March 7, 2016

Revised De Minimis Determination for Incidental Trace Amounts of Radiological Material found in Pier 12 Dredged Sediments. Naval Base San Diego P-327 Milcon Pier 12 Replacement Project (USACE Permit #2010-00123-RRS)

Objective

This memorandum shows three lines of evidence that the Navy has met the criteria set forth in 40 CFR part 227 – Criteria for the Evaluation of Permit Applications for Ocean Dumping to support the disposal of 65,000 cy of clean sediment with a relatively small number of discrete objects with Radium 226 (Ra-226) at Pier 12 located at Naval Base San Diego. The main objective is to show enough information to allow EPA and the USACE to determine pursuant to the Marine Resource Protection and Sanctuaries Act (MPRSA) that the "proposed disposal will not unduly degrade or endanger the marine environment….." and that it will meet the requirements of 40 CFR part 227.6. If EPA and the USACE determine that the objective has been met, then the Navy will be able to dispose of the 65,000 cy of sediment directly to an EPA designated Ocean Disposal Site named LA-5 located off the coast of San Diego, California. The lines of evidence include:

1. **Sediment is clean and indistinguishable from background.** Sediment Cores were taken in-situ within the Pier 12 footprint and analyzed for radioactivity. The analytical results showed radioactivity concentrations are at background levels.. The sediment core sample results show that the sediment does not contain radioactivity above the naturally occurring background levels.
2. **The Discrete objects do not pose a risk to the marine environment.** Out of 11,700 cy of sediment dredged, 54 objects containing Ra-226 with radiation dose rates that ranged from 0.0008 rad/day to 0.240 rad/day were discovered after mechanical screening and radiological scanning the dredged sediment. The average would equate to less than one item per 200 cubic yards of dredged materials. The Department of Energy conducted several studies to determine a screening criterion or Biota Concentration Guide to protect aquatic animals from exposure to ionizing radiation. According to DOE Order 5400.5, any absorbed dose below 1 rad/day will not have any observed effect to any aquatic animal or plant. The highest dose seen at Pier 12 is 0.240 rad/day from a deck marker. Each individual objects's radiation is also below or within the screening criteria range for environmental health of whole sediments developed by the International Atomic Energy Association under the London Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter and set out at Annex 9 of that document. That would classify the radiation level of the objects as "de minimis".
3. **The sum of the activities from the discrete objects do not pose a risk if uniformly distributed within the dredged sediment.** The London Convention's "de minimis" screening criteria assumes uniform concentrations of radioactivity in sediments. Therefore it is difficult to apply these criteria to a sparse scatter of small discrete objects. One way to compare these criteria to Pier 12 sediment would be to calculate the object's activity if uniformly distributed in the dredged sediments. Extrapolating the observed dose rates of Pier 12 sediment using this method yields a very small number far below published screening criteria to protect environmental marine ecosystem health. A more conservative approach would be to assume the sediment to be uniformly composed of deck markers as radioactive as the highest dose rate of 0.240 rad/day. Even that is below the DOE Order 5400.5 criterion of one rad per day, referenced above. Therefore, even the most conservative averaging assumption could support a determination of de minimis radiation.

Conservative assumptions aside, the memorandum uses the data to establish that the Pier 12 sediments can be considered as clean sediment with incidental traces of material with de minimis radioactive activity, thus are

suitable for open ocean disposal at LA-5 which is consistent with the approved USACE Permit SPL-2010-01123-RRS.

Background

The USN is undertaking a construction project (MILCON Project P-327) at Pier 12 to create a homeport for the USS Zumwalt. In accordance with the USACE permit (ENG FORM 1721/SPL-2015-00431-RRS) a maximum total volume of 479,125 cubic yards (cy) of sediment will be dredged from the area encompassing the existing Pier 12 area and the proposed area of the new Pier 12 (Figure 1). The project design dredge depth is -37' MLLW, plus 2 feet over dredge. A minimum of 45,160 cy of material with elevated chemical contaminants will be dredged and offloaded to a confined disposal facility and screened to remove munitions and RAD prior to being transported to an approved upland landfill. The remaining volume, approximately 433,965 cy of clean material will be disposed of at the LA-5 ocean disposal site.

Figure 2 shows the existing and new pier, as well as the dredge areas. Figure 2 also highlights the areas which were determined unsuitable for discharge back into waters of the U.S. per "Green Book" sediment analysis. Sediments beyond these identified footprints have been previously approved for disposal at LA-5.

During dredging operations two discrete radioactive objects containing radium-226 (Ra-226) were found in Pier 12 sediments being screened for upland disposal. The objects consisted of a ship's radium deck marker and a piece of rope with the radioactivity levels of approximately 0.54 and 0.6 microcuries (µCi) of Ra-226. The Navy informed the U.S. Environmental Protection Agency (EPA) and the U.S. Army Corps of Engineers (USACE) of these findings in the NAVFAC SW Point Paper dated 28 July 2014. (NBSD Pier 12 Final Work Plan).

The unexpected discovery of radioactive objects revealed the potential for radiological objects to be found within materials that had been designated for unconfined aquatic disposal and upland disposal (18 July 2014 NAVFAC SW Point Paper). The Navy, with the dredging contracting Manson Construction, developed a program to screen for munitions and RAD for all of the material above the previous design depth of -30 ft MLLW. The Navy elected to screen for anthropogenic radioactive objects in approximately 65,000 cy of clean material currently designated for disposal at LA-5. The radiological screening process requires direct handling of the sediment which triggers the requirement to screen for munitions for safety purposes. The radiological and munitions screening program calls for very slow methodical process that includes: 1.) Drying the dredged sediment; 2.) Sifting the dried material through a ¾" screen to remove possible munitions and radiological objects of concern; 3.) Spreading the dried and screened material in 8" lifts on a designated radiological screening yard and manually scanning for radiological objects that are smaller than ¾"; 4.) Removing any object of concern and sampling the surrounding material. This process takes approximately 7 weeks to process sediment from start to finish.

Figure 1 provides a generalized profile of the Pier 12 dredging project. To date

- Approximately 85,000 cy of material has been dredged and disposed at LA-5. Approximately 24,000 cy of sediment has been dredged from within the upland disposal footprint (see USACE Permit Figure *Pier 12 Dredged Volume Estimates*). These sediments have been disposed at an upland facility.
- An additional 40,000 cy of sediment within the upland disposal footprint will be removed from Pier 12 which will still requires RAD and MEC/MPPEH screening prior to upland disposal.
- The 65,000 cy of dredged material that is the focus of this memorandum consists of the remaining sediments located above the previous design depth (-30 ft MLLW), and the sediments outside of the

upland disposal footprint from the surface to the native sediment line. These sediments are slated for unconfined aquatic disposal at LA-5 and currently intended for RAD and MEC/MPPH screening.

- There are 240,000 cy of native material (below -30 ft MLLW) previously approved for disposal at LA-5 that does not require screening for RAD or MEC/MPPH

Reason for Reconsidering Value of Radiological Screening

The Navy has evaluated the radiological field data collected and believe that there has been sufficient characterization of the material to meet the requirements in 40 CFR 227.4-227.6 to prove that any low-level radioactive objects are trace constituents in otherwise clean dredged material (40 CFR 227.6) that do not pose an adverse effect on human health and the environment and is acceptable for ocean disposal.

The Navy submits that continued screening for RAD and MEC/MPPEH in the target 65,000 cy is unwarranted. The Pier 12 construction project cannot be completed within the existing budget and schedule constraints by continuing to screen for radiological materials in the 65,000 cy slated for disposal at LA-5. The dredged material screening procedures have negatively impacted production rates; the schedule, cost, and ultimately the Navy's mission to homeport the USS Zumwalt. The elimination of the screening will also eliminate any unnecessary air, traffic and noise pollution caused by the machinery and trucks required to dry, process and screen the sediment. The major delay to the Pier 12 project is creating a national security concern that may affect other naval defense activities.

Laws, Regulations and Guidance

40 CFR part 227 – Criteria for Evaluation of Permit Applications for Ocean Dumping of Materials, subsection 227.4 states that the Navy must demonstrate (a) No unacceptable adverse effects on human health and no significant damage to the resources of the marine environment; (b) No unacceptable adverse effect on the marine ecosystem; (c) No unacceptable adverse persistent or permanent effects due to the dumping of the particular volumes or concentrations of these materials; and (d) No unacceptable adverse effect on the ocean for other uses as a result of direct environmental impact".

The particular material(s) in question are "Dredged materials" covered by 40 CFR subpart 227.13. In our case, the sediment fits the definition at subpart 227.13(c) which is defined as sediment that is environmentally acceptable for ocean dumping if it passes testing. The sediment did pass testing including bioassay. The radioactive items did not affect it, as the material consists of relatively few discrete objects. Core sampling has addressed the radioactivity. The results have satisfied the USEPA and the U.S. Army Corps of Engineers that the sediment as a whole contains naturally occurring radioactivity that is indistinguishable from background. Otherwise acceptable or clean sediment with certain trace constituents such as mutagens and teratogens are still permissible for ocean disposal as long as they meet the requirements of subpart 227.6. In our case we can say that they are trace constituents as they occur at a rate of less than one item (from a paint chip to a marker to a piece of rope) in every 200 cubic yards of material and they are small discrete objects with radioactivity below or within applicable screening criteria set to protect receptors in the environment. Again, these screening criteria are set for whole sediment, so application to discrete objects is a very conservative approach.

The contaminant of concern addressed by this memo is the scatter of discrete objects that contain radium 226. The analysis here can depend on screening level criteria referenced in this memo, which themselves are based on extensive testing and scientific literature and expert opinion.

As referenced above, the aquatic screening criteria for radioactivity were drawn from two places: DOE Order 5400.5, and Annex 9 of the London Convention. Both are relevant in that they specifically deal with environmental health and receptors. Annex 9 is further implicated because the MPRSA and it's regulations, among other things, apply the standards and criteria applicable to the United States under the London Convention. See 40 CFR subpart 227.1(b). Therefore the "trace constituent" concept from subpart 227.6 could be said to implement Annex 9. The trace concept in subpart 227.6 is generally directed toward avoiding undesirable environmental effects and health effects. The concept of "de minimis" is concerned with those effects as they relate to radionuclides. Essentially, a "de minimis" source is one that is, as simplified for the sake of this discussion, "exempt", within the meaning Annex 9. That is, it "applies to sources or practices that need not be subject to some or all aspects of regulatory control on the basis that the exposure and the potential exposure are too small to warrant regulatory control …." See Annex 9 page 4. For purposes of regulating dredged sediment with radionuclides then "de minimis" and "trace" are interrelated, if not the same.

For this project, the Navy has informed and will continue to inform NRC of the progress of the disposal of clean sediment with potential discrete objects with Ra-226. The NRC does not require a Memorandum of Agreement for transport or possession of any Ra-226 items that may be co-located within the 65,000 cy of sediment, since this project is operating under a MILCON site and is not a CERCLA response action. The Navy plans to starting dredging the 65,000cy from the San Diego Bay in summer of 2016.

Three Lines of Evidence of Trace and De Minimis Radiological Material

1. **Sediment is clean and indistinguishable from background.**
2. **Discrete objects do not pose a risk to the marine environment.**
3. **The total activity of objects do not pose a risk if uniformly distributed within the dredged sediment.**

1. Sediment is clean and indistinguishable from background.

EPA's comments to the Work Plan were succinct as to the sampling and evaluation procedures to be used for the 65,000 cy. Those comments are consistent on EPA's process on evaluating sediment for ocean disposal. The Navy followed all of the suggestions and recommendation for approval of ocean disposal.

- *Comment 45. Section 2.3 (page 9) - The 65,000 cubic yards of dredged material proposed for ocean disposal must be sampled directly and scanned for radiation. This can probably be done with 4-6 cores in two composites, homogenized and analyzed as two samples. If the sample results indicate significant elevated radiation (see next note, #2), then the individual cores can be analyzed to identify a radiation hotspot if necessary. The proposed surrogate measurement of the 18,000 cubic yards already at the CDF would not characterize the in situ 65,000 cubic yards. Per 40 CFR 227.5, any uncharacterized materials are presumed to be unsuitable for ocean disposal unless otherwise characterized.*
- *Comment 46. The screening criteria should be ambient ocean values for the radionuclides of concern (i.e., known ambient values, IAEA screening values) - nothing significantly above background/ ambient levels can be dumped into ocean waters.*
- *Comment 47. Any dredged material approved for ocean disposal cannot have more than trace amounts of radioactive material, deemed as prohibited per 40 CFR 227.5. Also what value would be acceptable as trace for ocean disposal (per IAEA guidance)?*

The evaluation procedures applied herein are consistent with EPA's comments, and previous decisions made by the EPA and USACE for dredged material disposal for potential radioactive sediments (see below). The initial

evaluation compares the Pier 12 data to background data (*EPA Comments 45 and 46*). The Navy could not identify any ambient values for LA-5 specifically, but according the Environmental Impact Statement for LA-5, much of the material at LA-5 is from San Diego Naval maintenance dredging projects. Comparisons are thus made to the 1999 EPA *Radiological Survey of Naval Facilities on San Diego Bay*. The EPA identified stations it considered to be "background" in that study. The Navy evaluated data collected from the 46 core samples taken within the 65,000 cy dredge footprint at Pier 12 within the context of EPA's background study as the basis used in this evaluation. Radiological scanning was performed along the entire length of each of the 46 cores. The highest reading was recorded for that location and is shown on Table 2.

Comparison of Core-Samples to the EPA 1999 Background Levels

Element	Number of Samples	Number Detected Values	Mean	Median	Minimum	Maxium	1999 EPA Background Average
			Activity (pCi / g-dry weight)				
Radiological Core Samples - ALL							
Radium 226 [1]	46	46	0.4176	0.4045	0.1830	0.7290	0.4303
Cesium 137 [2]	46	2	0.0106	0.0020	-0.0260	0.1310	0.0101
Cobalt 60 [3]	46	0	0.0017	0.0015	-0.0280	0.0320	ND
Strontium (total) [4]	46	0	-0.0100	-0.0110	-0.2810	0.1420	not measured

These criteria are then consistent with EPA's direction that any material to be disposed of at LA-5 should be at or below IAEA "screening" (Comment 46) or "trace" (Comment 47) values which are pose no unacceptable adverse effects on human health and marine ecology per 40 CFR 227.4 to 227.6. In terms of the law the 54 objects distributed in 11,700 cubic yards of material constitute only a trace constituent per 40 CFR 227.6, and their radioactivity is de minimis within the meaning of the IAEA 2015 *Guidelines for the Application of the De Minimis Concept under Annex 9 of the London Convention and Protocol.*

Measurements made on the sediments at Pier 12 were in the reference units used in the United States: millirem (mrem), Rad, and microcuries (µCi). The units used by the IAEA are in the internationally accepted units. The specific assessment estimates radiation doses in microsieverts (µSv) in a year that could be received by human beings or radiation dose rates in micrograys per hour (µGy/hr) that could be received by marine flora and fauna exposed directly and indirectly to the radioactivity in Becquerel (Bq) in the candidate material to be disposed at sea. For these comparisons, the measured values in U.S. units were used in all exposure calculations, and then converted to the international units. (100 rem = 1 Sv, 100 rad = 1 Gy, 1 Ci = 3.7×10^{10} Bq)

Forty six (46) *in situ* vibracores collected within the dredging prism at Pier 12 (Figure 3, Tables 1 and 2). Forty (40) cores were taken from within the total PCB (upland disposal) footprint. (Figure 2; Dredge Cells A – G) and six cores were collected outside the upland disposal target areas (Dredge Cells D – G). The cores were collected from the mudline down into native material, or to refusal. (Tables 1-2). Thus the sediments in the cores encompassed (a) the sediments targeted for upland disposal, (b) clean sediments underlying the sediments targeted for upland disposal, but above the native material, (c) sediments outside the upland disposal footprint, and (d) the native sediments. Much of the sediment that was removed for upland disposal was located near in the area of the demolished pier. (Figure 2). The source of the rad objects would have originated from past ship activities that were berthed at the demolished pier.

All 46 vibracore samples were extruded, measured for recovery, logged for lithology and photographed. Each core was first checked for any obvious radiological objects (e.g., dials, buttons, wire) and the scanned for radiological activity with a scintillation counter along the entire length of the core from mudline to the bottom of the core (Table 2). Sediment collection and analysis procedures are described in Section 3.3 of the Work Plan. There were no radiological objects found in any of the 46 vibracore samples.

A discrete sediment sample from each core was collected at the point of highest gamma counter reading (Table 3). The sample interval was recorded relative to Mean Lower Low Water, and then sent to the laboratory for analysis of Radium 226, Cesium 137, Cobalt 60, and total strontium. Of those 46 discrete laboratory analysis samples, 6 samples were collected from above -30 ft MLLW; the results for these cores are representative of 65,000 cy designated for open water disposal and currently subject to the ¾ inch dredged material screening for radiological materials in the Work Plan. For the remaining 40 discrete samples the highest measured radioactivity within the core was within the native sediments (below -30 ft MLLW); that material is also set for open water disposal, but was not subject to the dredge plant screening for radiological material. No radiological objects were identified in any of the core samples. The laboratory results are presented in Appendix B.

Comparison of Pier 12 Core Data to Background Levels of Radionuclides.

Table 4 provides a comparison of the results from the discrete samples collected from each individual in situ vibracores to the background values as reported by EPA in the 1999 radiological surveys of San Diego Bay. Summary statistics (mean, median, minimum and maximum) were calculated from the laboratory results (Appendix B) for Ra-226, Cs-137, Co-60, and total strontium. The number of samples and the number of detected values are also included in Table 4. These summary statistics were calculated for core intervals < -30 ft MLLW, >30 ft MLLW, and for all cores (combined).

Natural background levels in the sediments at LA-5 could not be identified in the scientific literature. IAEA on-line publications were also searched for any values that might be relevant first to southern California, and then the eastern Pacific; there were no values identified. In the 1999 EPA study of San Diego Bay background was identified as a sampling location where representative levels of naturally occurring or existing radionuclides were measured, but were not likely to be related to Naval Station, San Diego; Naval Submarine Base, San Diego; or Naval Air Station/North Island, San Diego.

For Ra-226, the EPA calculated background values. For Cs-137 and Co-60 summary statistics were calculated as described above. Total strontium was not reported by EPA.

With the exception of one core sediment sample, all of the harbor sediment and core sediment samples, shoreline sediment samples, water samples, and biota samples from the San Diego Harbor contained no detectable levels of radioactivity other than those occurring naturally or attributable to fallout from atmospheric nuclear tests or the Chernobyl reactor accident in 1986.

For the six (6) samples collected above -30 ft MLLW, the mean and median values for radium-226 were below the 1999 EPA-reported background average (Table 4). This was also true for the samples collected below -30 ft MLLW, and for the full combined vibracore data set (all samples)

Samples collected below -30 ft MLLW are native sediments, and should be considered to be representative of natural background conditions. Gamma counts were collected from the full core

length, and the highest reading is reported in Table 2. A T-test assuming a difference of 0 and an alpha of 0.05 was conducted; the count means for the cores were 11397 (<-30 ft MLLW) and 11320 (>-30 ft MLLW), respectively. There was no significant difference between the two sample sets.

The Navy concludes that the measured levels of radioactivity for the Pier 12 sediments are within the range natural background levels as measured in San Diego Bay.

2. Discrete objects do not pose a risk to the marine environment.

Fifty-four (54) discrete radioactive objects with Ra-226 were identified from approximately 11,700 cy of dredged material slated for upland disposal during the physical screening process (Table 3). Each discrete object was identified and measured using a Ludlum Model 44-10 2-inch by 2-inch gamma scintillation detector or a detector such as a Ludlum Model 44-132 5.8-inch by 1-inch gamma scintillation detector or a Bicron G-5 FIDLER because of their high sensitivity to low-energy gamma and x-ray radiation, portability, and directional bias. Procedures for identifying radiological objects are discussed in Section 3.1 of the Work Plan.

The 54 objects ranged in size and activity. A piece of rope was the largest item at approximately 56" also had one of largest dose of 9 mrem/hr. The piece of rope was screened out using the larger 12" screen at the dredge site and found in the scrap metal debris. Note: The permit for the ocean disposal of 65,000 cy requires to screen the material with the 12" screen, the Navy is suggesting to eliminate the ¾" screen not the 12" screen. The smallest item found was the size of a grain of rice and also had the lowest activity of 0.034 mrem/hr. 33 objects out of the 54 were smaller than ¾".

Individual sources and Department of Defense criteria for Aquatic and Terrestrial Biota

The U.S. Department of Energy (DOE) is accountable to Congress and the public for the safe conduct of its activities that include waste management, disposal activities and the remediation of environmental contamination. In the DOD technical standards document published in 2002 titled, "A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota" states that the screening levels for the **"absorbed dose to aquatic animals should not exceed 1 rad/day (10mGy/day) from exposure to radiation or radioactive material releases into the aquatic environment. This dose limit is specified in DOE order 5400.5".**

It should be noted that these studies contained the following conservative assumptions:

1. The sediment is uniformly contaminated. When studying a uniformly contaminated sediment column, the studies also assume that the receptor is being exposed continuously throughout its lifetime.
    a. The exposure to a discrete item on the bottom of the ocean is a more conservative factor than exposure to 65,000 cy of uniformly contaminated sediment. A receptor can only be continuously exposed if it lives its entire life directly on top of the object.
2. The receptor does not have any shielding from the source.
    a. Discrete objects disposed at LA 5 will have some form of shielding as either water or sediment.
3. Progeny of radionuclides and their decay chains are also included.

4. The radionuclides are presumed to be homogeneously distributed in the tissues of the receptor organism. This is unlikely to under-estimate the actual dose to the tissues of concern (i.e., reproductive organs).
5. The studies concluded that the embryo development in fish and the process of gametogenesis appear to be the most radiosensitive stages of all aquatic organisms tested.

The DOE criteria has also been approved and agreed upon by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), UK Environmental Agency, Advisory Committee on Radiation Protection (ACRP) and International Atomic Energy Agency (IAEA).

Description LA-5 – EPA permitted ocean disposal site

LA-5 is an EPA designated disposal area located in the Pacific Ocean off of the coast of San Diego. According to the Environmental Impact Statement for LA-5, the site lies on the slope of the continental shelf and ranges in depth of 130 m to 190m (426 ft to 623 ft). The dredged material is planned for disposed at LA-5 within the designated 100 fathom site (600 ft) that is used for disposal of material from South San Diego Bay since the 1970s . LA-5 is 6 miles west of Point Loma, and the prevailing conditions at the disposal site are such that the courser incidental rad material would be transported offshore by both the current and sediment slumping on the slope (EPA 1987 LA-5 EIS). These conditions are not conducive for transport of the objects to San Diego beaches.

The most dominant group of infauna are polychaetes, crustaceans, mollusk and echinoderms. The dominate benthic fish are flatfish and rockfish. Most fish species migrate to reproduce, with exception of the northern anchovy and the rockfish. Pelagic fish were not studied.

For ocean disposal, the marine ecology is the risk driver to protect the most sensitive receptor on the ocean floor. According to the DOE study, the most sensitive receptor is the embryo of a fish egg. In the case for LA-5, the highest risk would be a rock fish or flat fish laying its eggs directly on a discrete radioactive object. However, if this highly unlikely event should occur, none of the objects are at or above the screening criteria of 1 rad/day, which means the fish embryos would show no observable adverse effect.

The potential for uptake to fish that would subsequently be eaten by humans is not probable. According to the DOE study, not enough activity from the Ra-226 is available to bioaccumalate into fish tissue. Information related to the potential for ingestion of fish caught at or near LA-5 comes from the 1987 EIS (EPA 1987). While that information is now somewhat dated, that document indicates little commercial or recreational fishing within the LA-5 area. Any minimal radioactivity leaching from the sediment would be quickly diluted into the ocean water. Thus the probability of having a recreationally or commercially caught fish at the LA-5 site at levels exceeding the IAEA guidelines is very low.

None of the 54 discrete sources found at Pier 12 (Table 3) exceed the DOE criteria of 1 rad/day. The range of activity of the objects screened range from 0.000816 rad/day to 0.24 rad/day. See Figure 4.

3. The total activity of objects do not pose a risk if uniformly distributed within the dredged sediment.

The criteria mentioned in this paper have the same assumption: All of the sediment is uniformly radioactive. The sediment at Pier 12 does not fit this type of assumption because it is not uniformly contaminated and only has a sparse number of objects with radioactivity.

The Navy elected to evaluate the dredged material where known radioactive objects were identified in material slated for upland disposal and extrapolate the activity per cubic yard of dredged sediment to dose rates to workers on the disposal barges, the public, and to ecological receptors at the LA-5 disposal site following the IAEA guidance for trace or de minimis material. The criteria to protect the marine environment according to the IAEA guidance is shown below:

As stated in IAEA-TECDOC-1759, Section 5.3.6:

> *"The candidate material may be considered suitable for further consideration for disposal under the [London Convention and Protocol] if:*
>
> > *(i) The estimated annual individual doses to members of the crew [working on ships that transport the material to the disposal site] and to the public [who may be exposed to the material after it has been disposed of] are independently equal to, or less than, 10 µSv; and*
> >
> > *(ii) The estimated annual total collective dose is less than or equal to 1 man Sv; and*
> >
> > *(iii) The estimated dose rates for each marine reference animal and plant is below or equal to the corresponding DCRLs [derived consideration reference levels].*
>
> *"If the material satisfies all the criteria for humans (crew and public) and flora and fauna [reference animals and plants] it is defined as de minimis without further consideration."*

Human Health Evaluation

This section summarizes the evaluation of potential doses to individuals and collective doses to dredged disposal barge crew and the public. For human health, the doses to humans were calculated following IAEA-TECDOC-1759, Section 5.3. The limitation of individual risk is applied by considering the radiation doses in a group of individuals most likely to receive the highest effective doses from the practice, i.e., the critical group. Depending on the practice, the critical group may consist of workers or members of the public. Detailed assumptions and calculations are presented in Appendix A.

Criterion (i) - Individual Doses to Humans

Screening coefficients for dose per unit activity concentration for Ra-226 in uniformly contaminated sediment necessary to calculate annual individual doses for crew and the public are given in IAEA-TECDOC-1759, see table below, as 6.0×10^{-2} and 2.6×10^{-2} µSv per becquerel per kilogram (Bq/kg) dry weight, respectively, for crew and the

public. It is noted that the screening coefficients for this and other dose calculations that follow include the contribution of progeny of the radionuclide (226Ra) assuming secular equilibrium.

Radiological screening of the surface sediment performed to date has resulted in the recovery of discrete radioactive debris and devices totaling 54 objects, with a total activity of 7.81×10^6 Bq. Approximately 11,700 cy of sediment have been radiologically screened to date, which is equivalent to 2.37×10^7 kilograms (kg), assuming a sediment density of 2.65 g/cm3. The total radioactivity of the 54 objects (7.81×10^6 Bq) distributed over the radiologically screened volume of sediment (2.37×10^7 kg) yields a radionuclide activity concentration of 0.33 Bq/kg. See Appendix A for more details and calculations.

The table below presents the individual exposure IAEA reference criteria, the Bq/kg activity and the estimated activity upon the identified radioactive objects. The calculated activity would result in a dose that is well below the IAEA reference criteria: less than 0.26% of the crew individual dose and 0.12% of the public individual dose.

Summary of calculated activity compared to IAEA De Minimis criteria (details in Appendix A).

Subject of exposure	IAEA Reference Criteria	Reference Criteria Bq/kg Equivalent	Calculated Pier 12 Activity Bq/kg
Crew individual dose	10 µSv in a year	128	0.3
Public individual dose		296	
Crew collective dose	1 man Sv in a year	1.28E+05	
Public collective dose		6.41E+02	
Marine fish, dose rate	40–400 µGy/h	3.14E+06	
Marine crustacean, dose	400–4000 µGy/h	2.80E+07	
Seaweed, dose rate	40–400 µGy/h	5.04E+06	

Criterion (ii) - Collective Doses to Humans

The individual risk level is most helpful in putting radiation risks to individuals into perspective. In most practical situations, however, the total health detriment is also of interest in considering source-related assessments. Collective doses to humans are calculated using IAEA-TECDOC-1759, Section 5.3.3. Screening coefficients for dose per unit activity concentration for Ra-226 necessary to calculate annual collective doses for crew and the public are given in IAEA-TECDOC-1759, as 6.0×10^{-6} and 1.2×10^{-3} man Sv per Bq/kg dry weight, respectively, for crew and the public.

The table above also presents the collective dose IAEA reference criteria (µSv), the Bq/kg reference activity equivalent, and the estimated overall activity based upon the identified radioactive objects found within the 11,700 cy of sediment. The calculated collective activity is substantively below the IAEA reference criteria: less than 0.0003% of the collective crew dose and 0.06% of the collective public individual dose.

Ecological Evaluation

Criterion (iii) - Dose Rates to Marine Flora and Fauna

The International Commission on Radiation Protection has developed radiological criteria for reference animals and plants (RAP) introduced as absorbed dose rates for chronic exposures that serve as markers at which one should pause in order for the known radiation effects data to be considered alongside other relevant factors when considering managerial options. The selected RAPs are fish, crustacean, and seaweed. Absorbed dose

rates to RAP are calculated using IAEA-TECDOC-1759, Section 5.3.4. Screening coefficients per unit activity concentration for Ra-226 are given in IAEA-TECDOC-1759, as $9.8x10^{-6}$, $1.1x10^{-5}$, and $6.1x10^{-6}$ µGy/hr per Bq/kg, respectively, for fish, crustacean, and seaweed.

Using the screening coefficients for RAP ($9.8x10^{-6}$, $1.1x10^{-5}$, and $6.1x10^{-6}$ µGy/hr per Bq/kg, respectively, for fish, crustacean, and seaweed), the radionuclide activity concentrations that result in an absorbed dose rate in RAP ranging from 40 to 400 µGy/hr are $3.14x10^{6}$ Bq/kg for fish, $2.80x10^{7}$ Bq/kg for crustacean, and $5.04x10^{6}$ Bq/kg for seaweed.

> Using the same approach as was used previously in calculating individual and collective doses to humans, the total radionuclide activity concentration in the surface sediment radiologically screened to date is 0.33 Bq/kg. As shown in summary table, this radionuclide activity concentration is much less than the concentration needed to produce absorbed dose rates ranging from 40 to 400 µGy/hr to fish, crustacean, and seaweed (1.1E-5%, 1.2E-6%, and 6.6E-6% of the reference criteria, respectively).

Regulatory Evaluation Precedents for Radioactive-Dredged Material Disposal

The Navy requested the assistance of the U.S. Army Corps of Engineer's Environmental Research and Development Center (ERDC) in identifying projects where dredged material for open water disposal had been evaluated for radiological materials. ERDC identified one project in Louisiana (Barataria Bay) that had been suitable for open water disposal based on evaluating the dredged material according to the IAEA de minimis guidance documents. ERDC further recommended contact with the USACE New England District. Two projects were identified by Mr. Norm Farris that were reviewed by the New England District and approved for ocean disposal. Those determinations were based on comparisons to background concentrations of the radionuclides of concern. Those three projects are further described, below.

Bayou Rigaud, LA.

ERDC conducted the evaluation of sediments associated with a dredging project of approximately 382,280 cy of sediment in Bayou Rigaud, Louisiana (Steevens et al 2003[1]). The sediments were thought to contain elevated levels of radioactivity as a result of the release of produced waters during petroleum drilling and production. Ra-226, Ra-228, and Cs-137 were the principal radionuclides of concern. Sediment, water and mussel tissue samples were collected and analyzed. The IAEA de minimis guidelines were applied to evaluate human health exposure/risks, but at that time the IAEA had not developed specific procedures/criteria for evaluating risks to flora and fauna. For ecological receptors ERDC used U.S. Department of Energy guidelines, and specifically the RAD-BCG calculator. The estimated dose rates to human and ecological receptors from measured Bayou Rigaud sediments were found to be below the respective IAEA/DOE criteria; the material was deemed suitable for open water disposal.

Thames River, Uncasville CT[2]

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[1] J.A. Steevens, E.J. Antonio, R. Engler, L. Mathies , 2003. Assessment of radionuclides in sediments proposed for dredging. International Conference on the Protection of the Environment from the Effects of Ionizing Radiation. October 6-10 Stockholm Sweden. Contributed papers. pp 44 – 38.

[2] Source: Memorandum provided by Norm Francis, USACE New England District. Evaluation of the Radiological Testing Results for the Mohegan Tribal Gaming Authority, Thames River, Uncasville, CT, Application Number NAE-2007-3165. 23 July 2010.

For this development project the private applicant proposed to mechanically dredge the material and dispose of it at one of the open water sites in the New England District. The site formerly held a manufacturing plant (UNC Naval Products) that made nuclear reactors for submarines. To characterize the sediment, ten cores were collected from the project footprint and the sediments were subject to bulk sediment chemistry analysis, a 10-day bioassay, a 28-day bioassay/bioaccumulation test and a suspended particulate assay. In addition to the bulk sediment chemistry, analyses for the presence of elevated uranium radioactivity was required at each core location. Samples were collected from five stations and analyzed by gamma spectroscopy for U-235, TH-234, Co-60, and Cs-137. Based on these analyses, the Corps concluded that no significant radiological contamination existed beyond natural background radiation levels and natural radioisotope profiles. The material was deemed suitable for open water disposal.

Brewer Glen Cove Marina, NY[3]

Maintenance navigation dredging at the Brewer Glen Cove Marina located in New York required radiological characterization for the approximately 24,000 cy sediment to be offshore disposed. This project was downstream from Glen Cove Creek and the Li Tungsten Superfund Site. The major concern in Glen Cove Creek was the possibility that radioactive slag material (small gravel to cobble-sized slag) migrated from the Li Tungsten site to the bottom sediments of Glen Cove Creek. A 2002 USACE study in upstream in Glen Cove Creek revealed hot spots as determined by gross gamma counts of up to 1,000,000 count per minute; principal radionuclides were radium and thorium. Individual cores were collected and subject to gross gamma count measures. The sampling plan for the project provided the following evaluation for radiological contamination: “If the scan detects 2 times background, sampling should stop and the project [be] rescoped for radiological contamination”. Under this provision, the Corps and EPA agreed that any reading less than twice the background levels would be interpreted as a less than critical value. It was assumed that these low values would not have significant environmental impact and that further radiological characterization would not be needed (Suitability Determination Memorandum, CENAE-R-PT (1145-2-303B), 21 August 2003). Radiological levels (in cpm) were at or near background levels for eight cores designated by the sampling plan and for an additional 127 stations independently sampled by the applicant’s agent. Background gross gamma counts from the boat yard docks were 1200 cpm (n = 9). When these values are converted to annual dose exposure rates, they are only 20% higher than the dock background rates and a fifth of those measured as background exposure rates in a Brookhaven National Laboratory study (BNL, 1999). In 2003, the agencies determined that this material was suitable for open water disposal.

Conclusion

Per 40 CFR 227.4-227.6, IAEA standards and DOE guidance, the sediment within the 65,000 cy slated for ocean disposal are well below trace levels that would not result in an unacceptable adverse effect on human health and the marine environment. The original approved permit for ocean disposal will be not be modified and will be followed according to its original intent. The original permit requires a 12”screen to remove large debris before disposing to LA-5. The screening process to remove possible radioactive objects is not necessary and does not need to be performed before being disposed to the ocean.

References

[3] Source: Suitability Determination Memorandum, Brewers Cover Marina. CENAE-R-PT (1145-2-303B), 21 August 2003

DOE, 2002. A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota. DOE-STD-1153-2002. Available online at: http://nnsa.energy.gov/sites/default/files/nnsa/inlinefiles/doe%202002a.pdf

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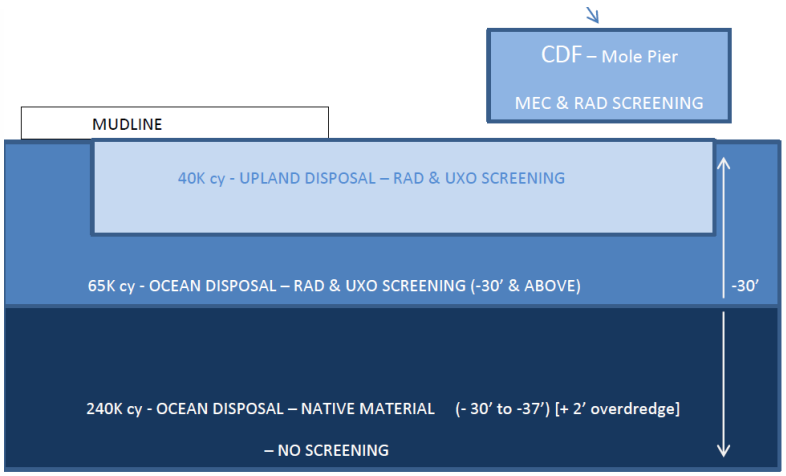
IAEA, 2015. Determining the Suitability of Materials for Disposal at Sea under the London Convention 1972 and London Protocol 1996: A Radiological Assessment Procedure. IAEA-TECDOC-1759, IAEA, Vienna (2015). Available online at http://www-pub.iaea.org/books/IAEABooks/10841/Determining-the-Suitability-of-Materials-for-Disposal-at-Sea-under-the-London-Convention-1

Figure 1. Dredging Overview at Pier 1

- Total Dredge Volume ~480,000 cy
- Completed dredging volume (85K Ocean Disposed + 22 K Upland)
- 40,000 CY of dredge material needs to be removed from pier 12 which requires RAD and MEC/MPPEH screening. These dredge spoils require upland disposal. 18,000 cy will be disposed of in a CDF at the Mole Pier (1) and 40,000 cy to upland disposal (2)
- 65,000 cy of dredged material slated for open water disposal has required is subject to RAD and MEC/MPPH screening. This material is generally above -30 ft MLLW.
- 240,000 cy of material below -30 ft MLLW is considered to be native material and has been deemed suitable for open water disposal without screening for RAD or MEC/MPPH



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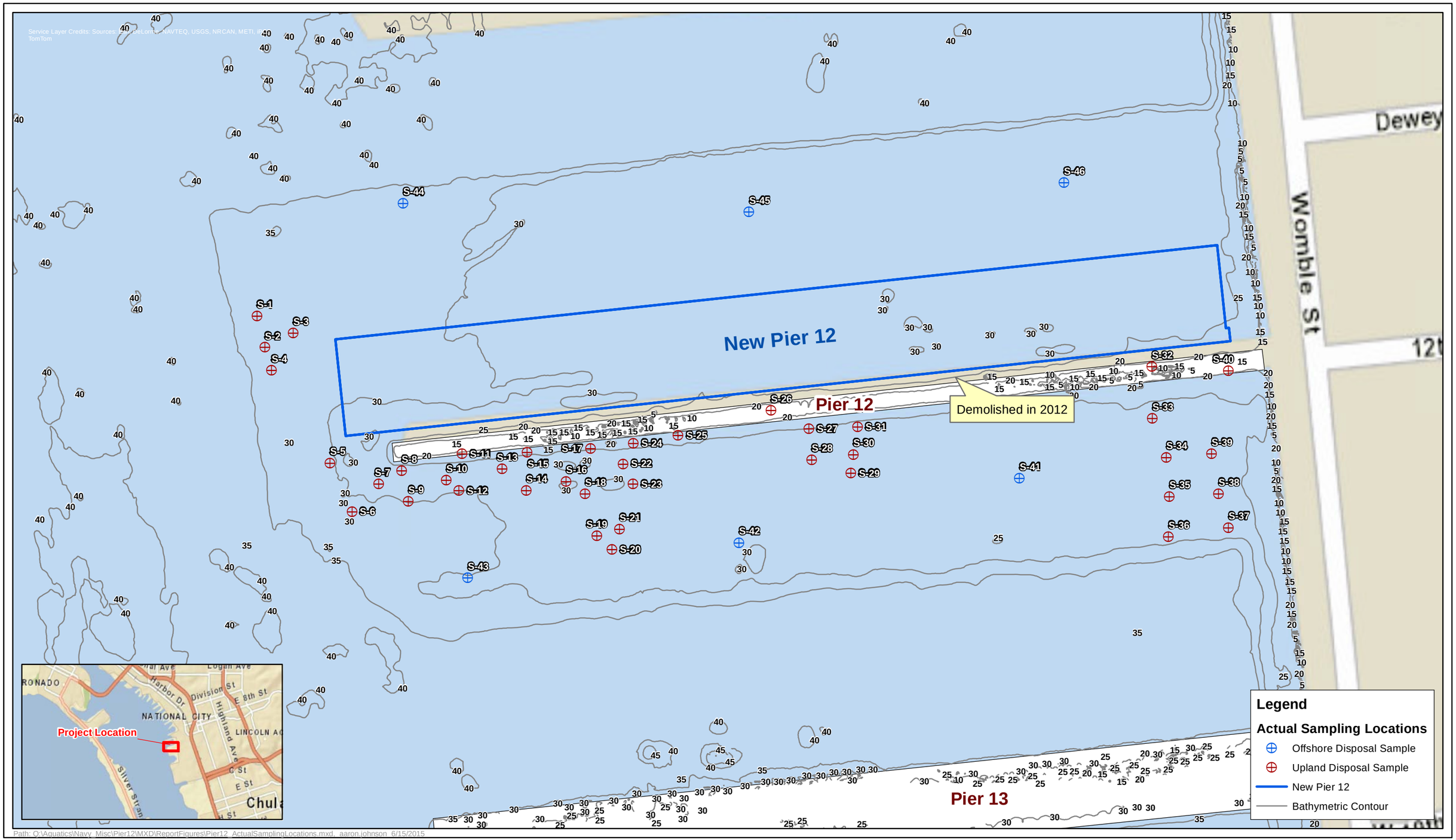
PIER 12 - PLAN

Figure 2. Pier 12 Dredged Material Areas

GRAPHIC SCALE	DATE		NAVAL FACILITIES ENGINEERING COMMAND SOUTHWEST DIVISION SAN DIEGO, CA	
NO SCALE	FEB 2011	MOFFATT & NICHOL • BLAYLOCK Contract Number N62473-08-D-8619	NAVAL BASE SAN DIEGO, CA PIER 12 DISPOSAL LOCATIONS	FIG. NO. 2



Path: Q:\Aquatics\Navy_Misc\Pier12\MXD\ReportFigures\Pier12_ActualSamplingLocations.mxd, aaron.johnson 6/15/2015

Figure 3. Radiological Core Sampling Areas

Actual Sampling Locations
Pier 12 Radiological Surveys
Naval Base San Diego
San Diego, California

FIGURE
3

Table 1. Vibracore Sampling Locations and Field Notes (see Figure 3)

Station Identifier	Latitude WGS84 (dd°mm.mmm')	Longitude WGS84 (dd°mm.mmm')	Date	Time	Attempt	Existing Mudline (ft MLLW)	Target Core Length (ft)	Target Core Depth (MLLW)	Penetration Depth (ft core)	Penetration Depth (MLLW)	Recovered Core Length (ft)	Notes
1	32° 39.875	-117° 07.461	6/9/2015	0805	1	32.02	4.5	36.5	0.5	32.5	--	Total core refusal. Moved 10 feet south for attempt 2.
	32° 39.871	-117° 07.462	6/9/2015	0810	2	31.82	4.5	36.3	0.5	32.3	--	Hard pan, no recovery. Total core refusal.
	32° 39.871	-117° 07.462	6/9/2015	0815	3	31.82	4.5	36.3	1.0	32.8	0.8	Hard pan, core refusal at 1 foot. Retrieved 8 inches of sediment.
2	32° 39.862	-117° 07.459	6/11/2015	0800	1	31.32	4.5	35.8	3.0	34.3	--	Vibracore tipping at 2 feet penetration. Very hard material from 2.5 to 3 feet. Total core refusal, no recovery.
	32° 39.862	-117° 07.459	6/11/2015	0805	2	31.32	4.5	35.8	2.0	33.3	1.1	Vibracore tipping at 2 feet penetration. Refusal at 2 feet, sample retrieved. Plug is sandy with shell hash and made of formational native dry clayey sand.
3	32° 39.866	-117° 07.450	6/11/2015	0825	1	31.65	4.5	36.2	3.5	35.2	2.0	Refusal at 3.5 feet penetration. Formational native plug (dry clayey sand with shell hash).
4	32° 39.856	-117° 07.457	6/8/2015	0810	1	28.07	4.5	32.6	4.5	32.6	3.3	Reached formational native material. Hard at 3 feet penetration.
5	32° 39.831	-117° 07.438	6/8/2015	0855	1	29.07	6	35.1	5.8	34.9	4.6	Reached formational native material. Hard at 4 feet penetration.
6	32° 39.818	-117° 07.431	6/8/2015	0955	1	30.16	6	36.2	6.0	36.2	4.2	Reached formational native material. Hard at 5 feet penetration. Clayey sand plug.
7	32° 39.825	-117° 07.422	6/9/2015	1115	1	29.73	6	35.7	5.8	35.5	3.9	Refusal at 5.8 feet. Formational native material in plug.
8	32° 39.829	-117° 07.415	6/11/2015	0910	1	24.72	6	30.7	6.0	30.7	4.9	Full penetration; soft plug.
9	32° 39.821	-117° 07.412	6/9/2015	0855	1	25.68	6	31.7	6.0	31.7	3.2	Full penetration.
10	32° 39.827	-117° 07.400	6/9/2015	1050	1	27.85	6	33.9	6.0	33.9	5.0	Full penetration.
11	32° 39.834	-117° 07.395	6/11/2015	0935	1	23.02	6	29.0	6.0	29.0	5.1	Moved sampling location 10 feet west to avoid magnetic signature at proposed sampling point. No refusal; soft plug with shell hash.
12	32° 39.824	-117° 07.396	6/9/2015	0920	1	28.31	6	34.3	6.0	34.3	4.5	Full penetration.
13	32° 39.830	-117° 07.382	6/9/2015	1005	1	25.72	6	31.7	6.0	31.7	6.0	Full penetration.
14	32° 39.824	-117° 07.374	6/9/2015	0945	1	26.80	6	32.8	6.0	32.8	4.7	Full penetration.
15	32° 39.834	-117° 07.374	6/10/2015	1245	1	26.04	6	32.0	6.0	32.0	4.7	Hard resistance at 2 feet. Full penetration. Sand plug.
16	32° 39.826	-117° 07.362	6/10/2015	1130	1	29.07	6	35.1	4.8	33.9	3.6	Adjusted location because of magnetic signature under proposed sampling location. Very hard at 4.5 feet penetration. Refusal at 4.8 feet. Plug is very sandy, compacted, and dry. Plug is made of formational native material (clayey sand).
17	32° 39.836	-117° 07.354	6/10/2015	1300	1	27.73	6	33.7	6.0	33.7	5.1	Full penetration. Sandy plug with shell hash.
18	32° 39.823	-117° 07.355	6/8/2015	1500	1	28.09	6	34.1	6.0	34.1	4.6	Full penetration.
19	32° 39.812	-117° 07.351	6/8/2015	1335	1	28.53	6	34.5	6.0	34.5	3.8	Full penetration.
20	32° 39.805	-117° 07.345	6/8/2015	1035	1	28.52	6	34.5	4.5	33.0	3.2	Material hard at 4.5 feet, vibracore refusal, no formational native material in plug.
	32° 39.808	-117° 07.347	6/8/2015	1055	2	28.44	6	34.4	4.0	32.4	2.0	Material hard at 4.0 feet, no formational native material in plug.
	32° 39.808	-117° 07.347	6/8/2015	1115	3	28.44	6	34.4	4.0	32.4	3.0	No formational native material in plug; vibracore refusal.
21	32° 39.813	-117° 07.344	6/8/2015	1410	1	28.61	6	34.6	6.0	34.6	5.0	Full penetration.
22	32° 39.831	-117° 07.343	6/10/2015	0925	1	24.29	6	30.3	6.0	30.3	5.7	Full penetration. Material appears soft at bottom of core. Sediment has odor. Core sleeve is completely full (sediment expanded upon extraction). Lots of shells in sediment.
23	32° 39.826	-117° 07.340	6/8/2015	1525	1	27.34	6	33.3	6.0	33.3	4.5	Full penetration.
24	32° 39.837	-117° 07.340	6/10/2015	0945	1	24.24	6	30.2	6.0	30.2	5.4	Full penetration. Good recovery; no plug.
25	32° 39.839	-117° 07.325	6/10/2015	1015	1	23.01	4.5	27.5	4.5	27.5	4.2	Full penetration, soft plug.

Table 1. Vibracore Sampling Locations and Field Notes (see Figure 3)

Station Identifier	Latitude WGS84 (dd°mm.mmm')	Longitude WGS84 (dd°mm.mmm')	Date	Time	Attempt	Existing Mudline (ft MLLW)	Target Core Length (ft)	Target Core Depth (MLLW)	Penetration Depth (ft core)	Penetration Depth (MLLW)	Recovered Core Length (ft)	Notes
26	32° 39.846	-117° 07.296	6/10/2015	1050	1	19.76	4.5	24.3	4.5	24.3	3.9	Full penetration, soft plug.
27	32° 39.841	-117° 07.283	6/9/2015	1410	1	26.45	4.5	31.0	6.0	32.5	4.2	Full penetration.
28	32° 39.833	-117° 07.282	6/9/2015	1345	1	28.47	4.5	33.0	4.5	33.0	2.9	Full penetration; very hard plug.
29	32° 39.829	-117° 07.269	6/10/2015	0800	1	26.32	4.5	30.8	4.5	30.8	4.1	Full penetration. Solid plug of formational native material.
30	32° 39.834	-117° 07.269	6/10/2015	0825	1	26.04	4.5	30.5	4.5	30.5	3.2	Full penetration. Sandy plug.
31	32° 39.842	-117° 07.268	6/10/2015	0850	1	24.85	4.5	29.4	5.0	29.9	4.8	Full penetration. Plug of sand and shell hash.
32	32° 39.859	-117° 07.173	6/11/2015	1110	1	21.78	4.5	26.3	4.5	26.3	4.5	Moved 10 feet starboard (west) to avoid magnetic signature at proposed sampling location. Full penetration; soft plug – sand with shell hash.
33	32° 39.845	-117° 07.172	6/11/2015	1010	1	26.58	4.5	31.1	1.0	27.6	--	Surface is very hard; vibracore unable to penetrate more than 1-foot. Total core refusal/no recovery.
	32° 39.845	-117° 07.172	6/11/2015	1020	2	23.66	4.5	28.2	6.0	29.7	5.2	Moved 10 feet toward pier to see if core could be recovered. Sediment very hard at 4 feet. Shell hash/sand plug.
34	32° 39.834	-117° 07.168	6/11/2015	1200	1	26.31	4.5	30.8	4.5	30.8	3.1	Full penetration; plug is sand and shell hash.
35	32° 39.824	-117° 07.167	6/11/2015	1350	1	26.99	4.5	31.5	4.5	31.5	3.5	Full penetration; formational native at base of core, clayey sand.
36	32° 39.813	-117° 07.167	6/12/2015	0810	1	27.85	4.5	32.4	4.5	32.4	2.8	Full penetration; clean/formational native plug
37	32° 39.815	-117° 07.147	6/12/2015	0830	1	27.36	4.5	31.9	4.5	31.9	1.7	Full penetration; no refusal. Plug is hard, formational native clayey sand
38	32° 39.824	-117° 07.151	6/11/2015	1410	1	26.76	4.5	31.3	4.0	30.8	3.0	Refusal at 4.0 feet; native formational material in plug (clayey sand).
39	32° 39.835	-117° 07.153	6/11/2015	1310	1	26.35	4.5	30.9	4.5	30.9	3.3	Full penetration; clayey sand (formational native) plug.
40	32° 39.858	-117° 07.148	6/11/2015	1135	1	19.54	4.5	24.0	4.5	24.0	4.5	Full penetration; sand plug with shell hash.
41	32° 39.828	-117° 07.215	6/10/2015	1335	1	26.78	6	32.8	6.0	32.8	4.1	Full penetration; sand plug with shell hash.
42	32° 39.810	-117° 07.305	6/8/2015	1200	1	29.30	6	35.3	4.0	33.3	1.8	Material hard at 4 feet penetration. No formational native material in plug.
	32° 39.810	-117° 07.305	6/8/2015	1215	2	29.30	6	35.3	4.0	33.3	1.5	Material hard at 4 feet penetration. No formational native material in plug.
	32° 39.810	-117° 07.305	6/8/2015	1235	3	29.30	6	35.3	3.0	32.3	1.0	Material hard at 3 feet penetration. No formational native material in plug.
43	32° 39.800	-117° 07.391	6/9/2015	1200	1	30.08	6	36.1	4.0	34.1	2.3	Material hard at 3 feet, core refusal at 4 feet penetration. Very dry sand at base of core; full sand core retrieved. Core plug fell out on retrieval.
	32° 39.800	-117° 07.393	6/9/2015	1215	2	29.90	6	35.9	5.0	34.9	2.3	Moved 10 feet west for attempt 2; clay on side of core barrel but no plug. Core refusal at 5 feet penetration.
	32° 39.800	-117° 07.393	6/9/2015	1225	3	29.90	6	35.9	5.0	34.9	1.2	Same location as attempt 2. Refusal at 5 feet penetration. Core is hard packed and dry sand. No plug.
44	32° 39.902	-117° 07.415	6/12/2015	0915	1	30.08	6	36.1	4.5	34.6	2.5	Hard @ 4.2 feet penetration. Clay on outside of core barrel. No plug. Clayey sand at base of core (formational native material).
45	32° 39.900	-117° 07.303	6/12/2015	0950	1	25.91	6	31.9	3.5	29.4	1.7	At 3.5 feet penetration the vibracore began to tip. Refusal at 3.5 feet. Plug in core barrel made of clayey sand (formational native material).
46	32° 39.909	-117° 07.201	6/10/2015	1425	1	26.49	6	32.5	6.0	32.5	4.7	Full penetration; no plug.

Table 2. Vibracore Sample Gamma Count Reading and Laboratory Sample Elevation

Sample ID Number	Date	Field Core Location	Water Depth at Mudline (-ft MLLW)	Sample Depth for Cores (ft MLLW)	Dose Readings on Core Samples		
					Analysis	2x2 1 min	ur/hr
Radiological Core Samples Collected for Open Water Characterization (Dredge Cells D - G)							
J292-DM-061	6/10/2015	41	-26.78	-33.8 to -34.5'	Ra-226, Sr-90	11,778	13
J292-DM-062	6/8/2015	42	-29.3	-32.6 to -33.3'	Ra-226, Sr-90	11,423	14
J292-DM-063	6/9/2015	43	-29.9	-35.3 to -36.0'	Ra-226, Sr-90	10,395	13
J292-DM-064	6/12/2015	44	-30.08	-34.3 to -35.0'	Ra-226, Sr-90	11,021	12
J292-DM-065	6/12/2015	45	-25.91	-32.-3 to -33.0'	Ra-226, Sr-90	11,108	12
J292-DM-066	6/10/2015	46	-26.49	-34.3 to -35.0'	Ra-226, Sr-90	11,806	13
Radiological Core Samples Collected from 50 ppb target areas (Dredge Cells A - G)							
Core Samples Collected at, or shallower, than -30 ft MLLW							
J292-DM-046	6/10/2015	26	-19.76	-24.6 to -25.3'	Ra-226, Sr-90	11,856	13
J292-DM-060	6/11/2015	40	-19.54	-24.8 to -25.5'	Ra-226, Sr-90	11,673	13
J292-DM-052	6/11/2015	32	-21.78	-27.3 to -28.0'	Ra-226, Sr-90	11,447	13
J292-DM-045	6/10/2015	25	-23.01	-28.3 to -29.0'	Ra-226, Sr-90	11,725	13
J292-DM-029	6/9/2015	9	-29.5	-29.5 to 30.2'	Ra-226, Sr-90	10,431	13
J292-DM-054	6/11/2015	34	-26.31	-29.9 to 30.6'	Ra-226, Sr-90	11,249	12
Core Samples Collected deeper than -30 ft MLLW							
J292-DM-053	6/11/2015	33	-23.66	-30.5 to -31.2'	Ra-226, Sr-90	11,350	13
J292-DM-058	6/11/2015	38	-26.76	-30.8 to -31.5'	Ra-226, Sr-90	11,250	13
J292-DM-031	6/11/2015	11	-23.02	-31.-3 to -32.0'	Ra-226, Sr-90	11,612	13
J292-DM-044	6/10/2015	24	-24.24	-31.-3 to -32.0'	Ra-226, Sr-90	11,843	13
J292-DM-059	6/11/2015	39	-26.35	-31.-3 to -32.0'	Ra-226, Sr-90	11,449	13
J292-DM-042	6/10/2015	22	-24.29	-31.6 to -32.3	Ra-226, Sr-90	11,886	13
J292-DM-047	6/9/2015	27	-26.45	-31.6 to -35.-3'	Ra-226, Sr-90	10,258	13
J292-DM-051	6/10/2015	31	-24.85	-31.7 to -32.5'	Ra-226, Sr-90	11,573	13
J292-DM-033	6/9/2015	13	-25.72	-31.8 to -32.5'	Ra-226, Sr-90	10,367	13
J292-DM-024	6/8/2015	4	-28.07	-31.9 to -32.6'	Ra-226, Sr-90	11,358	14
J292-DM-055	6/11/2015	35	-26.99	-32.-3 to -33.0'	Ra-226, Sr-90	11,206	12
J292-DM-040	6/8/2015	20	-28.52	-32.4 to -33.0'	Ra-226, Sr-90	11,591	14
J292-DM-035	6/10/2015	15	-26.04	-32.4 to -33.1'	Ra-226, Sr-90	12,566	13
J292-DM-043	6/8/2015	23	-27.34	-32.7 to -33.3'	Ra-226, Sr-90	11,129	14
J292-DM-050	6/10/2015	30	-26.04	-32.8 to -33.5'	Ra-226, Sr-90	12,022	13
J292-DM-034	6/9/2015	14	-26.8	-33.0 to -33.7'	Ra-226, Sr-90	10,593	13
J292-DM-028	6/11/2015	8	-24.72	-33.3 to -34.0'	Ra-226, Sr-90	11,628	13
J292-DM-032	6/9/2015	12	-28.31	-33.3 to -34.0'	Ra-226, Sr-90	10,661	13
J292-DM-049	6/10/2015	29	-26.32	-33.3 to -34.0'	Ra-226, Sr-90	11,674	13
J292-DM-038	6/8/2015	18	-28.09	-33.4 to -34.1'	Ra-226, Sr-90	11,263	14
J292-DM-021	6/9/2015	1	-31.8	-33.8 to -34.5'	Ra-226, Sr-90	10,935	14
J292-DM-030	6/9/2015	10	-27.85	-33.8 to -34.5'	Ra-226, Sr-90	10,106	13
J292-DM-039	6/8/2015	19	-28.53	-33.9 to -34.5'	Ra-226, Sr-90	11,057	14
J292-DM-041	6/8/2015	21	-28.61	-33.9 to -34.6'	Ra-226, Sr-90	11,280	13
J292-DM-036	6/10/2015	16	-29.07	-34.1 to -34.8'	Ra-226, Sr-90	11,641	13
J292-DM-025	6/8/2015	5	-29.07	-34.2 to -34.9'	Ra-226, Sr-90	11,825	13
J292-DM-037	6/10/2015	17	-27.73	-34.3 to -35.0'	Ra-226, Sr-90	12,011	13
J292-DM-048	6/9/2015	28	-28.47	-34.8 to -35.5'	Ra-226, Sr-90	10,397	13
J292-DM-057	6/12/2015	37	-27.36	-35.-3 to -36.0'	Ra-226, Sr-90	11,530	12
J292-DM-026	6/8/2015	6	-30.16	-35.5 to -36.2'	Ra-226, Sr-90	11,561	14
J292-DM-027	6/9/2015	7	-29.73	-35.5 to -36.2'	Ra-226, Sr-90	10,532	13
J292-DM-056	6/12/2015	36	-27.85	-35.8 to -36.5'	Ra-226, Sr-90	11,434	12
J292-DM-022	6/11/2015	2	-31.32	-36.5 to -37.2'	Ra-226, Sr-90	11,911	12
J292-DM-023	6/11/2015	3	-31.65	-38.1 to -38.8'	Ra-226, Sr-90	11,781	12

Radioactive Object Collection Log

Item #	Description	Dose Rate MR/HR	Location of Discovery	Depth Located (inches)	1 inch Reading 2X2 cnts	Dose Rate @ 30 cm (mR/hr)	Calculated Activity (µCi)	Date-Time	Comments (isotopic identification)
RO-001	Deck Marker	2.4	SU-REF	12	716,017	0.050	6.1	5/18/15-1258	RA-226 & unknown low energy peak
RO-002	Deck Marker	1.2	SU-REF	12	507,717	0.075	9.2	5/18/15-1303	RA-226: Attached to corroded piece of metal
RO-003	Deck Marker	2	SU-REF	11	560,869	0.070	8.6	5/18/15-1315	RA-226
RO-004	Deck Marker	2	SU-REF	7	644,563	0.060	7.3	5/18/15-1330	RA-226
RO-005	Unknown	0.5	Scrap Metal	N/A	177,053	0.040	4.9	5/21/15-1300	Ra-226
RO-006	Ra-226 Rope	9	Scrap Metal	N/A	1,463,641	0.280	34.3	5/21/15-1330	Ra-226
RO-007	Ra-226 Rope	1.4	Screen Plant	N/A	439,679	0.060	7.3	5/22/15-1600	Ra-226
RO-008	Ra-226 Rope	0.7	REF Pad-Base	10	168,659	0.040	4.9	5/26/15-1600	Ra-226
RO-009	Ra-226 Rope	4.6	Screen Plant	N/A	1,204,420	0.120	14.7	5/26/15-1630	Ra-226
RO-010	Ra-226 Rope	0.3	REF Pad-Base	4	71,718	0.028	3.4	5/27/15-0930	Ra-226
RO-011	Control Knob	0.6	SU-002	3	188,686	0.028	3.4	5/27/15-1620	Ra-226
RO-012	Ra-226 Rope	0.4	SU-005	5	112,750	0.015	1.8	6/01/15-1115	Ra-226
RO-013	Control Knob	0.9	SU-005	3	255,249	0.020	2.4	6/01/15-1115	Ra-226
RO-014	Ra-226 Rope	0.9	SU-003	3	214,792	0.020	2.4	6/02/15-1000	Ra-226
RO-015	Ra-226 Rope	1	SU-003	3	227,705	0.020	2.4	6/02/15-1030	Ra-226
RO-016	Ra-226 Rope	4.4	Screen Plant	N/A	1,408,398	0.110	13.5	6/02/15-1630	Ra-226
RO-017	Ra-226 Rope	0.5	SU-006	4	121,146	0.015	1.8	6/03/15-1345	Ra-226
RO-018	Deck Marker damaged / broken	0.3	SU-006	5	72,626	0.013	1.6	6/03/15-1440	Ra-226
RO-019	Deck Marker damaged	1.3	CDF	surface	395,626	0.024	2.9	6/05/15-0740	Ra-226, removed 1 cuft pf soil surrounding deck marker
RO-020	Deck Marker	1.7	Screen Plant	N/A	542,739	0.026	3.2	6/05/15-1230	Ra-226
RO-021	Deck Marker	3	Screen Plant area	N/A	800,377	0.032	3.9	6/08/15-1130	Ra-226
RO-022	Ra-226 Rope	2	Screen Plant area	N/A	639,226	0.050	6.1	6/17/15-0730	Ra-226
RO-023	Ra-226 Rope	2	CDF	2	605,972	0.033	4.0	6/18/15-0730	Ra-226
RO-024	Ra-226 Rope	0.24	Scrap Metal	N/A	74,943	0.013	1.6	7/28/15-0930	Ra-226
RO-025	Deck Marker	2	Screen Plant	N/A	407,090	0.016	2.0	9/21/2015-1410	Ra-226
RO-026	Deck Marker	3.6	Screen Plant	N/A	674,247	0.045	5.5	9/22/2015-1620	Ra-226
RO-027	Button	1	SU-007	4	173,882	0.009	1.1	9/23/2015-1100	Ra-226
RO-028	Deck Marker	2.8	Screen Plant	N/A	607,726	0.038	4.6	9/23/2015-1212	Ra-226
RO-029	Ra-226 Rope	0.7	Screen Plant	N/A	267,233	0.018	2.2	9/25/2015-1650	Ra-226
RO-030	Button	1.2	Screen Plant	N/A	267,978	0.015	1.8	10/1/2015-1300	Ra-226
RO-031	Deck Marker	1	Screen Plant	N/A	215,252	0.011	1.4	10/2/2015-1300	Ra-226
RO-032	Ra-226 Rope	0.08	Screen Plant	N/A	31,583	0.003	0.4	10/2/2015-1305	Ra-226
RO-033	Ra-226 Rope	0.125	SU-008	3	35,715	0.003	0.4	10/2/2015-1445	Ra-226
RO-034	Deck Marker	10	Screen Plant	10	1,052,299	0.067	8.2	10/5/2015--1200	Ra-226
RO-035	Ra-226 Rope	0.42	Screen Plant	3	117,822	0.006	0.7	10/5/2015-1430	Ra-226
RO-036	Ra-226 Rope	1	Screen Plant	2	281,302	0.018	2.2	10/5/2015-1430	Ra-226
RO-037	Deck Marker	2	Screen Plant	N/A	445,202	0.022	2.7	10/5/2015-1500	Ra-226
RO-038	Button	0.7	Su-007	8	184,028	0.006	0.7	10/7/2015-1600	Ra-226
RO-039	Ra-226 Rope	0.17	Su-007	0	52,369	0.005	0.2	10/9/2015-0940	Ra-226
RO-040	Ra-226 Rope	0.22	Su-008	8	55,743	0.006	0.3	10/12/2015-1230	Ra-226
RO-041	Ra-226 Rope	0.34	Su-008	8	123,543	0.005	0.3	10/12/2015-1400	Ra-226
RO-042	Button	4.4	SU-009	4	879,591	0.088	10.8	10/13/2015-1200	Ra-226
RO-043	Ra-226 Rope	0.3	SU-009	7	90,083	0.005	0.6	10/13/2015-1218	Ra-226
RO-044	Fragment	0.034	SU-009	0	15,666	0.000	0.1	10/13/2015-1520	Ra-226
RO-045	Fragment	0.03	SU-010	0	11,367	0.000	0.1	11/13/2015-1100	Ra-226
RO-046	Ra-226 Rope	0.6	SU-012	8	174,340	0.011	1.3	12/1/2015-1315	Ra-226
RO-047	Ra-226 Rope	0.6	SU-012	7	143,742	0.007	0.9	12/2/2015-0830	Ra-226
RO-048	Deck Marker damaged / broken	0.05	SU-013	2	42,002	0.003	0.4	12/10/2015-0901	Ra-226
RO-049	Ra-226 Rope	0.8	SU-014	6	182,525	0.019	2.3	1/21/2016-0940	Ra-226
RO-050	Deck Marker	1	Screen Plant	2	455,592	0.027	3.3	1/22/2016-1530	Ra-226
RO-051	Ra-226 Rope	0.21	SU-015	4	144,867	0.004	0.5	1/29/2016-1200	Ra-226
RO-052	Ra-226 Rope	0.6	SU-016	4	794,125	0.003	1.6	2/11/2016-0942	Ra-226
RO-053	Ra-226 Rope	0.22	SU-016	2	249,455	0.001	0.6	2/11/2016-1115	Ra-226

Table 4. Comparison of Vibracore Samples and Waste Characterization Samples to EPA 1999 Background Levels							
Element	**Number of Samples**	**Number Detected Values**	**Mean**	**Median**	**Minimum**	**Maxium**	**1999 EPA Background Average**
			Activity (pCi / g-dry weight)				
Radiological Core Samples Collected from above 30 ft MLLW (65,000 cy characteriztion)							
Radium 226 [1]	6	6	0.3807	0.3960	0.2080	0.4970	0.4303
Cesium 137 [2]	6	1	0.0508	0.0505	0.0000	0.1310	0.0101
Cobalt 60 [3]	6	0	0.0045	0.0015	-0.0100	0.0260	ND
Strontium (total) [4]	6	1	-0.0059	-0.0085	-0.2810	0.1420	not measured
Radiological Core Samples Collected from below 30 ft MLLW (native material characteriztion)							
Radium 226 [1]	40	40	0.4231	0.4070	0.1830	0.7290	0.4303
Cesium 137 [2]	40	1	0.0046	0.0030	-0.0260	0.0830	0.0101
Cobalt 60 [3]	40	0	0.0013	0.0015	-0.0280	0.0320	ND
Strontium (total) [4]	40	1	-0.0377	-0.0240	-0.2460	0.0790	not measured
Radiological Core Samples - ALL							
Radium 226 [1]	46	46	0.4176	0.4045	0.1830	0.7290	0.4303
Cesium 137 [2]	46	2	0.0106	0.0020	-0.0260	0.1310	0.0101
Cobalt 60 [3]	46	0	0.0017	0.0015	-0.0280	0.0320	ND
Strontium (total) [4]	46	0	-0.0100	-0.0110	-0.2810	0.1420	not measured

1. Radium background values from UEPA 1999 Table A.13

2. Cesium summary statistics calculated using all values including non-detected values at the reporting limit. 1999 USN Background based on 1/4 detected samples

3. Cobalt 60 summary statistics calculated using all values including non-detected values at the reporting limit. The 1999 USN Sediment Study had no detections of Co60 in any sediment, inlcuding background stations.

4. Total strontium summary statistics calculated using all values, included non-detected values at the reporting limit. The 1999 USN Sediment study did not measure for strontium

APPENDIX A

Human Health and Ecological Assessment of Sediment Dredged from Pier 12 Berthing Areas at Naval Base San Diego as "*de minimis*" for Ocean Disposal Purposes under the London Convention and Protocol

Introduction

The U.S. Navy is conducting dredging and disposal operations as part of the Pier 12 replacement project (P-327 MILCON) at Naval Base San Diego (NBSD). Pier berthing areas will be deepened to a depth of 37 feet. This involves the removal of approximately 58,000 cubic yards (cy) of shallow surface sediment destined for upland disposal and 65,000 cy of deeper subsurface and native sediment destined for ocean disposal at LA-5.

This white paper assesses whether the 65,000 cy of subsurface and native sediment can be regarded as containing *de minimis* levels of radioactivity for the purpose of the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972 and 1996 Protocol Thereto (the London Convention and Protocol), and thereby be considered suitable for ocean disposal. The 58,000 cy of surface sediment has been determined to not be suitable for ocean disposal for reasons other than radioactivity content.

'*De minimis*' Criteria for Ocean Disposal of Material under the London Convention and Protocol

The London Convention and Protocol prohibits the disposal of radioactive wastes and other radioactive matter at sea. However, all materials, including natural and inert materials, contain radionuclides of natural origin and are frequently contaminated with artificial radionuclides from such anthropogenic sources as fallout due to past atmospheric nuclear testing, nuclear accidents and authorized discharges from nuclear and radioactive installations. The Contracting Parties to the London Convention and Protocol requested that the International Atomic Energy Agency (IAEA) develop definitions and guidelines so that candidate materials containing less than *de minimis* levels of radioactivity can be regarded as 'non-radioactive' and disposed of at sea pursuant to the provisions of the London Convention and Protocol.

The IAEA presented its guidance on *de minimis* in IAEA-TECDOC-1068, *Application of Radiological Exclusion and Exemption Principles to Sea Disposal* (IAEA, 1999). The guidance establishes four measures for assessing whether candidate materials can be considered *de minimis* for ocean disposal without further consideration as follows:

> "*Materials eligible for consideration for dumping at sea under the London Convention that can be assigned as 'de minimis' (exempt) without further consideration from the perspective of their radionuclide content are therefore those containing only:*
>
> *(1) natural radionuclides in environmental and raw materials, unless there is concern on the part of the national regulatory authority that the radiation field would be substantially modified;*
>
> *(2) radionuclides in materials derived from activities involving some modification of the natural radionuclide composition that has been considered by the national regulatory authority, and deemed not to warrant radiological control, having taken proper account of the marine environmental and other conditions relevant to the disposal, re-use and relocation of such*

materials;

(3) widely-distributed radionuclides resulting from global fallout from nuclear weapons tests, satellite burnup in the stratosphere, and accidents, that have led to widespread dispersion of radionuclides that are deemed by the national regulatory authority not to warrant intervention; and

(4) radionuclides arising from sources and practices that have been exempted or cleared nationally from radiological control, pursuant to the application of the international criteria for exemption and clearance, where proper account has been taken of the marine environmental and other conditions relevant to potential disposal, re-use and relocation of such materials."

The 65,000 cy of subsurface and native sediment to be dredged readily meet the first three measures. Pursuant to the first measure, the sediment contains only natural radionuclides in its environmental make-up. The natural radionuclide composition of the sediment has not been modified; therefore, the second measure does not apply. Beyond the natural radionuclides in its material composition, the native sediment may contain widely-distributed radionuclides resulting from global fallout from nuclear weapon tests, burnup in the stratosphere, and accidents pursuant to the third measure.

The fourth measure addresses radionuclides arising from sources and practices where proper account has not been taken of the marine environmental and other conditions relevant to potential disposal. This measure may be considered as not met for the following reason. Pier 12 is located on an active Navy base that has been in operation for roughly 90 years. Historical operations at NBSD from the 1940's to the 1970's included performing ship repair and decommissioning activities involving the use, handling, and replacement of radioluminescent devices (time pieces, compasses, dials, gauges, switches, and deck/personnel markers). Radioluminescent devices containing radium-226 (^{226}Ra) were used on personnel, support equipment, aircraft, ships, and vehicles and historically may have been disposed of on land or at the piers or pier heads at NBSD. Radiological screening of the surface sediment performed to date has resulted in the recovery of discrete radioactive debris and devices containing ^{226}Ra confirming the historical impact. Though the subsurface and native sediment is much less likely to contain discrete radioactive debris and devices than the surface sediment, the potential nevertheless remains. Therefore, a specific radiological assessment to determine if the sediment can be treated as *de minimis* for ocean disposal purposes under the London Convention and Protocol is warranted.

It should be noted that widely-distributed contamination of the sediment with other than discrete radioactive debris and devices is not suspected. This is confirmed by samples collected from both the surface sediment and the subsurface and native sediment. The sample results were compared with a radiological survey of San Diego Harbor performed by the United States Environmental Protection Agency (EPA) in March, 1997. Radioactivity measured in the samples is consistent with the EPA results and is therefore considered to be constituent material of the sediment itself and not a result of contamination. See Attachment 1 for discussion of sediment sample results and comparison with the 1997 EPA study.

<u>Specific Radiological Assessments of Candidate Materials</u>

Candidate materials that cannot be exempted without further consideration, such as the 65,000 cy of subsurface and native sediment, may be subjected to a specific assessment to determine if they still qualify as *de minimis* for the purposes of the London Convention and Protocol. By direction of the

Contracting Parties to the London Convention and Protocol, the IAEA prepared additional guidance contained in IAEA-TECDOC-1759, *Determining the Suitability of Materials for Disposal at Sea under the London Convention 1972 and London Protocol 1996: A Radiological Assessment Procedure* (IAEA, 2015). This guidance applies the *de minimis* concept similarly to people and to marine flora and fauna. It is based on the assessment of individual and collective dose to humans (workers and members of the public) and dose rates to marine flora and fauna. The assessment method, despite being of a generic nature, introduces cautious assumptions regarding the dispersion of radionuclides in the ocean, the inclusion of comprehensive radiation exposure pathways, and the consideration of the habit data.

The specific assessment estimates radiation doses in microsieverts (µSv) in a year that could be received by human beings or radiation dose rates in micrograys per hour (µGy/hr) that could be received by marine flora and fauna exposed directly and indirectly to the radioactivity in the candidate material to be disposed at sea. As stated in IAEA-TECDOC-1759, Section 5.3.6:

> *"The candidate material may be considered suitable for further consideration for disposal under the [London Convention and Protocol] if:*
>
> > *(i) The estimated annual individual doses to members of the crew [working on ships that transport the material to the disposal site] and to the public [who may be exposed to the material after it has been disposed of] are independently equal to, or less than, 10 µSv; and*
> > *(ii) The estimated annual total collective dose is less than or equal to 1 man Sv; and*
> > *(iii) The estimated dose rates for each marine reference animal and plant is below or equal to the corresponding DCRLs [derived consideration reference levels].*
>
> *"If the material satisfies all the criteria for humans (crew and public) and flora and fauna [reference animals and plants] it is defined as de minimis without further consideration."*

<u>Criterion (i) - Individual Doses to Humans</u>

The limitation of individual risk is applied by considering the radiation doses in a group of individuals most likely to receive the highest effective doses from the practice, i.e., the critical group. Depending on the practice, the critical group may consist of workers or members of the public. Individual doses to humans are calculated using IAEA-TECDOC-1759, Section 5.3.2.

Screening coefficients for dose per unit activity concentration for ^{226}Ra necessary to calculate annual individual doses for crew and the public are given in IAEA-TECDOC-1759, Table 2, as 6.0×10^{-2} and 2.6×10^{-2} µSv per becquerel per kilogram (Bq/kg) dry weight, respectively, for crew and the public. It is noted that the screening coefficients for this and other dose calculations that follow include the contribution of progeny of the radionuclide (^{226}Ra) assuming secular equilibrium.

The radionuclide activity concentration in the candidate material can be calculated using IAEA-TECDOC-1759 Equations 1 through 4 simplified for a single radionuclide (^{226}Ra) below:

$$E_{ind} = \frac{M_A}{M_R} D_{ind} \; x \; C_{ind}$$

where:

E_{ind} = total annual individual dose for crew or the public (µSv)
M_A = actual mass of candidate material planned to be disposed of (kg, dry weight)

M_R = reference annual dumped mass used to calculate the screening coefficients ($1x10^8$ kg)
D_{ind} = screening coefficient from IAEA-TECDOC-1759, Table 2 (µSv per Bq/kg)
C_{ind} = radionuclide activity concentration for annual individual dose (Bq/kg, dry weight)

By setting E_{ind} equal to the *de minimis* criterion for individual dose to humans (10 µSv in a year), the corresponding radionuclide activity concentration (C) can be calculated. The actual planned mass of candidate material planned to be disposed of (M_A) is 65,000 cy of subsurface and native sediment. Using a conversion factor of 1 cy = 2,000 kilograms (kg), which assumes a sediment density of approximately 2.6 grams per cubic centimeter (g/cm^3), M_A equals $1.3x10^8$ kg.

$$C_{ind} = \frac{(E_{ind})(M_R)}{(D_{ind})(M_A)} = \frac{(10\ \mu Sv)(1x10^8\ kg)}{(D_{ind})(1.3x10^8\ kg)}$$

Applying the screening coefficients for annual individual doses for crew and the public ($6.0x10^{-2}$ and $2.6x10^{-2}$ µSv per Bq/kg, respectively), the radionuclide activity concentrations that result in an annual individual dose of 10 µSv are 128 Bq/kg for crew and 296 Bq/kg for the public.

The calculations above assume widely-distributed contamination rather than contamination in the form of radioactive debris and devices that would be found in the sediment dredged from the Pier 12 berthing area. To correlate the two types of contamination, the total radioactivity of the radioactive debris and devices is assumed to result in a dose equivalent to widely-distributed radioactivity given the same volume of sediment. Radiological screening of the surface sediment performed to date has resulted in the recovery of discrete radioactive debris and devices totaling 54 objects, with a total activity of $7.81x10^6$ Bq. Approximately 11,700 cy of sediment have been radiologically screened to date, which is equivalent to $2.37x10^7$ kilograms (kg), assuming a sediment density of 2.65 g/cm^3. The total radioactivity of the 54 objects ($7.81x10^6$ Bq) distributed over the radiologically screened volume of sediment ($2.37x10^7$ kg) yields a radionuclide activity concentration of 0.33 Bq/kg. This radionuclide activity concentration is much less than the concentration needed to produce an annual individual dose of 10 µSv to either crew members or members of the public.

The assessment above is based on results from the radiological screening of surface sediment, which has a much higher potential for radioactive debris and devices than does subsurface and native sediment. Therefore, the conclusion that the criterion for individual dose to humans is met can be extended safely to subsurface and native sediment.

<u>Criterion (ii) - Collective Doses to Humans</u>

The individual risk level is most helpful in putting radiation risks to individuals into perspective. In most practical situations, however, the total health detriment is also of interest in considering source-related assessments. Collective doses to humans are calculated using IAEA-TECDOC-1759, Section 5.3.3.

Screening coefficients for dose per unit activity concentration for ^{226}Ra necessary to calculate annual collective doses for crew and the public are given in IAEA-TECDOC-1759, Table 2, as $6.0x10^{-6}$ and $1.2x10^{-3}$ man Sv per Bq/kg dry weight, respectively, for crew and the public.

The radionuclide activity concentration in the candidate material can be calculated using IAEA-TECDOC-1759 Equations 5 through 8 simplified for a single radionuclide (^{226}Ra) below:

$$E_{coll} = \frac{M_A}{M_R} D_{coll}\ x\ C_{coll}$$

where variables not previously defined:

E_{coll} = total annual collective dose for crew or the public (man Sv)
D_{coll} = screening coefficient from IAEA-TECDOC-1759, Table 2 (man Sv per Bq/kg)
C_{coll} = radionuclide activity concentration for annual collective dose (Bq/kg, dry weight)

By setting E_{coll} equal to the *de minimis* criterion for collective dose to humans (1 man Sv), the corresponding radionuclide activity concentration (C_{coll}) can be calculated.

$$C_{coll} = \frac{(E_{coll})(M_R)}{(D_{coll})(M_A)} = \frac{(1\ man\ Sv)(1x10^8\ kg)}{(D_{coll})(1.3x10^8\ kg)}$$

Using the screening coefficients for annual collective doses for crew and the public ($6.0x10^{-6}$ and $1.2x10^{-3}$ man Sv per Bq/kg, respectively), the radionuclide activity concentrations that result in an annual collective dose of 1 man Sv are $1.28x10^5$ Bq/kg for crew and 641 Bq/kg for the public. The final step is to sum the total collective dose to the crew and the public, which equals $1.29x10^5$ Bq/kg.

The calculations above assume widely-distributed contamination rather than contamination in the form of radioactive debris and devices that would be found in the sediment dredged from the Pier 12 berthing area. Using the same approach as was used in calculating individual doses to humans, the total radionuclide activity concentration in the surface sediment radiologically screened to date is 0.45 Bq/kg. This radionuclide activity concentration is much less than the concentration needed to produce an annual collective dose of 1 man Sv to crew members and members of the public.

The assessment above is based on results from the radiological screening of surface sediment, which has a much higher potential for radioactive debris and devices than does subsurface and native sediment. Therefore, the conclusion that the criterion for collective dose to humans is met can be extended safely to subsurface and native sediment.

<u>Criterion (iii) - Dose Rates to Marine Flora and Fauna</u>

The International Commission on Radiation Protection has developed radiological criteria for reference animals and plants (RAP) introduced as absorbed dose rates for chronic exposures that serve as markers at which one should pause in order for the known radiation effects data to be considered alongside other relevant factors when considering managerial options. The selected RAPs are fish, crustacean, and seaweed. Absorbed dose rates to RAP are calculated using IAEA-TECDOC-1759, Section 5.3.4.

Screening coefficients per unit activity concentration for ^{226}Ra are given in IAEA-TECDOC-1759, Table 2, as $9.8x10^{-6}$, $1.1x10^{-5}$, and $6.1x10^{-6}$ µGy/hr per Bq/kg, respectively, for fish, crustacean, and seaweed.

The radionuclide activity concentration in the candidate material can be calculated using IAEA-TECDOC-1759 Equations 10 and 11 simplified for a single radionuclide (^{226}Ra) below:

$$E_{RAP} = \frac{M_A}{M_R} D_{RAP}\ x\ C_{RAP}$$

where variables not previously defined:

E_{RAP} = absorbed dose rate in RAP (µGy/hr)
D_{RAP} = screening coefficient for RAP from IAEA-TECDOC-1759, Table 2 (µGy/hr per Bq/kg)
C_{RAP} = radionuclide activity concentration for dose rate in RAP (Bq/kg, dry weight)

By setting E_{RAP} equal to the *de minimis* criteria for the absorbed dose rate to RAP, which range from 40 to 400 µGy/hr), the corresponding radionuclide activity concentration (C_{RAP}) can be calculated.

$$C_{RAP} = \frac{(E_{RAP})(M_R)}{(D_{RAP})(M_A)} = \frac{(E_{RAP})(1x10^8\ kg)}{(D_{RAP})(1.3x10^8\ kg)}$$

Using the screening coefficients for RAP ($9.8x10^{-6}$, $1.1x10^{-5}$, and $6.1x10^{-6}$ µGy/hr per Bq/kg, respectively, for fish, crustacean, and seaweed), the radionuclide activity concentrations that result in an absorbed dose rate in RAP ranging from 40 to 400 µGy/hr are $3.14x10^6$ Bq/kg for fish, $2.80x10^7$ Bq/kg for crustacean, and $5.04x10^6$ Bq/kg for seaweed.

Using the same approach as was used previously in calculating individual and collective doses to humans, the total radionuclide activity concentration in the surface sediment radiologically screened to date is 0.45 Bq/kg. This radionuclide activity concentration is much less than the concentration needed to produce absorbed dose rates ranging from 40 to 400 µGy/hr to fish, crustacean, and seaweed.

The assessment above is based on results from the radiological screening of surface sediment, which has a much higher potential for radioactive debris and devices than does subsurface and native sediment. Therefore, the conclusion that the criterion for absorbed dose rates to marine flora and fauna is met can be extended safely to subsurface and native sediment.

Summary and Conclusion

The 65,000 cy of subsurface and native sediment does not meet the four measures established in IAEA-TECDOC-1068 to be considered *de minimis* without further consideration. However, a specific assessment performed in accordance with IAEA-TECDOC-1759 found that it does satisfy all the criteria for humans (crew and public) and marine flora and fauna [RAP] and may be defined as *de minimis* without further consideration for ocean disposal purposes under the London Convention and Protocol. Therefore, the 65,000 cy of subsurface and native sediment is suitable for ocean disposal.

References

EPA, 1999. *Radiological Survey of Naval Facilities on San Diego Bay*. EPA-402-R-98-011. January. 1999.

IAEA, 1999. *Application of Radiological Exclusion and Exemption Principles to Sea Disposal*. IAEA-TECDOC-1068, IAEA, Vienna (1999).

IAEA, 2015. *Determining the Suitability of Materials for Disposal at Sea under the London Convention 1972 and London Protocol 1996: A Radiological Assessment Procedure*. IAEA-TECDOC-1759, IAEA, Vienna (2015).

Attachment 1
Sediment Sample Results and Comparison with a Previous San Diego Harbor Study

Forty samples were collected in-situ from 40,000 cy of surface sediment destined for upland disposal but yet to be dredged (18,000 cy of the 58,000 cy of sediment destined for upland disposal was dredged previously). A similar sampling frequency (i.e., approximately one sample every 1,000 cy) was used. In addition, six samples were collected from subsurface and native sediment destined for ocean disposal. The sediment sampling included the area immediately adjacent to the south of the old Pier 12, which would be an area most impacted by ship-shore operations over the years. Sampling also included areas further removed from the old pier where the impact from ship-shore operations would be expected to have been much less. The ^{226}Ra sample results are given in the following table.

Table 1 - In-Situ Sediment Sample ^{226}Ra Data Summary

Statistical Parameter	Value (pCi/g)
Count (#)	46
Min	0.183
Max	0.729
Range	0.546
Median	0.405
Mean	0.418
Std Dev	0.140
Kurtosis	-0.59
Skewness	0.29
>Mean+1σ	8
>Mean+2σ	1

Sample results were graphed to identify patterns, relationships, or potential anomalies in the data that might go unnoticed using purely numerical methods. A cumulative frequency diagram, Figure 1, plots the data assuming they are normally distributed. The more normal the data distribution, the more linear the plotted data appear. As accentuated by the superimposed straight lines, the plotted data appear to be a single normally distributed population. There do not appear to be multiple populations evidenced by bent lines or outliers that could be suggestive of dissimilar ^{226}Ra concentrations as would be found in localized contamination in the sediment.

A frequency plot, Figure 2, shows the plotted in an expected Gaussian or bell-shaped (i.e., normal) distribution. There are no outliers or bimodality in the plotted data that would suggest the presence of dissimilar ^{226}Ra concentrations as would be found in localized contamination in the sediment.

A radiological survey of San Diego Harbor was performed by the United States Environmental Protection Agency (EPA) in March, 1997. The survey, documented in the *Radiological Survey of Naval Facilities on San Diego Bay*, EPA-402-R-98-011 (EPA, 1999), collected harbor bottom sediment (grab and core) samples. The results of the harbor sediment (grab and core) samples collected near Pier 12 are given in Tables 1 and 2. Surface sediment samples reported ^{226}Ra concentrations ranging from 1.01 to 1.54 pCi/g (see Table 1). Vertical concentrations from a single sample collected near Pier 12 that would represent subsurface and native sediment reported ^{226}Ra concentrations ranging from 0.46 to 0.54 pCi/g (see Table 2).

Figure 1 - Cumulative Frequency Diagram

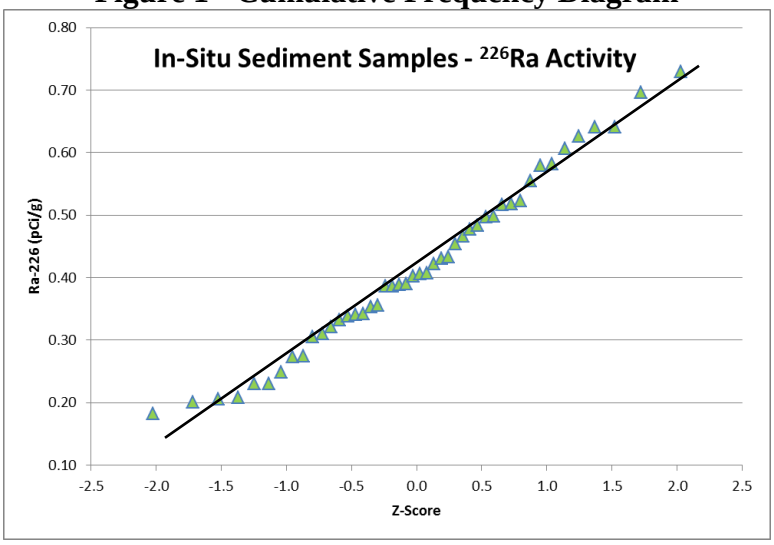


Figure 2 - Frequency Plot

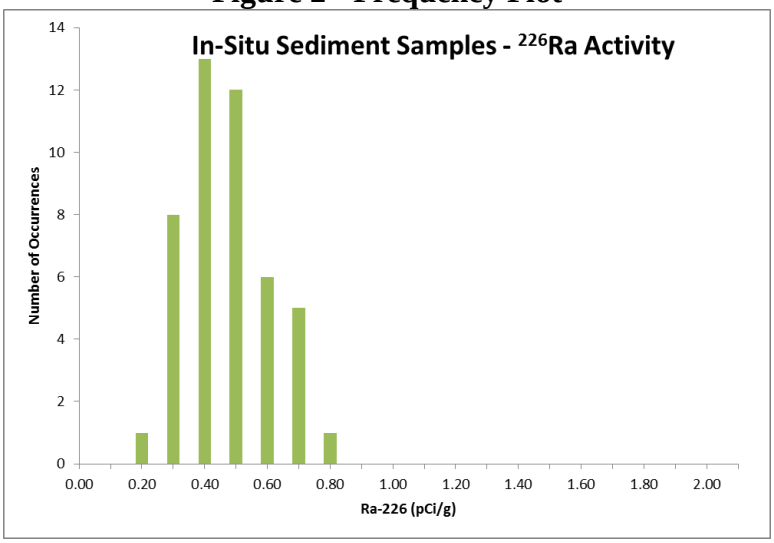
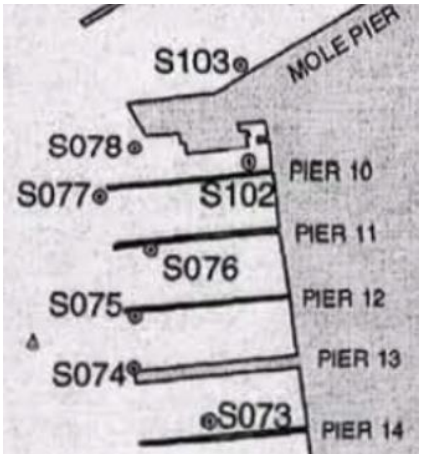


Table 2 - Results of Harbor Sediment Samples Collected Near Pier 12[a]

Sample Location	Location Description	^{226}Ra pCi/g (± 2σ counting error)
S073	N side middle of Pier 14	1.33 ± 0.26
S074	N side end of Pier 13	1.45 ± 0.28
S075	S side end of Pier 12	1.01 ± 0.23
S076	S side middle of Pier 11	1.44 ± 0.28
S077	S side end of Pier 10	1.10 ± 0.23
S078	S side of Mole Pier	1.49 ± 0.23
S102	S side of Mole Pier	1.41 ± 0.21
S103	S side of 7th St. Channel	1.54 ± 0.22



Note:
[a] Source: *Radiological Survey of Naval Facilities on San Diego Bay*, EPA-402-R-98-011 (EPA, 1999), Table 1, Table A.11.a, and Figure 4.4

Table 3 - Results of Core Sediment Sample S076 Collected Near Pier 12[a]

Vertical Sample Location	^{226}Ra pCi/g (± 2σ counting error)
Top 5 cm	0.46 ± 0.12
2nd 5 cm	0.50 ± 0.13
3rd 5 cm	0.54 ± 0.09
Bottom 12 cm	0.64 ± 0.06

Note:
[a] Source: *Radiological Survey of Naval Facilities on San Diego Bay*, EPA-402-R-98-011 (EPA, 1999), Table A.17.a.

Relative to the previous study of the San Diego harbor sediment, the mean value of the in-situ sediment samples (0.402 pCi/g) is consistent with the harbor core sediment sample S076, which was collected adjacent to the old Pier 12, with ^{226}Ra values ranging from 0.46 to 0.64 pCi/g. They are significantly lower than the results of the harbor surface sediment samples collected in the general harbor area around the old Pier 12. Those sample results for ^{226}Ra range from 1.01 to 1.54 pCi/g.

APPENDIX B

Table 2. Vibracore Sample Gamma Count Reading and Laboratory Sample Elevation

Sample ID Number	Date	Time	Sampler	Field Core Location	Water Depth at Mudline (-ft MLLW)	Sample Depth for Cores (ft MLLW)	Dose Readings on Core Samples		
							Analysis	2x2 1 min	ur/hr
J292-DM-021	6/9/2015	8:15	C.R.	1	-31.8	-33.8 to -34.5'	Ra-226, Sr-90	10,935	14
J292-DM-022	6/11/2015	8:05	C.R.	2	-31.32	-36.5 to -37.2'	Ra-226, Sr-90	11,911	12
J292-DM-023	6/11/2015	8:25	C.R.	3	-31.65	-38.1 to -38.8'	Ra-226, Sr-90	11,781	12
J292-DM-024	6/8/2015	8:20	C.R.	4	-28.07	-31.9 to -32.6'	Ra-226, Sr-90	11,358	14
J292-DM-025	6/8/2015	8:55	C.R.	5	-29.07	-34.2 to -34.9'	Ra-226, Sr-90	11,825	13
J292-DM-026	6/8/2015	9:55	C.R.	6	-30.16	-35.5 to -36.2'	Ra-226, Sr-90	11,561	14
J292-DM-027	6/9/2015	11:15	C.R.	7	-29.73	-35.5 to -36.2'	Ra-226, Sr-90	10,532	13
J292-DM-028	6/11/2015	9:10	C.R.	8	-24.72	-33.3 to -34.0'	Ra-226, Sr-90	11,628	13
J292-DM-029	6/9/2015	8:55	C.R.	9	-29.5	-29.5 to 30.2'	Ra-226, Sr-90	10,431	13
J292-DM-030	6/9/2015	10:50	C.R.	10	-27.85	-33.8 to -34.5'	Ra-226, Sr-90	10,106	13
J292-DM-031	6/11/2015	9:35	C.R.	11	-23.02	-31.-3 to -32.0'	Ra-226, Sr-90	11,612	13
J292-DM-032	6/9/2015	9:20	C.R.	12	-28.31	-33.3 to -34.0'	Ra-226, Sr-90	10,661	13
J292-DM-033	6/9/2015	10:05	C.R.	13	-25.72	-31.8 to -32.5'	Ra-226, Sr-90	10,367	13
J292-DM-034	6/9/2015	9:45	C.R.	14	-26.8	-33.0 to -33.7'	Ra-226, Sr-90	10,593	13
J292-DM-035	6/10/2015	12:45	C.R.	15	-26.04	-32.4 to -33.1'	Ra-226, Sr-90	12,566	13
J292-DM-036	6/10/2015	11:30	C.R.	16	-29.07	-34.1 to -34.8'	Ra-226, Sr-90	11,641	13
J292-DM-037	6/10/2015	13:00	C.R.	17	-27.73	-34.3 to -35.0'	Ra-226, Sr-90	12,011	13
J292-DM-038	6/8/2015	15:00	C.R.	18	-28.09	-33.4 to -34.1'	Ra-226, Sr-90	11,263	14
J292-DM-039	6/8/2015	13:35	C.R.	19	-28.53	-33.9 to -34.5'	Ra-226, Sr-90	11,057	14
J292-DM-040	6/8/2015	10:35	C.R.	20	-28.52	-32.4 to -33.0'	Ra-226, Sr-90	11,591	14
J292-DM-041	6/8/2015	14:00	C.R.	21	-28.61	-33.9 to -34.6'	Ra-226, Sr-90	11,280	13
J292-DM-042	6/10/2015	9:25	C.R.	22	-24.29	-31.6 to -32.3	Ra-226, Sr-90	11,886	13
J292-DM-043	6/8/2015	15:25	C.R.	23	-27.34	-32.7 to -33.3'	Ra-226, Sr-90	11,129	14
J292-DM-044	6/10/2015	9:45	C.R.	24	-24.24	-31.-3 to -32.0'	Ra-226, Sr-90	11,843	13
J292-DM-045	6/10/2015	10:15	C.R.	25	-23.01	-28.3 to -29.0'	Ra-226, Sr-90	11,725	13
J292-DM-046	6/10/2015	10:50	C.R.	26	-19.76	-24.6 to -25.3'	Ra-226, Sr-90	11,856	13
J292-DM-047	6/9/2015	14:10	C.R.	27	-26.45	-31.6 to -35.-3'	Ra-226, Sr-90	10,258	13
J292-DM-048	6/9/2015	13:45	C.R.	28	-28.47	-34.8 to -35.5'	Ra-226, Sr-90	10,397	13
J292-DM-049	6/10/2015	8:00	C.R.	29	-26.32	-33.3 to -34.0'	Ra-226, Sr-90	11,674	13
J292-DM-050	6/10/2015	8:25	C.R.	30	-26.04	-32.8 to -33.5'	Ra-226, Sr-90	12,022	13
J292-DM-051	6/10/2015	8:50	C.R.	31	-24.85	-31.7 to -32.5'	Ra-226, Sr-90	11,573	13
J292-DM-052	6/11/2015	11:10	C.R.	32	-21.78	-27.3 to -28.0'	Ra-226, Sr-90	11,447	13
J292-DM-053	6/11/2015	10:20	C.R.	33	-23.66	-30.5 to -31.2'	Ra-226, Sr-90	11,350	13
J292-DM-054	6/11/2015	12:00	C.R.	34	-26.31	-29.9 to 30.6'	Ra-226, Sr-90	11,249	12
J292-DM-055	6/11/2015	13:50	C.R.	35	-26.99	-32.-3 to -33.0'	Ra-226, Sr-90	11,206	12
J292-DM-056	6/12/2015	8:10	C.R.	36	-27.85	-35.8 to -36.5'	Ra-226, Sr-90	11,434	12
J292-DM-057	6/12/2015	8:30	C.R.	37	-27.36	-35.-3 to -36.0'	Ra-226, Sr-90	11,530	12
J292-DM-058	6/11/2015	14:10	C.R.	38	-26.76	-30.8 to -31.5'	Ra-226, Sr-90	11,250	13
J292-DM-059	6/11/2015	13:10	C.R.	39	-26.35	-31.-3 to -32.0'	Ra-226, Sr-90	11,449	13

Table 2. Vibracore Sample Gamma Count Reading and Laboratory Sample Elevation

Sample ID Number	Date	Time	Sampler	Field Core Location	Water Depth at Mudline (-ft MLLW)	Sample Depth for Cores (ft MLLW)	Dose Readings on Core Samples		
							Analysis	2x2 1 min	ur/hr
J292-DM-060	6/11/2015	11:35	C.R.	40	-19.54	-24.8 to -25.5'	Ra-226, Sr-90	11,673	13
J292-DM-061	6/10/2015	13:35	C.R.	41	-26.78	-33.8 to -34.5'	Ra-226, Sr-90	11,778	13
J292-DM-062	6/8/2015	12:00	C.R.	42	-29.3	-32.6 to -33.3'	Ra-226, Sr-90	11,423	14
J292-DM-063	6/9/2015	12:25	C.R.	43	-29.9	-35.3 to -36.0'	Ra-226, Sr-90	10,395	13
J292-DM-064	6/12/2015	9:15	C.R.	44	-30.08	-34.3 to -35.0'	Ra-226, Sr-90	11,021	12
J292-DM-065	6/12/2015	9:50	C.R.	45	-25.91	-32.-3 to -33.0'	Ra-226, Sr-90	11,108	12
J292-DM-066	6/10/2015	14:25	C.R.	46	-26.49	-34.3 to -35.0'	Ra-226, Sr-90	11,806	13

Discrete Core Sample Laboratory Data (see Table 2 for station id)

Sample ID	Analysis Code	Nuclide	Activity	Flag	Activity Units
J292-DM-021	E901.1	Cobalt 60	-0.00100	U	PCI/G
J292-DM-021	E901.1	Cesium 137	-0.0190	U	PCI/G
J292-DM-021	E901.1	Radium 226	0.408		PCI/G
J292-DM-021	E905.0	Strontium Total	-0.0330	U	PCI/G
J292-DM-022	E901.1	Radium 226	0.183		PCI/G
J292-DM-022	E901.1	Cobalt 60	0.0100	U	PCI/G
J292-DM-022	E901.1	Cesium 137	0.0280	U	PCI/G
J292-DM-022	E905.0	Strontium Total	-0.0350	U	PCI/G
J292-DM-023	E901.1	Cobalt 60	0.0120	U	PCI/G
J292-DM-023	E901.1	Cesium 137	0.0150	U	PCI/G
J292-DM-023	E901.1	Radium 226	0.306		PCI/G
J292-DM-023	E905.0	Strontium Total	0.00400	U	PCI/G
J292-DM-024	E901.1	Radium 226	0.342		PCI/G
J292-DM-024	E901.1	Cobalt 60	-0.0220	U	PCI/G
J292-DM-024	E901.1	Cesium 137	-0.0260	U	PCI/G
J292-DM-024	E905.0	Strontium Total	0.0200	U	PCI/G
J292-DM-025	E901.1	Cobalt 60	0.0130	U	PCI/G
J292-DM-025	E901.1	Cesium 137	0.0150	U	PCI/G
J292-DM-025	E901.1	Radium 226	0.499		PCI/G
J292-DM-025	E905.0	Strontium Total	0.142	U	PCI/G
J292-DM-026	E901.1	Cobalt 60	-0.0150	U	PCI/G
J292-DM-026	E901.1	Cesium 137	0.00800	U	PCI/G
J292-DM-026	E901.1	Radium 226	0.431		PCI/G
J292-DM-026	E905.0	Strontium Total	-0.00500	U	PCI/G
J292-DM-027	E901.1	Radium 226	0.231		PCI/G
J292-DM-027	E901.1	Cobalt 60	0.00	U	PCI/G
J292-DM-027	E901.1	Cesium 137	0.00	U	PCI/G
J292-DM-027	E905.0	Strontium Total	0.0800	U	PCI/G
J292-DM-028	E901.1	Cobalt 60	0.00600	U	PCI/G
J292-DM-028	E901.1	Radium 226	0.275		PCI/G
J292-DM-028	E901.1	Cesium 137	0.0280	U	PCI/G
J292-DM-028	E905.0	Strontium Total	-0.0590	U	PCI/G
J292-DM-029	E901.1	Radium 226	0.497		PCI/G
J292-DM-029	E901.1	Cobalt 60	-0.0100	U	PCI/G
J292-DM-029	E901.1	Cesium 137	0.0120	U	PCI/G
J292-DM-029	E905.0	Strontium Total	-0.0300	U	PCI/G
J292-DM-030	E901.1	Cobalt 60	-0.00500	U	PCI/G
J292-DM-030	E901.1	Cesium 137	-0.00200	U	PCI/G
J292-DM-030	E901.1	Radium 226	0.274		PCI/G
J292-DM-030	E905.0	Strontium Total	-0.127	U	PCI/G
J292-DM-031	E901.1	Cobalt 60	0.0170	U	PCI/G
J292-DM-031	E901.1	Cesium 137	0.00	U	PCI/G
J292-DM-031	E901.1	Radium 226	0.356		PCI/G
J292-DM-031	E905.0	Strontium Total	0.106	U	PCI/G
J292-DM-032	E901.1	Cobalt 60	0.00100	U	PCI/G
J292-DM-032	E901.1	Cesium 137	0.00600	U	PCI/G
J292-DM-032	E901.1	Radium 226	0.354		PCI/G
J292-DM-032	E905.0	Strontium Total	-0.0460	U	PCI/G
J292-DM-033	E901.1	Cobalt 60	-0.00500	U	PCI/G
J292-DM-033	E901.1	Cesium 137	0.0150	U	PCI/G

Discrete Core Sample Laboratory Data (see Table 2 for station id)

Sample ID	Analysis Code	Nuclide	Activity	Flag	Activity Units
J292-DM-033	E901.1	Radium 226	0.387		PCI/G
J292-DM-033	E905.0	Strontium Total	-0.0920	U	PCI/G
J292-DM-034	E901.1	Cobalt 60	-0.00100	U	PCI/G
J292-DM-034	E901.1	Cesium 137	-0.0140	U	PCI/G
J292-DM-034	E901.1	Radium 226	0.433		PCI/G
J292-DM-034	E905.0	Strontium Total	-0.00500	U	PCI/G
J292-DM-035	E901.1	Cobalt 60	0.0320	U	PCI/G
J292-DM-035	E901.1	Cesium 137	0.0830		PCI/G
J292-DM-035	E901.1	Radium 226	0.311		PCI/G
J292-DM-035	E905.0	Strontium Total	0.0490	U	PCI/G
J292-DM-036	E901.1	Cesium 137	0.00100	U	PCI/G
J292-DM-036	E901.1	Radium 226	0.582		PCI/G
J292-DM-036	E901.1	Cobalt 60	-0.0180	U	PCI/G
J292-DM-036	E905.0	Strontium Total	0.110	U	PCI/G
J292-DM-037	E901.1	Radium 226	0.341		PCI/G
J292-DM-037	E901.1	Cobalt 60	0.0150	U	PCI/G
J292-DM-037	E901.1	Cesium 137	0.0120	U	PCI/G
J292-DM-037	E905.0	Strontium Total	-0.0380	U	PCI/G
J292-DM-038	E901.1	Cobalt 60	0.0180	U	PCI/G
J292-DM-038	E901.1	Cesium 137	0.00	U	PCI/G
J292-DM-038	E901.1	Radium 226	0.729		PCI/G
J292-DM-038	E905.0	Strontium Total	0.0810	U	PCI/G
J292-DM-039	E901.1	Cobalt 60	0.00300	U	PCI/G
J292-DM-039	E901.1	Cesium 137	-0.00200	U	PCI/G
J292-DM-039	E901.1	Radium 226	0.206		PCI/G
J292-DM-039	E905.0	Strontium Total	-0.0480	U	PCI/G
J292-DM-040	E901.1	Cobalt 60	0.00600	U	PCI/G
J292-DM-040	E901.1	Cesium 137	-0.0210	U	PCI/G
J292-DM-040	E901.1	Radium 226	0.523		PCI/G
J292-DM-040	E905.0	Strontium Total	-0.0150	U	PCI/G
J292-DM-041	E901.1	Cobalt 60	-0.00100	U	PCI/G
J292-DM-041	E901.1	Cesium 137	-0.00300	U	PCI/G
J292-DM-041	E901.1	Radium 226	0.386		PCI/G
J292-DM-041	E905.0	Strontium Total	-0.0120	U	PCI/G
J292-DM-042	E901.1	Radium 226	0.606		PCI/G
J292-DM-042	E901.1	Cobalt 60	0.0130	U	PCI/G
J292-DM-042	E901.1	Cesium 137	0.00	U	PCI/G
J292-DM-042	E905.0	Strontium Total	0.0690	U	PCI/G
J292-DM-043	E901.1	Cobalt 60	0.00800	U	PCI/G
J292-DM-043	E901.1	Cesium 137	-0.00200	U	PCI/G
J292-DM-043	E901.1	Radium 226	0.466		PCI/G
J292-DM-043	E905.0	Strontium Total	0.127	U	PCI/G
J292-DM-044	E901.1	Cobalt 60	0.00200	U	PCI/G
J292-DM-044	E901.1	Cesium 137	0.0130	U	PCI/G
J292-DM-044	E901.1	Radium 226	0.517		PCI/G
J292-DM-044	E905.0	Strontium Total	0.0460	U	PCI/G
J292-DM-045	E901.1	Radium 226	0.403		PCI/G
J292-DM-045	E901.1	Cobalt 60	-0.00200	U	PCI/G
J292-DM-045	E901.1	Cesium 137	0.0430	U	PCI/G
J292-DM-045	E905.0	Strontium Total	-0.246		PCI/G

Discrete Core Sample Laboratory Data (see Table 2 for station id)

Sample ID	Analysis Code	Nuclide	Activity	Flag	Activity Units
J292-DM-046	E901.1	Cobalt 60	0.0100	U	PCI/G
J292-DM-046	E901.1	Cesium 137	0.131		PCI/G
J292-DM-046	E901.1	Radium 226	0.389		PCI/G
J292-DM-046	E905.0	Strontium Total	-0.0380	U	PCI/G
J292-DM-047	E901.1	Cobalt 60	0.00700	U	PCI/G
J292-DM-047	E901.1	Cesium 137	-0.0170	U	PCI/G
J292-DM-047	E901.1	Radium 226	0.484		PCI/G
J292-DM-047	E905.0	Strontium Total	0.0130	U	PCI/G
J292-DM-048	E901.1	Cobalt 60	0.0230	U	PCI/G
J292-DM-048	E901.1	Cesium 137	-0.0130	U	PCI/G
J292-DM-048	E901.1	Radium 226	0.626		PCI/G
J292-DM-048	E905.0	Strontium Total	-0.0200	U	PCI/G
J292-DM-049	E901.1	Cesium 137	0.00	U	PCI/G
J292-DM-049	E901.1	Radium 226	0.641		PCI/G
J292-DM-049	E901.1	Cobalt 60	-0.0180	U	PCI/G
J292-DM-049	E905.0	Strontium Total	-0.00700	U	PCI/G
J292-DM-050	E901.1	Radium 226	0.579		PCI/G
J292-DM-050	E901.1	Cobalt 60	0.0140	U	PCI/G
J292-DM-050	E901.1	Cesium 137	0.00	U	PCI/G
J292-DM-050	E905.0	Strontium Total	-0.0720	U	PCI/G
J292-DM-051	E901.1	Cobalt 60	-0.00200	U	PCI/G
J292-DM-051	E901.1	Cesium 137	-0.0140	U	PCI/G
J292-DM-051	E901.1	Radium 226	0.201		PCI/G
J292-DM-051	E905.0	Strontium Total	-0.0340	U	PCI/G
J292-DM-052	E901.1	Cobalt 60	0.00300	U	PCI/G
J292-DM-052	E901.1	Cesium 137	0.0580	U	PCI/G
J292-DM-052	E901.1	Radium 226	0.208		PCI/G
J292-DM-052	E905.0	Strontium Total	0.0270	U	PCI/G
J292-DM-053	E901.1	Radium 226	0.390		PCI/G
J292-DM-053	E901.1	Cobalt 60	0.00600	U	PCI/G
J292-DM-053	E901.1	Cesium 137	0.00300	U	PCI/G
J292-DM-053	E905.0	Strontium Total	-0.0570	U	PCI/G
J292-DM-054	E901.1	Cobalt 60	0.00	U	PCI/G
J292-DM-054	E901.1	Radium 226	0.333		PCI/G
J292-DM-054	E901.1	Cesium 137	0.00	U	PCI/G
J292-DM-054	E905.0	Strontium Total	0.0790	U	PCI/G
J292-DM-055	E901.1	Radium 226	0.249		PCI/G
J292-DM-055	E901.1	Cobalt 60	-0.00100	U	PCI/G
J292-DM-055	E901.1	Cesium 137	0.00900	U	PCI/G
J292-DM-055	E905.0	Strontium Total	0.0660	U	PCI/G
J292-DM-056	E901.1	Cobalt 60	-0.0280	U	PCI/G
J292-DM-056	E901.1	Cesium 137	-0.00200	U	PCI/G
J292-DM-056	E901.1	Radium 226	0.406		PCI/G
J292-DM-056	E905.0	Strontium Total	-0.0530	U	PCI/G
J292-DM-057	E901.1	Cobalt 60	-0.0270	U	PCI/G
J292-DM-057	E901.1	Cesium 137	0.00900	U	PCI/G
J292-DM-057	E901.1	Radium 226	0.478		PCI/G
J292-DM-057	E905.0	Strontium Total	-0.195	U	PCI/G
J292-DM-058	E901.1	Radium 226	0.518		PCI/G
J292-DM-058	E901.1	Cobalt 60	0.00500	U	PCI/G

Discrete Core Sample Laboratory Data (see Table 2 for station id)

Sample ID	Analysis Code	Nuclide	Activity	Flag	Activity Units
J292-DM-058	E901.1	Cesium 137	0.00900	U	PCI/G
J292-DM-058	E905.0	Strontium Total	-0.00200	U	PCI/G
J292-DM-059	E901.1	Cobalt 60	-0.00200	U	PCI/G
J292-DM-059	E901.1	Cesium 137	0.0290	U	PCI/G
J292-DM-059	E901.1	Radium 226	0.322		PCI/G
J292-DM-059	E905.0	Strontium Total	0.0790	U	PCI/G
J292-DM-060	E901.1	Cobalt 60	0.0260	U	PCI/G
J292-DM-060	E901.1	Cesium 137	0.0610	U	PCI/G
J292-DM-060	E901.1	Radium 226	0.454		PCI/G
J292-DM-060	E905.0	Strontium Total	-0.0180	U	PCI/G
J292-DM-061	E901.1	Radium 226	0.422		PCI/G
J292-DM-061	E901.1	Cobalt 60	0.00700	U	PCI/G
J292-DM-061	E901.1	Cesium 137	0.0130	U	PCI/G
J292-DM-061	E905.0	Strontium Total	0.0450	U	PCI/G
J292-DM-062	E901.1	Cobalt 60	0.00	U	PCI/G
J292-DM-062	E901.1	Cesium 137	0.00	U	PCI/G
J292-DM-062	E901.1	Radium 226	0.641		PCI/G
J292-DM-062	E905.0	Strontium Total	0.101	U	PCI/G
J292-DM-063	E901.1	Radium 226	0.231		PCI/G
J292-DM-063	E901.1	Cobalt 60	0.0110	U	PCI/G
J292-DM-063	E901.1	Cesium 137	-0.00200	U	PCI/G
J292-DM-063	E905.0	Strontium Total	-0.0580	U	PCI/G
J292-DM-064	E901.1	Cobalt 60	-0.0150	U	PCI/G
J292-DM-064	E901.1	Cesium 137	-0.0180	U	PCI/G
J292-DM-064	E901.1	Radium 226	0.696		PCI/G
J292-DM-064	E905.0	Strontium Total	-0.0100	U	PCI/G
J292-DM-065	E901.1	Cobalt 60	-0.00600	U	PCI/G
J292-DM-065	E901.1	Cesium 137	0.00300	U	PCI/G
J292-DM-065	E901.1	Radium 226	0.555		PCI/G
J292-DM-065	E905.0	Strontium Total	-0.281		PCI/G
J292-DM-066	E901.1	Cobalt 60	-0.0110	U	PCI/G
J292-DM-066	E901.1	Cesium 137	0.0390	U	PCI/G
J292-DM-066	E901.1	Radium 226	0.339		PCI/G
J292-DM-066	E905.0	Strontium Total	-0.0700	U	PCI/G

This data has not been subjected to independent validation.

U = The associated value is not detected.