	9.70 ± 0.49
KBSB 021-C	32-49	99.02710	0.727 ± 0.059	0.35 ± 0.34	0.818 ± 0.042	0.83 ± 0.22	0.267 ± 0.026	ND	< 0.04	0.162 ± 0.020	9.98 ± 0.42

TABLE A.11–*Continued*

Sample ID	Core Slice (cm)	NAREL ID	Activity ($pCi/g_{dry} \pm 2\sigma$ counting error)								
			^{228}Ra	^{224}Ra	^{212}Pb	^{212}Bi	^{208}Tl	^{7}Be	^{60}Co	^{137}Cs	^{40}K
KBSB 026-C	00-05	99.02711	ND	ND	1.08 ± 0.20	ND	0.27 ± 0.15	ND	< 0.25	0.17 ± 0.10	10.1 ± 2.0
KBSB 026-C	05-10	99.02712	0.75 ± 0.18	ND	0.81 ± 0.13	1.03 ± 0.70	0.316 ± 0.080	1.10 ± 0.77	< 0.14	0.087 ± 0.055	9.2 ± 1.2
KBSB 026-C	10-15	99.02713	0.59 ± 0.24	ND	0.92 ± 0.15	1.74 ± 0.82	0.25 ± 0.10	1.77 ± 0.92	< 0.15	0.095 ± 0.062	10.8 ± 1.3
KBSB 026-C	15-32	99.02714	0.776 ± 0.078	0.52 ± 0.57	0.867 ± 0.054	0.88 ± 0.27	0.279 ± 0.030	0.42 ± 0.27	< 0.05	0.155 ± 0.024	9.46 ± 0.48
KBSB 026-C	32-49	99.02715	0.797 ± 0.061	0.57 ± 0.36	0.848 ± 0.042	0.90 ± 0.24	0.283 ± 0.026	ND	< 0.04	0.147 ± 0.019	10.40 ± 0.43
KBSB 035-C	00-05	99.02692	0.83 ± 0.19	1.3 ± 1.4	0.93 ± 0.13	0.92 ± 0.75	0.268 ± 0.075	ND	< 0.11	0.052 ± 0.046	7.4 ± 1.1
KBSB 035-C	05-10	99.02693	0.72 ± 0.15	0.83 ± 0.96	0.897 ± 0.098	0.71 ± 0.43	0.323 ± 0.058	ND	< 0.09	0.052 ± 0.034	7.87 ± 0.89
KBSB 035-C	10-15	99.02694	1.03 ± 0.14	ND	1.08 ± 0.11	0.69 ± 0.53	0.317 ± 0.053	ND	< 0.11	0.118 ± 0.043	10.6 ± 1.0
KBSB 035-C	15-33	99.02695	0.759 ± 0.062	0.72 ± 0.29	0.776 ± 0.055	0.77 ± 0.18	0.249 ± 0.024	ND	< 0.03	0.071 ± 0.013	7.92 ± 0.55
KBSB 035-C	33-51	99.02696	0.806 ± 0.079	0.92 ± 0.46	0.810 ± 0.065	0.80 ± 0.26	0.261 ± 0.032	ND	< 0.04	0.100 ± 0.020	8.01 ± 0.65
KBSB 036-C	00-05	99.02688	0.70 ± 0.22	ND	0.94 ± 0.15	ND	0.318 ± 0.093	ND	< 0.13	ND	7.9 ± 1.2
KBSB 036-C	05-10	99.02689	0.61 ± 0.21	ND	0.70 ± 0.13	ND	0.246 ± 0.080	ND	< 0.12	0.101 ± 0.052	8.6 ± 1.2
KBSB 036-C	10-15	99.02690	0.62 ± 0.17	ND	0.85 ± 0.13	0.92 ± 0.65	0.258 ± 0.084	ND	< 0.13	0.099 ± 0.052	9.4 ± 1.3
KBSB 036-C	15-30	99.02691	0.857 ± 0.085	0.75 ± 0.59	0.877 ± 0.072	0.72 ± 0.26	0.272 ± 0.033	ND	< 0.05	0.084 ± 0.022	8.69 ± 0.68
KBSB 037-C	00-05	99.02697	0.75 ± 0.22	ND	0.73 ± 0.17	ND	0.265 ± 0.095	2.01 ± 0.90	< 0.18	0.092 ± 0.060	9.7 ± 1.5
KBSB 037-C	05-10	99.02698	0.74 ± 0.25	1.4 ± 1.9	1.01 ± 0.17	ND	0.32 ± 0.11	0.74 ± 0.65	< 0.14	0.125 ± 0.057	9.3 ± 1.4
KBSB 037-C	10-15	99.02699	0.52 ± 0.23	1.1 ± 1.6	0.86 ± 0.15	1.23 ± 0.69	0.225 ± 0.087	1.14 ± 0.69	< 0.13	0.117 ± 0.060	8.9 ± 1.3
KBSB 037-C	15-27	99.02700	0.777 ± 0.091	ND	0.836 ± 0.071	0.69 ± 0.33	0.304 ± 0.037	ND	< 0.06	0.149 ± 0.032	9.57 ± 0.77
KBSB 037-C	27-39	99.02701	0.615 ± 0.095	0.81 ± 0.68	0.738 ± 0.064	0.76 ± 0.35	0.201 ± 0.039	ND	< 0.06	0.138 ± 0.031	9.66 ± 0.64

TABLE A.11–*Continued*

Sample ID	Core Slice (cm)	NAREL ID	Activity ($pCi/g_{dry} \pm 2\sigma$ counting error)								
			^{228}Ra	^{224}Ra	^{212}Pb	^{212}Bi	^{208}Tl	^{7}Be	^{60}Co	^{137}Cs	^{40}K
KBSB 039-C	00-05	99.02684	0.76 ± 0.13	ND	0.870 ± 0.094	1.22 ± 0.63	0.271 ± 0.050	0.74 ± 0.47	< 0.11	0.076 ± 0.046	9.43 ± 0.96
KBSB 039-C	05-10	99.02685	0.969 ± 0.095	0.89 ± 0.53	1.100 ± 0.084	0.92 ± 0.32	0.346 ± 0.039	ND	< 0.06	0.048 ± 0.022	9.91 ± 0.77
KBSB 039-C	10-15	99.02686	0.89 ± 0.11	0.67 ± 0.72	0.950 ± 0.090	0.82 ± 0.39	0.311 ± 0.047	ND	< 0.07	0.071 ± 0.036	7.16 ± 0.75
KBSB 039-C	15-30	99.02687	0.741 ± 0.066	0.60 ± 0.44	0.809 ± 0.060	0.71 ± 0.22	0.242 ± 0.025	ND	< 0.04	0.019 ± 0.015	6.63 ± 0.50
KBSB 053-C	00-05	99.02702	1.13 ± 0.15	ND	0.68 ± 0.10	0.82 ± 0.65	0.224 ± 0.062	ND	< 0.11	0.129 ± 0.047	8.25 ± 0.89
KBSB 053-C	05-10	99.02703	0.61 ± 0.22	ND	0.91 ± 0.15	ND	0.236 ± 0.087	ND	< 0.14	0.221 ± 0.056	8.6 ± 1.1
KBSB 053-C	10-15	99.02704	0.61 ± 0.19	1.1 ± 1.4	0.67 ± 0.11	0.86 ± 0.62	0.228 ± 0.075	ND	< 0.12	0.142 ± 0.049	8.8 ± 1.0
KBSB 053-C	15-31	99.02705	0.782 ± 0.057	0.35 ± 0.37	0.839 ± 0.039	0.67 ± 0.22	0.271 ± 0.023	ND	< 0.05	0.197 ± 0.022	9.08 ± 0.41

Note: ND indicates the radionuclide was not detected by gamma spectrometry.

"< X" indicates the radionuclide was not detected and X was the minimum detectable concentration for the nuclide in this sample.

No other gamma-emitting radionuclides were detected in these samples.

TABLE A.12
Gross Alpha and Gross Beta Activity Results for Sediment Core Samples

Sample ID	Core Slice (cm)	NAREL ID	Activity ($pCi/g_{dry} \pm 2\sigma$ counting error)	
			Gross Alpha	Gross Beta
STUDY SAMPLES				
KBSB 008-C	00-05	99.02679	7.1 ± 3.5	16.4 ± 3.6
KBSB 008-C	05-10	99.02680	4.7 ± 2.9	15.7 ± 3.4
KBSB 008-C	10-15	99.02681	4.6 ± 3.0	15.6 ± 3.6
KBSB 008-C	15-32	99.02682	6.6 ± 3.7	15.0 ± 3.6
KBSB 008-C	32-49	99.02683	7.0 ± 3.7	17.7 ± 3.6
KBSB 017-C	00-05	99.02674	6.5 ± 3.4	12.6 ± 3.4
KBSB 017-C	05-10	99.02675	3.8 ± 2.8	7.0 ± 2.9
KBSB 017-C	10-15	99.02676	2.7 ± 2.8	4.3 ± 2.8
KBSB 017-C	15-28	99.02677	0.0 ± 2.0	5.8 ± 2.8
KBSB 017-C	28-41	99.02678	1.2 ± 1.9	5.8 ± 2.8
KBSB 021-C	00-05	99.02706	6.6 ± 3.5	17.1 ± 3.7
KBSB 021-C	05-10	99.02707	9.7 ± 4.0	17.3 ± 3.7
KBSB 021-C	10-15	99.02708	6.0 ± 3.3	17.3 ± 3.6
KBSB 021-C	15-32	99.02709	12.6 ± 4.5	16.9 ± 3.7
KBSB 021-C	32-49	99.02710	8.7 ± 3.7	16.0 ± 3.5
KBSB 026-C	00-05	99.02711	4.5 ± 3.2	14.6 ± 3.5
KBSB 026-C	05-10	99.02712	9.8 ± 4.1	17.0 ± 3.7
KBSB 026-C	10-15	99.02713	9.6 ± 4.0	17.8 ± 3.7
KBSB 026-C	15-32	99.02714	5.7 ± 3.2	17.7 ± 3.6
KBSB 026-C	32-49	99.02715	11.8 ± 4.4	15.2 ± 3.7

TABLE A.12 – *Continued*

Sample ID	Core Slice (cm)	NAREL ID	Activity ($pCi/g_{dry} \pm 2\sigma$ counting error)	
			Gross Alpha	Gross Beta
KBSB 035-C	00-05	99.02692	6.2 ± 3.5	11.9 ± 3.3
KBSB 035-C	05-10	99.02693	7.4 ± 3.4	14.1 ± 3.4
KBSB 035-C	10-15	99.02694	6.4 ± 3.2	14.6 ± 3.5
KBSB 035-C	15-33	99.02695	4.8 ± 2.9	12.4 ± 3.4
KBSB 035-C	33-51	99.02696	4.8 ± 3.0	14.9 ± 3.5
KBSB 036-C	00-05	99.02688	5.3 ± 3.2	13.2 ± 3.4
KBSB 036-C	05-10	99.02689	4.7 ± 3.4	16.5 ± 4.9
KBSB 036-C	10-15	99.02690	5.3 ± 3.9	12.9 ± 4.4
KBSB 036-C	15-30	99.02691	5.5 ± 3.2	16.5 ± 3.6
KBSB 037-C	00-05	99.02697	5.6 ± 3.3	17.2 ± 3.8
KBSB 037-C	05-10	99.02698	8.4 ± 3.8	18.5 ± 3.7
KBSB 037-C	10-15	99.02699	5.8 ± 3.2	18.2 ± 3.7
KBSB 037-C	15-27	99.02700	4.5 ± 3.3	14.3 ± 3.5
KBSB 037-C	27-39	99.02701	10.4 ± 4.2	19.5 ± 3.8
KBSB 039-C	00-05	99.02684	6.5 ± 3.5	18.7 ± 4.0
KBSB 039-C	05-10	99.02685	11.9 ± 4.4	24.3 ± 4.1
KBSB 039-C	10-15	99.02686	6.1 ± 3.3	14.0 ± 3.3
KBSB 039-C	15-30	99.02687	8.6 ± 3.8	17.7 ± 3.7
KBSB 053-C	00-05	99.02702	7.0 ± 3.5	16.9 ± 3.7
KBSB 053-C	05-10	99.02703	10.5 ± 4.1	14.8 ± 3.5
KBSB 053-C	10-15	99.02704	5.3 ± 3.3	14.0 ± 3.5
KBSB 053-C	15-31	99.02705	7.2 ± 3.8	19.2 ± 4.0

TABLE A.13
Gamma Spectrometry Results for Biota Samples

Sample ID	NAREL ID	Activity ($pCi/g_{wet} \pm 2\sigma$ counting error)										
		^{226}Ra	^{214}Pb	^{214}Bi	^{228}Ra	^{212}Pb	^{212}Bi	^{208}Tl	^{7}Be	^{60}Co	^{137}Cs	^{40}K
STUDY SAMPLES												
KBSB 012-BO	99.02558	ND	0.0299 ± 0.0051	0.0309 ± 0.0043	0.0681 ± 0.0070	0.0311 ± 0.0057	ND	0.0101 ± 0.0022	0.069 ± 0.017	< 0.004	0.0028 ± 0.0017	0.511 ± 0.042
KBSB 019-BMG	99.02620	ND	ND	ND	ND	ND	ND	0.0024 ± 0.0030	0.519 ± 0.046	< 0.007	ND	3.32 ± 0.21
KBSB 020-BO	99.02561	0.059 ± 0.064	0.0213 ± 0.0049	0.0214 ± 0.0046	0.0566 ± 0.0067	0.0279 ± 0.0058	ND	0.0084 ± 0.0024	0.039 ± 0.017	< 0.004	0.0028 ± 0.0018	0.445 ± 0.040
KBSB 023-BO	99.02617	ND	ND	ND	ND	ND	ND	ND	0.700 ± 0.049	< 0.005	ND	2.68 ± 0.17
KBSB 025-BO	99.02559	0.067 ± 0.074	0.0287 ± 0.0051	0.0295 ± 0.0047	0.0638 ± 0.0071	0.0290 ± 0.0057	0.040 ± 0.025	0.0092 ± 0.0024	0.056 ± 0.018	< 0.004	0.0025 ± 0.0019	0.434 ± 0.040
KBSB 031-BO	99.02560	ND	0.0226 ± 0.0049	0.0237 ± 0.0045	0.0623 ± 0.0071	0.0362 ± 0.0061	0.035 ± 0.025	0.0118 ± 0.0024	0.042 ± 0.018	< 0.004	0.0027 ± 0.0020	0.483 ± 0.042
KBSB 040-BMG	99.02619	ND	0.0263 ± 0.0078	0.0260 ± 0.0068	0.0349 ± 0.0090	0.0310 ± 0.0087	ND	0.0112 ± 0.0037	0.647 ± 0.055	< 0.008	0.0109 ± 0.0036	3.95 ± 0.25
KBSB 046-BMG	99.02583	ND	ND	ND	ND	ND	ND	ND	0.125 ± 0.025	< 0.006	ND	3.41 ± 0.21
KBSB 048-BMG	99.02582	ND	ND	ND	ND	ND	ND	0.0032 ± 0.0031	0.142 ± 0.026	< 0.007	ND	3.82 ± 0.24
KBSB 054-BMG	99.02618	ND	0.0223 ± 0.0065	0.0190 ± 0.0058	ND	0.0255 ± 0.0072	ND	0.0056 ± 0.0031	0.213 ± 0.029	< 0.007	ND	3.09 ± 0.20
BACKGROUND SAMPLES												
KBSB 056-BMG-BK	99.02621	ND	0.0176 ± 0.0069	0.0205 ± 0.0064	ND	0.0140 ± 0.0076	ND	0.0057 ± 0.0033	0.230 ± 0.035	< 0.007	ND	3.33 ± 0.21
KBSB 56-BMG-BK-DU	99.02584	ND	0.0162 ± 0.0069	0.0179 ± 0.0060	ND	0.0190 ± 0.0083	ND	0.0040 ± 0.0032	0.208 ± 0.031	< 0.006	0.0043 ± 0.0030	3.64 ± 0.23

Note: ND indicates the radionuclide was not detected by gamma spectrometry.
"< X" indicates the radionuclide was not detected and X was the minimum detectable concentration for the nuclide in this sample.
No other gamma-emitting radionuclides were detected in these samples.

TABLE A.14
Gross Alpha and Gross Beta Activity Results for Biota Samples

Sample ID	NAREL ID	Activity ($pCi/g_{wet} \pm 2\sigma$ counting error)	
		Gross Alpha	Gross Beta
STUDY SAMPLES			
KBSB 012-BO	99.02558	0.7 ± 2.0	0.7 ± 1.6
KBSB 019-BMG	99.02620	0.085 ± 0.082	3.23 ± 0.25
KBSB 020-BO	99.02561	0.1 ± 1.1	3.7 ± 2.0
KBSB 023-B?	99.02617	0.029 ± 0.088	2.83 ± 0.25
KBSB 025-BO	99.02559	0.9 ± 1.3	0.2 ± 1.6
KBSB 031-BO	99.02560	0.7 ± 1.2	0.2 ± 1.6
KBSB 040-BMG	99.02619	0.41 ± 0.20	4.15 ± 0.37
KBSB 046-BMG	99.02583	0.061 ± 0.091	4.17 ± 0.32
KBSB 048-BMG	99.02582	0.032 ± 0.071	3.88 ± 0.28
KBSB 054-BMG	99.02618	0.069 ± 0.093	3.56 ± 0.30
BACKGROUND SAMPLES			
KBSB 056-BMG-BK	99.02621	0.26 ± 0.17	4.30 ± 0.36
KBSB 056-BMG-BK-DU	99.02584	0.17 ± 0.14	4.30 ± 0.35