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REFERENCES APPLICABLE TO THE HISTORICAL RADIOLOGICAL ASSESSMENT VOLUMES I AND II CNC CHARLESTON SC

5/1/1983

NAVAL ENERGY AND ENVIRONMENTAL SUPPORT ACTIVITY

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(Applicable to)

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CHARLESTON NAVAL SHIPYARD
Volumes I and II

and

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May 1983

INITIAL ASSESSMENT STUDY OF NAVAL BASE CHARLESTON, CHARLESTON, SOUTH CAROLINA

NEESA Report No. 13-007

NAVAL ENERGY AND ENVIRONMENTAL SUPPORT ACTIVITY
Port Hueneme, California 93043

INITIAL ASSESSMENT STUDY
NAVAL BASE CHARLESTON

UIC No. N61466

May 1983

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EXECUTIVE SUMMARY

This report presents the results of an Initial Assessment Study (IAS) conducted at Naval Base Charleston (NAVBASE Charleston). The purpose of an IAS is to identify and assess sites posing a potential threat to human health or the environment due to contamination from past hazardous materials operations.

Based on information from historical records, aerial photographs, field inspections, and personnel interviews, a total of eight potentially contaminated sites were identified at NAVBASE Charleston. Each of the sites was evaluated with regard to contamination characteristics, migration pathways, and pollutant receptors.

The study concludes that, while none of the sites pose an immediate threat to human health or the environment, each warrants further investigation under the Navy Assessment and Control of Installation Pollutants (NACIP) Program, to assess potential long-term impacts. A Confirmation Study, involving actual sampling and monitoring of the eight sites, is recommended to confirm or deny the existence of the suspected contamination and to quantify the extent of any problems which may exist. The eight sites recommended for confirmation are listed below in order of priority:

1. Base Sanitary Landfill, Site No. 1.
2. Chemical Disposal Area, Site No. 2.
3. Oil Sludge Pits, Site No. 3.
4. Polychlorinated Biphenyl (PCB) Storage Area, Site No. 6.
5. Former Pesticide Mixing Area, Site No. 7.
6. Petroleum, Oils, and Lubricants (POL) Transfer Point, Site No. 4.
7. Caustic Pond, Site No. 8.
8. Former Firefighting Training Pit, Site No. 5.

The results of the Confirmation Study will be used to evaluate the necessity of conducting mitigating actions or cleanup operations.

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FOREWORD

The Navy Assessment and Control of Installation Pollutants (NACIP) Program was promulgated by OPNAVNOTE 6240 of 11 Sep 1980 and Marine Corps Order 6280.1 of 30 Jan 1981. The purpose of the Program is to systematically identify, assess, and control contamination from past hazardous material operations which pose a threat to human health or to the environment.

An Initial Assessment Study (IAS) was performed at Naval Base Charleston (NAVBASE Charleston), Charleston, S.C., by a team of specialists under contract to the Naval Energy and Environmental Support Activity (NEESA), Port Hueneme, Calif. Further confirmation studies under the NACIP Program are recommended at several areas at the activity. Sections dealing with significant findings, conclusions, and recommendations are presented in the earlier section of the report. The later technical sections provide more in-depth discussions on important aspects of the study.

For further information, contact the Officer in Charge, 112N, Naval Energy and Environmental Support Activity (NEESA), Port Hueneme, Calif. 93043; AUTOVON 360-3351 or commercial 805-982-3351.

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INITIAL ASSESSMENT STUDY
NAVAL BASE CHARLESTON

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INITIAL ASSESSMENT STUDY OF NAVAL BASE CHARLESTON

SECTION 1.0 INTRODUCTION

1.1 PURPOSE OF THE INITIAL ASSESSMENT STUDY

As directed by the Chief of Naval Operations (CNO), the Naval Energy and Environmental Support Activity (NEESA) conducts Initial Assessment Studies (IASs) to collect and evaluate evidence which indicates the existence of pollutants which may have contaminated a site and which may pose a health hazard to people located on or off the installation. These studies represent the first phase of the Navy Assessment and Control of Installation Pollutants (NACIP) Program, which is designed to:

- Identify any environmental contamination resulting from past hazardous material storage, handling, and waste disposal operations at shore installations;
- Assess the impact, or potential for impact, of the contamination on public health and the environment, both at the installation and in surrounding civilian communities; and
- Provide corrective measures, as needed, to prevent contamination from causing any adverse effects on public health or the environment.

1.2 AUTHORITY

The CNO initiated the NACIP Program through OPNAVNOTE 6240 ser 45/733503 of 11 Sep 1980 and Marine Corps Order 6280.1 of 30 Jan 1981.

1.3 SEQUENCE OF EVENTS

1. Naval Base Charleston (NAVBASE Charleston) was designated for an IAS by COMNAVFACENGCOM message 261410Z January 1981.

2. The Commander of Naval Shipyard Charleston (NSY) was notified by the Chief of Naval Material (CNM) via the Commander of the Naval Sea Systems Command (NAVSEA) and by NEESA of the selection of NAVBASE Charleston for an IAS. The NACIP Program Management Plan, the IAS Statement of Work, and Activity Support Requirements for the IAS were forwarded to the installation to outline assessment scope, provide guidelines to

personnel, and request advance information for review by the IAS team.

3. NAVBASE Charleston and Naval Facilities Engineering Command (NAVFAC), Southern Division (SOUTHDIV) personnel were briefed by a NEESA representative, Mr. Rick Gardner, on 8 Jul 1981, prior to the IAS.

4. Various government agencies were contacted for documents pertinent to the IAS effort. Agencies contacted include:

   a. NEESA Information Management Department

   b. NEESA Information Services Department

   c. NAVFAC Historian, Naval Construction Batallion Center (NCBC), Port Hueneme, Calif.

   d. South Carolina Geological Survey

   e. South Carolina Agricultural Experiment Station

   f. U.S. Geological Survey (USGS)

   g. The National Archives and Records Service, General Services Administration, Cartographic Branch, Pennsylvania Ave. at 8th St. NW, Washington, D.C.

   h. The National Archives, Washington, D.C., Record Group 80--CNO

   i. The National Archives, Washington, D.C., Record Group 71--Bureau of Yards and Docks

   j. The National Archives, Suitland, Md., Record Group 181--Naval Districts and Shore Establishments

   k. Navy History Office, Washington Navy Yard

   l. SOUTHDIV Facilities Planning and Real Estate Department and Facilities Management Department

   m. Public Works NSY

   n. The National Archives and Records Center, Atlanta, Ga., Record Group 181

   o. Naval Supply Center Charleston (NSC), Management Analysts Office

   p. Naval Security Group Command Headquarters (COMNAVSECGRU)

q. Naval Station Charleston (NAVSTA), Naval Base, Administrative Office

r. Ordnance Environmental Support Office (OESO), Indian Head, Md.

s. NAVFAC Headquarters, Real Estate Branch, Alexandria, Va.

t. NAVSEA, Documents Branch, Alexandria, Va.

u. Department of Defense Explosives Safety Board (DDESB), Alexandria, Va.

v. U.S. Army Corps of Engineers (COE)

w. Defense Mapping Agency, Office of Distribution Services, Washington, D.C.

5. The onsite phase of the IAS was conducted from 27 Jul-6 Aug 1981. The information presented in this report is current, as of the date of the onsite search. The following personnel from ESE, under Contract No. N62474-81-C-9383, were assigned to the IAS team:

   Dr. Bruce McMaster, Chemist, Project Manager
   Dr. John Bonds, Chemist, Team Leader
   Mr. Russell Bowen, Civil Engineer
   Mr. Steve Denahan, Hydrogeologist
   Mr. Ernest Frey, Civil Engineer
   Mr. Charles Hendry, Chemist
   Ms. Carla Jones, Historian/Document Coordinator
   Mr. John Wiese, Ecologist

6. In addition to records reviews, interviews were conducted with current and former employees. Ground and aerial tours of the installation were made, and photographs were taken. The use of "Personal Communication" as a reference citation in this report identifies information received via interviews or through unpublished reports such as interoffice memoranda. Information received from an interview was generally verified by one or more additional interview(s) or by comparison with documented data. In particular, substantiation was obtained for interview data impacting conclusions and recommendations.

1.4 SUBSEQUENT NACIP STUDIES

The second phase of the NACIP Program is the Confirmation Study. During confirmation, extensive sampling and monitoring are conducted to confirm or refute the existence of suspected migrating contamination at sites identified during an IAS. If significant impacts on public health or the environment are found to exist, the study recommends remedial actions to be taken.

A Confirmation Study is recommended only if the following circumstances exist:

1. Sufficient evidence exists to suspect that the activity is contaminated, and

2. The contamination presents a potential danger to:

   a. The health of civilians in nearby communities or personnel within the activity fenceline, or
   b. The environment within or outside the activity.

Further studies are not conducted under the NACIP Program if these criteria are not met.

SECTION 2.0
DISCUSSION OF SIGNIFICANT FINDINGS

This section summarizes the significant findings of the IAS at NAVBASE Charleston with regard to the installation's geohydrology and the characteristics of specific waste disposal and spill sites on the installation. The IAS of NAVBASE Charleston identified eight potentially contaminated areas onbase; the locations of these eight waste disposal and spill sites are shown in figure 2.1-1. The significant findings with regard to each of these eight areas are discussed in the following sections.

Regarding geohydrology, those aspects which are most relevant to potential contaminant migration pathways and potential receptors of contaminants are detailed.

The characteristics of waste disposal and spill sites are described on a site-by-site basis, summarizing those findings which are most significant with respect to the presence of toxic or hazardous contaminants.

SOUTHDIV is currently conducting a monitoring program under contract to assess contamination at five sites on NAVBASE Charleston. This program includes the installation and sampling of monitoring wells at six locations: the base sanitary landfill (site 1), the chemical disposal area (site 2), the oil sludge pits (site 3), the polychlorinated biphenyl storage area (site 6), the former pesticide mixing area (site 7), and the caustic pond (site 8). A series of shallow soil borings was also made near Bldg. X-10. In addition, soils were sampled and analyzed for PCB content in the PCB storage area (site 6). These sample sites are shown in figure 2.1-2.

2.1 GEOHYDROLOGY

The soils at NAVBASE Charleston are generally fine-grained and only slowly permeable. This type of soil, combined with the basically level topography, causes drainage problems at the base. The permeability of the organically rich clays underlying the surface soils is also rather low. These highly organic clays, which range in thickness from 15 feet to 50 feet, are very soft, have extremely high water contents, and cause foundation problems on the base. Under these soft clays lies the Cooper Marl, a 200-foot-thick unit of stiff, calcareous clay. Flow in the shallow groundwater system is slow because of the fine-grained nature of the sediments and the low gradient. No use is made of the shallow ground water at NAVBASE Charleston, and there are no downgradient users of the shallow aquifer. The Cooper River and Shipyard Creek, which are the base boundaries, also are the shallow aquifer system boundaries.

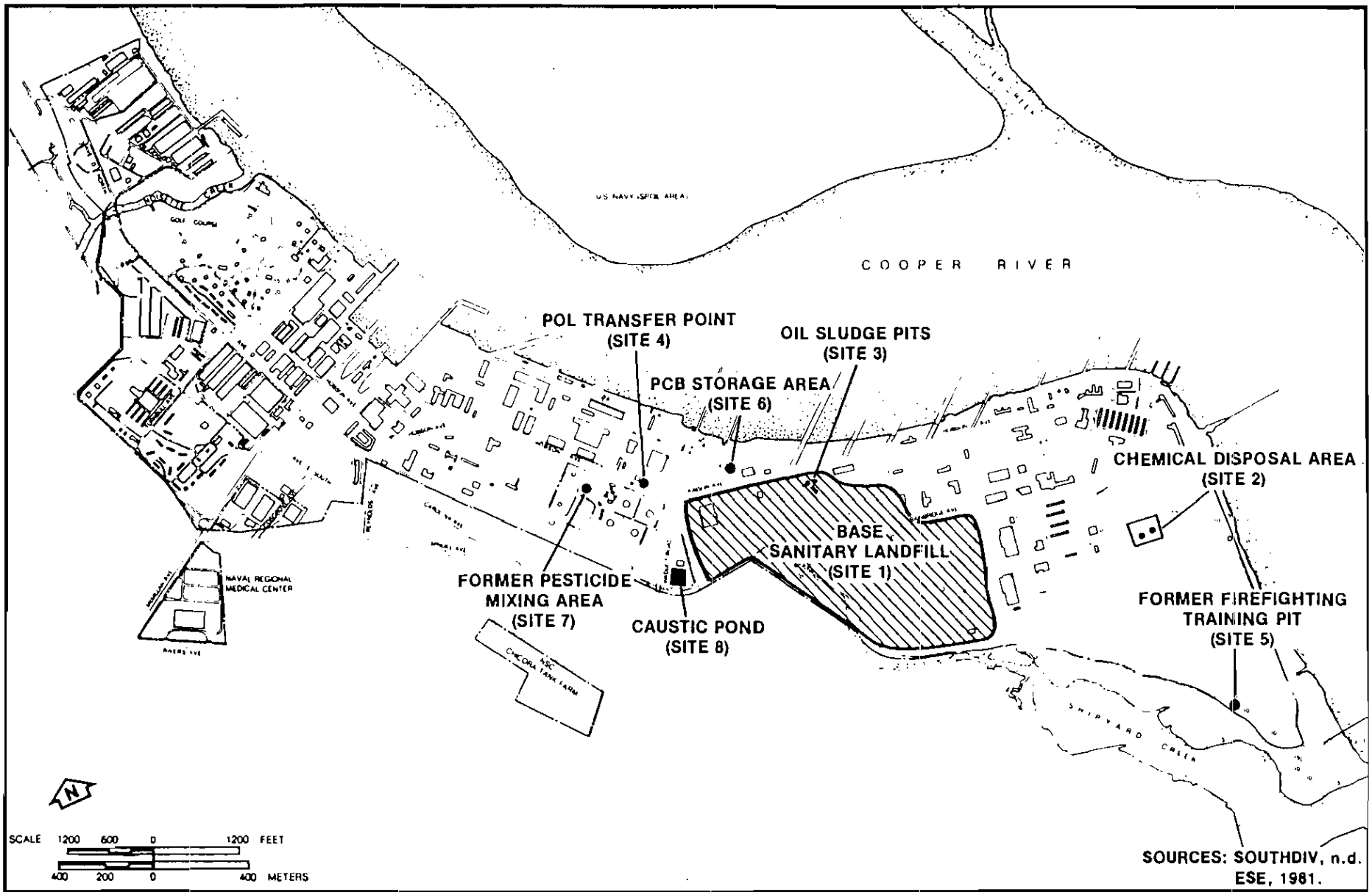
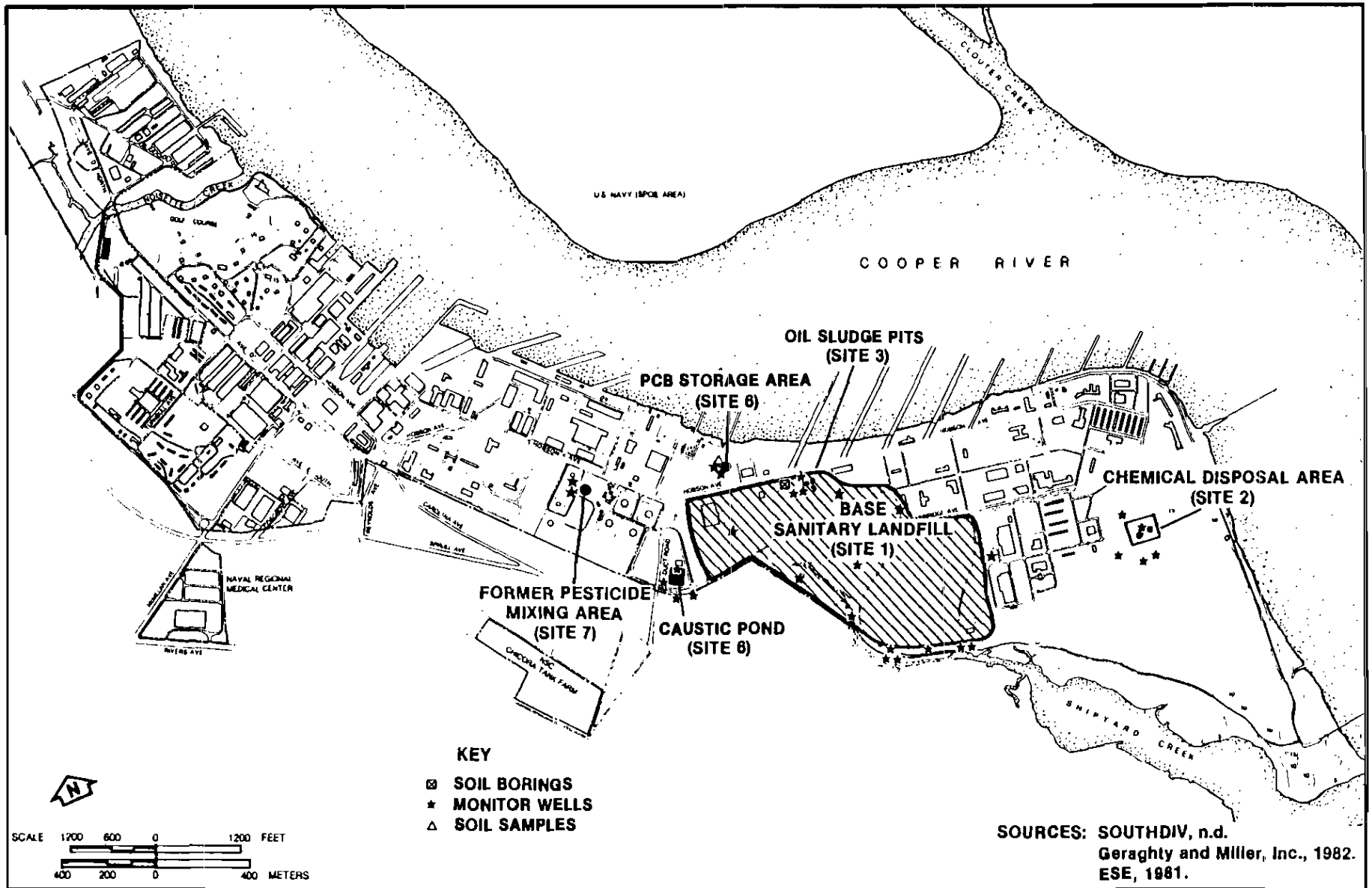


Figure 2.1-1
POTENTIAL CONTAMINATION MAP

INITIAL ASSESSMENT STUDY
NAVAL BASE CHARLESTON



SOURCES: SOUTHDIV, n.d.
Geraghty and Miller, Inc., 1982.
ESE, 1981.

Figure 2.1-2
LOCATIONS OF SAMPLING POINTS IN PRESENT SOUTHDIV MONITORING PROGRAM

INITIAL ASSESSMENT STUDY
NAVAL BASE CHARLESTON

Thus, all shallow ground water onsite eventually discharges to the Cooper River, either directly or through its tributaries.

A deeper confined aquifer (beneath the Cooper Marl), known as the Santee Limestone, is not subject to contamination from surface sources because its hydraulic head is above the top of the Cooper Marl, resulting in a net upward flow of water from the Santee into the shallower materials.

The deeper groundwater resources at NAVBASE Charleston are not used for onsite potable water supply, and the deeper aquifer in the vicinity of NAVBASE Charleston is not used for potable supply.

Surface water resources at NAVBASE Charleston include Noisette Creek, Shipyard Creek, and the Cooper River. Potable water for NAVBASE Charleston or the surrounding area is not obtained from any of these sources. These surface waters and the stormwater drainage system provide a potential migratory pathway. Thus, pathways exist on NAVBASE Charleston for contaminants to migrate offsite, either by surface runoff or through the ground water in the shallow aquifer.

2.2 WASTE DISPOSAL AND SPILL SITES

The IAS of NAVBASE Charleston resulted in the location of eight areas within the installation boundaries which are potentially contaminated. The locations of these eight sites are shown in figure 2.1-1. Brief descriptions of the pertinent characteristics of these eight sites are presented in the following subsections.

2.2.1 Base Sanitary Landfill (Site 1)

Since the 1930s, solid wastes, including sludges, were generally disposed of in the base sanitary landfill at the southwestern portion of the installation (see section 6.6.2) until it was closed in 1973. Since 1973, solid wastes generally have been contract hauled offbase.

Waste materials generated on the base that were reportedly landfilled in its southwestern portion included: asbestos, acids, PCBs, waste oils, waste solvents, waste paints, paint sludges, mercury, metal sludge, acid neutralization sludge, various inorganic and organic chemicals, and sanitary wastes. The quantities of these wastes disposed of are unknown, but are believed to be large, based on current generation rates.

No data are available regarding permeability rates or range for soils adjacent to the landfill. However, field inspection of soils in the vicinity of the landfill during the IAS site visit indicated a texture that typically has low permeability. Although a geologic assessment of NAVBASE Charleston indicates that all shallow ground water onbase eventually discharges to the Cooper River either directly or indirectly via its tributaries (e.g., Shipyard Creek), the flow rate in the shallow system is expected to be rather slow due to the fine-grained

nature of the sediments and the low gradient. However, the nature of the soils could permit the slow migration of leachates originating at the landfill toward Shipyard Creek and/or the Cooper River.

Leachates entering the shallow ground water do not affect potable water sources. The shallow groundwater system is not developed for potable water use onbase. No potable use is made of the shallow ground water downgradient of NAVBASE Charleston, since the Cooper River and Shipyard Creek surface waters intercept the shallow groundwater flow at the base boundaries. The deeper aquifer (Santee Limestone) is not threatened by potential contamination in the shallow system, because the Santee has a hydraulic head above its confining bed at NAVBASE Charleston, resulting in an upward water flow.

SOUTHDIV has installed groundwater monitoring wells around the landfill (see figure 2.1-2) to characterize the chemical quality of the ground water adjacent to the landfill. These wells were initially sampled during July 1981, and the samples were analyzed for several physical and chemical parameters. Subsequent sampling was performed in February 1982, and analyses were conducted for inorganic and organic priority pollutants. The complete results of these sampling efforts were reported in Geraghty and Miller, Inc. (1982); table 2.2-1 summarizes the data for constituents reported above analytical detection. As shown, several trace metals and chlorinated organics are present in the ground water in the vicinity of the landfill. These constituents likely reflect past disposal of metal plating sludges, waste chemicals, and industrial degreasing solvents disposed of in the landfill. Ground water in the vicinity of the landfill is expected to flow toward Shipyard Creek or the Cooper River. It is expected that the soils would provide some degree of attenuation of these pollutants, and substantial dilution would occur upon entering the riverine systems. Quantitative estimates of these processes are not possible with available data.

2.2.2 Chemical Disposal Area (Site 2)

An unknown amount and variety of chemicals, which reportedly include Decontaminating Agent Non-Corrosive (DANC) and DS-2, have been disposed of by burial at the skeet and pistol ranges. DANC consists of separately packaged components of tetrachloroethane and dichloro-dimethyl-hydantoin. DS-2 is a ternary mixture of 70 percent diethylene triamine, 28 percent methyl cellosolve, and 3 percent sodium hydroxide. In 1972 and 1974, construction crews unearthed drums of chemicals in the skeet range, and some workers suffered minor chemical burns. It was also reported that unknown chemicals were buried both at the skeet range and behind the dike at the pistol range. In 1977, ten 5-gallon cannisters of DS-2 were reportedly buried at the skeet range. Due to the suspected small quantities buried, the impermeable nature of the soils, and the low hydraulic gradient in the area, contaminant migration is not believed to be likely. However, construction activities are proposed for the site, and because the types, quantities, and exact locations of these burials are unknown, this area represents a potential

Table 2.2-1
Summary of Trace Metal and Organics Data for the Landfill Monitoring Wells

Constituent	Concentration Range (ug/l)
Metals	
Arsenic (As)	<10-70
Barium (Ba)	370-4,620
Chromium (Cr)	<5-8.2
Mercury (Hg)	<0.1-0.4
Lead (Pb)	<5-22
Acid Organics	
Pentachlorophenol	ND-15
Phenol	--
2,4,6 Trichlorophenol	--
2,4 Dichlorophenol	--
4,6 Dinitro-o-cresol	--
Base/Neutral Organics	
1,4 Dichlorobenzene	--
2,4 Dinitrotoluene	--
N-nitrosodiphenylamine	--
Bis(2-ethylhexyl) phthalate	ND-90
Diethyl phthalate	--
Di-n-butyl phthalate	--
Naphthalene	--
Acenaphthene	--
Anthracene/Phenanthrene	--
Indeno(1,2,3-cd)pyrenee	--
Volatile Organics	
Methylene chloride	ND-1,600
Chlorobenzene	ND-50
Chloroform	ND-5.4
Dibromochloromethane	ND-3.4

ug/l = micrograms per liter.
ND = Not detected.
-- = 1 to 9 ug/l.

Sources: Geraghty and Miller, Inc., 1982.
ESE, 1983.

safety hazard. It may be possible to locate the specific burial areas through the use of geophysical remote-sensing detection techniques.

SOUTHDIV currently has a study in progress to determine if contaminant migration is occurring. Several monitor wells have been located in the vicinity, and groundwater samples have been collected.

2.2.3 Oil Sludge Pits (Site 3)

During the period 1944-71, oil sludges produced on the installation were disposed of in three unlined pits near Bldg. X-10. These pits are readily visible in aerial photographs taken in 1944 and 1951. These aerial photographs are available through NEESA or the Cartographic Branch of the National Archives (see section 1.3 for a complete address). During the period of use, heavy rains would occasionally cause the pits to overflow, creating oil spills in the low areas adjacent to the pits. These areas were subsequently covered with fill, trapping the oil in the subsoil. Two of the pits were covered by 1956. From 1971 to 1974, the remaining pit was open but was not used for the disposal of oil or sludge. In 1974, this pit was pumped to remove the oil and filled with clean compacted fill. Portions of the area have now been converted into a parking lot.

SOUTHDIV is currently funding a study to determine the location of the pits. The IAS team observed several test borings in the area and noted that they were filled with oil. Using a post hole digger, the IAS team made several additional test holes in the area which also filled with oil. The areal extent of the oil contamination is unknown; however, based on the inferred groundwater gradient, the oil is suspected to be slowly migrating toward the Cooper River. Several oil slicks of undetermined origin have been reported in the Cooper River near the oil pit area. These may be the result of oil which has migrated from the sludge pit area. Oil leaching into the Cooper River could create environmental degradation.

2.2.4 Petroleum, Oil, and Lubricants (POL) Transfer Point (Site 4)

The POL transfer point is located immediately east of Hobson Ave., directly across from aboveground POL storage tank 3900E. At this location, POL is transferred from railroad tank cars to the storage tanks. During transfer operations, several oil spills have occurred, and oil has leached into the subsoils. In 1981, during the construction of a fence, workers digging holes for fenceposts reported that the holes were filling with oil. The amount of POL in the soil of this area and the areal extent of the contamination are unknown. Subsurface POL could migrate to the Cooper River, resulting in potential environmental degradation.

2.2.5 Former Firefighting Training Pit (Site 5)

An unlined firefighting training pit, reportedly measuring between 30 and 50 feet in diameter, was located on the southern end of

NAVBASE Charleston from 1966-71 and contained waste oil, gasoline, and alcohol burned during firefighting training exercises. The pit area is not readily discernible from the ground, but its location is apparent when viewed from the air. Aerial photographs taken in 1971 clearly show the location of the pit. These photographs are available through NEESA or Public Works NSY. In 1971, the pit was cited by the U.S. Coast Guard for an oil spill following heavy rainfall, which caused the oil in the pit to overflow into Shipyard Creek. The pit was closed in 1972 by leveling and covering with bottom ash, and 4 inches of sludge reportedly lay at its bottom. The amount of oil which may have leached into the subsoil and the areal extent of the pit are unknown. Any oil currently remaining in the soil could leach into Shipyard Creek, resulting in potential environmental degradation.

2.2.6 PCB Storage Area (Site 6)

Out-of-service transformers containing PCB fluids are stored in Bldg. 3902 in the "Old Corral" area. Prior to 1976, out-of-service transformers were brought to the concrete pad on the south side of the building prior to transportation offbase. Transformers were either sold intact or drained prior to sale. The area around this concrete pad shows evidence of past oil spills, which may have contained PCBs. Due to the intermittent drainage of transformer oil and the unknown concentrations of PCBs therein, it is not possible to estimate the total amount of PCBs released to the soil. At the time of the IAS site survey, SOUTHDIV was conducting soil sampling around this concrete pad to determine the extent of PCB contamination.

2.2.7 Former Pesticide Mixing Area (Site 7)

Prior to 1971, pesticide equipment was rinsed at the area to the north of Bldg. 42. Wastewater generated by the cleaning of mixing and spraying equipment was allowed to drain into the soils of this area. Although these activities ceased at this location in 1971, an area measuring approximately 20 square yards remains completely devoid of vegetation, indicating that the soils in this area may be contaminated by unknown quantities of various pesticides.

2.2.8 Caustic Pond (Site 8)

The caustic pond, located near the junction of Bainbridge Ave. and Viaduct Rd., was used for the disposal of calcium hydroxide from the early 1940s through the early 1970s. The calcium hydroxide was generated as a byproduct of the reaction of water with calcium carbide to produce acetylene gas. During operation, water saturated with calcium hydroxide was allowed to settle in the pond, while excess water was discharged to Shipyard Creek. Although part of this pond was filled during the construction of Bainbridge Ave., a section of the pond still remains. The amount and areal extent of the calcium hydroxide is unknown; however, soil borings conducted during the IAS indicate sludge to a depth of 1 foot. Due to the acidity of the soils and ground water, the pH of the ground water is not expected to be elevated by the calcium

hydroxide nor is it expected that any problems would occur if the shallow aquifer were used for wells outside the base. No records were found to indicate that the shallow aquifer is being used adjacent to this area and outside the installation.

A variety of plant and animal species were recorded in the caustic pond and on adjoining areas during the IAS site survey. Grasses and herbaceous vegetation extended to the water's edge, and sedges, algae, and other aquatic plants grew in shallow portions of the pond. Tadpoles, fish (*Gambusia affinis*), and insect larvae were observed in the pond.

The greatest potential problem is the possibility of caustic burns if the calcium hydroxide is disturbed by personnel unfamiliar with the area. Such burns could occur if the skin were to come in direct contact with the calcium hydroxide sludge. SOUTHDIV is currently conducting a study in this area and has installed monitor wells. The migration of leachate from the caustic pond could be determined by measuring pH levels and calcium concentrations in the ground water.

SECTION 3.0
CONCLUSIONS

This section presents the conclusions of the IAS investigation of NAVBASE Charleston with regard to installation geohydrology as it relates to potential contaminant migration pathways and receptors and with regard to the potential for contaminant migration from the eight disposal and spill sites discussed in section 2.2. In addition, conclusions are presented for each of the eight sites with regard to contamination and contaminant migration potential. Relevant significant findings are also summarized for each site.

3.1 GEOHYDROLOGY

The potential for contaminant migration by both surface and subsurface pathways exists at NAVBASE Charleston. Potential receptors for migrating contaminants consist of surface waters and ground water. Surface water resources at NAVBASE Charleston include Noisette Creek, Shipyard Creek, and the Cooper River. Potential contamination of these surface waters and subsequent migration of contaminants beyond installation boundaries may occur as a result of direct surface runoff via stormwater drainages or the interception of the shallow ground water by surface waters along Shipyard Creek and the Cooper River. The quantities and concentrations of contaminants potentially entering these surface waters from NAVBASE Charleston cannot be estimated due to several nonpoint sources and the high degree of dilution due to river currents and tidal flushing of Shipyard Creek and the Cooper River.

Leaching rates and subsequent subsurface migration of contaminants are expected to be slow as a result of installation soil and ground water characteristics. The soils at NAVBASE Charleston are generally fine-grained and only slowly permeable. This type of soil, combined with the low gradient due to the basically level topography of the site, lead to slow contaminant migration rates. The permeability of the organically rich clays underlying the surface soils is also rather low. These highly organic clays range in thickness from 15 feet to 50 feet and are underlain by the Cooper Marl, a 200-foot-thick layer of stiff, calcareous clay.

Contaminants reaching the ground water at NAVBASE Charleston could migrate within the boundaries of the installation via the shallow groundwater system. This migration rate would be slow due to the soil texture and low gradient and would terminate at Shipyard Creek and the Cooper River, which represent the downgradient boundaries of the shallow groundwater system. The deep aquifer beneath the Cooper Marl is not subject to contamination from surface sources onbase because its hydraulic head is above the top of the former, resulting in a net upward flow into the shallower system.

As a result, the shallow groundwater system within installation boundaries is the sole potential groundwater migration route for contaminants at NAVBASE Charleston. No human health hazards are expected from the potential presence of contaminants in the shallow groundwater system, because the latter is not used for potable water supply at NAVBASE Charleston. In addition, some contaminants, particularly metals, are likely to be attenuated by adsorption onto clay minerals. Likewise, potential contaminant migration via the shallow groundwater system does not threaten human health offbase, because this flow is intercepted by surface waters at the installation boundaries. In addition, the shallow groundwater system is not significantly developed for potable use in the vicinity of NAVBASE Charleston.

3.2 WASTE DISPOSAL AND SPILL SITES

Each of the eight waste disposal and spill sites identified by the IAS team was evaluated using a Confirmation Study Ranking System (CSRS) developed by NEESA for the NACIP Program. The system is a two-step procedure for systematically evaluating a site's potential hazard to human health and the environment, based on evidence collected during the IAS.

Step 1 of the system is a flowchart, which eliminates innocuous sites from further consideration. Step 2 is a rating model which assigns a numerical score, within a range of 0 to 100, to indicate the potential hazard of a site. Scores are a reflection of the characteristics of the wastes disposed of at a site, potential contaminant migration pathways, and possible contaminant receptors on and off the installation. CSRS scores and engineering judgment are then used to evaluate the need for a Confirmation Study, based on the criteria stipulated in section 1.4. A more detailed description of the CSRS is contained in NEESA Report 20.2-042.

The CSRS system was applied to the eight disposal and spill sites identified at NAVBASE Charleston, and results are summarized in table 3.2-1. Based on the application of the CSRS system and engineering judgment to the eight disposal and spill sites identified at NAVBASE Charleston, all eight sites are recommended for Confirmation Studies. The following subsections summarize the relevant conclusions for each of the eight waste disposal and spill sites evaluated.

3.2.1 Base Sanitary Landfill (Site 1)

From the 1930s until 1973, waste materials generated on the base were landfilled in its southwestern portion. Items reportedly disposed of in this landfill included: asbestos, acids, PCBs, waste oils, waste solvents, waste paints, paint sludges, mercury, metal sludge, acid neutralization sludge, various inorganic and organic chemicals, and sanitary wastes. The quantities of these wastes disposed of are unknown, but are believed to be large, based on current generation rates. Based on an analysis of landfill contents, the subsoils in this

Table 3.2-1
Site Recommendations

Site Number	Site Name	Confirmation Study Recommended?
1	Base Sanitary Landfill	Yes
2	Chemical Disposal Area	Yes
3	Oil Sludge Pits	Yes
4	POL Transfer Point	Yes
5	Former Firefighting Training Pit	Yes
6	PCB Storage Area	Yes
7	Former Pesticide Mixing Area	Yes
8	Caustic Pond	Yes

Source: ESE, 1981.

area are potentially contaminated. Although no data are available regarding permeability rates or range for soils adjacent to the base sanitary landfill, a field inspection of these soils at the landfill indicated which soil typically permits the slow migration of ground water in the shallow system toward Shipyard Creek. As a result, any leachate from the landfill could migrate toward Shipyard Creek.

The potential contamination of the shallow groundwater system by landfill leachates is currently being investigated by SOUTHDIV at a series of monitoring wells located at the southernmost, downgradient portion of the landfill.

3.2.2 Chemical Disposal Area (Site 2)

An unknown amount and variety of chemicals, which reportedly include DANC and DS-2, have been disposed of by burial at the skeet and pistol ranges. In 1972 and 1974, construction crews unearthed drums of chemicals at the skeet range, and some workers suffered minor chemical burns. It also was reported that unknown chemicals were buried both at the skeet range and behind the dike at the pistol range. In 1977, ten 5-gallon cannisters of DS-2 were reportedly buried at the skeet range.

The probability of contaminant migration is unlikely at this site due to the suspected small quantities of chemicals buried and the impermeable nature of the soils and low hydraulic gradient in this area. However, the buried chemicals may represent a potential safety hazard during the proposed excavation and construction activities at this site, because the types, total quantities, and exact locations of these burials are unknown.

SOUTHDIV has installed several monitoring wells in the vicinity of the chemical disposal area to determine if contaminant migration is occurring.

3.2.3 Oil Sludge Pits (Site 3)

During the period 1944-71, oil sludges produced on the installation were disposed of in three, unlined pits near Bldg. X-10. These pits are readily visible in aerial photographs taken in 1944 and 1951. During the period of use, heavy rains would occasionally cause the pits to overflow, creating oil spills in low areas adjacent to the pits. These low areas subsequently were covered with fill, and the oil remained trapped in the subsoil. Prior to 1955, two of the pits were filled. In 1974, the remaining pit was pumped to remove the oil and filled with clean, compacted fill. Portions of the area have now been converted into a parking lot. The IAS team observed several test borings in the area and noted that they were filled with oil. The IAS team made several additional test holes in the area and found oil. The areal extent of the oil contamination is unknown; however, based on the inferred groundwater gradient, oil is suspected to be slowly migrating toward the Cooper River. Oil leaching into the Cooper River could

create environmental degradation to the aquatic communities. No impacts to human health are anticipated.

3.2.4 POL Transfer Point (Site 4)

The POL transfer point is located immediately east of Hobson Ave., directly across from aboveground POL storage tank 3900E. At this location, POL is transferred to and from railroad tank cars. During the use of this area, several oil spills have occurred, and oil has leached into the subsoils. In 1981, during the construction of a fence, workers digging holes for fenceposts reported that the holes were filling with oil. The amount of POL in the soil of this area and the areal extent of the contamination are unknown. POL could be migrating to the Cooper River. If POL reaches the Cooper River, it may cause degradation of the Cooper River aquatic communities; however, no adverse impacts on the terrestrial biota of the base are expected.

3.2.5 Former Firefighting Training Pit (Site 5)

An unlined firefighting training pit, reportedly measuring between 30 and 50 feet in diameter, was located on the southern end of NAVBASE Charleston. This pit reportedly existed from 1966-71 and was used to contain waste oil, gasoline, and alcohol burned during firefighting training exercises. The amount of POL which may have leached into the subsoil and the areal extent of residual contamination are unknown. Currently, the pit is separated from Shipyard Creek by a dense zone of shrubs and hardwoods, as well as a roadbed. However, any POL remaining in the soil could leach into Shipyard Creek, resulting in the potential degradation of aquatic and littoral communities.

3.2.6 PCB Storage Area (Site 6)

Out-of-service electrical items such as rectifiers, transformers, and capacitors are stored in Bldgs. 3902 and 1069. Prior to 1976, a number of transformers also were drained near the concrete pad on the south side of Bldg. 3902. As a result, the soil around the pad received transformer oils which possibly contained PCBs. Due to the intermittent drainage of fluids and unknown concentrations of PCBs, it is not possible to estimate the total amount of PCBs released to the soils. SOUTHDIV currently is conducting a study program to determine if these soils are contaminated with PCBs.

3.2.7 Former Pesticide Mixing Area (Site 7)

Prior to 1980, the area to the north of Bldg. 42 was used for pesticide mixing. Wastewater generated by the cleaning of mixing and spraying equipment was allowed to drain into the soils of this area. Although these activities ceased in 1980, an area of approximately 20 square yards remains completely barren. The soils in this area are potentially contaminated by unknown quantities of various pesticides, which could be transported to Shipyard Creek via stormwater runoff.

Such potentially contaminated runoff may cause environmental degradation to aquatic and littoral communities of Shipyard Creek.

3.2.8 Caustic Pit (Site 8)

The caustic pit, located near the junction of Bainbridge Ave. and Viaduct Rd., was used for the disposal of calcium hydroxide sludge during the period of the early 1940s through the early 1970s. Although part of this pond was filled during the construction of Bainbridge Ave., an open section still remains. The amount and areal extent of the calcium hydroxide is unknown.

The caustic pit represents little hazard if left undisturbed and if public access is prohibited. The pit represents a possible safety hazard due to the potential for caustic burns to personnel disturbing the ground.

SECTION 4.0
RECOMMENDATIONS

4.1 INTRODUCTION

Based on the foregoing significant findings and conclusions, eight sites at NAVBASE Charleston are suspected of being potentially contaminated. The geologic and geohydrologic character of the associated soils permits the potential migration of contaminants from the disposal and spill sites, resulting in a potential threat to human health or to the environment. The locations of each of these eight sites are shown in figure 4.1-1.

Additional information regarding the location or extent of the contaminated areas and the potential for contaminant migration is required before the need for action (if any) can be identified. Therefore, it is recommended that a Confirmation Study, Phase II of the NACIP Program, be performed at NAVBASE Charleston.

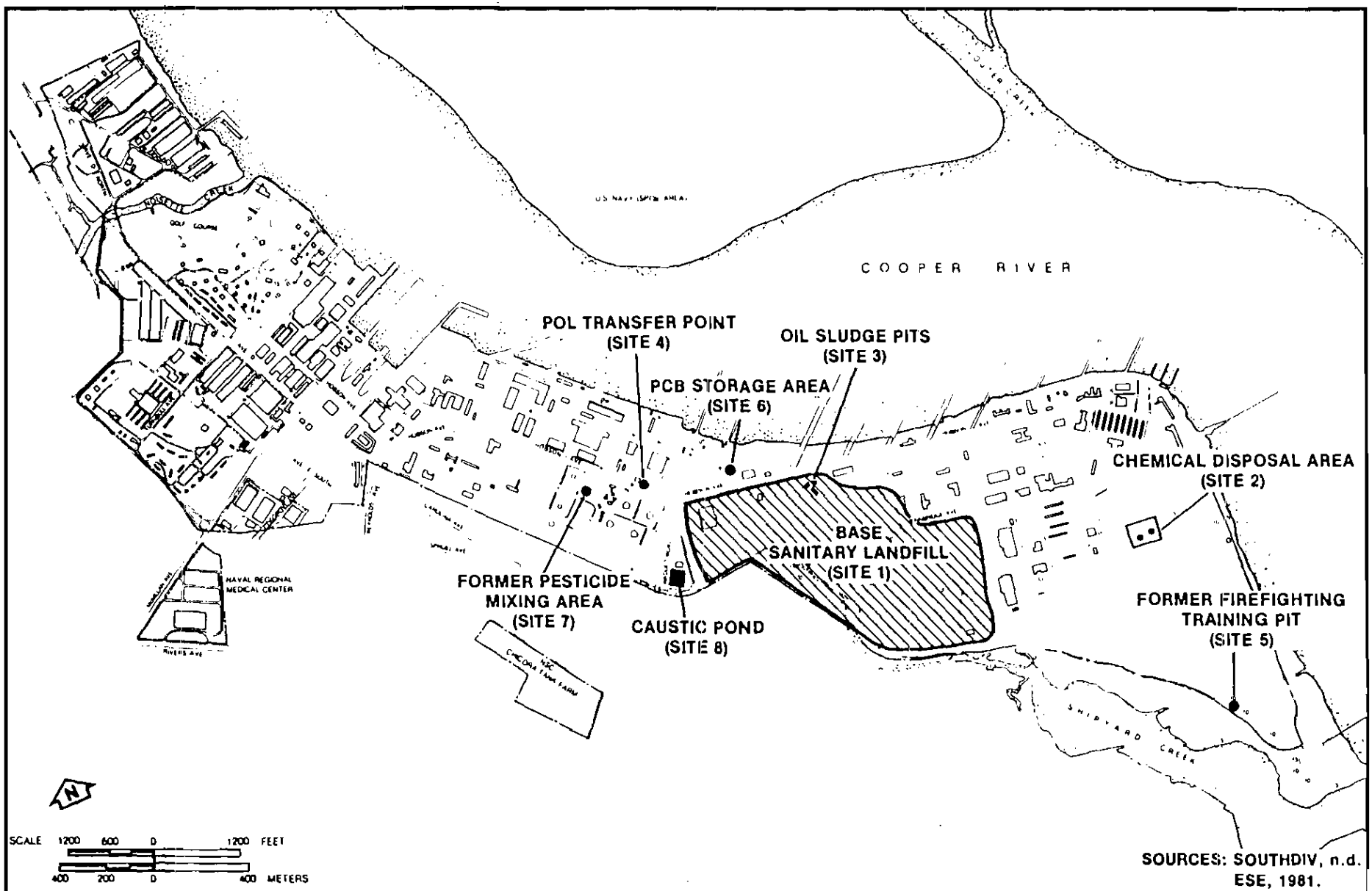
Eight waste disposal sites at NAVBASE Charleston are recommended for confirmation. Table 4.1-1 identifies these sites and provides a ranking of their relative risk potentials. In general, those sites with higher rankings are of more immediate concern (in particular, site 1) and are of higher priority with regard to the need for confirmation.

It is recommended that the SOUTHDIV Planning Department be advised of the locations of the contaminated areas identified in this IAS and that all new construction at NAVBASE Charleston be coordinated through the SOUTHDIV Facilities Planning and Real Estate Department and the Environmental Branch of the Facilities Management Department.

4.2 CONFIRMATION STUDY

It is recommended that the areas which warrant further investigation under the Confirmation Study include: base sanitary landfill (site 1), chemical disposal area (site 2), oil sludge pits (site 3), POL transfer point (site 4), former firefighting training pit (site 5), PCB storage area (site 6), former pesticide mixing area (site 7), and the caustic pond (site 8).

For the reasons presented in the Discussion of Significant Findings (section 2.0), two of these areas [caustic pond (site 8) and chemical disposal area (site 2)] do not pose an environmental threat but represent a safety hazard to base personnel. For these areas, it is recommended that the extent of the contaminated area be defined by the Confirmation Study and the contaminants be removed (or adequately posted as a potential safety hazard).



SOURCES: SOUTHDIV, n.d.
ESE, 1981.

Figure 4.1-1
POTENTIAL CONTAMINATION MAP

INITIAL ASSESSMENT STUDY
NAVAL BASE CHARLESTON

Table 4.1-1
Summary of Site Recommendations

Site Number	Site Name	CSRS Score	Monitor Wells	Soil Borings	Soil Samples	Field Analytical Techniques	Laboratory Analytical Parameters
1	Base Sanitary	31	7	--	--	--	Heavy metals (As, Ba, Cd, Cr, Cu, Hg, Ni, Pb, Ag, and Zn), cyanides, oil and grease or petroleum hydrocarbons, PCBs, and EPA priority pollutant volatile organic compounds
2	Chemical Disposal Area	26	--	--	--	GPR, magnetometer metal detector, and EM	--
3	Oil Sludge Pits Option 1	26	--	150*	--	Portable GC	--
	Option 2		--	10*	--	GPR, EM, and portable GC	--
4	POL Transfer Point Option 1	12	--	100*	--	Portable GC	--
	Option 2		--	10*	--	GPR, EM, and portable GC	--
5	Former Firefighting Training Pit	5	--	5†	5	Portable GC	--
6	PCB Storage Area	22	--	--	25	--	PCBs

Table 4.1-1
Summary of Site Recommendations
(Continued, Page 2 of 2)

Site Number	Site Name	CSRS Score	Monitor Wells	Soil Borings	Soil Samples	Field Analytical Techniques	Laboratory Analytical Parameters
7	Former Pesticide Mixing Area	13	--	--	5	--	Organochlorine pesticides (aldrin, BHC, lindane, chlordane, DDT, DDE, endrin, heptachlor, heptachlor epoxide, methoxychlor, toxaphene), organophosphate pesticides [diazinon, malathion, parathion, thimet (phorate), trithion], chlorinated phenoxy herbicides [2,4-D, 2,4,5-T, 2,4,5-TP (Silvex)], and total As
8	Caustic Pond	7	--	25-50†	--	--	--

* Power auger.
† Hand auger.

Abbreviations:

As = arsenic.
Ba = barium.
Cd = cadmium.
Cr = chromium.
Cu = copper.
Hg = mercury.
Ni = nickel.
Pb = lead.
Ag = silver.
Zn = zinc.

EPA = U.S. Environmental Protection Agency.
GPR = Ground-penetrating radar.
EM = Electromagnetism.
GC = Gas chromatograph.

Source: ESE, 1981.

The remaining six areas pose a potential environmental threat and require confirmational monitoring before the necessity and/or procedures for corrective action can be determined.

Table 4.1-1 summarizes the recommended monitoring program for the eight areas included in the Confirmation Study. The detailed approach for each area is described below. It is recommended that personnel from Public Works NSY be consulted regarding the locations of contaminant sources prior to the selection of sampling points.

4.2.1 Base Sanitary Landfill (Site 1)

The recommended monitoring program for the base sanitary landfill consists of the evaluation of hydrogeological characteristics (subsurface stratigraphy, permeability, and piezometry) and groundwater quality adjacent to the landfill. It is recommended that six monitor wells be installed around the perimeter of the landfill. One background well should be installed onsite, upgradient of the landfill and away from other potential contaminant sources. It is further recommended that the results of the current SOUTHDIV monitoring effort be evaluated prior to well installation to incorporate any data from that study into the design of the landfill monitoring program.

4.2.1.1 Well Installation

It is recommended that all wells be drilled to the top of the Cooper Marl (approximately 20 to 60 feet) and screened over their entire saturated length. Detailed logs of each boring should be made, including well construction diagrams. Shelby tube samples taken during drilling should be tested to determine vertical permeability. Filter pack material should be medium-fine sand, used with an appropriate slot-size screen. The top of the filter packs should be bentonite sealed and the annulus grouted to the surface. Wells should be protected with 8-inch black pipe fitted with locking caps. All wells should be developed to the fullest extent possible and surveyed by a registered surveyor to obtain accurate elevations.

4.2.1.2 Groundwater Monitoring

A two-phased groundwater monitoring effort consisting of verification and characterization phases is recommended. For the verification phase, groundwater sampling would involve the collection of one sample from each well over the entire saturated zone. Water levels should be measured after well development and at the time of sampling. Water level measurements should be made simultaneously at all wells to avoid tidal interferences. Slug tests should be conducted at all wells to determine horizontal permeability and to enable an evaluation of flow rates.

Table 4-1.1 lists the parameters recommended for analysis for the verification phase. The individual chemical parameters recommended for analysis in the water samples obtained from the monitoring wells are

keyed to suspected contaminants in the landfill. From among the organic compounds on EPA's priority pollutant listing, only the volatile organics are recommended.

If contamination is detected in the wells during the verification phase, then a confirmatory phase is recommended. Surface water samples from Shipyard Creek and/or the Cooper River should be collected at probable entry points of landfill leachate into the surface body and analyzed for contaminants present in the monitor wells. Wells which show evidence of contamination on the first sampling should be resampled at several elevations and reanalyzed for contaminants present to allow the development of a vertical profile of contaminant concentration.

4.2.2 Chemical Disposal Area (Site 2)

Migration of contaminants from the chemical disposal area is not anticipated to be a significant problem because of the small quantities of chemicals believed to be buried, the rather impermeable nature of the subsurface, and the low hydraulic gradient. Therefore, groundwater monitoring is not recommended for this disposal area. However, the presence of these buried substances does pose a threat to the safety of base personnel, since future development is planned for this area. Because of the toxic nature of the buried chemicals (which include DS-2 and DANC), the shallowness of the burials, and the fact that regrading of the burial area is planned, safety is a significant problem. It is recommended that individual burial locations in the pistol and skeet ranges be identified using a combination of shallow geophysical techniques. GPR, magnetometers, metal detectors, and shallow EM would be the most effective geophysical methods for these tasks. As a remedial action, once the chemicals are located, they should be excavated using proper safety procedures and properly disposed of offbase.

4.2.3 Oil Sludge Pits (Site 3)

The extent of the oil contamination in these areas should be delineated by one of two methods. The area which is grossly contaminated (liquid oil in subsurface) should be mapped separately from the area which exhibits only oily residue in the soil. For either option, the area requiring investigation may need to be expanded, pending the outcome of the initial investigation, since oil may have migrated from the initially contaminated area. Once the contaminated area has been delineated, the oil and oily residue should be removed and disposed of.

As mentioned in section 2.3, oil may be migrating from the former disposal areas to the Cooper River, potentially degrading aquatic habitats. Section 6.7.2.1 describes the potential impacts of oil on aquatic ecosystems in more detail. Several oil slicks have been observed in the Cooper River near the oil pit area.

4.2.3.1 Option 1

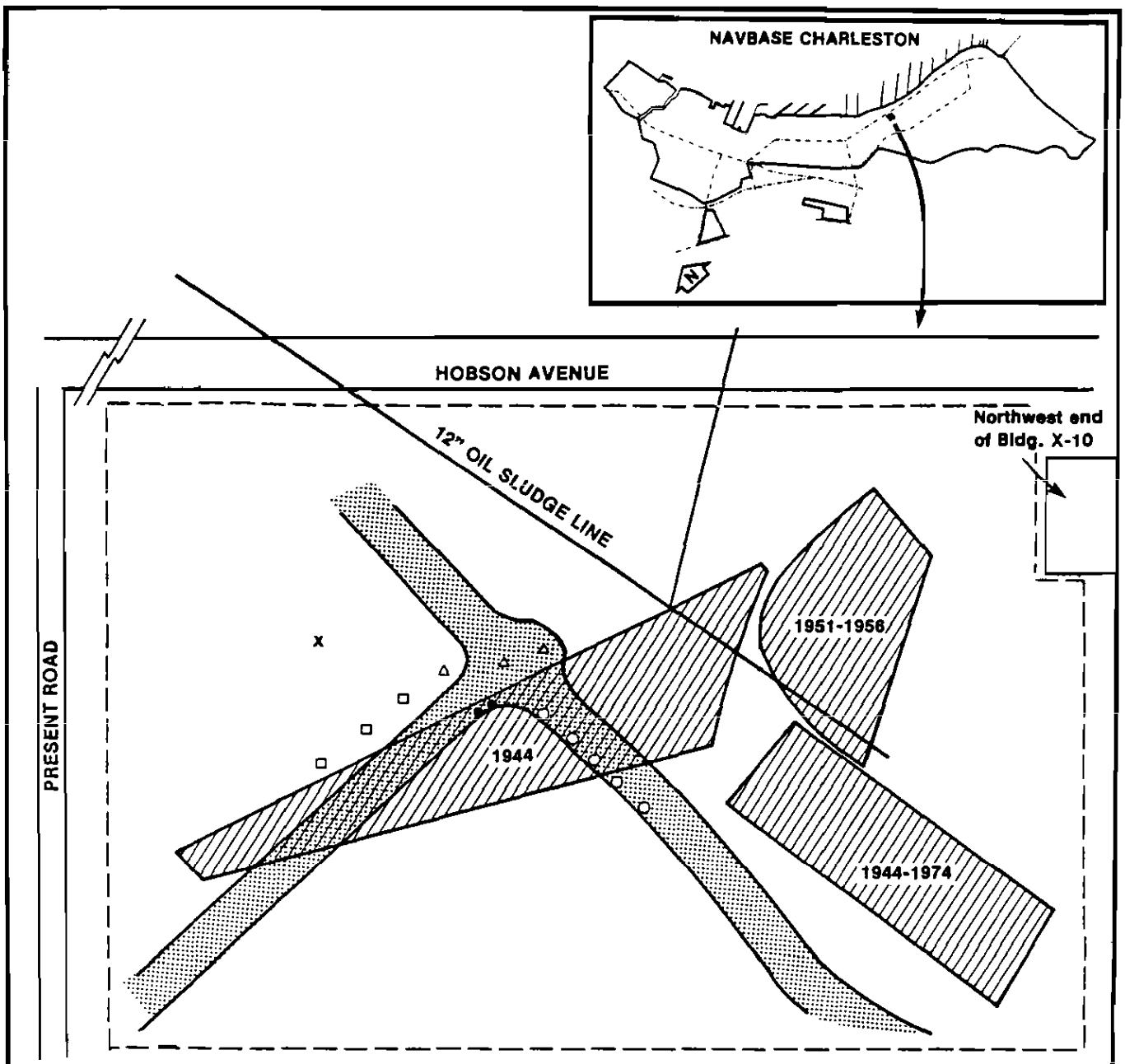
Mapping could be accomplished by a large number of shallow borings on a grid system throughout the area of suspected contamination. The area which should be investigated initially is identified in figure 4.1-2. The entire area is potentially contaminated by liquid oil or oily residue due to either disposal of or spills of oil. Approximately 150 shallow borings should be made in the indicated rectangular area. Each boring should be at the center of a rectangular subsection formed by dividing the area under investigation into 150 equal parts. Borings should be to groundwater level and should be made with a tractor-mounted, power post hole auger. Considerable disturbance to the area (now used as a parking lot) would result. Each boring should be visually inspected for the presence of oil. For those borings with no visible liquid oil present, a potable GC should be used to check for hydrocarbons to establish the presence or absence of oily residue.

4.2.3.2 Option 2

An alternative technique to a soil boring network would be to employ geophysical methods to define the extent of the contaminated area. GPR and shallow EM would be the most appropriate methods. The area to be investigated initially would be the same as for option 1 (figure 4.1-2). A small number (approximately 10) of 4-foot soil borings would still be required for verification and calibration purposes, but this approach would cause much less surface disturbance and would take less time. Interpretation of GPR data would probably yield an evaluation of the thickness and location of the liquid oil layer in the ground. The area subtly contaminated (no liquid oil present) could be mapped using a hand auger of small diameter (1 inch) and a portable GC to check for hydrocarbons, a method which would minimize surface disturbance.

4.2.4 POL Transfer Point (Site 4)

The nature of the contamination problem at this area is similar to that of the oil sludge pits (site 3), i.e., the presence of underground oil and oily residue. However, much less information is available regarding the probable source and extent of the problem. A similar program should be undertaken to define the extent of the contaminated area, using either a power auger and a portable GC or geophysical means (GPR and EM) and a portable GC. The area to be investigated should originate at the location where oil has been observed in post holes and expanded outward. Due to the uncertain nature of the monitoring program, the number of borings indicated in table 4.1-1 for either option should be considered approximate. Once the extent of the contaminated area is defined, oil and oily residue should be removed and disposed of, or recycled, if possible.



KEY

- -- BOUNDARY OF AREA TO BE INVESTIGATED
- ● GERAGHTY AND MILLER WELLS
- △ GERAGHTY AND MILLER SOIL BORINGS (OIL VISIBLE)
- □ ESE POSTHOLE (OIL VISIBLE)
- X ESE POSTHOLE (NO OIL VISIBLE)
- ○ ESE SOIL AUGER HOLE (OILY ODOR)
- SLUDGE PITS WITH APPROXIMATE DATES OF OPERATION
- CINDER ROADS

NOT TO SCALE

SOURCES: SOUTHDIV, n.d.
ESE, 1981.

Figure 4.1-2
RECOMMENDED AREA FOR OIL SLUDGE PIT INVESTIGATION

INITIAL ASSESSMENT STUDY
NAVAL BASE CHARLESTON

4.2.5 Former Firefighting Training Pit (Site 5)

The area is suspected to contain oil residue over a 30- to 50-foot circular area. The residue resulted when the pit was closed by mixing a residual sludge with soils and covering the area.

The area is located within 50 feet of the edge of the unpaved road, adjacent to the western boundary of the installation bordering Shipyard Creek (see figure 4.1-1). The area is located approximately 0.2 mile north of the intersection of the unpaved road with Horvath Rd.

Five shallow soil borings should be made with a hand-operated bucket auger in the area of the pit to verify the suspected presence of oily residue in the soil. Samples should be visually inspected and smelled to determine presence of POL. If a portable GC is onsite for use at the oil sludge pit (site 3) or POL transfer point (site 4) areas, then it could also be used to examine soils for hydrocarbon content from this site. If soils are found to be contaminated, they should be removed and disposed of as a remedial measure. Alternatively, it may be possible to degrade the residual sludge biochemically in place by nutrient enrichment and disking.

4.2.6 PCB Storage Area (Site 6)

It is recommended that sampling of the soils for PCB contamination be conducted in the area around the concrete pad located adjacent to Bldg. 3902 in the "Old Corral" area of Public Works NSY. Samples should be taken adjacent to the concrete pad of the top composite 12 inches of soil, which is visibly stained with transformer fluids. These samples should be analyzed as discrete samples (i.e., not composited with other samples). It is also recommended that soil samples be taken within an approximate 50-foot radius of the pad to delineate the extent of possible PCB contamination. A total of approximately 25 samples is recommended.

4.2.7 Former Pesticide Mixing Area (Site 7)

Sampling of the soils is recommended in the area devoid of vegetation in the former pesticide mixing area north of Bldg. 42. The area is roughly rectangular and measures approximately 2 by 10 yards. It is recommended that soil samples be taken of the top composite 12 inches of soil at 5 locations in this area (1 at each of the 4 corners and 1 in the center of the rectangular area) and analyzed for the parameters listed in table 4.1-1. If the analyses for the area indicate that the soils are contaminated, several soil borings should be made and the cores segmented by depth and analyzed to determine the extent of vertical migration, and, ultimately, the volume of soil which is contaminated.

4.2.8 Caustic Pond (Site 8)

Migration of excess alkalinity from this area is not expected to be an environmental threat, due to the low permeability of the subsurface soils, the natural acidity expected to be present in the soils and ground water in the area, and the tendency of the calcium hydroxide sludge to form a crust which limits its solubility. A potential safety hazard to base personnel may exist, if the calcium hydroxide is disturbed by construction personnel or other individuals unfamiliar with the area. Direct contact with newly exposed calcium hydroxide is the only potential problem. During the IAS site visit, the pond and adjoining areas had stabilized and were supporting vegetation and terrestrial and aquatic animals. It is recommended that the location of the residual caustic sludge be defined.

Shallow soil borings should be made around the current pond area to delineate the horizontal and vertical extent of the calcium hydroxide sludge. These borings could be made with a hand-operated soil auger (1 inch) to a depth of approximately 1 foot. Approximately 25 to 50 borings should be adequate to define the location of the residual sludge. No samples need to be analyzed for chemical characteristics, because the appearance of the sludge is visually distinct. The sludge is white and fine-grained and is easily distinguishable from the soils in the area.

Once the location of the residual sludge has been determined, it is recommended that one of the following alternatives be implemented:

1. The contaminated area be permanently identified as a potential hazard, with signs at the actual location and also on the installation base map; or

2. The calcium hydroxide sludge be neutralized in situ by the use of a dilute solution of an appropriate acid (e.g., dilute hydrochloric acid solution). The sludge outside of the ponded area could be repeatedly disked to bring it to the surface and treated with acid solution until neutralized. The sludge in the ponded area could be similarly treated after the pond is drained.

SECTION 5.0
BACKGROUND

5.1 GENERAL

5.1.1 Location and Organization

The Charleston Naval Complex is located in Charleston and Berkeley Counties on South Carolina's central coast, north of the City of Charleston's central business district (see figure 5.1-1). The Complex is divided into two major areas, Naval Base North and Naval Base South. Activities on Naval Base North are outside the scope of this report, however, which deals only with the second area, Naval Base South, hereafter referred to as NAVBASE Charleston. The NAVSTA Annex (RADAR Site) was not included in the study.

NAVBASE Charleston is located on the banks of the Cooper River in Charleston County, S.C., approximately 5 miles north of the City of Charleston. The installation consists of two major areas: an undeveloped spoil area on the east bank of the Cooper River on Daniel Island in Berkeley County, and a developed area on the west bank of the Cooper River. The developed portion of NAVBASE Charleston lies on a peninsula, bounded on the west by the Ashley River and the east by the Cooper River. The western boundary of the developed area adjoins the City of North Charleston, and the eastern boundary the Cooper River between river mile 10 and river mile 14. NAVBASE Charleston facilities adjacent to the main developed area of the base include the Naval Regional Medical Center (NRMC) and the Chicora Tank Farm, both located within 0.5 mile west of the reservation.

NAVBASE Charleston covers approximately 3,300 acres (SOUTHDIV, n.d.). Navy activities and commands which maintain real property on NAVBASE Charleston include:

1.	NSY	1,908.22 acres
2.	NAVSTA	1,153.11 acres
3.	NSC	192.72 acres
4.	NRMC	23.79 acres
5.	Fleet and Mine Warfare Training Center (FMWTC)	10.40 acres

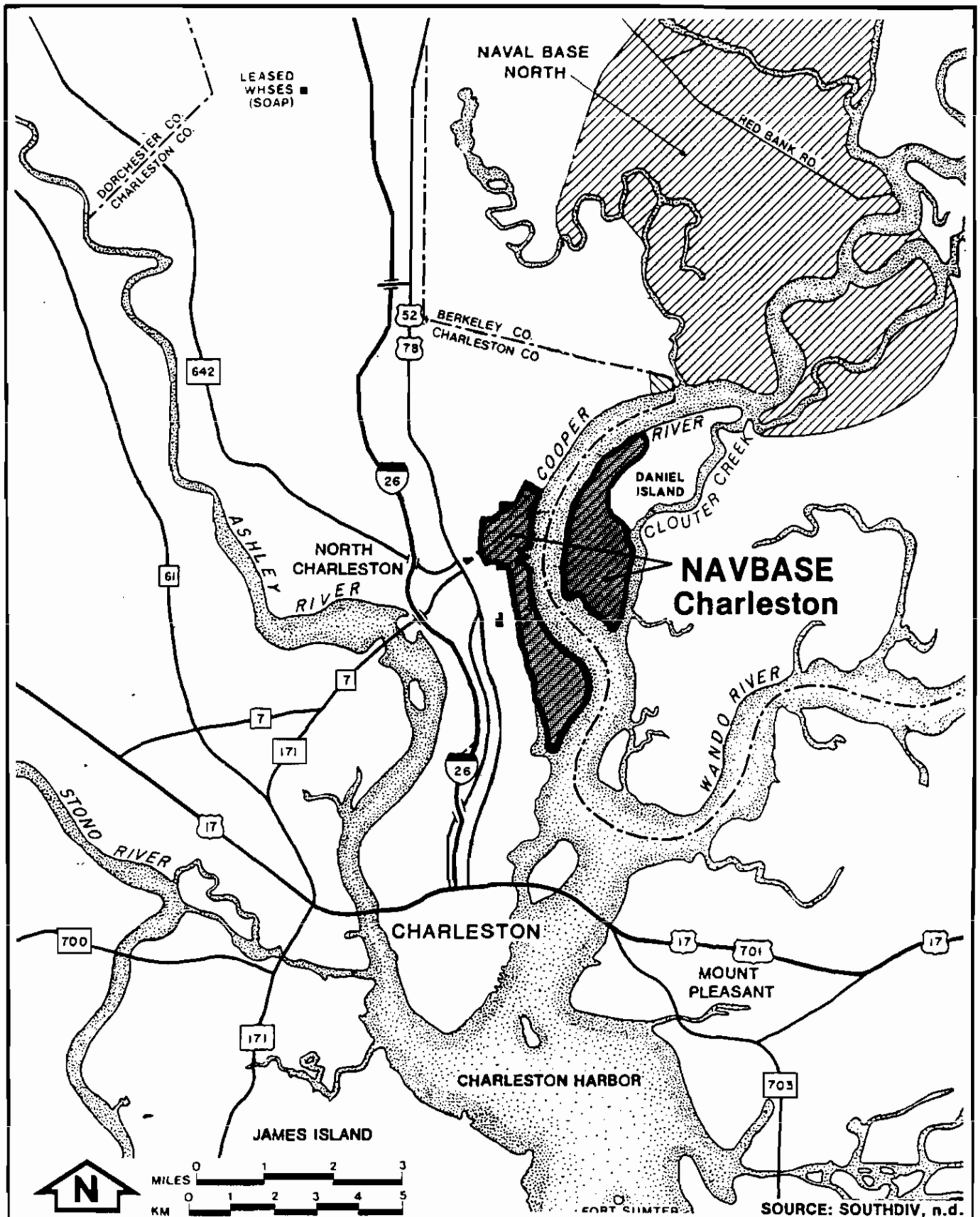


Figure 5.1-1
LOCATION MAP OF NAVBASE CHARLESTON

INITIAL ASSESSMENT STUDY
NAVAL BASE CHARLESTON

6.	Fleet Ballistic Missile Submarine Training Center (FBMSTC)	6.88 acres
7.	Navy Reserve Center (NRC)	4.50 acres
	TOTAL ACREAGE	3,299.62 acres

The locations of these land holdings are shown in figure 5.1-2. NSY controls the spoil area to the east of the Cooper River and the majority of the central one-third of the developed area on the west bank of the river. The southern one-third of developed area of the main base is controlled primarily by NAVSTA. NSC and NAVSTA are the major landholders on the northern one-third of the developed area. NSC also controls the offbase Chicora Tank Farm.

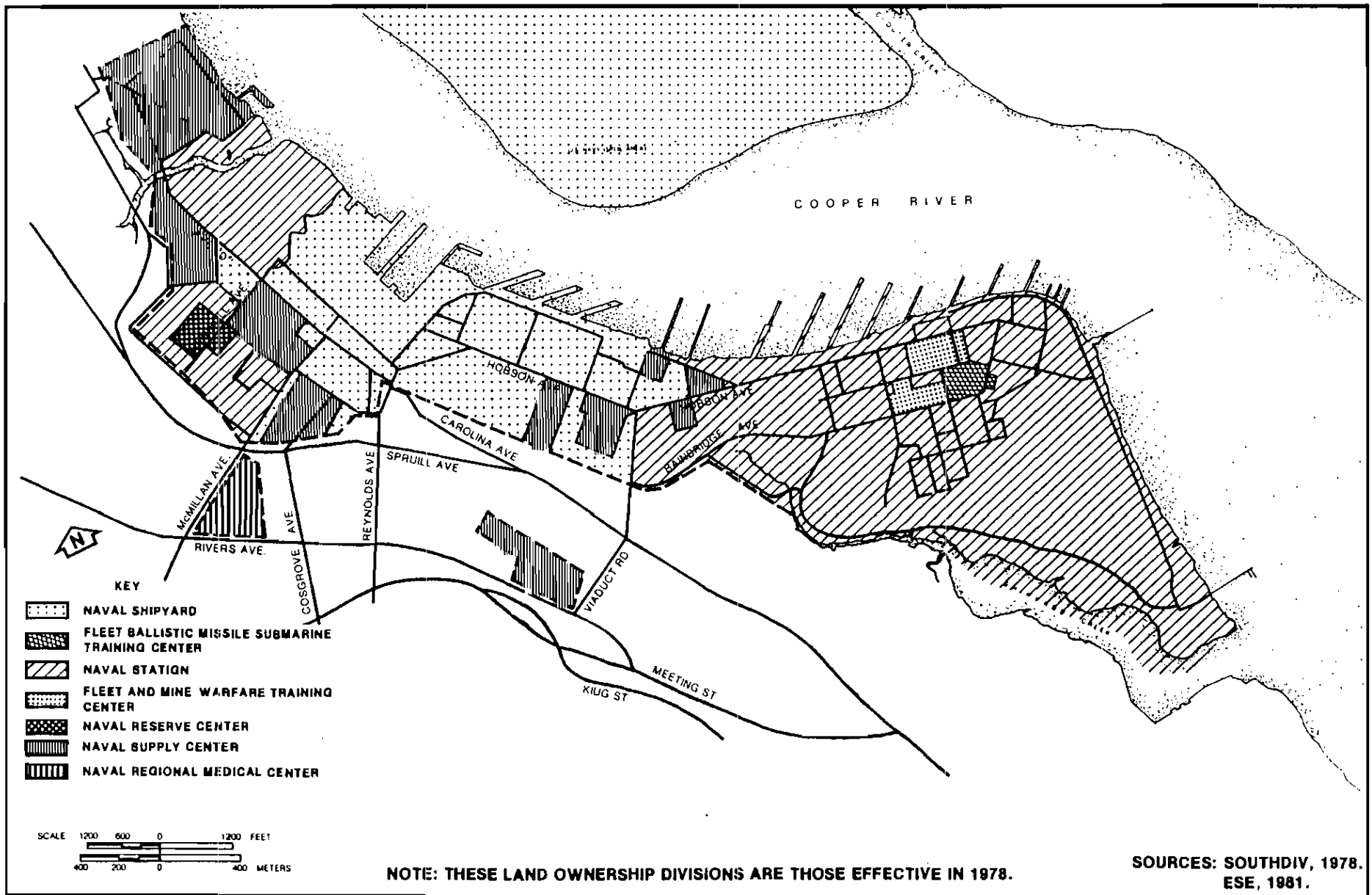
NAVBASE Charleston houses the base Commander, who also functions as CNO Area Coordinator for the Southeastern United States. His general duties as Commander include command of assigned shore activities, coordination of logistic support for fleet units and other naval districts, and area coordination responsibility over designated shore activities. He "represents the Secretary of the Navy (SECNAV) and CNO in assigned matters, exercises area coordination responsibilities over all shore activities and personnel in the Southeastern United States, exercises command of assigned Naval Shore activities, coordinates fleet support matters, coordinates public affairs matters, and performs other functions as directed by CNO" (SOUTHDIV, 1978).

This report is concerned with activities and commands on NAVBASE Charleston, as listed above, as well as the Marine Corps Barracks, the Naval Security Group Activity (NAVSECGRUACT) (tenants on the base), and the Naval Electronics Systems Engineering Center (NESEC), west of the base on Interstate 26 and Gore Rd.

5.1.2 Host/Tenant Relationships and Missions of Specified Activities

Of the nine activities examined in the context of this report, only the Marine Corps Barracks and NAVSECGRUACT are identified as tenants on NAVBASE Charleston, both occupying facilities controlled by NAVSTA. NESEC is located outside the base in a building leased through the General Services Administration (GSA) (Personal Communication, 1981).

The remaining six activities are land owners on the base, with the NAVSTA, NSY, and NSC holding the greatest acreage and serving as hosts for various tenants. Tenants of these activities which are generators of hazardous waste are discussed in section 6.0.



NOTE: THESE LAND OWNERSHIP DIVISIONS ARE THOSE EFFECTIVE IN 1978.

SOURCES: SOUTHDIV, 1978.
ESE, 1981.

Figure 5.1-2
LAND OWNERSHIP ON NAVBASE CHARLESTON

INITIAL ASSESSMENT STUDY
NAVAL BASE CHARLESTON

Official mission statements for each of the nine activities discussed in this report appear below. Refer to section 5.2, Historical Overview, for further details.

1. NAVSTA: Provides, as appropriate, logistic support for the operating forces of the Navy and for dependent activities and other commands as assigned.

2. NSY: Provides logistic support for assigned ships and service craft; performs authorized work in conversion, overhaul, repair, alteration, drydocking, and outfitting of ships and craft as assigned; performs manufacturing research, development, and test work as assigned; and provides services and material to other activities and units as directed by competent authority.

3. NSC: Provides supply and support services to fleet units and shore activities and performs other functions as directed by its major claimant, the Naval Supply Systems Command.

4. FBMSTC: Trains fleet ballistic missile (FBM) personnel in order to bring them to a higher level of proficiency in the skills required to operate FBM submarines and the Polaris/ Poseidon Weapons Systems.

5. FMWTC: Provides general shipboard training, as well as specialized training, in mine warfare (SOUTHDIV, n.d.).

6. NAVSECGRUACT: Performs Naval Security Group functions as directed (COMNAVSECGRU, 1980b).

7. NESEC: Provides electronics support in the maintenance and modification of communications equipment, such as automatic air traffic control equipment, for the Atlantic Naval Fleet and associated shore communication systems (Personal Communication, 1981).

8. Marine Corps Barracks Detachment: Provides perimeter security for the Naval Complex, under the command of the Marine Corps Barracks, Naval Weapons Station (NWS) (Personal Communication, 1981).

9. NRMC: Provides improved patient care through improved utilization of resources, including medical personnel, and commands and coordinates the various Naval medical facilities and programs available to the Charleston military community (SOUTHDIV, n.d.).

5.1.3 Leases and Agreements

Three non-Federal operations currently perform general ship repair work under contract to the Government on property owned by NSY. These include:

1. Braswell Shipyards, Inc.--occupying a 0.290-acre area on Shipyard Creek, west of Bainbridge Ave.;

2. Sandblasters, Inc.--occupying a tract of land measuring 0.28 acre, contiguous to the southern boundary of the Braswell property; and

3. Metal Trades, Inc.--occupying 0.27 acre of land adjacent to Sandblasters, Inc.

Records of the SOUTHDIV Real Estate Office indicate that Metal Trades and Sandblasters have occupied their present sites since 1975, and Braswell has been operating in its present location since 1979. From approximately 1970 to 1979, Braswell was located between Bainbridge and Hobson Aves. The land on which these facilities currently lie was primarily marsh and undeveloped prior to their arrival. The potential for these companies to produce hazardous waste is discussed in section 6.1.1.14.

NSC has issued a grazing lease for 22 acres of land on Chicora Tank Farm, 0.5 mile from the main gate, to Mr. Hyman Moody. The purpose of the lease is to maintain a vegetative ground cover, prevent soil erosion, and reduce maintenance costs. The lessee is obligated to pulverize and spread manure over the area, apply 5-10-10 fertilizer annually at the rate of 400 pounds per acre on a 5-acre area, and apply the EPA-registered herbicide, Round-Up, to the perimeter fence every 2 years.

A search of SOUTHDIV Real Estate Office records indicated that a variety of out licenses and leases have been granted over the years for sewer line easements, local gun club practice ranges, lands used by a local construction company, etc. Records are not sufficiently detailed, however, to permit analysis of the potential for these activities to produce hazardous waste.

Additional information on past permits and licenses was disclosed by a search of Department of the Navy files. Correspondence dating from 1928 was found regarding issuance of a right-of-way to Standard Oil of New Jersey for a suction line runway and pipeline necessary for establishing a loading station across Marsh Island, an area about 500 yards from the southern tip of the base. In 1930, Gulf Refining Co. was granted permission to deposit dredged material on marsh land at the southern end of the base. In May 1934, Maybank Fertilizer

Corp. received a permit to use a 10-foot right-of-way over a small marshy island in the Cooper River.

5.1.4 Legal Claims

According to the base Legal Assistance Office, only one court action has been brought against NAVBASE Charleston. This involved violation of South Carolina's Pollution Control Act by a 250-foot smokestack serving five coal-fired boilers in Bldg. 32 on NSY property. The violation was the result of the malfunctioning of the stack's electrostatic precipitator. Legal action was initiated in May 1979, and the Navy was assessed a fine of $1,700 per month commencing 1 Jul 1979. Payment continued until February 1981, when the stack was determined to be in compliance with the State's allowable emission standards, following repair of the electrostatic precipitator. On 26 Feb 1981, the case against the Navy was dismissed (Personal Communication, 1981).

A number of employees of NSY have attempted to bring suit against various manufacturers of asbestos products used at NSY because of health problems resulting from prolonged exposure to the substance. No asbestosis cases have reached the claims stage, however, and reportedly no claims have been made against NAVBASE Charleston (Personal Communication, 1981).

5.1.5 Adjacent Land Use

As illustrated by figure 5.1-3, the areas surrounding NAVBASE Charleston are heavily developed and characterized by commercial, industrial, residential, and school land uses. Commercial areas are located primarily west of NAVBASE Charleston; industrial areas lie to the north and along the west bank of Shipyard Creek.

Two major industrial areas are sources of potential hazardous waste. The first is located approximately 0.5 mile north of Noisette Creek on Cooper River and includes Sinclair Refining Co. and the Coastal Terminal Co. Tank Farm (see figure 5.1-4). Land across the river houses the AMOCO Chemical Co., which receives monthly visits from two 30,000-ton tankers (SOUTHDIV, 1978).

The western bank of Shipyard Creek is now, and has been for many years, an area of high industrial concentration. Maps dating from early in the 20th century show the presence of railways in this area, a feature which, when combined with nearby waterways, makes the area ideal for heavy industry. Figure 5.1-4 identifies various companies recently in operation in the area. Although ownership changes from time to time, the land remains under the control of chemical, fertilizer, oil refining, metallurgical, and lumber operations. In the last 6 months, Etiwan Fertilizer Co. (see figure 5.1-5) has been replaced by Massey Coal Co. Two years ago, McAlloy Alloys acquired the site shown in figure 5.1-5 as occupied by Pittsburgh Metallurgical Co. McAlloy's plant has been cited for noncompliance with air pollution regulations as

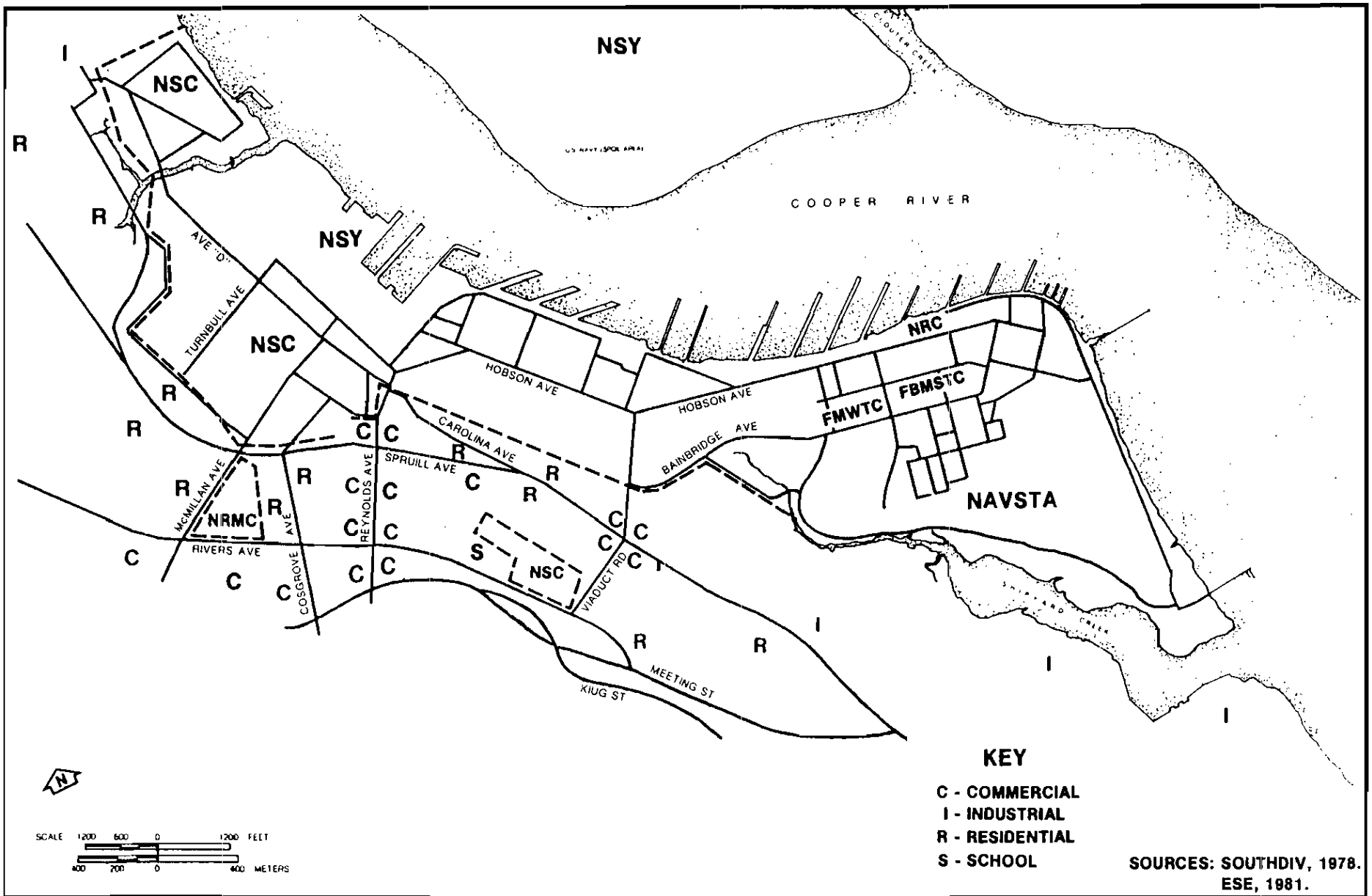


Figure 5.1-3
LAND USE/ZONING IN THE VICINITY OF NAVBASE CHARLESTON

INITIAL ASSESSMENT STUDY
NAVAL BASE CHARLESTON

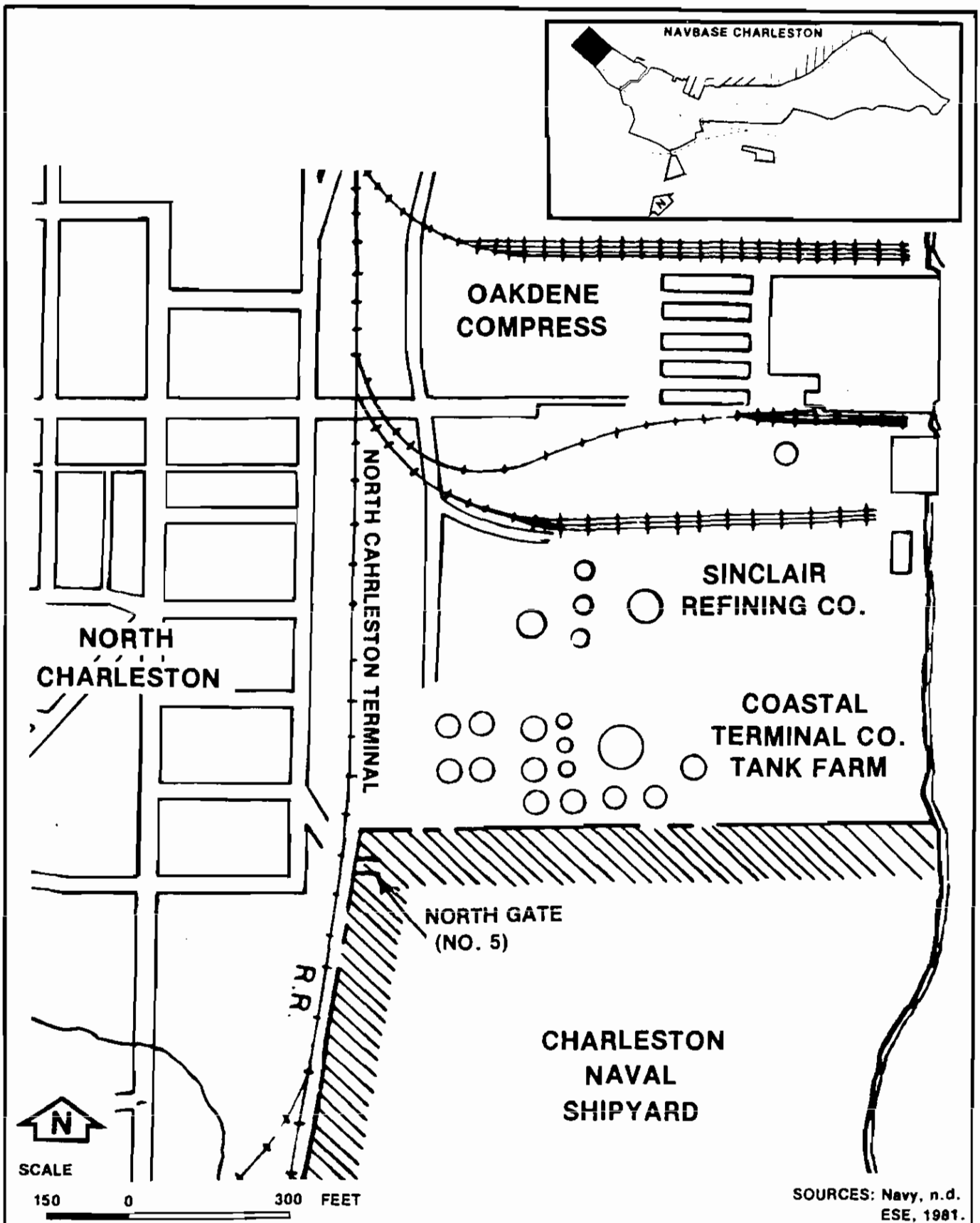
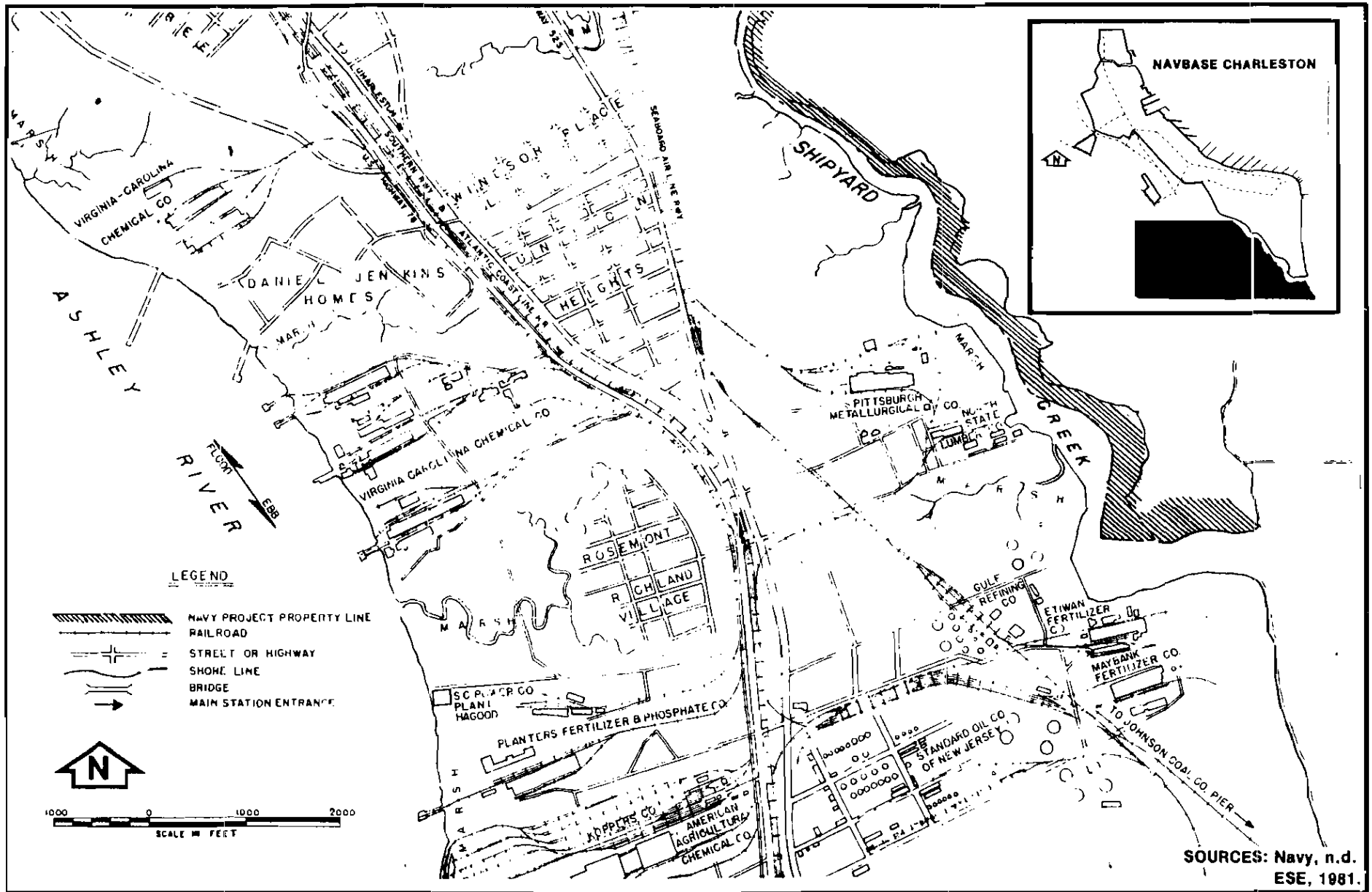


Figure 5.1-4
INDUSTRIAL AREAS TO THE NORTH OF NAVBASE CHARLESTON

INITIAL ASSESSMENT STUDY
NAVAL BASE CHARLESTON



SOURCES: Navy, n.d.
ESE, 1981.

Figure 5.1-5
INDUSTRIAL AREAS TO THE SOUTHWEST OF NAVBASE CHARLESTON

INITIAL ASSESSMENT STUDY
NAVAL BASE CHARLESTON

a result of chromium reduction operations (Personal Communication, 1981).

The eastern bank of the Ashley River is also dotted with industries, including Virginia-Carolina Chemical Co., South Carolina Power Co. Plant, Planters Fertilizer and Phosphate Co., Koppers Co., and American Agricultural Chemical Co. (Navy, n.d.).

The east bank of the Cooper River is undeveloped and contains extensive wetlands along Clouter Creek and Thomas Island. Active dredge spoil disposal areas are located on U.S. Naval Reservation property between the Cooper River and Clouter Creek, offsite on the southern portion of Daniel Island, and on Drum Island. Continuous maintenance dredging of Charleston Harbor and the Cooper ship channel removes and deposits approximately 60 million cubic yards of silt annually (SOUTHDIV, n.d.).

5.2 HISTORICAL OVERVIEW

Since the early years of English colonial rule, the area around Charleston Harbor has been a center of naval interest. During the Civil War, northern naval forces established a base at Port Royal on Parris Island south of Charleston. During the Spanish-American War, shops and a drydock were constructed on Port Royal, and the facility became an active docking and repair base. In 1901, however, following consideration by a board of naval officers appointed by SECNAV, a recommendation was made to transfer the naval station from Port Royal to Charleston Neck, an area about 6.5 miles from the tip of the peninsula formed by the Ashley and Cooper Rivers. This new location was preferred over Port Royal due to: (1) the existence of a dredged channel, at least 25 feet deep, which was well marked for navigation; (2) proximity to the strong fortification of Charleston; (3) greater protection from storm tides; (4) ample anchorage for heavy vessels; (5) improved transportation connections, i.e., three railroad lines and regular steamer traffic; and (6) facilities for the importation of unskilled labor. On 31 Aug 1901, therefore, the U.S. Navy took possession of 2,250 acres of hardland and marsh areas and established the U.S. Naval Yard, the mission of which was to make repairs to the smaller vessels of the fleet and supply them with stores. During the period 1901-15, a number of main shops, the powerhouse, the first drydock (No. 1), four piers, administration and storage space, a dispensary, officer quarters, and other miscellaneous facilities were constructed. In 1904 and 1909, marine barracks and officer quarters were constructed to house a contingent of Marines, who arrived 1 Oct 1903.

Work conducted at the Yard at this time involved repairing, limited overhauling, and supplying stores for smaller vessels, and as of 30 Jun 1915, involved 1,240 employees. In 1912, a Machinist's Mates School was established at the Navy Yard to provide vocational training.

The advent of World War I was reflected at the Navy Yard by an expansion of facilities and the implementation of a more diversified

mission. Repairs to torpedo craft and other small vessels, major alterations to vessels (including destroyers), and construction of smaller fleet vessels (including gunboats and destroyers) comprised the majority of industrial activities. In addition, machine parts and clothing were manufactured.

In 1916, under an Act of Congress, the channel between Charleston and the Navy Yard was dredged to a depth of 30 feet (low tide). Over $3 million was expended to improve facilities at the Navy Yard through temporary construction of housing, hospital facilities, storage space, shops, ship building facilities, and miscellaneous improvements. Employment rose to 3,600 and the workload increased to include alterations and repairs to 160 vessels and construction of 18 new vessels.

During its development, many low-lying areas of the base were filled with dredged spoil from the Cooper River. Filling operations began about 1918 near Noisette Creek on the northern end of the base and continued through the 1960s, after which time spoil was deposited on the opposite side of the Cooper River. Figure 5.2-1 shows the areas filled by dredged spoil and solid waste and the approximate dates of filling.

Activity throughout the history of the Navy Yard peaked and declined in response to American military involvement. With the return of peace after World War I, the Yard experienced a severe curtailment of workload and facilities development. In fact, on 10 Jul 1922, Franklin Roosevelt, acting SECNAV, issued General Order No. 87 for the closure of the Navy Yard. A tentative closure date of 1 Sep was set but later extended to 1 Nov. Public opinion, represented by the Charleston Chamber of Commerce, however, successfully appealed to the Government in favor of maintaining the Yard. The mission of the Yard was rewritten, as follows:

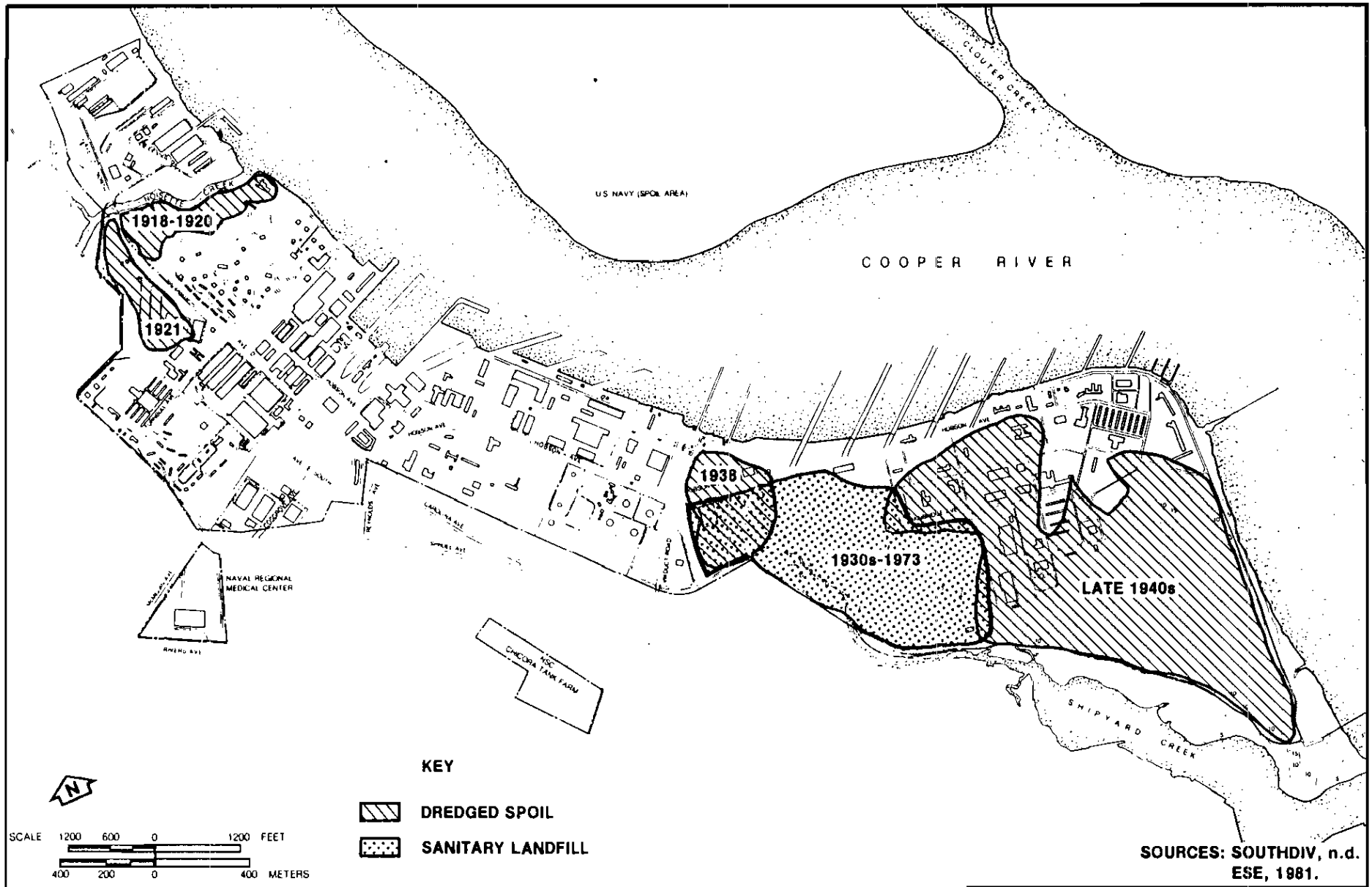
1. To maintain the Yard in operating condition, available for future use in emergency;

2. To maintain a nucleus working force which would permit expansion when required to undertake ordinary maintenance work of naval vessels and new ship construction; and

3. To keep the nucleus force employed to the best advantage possible in routine maintenance of naval vessels, obtaining greatest productive labor possible with a reduced force without permitting undue deterioration of plant (General Order No. 87).

Although no documentation exists, it is felt by historians of the Navy Yard that the Clothing Factory was disbanded during this time.

The post-World War I era (1920-32) was a period of major reorganization at the Navy Yard. Up to that time, activities were coordinated by about 14 independent Heads of Department. To increase effective authority, these were consolidated into two major divisions:



SOURCES: SOUTHDIV, n.d.
ESE, 1981.

Figure 5.2-1
AREAS FILLED AND APPROXIMATE DATES OF FILLING OPERATIONS

INITIAL ASSESSMENT STUDY
NAVAL BASE CHARLESTON

industrial activities were placed under one officer named "Manager," and military activities under another officer known as "Captain of the Yard." Since many of the temporary facilities erected during World War I were demolished, many shops were also consolidated. In 1922, the emergency hospital was closed and the dispensary in Bldg. 19 was reoccupied and designated as a hospital. Light repair work continued during this period, and six new vessels were constructed. Employment declined by 1932 to 535 employees.

In 1932, the Coast Guard received a piece of land near pier 317A and a landing field was constructed in the southern part of the Navy Yard. The field appears as a cross-shaped formation on maps dating from 1927.

The slowdown of activities at the Navy Yard did not extend far into the 1930s. In 1933, orders for the construction of many new vessels were received, resulting in increased staffing. The economic depression of the 1930s introduced financial assistance programs, such as Works Projects Administration (WPA) and Public Works Administration (PWA), which provided funds for the extensive buildup of facilities during the period 1933-38. Buildings were torn down, relocated, expanded, or replaced. By the time World War II began, the Charleston Navy Yard had become a first-class naval facility. Its mission was primarily to provide logistic support to the operating forces in the form of efficient and economical new construction, repairs, overhaul, alterations, conversions, and dockings of destroyers and small vessels. Outfitting of ships, related special manufacturing, and necessary replenishment of stores and supplies were made available to nearby ships and shore activities.

A number of significant changes occurred during the World War II era. On 14 Sep 1945, by general order, the U.S. Naval Base, Charleston, S.C., was formally commissioned, and the Navy Yard was redesignated NSY and became a component of the U.S. Naval Base, under the military control of the 6th Naval District. Another important development was the purchase of 196 additional acres of land on the northern and eastern boundaries of NSY for additional storage space. Combined with the reclamation of marsh land in the southern part of NSY, this increased the size of NSY nearly two-fold.

The addition of a variety of new shops, drydocks, and piers and the escalation of military activity during World War II caused this to be the period of greatest military ship construction in NSY history. A total of 256 ships was built between 1939 and 1946, compared to a total of 36 between 1913 and 1938. In July of 1942, the first women were employed at NSY, and, in 1943, employment peaked at 25,948 total employees (Navy, 1981).

Some time between 1938 and 1943, a landing area for lighter-than-air (LTA) craft was established at the southern tip of the base. Two LTA landing circles are visible on maps dating from 1943, but no other documentation of this activity was found.

Following the end of World War II, the work of constructing new vessels was slowed, and the major workload of NSY involved disposing of surplus stock and decommissioning ships. This work was particularly heavy in 1946, but by 1948 normal repair, overhaul, and alteration of active fleet vessels were resumed. In 1948, NSY was designated a submarine repair and overhaul yard, including, by 1958, radiological decontamination. The mission of NSY remained one of providing construction, conversion, overhaul, alteration, repair, drydock overhaul, and outfitting of vessels in support of active and reserve fleet vessels, but a research, development, and testing function was also added at this time. In addition, NSY became the east coast center for mine warfare ship support (Navy, 1981).

In March 1952, fleet training involving firefighting, damage control, etc., became a part of activities on NAVBASE Charleston. In January 1959, responsibility for mine warfare training was moved from Yorktown, Va. to Charleston. These two forms of training were conducted separately until 1972, when they were combined to become the FMWTC, currently a tenant of NAVSTA (Personal Communication, 1981).

In 1961, Polaris submarines were commencing patrols and NSY was given design support responsibilities. These responsibilities continue to the present, and new ships of various classes are continuously assigned to NSY for operational homeporting and shipyard overhaul. To accommodate the demands of these ships, shops on NSY have been expanded and equipped, including a drydock designed for the servicing of FBM submarines and other nuclear-powered ships (Navy, 1981).

The presence of nuclear-powered submarines at NAVBASE Charleston led to the establishment, in 1962, of FBMSTC, a tenant of NAVSTA. Submarines undergo continuous design modification and are, therefore, the only ships which operate on a two-crew concept: while one crew is on board operating the ship, the other is being trained in the repair and operation of the latest equipment, as well as in navigation, weapons, engineering, operations, and tactics (Personal Communication, 1981).

In July 1959, NAVSTA was established as a major element of NAVBASE Charleston, replacing the Naval Receiving Station and Minecraft Support Base. The formation of NAVSTA resulted in the emergence of NAVBASE Charleston as the east coast recipient of the greatest influx of ships. NAVSTA has become the second largest component and landowner of NAVBASE Charleston and currently hosts the largest number of tenants (SOUTHDIV, n.d.). The mission of NAVSTA, which is to provide port services, including berthing, tugs, pilots, cranes, fueling, sludge removal for pollution control, and ammunition handling services to the operating forces of the Navy, has remained constant since its inception. In addition, NAVSTA operates a correctional center for prisoners of the southeast, conducts legal investigations, provides legal assistance, and holds courts-martial for military personnel (SOUTHDIV, 1978).

NSC was dedicated on 2 Jan 1964, following the expansion of the FBM weapons system. It is now one of the largest naval supply centers and functions in support of over 100 active fleet ships and 125 shore installations in the United States and overseas, including the United Kingdom Polaris Missile Program. Services provided by NSC include:

1. Furnishing food, parts, and equipment to customers;

2. Maintaining accounting and payroll services for 104 shore activities in the Southeastern United States;

3. Sending and receiving messages through an Automatic Digital Network (AUTODIN) station;

4. Handling personal property and automobiles for Navy and Marine Corps personnel moving in and out of the Charleston area;

5. Providing contract and purchasing services for Naval units in the Southeastern Contracting Region;

6. Ensuring that ships which come in for overhaul have the proper material aboard to support their equipment through a Supply Operations Assistance Program (SOAP);

7. Operating a program of assistance in food preparation and management for Navy activities in the Southeast;

8. Performing packaging and preservation services; and

9. Operating a petroleum laboratory and providing a quality surveillance of all petroleum products stored and issued (SOUTHDIV, 1978; SOUTHDIV, n.d.; COMNAVSECGRU, 1980a).

NAVSECGRUACT, a tenant of NAVSTA, was established on 21 Apr 1965 to provide security of classified information on NAVBASE Charleston.

Located outside the perimeter of NAVBASE Charleston, NRMC was established 1 Jul 1972 to provide a variety of medical, surgical, and outpatient care services to military personnel in the Charleston area (SOUTHDIV, 1978).

No formal survey for historic or archaeological sites has been conducted on NAVSTA, and no records have been found to indicate that surveys have been made for other areas of NAVBASE Charleston. There are, however, several items of historical interest onsite. Among these is Bldg. 590, known as "Marshlands Plantation House." This house is of historical interest since it was built around 1810 and is reportedly on a historical register. In 1960, plans were made to build drydock No. 5 on the site occupied by this house. The "Marshlands Plantation House" was floated by barge to the State-owned Ft. Johnson when construction of drydock No. 5 commenced (Personal Communication, 1981).

5.3 PHYSICAL FEATURES

5.3.1 Climatology

Due to the proximity of the ocean, the climate of Charleston is mild and temperate. Daily weather is controlled largely by the movement of pressure systems across the country and by the diurnal effects of the land-sea breeze. Exchanges of air masses are relatively few in summer, when masses of warm, humid, maritime-tropical (mT) air persist for long periods under Bermuda high pressure conditions. Winters are characterized by movements of frontal systems and by replacement of mT air with cool, dry, continental-polar (cP) air.

5.3.1.1 Temperature

Average daily temperatures recorded during each month by the National Weather Service at the Charleston Municipal Airport are shown in table 5.3-1. The coldest month is January, when daily temperatures typically range from 37 to 60 degrees Fahrenheit (°F). In July, the warmest month, the average daily temperature extremes vary between 72 and 90°F. The smaller diurnal temperature variation in summer is due to higher moisture content of the atmosphere on the average day. The record high and low temperatures measured at the airport are 102.9° and 8.0°F, respectively. Normally, 60 days per year temperatures will be at 90°F or above, while 33 days of the year freezing temperatures will predominate. The average first occurrence of freezing temperatures is 10 Oct, while the average last occurrence is 19 Feb [Army, 1976c; U.S. Soil Conservation Service (USSCS), 1971; NAVFAC, 1976].

5.3.1.2 Precipitation

The average annual rainfall in Charleston is 49.2 inches, with a summer peak of over 7.5 inches occurring in July. The four summer months (June through September) experience over 50 percent of the annual rainfall. Rain storms during the summer are due to strong convective atmospheric motions, which trigger 72 percent of the average 57 thunderstorms per year. Rainfall during the winter is generally associated with the interface of cP frontal air masses replacing mT air. With the exception of the 7 inches dropped during the winter storm of 10-11 Feb 1973, only traces (less than 0.04 inch) of snow are usually experienced, mostly in January and February (Army, 1976c; USSCS, 1971; NAVFAC, 1976).

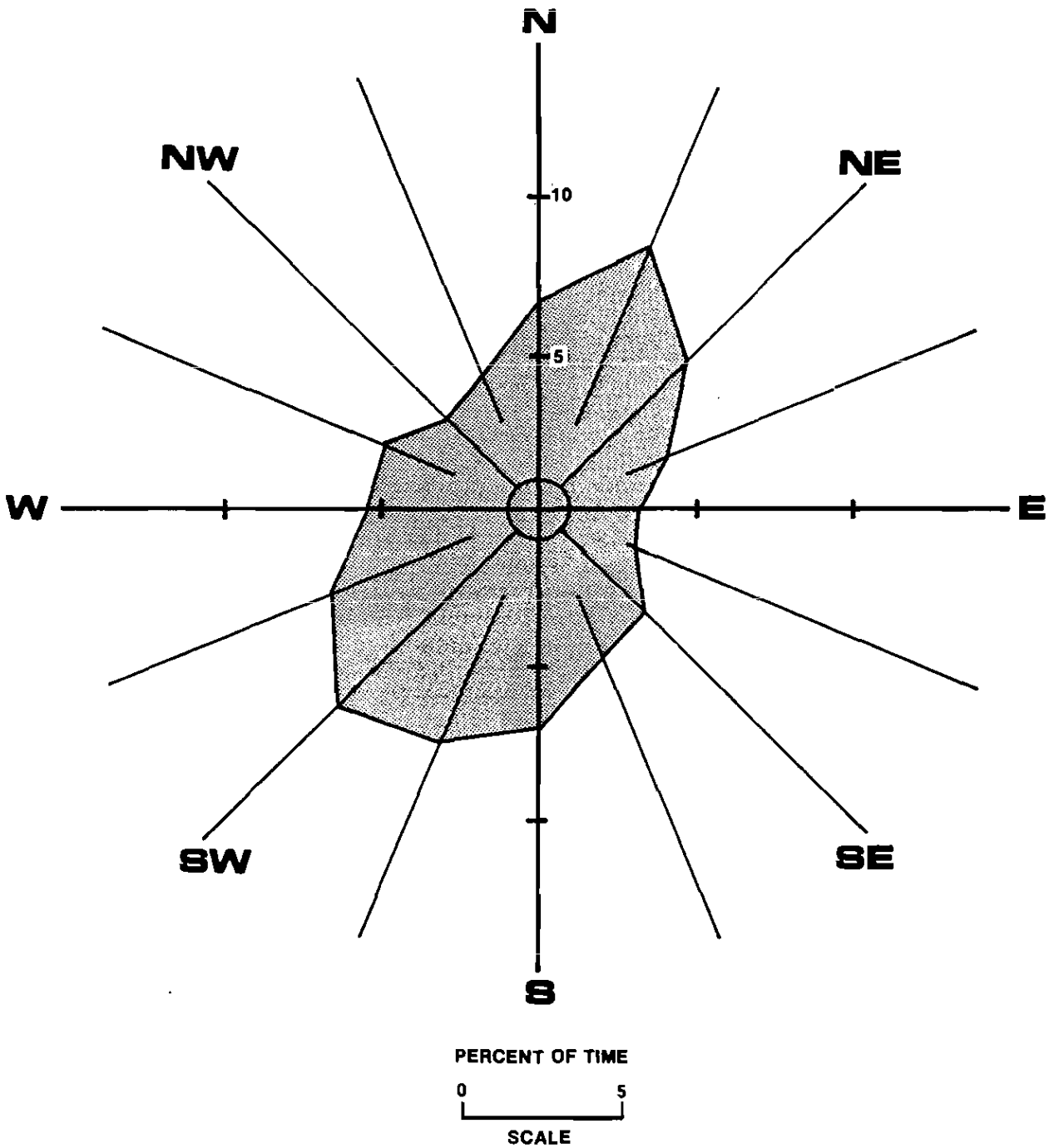
5.3.1.3 Wind

The mean wind speed recorded at the Charleston Airport is 9 miles per hour, with prevailing wind directions (table 5.3-1; figure 5.3-1) of north-northeast during the winter months and south-southwest during the summer months (Army, 1976c; USSCS, 1971; NAVFAC, 1976).

Table 5.3-1
Annual and Monthly Climatological Data Recorded by the National Weather Service at Charleston Municipal Airport, Charleston, S.C.

Time	Normal Daily Temperature, °F		Normal Total Precipitation (inches)	Prevailing Direction of Winds	Heavy Fog (Days)
	Maximum	Minimum			
Years of Record	1947-76	1947-76	1947-76	1962-76	1956-76
January	61.2	38.3	2.54	SW	4
February	62.5	40.4	3.29	NNE	2
March	68.0	45.4	3.93	SSW	2
April	76.9	52.7	2.88	SSW	2
May	83.9	61.8	3.61	S	2
June	89.2	69.1	4.98	S	2
July	89.2	72.0	7.71	SW	1
August	88.8	70.5	6.61	SW	1
September	84.9	66.2	5.83	NNE	2
October	77.2	55.1	2.84	NNE	3
November	67.9	43.9	2.09	N	4
December	61.3	38.6	2.85	NNE	3
Annual	75.9	54.5	49.16	NNE	28

Source: Army, 1976c.



SOURCES: NAVFAC, 1976.
ESE, 1981.

Figure 5.3-1
TEN-YEAR AVERAGE WIND DIRECTION FOR CHARLESTON AIRPORT, SOUTH CAROLINA

INITIAL ASSESSMENT STUDY
NAVAL BASE CHARLESTON

5.3.1.4 Storms

There are an average of 66 electrical storms every year, occurring most frequently during the summer convective storm season. Late summer to early fall is the period of maximum threat from hurricanes. Major hurricanes affecting the Charleston area occurred in August of 1885, 1893, 1911, 1940, 1952, and September of 1928 and 1959. A storm tide of 11 feet above mean low water, the highest for which records are available, was recorded during the August 1893 hurricane (Army, 1976c; USSCS, 1971; NAVFAC, 1976). Recently, hurricanes David (September 1979) and Dennis (August 1981) have affected the Charleston area.

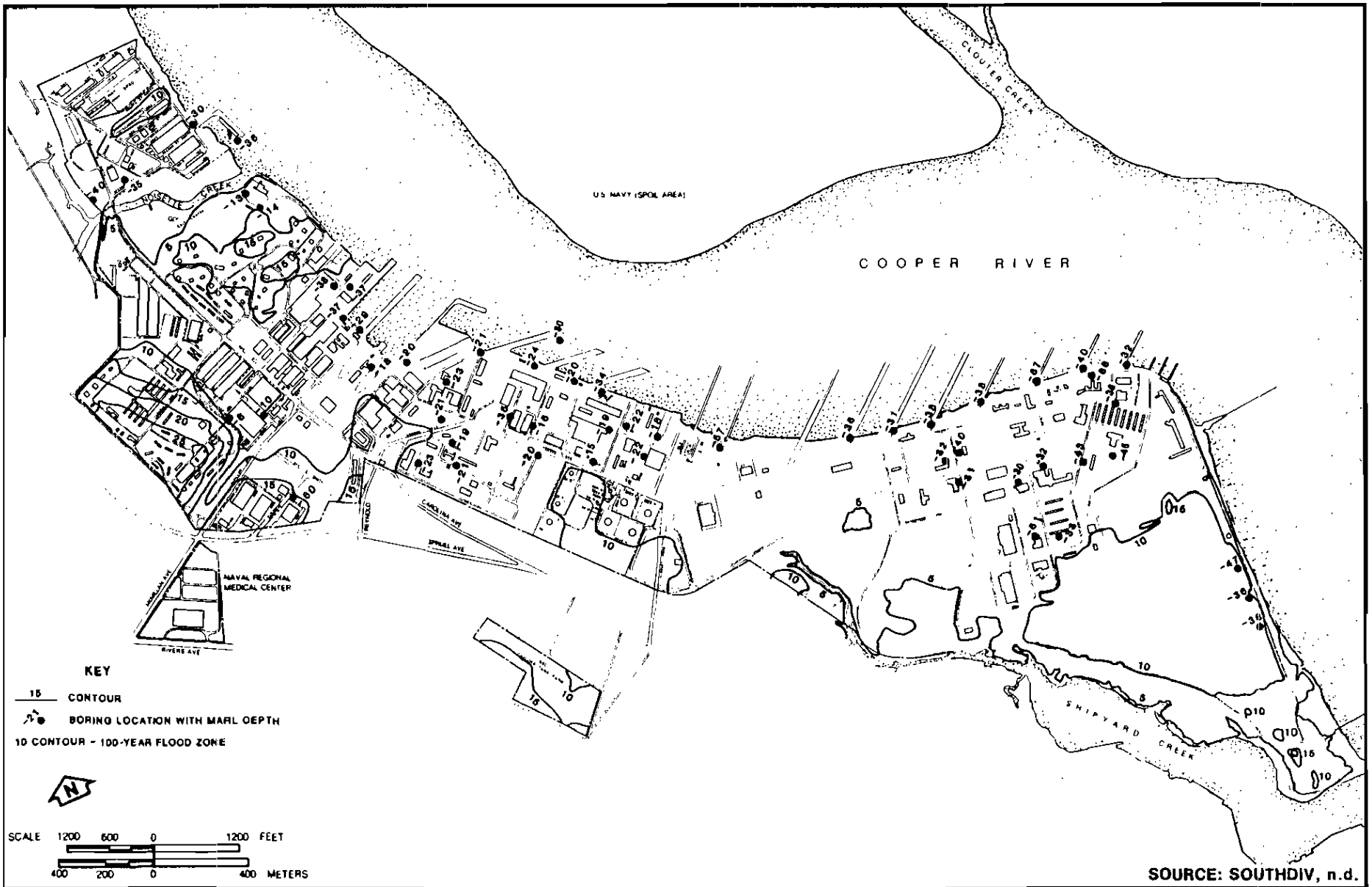
5.3.2 Topography

NAVBASE Charleston is located on the eastern edge of a low, narrow finger of land separating the Ashley and Cooper Rivers (see figure 5.1-1). The topography of the area is typical of South Carolina's Lower Coastal Plain, with low relief plains broken only by the meandering courses of the many sluggish streams and rivers flowing toward the coast and by an occasional marine terrace escarpment. Topography at NAVBASE Charleston is essentially flat, with elevations ranging from just over 20 feet in the northwestern part of the base to sea level at the Cooper River (see figure 5.3-2). Much of the original topography of NAVBASE Charleston has been modified by man's activities. The southern end of the base originally was a tidal marsh drained by Shipyard Creek and its tributaries. Over the last 70 years, this area has been filled with both solid wastes and dredged spoil. Most of the base is within the 100-year flood zone, which is below 10 feet in elevation.

5.3.3 Geology

The geology of the Charleston area is typical of the southern part of the Atlantic Coastal Plain. A seaward-thickening wedge of Cretaceous and younger sediments is underlain by older igneous and metamorphic basement rock (see figure 5.3-3). At NAVBASE Charleston, Recent and/or Pleistocene sands, silts, and clays of high organic content are exposed at the surface. These materials are underlain by a plastic calcareous clay known as the Cooper Marl. Figure 5.3-2 shows the depth to the marl at various points on the base, as well as the surface topography. At NAVBASE Charleston, the Cooper Marl is underlain by the Santee Limestone and older rocks. Figure 5.3-4 shows a generalized north-south cross section along the approximate center of the base.

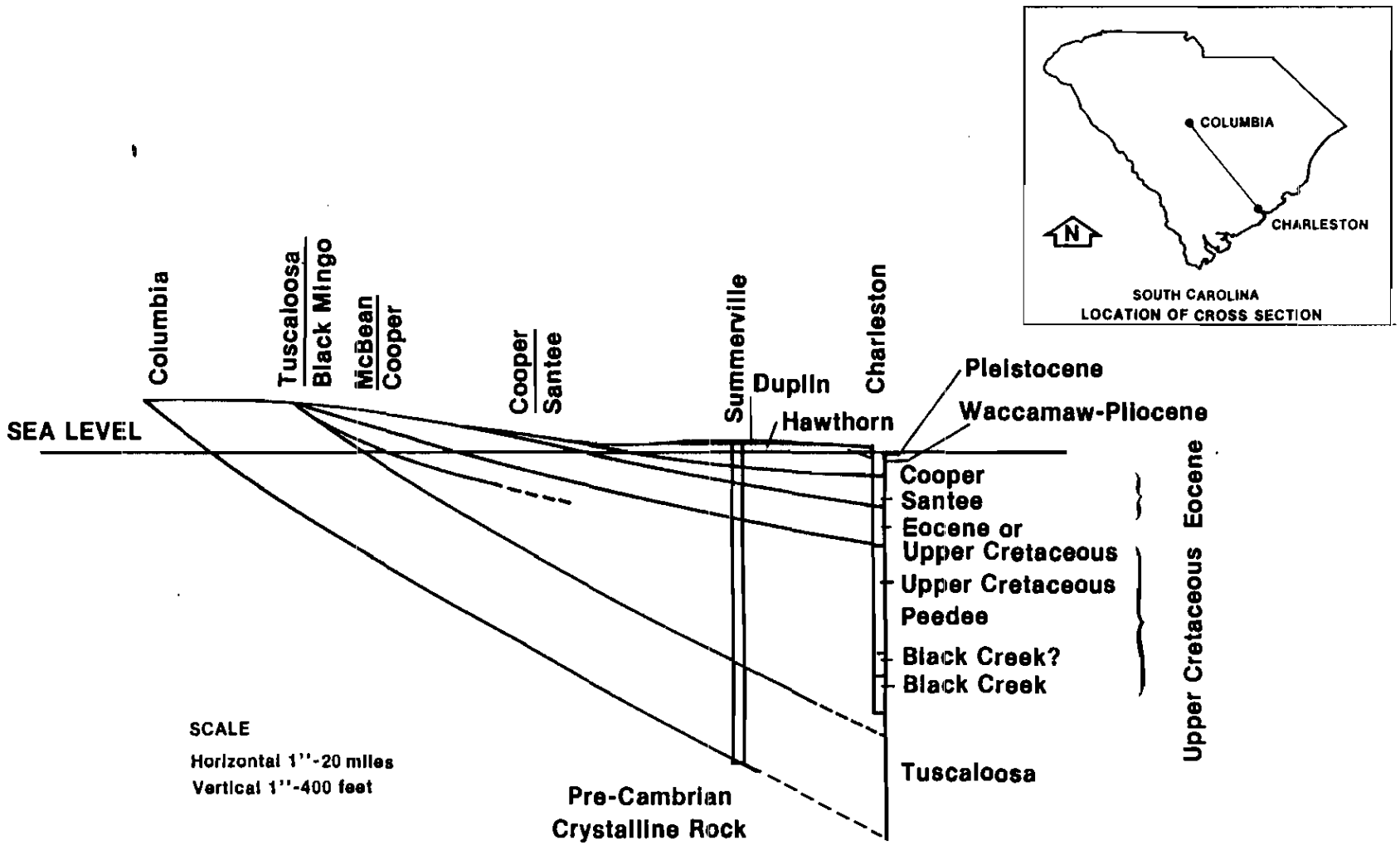
The Charleston area has a history of seismic activity, dominated by the Great Charleston Earthquake of 1886. Four hundred and two earthquakes were recorded in the Charleston area during the period 1754-1970.



SOURCE: SOUTHDIV, n.d.

Figure 5.3-2
TOPOGRAPHY AND SUBSOIL OF NAVBASE CHARLESTON

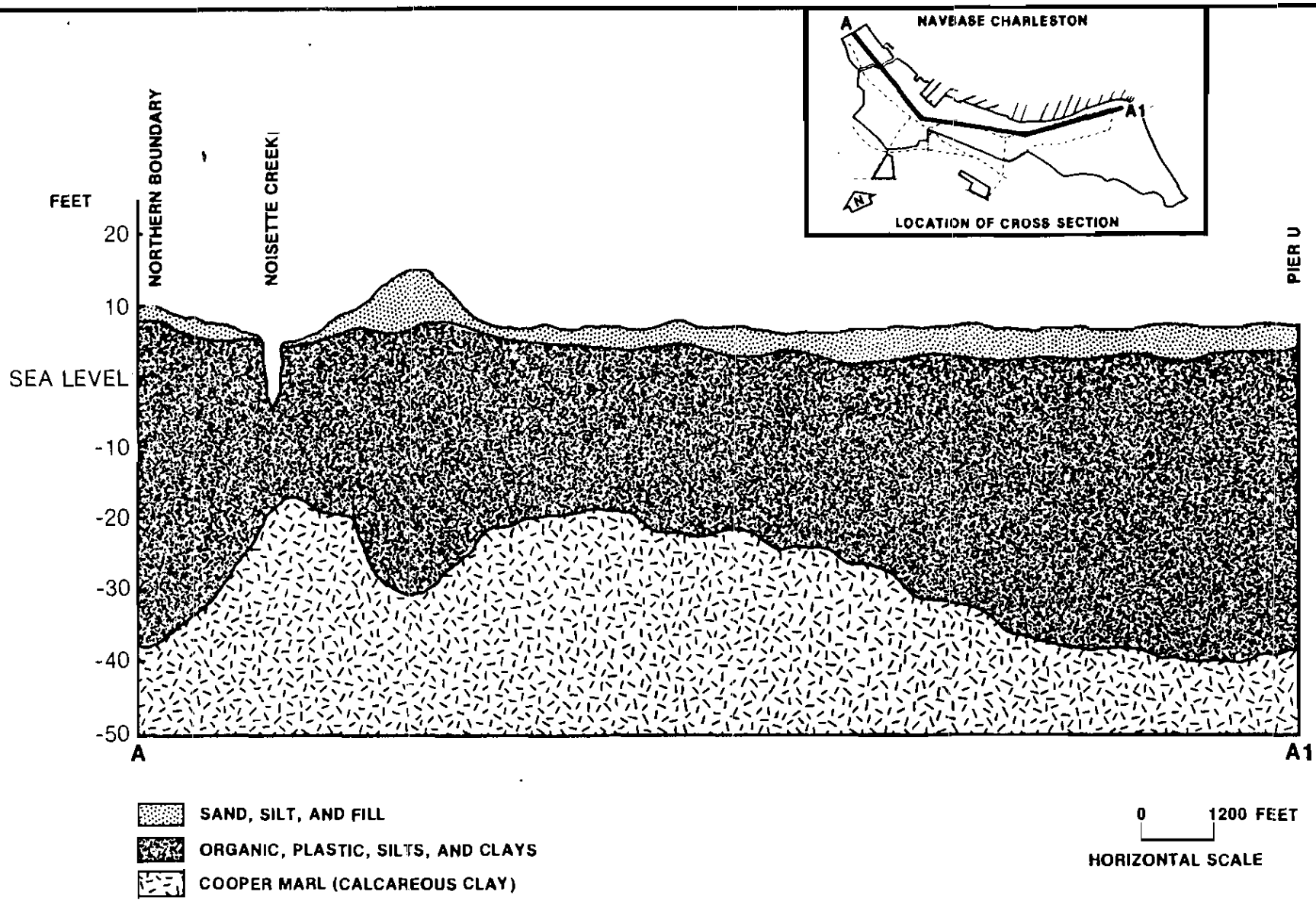
INITIAL ASSESSMENT STUDY
NAVAL BASE CHARLESTON



SOURCES: NAVFAC, 1976.
ESE, 1981.

Figure 5.3-3
EAST-WEST GEOLOGIC CROSS SECTION FROM THE COAST INLAND THROUGH CHARLESTON, S.C.

INITIAL ASSESSMENT STUDY
NAVAL BASE CHARLESTON



SOURCE: ESE, 1981.

Figure 5.3-4
GENERALIZED GEOLOGIC CROSS SECTION
THROUGH NAVBASE CHARLESTON

INITIAL ASSESSMENT STUDY
NAVAL BASE CHARLESTON

The surface soils on NAVBASE Charleston have been extensively disturbed by a long history of intensive use. The natural surface soils were probably fine-grained materials typical of tidal marsh environments. Most of the southern portion of the base has been covered with dredged spoil. This spoil is an unsorted mixture of sands, silts, and clays. Most areas of the base have been either filled or reworked. No data are available concerning permeability rate and range for the soils at NAVBASE Charleston; however, the permeability of the surface soils is rather low, as evidenced by the fine-grained nature of the soils observed on the site visit and the reported history of poor drainage on NAVBASE Charleston.

5.3.4 Hydrology

5.3.4.1 Surface Hydrology

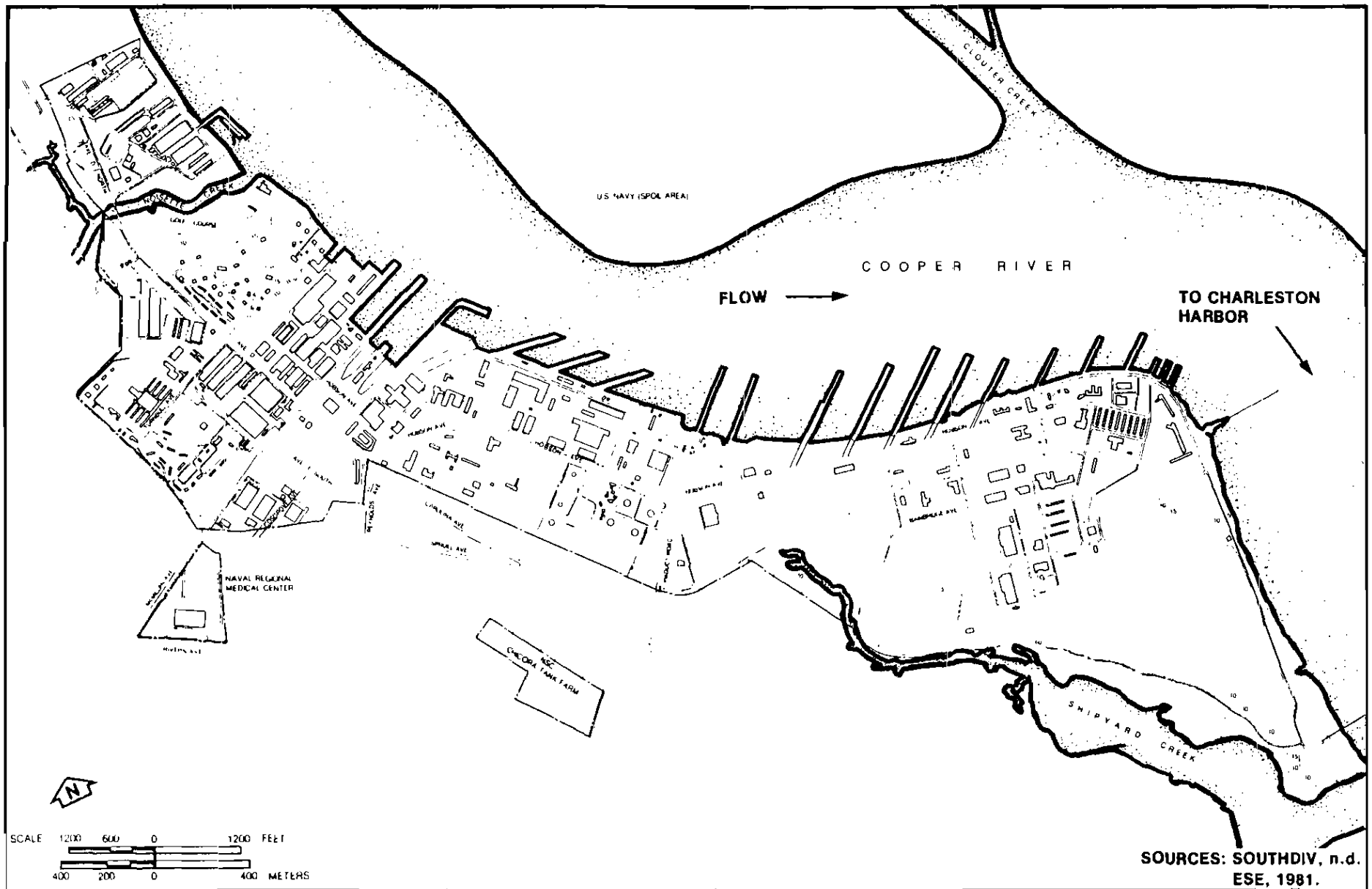
The southern portion of NAVBASE Charleston is drained by Shipyard Creek and the northern portion by Noisette Creek (figure 5.3-5). Both creeks drain into the Cooper River. Surface drainage in the NSY and NAVSTA areas is directly into the Cooper River, which empties into Charleston Harbor. The stormwater collection system and drainage of the developed areas of the installation are discussed in detail in section 6.6.1.2.

Shipyard Creek is a small tidal tributary, about 2 miles in length, which extends southeastward along the southwest boundary of NAVBASE Charleston to the Cooper River, at a point opposite the southern tip of Daniel Island (river mile 9). Docking facilities are located along the west shore of the lower mile of channel, while the east shore is bounded by tidal marshland along its entire length.

Noisette Creek, which transects the northern portion of NAVBASE Charleston, is a tidal tributary approximately 2.5 miles long. The creek flows almost directly eastward from its headwaters in the City of North Charleston and empties into the Cooper River at river mile 13.

The Cooper River Basin comprises 722 square miles of Coastal Plain in South Carolina. The Cooper River has its origin at the confluence of its east and west branches, from which it flows 31 miles southward to its outlet in Charleston Harbor. Lake Moultrie in the upper part of the Cooper River Basin, approximately 40 miles upstream of NAVBASE Charleston, was constructed by the South Carolina Public Service Authority in 1942 as part of the Santee-Cooper Project. This lake intercepts drainage of about 300 square miles of the Cooper River Basin. Except for short intervening stretches, the west bank of the river is lined with Federal, State, and private docking facilities, including those of NAVBASE Charleston.

Prior to the completion of the Santee-Cooper Project by the State of South Carolina in 1942, Charleston Harbor was considered one of the finest natural harbors on the Atlantic Coast, with depths in many areas exceeding 65 feet. Following completion of the project, the



SOURCES: SOUTHDIV, n.d.
ESE, 1981.

Figure 5.3-5
SURFACE WATERS ON NAVBASE CHARLESTON

INITIAL ASSESSMENT STUDY
NAVAL BASE CHARLESTON

average discharge into the Cooper River increased by a factor of greater than 200, from 528 to 124,174 gallons per second. This resulted in shoaling and silt accumulation in the lower reaches of the Cooper River and in Charleston Harbor. As a result, annual maintenance dredging requirements increased from less than 500,000 cubic yards per day to more than 1 million cubic yards per day. Because of this shoaling problem, the Charleston Harbor estuary has been subject for many years to water quality changes associated with dredging operations. Most of the material creating these shoals is of Piedmont origin, and only a small amount can be attributed to bank erosion. The increased freshwater flow has resulted in the formation of density currents in the harbor which have a predominant upstream bottom flow and, consequently, trap sediment within the harbor.

5.3.4.2 Geohydrology

Most potable water on the Charleston peninsula is supplied by surface water sources (Edisto River). See section 6.3.1 for a discussion of potable water supply. Although both the Cooper Marl and the Santee Limestone function as aquifers in other areas, neither is significantly developed in the Charleston area. In the vicinity of NAVBASE Charleston, the quality of the water from the Santee is not suitable for potable supply; total dissolved solids (TDS) from natural sources range from 1,000 to 1,500 parts per million (ppm).

In the Charleston area, the Cooper Marl is rather impermeable and acts as the confining bed for the Santee, which is not as permeable as in other areas and forms a confined aquifer. Ground water in the Santee, which occurs at about -328 feet mean sea level (MSL) in the Charleston area, flows generally to the southeast. Some wells in the vicinity of NAVBASE Charleston are pumping from the Santee for industrial purposes. In July 1981, the water level of a well in the Santee under NAVBASE Charleston measured 15 feet MSL, indicating that the gradient across the confining bed, the Cooper Marl, is artesian. That is, water from the Santee moves upward through the Cooper to discharge into the incised river valleys.

In the shallow aquifer on NAVBASE Charleston, water flows toward the Cooper River or Shipyard Creek, due to the fine-grained texture of the sediments and the level topography on the naval base. The water table is within 3 to 7 feet of the ground surface. The shallow ground water continually discharges to the Cooper River and Shipyard Creek.

5.3.4.3 Migration Potential

All the shallow ground water at NAVBASE Charleston eventually discharges to the Cooper River either directly or indirectly via its tributaries. Contaminants, if present, in the shallow groundwater system would eventually discharge into the Cooper River if not attenuated by subsurface soils. However, flow rate in the shallow system is expected to be rather slow due to the fine-grained nature of

the sediments and the low gradient. Some contaminants, particularly metals, are likely to be attenuated by adsorption onto clay minerals. Furthermore, no potable use is made of the shallow groundwater downgradient of NAVBASE Charleston, since the Cooper River and Shipyard Creek are the base boundaries and also the downgradient boundaries of the shallow groundwater system. It is possible that residential wells in the shallow aquifer exist upgradient of NAVBASE Charleston. However, these wells are not threatened by contaminant migration from NAVBASE Charleston, since they are upgradient and since reversal of the natural gradient by pumpage from any shallow residential wells would be extremely unlikely due to the very small capacity of this type of well. The shallow groundwater system is not used for potable supply at NAVBASE Charleston.

In summary, potential contaminants from installation operations entering the shallow groundwater system do not threaten the health of onbase personnel, since the shallow system is not developed for potable use at NAVBASE Charleston. Likewise, contaminant migration via the shallow groundwater system does not threaten human health off the installation, since shallow groundwater flow is intercepted by surface waters at the installation boundaries and since the shallow system is not significantly developed in the vicinity of NAVBASE Charleston. Contaminants entering the shallow groundwater system at NAVBASE Charleston do, however, represent a potential threat to the environment, since contaminants have the potential to migrate via the shallow system to adjacent surface waters. Although aquatic habitats in the Cooper River, Noisette Creek, and Shipyard Creek may be threatened, human health is not threatened by contaminant migration, since these surface bodies do not function as potable supplies.

The deeper aquifer (Santee Limestone) is not threatened by potential contamination in the shallow system because the Santee has a hydraulic head above its confining bed (the Cooper Marl) at NAVBASE Charleston. Consequently, water flows upward through the Cooper, thus preventing the movement of contaminants into the Santee. Furthermore, water in the Santee is not of potable quality in the vicinity of NAVBASE Charleston, and the aquifer is not significantly developed for potable supply.

Pathways also exist for any surface contaminants present at NAVBASE Charleston to migrate beyond installation boundaries via stormwater drainage. Stormwater is conveyed by natural and manmade drainage channels to the Cooper River or its tidal tributaries. The northern end of the base drains to Noisette Creek or the Cooper River. The heavily industrialized central portion of the base, which includes NSY, drains to the Cooper River. Developed portions of NAVSTA at the southern end of NAVBASE Charleston drain stormwater runoff to the Cooper River. Undeveloped areas of NAVSTA are drained by surface flow to either the Cooper River or Shipyard Creek, depending on the drainage patterns of the area. Thus, surface contaminants at NAVBASE Charleston have the potential to migrate off the installation into the Cooper River either directly or through its tributaries. Potentially migrating

surface contaminants represent a threat to the aquatic habitats in the Cooper River, Noisette Creek, and Shipyard Creek but do not threaten human health.

5.4 BIOLOGICAL FEATURES

5.4.1 Regional Ecology

The primary vegetation associations in coastal Charleston County, S.C., are typical of those found along the South Atlantic coastline and range from barren shoreline to outer Coastal Plain forest (Bailey, 1976; Steele, 1974; Shealy and Bishop, 1979). Extensive tidal marshes lie between barrier beaches and uplands and line inlets and river basins. Due to the flat topography of the lower Coastal Plain and the abundance of streams and creeks, tidal marsh covers more than 20 percent of Charleston County (SOUTHDIV, n.d.). Uplands adjoining these tidal marshes contain pine flatwoods, mixed hardwood-pine forests, freshwater marshes, and hardwood swamps.

The wildlife composition of coastal Charleston County is diverse and includes terrestrial, aquatic, and marine mammals; numerous resident and migratory inland and coastal birds; and a variety of reptiles and amphibians. Finfish and shellfish are abundant in the estuarine waters of Charleston Harbor, Cooper River, Wando River, and associated tributaries.

A discussion of vegetation associations and fish and wildlife resources of coastal Charleston County, S.C., is provided in the appendix.

5.4.2 Ecology of NAVBASE Charleston

Industrial and maintenance facilities, storage and refurbishing yards, drydocks, piers, and administrative and housing areas cover most of NAVBASE Charleston's acreage. Interspersed, undeveloped areas consist of improved and semi-improved grounds. However, limited areas of woodland and ruderal tracts are located on the southwestern and southern portion of NAVBASE Charleston, and tidal marsh adjoins Shipyard Creek, Noisette Creek, and sections of the Cooper River. Due to the high degree of development and limited acreage available, the potential for woodland and wildlife resource management is low, and no forest and wildlife management plans are available for NAVBASE Charleston. However, a Natural Resources Conservation Plan is available for the NWS, and a land management plan has been developed for the entire Charleston Naval Base Complex (SOUTHDIV, 1977). This plan is designed to "establish a long-term program required for balanced management and beneficial use of natural resources in accordance with their capability potential and land use requirements" (SOUTHDIV, 1977).

5.4.2.1 Terrestrial Ecosystems

Terrestrial ecosystems on NAVBASE Charleston include ruderal areas, such as old landfill sites and spoil disposal areas, woodlands,

and improved and semi-improved grounds. Ruderal areas (defined as disturbed areas covered by weeds and other plant species characteristic of early successional stages) are primarily located on NAVSTA property on the southern and southwestern portions of NAVBASE Charleston and include Clouter Creek spoil disposal areas on the east bank of Cooper River. Ruderal areas south of Bainbridge Ave. and west of the base commissary, north of Shipyard Creek, and southwest of the pistol and skeet ranges are covered by grasses, forbs, shrubs, and scattered trees. A spoil successional forest covers the southern tip of NAVBASE Charleston. Terrestrial ecosystems at NAVBASE Charleston are described in further detail in the appendix.

5.4.2.2 Wetland Ecosystems

Wetlands on NAVBASE Charleston include tidal marshes along Shipyard Creek, Noisette Creek, and sections of the Cooper River; scattered and small freshwater marshes less than 1 acre in size; and several small drainages bordered by shrub thickets. These ecosystems are described in detail in the appendix.

5.4.2.3 Aquatic Ecosystems

Aquatic ecosystems on and in the vicinity of NAVBASE Charleston include the Cooper River, Shipyard Creek, Noisette Creek, Clouter Creek, Wando River, and the upper section of Charleston Harbor. These waters are surrounded by extensive *Spartina-Juncus* marshes and, as a result, are rich in nutrients and detritus. Key characteristics of these streams are listed in the appendix, table A-6.

Charleston Harbor and lower sections of the Cooper and Wando Rivers are important nursery grounds for finfish and shellfish (State of South Carolina, 1972; Lagman *et al.*, 1979; Gusey, 1981) and contain important populations of game and commercially important species. The Cooper River annually receives large runs of anadromous fish, which ascend the river to spawn. Such species include striped bass, blueback herring, and shad. Additional game and commercially important fish occurring in Charleston Harbor and the lower Cooper River are listed in the appendix, table A-7.

Invertebrates and mollusks of commercial importance occurring in Cooper River, Wando River, and Charleston Harbor include shrimp, blue crab, and shellfish. Approximately 30 percent of the 1972 South Carolina shrimp production was captured in the Charleston Harbor area (State of South Carolina, 1972), which has also been identified as containing significant amounts of shellfish (Gusey, 1981).

Aquatic mammals recorded in the estuarine ecosystem of Charleston Harbor or lower Cooper River are listed in table A-8. Resident birds and reptiles are discussed in the appendix.

5.4.3 Threatened and Endangered Species

The U.S. Fish and Wildlife Service (FWS) protects Federally listed animal and plant species under the Endangered Species Act of 1973 [Public Law (P.L.) 93-205, as amended] and under section 4 of the Act, Associated Critical Habitats. A list of Federally protected endangered and threatened species is updated and published annually in the Federal Register, most recently on 20 May 1980 (FWS, 1980a).

In addition to Federally listed species, the State of South Carolina protects a number of resident wildlife and fish species under its Nongame and Endangered Species Conservation Act of 1974 (South Carolina Code of Laws, chapter 15, sections 50-15-10 through 50-15-90, 1976). In addition, a number of marine turtles are protected by South Carolina Wildlife and Marine Resources Department Regulation No. 123-150.

A survey of FWS- and South Carolina-protected species lists showed a number of endangered and threatened species occurring or potentially occurring in the vicinity of NAVBASE Charleston and nearby Charleston Harbor. Twelve animal and one plant species occurring or potentially occurring in the vicinity of NAVBASE Charleston are listed as endangered or threatened by FWS and South Carolina Wildlife and Marine Resources Department (WMRD). These species, along with their status and potential for occurrence on NAVBASE Charleston property, are listed in table 5.4-1. No adverse impacts on these species due to installation operations are expected based on their absence or rare occurrence in the NAVBASE Charleston area.

Table 5.4-1
Federal and State of South Carolina Endangered and Threatened Species
Occurring or Potentially Occurring in the Vicinity of NAVBASE Charleston

Species	Status Federal/South Carolina	Likelihood of Occurrence on NAVBASE Charleston
Florida manatee (*Trichechus manatus*)	Endangered/Endangered	Occasional Transient
Florida panther (*Felis concolor coryi*)	Endangered/Endangered	None
Southern bald eagle (*Haliaeetus l. leucocephalus*)	Endangered/Endangered	Occasional Transient
Peregrine falcon (*Falco peregrinus*)	Endangered/Endangered	Occasional Transient
Brown pelican (*Pelecanus occidentalis*)	Endangered/Endangered	Occasional Transient
Bachman's warbler (*Vermivora bachmanii*)	Endangered/Endangered	None
Kirtland's warbler (*Dendroica kirtlandii*)	Endangered/Endangered	None
Red-cockaded woodpecker (*Picoides borealis*)	Endangered/Endangered	None
American alligator (*Alligator mississippiensis*)	Threatened/Endangered	Occasional
Green turtle (*Chelonia mydas*)	Threatened/Endangered	None
Loggerhead turtle (*Caretta caretta*)	Threatened/Endangered	None
Short-nosed sturgeon (*Accipenser brevirostrum*)	Endangered/Endangered	Occasional Transient
Bunched arrowhead (*Sagittaria fasciculata*)	Endangered/Not Listed	None

* Occasional: Area resident, may be expected on or in vicinity of NAVBASE Charleston on occasion. Not expected to nest onsite due to lack of suitable habitat;
Occasional Transient: Occasionally reported from lower Cooper River/Charleston Harbor area. These species are migratory and not expected to remain in vicinity of site;
None: Species reported from vicinity, but suitable habitat lacking on NAVBASE Charleston.

Sources: State of South Carolina, 1976.
ESE, 1981.

SECTION 6.0
ACTIVITY FINDINGS

6.1 INDUSTRIAL OPERATIONS

NAVBASE Charleston is an extensive industrial complex containing virtually all shipyard and dockside operations required to manufacture, repair, overhaul, and refuel naval vessels. There are 19 piers and 5 drydocks at NAVBASE Charleston; however, 1 of the piers (pier A) is currently inactive, and 2 of the drydocks (Nos. 3 and 4) are currently used for storage purposes alone.

This section presents a description of each industrial operation conducted on NAVBASE Charleston. Information is presented for each major NAVBASE Charleston activity, including:

1. Naval Shipyard (NSY)
2. Naval Station (NAVSTA)
3. Naval Supply Center (NSC)
4. Naval Reserve Center (NRC)
5. Fleet and Mine Warfare Training Center (FMWTC)
6. Fleet Ballistic Missile Submarine Training Center (FBMSTC)
7. Naval Electronics Systems Engineering Center (NESEC)
8. Marine Corps Barracks
9. Naval Security Group Activity (NAVSECGRUACT)

In addition to describing industrial operations, wastes generated by each industrial operation are identified. Because the industrial processes have not changed significantly since they began in the early 1900s, the types of wastes currently generated are generally the same as those generated by past industrial operations. Most industrial activities on NAVBASE Charleston began operation during the period of 1901 to 1921 and are still in operation today. For those industrial operations which have significantly modified their processes, the process modifications and resulting changes in types of waste generated are addressed in detail in the sections specifically describing those operations. Moreover, for those operations with a period of operation different from that described above, the period of operation is specifically identified.

Although the types of wastes generated by industrial operations essentially have remained the same over the years, waste generation rates may have fluctuated considerably as a result of varying production requirements. Waste generation rates were presumably the highest during World Wars I and II when production rates of industrial operations were at their peak. Current waste generation rates are identified for most industrial operations. Because of the lack of historical information regarding past generation rates, best engineering judgment was applied where possible to provide a rough estimate of past rates. Generally, it can be inferred that the order of magnitude of past generation rates is generally close to that of current rates.

Between the 1930s and 1973, solid wastes, including sludges, were generally disposed of in the base sanitary landfill (site 1) (see section 6.6.2). Since 1973, solid wastes have been generally contract hauled offbase.

Prior to 1972, disposal of liquid industrial wastes generally involved discharge to a combined sanitary, industrial, and storm wastewater sewer system and ultimately to the Cooper River, until more stringent environmental regulations established in the 1970s precluded this practice. With the installation of a separate sanitary/industrial sewer system in 1972, the sanitary and industrial wastewater discharges were separated from the storm system and routed via a separate sewer system to the North Charleston Consolidated Public Service District (NCCPSD) rather than to the Cooper River (see section 6.6). Industrial pretreatment systems currently in use include oil-water separation, acid neutralization, and metals precipitation.

In 1975, sanitary sewer connections were installed on the piers for the use of docked ships. Improvements to this system were made in 1978. Some ships were not capable of using the dock system because their onboard sanitary system was not compatible with the dock system. Some overboard discharge of sanitary wastewater by docked ships occurred until April 1981, when Federal law prohibited such discharges. Modifications to the collections system and to the ships using the system corrected the condition.

Although waste disposal methods are identified in this section under industrial operations, section 6.6 addresses waste treatment and disposal in more detail.

6.1.1 Naval Shipyard

NSY provides logistic support for assigned ships and service craft, including conversion, overhaul, repair, alteration, drydocking, and outfitting. Other industrial operations performed at NSY include manufacturing, research, development, and testing of equipment used on

ships and service craft. Major industrial operations performed at NSY are described in detail below.

6.1.1.1 Foundry

The Foundry is located in Bldg. 9, and it is here that metal parts used in refitting ships assigned to NSY are cast. The Foundry does not produce hazardous waste, and hazardous materials are not used in its operations. There are no records of past hazardous waste-generating operations by the Foundry (Personal Communication, 1981).

6.1.1.2 Shipfitter Shop

The industrial operations performed at the Shipfitter Shop (Bldgs. 2 and 2A) consist of cutting and machining large metal plates used in the initial steps of building or major repair work of ships. Equipment used in this shop is capable of shearing, punching, planing, cutting, and rolling metal plates 1 to 1.5 inches thick. No hazardous wastes are currently generated by these operations or have been generated in the past, because these operations have not changed significantly over the years (Personal Communication, 1981).

6.1.1.3 Sheetmetal Shop

The Sheetmetal Shop performs light-gauge sheetmetal fabrication and a limited amount of degreasing. About 5 years ago, this shop was relocated from Bldg. 44 to its current location in Bldg. 59. No significant quantities of industrial wastes are generated at the Sheetmetal Shop. A minimal volume of cutting oil is used in cutting sheetmetal, and most of it adheres to the sheetmetal and metal shavings. All sheetmetal waste, including metal shavings, is periodically sold to salvaging contractors under the administration of the Defense Property Disposal Office (DPDO). Metal waste generated by past operations was also sold to salvaging contractors.

In 1979, a 400-gallon degreasing tank was installed in the Sheetmetal Shop. It was reported by Sheetmetal Shop personnel that its use is infrequent. Penetone 998®, which primarily consists of phosphoric acid, is used as the degreasing solution in this tank and has yet to become contaminated to the point of requiring disposal. Losses from evaporation are supplemented by the addition of fresh Penetone®. During the onsite investigation of the Sheetmetal Shop, the degreasing tank was inoperable because the electric heaters used to heat the degreasing solution were not functioning. Prior to 1979, degreasing of sheetmetal parts was conducted by the Pickling Shop. Degreasing was accomplished by immersing the sheetmetal into acidic pickling baths (Personal Communication, 1981). The description of the Pickling Shop presented later in this section addresses this degreasing process and related waste disposal practices in greater detail.

6.1.1.4 Boiler Shop

Boilers onboard ships are repaired by Boiler Shop personnel. For the last 6 years, the Boiler Shop has been located in Bldg. 59; during the preceding 50 years, however, it was located in Bldg. 9. In the past, when boilers were relined with asbestos, hazardous wastes were generated during "rip-out" operations in which the firebrick and asbestos lining was chipped away with air hammers. A substitute material is now being used in Navy boilers, and only about 1,000 pounds of asbestos is contract hauled annually from NSY. The amount removed is expected to diminish as the older boilers are replaced. Past quantities of asbestos disposed of in the base sanitary landfill (site 1) were significantly greater than 1,000 pounds per year because of the past lack of substitute materials.

Boiler tubes, preserved with Cosmoline® grease to prevent rust, are received at the Boiler Shop. The Cosmoline® is removed by a bath of kerosene, and all grease is removed in another bath of hot water, trisodiumphosphate, caustic, and detergents. After this second bath, the tubes are steam rinsed. Although this operation does not generate hazardous waste, it does produce approximately 800 gallons of contaminated kerosene semiannually. This material is pumped out by the Temporary Services Shop and put into the NSC waste oil reclamation system. The contents of the second bath are discharged to the sanitary sewer. Prior to the installation of the sanitary sewer, this waste was discharged to the Cooper River via the combined sewer system (Personal Communication, 1981).

6.1.1.5 Welding Shop

The Welding Shop is located in Bldg. 2, where it has been since before World War II. Welding Shop personnel perform welding operations on ships assigned to NSY for repair. This facility does not generate hazardous waste, and hazardous materials are not used in its operation (Personal Communication, 1981; Williams-Russell and Assoc., Inc., 1980). Past operations were not believed to have generated hazardous wastes, because the welding operations have not changed significantly over the years.

6.1.1.6 Electrical Shop

Electrical Shop operations include the manufacture and repair of industrial electrical equipment used in naval vessels. The Electrical Shop is located in Bldg. 177, where it has been since July 1955. Prior to that time, the Electrical Shop was not a consolidated operation; rather, electrical work was performed in several small electrical shops located throughout NSY. Information on the previous locations of each of these small electrical shops was not available to the IAS team.

Electrical Shop operations which generate waste include the following:

1. Insulation of wire for motor armatures by coating it in vats with varnish,

2. Cleaning metal components with a solvent cleaner,

3. Salvaging spent electrical batteries from naval vessels, and

4. Battery restoring and recharging.

Approximately 300 gallons of waste sludge is currently generated per year by the wire-insulation process. Past sludge generation rates were probably similar to current rates, except during periods of high production (World Wars I and II) when they were significantly higher. Through 1973, when the base sanitary landfill (site 1) was closed, the sludge was removed from the bottom of the varnish vats once a year, placed in 55-gallon drums, hauled to the base sanitary landfill (site 1), and then poured from the drums into the landfill. Since 1974, the sludge has been contract hauled offbase.

Approximately 300 gallons of waste metal-cleaning solvent is generated per year. Past generation rates were probably similar to current rates, except during World Wars I and II when they were significantly higher. Prior to approximately 1972, the spent solvent was discharged to the combined sewer system and ultimately to the Cooper River. Since 1972, the spent solvent was contract hauled offbase.

Both the battery salvaging operation and the battery restoring and recharging operation generate an acidic waste stream. Although neither operation is located in Bldg. 177 with the Electrical Shop, both are managed by the Electrical Shop. The battery salvaging operation is located adjacent to drydock No. 4, and the battery restoring and recharging operation is located in Bldg. 68. The battery salvaging operation consists of draining the acid electrolyte from spent batteries removed from naval vessels, rinsing the battery casings and electrodes with water, and recovering the lead electrodes. The recovered lead is sold to salvaging contractors. The combined waste stream of waste acid and wastewater is collected and routed to the acid neutralization facility. This facility also receives acidic wastewater from the battery restoring and recharging operation. Small acid spills frequently occur during battery restoring and recharging, and the acid and rinsewater drain to a sump located in Bldg. 68. From the sump, the acidic wastewater is pumped to the previously mentioned acid neutralization facility. The combined wastewater is neutralized by the addition of soda ash and discharged to the sanitary sewer and ultimately to NCCPSD. A more detailed description of the acid neutralization facility is presented in section 6.6.1. Prior to the installation of the acid neutralization facility in the mid-1970s, the acidic waste streams were discharged to the sewer system without treatment. Prior to 1972, the waste streams were discharged to the combined sewer system leading to

the Cooper River. From 1972 until the installation of the acid neutralization facility, the acidic wastewater was discharged to NCCPSD without pretreatment.

About 200 gallons of sludge is currently generated every 6 months by the neutralization process and is contract hauled. It was reported that this sludge generation rate is similar to that occurring in the past. Since the mid-1970s, the sludge has been contract hauled offbase.

Although current Electrical Shop operations involving the handling of mercury in electrical equipment (e.g., switches) do not result in the release of significant quantities of mercury to the environment, past operations did. Past operations which generated significant quantities of mercury included the repair of navigational equipment, particularly gyroscopes. Prior to 1973, there were no established procedures for handling mercury to avoid health and environmental problems. As a result, about 2 percent of the mercury contained in electrical equipment being repaired or discarded was lost by spillage in the surrounding work area or by adhering to the interior of discarded equipment. The remaining 98 percent was recovered for reuse. Mercury contained in discarded equipment was either included with scrap metal, sold for reclamation, or included with waste disposed of in the base sanitary landfill (site 1). Currently, more intensive efforts are expended to recover all mercury such that a minimal amount is lost, and virtually all mercury is sold to private contractors for reclamation (Personal Communication, 1981).

6.1.1.7 Electronics Shop

Electronics Shop operations consist of the repair and modification of electronic equipment. Prior to about 1956, the Electronics Shop was located in Bldg. 10. Since then, the shop has been located in Bldg. 177.

The only activity in the Electronics Shop which generates industrial waste is a water curtain spray paint booth. Water is recirculated during painting but requires disposal once every 3 to 4 months because of the buildup of fugitive paint. Prior to the installation of the separate sanitary/industrial wastewater sewer system in 1972, this wastewater was discharged to the Cooper River via the combined sewer system. Since 1972, this wastewater has been discharged to the sanitary/industrial sewer system. Approximately 50 gallons of sludge, accumulated in the water curtain recirculation system, is cleaned out following drainage of the wastewater to the sewer system. Past sludge accumulation rates were probably similar to current rates. Prior to 1973, the sludge was placed in a 55-gallon drum and hauled to the base sanitary landfill (site 1) for disposal. Since 1973, the sludge has been drummed and contract hauled offbase (Personal Communication, 1981).

6.1.1.8 Machine Shop 31

Industrial operations performed at this shop consist of machining and metal electroplating using cadmium, copper, chromium, lead, nickel, and silver and anodizing. Anodizing processes include coating steel piping used in hydraulic equipment with phosphate and treating aluminum with alodine. The machining operation is located in Bldg. 3, and the electroplating operation is located in Bldg. 44.

The primary function of the machining operation is heavy machine work, including lathing, cutting, grinding, drilling, and punching of large metal components. Industrial wastes generated by this shop consist of metal waste and waste oil. The waste oil originates from machining operations and from draining metal components containing oil, such as engines. The metal waste is sold to salvaging contractors through DPDO. The waste oil drains to an underground storage tank. The tank is periodically pumped out, and the waste oil is hauled to the NSC waste oil reclamation facility. About 1,000 gallons of waste oil is removed from the underground storage tank annually.

The only industrial waste generated by the electroplating operation is rinsewater containing fugitive toxic metals and cyanide from the electroplating baths. It was reported that spent plating baths are not a source of wastewater, because plating bath contaminants are removed through filtration, and plating bath losses are augmented by the addition of fresh plating solution. The filtered material has been contract hauled offbase since 1973. Contaminants removed from the plating baths prior to 1973 were probably disposed of in the base landfill. The quantity of filtered material is minimal compared to the quantity of sludge generated by waste rinsewater pretreatment.

Waste rinsewater is generated when rinsing baths used to clean metal surfaces before and after electroplating become contaminated with fugitive metals requiring disposal. Prior to 1972, untreated rinsewater was discharged to the Cooper River via the combined sewer system. In late 1971 or early 1972, the rinsewater was segregated from stormwater and sanitary wastewater into two waste streams, and a pretreatment system was installed. The pretreatment system services only one of the two waste streams--the one consisting of rinsewaters containing pollutants other than cyanide, particularly chromium and other heavy metals. Metal removal is provided by the pretreatment system through chemical precipitation using soda ash. The other waste stream, consisting of cyanide-bearing rinsewater, receives no pretreatment. Both waste streams are discharged to the sanitary sewer system and ultimately to NCCPSD.

The non-cyanide-bearing waste stream is treated on a batch basis once every 2 weeks. Approximately 1,200 gallons is treated in each batch and then discharged to the sewer, and approximately 250 gallons of sludge is generated as a result of the pretreatment of each batch. Although past wastewater and sludge generation rates have

presumably varied considerably due to varying production rates, in general, the order of magnitude of past rates is probably similar to current rates. However, this assumption may not be true for the peak production periods during World Wars I and II when rates were probably much higher.

The sludge generated from 1972, when the metals removal pretreatment system was installed, until 1973 was placed in 55-gallon drums and hauled to the base sanitary landfill (site 1) for disposal. Since 1973, the sludge has been drummed and contract hauled offpost.

The current and past rates of discharge for the cyanide-bearing waste stream are unknown; however, volumes discharged are known to be less than that of the non-cyanide-bearing waste stream.

6.1.1.9 Machine Shop 38

The primary function of Machine Shop 38 is light machine work, including the repair of machinery such as turbines and engines. This shop has been located in Bldg. 80 since the early 1940s. Prior to that time, it was located in Bldg. 44 and was under the operation of Machine Shop 31.

Industrial wastes currently generated by this shop, as well as waste generation rates, are presented in table 6.1-1. Past waste generation rates were probably similar to current rates, except during World Wars I and II when they were much higher. The source of the waste oil is a gravity oil-water separator, which receives waste oil from engines and other machinery, and oily wastewater from cleanup operations. The separator effluent is currently discharged to the sanitary sewer system, and the recovered oil is periodically pumped into a tank truck which transports it to the NSC waste oil reclamation facility. Prior to the installation of the separate sanitary/industrial wastewater sewer system in 1972, the waste oil and oily wastewater were disposed of in the combined sewer system without prior oil-water separation. Since 1972, this waste stream has been discharged to the sanitary/industrial sewer system; however, the oil-water separator was not installed until sometime in the mid-1970s.

Solvents, primarily 1,1,1,-trichloroethane and freon, are used as degreasers and other types of cleaners and are, therefore, generated as wastes. Potassium hydroxide solution originates in oxygen generators used on naval submarines which have been assigned to NAVBASE Charleston since 1948. Hydraulic fluids containing chlorinated organic substances are recovered during the repair of hydraulic equipment used in naval vessels. Prior to 1972, these liquid wastes were discharged to the Cooper River via the combined sewer system. When this disposal practice was discontinued, these wastes were placed in 55-gallon drums and hauled offbase. In addition, disposal of some of these drummed wastes in the base landfill probably occurred shortly before the landfill was closed in 1973.

Table 6.1-1
Potentially Hazardous Waste Generation Rates--
Machine Shop 38

Waste	Generation Rate (gal/yr)
Waste oil	500
Solvents (primarily 1,1,1-trichloroethane and freon)	200
Potassium hydroxide solution	40
Hydraulic fluid	15

gal/yr = gallons per year.

Source: Personal Communication, 1981.

6.1.1.10 Pipe Shop

Operations at the Pipe Shop, located in Bldg. 56, include the bending, cutting, and connecting of pipes. Degreasing of pipes and other metal components is performed in the Pickling Shop, which is under the supervision of the Pipe Shop. The Pickling Shop is located in Bldg. 221, and operations conducted there are described in detail in section 6.1.1.15.

No hazardous wastes are generated by Pipe Shop operations; however, hazardous wastes are generated by the Pickling Shop (see section 6.1.1.15). There are no records indicating past generation of hazardous waste by the Pipe Shop (Personal Communication, 1981).

6.1.1.11 Central Tool Shop

The Central Tool Shop, located in Bldg. 43, is responsible for performing the following three main functions:

1. Procurement and storage of lubricants and hydraulic fluids,

2. Lubrication and maintenance of shipyard machinery, and

3. Operation and maintenance of barges and railcars used to store and transport oily waste/waste oil to the NSC waste oil reclamation facility.

The only industrial wastes currently generated by the Central Tool Shop are waste oils, solvents, and hydraulic fluids. Approximately 11,000 gallons of lubricant oil is currently used on an annual basis in lubricating NSY machinery, and as much as 35 percent, or 3,800 gallons, is recovered by draining old oil from machinery. The remaining 7,200 gallons is lost as a result of volatilization and/or spillage occurring during oil changes. Recovered oil is placed in 55-gallon drums and transported to the NSC waste oil reclamation facility (see section 6.1.3). It was reported by Central Tool Shop personnel that, prior to approximately 1966, the waste oil was drummed and sold to private contractors for reclamation. Past generation rates of waste oil were probably similar to current rates, except during World Wars I and II when they were much higher.

The operation and maintenance of the railcars and barges used to store and transport oily waste/waste oil to the NSC waste oil reclamation facility do not generate hazardous wastes. The oily waste/waste oil stored and transported by the railcars and barges is generated in the naval vessels docked at the shipyard piers or located in the drydocks for repairs. The generation and handling of this waste is addressed in more detail in section 6.4.1.

A past operation of the Central Tool Shop which generated hazardous waste was the repair of electrical equipment, such as transformers, containing PCB fluids. This operation was performed until

approximately 1976. It was reported by Central Tool Shop personnel that small PCB spills were a common occurrence during electrical equipment repairs. The typical cleanup procedure consisted of placing absorbent material on the spill and depositing the saturated material in trash cans. The trash can contents were then transported to the base sanitary landfill (site 1) for disposal. The amount of PCB-contaminated waste disposed of in this manner is unknown (Personal Communication, 1981).

6.1.1.12 Paint Shop

Sandblasting and painting of ships assigned to NSY and ship components are performed in Bldgs. 223 and 212 by Paint Shop personnel. Prior to 1974, the Paint Shop was located near Bldg. 226. The Paint Shop's previous building has been demolished, and, in June 1974, Paint Shop operations were moved to their current locations.

Currently, two metallic paints are used regularly in the Paint Shop: a lead-based primer and a copper-containing bottom paint. These types of paint are of historical interest because they typify those used as steel primers and bottom paints. A total of 3,000 gallons of paint is used each month in Paint Shop operations. No records exist indicating the past or present application of organo-tin paints at NSY. However, sandblasting operations at NSY have reportedly removed organo-tin paints applied to ship hulls at other locations. Thus, although organo-tin paints have not been applied at NSY, sandblasting grit containing organo-tin paints has been generated at NSY.

Paint wastes are hazardous because they may contain cadmium, chromium, lead, cyanide, toluene, or tetrachloroethylene. The solvents used in the painting process (toluene and tetrachloroethylene) also have the potential of being classified as hazardous on the basis of toxicity and ignitability. About 226 tons of paint wastes and solvents is currently generated on an annual basis and stored on a concrete pad located near Bldg. 223 and adjacent to the Cooper River. This storage facility is described in detail in section 6.4.5. Since the late 1960s, a private contractor has been hired to dispose of all paint wastes, including paints, solvents, and paint sludge. Prior to the use of a disposal contractor, painting wastes were disposed of in the base sanitary landfill (site 1).

Two water curtain spray booths are operated in the Paint Shop. When the water curtain is cleaned, the paint sludge (approximately 1,000 pounds) from the booth is collected and disposed of by private contractor, and the water is discharged to the sanitary sewer. Prior to the 1960s, the paint sludge was disposed of in the base sanitary landfill (site 1), and the wastewater was discharged to the Cooper River prior to the installation of the sanitary sewer.

Waste from sandblasting operations conducted in Bldg. 223 and at outside areas (including drydocks and the area adjacent to Bldg. 223) has been subjected to the Extraction Procedure (EP) Toxicity Test and found to be nonhazardous (Technical Services, Inc., 1980). Waste

sandblasting materials are disposed of offsite. Prior to 1974, waste sandblasting materials were disposed of in the base sanitary landfill (site 1) (Personal Communication, 1981; Williams-Russell and Assoc., Inc., 1980).

6.1.1.13 Woodwork Shop

The Woodwork Shop performs all wood sawing, planing, finishing, and fabrication required to maintain, modify, and/or manufacture equipment and furniture for other shipyard operations and naval vessels. Past Woodwork Shop activities have included the use of a 2,500-gallon dip tank to apply a fire retardant solution to wood products. It was reported that the manufacturer of the fire retardant was Para Products, Inc.; however, the composition of the fire retardant is unknown. Fire retardants are generally formulations of salts, the principal ones being borates, phosphates, and ammonium compounds. The application of fire retardant to wood at the Woodwork Shop did not generate any waste. Fresh fire retardant was added to the dip tank to make up for losses due to evaporation and absorption into the treated wood. The application of fire retardant to wood was discontinued in February 1981 when the practice of purchasing wood already treated with fire retardant began. Prior to the time of the site visit, approximately 2,000 gallons of the fire retardant solution, which remained in the dip tank, was contract hauled offbase to an EPA-approved landfill for disposal (Personal Communication, 1981).

6.1.1.14 Supervisor of Shipbuilding Conversion and Repair (SUPSHIP)

SUPSHIP was established in June 1950. The procurement and monitoring of contracted services for shipbuilding conversion and repairs are the sole functions of SUPSHIP personnel. No repair or production services are performed by SUPSHIP itself. Since the early 1970s, the principal contractors procured by SUPSHIP have been Metal Trades, Inc., Braswell Shipyards, and Sandblasting, Inc., all of which have facilities onbase. Since SUPSHIP does not generally establish contractual agreements regarding hazardous waste disposal by contractors, SUPSHIP has no records of quantities of wastes generated by contractors and methods of waste disposal. Contractors are responsible for handling and disposing of hazardous wastes generated by their operations. Records indicate that Metals Trades, Inc. and Sandblasters, Inc. were established onbase after 1975. This period is subsequent to the closure of the base sanitary landfill (site 1) and, consequently, these contractors could not have disposed in the landfill. However, Braswell has been onbase since approximately 1970 and it is likely that some hazardous wastes, such as waste solvents and paints, were disposed of in the base landfill (Personal Communication, 1981). The quantities of wastes generated by these contractors are unknown, but are expected to be small considering the size of the operations.

6.1.1.15 Pickling Shop

The Pickling Shop has been in its current location since the early 1940s. Until May 1970, when Bldg. 221 was constructed, the facility was located out in the open, with only the pickling tanks covered by a roof. The Pickling Shop is under the supervision of the Pipe Shop.

Current operations include degreasing with a "dry cleaning fluid" (Stoddard solvent), hydrochloric acid bath, iridite bath, nitric acid bath, paint stripper bath, bright dip (sodium dichromate), sulfuric acid bath, trisodium phosphate bath, and deoxyisoprep bath. The tanks used for these baths range in size from approximately 1,500 gallons to 2,400 gallons. The baths are changed every 3 to 6 months, depending on the amount of use, and the spent pickling baths are contract hauled. The quantities of waste currently generated in the Pickling Shop on an annual basis are: spent pickling acids and other corrosives (1,375 gallons), bright dip (275 gallons), and trisodium phosphate (1,210 gallons). Since 1974, Public Works NSY has arranged for a private contractor to dispose of spent pickling waste. Prior to that time, the contents of spent pickling baths were discharged to the Cooper River via the storm drainage system (Personal Communication, 1981; Williams-Russell and Assoc., Inc., 1980).

6.1.1.16 Temporary Services Shop

The Temporary Services Shop was established in 1950 and has been located in Bldg. 9 for approximately 6 years. The duties of Temporary Services include draining and cleaning of shipboard tanks, draining of chemical tankage, and wet layup of boilers on NAVBASE Charleston. Approximately 40,000 gallons of flushing solutions is currently generated annually by the Temporary Services Shop.

Shipboard tanks are treated in accordance with prescribed Navy methods, which vary depending on the intended use of the tank. Chemicals used to treat the various tanks are caustic soda, sulfamic acid, trisodium phosphate, nonionic detergent, and calcium and sodium hypochlorite. When these materials are removed from the treated tank, they are disposed of by private contractor. Since February 1981, Public Works NSY has directed the disposal of spent tank-treatment chemicals. Prior to that time, the NSY Quality Control Laboratory directed the neutralization of these materials. After neutralization, the materials were discharged to the storm sewer, which emptied into the Cooper River.

Since February 1981, all tank-treatment chemicals, except chlorinated water, have been contract hauled by an EPA-approved contractor. Chlorinated water, used to treat potable water holding tanks onboard ship, is stored and periodically diluted and discharged to the sanitary sewer.

Wet layup of the ship's boiler requires the use of chemicals such as hydrazine and morpholine. These chemicals, used as corrosion inhibitors and antioxidants while the boilers are not in use, are received and pumped out by Temporary Service Shop personnel. Hydrazine is listed as a hazardous waste under EPA hazardarous waste regulations (EPA, 1980a). Prior to February 1981, wastes containing hydrazine were discharged to the Cooper River; since that time, however, wastes from boiler layup have been contract hauled. Estimates of the volume of boiler layup water generated on an average basis were not available because of the wide fluctuation in boiler layup activities and the lack of pertinent records. However, because the chemicals contained in the layup water are biodegradable and were likely well diffused in the Cooper River following discharge, no adverse environmental impacts are expected as a result of the past disposal of boiler layup water.

Tanks involved in other operations, such as the boiler tube degreasing bath in the Boiler Shop and the oil-water separator in the Central Tool Shop, are also pumped out by Temporary Services Shop personnel. Waste oils are taken to the NSC-operated waste oil reclamation system. This method of waste oil recovery has been used since the establishment of the Temporary Services Shop in 1950 (Personal Communication, 1981; Williams-Russell and Assoc., Inc., 1980).

6.1.1.17 Public Works Naval Shipyard

Public Works NSY has been located at NAVBASE Charleston since the founding of the Naval Yard in 1901. Public Works NSY personnel provide services to NSY and, in some cases, to NAVBASE Charleston as a whole. Services include utilities, large equipment maintenance, pest control, and environmental management.

Public Works NSY areas where hazardous wastes currently are generated include vehicle maintenance (Bldgs. 25, 1199, and 1169), building maintenance (Bldg. 25), and pest control (Bldg. 381). Wastes generated in the vehicle maintenance areas are cleaning solvents and waste oil. Cleaning solvents are disposed of by contractor. No information was available on the past disposal practices of cleaning solvents or waste oil. Waste oils are recycled through the NSC waste oil reclamation facility. The building maintenance group generates paint waste, which is disposed of by contractor along with waste from the Paint Shop (Bldg. 223) (see section 6.1.1.12). Pest control wastes are discussed in section 6.4.3 of this report.

The environmental section of Public Works NSY, in addition to other duties, is responsible for all supervision of NAVBASE Charleston hazardous waste contracting. This group also supervises cleanup of any hazardous waste spill on NAVBASE Charleston, as well as the disposal of the spilled material (Williams-Russell and Assoc., Inc., 1980).

6.1.1.18 Atlantic Fleet Audio Visual, Inc. (AFAV)

A tenant of NSY, AFAV provides photographic and audio visual services for the Atlantic Naval Fleet and NSY. AFAV has been in operation since 1975 and is located in Bldg. 234. Wastes generated by AFAV include waste hypo-solution, which contains silver, black fixer, and developer solution. Approximately 1,500 gallons of waste hypo-solution is generated annually, and silver recovery is provided prior to discharging this solution to the sanitary sewer. An electrolytic silver recovery process is utilized in the silver recovery unit. Cartridges containing recovered silver are reportedly sold to private contractors. In addition, approximately 72 gallons of bleach fixer and 200 gallons of developer solution are discharged to the sanitary sewer annually. Past waste disposal also involved discharge to the sanitary sewer and ultimately to NCCPSD (Personal Communication, 1981; Williams-Russell and Assoc., Inc., 1980).

6.1.2 Naval Station

6.1.2.1 Shore Intermediate Maintenance Activity (SIMA)

A tenant of NAVSTA, SIMA has been located in Bldgs. NS23 and NS26 since its inception in 1958. Periodic maintenance is performed by SIMA personnel on ships, to extend the ships' length of service before extensive maintenance is required at the shipyard.

Current operations generate the following hazardous waste annually: boiler cleaning solution (sulfuric acid or nitric acid) (50,000 gallons), cleaning solvents (chlorinated hydrocarbons) (1,800 gallons), asbestos (2 cubic yards), and boiler test chemicals (mercuric nitrite) (3,400 pounds). The boiler cleaning solution is currently neutralized and discharged overboard. Cleaning solvents, asbestos, and boiler test chemicals are disposed of by contractors engaged by Public Works NSY.

Historical records of waste handling are limited due to the rapid turnover of the SIMA personnel in this activity. By examining current practices, however, it can be assumed that no special handling occurred in the past, liquid wastes were discharged to the combined sewer systems, and solid wastes were sent to the base sanitary landfill (site 1). Ship boiler cleaning solutions were discharged overboard to the Cooper River (Personal Communication, 1981; Williams-Russell and Assoc., Inc., 1980).

6.1.2.2 Public Works Naval Station

Wastes generated by Public Works NAVSTA include waste oil from the vehicle maintenance program and a small amount of degreaser (trichloroethylene) from the lawn-mowing maintenance facility. Waste oils are disposed of by recycling the oil through the NSC waste oil reclamation facility. The degreaser tank, which has reportedly not been

emptied to date, will be disposed of by a contractor hired by Public Works NSY when required (Personal Communication, 1981).

6.1.2.3 Commander, Marine Warfare Command (CMWC)

CMWC is strictly an administrative branch of the Commander in Chief of the Atlantic Fleet (CINCLANTFLT) and is a tenant on NAVSTA. The only industrial waste generated at MWC is waste photographic developing solution. Prior to 1972, the waste developing solution was discharged to the Cooper River via the combined sewer system. From 1972 until 1979, the waste solution was discharged to the sanitary sewer. Silver recovery was not practiced prior to discharge to the sewer systems. Since 1979, this waste has been transferred to AFAV (see section 6.1.1.18) for silver recovery. Approximately 60 gallons of this solution is currently generated annually (Personal Communication, 1981).

6.1.2.4 Surface Forces Readiness Support (SFRS)

SFRS coordinates the transferring of ship wastes, other than oily wastes, to land during ship maintenance at NAVSTA. SFRS is located on NAVSTA property. Wastes generated by SFRS operations include dilute solutions of sodium nitrate and mercuric nitrate. The sodium nitrate solution is actually boiler layup water that is pumped off ships; the sodium nitrate is added to the water to prevent rusting. Approximately 15,000 gallons of boiler layup water is currently pumped annually off ships and discharged to the dockside sewer. In the past, boiler layup water was probably discharged overboard.

Approximately 5 gallons of mercuric nitrate solution (maximum concentration of 0.2 grams mercuric nitrate per liter), used in boiler water salinity testing, is currently generated on a monthly basis. Subsequent handling of this solution is conducted by private contractor. Prior to 1972, this waste solution was probably discharged to the Cooper River via the combined sewer system.

6.1.3 Naval Supply Center

NSC is involved in storing chemicals and operating a printing shop, two oil tank farms, and a waste oil reclamation facility. The storage and handling of chemicals by NSC are discussed in section 6.4. A description of the tank farms and waste oil reclamation facility is presented in section 6.4.1. The coal storage area described in section 6.4.6 is on property controlled by NSC, but the coal is owned by NSY.

Since May 1979, the Publication and Printing Service has been located in Bldg. 1628. For approximately 30 years prior to that time, it was housed in Bldg. 35. This service supplies the printing needs of much of the Commander, NAVBASE Charleston (COMNAVBASE) area of cognizance and is a tenant of NSC.

Prior to 1979, wastes generated at Bldg. 35 included an unknown quantity of ferric chloride acid etching bath, lithographic developing solution, and photographic developing solution. Prior to 1971, these wastes were discharged without treatment to the combined sewer system and, hence, to the Cooper River. Since 1972, these wastes have been discharged to the NCCPSD sanitary sewer system with no pretreatment. In addition, solvents are periodically used to clean printing surfaces. Rags, provided by a commercial supplier, are moistened with the solvents and used to wipe down the presses. After use, the rags are returned to the supplier for reuse. No waste solvents are produced.

When the printing service moved to new facilities in 1979 (Bldg. 1628), the ferric chloride operation was discontinued; the photographic developing solution recycling program was instituted; and a silver recovery program was established for photographic developing solution, paper, and film. The lithographic solution is currently discharged to the sanitary sewer along with spent developing fluid. Film and paper are sent to DPDO to be sold for silver recovery (Personal Communication, 1981).

6.1.4 Naval Reserve Center

NRC, a tenant of NAVSTA, provides recruiting and training facilities for naval reserve personnel. No hazardous waste is routinely generated at this facility. Motor oils generated from the vehicle maintenance program are taken to the NSC waste oil reclamation facility. There are no records indicating past generation of hazardous waste by NRC.

6.1.5 Fleet and Mine Warfare Training Center

Operations at FMWTC, which is located on NAVSTA, include a firefighting training school and a laboratory for testing boiler waters. FMWTC has been in operation since approximately 1956.

The firefighting school uses approximately 20,000 gallons of No. 2 diesel oil per year and 2,000 gallons of gasoline per year in training operations. Training exercises include extinguishing ignited diesel oil and gasoline. Diesel oil floating on water in tanks is burned in enclosed, paved areas. Gasoline is burned directly on the ground in a bermed area; however, it is unlikely that significant amounts seep into the ground because most of the gasoline burns or evaporates.

Oily wastewater is periodically removed from the tanks used for diesel fuel-on-water burning and passed through a gravity oil-water separator prior to being discharged to the sanitary sewer leading to NCCPSD. The effluent contains Aqueous Film-Forming Foam (AFFF) used in firefighting exercises. It was reported that the quantity of AFFF used (less than 50 gallons/week) is well below the discharge limitation imposed by NCCPSD. Prior to 1972, the wastewater was probably discharged to the Cooper River via the combined sewer system. Less

than 50 gallons of waste oil per month accumulates in the oil-water separator. This waste oil is periodically removed and transported to the NSC waste oil reclamation facility. In the past, the waste oil was transported offsite by private contractors for reclamation.

The boiler water testing laboratory currently generates less than 5 gallons of dilute mercuric nitrate solution per week. This solution is used to train personnel to test the salinity of boiler water. Waste mercuric nitrate solution is picked up by Public Works NSY and contractor hauled. According to FMWTC personnel, this waste solution was handled in the past by private contractors who reclaimed the mercury.

6.1.6 Fleet Ballistic Missile Submarine Training Center

FBMSTC operates a school on NAVSTA to train personnel in the operation of ballistic missile submarines. FBMSTC has been in operation since 1962. Industrial wastes generated by FBMSTC include the following:

1. Oily wastewater from bilges on simulated training submarines,
2. Hydraulic oils,
3. Freon-based degreasing solvent,
4. Monoethanolamine used as a chelating agent in carbon dioxide scrubbers, and
5. Potassium hydroxide solution used in oxygen generators.

Oily wastewater is routed through a gravity oil-water separator prior to being discharged to the sanitary sewer system. Prior to 1972, the wastewater was discharged to the Cooper River via the combined sewer system. Waste oil which accumulates in the separator is periodically removed and transported to the NSC waste oil reclamation facility. Approximately 500 gallons of waste oil is removed from the separator annually (Williams-Russell and Assoc., Inc., 1980). In the past, waste oil was sold to private contractors for reclamation.

Six to ten 55-gallon drums of waste hydraulic oils are currently generated annually. These oils are currently hauled to the NSC waste oil reclamation center. In the past, the waste oils were sold to private contractors for reclamation.

Fewer than five 55-gallon drums of the freon-based degreasing solvent are generated annually. Prior to the early 1970s, the waste solvent was probably discharged to the Cooper River via the combined sewer system. When this disposal practice was discontinued, the waste solvent was placed in 55-gallon drums and hauled to disposal facilities. Disposal of some of this waste in the base sanitary landfill (site 1)

probably occurred shortly before the landfill was closed in 1973. Since 1973, these wastes have been contract hauled offbase.

Approximately 9 gallons of waste monoethanolamine and 60 gallons of waste potassium hydroxide solution are currently generated on an annual basis. These wastes have always been diluted and disposed of down laboratory drains. Prior to the early 1970s, these wastes were discharged to the Cooper River via the combined sewer system. Since then, these wastes have been discharged to the NCCPSD sanitary sewer system; however, a different disposal procedure is currently being developed. The new procedure will probably involve contract hauling offsite to an approved disposal facility (Personal Communication, 1981; Williams-Russell and Assoc., Inc., 1980).

6.1.7 Naval Electronics Systems Engineering Center

NESEC primarily provides electronics support in the maintenance and modification of communication equipment, such as automatic air traffic control equipment, for the Atlantic Naval Fleet and associated shore communication systems. NESEC has been in operation since 1966 and is located offbase in North Charleston. The only industrial wastes generated by NESEC are spent nickel-cadmium batteries, which are sold to salvaging contractors. No other wastes have been generated by NESEC operations (Personal Communication, 1981).

6.1.8 Marine Corps Barracks

Marine Corps personnel stationed at NAVBASE Charleston maintain a small motor pool operation, which generates a minimal quantity of waste oil. This waste oil is taken to the NSC waste and reclamation facility. There are no records indicating past generation of hazardous waste by Marine Corps Barracks personnel.

6.1.9 Naval Security Group Activity

NAVSECGRUACT, which is a tenant of NAVSTA, is responsible for performing Signal Security Operations (SIGSEC) and Electronic Warfare Support Measures/Electronic Intelligence Technical Guidance Unit (ESM/ELINT TGU) functions, as well as providing cryptologic equipment, maintenance, and personnel support to Atlantic Fleet Cryptologic Direct Support Elements Afloat and other mobile units. No hazardous wastes are generated by NAVSECGRUACT, and there are no records of any past operations generating hazardous wastes.

A gas/diesel-fuel-powered incinerator is located behind the building occupied by NAVSECGRUACT (Bldg. NS-84) and is owned and operated by NAVSTA. This incinerator is used to burn classified printed matter (Personal Communication, 1981).

6.1.10 Summary of Hazardous Waste Generation by Industrial Operations

Table 6.1-2 summarizes the types and quantities of industrial wastes generated and the methods of waste treatment and disposal practiced by each industrial operation at NAVBASE Charleston. In some cases, waste generation rates are those presented in the Hazardous Waste Management Survey (HWMS) (3 Dec 1980). Industrial operations, and the resulting types and quantities of wastes generated, have not changed significantly, if at all, since 1980. Thus, for those instances in which waste generation rates were not available during the onsite survey, the 1980 HWMS rates reportedly provide reasonable estimates of current rates.

The waste generation rates presented in table 6.1-2 indicate that the most significant quantities of hazardous wastes which are currently contract hauled offbase include electroplating sludge (generated in the metal plating waste treatment facility), paint waste, and solvents. The most significant quantities of liquid industrial wastes discharged to the sanitary sewer system include electroplating wastewater (effluent from the metal plating waste treatment facility) and boiler layup water (sodium nitrate solution).

6.2 LABORATORY OPERATIONS

6.2.1 Quality Assurance (QA) Laboratory Complex

The QA laboratory at NAVBASE Charleston conducts structural and chemical analyses of materials supplied to or generated by NSY. The laboratory officially has been in existence since 1965, although it was reported that check laboratories have always been associated with NSY. Tests are conducted at the laboratory primarily by instrumental methods, with very little wet chemical types of analyses; reportedly, no hazardous wastes are generated. The laboratory has, in the past, conducted analyses of wastes generated by NSY operations and has provided treatment and disposal guidance (e.g., the neutralization of strong acids or bases before disposal into the sewer).

6.2.2 Dental Clinic Laboratory

The Dental Clinic at NAVBASE Charleston has been in existence for 15 years. For the past 5 years it has been located in Bldg. 675 and prior to that, in Bldg. 79. The Dental Clinic Laboratory generates three hazardous wastes: (1) scrap amalgam (mercury and silver), (2) beryllium and nickel filings, and (3) waste X-ray solution.

Scrap amalgam (mercury and silver) is stored at the clinic until approximately 3 to 5 pounds has accumulated. At that time, Defense Logistics Agency (DLA) is notified, and the amalgam is sent to DLA at Colts Neck, N.J., for recovery. This occurs two or three times per year.

Table 6.1-2
Summary of Industrial Waste Generation Rates and Treatment and Disposal Methods

Operation	Period of Operation	Industrial Wastes	Current Annual Waste Generation Rate ESE*	Current Annual Waste Generation Rate W-R†	Current Treatment Method	Current Disposal Method	Past Disposal Method
NSY							
Foundry	Early 1900s to date	None	—	—	—	—	—
Shipfitter Shop	Early 1900s to date	None	—	—	—	—	—
Sheetmetal Shop	Early 1900s to date	None	—	—	—	—	—
Boiler Shop	Early 1900s to date	Asbestos	1,000 lbs	ND**	—	Contract Hauled	Base Landfill
		Waste Kerosene	1,600 gal	ND	None	NSC-WORF***	NSC-WORF
Welding Shop	Early 1900s to date	None	—	—	—	—	—
Electrical Shop	Early 1900s to date	Varnish Sludge	300 gal	ND	None	Contract Hauled	Base Landfill
		Solvent	300 gal	ND	None	Contract Hauled	Cooper River
		Acidic Wastewater	NNI††	3,000 gal	Neutralization with Soda Ash	Sanitary Sewer	Cooper River
		Acid Neutralization Sludge	400 gal	ND	None	Contract Hauled	Contract Hauled
		Mercury	ND	ND	None	Sold to Private Contractors	Fugitive Quantities to Base Landfill
Electronics Shop	Early 1900s to date	Paint Wastewater	ND	ND	None	Sanitary Sewer	Cooper River
		Paint Sludge	200 gal	ND	None	Contract Hauled	Base Landfill
Machine Shop 31	Early 1900s to date	Electroplating Wastewater (cyanide and non-cyanide bearing)	<62,400 gal	40,000 gal	Metals Removal	Sanitary Sewer	Cooper River
		Electroplating Sludge	4,200 lbs	12,400 lbs	None	Contract Hauled	Base Landfill
		Waste Oil	1,000 gal	ND	None	NSC-WORF	NSC-WORF
Machine Shop 38	Early 1900s to date	Waste Oil	500 gal	3,000 gal	None	NSC-WORF	NSC-WORF
		Solvents	200 gal	ND	None	Contract Hauled	Cooper River
		Potassium Hydroxide Solution	40 gal	ND	None	Contract Hauled	Cooper River
		Hydraulic Fluid	15 gal	ND	None	Contract Hauled	Cooper River

Table 6.1-2
Summary of Industrial Waste Generation Rates and Treatment and Diaposal Methods
(Continued, Page 2 of 4)

Operation	Period of Operation	Industrial Wastes	Current Annual Waste Generation Rate ESE*	Current Annual Waste Generation Rate W-RI	Current Treatment Method	Current Disposal Method	Past Disposal Method
Central Tool Shop	Early 1900s to date	Lubricating Oil	3,800 gal	ND	None	NSC-WORF	NSC-WORF
		PCB Fluids from Past Operations	NNI	ND	None	—	Base Landfill
Paint Shop	Early 1900s to date	Paint Waste and Solvents	ND	226 tons	None	Contract Hauled	Base Landfill
		Paint Wastewater	ND	ND	None	Sanitary Sewer	Cooper River
Woodwork Shop	Early 1900s to date	None	—	—	—	—	—
SUPSHIP	June 1950 to date	None	—	—	—	—	—
SUPSHIP Contractors	June 1950 to date	Predominantly Paint Waste and Solventa	ND	ND	ND	Contractor's Responsibility	Base Landfill
Pipe Shop	Early 1950s to date	None	—	—	—	—	—
Pickling Shop	Early 1950s to date	Spent Pickling Baths	NNI	1,375 gal	None	Contract Hauled	Cooper River
		Bright Dip (sodium dichromate)	NNI	275 gal	None	Contract Hauled	Cooper River
		Trisodium Phosphate	NNI	1,210 gal	None	Contract Hauled	Cooper River
Temporary Service Shop	1950 to date	Tank Flushing Solutions	NNI	40,000 gal	None	Contract Hauled	Cooper River
Public Works	Early 1950s to date	Waste Oil	ND	ND	None	NSC-WORF	NSC-WORF
		Solvents	ND	ND	None	Contract Hauled	Cooper River
		Paint Waste	ND	ND	None	Contract Hauled	Base Landfill
AFAV	1975 to date	Waste Hypo-Solution	NNI	1,500 gal	Silver Recovery	Sanitary Sewer	Sanitary Sewer
		Bleach Fixer	NNI	72 gal	None	Sanitary Sewer	Sanitary Sewer
		Developer Solution	NNI	200 gal	None	Sanitary Sewer	Sanitary Sewer

Table 6.1-2
Summary of Industrial Waste Generation Rates and Treatment and Disposal Methods
(Continued, Page 3 of 4)

Operation	Period of Operation	Industrial Wastes	Current Annual Waste Generation Rate ESE*	Current Annual Waste Generation Rate W-RI	Current Treatment Method	Current Disposal Method	Past Disposal Method
NAVSTA STMA	1958 to date	Boiler Cleaning Solutions	NNI	50,000 gal	Neutralization	Cooper River	Cooper River
		Solvents	NNI	1,800 gal	None	Contract Hauled	Cooper River
		Asbestos	NNI	2 y^3	None	Contract Hauled	Base Landfill
		Mercuric Nitrate Solution	3,400 lbs	ND	None	Sold to Private Contractors	Cooper River
Public Works		Degreaser (tri-chloroethylene)	Minimal	ND	None	Contract Hauled	Cooper River
		Waste Oil	NNI	55-110 gal	None	NSC-WORF	NSC-WORF
MWC		Photo Developing Solution	60 gal	50-60 gal	Silver Recovery	Sanitary Sewer	Cooper River
SFRS		Boiler Layup Water (Sodium Nitrate Solution)	15,000 gal	15,000 gal	None	Sanitary Sewer	Cooper River
		Mercuric Nitrate Solution	60 gal	400 gal	None	Sold to Private Contractors	Cooper River
Navy Dental Clinic	1966 to date	Silver, Mercury Amalgams	6-15 lbs	ND	None	Turned over to DLA for Recovery	DLA
		Beryllium, Nickel Filings	130 lbs	140	None	Contract Hauled	Base Landfill
		X-Ray Solutions	60 gal	60 gal	Silver Recovery	NRMC	NRMC
Marine Corps Barracks		Waste Oil	ND		None	NSC-WORF	ND

Table 6.1-2
Summary of Industrial Waste Generation Rates and Treatment and Disposal Methods
(Continued, Page 4 of 4)

Operation	Period of Operation	Industrial Wastes	Current Annual Waste Generation Rate ESE*	Current Annual Waste Generation Rate W-R†	Current Treatment Method	Current Disposal Method	Past Disposal Method
NSC NSC-WORF	1950 to date	Waste Oil	200,000 gal	ND	Oil-Water Separation	Stored Onsite	Oil Sludge Pits
Navy Publication	1950 to date	Photo Developing Solution	ND	ND	Silver Recovery	Sanitary Sewer	Cooper River
		Lithographic Developing Solution	NNI	60 gal	None	Sanitary Sewer	Cooper River
NRC		Waste Oil	Minimal	350 gal	None	NSC-WORF	NSC-WORF
FMWTC	1956 to date	Waste Oil	600 gal	ND	None	NSC-WORF	NSC-WORF
		Mercuric Nitrate Solution	<260 gal	110 gal	None	Sold to Private Contractors	Sold to Private Contractors
FBMSTC	1962 to date	Waste Oil	NNI	500 gal	None	NSC-WORF	NSC-WORF
		Hydraulic Oils	NNI	330-550 gal	None	NSC-WORF	NSC-WORF
		Solvent	ND	<300 gal	None	Contract Hauled	Cooper River
		Monoethanolamine	9 gal	ND	None	Contract Hauled	Cooper River
		Potassium Hydroxide Solution	60 gal	ND	None	Contract Hauled	Cooper River
NRMC	1972 to date	Waste Chemicals and Solvents	300 gal	—	—	Contract Hauled	Contract Hauled
		Infectious Wastes	—	—	—	Incineration	Incineration
		Waste X-Ray Solution	5,500 gal	ND	Silver Recovery	Sanitary Sewer	Sanitary Sewer
NESEC	1966 to date	None	—	—	—	—	—

* Data collected by ESE during site survey.
† Williams-Russell and Assoc., Inc., 1980.
** ND = no data.
†† NNI = no new information.
*** Waste oil reclamation facility.

Source: ESE, 1981.

Beryllium and nickel filings are generated at the clinic during the production of prosthetics. In the past year, these filings have been collected by Public Works NSY and stored at Bldg. 381 for disposal as hazardous waste. It was reported that approximately 15 pounds of filings is generated every 6 weeks. Prior to 1980, these filings reportedly went to the dumpster.

Spent X-ray solution (60 gallons/year) is sent to NRMC for processing.

Hazardous wastes generated by the Dental Clinic Laboratory and disposal methods employed are summarized in table 6.1-2.

6.2.3 Naval Regional Medical Center

Laboratories within NRMC generate: (1) waste chemicals and solvents, (2) infectious wastes, and (3) waste X-ray solutions.

Waste and/or excess solvents and chemicals (35 to 50 gallons every 2 months) are stored at NRMC and collected for disposal by the Public Works NSY hazardous waste contractor (Groce Labs, Greer, S.C.). This procedure reportedly has been practiced for the past 1.5 years. Prior to that, these items were disposed of by contract through hospital supply.

Infectious wastes generated at NRMC, as well as excess pharmaceutical chemicals, are disposed of by incineration.

Spent X-ray solution (15 gallons/day) is disposed of by flushing into the sanitary sewer system following silver removal.

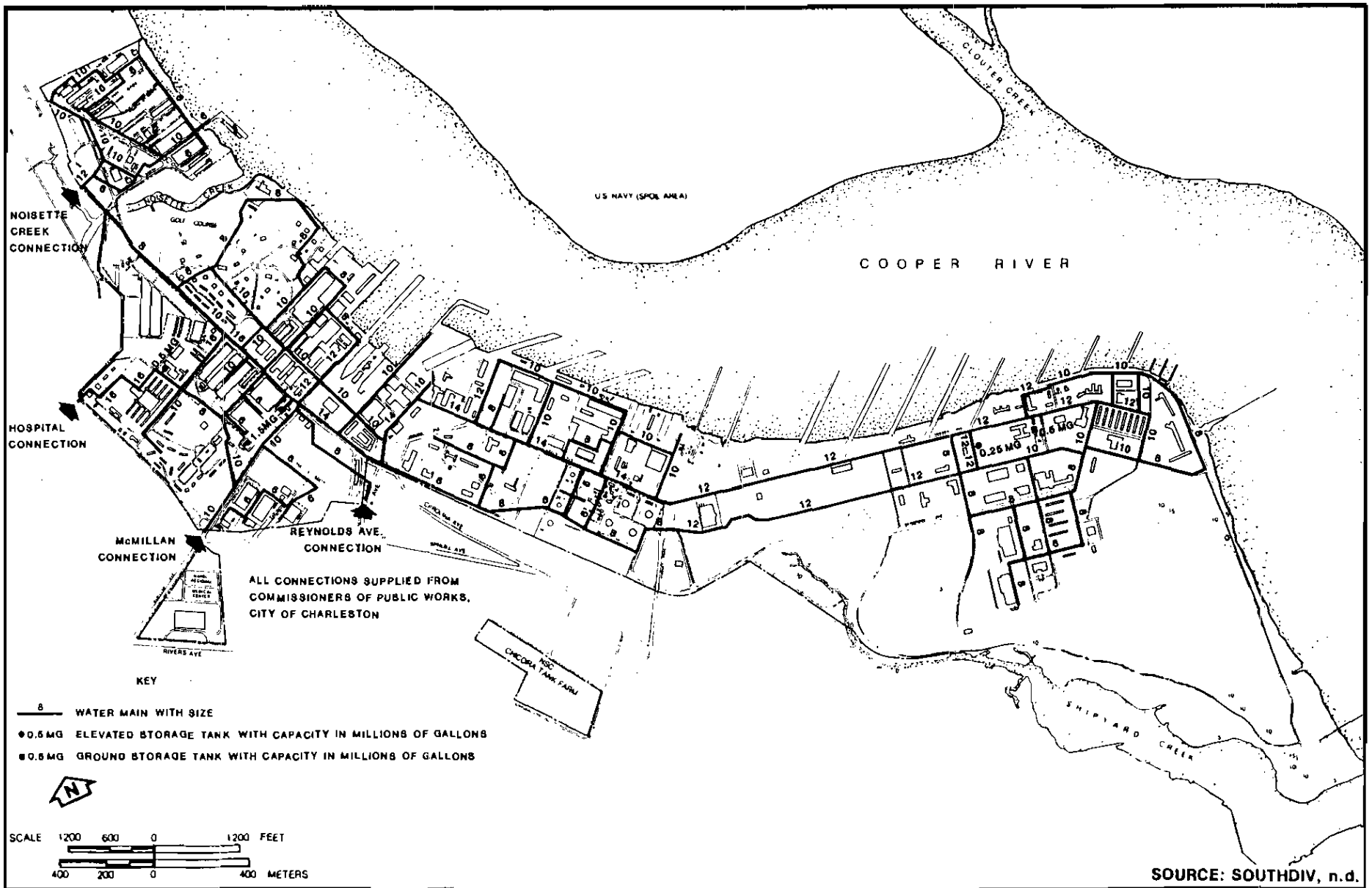
Table 6.1-2 summarizes hazardous wastes generated by NRMC, as well as the disposal methods employed.

6.3 UTILITIES

6.3.1 Potable Water

Since its establishment in 1901, NAVBASE Charleston has received potable water from the City of Charleston. Potable water is supplied to NAVBASE Charleston through four metered lines: one 16-inch, one 12-inch, and two 8-inch. Area distribution is through 8-inch and 10-inch looped systems. The City of Charleston currently treats water by prechlorination, coagulation, filtration, and postchlorination. NAVBASE Charleston monitors chlorine concentrations in the distribution system to maintain a free chlorine residual of 0.2 milligram per liter (mg/l).

A potable water storage capacity of 2.75 million gallons is available to NAVBASE Charleston. Water is stored in two elevated tanks (500,000 gallons and 250,000 gallons) and two ground storage tanks (1,500,000 gallons and 500,000 gallons). A map of the primary water mains is shown in figure 6.3-1 (SOUTHDIV, 1978).



SOURCE: SOUTHDIV, n.d.

Figure 6.3-1
PRIMARY WATER MAINS ON NAVBASE CHARLESTON

INITIAL ASSESSMENT STUDY
NAVAL BASE CHARLESTON

6.3.2 Heating

Heat and high pressure steam are supplied by 103 boilers on NAVBASE Charleston. These boilers are of three types: coal automatic stoker-fired, oil-gun-type burners, and gas-gun-type burners. The largest boiler facility is the coal-fired boiler in Bldg. 32, the central power plant. This facility provides 400 pounds per square inch-gauge (psig) steam to the NSY area of NAVBASE Charleston.

Most of the boilers are low-pressure boilers for heating and have not required boiler water treatment. The boilers which provide high-pressure steam require water treatment, using trisodium phosphate, caustic soda, and tannin or sodium sulphite. The boiler blowdown is discharged to the sanitary sewer system. In the past, the sanitary sewer system was accidentally contaminated by oil from broken oil lines within the boiler plant. Oil-water separators have been installed in problem areas to prevent oil contamination of the sanitary sewer system.

Natural gas is supplied to NAVBASE Charleston by South Carolina Electric and Gas Co. NRMC and NSY industrial areas are the primary users of natural gas on NAVBASE Charleston.

6.3.3 Acetylene Production

During the early 1940s, an acetylene production plant was built to provide welding gas for NSY. Acetylene was produced by reacting calcium carbide with water, as shown in the following equation:

$$[CaC_2 + 2H_2O \longrightarrow Ca(OH)_2 + C_2H_2]$$

Caustic calcium hydroxide is a byproduct of this reaction. The calcium hydroxide (hydrated lime) was discharged from the plant in the form of a slurry and held in a 2.5-acre disposal pond. This disposal operation continued until the early 1970s, when the plant was closed. The quantity of calcium hydroxide generated by this operation is unknown.

The acetylene used for welding at NAVBASE Charleston has been replaced by MAPP gas, an industrial welding gas.

6.4 MATERIAL HANDLING AND STORAGE

The handling and storage of hazardous materials at NAVBASE Charleston are conducted by NSC (POL and chemicals), Public Works NSY (chemicals, pesticides, paint wastes, and coal), and DPDO (chemicals and PCB items). The discussion of material handling and storage is segregated into material type as follows:

1. POL,

2. Chemicals,

3. Pesticides,

4. PCBs,

5. Paint waste,

6. Coal, and

7. Ordnance.

6.4.1 Petroleum, Oil, and Lubricants

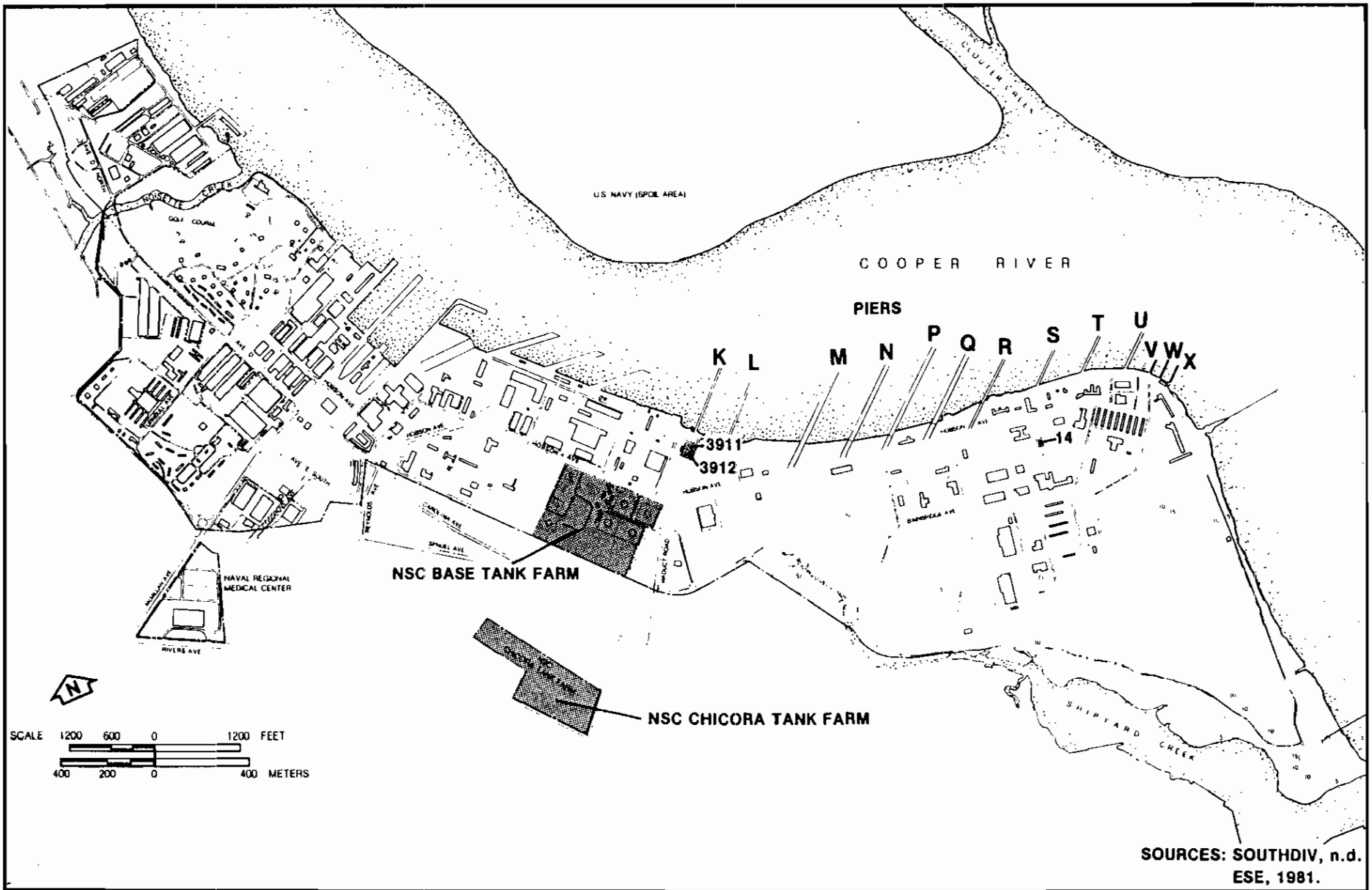
The major storage facilities for POL consist of two tank farms located at NSC. Other POL storage facilities are located elsewhere at NSC and throughout NSY and NAVSTA. Spill Prevention Control and Countermeasure (SPCC) plans have been prepared for the POL storage areas in NSC, NSY, and NAVSTA. In addition to the POL storage areas, there is a waste oil reclamation facility located at NSC.

6.4.1.1 POL Storage

The largest POL storage area exists at NSC, where bulk quantities of diesel oil, Navy Special Fuel Oil (NSFO), and waste oil are stored. The storage areas are concentrated in two tank farms, the Base Tank Farm and the Chicora Tank Farm. Other NSC POL storage areas which are separate from the two tank farms include tanks 3911, 3912, and 14. The locations of the tank farms and other POL storage tanks identified above are shown in figure 6.4-1. The layouts of storage tanks within the Base and Chicora Tank Farms are shown in figures 6.4-2 and 6.4-3, respectively. As shown in figure 6.4-1, the Chicora Tank Farm is located approximately 0.3 mile southwest of NAVBASE Charleston. Table 6.4-1 presents a description of each NSC POL storage tank. The information presented in this table is based on the report entitled "Oily Waste/Waste Oil Management Study" (February 1981) prepared by The Chester Engineers (1981). This report was being reviewed by the Environmental Engineering Division of Public Works NSY for final approval during the IAS.

Tanks 39A and 39D of the Base Tank Farm were constructed in the early 1900s, and the remaining tanks in the Base and Chicora Tank Farms were constructed between 1936 and 1944. The two tank farms are connected by three pipelines: one to convey diesel oil, one to convey NSFO, and one to convey waste oil.

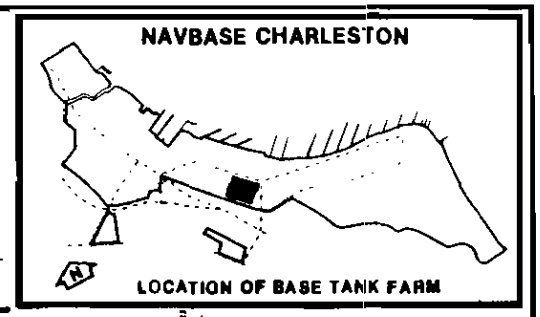
In addition to the POL storage tanks in the Base and Chicora Tank Farms, NSC is also responsible for the operation and maintenance of tanks 3911, 3912, and 14. As shown in table 6.4-1, tanks 3911 and 3912 are used to store lubricating oil, and tank 14 is used to store diesel oil. Tank 14 was used to store diesel oil but has not been used in 3 or 4 years and is currently empty.

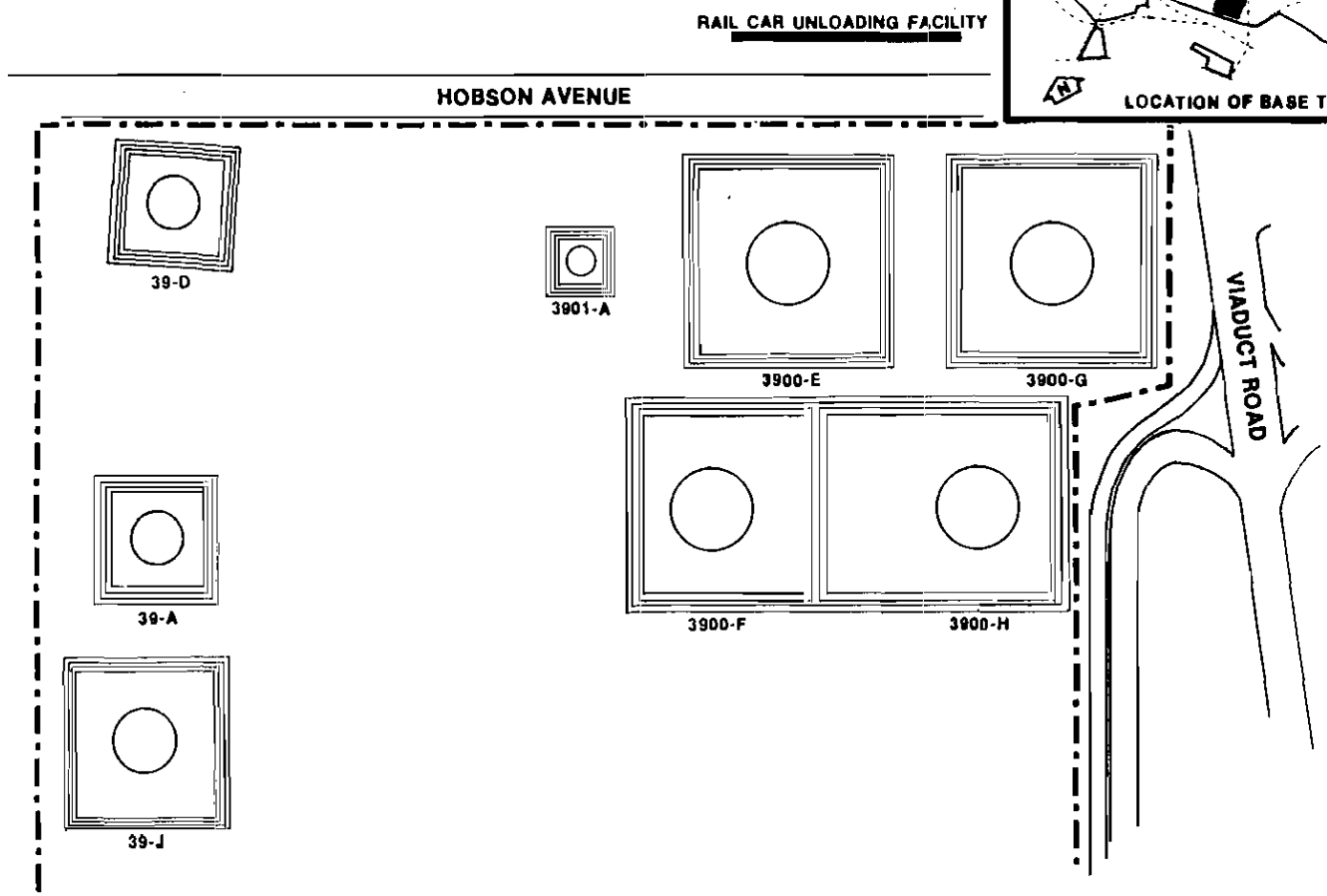


SOURCES: SOUTHDIV, n.d.
ESE, 1981.

Figure 6.4-1
LOCATIONS OF NSC POL STORAGE AREAS

INITIAL ASSESSMENT STUDY
NAVAL BASE CHARLESTON





KEY

TANK	CAPACITY (BARRELS)	FUEL TYPE
39A	17,500	WASTE OIL
39D	17,500	WASTE OIL
39J	17,500	EMPTY
3900E	55,000	DIESEL OIL
3900F	55,000	DIESEL OIL
3900G	55,000	EMPTY
3900H	55,000	EMPTY
3901A	2,500	WASTE OIL

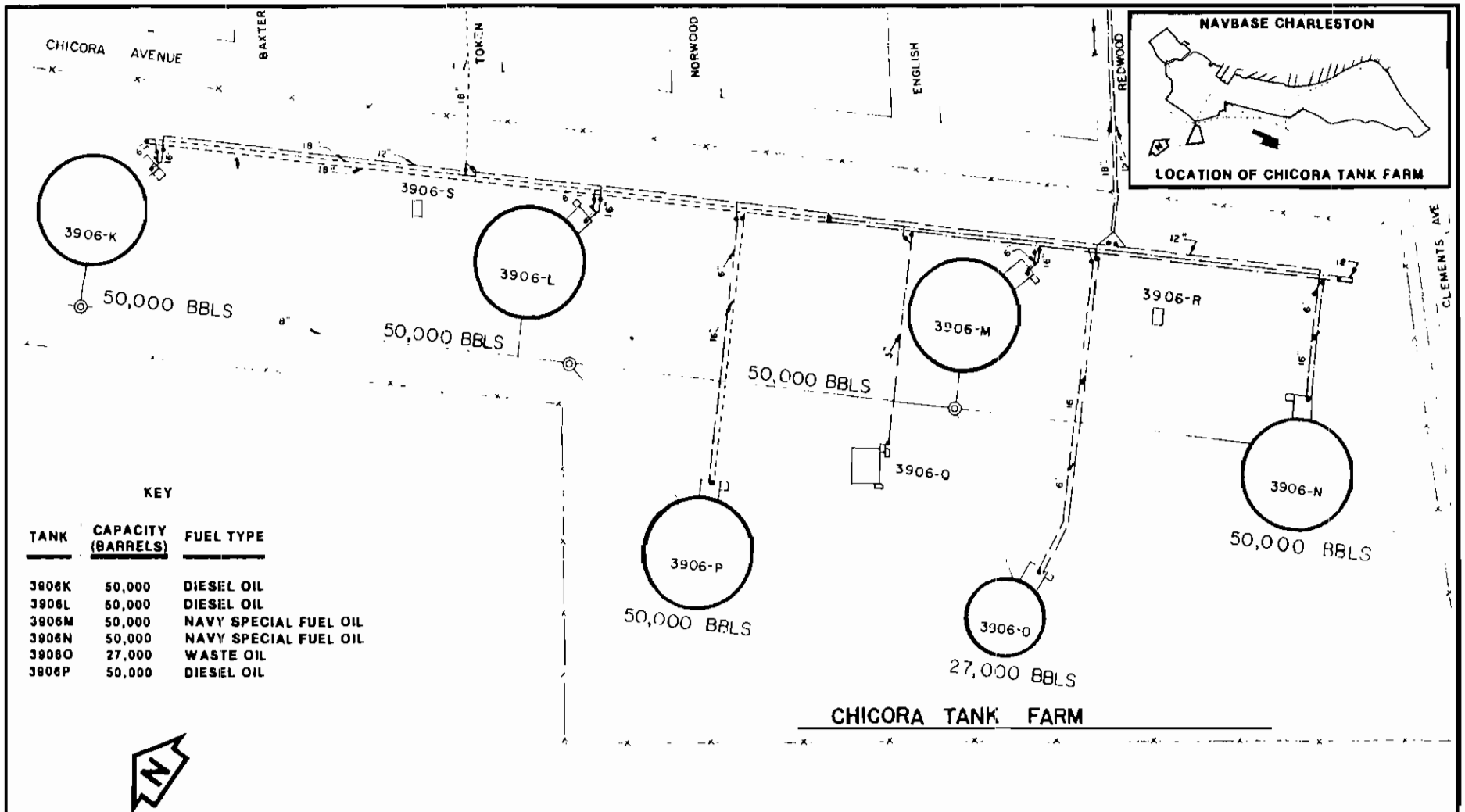
SCALE

100 50 0 100 FEET

SOURCES: SOUTHDIV, 1979.
ESE, 1981.

Figure 6.4-2
BASE TANK FARM LAYOUT

INITIAL ASSESSMENT STUDY
NAVAL BASE CHARLESTON



KEY

TANK	CAPACITY (BARRELS)	FUEL TYPE
3906K	50,000	DIESEL OIL
3906L	50,000	DIESEL OIL
3906M	50,000	NAVY SPECIAL FUEL OIL
3906N	50,000	NAVY SPECIAL FUEL OIL
3906O	27,000	WASTE OIL
3906P	50,000	DIESEL OIL

SCALE
100 50 0 100 FEET

SOURCES: SOUTHDIV, 1979.
ESE, 1981.

Figure 6.4-3
CHICORA TANK FARM LAYOUT

INITIAL ASSESSMENT STUDY
NAVAL BASE CHARLESTON

Table 6.4-1
Description of Bulk Storage Tanks in the
Base and Chicora Tank Farms

Tank Identification	Capacity (Barrels)	Fuel Type*	Construction†
39A	17,500	WO	AG-S
39D	17,500	WO	AG-S
39J	17,500	Empty	AG-S
3900E	55,000	D	AG-S
3900F	55,000	D	AG-S
3900G	55,000	Empty	AG-C
3900H	55,000	Empty	AG-C
3901A	2,500	WO	AG-S
3906K	50,000	D	UG-C
3906L	50,000	D	UG-C
3906M	50,000	NSFO	UG-C
3906N	50,000	NSFO	UG-C
3906O	27,000	WO	UG-C
3906P	50,000	D	UG-C
3911	1,190	L	AG-S
3912	1,190	L	AG-S
14	5,238	Empty	AG-S

* D = Diesel Oil.
L = Lubricant Oil.
WO = Waste Oil.
† AG = Aboveground.
UG = Underground.
S = Steel.
C = Concrete.

Source: The Chester Engineers, 1981.

The POL storage facilities in NSY and NAVSTA are considerably smaller than those at NSC and generally consist of numerous small to mid-size tanks used to store diesel oil and gasoline. These tanks are located throughout NSY and NAVSTA and are not consolidated in any specific area.

6.4.1.2 POL Distribution

Fuel and waste oil are transferred to the Base and Chicora Tank Farms via underground pipelines leading from pier K. The loading rack adjacent to tanks 3911 and 3912 receives lubricating oil by rail tank car and issues the oil to trucks for distribution. Diesel oil was pumped from tank 14, which is currently empty, to piers S, T, and U, but this practice was discontinued for a number of reasons, including more efficient distribution of diesel oil between the tank farms and pier K. Pier K is the only major fueling pier at NAVBASE Charleston, and it is the only pier where major quantities of waste oil are unloaded from waste oil barges. In the past, pier M was also used for the transfer of fuel and waste oil. All fuel and waste oil lines leading to pier M have been abandoned. Waste oil may consist of either oil, which has become contaminated but is still predominantly oil, or oily wastewater such as that pumped from bilges. Some waste oil generated by industrial operations becomes contaminated with waste solvents, especially in cases where oil-water separators receive spillage from degreasing operations which use solvents. However, the volume of solvent compared to the total volume of waste oil is minimal.

The waste oil unloaded from barges at pier K is pumped to the Base Tank Farm for waste oil reclamation. This facility not only receives waste oil from pier K, but also from the unloading station at the tank farm, which unloads waste oil from tank cars and small mobile containers.

Current practices for the transfer of POL and waste oils to the NSC tank farms and waste oil reclamation facility from ships and industrial operations at NAVBASE Charleston are described below.

6.4.1.2.1 Fuel Oils Removed from Ships

Samples of fuel oils that require removal from ships in the shipyard or at NAVSTA are analyzed by the NSC's petroleum inspector for determination of acceptability. If the oil is acceptable as fuel, it is unloaded into a fuel oil barge or railroad tank cars. Fuel oil from ships at NAVSTA is removed by barge, whether it be returned for credit by defueling barge or for waste oil by waste oil barge. Fuel oil removed from ships in the shipyard may be removed by railroad tank cars or by barge, depending on the quantity removed. Quantities of fuel oil in excess of 15,000 gallons are removed at any berth in the shipyard by pumping into one of two oil barges which transport the fuel oil to pier K, where it is ultimately unloaded and pumped to the NSC tank farms. Quantities of fuel oil less than 15,000 gallons are unloaded by pumping into railroad tank cars which transport the oil to the tank car

loading/unloading area adjacent to the NSC Base Tank Farm. If the oil is found to be unacceptable as fuel, it is transported to the NSC waste oil reclamation facility by waste oil barge or by railroad tank cars, as described previously for oil returned for credit.

6.4.1.2.2 Lubricating Oils Removed from Ships

Lubricating oils removed from ships are generally stored at NSY for reuse. The off-loaded lubricating oil is either stored in railroad tank cars or metal holding tanks. Samples of the lubricating oil are removed from the tank car or the metal holding tank for analysis by the Laboratory Division, QA Office, of NSY to determine its acceptability for reuse. If the oil is acceptable for reuse, it is pumped back onto the ship. If the oil is below minimum specifications, it is transported by railroad tank car or in the metal holding tank container to the NSC waste oil reclamation facility.

6.4.1.2.3 Tank Strippings Removal from Ships

The oily waste generated from the cleaning of oil storage tanks on ships is vacuumed into a waste oil barge or railroad tank car for transport to the NSC waste oil reclamation facility.

6.4.1.2.4 Oily Wastewater Removal from Shipyard Ships' Bilges

Ships' bilge water, generated during ship maintenance and overhaul, is collected in 1 or more of 22 vacuum cans located on the piers and drydock areas in NSY. Current vacuum can operations include the manual discharge of the water fraction of the oily wastewater to the sanitary sewer by opening a valve at the bottom of the vacuum can until the first sign of oil appears. At this time, the valve is closed and the vacuum can is ready for use. When no additional water can be bled from the can, it is transported to the NSC waste oil reclamation facility. Once the can is emptied, it is returned to NSY for reuse.

6.4.1.2.5 Oily Wastewater Removal from Naval Station Ships' Bilges

Bilge water removed from ships in NAVSTA is discharged into one or more of five donuts (floating oil-water separators). The oil phase is retained in the donut and water is discharged to the Cooper River. When the donuts become full of waste oil, the waste oil is then transferred to a waste oil barge, which ultimately transports it to pier K where the waste oil is unloaded and transferred to the NSC waste oil reclamation facility.

6.4.1.2.6 Waste Oil Generated by NAVBASE Charleston Industrial Operations

Any waste oil that is generated by industrial operations at NAVBASE Charleston is transported in drums or metal holding tank to the NSC waste oil reclamation facility. Waste oil which accumulates in oil-water separators located throughout NAVBASE Charleston is pumped

out into a 500-gallon tank truck and transported to the NSC waste oil reclamation facility.

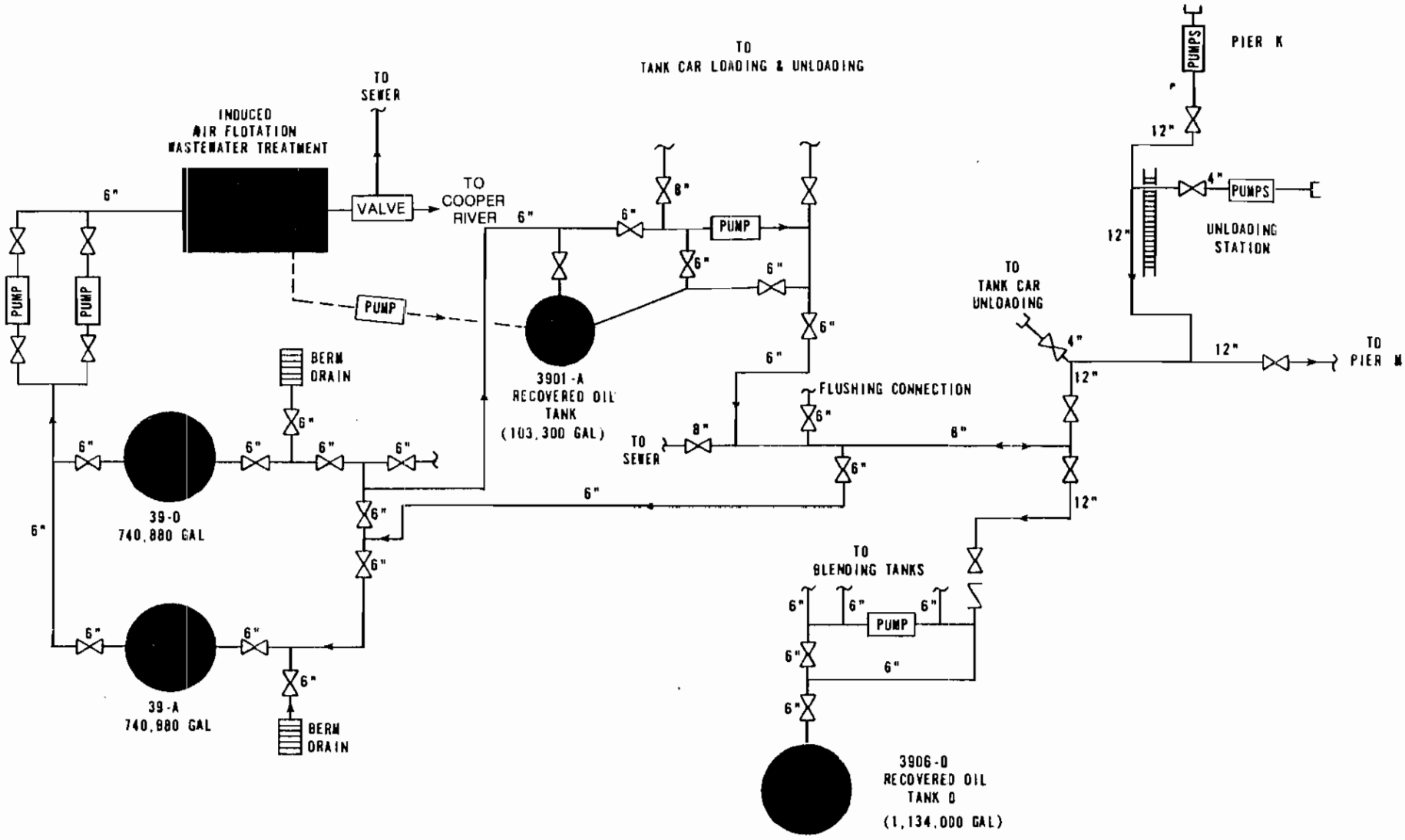
6.4.1.2.7 Oil Spills

Upon discovery of a spill entering a sewer or flowing directly to the Cooper River, NAVSTA is alerted to dispatch oil sorbent/skimming equipment to the spill location. Oil recovered from any spill cleanup is transferred to pier K, where it is unloaded and pumped to the NSC waste oil reclamation facility.

6.4.1.3 Waste Oil Reclamation Facility

The NSC waste oil reclamation facility has been in operation since 1950. Figure 6.4-4 presents a schematic diagram of this facility. All waste oil unloaded either at pier K, the railroad tank car unloading facility, or at the tank truck unloading facility is pumped to the NSC waste oil reclamation facility. The waste oil first enters one of two 740,880-gallon storage tanks (tank 39A or 39D), where gravity oil-water separation occurs. Following gravity oil-water separation, the water phase is drawn off and pumped to the induced air flotation (IAF) unit for additional oil removal. A synthetic polymer coagulant may be manually added to the IAF unit influent to promote removal of emulsified oils. Although the discharge of the IAF unit effluent to the Cooper River is covered under the NAVBASE Charleston National Pollutant Discharge Elimination System (NPDES) permit, the effluent is currently discharged to the sanitary sewer. This disposal method is practiced because the NPDES maximum daily oil and grease limitation of 15 mg/l cannot be met; however, the oil and grease limitation of 100 mg/l for discharge to the North Charleston Sewer District can be met.

Oil which is separated by gravity separation in the two surge tanks is pumped to tank 3906-0 in the Chicora Tank Farm for storage. Oil removed in the IAF unit is pumped to a 103,300-gallon storage tank (tank 3901-A). Subnatant water from tank 3901-A is pumped back to one of the surge tanks for further processing. Supernatant oil from tank 3901-A is pumped to tank 3906-0 in the Chicora Tank Farm. The mixture of oil stored in tank 3906-0 is allowed to separate by gravity settling. Sampling and analysis of the resulting oil layers are conducted to determine the oil fraction acceptable for blending with NSFO. The total volume of waste oil treated by the NSC waste oil reclamation facility between June 1979 and May 1980 was 4.9 million gallons, and the total volume of oil reclaimed during this period was 1.2 million gallons (The Chester Engineers, 1981). It was reported that approximately 27,000 cubic feet of oily sludge, unacceptable for reuse, is currently stored in tank 3906-0. Methods for disposing of this oily sludge are currently being investigated by NSC. This sludge has been accumulating since 1971. Prior to 1971, oily sludge was stored in three unlined, excavated pits (site 3). These sludge pits are described in more detail in section 6.6.2.2. No additional oily sludge accumulations in POL storage tanks were reported.



SOURCE: The Chester Engineers, 1981.

Figure 6.4-4
SCHEMATIC DIAGRAM OF THE NSC WASTE OIL RECLAMATION FACILITY

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6.4.1.4 POL Spills

It was reported that the only major oil spill occurring in the last 16 years at NSC POL storage facilities occurred in 1971, when oil overflowed the sludge pits during a period of heavy rainfall. This spill is described in more detail in section 6.6.2.2. No other major spills have occurred at NSC, and the tank inspection procedures described in the NSC SPCC plan are reportedly performed on a routine basis. All underground tanks and pipelines are pressure checked annually for leaks (Personal Communication, 1981). All NSC POL aboveground storage tanks with capacities equal to or greater than 660 gallons are bermed with earthen or concrete berms.

One potential problem area associated with NAVBASE Charleston POL storage facilities, other than the past waste oil sludge pits, is the railcar tank unloading area located on NSY-controlled property (POL transfer point, site 4), adjacent to the Base Tank Farm (figure 6.4-5). When holes for fence posts were being dug in this area earlier this year, seepage of oil into the holes occurred approximately 2 feet below the ground surface. Potential causes for this oil contamination include the frequent oil spillage in the railcar tank unloading area and past leakage from currently abandoned underground pipelines (Personal Communication, 1981).

Numerous small oil spills have been observed along the Cooper River shoreline at NAVBASE Charleston. These spills probably resulted from small quantities of POL entering the storm sewer system or from small quantities of POL being discharged directly into the river from dockside or from naval vessels.

An additional area which is potentially contaminated with waste oil is the former firefighting training pit (site 5), located near the southern end of NAVBASE Charleston (figure 6.4-5). The pit was in use from 1965 to 1971. Section 6.6.2.4 contains a more detailed description of the firefighting training pit.

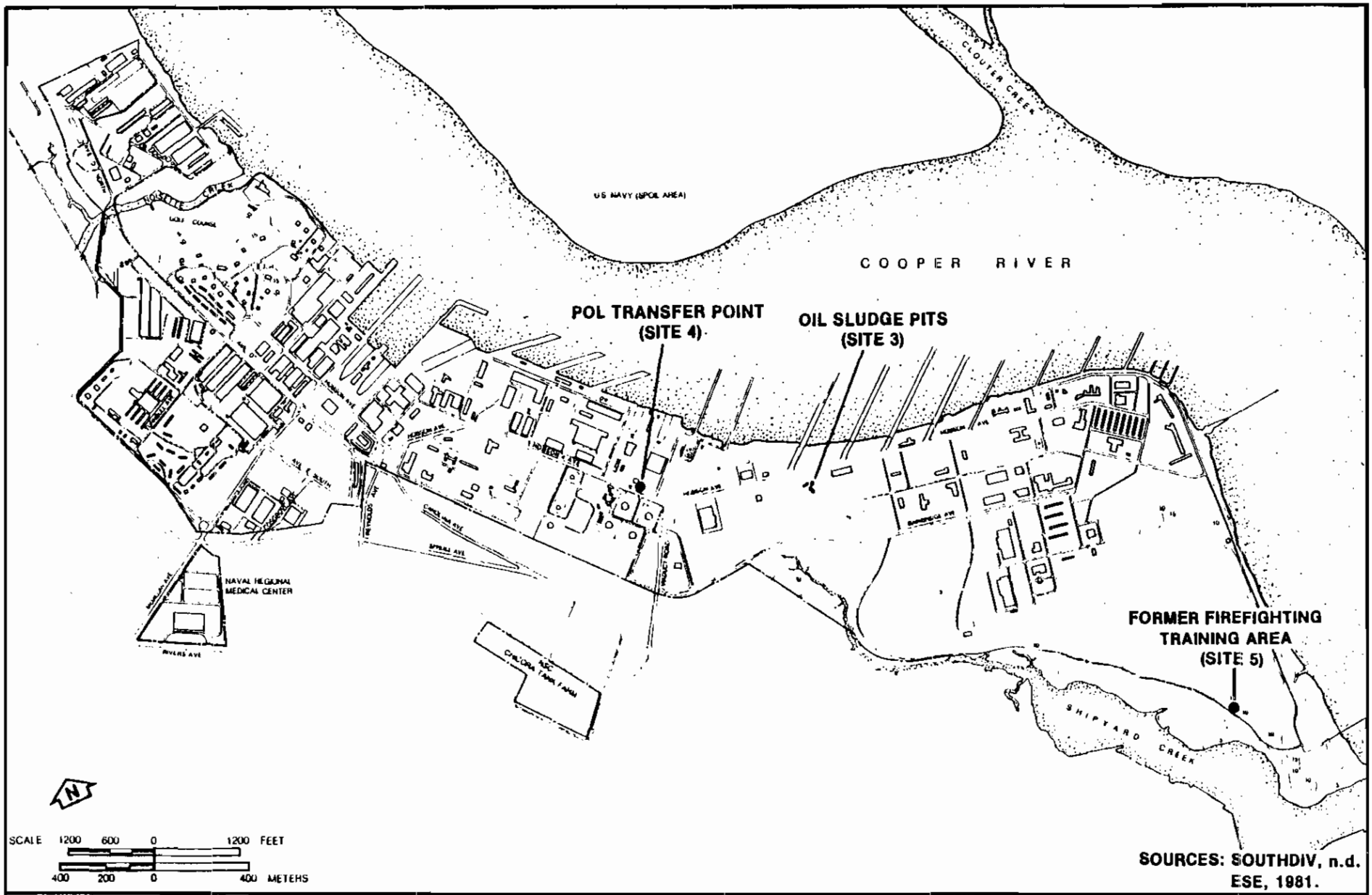
6.4.2 Chemicals

Hazardous chemical items at NAVBASE Charleston are stored, handled, and disposed of by NSC, DPDO, and Public Works NSY.

6.4.2.1 Naval Supply Center

NSC stores, handles, and ultimately transfers for disposal many items used by NAVBASE Charleston and used aboard surface and subsurface naval vessels. The following discussion of NSC concerns only chemical items handled by NSC. A computerized listing of hazardous materials stored by NSC was recently compiled by NSC and is contained in a report by Williams-Russell and Assoc., Inc. (1980).

Excess chemicals (out-of-shelf date) generated by NSC are turned over to DPDO for disposal. DPDO recycles these within the



SOURCES: SOUTHDIV, n.d.
ESE, 1981.

Figure 6.4-5
POL-CONTAMINATED AREAS

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Department of Defense (DOD) or other Federal agencies, or they are taken by State agencies for use in school and university laboratories. These items also may be sold to chemical contractors for recovery. DPDO will not accept physical custody of certain "hazardous" materials for which NSC requests disposal. DPDO, however, accepts paper accountability and proceeds with processing the recycling or sale of these items as above, with NSC storing the item until transfer elsewhere.

Excess Nuclear Reactor Propulsion (NRP) program water chemicals generated by NSC will not be accepted (physically or paper accountability) by DPDO. These items have been stored by NSC in Bldgs. 1604 and 1605 for approximately the last 10 years. In the past year, these items (28,134 pounds, including over 13,300 pounds of hazardous chemicals) were demilitarized (i.e., labels were removed) by Public Works NSY and disposed of by a hazardous waste contractor (Groce Labs, Greer, S.C.). Prior to about 1971, no records exist on the disposal of these items. NSY began servicing nuclear vessels in 1962, at which time excess NRP water chemicals began accumulating. Considering solid waste disposal procedures practiced at NAVBASE Charleston (see section 6.6.2) prior to 1971, these items are believed to have been disposed of in the base sanitary landfill (site 1), which ceased operations in 1973.

Currently, excess NRP water chemicals are turned over to Public Works NSY for demilitarization and disposal by the hazardous waste contractor (Groce Labs, Greer, S.C.).

6.4.2.2 Defense Property Disposal Office

The DPDO located at NAVBASE Charleston receives excess property from NAVBASE Charleston, as well as from other DOD installations in the area. This property is then recycled within DOD, other Federal or State agencies, or contract sold to the highest bidder. The following discussion of DPDO concerns only the handling and disposal of excess chemicals.

PCBs contained in electrical equipment handled by DPDO are discussed in section 6.4.4.

Chemical items within DOD are categorized into three classes by DPDO: (1) those for which DPDO will take both paper accountability and physical custody, (2) those for which DPDO will take paper accountability but not physical custody, and (3) those for which DPDO will accept neither paper accountability nor physical custody.

Most items fall into the first category. These chemicals are then recycled within DOD or other Federal agencies or taken by State agencies for use in school or university laboratories. These items could also be sold to chemical contractors for recovery.

Chemicals in the second category are designated by DPDO as "hazardous" and will not be physically accepted by DPDO. DPDO does, however, accept paper accountability for these items and proceeds with

processing, as described for category 1 chemicals above. These items are retained by the generator (e.g., NSC or Public Works NSY) until the paper work is completed by DPDO and the items are transported off NAVBASE Charleston.

Items in the third category include NRP water chemicals, classified chemicals, and radioactive substances. Disposal of NRP water chemicals is discussed in section 6.4.2.1. Handling, storage, and disposal of radioactive materials are addressed in section 6.4.8.

6.4.2.3 Public Works Naval Shipyard

Public Works NSY receives waste chemicals for storage and disposal from various generators at NAVBASE Charleston. As discussed above, NSC turns over excess NRP water chemicals to Public Works NSY for storage, demilitarization, and disposal by the Public Works NSY hazardous waste contractor (Groce Labs, Greer, S.C.). PCB-containing electrical items taken from service by Public Works NSY are stored by Public Works NSY in Bldgs. 3902 and 1069. Paper accountability for these items is with DPDO. PCBs are discussed in detail in section 6.4.4. Pesticide chemical storage and handling are also under the supervision of Public Works NSY, as discussed in section 6.4.3. Public Works NSY recently compiled a list of hazardous wastes on NAVBASE Charleston. Disposal of chemicals is by the hazardous waste contractor (Groce Labs, Greer, S.C.). PCB disposal will be by DLA, which is currently soliciting bids for disposal.

6.4.3 Pesticides

Pesticides (insecticides, herbicides, fungicides, and rodenticides) have been and are currently being used throughout NAVBASE Charleston to maintain grounds and structures and to prevent pest-related health problems. Pest control services offered at NAVBASE Charleston include the following: (1) household, structural, health-related, and nuisance insect and rodent control programs; (2) weed control programs at security fences, parking areas, railroad tracks, and utility sites; and (3) programs involving turf areas (e.g., golf course) and ornamental trees and shrubs. The storage, mixing, and application of pesticides at NAVBASE Charleston are under the jurisdiction of shop 07 (maintenance) of the Public Works NSY.

All pesticide chemicals and application rates are recorded monthly on DOD form 1532. Records exist from 1966 to the present regarding pesticide usage. These are on file in the entomologist's office at SOUTHDIV. Examination of these forms over the period of record did not indicate excessive usage of pesticides at NAVBASE Charleston.

6.4.3.1 Storage

Insecticides and rodenticides are currently (since 1980) stored in the Pest Control Shop, Bldg. 381. This is a modern, steel building

with a concrete floor. The building is equipped with a bermed storage area for these chemicals. Table 6.4-2 lists the insecticides and rodenticides currently stored in Bldg. 381. Herbicides are stored separately in Bldg. 1316, adjacent to Bldg. 381, which also has a concrete floor. The inventory of herbicides stored in Bldg. 1316 is also given in table 6.4-2. Prior to construction of Bldg. 381 in 1980, all pesticides were stored in Bldg. 42A, a wooden frame building with an unbermed concrete floor.

6.4.3.2 Mixing, Rinsing, and Disposal

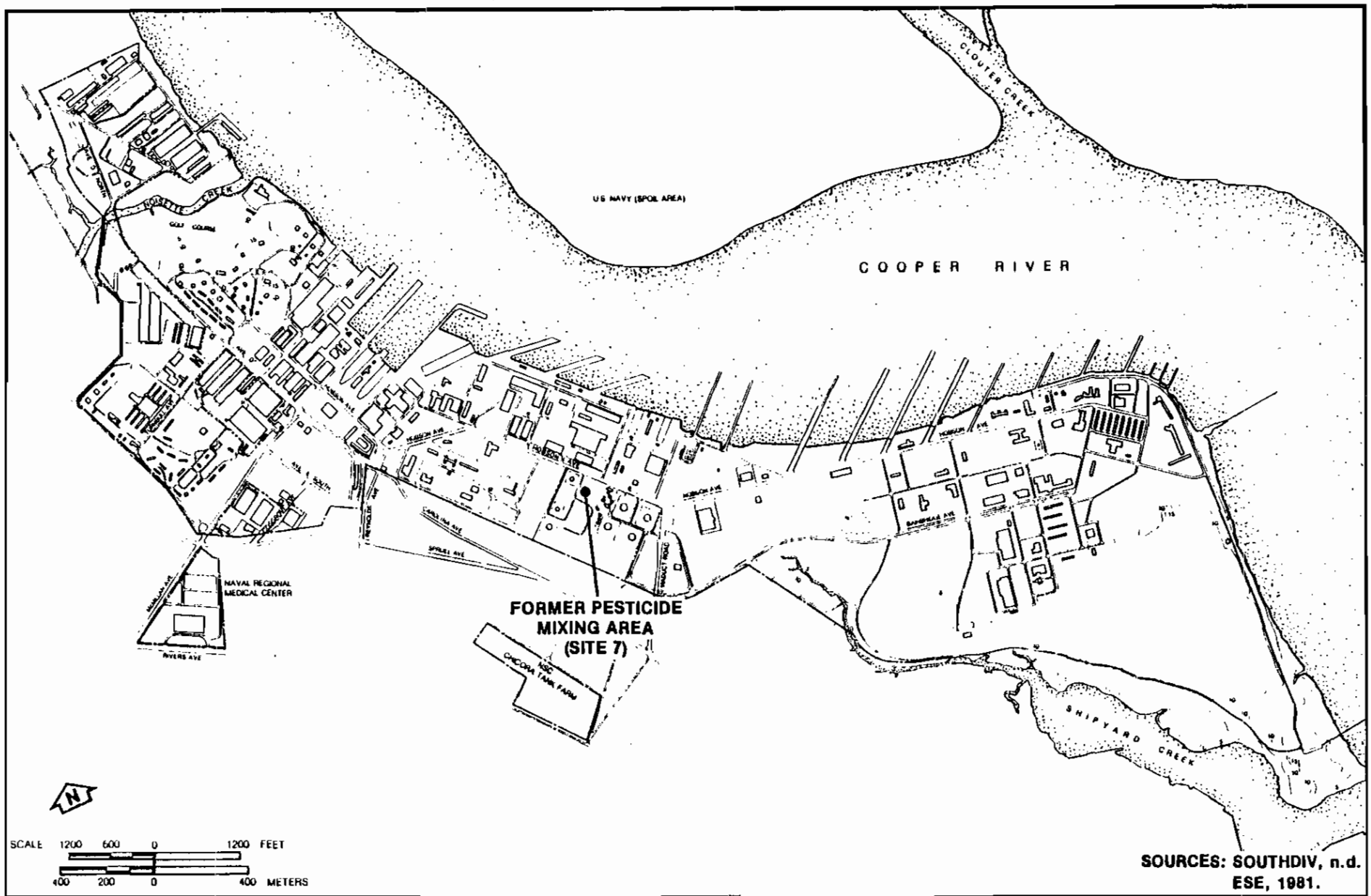
Bldg. 381 is equipped with a modern formulation and mixing room. Sink and floor drains are connected to the sanitary sewer system. An equipment rinse area is provided at a wash rack adjacent to Bldg. 381. The wash rack is also connected to the sanitary sewer system. Prior to 1980, Bldgs. 42 and 42A were the Pest Control Shop. An area north of Bldg. 42 was used as a pesticide mixing and equipment rinse area until about 10 years ago. An area (approximately 20 square yards) at the site where mixing occurred and equipment was formerly rinsed (site 7) is devoid of vegetation (see figure 6.4-6). Approximately 10 years ago, operations were moved to the northeast corner of Bldg. 42A, upon completion of a project extending the waterline to this point outside the building. These operations ceased in 1980, when the Pest Control Shop was moved to Bldg. 381. Triple rinsing was required before pesticide container disposal and was done mainly inside Bldg. 42A throughout this time. The drain with this rinse water discharged directly to the ground next to Bldg. 42A. In the early 1970s, this drain was connected to the sanitary sewer.

Since the construction of the new Pest Control Shop, liquid wastes from rinsing, mixing, etc., have gone into the sanitary sewer system. Empty pesticide containers reportedly have always been rinsed, punched with holes, and disposed of as ordinary solid waste.

6.4.3.3 Soil Sampling

Sampling of the soils in the vicinity of Bldg. 42A was conducted by SOUTHDIV in 1977. The results of this sampling are given in table 6.4-3. As shown, two composite soil samples were taken and analyzed. One composite sample was taken at the former mixing discharge area in the immediate vicinity of Bldg. 42A, and the second composite sample was taken from a drainage ditch leading away from Bldg. 42A. The composite sample taken at the discharge area within 20 feet of Bldg. 42A showed detectable levels of the herbicide 2,4-D, as well as arsenic. The composite sample taken from the larger drainage ditch area (20 acres) around the old Pest Control Shop showed no detectable levels of pesticides. The area north of Bldg. 42 (site 7), which was used for equipment rinsing and which is now devoid of vegetation, was not included in the soil sampling.

Until the 1950s, herbicides containing arsenic (sodium arsenite) were in common use as weed killers along railroad tracks in



SOURCES: SOUTHDIV, n.d.
ESE, 1981.

Figure 6.4-6
FORMER PESTICIDE MIXING AREA (SITE 7)

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Table 6.4-3
Results of Pesticide Sampling and Analysis in the Area of the Old Pest Control Shop (Bldgs. 42 and 42A)

Parameter	Charleston Naval Shipyard 31 Aug 1977, Station PS02 Composite Soil Sample Taken Within 20 Feet of Bldg. 42A (in mg/kg)	Charleston Naval Shipyard 31 Aug 1977, Station ST01 Composite Soil Sample Taken in Area of 20 Acres Adjacent to Bldgs. 42 and 42A (in mg/kg)
Chlorinated Hydrocarbons		
Aldrin	<0.002	<0.002
BHC	<0.002	<0.002
Lindane	<0.002	<0.002
Chlordane	<0.005	<0.005
DDT	<0.002	<0.002
DDE	<0.002	<0.002
Endrin	<0.002	<0.002
Heptachlor	<0.002	<0.002
Heptachlor Epoxide	<0.002	<0.002
Methoxychlor	<0.01	<0.01
Toxaphene	<0.01	<0.01
PCB	<0.1	<0.1
Organic Phosphates		
Diazinon	<0.01	<0.01
Malathion	<0.01	<0.01
Parathion	<0.01	<0.01
Thimet (Phorate)	<0.01	<0.01
Trithion	<0.01	<0.01
Chlorinated Phenoxy Herbicides		
2,4-D	0.19	<0.01
2,4,5-T	<0.01	<0.01
2,4,5-TP (Silvex)	<0.01	<0.01
Total Arsenic	33	<0.1

mg/kg = milligrams per kilogram.

Source: Personal Communication, 1981.

the United States. Use of sodium arsenite at NAVBASE Charleston began in 1926 and reportedly ended in the mid-1950s. Arsenic trioxide was reportedly applied at a rate of approximately 20 pounds per mile of track per year. It is expected that the soils near the older railroad rights-of-way would have elevated arsenic levels. Arsenic trioxide is not biodegradable.

6.4.4 Polychlorinated Biphenyls

Control of PCBs began in 1976, when Congress enacted the Toxic Substances Control Act (TOSCA). Section 6(e) of this law required EPA to establish rules to govern the manufacture, use, and disposal of PCBs.

Electrical equipment (transformers, rectifiers, capacitors) containing PCB (greater than 500 ppm) and PCB-contaminated (50 to 500 ppm) fluids have been used and are currently in use at NAVBASE Charleston.

6.4.4.1 In-Service Items

An inventory of in-service electrical items containing PCB fluids was recently (19 Jul 1981) completed by Public Works NSY. A total of 132 items was identified as containing PCBs. Total volume of PCB fluid was estimated at 32,415 gallons. It was reported that all in-service electrical items containing PCBs have been labelled according to EPA regulations (EPA, 1980c).

6.4.4.2 Out-of-Service Items

At the time of the site visit, 57 out-of-service electrical items containing PCB and PCB-contaminated fluids were being stored at NAVBASE Charleston. Table 6.4-4 lists these out-of-service items, their storage location, and PCB concentration. DPDO maintains paper accountability of all PCB electrical items but does not receive physical custody of these items because of the lack of a proper storage facility as required by EPA (1980c). Therefore, all out-of-service PCB items are currently stored by Public Works NSY. Rectifiers containing PCBs are stored in Bldg. 1069, while transformers and capacitors containing PCBs are stored in Bldg. 3902 in the "Old Corral" area. Both storage areas have concrete floors and are bermed.

Out-of-service electrical items containing PCBs have been stored awaiting disposal since about 1976. Currently, DLA is soliciting bids for disposal of these items at NAVBASE Charleston, as well as at other DOD installations.

Prior to 1976, unserviceable electrical items at NAVBASE Charleston were sold by DPDO as excess property to the highest bidder. The buyer of the item was required to transport the item off NAVBASE Charleston. If the buyer had use for the fluid, it usually remained in the electrical equipment and was transported off NAVBASE Charleston. If not (e.g., if the buyer wanted the copper coil in the equipment), the

Table 6.4-4
Inventory of Out-of-Service PCB Items on NAVBASE Charleston

Item	Serial Number	Location	Fluid Type	Fluid Amount (gal)	PCB Concentration (ppm)
1. Rectifier	3880-1	Bldg. 1069	Inerteen	70	>500
2. Rectifier	—	Bldg. 1069	Askerol	70	>500
3. Rectifier	D5154-AB	Bldg. 1069	Askerol	70	>500
4. Rectifier	05154-34A8	Bldg. 1069	Askerol	70	>500
5. Rectifier	—	Bldg. 1069	Askerol	70	>500
6. Rectifier	—	Bldg. 1069	Askerol	70	>500
7. Rectifier	—	Bldg. 1069	Askerol	70	>500
8. Rectifier	05154	Bldg. 1069	Askerol	70	>500
9. Rectifier	05154-27AB	Bldg. 1069	Askerol	70	>500
10. Rectifier	—	Bldg. 1069	Askerol	70	>500
11. Rectifier	3880-9	Bldg. 1069	Inerteen	70	>500
12. Rectifier	—	Bldg. 1069	Askerol	70	>500
13. Rectifier	—	Bldg. 1069	Inerteen	70	>500
14. Transformer	1003R*	Bldg. 1603	80 percent water and 20 percent ethylene glycol	—	>500
15. Transformer	—	Bldg. 3902	Oil	—	>500
16. Transformer	E959201-63P	Bldg. 3902	Oil	15	>500
17. Capacitor	L414021	Bldg. 3902	Oil	10	>500
18. Transformer	—	Bldg. 3902	Oil	—	>500
19. Transformer	6719458	Bldg. 3902	Oil	—	>500
20. Capacitor	L398350	Bldg. 3902	Oil	10	>500
21. Capacitor	L398350	Bldg. 3902	Oil	10	>500
22. Transformer	E687857	Bldg. 3902	Oil	92	>500
23. Transformer	RHA0040	Bldg. 3902	Oil	255	>500
24. Transformer	F12424763P	Bldg. 3902	Oil	310	>500
25. Transformer	31839	Bldg. 3902	Oil	147	>500
26. Transformer	E937127-63P	Bldg. 3902	Oil	—	75
27. Transformer	3100854	Bldg. 3902	Oil	—	301
28. Transformer	933926	Bldg. 3902	Oil	22	111
29. Transformer	384295	Bldg. 3902	Oil	—	112

Table 6.4-4
Inventory of Out-of-Service PCB Items on NAVBASE Charleston
(Continued, Page 2 of 2)

Item	Serial Number	Location	Fluid Type	Fluid Amount (gal)	PCB Concentration (ppm)
30. Transformer	310085	Bldg. 3902	Oil	—	>500
31. Transformer	933927	Bldg. 3902	Oil	32	217
32. Transformer	1747347	Bldg. 3902	Oil	110	414
33. Transformer	3100859	Bldg. 3902	Oil	—	157
34. Transformer	20216	Bldg. 3902	Oil	76	111
35. Transformer	20217	Bldg. 3902	Oil	76	77
36. Transformer	6972180	Bldg. 3902	Oil	18.5	59
37. Transformer	6652519	Bldg. 3902	Oil	—	77
38. Transformer	997619	Bldg. 3902	Oil	56	60
39. Transformer	297893	Bldg. 3902	Oil	—	206
40. Transformer	—	Bldg. 3902	Oil	—	112
41. Transformer	F630565-67P	Bldg. 3902	Oil	—	465
42. Transformer	D572603	Bldg. 3902	Oil	307	>500
43. Transformer	B980241	Bldg. 3902	Oil	375	>500
44. Transformer	437892B	Bldg. 3902	Oil	2	>500
45. Transformer	55J16864	Public Works NAVSTA	Oil	—	87
46. Transformer	RBJ8184	Public Works NAVSTA	Oil	229	>500
47. Transformer	75M115022	Public Works NAVSTA	Oil	—	94
48. Transformer	G856254	Public Works NAVSTA	Oil	110	>500
49. Transformer	69B7739	Public Works NAVSTA	Oil	—	111
50. Transformer	34428	Public Works NAVSTA	Oil	17	180
51. Transformer	34430	Public Works NAVSTA	Oil	17	493
52. Transformer	D322282-59P	Public Works NAVSTA	Oil	—	105
53. Transformer	D381102-59P	Public Works NAVSTA	Oil	—	88
54. Transformer	D362079-59P	Public Works NAVSTA	Oil	--	77
55. Containers	Stock No. 915000 PCB Liquid	Bldg. 3902	Oil	25	>500
56. Containers	Stock No. 915001 PCB Liquid	Bldg. 3902	Oil	3	>500
57. Transformer	6961517	Bldg. 3902	Oil	33	446

* Disposal action currently in process.

-- = Not available.

Source: Personal Communication, 1981.

fluid was drained to reduce the weight of the item. The area around the concrete pad (Bldg. 3902) in the "Old Corral" area (site 6) showed evidence of past oil spills reportedly from the draining of the fluids from electrical equipment (see figure 6.4-7). Due to the intermittent drainage of fluids as discussed above and the unknown concentrations of PCBs, it is not possible to estimate the total amount of PCBs potentially released to the soils in this area. Concurrent with the IAS site visit, Public Works NSY sampled soils from four visibly stained areas adjacent to the concrete pad and subsequently analyzed the soils for PCBs. The analysis (table 6.4-5) did not detect PCBs in these soils at levels that would define them as PCB-contaminated. All levels were below 50 ppm.

6.4.5 Waste Paint and Solvent Storage

About 226 tons of paint wastes and solvents is currently generated on an annual basis (Williams-Russell and Assoc., Inc., 1980). These wastes were stored on an uncovered concrete pad measuring 20 feet wide by 180 feet long, located near Bldg. 223, and adjacent to the Cooper River (see figure 6.4-8). This pad has been in use since 1973.

The paint waste storage area is operated by Public Works NSY. It was reported that the construction of a new storage facility is currently being evaluated by the Environmental Engineering Division of Public Works NSY and SOUTHDIV.

6.4.6 Coal Storage

Since the mid-1940s, the coal for the steam generation plant (Bldg. 32) has been stored on NSC property in the northwest corner of the base (see figure 6.4-9). Although the coal pile is located on NSC-controlled real estate, the coal is the property of NSY. The coal pile, adjacent to the rail supply tracks, is approximately 80 feet wide by 400 feet long.

There are no water quality or sediment data available for Noisette Creek, and no water quality data are available for the Cooper River near the mouth of Noisette Creek. The heavy metals content of sediments in the Cooper River near the mouth of Noisette Creek is not significantly different from those of other locations on the Cooper River (see section 6.7.1).

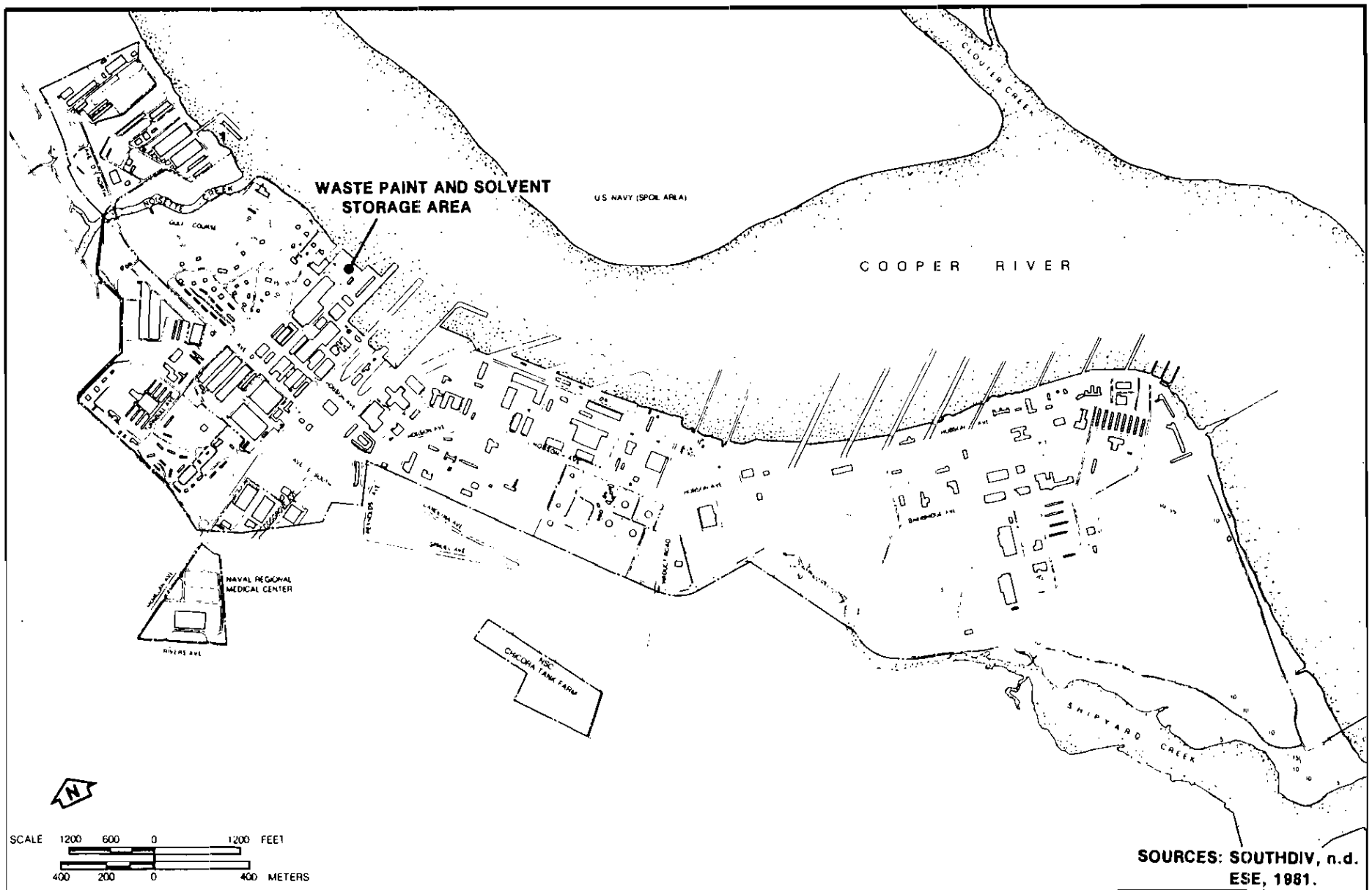
6.4.7 Firing Ranges and Ordnance

Two firing ranges are located in the south-central area of NAVBASE Charleston (figure 6.4-10). The skeet range, located east of Bldg. 675 (Dental Clinic), consists of the skeet range office (Bldg. 1887) and extensive grasslands. All gauge shotguns are fired, and the field of fire extends southward over grasslands and old spoil areas. The outdoor pistol range is located due east of the skeet range,

Table 6.4-5
Results of the Public Works NSY PCB Analysis

Parameter	Sample 1 Taken Within 10 Feet of Bldg. 3902 and 1 Foot from the Slab (4 Inches Deep)	Sample 2 Taken 12 Feet from Sample 1, 5 Feet from the Slab (2 to 4 Inches Deep)	Sample 3 Taken 10 Feet from the Corner of Bldg. 3902, 1 Foot from the Slab (2 to 4 Inches Deep)	Sample 4 Taken 12 Feet from Sample 3, 1 Foot from the Slab (2 to 4 Inches Deep)
Arochlor 1260	0.8 ppm	2.8 ppm	0.9 ppm	35.0 ppm

Source: NSY, 1981.



SOURCES: SOUTHDIV, n.d.
ESE, 1981.

Figure 6.4-8
WASTE PAINT AND SOLVENT STORAGE AREA

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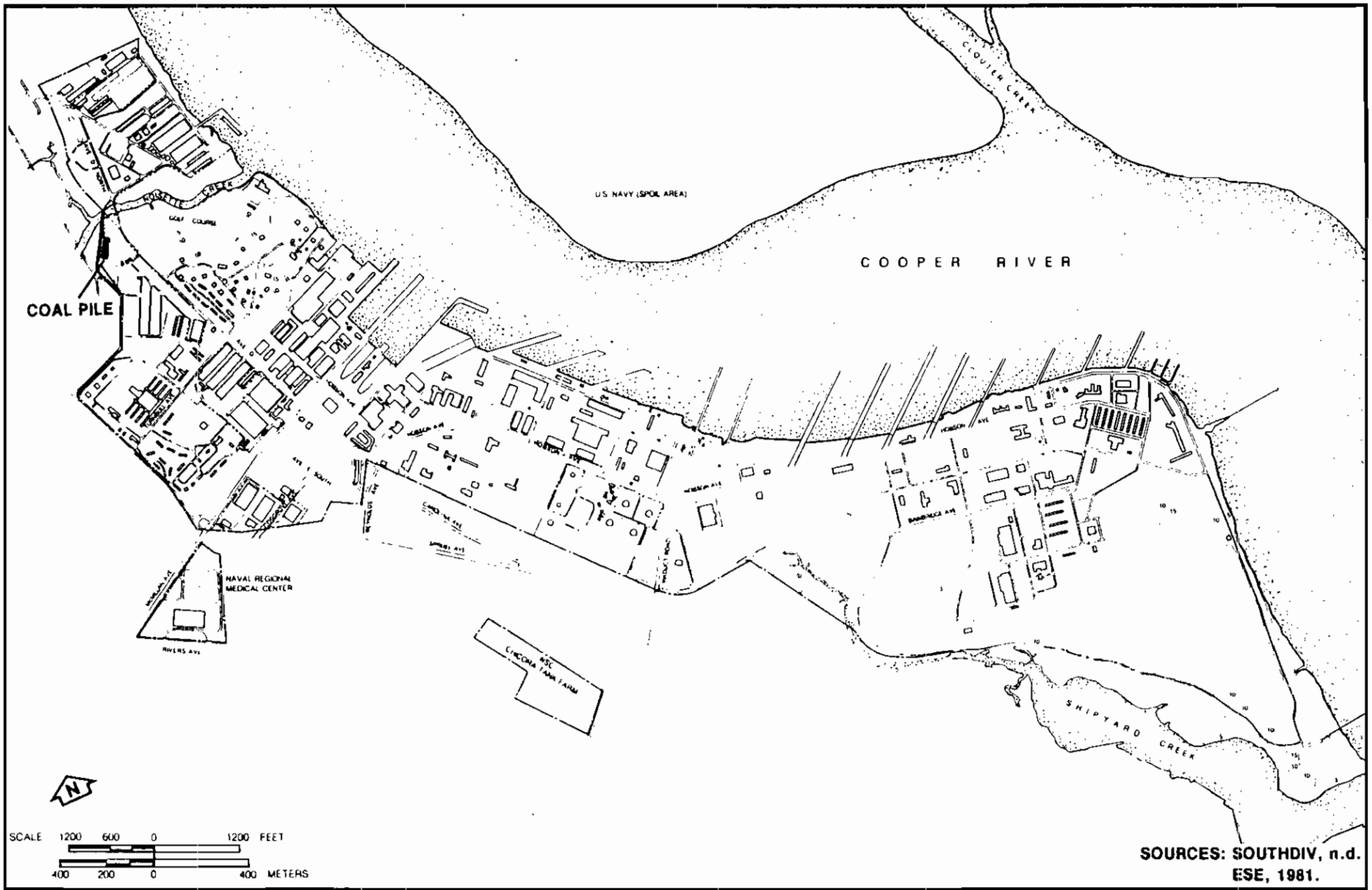
NAVAL BASE CHARLESTON



SOURCES: SOUTHDIV, n.d.
ESE, 1981.

Figure 6.4-9
LOCATION OF THE NSY COAL PILE

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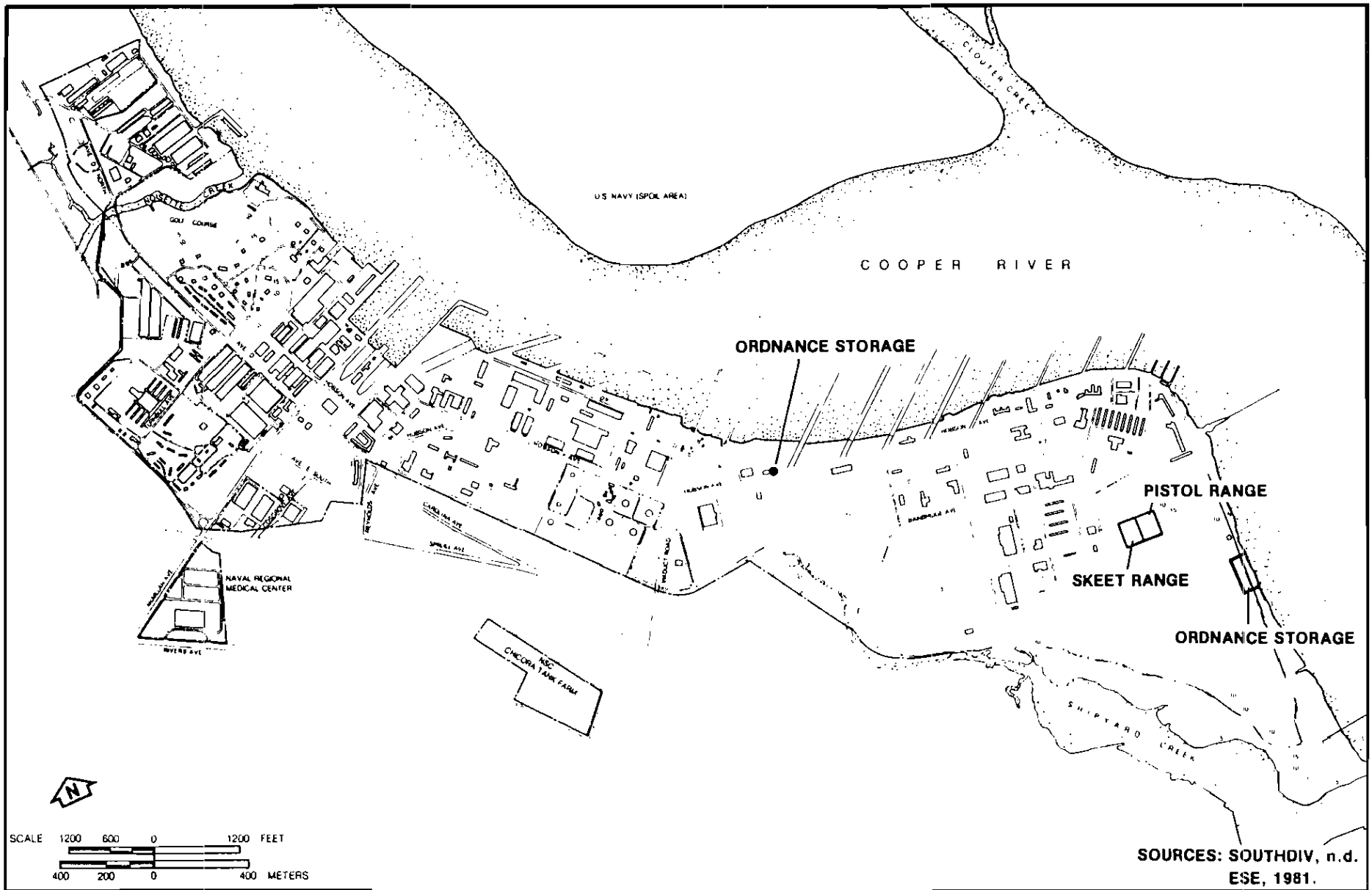
NAVAL BASE CHARLESTON



SOURCES: SOUTHDIV, n.d.
ESE, 1981.

Figure 6.4-10
FIRING RANGES AND ORDNANCE STORAGE AREAS ON NAVBASE CHARLESTON

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NAVAL BASE CHARLESTON

next to Bldg. NS-22. The field of fire extends southward into an earth backstop and is separated from the adjoining skeet areas by a steel-plated wall.

Small arms up to and including 7.62-millimeter (mm) and 12-gauge shotguns are fired at the pistol range. Calibers fired include .22, .32, .38, .45, 5.56 (M-16), and 7.62 (M-14, M-60). The pistol range is currently closed.

Conventional ordnance stored at NAVBASE Charleston includes small arms ammunition (12-gauge through 50-caliber), 40-mm solutions charges, some high explosives (HE) fuzes, and mines and torpedoes without HE. HE fuzes are stored in magazine 56, saluting charges and small arms ammunition in magazine 55. Inert torpedoes, containing no HE charges, are stored in Bldg. 132. Mine assembly and storage are performed at FMWTC.

No explosive ordnance disposal (EOD) is performed at NAVBASE Charleston. In the past, limited EOD actions involving black powder projectiles from the Civil War reportedly were performed on the Clouter Creek spoil area across the Cooper River. Three former ordnance storage buildings are located on Daniel Island, east of pier G. These facilities are no longer in use. Two areas in the Cooper River are identified on a map of the base as locations where depth bombs and torpedoes (two each) were dropped during World War II.

Ordnance operations at NAVBASE Charleston consist of limited receiving and transferring munitions to NWS, north of NAVBASE Charleston. NWS (the former Naval Ammunition Depot) provides the material support for assigned weapons and weapons systems, including the support of fleet and shore activities with guided missiles and conventional ammunition (NWS, 1977). The handling and transfer of munitions at NAVBASE Charleston result in Explosive Safety Quantity Distance (ESQD) arcs, which extend across the Cooper River (SOUTHDIV, 1978).

6.4.8 Radiological Materials

A review of operations at the time of the study and historical documents made available to NEESA indicate that the use, handling, storage, and disposal of radioactive materials at NAVBASE Charleston were being conducted in accordance with Federal regulations and presented no known hazard to personnel or the environment (NEESA RASO, 1979a and 1979b). A review of operations dealing with NAVSEA, Code 08, operations were outside the scope of this document.

6.5 TRAINING OPERATIONS

The primary mission of NAVBASE Charleston is to provide supply and support services to fleet units (surface and submarine); logistic support for operating forces of the Navy; and shore activities, as

assigned. As a result, training activities at NAVBASE Charleston are limited to:

1. FBMSTC,

2. FMWTC, and

3. NRC.

6.5.1 Fleet Ballistic Missile Submarine Training Center

FBMSTC is charged with training FBM submarine personnel to operate FBM submarines and associated weapons systems. FBMSTC is located on the southeastern portion of NAVBASE Charleston in Bldg. FBM-61 (figure 5.1-3); an operational trainer facility will be located in Bldg. P-114.

Training takes place in classrooms, laboratories, and actual FBM submarine equipment and includes training in navigation, weapons, engineering, operations, and submarine tactics. Wastes generated by FBMSTC are listed in section 6.1.6.

6.5.2 Fleet and Mine Warfare Training Center

FMWTC is comprised of the former Naval Schools of Mine Warfare and the Carner Fleet Training Center. It provides general shipboard training as well as specialized training in mine warfare. FMWTC also operates a firefighting training school and a laboratory for testing boiler waters. Wastes generated by FMWTC and waste handling are discussed in section 6.1.5.

FMWTC is located in the southeastern portion of NAVBASE Charleston (figure 5.1-3). Training and instruction buildings include Bldgs. 202, 643, and 647; mock-up structures are located in area K-18.

6.5.3 Naval Reserve Center

FBMSTC, FMWTC, and NRC conduct training activities at NAVBASE Charleston; no other troop training is performed. NRC is located on the southeastern portion of NAVBASE Charleston in Bldgs. RTC1 and 206. NRC provides recruiting and training facilities for naval reserve personnel along with Destroyer Squadron 34.

6.6 WASTE TREATMENT AND DISPOSAL

6.6.1 Liquid Waste Treatment and Disposal

During the development of NAVBASE Charleston from 1901 to 1972, the sanitary, stormwater, and industrial sewer systems were established as a combined wastewater system. The final discharge points for this system were the many outfalls along the Cooper River.

6.6.1.1 Sanitary Wastewater

With the installation of a separate sanitary sewer system in 1972, sanitary and industrial discharges were separated from the combined system (see figure 6.6-1). The effluent from this separate system was discharged to NCCPSD rather than to the Cooper River. A number of changes to the sanitary sewer system have occurred since its installation. In 1974 and 1976, repairs and alterations included the connection of existing buildings to the sanitary system and the installation of oil-water separators and acid neutralization facilities to pretreat industrial wastewater prior to discharge to the sanitary sewer system.

In 1975, the sanitary sewer connections were installed on the piers for use by docked ships. Improvements to this system were made in 1978. Some ships were not capable of using the dock system because their onboard sanitary system was not compatible with the dock system. Modifications to the collection system and to the ships using the system have remedied this condition.

Some overboard discharge of sanitary wastewater by docked ships occurred until April 1981, when Federal law prohibited such discharges.

NCCPSD requires quarterly monitoring of effluent (North Charleston Sewer District, 1972) from NAVBASE Charleston, and NAVBASE Charleston is currently in compliance with NCCPSD requirements [SOUTHDIV Regional Environmental Support Office (RESO), 1981].

6.6.1.2 Stormwater Drainage

No single collection system exists for the disposal of stormwater runoff. Numerous local systems of inlets and pipes carry runoff by gravity to the nearest natural drainage channels or waterways. The northern NSC area has eight outfalls to the Cooper River and two to Noisette Creek. The developed portion in the center of NAVBASE Charleston is drained to the Cooper River through a variety of piping and area drainage. Developed portions of NAVSTA at the southern end of NAVBASE Charleston drain the stormwater runoff to the Cooper River. Undeveloped areas of NAVSTA are drained by surface flow to either the Cooper River or Shipyard Creek, depending on the drainage patterns of the area.

Stormwater discharges are permitted under NPDES permit SC 0003816. A map of the stormwater drainage system is shown in figure 6.6-2.

6.6.1.3 Industrial Wastewater

As discussed earlier in this section, prior to 1972, a combined wastewater collection system conveyed all wastewaters generated at NAVBASE Charleston, including industrial wastewater, to the Cooper River. Limited industrial wastewater pretreatment was practiced prior

to 1972. Since 1972, industrial wastewater treatment and disposal have consisted of pretreatment and discharge to the sanitary sewer system, which conveys industrial and sanitary wastewaters to the NCCPSD. Several direct discharging operations, such as vehicle maintenance and cleaning and blowdown from the space heating boiler, are permitted to discharge to the Cooper River under NPDES permit No. SC 0003816.

Pretreatment methods include gravity oil-water separation, acid neutralization, or metals removal. Many of the oil-water separators were installed in 1974 and 1976 during alterations made to the sanitary sewer system because of oil contamination problems at the municipal treatment plant. Twelve oil-water separators are currently used in areas where the industrial operations may introduce petroleum products to the sanitary sewers. Each oil-water separator has a holding tank for the oily fraction. This tank is pumped out periodically on an "as needed" basis, and the waste oil is transported to the NSC waste oil reclamation facility.

6.6.1.4 Acid Neutralization

As discussed in section 6.1.1.6, acidic wastewater generated by the battery salvaging and restoring and recharging operations is collected and neutralized prior to being discharged to the sanitary sewer. A sketch of the acid neutralization facility, which is located adjacent to drydock No. 4, is presented in figure 6.6-3. As shown in this figure, the acid neutralization facility consists of a concrete underground tank with two compartments. The first compartment serves as a holding and mixing tank. Acidic wastewater from the battery salvaging operation drains by gravity to the first compartment, and wastewater from the battery restoring and recharging operation is pumped to the first compartment from a sump located in Bldg. 68. When a sufficient volume of wastewater collects in the first compartment, the mechanical agitator is activated, and soda ash is added to adjust the pH to approximately 6.5. Following pH adjustment, the wastewater is transferred to the second compartment, which serves as a settling tank. The suspended material in the wastewater is allowed to settle for about 4 hours, then the clarified wastewater is discharged to the sanitary sewer. Approximately 3,000 gallons of wastewater is treated annually in the acid neutralization facility, and approximately 200 gallons of sludge is removed from both compartments of the facility approximately once every 6 months. The sludge is contract hauled offbase by an EPA-approved contractor (Personal Communication, 1981; Williams-Russell and Assoc., Inc., 1980).

6.6.1.5 Metal Plating Waste Treatment

As discussed in section 6.1.1.8, non-cyanide-bearing rinsewater from the electroplating operation is collected and treated for metals removal prior to being discharged to the sanitary sewer. Cyanide-bearing rinsewater is also collected; however, no pretreatment is provided for this waste stream prior to being discharged to the sanitary sewer. The non-cyanide-bearing rinsewater is generally acidic, and the

principal pollutant is chromium; therefore, NAVBASE Charleston personnel refer to the wastewater as chromic acid wastewater.

Figure 6.6-4 presents a sketch of the metal plating waste treatment facility, located between Bldgs. 44 and 5. The treatment facility consists of two underground concrete holding tanks, one for the chromic acid wastewater and one for the cyanide wastewater, and a clarifier. The chromic acid wastewater drains to the chromic acid holding tank, which has a working capacity of 1,200 gallons. Approximately once every 2 weeks, the chromic acid holding tank becomes full, at which time the wastewater is pumped from the holding tank to the clarifier. After pumping the wastewater to the clarifier, soda ash is added and manually mixed with the wastewater to adjust the pH to approximately 8.5 to chemically precipitate chromium and other metals. Following pH adjustment, the suspended material in the wastewater is allowed to settle for approximately 48 hours and then the clarified wastewater is discharged to the sanitary sewer. Sludge accumulating in the bottom of the clarifier is removed. The sludge generated from 1972, when the metals removal pretreatment system was installed, until 1973 was disposed of in the base sanitary landfill (site 1). Since 1973, the sludge has been contract hauled offbase. Approximately 31,200 gallons of chromic acid wastewater is treated annually in the metal waste treatment facility, and approximately 6,500 gallons of sludge is removed from the facility per year.

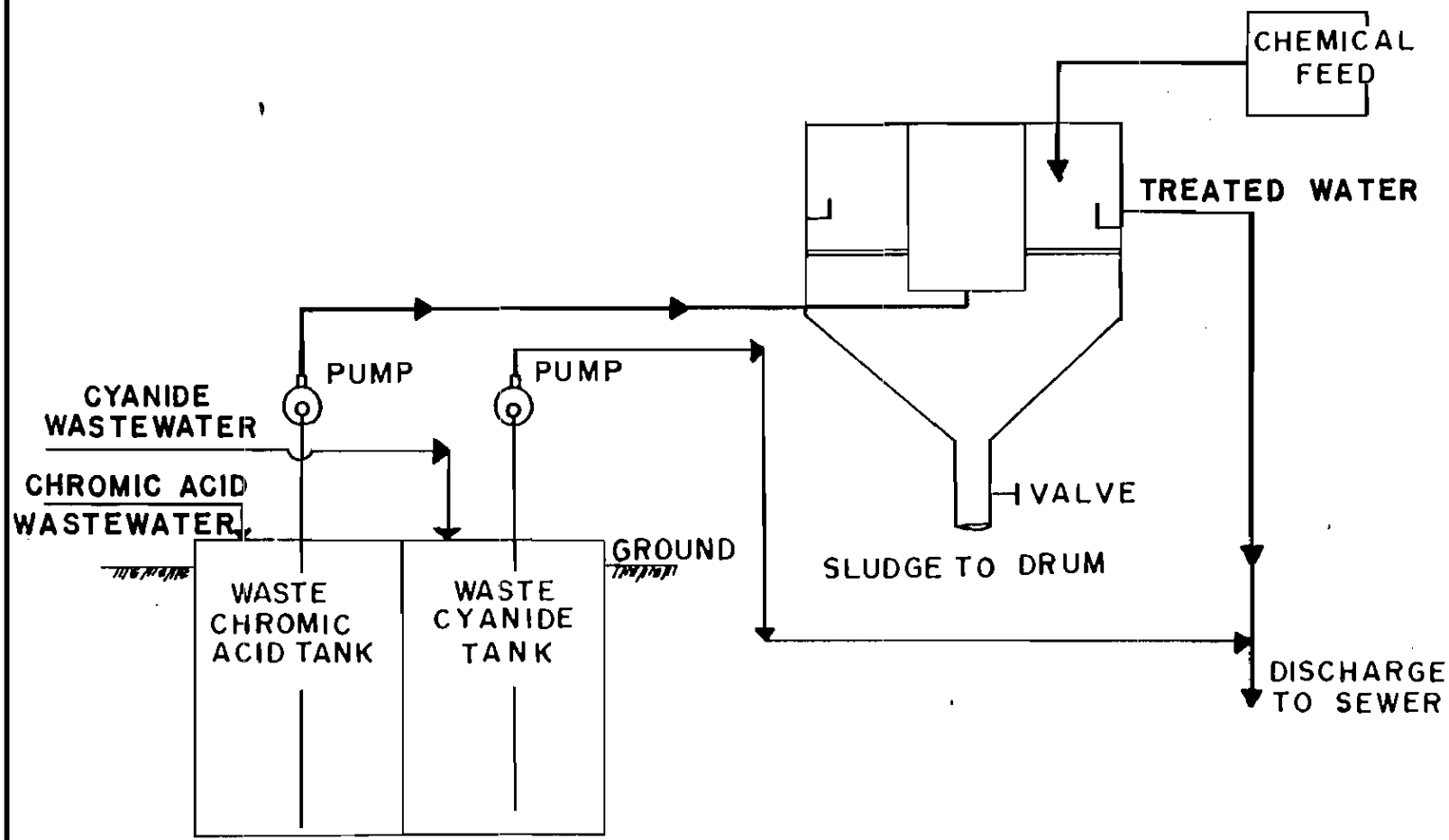
The cyanide wastewater drains to the cyanide waste holding tank, which also has a working capacity of 1,200 gallons. When the holding tank becomes full, the cyanide wastewater is pumped directly to the sanitary sewer. The rate of discharge of cyanide wastewater to the holding tank is extremely variable, such that pumping of the wastewater to the sewer is not performed on a regular basis but rather on an "as-needed" basis. Due to the variability of the cyanide wastewater discharge, the volume of wastewater discharged annually is unknown. However, the cyanide wastewater discharge is known to be less than the annual chromic acid wastewater discharge of 31,200 gallons.

6.6.2 Solid Waste Disposal

6.6.2.1 Base Sanitary Landfill (Site 1)

Most solid wastes currently generated at NAVBASE Charleston are hauled offbase. A small amount of bottom ash from the coal-fired power plant is retained and spread on roads to enhance traction.

Prior to 1973, all solid waste reportedly was disposed of onsite in a landfill. Wastes included household garbage, asbestos, drummed industrial liquid wastes, waste solvents, waste paints, paint sludge, PCBs, metal sludge, acid neutralization sludge, mercury, and other waste chemicals. Most wastes from the industrial shops in NSY were disposed of in the landfill. Table 6.6-1 lists industrial wastes reportedly landfilled. The landfill was operated as an area fill (i.e.,



SOURCES: Williams-Russell and Assoc., Inc., 1980.
ESE, 1981.

Figure 6.6-4
METAL PLATING WASTE TREATMENT FACILITY

INITIAL ASSESSMENT STUDY
NAVAL BASE CHARLESTON

Table 6.6-1
Industrial Wastes Disposed of in the Base Sanitary Landfill (Site 1)

Waste	Origin	Current Annual Generation Rate	Years of Disposal
Asbestos	Boiler Shop	1,000 lbs	70
Asbestos	SIMA	2 yds^3	15
Varnish Sludge	Electrical Shop	300 gal	70
Mercury	Electrical Shop	25 lbs	70
Acid Neutralization Sludge	Electrical Shop	400 gal	70
Paint Sludge	Electronics Shop	200 gal	70
Metal Sludge	Machine Shop 31	50,000 lbs	70
PCB Fluids	Central Tool Shop	None	40
Paint Wastes	Paint Shop	226 tons	70
Toxic NRP Water Chemicals	NSC	1,330 lbs	10

yds^3 = cubic yards.

Source: ESE, 1981.

no trenches were dug), and, to reduce the volume, most wastes were burned. The landfill site is located along the western edge of NAVBASE Charleston, south of Viaduct Rd. (see figure 6.6-5). Before landfilling, this area was a tidal marsh bordering Shipyard Creek. Wastes were deposited directly into the marsh and were often flooded by high tides. Materials which would not burn (such as concrete rubble, drums, and metal scrap) were placed on the leading edge of the fill, sometimes in the tidal waters. Combustible waste materials were burned daily, and the burned residue was pushed into the marsh with a bulldozer. Cover material was applied on an irregular, "as-available" basis. Soils from onsite building excavations, spoil dredged from the river, and bottom ash from the power plant were all used as cover material. Landfilling in this area began in the 1930s and continued until 1973.

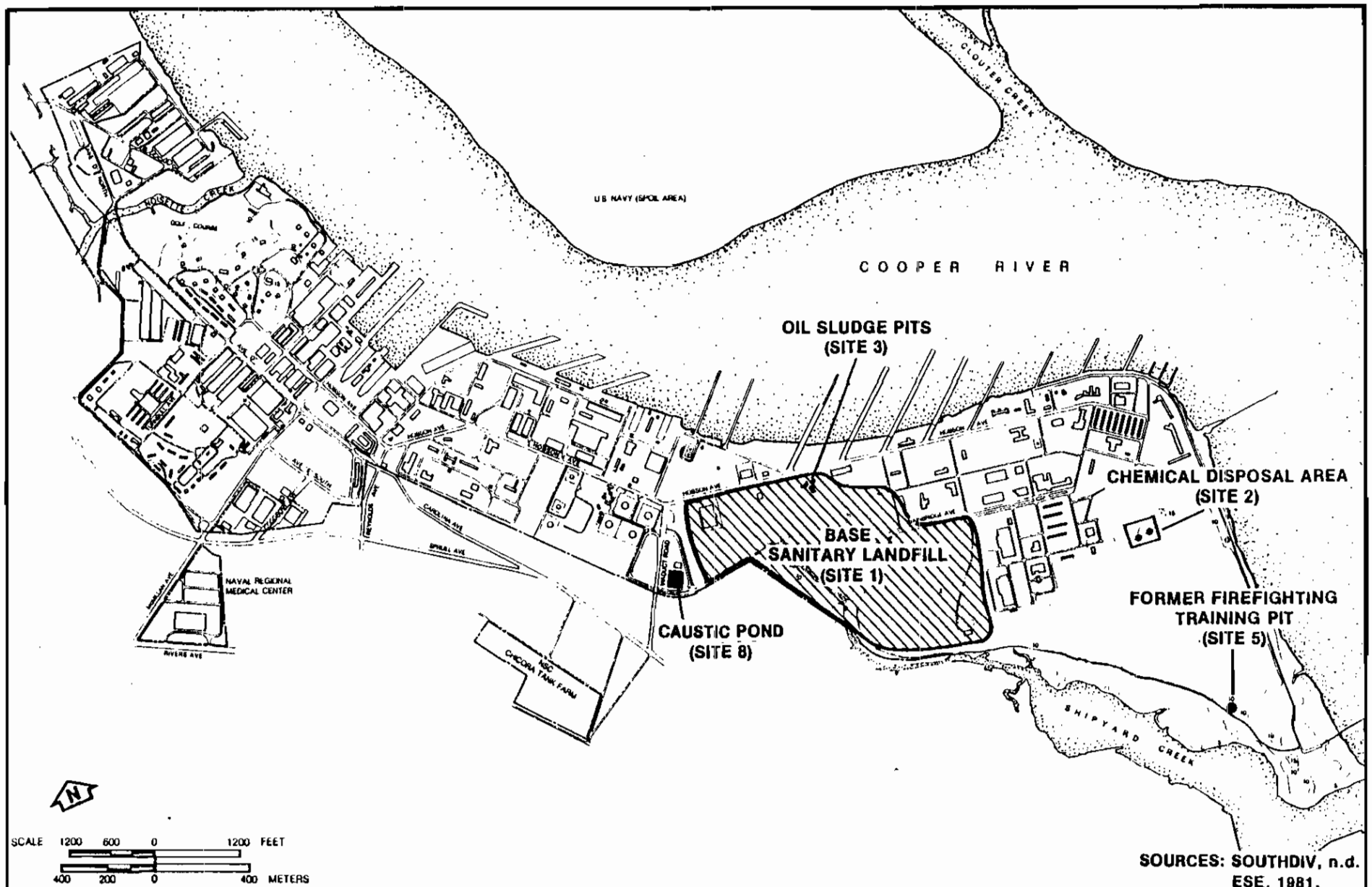
In the past, boiler rebuilding operations ("rip-out" operations) (see section 6.1.1.4) resulted in a mixture of firebrick and asbestos, which was placed in a trash receptacle and taken to the base landfill. Around 1968, a special procedure involving double bagging of asbestos material was instituted in an attempt to control the disposal of asbestos. The asbestos continued to be disposed of in the base landfill until it was closed in 1973. Currently, special handling procedures are required, and the asbestos is disposed of by an EPA-approved contractor.

The landfill was cited by EPA and the State of South Carolina in 1970 for placement of wastes in tidal waters and for insufficient cover. After final closure, 2 feet of soil cover was applied to the entire fill area.

6.6.2.2 Oil Sludge Pits (Site 3)

From 1944 to 1971, waste oil and sludge from NAVBASE Charleston and from ships in port were disposed of in three unlined pits, which can be located in historical aerial photographs (see figure 6.6-6). These aerial photographs are available through NEESA or the Cartographic Branch of the National Archives (see section 1.3 for a complete address). By 1956, two of the three pits had been covered. There are no records to indicate that oil was removed from these pits prior to the application of a cover. The rectangular oil sludge pit was in regular use between 1944 and 1971 and was permanently closed in 1974. From 1971 to 1974, the rectangular pit remained open but was no longer used for the disposal of oil and sludge. In 1974, the rectangular pit was pumped out and filled with clean, compacted fill. The sludge pumped from the pit was sold to a recycler.

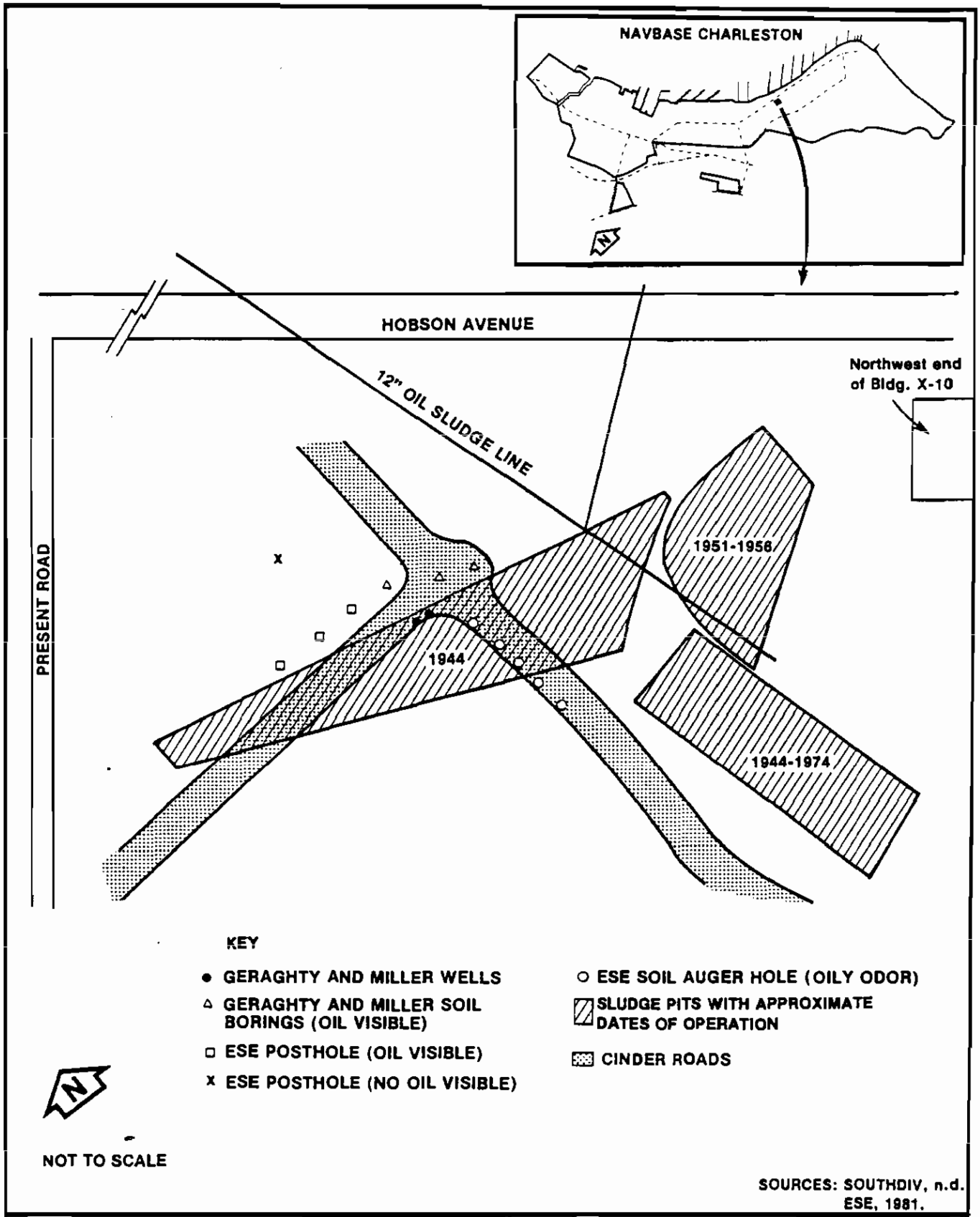
Periodically, heavy rains would cause the oil pits to overflow. No catchment berms were provided to contain spills. Oil generally ran to the west into the marsh/landfill area during these spills. One such spill is evident in an aerial photograph from 1951. During the 1950s, the spills were localized to the area around the pit due to landfilling operations in the adjacent marsh. Another large spill was reported to



SOURCES: SOUTHDIV, n.d.
ESE, 1981.

Figure 6.6-5
SOLID WASTE DISPOSAL AREAS

INITIAL ASSESSMENT STUDY
NAVAL BASE CHARLESTON



SOURCES: SOUTHDIV, n.d.
ESE, 1981.

Figure 6.6-6
LOCATIONS OF FORMER OIL SLUDGE PIT AREAS ON NAVBASE CHARLESTON

INITIAL ASSESSMENT STUDY
NAVAL BASE CHARLESTON

have occurred in the summer of 1971. During this spill, oil from the pits reportedly ran across Hobson Ave. and into the Cooper River.

When current groundwater levels are high, due to especially high tides or excessive rainfall, oil reportedly seeps from the ground in this area. At the time of the onsite assessment, the IAS team observed approximately 1 foot of oil floating on the surface of the ground water in the borings in the area of the oil sludge pits. The exact configuration of the oil lens was not determined at the time of the assessment. A noncontact terrain conductivity meter (Geonics EM-31®) was employed to define the extent of the oil lens, but the extreme heterogeneity of the shallow subsurface and the presence of many buried conductors prevented a definitive interpretation of the data. Several shallow holes (2 to 5 feet deep) were dug at conductivity lows, and oil was found in each (see figure 6.6-6).

6.6.2.3 Chemical Disposal Area (Site 2)

Undisclosed amounts of a variety of chemicals, including the decontaminants DANC and DS-2, were reportedly buried in the area of the pistol and skeet ranges (see figure 6.6-5). In 1972 and 1974, construction crews working in the area unearthed drums of chemicals, and minor injuries resulted [NAVBASE Charleston, Code 18(440), 1974; Naval Construction Battalion Unit 412, 1974; NRMC, 1974a; NRMC, 1974b]. Reportedly, in the 1960s, unknown chemicals of several types were buried in the skeet range and the dike behind the pistol range (see figure 6.6-5). In 1977, ten 5-gallon cannisters of DS-2 were reportedly buried in the skeet range.

6.6.2.4 Former Firefighting Training Pit (Site 5)

A circular, unlined pit, measuring 30 to 50 feet in diameter and 18 inches deep, was used from 1966 to 1971 to burn waste oil, gasoline, or alcohol for the training of NAVSTA firefighters. This pit was located near the southern end of NAVBASE Charleston, on the Shipyard Creek side (see figure 6.6-5). Most of the flammable material was burned during each training exercise. This pit was not intended for storage or disposal but strictly for training. Despite the installation of a drain, heavy rains caused the pit to fill with water, displacing the oil and allowing it to flow into Shipyard Creek. Coast Guard citations on these spills led to closure of the pit in 1971, and in 1972, it was leveled and covered with bottom ash. At the time of leveling, there was reportedly 4 inches of oily sludge in the bottom of the pit. No oil or oily residue could be located in the area of the pit during the site assessment. The pit area is not readily discernible from the ground, but its location is apparent from the air and is also clearly shown on aerial photographs taken in 1971. These aerial photographs are available through NEESA or Public Works NSY.

6.6.2.5 Caustic Pond (Site 8)

The caustic pond, located near the junction of Bainbridge Ave. and Viaduct Rd., was used between the early 1940s and the early 1970s for the disposal of lime sludge generated as a byproduct of acetylene production. Water saturated with lime was allowed to settle in a pond, while excess water was discharged to Shipyard Creek. Part of the pond was filled in during construction of Bainbridge Ave. The pond was abandoned rather than closed, and no lime was removed or covered when the acetylene production ceased. The remainder of the pond (the portion which was not filled by the Bainbridge Ave. construction) still exists, and lime sludge can be seen on the water's edge. Trees, shrubs, and grass grow down to the water's edge, and aquatic plants grow in the pond itself. A litmus paper test of the pond water conducted during the onsite assessment yielded a pH of 7. Shallow (2.5-foot) soil borings in the area indicated the presence of approximately 1 foot of lime sludge in the area of the current pond. The pH of water in a fresh exposure of the sludge was 11. The sludge exposed in the pond has apparently formed a carbonate crust, allowing the pond water to remain essentially neutral.

6.7 IMPACTS OF INSTALLATION OPERATIONS

6.7.1 Water Quality

6.7.1.1 Surface Water

NAVBASE Charleston is located on the west bank of the Cooper River, between river miles 9 and 12 (figure 5.3-5). The northern portion of the base is drained by Noisette Creek, while the southern portion is drained by Shipyard Creek; both empty into the Cooper River. The Cooper River is a meandering stream, bordered on the east by backwater marsh and on the west by upland areas with established industry, military facilities, and the cities of Charleston and North Charleston. The Cooper River empties into Charleston Harbor, 4 miles south of NAVBASE Charleston. The South Carolina Department of Health and Environmental Control (SCDHEC) has classified the lower 30 miles of the Cooper River and Charleston Harbor as class SC waters (State of South Carolina, 1971; 1980). Class SC waters are defined as "waters suitable for crabbing, commercial fishing, and for the survival and propagation of marine fauna and flora." Water quality standards for class SC waters are given in table 6.7-1.

Water quality and sediment chemistry data for the Cooper River-Charleston Harbor area are available from several major studies. These studies are listed in table 6.7-2. Each study was reviewed for possible impacts to water quality related to NAVBASE Charleston activities. These are discussed in the following paragraphs.

SCDHEC routinely samples seven water quality monitoring sites along the length of the river to ensure that the waters of the Cooper River maintain State water quality standards. Parameters include

Table 6.7-1
Water Quality Standards for the Lower Cooper River--
Charleston Harbor Area

Items	Specifications*
1. Garbage, cinders, ashes, oils, sludge, or other refuse	None.
2. Toxic wastes, oils, deleterious substances, colored or other wastes	None alone or in combination with other substances or wastes in sufficient amounts as to be injurious to edible fish or the culture or propagation thereof or which in any manner shall adversely affect the flavor, color, odor, or sanitary condition of fish or impair the waters for any other best usage as determined for the specific waters which are assigned to this class.
3. DO	Not less than 4 mg/l.
4. Fecal coliform	Not to exceed a geometric mean of 1,000/100 ml, based on five consecutive samples during any 30-day period; nor to exceed 2,000/100 ml in more than 20 percent of the samples examined during such period (not applicable during or immediately following periods of rainfall).
5. pH	Shall not vary more than one pH unit above or below that of effluent-free waters in the same geological area having a similar total salinity, alkalinity, and temperature, but not lower than 6.75 or above 8.5.

* Class SC water (State of South Carolina, 1971).

DO = dissolved oxygen.
ml = milliliters.

Source: ESE, 1981.

Table 6.7-2
Water Quality and Sediment Chemistry Studies of the Cooper River--Charleston Harbor Area

Parameters*	Sample Type	Sampling Location	Sampling Date	Reference
Phys., C, N	Water	Cooper River--7 Stations Cooper River--7 Stations	1955-79	Inabinet, 1979
Phys., C, N, M, Pest., B	Water	Cooper River--8 Stations	1971	EPA, 1974
Pest.	Water	Cooper River--2 Stations	1971	Gibson, 1974
Phys., C, N	Water	Cooper River--4 Stations Charleston Harbor--1 Station	1973-75	Mathews and Shealy, 1978
Pest., PCBs	Sediment	Cooper River--7 Stations Clouter Creek--2 Stations	1971	Gibson, 1974
Phys., C, N, M	Sediment	Cooper River--9 Stations Clouter Creek--3 Stations	1972	Gibson, 1974
Phys., C, N, M	Sediment	Cooper River--26 Stations Shipyard Creek--4 Stations Charleston Harbor--9 Stations Goose Creek--1 Station	1971	EPA, 1972
Phys., C, N, M	Sediment	Cooper River--2 Stations Shipyard Creek--1 Station Wando River--1 Station Atlantic Ocean--1 Station	1975	Army, 1976a
N, M, Pest., PCBs	Sediment Elutriate	Cooper River--6 Stations Shipyard Creek--1 Station Charleston Harbor--2 Stations Spoil Banks--4 Stations	1979	Jones, Edmunds and Assoc., Inc., 1979

* Phys. = Physical; C = Chemical; N = Nutrients; M = Metals; Pest. = Pesticides; PCBs = Polychlorinated biphenyls; B = Biological.

DO, biochemical oxygen demand (BOD), pH, ammonia-nitrogen (NH_3-N), total Kjeldahl nitrogen (TKN), nitrite plus nitrate (NO_2 + NO_3), total phosphorus (TP), and chloride (CL). Inabinet (1979) recently examined the data collected for the period of record (table 6.7-2) and reported that, in general, the waters of the Cooper River have maintained State water quality standards. In addition, Inabinet (1979) compared the data collected during 1977-78 at the seven SCDHEC stations with those data collected at the same stations averaged over the period of record (1955 to 1977) and found a significant reduction in the nutrient (nitrogen and phosphorus) levels in the Cooper River, as well as a small decrease in the BOD levels throughout the river. This improvement in water quality was attributed by Inabient (1979) to the elimination of all untreated wastewater effluents from the Cooper River, as directed in the early 1970s by State and Federal water pollution control legislation. Untreated sanitary and industrial wastewater effluents into the Cooper River from NAVBASE Charleston were eliminated in early 1972 by pretreatment and diversion to the City of Charleston's sewage treatment plant (STP) (see section 6.6.1.1).

The most recent comprehensive water quality study on the Cooper River was conducted by EPA (1974). This study was published in 1974 by the South Carolina Water Resources Commission as part of the Cooper River Environmental Study (EPA, 1974). The main objective of this study was to develop capability for predicting changes in water quality which might result from rediversion of the Cooper River. To accomplish this, EPA (1974) sampled the river at eight locations during October (high flow) and November (low flow) 1971. Analyses were performed for physical and chemical parameters, including nutrients, metals, pesticides, and biological parameters (coliforms). The water quality of the river, in general, met the State class SC standards (table 6.7-1) during both high- and low-flow conditions at all stations. Several stations exhibited contraventions of pH minimum (less than 6.75) during low-flow conditions in October and November. The low pH values during low-flow conditions were likely attributable to naturally occurring organic (humic and fulvic) acids. No DO values less than the standard (4.0 mg/l) were recorded. The data for chloride indicate that the lower reaches of the river (below river mile 20) are tidally influenced. As expected, the extent of saline ocean water penetration up the river was a function of river flow and tidal cycles.

Concentrations of copper, chromium, lead, zinc, manganese, iron, and mercury were measured at four locations by EPA (1974). Highest concentrations of copper, lead, zinc, manganese, and iron were found at the southernmost station which was located adjacent to NAVBASE Charleston. EPA water quality criteria for these metals are given in table 6.7-3. Chromium levels at all stations were less than the analytical detection limit (less than 20 ug/l). Levels of copper and zinc were slightly above saltwater aquatic life criteria. Concentrations of mercury and manganese at all stations were less than the saltwater aquatic life criteria. Seawater concentrations of mercury

Table 6.7-3
Water Quality Criteria for Chromium (Cr), Copper (Cu), Lead (Pb), Manganese (Mn), Zinc (Zn), Iron (Fe), and Mercury (Hg)

Parameter	Criteria
Chromium (Cr)	50 ug/l for domestic water supply;* to protect saltwater aquatic life: 1,260 ug/l, hexavalent; 10,300 ug/l, trivalent.
Copper (Cu)	1,000 ug/l for domestic water supplies;* to protect saltwater aquatic life: 23 ug/l.
Lead (Pb)	50 ug/l for domestic water supply;* to protect saltwater aquatic life: 668 ug/l.
Manganese (Mn)	50 ug/l for domestic water supply;* 100 ug/l for protection of consumers of marine mollusks.
Zinc (Zn)	5,000 ug/l for domestic water supplies;* to protect saltwater aquatic life: 170 ug/l.
Mercury (Hg)	2.0 ug/l for domestic water supply;* to protect saltwater aquatic life: 3.7 ug/l.

* The portion of the Cooper River at NAVBASE Charleston is not classified for use as a potable water source.

Sources: EPA, 1976b.
EPA, 1980f.
EPA, 1981.

The EPA (1974) sampling occurred 1 year prior to the diversion of sanitary and industrial wastewaters from the Cooper River. Due to tidal flow reversals and mixing in the lower stretch of the Cooper River, it is not possible to identify NAVBASE Charleston as the source of these contaminants. No data exist to assess the impact of the subsequent wastewater diversion on motal levels in the river.

Pesticides were analyzed during the October (high-flow) sampling. Eighteen pesticides were analyzed from composite water samples collected at each station. All samples analyzed were below the analytical detection limit for all 18 pesticides (table 6.7-4).

Gibson (1974) also reported data for 15 pesticides and degradation products during a May 1971 sampling at two locations in the Cooper River. One sampling station (PB-10) was located above the "tee" approximately 25 km north of NAVBASE Charleston, while the other station (PB-1) was located at the point of confluence of the Cooper River with Charleston Harbor. All samples were less than analytical detection, except for Silvex, which was just detectable at PB-10. The presence of this herbicide in the river likely was due to agricultural runoff.

Mathews and Shealy (1978) sampled four stations in the Cooper River and one station in Charleston Harbor during 1973-75. Physical, chemical, and nutrient parameters were reported. As expected, salinity and nutrients in the Cooper River increased toward the river mouth. No other analyses were conducted.

6.7.1.2 Sediment Analyses

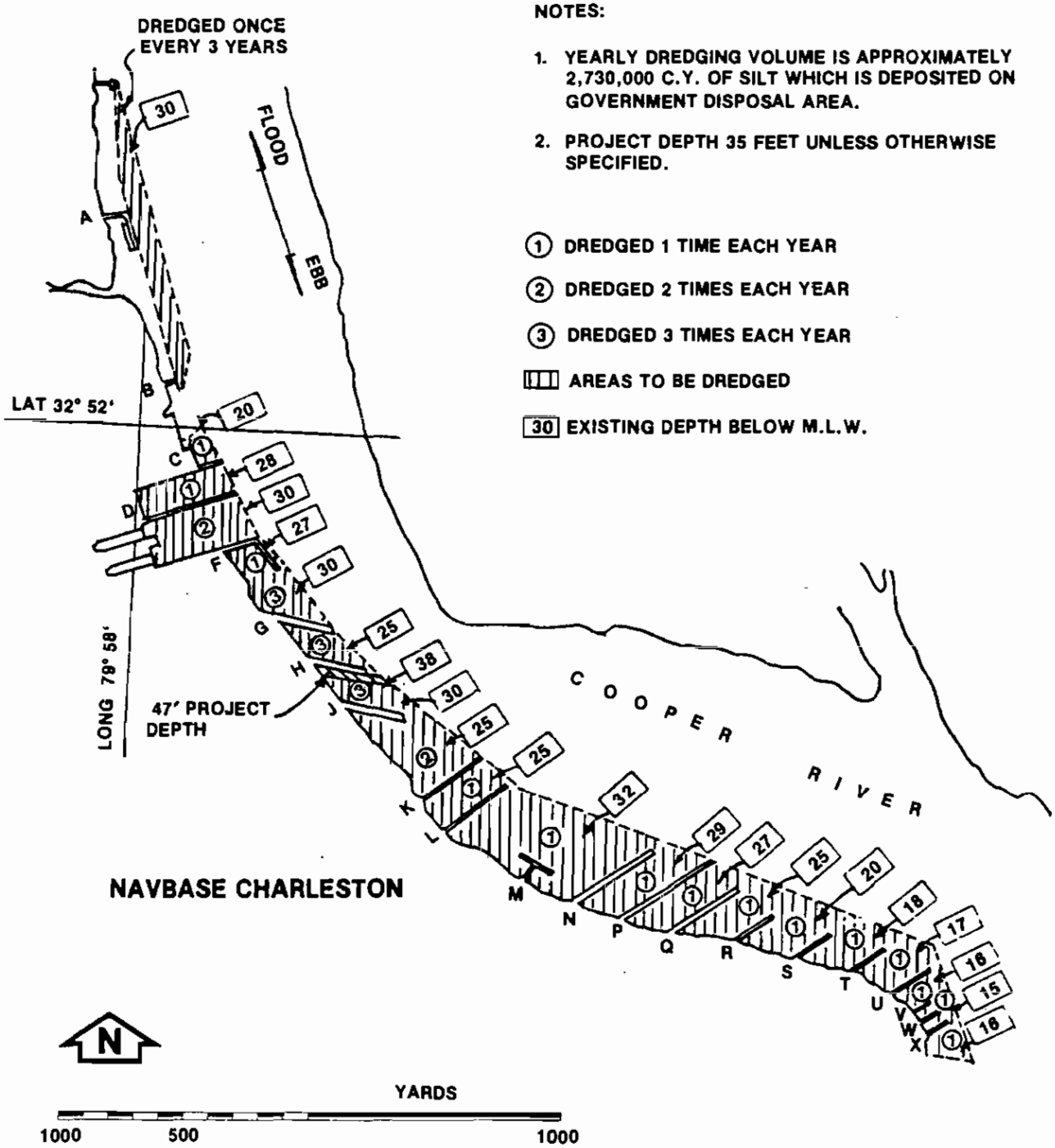
The tidal intrusion of a dense saline wedge into Charleston Harbor and the lighter, nonsaline, Cooper River water overriding this wedge result in decreased river velocities and subsequent settling of suspended matter. Additionally, the presence of a salinity differential between the top and bottom strata of the harbor causes bottom flood currents to predominate over the bottom ebb currents; thus, the resulting upstream movement of bottom currents within the harbor and lower reaches of the Cooper River constitutes an effective sediment trap (Army, 1976b). Dredging operations are conducted annually to maintain the channels in the river and harbor. Additionally, the Navy conducts dredging operations at NAVBASE Charleston to maintain project depths in the areas between the piers (figure 6.7-1). As shown in figure 6.7-1, dredging occurs one, two, or three times per year in this area. Approximately 2,730,000 cubic yards of material is removed annually from the area in front of and between NAVBASE Charleston piers and docks (Army, 1976b). Disposal of dredge material occurs at designated spoil bank areas along the eastern shore of the Cooper River. Most of the southern portion of NAVBASE Charleston was a spoil disposal area during the years 1940-60.

Concern over the effects of the disposal of this spoil material and possible toxic substances associated with this material has resulted

Table 6.7-4
Pesticide Analysis for Cooper River Stations

Pesticide	Concentration (All Stations) (ug/l)
Aldrin	<0.005
Lindane	<0.002
Chlordane	<0.05
Chlorobenzilate	<0.5
DDD	<0.01
DDE	<0.01
DDT	<0.02
Dieldrin	<0.01
Endrin	<0.02
Heptachlor Epoxide	<0.01
Heptachlor	<0.005
Methoxychlor	<0.1
Toxaphene	<0.25
Diazinon	<0.2
Guthion	<0.5
Malathion	<0.2
Methyl Parathion	<0.02
Parathion	<0.04

Source: EPA, 1974.



NOTES:

1. YEARLY DREDGING VOLUME IS APPROXIMATELY 2,730,000 C.Y. OF SILT WHICH IS DEPOSITED ON GOVERNMENT DISPOSAL AREA.
2. PROJECT DEPTH 35 FEET UNLESS OTHERWISE SPECIFIED.

(1) DREDGED 1 TIME EACH YEAR

(2) DREDGED 2 TIMES EACH YEAR

(3) DREDGED 3 TIMES EACH YEAR

AREAS TO BE DREDGED

30 EXISTING DEPTH BELOW M.L.W.

SOURCE: Army, 1976b.

Figure 6.7-1
NAVAL DREDGING AROUND PIERS AND SLIPS

INITIAL ASSESSMENT STUDY NAVAL BASE CHARLESTON

in several sediment chemistry studies (Gibson, 1974; EPA, 1972; Army, 1976a; Jones, Edmunds and Assoc., Inc., 1979). Table 6.7-2 lists these studies, the parameters measured, and the sampling dates discussed below. These studies were reviewed for possible impacts related to NAVBASE Charleston activities. Each study is discussed in the following paragraphs.

Gibson (1974) reported pesticide and PCB data for sediments collected at seven stations in the Cooper River and two stations in Clouter Creek. Two stations were adjacent to NAVBASE Charleston. PCBs were detected in concentrations which interfered with the pesticide determinations in all but two samples. PCBs appear to be ubiquitous in the Cooper River and were detected well upstream in the river; thus, NAVBASE Charleston cannot be identified as the source of these contaminants.

A cooperative sediment sampling and analysis effort in August 1972 between the South Carolina Water Resources Commission and EPA Region IV was conducted for the Charleston Harbor area, including the Atlantic Intracoastal Waterway (AIWW), Stono River, Wando River, Cooper River, Clouter Creek, and Ashley River (Gibson, 1974). This sampling effort included nine stations in the Cooper River, just upriver of NAVBASE Charleston. The analyses included lead, zinc, and mercury. The average values reported for these metals were neither higher nor lower than average levels found in the sediments of other rivers in the area, as follows:

	Lead mg/kg (wet)	Zinc mg/kg (wet)	Mercury mg/kg (dry)
Ashley River	32.7	45.8	0.45
Cooper River	28.9	25.7	0.29
AIWW	20.8	31.5	0.22
Wando River	23.0	24.2	0.50
Stono River	16.3	17.5	0.27

Since the Cooper River sediments exhibited levels roughly similar to other rivers in the area, NAVBASE Charleston probably was not a significant source of these metals to the sediments.

The most comprehensive sampling and analysis study of the Cooper River sediments was conducted by EPA Region IV (EPA, 1972). During March 1971, the Charleston District COE obtained 41 samples from sites selected by an EPA representative. EPA analyzed these samples for solids, oil and grease, organic nitrogen, TKN, TP, chemical oxygen demand (COD), trace metals, and radioactivity. Radioactivity levels and mercury levels were less than the analytical detection limits for these parameters at the above locations. Average values for lead, zinc, copper, and chromium were calculated from the raw data reported by EPA (1972) for the nine stations (Nos. 1-9) upstream of NAVBASE Charleston, the eight stations (Nos. 10-17) adjacent to NAVBASE Charleston, and the four stations (Nos. 18-21) in Shipyard Creek. These are given in table 6.7-5. In general, the data show higher concentrations of all

Table 6.7-5
Average Concentrations and Standard Deviations
of Trace Metals in Cooper River Bottom Sediments

Location (Station Grouping)	Station No.	No. of Samples	Concentration* (Percent Dry Weight) Lead	Zinc	Copper	Chromium
Cooper River, stations upstream of NAVBASE Charleston*	1-9	9	32.9[a]† (16.2)	108.2[b] (47.1)	41.4[c] (22.4)	59.0[d] (24.9)
Cooper River, stations adjacent to NAVBASE Charleston	10-17	8	38.9[a] (10.1)	129.4[b] (67.7)	44.6[c] (11.9)	68.5[d] (24.9)
Shipyard Creek stations	18-21	4	45.5[a]† (25.1)	140.5[b] (24.6)	44.3[c] (2.6)	131.8[e] (105.9)

* The grouping of the nine stations upstream of NAVBASE Charleston is assumed to be a valid "background" (i.e., representative of sediments not influenced by the installation). This assumption is based on the fact that net flux of sediment mass is in a downstream direction, even though tidal action coupled with low river flow could produce upstream flow vectors in the Cooper River adjacent to the installation.

† Averages of values reported; numbers in parentheses are standard deviations. Means with the same letter superscript are not significantly different at the 0.05 confidence level.

Source: ESE, 1981.

four metals in the sediments of the Cooper River adjacent to NAVBASE Charleston and in Shipyard Creek than upstream of the base. Statistical analysis of the data, however, shows that the values are not significant at the 0.05-confidence level, with the exception of chromium which is significantly higher in Shipyard Creek (131.8 percent) sediments than in Cooper River sediments, both upstream and adjacent to the base (table 6.7-5). The shoreline of Shipyard Creek is highly industrialized, and the source(s) of chromium is unknown. No criteria exist for sediment metal concentration. The source of contaminants, particularly trace metals, found in the sediments cannot be determined due to the presence of numerous industries and manufacturing plants along the Cooper River and Shipyard Creek. Due to extensive system mixing of contaminants from other sources in the adjoining areas in the past and currently, it is impossible to identify the degree of contamination originating from NAVBASE Charleston and to determine the degree of sediment contamination from past operations.

The Charleston District COE sampled the sediments at five locations in the lower Cooper River and Charleston Harbor in December 1975. Two stations were located adjacent to NAVBASE Charleston: station CH-04, in the Cooper River out from the Degaussing Station, and station CH-05 in Shipyard Creek. Analyses included physical and chemical parameters, including trace metals. Lead, zinc, arsenic, chromium, nickel, beryllium, and vanadium were higher at stations CH-04 and CH-05 than at the other stations. Replicate analyses were not performed; thus it is not possible to assess the statistical significance of the data. Levels of mercury and selenium were below analytical detection.

As discussed above, the sediments in the river are dredged annually, with the spoil material deposited on the east shore spoil banks. A bioassay evaluation was recently (1979) conducted of sediments in the lower Cooper River, Charleston Harbor, and dredge spoil areas (Jones, Edmunds and Assoc., Inc., 1979). This study was conducted to evaluate the potential effects of ocean dumping of the spoil material. Nine sites were sampled in Charleston Harbor and the lower Cooper River and four sites in the dredge spoil disposal areas. The sediments were sampled and elutriated with sea water, with bioassays performed on both the solid phase and elutriates. Bioassay test species included grass shrimp (*Palaemonetes pugio*), mysid shrimp (*Mysidopsis bigelowi*), copepods (*Centropages hamatus*), and haustorids (*Neohaustorius schmitzi*). Jones, Edmunds and Assoc., Inc., (1979) concluded that none of the 13 sediments would exceed any limiting permissible concentrations (LPC), based on suspended particulate or liquid phase bioassays.

6.7.1.3 Ground Water

Groundwater quality data for NAVBASE Charleston are available from USGS chemical analysis of water from a 2,136-foot well located at NSY (Gardner and Johnson, 1974). These data are presented in table 6.7-6. The well penetrates the Black Creek Formation, of which

Table 6.7-6
Chemical Analysis of Ground Water from a
Deep Well (2,136 feet) Located at NSY

Parameter	Date of Sample Collection	
	23 Jun 1962	9 Sep 1966
pH	8.6	8.4
Specific Conductance	1,380	1,540
Color	--	20
Total Hardness (as $CaCO_3$)	6	6
PO_4	--	0
NO_3	0.5	0.2
F	3.0	3.7
Cl	77	78
SO_4	1.4	0
HCO_3	818	836
K	7.0	3.8
Na	390	392
Mg	0.4	0.5
Ca	2.0	1.4
Mn	0.01	0
Fe	0.5	0.5
Al	0.0	0.1
SiO_2	--	15
Total Solids	--	926

Note: All values are in mg/l, except pH (units) and specific conductance (umhos/cm).

-- = Not reported.

Abbreviations:

$CaCO_3$ = calcium carbonate.
PO_4 = phosphate.
NO_3 = nitrate.
F = fluorine.
Cl = chlorine.
SO_4 = sulfate.
HCO_3 = bicarbonate.
K = potassium.
Na = sodium.
Mg = magnesium.
Ca = calcium.
Mn = manganese.
Fe = iron.
Al = aluminum.
SiO_2 = silicon dioxide.
umhos/cm = micromhos per centimeter.

Source: Gardner and Johnson, 1974.

6.7.2.2 Dredging and Spoil Disposal

The Cooper River and Charleston Harbor have a shoaling problem, and approximately 60 million cubic yards of silt must be removed annually to maintain a 35-foot shipping channel (SOUTHDIV, n.d.). COE is charged with dredging the river channel and NAVBASE Charleston docking berths. Dredged spoil is disposed of on a designated spoil disposal area on the east bank of the Cooper River, due east of NAVBASE Charleston. When filled to capacity, additional upland or wetland areas will be required for a new spoil disposal area.

Maintenance dredging of the river channel may adversely impact aquatic biota through habitat destruction/modification, siltation, or displacement. Spoil disposal in new areas causes the destruction of existing habitats or wetlands. Although such spoil disposal has little benefit to wildlife during early phases, stabilized spoil banks provide valuable roosting and nesting habitats for a variety of shore and water birds (Parnell et al., 1978). Following the establishment of shrub and tree communities (as on the southern portion of NAVBASE Charleston), former spoil areas can provide wildlife habitat for a variety of species.

6.7.2.3 Endangered and Threatened Species

Twelve animal species and one plant species listed as endangered or threatened by FWS and WMRD have been reported from coastal Charleston County (table 5.4-2). Six of these species are occasional transients in the lower Cooper River and associated wetlands along NAVBASE Charleston. No adverse impacts were determined on these species from past or present base activities. None of these six protected species is expected to remain or reproduce in the vicinity of NAVBASE Charleston due to:

1. Absence of extensive areas of suitable feeding habitat (manatee, short-nosed sturgeon), and

2. Absence of suitable nest sites (bald eagle, peregrine falcon, brown pelican, alligator).

6.7.2.4 Summary

Potential impacts from POL, spoil dredging and disposal, surface runoff, and other NAVBASE Charleston activities on onsite and surrounding wildlife and vegetation are partially mitigated or eliminated due to:

1. The presence of highly developed industrial, commercial, and residential areas along the northern, western, and southern boundaries of the base.

2. The high degree of development on NAVBASE Charleston property. As a result, the base lacks extensive tracts of natural terrestrial habitats and has limited amounts of wildlife habitat (ruderal areas, tidal marsh). This is reflected in the onsite species composition, which consists primarily of common species or species adapted to urban habitats.

3. The location of NAVBASE Charleston, which is too far upstream for many estuarine or marine species (such as marine turtles, seals, or cetaceans), yet waters are too saline for most amphibians and Sagittaria fasciculata (listed as endangered by FWS).

4. The absence of most protected species listed as endangered or threatened by FWS and the State of South Carolina from NAVBASE Charleston property. A 1979 letter from the FWS Endangered Species Coordinator states that: "Charleston Naval Station/ Naval Base does not have any areas that may be classified as 'critical habitat,' nor does it appear that operation of this facility will present any foreseeable problem for Federally listed endangered and threatened species" (Personal Communication, 1979).

5. The use of existing dredge spoil disposal areas located on the east bank of the Cooper River.

6. Landscaping throughout developed portions of NAVBASE Charleston (SOUTHDIV, 1977), which helps retain surface runoff and provides habitat for several species of wildlife.

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APPENDIX

Biota on NAVBASE Charleston and Vicinity

APPENDIX

REGIONAL ECOLOGY

Vegetation associations in coastal Charleston County, S.C., are typical of those found along the South Atlantic coastline and range from barren shoreline to outer Coastal Plain forest (Bailey, 1976; Steele, 1974; Shealy and Bishop, 1979). Along the Atlantic, bare sandy beach separates the surf from sand dunes covered by halophytes such as salt-meadow cordgrass (Spartina patens), sandspur (Cenchrus tribuloides), sea oats (Unicola paniculata), sea rocket (Cakile harperi), and sea-purslane (Sesuvium portulacastrum).

Extensive tidal marshes, dominated by cordgrass (Spartina spp.) and spike rush (Juncus roemerianus), occur between beaches and uplands and along inlets and river basins. Due to the flat topography and numerous streams and creeks, tidal marsh covers more than 20 percent of Charleston County (SOUTHDIV, n.d.). Uplands adjoining these marshes support pine flatwoods and Coastal Plain forest, and contain freshwater marshes and hardwood swamps.

Plant-species composition in coastal Charleston County is determined by proximity to salt water and by degree of inundation. This relationship results in a well-defined vegetation zonation between shoreline and uplands (Kurz and Wagner, 1957). Tidal shoreline areas, frequently inundated by salt water, contain a saltmarsh cordgrass (Spartina alterniflora) zone. An adjoining zone of spike rush grows on slightly higher ground, which is subject to less flooding. A barren zone commonly occurs at the high tide line where phytotoxic salt and chlorine levels exclude most seed plants; less toxic submerged portions of this zone support spikegrass (Distichlis spicata) and glassworts (Salicornia spp.).

Cordgrass and rushes cover the lower portions and shrub communities the higher portions of tidal marshes, spoil banks, and barrier beaches in Charleston County. Groundsel-bush (Baccharis halimifolia), marsh elder (Iva frutescens), youpon (Ilex vomitoria), and wax myrtle (Myrica cerifera) dominate coastal shrub zones. Interspersed trees include live oak (Quercus virginiana), southern red cedar (Juniperus silicicola), and cabbage palm (Sabal palmetto).

Pine flatwoods adjoining tidal marsh are dominated by slash pine (Pinus elliottii) and longleaf pine (P. palustris), with an understory of gallberry (Ilex glabra), wax myrtle, palmetto (Serenoa repens), and wiregrass (Aristida stricta), among others.

Mixed southeastern coastal forest and hardwood swamps are dominated by oaks, pines, gums (Liquidambar styraciflua, Nyssa spp.),

hickories (Carya spp.), ashes (Fraxinus spp.), and bays (Magnolia spp., Gordonia sp., Persea sp.). An annotated checklist of the coastal zone vegetation of South Carolina is found in Zingmark (1978).

The wildlife composition of coastal Charleston County is diverse and includes terrestrial, aquatic, and marine mammals; numerous resident and migratory inland and coastal birds; and a variety of reptiles and amphibians. This diversity of vertebrates results from a variety of wildlife habitats, ranging from coastal and estuarine wetlands to upland oak hammocks and pine flatwoods. Due to its location, the South Carolina coastal region also represents the southern- and northernmost range limits for a number of terrestrial and aquatic species (Zingmark, 1978). In addition, this coastal area serves as an important stopover and wintering area for migrant birds following the Atlantic flyway. The South Atlantic region has supported about 40 percent of the Atlantic flyway wintering bird population, with more than 310,000 waterfowl remaining annually in coastal South Carolina during 1977-79 (Gusey, 1981).

Thirty-nine species of terrestrial mammals are native to the coastal region of South Carolina (Sanders, 1978) and may be expected to appear in Charleston Harbor. Marine mammals which occur regularly along the coast include one species each of seal, sirenian (manatee), and cetacean. Nineteen species of cetaceans (whales and dolphins) have been reported in the area from strandings. Excluding feral, extirpated, and accidental species, a total of 67 mammal species have been recorded in the South Carolina coastal area; their status and distributions are listed in Sanders (1978).

Almost 400 species of birds occur in the South Atlantic region between North Carolina and Florida (Gusey, 1981). Of these, 358 species of inland, coastal, and oceanic birds have been reported from coastal South Carolina (Forsythe, 1978).

An abundance of wetlands and aquatic habitats in coastal Charleston County provides excellent breeding and feeding areas for wading, shore, marsh, and water birds. In the vicinity of Charleston Harbor, three nesting colonies (Deveaux Bank, Bird Key, Drum Island) support up to 27,000 pairs of pelicans, herons, egrets, ibis, terns, gulls, skimmers, and oystercatchers (Custer and Osborne, 1975; Osborne and Custer, 1978; Gusey, 1981). Bird composition and population estimates on Drum Island, a spoil bank 1.5 miles south of NAVBASE Charleston, are listed in table A-1.

The herpetofauna of the South Carolina coastal zone contains approximately 83 percent of all species recorded in the state, including 65 species of reptiles and 45 species of amphibians. Although few amphibians occur in tidal habitats, reptiles, especially turtles, are abundant. The diamondback terrapin (Malaclemys terrapin) is the most common turtle in estuaries, saltmarshes, and brackish habitats of Charleston County; Atlantic loggerhead (Caretta caretta) is the most common marine turtle (Gibbons, 1978).

Table A-1
Breeding Bird Composition on Drum Island,
Charleston County, S.C.

Species	No. of Pairs Nesting*	Nesting Period
White ibis (Eudocimus alba)	1,500-4,000	Late February - August
Glossy ibis (Plegadis falcinellus)	200-2,500	March - late July
Cattle egret (Bubulcus ibis)	1,500-2,500	April - early September
Snowy egret (Egretta thula)	1,000-2,500	March - August
Little blue heron (Florida caerulea)	700-2,000	March - late July
Louisiana heron (Hydranassa tricolor)	500-1,500	March - August
Great egret (Casmerodius albus)	150-250	February - late July
Black-crowned night heron (Nycticorax nycticorax)	75-200	February - late August
Yellow-crowned night heron (Nyctanassa violacea)	50-200	February - August
Green heron (Butorides virescens)	5-10	March - August
Black-necked stilt (Himantopus mexicanus)	1-4	March - June

* Annual fluctuations depending on population, size, and survey dates.

Source: Gusey, 1981.

Protected wildlife species listed as threatened or endangered by FWS and State of South Carolina are discussed below.

Fish and aquatic invertebrates are abundant in the estuarine waters of lower Cooper River, Wando River, and Charleston Harbor. Forty-five species of fish and three species of invertebrates were caught during a 1972 tidal stream survey in the lower Cooper River Estuary (Lagman, et al., 1979). Ten of the 45 fish species constituted 95 percent of the total catch, and 3 species [immature Atlantic croaker (Micropogon undulatus), Atlantic menhaden (Brevoortia tyrannus), and mummichog (Fundulus heteroclitus)] accounted for 75 percent.

Stream surveys in Clouter Creek (two sites) and the Bushy Park industrial area (one site) produced a biomass of 249 pounds per acre. Invertebrates comprised 63 percent of this weight, fish 37 percent. Grass shrimp (Palaemonetes pugio) comprised 52 percent of the total biomass. Six species of fish, including American eel (Anguilla rostrata), striped mullet (Mugil cephalus), Atlantic croaker, Atlantic menhaden, white catfish (Ictalurus catus), and mummichog, composed 75 percent of the total fish biomass.

TERRESTRIAL ECOSYSTEMS

Dominant plant species occurring in open and wooded ruderal areas are listed in table A-2. Vegetation cover in ruderal areas ranges from less than 60-percent coverage in the northern, most recently disturbed areas to 100-percent coverage in the shrub- and tree-covered southern and western portions. The Clouter Creek spoil disposal area consists primarily of bare spoil material.

Nature hardwoods and pines, some measuring more than 3.5 feet in diameter at breast height (dbh), cover the housing area south of the golf course. Oaks and pines comprise the dominant canopy species, laurel and azaleas the dominant understory species in this area (table A-2).

Improved and semi-improved areas are found throughout the developed portions of NAVBASE Charleston. The locations of improved and semi-improved areas are shown in the base management plan (SOUTHDIV, 1977). Such areas consist primarily of maintained (seeded, sodded, mowed) grasslands with planted trees and shrubs.

Wildlife species recorded in these terrestrial habitats during a 3-day site survey of NAVBASE Charleston on 3-5 Aug 1981 consisted of common species and species adapted to urban habitats. Opossum, raccoon, eastern cottontail, marsh rabbit, and gray squirrel were the larger mammals recorded in shrub thickets and spoil successional forests.

Additional mammals expected in onsite terrestrial habitats include bats, moles, shrews, mice, and rats. Gray squirrel was the most conspicuous mammal in the wooded housing area. Due to the urban setting

Table A-2
Dominant Plants Recorded on NAVBASE Charleston

Plant	Common Name	Scientific Name
Ruderal Areas:		
Grasses		
	Broomsedge	(Andropogon viginicus)
	Bluegrasses	(Poa spp.)
	Sedges	(Carex spp.)
	Rushes	(Fimbristylis sp.)
	Curly dock	(Rumex crispus)
Forbs		
	Sheep sorrel	(Rumex acetocella)
	Green ameranth	(Ameranthus viridens)
	Pigweed	(Chenopodium album)
	Morning glory	(Ipomoea trichocarpa)
	Pokeweed	(Phytolacca americana)
	Coffeeweeds	(Cassia spp.)
	Virginia creeper	(Parthenocissus quinquefolia)
	Dogfennel	(Anthemis sp.)
	Poison ivy	(Toxicodendron radicans)
	Trumpet vine	(Campsis radicans)
	Honeysuckle	(Lonicera japonica)
Shrubs and Trees		
	Groundsel bush	(Baccharis halimifolia)
	Marsh elder	(Iva frutescens)
	Wax myrtle	(Myrica cerifera)
	Southern red cedar.	(Juniperus silicicola)
	Winged sumac	(Rhus copallina)
	Black cherry	(Prunus serotina)
Spoil Forest		
	Mulberry	(Morus rubra)
	Hackberry	(Celtis laevigata)
	Tallowtree	(Sapium sebiferum)
	Red maple	(Acer rubrum)
Married Officer's Housing Area:		
	Live oak	(Quercus virginiana)
	Water oak	(Quercus niger)
	Pin oak	(Quercus palustris)
	Loblolly pine	(Pinus taeda)
	Longleaf pine	(Pinus palustris)
	Hickory	(Carya sp.)
	Flowering dogwood	(Cornus florida)
	Red cedar	(Juniperus silicicola)
	Southern magnolia	(Magnolia grandiflora)
	Azalea	(Rhododendran spp.)

Source: ESE, 1981.

of the installation, white-tailed deer (Odocoileus virginiana) are not expected to occur on NAVBASE Charleston; however, limited habitat exists on the southern, wooded portion of the base.

Birds were abundant in open ruderal areas, shrub thickets, and woodlands. Terrestrial bird species most commonly observed during the August survey are listed in table A-3. Ospreys (Pandion haliaetus) nest on an antenna on the southern portion of NAVBASE Charleston.

Six-lined racerunner and green anole were common in open spoil and shrub thicket habitats, respectively. Common reptiles expected but not observed include eastern box turtle, southern black racer, and yellow rat snake.

WETLAND ECOSYSTEMS

Tidal marshes along Shipyard Creek, Noisette Creek, and Cooper River are similar and consist of homogeneous expanses of cordgrass (Spartina alterniflora, S. patens). Low sections of these marshes are inundated during high tides, while higher, drier areas support small shrub communities and hardwood stands (table A-4). Cabbage palm and small live oak grow on surrounding, noninundated areas along Shipyard and Noisette Creeks.

A small, freshwater marsh is located between Dyess and Hobson Ave., southeast of Bldg. 161. This marsh is overgrown by dense cattail, mallow, and bladderpod. Willows, shrubs, reeds, and briers surround inundated portions of the marsh, along with numerous tallow and mulberry trees.

Small, onsite drainages are fringed by cordgrass, reeds, and shrubs. Such drainages are located east of the coal storage area south of Noisette Creek, in the upper Shipyard Creek basin, and along the southern boundary road.

The wildlife composition in NAVBASE Charleston wetlands varies with vegetation structure. Based on track sightings, raccoon, marsh rabbit, and muskrat are the most common mammals in onsite marshes, feeding on ubiquitous fiddlercrab (Uca sp.) and marsh vegetation.

Wading birds, rails, blackbirds, marshwrens, and ospreys are commonly observed in onsite Spartina marshes. Migratory waterfowl are expected to utilize these marshes during fall and winter (State of South Carolina, 1972).

Marshes and drainages covered by dense cattail-shrub vegetation contain red-winged blackbirds, common yellowthroats, and catbirds. Bird species diversity in this, as well as in all other NAVBASE Charleston habitats, is expected to increase during spring and fall migratory periods.

Although no reptiles or amphibians were recorded in NAVBASE Charleston marshes during the August survey, the diamondback terrapin (Malaclemys terrapin) is expected to be the most common reptile in tidal marshes (Army, 1977). This commercially valuable species is common in estuaries, saltmarshes, and brackish habitats along the South Carolina coast (Gibbons, 1978).

Common wildlife species observed on NAVBASE Charleston wetlands and marshes are listed in table A-5.

AQUATIC ECOSYSTEMS

Calculations of biomass production, added to these systems annually, are discussed in State of South Carolina, 1972. Seventy fish species were recorded in Charleston Harbor in a 1971 Marine Resource Center study (State of South Carolina, 1972), and 73 fish species have been identified in the Cooper River (Army, 1976b). Numerous bluecrabs and fiddler crabs were observed in inter-tidal areas of NAVBASE Charleston.

Pelicans (Pelecanus occidentalis), gulls, terns, cormorants, and migratory loons, grebes, and waterfowl are the most common and conspicuous birds of the lower Cooper River and Charleston Harbor. Resident and migratory waterbirds recorded in the vicinity of NAVBASE Charleston are listed in Army (1976b; 1977).

The diamondback terrapin is the only resident reptile of estuarine areas, with the exception of an occasional Atlantic loggerhead turtle (Caretta caretta), alligator (Alligator mississippiensis), and occasional snakes (Nerodia spp.) [U.S. National Oceanographic and Atmospheric Administration (NOAA), 1979].

A summary of aquatic ecosystems on NAVBASE Charleston and vicinity appears in table A-6. Tables A-7 and A-8 provide listings of fish and aquatic mammals occurring in Charleston Harbor and/or the Lower Cooper River.

THREATENED AND ENDANGERED SPECIES

South Carolina endangered species are "any species or subspecies of wildlife whose prospects of survival or recruitment within the State are in jeopardy or are likely within the forseeable future to become so," due to habitat destruction or modification; overutilization; effects of disease, pollution, or predation; and natural or manmade factors affecting its prospects for survival or recruitment within the state. It also includes all species on the Federal list (State of South Carolina, 1976).

Additional endangered species occurring along the coast of South Carolina include three species of marine turtles and seven species of cetaceans (Zingmark, 1978; Hall, 1981). These species are not expected

Table A-5
Common Wetland Mammals and Birds Recorded on NAVBASE Charleston During an August 1981 Site Survey

Animal	Common Name	Scientific Name
Mammals		
	Muskrat	(*Ondatra zibethica*)
	Raccoon	(*Procyon lotor*)
	Marsh rabbit	(*Sylvilagus palustris*)
Birds		
	Osprey	(*Pandion haliaetus*)
	Great egret	(*Casmerodius albus*)
	Snowy egret	(*Egretta thula*)
	Little blue heron	(*Florida caerulea*)
	Clapper rail	(*Rallus longirostris*)
	Boat-tailed grackle	(*Quiscalus major*)
	Red-winged blackbird	(*Agelaius phoenicus*)
	Long-billed marsh wren	(*Cistothorus palustris*)
	Common yellowthroat	(*Geothlypsis trichas*)

Source: ESE, 1981.

Table A-6
Aquatic Ecosystems on NAVBASE Charleston and Vicinity

Habitat	Ecology
Cooper River	The Cooper River Basin comprises 720 square miles of Coastal Plain in South Carolina. The Cooper River originates at the confluence of its east and west branches in Berkely County, S.C. and flows 32-miles southward to its outlet in Charleston Harbor. Its flow contains a large volume of water released from Pinopolis Dam for power generation. With the exception of some undeveloped sections, the west bank of the Cooper River is lined with Federal, State, and private docking facilities. Its east bank is largely undeveloped but contains a number of spoil disposal areas.
Shipyard Creek	Shipyard Creek is a small tributary, less than 1 mile in length, extending southeastward along the southwestern boundary of NAVBASE Charleston; it joins the Cooper River at river mile 8.7. Docking facilities are located along its western shore, while tidal marsh covers most of the eastern shoreline.
Noisette Creek	Noisette Creek is a small tributary of the Cooper River traversing the northern-most portion of NAVBASE Charleston. This shallow creek is surrounded by tidal marsh along most of its 2-mile length.
Clouter Creek	Clouter Creek is a small branch of the Cooper River surrounding the Naval spoil disposal area and adjoining marshes between river miles 11 and 15. Both sides of Clouter Creek are lined by extensive tidal marshes.

Table A-6
Aquatic Ecosystems on NAVBASE Charleston and Vicinity
(Continued, Page 2 of 2)

Habitat	Ecology
Wando River	The Wando River is a small coastal stream, with a watershed of approximately 120 square miles. It flows along the eastern shore of Daniel Island and joins the Cooper River at the southern tip of this island, 1 mile north of Grace Memorial (U.S. 17) Bridge. The lower Wando River is bordered by tidal marshes, the upper section by woodland.
Charleston Harbor	Charleston Harbor is a natural harbor, approximately 25 square miles in size and between 10 and 25 feet in depth; the depth in the ship channel is maintained at 35 feet. The City of Charleston is located in the northwestern corner of the harbor; smaller municipalities are located along its eastern shore. Spoil areas, islands, tidal flats, shoals, and extensive saltmarsh communities are located in and around this harbor. As discussed in section 5.4-2, Charleston Harbor provides important summer and wintering habitats for gulls, terns, pelicans, ospreys, and migratory waterfowl and shorebirds. It contains important nursery grounds for a variety of finfish and shellfish and supports an extensive sport and commercial fishery. The Charleston Harbor estuary has been studied to provide a complete inventory and evaluation of associated wetlands to determine their quality and quantity (State of South Carolina, 1972).

Source: Army, 1976b; Army, 1977.

Table A-7
Game and Commercially Important Fin- and Shellfish
Occurring in Charleston Harbor and the Lower Cooper River

Animal	Common Name	Scientific Name
Fish		
	Striped bass	(Marone saxatilis)
	Blueback herring	(Alosa aestivalis)
	Shad	(Alosa sapidissima)
	Spot	(Leiostomus xanthurus)
	Weakfish	(Cynoscion sp.)
	Atlantic croaker	(Micropogon undulatus)
	Red drum	(Sciaenops ocellata)
	Northern kingfish	(Menticirrhus sexatilis)
	Bluefish	(Pomatomus saltatrix)
	Summer flounder	(Paralichthys lethostigma)
	Catfish	(Ictalurus spp.)
Invertebrates and Mollusks		
	White shrimp	(Penaeus setiferus)
	Brown shrimp	(Penaeus aztecus)
	Blue crab	(Callinectes sapidus)
	Scallops	(Aequipecten sp.)
	Quahogs	(Mercenaria sp.)
	Oyster	(Crassostrea virginica)

Sources: Army, 1976b; Army, 1977; Shell Oil Co., 1981.

Table A-8
Aquatic Mammals Recorded in Charleston Harbor or the
Lower Cooper River, Charleston County, S.C.

Common Name	Scientific Name
Muskrat	(Ondatra zibethica)
River otter	(Lutra canadensis)
Harbor seal	(Phoca vitulina)
Bottle-nosed dolphin	(Tursiops truncatus)
Common dolphin	(Delphinus delphis)
Manatee	(Trichechus manatus)

Sources: Shell Oil Co., 1981; Army, 1977; ESE, 1981.

to enter Charleston Harbor or the lower Cooper River. The Eskimo curlew (Numenius borealis) and ivory-billed woodpecker (Campephilus principalis) are assumed extirpated in South Carolina (c.f.: Forsythe, 1978; State of South Carolina and The Citadel, 1976). Reported ranges for other South Carolina endangered species lie outside the Charleston County area.

The following species may occur on or in the vicinity of NAVBASE Charleston:

1. Florida manatee (Trichechus manatus)--Listed as endangered by FWS and WMRD, this marine mammal is an uncommon summer resident of South Carolina coastal waters. Manatees are expected to occur in Charleston Harbor and have been observed in the Cooper River along NAVBASE Charleston (Personal Communication, 1981).

2. Florida panther (Felis concolor coryi)--Listed as endangered by FWS and WMRD, some panthers may still exist in large river swamps of the South Carolina Coastal Plain (c.f.: Sanders, 1978; State of South Carolina and The Citadel, 1976). However, recent observations and reports have not been verified. No panthers are expected in the vicinity of NAVBASE Charleston, due to its urban setting and absence of suitable habitat.

3. Southern bald eagle (Haliaeetus l. leucocephalus)--Listed as endangered by FWS and WMRD, bald eagles occur in South Carolina as summer residents and winter migrants. They occur primarily on the Coastal Plain and may be expected along the Cooper River and Charleston Harbor. No nesting is expected at NAVBASE Charleston, due to its urban setting and lack of suitable nesting habitat.

4. Peregrine falcon (Falco peregrinus)--The American peregrine falcon (F. p. anatum) and Arctic peregrine falcon (F. p. tundrius), both listed as endangered by FWS and WMRD, are two subspecies occurring in coastal South Carolina during fall and winter migration periods (State of South Carolina and The Citadel, 1976; FWS, 1979). No nest sites are known from Charleston County, and no release sites or hack sites are planned (FWS, 1979). Due to the scarcity of this species and the absence of suitable feeding habitats, no peregrine falcons are expected at NAVBASE Charleston.

5. Brown pelican (Pelecanus occidentalis)--This species is listed as endangered by FWS and WMRD, but is a common resident of coastal Charleston County. Approximately 1,000 breeding brown pelicans were recorded nesting on Devaux Bank in 1975 and 1976 (Custer and Osborn, 1975). Colonial nesting occurs on coastal islands, and feeding occurs in coastal and estuarine water. No pelicans are expected to

nest in the vicinity of NAVBASE Charleston, and only occasional individuals are expected on the lower Cooper River.

6. Bachman's warbler (Vermivora bachmanii)--This species is listed as endangered by FWS and WMRD. It is the rarest and least known of North American warblers and, unless extirpated, would be expected in wooded swamps of the South Carolina Coastal Plain (Forsythe, 1978). Bachman's warbler is sporadically reported from the I'On Swamp in the Francis Marion National Forest (State of South Carolina and The Citadel, 1976). Due to the scarcity of this species and the absence of suitable habitat in the vicinity of NAVBASE Charleston, this species is not expected to occur onbase.

7. Kirtland's warbler (Dendroica kirtlandii)--This species is listed as endangered by FWS and WMRD and is the second rarest North American warbler. It nests exclusively in northern lower Michigan and is a rare transient on migration through South Carolina (nine records) (State of South Carolina and The Citadel, 1976). Due to its scarcity and to the absence of suitable habitat, this species is not expected on or in the vicinity of NAVBASE Charleston.

8. Red-cockaded woodpecker (Picoides borealis)--Although listed as endangered by FWS and WMRD, this species is fairly common in some areas of South Carolina, including sections of the Francis Marion National Forest (State of South Carolina and The Citadel, 1976; NWS, 1977). This species requires stands of mature pines (80+ years old) with an open understory (Thompson, 1971; State of South Carolina and The Citadel, 1976). Due to the absence of suitable habitat, this species is not expected on NAVBASE Charleston.

9. American alligator (Alligator mississippiensis)--In South Carolina, FWS lists the alligator as threatened in areas east of alternate U.S. Highway 17 between Georgetown and Walterboro and as endangered in areas west thereof (FWS, 1980b); it is listed as endangered by WMRD. Alligators are primarily found in fresh and brackish wetlands but also occur in estuaries. They have been reported from NWS (NWS, 1977) and lower Wando River (Army, 1977). Due to the presence of estuarine habitats on NAVBASE Charleston and the presence of alligators in the lower Cooper-Wando River area, alligators may be occasionally expected on or in the vicinity of NAVBASE Charleston.

10. Atlantic green turtle (Chelonia mydas)--This turtle is listed as threatened by FWS in South Carolina and as endangered by WMRD. This strictly marine turtle is rarely encountered during the summer months off the South Carolina coasts (Gibbons, 1978). It may have formerly nested on State

code of federal regulations

Energy

10

PARTS 0 TO 50

Revised as of January 1, 1994

PART 20

NATIONAL ARCHIVES AND RECORDS ADMINISTRATION
1985

(i) Sections 53, 57, 62, 63, 81, 82, 101, 103, 104, 107, or 109 of the Atomic Energy Act of 1954, as amended;

(ii) Section 206 of the Energy Reorganization Act;

(iii) Any rule, regulation, or order issued pursuant to the sections specified in paragraph (b)(1)(i) of this section;

(iv) Any term, condition, or limitation of any license issued under the sections specified in paragraph (b)(1)(i) of this section.

(2) For any violation for which a license may be revoked under section 186 of the Atomic Energy Act of 1954, as amended.

[57 FR 55071, Nov. 24, 1992]

§ 19.31 Application for exemptions.

The Commission may upon application by any licensee or upon its own initiative, grant such exemptions from the requirements of the regulations in this part as it determines are authorized by law and will not result in undue hazard to life or property.

§ 19.32 Discrimination prohibited.

No person shall on the ground of sex be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any program or activity licensed by the Nuclear Regulatory Commission. This provision will be enforced through agency provisions and rules similar to those already established, with respect to racial and other discrimination, under title VI of the Civil Rights Act of 1964. This remedy is not exclusive, however, and will not prejudice or cut off any other legal remedies available to a discriminatee.

[40 FR 8783, Mar. 3, 1975]

§ 19.40 Criminal penalties.

(a) Section 223 of the Atomic Energy Act of 1954, as amended, provides for criminal sanctions for willful violation of, attempted violation of, or conspiracy to violate, any regulation issued under sections 161b, 161i, or 161o of the Act. For purposes of section 223, all the regulations in part 19 are issued under one or more of sections 161b, 161i, or 161o, except for the sections listed in paragraph (b) of this section.

(b) The regulations in part 19 that are not issued under sections 161b, 161i, or 161o for the purposes of section 223 are as follows: §§ 19.1, 19.2, 19.3, 19.4, 19.5, 19.8, 19.16, 19.17, 19.18, 19.30, 19.31, and 19.40.

[57 FR 55071, Nov. 24, 1992]

PART 20—STANDARDS FOR PROTECTION AGAINST RADIATION

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APPENDIX B TO PART 20—ANNUAL LIMITS ON INTAKE (ALIS) AND DERIVED AIR CONCENTRATIONS (DACS) OF RADIONUCLIDES FOR OCCUPATIONAL EXPOSURE; EFFLUENT CONCENTRATIONS; CONCENTRATIONS FOR RELEASE TO SEWERAGE
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APPENDIX E TO PART 20—[RESERVED]
APPENDIX F TO PART 20—REQUIREMENTS FOR LOW-LEVEL-WASTE TRANSFER FOR DISPOSAL AT LAND DISPOSAL FACILITIES AND MANIFESTS

AUTHORITY: Secs. 53, 63, 65, 81, 103, 104, 161, 182, 186, 68 Stat. 930, 933, 935, 936, 937, 948, 953, 955, as amended (2 U.S.C. 2073, 2093, 2095, 2111, 2133, 2134, 2201, 2232, 2236), secs. 201, as amended, 202, 206, 88 Stat. 1242, as amended, 1244, 1246 (42 U.S.C. 5841, 5842, 5846).

Subpart A—General Provisions

SOURCE: 56 FR 23391, May 21, 1991, unless otherwise noted.

§ 20.1001 Purpose.

(a) The regulations in this part establish standards for protection against ionizing radiation resulting from activities conducted under licenses issued by the Nuclear Regulatory Commission. These regulations are issued under the Atomic Energy Act of 1954, as amended, and the Energy Reorganization Act of 1974, as amended.

(b) It is the purpose of the regulations in this part to control the receipt, possession, use, transfer, and disposal of licensed material by any licensee in such a manner that the total dose to an individual (including doses

resulting from licensed and unlicensed radioactive material and from radiation sources other than background radiation) does not exceed the standards for protection against radiation prescribed in the regulations in this part. However, nothing in this part shall be construed as limiting actions that may be necessary to protect health and safety.

§ 20.1002 Scope.

The regulations in this part apply to persons licensed by the Commission to receive, possess, use, transfer, or dispose of byproduct, source, or special nuclear material or to operate a production or utilization facility under parts 30 through 36, 39, 40, 50, 60, 61, 70, or 72 of this chapter. The limits in this part do not apply to doses due to background radiation, to exposure of patients to radiation for the purpose of medical diagnosis or therapy, or to voluntary participation in medical research programs.

[56 FR 23391, May 21, 1991, as amended at 58 FR 7736, Feb. 9, 1993]

§ 20.1003 Definitions.

As used in this part:

Absorbed dose means the energy imparted by ionizing radiation per unit mass of irradiated material. The units of absorbed dose are the rad and the gray (Gy).

Act means the Atomic Energy Act of 1954 (42 U.S.C. 2011 *et seq.*), as amended.

Activity is the rate of disintegration (transformation) or decay of radioactive material. The units of activity are the curie (Ci) and the becquerel (Bq).

Adult means an individual 18 or more years of age.

Airborne radioactive material means radioactive material dispersed in the air in the form of dusts, fumes, particulates, mists, vapors, or gases.

Airborne radioactivity area means a room, enclosure, or area in which airborne radioactive materials, composed wholly or partly of licensed material, exist in concentrations—

(1) In excess of the derived air concentrations (DACs) specified in appendix B, to §§ 20.1001–20.2401, or

(2) To such a degree that an individual present in the area without respiratory protective equipment could exceed, during the hours an individual is present in a week, an intake of 0.6 percent of the annual limit on intake (ALI) or 12 DAC-hours.

ALARA (acronym for "as low as is reasonably achievable") means making every reasonable effort to maintain exposures to radiation as far below the dose limits in this part as is practical consistent with the purpose for which the licensed activity is undertaken, taking into account the state of technology, the economics of improvements in relation to state of technology, the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations, and in relation to utilization of nuclear energy and licensed materials in the public interest.

Annual limit on intake (ALI) means the derived limit for the amount of radioactive material taken into the body of an adult worker by inhalation or ingestion in a year. ALI is the smallest value of intake of a given radionuclide in a year by the reference man that would result in a committed effective dose equivalent of 5 rems (0.05 Sv) or a committed dose equivalent of 50 rems (0.5 Sv) to any individual organ or tissue. (ALI values for intake by ingestion and by inhalation of selected radionuclides are given in Table 1, Columns 1 and 2, of appendix B to §§ 20.1001–20.2401).

Background radiation means radiation from cosmic sources; naturally occurring radioactive materials, including radon (except as a decay product of source or special nuclear material) and global fallout as it exists in the environment from the testing of nuclear explosive devices. "Background radiation" does not include radiation from source, byproduct, or special nuclear materials regulated by the Commission.

Bioassay (radiobioassay) means the determination of kinds, quantities or concentrations, and, in some cases, the locations of radioactive material in the human body, whether by direct measurement (in vivo counting) or by analysis and evaluation of materials excreted or removed from the human body.

Byproduct material means—

(1) Any radioactive material (except special nuclear material) yielded in, or made radioactive by, exposure to the radiation incident to the process of producing or utilizing special nuclear material; and

(2) The tailings or wastes produced by the extraction or concentration of uranium or thorium from ore processed primarily for its source material content, including discrete surface wastes resulting from uranium solution extraction processes. Underground ore bodies depleted by these solution extraction operations do not constitute "byproduct material" within this definition.

Class (or *lung class* or *inhalation class*) means a classification scheme for inhaled material according to its rate of clearance from the pulmonary region of the lung. Materials are classified as D, W, or Y, which applies to a range of clearance half-times: for Class D (Days) of less than 10 days, for Class W (Weeks) from 10 to 100 days, and for Class Y (Years) of greater than 100 days.

Collective dose is the sum of the individual doses received in a given period of time by a specified population from exposure to a specified source of radiation.

Commission means the Nuclear Regulatory Commission or its duly authorized representatives.

Committed dose equivalent ($H_{T,50}$) means the dose equivalent to organs or tissues of reference (T) that will be received from an intake of radioactive material by an individual during the 50-year period following the intake.

Committed effective dose equivalent ($H_{E,50}$) is the sum of the products of the weighting factors applicable to each of the body organs or tissues that are irradiated and the committed dose equivalent to these organs or tissues ($H_{E,50} = \Sigma w_T H_{T,50}$).

Controlled area means an area, outside of a restricted area but inside the site boundary, access to which can be limited by the licensee for any reason.

Declared pregnant woman means a woman who has voluntarily informed her employer, in writing, of her pregnancy and the estimated date of conception.

Deep-dose equivalent (H_d), which applies to external whole-body exposure, is the dose equivalent at a tissue depth of 1 cm (1000 mg/cm^2).

Department means the Department of Energy established by the Department of Energy Organization Act (Pub. L. 95–91, 91 Stat. 565, 42 U.S.C. 7101 *et seq.*) to the extent that the Department, or its duly authorized representatives, exercises functions formerly vested in the U.S. Atomic Energy Commission, its Chairman, members, officers, and components and transferred to the U.S. Energy Research and Development Administration and to the Administrator thereof pursuant to sections 104 (b), (c), and (d) of the Energy Reorganization Act of 1974 (Pub. L. 93–438, 88 Stat. 1233 at 1237, 42 U.S.C. 5814) and retransferred to the Secretary of Energy pursuant to section 301(a) of the Department of Energy Organization Act (Pub. L. 95–91, 91 Stat 565 at 577–578, 42 U.S.C. 7151).

Derived air concentration (DAC) means the concentration of a given radionuclide in air which, if breathed by the reference man for a working year of 2,000 hours under conditions of light work (inhalation rate 1.2 cubic meters of air per hour), results in an intake of one ALI. DAC values are given in Table 1, Column 3, of appendix B to §§ 20.1001–20.2401.

Derived air concentration-hour (DAC-hour) is the product of the concentration of radioactive material in air (expressed as a fraction or multiple of the derived air concentration for each radionuclide) and the time of exposure to that radionuclide, in hours. A licensee may take 2,000 DAC-hours to represent one ALI, equivalent to a committed effective dose equivalent of 5 rems (0.05 Sv).

Dose or *radiation dose* is a generic term that means absorbed dose, dose equivalent, effective dose equivalent, committed dose equivalent, committed effective dose equivalent, or total effective dose equivalent, as defined in other paragraphs of this section.

Dose equivalent (H_T) means the product of the absorbed dose in tissue, quality factor, and all other necessary modifying factors at the location of interest. The units of dose equivalent are the rem and sievert (Sv).

Dosimetry processor means an individual or organization that processes and evaluates individual monitoring equipment in order to determine the radiation dose delivered to the equipment.

Effective dose equivalent (H_E) is the sum of the products of the dose equivalent to the organ or tissue (H_T) and the weighting factors (w_T) applicable to each of the body organs or tissues that are irradiated ($H_E = \Sigma w_T H_T$).

Embryo/fetus means the developing human organism from conception until the time of birth.

Entrance or access point means any location through which an individual could gain access to radiation areas or to radioactive materials. This includes entry or exit portals of sufficient size to permit human entry, irrespective of their intended use.

Exposure means being exposed to ionizing radiation or to radioactive material.

External dose means that portion of the dose equivalent received from radiation sources outside the body.

Extremity means hand, elbow, arm below the elbow, foot, knee, or leg below the knee.

Eye dose equivalent applies to the external exposure of the lens of the eye and is taken as the dose equivalent at a tissue depth of 0.3 centimeter (300 mg/cm²).

Generally applicable environmental radiation standards means standards issued by the Environmental Protection Agency (EPA) under the authority of the Atomic Energy Act of 1954, as amended, that impose limits on radiation exposures or levels, or concentrations or quantities of radioactive material, in the general environment outside the boundaries of locations under the control of persons possessing or using radioactive material.

Government agency means any executive department, commission, independent establishment, corporation wholly or partly owned by the United States of America, which is an instrumentality of the United States, or any board, bureau, division, service, office, officer, authority, administration, or other establishment in the executive branch of the Government.

Gray [See § 20.1004].

High radiation area means an area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 0.1 rem (1 mSv) in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.

Individual means any human being.

Individual monitoring means—

(1) The assessment of dose equivalent by the use of devices designed to be worn by an individual;

(2) The assessment of committed effective dose equivalent by bioassay (see *Bioassay*) or by determination of the time-weighted air concentrations to which an individual has been exposed, i.e., DAC-hours; or

(3) The assessment of dose equivalent by the use of survey data.

Individual Monitoring Devices (individual monitoring equipment) means devices designed to be worn by a single individual for the assessment of dose equivalent such as film badges, thermoluminescent dosimeters (TLDs), pocket ionization chambers, and personal ("lapel") air sampling devices.

Internal dose means that portion of the dose equivalent received from radioactive material taken into the body.

License means a license issued under the regulations in parts 30 through 36, 39, 40, 50, 60, 61, 70, or 72 of this chapter.

Licensed material means source material, special nuclear material, or byproduct material received, possessed, used, transferred or disposed of under a general or specific license issued by the Commission.

Licensee means the holder of a license.

Limits (dose limits) means the permissible upper bounds of radiation doses.

Lost or missing licensed material means licensed material whose location is unknown. It includes material that has been shipped but has not reached its destination and whose location cannot be readily traced in the transportation system.

Member of the public means an individual in a controlled or unrestricted area. However, an individual is not a member of the public during any period in which the individual receives an occupational dose.

Minor means an individual less than 18 years of age.

Monitoring (radiation monitoring, radiation protection monitoring) means the measurement of radiation levels, concentrations, surface area concentrations or quantities of radioactive material and the use of the results of these measurements to evaluate potential exposures and doses.

Nonstochastic effect means health effects, the severity of which varies with the dose and for which a threshold is believed to exist. Radiation-induced cataract formation is an example of a nonstochastic effect (also called a deterministic effect).

NRC means the Nuclear Regulatory Commission or its duly authorized representatives.

Occupational dose means the dose received by an individual in a restricted area or in the course of employment in which the individual's assigned duties involve exposure to radiation and to radioactive material from licensed and unlicensed sources of radiation, whether in the possession of the licensee or other person. Occupational dose does not include dose received from background radiation, as a patient from medical practices, from voluntary participation in medical research programs, or as a member of the general public.

Person means—

(1) Any individual, corporation, partnership, firm, association, trust, estate, public or private institution, group, Government agency other than the Commission or the Department of Energy (except that the Department shall be considered a person within the meaning of the regulations in 10 CFR chapter I to the extent that its facilities and activities are subject to the licensing and related regulatory authority of the Commission under section 202 of the Energy Reorganization Act of 1974 (88 Stat. 1244), the Uranium Mill Tailings Radiation Control Act of 1978 (92 Stat. 3021), the Nuclear Waste Policy Act of 1982 (96 Stat. 2201), and section 3(b)(2) of the Low-Level Radioactive Waste Policy Amendments Act of 1985 (99 Stat. 1842)), any State or any political subdivision of or any political entity within a State, any foreign government or nation or any political subdivision of any such government or nation, or other entity; and

(2) Any legal successor, representative, agent, or agency of the foregoing.

Planned special exposure means an infrequent exposure to radiation, separate from and in addition to the annual dose limits.

Public dose means the dose received by a member of the public from exposure to radiation and to radioactive material released by a licensee, or to another source of radiation either within a licensee's controlled area or in unrestricted areas. It does not include occupational dose or doses received from background radiation, as a patient from medical practices, or from voluntary participation in medical research programs.

Quality Factor (Q) means the modifying factor (listed in tables 1004(b).1 and 1004(b).2 of § 20.1004) that is used to derive dose equivalent from absorbed dose.

Quarter means a period of time equal to one-fourth of the year observed by the licensee (approximately 13 consecutive weeks), providing that the beginning of the first quarter in a year coincides with the starting date of the year and that no day is omitted or duplicated in consecutive quarters.

Rad (See § 20.1004).

Radiation (ionizing radiation) means alpha particles, beta particles, gamma rays, x-rays, neutrons, high-speed electrons, high-speed protons, and other particles capable of producing ions. Radiation, as used in this part, does not include non-ionizing radiation, such as radio- or microwaves, or visible, infrared, or ultraviolet light.

Radiation area means an area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 0.005 rem (0.05 mSv) in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.

Reference man means a hypothetical aggregation of human physical and physiological characteristics arrived at by international consensus. These characteristics may be used by researchers and public health workers to standardize results of experiments and

to relate biological insult to a common base.

Rem (See § 20.1004).

Respiratory protective device means an apparatus, such as a respirator, used to reduce the individual's intake of airborne radioactive materials.

Restricted area means an area, access to which is limited by the licensee for the purpose of protecting individuals against undue risks from exposure to radiation and radioactive materials. Restricted area does not include areas used as residential quarters, but separate rooms in a residential building may be set apart as a restricted area.

Sanitary sewerage means a system of public sewers for carrying off waste water and refuse, but excluding sewage treatment facilities, septic tanks, and leach fields owned or operated by the licensee.

Shallow-dose equivalent (H_S), which applies to the external exposure of the skin or an extremity, is taken as the dose equivalent at a tissue depth of 0.007 centimeter (7 mg/cm^2) averaged over an area of 1 square centimeter.

Sievert (See § 20.1004).

Site boundary means that line beyond which the land or property is not owned, leased, or otherwise controlled by the licensee.

Source material means—

(1) Uranium or thorium or any combination of uranium and thorium in any physical or chemical form; or

(2) Ores that contain, by weight, one-twentieth of 1 percent (0.05 percent), or more, of uranium, thorium, or any combination of uranium and thorium. Source material does not include special nuclear material.

Special nuclear material means—

(1) Plutonium, uranium-233, uranium enriched in the isotope 233 or in the isotope 235, and any other material that the Commission, pursuant to the provisions of section 51 of the Act, determines to be special nuclear material, but does not include source material; or

(2) Any material artificially enriched by any of the foregoing but does not include source material.

Stochastic effects means health effects that occur randomly and for which the probability of the effect occurring, rather than its severity, is assumed to be a linear function of dose without threshold. Hereditary effects and cancer incidence are examples of stochastic effects.

Survey means an evalulation of the radiological conditions and potential hazards incident to the production, use, transfer, release, disposal, or presence of radioactive material or other sources of radiation. When appropriate, such an evaluation includes a physical survey of the location of radioactive material and measurements or calculations of levels of radiation, or concentrations or quantities of radioactive material present.

Total Effective Dose Equivalent (TEDE) means the sum of the deep-dose equivalent (for external exposures) and the committed effective dose equivalent (for internal exposures).

Unrestricted area means an area, access to which is neither limited nor controlled by the licensee.

Uranium fuel cycle means the operations of milling of uranium ore, chemical conversion of uranium, isotopic enrichment of uranium, fabrication of uranium fuel, generation of electricity by a light-water-cooled nuclear power plant using uranium fuel, and reprocessing of spent uranium fuel to the extent that these activities directly support the production of electrical power for public use. Uranium fuel cycle does not include mining operations, operations at waste disposal sites, transportation of radioactive material in support of these operations, and the reuse of recovered non-uranium special nuclear and byproduct materials from the cycle.

Very high radiation area means an area, accessible to individuals, in which radiation levels could result in an individual receiving an absorbed dose in excess of 500 rads (5 grays) in 1 hour at 1 meter from a radiation source or from any surface that the radiation penetrates.

(NOTE: At very high doses received at high dose rates, units of absorbed dose (e.g., rads and grays) are appropriate, rather than units of dose equivalent (e.g., rems and sieverts)).

Week means 7 consecutive days starting on Sunday.

Weighting factor w_T, for an organ or tissue (T) is the proportion of the risk of stochastic effects resulting from irradiation of that organ or tissue to the total risk of stochastic effects when the whole body is irradiated uniformly. For calculating the effective dose equivalent, the values of w_T are:

ORGAN DOSE WEIGHTING FACTORS

Organ or tissue	w_T
Gonads	0.25
Breast	0.15
Red bone marrow	0.12
Lung	0.12
Thyroid	0.03
Bone surfaces	0.03
Remainder	[1] 0.30
Whole Body	[2] 1.00

[1] 0.30 results from 0.06 for each of 5 "remainder" organs (excluding the skin and the lens of the eye) that receive the highest doses.

[2] For the purpose of weighting the external whole body dose (for adding it to the internal dose), a single weighting factor, w_T=1.0, has been specified. The use of other weighting factors for external exposure will be approved on a case-by-case basis until such time as specific guidance is issued.

Whole body means, for purposes of external exposure, head, trunk (including male gonads), arms above the elbow, or legs above the knee.

Working level (WL) is any combination of short-lived radon daughters (for radon-222: polonium-218, lead-214, bismuth-214, and polonium-214; and for radon-220: polonium-216, lead-212, bismuth-212, and polonium-212) in 1 liter of air that will result in the ultimate emission of 1.3×10^5 MeV of potential alpha particle energy.

Working level month (WLM) means an exposure to 1 working level for 170 hours (2,000 working hours per year/12 months per year=approximately 170 hours per month).

Year means the period of time beginning in January used to determine compliance with the provisions of this part. The licensee may change the starting date of the year used to determine compliance by the licensee provided that the change is made at the beginning of the year and that no day is omitted or duplicated in consecutive years.

[56 FR 23391, May 21, 1991, as amended at 57 FR 57878, Dec. 8, 1992; 58 FR 7736, Feb. 9, 1993]

§ 20.1004 Units of radiation dose.

(a) Definitions. As used in this part, the units of radiation dose are:

Gray (Gy) is the SI unit of absorbed dose. One gray is equal to an absorbed dose of 1 Joule/kilogram (100 rads).

Rad is the special unit of absorbed dose. One rad is equal to an absorbed dose of 100 ergs/gram or 0.01 joule/kilogram (0.01 gray).

Rem is the special unit of any of the quantities expressed as dose equivalent. The dose equivalent in rems is equal to the absorbed dose in rads multiplied by the quality factor (1 rem=0.01 sievert).

Sievert is the SI unit of any of the quantities expressed as dose equivalent. The dose equivalent in sieverts is equal to the absorbed dose in grays multiplied by the quality factor (1 Sv=100 rems).

(b) As used in this part, the quality factors for converting absorbed dose to dose equivalent are shown in table 1004(b).1.

TABLE 1004(b).1—QUALITY FACTORS AND ABSORBED DOSE EQUIVALENCIES

Type of radiation	Quality factor (Q)	Absorbed dose equal to a unit dose equivalent [a]
X-, gamma, or beta radiation	1	1
Alpha particles, multiple-charged particles, fission fragments and heavy particles of unknown charge	20	0.05
Neutrons of unknown energy	10	0.1
High-energy protons	10	0.1

[a] Absorbed dose in rad equal to 1 rem or the absorbed dose in gray equal to 1 sievert.

(c) If it is more convenient to measure the neutron fluence rate than to determine the neutron dose equivalent rate in rems per hour or sieverts per hour, as provided in paragraph (b) of this section, 1 rem (0.01 Sv) of neutron radiation of unknown energies may, for purposes of the regulations in this part, be assumed to result from a total fluence of 25 million neutrons per square centimeter incident upon the body. If sufficient information exists to estimate the approximate energy distribution of the neutrons, the licensee may use the fluence rate per unit dose equivalent or the appropriate Q value from table 1004(b).2 to convert a measured tissue dose in rads to dose equivalent in rems.

TABLE 1004(b).2—MEAN QUALITY FACTORS, Q, AND FLUENCE PER UNIT DOSE EQUIVALENT FOR MONOENERGETIC NEUTRONS

	Neutron energy (MeV)	Quality factor[a] (Q)	Fluence per unit dose equivalent[b] (neutrons cm^{-2} rem^{-1})
(thermal)	2.5×10^{-8}	2	980×10^{6}
	1×10^{-7}	2	980×10^{6}
	1×10^{-6}	2	810×10^{6}
	1×10^{-5}	2	810×10^{6}
	1×10^{-4}	2	840×10^{6}
	1×10^{-3}	2	980×10^{6}
	1×10^{-2}	2.5	1010×10^{6}
	1×10^{-1}	7.5	170×10^{6}
	5×10^{-1}	11	39×10^{6}
	1	11	27×10^{6}
	2.5	9	29×10^{6}
	5	8	23×10^{6}
	7	7	24×10^{6}
	10	6.5	24×10^{6}
	14	7.5	17×10^{6}
	20	8	16×10^{6}
	40	7	14×10^{6}
	60	5.5	16×10^{6}
	1×10^{2}	4	20×10^{6}
	2×10^{2}	3.5	19×10^{6}
	3×10^{2}	3.5	16×10^{6}
	4×10^{2}	3.5	14×10^{6}

[a] Value of quality factor (Q) at the point where the dose equivalent is maximum in a 30-cm diameter cylinder tissue-equivalent phantom.
[b] Monoenergetic neutrons incident normally on a 30-cm diameter cylinder tissue-equivalent phantom.

§ 20.1005 Units of radioactivity.

For the purposes of this part, activity is expressed in the special unit of curies (Ci) or in the SI unit of becquerels (Bq), or their multiples, or disintegrations (transformations) per unit of time.

(a) One becquerel=1 disintegration per second (s^{-1}).

(b) One curie=3.7×10^{10} disintegrations per second=3.7×10^{10} becquerels=2.22×10^{12} disintegrations per minute.

[56 FR 23391, May 21, 1991; 56 FR 61352, Dec. 3, 1991]

§ 20.1006 Interpretations.

Except as specifically authorized by the Commission in writing, no interpretation of the meaning of the regulations in this part by an officer or employee of the Commission other than a written interpretation by the General Counsel will be recognized to be binding upon the Commission.

§ 20.1007 Communications.

Unless otherwise specified, communications or reports concerning the regulations in this part should be addressed to the Executive Director for Operations, U.S. Nuclear Regulatory Commission, Washington, DC 20555. A communication, report, or application may be delivered in person to the Office of the Executive Director for Operations, 11555 Rockville Pike, Rockville, MD 20852.

§ 20.1008—[Reserved]

§ 20.1009 Reporting, recording, and application requirements: OMB approval.

(a) The Nuclear Regulatory Commission has submitted the information collection requirements contained in this part to the Office of Management and Budget (OMB) for approval as required by the Paperwork Reduction Act of 1980 (44 U.S.C. 3501 *et seq.*). OMB has approved the information collection requirements contained in this part under control number 3150-0014.

(b) The approved information collection requirements contained in this part appear in §§ 20.1101, 20.1202, 20.1204, 20.1206, 20.1301, 20.1501, 20.1601, 20.1703, 20.1901, 20.1902, 20.1904, 20.1906, 20.2002, 20.2004, 20.2006, 20.2102, 20.2103, 20.2104, 20.2105, 20.2106, 20.2107, 20.2108, 20.2110, 20.2201, 20.2202, 20.2203, 20.2204, 20.2206, and appendix F to 20.1001-20.2401.

(c) This part contains information collection requirements in addition to those approved under the control number specified in paragraph (a) of this section. These information collection requirements and the control numbers under which they are approved are as follows:

(1) In § 20.2104, NRC Form 4 is approved under control number 3150-0005.

(2) In §§ 20.2106 and 20.2206, NRC Form 5 is approved under control number 3150-0006.

[57 FR 57878, Dec. 8, 1992]

Subpart B—Radiation Protection Programs

SOURCE: 56 FR 23396, May 21, 1991, unless otherwise noted.

§ 20.1101 Radiation protection programs.

(a) Each licensee shall develop, document, and implement a radiation protection program commensurate with the scope and extent of licensed activities and sufficient to ensure compliance with the provisions of this part. (See § 20.2102 for recordkeeping requirements relating to these programs.)

(b) The licensee shall use, to the extent practicable, procedures and engineering controls based upon sound radiation protection principles to achieve occupational doses and doses to members of the public that are as low as is reasonably achievable (ALARA).

(c) The licensee shall periodically (at least annually) review the radiation protection program content and implementation.

Subpart C—Occupational Dose Limits

SOURCE: 56 FR 23396, May 21, 1991, unless otherwise noted.

§ 20.1201 Occupational dose limits for adults.

(a) The licensee shall control the occupational dose to individual adults, except for planned special exposures under § 20.1206, to the following dose limits.

(1) An annual limit, which is the more limiting of—

(i) The total effective dose equivalent being equal to 5 rems (0.05 Sv); or

(ii) The sum of the deep-dose equivalent and the committed dose equivalent to any individual organ or tissue other than the lens of the eye being equal to 50 rems (0.5 Sv).

(2) The annual limits to the lens of the eye, to the skin, and to the extremities, which are:

(i) An eye dose equivalent of 15 rems (0.15 Sv), and

(ii) A shallow-dose equivalent of 50 rems (0.50 Sv) to the skin or to any extremity.

(b) Doses received in excess of the annual limits, including doses received during accidents, emergencies, and planned special exposures, must be subtracted from the limits for planned special exposures that the individual may receive during the current year (see § 20.1206(e)(1)) and during the individual's lifetime (see § 20.1206(e)(2)).

(c) The assigned deep-dose equivalent and shallow-dose equivalent must be for the part of the body receiving the highest exposure. The deep-dose equivalent, eye dose equivalent and shallow-dose equivalent may be assessed from surveys or other radiation measurements for the purpose of demonstrating compliance with the occupational dose limits, if the individual monitoring device was not in the region of highest potential exposure, or the results of individual monitoring are unavailable.

(d) Derived air concentration (DAC) and annual limit on intake (ALI) values are presented in table 1 of appendix B to §§ 20.1001-20.2401 and may be used to determine the individual's dose (see § 20.2106) and to demonstrate compliance with the occupational dose limits.

(e) In addition to the annual dose limits, the licensee shall limit the soluble uranium intake by an individual to 10 milligrams in a week in consideration of chemical toxicity (see footnote 3 of appendix B to §§ 20.1001-20.2401).

(f) The licensee shall reduce the dose that an individual may be allowed to receive in the current year by the amount of occupational dose received while employed by any other person (see § 20.2104(e)).

§ 20.1202 Compliance with requirements for summation of external and internal doses.

(a) If the licensee is required to monitor under both §§ 20.1502(a) and (b), the licensee shall demonstrate compliance with the dose limits by summing external and internal doses. If the licensee is required to monitor only under § 20.1502(a) or only under § 20.1502(b), then summation is not required to demonstrate compliance with the dose limits. The licensee may demonstrate compliance with the requirements for summation of external and internal doses by meeting one of the conditions specified in paragraph (b) of this section and the conditions in paragraphs (c) and (d) of this section.

(NOTE: The dose equivalents for the lens of the eye, the skin, and the extremities are not included in the summation, but are subject to separate limits.)

(b) *Intake by inhalation.* If the only intake of radionuclides is by inhalation, the total effective dose equivalent limit is not exceeded if the sum of the deep-dose equivalent divided by the total effective dose equivalent limit,

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and one of the following, does not exceed unity:

(1) The sum of the fractions of the inhalation ALI for each radionuclide, or

(2) The total number of derived air concentration-hours (DAC-hours) for all radionuclides divided by 2,000, or

(3) The sum of the calculated committed effective dose equivalents to all significantly irradiated[1] organs or tissues (T) calculated from bioassay data using appropriate biological models and expressed as a fraction of the annual limit.

(c) *Intake by oral ingestion.* If the occupationally exposed individual also receives an intake of radionuclides by oral ingestion greater than 10 percent of the applicable oral ALI, the licensee shall account for this intake and include it in demonstrating compliance with the limits.

(d) *Intake through wounds or absorption through skin.* The licensee shall evaluate and, to the extent practical, account for intakes through wounds or skin absorption.

NOTE: The intake through intact skin has been included in the calculation of DAC for hydrogen-3 and does not need to be further evaluated.

[56 FR 23396, May 21, 1991, as amended at 57 FR 57878, Dec. 8, 1992]

§ 20.1203 Determination of external dose from airborne radioactive material.

Licensees shall, when determining the dose from airborne radioactive material, include the contribution to the deep-dose equivalent, eye dose equivalent, and shallow-dose equivalent from external exposure to the radioactive cloud (see appendix B to §§ 20.1001-20.2401, footnotes 1 and 2).

NOTE: Airborne radioactivity measurements and DAC values should not be used as the primary means to assess the deep-dose equivalent when the airborne radioactive material includes radionuclides other than noble gases or if the cloud of airborne radioactive material is not relatively uniform. The determination of the deep-dose equivalent to an individual should be based upon measurements using instruments or individual monitoring devices.

§ 20.1204 Determination of internal exposure.

(a) For purposes of assessing dose used to determine compliance with occupational dose equivalent limits, the licensee shall, when required under § 20.1502, take suitable and timely measurements of—

(1) Concentrations of radioactive materials in air in work areas; or

(2) Quantities of radionuclides in the body; or

(3) Quantities of radionuclides excreted from the body; or

(4) Combinations of these measurements.

(b) Unless respiratory protective equipment is used, as provided in § 20.1703, or the assessment of intake is based on bioassays, the licensee shall assume that an individual inhales radioactive material at the airborne concentration in which the individual is present.

(c) When specific information on the physical and biochemical properties of the radionuclides taken into the body or the behavior or the material in an individual is known, the licensee may—

(1) Use that information to calculate the committed effective dose equivalent, and, if used, the licensee shall document that information in the individual's record; and

(2) Upon prior approval of the Commission, adjust the DAC or ALI values to reflect the actual physical and chemical characteristics of airborne radioactive material (e.g., aerosol size distribution or density); and

(3) Separately assess the contribution of fractional intakes of Class D, W, or Y compounds of a given radionuclide (see appendix B to §§ 20.1001-20.2401) to the committed effective dose equivalent.

(d) If the licensee chooses to assess intakes of Class Y material using the measurements given in § 20.1204(a)(2) or (3), the licensee may delay the recording and reporting of the assessments for periods up to 7 months, unless otherwise required by §§ 20.2202 or 20.2203, in order to permit the licensee to make additional measurements basic to the assessments.

(e) If the identity and concentration of each radionuclide in a mixture are known, the fraction of the DAC applicable to the mixture for use in calculating DAC-hours must be either—

(1) The sum of the ratios of the concentration to the appropriate DAC value (e.g., D, W, Y) from appendix B to §§ 20.1001-20.2401 for each radio-nuclide in the mixture; or

(2) The ratio of the total concentration for all radionuclides in the mixture to the most restrictive DAC value for any radionuclide in the mixture.

(f) If the identity of each radionuclide in a mixture is known, but the concentration of one or more of the radionuclides in the mixture is not known, the DAC for the mixture must be the most restrictive DAC of any radionuclide in the mixture.

(g) When a mixture of radionuclides in air exists, licensees may disregard certain radionuclides in the mixture if—

(1) The licensee uses the total activity of the mixture in demonstrating compliance with the dose limits in § 20.1201 and in complying with the monitoring requirements in § 20.1502(b), and

(2) The concentration of any radionuclide disregarded is less than 10 percent of its DAC, and

(3) The sum of these percentages for all of the radionuclides disregarded in the mixture does not exceed 30 percent.

(h)(1) In order to calculate the committed effective dose equivalent, the licensee may assume that the inhalation of one ALI, or an exposure of 2,000 DAC-hours, results in a committed effective dose equivalent of 5 rems (0.05 Sv) for radionuclides that have their ALIs or DACs based on the committed effective dose equivalent.

(2) When the ALI (and the associated DAC) is determined by the nonstochastic organ dose limit of 50 rems (0.5 Sv), the intake of radionuclides that would result in a committed effective dose equivalent of 5 rems (0.05 Sv) (the stochastic ALI) is listed in parentheses in table 1 of appendix B to §§ 20.1001-20.2401. In this case, the licensee may, as a simplifying assumption, use the stochastic ALIs to determine committed effective dose equivalent. However, if the licensee uses the stochastic ALIs, the licensee must also demonstrate that the limit in § 20.1201(a)(1)(ii) is met.

§ 20.1205 [Reserved]

§ 20.1206 Planned special exposures.

A licensee may authorize an adult worker to receive doses in addition to and accounted for separately from the doses received under the limits specified in § 20.1201 provided that each of the following conditions is satisfied—

(a) The licensee authorizes a planned special exposure only in an exceptional situation when alternatives that might avoid the higher exposure are unavailable or impractical.

(b) The licensee (and employer if the employer is not the licensee) specifically authorizes the planned special exposure, in writing, before the exposure occurs.

(c) Before a planned special exposure, the licensee ensures that the individuals involved are—

(1) Informed of the purpose of the planned operation;

(2) Informed of the estimated doses and associated potential risks and specific radiation levels or other conditions that might be involved in performing the task; and

(3) Instructed in the measures to be taken to keep the dose ALARA considering other risks that may be present.

(d) Prior to permitting an individual to participate in a planned special exposure, the licensee ascertains prior doses as required by § 20.2104(b) during the lifetime of the individual for each individual involved.

(e) Subject to § 20.1201(b), the licensee does not authorize a planned special exposure that would cause an individual to receive a dose from all planned special exposures and all doses in excess of the limits to exceed—

(1) The numerical values of any of the dose limits in § 20.1201(a) in any year; and

(2) Five times the annual dose limits in § 20.1201(a) during the individual's lifetime.

(f) The licensee maintains records of the conduct of a planned special exposure in accordance with § 20.2105 and

[1] An organ or tissue is deemed to be significantly irradiated if, for that organ or tissue, the product of the weighting factor, w_T, and the committed dose equivalent, $H_{T,50}$, per unit intake is greater than 10 percent of the maximum weighted value of $H_{T,50}$, (i.e., $W_T H_{T,50}$) per unit intake for any organ or tissue.

submits a written report in accordance with § 20.2204.

(g) The licensee records the best estimate of the dose resulting from the planned special exposure in the individual's record and informs the individual, in writing, of the dose within 30 days from the date of the planned special exposure. The dose from planned special exposures is not to be considered in controlling future occupational dose of the individual under § 20.1201(a) but is to be included in evaluations required by § 20.1206 (d) and (e).

§ 20.1207 Occupational dose limits for minors.

The annual occupational dose limits for minors are 10 percent of the annual dose limits specified for adult workers in § 20.1201.

§ 20.1208 Dose to an embryo/fetus.

(a) The licensee shall ensure that the dose to an embryo/fetus during the entire pregnancy, due to occupational exposure of a declared pregnant woman, does not exceed 0.5 rem (5 mSv). (For recordkeeping requirements, see § 20.2106.)

(b) The licensee shall make efforts to avoid substantial variation above a uniform monthly exposure rate to a declared pregnant woman so as to satisfy the limit in paragraph (a) of this section.

(c) The dose to an embryo/fetus shall be taken as the sum of—

(1) The deep-dose equivalent to the declared pregnant woman; and

(2) The dose to the embryo/fetus from radionuclides in the embryo/fetus and radionuclides in the declared pregnant woman.

(d) If the dose to the embryo/fetus is found to have exceeded 0.5 rem (5 mSv), or is within 0.05 rem (0.5 mSv) of this dose, by the time the woman declares the pregnancy to the licensee, the licensee shall be deemed to be in compliance with paragraph (a) of this section if the additional dose to the embryo/fetus does not exceed 0.05 rem (0.5 mSv) during the remainder of the pregnancy.

Subpart D—Radiation Dose Limits for Individual Members of the Public

SOURCE: 56 FR 23398, May 21, 1991, unless otherwise noted.

§ 20.1301 Dose limits for individual members of the public.

(a) Each licensee shall conduct operations so that—

(1) The total effective dose equivalent to individual members of the public from the licensed operation does not exceed 0.1 rem (1 mSv) in a year, exclusive of the dose contribution from the licensee's disposal of radioactive material into sanitary sewerage in accordance with § 20.2003, and

(2) The dose in any unrestricted area from external sources does not exceed 0.002 rem (0.02 mSv) in any one hour.

(b) If the licensee permits members of the public to have access to controlled areas, the limits for members of the public continue to apply to those individuals.

(c) A licensee or license applicant may apply for prior NRC authorization to operate up to an annual dose limit for an individual member of the public of 0.5 rem (5 mSv). The licensee or license applicant shall include the following information in this application:

(1) Demonstration of the need for and the expected duration of operations in excess of the limit in paragraph (a) of this section;

(2) The licensee's program to assess and control dose within the 0.5 rem (5 mSv) annual limit; and

(3) The procedures to be followed to maintain the dose as low as is reasonably achievable.

(d) In addition to the requirements of this part, a licensee subject to the provisions of EPA's generally applicable environmental radiation standards in 40 CFR part 190 shall comply with those standards.

(e) The Commission may impose additional restrictions on radiation levels in unrestricted areas and on the total quantity of radionuclides that a licensee may release in effluents in order to restrict the collective dose.

§ 20.1302 Compliance with dose limits for individual members of the public.

(a) The licensee shall make or cause to be made, as appropriate, surveys of radiation levels in unrestricted and controlled areas and radioactive materials in effluents released to unrestricted and controlled areas to demonstrate compliance with the dose limits for individual members of the public in § 20.1301.

(b) A licensee shall show compliance with the annual dose limit in § 20.1301 by—

(1) Demonstrating by measurement or calculation that the total effective dose equivalent to the individual likely to receive the highest dose from the licensed operation does not exceed the annual dose limit; or

(2) Demonstrating that—

(i) The annual average concentrations of radioactive material released in gaseous and liquid effluents at the boundary of the unrestricted area do not exceed the values specified in table 2 of appendix B to §§ 20.1001–20.2401; and

(ii) If an individual were continuously present in an unrestricted area, the dose from external sources would not exceed 0.002 rem (0.02 mSv) in an hour and 0.05 rem (0.5 mSv) in a year.

(c) Upon approval from the Commission, the licensee may adjust the effluent concentration values in appendix B to §§ 20.1001–20.2401, table 2, for members of the public, to take into account the actual physical and chemical characteristics of the effluents (e.g., aerosol size distribution, solubility, density, radioactive decay equilibrium, chemical form).

[56 FR 23398, May 21, 1991; 56 FR 61352, Dec. 3, 1991, as amended at 57 FR 57878, Dec. 8, 1992]

Subpart E—(Reserved)

Subpart F—Surveys and Monitoring

SOURCE: 56 FR 23398, May 21, 1991, unless otherwise noted.

§ 20.1501 General.

(a) Each licensee shall make or cause to be made, surveys that—

(1) May be necessary for the licensee to comply with the regulations in this part; and

(2) Are reasonable under the circumstances to evaluate—

(i) The extent of radiation levels; and

(ii) Concentrations or quantities of radioactive material; and

(iii) The potential radiological hazards that could be present.

(b) The licensee shall ensure that instruments and equipment used for quantitative radiation measurements (e.g., dose rate and effluent monitoring) are calibrated periodically for the radiation measured.

(c) All personnel dosimeters (except for direct and indirect reading pocket ionization chambers and those dosimeters used to measure the dose to the extremities) that require processing to determine the radiation dose and that are used by licensees to comply with § 20.1201, with other applicable provisions of this chapter, or with conditions specified in a license must be processed and evaluated by a dosimetry processor—

(1) Holding current personnel dosimetry accreditation from the National Voluntary Laboratory Accreditation Program (NVLAP) of the National Institute of Standards and Technology; and

(2) Approved in this accreditation process for the type of radiation or radiations included in the NVLAP program that most closely approximates the type of radiation or radiations for which the individual wearing the dosimeter is monitored.

§ 20.1502 Conditions requiring individual monitoring of external and internal occupational dose.

Each licensee shall monitor exposures to radiation and radioactive material at levels sufficient to demonstrate compliance with the occupational dose limits of this part. As a minimum—

(a) Each licensee shall monitor occupational exposure to radiation and shall supply and require the use of individual monitoring devices by—

(1) Adults likely to receive, in 1 year from sources external to the body, a dose in excess of 10 percent of the limits in § 20.1201(a),

(2) Minors and declared pregnant women likely to receive, in 1 year from sources external to the body, a dose in excess of 10 percent of any of the applicable limits in § 20.1207 or § 20.1208, and

(3) Individuals entering a high or very high radiation area.

(b) Each licensee shall monitor (see § 20.1204) the occupational intake of radioactive material by and assess the committed effective dose equivalent to—

(1) Adults likely to receive, in 1 year, an intake in excess of 10 percent of the applicable ALI(s) in table 1, Columns 1 and 2, of appendix B to §§ 20.1001–20.2401; and

(2) Minors and declared pregnant women likely to receive, in 1 year, a committed effective dose equivalent in excess of 0.05 rem (0.5 mSv).

Subpart G—Control of Exposure From External Sources in Restricted Areas

SOURCE: 56 FR 23398, May 21, 1991, unless otherwise noted.

§ 20.1601 Control of access to high radiation areas.

(a) The licensee shall ensure that each entrance or access point to a high radiation area has one or more of the following features—

(1) A control device that, upon entry into the area, causes the level of radiation to be reduced below that level at which an individual might receive a deep-dose equivalent of 0.1 rem (1 mSv) in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates;

(2) A control device that energizes a conspicuous visible or audible alarm signal so that the individual entering the high radiation area and the supervisor of the activity are made aware of the entry; or

(3) Entryways that are locked, except during periods when access to the areas is required, with positive control over each individual entry.

(b) In place of the controls required by paragraph (a) of this section for a high radiation area, the licensee may substitute continuous direct or electronic surveillance that is capable of preventing unauthorized entry.

(c) A licensee may apply to the Commission for approval of alternative methods for controlling access to high radiation areas.

(d) The licensee shall establish the controls required by paragraphs (a) and (c) of this section in a way that does not prevent individuals from leaving a high radiation area.

(e) Control is not required for each entrance or access point to a room or other area that is a high radiation area solely because of the presence of radioactive materials prepared for transport and packaged and labeled in accordance with the regulations of the Department of Transportation provided that—

(1) The packages do not remain in the area longer than 3 days; and

(2) The dose rate at 1 meter from the external surface of any package does not exceed 0.01 rem (0.1 mSv) per hour.

(f) Control of entrance or access to rooms or other areas in hospitals is not required solely because of the presence of patients containing radioactive material, provided that there are personnel in attendance who will take the necessary precautions to prevent the exposure of individuals to radiation or radioactive material in excess of the limits established in this part and to operate within the ALARA provisions of the licensee's radiation protection program.

§ 20.1602 Control of access to very high radiation areas.

In addition to the requirements in § 20.1601, the licensee shall institute additional measures to ensure that an individual is not able to gain unauthorized or inadvertent access to areas in which radiation levels could be encountered at 500 rads (5 grays) or more in 1 hour at 1 meter from a radiation source or any surface through which the radiation penetrates.

Subpart H—Respiratory Protection and Controls to Restrict Internal Exposure in Restricted Areas

SOURCE: 56 FR 23400, May 21, 1991, unless otherwise noted.

§ 20.1701 Use of process or other engineering controls.

The licensee shall use, to the extent practicable, process or other engineering controls (e.g., containment or ventilation) to control the concentrations of radioactive material in air.

§ 20.1702 Use of other controls.

When it is not practicable to apply process or other engineering controls to control the concentrations of radioactive material in air to values below those that define an airborne radioactivity area, the licensee shall, consistent with maintaining the total effective dose equivalent ALARA, increase monitoring and limit intakes by one or more of the following means:

(a) Control of access;

(b) Limitation of exposure times;

(c) Use of respiratory protection equipment; or

(d) Other controls.

§ 20.1703 Use of individual respiratory protection equipment.

(a) If the licensee uses respiratory protection equipment to limit intakes pursuant to § 20.1702—

(1) The licensee shall use only respiratory protection equipment that is tested and certified or had certification extended by the National Institute for Occupational Safety and Health/Mine Safety and Health Administration (NIOSH/MSHA).

(2) If the licensee wishes to use equipment that has not been tested or certified by NIOSH/MSHA, has not had certification extended by NIOSH/MSHA, or for which there is no schedule for testing or certification, the licensee shall submit an application for authorized use of that equipment, including a demonstration by testing, or a demonstration on the basis of reliable test information, that the material and performance characteristics of the equipment are capable of providing the proposed degree of protection under anticipated conditions of use.

(3) The licensee shall implement and maintain a respiratory protection program that includes—

(i) Air sampling sufficient to identify the potential hazard, permit proper equipment selection, and estimate exposures;

(ii) Surveys and bioassays, as appropriate, to evaluate actual intakes;

(iii) Testing of respirators for operability immediately prior to each use;

(iv) Written procedures regarding selection, fitting, issuance, maintenance, and testing of respirators, including testing for operability immediately prior to each use; supervision and training of personnel; monitoring, including air sampling and bioassays; and recordkeeping; and

(v) Determination by a physician prior to initial fitting of respirators, and at least every 12 months thereafter, that the individual user is physically able to use the respiratory protection equipment.

(4) The licensee shall issue a written policy statement on respirator usage covering—

(i) The use of process or other engineering controls, instead of respirators;

(ii) The routine, nonroutine, and emergency use of respirators; and

(iii) The periods of respirator use and relief from respirator use.

(5) The licensee shall advise each respirator user that the user may leave the area at any time for relief from respirator use in the event of equipment malfunction, physical or psychological distress, procedural or communication failure, significant deterioration of operating conditions, or any other conditions that might require such relief.

(6) The licensee shall use equipment within limitations for type and mode of use and shall provide proper visual, communication, and other special capabilities (such as adequate skin protection) when needed.

(b) In estimating exposure of individuals to airborne radioactive materials, the licensee may make allowance for respiratory protection equipment used to limit intakes pursuant to § 20.1702, provided that the following conditions, in addition to those in § 20.1703(a), are satisfied:

(1) The licensee selects respiratory protection equipment that provides a protection factor (see appendix A to §§ 20.1001–20.2401) greater than the multiple by which peak concentrations of airborne radioactive materials in the working area are expected to exceed the values specified in appendix B to §§ 20.1001–20.2401, table I, column 3. If

the selection of a respiratory protection device with a protection factor greater than the peak concentration is inconsistent with the goal specified in § 20.1702 of keeping the total effective dose equivalent ALARA, the licensee may select respiratory protection equipment with a lower protection factor only if such a selection would result in keeping the total effective dose equivalent ALARA. The concentration of radioactive material in the air that is inhaled when respirators are worn may be initially estimated by dividing the average concentration in air, during each period of uninterrupted use, by the protection factor. If the exposure is later found to be greater than estimated, the corrected value must be used; if the exposure is later found to be less than estimated, the corrected value may be used.

(2) The licensee shall obtain authorization from the Commission before assigning respiratory protection factors in excess of those specified in appendix A to §§ 20.1001–20.2401. The Commission may authorize a licensee to use higher protection factors on receipt of an application that—

(i) Describes the situation for which a need exists for higher protection factors, and

(ii) Demonstrates that the respiratory protection equipment provides these higher protection factors under the proposed conditions of use.

(c) The licensee shall use as emergency devices only respiratory protection equipment that has been specifically certified or had certification extended for emergency use by NIOSH/MSHA.

(d) The licensee shall notify, in writing, the Regional Administrator of the appropriate NRC Regional Office listed in appendix D to §§ 20.1001–20.2401 at least 30 days before the date that respiratory protection equipment is first used under the provisions of either § 20.1703 (a) or (b).

[56 FR 23400, May 21, 1991, as amended at 57 FR 57878, Dec. 8, 1992]

§ 20.1704 Further restrictions on the use of respiratory protection equipment.

The Commission may impose restrictions in addition to those in §§ 20.1702, 20.1703, and appendix A to §§ 20.1001–20.2401 to—

(a) Ensure that the respiratory protection program of the licensee is adequate to limit exposures of individuals to airborne radioactive materials; and

(b) Limit the extent to which a licensee may use respiratory protection equipment instead of process or other engineering controls.

Subpart I—Storage and Control of Licensed Material

SOURCE: 56 FR 23401, May 21, 1991, unless otherwise noted.

§ 20.1801 Security of stored material.

The licensee shall secure from unauthorized removal or access licensed materials that are stored in controlled or unrestricted areas.

§ 20.1802 Control of material not in storage.

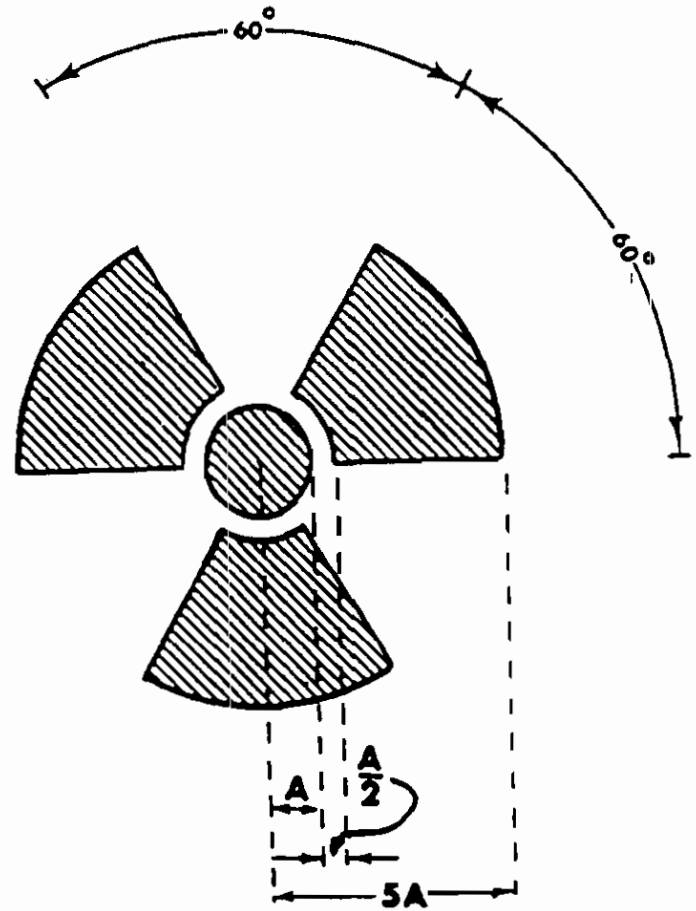
The licensee shall control and maintain constant surveillance of licensed material that is in a controlled or unrestricted area and that is not in storage.

Subpart J—Precautionary Procedures

SOURCE: 56 FR 23401, May 21, 1991, unless otherwise noted.

§ 20.1901 Caution signs.

(a) *Standard radiation symbol.* Unless otherwise authorized by the Commission, the symbol prescribed by this part shall use the colors magenta, or purple, or black on yellow background. The symbol prescribed by this part is the three-bladed design:



RADIATION SYMBOL

(1) Cross-hatched area is to be magenta, or purple, or black, and

(2) The background is to be yellow.

(b) *Exception to color requirements for standard radiation symbol.* Notwithstanding the requirements of paragraph (a) of this section, licensees are authorized to label sources, source holders, or device components containing sources of licensed materials that are subjected to high temperatures, with conspicuously etched or stamped radiation caution symbols and without a color requirement.

(c) *Additional information on signs and labels.* In addition to the contents of signs and labels prescribed in this part, the licensee may provide, on or near the required signs and labels, additional information, as appropriate, to make individuals aware of potential radiation exposures and to minimize the exposures.

§ 20.1902 Posting requirements.

(a) *Posting of radiation areas.* The licensee shall post each radiation area with a conspicuous sign or signs bearing the radiation symbol and the words "CAUTION, RADIATION AREA."

(b) *Posting of high radiation areas.* The licensee shall post each high radiation area with a conspicuous sign or signs bearing the radiation symbol and the words "CAUTION, HIGH RADIATION AREA" or "DANGER, HIGH RADIATION AREA."

(c) *Posting of very high radiation areas.* The licensee shall post each very high radiation area with a conspicuous sign or signs bearing the radiation symbol and words "GRAVE DANGER, VERY HIGH RADIATION AREA."

(d) *Posting of airborne radioactivity areas.* The licensee shall post each airborne radioactivity area with a conspicuous sign or signs bearing the radiation symbol and the words "CAUTION, AIRBORNE RADIOACTIVITY AREA" or "DANGER, AIRBORNE RADIOACTIVITY AREA."

(e) *Posting of areas or rooms in which licensed material is used or stored.* The licensee shall post each area or room in which there is used or stored an amount of licensed material exceeding 10 times the quantity of such material specified in appendix C to §§ 20.1001-20.2401 with a conspicuous sign or signs bearing the radiation symbol and the words "CAUTION, RADIOACTIVE MATERIAL(S)" or "DANGER, RADIOACTIVE MATERIAL(S)."

§ 20.1903 Exceptions to posting requirements.

(a) A licensee is not required to post caution signs in areas or rooms containing radioactive materials for periods of less than 8 hours, if each of the following conditions is met:

(1) The materials are constantly attended during these periods by an individual who takes the precautions necessary to prevent the exposure of individuals to radiation or radioactive materials in excess of the limits established in this part; and

(2) The area or room is subject to the licensee's control.

(b) Rooms or other areas in hospitals that are occupied by patients are not required to be posted with caution signs pursuant to § 20.1902 provided that the patient could be released from confinement pursuant to § 35.75 of this chapter.

(c) A room or area is not required to be posted with a caution sign because of the presence of a sealed source provided the radiation level at 30 centimeters from the surface of the source container or housing does not exceed 0.005 rem (0.05 mSv) per hour.

[56 FR 23401, May 21, 1991, as amended at 57 FR 39357, Aug. 31, 1992]

§ 20.1904 Labeling containers.

(a) The licensee shall ensure that each container of licensed material bears a durable, clearly visible label bearing the radiation symbol and the words "CAUTION, RADIOACTIVE MATERIAL" or "DANGER, RADIOACTIVE MATERIAL." The label must also provide sufficient information (such as the radionuclide(s) present, an estimate of the quantity of radioactivity, the date for which the activity is estimated, radiation levels, kinds of materials, and mass enrichment) to permit individuals handling or using the containers, or working in the vicinity of the containers, to take precautions to avoid or minimize exposures.

(b) Each licensee shall, prior to removal or disposal of empty uncontaminated containers to unrestricted areas, remove or deface the radioactive material label or otherwise clearly indicate that the container no longer contains radioactive materials.

§ 20.1905 Exemptions to labeling requirements.

A licensee is not required to label—

(a) Containers holding licensed material in quantities less than the quantities listed in appendix C to §§ 20.1001-20.2401; or

(b) Containers holding licensed material in concentrations less than those specified in table 3 of appendix B to §§ 20.1001-20.2401; or

(c) Containers attended by an individual who takes the precautions necessary to prevent the exposure of individuals in excess of the limits established by this part; or

(d) Containers when they are in transport and packaged and labeled in accordance with the regulations of the Department of Transportation,[3] or

(e) Containers that are accessible only to individuals authorized to handle or use them, or to work in the vicinity of the containers, if the contents are identified to these individuals by a readily available written record (examples of containers of this type are containers in locations such as water-filled canals, storage vaults, or hot cells). The record must be retained as long as the containers are in use for the purpose indicated on the record; or

(f) Installed manufacturing or process equipment, such as reactor components, piping, and tanks.

§ 20.1906 Procedures for receiving and opening packages.

(a) Each licensee who expects to receive a package containing quantities of radioactive material in excess of a Type A quantity, as defined in § 71.4 and appendix A to part 71 of this chapter, shall make arrangements to receive—

(1) The package when the carrier offers it for delivery; or

(2) Notification of the arrival of the package at the carrier's terminal and to take possession of the package expeditiously.

(b) Each licensee shall—

(1) Monitor the external surfaces of a labeled[3a] package for radioactive contamination unless the package contains only radioactive material in the form of a gas or in special form as defined in 10 CFR 71.4;

(2) Monitor the external surfaces of a labeled[3a] package for radiation levels unless the package contains quantities of radioactive material that are less than or equal to the Type A quantity, as defined in § 71.4 and appendix A to part 71 of this chapter; and

(3) Monitor all packages known to contain radioactive material for radioactive contamination and radiation levels if there is evidence of degradation of package integrity, such as packages that are crushed, wet, or damaged.

(c) The licensee shall perform the monitoring required by paragraph (b) of this section as soon as practicable after receipt of the package, but not later than 3 hours after the package is received at the licensee's facility if it is received during the licensee's normal working hours, or not later than 3 hours from the beginning of the next working day if it is received after working hours.

(d) The licensee shall immediately notify the final delivery carrier and, by telephone and telegram, mailgram, or facsimile, the Administrator of the appropriate NRC Regional Office listed in appendix D to §§ 20.1001-20.2401 when—

(1) Removable radioactive surface contamination exceeds the limits of § 71.87(i) of this chapter; or

(2) External radiation levels exceed the limits of § 71.47 of this chapter.

(e) Each licensee shall—

(1) Establish, maintain, and retain written procedures for safely opening packages in which radioactive material is received; and

(2) Ensure that the procedures are followed and that due consideration is given to special instructions for the type of package being opened.

(f) Licensees transferring special form sources in licensee-owned or licensee-operated vehicles to and from a work site are exempt from the contamination monitoring requirements of paragraph (b) of this section, but are not exempt from the survey requirement in paragraph (b) of this section for measuring radiation levels that is required to ensure that the source is still properly lodged in its shield.

[56 FR 23401, May 21, 1991, as amended at 57 FR 39357, Aug. 31, 1992]

Subpart K—Waste Disposal

SOURCE: 56 FR 23403, May 21, 1991, unless otherwise noted.

[3] Labeling of packages containing radioactive materials is required by the Department of Transportation (DOT) if the amount and type of radioactive material exceeds the limits for an excepted quantity or article as defined and limited by DOT regulations 49 CFR 173.403 (m) and (w) and 173.421-424.

[3a] Labeled with a Radioactive White I, Yellow II, or Yellow III label as specified in U.S. Department of Transportation regulations, 49 CFR 172.403 and 172.436-440.

§ 20.2001 General requirements.

(a) A licensee shall dispose of licensed material only—

(1) By transfer to an authorized recipient as provided in § 20.2006 or in the regulations in parts 30, 40, 60, 61, 70, or 72 of this chapter; or

(2) By decay in storage; or

(3) By release in effluents within the limits in § 20.1301; or

(4) As authorized under §§ 20.2002, 20.2003, 20.2004, or § 20.2005.

(b) A person must be specifically licensed to receive waste containing licensed material from other persons for:

(1) Treatment prior to disposal; or

(2) Treatment or disposal by incineration; or

(3) Decay in storage; or

(4) Disposal at a land disposal facility licensed under part 61 of this chapter; or

(5) Disposal at a geologic repository under part 60 of this chapter.

§ 20.2002 Method for obtaining approval of proposed disposal procedures.

A licensee or applicant for a license may apply to the Commission for approval of proposed procedures, not otherwise authorized in the regulations in this chapter, to dispose of licensed material generated in the licensee's activities. Each application shall include:

(a) A description of the waste containing licensed material to be disposed of, including the physical and chemical properties important to risk evaluation, and the proposed manner and conditions of waste disposal; and

(b) An analysis and evaluation of pertinent information on the nature of the environment; and

(c) The nature and location of other potentially affected licensed and unlicensed facilities; and

(d) Analyses and procedures to ensure that doses are maintained ALARA and within the dose limits in this part.

§ 20.2003 Disposal by release into sanitary sewerage.

(a) A licensee may discharge licensed material into sanitary sewerage if each of the following conditions is satisfied:

(1) The material is readily soluble (or is readily dispersible biological material) in water; and

(2) The quantity of licensed or other radioactive material that the licensee releases into the sewer in 1 month divided by the average monthly volume of water released into the sewer by the licensee does not exceed the concentration listed in table 3 of appendix B to §§ 20.1001–20.2401; and

(3) If more than one radionuclide is released, the following conditions must also be satisfied:

(i) The licensee shall determine the fraction of the limit in table 3 of appendix B to §§ 20.1001–20.2401 represented by discharges into sanitary sewerage by dividing the actual monthly average concentration of each radionuclide released by the licensee into the sewer by the concentration of that radionuclide listed in table 3 of appendix B to §§ 20.1001–20.2401; and

(ii) The sum of the fractions for each radionuclide required by paragraph (a)(3)(i) of this section does not exceed unity; and

(4) The total quantity of licensed and other radioactive material that the licensee releases into the sanitary sewerage system in a year does not exceed 5 curies (185 GBq) of hydrogen-3, 1 curie (37 GBq) of carbon-14, and 1 curie (37 GBq) of all other radioactive materials combined.

(b) Excreta from individuals undergoing medical diagnosis or therapy with radioactive material are not subject to the limitations contained in paragraph (a) of this section.

§ 20.2004 Treatment or disposal by incineration.

(a) A licensee may treat or dispose of licensed material by incineration only:

(1) As authorized by paragraph (b) of this section; or

(2) If the material is in a form and concentration specified in § 20.2005; or

(3) As specifically approved by the Commission pursuant to § 20.2002.

(b) (1) Waste oils (petroleum derived or synthetic oils used principally as lubricants, coolants, hydraulic or insulating fluids, or metalworking oils) that have been radioactively contaminated in the course of the operation or maintenance of a nuclear power reactor licensed under part 50 of this chapter may be incinerated on the site where generated provided that the total radioactive effluents from the facility, including the effluents from such incineration, conform to the requirements of appendix I to part 50 of this chapter and the effluent release limits contained in applicable license conditions other than effluent limits specifically related to incineration of waste oil. The licensee shall report any changes or additions to the information supplied under §§ 50.34 and 50.34a of this chapter associated with this incineration pursuant to § 50.71 of this chapter, as appropriate. The licensee shall also follow the procedures of § 50.59 of this chapter with respect to such changes to the facility or procedures.

(2) Solid residues produced in the process of incinerating waste oils must be disposed of as provided by § 20.2001.

(3) The provisions of this section authorize onsite waste oil incineration under the terms of this section and supersede any provision in an individual plant license or technical specification that may be inconsistent.

[57 FR 57656, Dec. 7, 1992]

§ 20.2005 Disposal of specific wastes.

(a) A licensee may dispose of the following licensed material as if it were not radioactive:

(1) 0.05 microcurie (1.85 kBq), or less, of hydrogen-3 or carbon-14 per gram of medium used for liquid scintillation counting; and

(2) 0.05 microcurie (1.85 kBq), or less, of hydrogen-3 or carbon-14 per gram of animal tissue, averaged over the weight of the entire animal.

(b) A licensee may not dispose of tissue under paragraph (a)(2) of this section in a manner that would permit its use either as food for humans or as animal feed.

(c) The licensee shall maintain records in accordance with § 20.2108.

§ 20.2006 Transfer for disposal and manifests.

(a) The requirements of this section and appendix F to §§ 20.1001–20.2401 are designed to control transfers of low-level radioactive waste intended for disposal at a land disposal facility (as defined in part 61 of this chapter), establish a manifest tracking system, and supplement existing requirements concerning transfers and recordkeeping for those wastes.

(b) Each shipment of radioactive waste intended for disposal at a licensed land disposal facility must be accompanied by a shipment manifest as specified in section I of appendix F to §§ 20.1001–20.2401.

(c) Each shipment manifest must include a certification by the waste generator as specified in section II of appendix F to §§ 20.1001–20.2401.

(d) Each person involved in the transfer for disposal and disposal of waste, including the waste generator, waste collector, waste processor, and disposal facility operator, shall comply with the requirements specified in section III of appendix F to §§ 20.1001–20.2401.

§ 20.2007 Compliance with environmental and health protection regulations.

Nothing in this subpart relieves the licensee from complying with other applicable Federal, State, and local regulations governing any other toxic or hazardous properties of materials that may be disposed of under this subpart.

Subpart L—Records

SOURCE: 56 FR 23404, May 21, 1991, unless otherwise noted.

§ 20.2101 General provisions.

(a) Each licensee shall use the units: curie, rad, rem, including multiples and subdivisions, and shall clearly indicate the units of all quantities on records required by this part.

(b) The licensee shall make a clear distinction among the quantities entered on the records required by this part (e.g., total effective dose equivalent, shallow-dose equivalent, eye dose equivalent, deep-dose equivalent, committed effective dose equivalent).

§ 20.2102 Records of radiation protection programs.

(a) Each licensee shall maintain records of the radiation protection program, including:

(1) The provisions of the program; and

(2) Audits and other reviews of program content and implementation.

(b) The licensee shall retain the records required by paragraph (a)(1) of this section until the Commission terminates each pertinent license requiring the record. The licensee shall retain the records required by paragraph (a)(2) of this section for 3 years after the record is made.

§ 20.2103 Records of surveys.

(a) Each licensee shall maintain records showing the results of surveys and calibrations required by §§ 20.1501 and 20.1906(b). The licensee shall retain these records for 3 years after the record is made.

(b) The licensee shall retain each of the following records until the Commission terminates each pertinent license requiring the record:

(1) Records of the results of surveys to determine the dose from external sources and used, in the absence of or in combination with individual monitoring data, in the assessment of individual dose equivalents; and

(2) Records of the results of measurements and calculations used to determine individual intakes of radioactive material and used in the assessment of internal dose; and

(3) Records showing the results of air sampling, surveys, and bioassays required pursuant to § 20.1703(a)(3) (i) and (ii); and

(4) Records of the results of measurements and calculations used to evaluate the release of radioactive effluents to the environment.

§ 20.2104 Determination of prior occupational dose.

(a) For each individual who may enter the licensee's restricted or controlled area and is likely to receive, in a year, an occupational dose requiring monitoring pursuant to § 20.1502, the licensee shall—

(1) Determine the occupational radiation dose received during the current year; and

(2) Attempt to obtain the records of cumulative occupational radiation dose.

(b) Prior to permitting an individual to participate in a planned special exposure, the licensee shall determine—

(1) The internal and external doses from all previous planned special exposures; and

(2) All doses in excess of the limits (including doses received during accidents and emergencies) received during the lifetime of the individual.

(c) In complying with the requirements of paragraph (a) of this section, a licensee may—

(1) Accept, as a record of the occupational dose that the individual received during the current year, a written signed statement from the individual, or from the individual's most recent employer for work involving radiation exposure, that discloses the nature and the amount of any occupational dose that the individual may have received during the current year;

(2) Accept, as the record of cumulative radiation dose, an up-to-date NRC Form 4, or equivalent, signed by the individual and countersigned by an appropriate official of the most recent employer for work involving radiation exposure, or the individual's current employer (if the individual is not employed by the licensee); and

(3) Obtain reports of the individual's dose equivalent(s) from the most recent employer for work involving radiation exposure, or the individual's current employer (if the individual is not employed by the licensee) by telephone, telegram, electronic media, or letter. The licensee shall request a written verification of the dose data if the authenticity of the transmitted report cannot be established.

(d) The licensee shall record the exposure history of each individual, as required by paragraph (a) of this section, on NRC Form 4, or other clear and legible record, including all of the information required by NRC Form 4[4]. The form or record must show each period in which the individual received occupational exposure to radiation or radioactive material and must be signed by the individual who received the exposure. For each period for which the licensee obtains reports, the licensee shall use the dose shown in the report in preparing the NRC Form 4. For any period in which the licensee does not obtain a report, the licensee shall place a notation on the NRC Form 4 indicating the periods of time for which data are not available.

(e) If the licensee is unable to obtain a complete record of an individual's current and previously accumulated occupational dose, the licensee shall assume—

(1) In establishing administrative controls under § 20.1201(f) for the current year, that the allowable dose limit for the individual is reduced by 1.25 rems (12.5 mSv) for each quarter for which records were unavailable and the individual was engaged in activities that could have resulted in occupational radiation exposure; and

(2) That the individual is not available for planned special exposures.

(f) The licensee shall retain the records on NRC Form 4 or equivalent until the Commission terminates each pertinent license requiring this record. The licensee shall retain records used in preparing NRC Form 4 for 3 years after the record is made.

[56 FR 23404, May 21, 1991, as amended at 57 FR 57878, Dec. 8, 1992]

§ 20.2105 Records of planned special exposures.

(a) For each use of the provisions of § 20.1206 for planned special exposures, the licensee shall maintain records that describe—

(1) The exceptional circumstances requiring the use of a planned special exposure; and

(2) The name of the management official who authorized the planned special exposure and a copy of the signed authorization; and

(3) What actions were necessary; and

(4) Why the actions were necessary; and

(5) How doses were maintained ALARA; and

(6) What individual and collective doses were expected to result, and the doses actually received in the planned special exposure.

(b) The licensee shall retain the records until the Commission terminates each pertinent license requiring these records.

§ 20.2106 Records of individual monitoring results.

(a) *Recordkeeping requirement.* Each licensee shall maintain records of doses received by all individuals for whom monitoring was required pursuant to § 20.1502, and records of doses received during planned special exposures, accidents, and emergency conditions. These records[5] must include, when applicable—

(1) The deep-dose equivalent to the whole body, eye dose equivalent, shallow-dose equivalent to the skin, and shallow-dose equivalent to the extremities; and

(2) The estimated intake or body burden of radionuclides (see § 20.1202); and

(3) The committed effective dose equivalent assigned to the intake or body burden of radionuclides; and

(4) The specific information used to calculate the committed effective dose equivalent pursuant to § 20.1204(c); and

(5) The total effective dose equivalent when required by § 20.1202; and

(6) The total of the deep-dose equivalent and the committed dose to the organ receiving the highest total dose.

(b) *Recordkeeping frequency.* The licensee shall make entries of the records specified in paragraph (a) of this section at least annually.

(c) *Recordkeeping format.* The licensee shall maintain the records specified in paragraph (a) of this section on NRC Form 5, in accordance with the instructions for NRC Form 5, or in clear and legible records containing all the information required by NRC Form 5.

(d) *Privacy protection.* The records required under this section should be protected from public disclosure because of their personal privacy nature. These records are protected by most State privacy laws and, when transferred to the NRC, are protected by the Privacy Act of 1974, Public Law 93-579, 5 U.S.C. 552a, and the Commission's regulations in 10 CFR part 9.

[4] Licensees are not required to partition historical dose between external dose equivalent(s) and internal committed dose equivalent(s). Further, occupational exposure histories obtained and recorded on NRC Form 4 before January 1, 1994, might not have included effective dose equivalent, but may be used in the absence of specific information on the intake of radionuclides by the individual.

[5] Assessments of dose equivalent and records made using units in effect before the licensee's adoption of this part need not be changed.

(e) The licensee shall maintain the records of dose to an embryo/fetus with the records of dose to the declared pregnant woman. The declaration of pregnancy shall also be kept on file, but may be maintained separately from the dose records.

(f) The licensee shall retain each required form or record until the Commission terminates each pertinent license requiring the record.

§ 20.2107 Records of dose to individual members of the public.

(a) Each licensee shall maintain records sufficient to demonstrate compliance with the dose limit for individual members of the public (see § 20.1301).

(b) The licensee shall retain the records required by paragraph (a) of this section until the Commission terminates each pertinent license requiring the record.

§ 20.2108 Records of waste disposal.

(a) Each licensee shall maintain records of the disposal of licensed materials made under §§ 20.2002, 20.2003, 20.2004, 20.2005, 10 CFR part 61 and disposal by burial in soil, including burials authorized before January 28, 1981.[6]

(b) The licensee shall retain the records required by paragraph (a) of this section until the Commission terminates each pertinent license requiring the record.

§ 20.2109 [Reserved]

§ 20.2110 Form of records.

Each record required by this part must be legible throughout the specified retention period. The record may be the original or a reproduced copy or a microform provided that the copy or microform is authenticated by authorized personnel and that the microform is capable of producing a clear copy throughout the required retention period. The record may also be stored in electronic media with the capability for producing legible, accurate, and complete records during the required retention period. Records, such as letters, drawings, and specifications, must include all pertinent information, such as stamps, initials, and signatures. The licensee shall maintain adequate safeguards against tampering with and loss of records.

[6] A previous § 20.304 permitted burial of small quantities of licensed materials in soil before January 28, 1981, without specific Commission authorization.

Subpart M—Reports

SOURCE: 56 FR 23406, May 21, 1991, unless otherwise noted.

§ 20.2201 Reports of theft or loss of licensed material.

(a) Telephone reports. (1) Each licensee shall report by telephone as follows:

(i) Immediately after its occurrence becomes known to the licensee, any lost, stolen, or missing licensed material in an aggregate quantity equal to or greater than 1,000 times the quantity specified in appendix C to §§ 20.1001-20.2401 under such circumstances that it appears to the licensee that an exposure could result to persons in unrestricted areas; or

(ii) Within 30 days after the occurrence of any lost, stolen, or missing licensed material becomes known to the licensee, all licensed material in a quantity greater than 10 times the quantity specified in appendix C to §§ 20.1001-20.2401 that is still missing at this time.

(2) Reports must be made as follows:

(i) Licensees having an installed Emergency Notification System shall make the reports to the NRC Operations Center in accordance with § 50.72 of this chapter, and

(ii) All other licensees shall make reports by telephone to the NRC Operations Center (301-951-0550).

(b) *Written reports.* (1) Each licensee required to make a report under paragraph (a) of this section shall, within 30 days after making the telephone report, make a written report setting forth the following information:

(i) A description of the licensed material involved, including kind, quantity, and chemical and physical form; and

(ii) A description of the circumstances under which the loss or theft occurred; and

(iii) A statement of disposition, or probable disposition, of the licensed material involved; and

(iv) Exposures of individuals to radiation, circumstances under which the exposures occurred, and the possible total effective dose equivalent to persons in unrestricted areas; and

(v) Actions that have been taken, or will be taken, to recover the material; and

(vi) Procedures or measures that have been, or will be, adopted to ensure against a recurrence of the loss or theft of licensed material.

(2) Reports must be made as follows:

(i) For holders of an operating license for a nuclear power plant, the events included in paragraph (b) of this section must be reported in accordance with the procedures described in § 50.73(b), (c), (d), (e), and (g) of this chapter and must include the information required in paragraph (b)(1) of this section, and

(ii) All other licensees shall make reports to the Administrator of the appropriate NRC Regional Office listed in appendix D to §§ 20.1001-20.2401.

(c) A duplicate report is not required under paragraph (b) of this section if the licensee is also required to submit a report pursuant to §§ 30.55(c), 40.64(c), 50.72, 50.73, 70.52, 73.27(b), 73.67(e)(3)(vi), 73.67(g)(3)(iii), 73.71, or § 150.19(c) of this chapter.

(d) Subsequent to filing the written report, the licensee shall also report any additional substantive information on the loss or theft within 30 days after the licensee learns of such information.

(e) The licensee shall prepare any report filed with the Commission pursuant to this section so that names of individuals who may have received exposure to radiation are stated in a separate and detachable part of the report.

[56 FR 23406, May 21, 1991, as amended at 58 FR 69220, Dec. 30, 1993]

§ 20.2202 Notification of incidents.

(a) Immediate notification. Notwithstanding any other requirements for notification, each licensee shall immediately report any event involving byproduct, source, or special nuclear material possessed by the licensee that may have caused or threatens to cause any of the following conditions—

(1) An individual to receive—

(i) A total effective dose equivalent of 25 rems (0.25 Sv) or more; or

(ii) An eye dose equivalent of 75 rems (0.75 Sv) or more; or

(iii) A shallow-dose equivalent to the skin or extremities of 250 rads (2.5 Gy) or more; or

(2) The release of radioactive material, inside or outside of a restricted area, so that, had an individual been present for 24 hours, the individual could have received an intake five times the annual limit on intake (the provisions of this paragraph do not apply to locations where personnel are not normally stationed during routine operations, such as hot-cells or process enclosures).

(b) Twenty-four hour notification. Each licensee shall, within 24 hours of discovery of the event, report any event involving loss of control of licensed material possessed by the licensee that may have caused, or threatens to cause, any of the following conditions:

(1) An individual to receive, in a period of 24 hours—

(i) A total effective dose equivalent exceeding 5 rems (0.05 Sv); or

(ii) An eye dose equivalent exceeding 15 rems (0.15 Sv); or

(iii) A shallow-dose equivalent to the skin or extremities exceeding 50 rems (0.5 Sv); or

(2) The release of radioactive material, inside or outside of a restricted area, so that, had an individual been present for 24 hours, the individual could have received an intake in excess of one occupational annual limit on intake (the provisions of this paragraph do not apply to locations where personnel are not normally stationed during routine operations, such as hot-cells or process enclosures).

(c) The licensee shall prepare any report filed with the Commission pursuant to this section so that names of individuals who have received exposure to radiation or radioactive material are stated in a separate and detachable part of the report.

(d) Reports made by licensees in response to the requirements of this section must be made as follows:

(1) Licensees having an installed Emergency Notification System shall

make the reports required by paragraphs (a) and (b) of this section to the NRC Operations Center in accordance with 10 CFR 50.72; and

(2) All other licensees shall make the reports required by paragraphs (a) and (b) of this section by telephone to the NRC Operations Center (301-951-0550) and by telegram, mailgram, or facsimile to the Administrator of the appropriate NRC Regional Office listed in appendix D to this part.

(e) The provisions of this section do not include doses that result from planned special exposures, that are within the limits for planned special exposures, and that are reported under § 20.2204.

[56 FR 23406, May 21, 1991, as amended at 56 FR 40766, Aug. 16, 1991; 57 FR 57879, Dec. 8, 1992; 58 FR 69220, Dec. 30, 1993]

§ 20.2203 Reports of exposures, radiation levels, and concentrations of radioactive material exceeding the limits.

(a) Reportable events. In addition to the notification required by § 20.2202, each licensee shall submit a written report within 30 days after learning of any of the following occurrences:

(1) Any incident for which notification is required by § 20.2202; or

(2) Doses in excess of any of the following:

(i) The occupational dose limits for adults in § 20.1201; or

(ii) The occupational dose limits for a minor in § 20.1207; or

(iii) The limits for an embryo/fetus of a declared pregnant woman in § 20.1208; or

(iv) The limits for an individual member of the public in § 20.1301; or

(v) Any applicable limit in the license; or

(3) Levels of radiation or concentrations of radioactive material in—

(i) A restricted area in excess of any applicable limit in the license; or

(ii) An unrestricted area in excess of 10 times any applicable limit set forth in this part or in the license (whether or not involving exposure of any individual in excess of the limits in § 20.1301); or

(4) For licensees subject to the provisions of EPA's generally applicable environmental radiation standards in 40 CFR part 190, levels of radiation or releases of radioactive material in excess of those standards, or of license conditions related to those standards.

(b) Contents of reports. (1) Each report required by paragraph (a) of this section must describe the extent of exposure of individuals to radiation and radioactive material, including, as appropriate:

(i) Estimates of each individual's dose; and

(ii) The levels of radiation and concentrations of radioactive material involved; and

(iii) The cause of the elevated exposures, dose rates, or concentrations; and

(iv) Corrective steps taken or planned to ensure against a recurrence, including the schedule for achieving conformance with applicable limits, generally applicable environmental standards, and associated license conditions.

(2) Each report filed pursuant to paragraph (a) of this section must include for each individual[7] exposed: the name, Social Security account number, and date of birth. The report must be prepared so that this information is stated in a separate and detachable part of the report.

(c) For holders of an operating license for a nuclear power plant, the occurrences included in paragraph (a) of this section must be reported in accordance with the procedures described in § 50.73(b), (c), (d), (e), and (g) of this chapter and must also include the information required by paragraph (b) of this section. Occurrences reported in accordance with § 50.73 of this chapter need not be reported by a duplicate report under paragraph (a) of this section.

(d) All licensees, other than those holding an operating license for a nuclear power plant, who make reports under paragraph (a) of this section shall submit the report in writing to the U.S. Nuclear Regulatory Commission, Document Control Desk, Washington, DC 20555, with a copy to the appropriate NRC Regional Office listed in appendix D to §§ 20.1001–20.2401.

[7] With respect to the limit for the embryo-fetus (§ 20.1208), the identifiers should be those of the declared pregnant woman.

§ 20.2204 Reports of planned special exposures.

The licensee shall submit a written report to the Administrator of the appropriate NRC Regional Office listed in appendix D to §§ 20.1001–20.2401 within 30 days following any planned special exposure conducted in accordance with § 20.1206, informing the Commission that a planned special exposure was conducted and indicating the date the planned special exposure occurred and the information required by § 20.2105.

§ 20.2205 [Reserved]

§ 20.2206 Reports of individual monitoring.

(a) This section applies to each person licensed by the Commission to—

(1) Operate a nuclear reactor designed to produce electrical or heat energy pursuant to § 50.21(b) or § 50.22 of this chapter or a testing facility as defined in § 50.2 of this chapter; or

(2) Possess or use byproduct material for purposes of radiography pursuant to Parts 30 and 34 of this chapter; or

(3) Possess or use at any one time, for purposes of fuel processing, fabricating, or reprocessing, special nuclear material in a quantity exceeding 5,000 grams of contained uranium-235, uranium-233, or plutonium, or any combination thereof pursuant to part 70 of this chapter; or

(4) Possess high-level radioactive waste at a geologic repository operations area pursuant to part 60 of this chapter; or

(5) Possess spent fuel in an independent spent fuel storage installation (ISFSI) pursuant to part 72 of this chapter; or

(6) Receive radioactive waste from other persons for disposal under part 61 of this chapter; or

(7) Possess or use at any time, for processing or manufacturing for distribution pursuant to parts 30, 32, 33 or 35 of this chapter, byproduct material in quantities exceeding any one of the following quantitites:

Radionuclide	Quantity of radionuclide[1] in curies
Cesium-137	1
Cobalt-60	1
Gold-198	100
Iodine-131	1
Iridium-192	10
Krypton-85	1,000
Promethium-147	10
Techetium-99m	1,000

[1] The Commission may require as a license condition, or by rule, regulation, or order pursuant to § 20.2302, reports from licensees who are licensed to use radionuclides not on this list, in quantities sufficient to cause comparable radiation levels.

(b) Each licensee in a category listed in paragraph (a) of this section shall submit an annual report of the results of individual monitoring carried out by the licensee for each individual for whom monitoring was required by § 20.1502 during that year. The licensee may include additional data for individuals for whom monitoring was provided but not required. The licensee shall use Form NRC 5 or electronic media containing all the information required by Form NRC 5.

(c) The licensee shall file the report required by § 20.2206(b), covering the preceding year, on or before April 30 of each year. The licensee shall submit the report to the REIRS Project Manager, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, Washington, DC 20555.

[56 FR 23406, May 21, 1991, as amended at 56 FR 32072, July 15, 1991]

Subpart N—Exemptions and Additional Requirements

SOURCE: 56 FR 23408, May 21, 1991, unless otherwise noted.

§ 20.2301 Applications for exemptions.

The Commission may, upon application by a licensee or upon its own initiative, grant an exemption from the requirements of the regulations in this part if it determines the exemption is authorized by law and would not result in undue hazard to life or property.

§ 20.2302 Additional requirements.

The Commission may, by rule, regulation, or order, impose requirements on a licensee, in addition to those established in the regulations in this part, as it deems appropriate or necessary to protect health or to minimize danger to life or property.

nications equipment whenever supplied-air suits are used.

(j) No approval schedules are currently available for this equipment. Equipment is to be evaluated by testing or on the basis of reliable test information.

(k) This type of respirator may provide greater protection and be used as an emergency device in unknown concentrations for protection against inhalation hazards. External radiation hazards and other limitations to permitted exposure, such as skin absorption, must be taken into account in such circumstances.

(l) Quantitative fit testing shall be performed on each individual and no more than 0.02% leakage is allowed with this type of apparatus. Perceptible outward leakage of gas from this or any positive pressure self-contained breathing apparatus is unacceptable because service life will be reduced substantially. Special training in the use of this type of apparatus shall be provided to the wearer.

NOTE 1: Protection factors for respirators as may be approved by the U.S. Bureau of Mines/National Institute for Occupational Safety and Health (NIOSH), according to applicable approvals for respirators for type and mode of use to protect against airborne radionuclides, may be used to the extent that they do not exceed the protection factors listed in this table. The protection factors listed in this table may not be appropriate to circumstances where chemical or other respiratory hazards exist in addition to radioactive hazards. The selection and use of respirators for such circumstances should take into account applicable approvals of the U.S. Bureau of Mines/NIOSH.

NOTE 2: Radioactive contaminants for which the concentration values in Table 1, Column 3 of Appendix B to §§20.1001-20.2401 of this part are based on internal dose due to inhalation may, in addition, present external exposure hazards at higher concentrations. Under these circumstances, limitations on occupancy may have to be governed by external dose limits.

[56 FR 23408, May 21, 1991. Redesignated at 58 FR 67659, Dec. 22, 1993]

APPENDIX B TO PART 20—ANNUAL LIMITS ON INTAKE (ALIS) AND DERIVED AIR CONCENTRATIONS (DACS) OF RADIONUCLIDES FOR OCCUPATIONAL EXPOSURE; EFFLUENT CONCENTRATIONS; CONCENTRATIONS FOR RELEASE TO SEWERAGE

Introduction

For each radionuclide Table I indicates the chemical form which is to be used for selecting the appropriate ALI or DAC value. The ALIs and DACs for inhalation are given for an aerosol with an activity median aerodynamic diameter (AMAD) of 1 μm and for three classes (D,W,Y) of radioactive material, which refer to their retention (approximately days, weeks or years) in the pulmonary region of the lung. This classification applies to a range of clearance half-times of less than 10 days for D, for W from 10 to 100 days, and for Y greater than 100 days. The class (D, W, or Y) given in the column headed "Class" applies only to the inhalation ALIs and DACs given in Table 1, columns 2 and 3. Table 2 provides concentration limits for airborne and liquid effluents released to the general environment. Table 3 provides concentration limits for discharges to sanitary sewer systems.

Notation

The values in Tables 1, 2, and 3 are presented in the computer "E" notation. In this notation a value of 6E-02 represents a value of 6×10^{-2} or 0.06, 6E+2 represents 6×10^{2} or 600, and 6E+0 represents 6×10^{0} or 6.

Table 1 "Occupational"

Note that the columns in Table 1, of this appendix captioned "Oral Ingestion ALI," "Inhalation ALI," and "DAC," are applicable to occupational exposure to radioactive material.

The ALIs in this appendix are the annual intakes of a given radionuclide by "Reference Man" which would result in either (1) a committed effective dose equivalent of 5 rems (stochastic ALI) or (2) a committed dose equivalent of 50 rems to an organ or tissue (non-stochastic ALI). The stochastic ALIs were derived to result in a risk, due to irradiation of organs and tissues, comparable to the risk associated with deep dose equivalent to the whole body of 5 rems. The derivation includes multiplying the committed dose equivalent to an organ or tissue by a weighting factor, w_T. This weighting factor is the proportion of the risk of stochastic effects resulting from irradiation of the organ or tissue, T, to the total risk of stochastic effects when the whole body is irradiated uniformly. The values of w_T are listed under the definition of weighting factor in §20.1003. The non-stochastic ALIs were derived to avoid non-stochastic effects, such as prompt damage to tissue or reduction in organ function.

A value of w_T=0.06 is applicable to each of the five organs or tissues in the "remainder" category receiving the highest dose equivalents, and the dose equivalents of all other remaining tissues may be disregarded. The following parts of the GI tract—stomach, small intestine, upper large intestine, and lower large intestine—are to be treated as four separate organs.

Note that the dose equivalents for extremities (hands and forearms, feet and lower legs), skin, and lens of the eye are not considered in computing the committed effective dose equivalent, but are subject to limits that must be met separately.

When an ALI is defined by the stochastic dose limit, this value alone, is given. When an ALI is determined by the non-stochastic dose limit to an organ, the organ or tissue to which the limit applies is shown, and the ALI for the stochastic limit is shown in parentheses. (Abbreviated organ or tissue designations are used: LLI wall = lower large intestine wall; St. wall = stomach wall; Blad wall = bladder wall; and Bone surf = bone surface.)

The use of the ALIs listed first, the more limiting of the stochastic and non-stochastic ALIs, will ensure that non-stochastic effects are avoided and that the risk of stochastic effects is limited to an acceptably low value. If, in a particular situation involving a radionuclide for which the non-stochastic ALI is limiting, use of that non-stochastic ALI is considered unduly conservative, the licensee may use the stochastic ALI to determine the committed effective dose equivalent. However, the licensee shall also ensure that the 50-rem dose equivalent limit for any organ or tissue is not exceeded by the sum of the external deep dose equivalent plus the internal committed dose to that organ (not the effective dose). For the case where there is no external dose contribution, this would be demonstrated if the sum of the fractions of the nonstochastic ALIs (ALI_{ns}) that contribute to the committed dose equivalent to the organ receiving the highest dose does not exceed unity (i.e., Σ (intake (in μCi) of each radionuclide/ALI_{ns}) <1.0). If there is an external deep dose equivalent contribution of H_d then this sum must be less than $1-(H_d/50)$ instead of being <1.0.

The derived air concentration (DAC) values are derived limits intended to control chronic occupational exposures. The relationship between the DAC and the ALI is given by: DAC=ALI(in μCi)/(2000 hours per working year×60 minutes/hour×2×10^{4} ml per minute)=[ALI/2.4×10^{8}] μCi/ml, where 2×10^{4} ml is the volume of air breathed per minute at work by "Reference Man" under working conditions of "light work."

The DAC values relate to one of two modes of exposure: either external submersion or the internal committed dose equivalents resulting from inhalation of radioactive materials. Derived air concentrations based upon submersion are for immersion in a semi-infinite cloud of uniform concentration and apply to each radionuclide separately.

The ALI and DAC values relate to exposure to the single radionuclide named, but also include contributions from the in-growth of any daughter radionuclide produced in the body by the decay of the parent. However, intakes that include both the parent and daughter radionuclides should be treated by the general method appropriate for mixtures.

The value of ALI and DAC do not apply directly when the individual both ingests and inhales a radionuclide, when the individual is exposed to a mixture of radionuclides by either inhalation or ingestion or both, or when the individual is exposed to both internal and external radiation (see §20.1202). When an individual is exposed to radioactive materials which fall under several of the translocation classifications (i.e., Class D, Class W, or Class Y) of the same radionuclide, the exposure may be evaluated as if it were a mixture of different radionuclides.

It should be noted that the classification of a compound as Class D, W, or Y is based on the chemical form of the compound and does not take into account the radiological half-life of different radioisotopes. For this reason, values are given for Class D, W, and Y compounds, even for very short-lived radionuclides.

Table 2

The columns in Table 2 of this appendix captioned "Effluents," "Air," and "Water," are applicable to the assessment and control of dose to the public, particularly in the implementation of the provisions of §20.1302. The concentration values given in Columns 1 and 2 of Table 2 are equivalent to the radionuclide concentrations which, if inhaled or ingested continuously over the course of a year, would produce a total effective dose equivalent of 0.05 rem (50 millirem or 0.5 millisievserts).

Consideration of non-stochastic limits has not been included in deriving the air and water effluent concentration limits because non-stochastic effects are presumed not to occur at the dose levels established for individual members of the public. For radionuclides, where the non-stochastic limit was governing in deriving the occupational DAC, the stochastic ALI was used in deriving the corresponding airborne effluent limit in Table 2. For this reason, the DAC and airborne effluent limits are not always proportional as was the case in appendix B to §§20.1-20.601.

The air concentration values listed in Table 2, Column 1, were derived by one of two methods. For those radionuclides for which the stochastic limit is governing, the occupational stochastic inhalation ALI was divided by 2.4×10^{9} ml, relating the inhalation ALI to the DAC, as explained above, and then divided by a factor of 300. The factor of 300 includes the following components: a factor of 50 to relate the 5-rem annual occupational dose limit to the 0.1-rem limit for members of the public, a factor of 3 to adjust for the difference in exposure time and the inhalation rate for a worker and that for members of the public; and a factor of 2 to adjust the occupational values (derived for

adults) so that they are applicable to other age groups.

For those radionuclides for which submersion (external dose) is limiting, the occupational DAC in Table 1, Column 3, was divided by 219. The factor of 219 is composed of a factor of 50, as described above, and a factor of 4.38 relating occupational exposure for 2,000 hours per year to full-time exposure (8,760 hours per year). Note that an additional factor of 2 for age considerations is not warranted in the submersion case.

The water concentrations were derived by taking the most restrictive occupational stochastic oral ingestion ALI and dividing by 7.3×10^7. The factor of 7.3×10^7 (ml) includes the following components: the factors of 50 and 2 described above and a factor of 7.3×10^5 (ml) which is the annual water intake of "Reference Man."

Note 2 of this appendix provides groupings of radionuclides which are applicable to unknown mixtures of radionuclides. These groupings (including occupational inhalation ALIs and DACs, air and water effluent concentrations and sewerage) require demonstrating that the most limiting radionuclides in successive classes are absent. The limit for the unknown mixture is defined when the presence of one of the listed radionuclides cannot be definitely excluded either from knowledge of the radionuclide composition of the source or from actual measurements.

Table 3 "Sewer Disposal"

The monthly average concentrations for release to sanitary sewers are applicable to the provisions in §20.2003. The concentration values were derived by taking the most restrictive occupational stochastic oral ingestion ALI and dividing by 7.3×10^6(ml). The factor of 7.3×10^6(ml) is composed of a factor of 7.3×10^5(ml), the annual water intake by "Reference Man," and a factor of 10, such that the concentrations, if the sewage released by the licensee were the only source of water ingested by a reference man during a year, would result in a committed effective dose equivalent of 0.5 rem.

LIST OF ELEMENTS

Name	Atomic Symbol	Atomic No.
Actinium	Ac	89
Aluminum	Al	13
Americium	Am	95
Antimony	Sb	51
Argon	Ar	18
Arsenic	As	33
Astatine	At	85
Barium	Ba	56
Berkelium	Bk	97
Beryllium	Be	4
Bismuth	Bi	83
Bromine	Br	35

LIST OF ELEMENTS—Continued

Name	Atomic Symbol	Atomic No.
Cadmium	Cd	48
Calcium	Ca	20
Californium	Cf	98
Carbon	C	6
Cerium	Ce	58
Cesium	Cs	55
Chlorine	Cl	17
Chromium	Cr	24
Cobalt	Co	27
Copper	Cu	29
Curium	Cm	96
Dysprosium	Dy	66
Einsteinium	Es	99
Erbium	Er	68
Europium	Eu	63
Fermium	Fm	100
Fluorine	F	9
Francium	Fr	87
Gadolinium	Gd	64
Gallium	Ga	31
Germanium	Ge	32
Gold	Au	79
Hafnium	Hf	72
Holmium	Ho	67
Hydrogen	H	1
Indium	In	49
Iodine	I	53
Iridium	Ir	77
Iron	Fe	26
Krypton	Kr	36
Lanthanum	La	57
Lead	Pb	82
Lutetium	Lu	71
Magnesium	Mg	12
Manganese	Mn	25
Mendelevium	Md	101
Mercury	Hg	80
Molybdenum	Mo	42
Neodymium	Nd	60
Neptunium	Np	93
Nickel	Ni	28
Niobium	Nb	41
Osmium	Os	76
Palladium	Pd	46
Phosphorus	P	15
Platinum	Pt	78
Plutonium	Pu	94
Polonium	Po	84
Potassium	K	19
Praseodymium	Pr	59
Promethium	Pm	61
Protactinium	Pa	91
Radium	Ra	88
Radon	Rn	86
Rhenium	Re	75
Rhodium	Rh	45
Rubidium	Rb	37
Ruthenium	Ru	44
Samarium	Sm	62
Scandium	Sc	21
Selenium	Se	34
Silicon	Si	14
Silver	Ag	47
Sodium	Na	11
Strontium	Sr	38
Sulfur	S	16
Tantalum	Ta	73
Technetium	Tc	43
Tellurium	Te	52
Terbium	Tb	65

LIST OF ELEMENTS—Continued

Name	Atomic Symbol	Atomic No.
Thallium	Tl	81
Thorium	Th	90
Thulium	Tm	69
Tin	Sn	50
Titanium	Ti	22
Tungsten	W	74
Uranium	U	92

LIST OF ELEMENTS—Continued

Name	Atomic Symbol	Atomic No.
Vanadium	V	23
Xenon	Xe	54
Ytterbium	Yb	70
Yttrium	Y	39
Zinc	Zn	30
Zirconium	Zr	40

Atomic No.	Radionuclide	Class	Table 1 Occupational Values: Col. 1 Oral Ingestion ALI (µCi)	Col. 2 Inhalation ALI (µCi)	Col. 3 Inhalation DAC (µCi/ml)	Table 2 Effluent Concentrations: Col. 1 Air (µCi/ml)	Col. 2 Water (µCi/ml)	Table 3 Releases to Sewers: Monthly Average Concentration (µCi/ml)
1	Hydrogen-3	Water, DAC (includes skin absorption	8E+4	8E+4	2E-5	1E-7	1E-3	1E-2
		Gas (HT or T_2) Submersion[1]: Use above values as HT and T_2 oxidize in air and in the body to HTO						
4	Beryllium-7	W, all compounds except those given for Y	4E+4	2E+4	9E-6	3E-8	6E-4	6E-3
		Y, oxides, halides and nitrates	-	2E+4	8E-6	3E-8	-	-
4	Beryllium-10	W, see ^{7}Be	1E+3	2E+2	6E-8	2E-10	-	-
			LLI wall (1E+3)	-	-	-	2E-5	2E-4
		Y, see ^{7}Be	-	1E+1	6E-9	2E-11	-	-
6	Carbon-11[2]	Monoxide	-	1E+6	5E-4	2E-6	-	-
		Dioxide	-	6E+5	3E-4	9E-7	-	-
		Compounds	4E+5	4E+5	2E-4	6E-7	6E-3	6E-2
6	Carbon-14	Monoxide	-	2E+6	7E-4	2E-6	-	-
		Dioxide	-	2E+5	9E-5	3E-7	-	-
		Compounds	2E+3	2E+3	1E-6	3E-9	3E-5	3E-4
9	Fluorine-18[2]	D, fluorides of H, Li, Na, K, Rb, Cs, and Fr	5E+4	7E+4	3E-5	1E-7	-	-
			St wall (5E+4)	-	-	-	7E-4	7E-3
		W, fluorides of Be, Mg, Ca, Sr, Ba, Ra, Al, Ga, In, Tl, As, Sb, Bi, Fe, Ru, Os, Co, Ni, Pd, Pt, Cu, Ag, Au, Zn, Cd, Hg, Sc, Y, Ti, Zr, V, Nb, Ta, Mn, Tc, and Re	-	9E+4	4E-5	1E-7	-	-
		Y, lanthanum fluoride	-	8E+4	3E-5	1E-7	-	-
11	Sodium-22	D, all compounds	4E+2	6E+2	3E-7	9E-10	6E-6	6E-5
11	Sodium-24	D, all compounds	4E+3	5E+3	2E-6	7E-9	5E-5	5E-4
12	Magnesium-28	D, all compounds except those given for W	7E+2	2E+3	7E-7	2E-9	9E-6	9E-5
		W, oxides, hydroxides, carbides, halides, and nitrates	-	1E+3	5E-7	2E-9	-	-
13	Aluminum-26	D, all compounds except those given for W	4E+2	6E+1	3E-8	9E-11	6E-6	6E-5
		W, oxides, hydroxides, carbides, halides, and nitrates	-	9E+1	4E-8	1E-10	-	-

Atomic No.	Radionuclide	Class	Table 1 Occupational Values: Col. 1 Oral Ingestion ALI (µCi)	Col. 2 Inhalation ALI (µCi)	Col. 3 Inhalation DAC (µCi/ml)	Table 2 Effluent Concentrations: Col. 1 Air (µCi/ml)	Col. 2 Water (µCi/ml)	Table 3 Releases to Sewers: Monthly Average Concentration (µCi/ml)
14	Silicon-31	D, all compounds except those given for W and Y	9E+3	3E+4	1E-5	4E-8	1E-4	1E-3
		W, oxides, hydroxides, carbides, and nitrates	-	3E+4	1E-5	5E-8	-	-
		Y, aluminosilicate glass	-	3E+4	1E-5	4E-8	-	-
14	Silicon-32	D, see ^{31}Si	2E+3	2E+2	1E-7	3E-10	-	-
			LLI wall (3E+3)	-	-	-	4E-5	4E-4
		W, see ^{31}Si	-	1E+2	5E-8	2E-10	-	-
		Y, see ^{31}Si	-	5E+0	2E-9	7E-12	-	-
15	Phosphorus-32	D, all compounds except phosphates given for W	6E+2	9E+2	4E-7	1E-9	9E-6	9E-5
		W, phosphates of Zn^{2+}, S^{3+}, Mg^{2+}, Fe^{3+}, Bi^{3+}, and lanthanides	-	4E+2	2E-7	5E-10	-	-
15	Phosphorus-33	D, see ^{32}P	6E+3	8E+3	4E-6	1E-8	8E-5	8E-4
		W, see ^{32}P	-	3E+3	1E-6	4E-9	-	-
16	Sulfur-35	Vapor	-	1E+4	6E-6	2E-8	-	-
		D, sulfides and sulfates except those given for W	1E+4	2E+4	7E-6	2E-8	-	-
			LLI wall (8E+3)	-	-	-	1E-4	1E-3
		W, elemental sulfur, sulfides of Sr, Ra, Ge, Sn, Pb, As, Sb, Bi, Cu, Ag, Au, In, Cd, Hg, W, and Mo. Sulfates of Ca, Sr, Ba, Ra, As, Sb, and Bi	6E+3					
			-	2E+3	9E-7	3E-9	-	-
17	Chlorine-36	D, chlorides of H, Li, Na, K, Rb, Cs, and Fr	2E+3	2E+3	1E-6	3E-9	2E-5	2E-4
		W, chlorides of lanthanides, Be, Mg, Ca, Sr, Ba, Ra, Al, Ga, In, Tl, Ge, Sn, Pb, As, Sb, Bi, Fe, Ru, Os, Co, Rh, Ir, Ni, Pd, Pt, Cu, Ag, Au, Zn, Cd, Hg, Sc, Y, Ti, Zr, Hf, V, Nb, Ta, Cr, Mo, W, Mn, Tc, and Re	-	2E+2	1E-7	3E-10	-	-

Atomic No.	Radionuclide	Class	Table 1 Occupational Values: Col. 1 Oral Ingestion ALI (µCi)	Col. 2 Inhalation ALI (µCi)	Col. 3 Inhalation DAC (µCi/ml)	Table 2 Effluent Concentrations: Col. 1 Air (µCi/ml)	Col. 2 Water (µCi/ml)	Table 3 Releases to Sewers: Monthly Average Concentration (µCi/ml)
17	Chlorine-38[2]	D, see ^{36}Cl	2E+4	4E+4	2E-5	6E-8	-	-
			St. wall (3E+4)	-	-	-	3E-4	3E-3
		W, see ^{36}Cl	-	5E+4	2E-5	6E-8	-	-
17	Chlorine-39[2]	D, see ^{36}Cl	2E+4	5E+4	2E-5	7E-8	-	-
			St. wall (4E+4)	-	-	-	5E-4	5E-3
		W, see ^{36}Cl	-	6E+4	2E-5	8E-8	-	-
18	Argon-37	Submersion[1]	-	-	1E+0	6E-3	-	-
18	Argon-39	Submersion[1]	-	-	2E-4	8E-7	-	-
18	Argon-41	Submersion[1]	-	-	3E-6	1E-8	-	-
19	Potassium-40	D, all compounds	3E+2	4E+2	2E-7	6E-10	4E-6	4E-5
19	Potassium-42	D, all compounds	5E+1	5E+3	2E-6	7E-9	6E-5	6E-4
19	Potassium-43	D, all compounds	6E+1	9E+1	4E-6	1E-8	9E-5	9E-4
19	Potassium-44[2]	D, all compounds	2E+4	7E+4	3E-5	9E-8	-	-
			St. wall (4E+4)	-	-	-	5E-4	5E-3
19	Potassium-45[2]	D, all compounds	3E+4	1E+5	5E-5	2E-7	-	-
			St. wall (5E+4)	-	-	-	7E-4	7E-3
20	Calcium-41	W, all compounds	3E+3	4E+3	2E-6	-	-	-
			Bone surf (4E+3)	Bone surf (4E+3)	-	5E-9	6E-5	6E-4
20	Calcium-45	W, all compounds	2E+3	8E+2	4E-7	1E-9	2E-5	2E-4
20	Calcium-47	W, all compounds	8E+2	9E+2	4E-7	1E-9	1E-5	1E-4
21	Scandium-43	Y, all compounds	7E+3	2E+4	9E-6	3E-8	1E-4	1E-3
21	Scandium-44m	Y, all compounds	5E+2	7E+2	3E-7	1E-9	7E-6	7E-5
21	Scandium-44	Y, all compounds	4E+3	1E+4	5E-6	2E-8	5E-5	5E-4
21	Scandium-46	Y, all compounds	9E+2	2E+2	1E-7	3E-10	1E-5	1E-4
21	Scandium-47	Y, all compounds	2E+3	3E+3	1E-6	4E-9	-	-
			LLI wall (3E+3)	-	-	-	4E-5	4E-4
21	Scandium-48	Y, all compounds	8E+2	1E+3	6E-7	2E-9	1E-5	1E-4
21	Scandium-49[2]	Y, all compounds	2E+4	5E+4	2E-5	8E-8	3E-4	3E-3
22	Titanium-44	D, all compounds except those given for W and Y	3E+2	1E+1	5E-9	2E-11	4E-6	4E-5
		W, oxides, hydroxides, carbides, halides, and nitrates	-	3E+1	1E-8	4E-11	-	-
		Y, $SrTiO_3$	-	6E+0	2E-9	8E-12	-	-

Atomic No.	Radionuclide	Class	Table 1 Occupational Values: Col. 1 Oral Ingestion ALI (µCi)	Col. 2 Inhalation ALI (µCi)	Col. 3 Inhalation DAC (µCi/ml)	Table 2 Effluent Concentrations: Col. 1 Air (µCi/ml)	Col. 2 Water (µCi/ml)	Table 3 Releases to Sewers: Monthly Average Concentration (µCi/ml)
22	Titanium-45	D, see ^{44}Ti	9E+3	3E+4	1E-5	3E-8	1E-4	1E-3
		W, see ^{44}Ti	-	4E+4	1E-5	5E-8	-	-
		Y, see ^{44}Ti	-	3E+4	1E-5	4E-8	-	-
23	Vanadium-47[2]	D, all compounds except those given for W	3E+4	8E+4	3E-5	1E-7	-	-
			St. wall (3E+4)	-	-	-	4E-4	4E-3
		W, oxides, hydroxides, carbides, and halides	-	1E+5	4E-5	1E-7	-	-
23	Vanadium-48	D, see ^{47}V	6E+2	1E+3	5E-7	2E-9	9E-6	9E-5
		W, see ^{47}V	-	6E+2	3E-7	9E-10	-	-
23	Vanadium-49	D, see ^{47}V	7E+4	3E+4	1E-5	-	-	-
			LLI wall (9E+4)	Bone surf (3E+4)	-	5E-8	1E-3	1E-2
		W, see ^{47}V	-	2E+4	8E-6	2E-8	-	-
24	Chromium-48	D, all compounds except those given for W and Y	6E+3	1E+4	5E-6	2E-8	8E-5	8E-4
		W, halides and nitrates	-	7E+3	3E-6	1E-8	-	-
		Y, oxides and hydroxides	-	7E+3	3E-6	2E-8	-	-
24	Chromium-49[2]	D, see ^{48}Cr	3E+4	8E+4	4E-5	1E-7	4E-4	4E-3
		W, see ^{48}Cr	-	1E+5	4E-5	1E-7	-	-
		Y, see ^{48}Cr	-	9E+4	4E-5	3E-7	-	-
24	Chromium-51	D, see ^{48}Cr	4E+4	5E+4	2E-5	6E-8	5E-4	5E-3
		W, see ^{48}Cr	-	2E+4	1E-5	3E-8	-	-
		Y, see ^{48}Cr	-	2E+4	8E-6	3E-8	-	-
25	Manganese-51[2]	D, all compounds except those given for W	2E+4	5E+4	2E-5	7E-8	3E-4	3E-3
		W, oxides, hydroxides, halides, and nitrates	-	6E+4	3E-5	8E-8	-	-
25	Manganese-52m[2]	D, see ^{51}Mn	3E+4	9E+4	4E-5	1E-7	-	-
			St. wall (4E+4)	-	-	-	5E-4	5E-3
		W, see ^{51}Mn	-	1E+5	4E-5	1E-7	-	-
25	Manganese-52	D, see ^{51}Mn	7E+2	1E+3	5E-7	2E-9	1E-5	1E-4
		W, see ^{51}Mn	-	9E+2	4E-7	1E-9	-	-
25	Manganese-53	D, see ^{51}Mn	5E+4	1E+4	5E-6	-	7E-4	7E-3
			-	Bone surf (2E+4)	-	3E-8	-	-
		W, see ^{51}Mn	-	1E+4	5E-6	2E-8	-	-
25	Manganese-54	D, see ^{51}Mn	2E+3	9E+2	4E-7	1E-9	3E-5	3E-4
		W, see ^{51}Mn	-	8E+2	3E-7	1E-9	-	-
25	Manganese-56	D, see ^{51}Mn	5E+3	2E+4	6E-6	2E-8	7E-5	7E-4
		W, see ^{51}Mn	-	2E+4	9E-6	3E-8	-	-

Atomic No.	Radionuclide	Class	Table 1 Occupational Values: Col. 1 Oral Ingestion ALI (µCi)	Col. 2 Inhalation ALI (µCi)	Col. 3 Inhalation DAC (µCi/ml)	Table 2 Effluent Concentrations: Col. 1 Air (µCi/ml)	Col. 2 Water (µCi/ml)	Table 3 Releases to Sewers: Monthly Average Concentration (µCi/ml)
26	Iron-52	D, all compounds except those given for W	9E+2	3E+3	1E-6	4E-9	1E-5	1E-4
		W, oxides, hydroxides, and halides	-	2E+3	1E-6	3E-9	-	-
26	Iron-55	D, see ^{52}Fe	9E+3	2E+3	8E-7	3E-9	1E-4	1E-3
		W, see ^{52}Fe	-	4E+3	2E-6	6E-9	-	-
26	Iron-59	D, see ^{52}Fe	8E+2	3E+2	1E-7	5E-10	1E-5	1E-4
		W, see ^{52}Fe	-	5E+2	2E-7	7E-10	-	-
26	Iron-60	D, see ^{52}Fe	3E+1	6E+0	3E-9	9E-12	4E-7	4E-6
		W, see ^{52}Fe	-	2E+1	8E-9	3E-11	-	-
27	Cobalt-55	W, all compounds except those given for Y	1E+3	3E+3	1E-6	4E-9	2E-5	2E-4
		Y, oxides, hydroxides, halides, and nitrates	-	3E+3	1E-6	4E-9	-	-
27	Cobalt-56	W, see ^{55}Co	5E+2	3E+2	1E-7	4E-10	6E-6	6E-5
		Y, see ^{55}Co	4E+2	2E+2	8E-8	3E-10	-	-
27	Cobalt-57	W, see ^{55}Co	8E+3	3E+3	1E-6	4E-9	6E-5	6E-4
		Y, see ^{55}Co	4E+3	7E+2	3E-7	9E-10	-	-
27	Cobalt-58m	W, see ^{55}Co	6E+4	9E+4	4E-5	1E-7	8E-4	8E-3
		Y, see ^{55}Co	-	6E+4	3E-5	9E-8	-	-
27	Cobalt-58	W, see ^{55}Co	2E+3	1E+3	5E-7	2E-9	2E-5	2E-4
		Y, see ^{55}Co	1E+3	7E+2	3E-7	1E-9	-	-
27	Cobalt-60m[2]	W, see ^{55}Co	1E+6	4E+6	2E-3	6E-6	-	-
			St. wall (1E+6)	-	-	-	2E-2	2E-1
		Y, see ^{55}Co	-	3E+6	1E-3	4E-6	-	-
27	Cobalt-60	W, see ^{55}Co	5E+2	2E+2	7E-8	2E-10	3E-6	3E-5
		Y, see ^{55}Co	2E+2	3E+1	1E-8	5E-11	-	-
27	Cobalt-61[2]	W, see ^{55}Co	2E+4	6E+4	3E-5	9E-8	3E-4	3E-3
		Y, see ^{55}Co	2E+4	6E+4	2E-5	8E-8	-	-
27	Cobalt-62m[2]	W, see ^{55}Co	4E+4	2E+5	7E-5	2E-7	-	-
			St. wall (5E+4)	-	-	-	7E-4	7E-3
		Y, see ^{55}Co	-	2E+5	6E-5	2E-7	-	-
28	Nickel-56	D, all compounds except those given for W	1E+3	2E+3	8E-7	3E-9	2E-5	2E-4
		W, oxides, hydroxides, and carbides	-	1E+3	5E-7	2E-9	-	-
		Vapor	-	1E+3	5E-7	2E-9	-	-
28	Nickel-57	D, see ^{56}Ni	2E+3	5E+3	2E-6	7E-9	2E-5	2E-4
		W, see ^{56}Ni	-	3E+3	1E-6	4E-9	-	-
		Vapor	-	6E+3	3E-6	9E-9	-	-

Atomic No.	Radionuclide	Class	Table 1 Occupational Values: Col. 1 Oral Ingestion ALI (µCi)	Col. 2 Inhalation ALI (µCi)	Col. 3 Inhalation DAC (µCi/ml)	Table 2 Effluent Concentrations: Col. 1 Air (µCi/ml)	Col. 2 Water (µCi/ml)	Table 3 Releases to Sewers: Monthly Average Concentration (µCi/ml)
28	Nickel-59	D, see ^{56}Ni	2E+4	4E+3	2E-6	5E-9	3E-4	3E-3
		W, see ^{56}Ni	-	7E+3	3E-6	1E-8	-	-
		Vapor	-	2E+3	8E-7	3E-9	-	-
28	Nickel-63	D, see ^{56}Ni	9E+3	2E+3	7E-7	2E-9	1E-4	1E-3
		W, see ^{56}Ni	-	3E+3	1E-6	4E-9	-	-
		Vapor	-	8E+2	3E-7	1E-9	-	-
28	Nickel-65	D, see ^{56}Ni	8E+1	2E+4	1E-5	3E-8	1E-4	1E-3
		W, see ^{56}Ni	-	3E+4	1E-5	4E-8	-	-
		Vapor	-	2E+4	7E-6	2E-8	-	-
28	Nickel-66	D, see ^{56}Ni	4E+2	2E+3	7E-7	2E-9	-	-
			LLI wall (5E+2)	-	-	-	6E-6	6E-5
		W, see ^{56}Ni	-	6E+2	3E-7	9E-10	-	-
		Vapor	-	3E+3	1E-6	4E-9	-	-
29	Copper-60[2]	D, all compounds except those given for W and Y	3E+4	9E+4	4E-5	1E-7	-	-
			St. wall (3E+4)	-	-	-	4E-4	4E-3
		W, sulfides, halides, and nitrates	-	1E+5	5E-5	2E-7	-	-
		Y, oxides and hydroxides	-	1E+5	4E-5	1E-7	-	-
29	Copper-61	D, see ^{60}Cu	1E+4	3E+4	1E-5	4E-8	2E-4	2E-3
		W, see ^{60}Cu	-	4E+4	2E-5	6E-8	-	-
		Y, see ^{60}Cu	-	4E+4	1E-5	5E-8	-	-
29	Copper-64	D, see ^{60}Cu	1E+4	3E+4	1E-5	4E-8	2E-4	2E-3
		W, see ^{60}Cu	-	2E+4	1E-5	3E-8	-	-
		Y, see ^{60}Cu	-	2E+4	9E-6	3E-8	-	-
29	Copper-67	D, see ^{60}Cu	5E+3	8E+3	3E-6	1E-8	6E-5	6E-4
		W, see ^{60}Cu	-	5E+3	2E-6	7E-9	-	-
		Y, see ^{60}Cu	-	5E+3	2E-6	6E-9	-	-
30	Zinc-62	Y, all compounds	1E+3	3E+3	1E-6	4E-9	2E-5	2E-4
30	Zinc-63[2]	Y, all compounds	2E+4	7E+4	3E-5	9E-8	-	-
			St. wall (3E+4)	-	-	-	3E-4	3E-3
30	Zinc-65	Y, all compounds	4E+2	3E+2	1E-7	4E-10	5E-6	5E-5
30	Zinc-69m	Y, all compounds	4E+3	7E+3	3E-6	1E-8	6E-5	6E-4
30	Zinc-69[2]	Y, all compounds	6E+4	1E+5	6E-5	2E-7	8E-4	8E-3
30	Zinc-71m	Y, all compounds	6E+3	2E+4	7E-6	2E-8	8E-5	8E-4
30	Zinc-72	Y, all compounds	1E+3	1E+3	5E-7	2E-9	1E-5	1E-4
31	Gallium-65[2]	D, all compounds except those given for W	5E+4	2E+5	7E-5	2E-7	-	-
			St. wall (6E+4)	-	-	-	9E-4	9E-3
		W, oxides, hydroxides, carbides, halides, and nitrates	-	2E+5	8E-5	3E-7	-	-

Atomic No.	Radionuclide	Class	Table 1 Occupational Values: Col. 1 Oral Ingestion ALI (µCi)	Col. 2 Inhalation ALI (µCi)	Col. 3 Inhalation DAC (µCi/ml)	Table 2 Effluent Concentrations: Col. 1 Air (µCi/ml)	Col. 2 Water (µCi/ml)	Table 3 Releases to Sewers: Monthly Average Concentration (µCi/ml)
31	Gallium-66	D, see ^{65}Ga	1E+3	4E+3	1E-6	5E-9	1E-5	1E-4
		W, see ^{65}Ga	-	3E+3	1E-6	4E-9	-	-
31	Gallium-67	D, see ^{65}Ga	7E+3	1E+4	6E-6	2E-8	1E-4	1E-3
		W, see ^{65}Ga	-	1E+4	4E-6	1E-8	-	-
31	Gallium-68[2]	D, see ^{65}Ga	2E+4	4E+4	2E-5	6E-8	2E-4	2E-3
		W, see ^{65}Ga	-	5E+4	2E-5	7E-8	-	-
31	Gallium-70[2]	D, see ^{65}Ga	5E+4	2E+5	7E-5	2E-7	-	-
			St. wall (7E+4)	-	-	-	1E-3	1E-2
		W, see ^{65}Ga	-	2E+5	8E-5	3E-7	-	-
31	Gallium-72	D, see ^{65}Ga	1E+3	4E+3	1E-6	5E-9	2E-5	2E-4
		W, see ^{65}Ga	-	3E+3	1E-6	4E-9	-	-
31	Gallium-73	D, see ^{65}Ga	5E+3	2E+4	6E-6	2E-8	7E-5	7E-4
		W, see ^{65}Ga	-	2E+4	6E-6	2E-8	-	-
32	Germanium-66	D, all compounds except those given for W	2E+4	3E+4	1E-5	4E-8	3E-4	3E-3
		W, oxides, sulfides, and halides	-	2E+4	8E-6	3E-8	-	-
32	Germanium-67[2]	D, see ^{66}Ge	3E+4	9E+4	4E-5	1E-7	-	-
			St. wall (4E+4)	-	-	-	6E-4	6E-3
		W, see ^{66}Ge	-	1E+5	4E-5	1E-7	-	-
32	Germanium-68	D, see ^{66}Ge	5E+3	4E+1	2E-6	5E-9	6E-5	6E+4
		W, see ^{66}Ge	-	1E+2	4E-8	1E-10	-	-
32	Germanium-69	D, see ^{66}Ge	1E+4	2E+4	8E-6	2E-8	2E-4	2E-3
		W, see ^{66}Ge	-	8E+3	3E-6	1E-8	-	-
32	Germanium-71	D, see ^{66}Ge	5E+5	4E+5	2E-4	6E-7	7E-3	7E-2
		W, see ^{66}Ge	-	4E+4	2E-5	6E-8	-	-
32	Germanium-75[2]	D, see ^{66}Ge	4E+4	8E+4	3E-5	1E-7	-	-
			St. wall (7E+4)	-	-	-	9E-4	9E-3
		W, see ^{66}Ge	-	8E+4	4E-5	1E-7	-	-
32	Germanium-77	D, see ^{66}Ge	9E+3	1E+4	4E-6	1E-8	1E-4	1E-3
		W, see ^{66}Ge	-	6E+3	2E-6	8E-9	-	-
32	Germanium-78[2]	D, see ^{66}Ge	2E+4	2E+4	9E-6	3E-8	-	-
			St. wall (2E+4)	-	-	-	3E-4	3E-3
		W, see ^{66}Ge	-	2E+4	9E-6	3E-8	-	-

Atomic No.	Radionuclide	Class	Table 1 Occupational Values: Col. 1 Oral Ingestion ALI (µCi)	Col. 2 Inhalation ALI (µCi)	Col. 3 Inhalation DAC (µCi/ml)	Table 2 Effluent Concentrations: Col. 1 Air (µCi/ml)	Col. 2 Water (µCi/ml)	Table 3 Releases to Sewers: Monthly Average Concentration (µCi/ml)
33	Arsenic-69[2]	W, all compounds	3E+4	1E+5	5E-5	2E-7	-	-
			St. wall (4E+4)	-	-	-	6E-4	6E-3
33	Arsenic-70[2]	W, all compounds	1E+4	5E+4	2E-5	7E-8	2E-4	2E-3
33	Arsenic-71	W, all compounds	4E+3	5E+3	2E-6	6E-9	5E-5	5E-4
33	Arsenic-72	W, all compounds	9E+2	1E+3	6E-7	2E-9	1E-5	1E-4
33	Arsenic-73	W, all compounds	8E+3	2E+3	7E-7	2E-9	1E-4	1E-3
33	Arsenic-74	W, all compounds	1E+3	8E+2	3E-7	1E-9	2E-5	2E-4
33	Arsenic-76	W, all compounds	1E+3	1E+3	6E-7	2E-9	1E-5	1E-4
33	Arsenic-77	W, all compounds	4E+3	5E+3	2E-6	7E-9	-	-
			LLI wall (5E+3)	-	-	-	6E-5	6E-4
33	Arsenic-78[2]	W, all compounds	8E+3	2E+4	9E-6	3E-8	1E-4	1E-3
34	Selenium-70[2]	D, all compounds except those given for W	2E+4	4E+4	2E-5	5E-8	1E-4	1E-3
		W, oxides, hydroxides, carbides, and elemental Se	1E+4	4E+4	2E-5	6E-8	-	-
34	Selenium-73m[2]	D, see ^{70}Se	6E+4	2E+5	6E-5	2E-7	4E-4	4E-3
		W, see ^{70}Se	3E+4	1E+5	6E-5	2E-7	-	-
34	Selenium-73	D, see ^{70}Se	3E+3	1E+4	5E-6	2E-8	4E-5	4E-4
		W, see ^{70}Se	-	2E+4	7E-6	2E-8	-	-
34	Selenium-75	D, see ^{70}Se	5E+2	7E+2	3E-7	1E-9	7E-6	7E-5
		W, see ^{70}Se	-	6E+2	3E-7	8E-10	-	-
34	Selenium-79	D, see ^{70}Se	6E+2	8E+2	3E-7	1E-9	8E-6	8E-5
		W, see ^{70}Se	-	6E+2	2E-7	8E-10	-	-
34	Selenium-81m[2]	D, see ^{70}Se	4E+4	7E+4	3E-5	9E-8	3E-4	3E-3
		W, see ^{70}Se	2E+4	7E+4	3E-5	3E-7	-	-
34	Selenium-81[2]	D, see ^{70}Se	6E+4	2E+5	9E-5	3E-7	-	-
			St. wall (8E+4)	-	-	-	1E-3	1E-2
		W, see ^{70}Se	-	2E+5	1E-4	3E-7	-	-
34	Selenium-83[2]	D, see ^{70}Se	4E+4	1E+5	5E-5	2E-7	4E-4	4E-3
		W, see ^{70}Se	3E+4	1E+5	5E-5	2E-7	-	-

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Atomic No.	Radionuclide	Class	Table 1 Occupational Values Col. 1 Oral Ingestion ALI (µCi)	Col. 2 Inhalation ALI (µCi)	Col. 3 Inhalation DAC (µCi/ml)	Table 2 Effluent Concentrations Col. 1 Air (µCi/ml)	Col. 2 Water (µCi/ml)	Table 3 Releases to Sewers Monthly Average Concentration (µCi/ml)
35	Bromine-74m[2]	D, bromides of H, Li, Na, K, Rb, Cs, and Fr	1E+4	4E+4	2E-5	5E-8	-	-
			St. wall (2E+4)	-	-	-	3E-4	3E-3
		W, bromides of lanthanides, Ba, Mg, Ca, Sr, Be, Ra, Al, Ga, In, Tl, Ge, Sn, Pb, As, Sb, Bi, Fe, Ru, Os, Co, Rh, Ir, Ni, Pd, Pt, Cu, Ag, Au, Zn, Cd, Hg, Sc, Y, Ti, Zr, Hf, V, Nb, Ta, Mn, Tc, and Re	-	4E+4	2E-5	6E-8	-	-
35	Bromine-74[2]	D, see ^{74m}Br	2E+4	7E+4	3E-5	1E-7	-	-
			St. wall (4E+4)	-	-	-	5E-4	5E-3
		W, see ^{74m}Br	-	8E+4	4E-5	1E-7	-	-
35	Bromine-75[2]	D, see ^{74m}Br	3E+4	5E+4	2E-5	7E-8	-	-
			St. wall (4E+4)	-	-	-	5E-4	5E-3
		W, see ^{74m}Br	-	5E+4	2E-5	7E-8	-	-
35	Bromine-76	D, see ^{74m}Br	4E+3	5E+3	2E-6	7E-9	5E-5	5E-4
		W, see ^{74m}Br	-	4E+3	2E-6	6E-9	-	-
35	Bromine-77	D, see ^{74m}Br	2E+4	2E+4	1E-5	3E-8	2E-4	2E-3
		W, see ^{74m}Br	-	2E+4	8E-6	3E-8	-	-
35	Bromine-80m	D, see ^{74m}Br	2E+4	2E+4	7E-5	2E-8	3E-4	3E-3
		W, see ^{74m}Br	-	1E+4	6E-6	2E-8	-	-
35	Bromine-80[2]	D, see ^{74m}Br	5E+4	2E+5	8E-5	3E-7	-	-
			St. wall (9E+4)	-	-	-	1E-3	1E-2
		W, see ^{74m}Br	-	2E+5	9E-5	3E-7	-	-
35	Bromine-82	D, see ^{74m}Br	3E+3	4E+3	1E-6	6E-9	4E-5	4E-4
		W, see ^{74m}Br	-	4E+3	2E-6	5E-9	-	-
35	Bromine-83	D, see ^{74m}Br	9E+4	6E+4	3E-5	9E-8	-	-
			St. wall (7E+4)	-	-	-	9E-4	9E-3
		W, see ^{74m}Br	-	6E+4	3E-5	9E-8	-	-
35	Bromine-84[2]	D, see ^{74m}Br	2E+4	6E+4	2E-5	8E-8	-	-
			St. wall (3E+4)	-	-	-	4E-4	4E-3
		W, see ^{74m}Br	-	6E+4	3E-5	9E-8	-	-
36	Krypton-74[2]	Submersion[1]	-	-	9E-6	1E-8	-	-
36	Krypton-76	Submersion[1]	-	-	9E-6	4E-8	-	-
36	Krypton-77[2]	Submersion[1]	-	-	4E-6	2E-8	-	-
36	Krypton-79	Submersion[1]	-	-	2E-5	7E-8	-	-
36	Krypton-81	Submersion[1]	-	-	7E-4	3E-6	-	-

Atomic No.	Radionuclide	Class	Table 1 Occupational Values Col. 1 Oral Ingestion ALI (µCi)	Col. 2 Inhalation ALI (µCi)	Col. 3 Inhalation DAC (µCi/ml)	Table 2 Effluent Concentrations Col. 1 Air (µCi/ml)	Col. 2 Water (µCi/ml)	Table 3 Releases to Sewers Monthly Average Concentration (µCi/ml)
36	Krypton-83m[2]	Submersion[1]			1E-2	5E-5	-	
36	Krypton-85m	Submersion[1]	-	-	2E-5	1E-7	-	
36	Krypton-85	Submersion[1]	-	-	1E-4	7E-7	-	-
36	Krypton-87[2]	Submersion[1]	-	-	9E-6	2E-8	-	-
36	Krypton-88	Submersion[1]	-	-	2E-6	9E-9	-	-
37	Rubidium-79[2]	D, all compounds	4E+4	1E+5	5E-5	2E-7	-	-
			St. wall (6E+4)	-	-	-	8E-4	8E-3
37	Rubidium-81m[2]	D, all compounds	2E+5	3E+5	1E-4	5E-7	-	-
			St. wall (3E+5)	-	-	-	4E-3	4E-2
37	Rubidium-81	D, all compounds	4E+4	5E+4	2E-5	7E-8	5E-4	5E-3
37	Rubidium-82m	D, all compounds	1E+4	2E+4	7E-6	2E-8	2E-4	2E-3
37	Rubidium-83	D, all compounds	6E+2	1E+3	4E-7	1E-9	9E-6	9E-5
37	Rubidium-84	D, all compounds	5E+2	8E+2	3E-7	1E-9	7E-6	7E-5
37	Rubidium-86	D, all compounds	5E+2	8E+2	3E-7	1E-9	7E-6	7E-5
37	Rubidium-87	D, all compounds	1E+3	2E+3	6E-7	2E-9	1E-5	1E-4
37	Rubidium-88[2]	D, all compounds	2E+4	6E+4	3E-5	9E-8	-	-
			St. wall (3E+4)	-	-	-	4E-4	4E-3
37	Rubidium-89[2]	D, all compounds	4E+4	1E+5	6E-5	2E-7	-	-
			St. wall (6E+4)	-	-	-	9E-4	9E-3
38	Strontium-80[2]	D, all soluble compounds except $SrTiO_3$	4E+3	1E+4	5E-6	2E-8	6E-5	6E-4
		Y, all insoluble compounds and $SrTiO_3$	-	1E+4	5E-6	2E-8	-	-
38	Strontium-81[2]	D, see ^{80}Sr	3E+4	8E+4	3E-5	1E-7	3E-4	3E-3
		Y, see ^{80}Sr	2E+4	8E+4	3E-5	1E-7	-	-
38	Strontium-82	D, see ^{80}Sr	3E+2	4E+2	2E-7	6E-10	-	-
			LLI wall (2E+2)	-	-	-	3E-6	3E-5
		Y, see ^{80}Sr	2E+2	9E+1	4E-8	1E-10	-	-
38	Strontium-83	D, see ^{80}Sr	3E+3	7E+3	3E-6	1E-8	3E-5	3E-4
		Y, see ^{80}Sr	2E+3	4E+3	1E-6	5E-9	-	-
38	Strontium-85m[2]	D, see ^{80}Sr	2E+5	6E+5	3E-4	9E-7	3E-3	3E-2
		Y, see ^{80}Sr	-	8E+5	4E-4	1E-6	-	-
38	Strontium-85	D, see ^{80}Sr	3E+3	3E+3	1E-6	4E-9	4E-5	4E-4
		Y, see ^{80}Sr	-	2E+3	6E-7	2E-9	-	-
38	Strontium-87m	D, see ^{80}Sr	5E+4	1E+5	5E-5	2E-7	6E-4	6E-3
		Y, see ^{80}Sr	4E+4	2E+5	6E-5	2E-7	-	-

Atomic No.	Radionuclide	Class	Table 1 Occupational Values: Col. 1 Oral Ingestion ALI (µCi)	Table 1 Occupational Values: Col. 2 Inhalation ALI (µCi)	Table 1 Occupational Values: Col. 3 Inhalation DAC (µCi/ml)	Table 2 Effluent Concentrations: Col. 1 Air (µCi/ml)	Table 2 Effluent Concentrations: Col. 2 Water (µCi/ml)	Table 3 Releases to Sewers: Monthly Average Concentration (µCi/ml)
38	Strontium-89	D, see ^{80}Sr	6E+2	8E+2	4E-7	1E-9	-	-
			LLI wall (6E+2)	-	-	-	8E-6	8E-5
		Y, see ^{80}Sr	5E+2	1E+2	6E-8	2E-10	-	-
38	Strontium-90	D, see ^{80}Sr	3E+1	2E+1	8E-9	-	-	-
			Bone surf (4E+1)	Bone surf (2E+1)	-	3E-11	5E-7	5E-6
		Y, see ^{80}Sr	-	4E+0	2E-9	6E-12	-	-
38	Strontium-91	D, see ^{80}Sr	2E+3	6E+3	2E-6	8E-9	2E-5	2E-4
		Y, see ^{80}Sr	-	4E+3	1E-6	5E-9	-	-
38	Strontium-92	D, see ^{80}Sr	3E+3	9E+3	4E-6	1E-8	4E-5	4E-4
		Y, see ^{80}Sr	-	7E+3	3E-6	9E-9	-	-
39	Yttrium-86m[2]	W, all compounds except those given for Y	2E+4	6E+4	2E-5	8E-0	3E-4	3E-3
		Y, oxides and hydroxides	-	5E+4	2E-5	8E-8	-	-
39	Yttrium-86	W, see ^{86m}Y	1E+3	3E+3	1E-6	5E-9	2E-5	2E-4
		Y, see ^{86m}Y	-	3E+3	1E-6	5E-9	-	-
39	Yttrium-87	W, see ^{86m}Y	2E+3	3E+3	1E-6	5E-9	3E-5	3E-4
		Y, see ^{86m}Y	-	3E+3	1E-6	5E-9	-	-
39	Yttrium-88	W, see ^{86m}Y	1E+3	3E+2	1E-7	3E-10	1E-5	1E-4
		Y, see ^{86m}Y	-	2E+2	1E-7	3E-10	-	-
39	Yttrium-90m	W, see ^{86m}Y	8E+3	1E+4	5E-6	2E-8	1E-4	1E-3
		Y, see ^{86m}Y	-	1E+4	5E-6	2E-8	-	-
39	Yttrium-90	W, see ^{86m}Y	4E+2	7E+2	3E-7	9E-10	-	-
			LLI wall (5E+2)	-	-	-	7E-6	7E-5
		Y, see ^{86m}Y	-	6E+2	3E-7	9E-10	-	-
39	Yttrium-91m[2]	W, see ^{86m}Y	1E+6	2E+6	1E-4	3E-7	2E-3	2E-2
		Y, see ^{86m}Y	-	2E+6	7E-5	2E-7	-	-
39	Yttrium-91	W, see ^{86m}Y	5E+2	2E+2	7E-8	2E-10	-	-
			LLI wall (6E+2)	-	-	-	6E-6	6E-5
		Y, see ^{86m}Y	-	1E+2	5E-8	2E-10	-	-
39	Yttrium-92	W, see ^{86m}Y	3E+3	9E+3	4E-6	1E-8	4E-5	4E-4
		Y, see ^{86m}Y	-	8E+3	3E-6	1E-8	-	-
39	Yttrium-93	W, see ^{86m}Y	1E+3	3E+3	1E-6	4E-9	2E-5	2E-4
		Y, see ^{86m}Y	-	2E+3	1E-6	3E-9	-	-
39	Yttrium-94[2]	W, see ^{86m}Y	2E+4	8E+4	3E-5	1E-7	-	-
			St. wall (3E+4)	-	-	-	4E-4	4E-3
		Y, see ^{86m}Y	-	8E+4	3E-5	1E-7	-	-
39	Yttrium-95[2]	W, see ^{86m}Y	4E+4	2E+5	8E-5	2E-7	-	-
			St. wall (5E+4)	-	-	-	7E-4	7E-3
		Y, see ^{86m}Y	-	1E+5	6E-5	2E-7	-	-

Atomic No.	Radionuclide	Class	Table 1 Occupational Values: Col. 1 Oral Ingestion ALI (µCi)	Table 1 Occupational Values: Col. 2 Inhalation ALI (µCi)	Table 1 Occupational Values: Col. 3 Inhalation DAC (µCi/ml)	Table 2 Effluent Concentrations: Col. 1 Air (µCi/ml)	Table 2 Effluent Concentrations: Col. 2 Water (µCi/ml)	Table 3 Releases to Sewers: Monthly Average Concentration (µCi/ml)
40	Zirconium-86	D, all compounds except those given for W and Y	1E+3	4E+3	2E-6	6E-9	2E-5	2E-4
		W, oxides, hydroxides, halides, and nitrates	-	3E+3	1E-6	4E-9	-	-
		Y, carbide	-	2E+3	1E-6	3E-9	-	-
40	Zirconium-88	D, see ^{86}Zr	4E+3	2E+2	9E-8	3E-10	5E-5	5E-4
		W, see ^{86}Zr	-	5E+2	2E-7	7E-10	-	-
		Y, see ^{86}Zr	-	3E+2	1E-7	4E-10	-	-
40	Zirconium-89	D, see ^{86}Zr	2E+3	4E+3	1E-6	5E-9	2E-5	2E-4
		W, see ^{86}Zr	-	2E+3	1E-6	3E-9	-	-
		Y, see ^{86}Zr	-	2E+3	1E-6	3E-9	-	-
40	Zirconium-93	D, see ^{86}Zr	1E+3	6E+0	3E-9	-	-	-
			Bone surf (3E+3)	Bone surf (2E+1)	-	2E-11	4E-5	4E-4
		W, see ^{86}Zr	-	2E+1	1E-8	-	-	-
			-	Bone surf (6E+1)	-	9E-11	-	-
		Y, see ^{86}Zr	-	6E+1	2E-8	-	-	-
			-	Bone surf (7E+1)	-	9E-11	-	-
40	Zirconium-95	D, see ^{86}Zr	1E+3	1E+2	5E-8	-	2E-5	2E-4
			-	Bone surf (3E+2)	-	4E-10	-	-
		W, see ^{86}Zr	-	4E+2	2E-7	5E-10	-	-
		Y, see ^{86}Zr	-	3E+2	1E-7	4E-10	-	-
40	Zirconium-97	D, see ^{86}Zr	6E+2	2E+3	8E-7	3E-9	9E-6	9E-5
		W, see ^{86}Zr	-	1E+3	6E-7	2E-9	-	-
		Y, see ^{86}Zr	-	1E+3	5E-7	2E-9	-	-
41	Niobium-88[2]	W, all compounds except those given for Y	5E+4	2E+5	9E-5	3E-7	-	-
			St. wall (7E+4)	-	-	-	1E-3	1E-2
		Y, oxides and hydroxides	-	2E+5	9E-5	3E-7	-	-
41	Niobium-89m[2] (66 min)	W, see ^{88}Nb	1E+4	4E+4	2E-5	6E-8	1E-4	1E-3
		Y, see ^{88}Nb	-	4E+4	2E-5	5E-8	-	-
41	Niobium-89 (122 min)	W, see ^{88}Nb	5E+3	2E+4	8E-6	3E-8	7E-5	7E-4
		Y, see ^{88}Nb	-	3E+4	6E-6	2E-8	-	-
41	Niobium-90	W, see ^{88}Nb	1E+3	3E+3	1E-6	4E-9	1E-5	1E-4
		Y, see ^{88}Nb	-	2E+3	1E-6	3E-9	-	-
41	Niobium-93m	W, see ^{88}Nb	9E+3	2E+3	8E-7	3E-9	-	-
			LLI wall (1E+4)	-	-	-	2E-4	2E-3
		Y, see ^{88}Nb	-	2E+2	7E-8	2E-10	-	-
41	Niobium-94	W, see ^{88}Nb	9E+2	2E+2	8E-8	3E-10	1E-5	1E-4
		Y, see ^{88}Nb	-	2E+1	6E-9	2E-11	-	-
41	Niobium-95m	W, see ^{88}Nb	2E+3	3E+3	1E-6	4E-9	-	-
			LLI wall (2E+3)	-	-	-	3E-5	3E-4
		Y, see ^{88}Nb	-	2E+3	9E-7	3E-9	-	-

Atomic No.	Radionuclide	Class	Table 1 Occupational Values Col. 1 Oral Ingestion ALI (µCi)	Col. 2 Inhalation ALI (µCi)	Col. 3 Inhalation DAC (µCi/ml)	Table 2 Effluent Concentrations Col. 1 Air (µCi/ml)	Col. 2 Water (µCi/ml)	Table 3 Releases to Sewers Monthly Average Concentration (µCi/ml)
41	Niobium-95	W, see ^{93m}Nb	2E+3	1E+3	5E-7	2E-9	3E-5	3E-4
		Y, see ^{93m}Nb	-	1E+3	5E-7	2E-9	-	-
41	Niobium-96	W, see ^{93m}Nb	1E+3	3E+3	1E-6	4E-9	2E-5	2E-4
		Y, see ^{93m}Nb	-	2E+3	1E-6	3E-9	-	-
41	Niobium-97[2]	W, see ^{93m}Nb	2E+4	8E+4	3E-5	1E-7	3E-4	3E-3
		Y, see ^{93m}Nb	-	7E+4	3E-5	1E-7	-	-
41	Niobium-98[2]	W, see ^{93m}Nb	1E+4	5E+4	2E-5	8E-8	2E-4	2E-3
		Y, see ^{93m}Nb	-	5E+4	2E-5	7E-8	-	-
42	Molybdenum-90	D, all compounds except those given for Y	4E+3	7E+3	3E-6	1E-8	3E-5	3E-4
		Y, oxides, hydroxides, and MoS_2	2E+3	5E+3	2E-6	6E-9	-	-
42	Molybdenum-93m	D, see ^{90}Mo	9E+3	2E+4	7E-6	2E-8	6E-5	6E-4
		Y, see ^{90}Mo	4E+3	1E+4	6E-6	2E-8	-	-
42	Molybdenum-93	D, see ^{90}Mo	4E+3	5E+3	2E-6	8E-9	5E-5	5E-4
		Y, see ^{90}Mo	7E+4	2E+2	8E-8	2E-10	-	-
42	Molybdenum-99	D, see ^{90}Mo	2E+3	3E+3	1E-6	4E-9	-	-
			LLI wall (1E+3)	-	-	-	2E-5	2E-4
		Y, see ^{90}Mo	1E+3	1E+3	6E-7	2E-9	-	-
42	Molybdenum-101[2]	D, see ^{90}Mo	4E+4	1E+5	6E-5	2E-7	-	-
			St. wall (5E+4)	-	-	-	7E-4	7E-3
		Y, see ^{90}Mo	-	1E+5	6E-5	2E-7	-	-
43	Technetium-93m[2]	D, all compounds except those given for W	7E+4	2E+5	6E-5	2E-7	1E-3	1E-2
		W, oxides, hydroxides, halides, and nitrates	-	3E+5	1E-4	4E-7	-	-
43	Technetium-93	D, see ^{93m}Tc	3E+4	7E+4	3E-5	1E-7	4E-4	4E-3
		W, see ^{93m}Tc	-	1E+5	4E-5	1E-7	-	-
43	Technetium-94m[2]	D, see ^{93m}Tc	2E+4	4E+4	2E-5	6E-8	3E-4	3E-3
		W, see ^{93m}Tc	-	6E+4	2E-5	8E-8	-	-
43	Technetium-94	D, see ^{93m}Tc	9E+3	2E+4	8E-6	3E-8	1E-4	1E-3
		W, see ^{93m}Tc	-	2E+4	1E-5	3E-8	-	-
43	Technetium-95m	D, see ^{93m}Tc	4E+3	5E+3	2E-6	8E-9	5E-5	5E-4
		W, see ^{93m}Tc	-	2E+3	8E-7	3E-9	-	-
43	Technetium-95	D, see ^{93m}Tc	1E+4	2E+4	9E-6	3E-8	1E-4	1E-3
		W, see ^{93m}Tc	-	2E+4	8E-6	3E-8	-	-
43	Technetium-96m[2]	D, see ^{93m}Tc	2E+5	3E+5	1E-4	4E-7	2E-3	2E-2
		W, see ^{93m}Tc	-	2E+5	1E-4	3E-7	-	-
43	Technetium-96	D, see ^{93m}Tc	2E+3	3E+3	1E-6	5E-8	3E-5	3E-4
		W, see ^{93m}Tc	-	2E+3	9E-7	3E-9	-	-
43	Technetium-97m	D, see ^{93m}Tc	5E+3	7E+3	3E-6	-	6E-5	6E-4
			-	St. wall (7E+3)	-	1E-8	-	-
		W, see ^{93m}Tc	-	1E+3	5E-7	2E-9	-	-

Atomic No.	Radionuclide	Class	Table 1 Occupational Values Col. 1 Oral Ingestion ALI (µCi)	Col. 2 Inhalation ALI (µCi)	Col. 3 Inhalation DAC (µCi/ml)	Table 2 Effluent Concentrations Col. 1 Air (µCi/ml)	Col. 2 Water (µCi/ml)	Table 3 Releases to Sewers Monthly Average Concentration (µCi/ml)
43	Technetium-97	D, see ^{93m}Tc	4E+4	5E+4	2E-5	7E-8	5E-4	5E-3
		W, see ^{93m}Tc	-	6E+3	2E-6	8E-9	-	-
43	Technetium-98	D, see ^{93m}Tc	1E+3	2E+3	7E-7	2E-9	1E-5	1E-4
		W, see ^{93m}Tc	-	3E+2	1E-7	4E-10	-	-
43	Technetium-99m	D, see ^{93m}Tc	8E+4	2E+5	6E-5	2E-7	1E-3	1E-2
		W, see ^{93m}Tc	-	2E+5	1E-4	3E-7	-	-
43	Technetium-99	D, see ^{93m}Tc	4E+3	5E+3	2E-6	-	6E-5	6E-4
			-	St. wall (6E+3)	-	8E-9	-	-
		W, see ^{93m}Tc	-	7E+2	3E-7	9E-10	-	-
43	Technetium-101[2]	D, see ^{93m}Tc	9E+4	3E+5	1E-4	5E-7	-	-
			St. wall (1E+5)	-	-	-	2E-3	2E-2
		W, see ^{93m}Tc	-	4E+5	2E-4	5E-7	-	-
43	Technetium-104[2]	D, see ^{93m}Tc	2E+4	7E+4	3E-5	1E-7	-	-
			St. wall (3E+4)	-	-	-	4E-4	4E-3
		W, see ^{93m}Tc	-	9E+4	4E-5	1E-7	-	-
44	Ruthenium-94[2]	D, all compounds except those given for W and Y	2E+4	4E+4	2E-5	6E-8	2E-4	2E-3
		W, halides	-	6E+4	3E-5	9E-8	-	-
		Y, oxides and hydroxides	-	6E+4	2E-5	8E-8	-	-
44	Ruthenium-97	D, see ^{94}Ru	8E+3	2E+4	8E-6	3E-8	1E-4	1E-3
		W, see ^{94}Ru	-	1E+4	5E-6	2E-8	-	-
		Y, see ^{94}Ru	-	1E+4	5E-6	2E-8	-	-
44	Ruthenium-103	D, see ^{94}Ru	2E+3	2E+3	7E-7	2E-9	3E-5	3E-4
		W, see ^{94}Ru	-	1E+3	4E-7	1E-9	-	-
		Y, see ^{94}Ru	-	6E+2	3E-7	9E-10	-	-
44	Ruthenium-105	D, see ^{94}Ru	5E+3	1E+4	6E-6	2E-8	7E-5	7E-4
		W, see ^{94}Ru	-	1E+4	6E-6	2E-8	-	-
		Y, see ^{94}Ru	-	1E+4	5E-6	2E-8	-	-
44	Ruthenium-106	D, see ^{94}Ru	2E+2	9E+1	4E-8	1E-10	-	-
			LLI wall (2E+2)	-	-	-	3E-6	3E-5
		W, see ^{94}Ru	-	5E+1	2E-8	8E-11	-	-
		Y, see ^{94}Ru	-	1E+1	5E-9	2E-11	-	-
45	Rhodium-99	D, all compounds except those given for W and Y	2E+4	6E+4	2E-5	8E-8	2E-4	2E-3
		W, halides	-	8E+4	3E-5	1E-7	-	-
		Y, oxides and hydroxides	-	7E+4	3E-5	9E-8	-	-
45	Rhodium-99	D, see ^{99m}Rh	2E+3	3E+3	1E-6	4E-8	3E-5	3E-4
		W, see ^{99m}Rh	-	2E+3	9E-7	3E-9	-	-
		Y, see ^{99m}Rh	-	2E+3	8E-7	3E-9	-	-

Atomic No.	Radionuclide	Class	Table 1 Occupational Values: Col. 1 Oral Ingestion ALI (µCi)	Table 1 Occupational Values: Col. 2 Inhalation ALI (µCi)	Table 1 Occupational Values: Col. 3 Inhalation DAC (µCi/ml)	Table 2 Effluent Concentrations: Col. 1 Air (µCi/ml)	Table 2 Effluent Concentrations: Col. 2 Water (µCi/ml)	Table 3 Releases to Sewers: Monthly Average Concentration (µCi/ml)
45	Rhodium-100	D, see ^{99m}Rh	2E+3	9E+3	2E-6	7E-9	2E-5	2E-4
		W, see ^{99m}Rh	-	4E+3	2E-6	6E-9	-	-
		Y, see ^{99m}Rh	-	4E+3	2E-6	5E-9	-	-
45	Rhodium-101m	D, see ^{99m}Rh	8E+3	1E+4	5E-6	2E-8	8E-5	8E-4
		W, see ^{99m}Rh	-	8E+3	4E-6	1E-8	-	-
		Y, see ^{99m}Rh	-	8E+3	3E-6	1E-8	-	-
45	Rhodium-101	D, see ^{99m}Rh	2E+3	5E+2	2E-7	7E-10	3E-5	3E-4
		W, see ^{99m}Rh	-	8E+2	3E-7	1E-9	-	-
		Y, see ^{99m}Rh	-	2E+2	6E-8	2E-10	-	-
45	Rhodium-102m	D, see ^{99m}Rh	1E+3	5E+2	2E-7	7E-10	-	-
			LLI wall (2E+3)	-	-	-	2E-5	2E-4
		W, see ^{99m}Rh	-	4E+2	2E-7	5E-10	-	-
		Y, see ^{99m}Rh	-	1E+2	5E-8	2E-10	-	-
45	Rhodium-102	D, see ^{99m}Rh	6E+2	9E+1	4E-8	1E-10	8E-6	8E-5
		W, see ^{99m}Rh	-	2E+2	7E-8	2E-10	-	-
		Y, see ^{99m}Rh	-	6E+1	2E-8	8E-11	-	-
45	Rhodium-103m[2]	D, see ^{99m}Rh	4E+6	1E+6	5E-4	2E-6	6E-3	6E-2
		W, see ^{99m}Rh	-	1E+6	5E-4	2E-6	-	-
		Y, see ^{99m}Rh	-	1E+6	5E-4	2E-6	-	-
45	Rhodium-105	D, see ^{99m}Rh	4E+3	1E+4	5E-6	2E-8	-	-
			LLI wall (4E+3)	-	-	-	5E-5	5E-4
		W, see ^{99m}Rh	-	6E+3	3E-6	9E-9	-	-
		Y, see ^{99m}Rh	-	6E+3	2E-6	8E-9	-	-
45	Rhodium-106m	D, see ^{99m}Rh	8E+3	3E+4	1E-5	4E-8	1E-4	1E-3
		W, see ^{99m}Rh	-	4E+4	2E-5	5E-8	-	-
		Y, see ^{99m}Rh	-	4E+4	1E-5	5E-8	-	-
45	Rhodium-107[2]	D, see ^{99m}Rh	7E+6	2E+5	1E-4	3E-7	-	-
			St. wall (9E+6)	-	-	-	1E-3	1E-2
		W, see ^{99m}Rh	-	3E+5	1E-4	4E-7	-	-
		Y, see ^{99m}Rh	-	3E+5	1E-4	3E-7	-	-
46	Palladium-100	D, all compounds except those given for W and Y	1E+3	1E+3	6E-7	2E-9	2E-5	2E-4
		W, nitrates	-	1E+3	9E-7	2E-9	-	-
		Y, oxides and hydroxides	-	1E+3	6E-7	2E-9	-	-
46	Palladium-101	D, see ^{100}Pd	1E+4	3E+4	1E-5	5E-8	2E-4	2E-3
		W, see ^{100}Pd	-	3E+4	1E-5	8E-8	-	-
		Y, see ^{100}Pd	-	3E+4	1E-5	4E-8	-	-
46	Palladium-103	D, see ^{100}Pd	6E+3	6E+3	3E-6	9E-9	-	-
			LLI wall (7E+3)	-	-	-	1E-4	1E-3
		W, see ^{100}Pd	-	4E+3	2E-6	6E-9	-	-
		Y, see ^{100}Pd	-	4E+3	1E-6	5E-9	-	-
46	Palladium-107	D, see ^{100}Pd	3E+4	2E+4	9E-6	-	-	-
			LLI wall (4E+4)	Kidneys (2E+4)	-	3E-8	5E-4	5E-3
		W, see ^{100}Pd	-	7E+3	3E-6	1E-8	-	-
		Y, see ^{100}Pd	-	4E+2	2E-7	6E-10	-	-

Atomic No.	Radionuclide	Class	Table 1 Occupational Values: Col. 1 Oral Ingestion ALI (µCi)	Table 1 Occupational Values: Col. 2 Inhalation ALI (µCi)	Table 1 Occupational Values: Col. 3 Inhalation DAC (µCi/ml)	Table 2 Effluent Concentrations: Col. 1 Air (µCi/ml)	Table 2 Effluent Concentrations: Col. 2 Water (µCi/ml)	Table 3 Releases to Sewers: Monthly Average Concentration (µCi/ml)
46	Palladium-109	D, see ^{100}Pd	2E+3	6E+3	3E-6	9E-9	3E-5	3E-4
		W, see ^{100}Pd	-	5E+3	2E-6	8E-9	-	-
		Y, see ^{100}Pd	-	5E+3	2E-6	6E-9	-	-
47	Silver-102[2]	D, all compounds except those given for W and Y	5E+4	2E+5	8E-5	2E-7	-	-
			St. wall (6E+4)	-	-	-	9E-4	9E-3
		W, nitrates and sulfides	-	2E+5	9E-5	3E-7	-	-
		Y, oxides and hydroxides	-	2E+5	8E-5	3E-7	-	-
47	Silver-103[2]	D, see ^{102}Ag	4E+4	1E+5	4E-5	1E-7	5E-4	5E-3
		W, see ^{102}Ag	-	1E+5	5E-5	2E-7	-	-
		Y, see ^{102}Ag	-	1E+5	5E-5	2E-7	-	-
47	Silver-104m[2]	D, see ^{102}Ag	3E+4	9E+4	4E-5	1E-7	4E-4	4E-3
		W, see ^{102}Ag	-	1E+5	5E-5	2E-7	-	-
		Y, see ^{102}Ag	-	1E+5	5E-5	2E-7	-	-
47	Silver-104[2]	D, see ^{102}Ag	2E+4	7E+4	3E-5	1E-7	3E-4	3E-3
		W, see ^{102}Ag	-	1E+5	6E-5	2E-7	-	-
		Y, see ^{102}Ag	-	1E+5	6E-5	2E-7	-	-
47	Silver-105	D, see ^{102}Ag	3E+3	1E+3	4E-7	1E-9	4E-5	4E-4
		W, see ^{102}Ag	-	2E+3	7E-7	2E-9	-	-
		Y, see ^{102}Ag	-	2E+3	7E-7	2E-9	-	-
47	Silver-106m	D, see ^{102}Ag	8E+2	7E+2	3E-7	1E-9	1E-5	1E-4
		W, see ^{102}Ag	-	9E+2	4E-7	1E-9	-	-
		Y, see ^{102}Ag	-	9E+2	4E-7	1E-9	-	-
47	Silver-106[2]	D, see ^{102}Ag	6E+4	2E+5	8E-5	3E-7	-	-
			St. wall (6E+4)	-	-	-	9E-4	9E-3
		W, see ^{102}Ag	-	2E+5	9E-5	3E-7	-	-
		Y, see ^{102}Ag	-	2E+5	8E-5	3E-7	-	-
47	Silver-108m	D, see ^{102}Ag	6E+2	2E+2	8E-8	3E-10	9E-6	9E-5
		W, see ^{102}Ag	-	3E+2	1E-7	4E-10	-	-
		Y, see ^{102}Ag	-	2E+1	1E-8	3E-11	-	-
47	Silver-110m	D, see ^{102}Ag	5E+2	1E+2	5E-8	2E-10	6E-6	6E-5
		W, see ^{102}Ag	-	2E+2	8E-8	3E-10	-	-
		Y, see ^{102}Ag	-	9E+1	4E-8	1E-10	-	-
47	Silver-111	D, see ^{102}Ag	9E+2	2E+3	6E-7	-	-	-
			LLI wall (1E+3)	Liver (2E+3)	-	2E-9	2E-5	2E-4
		W, see ^{102}Ag	-	9E+2	4E-7	1E-9	-	-
		Y, see ^{102}Ag	-	9E+2	4E-7	1E-9	-	-
47	Silver-112	D, see ^{102}Ag	3E+3	8E+3	3E-6	1E-8	4E-5	4E-4
		W, see ^{102}Ag	-	1E+4	4E-6	1E-8	-	-
		Y, see ^{102}Ag	-	9E+3	4E-6	1E-8	-	-

Atomic No.	Radionuclide	Class	Table 1 Occupational Values: Col. 1 Oral Ingestion ALI (µCi)	Table 1 Occupational Values: Col. 2 Inhalation ALI (µCi)	Table 1 Occupational Values: Col. 2 Inhalation DAC (µCi/ml)	Table 1 Occupational Values: Col. 3 Inhalation	Table 2 Effluent Concentrations: Col. 1 Air (µCi/ml)	Table 2 Effluent Concentrations: Col. 2 Water (µCi/ml)	Table 3 Releases to Sewers: Monthly Average Concentration (µCi/ml)
47	Silver-115[2]	D, see ^{102}Ag	3E+4 St. wall (3E+4)	9E+4	4E-8		1E-7	-	-
		W, see ^{102}Ag	-	-	-		-	4E-4	4E-3
		Y, see ^{102}Ag	-	9E+4	4E-8		1E-7	-	-
			-	8E+4	3E-5		1E-7	-	-
48	Cadmium-104[2]	D, all compounds except those given for W and Y	2E+4	7E+4	3E-5		9E-8	3E-4	3E-3
		W, sulfides, halides, and nitrates	-	1E+5	5E-5		2E-7	-	-
		Y, oxides and hydroxides	-	1E+5	5E-5		2E-7	-	-
48	Cadmium-107	D, see ^{104}Cd	2E+4	5E+4	2E-8		8E-8	3E-4	3E-3
		W, see ^{104}Cd	-	6E+4	2E-5		8E-8	-	-
		Y, see ^{104}Cd	-	5E+4	2E-8		7E-8	-	-
48	Cadmium-109	D, see ^{104}Cd	3E+2 Kidneys (4E+2)	4E+1 Kidneys (5E+1)	1E-8		-	-	-
		W, see ^{104}Cd	-	1E+2 Kidneys (1E+2)	5E-8		7E-11	6E-6	6E-5
		Y, see ^{104}Cd	-	1E+2	5E-8		2E-10	-	-
48	Cadmium-113m	D, see ^{104}Cd	2E+1 Kidneys (4E+1)	2E+0 Kidneys (4E+0)	1E-9		-	-	-
		W, see ^{104}Cd	-	8E+0 Kidneys (1E+1)	4E-8		5E-12	6E-7	5E-6
		Y, see ^{104}Cd	-	1E+1	5E-9		2E-11	-	-
48	Cadmium-113	D, see ^{104}Cd	2E+1 Kidneys (3E+1)	2E+0 Kidneys (3E+0)	9E-10		-	-	-
		W, see ^{104}Cd	-	8E+0 Kidneys (3E+1)	3E-9		5E-12	4E-7	4E-6
		Y, see ^{104}Cd	-	1E+1	6E-9		2E-11	-	-
48	Cadmium-115m	D, see ^{104}Cd	3E+2	5E+1 Kidneys (8E+1)	2E-8		-	4E-6	4E-5
		W, see ^{104}Cd	-	1E+2	5E-8		1E-10	-	-
		Y, see ^{104}Cd	-	1E+2	6E-8		2E-10	-	-
48	Cadmium-115	D, see ^{104}Cd	9E+2 LLI wall (1E+3)	1E+3	6E-7		2E-9	-	-
		W, see ^{104}Cd	-	1E+3	5E-7		-	1E-5	1E-4
		Y, see ^{104}Cd	-	1E+3	6E-7		2E-9	-	-
48	Cadmium-117m	D, see ^{104}Cd	5E+3	1E+4	5E-6		2E-8	6E-5	6E-4
		W, see ^{104}Cd	-	2E+4	7E-6		2E-8	-	-
		Y, see ^{104}Cd	-	1E+4	6E-6		2E-8	-	-

Atomic No.	Radionuclide	Class	Table 1 Occupational Values: Col. 1 Oral Ingestion ALI (µCi)	Table 1 Occupational Values: Col. 2 Inhalation ALI (µCi)	Table 1 Occupational Values: Col. 2 Inhalation DAC (µCi/ml)	Table 1 Occupational Values: Col. 3 Inhalation	Table 2 Effluent Concentrations: Col. 1 Air (µCi/ml)	Table 2 Effluent Concentrations: Col. 2 Water (µCi/ml)	Table 3 Releases to Sewers: Monthly Average Concentration (µCi/ml)
48	Cadmium-117	D, see ^{104}Cd	5E+3	3E+4	5E-6		2E-8	6E-5	6E-4
		W, see ^{104}Cd	-	2E+4	7E-6		2E-8	-	-
		Y, see ^{104}Cd	-	1E+4	6E-6		2E-8	-	-
49	Indium-109	D, all compounds except those given for W	2E+4	4E+4	2E-5		6E-8	3E-4	3E-3
		W, oxides, hydroxides, halides, and nitrates	-	6E+4	3E-5		9E-8	-	-
49	Indium-110[2] (69.1 min)	D, see ^{109}In	2E+4	4E+4	2E-5		8E-8	2E-4	2E-3
		W, see ^{109}In	-	6E+4	2E-5		8E-8	-	-
49	Indium-110 (4.9 h)	D, see ^{109}In	5E+3	2E+4	7E-6		2E-8	7E-5	7E-4
		W, see ^{109}In	-	2E+4	8E-6		3E-8	-	-
49	Indium-111	D, see ^{109}In	4E+3	6E+3	3E-6		9E-9	6E-5	6E-4
		W, see ^{109}In	-	6E+3	3E-6		9E-9	-	-
49	Indium-112[2]	D, see ^{109}In	2E+5	6E+5	3E-4		9E-7	2E-3	2E-2
		W, see ^{109}In	-	7E+5	3E-4		1E-6	-	-
49	Indium-113m[2]	D, see ^{109}In	5E+4	1E+5	6E-5		2E-7	7E-4	7E-3
		W, see ^{109}In	-	2E+5	8E-5		3E-7	-	-
49	Indium-114m	D, see ^{109}In	3E+2 LLI wall (4E+2)	6E+1	3E-8		9E-11	-	-
		W, see ^{109}In	-	1E+2	4E-8		1E-10	5E-6	5E-5
4	Indium-115m	D, see ^{109}In	1E+4	4E+4	2E-5		6E-8	2E-4	2E-3
		W, see ^{109}In	-	5E+4	2E-5		7E-8	-	-
49	Indium-115	D, see ^{109}In	4E+1	1E+0	6E-10		2E-12	5E-7	5E-6
		W, see ^{109}In	-	5E+0	2E-9		8E-12	-	-
49	Indium-116m[2]	D, see ^{109}In	2E+4	8E+4	3E-5		1E-7	3E-4	3E-3
		W, see ^{109}In	-	1E+5	5E-5		2E-7	-	-
49	Indium-117m[2]	D, see ^{109}In	1E+4	3E+4	1E-5		5E-8	2E-4	2E-3
		W, see ^{109}In	-	4E+4	2E-5		6E-8	-	-
49	Indium-117[2]	D, see ^{109}In	6E+4	2E+5	7E-5		2E-7	8E-4	8E-3
		W, see ^{109}In	-	2E+5	9E-5		3E-7	-	-
49	Indium-119m[2]	D, see ^{109}In	4E+4 St. wall (5E+4)	1E+5	5E-5		2E-7	-	-
		W, see ^{109}In	-	1E+5	6E-5		2E-7	7E-4	7E-3
50	Tin-110	D, all compounds except those given for W	4E+3	1E+4	5E-6		2E-8	5E-5	5E-4
		W, sulfides, oxides, hydroxides, halides, nitrates, and stannic phosphate	-	1E+4	5E-6		2E-8	-	-
50	Tin-111[2]	D, see ^{110}Sn	7E+4	2E+5	9E-5		3E-7	1E-3	1E-2
		W, see ^{110}Sn	-	3E+5	1E-4		4E-7	-	-

Atomic No.	Radionuclide	Class	Table 1 Occupational Values: Col. 1 Oral Ingestion ALI (μCi)	Table 1: Col. 2 Inhalation ALI (μCi)	Table 1: Col. 3 Inhalation DAC (μCi/ml)	Table 2 Effluent Concentrations: Col. 1 Air (μCi/ml)	Table 2: Col. 2 Water (μCi/ml)	Table 3 Releases to Sewers: Monthly Average Concentration (μCi/ml)
50	Tin-113	D, see ^{110}Sn	2E+3	1E+3	5E-7	2E-9	-	-
			LLI wall (2E+3)	-	-	-	3E-5	3E-4
		W, see ^{110}Sn	-	5E+2	2E-7	8E-10	-	-
50	Tin-117m	D, see ^{110}Sn	2E+3	1E+3	5E-7	-	-	-
			LLI wall (2E+3)	Bone surf (2E+3)	-	3E-9	3E-5	3E-4
		W, see ^{110}Sn	-	1E+3	6E-7	2E-9	-	-
50	Tin-119m	D, see ^{110}Sn	3E+3	2E+3	1E-6	3E-9	-	-
			LLI wall (4E+3)	-	-	-	6E-5	6E-4
		W, see ^{110}Sn	-	1E+3	4E-7	1E-9	-	-
50	Tin-121m	D, see ^{110}Sn	3E+3	9E+2	4E-7	1E-9	-	-
			LLI wall (4E+3)	-	-	-	5E-5	5E-4
		W, see ^{110}Sn	-	5E+2	2E-7	8E-10	-	-
50	Tin-121	D, see ^{110}Sn	6E+3	2E+4	6E-6	2E-8	-	-
			LLI wall (6E+3)	-	-	-	8E-5	8E-4
		W, see ^{110}Sn	-	1E+4	5E-6	2E-8	-	-
50	Tin-123m[2]	D, see ^{110}Sn	5E+4	1E+5	5E-5	2E-7	7E-4	7E-3
		W, see ^{110}Sn	-	1E+5	6E-5	2E-7	-	-
50	Tin-123	D, see ^{110}Sn	5E+2	6E+2	3E-7	9E-10	-	-
			LLI wall (6E+2)	-	-	-	9E-6	9E-5
		W, see ^{110}Sn	-	2E+2	7E-8	2E-10	-	-
50	Tin-125	D, see ^{110}Sn	4E+2	5E+2	4E-7	1E-9	-	-
			LLI wall (5E+2)	-	-	-	6E-6	6E-5
		W, see ^{110}Sn	-	4E+2	1E-7	5E-10	-	-
50	Tin-126	D, see ^{110}Sn	3E+2	6E+1	2E-8	8E-11	4E-6	4E-5
		W, see ^{110}Sn	-	7E+1	3E-8	9E-11	-	-
50	Tin-127	D, see ^{110}Sn	7E+3	2E+4	8E-6	3E-8	9E-5	9E-4
		W, see ^{110}Sn	-	2E+4	8E-6	3E-8	-	-
50	Tin-128[2]	D, see ^{110}Sn	9E+3	3E+4	1E-5	4E-8	1E-4	1E-3
		W, see ^{110}Sn	-	4E+4	1E-5	5E-8	-	-
51	Antimony-115[2]	D, all compounds except those given for W	8E+4	2E+5	1E-4	3E-7	1E-3	1E-2
		W, oxides, hydroxides, halides, sulfides, sulfates, and nitrates	-	3E+5	1E-4	4E-7	-	-
51	Antimony-116m[2]	D, see ^{115}Sb	2E+4	7E+4	3E-5	1E-7	3E-4	3E-3
		W, see ^{115}Sb	-	1E+5	6E-5	2E-7	-	-
51	Antimony-116[2]	D, see ^{115}Sb	7E+4	3E+5	1E-4	4E-7	-	-
			St. wall (9E+4)	-	-	-	1E-1	1E-2
		W, see ^{115}Sb	-	3E+5	1E-4	5E-7	-	-
51	Antimony-117	D, see ^{115}Sb	7E+4	2E+5	9E-5	3E-7	9E-4	9E-3
		W, see ^{115}Sb	-	3E+5	1E-4	4E-7	-	-

Atomic No.	Radionuclide	Class	Table 1 Occupational Values: Col. 1 Oral Ingestion ALI (μCi)	Table 1: Col. 2 Inhalation ALI (μCi)	Table 1: Col. 3 Inhalation DAC (μCi/ml)	Table 2 Effluent Concentrations: Col. 1 Air (μCi/ml)	Table 2: Col. 2 Water (μCi/ml)	Table 3 Releases to Sewers: Monthly Average Concentration (μCi/ml)
51	Antimony-118m	D, see ^{115}Sb	6E+3	2E+4	8E-6	3E-8	7E-5	7E-4
		W, see ^{115}Sb	5E+3	2E+4	9E-6	3E-8	-	-
51	Antimony-119	D, see ^{115}Sb	2E+4	5E+4	2E-5	6E-8	2E-4	2E-3
		W, see ^{115}Sb	2E+4	3E+4	1E-5	4E-8	-	-
51	Antimony-120[2] (16 min)	D, see ^{115}Sb	1E+5	4E+5	2E-4	6E-7	-	-
			St. wall (2E+5)	-	-	-	2E-3	2E-2
		W, see ^{115}Sb	-	5E+5	2E-4	7E-7	-	-
51	Antimony-120 (5.76 d)	D, see ^{115}Sb	1E+3	2E+3	9E-7	3E-9	1E-5	1E-4
		W, see ^{115}Sb	9E+2	1E+3	5E-7	2E-9	-	-
51	Antimony-122	D, see ^{115}Sb	8E+2	2E+3	1E-6	3E-9	-	-
			LLI wall (8E+2)	-	-	-	1E-5	1E-4
		W, see ^{115}Sb	7E+2	1E+3	4E-7	2E-9	-	-
51	Antimony-124m[2]	D, see ^{115}Sb	3E+5	8E+5	4E-4	1E-6	3E-3	3E-2
		W, see ^{115}Sb	2E+5	6E+5	2E-4	8E-7	-	-
51	Antimony-124	D, see ^{115}Sb	6E+2	9E+2	4E-7	1E-9	7E-8	7E-5
		W, see ^{115}Sb	5E+2	2E+2	1E-7	3E-10	-	-
51	Antimony-125	D, see ^{115}Sb	2E+3	2E+3	1E-6	3E-9	3E-5	3E-4
		W, see ^{115}Sb	-	5E+2	2E-7	7E-10	-	-
51	Antimony-126m[2]	D, see ^{115}Sb	5E+4	2E+5	8E-5	3E-7	-	-
			St. wall (7E+4)	-	-	-	9E-4	9E-3
		W, see ^{115}Sb	-	2E+5	8E-5	3E-7	-	-
51	Antimony-126	D, see ^{115}Sb	6E+2	1E+3	5E-7	2E-9	7E-6	7E-5
		W, see ^{115}Sb	5E+2	5E+2	2E-7	7E-10	-	-
51	Antimony-127	D, see ^{115}Sb	8E+2	2E+3	9E-7	3E-9	-	-
			LLI wall (8E+2)	-	-	-	1E-5	1E-4
		W, see ^{115}Sb	7E+2	9E+2	4E-7	1E-9	-	-
51	Antimony-128[2] (10.4 min)	D, see ^{115}Sb	8E+4	4E+5	2E-4	5E-7	-	-
			St. wall (1E+5)	-	-	-	1E-3	1E-2
		W, see ^{115}Sb	-	4E+5	2E-4	6E-7	-	-
51	Antimony-128 (9.01 h)	D, see ^{115}Sb	1E+3	4E+3	2E-6	6E-9	2E-5	2E-4
		W, see ^{115}Sb	-	3E+3	1E-6	5E-9	-	-
51	Antimony-129	D, see ^{115}Sb	3E+3	9E+3	4E-6	1E-8	4E-5	4E-4
		W, see ^{115}Sb	-	9E+3	4E-6	1E-8	-	-
51	Antimony-130[2]	D, see ^{115}Sb	2E+4	6E+4	3E-5	9E-8	3E-4	3E-3
		W, see ^{115}Sb	-	6E+4	3E-5	1E-7	-	-
51	Antimony-131[2]	D, see ^{115}Sb	1E+4	2E+4	1E-5	-	-	-
			Thyroid (2E+4)	Thyroid (4E+4)	-	6E-8	2E-4	2E-3
		W, see ^{115}Sb	-	2E+4	1E-5		-	-
			-	Thyroid (4E+4)	-	6E-8	-	-

Atomic No.	Radionuclide	Class	Table 1 Occupational Values: Col. 1 Oral Ingestion ALI (µCi)	Col. 2 Inhalation ALI (µCi)	Col. 3 Inhalation DAC (µCi/ml)	Table 2 Effluent Concentrations: Col. 1 Air (µCi/ml)	Col. 2 Water (µCi/ml)	Table 3 Releases to Sewers: Monthly Average Concentration (µCi/ml)
52	Tellurium-116	D, all compounds except those given for W	8E+3	2E+4	9E-6	3E-8	1E-4	1E-3
		W, oxides, hydroxides, and nitrates	-	3E+4	1E-5	4E-8	-	-
52	Tellurium-121m	D, see ^{116}Te	5E+2 Bone surf (7E+2)	2E+2 Bone surf (4E+2)	8E-8 -	- 5E-10	- 1E-5	- 1E-4
		W, see ^{116}Te	-	4E+2	2E-7	6E-10	-	-
52	Tellurium-121	D, see ^{116}Te	3E+3	4E+3	2E-6	6E-9	4E-5	4E-4
		W, see ^{116}Te	-	3E+3	1E-6	4E-9	-	-
52	Tellurium-123m	D, see ^{116}Te	6E+2 Bone surf (1E+3)	2E+2 Bone surf (5E+2)	9E-8 -	- 8E-10	- 1E-5	- 1E-4
		W, see ^{116}Te	-	5E+2	2E-7	8E-10	-	-
52	Tellurium-123	D, see ^{116}Te	5E+2 Bone surf (1E+3)	2E+2 Bone surf (5E+2)	6E-8 -	- 7E-10	- 2E-5	- 2E-4
		W, see ^{116}Te	-	4E+2	2E-7	-	-	-
			-	Bone surf (1E+3)	-	2E-9	-	-
52	Tellurium-125m	D, see ^{116}Te	1E+3 Bone surf (1E+3)	4E+2 Bone surf (1E+3)	2E-7 -	- 1E-9	- 2E-5	- 2E-4
		W, see ^{116}Te	-	7E+2	3E-7	1E-9	-	-
52	Tellurium-127m	D, see ^{116}Te	6E+2	3E+2 Bone surf	1E-7	-	9E-6	9E-5
			-	(4E+2)	-	6E-10	-	-
		W, see ^{116}Te	-	3E+2	1E-7	4E-10	-	-
52	Tellurium-127	D, see ^{116}Te	7E+3	2E+4	9E-6	3E-8	1E-4	1E-3
		W, see ^{116}Te	-	2E+4	7E-6	2E-8	-	-
52	Tellurium-129m	D, see ^{116}Te	5E+2	6E+2	3E-7	9E-10	7E-6	7E-5
		W, see ^{116}Te	-	2E+2	1E-7	3E-10	-	-
52	Tellurium-129[2]	D, see ^{116}Te	3E+4	6E+4	3E-5	9E-8	4E-4	4E-3
		W, see ^{116}Te	-	7E+4	3E-5	1E-7	-	-
52	Tellurium-131m	D, see ^{116}Te	3E+2 Thyroid (6E+2)	4E+2 Thyroid (1E+3)	2E-7 -	- 2E-9	- 8E-6	- 8E-5
		W, see ^{116}Te	-	4E+2	2E-7	-	-	-
			-	Thyroid (9E+2)	-	1E-9	-	-
52	Tellurium-131[2]	D, see ^{116}Te	3E+3 Thyroid (6E+3)	5E+3 Thyroid (1E+4)	2E-8 -	- 2E-8	- 8E-5	- 8E-4
		W, see ^{116}Te	-	5E+3	2E-6	-	-	-
			-	Thyroid (1E+4)	-	2E-8	-	-

Atomic No.	Radionuclide	Class	Table 1 Occupational Values: Col. 1 Oral Ingestion ALI (µCi)	Col. 2 Inhalation ALI (µCi)	Col. 3 Inhalation DAC (µCi/ml)	Table 2 Effluent Concentrations: Col. 1 Air (µCi/ml)	Col. 2 Water (µCi/ml)	Table 3 Releases to Sewers: Monthly Average Concentration (µCi/ml)
52	Tellurium-132	D, see ^{116}Te	2E+2 Thyroid (7E+2)	2E+2 Thyroid (8E+2)	9E-8 -	- 1E-9	- 9E-6	- 9E-5
		W, see ^{116}Te	-	2E+2	9E-8	-	-	-
			-	Thyroid (6E+2)	-	9E+10	-	-
52	Tellurium-133m[2]	D, see ^{116}Te	3E+3 Thyroid (6E+3)	5E+3 Thyroid (1E+4)	2E-6 -	- 2E-8	- 9E-5	- 9E-4
		W, see ^{116}Te	-	5E+3	2E-6	-	-	-
			-	Thyroid (1E+4)	-	2E-8	-	-
52	Tellurium-133[2]	D, see ^{116}Te	1E+4 Thyroid (3E+4)	2E+4 Thyroid (6E+4)	9E-6 -	- 8E-8	- 4E-4	- 4E-3
		W, see ^{116}Te	-	2E+4	9E-6	-	-	-
			-	Thyroid (6E+4)	-	8E-8	-	-
52	Tellurium-134[2]	D, see ^{116}Te	2E+4 Thyroid (2E+4)	2E+4 Thyroid (5E+4)	1E-5 -	- 7E-8	- 3E-4	- 3E-3
		W, see ^{116}Te	-	2E+4	1E-5	-	-	-
			-	Thyroid (5E+4)	-	7E-8	-	-
53	Iodine-120m[2]	D, all compounds	1E+4 Thyroid (1E+4)	2E+4	9E-6	3E-8	-	-
				-	-	-	2E-4	2E-3
53	Iodine-120[2]	D, all compounds	8E+3 Thyroid (8E+3)	9E+3 Thyroid (1E+4)	4E-8 -	- 2E-8	- 1E-4	- 1E-3
53	Iodine-121	D, all compounds	1E+4 Thyroid (3E+4)	2E+4 Thyroid (5E+4)	8E-6 -	- 7E-8	- 4E-4	- 4E-3
53	Iodine-123	D, all compounds	3E+3 Thyroid (1E+4)	6E+3 Thyroid (2E+4)	3E-6 -	- 2E-8	- 1E-4	- 1E-3
53	Iodine-124	D, all compounds	5E+1 Thyroid (2E+2)	8E+1 Thyroid (3E+2)	3E-8 -	- 4E-10	- 2E-6	- 2E-5
53	Iodine-125	D, all compounds	4E+1 Thyroid (1E+2)	6E+1 Thyroid (2E+2)	3E-8 -	- 3E-10	- 2E-6	- 2E-5
53	Iodine-126	D, all compounds	2E+1 Thyroid (7E+3)	4E+1 Thyroid (1E+2)	1E-8 -	- 2E-10	- 1E-6	- 1E-5
53	Iodine-128[2]	D, all compounds	4E+4 St. wall (6E+4)	1E+5 -	5E-5 -	2E-7 -	- 8E-4	- 8E-3
53	Iodine-129	D, all compounds	6E+0 Thyroid (2E+1)	9E+0 Thyroid (3E+1)	4E-9 -	- 4E-11	- 2E-7	- 2E-6

Atomic No.	Radionuclide	Class	Table 1 Occupational Values: Col. 1 Oral Ingestion ALI (µCi)	Col. 2 Inhalation ALI (µCi)	Col. 3 Inhalation DAC (µCi/ml)	Table 2 Effluent Concentrations: Col. 1 Air (µCi/ml)	Col. 2 Water (µCi/ml)	Table 3 Releases to Sewers: Monthly Average Concentration (µCi/ml)
53	Iodine-130	D, all compounds	4E+2 Thyroid (1E+3)	7E+2 Thyroid (2E+3)	3E-7 -	3E-9	2E-5	2E-4
53	Iodine-131	D, all compounds	3E+1 Thyroid (9E+1)	5E+1 Thyroid (2E+2)	2E-8 -	2E-10	1E-6	1E-5
53	Iodine-132m[2]	D, all compounds	4E+3 Thyroid (1E+4)	8E+3 Thyroid (2E+4)	4E-6 -	3E-8	1E-4	1E-3
53	Iodine-132	D, all compounds	4E+3 Thyroid (9E+3)	8E+3 Thyroid (1E+4)	3E-6 -	2E-8	1E-4	1E-3
53	Iodine-133	D, all compounds	1E+2 Thyroid (5E+2)	3E+2 Thyroid (9E+2)	1E-7 -	1E-9	7E-6	7E-5
53	Iodine-134[2]	D, all compounds	2E+4 Thyroid (3E+4)	5E+4 -	2E-5 -	6E-8	4E-4	4E-3
53	Iodine-135	D, all compounds	8E+2 Thyroid (3E+3)	2E+3 Thyroid (4E+3)	7E-7 -	6E-9	3E-5	3E-4
54	Xenon-120[2]	Submersion[1]	-	-	1E-5	4E-8	-	-
54	Xenon-121[2]	Submersion[1]	-	-	2E-6	1E-8	-	-
54	Xenon-122	Submersion[1]	-	-	7E-5	3E-7	-	-
54	Xenon-123	Submersion[1]	-	-	6E-6	3E-8	-	-
54	Xenon-125	Submersion[1]	-	-	2E-5	7E-8	-	-
54	Xenon-127	Submersion[1]	-	-	1E-5	6E-8	-	-
54	Xenon-129m	Submersion[1]	-	-	2E-4	9E-7	-	-
54	Xenon-131m	Submersion[1]	-	-	4E-4	2E-6	-	-
54	Xenon-133m	Submersion[1]	-	-	1E-4	6E-7	-	-
54	Xenon-133	Submersion[1]	-	-	1E-4	5E-7	-	-
54	Xenon-135m[2]	Submersion[1]	-	-	9E-6	4E-8	-	-
54	Xenon-135	Submersion[1]	-	-	1E-5	7E-8	-	-
54	Xenon-138[2]	Submersion[1]	-	-	4E-6	2E-8	-	-
55	Cesium-125[2]	D, all compounds	5E+4 St. wall (9E+4)	1E+5 -	6E-5 -	2E-7 -	1E-3	1E-2
55	Cesium-127	D, all compounds	6E+4	9E+4	4E-5	1E-7	9E-4	9E-3

Atomic No.	Radionuclide	Class	Table 1 Occupational Values: Col. 1 Oral Ingestion ALI (µCi)	Col. 2 Inhalation ALI (µCi)	Col. 3 Inhalation DAC (µCi/ml)	Table 2 Effluent Concentrations: Col. 1 Air (µCi/ml)	Col. 2 Water (µCi/ml)	Table 3 Releases to Sewers: Monthly Average Concentration (µCi/ml)
55	Cesium-129	D, all compounds	2E+4	3E+4	1E-5	5E-8	3E-4	3E-3
55	Cesium-130[2]	D, all compounds	6E+4 St. wall (1E+5)	2E+5 -	8E-5 -	3E-7 -	1E-3	1E-2
55	Cesium-131	D, all compounds	2E+4	3E+4	1E-5	4E-8	3E-4	3E-3
55	Cesium-132	D, all compounds	3E+3	4E+3	2E-6	6E-9	4E-5	4E-4
55	Cesium-134m	D, all compounds	1E+5 St. wall (1E+5)	1E+5 -	6E-5 -	2E-7 -	2E-3	2E-2
55	Cesium-134	D, all compounds	7E+1	1E+2	4E-8	2E-10	9E-7	9E-6
55	Cesium-135m[2]	D, all compounds	1E+5	2E+5	8E-5	3E-7	1E-3	1E-2
55	Cesium-135	D, all compounds	7E+2	1E+3	5E-7	2E-9	1E-5	1E-4
55	Cesium-136	D, all compounds	4E+2	7E+2	3E-7	9E-10	6E-6	6E-5
55	Cesium-137	D, all compounds	1E+2	2E+2	6E-8	2E-10	1E-6	1E-5
55	Cesium-138[2]	D, all compounds	2E+4 St. wall (3E+4)	6E+4 -	2E-5 -	8E-8 -	4E-4	4E-3
56	Barium-126[2]	D, all compounds	6E+3	2E+4	6E-6	2E-8	8E-5	8E-4
56	Barium-128	D, all compounds	5E+2	2E+3	7E-7	2E-9	7E-6	7E-5
56	Barium-131m[2]	D, all compounds	4E+5 St. wall (5E+5)	1E+6 -	6E-4 -	2E-6 -	7E-3	7E-2
56	Barium-131	D, all compounds	3E+3	8E+3	3E-6	1E-8	4E-5	4E-4
56	Barium-133m	D, all compounds	2E+3 LLI wall (3E+3)	9E+3 -	4E-6 -	1E-8 -	4E-5	4E-4
56	Barium-133	D, all compounds	2E+3	7E+2	3E-7	9E-10	2E-5	2E-4
56	Barium-135m	D, all compounds	3E+3	1E+4	5E-6	2E-8	4E-5	4E-4
56	Barium-139[2]	D, all compounds	1E+4	3E+4	1E-5	4E-8	2E-4	2E-3
56	Barium-140	D, all compounds	5E+2 LLI wall (6E+2)	1E+3 -	6E-7 -	2E-9 -	8E-6	8E-5
56	Barium-141[2]	D, all compounds	2E+4	7E+4	3E-5	1E-7	3E-4	3E-3
56	Barium-142[2]	D, all compounds	5E+4	1E+5	6E-5	2E-7	7E-4	7E-3
57	Lanthanum-131[2]	D, all compounds except those given for W	5E+4	1E+5	5E-5	2E-7	6E-4	6E-3
		W, oxides and hydroxides	-	2E+5	7E-5	2E-7	-	-

Atomic No.	Radionuclide	Class	Table 1 Occupational Values: Col. 1 Oral Ingestion ALI (µCi)	Col. 2 Inhalation ALI (µCi)	Col. 3 Inhalation DAC (µCi/ml)	Table 2 Effluent Concentrations: Col. 1 Air (µCi/ml)	Col. 2 Water (µCi/ml)	Table 3 Releases to Sewers: Monthly Average Concentration (µCi/ml)
57	Lanthanum-132	D, see ^{131}La	3E+3	1E+4	4E-6	1E-8	4E-5	4E-4
		W, see ^{131}La	-	1E+4	5E-6	2E-8	-	-
57	Lanthanum-135	D, see ^{131}La	4E+4	1E+5	4E-5	1E-7	5E-4	5E-3
		W, see ^{131}La	-	9E+4	4E-5	1E-7	-	-
57	Lanthanum-137	D, see ^{131}La	1E+4	6E+1	3E-8	-	2E-4	2E-3
			-	Liver (7E+1)	-	1E-10	-	-
		W, see ^{131}La	-	3E+2	1E-7	-	-	-
			-	Liver (3E+2)	-	4E-10	-	-
57	Lanthanum-138	D, see ^{131}La	9E+2	4E+0	1E-9	5E-12	1E-5	1E-4
		W, see ^{131}La	-	1E+1	6E-9	2E-11	-	-
57	Lanthanum-140	D, see ^{131}La	6E+2	1E+3	6E-7	2E-9	9E-6	9E-5
		W, see ^{131}La	-	1E+3	5E-7	2E-9	-	-
57	Lanthanum-141	D, see ^{131}La	4E+3	9E+1	4E-6	1E-8	5E-5	5E-4
		W, see ^{131}La	-	1E+4	5E-6	2E-8	-	-
57	Lanthanum-142[2]	D, see ^{131}La	9E+3	2E+4	9E-6	3E-8	1E-4	1E-3
		W, see ^{131}La	-	3E+4	1E-5	5E-8	-	-
57	Lanthanum-143[2]	D, see ^{131}La	4E+4	1E+5	4E-5	1E-7	-	-
			St. wall (4E+4)	-	-	-	5E-4	5E-3
		W, see ^{131}La	-	9E+4	4E-5	1E-7	-	-
58	Cerium-134	W, all compounds except those given for Y	5E+2	7E+2	3E-7	1E-9	-	-
			LLI wall (6E+2)	-	-	-	8E-6	8E-5
		Y, oxides, hydroxides, and fluorides	-	7E+2	3E-7	9E-10	-	-
58	Cerium-135	W, see ^{134}Ce	2E+3	4E+3	2E-6	5E-9	2E-5	2E-4
		Y, see ^{134}Ce	-	4E+3	3E-6	5E-9	-	-
58	Cerium-137m	W, see ^{134}Ce	2E+3	4E+3	2E-6	6E-9	-	-
			LLI wall (2E+3)	-	-	-	3E-5	3E-4
		Y, see ^{134}Ce	-	4E+3	2E-6	5E-9	-	-
58	Cerium-137	W, see ^{134}Ce	5E+4	1E+5	6E-5	2E-7	7E-4	7E-3
		Y, see ^{134}Ce	-	1E+5	5E-5	2E-7	-	-
58	Cerium-139	W, see ^{134}Ce	5E+3	8E+2	3E-7	1E-9	7E-5	7E-4
		Y, see ^{134}Ce	-	7E+2	3E-7	9E-10	-	-
58	Cerium-141	W, see ^{134}Ce	2E+3	7E+2	3E-7	1E-9	-	-
			LLI wall (2E+3)	-	-	-	3E-5	3E-4
		Y, see ^{134}Ce	-	6E+2	2E-7	8E-10	-	-
58	Cerium-143	W, see ^{134}Ce	1E+3	2E+3	8E-7	3E-9	-	-
			LLI wall (1E+3)	-	-	-	2E-5	2E-4
		Y, see ^{134}Ce	-	2E+3	7E-7	2E-9	-	-

Atomic No.	Radionuclide	Class	Table 1 Occupational Values: Col. 1 Oral Ingestion ALI (µCi)	Col. 2 Inhalation ALI (µCi)	Col. 3 Inhalation DAC (µCi/ml)	Table 2 Effluent Concentrations: Col. 1 Air (µCi/ml)	Col. 2 Water (µCi/ml)	Table 3 Releases to Sewers: Monthly Average Concentration (µCi/ml)
58	Cerium-144	W, see ^{134}Ce	2E+2	3E+1	1E-8	4E-11	-	-
			LLI wall (3E+2)	-	-	-	3E-6	3E-5
		Y, see ^{134}Ce	-	1E+1	6E-9	2E-11	-	-
59	Praseodymium-136[2]	W, all compounds except those given for Y	5E+4	2E+5	1E-4	3E-7	-	-
			St. wall (7E+4)	-	-	-	1E-3	1E-2
		Y, oxides, hydroxides, carbides, and fluorides	-	2E+5	9E-5	3E-7	-	-
59	Praseodymium-137[2]	W, see ^{136}Pr	4E+4	2E+5	6E-5	2E-7	5E-4	5E-3
		Y, see ^{136}Pr	-	1E+5	6E-5	2E-7	-	-
59	Praseodymium-138m	W, see ^{136}Pr	1E+4	5E+4	2E-5	8E-8	1E-4	1E-3
		Y, see ^{136}Pr	-	4E+4	2E-5	6E-8	-	-
59	Praseodymium-139	W, see ^{136}Pr	4E+4	1E+5	5E-5	2E-7	6E-4	6E-3
		Y, see ^{136}Pr	-	1E+5	5E-5	2E-7	-	-
59	Praseodymium-142m[2]	W, see ^{136}Pr	8E+4	2E+5	7E-5	2E-7	1E-3	1E-2
		Y, see ^{136}Pr	-	1E+5	6E-5	2E-7	-	-
59	Praseodymium-142	W, see ^{136}Pr	1E+3	2E+3	9E-7	3E-9	1E-5	1E-4
		Y, see ^{136}Pr	-	2E+3	8E-7	3E-9	-	-
59	Praseodymium-143	W, see ^{136}Pr	9E+2	8E+2	3E-7	1E-9	-	-
			LLI wall (1E+3)	-	-	-	2E-5	2E-4
		Y, see ^{136}Pr	-	7E+2	3E-7	9E-10	-	-
59	Praseodymium-144[2]	W, see ^{136}Pr	3E+4	1E+5	5E-5	2E-7	-	-
			St. wall (4E+4)	-	-	-	6E-4	6E-3
		Y, see ^{136}Pr	-	1E+5	5E-5	2E-7	-	-
59	Praseodymium-145	W, see ^{136}Pr	3E+3	9E+3	4E-6	1E-8	4E-5	4E-4
		Y, see ^{136}Pr	-	8E+3	3E-6	1E-8	-	-
59	Praseodymium-147[2]	W, see ^{136}Pr	5E+4	2E+5	8E-5	3E-7	-	-
			St. wall (8E+4)	-	-	-	1E-3	1E-2
		Y, see ^{136}Pr	-	2E+5	8E-5	3E-7	-	-
60	Neodymium-136[2]	W, all compounds except those given for Y	3E+4	6E+4	2E-5	8E-8	2E-4	2E-3
		Y, oxides, hydroxides, carbides, and fluorides	-	5E+4	2E-5	8E-8	-	-
60	Neodymium-138	W, see ^{136}Nd	2E+3	6E+3	3E-6	9E-9	3E-5	3E-4
		Y, see ^{136}Nd	-	5E+3	2E-6	7E-9	-	-
60	Neodymium-139m	W, see ^{136}Nd	5E+3	2E+4	7E-6	2E-8	7E-5	7E-4
		Y, see ^{136}Nd	-	1E+4	6E-6	2E-8	-	-

Atomic No.	Radionuclide	Class	Table 1 Occupational Values: Col. 1 Oral Ingestion ALI (µCi)	Col. 2 Inhalation ALI (µCi)	Col. 3 Inhalation DAC (µCi/ml)	Table 2 Effluent Concentrations: Col. 1 Air (µCi/ml)	Col. 2 Water (µCi/ml)	Table 3 Releases to Sewers: Monthly Average Concentration (µCi/ml)
60	Neodymium-139[2]	W, see ^{136}Nd Y, see ^{136}Nd	9E+4 -	3E+5 3E+5	1E-4 1E-4	5E-7 4E-7	1E-3 -	1E-2 -
60	Neodymium-141	W, see ^{136}Nd Y, see ^{136}Nd	2E+5 -	7E+5 6E+5	3E-4 3E-4	1E-4 9E-7	2E-3 -	2E-2 -
60	Neodymium-147	W, see ^{136}Nd	1E+3 LLI wall (1E+3)	9E+2	4E-7	1E-9	-	-
		Y, see ^{136}Nd	-	8E+2	4E-7	1E-9	2E-5 -	2E-4 -
60	Neodymium-149[2]	W, see ^{136}Nd Y, see ^{136}Nd	1E+4 -	1E+4 2E+4	1E-5 1E-5	4E-8 3E-8	1E-4 -	1E-3 -
60	Neodymium-151[2]	W, see ^{136}Nd Y, see ^{136}Nd	7E+4 -	2E+5 2E+5	8E-5 8E-5	3E-7 3E-7	9E-4 -	9E-3 -
61	Promethium-141[2]	W, all compounds except those given for Y	5E+4 St. wall (6E+4)	2E+5 -	8E-5 -	3E-7 -	- 8E-4	- 8E-3
		Y, oxides, hydroxides, carbides, and fluorides	-	2E+5	7E-5	2E-7	-	-
61	Promethium-143	W, see ^{141}Pm Y, see ^{141}Pm	5E+3 -	6E+2 7E+2	2E-7 3E-7	8E-10 1E-9	7E-5 -	7E-4 -
61	Promethium-144	W, see ^{141}Pm Y, see ^{141}Pm	1E+3 -	1E+2 1E+2	5E-8 5E-8	2E-10 2E-10	2E-5 -	2E-4 -
61	Promethium-145	W, see ^{141}Pm	1E+4 -	2E+2 Bone surf (2E+2)	7E-8 -	- 1E-10	1E-4 -	1E-3 -
		Y, see ^{141}Pm	-	2E+2	8E-8	2E-10	-	-
61	Promethium-146	W, see ^{141}Pm Y, see ^{141}Pm	2E+3 -	5E+1 4E+1	2E-8 2E-8	7E-11 6E-11	2E-5 -	2E-4 -
61	Promethium-147	W, see ^{141}Pm	4E+3 LLI wall (5E+3)	1E+2 Bone surf (2E+2)	5E-8 -	- 3E-10	- 7E-5	- 7E-4
		Y, see ^{141}Pm	-	1E+2	6E-8	2E-10	-	-
61	Promethium-148m	W, see ^{141}Pm Y, see ^{141}Pm	7E+2 -	3E+2 3E+2	1E-7 1E-7	4E-10 5E-10	1E-5 -	1E-4 -
61	Promethium-148	W, see ^{141}Pm	4E+2 LLI wall (5E+2)	5E+2 -	2E-7 -	8E-10 -	- 7E-6	- 7E-5
		Y, see ^{141}Pm	-	5E+2	2E-7	7E-10	-	-
61	Promethium-149	W, see ^{141}Pm	1E+3 LLI wall (1E+3)	2E+3 -	8E-7 -	3E-9 -	- 2E-5	- 2E-4
		Y, see ^{141}Pm	-	2E+3	8E-7	2E-9	-	-
61	Promethium-150	W, see ^{141}Pm Y, see ^{141}Pm	5E+3 -	2E+4 2E+4	8E-6 7E-6	3E-8 2E-8	7E-5 -	7E-4 -
61	Promethium-151	W, see ^{141}Pm Y, see ^{141}Pm	2E+3 -	4E+3 3E+3	1E-6 1E-6	5E-9 4E-9	2E-5 -	2E-4 -

Atomic No.	Radionuclide	Class	Table 1 Occupational Values: Col. 1 Oral Ingestion ALI (µCi)	Col. 2 Inhalation ALI (µCi)	Col. 3 Inhalation DAC (µCi/ml)	Table 2 Effluent Concentrations: Col. 1 Air (µCi/ml)	Col. 2 Water (µCi/ml)	Table 3 Releases to Sewers: Monthly Average Concentration (µCi/ml)
62	Samarium-141m[2]	W, all compounds	3E+4	1E+5	4E-5	1E-7	4E-4	4E-3
62	Samarium-141[2]	W, all compounds	5E+4 St. wall (6E+4)	2E+5 -	8E-5 -	2E-7 -	- 8E-4	- 8E-3
62	Samarium-142[2]	W, all compounds	8E+3	3E+4	1E-5	4E-8	1E-4	1E-3
62	Samarium-145	W, all compounds	6E+3	5E+2	2E-7	7E-10	8E-5	8E-4
62	Samarium-146	W, all compounds	1E+1 Bone surf (3E+1)	4E-2 Bone surf (6E-2)	1E-11 -	- 9E-14	- 3E-7	- 1E-6
62	Samarium-147	W, all compounds	2E+1 Bone surf (3E+1)	4E-2 Bone surf (7E-2)	2E-11 -	- 1E-13	- 4E-7	- 4E-6
62	Samarium-151	W, all compounds	1E+4 LLI wall (1E+4)	1E+2 Bone surf (2E+2)	4E-8 -	- 2E-10	- 2E-4	- 2E-3
62	Samarium-153	W, all compounds	2E+3 LLI wall (2E+3)	3E+3 -	1E-6 -	4E-9 -	- 3E-5	- 3E-4
62	Samarium-155[2]	W, all compounds	6E+4 St. wall (8E+4)	2E+5 -	9E-5 -	3E-7 -	- 1E-3	- 1E-2
62	Samarium-156	W, all compounds	5E+3	9E+3	4E-6	1E-8	7E-5	7E-4
63	Europium-145	W, all compounds	2E+3	2E+3	8E-7	3E-9	2E-5	2E-4
63	Europium-146	W, all compounds	1E+3	1E+3	5E-7	2E-9	1E-5	1E-4
63	Europium-147	W, all compounds	3E+3	2E+3	7E-7	2E-9	4E-5	4E-4
63	Europium-148	W, all compounds	1E+3	4E+2	1E-7	5E-10	1E-5	1E-4
63	Europium-149	W, all compounds	1E+4	3E+3	1E-6	4E-9	2E-4	2E-3
63	Europium-150 (12.62 h)	W, all compounds	3E+3	8E+3	4E-6	1E-8	4E-5	4E-4
63	Europium-150 (34.2 y)	W, all compounds	8E+2	2E+3	8E-9	3E-11	1E-5	1E-4
63	Europium-152m	W, all compounds	3E+3	6E+3	3E-6	9E-9	4E-5	4E-4
63	Europium-152	W, all compounds	8E+2	2E+1	1E-8	3E-11	1E-5	1E-4
63	Europium-154	W, all compounds	5E+2	2E+1	8E-9	3E-11	7E-6	7E-5
63	Europium-155	W, all compounds	4E+3 -	9E+1 Bone surf (1E+2)	4E-8 -	- 2E-10	5E-5 -	5E-4 -
63	Europium-156	W, all compounds	6E+2	5E+2	2E-7	6E-10	8E-6	8E-5

Atomic No.	Radionuclide	Class	Table 1 Occupational Values Col. 1 Oral Ingestion ALI (µCi)	Col. 2 Inhalation ALI (µCi)	Col. 3 Inhalation DAC (µCi/ml)	Table 2 Effluent Concentrations Col. 1 Air (µCi/ml)	Col. 2 Water (µCi/ml)	Table 3 Releases to Sewers Monthly Average Concentration (µCi/ml)
63	Europium-157	W, all compounds	2E+3	5E+3	2E-6	7E-9	3E-5	3E-4
63	Europium-158[2]	W, all compounds	2E+4	6E+4	2E-5	8E-8	3E-4	3E-3
64	Gadolinium-145[2]	D, all compounds except those given for W	5E+4	2E+5	8E-5	2E-7	-	-
			St. wall (5E+4)	-	-	-	6E-4	6E-3
		W, oxides, hydroxides, and fluorides	-	2E+5	7E-5	2E-7	-	-
64	Gadolinium-146	D, see ^{145}Gd	1E+3	1E+2	5E-8	2E-10	2E-5	2E-4
		W, see ^{145}Gd	-	3E+2	1E-7	6E-10	-	-
64	Gadolinium-147	D, see ^{145}Gd	2E+3	6E+3	2E-8	6E-9	3E-5	3E-4
		W, see ^{145}Gd	-	4E+3	1E-8	5E-9	-	-
64	Gadolinium-148	D, see ^{145}Gd	3E+1	8E-3	3E-12	-	-	-
			Bone surf (2E+1)	Bone surf (2E-2)	-	2E-14	3E-7	3E-6
		W, see ^{145}Gd	-	3E-2	1E-11	-	-	-
			-	Bone surf (6E-2)	-	8E-14	-	-
64	Gadolinium-149	D, see ^{145}Gd	3E+3	2E+3	9E-7	3E-9	4E-5	4E-4
		W, see ^{145}Gd	-	2E+3	1E-6	3E-9	-	-
64	Gadolinium-151	D, see ^{145}Gd	6E+3	4E+2	2E-7	-	9E-5	9E-4
			-	Bone surf (8E+2)	-	9E-10	-	-
		W, see ^{145}Gd	-	1E+3	5E-7	2E-9	-	-
64	Gadolinium-152	D, see ^{145}Gd	2E+1	1E-2	4E-12	-	-	-
			Bone surf (3E+1)	Bone surf (2E-2)	-	3E-14	4E-7	4E-6
		W, see ^{145}Gd	-	4E-2	2E-11	-	-	-
			-	Bone surf (8E-2)	-	3E-13	-	-
64	Gadolinium-153	D, see ^{145}Gd	9E+3	1E+2	6E-8	-	6E-5	6E-4
			-	Bone surf (2E+2)	-	3E-10	-	-
		W, see ^{145}Gd	-	6E+2	2E-7	8E-10	-	-
64	Gadolinium-159	D, see ^{145}Gd	3E+3	8E+3	3E-6	1E-8	6E-5	4E-4
		W, see ^{145}Gd	-	6E+3	2E-6	8E-9	-	-
65	Terbium-147[2]	W, all compounds	9E+3	3E+4	1E-5	5E-8	2E-4	1E-3
65	Terbium-148	W, all compounds	6E+3	2E+2	8E-7	3E-9	2E-5	7E-4
65	Terbium-150	W, all compounds	6E+3	2E+4	9E-6	3E-8	7E-5	7E-4
65	Terbium-151	W, all compounds	4E+3	9E+3	4E-6	1E-8	5E-5	5E-4
65	Terbium-153	W, all compounds	5E+3	2E+3	8E-6	1E-8	2E-5	7E-4
65	Terbium-154	W, all compounds	2E+3	4E+3	8E-6	6E-9	2E-5	2E-4
65	Terbium-155	W, all compounds	6E+3	8E+3	3E-6	1E-8	8E-5	8E-4
65	Terbium-156m (5.0 h)	W, all compounds	2E+4	3E+4	1E-5	4E-8	2E-4	2E-3

Atomic No.	Radionuclide	Class	Table I Occupational Values Col. 1 Oral Ingestion ALI (µCi)	Col. 2 Inhalation ALI (µCi)	Col. 3 Inhalation DAC (µCi/ml)	Table 2 Effluent Concentrations Col. 1 Air (µCi/ml)	Col. 2 Water (µCi/ml)	Table 3 Releases to Sewers Monthly Average Concentration (µCi/ml)
65	Terbium-156m (24.4 h)	W, all compounds	7E+3	8E+3	3E-6	1E-8	1E-4	1E-3
65	Terbium-156	W, all compounds	1E+3	1E+3	6E-7	2E-9	1E-5	1E-4
65	Terbium-157	W, all compounds	5E+4	3E+2	1E-7	-	-	-
			LLI wall (5E+4)	Bone surf (6E+2)	-	8E-10	7E-4	7E-3
65	Terbium-158	W, all compounds	1E+3	2E+1	8E-9	3E-11	2E-5	2E-4
65	Terbium-160	W, all compounds	8E+2	2E+2	9E-8	3E-10	1E-5	1E-4
65	Terbium-161	W, all compounds	2E+3	2E+3	7E-7	2E-9	-	-
			LLI wall (2E+3)	-	-	-	3E-5	3E-4
66	Dysprosium-155	W, all compounds	9E+3	3E+4	1E-5	4E-8	1E-4	1E-3
66	Dysprosium-157	W, all compounds	2E+4	6E+4	3E-5	9E-8	3E-4	3E-3
66	Dysprosium-159	W, all compounds	1E+4	2E+3	1E-6	3E-9	2E-4	2E-3
66	Dysprosium-165	W, all compounds	1E+4	5E+4	2E-5	6E-8	2E-4	2E-3
66	Dysprosium-166	W, all compounds	6E+2	7E+2	3E-7	1E-9	-	-
			LLI wall (8E+2)	-	-	-	1E-5	1E-4
67	Holmium-155[2]	W, all compounds	4E+4	2E+5	6E-5	2E-7	6E-4	6E-3
67	Holmium-157[2]	W, all compounds	3E+5	1E+6	6E-4	2E-6	4E-3	4E-2
67	Holmium-159[2]	W, all compounds	2E+5	1E+6	4E-4	1E-6	3E-3	3E-2
67	Holmium-161	W, all compounds	1E+5	4E+5	2E-4	6E-7	1E-3	1E-2
67	Holmium-162m[2]	W, all compounds	5E+4	3E+5	1E-4	4E-7	7E-4	7E-3
67	Holmium-162[2]	W, all compounds	6E+5	2E+6	1E-3	3E-6	-	-
			St. wall (8E+5)	-	-	-	1E-2	1E-1
67	Holmium-164m[2]	W, all compounds	1E+5	3E+5	1E-4	4E-7	1E-3	1E-2
67	Holmium-164[2]	W, all compounds	2E+5	6E+5	3E-4	9E-7	-	-
			St. wall (2E+5)	-	-	-	3E-3	3E-2
67	Holmium-166m	W, all compounds	6E+2	7E+0	3E-9	9E-12	9E-6	9E-5
67	Holmium-166	W, all compounds	9E+2	2E+3	7E-7	2E-9	-	-
			LLI wall (9E+2)	-	-	-	1E-5	1E-4
67	Holmium-167	W, all compounds	2E+4	6E+4	2E-5	8E-8	2E-4	2E-3
68	Erbium-161	W, all compounds	2E+4	6E+4	3E-5	9E-8	2E-4	2E-3
68	Erbium-165	W, all compounds	6E+4	2E+5	8E-5	3E-7	9E-4	9E-3

Atomic No.	Radionuclide	Class	Table 1 Occupational Values: Col. 1 Oral Ingestion ALI (µCi)	Col. 2 Inhalation ALI (µCi)	Col. 3 Inhalation DAC (µCi/ml)	Table 2 Effluent Concentrations: Col. 1 Air (µCi/ml)	Col. 2 Water (µCi/ml)	Table 3 Releases to Sewers: Monthly Average Concentration (µCi/ml)
68	Erbium-169	W, all compounds	3E+3	3E+3	1E-6	4E-9	-	-
			LLI wall (4E+3)	-	-	-	5E-5	5E-4
68	Erbium-171	W, all compounds	4E+3	1E+4	4E-6	1E-8	5E-5	5E-4
68	Erbium-172	W, all compounds	1E+3	1E+3	6E-7	2E-9	-	-
			LLI wall (1E+3)	-	-	-	2E-5	2E-4
69	Thulium-162[2]	W, all compounds	7E+4	3E+5	1E-4	4E-7	-	-
			St. wall (7E+4)	-	-	-	1E-3	1E-2
69	Thulium-166	W, all compounds	4E+3	1E+4	6E-6	2E-8	6E-5	6E-4
69	Thulium-167	W, all compounds	2E+3	2E+3	8E-7	3E-9	-	-
			LLI wall (2E+3)	-	-	-	3E-5	3E-4
69	Thulium-170	W, all compounds	8E+2	2E+2	9E-8	3E-10	-	-
			LLI wall (1E+3)	-	-	-	1E-5	1E-4
69	Thulium-171	W, all compounds	1E+4	3E+2	1E-7	-	-	-
			LLI wall (1E+4)	Bone surf (6E+2)	-	8E-10	2E-4	2E-3
69	Thulium-172	W, all compounds	7E+2	1E+3	5E-7	2E-9	-	-
			LLI wall (8E+2)	-	-	-	1E-5	1E-4
69	Thulium-173	W, all compounds	4E+3	1E+4	5E-6	2E-8	8E-5	8E-4
69	Thulium-175[2]	W, all compounds	7E+4	3E+5	1E-4	4E-7	-	-
			St. wall (9E+4)	-	-	-	1E-3	1E-2
70	Ytterbium-162[2]	W, all compounds except those given for Y	7E+4	3E+5	1E-4	4E-7	1E-3	1E-2
		Y, oxides, hydroxides, and fluorides	-	3E+5	1E-4	4E-7	-	-
70	Ytterbium-166	W, see ^{162}Yb	1E+3	2E+3	8E-7	3E-9	2E-5	2E-4
		Y, see ^{162}Yb	-	2E+3	8E-7	3E-9	-	-
70	Ytterbium-167[2]	W, see ^{162}Yb	3E+5	8E+5	3E-4	1E-6	4E-3	4E-2
		Y, see ^{162}Yb	-	7E+5	3E-4	1E-6	-	-
70	Ytterbium-169	W, see ^{162}Yb	2E+3	8E+2	4E-7	1E-9	2E-5	2E-4
		Y, see ^{162}Yb	-	7E+2	3E-7	1E-9	-	-
70	Ytterbium-175	W, see ^{162}Yb	3E+3	4E+3	1E-6	5E-9	-	-
			LLI wall (3E+3)	-	-	-	4E-5	4E-4
		Y, see ^{162}Yb	-	3E+3	1E-6	5E-9	-	-
70	Ytterbium-177[2]	W, see ^{162}Yb	2E+4	5E+4	2E-5	7E-8	2E-4	2E-3
		Y, see ^{162}Yb	-	5E+4	2E-5	6E-8	-	-
70	Ytterbium-178[2]	W, see ^{162}Yb	1E+4	4E+4	2E-5	6E-8	2E-4	2E-3
		Y, see ^{162}Yb	-	4E+4	2E-5	5E-8	-	-

Atomic No.	Radionuclide	Class	Table 1 Occupational Values: Col. 1 Oral Ingestion ALI (µCi)	Col. 2 Inhalation ALI (µCi)	Col. 3 Inhalation DAC (µCi/ml)	Table 2 Effluent Concentrations: Col. 1 Air (µCi/ml)	Col. 2 Water (µCi/ml)	Table 3 Releases to Sewers: Monthly Average Concentration (µCi/ml)
71	Lutetium-169	W, all compounds except those given for Y	3E+3	4E+3	2E-6	6E-9	3E-5	3E-4
		Y, oxides, hydroxides, and fluorides	-	4E+3	2E-6	6E-9	-	-
71	Lutetium-170	W, see ^{169}Lu	1E+3	2E+3	9E-7	3E-9	2E-5	2E-4
		Y, see ^{169}Lu	-	2E+3	8E-7	3E-9	-	-
71	Lutetium-171	W, see ^{169}Lu	2E+3	2E+3	8E-7	3E-9	3E-5	3E-4
		Y, see ^{169}Lu	-	2E+3	8E-7	3E-9	-	-
71	Lutetium-172	W, see ^{169}Lu	1E+3	1E+3	5E-7	2E-9	1E-5	1E-4
		Y, see ^{169}Lu	-	1E+3	5E-7	2E-9	-	-
71	Lutetium-173	W, see ^{169}Lu	5E+3	3E+2	1E-7	-	7E-5	7E-4
			-	Bone surf (5E+2)	-	6E-10	-	-
		Y, see ^{169}Lu	-	3E+2	1E-7	4E-10	-	-
71	Lutetium-174m	W, see ^{169}Lu	2E+3	2E+2	1E-7	-	-	-
			LLI wall (3E+3)	Bone surf (3E+2)	-	5E-10	4E-5	4E-4
		Y, see ^{169}Lu	-	2E+2	9E-8	3E-10	-	-
71	Lutetium-174	W, see ^{169}Lu	5E+3	1E+2	5E-8	-	7E-5	7E-4
			-	Bone surf (2E+2)	-	1E-10	-	-
		Y, see ^{169}Lu	-	2E+2	6E-8	2E-10	-	-
71	Lutetium-176m	W, see ^{169}Lu	8E+3	3E+4	1E-5	3E-8	1E-4	1E-3
		Y, see ^{169}Lu	-	2E+4	9E-6	3E-8	-	-
71	Lutetium-176	W, see ^{169}Lu	7E+2	5E+0	2E-9	-	1E-5	1E-4
			-	Bone surf (1E+1)	-	2E-11	-	-
		Y, see ^{169}Lu	-	8E+0	3E-9	1E-11	-	-
71	Lutetium-177m	W, see ^{169}Lu	7E+2	1E+2	5E-8	-	1E-5	1E-4
			-	Bone surf (1E+2)	-	2E-10	-	-
		Y, see ^{169}Lu	-	8E+1	3E-8	1E-10	-	-
71	Lutetium-177	W, see ^{169}Lu	2E+3	2E+3	9E-7	3E-9	-	-
			LLI wall (1E+3)	-	-	-	4E-5	4E-4
		Y, see ^{169}Lu	-	2E+1	9E-7	3E-9	-	-
71	Lutetium-178m[2]	W, see ^{169}Lu	5E+4	2E+5	8E-5	3E-7	-	-
			St. wall (6E+4)	-	-	-	8E-4	8E-3
		Y, see ^{169}Lu	-	2E+5	7E-5	2E-7	-	-
71	Lutetium-178[2]	W, see ^{169}Lu	4E+4	1E+5	5E-5	2E-7	-	-
			St. wall (4E+4)	-	-	-	6E-4	6E-3
		Y, see ^{169}Lu	-	1E+5	5E-5	2E-7	-	-
71	Lutetium-179	W, see ^{169}Lu	6E+3	2E+4	8E-6	3E-8	9E-5	9E-4
		Y, see ^{169}Lu	-	2E+4	6E-6	3E-8	-	-

Atomic No.	Radionuclide	Class	Table 1 Occupational Values Col. 1 Oral Ingestion ALI (µCi)	Col. 2 Inhalation ALI (µCi)	Col. 3 Inhalation DAC (µCi/ml)	Table 2 Effluent Concentrations Col. 1 Air (µCi/ml)	Col. 2 Water (µCi/ml)	Table 3 Releases to Sewers Monthly Average Concentration (µCi/ml)
72	Hafnium-170	D, all compounds except those given for W	3E+3	6E+3	2E-6	8E-9	4E-5	4E-4
		W, oxides, hydroxides, carbides, and nitrates	-	5E+3	2E-6	6E-9	-	-
72	Hafnium-172	D, see ^{170}Hf	1E+3	9E+0	4E-9	-	2E-5	2E-4
		W, see ^{170}Hf	-	Bone surf (2E+1)	-	3E-11	-	-
			-	4E+1	2E-8	-	-	-
			-	Bone surf (6E+1)	-	8E-11	-	-
72	Hafnium-173	D, see ^{170}Hf	5E+3	1E+4	5E-6	2E-8	7E-5	7E-4
		W, see ^{170}Hf	-	1E+4	5E-6	2E-8	-	-
72	Hafnium-175	D, see ^{170}Hf	3E+3	9E+2	4E-7	-	4E-5	4E-4
		W, see ^{170}Hf	-	Bone surf (1E+3)	-	1E-9	-	-
			-	1E+3	5E-7	2E-9	-	-
72	Hafnium-177m[2]	D, see ^{170}Hf	2E+4	6E+4	2E-5	8E-8	3E-4	3E-3
		W, see ^{170}Hf	-	9E+4	4E-5	1E-7	-	-
72	Hafnium-178m	D, see ^{170}Hf	3E+2	1E+0	5E-10	-	3E-6	3E-5
		W, see ^{170}Hf	-	Bone surf (2E+0)	-	3E-12	-	-
			-	5E+0	2E-9	-	-	-
			-	Bone surf (9E+0)	-	1E-11	-	-
72	Hafnium-179m	D, see ^{170}Hf	1E+3	3E+2	1E-7	-	1E-5	1E-4
		W, see ^{170}Hf	-	Bone surf (6E+2)	-	8E-10	-	-
			-	8E+2	3E-7	8E-10	-	-
72	Hafnium-180m	D, see ^{170}Hf	7E+3	2E+4	9E-8	3E-8	1E-4	1E-3
		W, see ^{170}Hf	-	3E+4	1E-5	4E-8	-	-
72	Hafnium-181	D, see ^{170}Hf	1E+3	2E+2	7E-8	-	2E-5	2E-4
		W, see ^{170}Hf	-	Bone surf (4E+2)	-	6E-10	-	-
			-	4E+2	2E-7	6E-10	-	-
72	Hafnium-182m[2]	D, see ^{170}Hf	4E+4	9E+4	4E-5	1E-7	5E-4	5E-3
		W, see ^{170}Hf	-	1E+5	6E-5	2E-7	-	-
72	Hafnium-182	D, see ^{170}Hf	2E+2	8E-1	3E-10	-	-	-
		W, see ^{170}Hf	Bone surf (4E+2)	Bone surf (2E+0)	-	2E-12	5E-6	5E-5
			-	3E+0	1E-9	-	-	-
			-	Bone surf (7E+0)	-	1E-11	-	-
72	Hafnium-183[2]	D, see ^{170}Hf	2E+4	5E+4	2E-5	6E-8	3E-4	3E-3
		W, see ^{170}Hf	-	8E+4	2E-5	8E-8	-	-
72	Hafnium-184	D, see ^{170}Hf	2E+3	8E+3	3E-6	1E-8	3E-5	3E-4
		W, see ^{170}Hf	-	6E+3	3E-6	9E-9	-	-

Atomic No.	Radionuclide	Class	Table 1 Occupational Values Col. 1 Oral Ingestion ALI (µCi)	Col. 2 Inhalation ALI (µCi)	Col. 3 Inhalation DAC (µCi/ml)	Table 2 Effluent Concentrations Col. 1 Air (µCi/ml)	Col. 2 Water (µCi/ml)	Table 3 Releases to Sewers Monthly Average Concentration (µCi/ml)
73	Tantalum-172[2]	W, all compounds except those given for Y	4E+4	1E+5	5E-5	2E-7	5E-4	5E-3
		Y, elemental Ta, oxides, hydroxides, halides, carbides, nitrates, and nitrides	-	1E+5	4E-5	1E-7	-	-
73	Tantalum-173	W, see ^{172}Ta	7E+3	2E+4	8E-6	3E-8	9E-5	9E-4
		Y, see ^{172}Ta	-	2E+4	7E-6	2E-8	-	-
73	Tantalum-174[2]	W, see ^{172}Ta	3E+4	1E+5	4E-5	1E-7	4E-4	4E-3
		Y, see ^{172}Ta	-	9E+4	4E-5	1E-7	-	-
73	Tantalum-175	W, see ^{172}Ta	6E+3	2E+4	7E-6	2E-8	8E-5	8E-4
		Y, see ^{172}Ta	-	1E+4	6E-6	2E-8	-	-
73	Tantalum-176	W, see ^{172}Ta	4E+3	1E+4	5E-6	2E-8	5E-5	5E-4
		Y, see ^{172}Ta	-	1E+4	5E-6	2E-8	-	-
73	Tantalum-177	W, see ^{172}Ta	1E+4	3E+4	8E-6	3E-8	2E-4	2E-3
		Y, see ^{172}Ta	-	2E+4	7E-6	2E-8	-	-
73	Tantalum-178	W, see ^{172}Ta	2E+4	9E+4	4E-5	1E-7	2E-4	2E-3
		Y, see ^{172}Ta	-	7E+4	3E-5	1E-7	-	-
73	Tantalum-179	W, see ^{172}Ta	2E+4	5E+3	2E-6	8E-9	3E-4	3E-3
		Y, see ^{172}Ta	-	9E+2	4E-7	1E-9	-	-
73	Tantalum-180m	W, see ^{172}Ta	2E+4	7E+4	3E-5	9E-8	3E-4	3E-3
		Y, see ^{172}Ta	-	6E+4	2E-5	8E-8	-	-
73	Tantalum-180	W, see ^{172}Ta	1E+3	4E+2	2E-7	6E-10	2E-5	2E-4
		Y, see ^{172}Ta	-	2E+1	1E-8	3E-11	-	-
73	Tantalum-182m[2]	W, see ^{172}Ta	2E+6 St. wall (2E+6)	6E+5	2E-4	8E-7	-	-
		Y, see ^{172}Ta	-	-	-	-	-	-
			-	4E+5	2E-4	6E-7	3E-3	3E-2
73	Tantalum-182	W, see ^{172}Ta	8E+2	3E+2	1E-7	9E-10	1E-5	1E-4
		Y, see ^{172}Ta	-	1E+2	6E-8	2E-10	-	-
73	Tantalum-183	W, see ^{172}Ta	9E+2 LLI wall (1E+3)	1E+3	5E-7	2E-9	-	-
		Y, see ^{172}Ta	-	-	-	-	-	-
			-	1E+3	4E-7	1E-9	2E-5	2E-4
73	Tantalum-184	W, see ^{172}Ta	2E+3	5E+3	2E-6	8E-9	3E-5	3E-4
		Y, see ^{172}Ta	-	5E+3	2E-6	7E-9	-	-
73	Tantalum-185[2]	W, see ^{172}Ta	3E+4	7E+4	3E-5	1E-7	4E-4	4E-3
		Y, see ^{172}Ta	-	6E+4	3E-5	9E-8	-	-
73	Tantalum-186[2]	W, see ^{172}Ta	3E+4 St. wall (2E+4)	2E+5	1E-4	3E-7	-	-
		Y, see ^{172}Ta	-	-	-	-	-	-
			-	2E+5	9E-5	3E-7	3E-3	3E-2
74	Tungsten-176	D, all compounds	1E+4	3E+4	2E-5	7E-8	3E-4	3E-3
74	Tungsten-177	D, all compounds	2E+4	9E+4	4E-5	1E-7	3E-4	3E-3

Atomic No.	Radionuclide	Class	Table 1 Occupational Values: Col. 1 Oral Ingestion ALI (µCi)	Col. 2 Inhalation ALI (µCi)	Col. 3 Inhalation DAC (µCi/ml)	Table 2 Effluent Concentrations: Col. 1 Air (µCi/ml)	Col. 2 Water (µCi/ml)	Table 3 Releases to Sewers: Monthly Average Concentration (µCi/ml)
74	Tungsten-178	D, all compounds	5E+3	2E+4	8E-6	3E-8	7E-5	7E-4
74	Tungsten-179[2]	D, all compounds	5E+6	2E+6	7E-4	2E-6	7E-3	7E-2
74	Tungsten-181	D, all compounds	2E+4	3E+4	1E-5	5E-8	2E-4	2E-3
74	Tungsten-185	D, all compounds	2E+3	7E+3	3E-6	9E-9	-	-
			LLI wall (3E+3)	-	-	-	4E-5	4E-4
74	Tungsten-187	D, all compounds	2E+3	9E+3	4E-6	1E-8	3E-5	3E-4
74	Tungsten-188	D, all compounds	4E+2	2E+3	9E-7	2E-9	-	-
			LLI wall (5E+2)	-	-	-	7E-6	7E-5
75	Rhenium-177[2]	D, all compounds except those given for W	9E+6	3E+5	1E-4	4E-7	-	-
			St. wall (2E+5)	-	-	-	2E-3	2E-2
		W, oxides, hydroxides, and nitrates	-	8E+5	1E-4	5E-7	-	-
75	Rhenium-178[2]	D, see ^{177}Re	7E+4	3E+5	1E-4	4E-7	-	-
			St. wall (1E+6)	-	-	-	1E-3	1E-2
		W, see ^{177}Re	-	3E+5	1E-4	4E-7	-	-
75	Rhenium-181	D, see ^{177}Re	5E+3	9E+3	4E-6	1E-8	7E-5	7E-4
		W, see ^{177}Re	-	8E+3	4E-6	1E-8	-	-
75	Rhenium-182 (12.7 h)	D, see ^{177}Re	7E+3	1E+4	5E-6	2E-8	9E-5	9E-4
		W, see ^{177}Re	-	2E+4	6E-6	2E-8	-	-
75	Rhenium-182 (64.0 h)	D, see ^{177}Re	1E+3	7E+1	3E-6	3E-9	2E-5	2E-4
		W, see ^{177}Re	-	2E+3	9E-7	3E-8	-	-
75	Rhenium-184m	D, see ^{177}Re	2E+3	3E+3	1E-6	4E-9	3E-5	3E-4
		W, see ^{177}Re	-	4E+2	2E-7	5E-10	-	-
75	Rhenium-184	D, see ^{177}Re	2E+3	4E+3	1E-6	5E-9	3E-5	3E-4
		W, see ^{177}Re	-	3E+3	9E-7	2E-9	-	-
75	Rhenium-186m	D, see ^{177}Re	1E+3	2E+3	7E-7	-	-	-
			St. wall (2E+3)	St. wall (2E+3)	-	3E-9	2E-5	2E-4
		W, see ^{177}Re	-	2E+2	6E-6	2E-10	-	-
75	Rhenium-186	D, see ^{177}Re	2E+3	3E+3	1E-6	4E-9	3E-5	3E-4
		W, see ^{177}Re	-	1E+3	7E-7	2E-9	-	-
75	Rhenium-187	D, see ^{177}Re	6E+5	8E+5	4E-4	-	8E-3	8E-2
			-	St. wall (9E+5)	-	1E-6	-	-
		W, see ^{177}Re	-	1E+6	4E-5	1E-7	-	-
75	Rhenium-188m[2]	D, see ^{177}Re	8E+4	1E+5	6E-5	2E-7	1E-3	1E-2
		W, see ^{177}Re	-	1E+5	6E-5	2E-7	-	-
75	Rhenium-188	D, see ^{177}Re	2E+3	3E+3	1E-6	4E-9	2E-5	2E-4
		W, see ^{177}Re	-	3E+3	1E-6	4E-9	-	-

Atomic No.	Radionuclide	Class	Table 1 Occupational Values: Col. 1 Oral Ingestion ALI (µCi)	Col. 2 Inhalation ALI (µCi)	Col. 3 Inhalation DAC (µCi/ml)	Table 2 Effluent Concentrations: Col. 1 Air (µCi/ml)	Col. 2 Water (µCi/ml)	Table 3 Releases to Sewers: Monthly Average Concentration (µCi/ml)
75	Rhenium-189	D, see ^{177}Re	3E+3	5E+3	2E-6	7E-9	4E-5	4E-4
		W, see ^{177}Re	-	4E+3	2E-6	6E-9	-	-
76	Osmium-180[2]	D; all compounds except those given for W and Y	1E+5	4E+5	2E-4	5E-7	1E-3	1E-2
		W, halides and nitrates	-	5E+5	2E-4	7E-7	-	-
		Y, oxides and hydroxides	-	5E+5	2E-4	6E-7	-	-
76	Osmium-181[2]	D, see ^{180}Os	1E+4	4E+4	2E-5	6E-8	2E-4	2E-3
		W, see ^{180}Os	-	5E+4	2E-5	6E-8	-	-
		Y, see ^{180}Os	-	4E+4	2E-5	6E-8	-	-
76	Osmium-182	D, see ^{180}Os	2E+3	6E+3	2E-6	8E-9	3E-5	3E-4
		W, see ^{180}Os	-	4E+3	2E-6	6E-9	-	-
		Y, see ^{180}Os	-	4E+3	2E-6	6E-9	-	-
76	Osmium-185	D, see ^{180}Os	2E+3	5E+2	2E-7	7E-10	3E-5	3E-4
		W, see ^{180}Os	-	8E+2	3E-7	1E-9	-	-
		Y, see ^{180}Os	-	8E+2	3E-7	1E-9	-	-
76	Osmium-189m	D, see ^{180}Os	8E+4	2E+5	1E-4	3E-7	1E-3	1E-2
		W, see ^{180}Os	-	2E+5	9E-5	3E-7	-	-
		Y, see ^{180}Os	-	2E+5	7E-5	2E-7	-	-
76	Osmium-191m	D, see ^{180}Os	1E+4	3E+4	1E-5	4E-8	2E-4	2E-3
		W, see ^{180}Os	-	2E+4	8E-6	3E-8	-	-
		Y, see ^{180}Os	-	2E+4	7E-6	2E-8	-	-
76	Osmium-191	D, see ^{180}Os	2E+3	2E+3	9E-7	3E-9	-	-
			LLI wall (3E+3)	-	-	-	3E-5	3E-4
		W, see ^{180}Os	-	2E+3	7E-7	2E-9	-	-
		Y, see ^{180}Os	-	1E+3	6E-7	2E-9	-	-
76	Osmium-193	D, see ^{180}Os	2E+3	5E+3	2E-6	6E-9	-	-
			LLI wall (2E+3)	-	-	-	2E-5	2E-4
		W, see ^{180}Os	-	9E+1	1E-6	4E-9	-	-
		Y, see ^{180}Os	-	3E+3	3E-6	4E-9	-	-
76	Osmium-194	D, see ^{180}Os	4E+2	4E+1	2E-8	6E-11	-	-
			LLI wall (6E+2)	-	-	-	8E-8	8E-5
		W, see ^{180}Os	-	6E+1	2E-8	8E-11	-	-
		Y, see ^{180}Os	-	8E+0	3E-9	1E-11	-	-
77	Iridium-182[2]	D; all compounds except those given for W and Y	4E+4	1E+5	6E-5	2E-7	-	-
			St. wall (4E+4)	-	-	-	6E-4	6E-3
		W, halides, nitrates, and metallic iridium	-	2E+5	6E-5	2E-7	-	-
		Y, oxides and hydroxides	-	1E+5	5E-5	2E-7	-	-
77	Iridium-184	D, see ^{182}Ir	8E+3	2E+4	1E-5	3E-8	3E-4	3E-3
		W, see ^{182}Ir	-	3E+4	1E-5	5E-8	-	-
		Y, see ^{182}Ir	-	3E+4	1E-5	4E-8	-	-

Atomic No.	Radionuclide	Class	Table 1 Occupational Values: Col. 1 Oral Ingestion ALI (µCi)	Col. 2 Inhalation ALI (µCi)	Col. 3 Inhalation DAC (µCi/ml)	Table 2 Effluent Concentrations: Col. 1 Air (µCi/ml)	Col. 2 Water (µCi/ml)	Table 3 Releases to Sewers: Monthly Average Concentration (µCi/ml)
77	Iridium-185	D, see ^{182}Ir	5E+3	1E+4	5E-6	2E-8	7E-5	7E-4
		W, see ^{182}Ir	-	1E+4	5E-6	2E-8	-	-
		Y, see ^{182}Ir	-	1E+4	4E-6	1E-8	-	-
77	Iridium-186	D, see ^{182}Ir	2E+3	8E+3	3E-6	1E-8	3E-5	3E-4
		W, see ^{182}Ir	-	6E+3	3E-6	9E-9	-	-
		Y, see ^{182}Ir	-	6E+3	2E-6	8E-9	-	-
77	Iridium-187	D, see ^{182}Ir	1E+4	2E+4	1E-5	5E-8	1E-4	1E-3
		W, see ^{182}Ir	-	3E+4	1E-5	4E-8	-	-
		Y, see ^{182}Ir	-	3E+4	1E-5	4E-8	-	-
77	Iridium-188	D, see ^{182}Ir	2E+3	5E+3	2E-6	6E-9	3E-5	3E-4
		W, see ^{182}Ir	-	4E+3	1E-6	5E-9	-	-
		Y, see ^{182}Ir	-	3E+3	1E-6	5E-8	-	-
77	Iridium-189	D, see ^{182}Ir	9E+3	5E+3	2E-6	7E-8	-	-
			LLI wall (5E+3)	-	-	-	7E-5	7E-4
		W, see ^{182}Ir	-	4E+3	2E-6	9E-9	-	-
		Y, see ^{182}Ir	-	4E+3	1E-6	5E-9	-	-
77	Iridium-190m[2]	D, see ^{182}Ir	2E+5	2E+5	8E-5	3E-7	2E-3	2E-2
		W, see ^{182}Ir	-	2E+5	9E-5	3E-7	-	-
		Y, see ^{182}Ir	-	2E+5	8E-5	3E-7	-	-
77	Iridium-190	D, see ^{182}Ir	1E+3	9E+2	4E-7	1E-9	1E-5	1E-4
		W, see ^{182}Ir	-	1E+3	4E-7	1E-9	-	-
		Y, see ^{182}Ir	-	9E+2	4E-7	1E-9	-	-
77	Iridium-192m	D, see ^{182}Ir	3E+0	8E+1	4E-8	1E-10	4E-5	4E-4
		W, see ^{182}Ir	-	2E+2	9E-8	3E-10	-	-
		Y, see ^{182}Ir	-	2E+1	6E-9	2E-11	-	-
77	Iridium-192	D, see ^{182}Ir	9E+2	3E+2	1E-7	4E-10	1E-5	1E-4
		W, see ^{182}Ir	-	4E+2	2E-7	6E-10	-	-
		Y, see ^{182}Ir	-	2E+2	8E-8	3E-10	-	-
77	Iridium-194m	D, see ^{182}Ir	5E+2	9E+1	4E-8	1E-10	9E-6	9E-5
		W, see ^{182}Ir	-	2E+2	7E-8	2E-10	-	-
		Y, see ^{182}Ir	-	1E+2	4E-8	1E-10	-	-
77	Iridium-194	D, see ^{182}Ir	1E+0	3E+3	1E-6	4E-9	1E-5	1E-4
		W, see ^{182}Ir	-	2E+3	9E-7	3E-9	-	-
		Y, see ^{182}Ir	-	2E+3	8E-7	3E-9	-	-
77	Iridium-195m	D, see ^{182}Ir	8E+3	2E+4	1E-5	3E-8	1E-4	1E-3
		W, see ^{182}Ir	-	3E+4	1E-5	4E-8	-	-
		Y, see ^{182}Ir	-	2E+4	9E-6	3E-8	-	-
77	Iridium-195	D, see ^{182}Ir	1E+4	4E+4	2E-5	6E-8	2E-4	2E-3
		W, see ^{182}Ir	-	5E+4	2E-5	7E-8	-	-
		Y, see ^{182}Ir	-	4E+4	2E-5	6E-8	-	-
78	Platinum-186	D, all compounds	1E+4	4E+4	2E-5	5E-8	2E-4	2E-3
78	Platinum-188	D, all compounds	2E+3	2E+3	7E-7	2E-9	2E-5	2E-4
78	Platinum-189	D, all compounds	3E+4	3E+4	1E-5	4E-8	1E-4	1E-3
78	Platinum-191	D, all compounds	4E+3	8E+3	4E-6	1E-8	5E-5	5E-4

Atomic No.	Radionuclide	Class	Table 1 Occupational Values: Col. 1 Oral Ingestion ALI (µCi)	Col. 2 Inhalation ALI (µCi)	Col. 3 Inhalation DAC (µCi/ml)	Table 2 Effluent Concentrations: Col. 1 Air (µCi/ml)	Col. 2 Water (µCi/ml)	Table 3 Releases to Sewers: Monthly Average Concentration (µCi/ml)
78	Platinum-193m	D, all compounds	3E+3	6E+3	3E-6	8E-9	-	-
			LLI wall (3E+4)	-	-	-	4E-5	4E-4
78	Platinum-193	D, all compounds	4E+4	2E+4	1E-5	3E-8	-	-
			LLI wall (5E+4)	-	-	-	6E-4	6E-3
78	Platinum-195m	D, all compounds	2E+3	4E+3	2E-6	6E-9	-	-
			LLI wall (2E+3)	-	-	-	3E-5	3E-4
78	Platinum-197m[2]	D, all compounds	2E+4	4E+4	2E-5	6E-8	2E-4	2E-3
78	Platinum-197	D, all compounds	3E+3	1E+4	4E-6	1E-8	4E-5	4E-4
78	Platinum-199[2]	D, all compounds	5E+4	1E+5	6E-5	2E-7	7E-4	7E-3
78	Platinum-200	D, all compounds	1E+3	3E+3	1E-6	5E-9	2E-5	2E-4
79	Gold-193	D, all compounds except those given for W and Y	9E+3	3E+4	1E-5	4E-8	1E-4	1E-3
		W, halides and nitrates	-	2E+4	9E-6	3E-8	-	-
		Y, oxides and hydroxides	-	2E+4	8E-6	3E-8	-	-
79	Gold-194	D, see ^{193}Au	3E+3	8E+3	3E-6	1E-8	4E-5	4E-4
		W, see ^{193}Au	-	5E+3	2E-6	8E-9	-	-
		Y, see ^{193}Au	-	5E+3	2E-6	7E-9	-	-
79	Gold-195	D, see ^{193}Au	5E+3	1E+4	6E-6	2E-8	7E-5	7E-4
		W, see ^{193}Au	-	1E+3	6E-7	2E-9	-	-
		Y, see ^{193}Au	-	4E+2	2E-7	6E-10	-	-
79	Gold-198m	D, see ^{193}Au	1E+3	3E+3	1E-6	4E-9	1E-5	1E-4
		W, see ^{193}Au	-	1E+3	5E-7	2E-9	-	-
		Y, see ^{193}Au	-	1E+3	5E-7	2E-9	-	-
79	Gold-198	D, see ^{193}Au	1E+0	4E+3	2E-6	5E-9	2E-5	2E-4
		W, see ^{193}Au	-	2E+3	8E-7	3E-9	-	-
		Y, see ^{193}Au	-	2E+3	7E-7	2E-9	-	-
79	Gold-199	D, see ^{193}Au	3E+3	9E+3	4E-6	1E-8	-	-
			LLI wall (3E+3)	-	-	-	4E-5	4E-4
		W, see ^{193}Au	-	4E+3	2E-6	6E-9	-	-
		Y, see ^{193}Au	-	4E+3	2E-6	5E-9	-	-
79	Gold-200m	D, see ^{193}Au	1E+3	4E+3	1E-6	5E-9	2E-5	2E-4
		W, see ^{193}Au	-	3E+3	1E-6	4E-9	-	-
		Y, see ^{193}Au	-	2E+3	1E-6	3E-9	-	-
79	Gold-200[2]	D, see ^{193}Au	3E+4	5E+4	3E-5	9E-8	4E-4	4E-3
		W, see ^{193}Au	-	8E+4	3E-6	1E-7	-	-
		Y, see ^{193}Au	-	7E+4	3E-5	1E-7	-	-
79	Gold-201[2]	D, see ^{193}Au	7E+4	2E+5	9E-5	3E-7	-	-
			St. wall (9E+4)	-	-	-	1E-3	1E-2
		W, see ^{193}Au	-	2E+5	1E-4	3E-7	-	-
		Y, see ^{193}Au	-	2E+5	9E-5	3E-7	-	-

Atomic No.	Radionuclide	Class	Table 1 Occupational Values: Col. 1 Oral Ingestion ALI (μCi)	Col. 2 Inhalation ALI (μCi)	Col. 3 Inhalation DAC (μCi/ml)	Table 2 Effluent Concentrations: Col. 1 Air (μCi/ml)	Col. 2 Water (μCi/ml)	Table 3 Releases to Sewers: Monthly Average Concentration (μCi/ml)
80	Mercury-193m	Vapor	-	8E+3	4E-6	1E-8	-	-
		Organic D	4E+3	1E+4	5E-6	2E-8	6E-5	6E-4
		D, sulfates	3E+3	9E+3	4E-6	1E-8	4E-5	4E-4
		W, oxides, hydroxides, halides, nitrates, and sulfides	-	8E+3	3E-6	1E-8	-	-
80	Mercury-193	Vapor	-	3E+4	1E-5	4E-8	-	-
		Organic D	2E+4	6E+4	3E-5	9E-8	3E-4	3E-3
		D, see ^{193m}Hg	2E+4	4E+4	2E-5	6E-8	2E-4	2E-3
		W, see ^{193m}Hg	-	4E+4	2E-5	6E-8	-	-
80	Mercury-194	Vapor	-	3E+1	1E-8	4E-11	-	-
		Organic D	2E+1	3E+1	1E-8	4E-11	2E-7	2E-6
		D, see ^{193m}Hg	8E+2	4E+1	2E-8	6E-11	1E-5	1E-4
		W, see ^{193m}Hg	-	1E+2	5E-8	2E-10	-	-
80	Mercury-195m	Vapor	-	4E+3	2E-6	6E-9	-	-
		Organic D	3E+3	6E+3	3E-6	8E-9	4E-5	4E-4
		D, see ^{193m}Hg	2E+3	5E+3	2E-6	7E-9	3E-5	3E-4
		W, see ^{193m}Hg	-	4E+3	2E-6	5E-9	-	-
80	Mercury-195	Vapor	-	3E+4	1E-5	4E-8	-	-
		Organic D	2E+4	5E+4	2E-5	6E-8	2E-4	2E-3
		D, see ^{193m}Hg	1E+4	4E+4	1E-5	5E-8	2E-4	2E-3
		W, see ^{193m}Hg	-	3E+4	1E-5	5E-8	-	-
80	Mercury-197m	Vapor	-	5E+3	2E-6	7E-9	-	-
		Organic D	4E+3	9E+3	4E-6	1E-8	5E-5	5E-4
		D, see ^{193m}Hg	3E+3	7E+3	3E-6	1E-8	4E-5	4E-4
		W, see ^{193m}Hg	-	5E+3	2E-6	7E-9	-	-
80	Mercury-197	Vapor	-	8E+3	4E-6	1E-8	-	-
		Organic D	7E+3	1E+4	6E-6	2E-8	9E-5	9E-4
		D, see ^{193m}Hg	6E+3	1E+4	5E-6	2E-6	8E-6	8E-4
		W, see ^{193m}Hg	-	9E+3	4E-6	1E-8	-	-
80	Mercury-199m[2]	Vapor	-	8E+4	3E-5	1E-7	-	-
		Organic D	6E+4	2E+5	7E-6	2E-7	-	-
			St. wall (1E+5)	-	-	-	1E-3	1E-2
		D, see ^{193m}Hg	6E+4	1E+5	6E-6	2E-7	8E-4	8E-3
		W, see ^{193m}Hg	-	2E+5	7E-5	2E-7	-	-
80	Mercury-203	Vapor	-	8E+2	4E-7	1E-9	-	-
		Organic D	5E+2	8E+2	3E-7	1E-9	7E-6	7E-5
		D, see ^{193m}Hg	2E+3	1E+3	5E-7	2E-9	3E-5	3E-4
		W, see ^{193m}Hg	-	1E+3	5E-7	2E-9	-	-
81	Thallium-194m[2]	D, all compounds	5E+4	2E+5	6E-5	2E-7	-	-
			St. wall (7E+4)	-	-	-	1E-3	1E-2

Atomic No.	Radionuclide	Class	Table 1 Occupational Values: Col. 1 Oral Ingestion ALI (μCi)	Col. 2 Inhalation ALI (μCi)	Col. 3 Inhalation DAC (μCi/ml)	Table 2 Effluent Concentrations: Col. 1 Air (μCi/ml)	Col. 2 Water (μCi/ml)	Table 3 Releases to Sewers: Monthly Average Concentration (μCi/ml)
81	Thallium-194[2]	D, all compounds	3E+5	6E+5	2E-4	8E-7	-	-
			St. wall (3E+5)	-	-	-	4E-3	4E-2
81	Thallium-195[2]	D, all compounds	6E+4	1E+5	5E-5	2E-7	9E-4	9E-3
81	Thallium-197	D, all compounds	7E+4	1E+5	5E-5	2E-7	1E-3	1E-2
81	Thallium-198m[2]	D, all compounds	3E+4	5E+4	2E-5	8E-8	4E-4	4E-3
81	Thallium-198	D, all compounds	2E+4	3E+4	1E-5	5E-8	3E-4	3E-3
81	Thallium-199	D, all compounds	6E+4	8E+4	4E-5	1E-7	9E-4	9E-3
81	Thallium-200	D, all compounds	8E+3	1E+4	5E-6	2E-8	1E-4	1E-3
81	Thallium-201	D, all compounds	2E+4	2E+4	9E-6	3E-8	2E-4	2E-3
81	Thallium-202	D, all compounds	4E+3	5E+3	2E-6	7E-9	5E-5	5E-4
81	Thallium-204	D, all compounds	2E+3	2E+3	9E-7	3E-9	2E-5	2E-4
82	Lead-195m[2]	D, all compounds	6E+4	2E+5	8E-5	3E-7	8E-4	8E-3
82	Lead-198	D, all compounds	3E+4	6E+4	3E-5	9E-8	4E-4	4E-3
82	Lead-199[2]	D, all compounds	2E+4	7E+4	3E-5	1E-7	3E-4	3E-3
82	Lead-200	D, all compounds	3E+3	6E+3	3E-6	9E-9	4E-5	4E-4
82	Lead-201	D, all compounds	7E+3	2E+4	8E-6	3E-8	1E-4	1E-3
82	Lead-202m	D, all compounds	9E+3	3E+4	1E-5	4E-8	1E-4	1E-3
82	Lead-202	D, all compounds	1E+2	5E+1	2E-8	7E-11	2E-6	2E-5
82	Lead-203	D, all compounds	5E+3	9E+3	4E-6	1E-8	7E-5	7E-4
82	Lead-205	D, all compounds	4E+3	1E+3	6E-7	2E-9	5E-5	5E-4
82	Lead-209	D, all compounds	2E+4	6E+4	2E-5	8E-8	3E-4	3E-3
82	Lead-210	D, all compounds	6E-1	2E-1	1E-10	-	-	-
			Bone surf (1E+0)	Bone surf (4E-1)	-	6E-13	1E-8	1E-7
82	Lead-211[2]	D, all compounds	1E+4	6E+2	3E-7	9E-10	2E-4	2E-3
82	Lead-212	D, all compounds	8E+1	3E+1	1E-8	5E-11	-	-
			Bone surf (1E+2)	-	-	-	2E-6	2E-5
82	Lead-214[2]	D, all compounds	9E+3	8E+2	3E-7	1E-9	1E-4	1E-3
83	Bismuth-200[2]	D, nitrates	3E+4	8E+4	4E-5	1E-7	4E-4	4E-3
		W, all other compounds	-	1E+5	4E-5	1E-7	-	-
83	Bismuth-201[2]	D, see ^{200}Bi	1E+4	3E+4	1E-5	4E-8	2E-4	2E-3
		W, see ^{200}Bi	-	6E+4	2E-5	5E-8	-	-
83	Bismuth-202[2]	D, see ^{200}Bi	1E+4	4E+4	2E-5	6E-8	2E-4	2E-3
		W, see ^{200}Bi	-	8E+4	3E-5	1E-7	-	-

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Atomic No.	Radionuclide	Class	Table 1 Occupational Values: Col. 1 Oral Ingestion ALI (µCi)	Col. 2 Inhalation ALI (µCi)	Col. 3 Inhalation DAC (µCi/ml)	Table 2 Effluent Concentrations: Col. 1 Air (µCi/ml)	Col. 2 Water (µCi/ml)	Table 3 Releases to Sewers: Monthly Average Concentration (µCi/ml)
83	Bismuth-203	D, see ^{200}Bi	2E+3	7E+3	3E-6	9E-9	3E-5	3E-4
		W, see ^{200}Bi	-	6E+3	3E-6	9E-9	-	-
83	Bismuth-205	D, see ^{200}Bi	1E+3	3E+3	1E-6	3E-9	2E-5	2E-4
		W, see ^{200}Bi	-	1E+3	5E-7	2E-9	-	-
83	Bismuth-206	D, see ^{200}Bi	6E+2	1E+3	6E-7	2E-9	9E-6	9E-5
		W, see ^{200}Bi	-	9E+2	4E-7	1E-9	-	-
83	Bismuth-207	D, see ^{200}Bi	1E+3	2E+3	7E-7	2E-9	1E-5	1E-4
		W, see ^{200}Bi	-	4E+2	1E-7	5E-10	-	-
83	Bismuth-210m	D, see ^{200}Bi	4E+1 Kidneys (6E+1)	5E+0 Kidneys (6E+0)	2E-9	-	-	-
			-		-	9E-12	6E-7	8E-6
		W, see ^{200}Bi	-	7E-1	3E-10	9E-13	-	-
83	Bismuth-210	D, see ^{200}Bi	8E+2	2E+2 Kidneys (4E+2)	1E-7	-	1E-5	1E-4
			-		-	5E-10	-	-
		W, see ^{200}Bi	-	3E+1	1E-8	4E-11	-	-
83	Bismuth-212[2]	D, see ^{200}Bi	5E+3	2E+2	1E-7	3E-10	7E-5	7E-4
		W, see ^{200}Bi	-	3E+2	1E-7	4E-10	-	-
83	Bismuth-213[2]	D, see ^{200}Bi	7E+3	3E+2	1E-7	4E-10	1E-4	1E-3
		W, see ^{200}Bi	-	4E+2	1E-7	5E-10	-	-
83	Bismuth-214[2]	D, see ^{200}Bi	2E+4 St. wall (2E+4)	8E+2	3E-7	1E-9	-	-
			-	-	-	-	3E-4	3E-3
		W, see ^{200}Bi	-	9E-2	4E-7	1E-9	-	-
84	Polonium-203[2]	D, all compounds except those given for W	3E+4	6E+4	3E-5	9E-8	3E-4	3E-3
		W, oxides, hydroxides, and nitrates	-	9E+4	4E-5	1E-7	-	-
84	Polonium-205[2]	D, see ^{203}Po	2E+4	4E+4	2E-5	5E-8	3E-4	3E-3
		W, see ^{203}Po	-	7E+4	3E-5	1E-7	-	-
84	Polonium-207	D, see ^{203}Po	8E+3	3E+4	1E-5	3E-8	1E-4	1E-3
		W, see ^{203}Po	-	3E+4	1E-5	4E-8	-	-
84	Polonium-210	D, see ^{203}Po	3E+0	6E-1	3E-10	9E-13	4E-8	4E-7
		W, see ^{203}Po	-	6E-1	3E-10	9E-13	-	-
85	Astatine-207[2]	D, halides	6E+3	3E+3	1E-6	4E-9	8E-5	8E-4
		W	-	2E+3	9E-7	3E-9	-	-
85	Astatine-211	D, halides	1E+2	8E+1	3E-8	1E-10	2E-6	2E-5
		W	-	5E+1	2E-8	8E-11	-	-
86	Radon-220	With daughters removed	-	2E+4	7E-6	2E-8	-	-
		With daughters present	-	2E+1 (or 12 working level months)	9E-9 (or 1.0 working level)	3E-11	-	-

Atomic No.	Radionuclide	Class	Table 1 Occupational Values: Col. 1 Oral Ingestion ALI (µCi)	Col. 2 Inhalation ALI (µCi)	Col. 1 Inhalation DAC (µCi/ml)	Table 2 Effluent Concentrations: Col. 1 Air (µCi/ml)	Col. 2 Water (µCi/ml)	Table 3 Releases to Sewers: Monthly Average Concentration (µCi/ml)
86	Radon-222	With daughters removed	-	1E+4	4E-6	1E-8	-	-
		With daughters present	-	1E+2 (or 4 working level months)	3E-8 (or 0.33 working level)	1E-10	-	-
87	Francium-222[2]	D, all compounds	2E+3	5E+2	2E-7	6E-10	3E-5	3E-4
87	Francium-223[2]	D, all compounds	6E+2	8E+2	3E-7	1E-9	8E-6	8E-5
88	Radium-223	W, all compounds	5E+0 Bone surf (9E+0)	7E-1	3E-10	9E-13	-	-
			-	-	-	-	1E-7	1E-6
88	Radium-224	W, all compounds	8E+0 Bone surf (2E+1)	2E+0	7E-10	2E-12	-	-
			-	-	-	-	2E-7	2E-6
88	Radium-225	W, all compounds	8E+0 Bone surf (2E+1)	7E-1	3E-10	9E-13	-	-
			-	-	-	-	2E-7	2E-6
88	Radium-226	W, all compounds	2E+0 Bone surf (5E+0)	6E-1	3E-10	9E-13	-	-
			-	-	-	-	6E-8	6E-7
88	Radium-227[2]	W, all compounds	2E+4 Bone surf (2E+4)	1E+4 Bone surf (2E+4)	6E-6	-	-	-
			-	-	-	3E-8	3E-4	3E-1
8	Radium-228	W, all compounds	2E+0 Bone surf (4E+0)	1E+0	5E-10	2E-12	-	-
			-	-	-	-	6E-8	6E-7
89	Actinium-224	D, all compounds except those given for W and Y	2E+3 LLI wall (2E+3)	3E+1 Bone surf (4E+1)	1E-8	-	-	-
			-	-	-	5E-11	3E-5	3E-4
		W, halides and nitrates	-	5E+1	2E-8	7E-11	-	-
		Y, oxides and hydroxides	-	5E+1	2E-8	6E-11	-	-
89	Actinium-225	D, see ^{224}Ac	5E+1 LLI wall (5E+1)	3E-1 Bone surf (5E-1)	1E-10	-	-	-
			-	-	-	7E-11	7E-7	7E-6
		W, see ^{224}Ac	-	6E-1	3E-10	9E-13	-	-
		Y, see ^{224}Ac	-	6E-1	3E-10	9E-13	-	-
89	Actinium-226	D, see ^{224}Ac	1E+2 LLI wall (1E+2)	3E+0 Bone surf (4E+0)	1E-9	-	-	-
			-	-	-	5E-12	2E-6	2E-5
		W, see ^{224}Ac	-	5E+0	2E-9	7E-12	-	-
		Y, see ^{224}Ac	-	5E+0	2E-9	6E-12	-	-
89	Actinium-227	D, see ^{224}Ac	2E-1 Bone surf (4E-1)	4E-4 Bone surf (8E-4)	2E-13	-	-	-
			-	-	-	1E-15	5E-9	5E-8
		W, see ^{224}Ac	-	2E-3 Bone surf (3E-3)	7E-13	-	-	-
			-	-	-	4E-15	-	-
		Y, see ^{224}Ac	-	4E-3	2E-12	6E-15	-	-

Atomic No.	Radionuclide	Class	Table 1 Occupational Values Col. 1 Oral Ingestion ALI (μCi)	Col. 2 Inhalation ALI (μCi)	Col. 3 Inhalation DAC (μCi/ml)	Table 2 Effluent Concentrations Col. 1 Air (μCi/ml)	Col. 2 Water (μCi/ml)	Table 3 Releases to Sewers Monthly Average Concentration (μCi/ml)
89	Actinium-228	D, see ^{224}Ac	2E+3	9E+0	4E-9	-	3E-5	3E-4
			-	Bone surf (2E+1)	-	2E-11	-	-
		W, see ^{224}Ac	-	4E+1	2E-8	-	-	-
			-	Bone surf (6E+1)	-	8E-11	-	-
		Y, see ^{224}Ac	-	4E+1	2E-8	6E-11	-	-
90	Thorium-226[2]	W, all compounds except those given for Y	5E+3	2E+2	6E-8	2E-10	-	-
			St. wall (5E+3)	-	-	-	7E-5	7E-4
		Y, oxides and hydroxides	-	1E+2	6E-8	2E-10	-	-
90	Thorium-227	W, see ^{226}Th	1E+2	3E-1	1E-10	5E-13	2E-6	2E-5
		Y, see ^{226}Th	-	3E-1	1E-10	5E-13	-	-
90	Thorium-228	W, see ^{226}Th	6E+0	1E-2	4E-12	-	-	-
			Bone surf (1E+1)	Bone surf (2E-2)	-	3E-14	2E-7	2E-6
		Y, see ^{226}Th	-	2E-2	7E-12	2E-14	-	-
90	Thorium-229	W, see ^{226}Th	6E-1	9E-4	4E-13	-	-	-
			Bone surf (1E+0)	Bone surf (2E-3)	-	3E-15	2E-8	2E-7
		Y, see ^{226}Th	-	2E-3	1E-12	-	-	-
			-	Bone surf (3E-3)	-	4E-15	-	-
90	Thorium-230	W, see ^{226}Th	4E+0	6E-3	3E-12	-	-	-
			Bone surf (9E+0)	Bone surf (2E-2)	-	2E-14	1E-7	1E-6
		Y, see ^{226}Th	-	2E-2	6E-12	-	-	-
			-	Bone surf (2E-2)	-	3E-14	-	-
90	Thorium-231	W, see ^{226}Th	4E+3	6E+3	3E-6	9E-9	5E-5	5E-4
		Y, see ^{226}Th	-	6E+3	3E-6	9E-9	-	-
90	Thorium-232	W, see ^{226}Th	7E-1	1E-3	5E-13	-	-	-
			Bone surf (2E+0)	Bone surf (3E-3)	-	4E-15	3E-8	3E-7
		Y, see ^{226}Th	-	3E-3	1E-12	-	-	-
			-	Bone surf (4E-3)	-	6E-15	-	-
90	Thorium-234	W, see ^{226}Th	3E+2	2E+2	8E-8	3E-10	-	-
			LLI wall (4E+2)	-	-	-	5E-6	5E-5
		Y, see ^{226}Th	-	2E+2	6E-8	2E-10	-	-
91	Protactinium-227[2]	W, all compounds except those given for Y	4E+3	1E+2	5E-8	2E-10	5E-5	5E-4
		Y, oxides and hydroxides	-	1E+2	4E-8	1E-10	-	-
91	Protactinium-228	W, see ^{227}Pa	1E+3	1E+1	5E-9	-	2E-5	2E-4
			-	Bone surf (2E+1)	-	3E-11	-	-
		Y, see ^{226}Pa	-	1E+1	5E-9	2E-11	-	-

Atomic No.	Radionuclide	Class	Table 1 Occupational Values Col. 1 Oral Ingestion ALI (μCi)	Col. 2 Inhalation ALI (μCi)	Col. 3 Inhalation DAC (μCi/ml)	Table 2 Effluent Concentrations Col. 1 Air (μCi/ml)	Col. 2 Water (μCi/ml)	Table 3 Releases to Sewers Monthly Average Concentration (μCi/ml)
91	Protactinium-230	W, see ^{227}Pa	6E+2	5E+0	2E-9	7E-12	-	-
			Bone surf (9E+2)	-	-	-	1E-5	1E-4
		Y, see ^{227}Pa	-	4E+0	1E-9	5E-12	-	-
91	Protactinium-231	W, see ^{227}Pa	2E-1	2E-3	6E-13	-	-	-
			Bone surf (5E-1)	Bone surf (4E-3)	-	6E-15	6E-9	6E-8
		Y, see ^{226}Pa	-	4E-3	2E-12	-	-	-
			-	Bone surf (6E-3)	-	8E-15	-	-
91	Protactinium-232	W, see ^{227}Pa	1E+1	2E+1	9E-9	-	2E-5	2E-4
			-	Bone surf (6E+1)	-	8E-11	-	-
		Y, see ^{227}Pa	-	6E+1	2E-8	-	-	-
			-	Bone surf (7E+1)	-	1E-10	-	-
91	Protactinium-233	W, see ^{227}Pa	1E+3	7E+2	3E-7	1E-9	-	-
			LLI wall (2E+3)	-	-	-	2E-5	2E-4
		Y, see ^{227}Pa	-	6E+2	2E-7	8E-10	-	-
91	Protactinium-234	W, see ^{227}Pa	2E+3	8E+3	3E-6	1E-8	3E-5	3E-4
		Y, see ^{227}Pa	-	7E+3	3E-6	9E-9	-	-
92	Uranium-230	D, UF_6, UO_2F_2, $UO_2(NO_3)_2$	4E+0	4E-1	2E-10	-	-	-
			Bone surf (6E+0)	Bone surf (6E-1)	-	8E-13	8E-8	8E-7
		W, UO_3, UF_4, UCl_4	-	4E-1	1E-10	5E-13	-	-
		Y, UO_2, U_3O_8	-	3E-1	1E-10	4E-13	-	-
92	Uranium-231	D, see ^{230}U	5E+3	8E+3	3E-6	1E-8	-	-
			LLI wall (4E+3)	-	-	-	6E-5	6E-4
		W, see ^{230}U	-	6E+3	2E-6	8E-9	-	-
		Y, see ^{230}U	-	5E+3	2E-6	6E-9	-	-
92	Uranium-232	D, see ^{230}U	2E+0	2E-1	9E-11	-	-	-
			Bone surf (4E+0)	Bone surf (4E-1)	-	6E-13	6E-8	6E-7
		W, see ^{230}U	-	4E-1	2E-10	5E-13	-	-
		Y, see ^{230}U	-	8E-3	3E-12	1E-14	-	-
92	Uranium-233	D, see ^{230}U	1E+1	1E+0	5E-10	-	-	-
			Bone surf (2E+1)	Bone surf (2E+0)	-	3E-12	3E-7	3E-6
		W, see ^{230}U	-	7E-1	3E-10	1E-12	-	-
		Y, see ^{230}U	-	4E-2	2E-11	5E-14	-	-
92	Uranium-234[3]	D, see ^{230}U	1E+1	1E+0	5E-10	-	-	-
			Bone surf (2E+1)	Bone surf (2E+0)	-	3E-12	3E-7	3E-6
		W, see ^{230}U	-	7E-1	3E-10	1E-12	-	-
		Y, see ^{230}U	-	4E-2	2E-11	5E-14	-	-

Atomic No.	Radionuclide	Class	Table 1 Occupational Values: Col. 1 Oral Ingestion ALI (µCi)	Table 1: Col. 2 Inhalation ALI (µCi)	Table 1: Col. 3 Inhalation DAC (µCi/ml)	Table 2 Effluent Concentrations: Col. 1 Air (µCi/ml)	Table 2: Col. 2 Water (µCi/ml)	Table 3 Releases to Sewers: Monthly Average Concentration (µCi/ml)
92	Uranium-235[3]	D, see ^{230}U	1E+1 Bone surf (2E+1)	1E+0 Bone surf (2E+0)	6E-10 -	- 3E-12	- 3E-7	- 3E-6
		W, see ^{230}U	-	8E-1	3E-10	3E-12	-	-
		Y, see ^{230}U	-	4E-2	2E-11	8E-14	-	-
92	Uranium-236	D, see ^{230}U	1E+1 Bone surf (2E+1)	1E+0 Bone surf (2E+0)	5E-10 -	3E-12	3E-7	3E-6
		W, see ^{230}U	-	8E-1	3E-10	1E-12	-	-
		Y, see ^{230}U	-	4E-2	2E-11	8E-14	-	-
92	Uranium-237	D, see ^{230}U	2E+3 LLI wall (2E+3)	3E+3 -	1E-6 -	4E-9 -	- 3E-5	- 3E-4
		W, see ^{230}U	-	2E+3	7E-7	2E-9	-	-
		Y, see ^{230}U	-	2E+3	6E-7	2E-9	-	-
92	Uranium-238[3]	D, see ^{230}U	1E+1 Bone surf (2E+1)	1E+0 Bone surf (2E+0)	6E-10 -	3E-12	3E-7	3E-6
		W, see ^{230}U	-	8E-1	3E-10	1E-12	-	-
		Y, see ^{230}U	-	4E-2	2E-11	6E-14	-	-
92	Uranium-239[2]	D, see ^{230}U	7E+4	2E+5	8E-5	3E-7	9E-4	9E-3
		W, see ^{230}U	-	2E+5	7E-5	2E-7	-	-
		Y, see ^{230}U	-	2E+5	6E-5	2E-7	-	-
92	Uranium-240	D, see ^{230}U	1E+3	4E+3	2E-6	5E-9	2E-5	2E-4
		W, see ^{230}U	-	3E+3	1E-6	4E-9	-	-
		Y, see ^{230}U	-	2E+3	1E-6	3E-9	-	-
92	Uranium-natural[3]	D, see ^{230}U	1E+1 Bone surf (2E+1)	1E+0 Bone surf (2E+0)	5E-10 -	3E-12	3E-7	3E-6
		W, see ^{230}U	-	8E-1	3E-10	9E-13	-	-
		Y, see ^{230}U	-	5E-2	2E-11	9E-14	-	-
9	Neptunium-232[2]	W, all compounds	1E+5	2E+3 Bone surf	7E-7	-	2E-3	2E-2
			-	(5E+2)	-	6E-9	-	-
93	Neptunium-233[2]	W, all compounds	8E+6	3E+6	1E-3	4E-6	1E-2	1E-1
93	Neptunium-234	W, all compounds	2E+3	3E+3	1E-6	4E-9	3E-5	3E-4
93	Neptunium-235	W, all compounds	2E+4 LLI wall (2E+4)	8E+2 Bone surf (1E+3)	3E-7 -	- 2E-9	- 3E-4	- 3E-3
93	Neptunium-236 (1.15E+5 y)	W, all compounds	3E+0 Bone surf (6E+0)	2E-2 Bone surf (5E-2)	9E-12 -	- 8E-14	- 9E-8	- 9E-7
93	Neptunium-236m (22.5 h)	W, all compounds	3E+3 Bone surf (4E+3)	3E+1 Bone surf (7E+1)	1E-8 -	- 1E-10	- 5E-5	- 5E-4
93	Neptunium-237	W, all compounds	5E-1 Bone surf (1E+0)	4E-3 Bone surf (1E-2)	2E-12 -	- 1E-14	- 2E-8	- 2E-7

Atomic No.	Radionuclide	Class	Table 1 Occupational Values: Col. 1 Oral Ingestion ALI (µCi)	Table 1: Col. 2 Inhalation ALI (µCi)	Table 1: Col. 3 Inhalation DAC (µCi/ml)	Table 2 Effluent Concentrations: Col. 1 Air (µCi/ml)	Table 2: Col. 2 Water (µCi/ml)	Table 3 Releases to Sewers: Monthly Average Concentration (µCi/ml)
93	Neptunium-238	W, all compounds	1E+3	8E+1 Bone surf	3E-8	-	2E-5	2E-4
			-	(2E+2)	-	2E-10	-	-
93	Neptunium-239	W, all compounds	2E+3 LLI wall (2E+3)	2E+3 -	9E-7 -	3E-9 -	- 2E-5	- 2E-4
93	Neptunium-240[2]	W, all compounds	2E+4	8E+4	3E-5	1E-7	3E-4	3E-3
94	Plutonium-234	W, all compounds	8E+3	2E+2	9E-8	3E-10	1E-4	1E-3
		except PuO_2 Y, PuO_2	-	2E+2	8E-8	3E-10	-	-
94	Plutonium-235[2]	W, see ^{234}Pu	9E+5	3E+6	1E-3	4E-6	1E-2	1E-1
		Y, see ^{234}Pu	-	3E+6	1E-3	3E-6	-	-
94	Plutonium-236	W, see ^{234}Pu	2E+0 Bone surf (4E+0)	2E-2 Bone surf (4E-2)	8E-12 -	- 5E-14	- 6E-8	- 6E-7
		Y, see ^{234}Pu	-	4E-2	2E-11	6E-14	-	-
94	Plutonium-237	W, see ^{234}Pu	1E+4	3E+3	1E-6	5E-9	2E-4	2E-3
		Y, see ^{234}Pu	-	3E+3	1E-6	4E-9	-	-
94	Plutonium-238	W, see ^{234}Pu	9E-1 Bone surf (2E+0)	7E-3 Bone surf (1E-2)	3E-12 -	- 2E-14	- 2E-8	- 2E-7
		Y, see ^{234}Pu	-	2E-2	8E-12	2E-14	-	-
94	Plutonium-239	W, see ^{234}Pu	8E-1 Bone surf (1E+0)	6E-3 Bone surf (1E-2)	3E-12 -	- 2E-14	- 2E-8	- 2E-7
		Y, see ^{234}Pu	-	2E-2	7E-12	-	-	-
			-	Bone surf (2E-2)	-	2E-14	-	-
94	Plutonium-240	W, see ^{234}Pu	8E-1 Bone surf (1E+0)	6E-3 Bone surf (1E-2)	3E-12 -	- 2E-14	- 2E-8	- 2E-7
		Y, see ^{234}Pu	-	2E-2	7E-12	-	-	-
			-	Bone surf (2E-2)	-	2E-14	-	-
94	Plutonium-241	W, see ^{234}Pu	4E+1 Bone surf (7E+1)	3E-1 Bone surf (6E-1)	1E-10 -	- 8E-13	- 1E-6	- 1E-5
		Y, see ^{234}Pu	-	8E-1	3E-10	-	-	-
			-	Bone surf (1E+0)	-	1E-12	-	-

Atomic No.	Radionuclide	Class	Table 1 Occupational Values: Col. 1 Oral Ingestion ALI (µCi)	Table 1 Occupational Values: Col. 2 Inhalation ALI (µCi)	Table 1 Occupational Values: Col. 2 Inhalation DAC (µCi/ml)	Table 1 Occupational Values: Col. 3 Inhalation ALI (µCi)	Table 1 Occupational Values: Col. 3 Inhalation DAC (µCi/ml)	Table 2 Effluent Concentrations: Col. 1 Air (µCi/ml)	Table 2 Effluent Concentrations: Col. 2 Water (µCi/ml)	Table 3 Releases to Sewers: Monthly Average Concentration (µCi/ml)
94	Plutonium-242	W, see ^{234}Pu	8E-1	7E-1	3E-12	-	-	-	-	-
			Bone surf (1E+0)	Bone surf (1E-2)	-			2E-14	2E-8	2E-7
		Y, see ^{234}Pu	-	2E-2	7E-12			-	-	-
			-	Bone surf (2E-2)	-			2E-14	-	-
94	Plutonium-243	W, see ^{234}Pu	2E+4	4E+4	2E-5			5E-8	2E-4	2E-3
		Y, see ^{234}Pu	-	4E+4	2E-5			5E-8	-	-
94	Plutonium-244	W, see ^{234}Pu	8E-1	7E-3	3E-12			-	-	-
			Bone surf (2E+0)	Bone surf (1E-2)	-			2E-14	2E-8	2E-7
		Y, see ^{234}Pu	-	2E-2	7E-12			-	-	-
			-	Bone surf (2E-2)	-			2E-14	-	-
94	Plutonium-245	W, see ^{234}Pu	2E+3	5E+3	2E-6			6E-9	3E-5	3E-4
		Y, see ^{234}Pu	-	4E+3	2E-6			6E-9	-	-
94	Plutonium-246	W, see ^{234}Pu	4E+2	3E+2	1E-7			4E-10	-	-
			LLI wall (4E+2)	-	-			-	6E-6	6E-5
		Y, see ^{234}Pu	-	3E+2	1E-7			4E-10	-	-
95	Americium-237[2]	W, all compounds	8E+4	3E+5	1E-4			4E-7	1E-3	1E-2
95	Americium-238[2]	W, all compounds	4E+4	3E+3	1E-6			-	5E-4	5E-3
			-	Bone surf (6E+3)	-			9E-9	-	-
95	Americium-239	W, all compounds	5E+3	1E+4	5E-6			2E-8	7E-5	7E-4
95	Americium-240	W, all compounds	2E+3	3E+3	1E-6			4E-9	3E-5	3E-4
95	Americium-241	W, all compounds	8E-1	6E-3	3E-12			-	-	-
			Bone surf (1E+0)	Bone surf (1E-2)	-			2E-14	2E-8	2E-7
95	Americium-242m	W, all compounds	8E-1	6E-3	3E-12			-	-	-
			Bone surf (1E+0)	Bone surf (1E-2)	-			2E-14	2E-8	2E-7
95	Americium-242	W, all compounds	4E+3	8E+1	4E-8			-	5E-5	5E-4
			-	Bone surf (9E+1)	-			1E-10	-	-
95	Americium-243	W, all compounds	8E-1	6E-3	3E-12			-	-	-
			Bone surf (1E+0)	Bone surf (1E-2)	-			2E-14	2E-8	2E-7
95	Americium-244m[2]	W, all compounds	6E+4	4E+3	2E-6			-	-	-
			St. wall (8E+4)	Bone surf (7E+3)	-			1E-8	1E-3	1E-2
95	Americium-244	W, all compounds	3E+3	2E+2	8E-8			-	4E-5	4E-4
			-	Bone surf (3E+2)	-			4E-10	-	-
95	Americium-245	W, all compounds	3E+4	8E+4	3E-5			1E-7	4E-4	4E-3

Atomic No.	Radionuclide	Class	Table 1 Occupational Values: Col. 1 Oral Ingestion ALI (µCi)	Table 1 Occupational Values: Col. 2 Inhalation ALI (µCi)	Table 1 Occupational Values: Col. 3 Inhalation DAC (µCi/ml)	Table 2 Effluent Concentrations: Col. 1 Air (µCi/ml)	Table 2 Effluent Concentrations: Col. 2 Water (µCi/ml)	Table 3 Releases to Sewers: Monthly Average Concentration (µCi/ml)
95	Americium-246m[2]	W, all compounds	5E+4	2E+5	8E-5	3E-7	-	-
			St. wall (6E+4)	-	-	-	8E-4	8E-3
95	Americium-246[2]	W, all compounds	3E+4	1E+5	4E-5	1E-7	4E-4	4E-3
96	Curium-238	W, all compounds	2E+4	1E+3	5E-7	2E-9	2E-4	2E-3
96	Curium-240	W, all compounds	6E+1	6E-1	2E-10	-	-	-
			Bone surf (8E+1)	Bone surf (6E-1)	-	9E-13	1E-6	1E-5
96	Curium-241	W, all compounds	1E+3	3E+1	1E-8	-	2E-5	2E-4
			-	Bone surf (4E+1)	-	5E-11	-	-
96	Curium-242	W, all compounds	3E+1	3E-1	1E-10	-	-	-
			Bone surf (5E+1)	Bone surf (3E-1)	-	4E-13	7E-7	7E-6
96	Curium-243	W, all compounds	1E+0	9E-3	4E-12	-	-	-
			Bone surf (2E+0)	Bone surf (2E-2)	-	2E-14	3E-8	3E-7
96	Curium-244	W, all compounds	1E+0	1E-2	5E-12	-	-	-
			Bone surf (3E+0)	Bone surf (2E-2)	-	3E-14	3E-8	3E-7
96	Curium-245	W, all compounds	7E-1	6E-3	3E-12	-	-	-
			Bone surf (1E+0)	Bone surf (1E-2)	-	2E-14	2E-8	2E-7
96	Curium-246	W, all compounds	7E-1	6E-3	3E-12	-	-	-
			Bone surf (1E+0)	Bone surf (1E-2)	-	2E-14	2E-8	2E-7
96	Curium-247	W, all compounds	8E-1	6E-3	3E-12	-	-	-
			Bone surf (1E+0)	Bone surf (1E-2)	-	2E-14	2E-8	2E-7
96	Curium-248	W, all compounds	2E-1	2E-3	7E-13	-	-	-
			Bone surf (4E-1)	Bone surf (3E-3)	-	4E-15	5E-9	5E-8
96	Curium-249[2]	W, all compounds	5E+4	2E+4	7E-6	-	7E-4	7E-3
			-	Bone surf (3E+4)	-	4E-8	-	-
96	Curium-250	W, all compounds	4E-2	3E-4	1E-13	-	-	-
			Bone surf (6E-2)	Bone surf (5E-4)	-	8E-16	9E-10	9E-9
97	Berkelium-245	W, all compounds	2E+3	1E+3	5E-7	2E-9	3E-5	3E-4
97	Berkelium-246	W, all compounds	3E+3	3E+3	1E-6	4E-9	4E-5	4E-4
97	Berkelium-247	W, all compounds	5E-1	4E-3	2E-12	-	-	-
			Bone surf (1E+0)	Bone surf (9E-3)	-	1E-14	2E-8	2E-7
97	Berkelium-249	W, all compounds	2E+2	2E+0	7E-10	-	-	-
			Bone surf (5E+2)	Bone surf (4E+0)	-	5E-12	6E-6	6E-5

Atomic No.	Radionuclide	Class	Table 1 Occupational Values: Col. 1 Oral Ingestion ALI (μCi)	Col. 2 Inhalation ALI (μCi)	Col. 3 Inhalation DAC (μCi/ml)	Table 2 Effluent Concentrations: Col. 1 Air (μCi/ml)	Col. 2 Water (μCi/ml)	Table 3 Releases to Sewers: Monthly Average Concentration (μCi/ml)
97	Berkelium-250	W, all compounds	9E+3	3E+2	1E-7	-	1E-4	1E-3
			-	Bone surf (7E+2)	-	1E-9	-	-
98	Californium-244[2]	W, all compounds except those given for Y	3E+4	6E+2	2E-7	8E-10	-	-
			St. wall (3E+4)	-	-	-	4E-4	4E-3
		Y, oxides and hydroxides	-	6E+2	2E-7	8E-10	-	-
98	Californium-246	W, see ^{244}Cf	4E+2	9E+0	4E-9	1E-11	5E-6	5E-5
		Y, see ^{244}Cf	-	9E+0	4E-9	1E-11	-	-
98	Californium-248	W, see ^{244}Cf	8E+0	6E-2	3E-11	-	-	-
			Bone surf (2E+1)	Bone surf (1E-1)	-	2E-13	2E-7	2E-6
		Y, see ^{244}Cf	-	1E-1	4E-11	1E-13	-	-
98	Californium-249	W, see ^{244}Cf	5E-1	4E-3	2E-12	-	-	-
			Bone surf (1E+0)	Bone surf (9E-3)	-	1E-14	2E-8	2E-7
		Y, see ^{244}Cf	-	1E-2	4E-12	-	-	-
			-	Bone surf (1E-2)	-	2E-14	-	-
98	Californium-250	W, see ^{244}Cf	1E+0	9E-3	4E-12	-	-	-
			Bone surf (2E+0)	Bone surf (2E-2)	-	3E-14	3E-8	3E-7
		Y, see ^{244}Cf	-	3E-2	1E-11	4E-14	-	-
98	Californium-251	W, see ^{244}Cf	5E-1	4E-3	2E-12	-	-	-
			Bone surf (1E+0)	Bone surf (9E-3)	-	1E-14	2E-8	2E-7
		Y, see ^{244}Cf	-	1E-2	4E-12	-	-	-
			-	Bone surf (1E-2)	-	2E-14	-	-
98	Californium-252	W, see ^{244}Cf	2E+0	2E-2	8E-12	-	-	-
			Bone surf (5E+0)	Bone surf (4E-2)	-	5E-14	7E-8	7E-7
		Y, see ^{244}Cf	-	3E-2	1E-11	5E-14	-	-
98	Californium-253	W, see ^{244}Cf	2E+2	2E+0	8E-10	3E-12	-	-
			Bone surf (4E+2)	-	-	-	5E-6	5E-5
		Y, see ^{244}Cf	-	2E+0	7E-10	2E-12	-	-
98	Californium-254	W, see ^{244}Cf	2E+0	2E-2	9E-12	3E-14	3E-8	3E-7
		Y, see ^{244}Cf	-	2E-2	7E-12	2E-14	-	-
99	Einsteinium-250	W, all compounds	4E+4	5E+2	2E-7	-	6E-4	6E-3
			-	Bone surf (1E+3)	-	2E-9	-	-
99	Einsteinium-251	W, all compounds	7E+3	9E+2	4E-7	-	1E-4	1E-3
			-	Bone surf (1E+3)	-	2E-9	-	-
99	Einsteinium-253	W, all compounds	2E+2	1E+0	6E-10	2E-12	2E-6	2E-5

Atomic No.	Radionuclide	Class	Table 1 Occupational Values: Col. 1 Oral Ingestion ALI (μCi)	Col. 2 Inhalation ALI (μCi)	Col. 3 Inhalation DAC (μCi/ml)	Table 2 Effluent Concentrations: Col. 1 Air (μCi/ml)	Col. 2 Water (μCi/ml)	Table 3 Releases to Sewers: Monthly Average Concentration (μCi/ml)
99	Einsteinium-254m	W, all compounds	3E+2	1E+1	4E-9	1E-11	-	-
			LLI wall (3E+2)	-	-	-	4E-6	4E-5
99	Einsteinium-254	W, all compounds	8E+0	7E-2	3E-11	-	-	-
			Bone surf (2E+1)	Bone surf (1E-1)	-	2E-13	2E-7	2E-6
100	Fermium-252	W, all compounds	5E+2	1E+1	5E-9	2E-11	6E-6	6E-5
100	Fermium-253	W, all compounds	1E+3	1E+1	4E-9	1E-11	1E-5	1E-4
100	Fermium-254	W, all compounds	3E+3	9E+1	4E-8	1E-10	4E-5	4E-4
100	Fermium-255	W, all compounds	5E+2	2E+1	9E-9	3E-11	7E-6	7E-5
100	Fermium-257	W, all compounds	2E+1	2E-1	7E-11	-	-	-
			Bone surf (4E+2)	Bone surf (2E-1)	-	3E-13	5E-7	5E-6
101	Mendelevium-257	W, all compounds	7E+3	8E+1	4E-8	-	1E-4	1E-3
			-	Bone surf (9E+1)	-	1E-10	-	-
101	Mendelevium-258	W, all compounds	3E+1	2E-1	1E-10	-	-	-
			Bone surf (5E+1)	Bone surf (3E-1)	-	5E-13	6E-7	6E-6
-	Any single radionuclide not listed above with decay mode other than alpha emission or spontaneous fission and with radioactive half-life less than 2 hours	Submersion[3]	-	2E+2	1E-7	1E-9	-	-
-	Any single radionuclide not listed above with decay mode other than alpha emission or spontaneous fission and with radioactive half-life greater than 2 hours		-	2E-1	1E-10	1E-12	1E-8	1E-7
-	Any single radionuclide not listed above that decays by alpha emission or spontaneous fission, or any mixture for which either the identity or the concentration of any radionuclide in the mixture is not known		-	4E-4	2E-13	1E-15	2E-9	2E-8

FOOTNOTES:

[1]"Submersion" means that values given are for submersion in a hemispherical semi-infinite cloud of airborne material.

[2]These radionuclides have radiological half-lives of less than 2 hours. The total effective dose equivalent received during operations with these radionuclides might include a significant contribution from external exposure. The DAC values for all radionuclides, other than those designated Class "Submersion," are based upon the committed effective dose equivalent due to the intake of the radionuclide into the body and do NOT include potentially significant contributions to dose equivalent from external exposures. The licensee may substitute 1E-7 μCi/ml for the listed DAC to account for the submersion dose prospectively, but should use individual monitoring devices or other radiation measuring instruments that measure external exposure to demonstrate compliance with the limits. (See § 20.1203.)

[3]For soluble mixtures of U-238, U-234, and U-235 in air, chemical toxicity may be the limiting factor (see § 20.1201(e)). If the percent by weight (enrichment) of U-235 is not greater than 5, the concentration value for a 40-hour workweek is 0.2 milligrams uranium per cubic meter of air average. For any enrichment, the product of the average concentration and time of exposure during a 40-hour workweek shall not exceed 8E-3 (SA) μCi-hr/ml, where SA is the specific activity of the uranium inhaled. The specific activity for natural uranium is 6.77E-7 curies per gram U. The specific activity for other mixtures of U-238, U-235, and U-234, if not known, shall be:

SA = 3.6E-7 curies/gram U U-depleted

SA = [0.4 + 0.38 (enrichment) + 0.0034 (enrichment)^2] E-6 , enrichment $\geq$ 0.72

where enrichment is the percentage by weight of U-235, expressed as percent.

NOTE:

1. If the identity of each radionuclide in a mixture is known but the concentration of one or more of the radionuclides in the mixture is not known, the DAC for the mixture shall be the most restrictive DAC of any radionuclide in the mixture.

2. If the identity of each radionuclide in the mixture is not known, but it is known that certain radionuclides specified in this appendix are not present in the mixture, the inhalation ALI, DAC, and effluent and sewage concentrations for the mixture are the lowest values specified in this appendix for any radionuclide that is not known to be absent from the mixture; or

Radionuclide	Table 1 Occupational Values			Table 2 Effluent Concentrations		Table 3 Releases to Sewers
	Col. 1 Oral Ingestion ALI (μCi)	Col. 2 Inhalation ALI (μCi)	Col. 3 Inhalation DAC (μCi/ml)	Col. 1 Air (μCi/ml)	Col. 2 Water (μCi/ml)	Monthly Average Concentration (μCi/ml)
If it is known that Ac-227-D and Cm-250-W are not present	-	7E-4	3E-13	-	-	-
If, in addition, it is known that Ac-227-W,Y, Th-229-W,Y, Th-230-W, Th-232-W,Y, Pa-231-W,Y, Np-237-W, Pu-239-W, Pu-240-W, Pu-242-W, Am-241-W, Am-242m-W, Am-243-W, Cm-245-W, Cm-246-W, Cm-247-W, Cm-248-W, Bk-247-W, Cf-249-W, and Cf-251-W are not present	-	7E-3	3E-12	-	-	-
If, in addition, it is known that Sm-146-W, Sm-147-W, Gd-148-D,W, Gd-152-D,W, Th-228-W,Y, Th-230-Y, U-232-Y, U-233-Y, U-234-Y, U-235-Y, U-236-Y, U-238-Y, Np-236-W, Pu-236-W,Y, Pu-238-W,Y, Pu-239-Y, Pu-240-Y, Pu-242-Y, Pu-244-W,Y, Cm-243-W, Cm-244-W, Cf-248-W, Cf-249-Y, Cf-250-W,Y, Cf-251-Y, Cf-252-W,Y, and Cf-254-W,Y are not present	-	7E-2	3E-11	-	-	-
If, in addition, it is known that Pb-210-D, Bi-210m-W, Po-210-D,W, Ra-223-W, Ra-225-W, Ra-226-W, Ac-225-D,W,Y, Th-227-W,Y, U-230-D,W,Y, U-232-D,W, Pu-241-W, Cm-240-W, Cm-242-W, Cf-248-Y, Es-254-W, Fm-257-W, and Md-258-W are not present	-	7E-1	3E-10	-	-	-

Radionuclide	Table 1 Occupational Values			Table 2 Effluent Concentrations		Table 3 Releases to Sewers
	Col. 1 Oral Ingestion ALI (μCi)	Col. 2 Inhalation ALI (μCi)	Col. 3 Inhalation DAC (μCi/ml)	Col. 1 Air (μCi/ml)	Col. 2 Water (μCi/ml)	Monthly Average Concentration (μCi/ml)
If, in addition, it is known that Si-32-Y, Ti-44-Y, Fe-60-D, Sr-90-Y, Zr-93-D, Cd-113m-D, Cd-113-D, In-115-D,W, La-138-D, Lu-176-W, Hf-178m-D,W, Hf-182-D,W, Bi-210m-D, Ra-224-W, Ra-228-W, Ac-226-D,W,Y, Pa-230-W,Y, U-233-D,W, U-234-D,W, U-235-D,W, U-236-D,W, U-238-D,W, Pu-241-Y, Bk-249-W, Cf-253-W,Y, and Es-253-W are not present	-	7E+0	3E-9	-	-	-
If it is known that Ac-227-D,W,Y, Th-229-W,Y, Th-232-W,Y, Pa-231-W,Y, Cm-248-W, and Cm-250-W are not present	-	-		1E-14	-	-
If, in addition, it is known that Sm-146-W, Gd-148-D,W, Gd-152-D, Th-228-W,Y, Th-230-W,Y, U-232-Y, U-233-Y, U-234-Y, U-235-Y, U-236-Y, U-238-Y, U-Nat-Y, Np-236-W, Np-237-W, Pu-236-W,Y, Pu-238-W,Y, Pu-239-W,Y, Pu-240-W,Y, Pu-242-W,Y, Pu-244-W,Y, Am-241-W, Am-242m-W, Am-243-W, Cm-243-W, Cm-244-W, Cm-245-W, Cm-246-W, Cm-247-W, Bk-247-W, Cf-249-W,Y, Cf-250-W,Y, Cf-251-W,Y, Cf-252-W,Y, and Cf-254-W,Y are not present			-	1E-13	-	-
If, in addition, it is known that Sm-147-W, Gd-152-W, Pb-210-D, Bi-210m-W, Po-210-D,W, Ra-223-W, Ra-225-W, Ra-226-W, Ac-225-D,W,Y, Th-227-W,Y, U-230-D,W,Y, U-232-D,W, U-Nat-W, Pu-241-W, Cm-240-W, Cm-242-W, Cf-248-W,Y, Es-254-W, Fm-257-W, and Md-258-W are not present			-	1E-12	-	-
If, in addition it is known that Fe-60, Sr-90, Cd-113m, Cd-113, In-115, I-129, Cs-134, Sm-145, Sm-147, Gd-148, Gd-152, Hg-194 (organic), Bi-210m, Ra-223, Ra-224, Ra-225, Ac-225, Th-228, Th-230, U-233, U-234, U-235, U-236, U-238, U-Nat, Cm-242, Cf-248, Es-254, Fm-257, and Md-258 are not present	-	-	-	-	1E-6	1E-5

3 If a mixture of radionuclides consists of uranium and its daughters in ore dust (10 μm AMAD particle distribution assumed) prior to chemical separation of the uranium from the ore, the following values may be used for the DAC of the mixture 6E-11 μCi of gross alpha activity from uranium-238, uranium-234, thorium-230, and radium-226 per milliliter of air; 3E-11 μCi of natural uranium per milliliter of air; or 45 micrograms of natural uranium per cubic meter of air.

4 If the identity and concentration of each radionuclide in a mixture are known, the limiting values should be derived as follows: determine, for each radionuclide in the mixture, the ratio between the concentration present in the mixture and the concentration otherwise established in Appendix B for the specific radionuclide when not in a mixture. The sum of such ratios for all of the radionuclides in the mixture may not exceed "1" (i.e., "unity")

Example: If radionuclides "A," "B," and "C" are present in concentrations C_A, C_B, and C_C, and if the applicable DACs are DAC_A, DAC_B, and DAC_C, respectively, then the concentrations shall be limited so that the following relationship exists:

$$\frac{C_A}{DAC_A} + \frac{C_B}{DAC_B} + \frac{C_C}{DAC_C} < 1$$

[56 FR 23409, May 21, 1991; 56 FR 61352, Dec. 3, 1991, as amended at 57 FR 57879, Dec. 8, 1992. Redesignated at 58 FR 67659, Dec. 22, 1993]

APPENDIX C TO PART 20—QUANTITIES [1] OF LICENSED MATERIAL REQUIRING LABELING

Radionuclide	Quantity (μCi)
Hydrogen-3	1,000
Beryllium-7	1,000
Beryllium-10	1
Carbon-11	1,000
Carbon-14	1,000
Fluorine-18	1,000
Sodium-22	10
Sodium-24	100
Magnesium-28	100
Aluminum-26	10
Silicon-31	1,000
Silicon-32	1
Phosphorus-32	10
Phosphorus-33	100
Sulfur-35	100
Chlorine-36	10
Chlorine-38	1,000
Chlorine-39	1,000
Argon-39	1,000
Argon-41	1,000
Potassium-40	100
Potassium-42	1,000
Potassium-43	1,000
Potassium-44	1,000
Potassium-45	1,000
Calcium-41	100
Calcium-45	100
Calcium-47	100
Scandium-43	1,000
Scandium-44m	100
Scandium-44	100
Scandium-46	10
Scandium-47	100
Scandium-48	100
Scandium-49	1,000
Titanium-44	1
Titanium-45	1,000
Vanadium-47	1,000
Vanadium-48	100
Vanadium-49	1,000
Chromium-48	1,000
Chromium-49	1,000
Chromium-51	1,000
Manganese-51	1,000
Manganese-52m	1,000
Manganese-52	100
Manganese-53	1,000
Manganese-54	100
Manganese-56	1,000
Iron-52	100
Iron-55	100
Iron-59	10
Iron-60	1
Cobalt-55	100
Cobalt-56	10
Cobalt-57	100
Cobalt-58m	1,000
Cobalt-58	100
Cobalt-60m	1,000
Cobalt-60	1
Cobalt-61	1,000
Cobalt-62m	1,000
Nickel-56	100
Nickel-57	100
Nickel-59	100
Nickel-63	100
Nickel-65	1,000
Nickel-66	10
Copper-60	1,000
Copper-61	1,000

APPENDIX C TO PART 20—QUANTITIES [1] OF LICENSED MATERIAL REQUIRING LABELING—Continued

Radionuclide	Quantity (μCi)
Copper-64	1,000
Copper-67	1,000
Zinc-62	100
Zinc-63	1,000
Zinc-65	10
Zinc-69m	100
Zinc-69	1,000
Zinc-71m	1,000
Zinc-72	100
Gallium-65	1,000
Gallium-66	100
Gallium-67	1,000
Gallium-68	1,000
Gallium-70	1,000
Gallium-72	100
Gallium-73	1,000
Germanium-68	1,000
Germanium-67	1,000
Germanium-68	10
Germanium-69	1,000
Germanium-71	1,000
Germanium-75	1,000
Germanium-77	1,000
Germanium-78	1,000
Arsenic-69	1,000
Arsenic-70	1,000
Arsenic-71	100
Arsenic-72	100
Arsenic-73	100
Arsenic-74	100
Arsenic-76	100
Arsenic-77	100
Arsenic-78	1,000
Selenium-70	1,000
Selenium-73m	1,000
Selenium-73	100
Selenium-75	100
Selenium-79	100
Selenium-81m	1,000
Selenium-81	1,000
Selenium-83	1,000
Bromine-74m	1,000
Bromine-74	1,000
Bromine-75	1,000
Bromine-76	100
Bromine-77	1,000
Bromine-80m	1,000
Bromine-80	1,000
Bromine-82	100
Bromine-83	1,000
Bromine-84	1,000
Krypton-74	1,000
Krypton-76	1,000
Krypton-77	1,000
Krypton-79	1,000
Krypton-81	1,000
Krypton-83m	1,000
Krypton-85m	1,000
Krypton-85	1,000
Krypton-87	1,000
Krypton-88	1,000
Rubidium-79	1,000
Rubidium-81m	1,000
Rubidium-81	1,000
Rubidium-82m	1,000
Rubidium-83	100
Rubidium-84	100
Rubidium-86	100
Rubidium-87	100

APPENDIX C TO PART 20—QUANTITIES[1] OF LICENSED MATERIAL REQUIRING LABELING—Continued

Radionuclide	Quantity (μCi)
Rubidium-88	1,000
Rubidium-89	1,000
Strontium-80	100
Strontium-81	1,000
Strontium-83	100
Strontium-85m	1,000
Strontium-85	100
Strontium-87m	1,000
Strontium-89	10
Strontium-90	0.1
Strontium-91	100
Strontium-92	100
Yttrium-86m	1,000
Yttrium-86	100
Yttrium-87	100
Yttrium-88	10
Yttrium-90m	1,000
Yttrium-90	10
Yttrium-91m	1,000
Yttrium-91	10
Yttrium-92	100
Yttrium-93	100
Yttrium-94	1,000
Yttrium-95	1,000
Zirconium-86	100
Zirconium-88	10
Zirconium-89	100
Zirconium-93	1
Zirconium-95	10
Zirconium-97	100
Niobium-88	1,000
Niobium-89m (66 min)	1,000
Niobium-89 (122 min)	1,000
Niobium-90	100
Niobium-93m	10
Niobium-94	1
Niobium-95m	100
Niobium-95	100
Niobium-96	100
Niobium-97	1,000
Niobium-98	1,000
Molybdanum-90	100
Molybdenum-93m	100
Molybdenum-93	10
Molybdenum-99	100
Molybdenum-101	1,000
Technetium-93m	1,000
Technetium-93	1,000
Technetium-94m	1,000
Technetium-94	1,000
Technetium-96m	1,000
Technetium-96	100
Technetium-97m	100
Technetium-97	1,000
Technetium-98	10
Technetium-99m	1,000
Technetium-99	100
Technetium-101	1,000
Technetium-104	1,000
Ruthenium-94	1,000
Ruthenium-97	1,000
Ruthenium-103	100
Ruthenium-105	1,000
Ruthenium-106	1
Rhodium-99m	1,000
Rhodium-99	100
Rhodium-100	100
Rhodium-101m	1,000
Rhodium-101	10

APPENDIX C TO PART 20—QUANTITIES[1] OF LICENSED MATERIAL REQUIRING LABELING—Continued

Radionuclide	Quantity (μCi)
Rhodium-102m	10
Rhodium-102	10
Rhodium-103m	1,000
Rhodium-105	100
Rhodium-106m	1,000
Rhodium-107	1,000
Palladium-100	100
Palladium-101	1,000
Palladium-103	100
Palladium-107	10
Palladium-109	100
Silver-102	1,000
Silver-103	1,000
Silver-104m	1,000
Silver-104	1,000
Silver-105	100
Silver-106m	100
Silver-106	1,000
Silver-108m	1
Silver-110m	10
Silver-111	100
Silver-112	100
Silver-115	1,000
Cadmium-104	1,000
Cadmium-107	1,000
Cadmium-109	1
Cadmium-113m	0.1
Cadmium-113	100
Cadmium-115m	10
Cadmium-115	100
Cadmium-117m	1,000
Cadmium-117	1,000
Indium-109	1,000
Indium-110 (69.1min.)	1,000
Indium-110 (4.9h)	1,000
Indium-111	100
Indium-112	1,000
Indium-113m	1,000
Indium-114m	10
Indium-115m	1,000
Indium-115	100
Indium-116m	1,000
Indium-117m	1,000
Indium-117	1,000
Indium-119m	1,000
Tin-110	100
Tin-111	1,000
Tin-113	100
Tin-117m	100
Tin-119m	100
Tin-121m	100
Tin-121	1,000
Tin-123m	1,000
Tin-123	10
Tin-125	10
Tin-126	10
Tin-127	1,000
Tin-128	1,000
Antimony-115	1,000
Antimony-116m	1,000
Antimony-116	1,000
Antimony-117	1,000
Antimony-118m	1,000
Antimony-119	1,000
Antimony-120 (16min.)	1,000
Antimony-120 (5.76d)	100
Antimony-122	100
Antimony-124m	1,000

APPENDIX C TO PART 20—QUANTITIES[1] OF LICENSED MATERIAL REQUIRING LABELING—Continued

Radionuclide	Quantity (μCi)
Antimony-124	10
Antimony-125	100
Antimony-126m	1,000
Antimony-126	100
Antimony-127	100
Antimony-128 (10.4min.)	1,000
Antimony-128 (9.01h)	100
Antimony-129	100
Antimony-130	1,000
Antimony-131	1,000
Tellurium-116	1,000
Tellurium-121m	10
Tellurium-121	100
Tellurium-123m	10
Tellurium-123	100
Tellurium-125m	10
Tellurium-127m	10
Tellurium-127	1,000
Tellurium-129m	10
Tellurium-129	1,000
Tellurium-131m	10
Tellurium-131	100
Tellurium-132	10
Tellurium-133m	100
Tellurium-133	1,000
Tellurium-134	1,000
Iodine-120m	1,000
Iodine-120	100
Iodine-121	1,000
Iodine-123	100
Iodine-124	10
Iodine-125	1
Iodine-126	1
Iodine-128	1,000
Iodine-129	1
Iodine-130	10
Iodine-131	1
Iodine-132m	100
Iodine-132	100
Iodine-133	10
Iodine-134	1,000
Iodine-135	100
Xenon-120	1,000
Xenon-121	1,000
Xenon-122	1,000
Xenon-123	1,000
Xenon-125	1,000
Xenon-127	1,000
Xenon-129m	1,000
Xenon-131m	1,000
Xenon-133m	1,000
Xenon-133	1,000
Xenon-135m	1,000
Xenon-135	1,000
Xenon-138	1,000
Cesium-125	1,000
Cesium-127	1,000
Cesium-129	1,000
Cesium-130	1,000
Cesium-131	1,000
Cesium-132	100
Cesium-134m	1,000
Cesium-134	10
Cesium-135m	1,000
Cesium-135	100
Cesium-136	10
Cesium-137	10
Cesium-138	1,000
Barium-126	1,000

APPENDIX C TO PART 20—QUANTITIES[1] OF LICENSED MATERIAL REQUIRING LABELING—Continued

Radionuclide	Quantity (μCi)
Barium-128	100
Barium-131m	1,000
Barium-131	100
Barium-133m	100
Barium-133	100
Barium-135m	100
Barium-139	1,000
Barium-140	100
Barium-141	1,000
Barium-142	1,000
Lanthanum-131	1,000
Lanthanum-132	100
Lanthanum-135	1,000
Lanthanum-137	10
Lanthanum-138	100
Lanthanum-140	100
Lanthanum-141	100
Lanthanum-142	1,000
Lanthanum-143	1,000
Cerium-134	100
Cerium-135	100
Cerium-137m	100
Cerium-137	1,000
Cerium-139	100
Cerium-141	100
Cerium-143	100
Cerium-144	1
Praseodymium-136	1,000
Praseodymium-137	1,000
Praseodymium-138m	1,000
Praseodymium-139	1,000
Praseodymium-142m	1,000
Praseodymium-142	100
Praseodymium-143	100
Preseodymium-144	1,000
Praseodymium-145	100
Praseodymium-147	1,000
Neodymium-138	1,000
Neodymium-138	100
Neodymium-139m	1,000
Neodymium-139	1,000
Neodymium-141	1,000
Neodymium-147	100
Neodymium-149	1,000
Neodymium-151	1,000
Promethium-141	1,000
Promethium-143	100
Promethium-144	10
Promethium-145	10
Promethium-146	1
Promethium-147	10
Promethium-148m	10
Promethium-148	10
Promethium-149	100
Promethium-150	1,000
Promethium-151	100
Samarium-141m	1,000
Samarium-141	1,000
Samarium-142	1,000
Samarium-145	100
Samarium-146	1
Samarium-147	100
Samarium-151	10
Samarium-153	100
Samarium-155	1,000
Samarium-156	1,000
Europium-145	100
Europium-146	100
Europium-147	100

APPENDIX C TO PART 20—QUANTITIES[1] OF LICENSED MATERIAL REQUIRING LABELING—Continued

Radionuclide	Quantity (μCi)
Europium-148	10
Europium-149	100
Europium-150 (12.62h)	100
Europium-150 (34.2y)	1
Europium-152m	100
Europium-152	1
Europium-154	1
Europium-155	10
Europium-156	100
Europium-157	100
Europium-158	1,000
Gadolinium-145	1,000
Gadolinium-146	10
Gadolinium-147	100
Gadolinium-148	0.001
Gadolinium-149	100
Gadolinium-151	10
Gadolinium-152	100
Gadolinium-153	10
Gadolinium-159	100
Terbium-147	1,000
Terbium-149	100
Terbium-150	1,000
Terbium-151	100
Terbium-153	1,000
Terbium-154	100
Terbium-155	1,000
Terbium-156m (5.0h)	1,000
Terbium-156m (24.4h)	1,000
Terbium-156	100
Terbium-157	10
Terbium-158	1
Terbium-160	10
Terbium-161	100
Dysprosium-155	1,000
Dysprosium-157	1,000
Dysprosium-159	100
Dysprosium-165	1,000
Dysprosium-166	100
Holmium-155	1,000
Holmium-157	1,000
Holmium-159	1,000
Holmium-161	1,000
Holmium-182m	1,000
Holmium-162	1,000
Holmium-164m	1,000
Holmium-164	1,000
Holmium-166m	1
Holmium-166	100
Holmium-167	1,000
Erbium-161	1,000
Erbium-165	1,000
Erbium-169	100
Erbium-171	100
Erbium-172	100
Thulium-162	1,000
Thulium-166	100
Thulium-167	100
Thulium-170	10
Thulium-171	10
Thulium-172	100
Thulium-173	100
Thulium-175	1,000
Ytterbium-162	1,000
Ytterbium-166	100
Ytterbium-167	1,000
Ytterbium-169	100
Ytterbium-175	100
Ytterbium-177	1,000

APPENDIX C TO PART 20—QUANTITIES[1] OF LICENSED MATERIAL REQUIRING LABELING—Continued

Radionuclide	Quantity (μCi)
Ytterbium-178	1,000
Lutetium-169	100
Lutetium-170	100
Lutetium-171	100
Lutetium-172	100
Lutetium-173	10
Lutetium-174m	10
Lutetium-174	10
Lutetium-176m	1,000
Lutetium-176	100
Lutetium-177m	10
Lutetium-177	100
Lutetium-178m	1,000
Lutetium-178	1,000
Lutetium-179	1,000
Hafnium-170	100
Hafnium-172	1
Hafnium-173	1,000
Hafnium-175	100
Hafnium-177m	1,000
Hafnium-178m	0.1
Hafnium-179m	10
Hafnium-180m	1,000
Hafnium-181	10
Hafnium-182m	1,000
Hafnium-182	0.1
Hafnium-183	1,000
Hafnium-184	100
Tantalum-172	1,000
Tantalum-173	1,000
Tantalum-174	1,000
Tantalum-175	1,000
Tantalum-176	100
Tantalum-177	1,000
Tantalum-178	1,000
Tantalum-179	100
Tantalum-180m	1,000
Tantalum-180	100
Tantalum-182m	1,000
Tantalum-182	10
Tantalum-183	100
Tantalum-184	100
Tantalum-185	1,000
Tantalum-188	1,000
Tungsten-176	1,000
Tungsten-177	1,000
Tungsten-178	1,000
Tungsten-179	1,000
Tungsten-181	1,000
Tungsten-185	100
Tungsten-187	100
Tungsten-188	10
Rhenium-177	1,000
Rhenium-178	1,000
Rhenium-181	1,000
Rhenium-182 (12.7h)	1,000
Rhenium-182 (64.0h)	100
Rhenium-184m	10
Rhenium-184	100
Rhenium-186m	10
Rhenium-186	100
Rhenium-187	1,000
Rhenium-188m	1,000
Rhenium-188	100
Rhenium-189	100
Osmium-180	1,000
Osmium-181	1,000
Osmium-182	100
Osmium-185	100

APPENDIX C TO PART 20—QUANTITIES[1] OF LICENSED MATERIAL REQUIRING LABELING—Continued

Radionuclide	Quantity (μCi)
Osmium-189m	1,000
Osmium-191m	1,000
Osmium-191	100
Osmium-193	100
Osmium-194	1
Iridium-182	1,000
Iridium-184	1,000
Iridium-185	1,000
Iridium-186	100
Iridium-187	1,000
Iridium-188	100
Iridium-189	100
Iridium-190m	1,000
Iridium-190	100
Iridium-192 (73.8d)	1
Iridium-192m (1.4min.)	10
Iridium-194m	10
Iridium-194	100
Iridium-195m	1,000
Iridium-195	1,000
Platinum-186	1,000
Platinum-188	100
Platinum-189	1,000
Platinum-191	100
Platinum-193m	100
Platinum-193	1,000
Platinum-195m	100
Platinum-197m	1,000
Platinum-197	100
Platinum-199	1,000
Platinum-200	100
Gold-193	1,000
Gold-194	100
Gold-195	10
Gold-198m	100
Gold-198	100
Gold-199	100
Gold-200m	100
Gold-200	1,000
Gold-201	1,000
Mercury-193m	100
Mercury-193	1,000
Mercury-194	1
Mercury-195m	100
Mercury-195	1,000
Mercury-197m	100
Mercury-197	1,000
Mercury-199m	1,000
Mercury-203	100
Thallium-194m	1,000
Thallium-194	1,000
Thallium-195	1,000
Thallium-197	1,000
Thallium-198m	1,000
Thallium-198	1,000
Thallium-199	1,000
Thallium-200	1,000
Thallium-201	1,000
Thallium-202	100
Thallium-204	100
Lead-195m	1,000
Lead-198	1,000
Lead-199	1,000
Lead-200	100
Lead-201	1,000
Lead-202m	1,000
Lead-202	10
Lead-203	1,000
Lead-205	100

APPENDIX C TO PART 20—QUANTITIES[1] OF LICENSED MATERIAL REQUIRING LABELING—Continued

Radionuclide	Quantity (μCi)
Lead-209	1,000
Lead-210	0.01
Lead-211	100
Lead-212	1
Lead-214	100
Bismuth-200	1,000
Bismuth-201	1,000
Bismuth-202	1,000
Bismuth-203	100
Bismuth-205	100
Bismuth-206	100
Bismuth-207	10
Bismuth-210m	0.1
Bismuth-210	1
Bismuth-212	10
Bismuth-213	10
Bismuth-214	100
Polonium-203	1,000
Polonium-205	1,000
Polonium-207	1,000
Polonium-210	0.1
Astatine-207	100
Astatine-211	10
Radon-220	1
Radon-222	1
Francium-222	100
Francium-223	100
Radium-223	0.1
Radium-224	0.1
Radium-225	0.1
Radium-226	0.1
Radium-227	1,000
Radium-228	0.1
Actinium-224	1
Actinium-225	0.01
Actinium-226	0.1
Actinium-227	0.001
Actinium-228	1
Thorium-228	10
Thorium-227	0.01
Thorium-228	0.001
Thorium-229	0.001
Thorium-230	0.001
Thorium-231	100
Thorium-232	100
Thorium-234	10
Thorium-natural	100
Protactinium-227	10
Protactinium-228	1
Protactinium-230	0.1
Protactinium-231	0.001
Protactinium-232	1
Protactinium-233	100
Protactinium-234	100
Uranium-230	0.01
Uranium-231	100
Uranium-232	0.001
Uranium-233	0.001
Uranium-234	0.001
Uranium-235	0.001
Uranium-236	0.001
Uranium-237	100
Uranium-238	100
Uranium-239	1,000
Uranium-240	100
Uranium-natural	100
Neptunium-232	100
Neptunium-233	1,000
Neptunium-234	100

APPENDIX C TO PART 20—QUANTITIES[1] OF LICENSED MATERIAL REQUIRING LABELING—Continued

Radionuclide	Quantity (μCi)
Neptunium-235	100
Neptunium-236 (1.15x10⁵y)	0.001
Neptunium-236 (22.5h)	1
Neptunium-237	0.001
Neptunium-238	10
Neptunium-239	100
Neptunium-240	1,000
Plutonium-234	10
Plutonium-235	1,000
Plutonium-236	0.001
Plutonium-237	100
Plutonium-238	0.001
Plutonium-239	0.001
Plutonium-240	0.001
Plutonium-241	0.01
Plutonium-242	0.001
Plutonium-243	1,000
Plutonium-244	0.001
Plutonium-245	100
Americium-237	1,000
Americium-238	100
Americium-239	1,000
Americium-240	100
Americium-241	0.001
Americium-242m	0.001
Americium-242	10
Americium-243	0.001
Americium-244m	100
Americium-244	10
Americium-245	1,000
Americium-246m	1,000
Americium-246	1,000
Curium-236	100
Curium-240	0.1
Curium-241	1
Curium-242	0.01
Curium-243	0.001
Curium-244	0.001
Curium-245	0.001
Curium-248	0.001
Curium-247	0.001
Curium-248	0.001
Curium-249	1,000
Berkelium-245	100
Berkelium-248	100
Berkelium-247	0.001
Berkelium-249	0.1
Berkelium-250	10

APPENDIX C TO PART 20—QUANTITIES[1] OF LICENSED MATERIAL REQUIRING LABELING—Continued

Radionuclide	Quantity (μCi)
Californium-244	100
Californium-246	1
Californium-248	0.01
Californium-249	0.001
Californium-250	0.001
Californium-251	0.001
Californium-252	0.001
Californium-253	0.1
Californium-254	0.001
Any alpha emitting radionuclide not listed above or mixtures of alpha emitters of unknown composition	0.001
Einsteinium-250	100
Einsteinium-251	100
Einsteinium-253	0.1
Einsteinium-254m	1
Einsteinium-254	0.01
Fermium-252	1
Fermium-253	1
Fermium-254	10
Fermium-255	1
Fermium-257	0.01
Mendelevium-257	10
Mendelevium-258	0.01
Any radionuclide other than alpha emitting radionuclides not listed above, or mixtures of beta emitters of unknown composition	0.01

[1] The quantities listed above were derived by taking 1/50th of the most restrictive ALI listed in table 1, columns 1 and 2, of appendix B to §§20.1001–20.2401 of this part, rounding to the nearest factor of 10, and arbitrarily constraining the values listed between 0.001 and 1,000 μCi. Values of 100 μCi have been assigned for radionuclides having a radioactive half-life in excess of 10⁹ years (except rhenium, 1000 μCi) to take into account their low specific activity.

NOTE: For purposes of §§20.1902(e), 20.1905(a), and 20.2201(a) where there is involved a combination of radionuclides in known amounts, the limit for the combination should be derived as follows: determine, for each radionuclide in the combination, the ratio between the quantity present in the combination and the limit otherwise established for the specific radionuclide when not in combination. The sum of such ratios for all radionuclides in the combination may not exceed "1" (i.e., "unity").

[56 FR 23465, May 21, 1991; 56 FR 61352, Dec. 3, 1991. Redesignated and amended at 58 FR 67659, Dec. 22, 1993]

Appendix D to Part 20—UNITED STATES NUCLEAR REGULATORY COMMISSION REGIONAL OFFICES

	Address	Telephone (24 hour)
Region I: Connecticut, Delaware, District of Columbia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont.	USNRC, Region I, 475 Allendale Road, King of Prussia, PA 19406.	(215) 337–5000, (FTS) 346–5000.
Region II: Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, Puerto Rico, South Carolina, Tennessee, Virginia, Virgin Islands, and West Virginia.	USNRC, Region II, 101 Marietta Street, NW., Suite 2900, Atlanta, GA 30323.	(404) 331–4503, (FTS) 841–4503.
Region III: Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, and Wisconsin.	USNRC, Region III, 801 Warrenville Road, Lisle, IL 60532-4351.	(708) 829–9500, (FTS) 829–9500.
Region IV: Arkansas, Colorado, Idaho, Kansas, Louisiana, Montana, Nebraska, New Mexico, North Dakota, Oklahoma, South Dakota, Texas, Utah, and Wyoming.	USNRC, Region IV, 611 Ryan Plaza Drive, Suite 1000, Arlington, TX 76011.	(817) 860–8100, (FTS) 728–8100.

Appendix D to Part 20—UNITED STATES NUCLEAR REGULATORY COMMISSION REGIONAL OFFICES—Continued

	Address	Telephone (24 hour)
Region IV: Field Office	USNRC, Region IV, Uranium Recovery Field Office, 730 Simms Street, Suite 100a, Golden, CO 80401, Mail: P.O. Box 25325, Denver, CO 80225.	(303) 231–5800, (FTS) 554–2805.
Region V: Alaska, Arizona, California, Hawaii, Nevada, Oregon, Washington, and U.S. territories and possessions in the Pacific.	USNRC, Region V, 1450 Maria Lane, Suite 210, Walnut Creek, CA 94596.	(510) 975–0200.

[56 FR 23468, May 21, 1991, as amended at 56 FR 41449, Aug. 21, 1991; 58 FR 64111, Dec. 6, 1993]

APPENDIX E TO PART 20—[RESERVED]

APPENDIX F TO PART 20— REQUIREMENTS FOR LOW-LEVEL-WASTE TRANSFER FOR DISPOSAL AT LAND DISPOSAL FACILITIES AND MANIFESTS

I. Manifest

The shipment manifest shall contain the name, address, and telephone number of the person generating the waste. The manifest shall also include the name, address, and telephone number or the name and EPA hazardous waste identification number of the person transporting the waste to the land disposal facility. The manifest must also indicate as completely as practicable: a physical description of the waste, the volume, radionuclide identity and quantity, the total radioactivity, and the principal chemical form. The solidification agent must be specified. Waste containing more than 0.1% chelating agents by weight must be identified and the weight percentage of the chelating agent estimated. Wastes classified as Class A, Class B, or Class C in §61.55 of this chapter must be clearly identified as such in the manifest. The total quantity of the radionuclides ^{3}H, ^{14}C, ^{99}Tc, and ^{129}I must be shown. The manifest required by this paragraph may be shipping papers used to meet Department of Transportation or Environmental Protection Agency regulations or requirements of the receiver, provided all the required information is included. Copies of manifests required by this section may be legible carbon copies or legible photocopies.

II. Certification

The waste generator shall include in the shipment manifest a certification that the transported materials are properly classified, described, packaged, marked, and labeled and are in proper condition for transportation according to the applicable regulations of the Department of Transportation and the Commission. An authorized representative of the waste generator shall sign and date the manifest.

III. Control and Tracking

A. Any generating licensee who transfers radioactive waste to a land disposal facility or a licensed waste collector shall comply with the requirements in paragraphs A.1 through 8 of this section. Any generating licensee who transfers waste to a licensed waste processor who treats or repackages waste shall comply with the requirements of paragraphs A.4 through 8 of this section. A licensee shall:

1. Prepare all wastes so that the waste is classified according to §61.55 of this chapter and meets the waste characteristics requirements in §61.56 of this chapter;

2. Label each package of waste to identify whether it is Class A waste, Class B waste, or Class C waste, in accordance with §61.55 of this chapter;

3. Conduct a quality control program to ensure compliance with §§61.55 and 61.56 of this chapter; the program must include management evaluation of audits;

4. Prepare shipping manifests to meet the requirements of sections I and II of this appendix;

5. Forward a copy of the manifest to the intended recipient, at the time of shipment, or deliver to a collector at the time the waste is collected, obtaining acknowledgment of receipt in the form of a signed copy of the manifest or equivalent documentation from the collector;

6. Include one copy of the manifest with the shipment;

7. Retain a copy of the manifest and documentation of acknowledgment of receipt as the record of transfer of licensed material as required by parts 30, 40, and 70 of this chapter; and

8. For any shipments or any part of a shipment for which acknowledgment of receipt has not been received within the times set forth in this section, conduct an investigation in accordance with paragraph E of this appendix.

B. Any waste collector licensee who handles only prepackaged waste shall:

1. Acknowledge receipt of the waste from the generator within 1 week of receipt by returning a signed copy of the manifest or equivalent documentation;

2. Prepare a new manifest to reflect consolidated shipments; the new manifest shall serve as a listing or index for the detailed generator manifests. Copies of the generator manifests shall be a part of the new manifest. The waste collector may prepare a new manifest without attaching the generator manifests, provided the new manifest contains for each package the information specified in section I of this appendix. The collector licensee shall certify that nothing has been done to the waste that would invalidate the generator's certification;

3. Forward a copy of the new manifest to the land disposal facility operator at the time of shipment;

4. Include the new manifest with the shipment to the disposal site;

5. Retain a copy of the manifest and documentation of acknowledgment of receipt as the record of transfer of licensed material as required by parts 30, 40, and 70 of this chapter, and retain information from generator manifest until the license is terminated; and

6. For any shipments or any part of a shipment for which acknowledgment of receipt is not received within the times set forth in this section, conduct an investigation in accordance with section III, E of this appendix.

C. Any licensed waste processor who treats or repackages wastes shall:

1. Acknowledge receipt of the waste from the generator within 1 week of receipt by returning a signed copy of the manifest or equivalent documentation;

2. Prepare a new manifest that meets the requirements of sections I and II of this appendix. Preparation of the new manifest reflects that the processor is responsible for the waste;

3. Prepare all wastes so that the waste is classified according to §61.55 of this chapter and meets the waste characteristics requirements in §61.56 of this chapter;

4. Label each package of waste to identify whether it is Class A waste, Class B waste, or Class C waste, in accordance with §§61.55 and 61.57 of this chapter;

5. Conduct a quality control program to ensure compliance with §§61.55 and 61.56 of this chapter. The program shall include management evaluation of audits;

6. Forward a copy of the new manifest to the disposal site operator or waste collector at the time of shipment, or deliver to a collector at the time the waste is collected, obtaining acknowledgment of receipt in the form of a signed copy of the manifest or equivalent documentation by the collector;

7. Include the new manifest with the shipment;

8. Retain copies of original manifests and new manifests and documentation of acknowledgment of receipt as the record of transfer of licensed material required by parts 30, 40, and 70 of this chapter; and

9. For any shipment or part of a shipment for which acknowledgment is not received within the times set forth in this section, conduct an investigation in accordance with section III. E of this appendix.

D. The land disposal facility operator shall:

1. Acknowledge receipt of the waste within 1 week of receipt by returning a signed copy of the manifest or equivalent documentation to the shipper. The shipper to be notified is the licensee who last possessed the waste and transferred the waste to the operator. The returned copy of the manifest or equivalent documentation shall indicate any discrepancies between materials listed on the manifest and materials received;

2. Maintain copies of all completed manifests or equivalent documentation until the license is terminated; and

3. Notify the shipper (i.e., the generator, the collector, or processor) and the Administrator of the nearest Commission Regional Office listed in appendix D to this part when any shipment or part of a shipment has not arrived within 60 days after the advance manifest was received.

E. Any shipment or part of a shipment for which acknowledgment is not received within the times set forth in this section must:

1. Be investigated by the shipper if the shipper has not received notification or receipt within 20 days after transfer; and

2. Be traced and reported. The investigation shall include tracing the shipment and filing a report with the nearest Commission Regional Office listed in appendix D to this part. Each licensee who conducts a trace investigation shall file a written report with the appropriate NRC Regional Office within 2 weeks of completion of the investigation.

[56 FR 23468, May 21, 1991, as amended at 57 FR 57879, Dec. 8, 1992. Redesignated at 58 FR 67659, Dec. 22, 1993.]

PART 21—REPORTING OF DEFECTS AND NONCOMPLIANCE

GENERAL PROVISIONS

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21.2 Scope.
21.3 Definitions.
21.4 Interpretations.
21.5 Communications.
21.6 Posting requirements.
21.7 Exemptions.
21.8 Information collection requirements: OMB approval.

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21.21 Notification of failure to comply or existence of a defect and its evaluation.

PROCUREMENT DOCUMENTS

21.31 Procurement documents.

INSPECTIONS, RECORDS

21.41 Inspections.
21.51 Maintenance and inspection of records.

ENFORCEMENT

21.61 Failure to notify.
21.62 Criminal penalties.

AUTHORITY: Sec. 161, 68 Stat. 948, as amended, sec. 234, 83 Stat. 444, as amended (42 U.S.C. 2201, 2282); secs. 201, as amended, 206, 88 Stat. 1242, as amended 1246 (42 U.S.C. 5841, 5846).

Section 21.2 also issued under secs. 135, 141, Pub. L. 97-425, 96 Stat. 2232, 2241 (42 U.S.C. 10155, 10161).

SOURCE: 42 FR 28893, June 6, 1977, unless otherwise noted.

GENERAL PROVISIONS

§21.1 Purpose.

The regulations in this part establish procedures and requirements for implementation of section 206 of the Energy Reorganization Act of 1974. That section requires any individual director or responsible officer of a firm constructing, owning, operating or supplying the components of any facility or activity which is licensed or otherwise regulated pursuant to the Atomic Energy Act of 1954, as amended, or the Energy Reorganization Act of 1974, who obtains information reasonably indicating: (a) That the facility, activity or basic component supplied to such facility or activity fails to comply with the Atomic Energy Act of 1954, as amended, or any applicable rule, regulation, order, or license of the Commission relating to substantial safety hazards or (b) that the facility, activity, or basic component supplied to such facility or activity contains defects, which could create a substantial safety hazard, to immediately notify the Commission of such failure to comply or such defect, unless he has actual knowledge that the Commission has been adequately informed of such defect or failure to comply.

§21.2 Scope.

(a) The regulations in this part apply, except as specifically provided otherwise in parts 31, 34, 35, 39, 40, 60, 61, 70, or part 72 of this chapter, to each individual, partnership, corporation, or other entity licensed pursuant to the regulations in this chapter to possess, use, or transfer within the United States source material, byproduct material, special nuclear material, and/or spent fuel and high level radioactive waste, or to construct, manufacture, possess, own, operate or transfer within the United States, any production or utilization facility or independent spent fuel storage installation (ISFSI) or monitored retrievable storage installation (MRS); and to each director and responsible officer of such a licensee. The regulations in this part apply also to each individual, corporation, partnership or other entity doing business within the United States, and each director and responsible officer of such organization, that constructs a production or utilization facility licensed for manufacture, construction, or operation pursuant to part 50 of this chapter, an ISFSI for the storage of spent fuel licensed pursuant to part 72 of this chapter, a MRS for the storage of spent fuel or high level radioactive waste pursuant to part 72 of this chapter, or a geologic repository for the disposal of high-level radioactive waste under part 60 of this chapter; or supplies basic components for a facility or activity licensed, other than for export, under parts 30, 40, 50, 60, 61, 70, 71, or part 72 of this chapter.

(b) For persons licensed to construct a facility under a construction permit issued under §50.23 of this chapter, evaluation of potential defects and failures to comply and reporting of defects and failures to comply under §50.55(e) of this chapter satisfies each person's evaluation, notification, and reporting obligation to report defects and failures to comply under this part and the responsibility of individual directors and responsible officers of such licensees to report defects under section 206 of the Energy Reorganization Act of 1974.

(c) For persons licensed to operate a nuclear power plant under part 50 of this chapter, evaluation of potential

C. National Council on Radiation Protection and Measurements "Exposure of the Population of the United States and Canada from Natural Background Radiation," NCRP Report No. 94, December 1987.

D. U.S. Navy Report, "Environmental Monitoring and Disposal of Radioactive Wastes from U.S. Naval Nuclear-Powered Ships and Their Support Facilities," Report NT-95-1, Department of the Navy, Washington, D.C. 20362, March 1995.

REPORT NT-95-1
MARCH 1995

ENVIRONMENTAL MONITORING AND DISPOSAL OF RADIOACTIVE WASTES FROM U.S. NAVAL NUCLEAR POWERED SHIPS AND THEIR SUPPORT FACILITIES

NAVAL NUCLEAR PROPULSION PROGRAM
DEPARTMENT OF THE NAVY
WASHINGTON, D.C. 20362

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ENVIRONMENTAL MONITORING AND DISPOSAL OF RADIOACTIVE WASTES FROM U.S. NAVAL NUCLEAR-POWERED SHIPS AND THEIR SUPPORT FACILITIES 1994

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ABSTRACT

The environmental effect of disposal of radioactive wastes originating from U.S. Naval nuclear propulsion plants and their support facilities is assessed. The total long-lived gamma radioactivity in liquids discharged to all ports and harbors from the one hundred twenty-one Naval nuclear-powered ships and supporting tenders, Naval bases and shipyards was less than 0.002 curie in 1994. This report confirms that procedures used by the Navy to control releases of radioactivity from U.S. Naval nuclear-powered ships and their support facilities are effective in protecting the environment and the health and safety of the general public. These procedures have ensured that no member of the general public has received measurable radiation exposure as a result of current operations of the Naval Nuclear Propulsion Program.

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SUMMARY

The radioactivity in materials discussed in this report originates in the pressurized water reactors of U.S. Naval nuclear-powered ships. As of the end of 1994, the U.S. Navy had 99 nuclear-powered submarines, 13 nuclear-powered surface ships and two moored training ships in operation. Support facilities involved in construction, maintenance, overhaul and refueling of these nuclear propulsion plants include eight shipyards, twelve tenders and four submarine bases. This report describes disposal of radioactive liquid, transportation and disposal of solid wastes, monitoring of the environment to determine the effect of radioactive releases, and updates reports on this subject issued by the Navy in references 1 through 5.* This report concludes that radioactivity associated with U.S. Naval nuclear-powered ships has had no significant or discernible effect on the quality of the environment. A summary of the radiological information supporting this conclusion follows:

From the start of the Naval Nuclear Propulsion Program, the policy of the U.S. Navy has been to reduce to the minimum practicable the amounts of radioactivity released into harbors. Navy procedures to accomplish this have been reviewed with the U.S. Department of Energy, the U.S. Nuclear Regulatory Commission and the U.S. Environmental Protection Agency. The total long-lived gamma radioactivity released within twelve miles from shore from all U.S. Naval nuclear-powered ships and their support facilities in recent years is shown in Table 1; this includes all harbors both U.S. and foreign entered by these ships.

As a measure of the significance of these data, if one person were able to drink the entire amount of radioactivity discharged into any harbor in any of the last twenty-four years, that person would not exceed the annual radiation exposure permitted for an individual worker by the Nuclear Regulatory Commission.

Environmental monitoring is conducted by the U.S. Navy in U.S. and foreign harbors frequented by U.S. Naval nuclear-powered ships. This monitoring consists of analyzing harbor sediment, water and marine life samples for radioactivity associated with Naval nuclear propulsion plants, radiation monitoring around the perimeter of support facilities and effluent monitoring. Environmental samples from each of these harbors are also checked at least annually by a Department of Energy laboratory to ensure analytical procedures are correct and standardized.

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* References are listed on page 32.

Independent environmental monitoring has been conducted by the Environmental Protection Agency in U.S. harbors during the past several decades. The results of these extensive, detailed surveys have been consistent with Navy results. These surveys have again confirmed that U.S. Naval nuclear-powered ships and support facilities have had no significant effect on the radioactivity of the environment.

TABLE 1 RADIOACTIVE LIQUID RELEASED TO HARBORS FROM U.S. NAVAL NUCLEAR-POWERED SHIPS AND THEIR SUPPORT FACILITIES

Year	Number of Ships In Operation	Radioactivity-Curies (less tritium)
1971	100	less than 0.002
1972	104	less than 0.002
1973	107	less than 0.002
1974	111	less than 0.002
1975	113	less than 0.002
1976	115	less than 0.002
1977	120	less than 0.002
1978	124	less than 0.002
1979	126	less than 0.002
1980	126	less than 0.002
1981	133	less than 0.002
1982	137	less than 0.002
1983	142	less than 0.002
1984	144	less than 0.002
1985	147	less than 0.002
1986	149	less than 0.002
1987	148	less than 0.002
1988	148	less than 0.002
1989	147	less than 0.002
1990	143	less than 0.002
1991	140	less than 0.002
1992	135	less than 0.002
1993	121	less than 0.002
1994	112	less than 0.002

RADIOACTIVE LIQUID PROCESSING AND CONTROL

Policy and Procedures Minimizing Release of Radioactivity in Harbors

The policy of the U.S. Navy is to reduce to the minimum practicable the amounts of radioactivity released to the environment, particularly within twelve miles of shore including harbors. This policy is consistent with applicable recommendations issued by the Federal Radiation Council (incorporated into the Environmental Protection Agency in 1970), U.S. Nuclear Regulatory Commission, National Council on Radiation Protection and Measurements, International Commission on Radiological Protection, International Atomic Energy Agency, and National Academy of Sciences--National Research Council (references 6 through 15). Keeping releases small minimizes the radioactivity available to build up in the environment or to concentrate in marine life. To implement this policy of minimizing releases, the Navy has issued standard instructions defining radioactive release limits and procedures to be used by U.S. Naval nuclear-powered ships and their support facilities. These instructions were reviewed by the U.S. Department of Energy, the U.S. Nuclear Regulatory Commission and the U.S. Environmental Protection Agency.

Source of Radioactivity

In the shipboard reactors, pressurized water circulating through the reactor core picks up the heat of nuclear reaction. The reactor cooling water circulates through a closed piping system to heat exchangers which transfer the heat to water in a secondary steam system isolated from the primary cooling water. The steam is then used as the source of power for the propulsion plant as well as for auxiliary machinery. Releases from the shipboard reactors occur primarily when reactor coolant water expands as a result of being heated to operating temperature; this coolant passes through a purification system ion exchange resin bed prior to being transferred from the ship.

The principal source of radioactivity in liquid effluents is trace amounts of corrosion and wear products from reactor plant metal surfaces in contact with reactor cooling water. Radionuclides with half-lives of approximately one day or greater in these corrosion and wear products include tungsten 187, chromium 51, hafnium 181, iron 59, iron 55, nickel 63, niobium 95, zirconium 95, tantalum 182, manganese 54, cobalt 58, and cobalt 60. The most predominant of these is cobalt 60, which has a 5.3 year half-life. Cobalt 60 also has the most restrictive concentration limit in water as listed by organizations which set radiological standards in references 6 and 7 for these corrosion and wear radionuclides. Therefore, cobalt 60 is the primary radionuclide of interest for naval nuclear propulsion plants.

Radioactivity Removal From Liquid at Shore Facilities

Radioactive liquids at shore facilities are collected in stainless steel tanks and processed through a processing system to remove most of the radioactivity (exclusive of tritium) prior to collection in a clean tank for reuse. Even after processing to approximately 10^{-8} microcuries of gamma radioactivity per milliliter, reactor coolant is reused rather than discharged. Figure 1 shows a simplified block diagram of the liquid processing system which consists of particulate filters, activated carbon bed filters, mixed hydrogen hydroxyl resin and colloid removal resin beds. This type of processing system has been developed and used successfully to produce high quality water containing very low radioactivity levels.

Liquid Releases in Harbors

The total amount of long-lived gamma radioactivity released into harbors and seas within twelve miles of shore have been less than 0.002 curie during each of the last twenty-four years. This total is for releases from U.S. Naval nuclear-powered ships and from the supporting shipyards, tenders and submarine bases, and at operating bases and home ports in the U.S. and overseas and all other U.S. and foreign ports which were visited by Naval nuclear-powered ships.

To put this small quantity of radioactivity into perspective, it is less than the quantity of naturally occurring radioactivity (reference 16) in the volume of saline harbor water occupied by a single nuclear-powered submarine.

Short-Lived Radionuclides

Reactor coolant also contains short-lived radionuclides with half-lives of seconds to hours. Their highest concentrations in reactor coolant are from nitrogen 16 (7 second half-life), nitrogen 13 (10 minute half-life), fluorine 18 (1.8 hour half-life), argon 41 (1.8 hour half-life) and manganese 56 (2.6 hour half-life). For the longest-lived of these, about one day after discharge from an operating reactor, the concentration is reduced to one thousandth of the initial concentration, and in about two days the concentration is reduced to one millionth. Further, essentially all of the water is transferred to shore facilities for processing and reuse rather than discharged. Consequently, these short-lived radionuclides are not important for liquid release considerations.

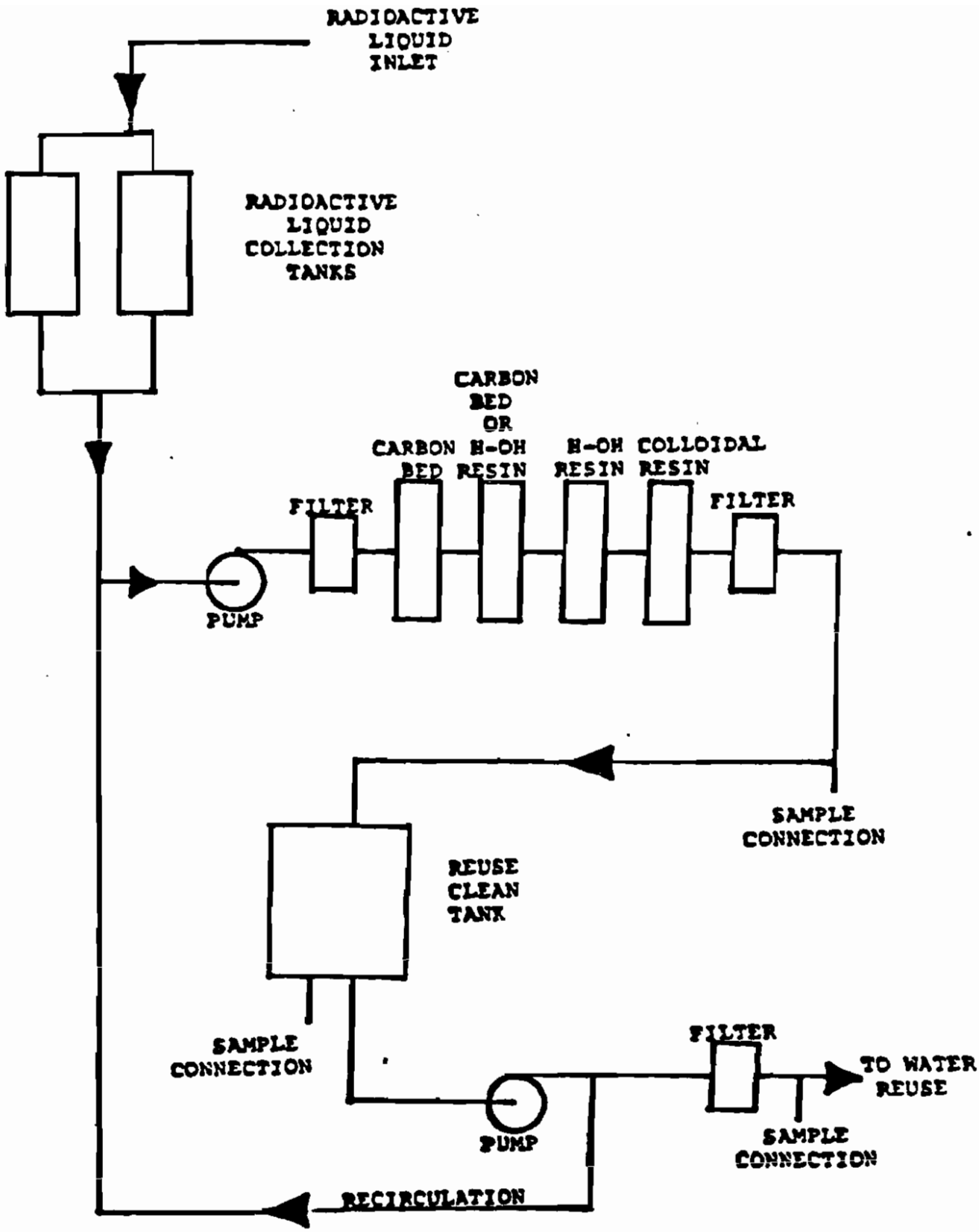


FIGURE 1
SIMPLIFIED DIAGRAM OF RADIOACTIVE LIQUID PROCESSING SYSTEM

Fission Product Radionuclides

Fission products produced in the reactor, including iodine and the fission gases krypton and xenon, are retained within the fuel elements. However, trace quantities of naturally occurring uranium impurities in reactor structural materials release small amounts of fission products to reactor coolant. The concentrations of fission products and the volumes of reactor coolant released are so low, however, that the total radioactivity attributed to long-lived fission product radionuclides comprises only a small fraction of the total long-lived gamma radioactivity releases discussed elsewhere in this section of this report.

Tritium

Small amounts of tritium are formed in reactor coolant systems as a result of neutron interaction with the approximately 0.015 percent of naturally occurring deuterium present in water, and other nuclear reactions. Although tritium has a twelve year half-life, the radiation produced is of such low energy that the radioactivity concentration guide issued by the International Commission on Radiological Protection, the National Council on Radiation Protection and Measurements, the U.S. Nuclear Regulatory Commission and by other standard-setting organizations is at least one hundred times higher for tritium than for cobalt 60. This tritium is in the oxide form and is chemically indistinguishable from water; therefore, it does not concentrate significantly in marine life or collect on sediment as do other radionuclides.

Tritium is naturally present in the environment because it is generated by cosmic radiation in the upper atmosphere. Reference 17 reports that the production rate from this source is about four million curies per year. This results in a global inventory of about seventy million curies of which about forty-five million curies are in the oceans (reference 18). Because of this naturally occurring tritium, much larger releases of tritium than are conceivable from Naval nuclear reactors would be required to make a measurable change in the background tritium concentration.

The total amount of tritium released annually from all U.S. Naval nuclear-powered ships and their supporting tenders, bases and shipyards has been less than two hundred curies. Most of this has been into the ocean greater than twelve miles from shore. The total tritium released annually from the entire nuclear Navy is less than single electrical generating nuclear power stations typically release each year (reference 19). Total tritium released annually into harbors within twelve miles of shore is less than one curie. Such releases are too small to increase measurably the tritium concentration in the environment. Therefore, tritium has not been combined with the data on other radionuclides in this section of this report.

Carbon 14

Carbon 14 is also formed in small quantities in reactor coolant systems as a result of neutron interactions with nitrogen and oxygen. Carbon 14 decays with a half-life of 5,730 years; however, only low energy beta radiation is emitted as a result of this decay process. As a result, the radioactivity concentration guide for carbon 14 in its chemical form in air issued by the International Commission on Radiological Protection, the National Council on Radiation Protection and Measurements, the U.S. Nuclear Regulatory Commission and by other standard-setting organizations is sixty times higher than for cobalt 60.

Carbon 14 occurs naturally in the environment. It is generated from cosmic radiation interactions with nitrogen and oxygen in the upper atmosphere and oxidized to form carbon dioxide. Carbon 14 is chemically indistinguishable from other isotopes of carbon. The carbon dioxide diffuses and convects throughout the atmosphere and enters the earth's carbon cycle. Reference 20 states that the earth's natural carbon 14 inventory is estimated to be about two hundred and fifty million curies of which approximately ninety-five percent resides in the oceans. The total amount of carbon 14 released annually from the operation of all U.S. Naval nuclear-powered ships and their supporting tenders, bases and shipyards has been less than one hundred curies, essentially all of which is released at sea beyond twelve miles from shore. Since the inventory of naturally occurring carbon 14 is so large, it is extremely unlikely that releases from Naval nuclear reactors could result in a measurable change in the background concentration of carbon 14.

Liquid Releases at Sea

Radioactive liquids incidental to the operation of the nuclear propulsion plants are released at sea under strict controls. These ocean releases are consistent with recommendations the Council on Environmental Quality made in 1970 to the President in reference 21, and consistent with the Marine Protection, Research and Sanctuaries Act, reference 22. Procedures and limits for ocean releases have been consistent with recommendations made by the National Academy of Sciences--National Research Council in reference 10 and by the International Atomic Energy Agency in reference 11. These releases have contained much less radioactivity than these reports considered would be acceptable. Total long-lived gamma radioactivity released farther than twelve miles from shore by U.S. Naval nuclear-powered ships and supporting tenders is shown in Table 2 for recent years. This is the total amount released from over one hundred ships at different times of the year in the open sea at long distances from land in small incremental amounts, and under rapid dispersal conditions due to wave action. The quantity of long-lived gamma radioactivity released to the open ocean in 1994 was 0.4 curie, which is less

than the naturally occurring radioactivity (reference 16) in a cube of sea water approximately one hundred yards on a side.

TABLE 2 TOTAL RADIOACTIVITY IN LIQUID RELEASED AT SEA ORIGINATING FROM U.S. NAVAL NUCLEAR-POWERED SHIPS

	Radioactivity-Curies (less tritium)
1975	0.4
1976	0.4
1977	0.4
1978	0.4
1979	0.4
1980	0.4
1981	0.4
1982	0.4
1983	0.4
1984	0.4
1985	0.4
1986	0.4
1987	0.4
1988	0.4
1989	0.4
1990	0.4
1991	0.4
1992	0.4
1993	0.4
1994	0.4

Loss of USS THRESHER and USS SCORPION

Two U.S. Naval nuclear-powered submarines have been lost at sea in the Atlantic Ocean. The submarine THRESHER sank 10 April 1963, 200 miles southeast of Maine in water 8,500 feet deep. The submarine SCORPION sank between 21 and 27 May 1968, 400 miles southwest of the Azores in more than 10,000 feet of water. The reactors used in all U.S. Naval submarines and surface ships are designed to minimize potential hazards to the environment even under the most severe casualty conditions such as the actual sinking of the ship. First, the reactor core is so designed that it is physically impossible for it to explode like a bomb. Second, the reactor fuel elements are made of materials that are extremely corrosion resistant, even in sea water. The reactor core could remain submerged in sea water for centuries without releases of fission products while the radioactivity decays, since the protective cladding on the fuel elements corrodes only a few millionths of an inch per year. Thus, in the event of a serious accident where the reactor is completely submerged in sea water, the fuel elements will remain intact for an indefinite period of time, and the radioactive material contained in these fuel elements should not be released. The maximum rate of release and dispersal

of the radioactivity in the ocean, even if the protective cladding on the fuel were destroyed, would be so low as to be insignificant.

Radioactive material could be released from this type of reactor only if the fuel elements were actually to melt and, in addition, the high-strength, all-welded reactor system boundary were to rupture. The reactor's many protective devices and inherent self-regulating features are designed to prevent any melting of the fuel elements. Flooding of a reactor with sea water furnishes additional cooling for the fuel elements and so provides added protection against the release of radioactive fission products.

Radiation measurements, water samples, bottom sediment samples and debris collected from the area where THRESHER sank were analyzed for radioactivity shortly after the sinking and again in 1965 by various laboratories. Similarly, sea water and bottom sediment samples taken near SCORPION's hull were analyzed for radioactivity. In 1977, 1983 and 1986, followup samples of water, sediment, and marine life were collected from the immediate THRESHER debris areas. In 1979 and 1986, followup samples of water, sediment, marine life and debris were collected from the immediate SCORPION debris areas. None of these samples showed any evidence of release of radioactivity from the reactor fuel elements in either THRESHER or SCORPION. However, cobalt 60 released from both THRESHER and SCORPION coolant systems was detectable at low levels in the sediment samples in the debris areas. Cobalt 60 was not detectable in samples of water or marine life. The maximum cobalt 60 concentration measured in the sediment at either site was 1.16×10^{-6} uCi/gm and most samples were much less than this concentration. This is less than one-tenth of the concentration of naturally occurring radioactivity in the sediment. For perspective, if a person's diet contained cobalt 60 at the maximum concentration detected in the sediment, that person would receive less than ten percent of the radiation exposure received from natural background radioactivity.

SCORPION carried two torpedoes with nuclear weapons containing plutonium. While the monitoring campaign was for the express purpose of assessing the impacts from the nuclear reactor, sediment, water, and marine life samples collected at the SCORPION site in 1986 were also analyzed for plutonium. Total plutonium radioactivity concentrations and the relative concentrations of plutonium isotopes were typical of background concentrations due to fallout from nuclear weapons testing. Thus, there is no evidence of leakage of plutonium from nuclear weapons that were on the submarine when it sank.

Summary information on the radiological surveys of the THRESHER and SCORPION sites was published in reference 23. In 1993, the Navy issued detailed unclassified reports of the radiological environmental monitoring of the THRESHER and SCORPION

sites, references 24 and 25. This monitoring demonstrates that the THRESHER and SCORPION have not had a significant effect on the radioactivity in the environment.

SOLID RADIOACTIVE WASTE DISPOSAL

During maintenance and overhaul operations, solid low-level radioactive wastes consisting of contaminated rags, plastic bags, paper, filters, ion exchange resin and scrap materials are collected from nuclear-powered ships and their support facilities. These low-level radioactive materials are required to be strictly controlled to prevent loss. These controls include Naval accountability procedures which require serialized tagging and marking and signatures by radiologically trained personnel.

Table 3 summarizes the total radioactivity and volumes of radioactive solid waste disposed of during the last five years. Table 3 includes all waste generated by U.S. Naval nuclear-powered ships and the listed support facilities since all radioactive solid waste generated by U.S. nuclear-powered ships is transferred to the listed facilities. The quantity of solid radioactive waste in any one year from a particular facility depends on the amount and type of support work performed that year. Table 3 does not include fuel or other classified radioactive components shipped to Department of Energy facilities.

Figure 2 shows that the total annual volume of solid low-level radioactive waste was substantially reduced in the 1970's, despite increasing numbers of ships. This reduction was accomplished simultaneously with reduction in personnel radiation exposure, as described in reference 26. This reduction was accomplished by several techniques including a total containment concept for radiological work which minimizes the spread of radioactivity to non-radioactive materials, use of preplanning and mockups to minimize rework, reusing rather than disposing of tools and equipment, use of radioactive liquid processing procedures which minimize depletion of processing media, use of compaction equipment and efficient packaging to fully use space in disposal containers, and separating solid waste that requires special disposal owing to its radioactive content from that which does not. The latter is achieved by work site controls and by use of sensitive detection equipment to detect radioactivity only slightly greater in concentration than that found in natural materials such as soil, rocks, water, and biological matter (see reference 18) thus requiring the material to be handled as radioactive for waste disposal purposes. Material which passes the screening provided by this sensitive detection equipment can be disposed of as ordinary waste. Challenging goals are set by each shipyard to ensure continuing management attention to minimizing generation of waste in radiological work.

The annual volume of solid low-level radioactive waste disposed of in 1994 by the entire Naval Nuclear Propulsion Program, as shown in Table 3, could be contained in a cube measuring about fifteen yards on a side. The total annual volume is approximately twenty-three percent of the solid low-level radioactive waste generated annually by all nuclear electric power reactors and approximately twelve percent of the total volume of solid low-level radioactive waste buried in all U.S. commercial disposal sites each year (reference 27).

Solid radioactive waste materials are packaged in strong tight containers, shielded as necessary and shipped to burial sites licensed by the U.S. Nuclear Regulatory Commission or a State under agreement with the Nuclear Regulatory Commission. Solid radioactive materials from Naval nuclear-powered ships have not been dumped at sea since 1970 when the Navy issued procedures prohibiting sea disposal of solid radioactive materials. Shipyards and other shore facilities have never been permitted to dispose of radioactive solid wastes by burial on their own sites.

The Low-Level Radioactive Waste Policy Amendments Act of 1985 establishes that the states are responsible, either individually or in multi-state compacts, for providing for the disposal of low-level radioactive waste from private and non-Department of Energy Federal Government generators. Under this law, a waste compact may prohibit disposal of waste from outside the compact. Only two waste disposal sites are operating. The Northwest Compact site in Richland, Washington accepts waste only from the Northwest and Rocky Mountain Compact, which includes Navy facilities in Washington and Hawaii. As of June 30, 1994, the Southeast Compact site in Barnwell, South Carolina accepted waste only from Southeast Compact generators. The Southeast Compact includes Navy facilities in Virginia, South Carolina and Georgia. The site in Barnwell, South Carolina is scheduled to close at the end of 1995.

In view of the significantly increased disposal fees and the anticipated closure of low-level radioactive waste disposal sites, a concerted effort has been underway to reevaluate radioactive equipment which was in storage for potential future use and to dispose of that equipment for which no specific future need was identified. For example, some of this equipment was no longer needed due to the declining fleet size. Due to this effort and the closure of Mare Island and Charleston Naval Shipyards, the amount of solid low-level radioactive waste shipped for disposal during the past four years was higher than in other recent years.

Beginning in 1996, low-level radioactive waste generators outside of the Northwest Compact (and the Rocky Mountain Compact) including hospitals, universities, nuclear power plants, and industrial users of radioactive materials will be forced to store their low-level radioactive waste until the states open new disposal sites. Navy facilities will be similarly affected.

TABLE 3 DISPOSED RADIOACTIVE SOLID WASTE FROM U.S. NAVAL NUCLEAR-POWERED SHIPS AND THEIR SUPPORT FACILITIES FOR 1990 THROUGH 1994

FACILITY	1990		1991		1992		1993		1994	
	THOUSAND CUBIC FEET	CURIES	THOUSAND CUBIC FEET	CURIES	THOUSAND CUBIC FEET	CURIES	THOUSAND CUBIC FEET	CURIES	THOUSAND CUBIC FEET	CURIES
Kittery, Maine Portsmouth Naval Shipyard	1	<1	4	9	2	2	0	0	3	17
Groton, New London, Conn. Electric Boat Division, State Pier and Sub Base	2	1	2	<1	1	<1	1	1	2	2
Newport News, Virginia Newport News Shipbuilding	8	52	15	3	19	5	9	<1	3	7
Norfolk, Virginia Naval Shipyard and Tenders	12	1	17	1	36	15	32	40	22	165
Charleston, South Carolina Naval Shipyard, Tenders, and Naval Nuclear Power Training Unit	8	138	13	122	8	14	9	246	22	48
Vallejo, California Mare Island Naval Shipyard	5	1	5	1	8	31	10	4	29	6
Bremerton, Washington Puget Sound Naval Shipyard	8	92	27	86	23	59	16	18	11	35
Pearl Harbor, Hawaii Naval Shipyard and Sub Base	5	1	3	6	3	1	2	3	2	50
TOTAL	49	287	86	229	100	228	79	313	94	330

NOTES:

(1) This table includes all radioactive waste from tenders and nuclear-powered ships. This radioactivity is primarily cobalt 60. This radioactive waste is shipped to burial facilities licensed by the U.S. Nuclear Regulatory Commission or a State.

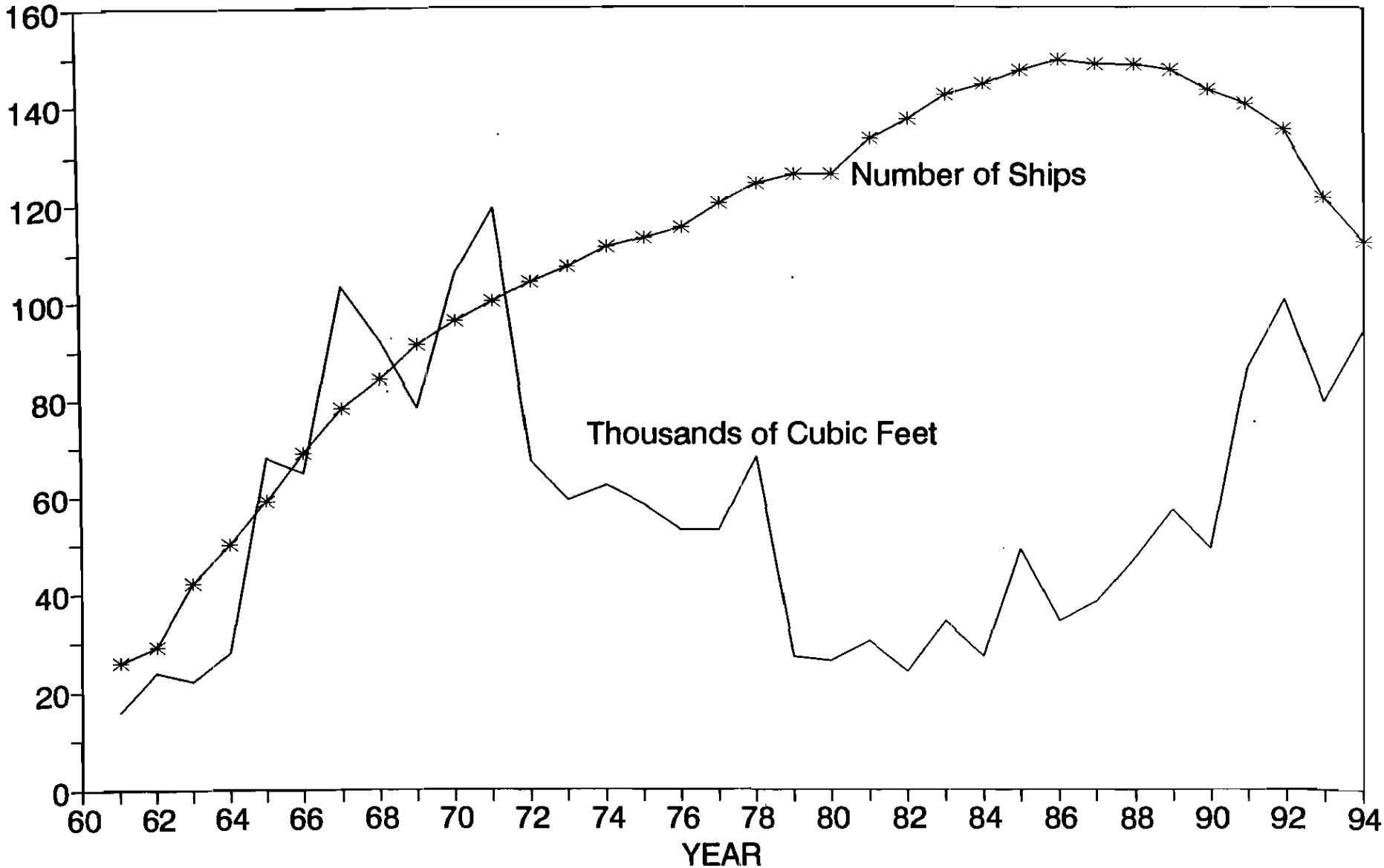
(2) Volumes less than 500 cubic feet are reported as 1 thousand cubic feet and activities less than 0.5 curie are reported as <1 curie.

(3) The Naval Nuclear Power Training Unit is the site of the moored training ships.

(4) Due to closure of a commercial disposal site and provisions of Federal and State law, radioactive waste generators in Maine, including Portsmouth Naval Shipyard, did not have access to a disposal site in 1993. Thus, no radioactive waste shipments were made to a disposal site in 1993 from this shipyard.

Figure 2:

Radioactive Solid Waste Disposal Volumes in the Naval Nuclear Propulsion Program 1961-1994



Deactivation of Ingalls Shipbuilding Radiological Facilities

From 1958 to 1980, Ingalls Shipbuilding was engaged in the construction and overhaul of Naval nuclear-powered ships in Pascagoula, Mississippi. The shipyard radiological facilities which supported this work were deactivated between 1980 and 1982 by removing and disposing of all radioactive material associated with Naval nuclear propulsion plants. Useful items, such as tools and equipment that were radioactively contaminated, were transferred to other organizations in the Naval Nuclear Propulsion Program. The remaining radioactive material was disposed of as solid waste.

Extensive radiological decommissioning surveys were performed to verify the removal of this radioactive material. Direct radiological surveys were performed on over 274,000 square feet of building and facility surfaces. Over 11,000 samples of these surfaces as well as soil, ground cover and concrete were taken from all areas where radioactive work was previously performed. These samples were analyzed using sensitive laboratory equipment. In addition, both the State of Mississippi and the U.S. Environmental Protection Agency (reference 28) performed overcheck surveys of the deactivated facilities. After these surveys were completed, the Ingalls facilities were released for unrestricted use. Personnel who subsequently occupy these facilities will not receive measurable radiation exposure above natural background levels that exist in areas not affected by Naval nuclear propulsion plant work. Reference 28 is the report of the survey of the Ingalls facilities by the Environmental Protection Agency.

Closure of Charleston and Mare Island Naval Shipyards

Mare Island Naval Shipyard was engaged in construction, overhaul, and refueling of Naval nuclear-powered ships from 1956 to 1995. Charleston Naval Shipyard was engaged in overhaul and refueling from 1959 to 1994. The 1993 round of the Base Closure and Realignment Act process approved closure of these shipyards. Similar to the process followed at Ingalls Shipbuilding, the radiological facilities at both Charleston and Mare Island are being deactivated.

As at Ingalls, extensive radiological decommissioning surveys are being performed to verify the removal of radioactive material. At each shipyard, direct radiological surveys will be performed on over 2,000,000 square feet of building and facility surfaces and over 40,000 samples of soil, ground cover, and concrete are being analyzed using sensitive laboratory equipment. This survey effort is approximately half completed at both shipyards. Only a few localized areas have been found with trace concentrations of cobalt 60 radioactivity. Simple, proven cleanup methods will remediate these areas. Both the radiological deactivation work and the survey work are being performed by shipyard workers. The

Navy's radiological deactivation and verification surveys will be completed by April 1996. Both the EPA and the states plan to perform overcheck surveys upon completion of the Navy work. Personnel who subsequently occupy these facilities will not receive measurable radiation exposure above natural background levels.

The successful radiological deactivation and closure work at Ingalls, Charleston, and Mare Island demonstrates that the stringent control over radioactivity exercised by the Naval Nuclear Propulsion Program from its inception has been successful in preventing radiological contamination of the environment and in avoiding expensive radiological liabilities at shipyards.

Mixed Radioactive and Hazardous Waste

Waste which is both radioactive and chemically hazardous is regulated under both the Atomic Energy Act and the Resource Conservation and Recovery Act (RCRA) as "mixed waste." Within the Naval Nuclear Propulsion Program, concerted efforts are taken to avoid commingling radioactive and chemically hazardous substances so as to minimize the potential for generation of mixed waste. For example, these efforts include avoiding the use of acetone solvents, lead-based paints, lead shielding in disposal containers, and chemical paint removers. As a result of Program efforts to avoid the use of chemically hazardous substances in radiological work, Program activities typically generate less than thirty-five cubic meters of mixed waste each year. This small amount of mixed waste, along with less than one hundred cubic meters of mixed waste from previous Program work, is stored pending the development of Department of Energy and commercial mixed waste treatment capacity required to deal with over 600,000 cubic meters of non-Program Department of Energy mixed waste. Pursuant to the requirements of the 1992 Federal Facility Compliance Act, mixed waste site treatment plans are being prepared and will be completed by October 1995 to address treatment of all Program mixed waste streams.

Disposal of Decommissioned, Defueled Naval Submarine Reactor Plants

During the 1980's, the nuclear powered submarines constructed in the 1950's and 1960's began to reach the end of their service life. In 1982, the Navy, with the Department of Energy as a cooperating agency, published a Draft Environmental Impact Statement (EIS) on the disposal of decommissioned, defueled Naval submarine reactor plants. The Draft EIS was widely distributed to individuals, environmental organizations, state and local officials, and other Federal agencies. All substantive comments were analyzed and addressed in the Final EIS which was issued in 1984 (reference 23). Although the Navy had evaluated the alternative of disposing of the defueled ships by sinking at sea, the preferred alternative identified in the Final EIS was to dispose of the defueled reactor plants at a Federal disposal facility already used for low-level radioactive waste disposal. In

December 1984, the Secretary of the Navy issued a Record of Decision to proceed with land disposal.

A submarine is constructed with the nuclear power plant inside a single section of the ship called the reactor compartment. Before the reactor compartment is disposed of, the nuclear fuel is removed and handled in the same manner as nuclear fuel removed during refueling of nuclear-powered ships. The defueled reactor compartments are removed from decommissioned submarines in drydocks at the Puget Sound Naval Shipyard in Bremerton, Washington. After removal from a submarine, the reactor compartment is sealed and loaded onto a barge for transport to the Port of Benton on the Columbia River near the Department of Energy Hanford Site. At the Port of Benton, the reactor compartment is transferred to a land transporter which carries the reactor compartment to the disposal trench on the Hanford Site. Further information on this process is contained in the Final EIS (reference 23). The first defueled reactor compartment was shipped to Hanford in 1986. Eight defueled reactor compartments were shipped in 1994, which brought the total number shipped to forty-three.

TRANSPORTATION OF RADIOACTIVE MATERIAL

Shipments of radioactive materials in the Naval Nuclear Propulsion Program are required to be made in accordance with applicable regulations of the U.S. Department of Transportation, U.S. Department of Energy, and U.S. Nuclear Regulatory Commission. The purpose of these regulations is to ensure that shipments of radioactive material are adequately controlled to protect the environment and the health and safety of the general public. These regulations are applicable to all radioactive material shipments.

The above regulations provide requirements for the container design, certification, and identification as applicable for the specific quantity, type and form of radioactivity being shipped. Naval shipping container design requirements invoke shielding and integrity specifications and meet all regulatory requirements. They provide for testing of container designs, training and qualification of workers who construct containers, and quality control inspections during fabrication to ensure the containers will meet their design requirements.

In addition to imposing requirements of Federal transportation regulations, the Navy has issued standard instructions to further control shipments of radioactivity associated with U.S. Naval nuclear propulsion plants. These standard instructions result in a quality assurance program which includes inspections and assessments by independent organizations and senior management. Organizations making shipments are required to prepare local procedures which require use of compliance checklists and management review to ensure compliance with applicable Department

of Transportation, Navy and disposal sites requirements. Only specially trained, designated people, knowledgeable in shipping regulations, are permitted to authorize shipments of radioactive material.

Protective transportation services such as signature security service or sealed shipping vehicles are required for these shipments to ensure point-to-point control and traceability of each shipment from shipper to receiver. A readily accessible log of all shipments in transit is maintained to enable prompt identification and provide the basis for advice on the nature of the shipment. Return receipts are required to be made in writing by receivers to ensure that radioactive material has not been lost in shipment. Receipt inspection of containers of radioactive material and accompanying documents are required promptly after receipt to monitor compliance. Even minor discrepancies from detailed shipping regulations are required to be reported to the shipper so that correction can be made in future shipments. This is done to ensure compliance with shipping regulations.

Radioactive materials shipped in the Naval Nuclear Propulsion Program include anticontamination clothing for laundry, small sealed sources used for calibrating radiation monitoring instruments, tools and equipment used for radioactive work, low-level radioactive waste, radioactive components and new and irradiated naval fuel. A total of approximately 1,000 shipments are made annually by Naval nuclear-powered ships and their support facilities, which is a small part of the more than two million shipments of radioactive materials made annually in the United States (reference 29).

Nearly all radioactive shipments in the Naval Nuclear Propulsion Program contain only low-level radioactivity classified under Department of Transportation regulations as low specific activity or limited quantity shipments. The predominant radionuclide associated with these shipments is cobalt 60 in the form of insoluble metallic oxide corrosion products attached to surfaces of materials inside shipping containers. Most low-level shipments are made by truck. Air transport is used occasionally in the Naval Nuclear Propulsion Program. These air shipments involve only very low-level radioactivity and are not shipped on passenger planes.

Approximately one quarter of the low-level radioactivity shipments are minute quantities in sealed instrument calibration check sources. These sources contain insignificant quantities of radioactivity which are comparable to the radioactivity in typical ionization type smoke detectors. Greater than one-half of these low-level shipments are anticontamination clothing, equipment and tools. The anticontamination laundry involves shipments of special outer clothing potentially contaminated with low levels of radioactivity while worn in controlled work areas. This laundry is

shipped by Nuclear Regulatory Commission or agreement state licensed contractors to their facilities for cleaning. On the average, one shipment of low-level radioactive waste per month is made from each facility listed in Table 3.

The remaining few shipments are new and irradiated naval fuel and radioactive components associated with reactors and these are shipped by the Department of Energy. Such shipments are made infrequently since Naval nuclear-powered ships need refueling infrequently. Measures are carried out to assist in safeguarding these shipments and assuring they reach their destination. Each irradiated naval fuel shipment is escorted by U.S. Government representatives and each shipping container is specifically designed to withstand extreme accident impacts, fire, or water immersion, and to prevent release of the material to the environment in the event of an accident. The cargo in the nuclear fuel and radioactive component shipments is non-explosive and non-flammable and, in addition, the radioactive material in the radioactive components is in an insoluble form that should not be dispersed even in the event of an accident.

Irradiated naval fuel shipments have historically been made to the Department of Energy's Idaho National Engineering Laboratory (INEL) for reprocessing. In 1992, the Department of Energy decided to stop reprocessing irradiated fuel at INEL. Under the National Environmental Policy Act, the Department of Energy is preparing an Environmental Impact Statement (EIS) covering the management of irradiated fuel for which it is responsible, including fuel removed from naval reactors. The Navy is a cooperating agency in this effort. A draft EIS was published in June 1994 and the final EIS will be published in April 1995. Future irradiated naval fuel shipments are covered by this evaluation.

For purposes of this report, estimates of annual radiation exposure to transportation crews and the general public from shipments of radioactive materials in the Naval Nuclear Propulsion Program have been made in a manner consistent with that employed by the Nuclear Regulatory Commission in reference 29. Based on comparisons of the types and numbers of radioactive shipments made, the total annual radiation exposure to all transportation crews for all shipments is estimated to be less than three man-rem. If one person were to receive all this exposure, that person would not exceed the annual radiation exposure permitted for an individual worker by the Nuclear Regulatory Commission. The total estimated radiation exposure accumulated by the public along transportation routes is not more than a few times higher than the exposure to transportation workers. The maximum exposure to any individual member of the public would be far less than that received from natural radiation.

More detailed exposure estimates for irradiated naval fuel shipments are described in the EIS cited above and demonstrate that

for over 600 container shipments made since 1957, the total population dose is less than two man-rem.

Shipments of radioactive materials associated with Naval nuclear propulsion plants have not resulted in any measurable release of radioactivity to the environment. There have never been any significant accidents involving release of radioactive material during shipment since the Naval Nuclear Propulsion Program began. In general, the few accidents that have occurred involved incidents such as broken truck axles or slight external damage to a shipping container with no release of radioactivity. In one incident a train collision resulted in minor denting of a new fuel shipping container with no loss of integrity of the container, no damage to the fuel and no release of radioactivity. In the only two instances that involved loss of contents, one quart containers holding samples with small amounts of radioactivity were broken in shipment. In one case this occurred when a cargo aircraft crashed. The other container was lost from a commercial ship. Both containers were recovered and there was no measurable radioactivity released since the original contents were less than one millionth of a curie.

The requirements of the Naval Nuclear Propulsion Program specify that the carriers for all radioactive material shipments shall have accident plans which identify the actions to be taken in the event the transportation vehicle is involved in an accident. These plans provide for notification of civil authorities and the originating facility. Also provided is a twenty-four hour telephone number at the originating facility for emergency guidance and assistance. The U.S. Navy would communicate with and cooperate fully with state radiological officials in the event of occurrences involving shipments of radioactive materials.

ENVIRONMENTAL MONITORING

To provide additional assurance that procedures used by the U.S. Navy to control radioactivity are adequate to protect the environment, the Navy conducts environmental monitoring in harbors frequented by its nuclear-powered ships. Environmental monitoring surveys for radioactivity are periodically performed in harbors where U.S. Naval nuclear-powered ships are built or overhauled and where these ships have home ports or operating bases. Samples from each harbor monitored are also checked at least annually by a U.S. Department of Energy laboratory to ensure analytical procedures are correct and standardized. The Department of Energy laboratory results have been consistent with shipyard results.

Navy Environmental Monitoring Program

The current Navy environmental monitoring program consists of analyzing samples of harbor sediment, water and marine life,

supplemented by shoreline surveys, posted dosimeters and effluent monitoring. Sampling harbor sediment and water each quarter year is emphasized since these materials would be the most likely affected by releases of radioactivity.

As discussed earlier, cobalt 60 is the predominant radionuclide of environmental interest resulting from Naval nuclear reactor operations. Therefore, Navy monitoring procedures require collecting in each harbor approximately twenty to one hundred twenty sediment samples once each quarter year for analysis to detect cobalt 60 and other gamma emitting radionuclides. Locations and numbers of sediment samples for a particular harbor depend on the size of the harbor and the number and separation of locations where nuclear-powered ships berth. Sampling points are selected to form a pattern around ship berthing locations and to provide points in areas away from these berthing locations. The sampling locations are selected individually for each harbor considering characteristics of the harbor.

Sediment samples are collected using a dredge which samples a surface area of thirty-six square inches and has been modified to collect only the top one-half to one inch of sediment. The top layer was selected because it should be more mobile and more accessible to marine life than deeper layers. The samples are drained of excess water and placed directly into a Marinelli container for analysis. Each sediment sample is analyzed for gamma radioactivity in the container in which it is collected using a solid state germanium detector with a multichannel analyzer. The gamma data is analyzed specifically for the presence of cobalt 60. Results of the sediment samples from harbors monitored by the Navy in the U.S. and possessions are summarized in Table 4.

Table 4 shows that most harbors do not have detectable levels of cobalt 60. As reported in the past, low levels of cobalt 60, less than three millionths of a microcurie per gram, are detected around a few operating base and shipyard piers where nuclear-powered ship maintenance and overhauls were conducted in the early 1960's. These low levels are well below the naturally occurring radioactivity levels in the harbors. The radioactivity detected is from operations in the early 1960's since releases such as shown earlier in Table 1 are too small to be detectable in the harbors. A measure of the significance of these low levels is that if all of a person's food (reference 30) were to contain three millionths of a microcurie of cobalt 60 per gram, that person would receive less than ten percent of the dose from natural background radiation (see reference 18). Cobalt 60 is not detectable in general harbor bottom areas away from these piers.

Low levels of cesium 137 were detected in some sediment samples. The cesium 137 detected is not related to Naval nuclear reactor operations because the high integrity Naval fuel retains fission products. The cesium 137 concentrations measured in the

sediment are due to world wide dispersion from weapons testing.

For comparison, references 31 and 32 contain evaluations by laboratories of the Environmental Protection Agency and of the Department of Energy of the effects on the environment from the accumulation of radionuclides near points of discharge from several nuclear facilities. The referenced reports conclude that radioactivity levels much greater than shown in Table 4 for Naval Nuclear Propulsion Program facilities have caused no significant radiation exposure to the general public.

TABLE 4 SUMMARY OF 1994 SURVEYS FOR COBALT 60 IN BOTTOM SEDIMENT OF U.S. HARBORS WHERE U.S. NAVAL NUCLEAR-POWERED SHIPS HAVE BEEN REGULARLY BASED, OVERHAULED OR BUILT

FACILITY	Range of Cobalt 60 Analytical Results (10^{-6}uCi/gm)	Number of Samples With Cobalt 60 Less Than $3x10^{-6}$uCi/gm	Number of Samples With Cobalt 60 Greater Than $3x10^{-6}$uCi/gm	Total Bottom Area With Cobalt 60 Over $3x10^{-6}$uCi/gm (Square Kilometers)
Kittery, Maine Portsmouth Naval Shipyard	<0.03 - <0.11	120	0	0
Groton, New London, Conn. Electric Boat Division, State Pier and Sub Base	<0.05 - <0.24	400	0	0
Newport News, Virginia Newport News Shipbuilding	<0.02 - <0.15	188	0	0
Norfolk, Virginia Naval Shipyard and Base	<0.03 - <0.16	280	0	0
Charleston, South Carolina Naval Shipyard, Naval Nuclear Power Training Unit, and Bases	<0.02 - <0.15	322	0	0
Kings Bay, Georgia	<0.02 - <0.12	100	0	0
San Diego, California Navy Piers	<0.02 - <0.16	252	0	0
Vallejo, California Mare Island Naval Shipyard	<0.02 - <0.22	228	0	0
Bremerton, Washington Naval Shipyard and Base	<0.01 - 0.17	302	0	0
Pearl Harbor, Hawaii Naval Shipyard and Sub Base	<0.02 - 0.21	204	0	0
Apra Harbor, Guam	<0.01 - <0.09	128	0	0
Port Canaveral, Florida	<0.02 - <0.11	80	0	0

NOTES:

(1) The "<" symbol indicates no cobalt 60 was detected in the sample. The number given is the minimum detectable activity (MDA) i.e., the concentration at which cobalt 60 could be detected if it were present. The MDA varies from sample to sample and location to location due to statistical fluctuations.

(2) uCi/gm = microcurie per gram. 1 uCi = $1x10^{-6}$curie (Ci).

(3) One square kilometer is approximately 0.4 square mile. Estimated total cobalt 60 in the top layer of sediment is 0.01 Ci. Samples from more than one foot deep from several harbors show that total cobalt 60 present may be two to five times that measured in the surface layer.

The maximum total radioactivity observed in a U.S. harbor is less than 0.05 curie of cobalt 60. This radioactivity is small compared to background. Based on the typical concentrations of naturally occurring radioactivity such as potassium 40, radium, uranium and thorium which are described in reference 16 for marine sediment, the natural radioactivity in the sediment of a typical harbor amounts to hundreds of curies.

In addition to Navy analysis of environmental samples, at least ten sediment samples from each harbor monitored have been sent each year to a Department of Energy laboratory, as a check of Navy results. This Department of Energy laboratory provides a further check on the quality of environmental sample analyses by participating in the quality control programs sponsored by the Department of Energy and the Environmental Protection Agency.

The check samples were analyzed for gamma radionuclides in a manner similar to Navy procedures but with greater sensitivity. Figure 3 depicts the gamma spectra for two such samples. Both spectra show the presence of abundant naturally occurring radionuclides which contribute to measured radioactivity even if cobalt 60 were not present. The upper spectrum is for a sample to which cobalt 60 has been added to achieve a concentration of approximately three millionths of a microcurie per gram and shows easily recognizable energy peaks due to the presence of this small concentration of cobalt 60. The lower spectrum is typical of most of the sediment samples with no detectable cobalt 60.

At least five water samples are taken in each harbor once each quarter year in areas where nuclear-powered ships berth and from upstream and downstream locations. These samples are analyzed for gamma radioactivity, including cobalt 60. A solid state germanium detector with a multichannel analyzer is used to measure gamma radioactivity and detect the presence of cobalt 60. Procedures for analysis will detect cobalt 60 if its concentration exceeds the Environmental Protection Agency drinking water limits of reference 14. No cobalt 60 has been detected in any of the water samples from all harbors monitored.

An Environmental Protection Agency evaluation in reference 33 shows that the cobalt 60 from Naval nuclear propulsion plants is in the form of metallic corrosion product particles which do not appear to be concentrated in the food chain. However, samples of marine life such as mollusks, crustaceans and marine plants have been collected from all harbors monitored. Marine life samples are also analyzed using a germanium detector with a multi-channel analyzer. The results of the marine life samples from harbors monitored by the Navy in the U.S. and possessions are summarized in Table 5. Table 5 demonstrates that no buildup of cobalt 60 associated with U.S. Naval nuclear-powered ships has been detected in these samples of marine life.

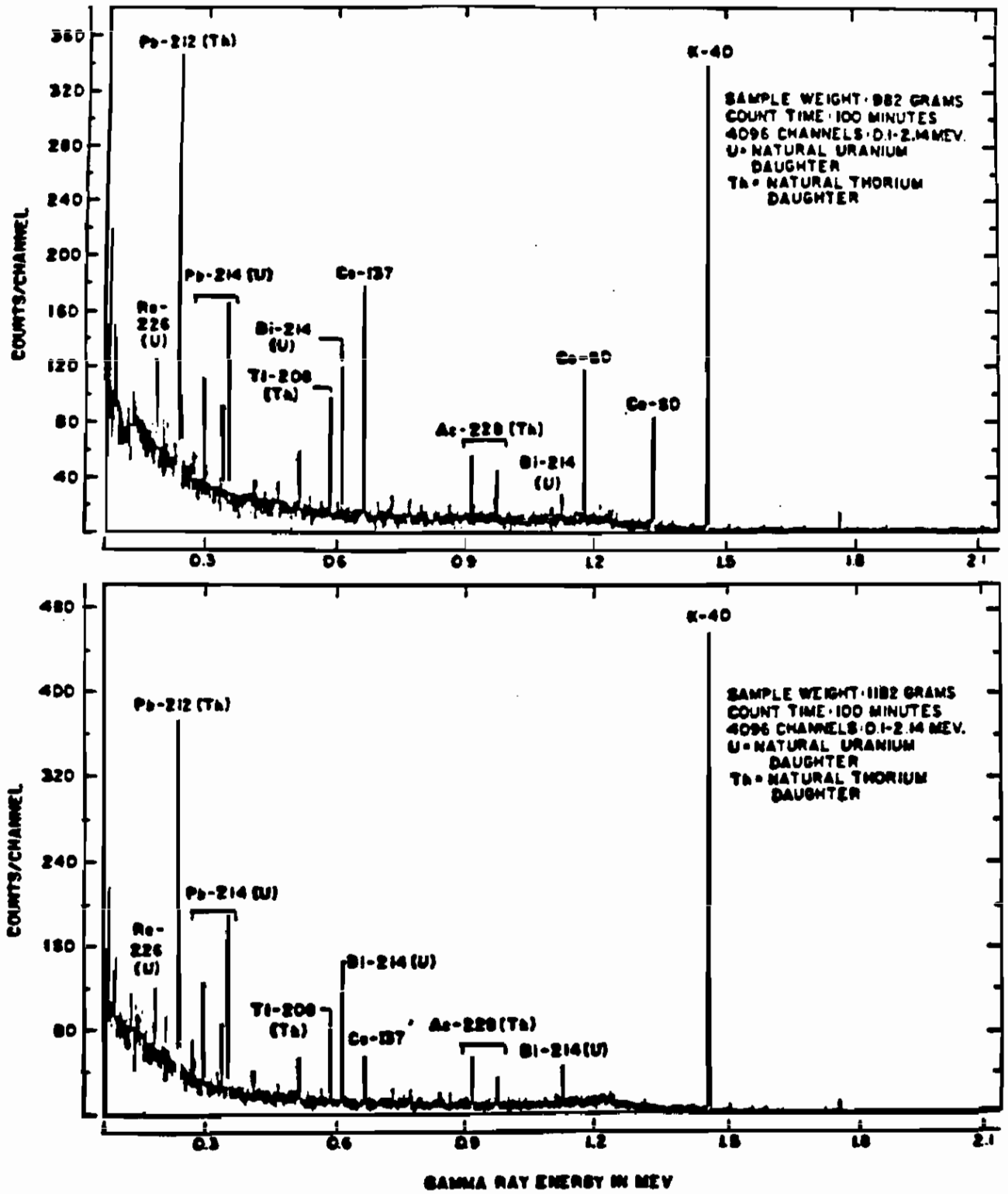


FIGURE 3
GAMMA SPECTRA OF HARBOR BOTTOM SEDIMENT SAMPLES WITH A GERMANIUM DETECTOR

TABLE 5 SUMMARY OF 1994 SURVEYS FOR COBALT 60 IN MARINE LIFE OF U.S. HARBORS WHERE U.S. NAVAL NUCLEAR-POWERED SHIPS HAVE BEEN REGULARLY BASED, OVERHAULED OR BUILT

FACILITY	Mollusks Cobalt 60 Analytical Results (10^{-6}uCi/gm)	Crustaceans Cobalt 60 Analytical Results (10^{-6}uCi/gm)	Marine Plants Cobalt 60 Analytical Results (10^{-6}uCi/gm)
Kittery, Maine Portsmouth Naval Shipyard	<0.07	<0.03	<0.10
Groton, New London, Conn. Electric Boat Division, State Pier and Sub Base	<0.05	<0.06	<0.09
Newport News, Virginia Newport News Shipbuilding	<0.08	<0.09	<0.05
Norfolk, Virginia Naval Shipyard and Base	<0.03	<0.05	<0.05
Charleston, South Carolina Naval Shipyard, Naval Nuclear Power Training Unit, and Bases	<0.04	<0.04	N/A
Kings Bay, Georgia	<0.02	<0.01	<0.02
San Diego, California Navy Piers	<0.01	<0.01	<0.01
Vallejo, California Mare Island Naval Shipyard	<0.09	<0.09	<0.19
Bremerton, Washington Naval Shipyard and Base	<0.08	<0.06	<0.12
Pearl Harbor, Hawaii Naval Shipyard and Sub Base	N/A	<0.05	<0.09
Apra Harbor, Guam	<0.01	<0.01	<0.01
Port Canaveral, Florida	<0.02	<0.01	<0.01

NOTES:
(1) The "<" symbol indicates no cobalt 60 was detected in the sample. The number given is the minimum detectable activity (MDA) i.e., the concentration at which cobalt 60 could be detected if it were present. The MDA varies from sample to sample and location to location due to statistical fluctuations.
(2) uCi/gm = microcurie per gram. 1 uCi = 1×10^{-6}curie (Ci).
(3) N/A = Not Available. Samples of marine life from this location were not available for collection.

In all monitored harbors, twice per year shoreline areas uncovered at low tide are surveyed for radiation levels with sensitive scintillation detectors to determine if any radioactivity from bottom sediment washed ashore. All results were the same as background radiation levels in these regions, approximately 0.01 millirem per hour. Thus, there is no evidence in these ports that these areas are being affected by nuclear-powered ship operations.

Ambient radiation levels are measured using sensitive thermoluminescent dosimeters continuously posted at locations outside the boundaries of areas where radiological work is performed. These dosimeters are also posted at locations remote from support facilities to measure background radiation levels from natural radioactivity. The results of dosimeters posted at support facilities between radiologically controlled areas and the general public and dosimeters posted at remote background locations up to several miles away are compared in Table 6. The range of dosimeter readings is also given since natural background radiation levels vary from location to location primarily due to the concentration of radionuclides in the soil (reference 18). The results of Table 6 show that Naval Nuclear Propulsion Program activities had no distinguishable effect on normal background radiation levels at the site perimeter.

Naval nuclear reactors and their support facilities are designed to ensure there are no significant discharges of radioactivity in airborne exhausts. Radiological controls are exercised in support facilities to preclude exposure of working personnel to airborne radioactivity exceeding one-tenth of the limits specified in reference 6. These controls, discussed in reference 26, include containment for radioactive materials and provide a barrier to prevent significant radioactivity from becoming airborne. Further, all air exhausted from these facilities is passed through high efficiency particulate air filters and monitored during discharge. Comparison of sensitive airborne radioactivity measurements in shipyards demonstrates that air exhausted from facilities actually contained a smaller amount of radioactivity than this same air contained when it was drawn from the environment into the facilities. There were no discharges of airborne radioactivity from these facilities above concentrations normally present in the atmosphere.

TABLE 6 SUMMARY OF 1994 OFF-SITE AND PERIMETER RADIATION MONITORING OF U.S. HARBORS WHERE U.S. NAVAL NUCLEAR-POWERED SHIPS HAVE BEEN REGULARLY BASED, OVERHAULED OR BUILT

FACILITY	Average Off-Site Dosimeter (mrem/qtr)	Range of Off-site Dosimeter (mrem/qtr)	Average Perimeter Dosimeter (mrem/qtr)	Range of Perimeter Dosimeter (mrem/qtr)
Kittery, Maine Portsmouth Naval Shipyard	19	15 - 23	19	15 - 22
Groton, New London, Conn. Electric Boat Division, State Pier and Sub Base	27	17 - 40	24	14 - 40
Newport News, Virginia Newport News Shipbuilding	13	11 - 16	14	10 - 18
Norfolk, Virginia Naval Shipyard and Base	26	19 - 31	18	11 - 31
Charleston, South Carolina Naval Shipyard, Naval Nuclear Power Training Unit, and Bases	23	17 - 29	21	11 - 30
Kings Bay, Georgia	19	13 - 26	21	15 - 30
San Diego, California Navy Piers	23	17 - 28	22	12 - 58
Vallejo, California Mare Island Naval Shipyard	17	11 - 23	17	10 - 30
Bremerton, Washington Naval Shipyard and Base	15	12 - 18	15	12 - 20
Pearl Harbor, Hawaii Naval Shipyard and Sub Base	15	12 - 18	15	12 - 18
Apra Harbor, Guam	17	13 - 21	15	10 - 23
Port Canaveral, Florida	19	12 - 26	21	15 - 27

NOTE:
(1) mrem/qtr = millirem per quarter year. 1 mrem = $1x10^{-3}$rem.

ENVIRONMENTAL PATHWAYS ANALYSIS

Results of monitoring of environmental samples described above have shown that environmental radioactivity levels have not been changed appreciably and therefore radiation exposure to the public from operations of nuclear powered ships and their support facilities is too low to measure. Nevertheless, an analysis has been performed to provide a quantitative estimate of the radiation exposure to which any member of the general public might be exposed as a result of radioactivity in liquid and airborne effluents.

For airborne effluents, the Environmental Protection Agency COMPLY computer program is used for this analysis, as required by EPA regulations in reference 34. Site specific input parameters include radionuclide releases, distance to members of the public, wind speed and direction, and food production. The releases of airborne effluents used in the analysis are summarized in Table 7. Cobalt 60 values include actual measurements of cobalt 60 emissions from the exhaust of Navy facilities in addition to very conservative estimates of other potential sources of cobalt 60. Values for other airborne radionuclides, including iodine 131, are conservative estimates based upon detailed study of land based naval nuclear propulsion prototype plants. For example, the release of tritium (in the form of water vapor) is based upon the very conservative assumption that half of the radioactive water handled by a large shipyard evaporates from collection and storage tanks. Thus, the actual exposures to members of the public are expected to be lower than the results of this analysis.

Results of the airborne effluent analysis are summarized in Table 8. Table 8 compares the estimated maximum exposure to a member of the public from Program effluents with guidelines of the Nuclear Regulatory Commission in reference 13. These numerical guidelines on calculated radiation exposures implement the concept that radioactivity in effluents from light water nuclear electric power reactors should be limited to amounts and quantities as low as reasonably achievable. Although these guidelines are not applicable to nuclear-powered ships and their support facilities they provide a context in which to judge the significance of radiation exposures from Program effluents. The estimated maximum radiation exposure to a member of the general public from releases of airborne radioactivity is also much less than the standard of 10 millirem per year established by the Environmental Protection Agency in reference 34.

TABLE 7 RADIONUCLIDE RELEASES USED FOR ENVIRONMENTAL PATHWAYS ANALYSIS

Radionuclide	Annual Airborne Release, Curie
Cobalt 60*	<0.0004
Tritium	1.0
Carbon 14	0.10
Krypton 83m	0.00075
Krypton 85m	0.0039
Krypton 85	0.000013
Krypton 87	0.0019
Krypton 88	0.0054
Xenon 131m	0.00068
Xenon 133m	0.0037
Xenon 133	0.11
Xenon 135	0.071
Argon 41	0.20
Iodine 131*	<0.00008

* Site specific values are used for these radionuclides. The tabulated values bound the site specific values used in the analysis.

For liquid effluents, the results of the environmental monitoring samples demonstrate that there is no significant radiation exposure to members of the public without the need for any detailed theoretical model calculations. For example, the samples of marine life obtained from the immediate vicinity of shipyard piers and drydocks did not have any detectable cobalt 60, even with sensitive analysis. Even if cobalt 60 were assumed to be present at concentrations just below the limits of detection shown in Table 5 and a person were to eat 40 pounds per year of mollusks and crustaceans caught directly from these areas, the person would receive much less than one millirem per year. Similarly, even though the Navy minimizes releases of radioactive liquids and there has never been any detectable cobalt 60 in harbor water, the water consumption pathway cannot result in any dose to the public since seawater is not used for drinking water consumption in the vicinity of these facilities. Thus, exposures to members of the public from the Naval Nuclear Propulsion Program liquid effluents are far less than the guidelines of the Nuclear Regulatory Commission which are listed in Table 8.

TABLE 8 ESTIMATED MAXIMUM RADIATION EXPOSURE TO AN INDIVIDUAL FOR ASSUMED LIQUID AND AIRBORNE RADIOACTIVITY RELEASES FROM SHIPYARDS ENGAGED IN NAVAL NUCLEAR PROPULSION WORK

	Maximum Exposure To An Individual	
	NRC Guideline millirem/year	Estimated Value millirem/year
From Radionuclides In Liquid Releases	3 whole body, or 10 any organ	less than 1
From Gaseous Radionuclides In Airborne Releases	5 whole body, or 15 skin	less than 0.1
From Other Radionuclides In Airborne Releases	15 any organ	less than 0.1

	Maximum Exposure To An Individual	
	EPA Regulation millirem/year	Estimated Value millirem/year
From Radioiodine In Airborne Releases	3	less than 0.03
From Other Radionuclides In Airborne Releases	10	less than 0.1

AUDITS AND REVIEWS

The requirements and procedures for control of radioactivity is an important part of the training programs for everyone involved with radioactivity in the Naval Nuclear Propulsion Program. Such training is part of the initial qualification of shipyard workers and of Naval personnel assigned to ships and bases, and is required to be repeated regularly. Emphasis on this training is part of the concept that radiological control personnel alone cannot cause radiological work to be well performed; production and operations personnel and all levels of management are required to be involved in the control of radioactivity.

Checks and balances of several kinds are also set up to help ensure control of radioactivity. First, written procedures exist which require verbatim compliance. Radiological control personnel monitor various steps in radioactive waste processing. In each shipyard an independent organization, separate from the radiological control organization, audits all aspects of radioactive waste processing. Audits are performed by representatives from Naval Reactors headquarters who are assigned full time at each shipyard. Radiological control personnel from headquarters also conduct periodic inspections of each shipyard. In addition, shipyards have made detailed assessments of the environmental effects of shipyard operations and have published reports on the results of these assessments. Similarly, there are multiple levels of audits and inspections for the other Navy shore facilities, tenders, and nuclear-powered ships and for other radiologically controlled functions such as transportation. Even the smallest audit findings are followed up to ensure proper recovery and permanent corrective actions are taken and to help minimize the potential for future deficiencies.

The policy of the Navy is to provide for close cooperation and effective communication with state radiological officials involving occurrences that might cause concern because of radiological effects outside the ships or shore facilities. The Navy has reviewed radioactive waste disposal, radiological environmental monitoring, transportation and other radiological matters with state radiological officials in the states where Navy nuclear-powered ships are based or overhauled. Although there were no occurrences in 1994 which resulted in radiological effects to the public outside these facilities, states were notified when inquiries showed public interest in the possibility that such events had occurred. The Navy has encouraged states to conduct independent radiological environmental monitoring in harbors where Naval nuclear-powered ships are based or overhauled; the results of monitoring by states have been consistent with Navy results.

The U.S. Environmental Protection Agency has conducted detailed reviews of the Navy's procedures for controlling radioactive waste and for radiological environmental monitoring. An Environmental Protection Agency laboratory has conducted detailed environmental surveys of selected U.S. harbors (references 28 and 35 through 43). This laboratory has performed these surveys in the harbors at Pascagoula, Mississippi; Charleston, South Carolina; Pearl Harbor, Hawaii; San Diego, Alameda, San Francisco and Vallejo, California; New London and Groton, Connecticut; Newport News, Portsmouth and Norfolk, Virginia; Kings Bay, Georgia; Kittery, Maine-Portsmouth, New Hampshire; and Bremerton and Bangor, Washington. Environmental Protection Agency results have been consistent with Navy results. The Environmental Protection Agency reports have concluded that operation of Naval nuclear-powered ships has had no adverse impact on public safety or health.

CONCLUSIONS

1. The total long-lived gamma radioactivity in liquids released into all ports and harbors from the U.S. Naval Nuclear Propulsion Program was less than 0.002 curie in 1994.

2. No increase of radioactivity above normal background levels has been detected in harbor water where U.S. Naval nuclear-powered ships are based, overhauled, or constructed.

3. Liquid releases from U.S. Naval nuclear-powered ships and their support facilities have not caused a measurable increase in the general background radioactivity of the environment.

4. Low level cobalt 60 radioactivity in harbor bottom sediment is detectable around a few operating base and shipyard piers from low level liquid releases in the 1960's. Concentrations of cobalt 60 are less than the concentrations of naturally occurring radionuclides around these piers. Cobalt 60 is not detectable in general harbor bottom areas away from these piers. The maximum total radioactivity observed in a U.S. harbor, less than 0.05 curie of cobalt 60, is small compared to the naturally occurring radioactivity. Comparison to previous environmental data summarized in references 1 through 5 shows that these environmental cobalt 60 levels are continuing to decrease.

5. Conservative estimates of radiation exposures to members of the public from the Naval Nuclear Propulsion Program are far less than either the U.S. Environmental Protection Agency environmental standards, the guidelines of the U.S. Nuclear Regulatory Commission or the exposure from natural background radioactivity.

6. Procedures used by the Navy to control releases of radioactivity from U.S. Naval nuclear-powered ships and their support facilities have been effective in protecting the environment and the health and safety of the general public. Independent radiological environmental monitoring performed by the U.S. Environmental Protection Agency and states have confirmed the adequacy of these procedures. These procedures have ensured that no member of the general public has received measurable radiation exposure as a result of current operations of the Naval Nuclear Propulsion Program.

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APPENDIX

ENVIRONMENTAL MONITORING SURVEY CHARTS

Environmental monitoring survey charts for harbors monitored for radioactivity associated with U.S. Naval nuclear-powered ships in the U.S. and possessions are listed below and included in this Appendix. The sampling locations for harbor water and harbor sediment are shown. In addition, shoreline survey areas and the locations of posted dosimetry devices are shown on the figures.

Figure No.	Location
	California
1	U.S. Naval Air Station, Alameda
2	Hunters Point Shipyard, San Francisco
3	Mare Island Naval Shipyard, Vallejo
4	San Diego Harbor
5	San Diego Harbor, Ballast Point Area
	Connecticut
6	Electric Boat Division, Groton
7	U.S. Naval Submarine Support Facility, New London Harbor
8	State Pier Area, New London
	Florida
9	Port Canaveral
	Georgia
10	U.S. Naval Submarine Base, Kings Bay
	Guam
11	Apra Harbor
	Hawaii
12	Pearl Harbor Area
13	Pearl Harbor Naval Shipyard
14	U.S. Naval Submarine Base, Pearl Harbor
	New Hampshire/Maine
15	Portsmouth Naval Shipyard
	South Carolina
16	U.S. Naval Station and Naval Shipyard, Charleston
17	U.S. Naval Weapons Station, Charleston

Virginia

18 Newport News Shipbuilding, Newport News

19 Norfolk Naval Shipyard, Portsmouth

20 U.S. Naval Station Norfolk

21 Norfolk--Portsmouth Virginia Area

Washington

22 Puget Sound Naval Shipyard

23 Bangor/Hood Canal

FIGURE 1
ENVIRONMENTAL MONITORING LOCATIONS AT
U.S. NAVAL AIR STATION ALAMEDA, CA

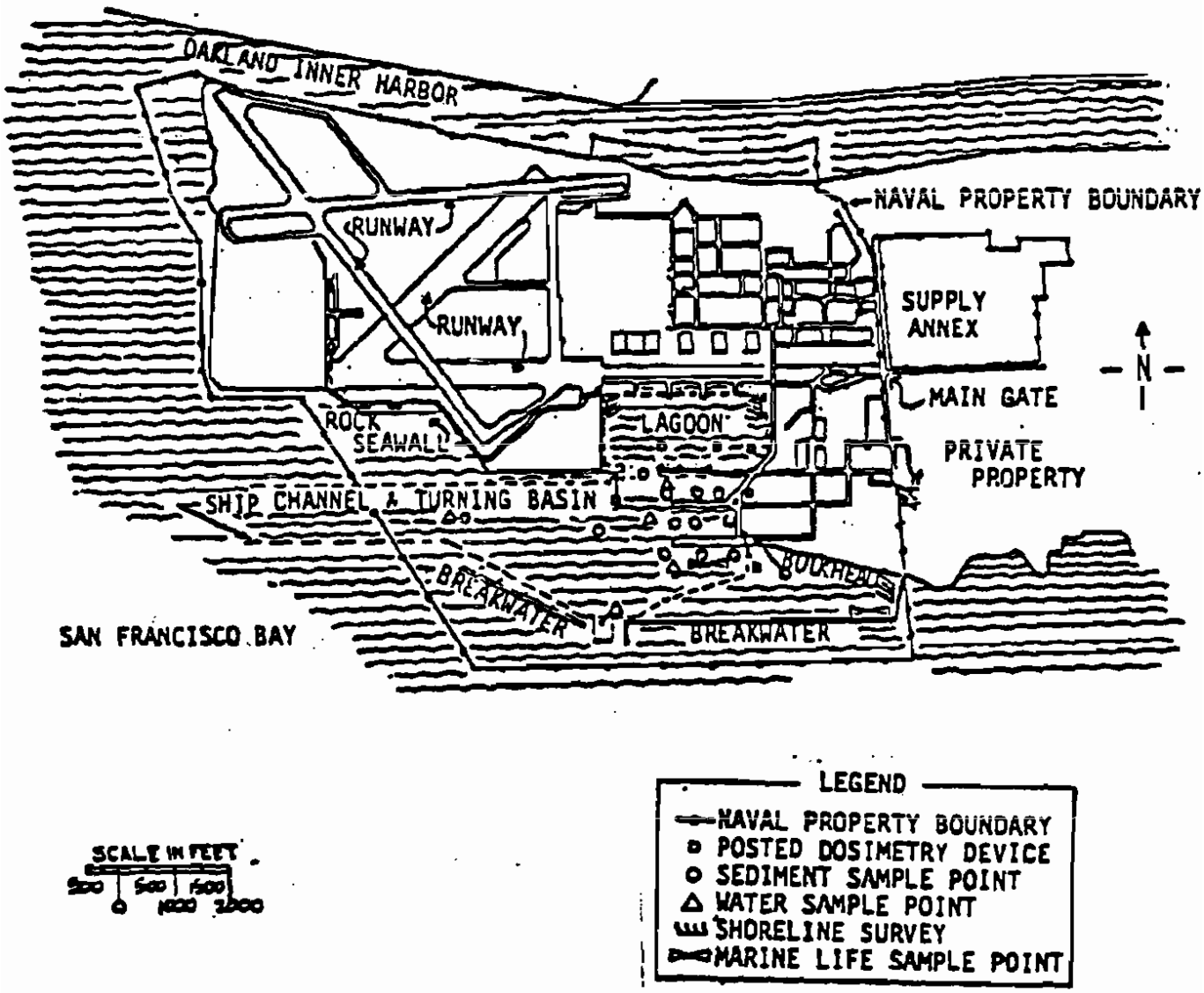


FIGURE 2
ENVIRONMENTAL MONITORING LOCATIONS AT
HUNTERS POINT SHIPYARD, SAN FRANCISCO, CA

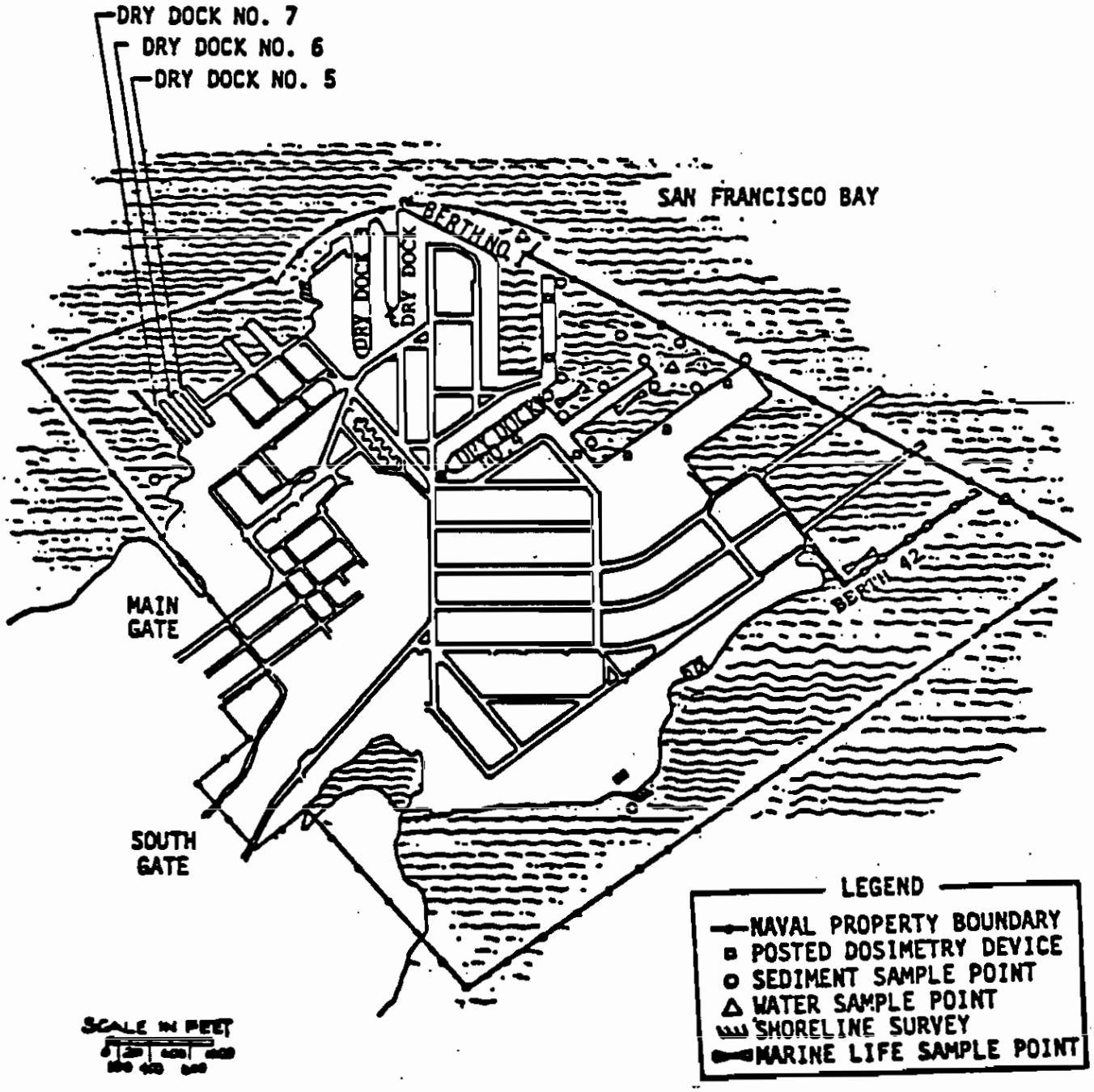


FIGURE 3
ENVIRONMENTAL MONITORING LOCATIONS AT
MARE ISLAND NAVAL SHIPYARD, VALLEJO, CA

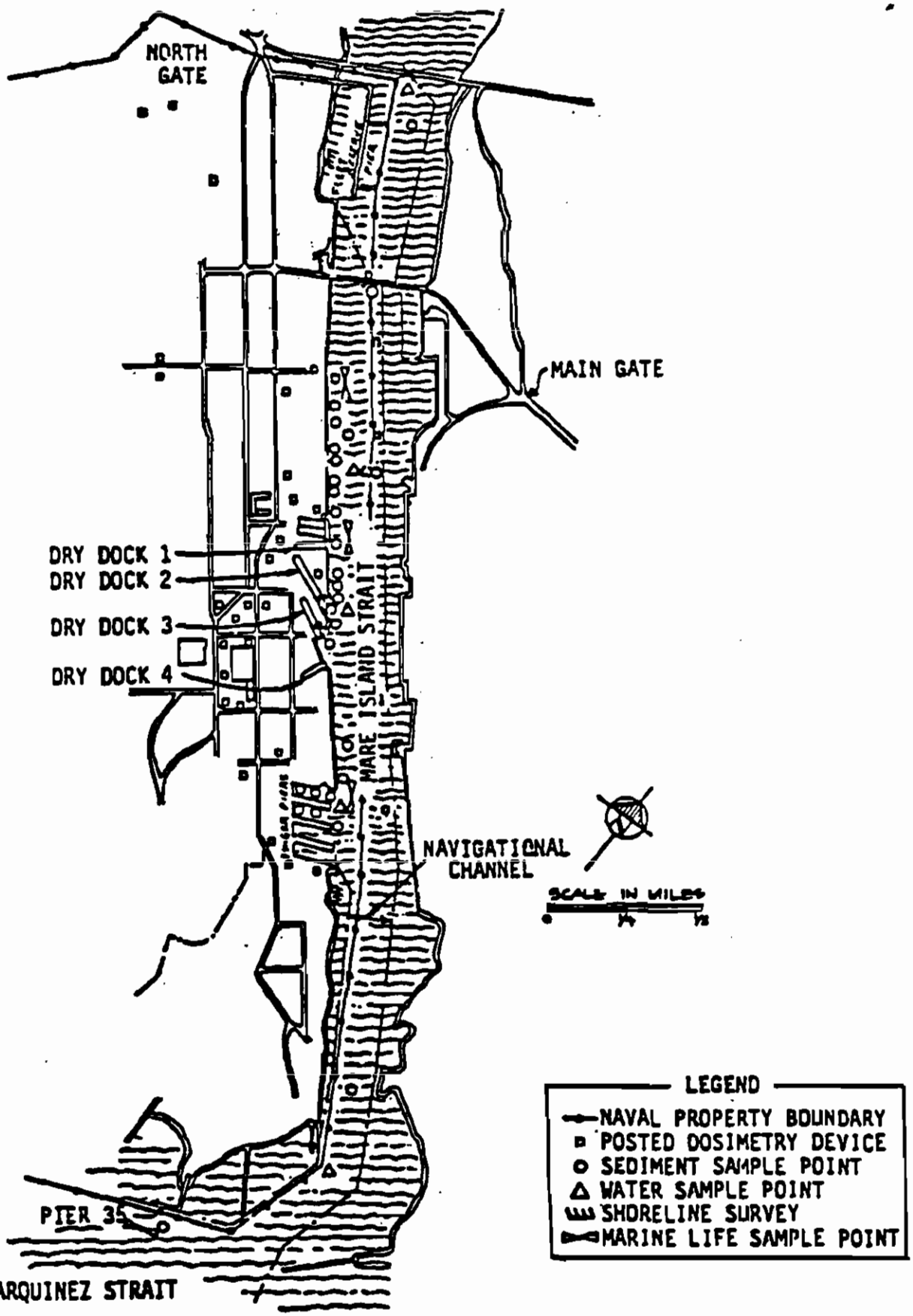
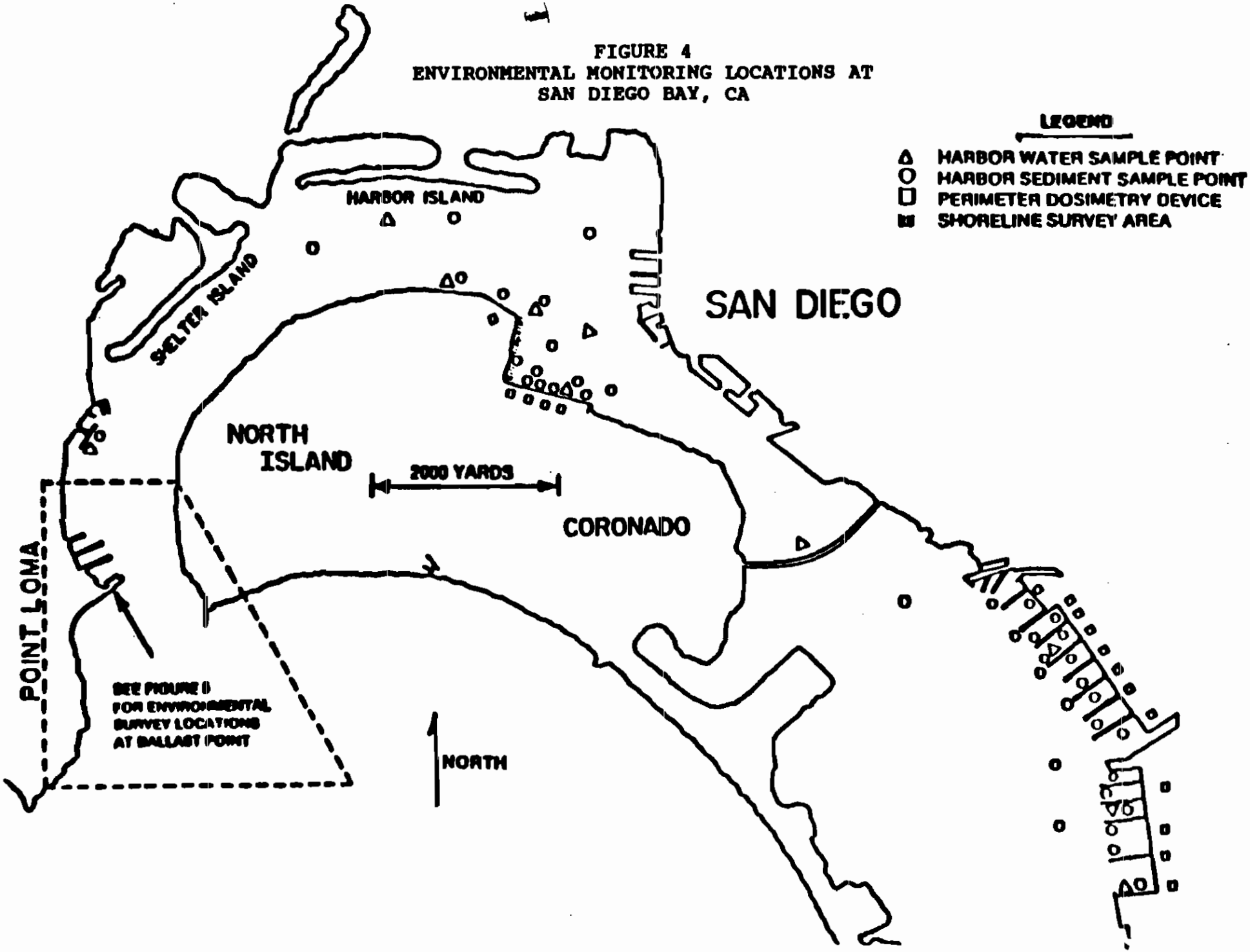


FIGURE 4
ENVIRONMENTAL MONITORING LOCATIONS AT
SAN DIEGO BAY, CA



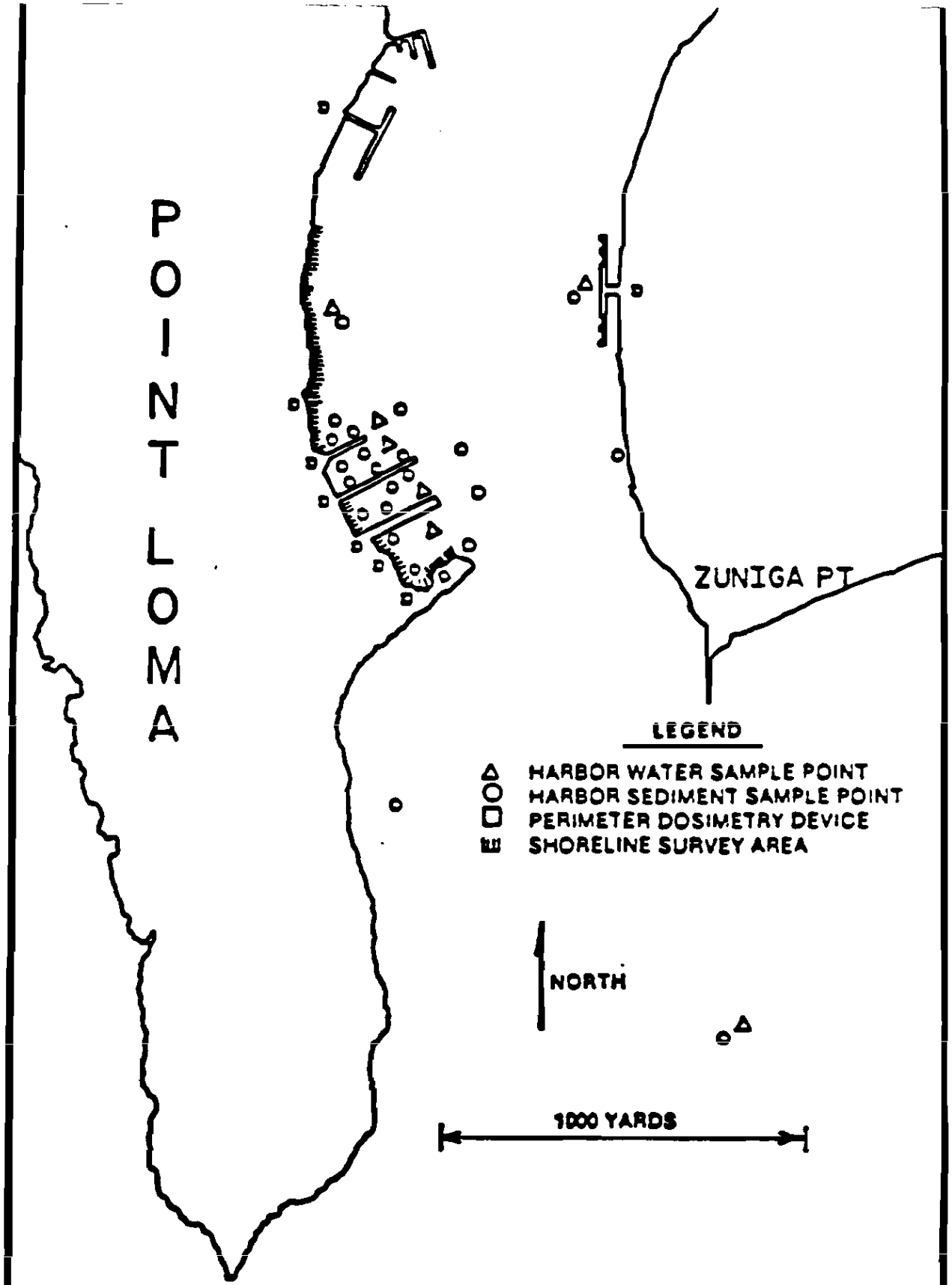
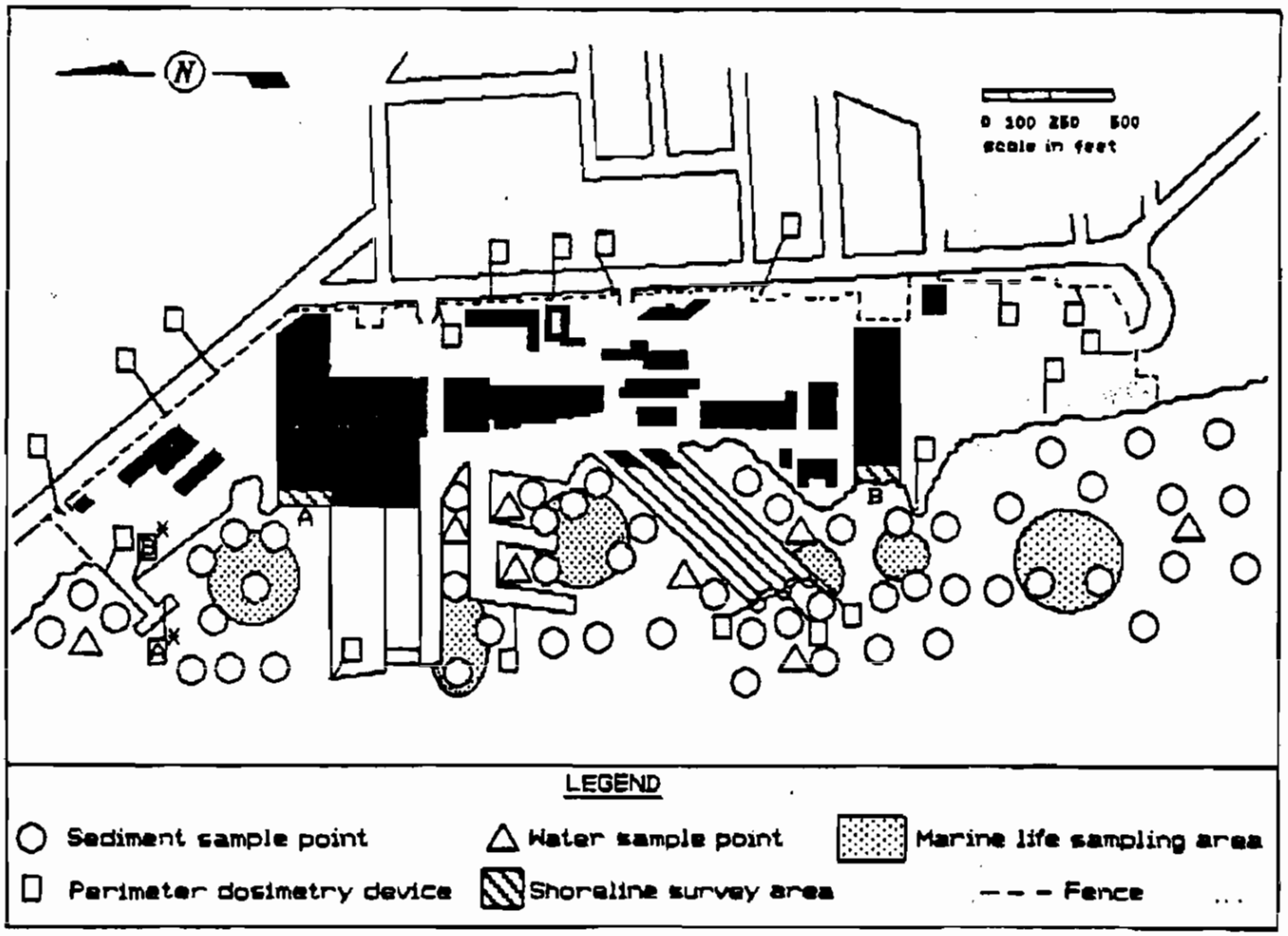


FIGURE 5
ENVIRONMENTAL MONITORING LOCATIONS AT
SAN DIEGO BAY - BALLAST POINT, CA

FIGURE 6
ENVIRONMENTAL MONITORING LOCATIONS AT
GENERAL DYNAMICS/ELECTRIC BOAT DIVISION SHIPYARD, GROTON, CT



* Location A was posted for the first and second quarters of 1994.

* Location B was posted for the third and fourth quarters of 1994.

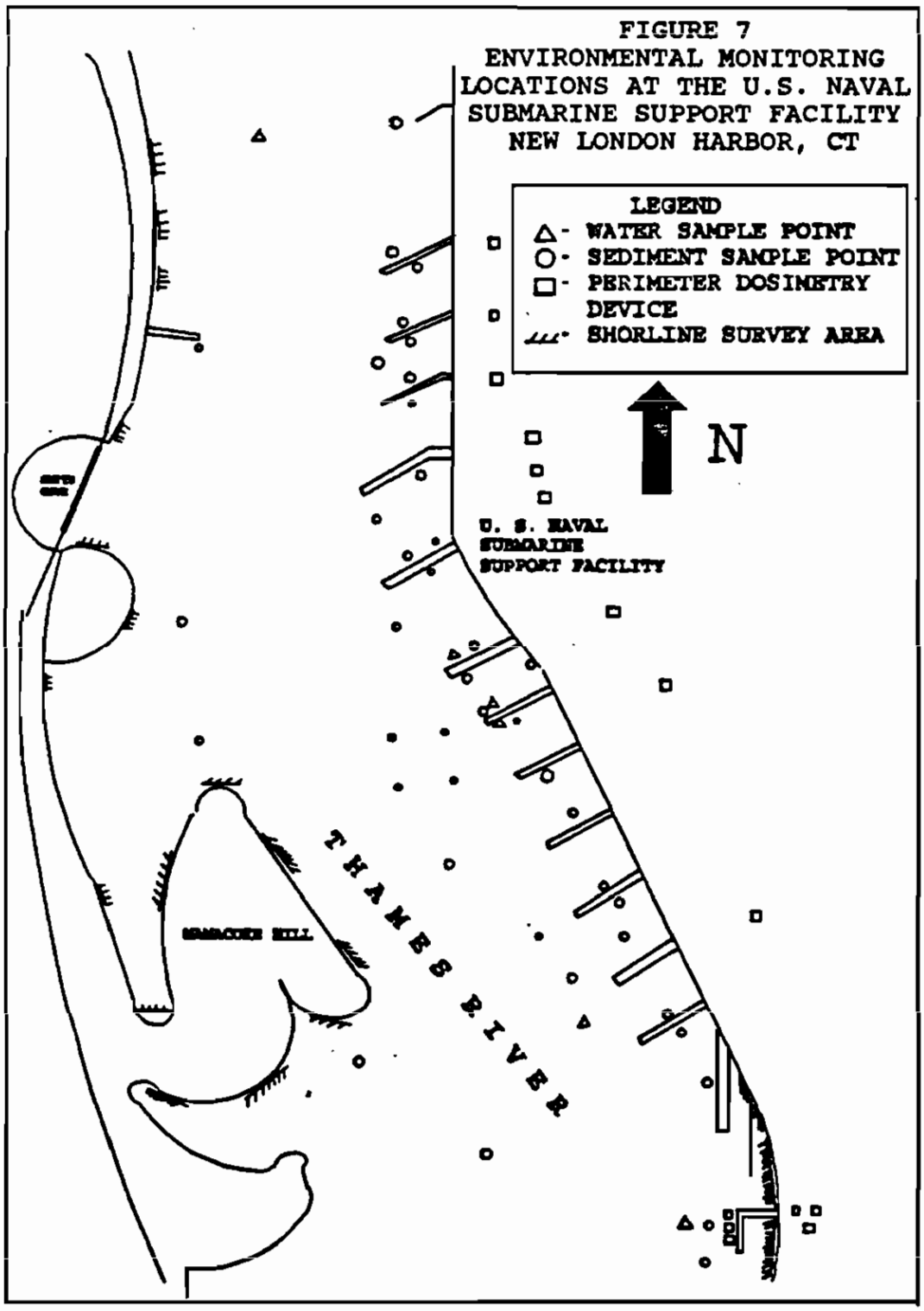


FIGURE 7
ENVIRONMENTAL MONITORING LOCATIONS AT THE U.S. NAVAL SUBMARINE SUPPORT FACILITY NEW LONDON HARBOR, CT

FIGURE 8
ENVIRONMENTAL MONITORING LOCATIONS AT
STATE PIER AREA, NEW LONDON, CT

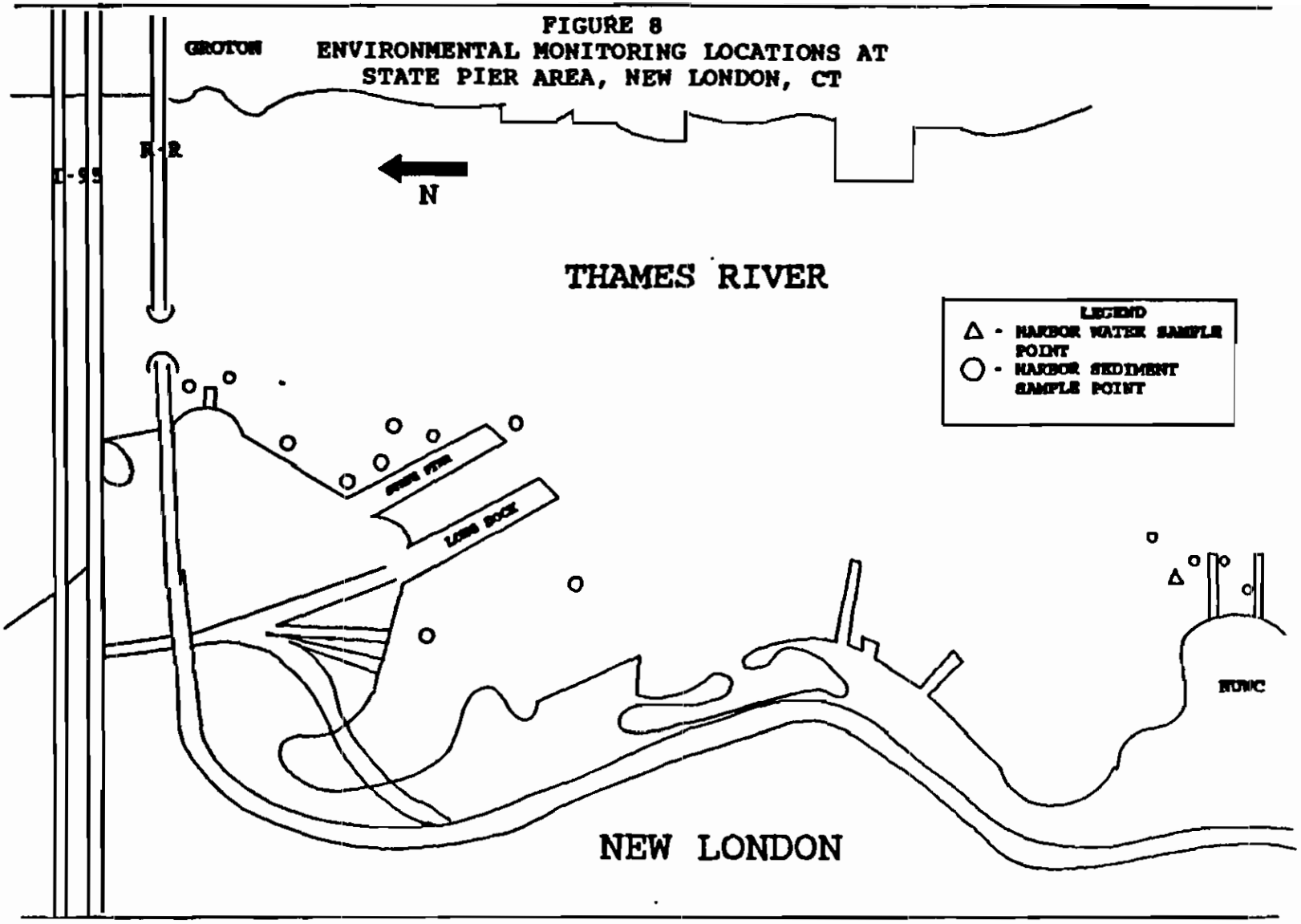


FIGURE 9
ENVIRONMENTAL MONITORING LOCATIONS AT
PORT CANAVERAL, FL

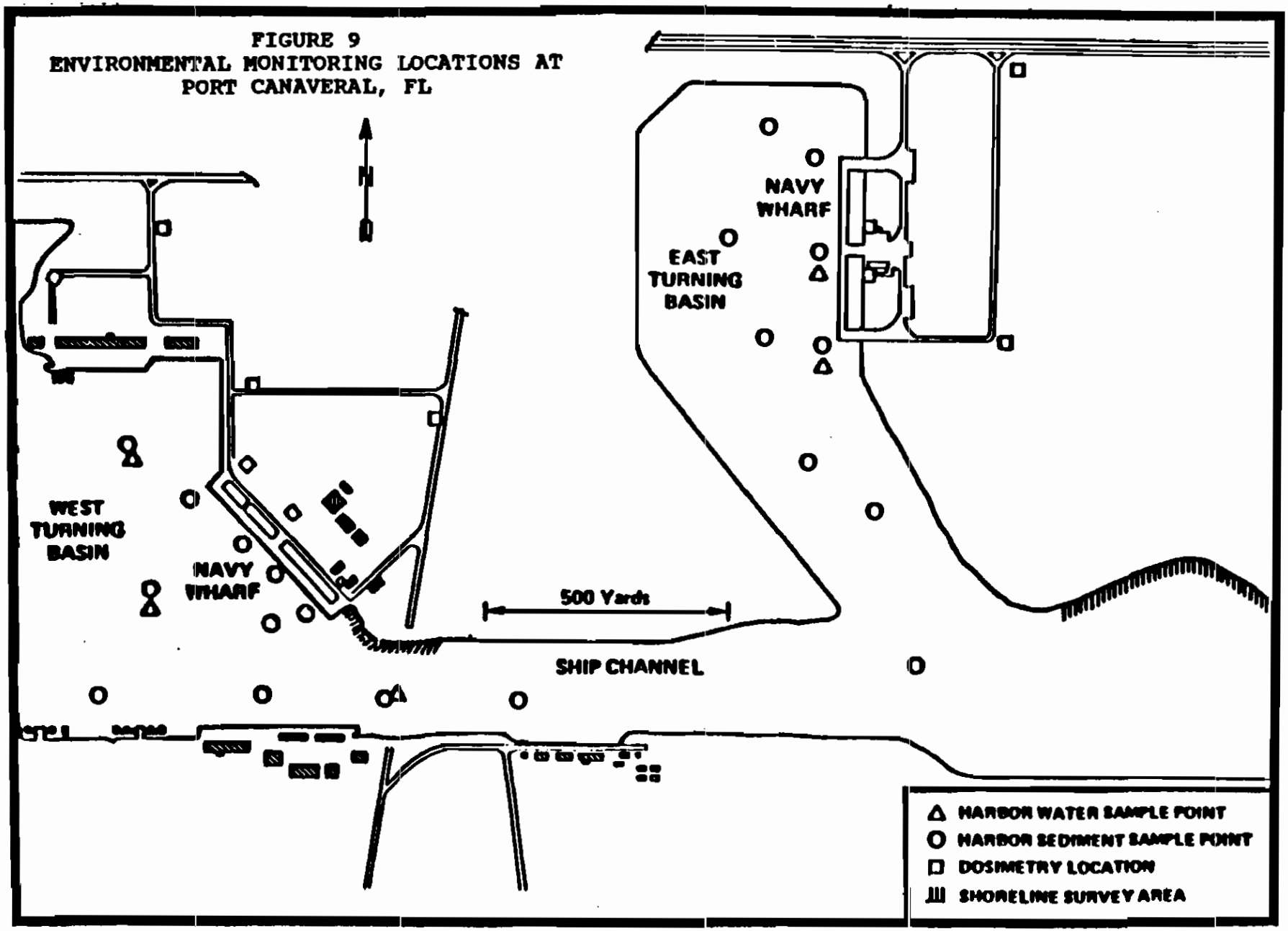
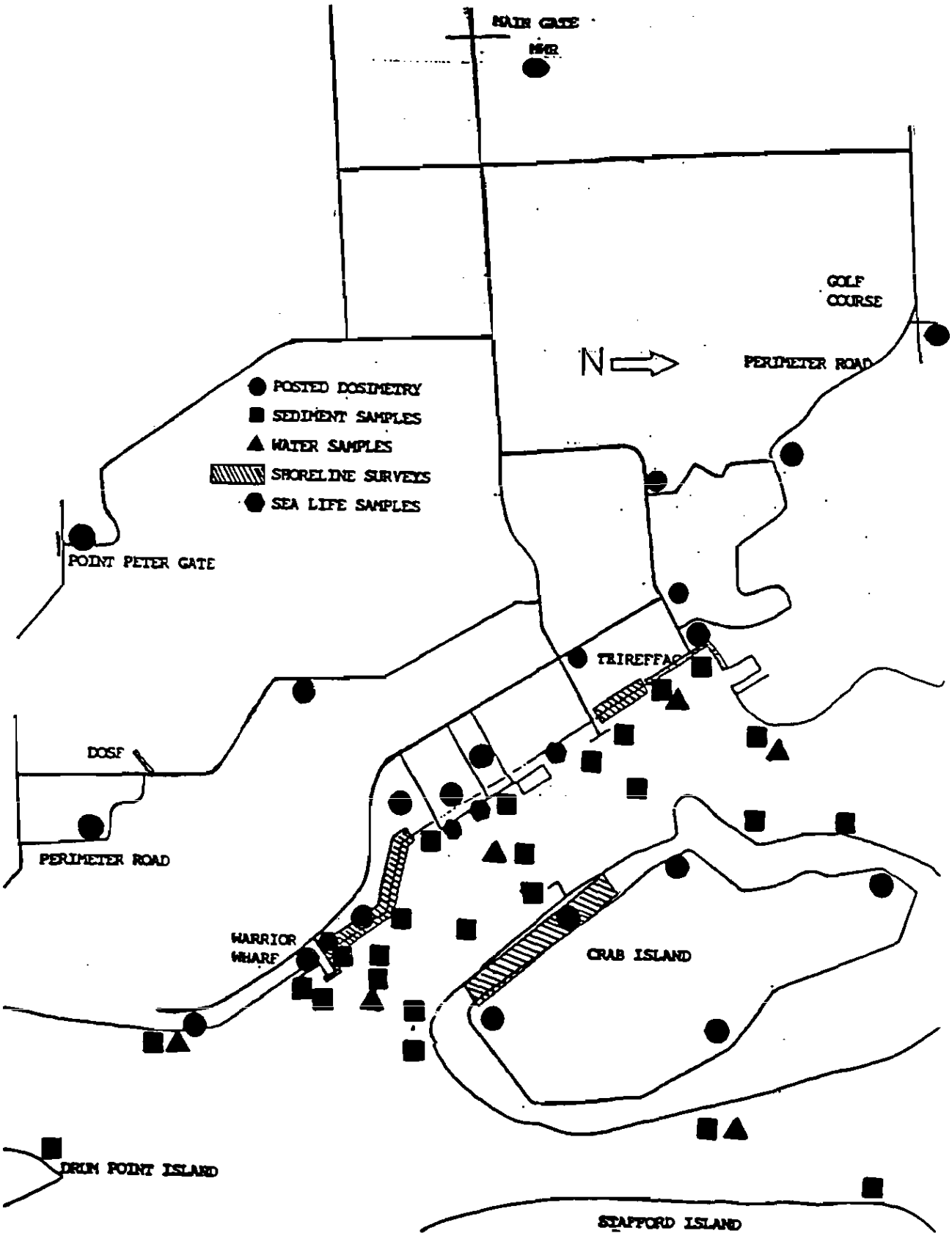


FIGURE 10
ENVIRONMENTAL MONITORING LOCATIONS AT
U.S. NAVAL SUBMARINE BASE, KINGS BAY, GA



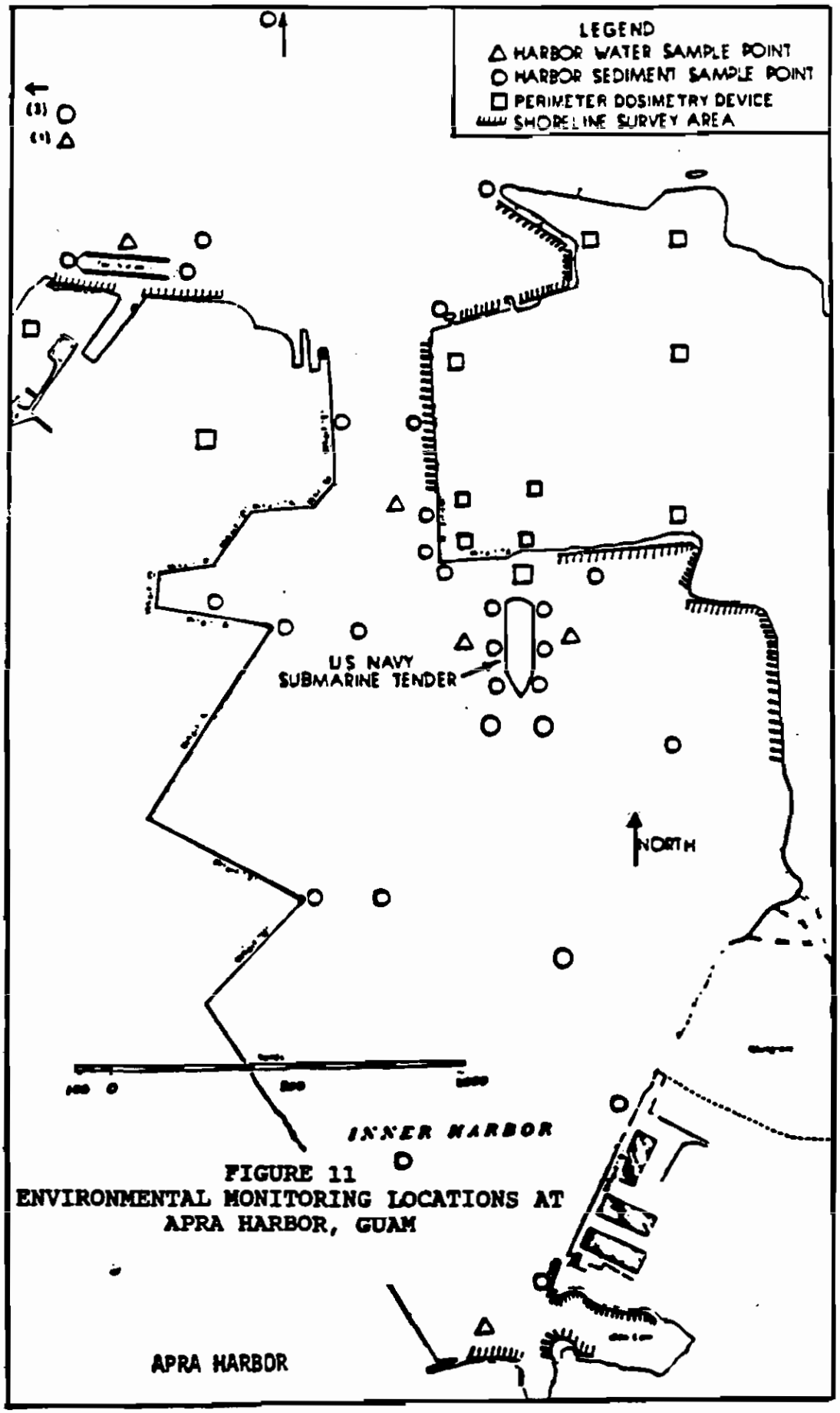


FIGURE 11
ENVIRONMENTAL MONITORING LOCATIONS AT
APRA HARBOR, GUAM

FIGURE 12
ENVIRONMENTAL MONITORING LOCATIONS AT
PEARL HARBOR AREAS, HI

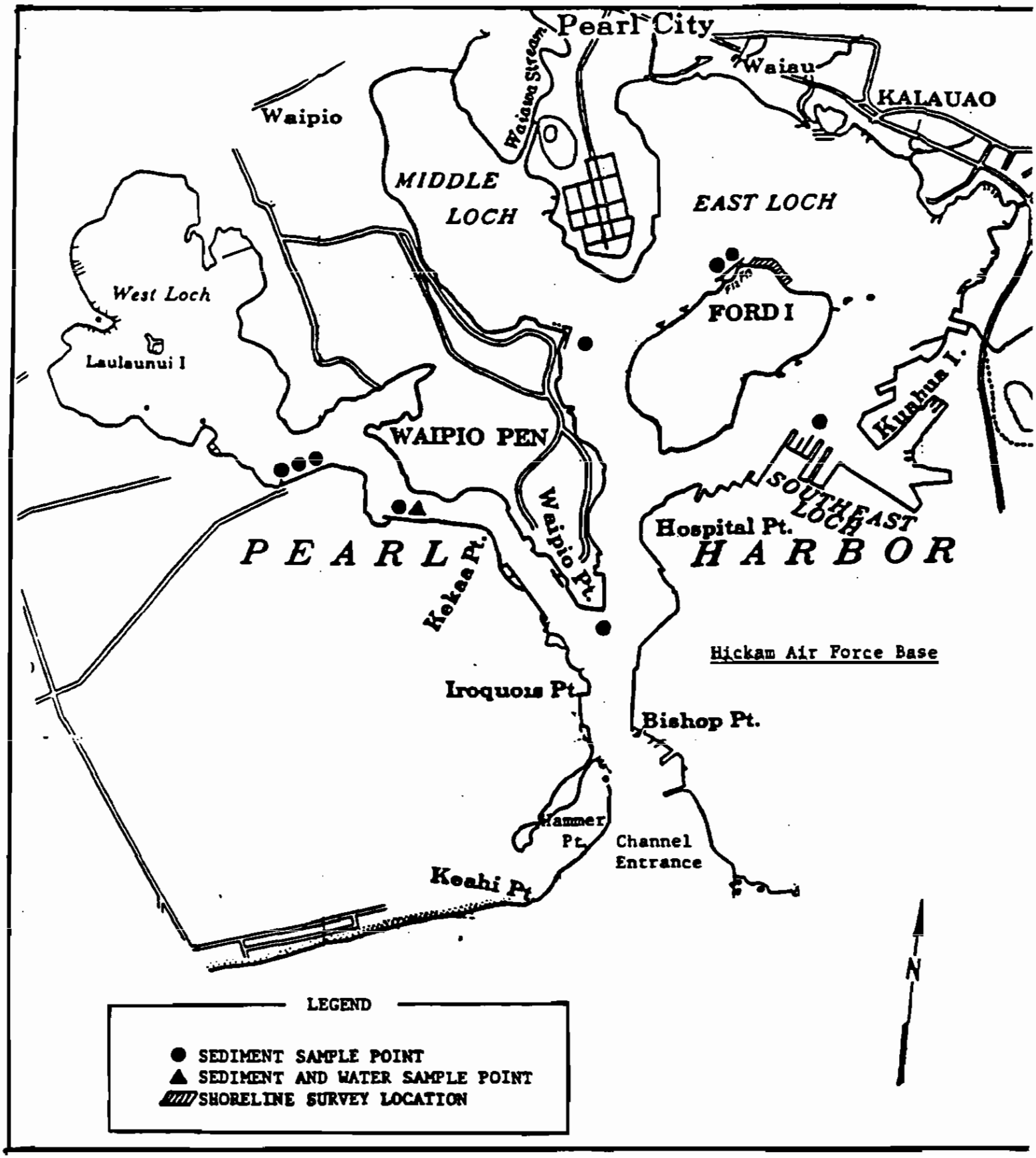
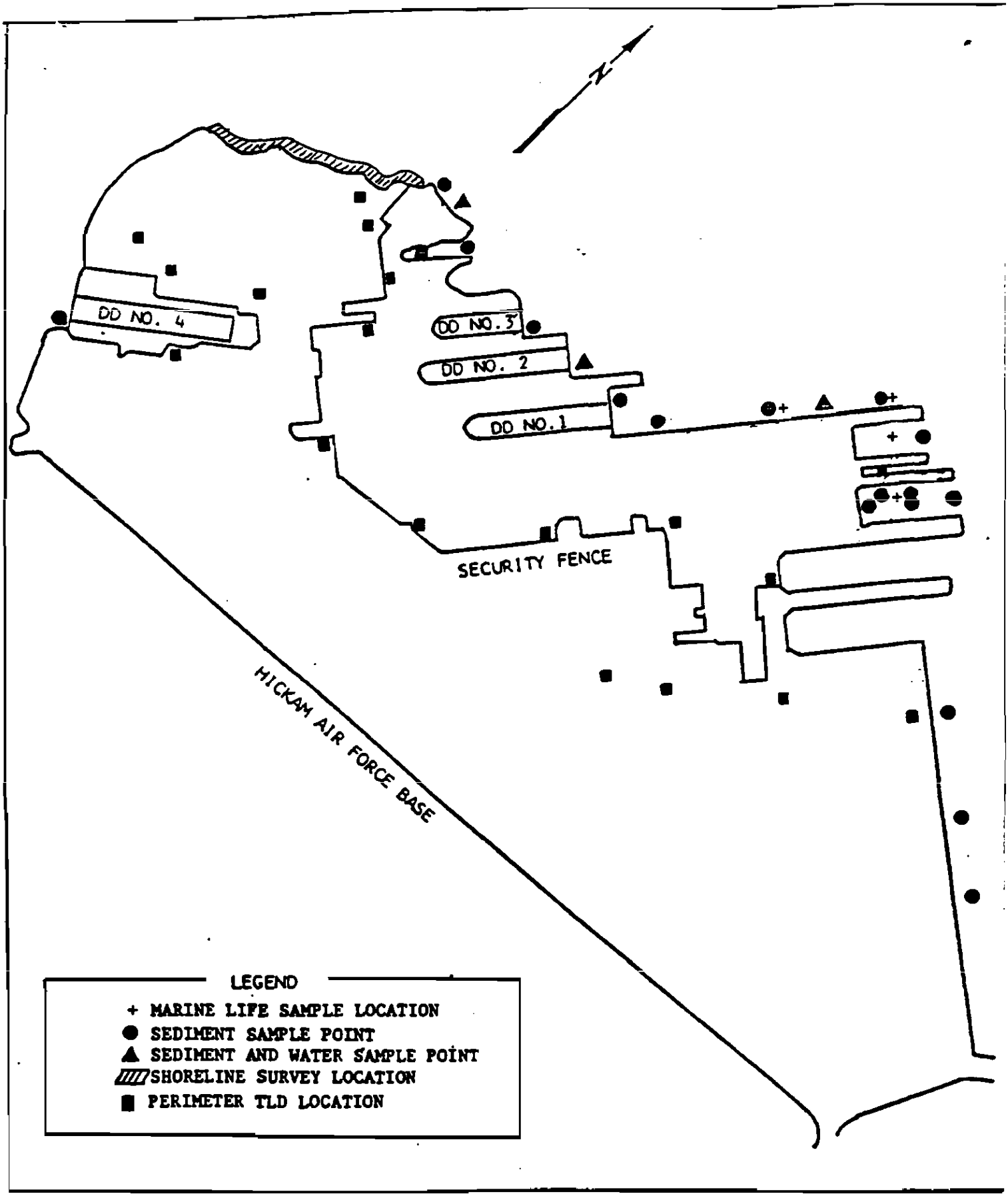


FIGURE 13
ENVIRONMENTAL MONITORING LOCATIONS AT
PEARL HARBOR NAVAL SHIPYARD, PEARL HARBOR, HI



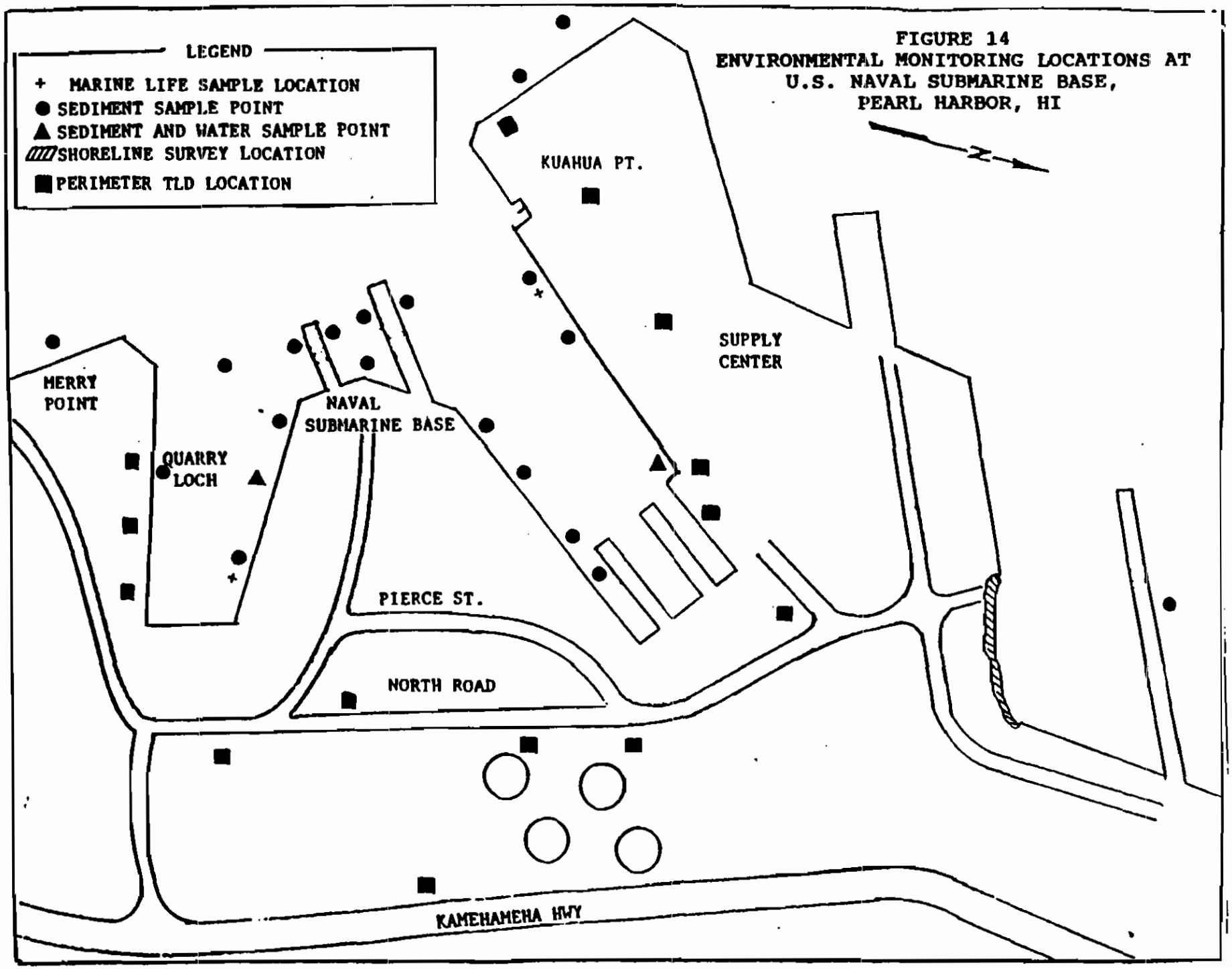


FIGURE 14
ENVIRONMENTAL MONITORING LOCATIONS AT
U.S. NAVAL SUBMARINE BASE,
PEARL HARBOR, HI

FIGURE 15
ENVIRONMENTAL MONITORING LOCATIONS AT
PORTSMOUTH NAVAL SHIPYARD, KITTERY, ME/PORTSMOUTH, NH

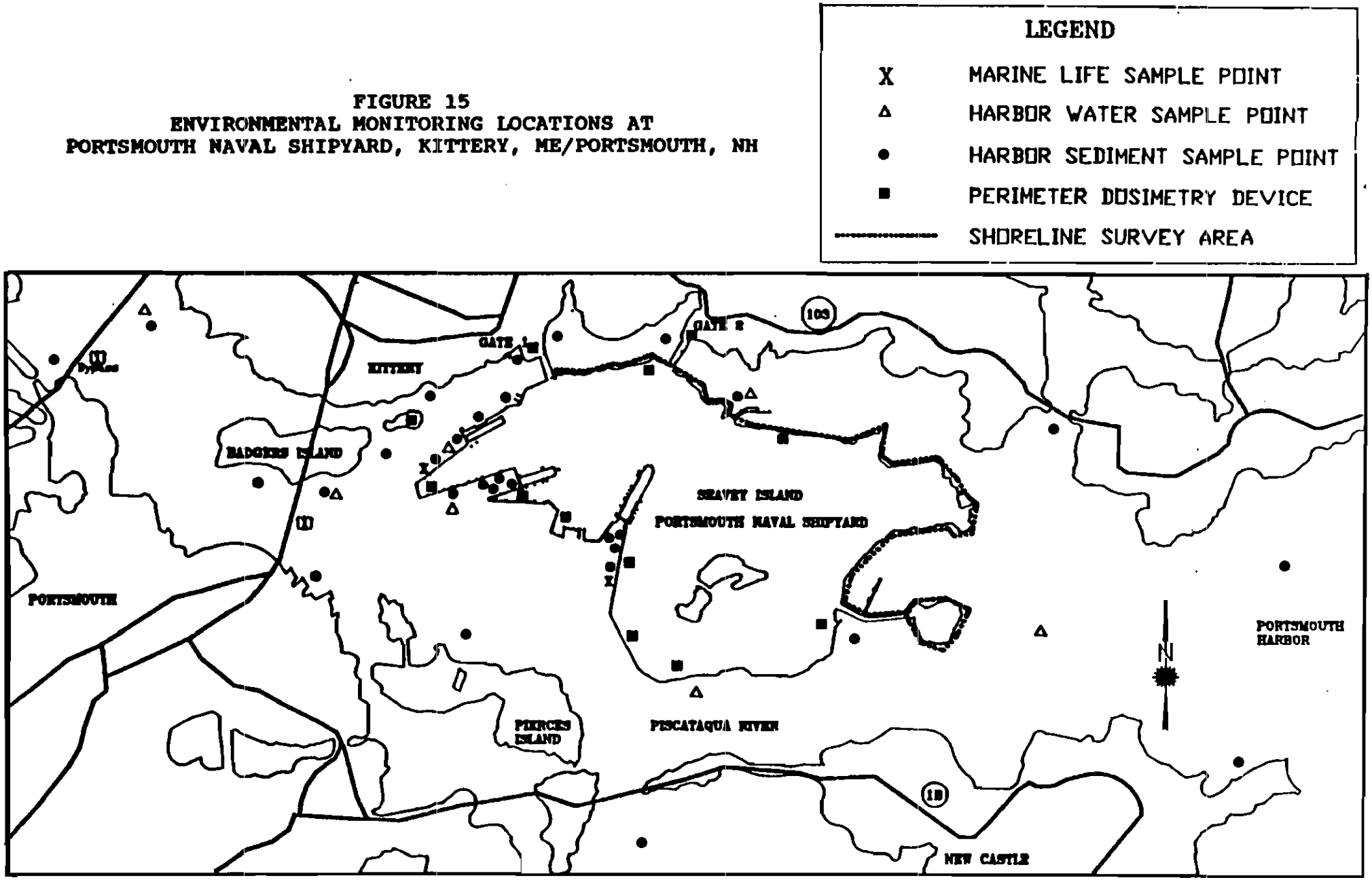


FIGURE 16
ENVIRONMENTAL MONITORING LOCATIONS AT
U.S. NAVAL BASE AND NAVAL SHIPYARD, CHARLESTON, SC

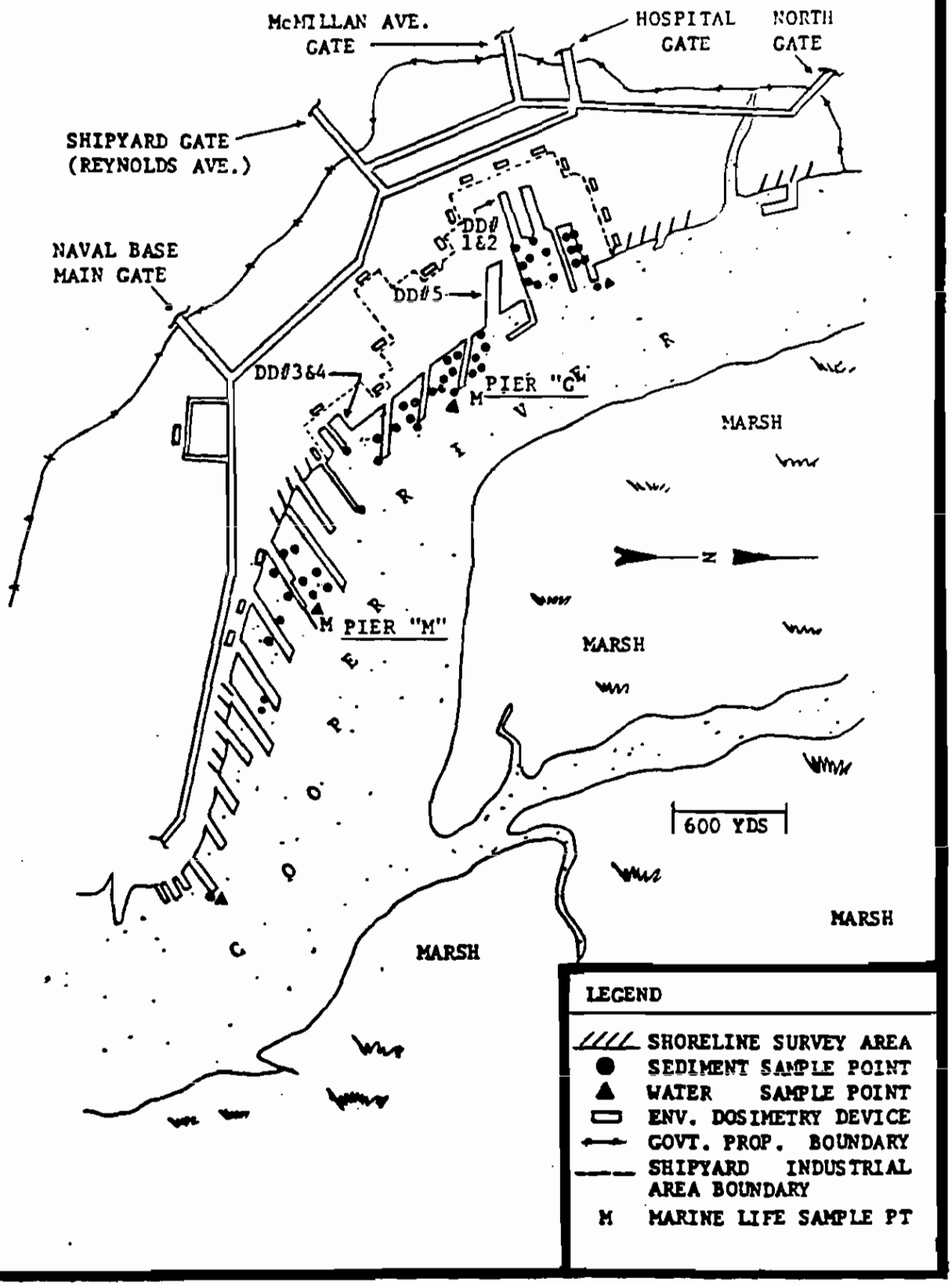


FIGURE 17
ENVIRONMENTAL MONITORING LOCATIONS AT
U.S. NAVAL WEAPONS STATION, CHARLESTON, SC

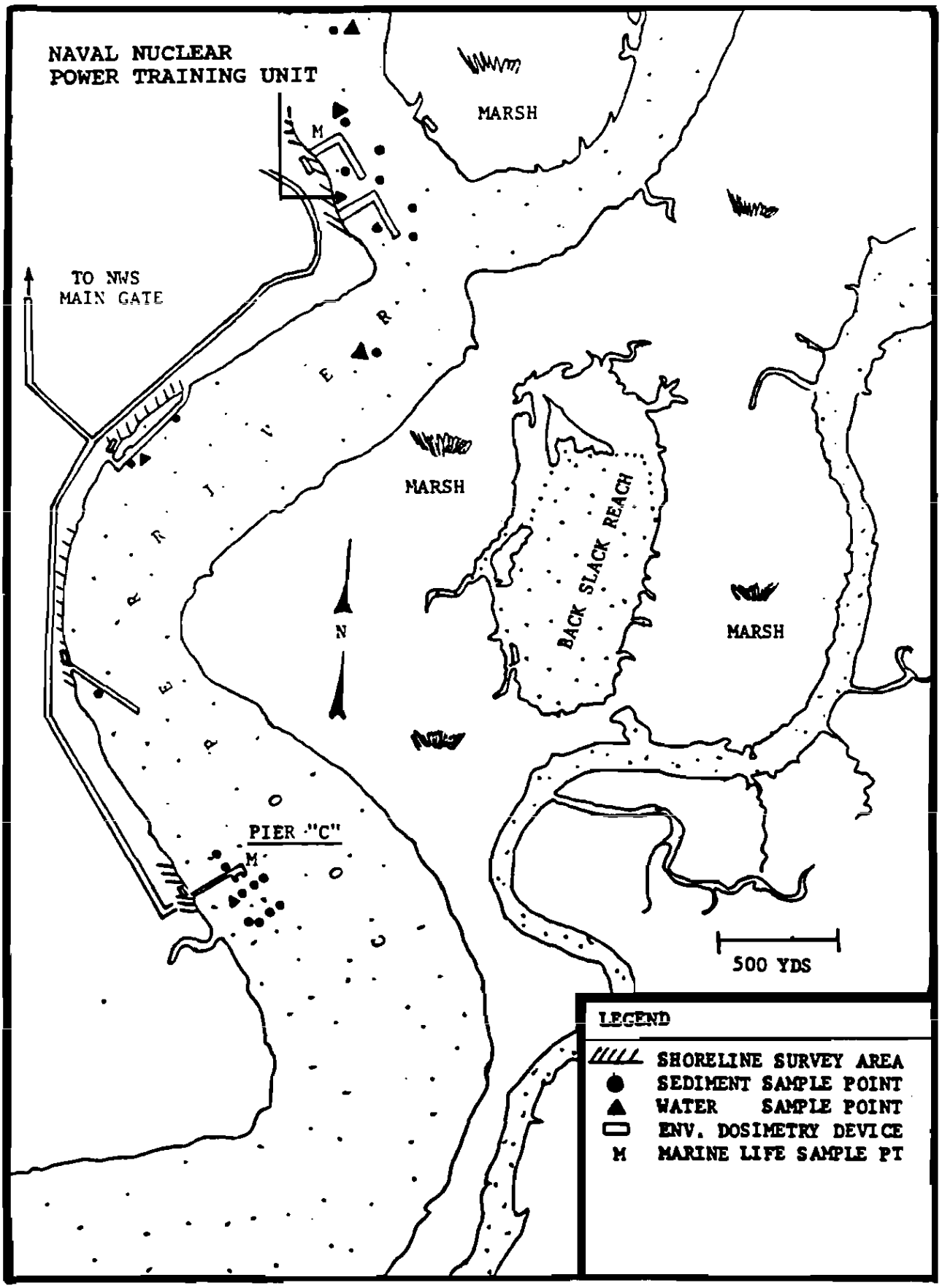


FIGURE 18
ENVIRONMENTAL MONITORING LOCATIONS AT
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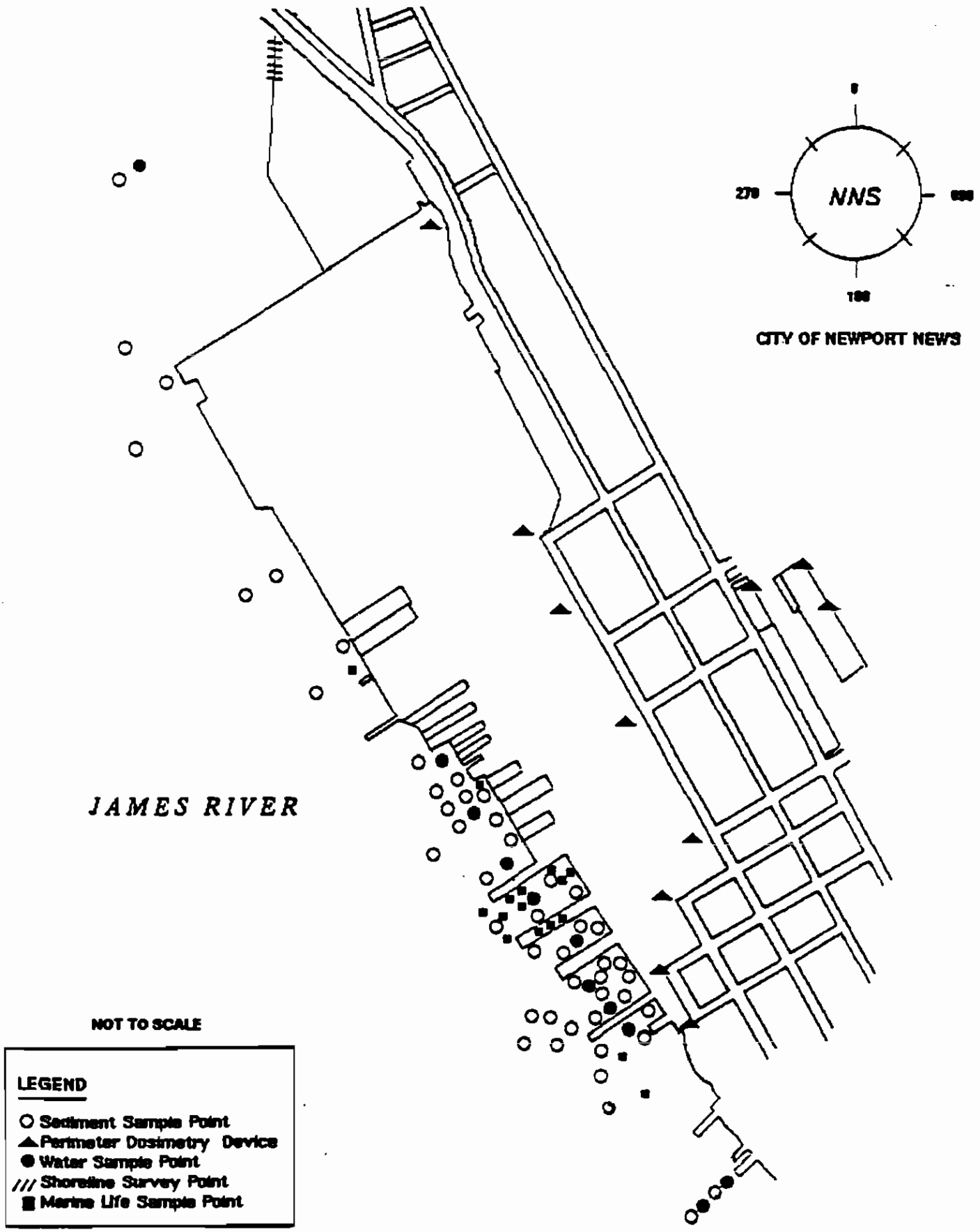

FIGURE 19
ENVIRONMENTAL MONITORING LOCATIONS AT
NORFOLK NAVAL SHIPYARD, PORTSMOUTH, VA

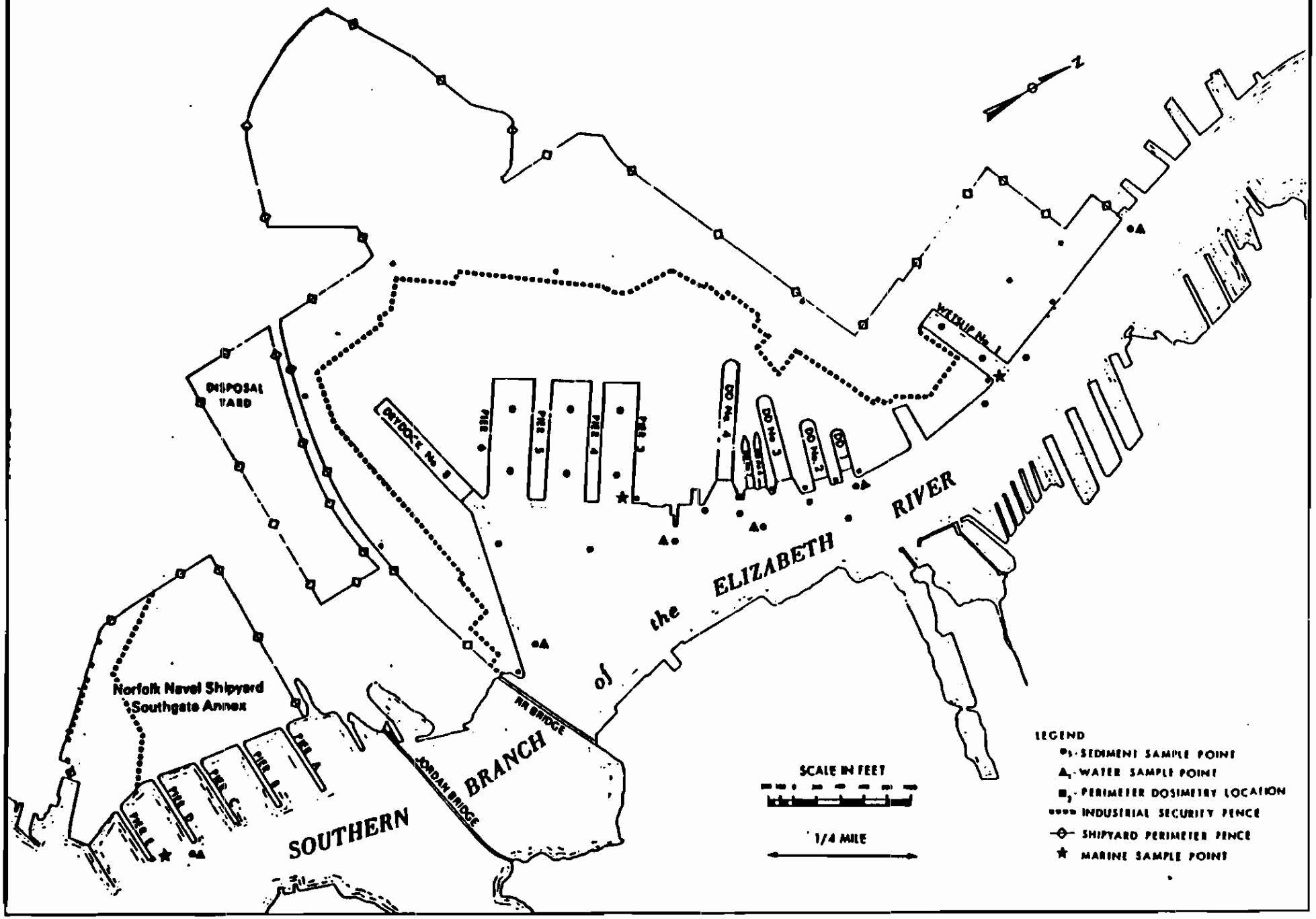

FIGURE 20
ENVIRONMENTAL MONITORING LOCATIONS AT
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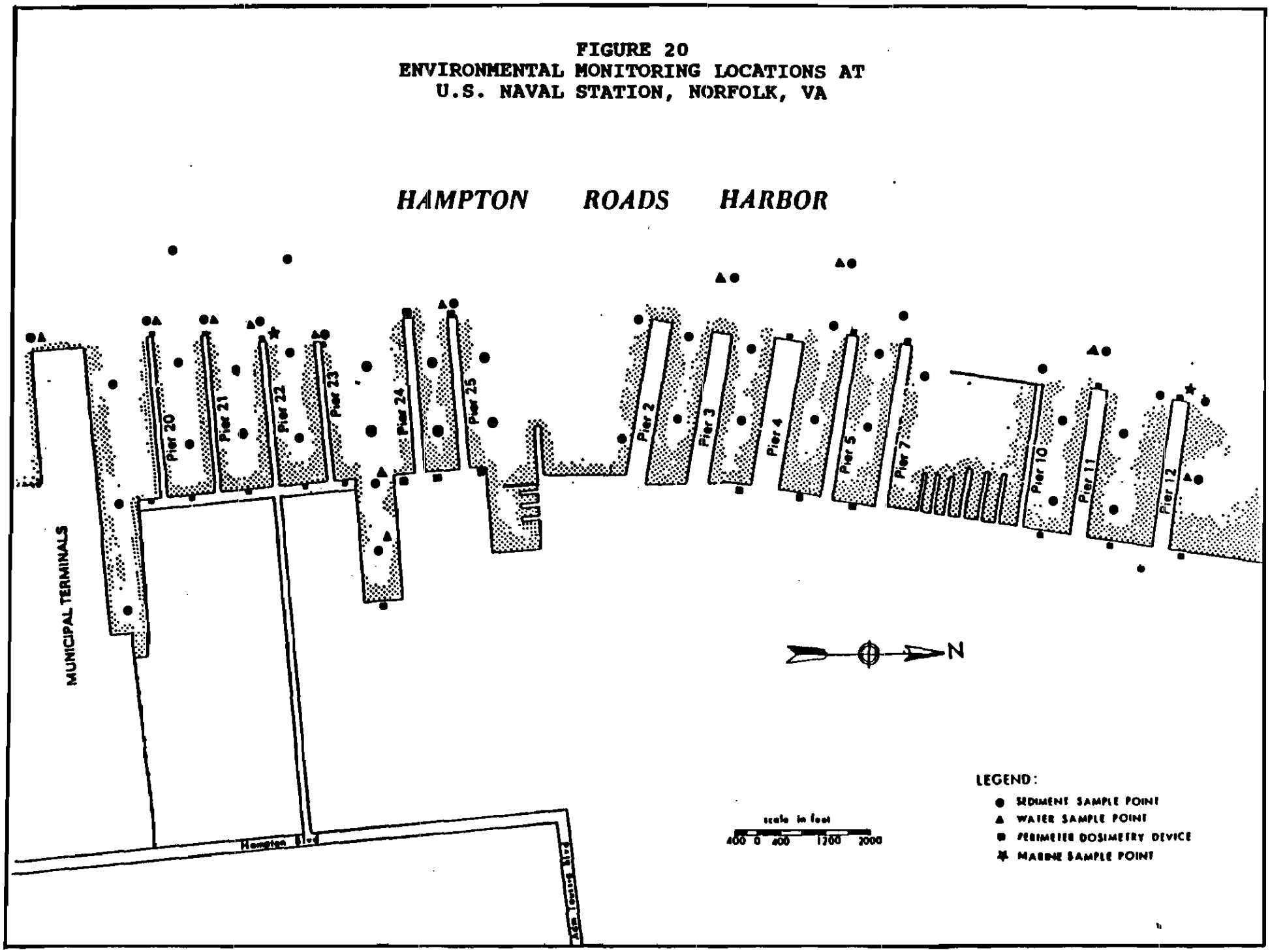

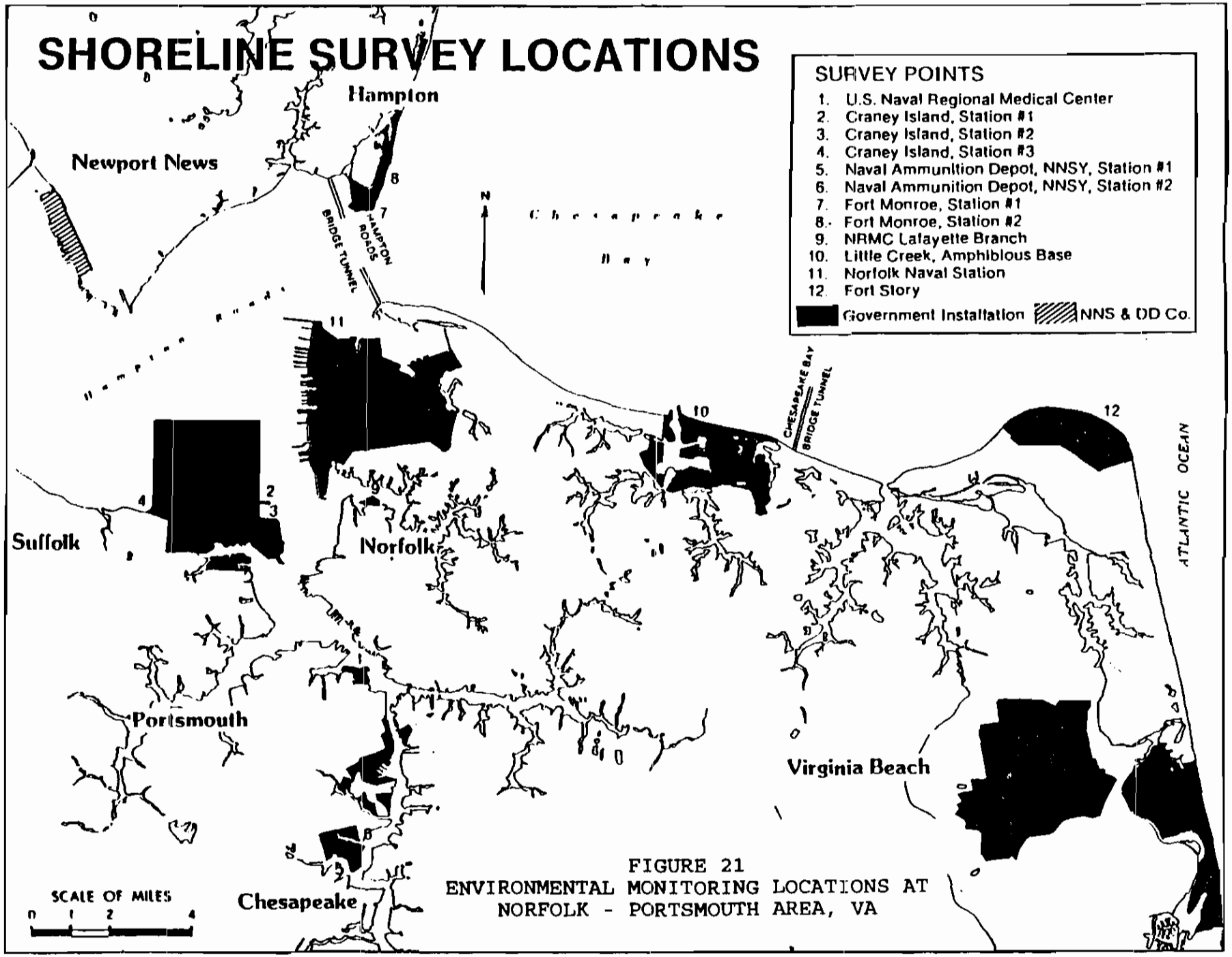

FIGURE 21
ENVIRONMENTAL MONITORING LOCATIONS AT
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NOFORN

FIGURE 22
ENVIRONMENTAL MONITORING LOCATIONS AT
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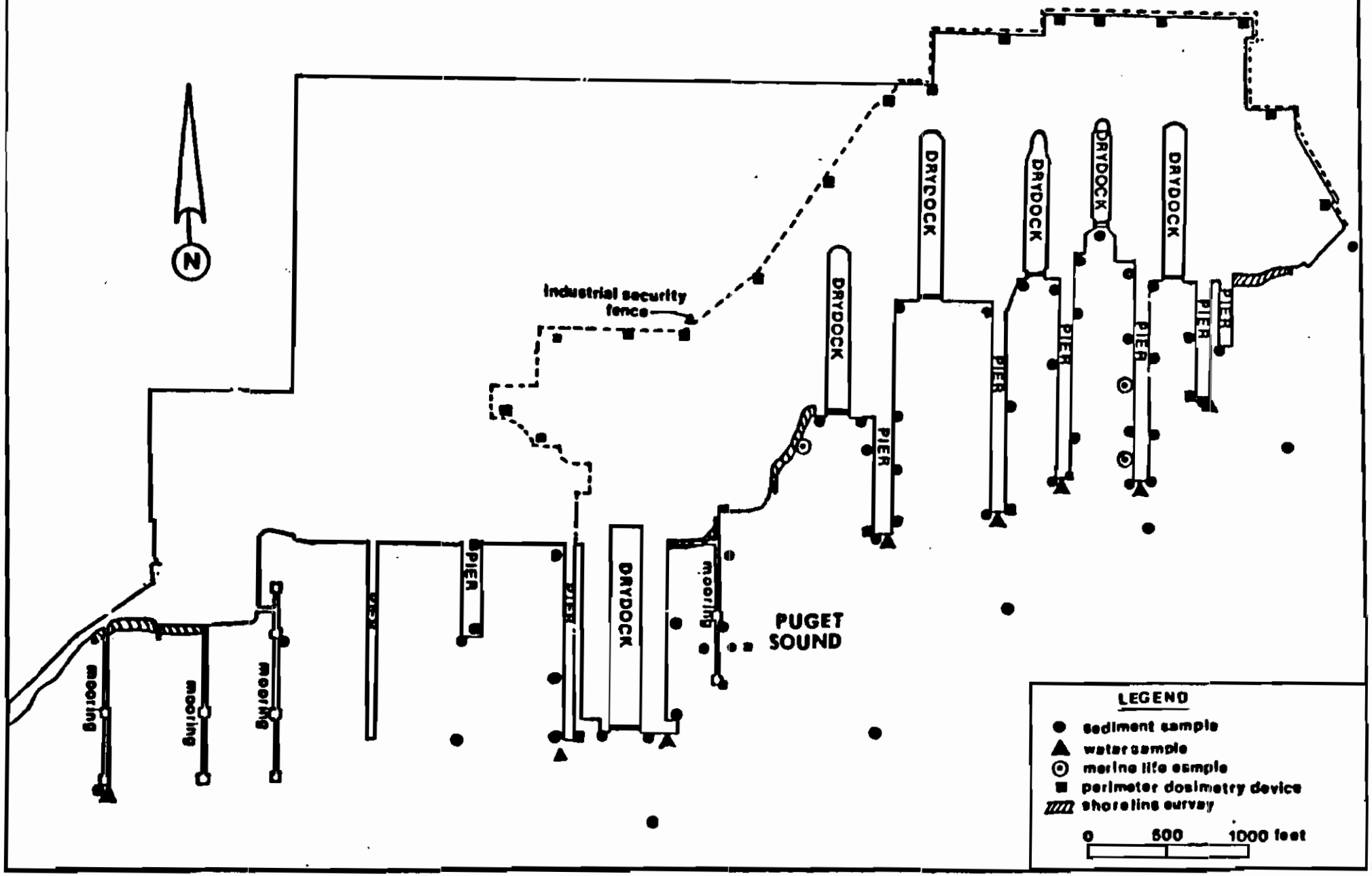

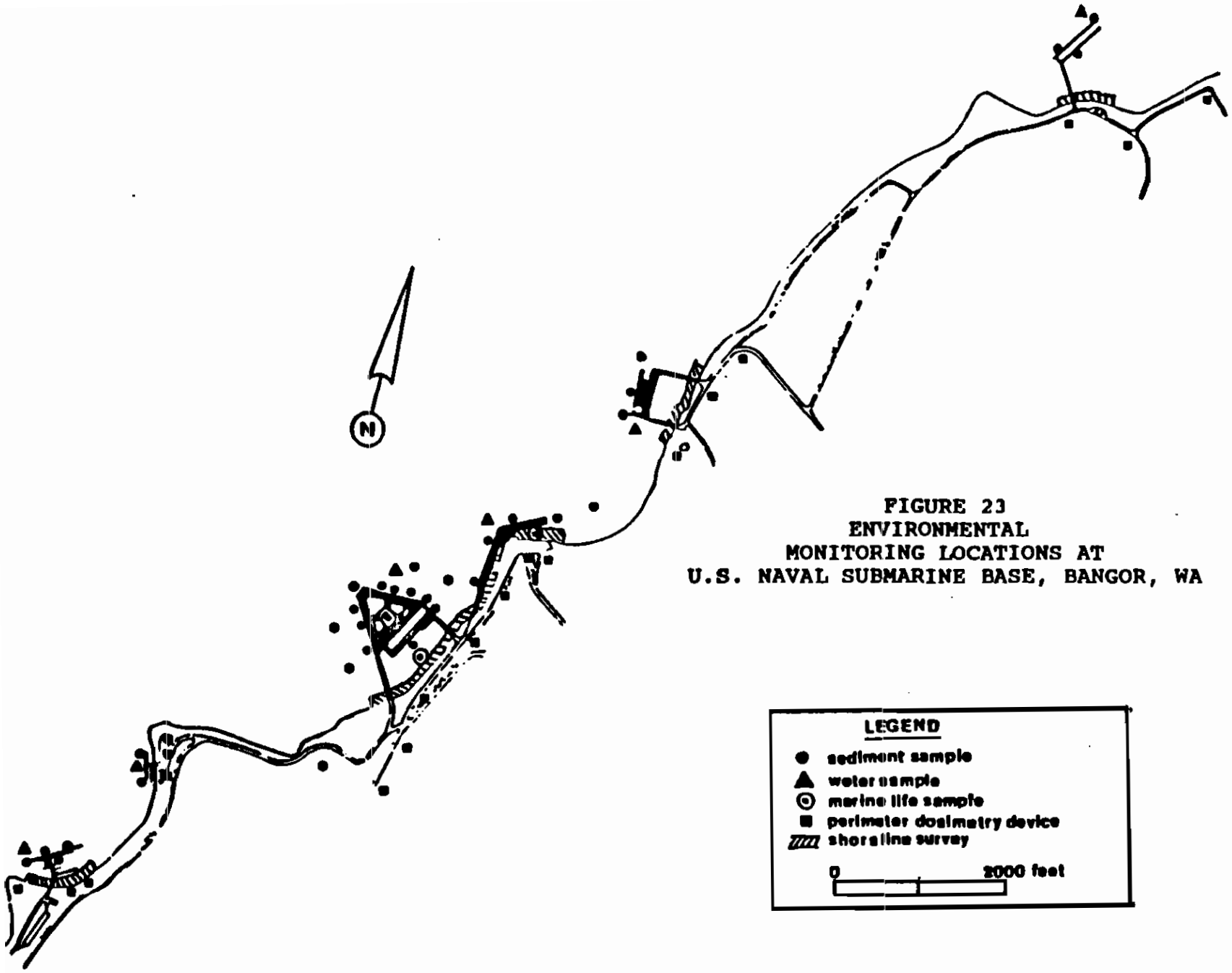

FIGURE 23
ENVIRONMENTAL
MONITORING LOCATIONS AT
U.S. NAVAL SUBMARINE BASE, BANGOR, WA

E. National Bureau of Standards Handbook 52, "Maximum Permissible Amounts of Radioisotopes in the Human Body and Maximum Permissible Concentrations in Air and Water," (NCRP Report No. 11) 1953.

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MAXIMUM PERMISSIBLE AMOUNTS OF RADIOISOTOPES IN THE HUMAN BODY AND MAXIMUM PERMISSIBLE CONCENTRATIONS IN AIR AND WATER

Handbook 52

Obsolete. See Handbook 69

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LABORATORY

U. S. Department of Commerce
National Bureau of Standards

U. S. Department of Commerce Sinclair Weeks, Secretary
National Bureau of Standards A. V. Astin, Director

Maximum Permissible Amounts of Radioisotopes in the Human Body and Maximum Permissible Concentrations in Air and Water

National Bureau of Standards Handbook 52
Issued March 20, 1953

For sale by the Superintendent of Documents, Washington 25, D. C. - Price 20 cents

Preface

The Advisory Committee on X-ray and Radium Protection was formed in 1929 upon the recommendation of the International Commission on Radiological Protection, under the sponsorship of the National Bureau of Standards and with the cooperation of the leading radiological organizations. The small committee functioned effectively until the advent of atomic energy, which introduced a large number of new and serious problems in the field of radiation protection.

At a meeting of this committee in December 1946, the representatives of the various participating organizations agreed that the problems in radiation protection had become so manifold that the committee should enlarge its scope and membership and should appropriately change its title to be more inclusive. Accordingly, at that time the name of the committee was changed to the National Committee on Radiation Protection. At the same time, the number of participating organizations was increased and the total membership considerably enlarged. In order to distribute the work load, nine working subcommittees have been established, as listed below. Each of these subcommittees is charged with the responsibility of preparing protection recommendations in its particular field. The reports of the subcommittees are approved by the main committee before publication.

The following parent organizations and individuals comprise the main committee:

American Medical Association: H. B. Williams.
American Radium Society: E. H. Quimby and J. E. Wirth.
American Roentgen Ray Society: R. R. Newell and J. L. Weatherwax.
National Bureau of Standards: L. S. Taylor, Chairman.
National Electrical Manufacturers Association: E. Dale Trout.
Radiological Society of North America: G. Failla and R. S. Stone.
U. S. Air Force: G. L. Hekhuis, Maj.
U. S. Army: T. F. Cook, Lt. Col.
U. S. Atomic Energy Commission: K. Z. Morgan and Shields Warren.
U. S. Navy: C. F. Behrens, Rear Adm.
U. S. Public Health Service: H. L. Andrews and E. G. Williams.

The following are the subcommittees and their chairmen:

Subcommittee 1. Permissible Dose from External Sources, G. Failla.
Subcommittee 2. Permissible Internal Dose, K. Z. Morgan.
Subcommittee 3. X-rays up to Two Million Volts, H. O. Wyckoff.
Subcommittee 4. Heavy Particles (Neutrons, Protons, and Heavier), D. Cowie.
Subcommittee 5. Electrons, Gamma Rays, and X-rays above Two Million Volts, H. W. Koch.
Subcommittee 6. Handling of Radioactive Isotopes and Fission Products, H. M. Parker.
Subcommittee 7. Monitoring Methods and Instruments, H. L. Andrews.
Subcommittee 8. Waste Disposal and Decontamination, J. H. Jensen.
Subcommittee 9. Protection Against Radiations from Radium, Cobalt-60, and Cesium-137 Encapsulated Sources.

With the increasing use of radioactive isotopes by industry, the medical profession, and research laboratories, it is essential that certain minimal precautions be taken to protect the users and the public. The recommendations contained in this Handbook represent what is believed to be the best available opinions on the subject as of this date. As our experience with radioisotopes broadens, we will undoubtedly be able to improve and strengthen the recommendations given in this report. In the meantime comments and suggestions will be welcomed by the committee.

One of the greatest difficulties encountered in the preparation of this Handbook lay in the interpretation of existing biological data dealing with the uptake and retention of radioactive materials by the body. Many variables are present in each experiment, and major discrepancies occur frequently between even the most reliable researches. A tremendous effort is presently being exerted to obtain a better understanding of the biological effects of radiation. In the 3 years, during which this report has been in preparation, so much progress has been made in the field that at times it has seemed almost hopeless to keep abreast of the changes. It is believed that the numerical values given in this report are such that errors, if any, will be in the direction of providing additional safety.

The present Handbook was prepared by the Subcommittee on Permissible Internal Dose. Its membership is as follows:

Karl Z. Morgan, Chairman.
A. M. Brues.
G. Failla.
J. G. Hamilton.
L. D. Marinelli.
H. M. Parker.
Charles H. Perry.
J. E. Rose.
Shields Warren.
Herman Lisco, Consultant.

A. V. Astin, *Director.*

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Maximum Permissible Amounts of Radioisotopes in the Human Body and Maximum Permissible Concentrations in Air and Water

A. Introduction

This is the first official published report of the Subcommittee on Permissible Internal Dose of the National Committee on Radiation Protection. It is the opinion of this Subcommittee that all unnecessary exposure to radioisotopes should be avoided. However, it is often impracticable, if not impossible, to prevent some radioisotopes from entering the body. Therefore, it is desirable to establish levels of maximum permissible exposure to serve as guides to safe operation and upper levels of exposure. In some cases there is considerable uncertainty about the maximum permissible values given in this report. However, because many persons are at present being exposed to certain of the radioisotopes, it is considered desirable to agree upon what are considered as safe working levels for these radioisotopes now rather than wait until more complete information is available. In this connection, it is well to bear in mind that persons may be exposed to radioisotopes for an indefinite period of time, perhaps a lifetime. [1] Because, in general, it is impossible to predict at the start how long a person will be exposed, permissible limits must be set on the assumption that the occupational exposure will continue throughout the working life of the individual and environmental exposures will continue for a lifetime. The values given in this report have been derived on the basis of continuous exposures for a lifetime [1] or for the equilibrium condition in which the rate of elimination has become equal to the rate of deposition in the body in all cases except for Ra^{226}, Sm^{151}, and Pu^{239}. Therefore, their use as interim values for a period of several years is fully justified. If future information indicates that these

[1] The effective half-lives of the radioisotopes considered in this report, with the exception of Ra^{226}, Sm^{151}, Pu^{239}, and Sr^{90}, are so short that the time of exposure is not critical in the calculations and the same maximum permissible concentrations in air and in water are obtained regardless of whether the exposure is for 30 years of occupational exposure, 70-years lifetime, or an infinite period.

values should be more or less conservative, they can be adjusted before anyone has been unduly inconvenienced or before damage can be expected to result. In any case, because of the uncertainties involved in the present values and in determining the actual accumulation and potential hazard of radioisotopes in the human body, it is strongly recommended that exposure be kept at a minimum insofar as it is practicable. Bearing in mind that in the future it may become necessary to lower some permissible limits, it is suggested that a factor of safety that may be as large as ten be used in the design and operation of permanent installations where large quantities of radioactive material are involved. This is particularly important in cases in which provision of additional protection later would be very difficult and expensive.

The values of maximum permissible amounts of the various radioisotopes in the human body and of the maximum permissible concentrations of these radioisotopes in air and water as given in this report are chosen by this Subcommittee as the most acceptable values after considering a preliminary report to the Committee (giving values recommended by various radiation protection committees, as listed under section F of this report) and after making comparisons with values calculated by use of the data summarized in table 4. This report considers only a few radioisotopes, and particularly those that are of present-day interest. Other radioisotopes will be considered in subsequent reports when such information about them is needed and as data become available to serve as a basis of acceptance of safe recommended values. Likewise, values given in this report must be revised from time to time as more biological information is obtained.

Efforts should be made to prevent the accumulation of dangerous quantities of radioisotopes in the body. Radioisotopes may enter the body by way of food and water, in the air we breathe, through wounds and abrasions, and through pores of the skin. The physical state (liquid, solid, or gas) and the chemical form of the radioisotope help determine the type of radiation hazard and to some extent the degree of retention in the body and magnitude of hazard. Other important factors that determine the radiation hazard are the quantities of radioactive material involved, the facilities and equipment available for handling radioisotopes, the training and experience of those working with the radioactive material, and the respect they have for appropriate radiation protection standards and procedures.

B. Radioisotopes More Hazardous Inside the Body Than Outside

Radioisotopes when contained inside the body present greater hazards than when they are limited to external sources, for the following reasons:

1. They irradiate the body continuously until they are eliminated.
2. The biological half-life is very long for some radioisotopes, and in most cases it is difficult, if not impossible, to increase appreciably the elimination rate from the body.
3. Sources inside the body are in intimate contact with the body tissue. This enables alpha and low-energy beta radiation (which, because of limited range, do not present an external hazard) to reach radiosensitive tissue inside the body and to dissipate all their energy in a small volume of tissue inside a critical body organ.
4. It is very difficult to measure the amount and distribution of a radioisotope in the body, and even if such information is obtained, it is impossible to assess the hazard accurately. Methods of urine and fecal analysis have been developed for some radioisotopes, but most of these analyses are very tedious, time consuming, and expensive.

C. Methods of Estimating Maximum Permissible Amounts and Concentrations

There are various methods of estimating maximum permissible levels of radiation exposure, maximum permissible amounts of radioisotopes inside the body, and maximum permissible concentrations in air and water. Some of these methods are given in the following paragraphs.

1. Comparison with X-ray or γ-ray damage

We have had considerable experience for more than 50 years with these radiations, and the Subcommittee on Permissible Dose from External Sources of the National Committee on Radiation Protection has set the relative biological effectiveness (RBE) and the maximum permissible exposure to various types of radiation, as listed in table 1. The values in table 1 were accepted by the Chalk River, Canada, Conference (Sept. 29 and 30, 1949) and the International Commission on Radiological Protection meeting in London (July 1950).

TABLE 1.

Type	Relative biological effectiveness (RBE)	Maximum permissible weekly dose in the bloodforming organs *
X, γ	1	0.3 r/week.
β	1	.3 rep/week.
α	20	.015 rep/week.

* The values in this column as agreed on at the Chalk River and London Conferences apply specifically to the bloodforming organs. For the purpose of this report these values are extended to apply to all body organs but not the epidermal skin layer.

2. Comparison with radium damage

There have been many years of experience in which man could observe and study the damaging effects of X-rays and radium. The effects of external exposure to radium were observed shortly after the discovery of radium, as was also the case with X-rays;[2] and man's experience with radium fixed in the body dates back more than 25 years. The radium content of the body can be obtained by measurement of the gamma radiation from the body, by measurement of the radon exhaled from the body, and by autopsy measurements. The National Committee on Radiation Protection has set the maximum permissible amount of radium-226 in the body as 0.1 μc. The NCRP Subcommittee on Permissible Internal Dose has made the estimate that the chronic damage of Pu^{239} relative to Ra^{226} for equal energy absorbed is 2.5, and for acute exposure the damage of Po^{210} relative to Ra^{226} for equal energy absorbed is 20. Preliminary indications are that the biological effectiveness of Po^{210} relative to Ra^{226} is considerably less than 20 on the basis of chronic damage.[3] Care must be taken that comparisons with radium are made with only those elements that behave similarly in the body.

3. Comparison with background concentrations of naturally occurring radioisotopes in our bodies, in the air we breathe, and in the water and food we consume

For example, if a large group of people in one part of the world has 10 times the average content of radium in the body

[2] For example, Mr. Grubbé at Chicago, Ill., sought medical aid for an X-ray dermatitis on the back of his hand in January 1896, the same month Roentgen announced the discovery of X-rays. Becquerel received a radium burn a few years after he announced the discovery of radioactive radiations emitted by uranium, when he made the mistake of carrying a glass tube of radium-bearing barium chloride in his vest pocket for a few days.

[3] The RBE of Po^{210} with respect to Ra^{226} is taken as 5 in table 3, A, which is based on chronic exposures.

as the rest of the people in the world, and if this group of people has shown no detectable disadvantages, the conclusions could be that these higher concentrations would be safe as maximum permissible values.

4. Experiments with animals

Experiments on mice, rats, dogs, pigs, etc., are being conducted by many laboratories in order to determine the initial retention, the concentration in the various body organs, and the biological half-life of specific isotopes. Careful observations are made on both the living and sacrificed animals in order to detect damage to the various body organs. Studies are made of blood changes, tumor production, sperm counts, reduction in life span, etc. These results are extrapolated to man by giving more weight to the data from species that are closest to man.

5. Experience with Man

Experience with man will give the only completely reliable data, and even here the statistical variation is so great that data should be obtained for a large number of cases in order to obtain reliable results. For ethical reasons there is a limit to the data one can obtain by direct observations on man. However, very useful data have been obtained from observations on man following the accidental ingestion and inhalation of radioisotopes. For example, urinalyses of persons who have inhaled Pu^{239} and Sr^{90} owing to carelessness or accidents have furnished some of the best estimates of the biological half-life of these radioisotopes in man. Small tracer doses of some of the radioisotopes with short effective half-lives can be administered to man to obtain valuable information about the initial retention and biological half-life. In some cases short-lived radioisotopes can be substituted to obtain essential data concerning the behavior of more dangerous long-lived radioisotopes. For example, 5.8-day Ca^{47} can be used in place of the 152-day Ca^{45}, or the 9-day Po^{206} can be used in place of the 138-day Po^{210}.

D. Factors that Determine the Hazards of Radioisotopes

The factors that determine the hazards of the various radioisotopes are as follows:

1. Quantities Available

None of the radioisotopes except those occurring naturally presented problems until the age of high-voltage accelerators, nuclear reactors, and atomic bombs. From the stand-

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point of common use and quantity available, I^{131}, P^{32}, Co^{60}, Sr^{90}, C^{14}, S^{35}, Ca^{45}, Au^{198}, Ra^{226}, Pu^{239}, and uranium present the major problems of irradiation inside the body.

2. Initial Body Retention

Large fractions of some elements such as iodine, strontium, and sodium are absorbed when they are taken into the body by any of the several routes and when available in their common chemical forms. In the case of elements like plutonium and uranium, only a small fraction is absorbed in the gastrointestinal tract. Therefore, the greater retention would increase the hazards from the first group as against those of the second. In dealing with the inhalation of radioisotopes, unless information specific to the radioisotope is available, it is assumed in the case of *soluble* compounds that 25 percent is retained in the lower respiratory tract. From this tract it goes to the blood stream, and a part of this goes to the critical organ within a few days. Fifty percent is held up in the upper respiratory tract and swallowed, so a fraction of that swallowed also reaches the critical organ. In the case of *insoluble* compounds, it is assumed that 12 percent is retained in the lower respiratory tract, which is usually taken as the critical organ when considering the inhalation of insoluble compounds. The rest is eliminated by exhalation and swallowing.

3. Fraction Going from Blood to Critical Body Tissue

Some elements in the blood stream are eliminated rapidly from the body, whereas large fractions of others are deposited in certain body organs.

4. Radiosensitivity of Tissue

Some body tissues are more radiosensitive than others. For example, the lymphatic tissue and bone marrow are much more radiosensitive than muscle or nerve tissue. Therefore, in equal concentrations an element like plutonium is more hazardous than uranium because the plutonium concentrates in the most sensitive part of the bone, whereas the uranium goes to other portions of the bone, the kidney, and various other relatively insensitive organs.

5. Size of Critical Organ

For a given number of microcuries of a radioisotope in a critical organ, it follows that the smaller the organ the greater the concentration and the greater the dose delivered

to the critical tissue. Iodine presents a much greater problem than sodium, since iodine is very selectively absorbed in a small body organ, the thyroid gland, whereas sodium is rather uniformly distributed throughout the body. In many cases the radioisotope is deposited in a large organ but localized in a small portion of that organ, so that, in effect, the mass of critical tissue may become very small.

6. Essentiality of the Critical Organ to the Proper Function of the Body

Some body organs are either not essential to the body function, or, when they are damaged or removed, special steps can be taken to supplement or compensate for their reduced function. It is for this reason that damage to the bone marrow, kidneys, eyes, etc., would represent perhaps a greater hazard than equal tissue damage to the thyroid gland.

7. Biological Half-life

Some elements like radium, plutonium, and strontium are deposited in critical body tissue where the rate of turnover is very slow or the biological half-life is many years. These radioisotopes are much more hazardous than radioisotopes like carbon, sodium, and sulfur (C^{14}, Na^{24}, and S^{35}), which have biological half-lives of a few days or weeks. The principal methods of elimination of radioisotopes from the body are by way of the urine, feces, exhalation, and perspiration. Usually elimination is much more rapid before the radioisotope is translocated from the blood to a more permanent area, such as the bone, than afterward. This time is usually of the order of a few days to a few weeks. After this initial period the elimination rate becomes more nearly exponential, and the application of the term "biological half-life" has real meaning.

8. Radioactive Half-lives of Intermediate Length

The mixture of $U^{238}+U^{234}+U^{235}$ that occurs in nature does not present much of a radiation hazard (if the radioactive daughter elements are removed); because with the very long, controlling half-life of U^{238} of 4.5×10^{9} years, it requires 1.5×10^{6} g of this uranium isotopic mixture to make up a curie of alpha activity. The maximum permissible amount of this mixture in the body (given in table 3,A) is 0.02 μc. This corresponds to about 0.03 g, and it is unlikely that a person would get this much uranium in his body.

If he did, it probably would result in a chemical hazard before the detrimental effects of radiation would show up. The U^{233}, with a half-life of 1.62×10^5 years (100 g/curie[4]), and Sr^{90}, with a half-life of 25 years (6.3×10^{-3} g/curie), are much greater hazards. In the case of Sr^{90} in equilibrium with Y^{90} the maximum permissible amount of Sr^{90} in the body is 1 μc, or only 6.3×10^{-9} g, which is about 10^{-13} of the mass of the human body. This concentration is so small and the rate of elimination so low once a maximum permissible amount of Sr^{90} in equilibrium with Y^{90} becomes fixed in the bone, that it is then very difficult, if not impossible, to make accurate estimates of the amount present. Therefore, if there is exposure to such radioisotopes, every precaution should be taken to minimize the body uptake, and urinalyses should be made frequently so that the amount going into the bone can be estimated from concentrations in the urine during the early portion of the period of exposure, when the elimination rate is much higher.

At the other extreme of specific activity, radioisotopes with very short half-lives do not present much of a hazard unless the exposure is maintained by continuous uptake, since the activity of such radioisotopes when deposited in the body soon decays to an insignificant level. As a rule-of-thumb one can remember that the activity is reduced to less than 1 percent after seven half lives ($2^{-7} = 0.008 = 0.8\%$). Examples of these short-lived radioisotopes are P^{32}, with a half-life of 14.3 days (3.5×10^{-6} g/curie), and N^{16}, with a half-life of 7.35 sec (10^{-11} g/curie). In general, radioisotopes with intermediate radioactive half-lives of about 5 to 50 years present the greatest hazards, other factors being equal, and the danger diminishes for radioisotopes with greater or smaller radioactive half-lives. The most important period of exposure to laboratory personnel is from the age of 20 to 45, because very few younger persons are employed by laboratories that handle radioisotopes, so they are not frequently subject to large internal doses of radioisotopes; and many of the chronic effects of radiation do not manifest themselves until 15 to 25 years after the radiation insult (and $45 + 25 = 70$ years, which is the average life span). The younger the person who accumulates the radioisotopes in his body the greater the hazard and the more serious the accumulation of intermediate-lived radioisotopes like Pu^{239}, Ra^{226}, Sr^{90}, and Po^{210} in the body. It is for this reason that added precautions should be observed not to take into the body radioisotopes like Sr^{90} that might be translocated to

[4] g/curie $= 7.66 \times 10^{-4} A T_r$, in which A = atomic weight, and T_r = radioactive half-life of the radioisotope in days.

the fetus; contaminated clothing should not be worn home, where it may present a radiation hazard to young members of the family; and dangerous quantities of radioisotopes should not be discharged into the air or into the public water supplies, where the population as a whole may be exposed. It is generally true also that fast-growing cells of the body are more subject to radiation damage than fully developed cells, and this is a good reason to be more cautious in permitting the accumulation of radioisotopes in young people or in women in the child-bearing age.

9. Energy of the radiation produced by the radioisotope

The radiation hazard associated with a radioisotope deposited in the body is proportional to the average energy of disintegration weighted for the biological effectiveness of the radiation. The total effective energy per disintegration of the Ra^{226} plus half[5] the energy of Rn^{222} and its alpha-emitting daughter products is 14.5 Mev. The energy per disintegration of Pu^{239} is 5.16 Mev, and so (on an energy basis alone) when equal curie amounts of Ra^{226} and Pu^{239} are deposited in the body, one would expect Ra^{226} to be about three times as hazardous as Pu^{239}. [Actually, it is thought that the fact that Pu^{239} is more densely concentrated in the radiosensitive portion of the bone than Ra^{226} more than compensates for this energy difference, so that the reverse may very well be true. The maximum permissible amount of Ra^{226} (in microcuries) in the body is taken to be about 2.5 times that of Pu^{239}.] Another interesting comparison is obtained by examining some of the beta- and gamma-emitting radioisotopes. In a comparison of H^3 with Na^{24} it is noted in table 4 that the effective energy per disintegration of H^3 is 0.006 Mev, and the effective energy per disintegration of Na^{24} is 2.7 Mev. On an energy basis alone the maximum permissible amount of H^3 in the body would be 450 times that of Na^{24}. In this case both Na^{24} and H^3 are assumed to be rather uniformly distributed in a similar manner throughout the body, so that the effective energy per disintegration is the principal factor determining the relative biological damage from these two radioisotopes when deposited in the body. The ratio of the maximum permissible amounts of the two radioisotopes in the body (using values from table 3, B) is approximately inversely proportional to the ratio of the effective energies.

[5] Experiments of R. D. Evans have indicated that about half of the radon escapes from the body.

10. Specific ionization and attenuation of energy in tissue

As indicated in table 1, alpha particles are considered to be 20 times as damaging on an energy-absorption basis as beta or gamma radiation because of their high specific ionization. The specific ionization in air of a 1-Mev alpha is about 6×10^4 ion pairs per centimeter path, whereas that of a 1-Mev beta is only 45 ion pairs per centimeter path. It is considered that for most of the gross damaging effects of radiation the concentrated energy loss in tissue produced by an alpha particle represents a greater hazard by a factor of 20 than the less dense energy loss in tissue represented by the greater penetration of beta and gamma radiation.

Beta radiation is absorbed mostly in the immediate vicinity of the atoms from which it is emitted, while the attenuation of gamma radiation of the same energy is much slower (e. g., if a beta emitter has a maximum energy of 2 Mev, a negligible fraction of the beta rays has the maximum range in tissue of about 1 cm. In the case of a 2-Mev gamma emitter, only about 3 percent of the gamma-ray energy is absorbed in the 1 cm of tissue). Hence in a small organ most of the beta radiation emitted in the organ will be absorbed in the organ, whereas gamma energy emitted in the same organ will be absorbed in a much larger volume of tissue or escape from the body altogether. Alpha radiation is even more localized than beta. For example, almost all the energy of the 5.9-Mev alpha from At^{211} is absorbed in the thyroid gland, where it localizes. An alpha ray must have an enery of about 7.5 Mev to penetrate the epidermal protective layer of skin about the body, which has a minimum thickness of about 0.07 mm. The range of a 70-kev beta ray is about 0.07 mm of tissue, so only a small fraction of 70-kev beta rays will penetrate this protective layer. Therefore, hazards from alpha and low-energy beta radiation can be controlled by keeping alpha and low-energy beta sources outside the body.

E. Maximum Permissible Concentrations of Radioisotopes

Table 2 lists provisional levels of permissible concentrations of unknown mixtures of radioisotopes in the air and water beyond the areas that are under the control of the installation responsible for the contamination. These values are believed to be safe [6] for exposure to any of the radioisotopes for periods of a few months. Table 2 is intended

[6] Safe values of maximum permissible concentration of radioisotopes are considered not to produce any readily detectable biological damage.

for use as a provisional guide when only the gross activity is known. After essentially all of the activity has been accounted for, maximum permissible concentrations should be based on values given in table 3, using the method of appendix 1 if needed. However, if the gross activities are always sufficiently lower than the values in table 2,[7] it may not be necessary in practice for one to determine which radioisotopes are involved.

The values given in table 2 do not refer to natural backgrounds but to additions to the natural background, caused by man.

TABLE 2. *Provisional levels of permissible concentration of radioactive contaminants for use beyond the control area (Oct. 1951)*

Medium in which contained	β or γ emitter (μc/ml)		α emitter (μc/ml)	
Air	10^{-6}	(a)	5×10^{-17}	(b)
Water	10^{-7}		10^{-7}	(c)

Table 3 lists recommended values of maximum permissible amounts of radioisotopes fixed in the total body and maximum permissible concentrations of these radioisotopes in the air and water one may take regularly into the body. These values were selected by the Subcommittee on Permissible Internal Dose after examining recommendations of radiation protection committees, as listed in section F of this report, and comparing them with calculations from data given in table 4. In some cases there was considerable spread in these values. The spread in values from the various sources of reference was greater than a factor of 10 in a few cases, but usually not over a factor of 2 or 3. The first reference number after each maximum permissible value given in table 3 indicates the reference leading to the choice. Other references are given if the values do not differ by more than ±50 percent. These uncertainties arise from the inconsistencies and voids in the biological data now available. Because of the many uncertainties involved, this Committee recommends that every effort be made to keep the concentrations of radioisotopes in air and water and in the body to a minimum. The goal should be *no* radioactive contamination of air and water and of the body if it can be accomplished with reasonable effort and expense. If such a goal cannot be attained, the average operating levels should be kept as far

[7] Only three radioisotopes, Ra^{226}, Pu^{239}, and Sr^{90}, are known to have values of maximum permissible concentration less than those in table 2. The values in table 2 are considered safe for any of the radioisotopes if (a) is reduced to 0.2×10^{-6} for Sr^{90}, if (b) is reduced to 2×10^{-13} for Pu^{239}, and (c) is reduced to 0.4×10^{-7} for Ra^{226}. See appendix 3.

below these recommended values as possible, and not above them for any extended periods of time. In many cases the values given in table 3 (and indicated by references G1 through G7 corresponding to the equation used) are calculated from the data in table 4. These calculated values assume uniform distribution within the critical body organ. However, uniform distribution never actually exists, and this is one of the reasons why a safety factor in applying the maximum permissible concentrations may be desirable and is suggested in the introduction to this discussion for applications that might lead to extensive contamination. The principle of the calculations has been to determine the uniform concentration of the radioisotope in the critical tissue that will irradiate it at a dose rate of (0.3/RBE) rep/week. The calculated values in table 3 are based on a continuous exposure, and in all cases except for Pu^{239}, Sm^{151}, and Ra^{226}, the effective half-lives are so short that the values have been calculated for an equilibrium period of exposure (see appendix 3).

In a few cases values are calculated for both soluble and insoluble compounds of the radioisotopes. Unless otherwise indicated, the values given in table 3 apply to soluble compounds. As more information becomes available, these calculations should be extended not only to other radioisotopes but to various compounds of each. Table 3 is divided for convenience into three parts. Part A applies to radioisotopes that are alpha emitters. Work with alpha emitters requires special ventilating equipment, special precautions to prevent the spread of contamination, and the use of monitoring instruments that are suitable to determine surface contamination and concentration of the contaminants in air and in water. When possible, separate laboratories should be set up for work with alpha-emitting radioisotopes and a separate section of the counting room should be devoted to alpha counting. Special waste processing and disposal facilities should be provided for work with the more dangerous alpha emitters.

Part B of table 3 lists beta- and gamma-emitting radioisotopes that are common elements in the body. They are listed as a group for two reasons: (1) they are of common interest to biologists and to medical people in many studies of living organisms, and (2) the maximum permissible concentrations of these radioisotopes can be estimated from a knowledge of the distribution and behavior of stable isotopes of the same elements in the body. Because the body is not an isotope separator, we can expect the radioisotopes to behave in the body in the same manner as the stable isotopes

of the same element, provided the average chemical forms are the same. The initial uptake, distribution, and biological elimination should be the same for the radioisotope as for the stable form of the same element. For example, equation H1 indicates that the biological half-life can be expressed as a function of the mass of the stable element in the critical organ, the daily intake of the stable element, and the fraction of the stable element taken into the body that reaches the critical organ. The critical organ is usually the organ of the body that has the greatest concentration of the radioisotope despoited in it. However, this is not always true because the biological half-life may be considerably different in various organs, and it is usually the total dose of radiation received by an organ that determines the principal damage from internal irradiation of radioisotopes. The critical organ should always be that organ that receives radiation damage that results in the greatest insult to the total body. Sometimes the critical organ may not be the one with the greatest concentration of the radioisotope or even the greatest local damage because of variations in radiosensitivity of the various body tissues and because some body organs are more vital to the existence of the whole organism. However, such cases are probably exceptional when dealing with chronic exposure.

Part C of table 3 lists other radioisotopes of interest because (1) they are commonly used in research, (2) they are commonly produced by nuclear reactors and accelerators, (3) they are among the more hazardous radioisotopes produced by nuclear reactors, (4) they are noble gases that escape from the reactors and associated operations, or (5) they are radioisotopes that are likely to be induced in water used for cooling a nuclear reactor.

Often a person is subject to radiation exposure from several different sources simultaneously. In any case, the maximum permissible concentration of radioisotopes in air and water and the external radiation should not exceed values that will permit an exposure of 0.3 rem/week to any part of the body except the epidermal skin layer. The maximum permissible dose to the basal layer of the epidermis (considered to be at a depth of 7 mg/cm^2) is 0.5 rem/week except in the case of the hands and forearms, where the maximum permissible value is 1.5 rem/week. A detailed discussion of how to treat the summation of exposures from various different radioactive sources is given in appendix 1.

The references in table 3, given in parentheses, refer both to radiation protection committees listed in section F and to general equations listed in section G. Nomenclature and

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additional equations are given in section H. The μc and $\mu c/cm^3$ values for natural uranium given in table 3 refer to the natural mixture of U^{238}, U^{235}, and U^{234} separated from the other daughter products. In the case of Ra, Rn, Sr^{90}, Ba^{140}, Ru^{106}, Cd^{109}, Cs^{137}, and Ce^{144} the μc and $\mu c/cm^3$ values are based on the disintegration rate of the parent isotope only, but the effective energy of the daughter products is added to that of the parent after proper weighting for biological effectiveness. Table 4 gives some of the constants used in equations listed in sections G and H. In column 2 of table 4 the energy values followed by α are the effective energies in terms of alpha radiation and are given by the equation

$$\sum[E_\alpha + 1/20(bE)_\beta + 1/20(bE)_\gamma],$$

in which E_α, $(bE)_\beta$, and $(bE)_\gamma$ are the effective energies of alpha, beta, and gamma radiation, respectively. In the case of Ra^{226} it was assumed that only half of Rn^{222} and its daughter products down to RaD^{210} were retained in the body. In the case of Rn^{222} in the body the effective energy in terms of alpha radiation of all the daughter products down to RaD^{210} is included. Much of the biological data given in table 4 is uncertain, and in many cases there are inconsistencies in the data available in the literature. The bibliography is a list of the references given in table 4. M. J. Cook and M. R. Ford, of Oak Ridge National Laboratory, assisted the Committee in collecting data used in these tables.

TABLE 3. *Maximum permissible amount of radioisotope in total body and maximum permissible concentration in air and water for continuous exposure (Oct. 1951)*

A. Common radioisotopes that are alpha emitters

Element	Organ (g)	Microcuries in total body [a]	Microcuries per milliliter of water [a]	Microcuries per milliliter of air [a]
Po^{210} (sol.)	Spleen, 150	0.02 (O4)	3×10^{-5} (O6)	2×10^{-10} (O5).
Po^{210} (insol.)	Lungs, 10^3	7×10^{-3} (G4)		7×10^{-11} (O5).
Rn^{222}+dr [c]	Body, 7×10^4		[f] 2×10^{-8} (G1)	
	Lungs, 10^3			10^{-8} (1,7).
Ra^{226}+½dr [a]	Bone, 7×10^3	0.1 (1,2,4,6,7)	4×10^{-8} (4,6,O6)	8×10^{-13} (6,7).
U-natural (sol.)	Kidneys, 300	0.2 (G5) [b]	7×10^{-3} (G6) [b]	1.7×10^{-11} (5,4) [b].
U-natural (insol.)	Lungs, 10^3	0.009 (G4)		1.7×10^{-11} (5,G5,4) [b].
U^{233} (sol.)	Bone, 7×10^3	0.04 (6)	1.5×10^{-4} (6)	1×10^{-10} (O5).
U^{233} (insol.)	Lungs, 10^3	0.008 (6,O4)		1.6×10^{-11} (6,O5).
Pu^{239} (sol.)	Bone, 7×10^3	0.04 (6,2)	1.5×10^{-5} (6)	2×10^{-12} (6).
Pu^{239} (insol.)	Lungs, 10^3	0.008 (G4)		2×10^{-12} (6,4).

See footnotes at end of table.

TABLE 3. *Maximum permissible amount of radioisotope in total body and maximum permissible concentration in air and water for continuous exposure (Oct. 1951)*—Continued

B. Beta- and gamma-emitting radioisotopes that are of interest because they are common body elements

Element and percentage in body [e]	Organ (g)	Microcuries in total body [a]	Microcuries per milliliter of water [a]	Microcuries per milliliter of air [a]
H^3 (HTO or H^3_2O), 10%.	Total body, 7×10^4.	10^4 (6,G4)	0.2 (G6)	2×10^{-3} (G5)
C^{14} (CO_2), 18%.	Fat, 10^4.	250 (G4)	3×10^{-3} (G6)	10^{-6} (6,G7,4).
	Bone, 7×10^3.	1,500 (O4)	4×10^{-3} (G6)	5×10^{-7} (G5)
Na^{24}, 0.15%.	Total body, 7×10^4.	15 (6,4,O4)	8×10^{-3} (6,G6,4)	2×10^{-6} (O5,4).
P^{32}, 1.0%.	Bone, 7×10^3.	10 (2,6,4,O4)	2×10^{-4} (6,4)	1×10^{-7} (G5)
S^{35}, 0.25%.	Skin, 2×10^3.	100 (6,O4)	5×10^{-3} (O6)	10^{-6} (4,G5)
Cl^{36}, 0.15%.	Total body, 7×10^4.	200 (G4)	2×10^{-3} (O6)	4×10^{-7} (G5).
K^{42}, 0.35%.	Muscle, 3×10^4	20 (G4)	1×10^{-2} (O6)	2×10^{-6} (G5).
Ca^{45}, 1.5%.	Bone, 7×10^3.	65 (O4)	5×10^{-4} (G6)	3×10^{-8} (G5).
Mn^{56}, 3×10^{-4}%.	Kidneys, 300	2 (G4)	0.15 (G6)	3×10^{-6} (G5).
	Liver, 1.7×10^3.	7.5 (G4)	0.3 (G6)	4×10^{-6} (G5).
Fe^{55}, Fe^{59} 0.004%.	Blood, 5×10^3	1×10^3 (G4)	4×10^{-3} (O6)	6×10^{-7} (G5).
	Blood, 5×10^3.	11 (G4)	1×10^{-4} (O6)	1.5×10^{-8} (G5).
Cu^{64}, 2×10^{-4}%.	Liver, 1.7×10^3.	1.5×10^2 (G4)	8×10^{-2} (G6)	6×10^{-6} (G5).
Zn^{65}, 0.003%.	Bone, 7×10^3	430 (G4)	6×10^{-2} (G6)	2×10^{-5} (G5).
I^{131}, 4×10^{-8}%.	Thyroid, 20.	0.3 (6,G4)	3×10^{-4} (6,G6)	3×10^{-3} (6,G5).

C. Other radioisotopes of current interest

Element	Organ (g)	Microcuries in total body [a]	Microcuries per milliliter of water [a]	Microcuries per milliliter of air [a]
Be^7	Bone, 7×10^3	670 (G4)	1 (G6)	4×10^{-5} (G5).
P^{32}	Bone, 7×10^3	24 (G4)	0.9 (G6)	10^{-4} (G5)
A^{41}	Total Body, 7×10^4	30 (G4)	5×10^{-4} (G2)	5×10^{-7} (G3).
Sc^{46}	Spleen, 150	6 (G4)	0.4 (G6)	7×10^{-7} (G5).
V^{48}	Bone, 7×10^3	20 (G4)	0.5 (G6)	10^{-6} (G5).
Cr^{51}	Kidneys, 300	390 (G4)	0.5 (G6)	8×10^{-4} (G5).
Co^{60}	Liver, 1.7×10^3.	3 (G4)	2×10^{-2} (O6)	10^{-5} (G5).
Ni^{59}	Liver, 1.7×10^3	39 (G4)	0.25 (O6)	2×10^{-3} (G5).
Ga^{72}	Bone, 7×10^3	8 (G4)	9 (G6)	3×10^{-6} (G5).
Ge^{71}	Kidneys, 300.	67 (G4)	9 (G6)	4×10^{-4} (G5).
As^{76}	Kidneys, 300	10 (G4)	0.2 (G6)	2×10^{-6} (G5).
Rb^{86}	Muscle, 3×10^4	60 (G4)	3×10^{-3} (G6)	4×10^{-7} (G5).
Sr^{89}	Bone, 7×10^3.	2 (2, 6)	[d] 7×10^{-3}	[d] 2×10^{-8}
Sr^{90}+Y^{90} [a]	Bone, 7×10^3	1 (2, 6).	8×10^{-7} (6)	2×10^{-10} (6, O5, 4).
Y^{91}	Bone, 7×10^3	15 (O4)	0.2 (G6)	4×10^{-5} (G5).
Nb^{95}	Bone, 7×10^3.	90 (G4)	4×10^{-3} (G6)	4×10^{-7} (G5).
Mo^{99}	Bone, 7×10^3.	50 (O4)	14 (G6)	2×10^{-3} (G5).
Tc^{99}	Kidneys, 300.	5 (G4)	3×10^{-2} (G6)	3×10^{-6} (G5).
Ru^{106}+Rh^{106} [a]	Kidneys, 300	4 (G4)	0.1 (G6)	3×10^{-5} (G5).
Rh^{105}	Kidneys, 300.	9 (G4)	1.5×10^{-3} (G6)	10^{-6} (G5)
Pd^{103}+Rh^{103} [a]	Kidneys, 300.	6 (G4)	1×10^{-1} (G6)	7×10^{-7} (G5).
Ag^{108}	Liver, 1.7×10^3.	18 (G4)	2 (G6)	10^{-5} (G5).

See footnotes at end of table.

TABLE 3. *Maximum permissible amount of radioisotope in total body and maximum permissible concentration in air and water for continuous exposure (Oct. 1951)*—Continued

C. Other radioisotopes of current interest—Continued				
Element	Organ (g)	Microcuries in total body [a]	Microcuries per milliliter of water [a]	Microcuries per milliliter of air [a]
Ag^{111}	Liver, 1.7×10^3.	36 (O4)	4 (G6)	3×10^{-3} (O5).
Cd^{109}+ Ag^{109m} [e].	Liver, 1.7×10^3.	40 (O4)	7×10^{-3} (O6)	7×10^{-6} (O5).
Sn^{113}	Bone, 7×10^3.	80 (G4)	0.2 (O6)	6×10^{-7} (O5).
Te^{127}	Kidneys, 300.	4 (G4)	3×10^{-2} (O6)	10^{-7} (O5).
Te^{129}	Kidneys, 300.	1.3 (G4)	10^{-1} (O6)	4×10^{-8} (O5).
Xe^{133}	Total body, 7×10^4.	300 (G4)	4×10^{-3} (O2)	4×10^{-6} (G3).
Xe^{135}	Total body, 7×10^4.	100 (O4)	1×10^{-1} (O2)	2×10^{-6} (G3, 4).
Cs^{137}+ [f] Ba^{137m} [e].	Muscle, 3×10^4.	90 (O4)	1.5×10^{-3} (O6)	2×10^{-7} (O5).
Ba^{140}+La^{140} [e].	Bone, 7×10^3	5 (O4)	2×10^{-2} (O6)	6×10^{-8} (O5).
La^{140}	Bone, 7×10^3	24 (G4)	1 (O6)	10^{-6} (O5).
Ce^{144}+ Pr^{144} [e].	Bone, 7×10^3	5 (O4)	4×10^{-2} (O6)	7×10^{-9} (O5).
Pr^{143}	Bone, 7×10^3	29 (G4)	0.4 (O6)	7.5×10^{-7} (O5).
Pm^{147}	Bone, 7×10^3	120 (O4)	1 (O6)	2×10^{-7} (O5).
Sm^{151}	Bone, 7×10^3	420 (G4)	0.2 (G6)	10^{-5} (G5).
Eu^{154}	Bone, 7×10^3	22 (G4)	3×10^{-2} (G6)	6×10^{-8} (O5).
Ho^{166}	Bone, 7×10^3	17 (G4)	23 (O6)	3×10^{-6} (O5).
Tm^{170}	Bone, 7×10^3	19 (G4)	0.25×10^{-1} (G6)	5×10^{-8} (O5).
Lu^{177}	Bone, 7×10^3	78 (G4)	24 (O6)	5×10^{-6} (O5).
Re^{183}	Thyroid, 20	35 (G4)	8×10^{-2} (G6)	8×10^{-6} (O5).
	Skin, 2×10^3	600 (G4)	0.2 (G6)	2×10^{-5} (O5).
Ir^{190}	Kidneys, 300.	21 (G4)	10^{-1} (O6)	7×10^{-7} (O5).
Ir^{192}	Kidneys, 300.	3.4 (G4)	9×10^{-4} (G6)	5×10^{-8} (O5).
Au^{198}	Kidneys, 300	10 (G4)	3×10^{-3} (O6)	1×10^{-7} (O5).
Au^{199}	Kidneys, 300	28 (O4)	7×10^{-2} (O6)	2.5×10^{-7} (O5).
Pb^{203}	Bone, 7×10^3	57 (O4)	0.1 (G6)	6.5×10^{-8} (O5).
At^{211}	Thyroid, 20	6×10^{-4} (O4)	2×10^{-8} (O6)	3×10^{-10} (O5).
Th^{234}	Bone, 7×10^3	120 (O4)	3 (O6)	6×10^{-7} (O5).
Am^{241}	Bone, 7×10^3	0.056 (G4)	10^{-4} (G6)	3×10^{-11} (O5).
Cm^{242}	Bone, 7×10^3	0.05 (O4)	9×10^{-4} (O6)	2×10^{-10} (O5).

[a] References were considered to apply if the values agreed within ±50 percent. Calculated values were rounded off to one significant figure. The principal reference responsible for the choice of a particular value was listed first. The notations O1, O2, etc., refer to equations in section G and the single numbers to references in section F.

[b] Based on chemical toxicity. The microcurie and microcurie-per-milliliter values are given for the natural mixture of U^{238}, U^{235}, and U^{234} with all the other radioisotopes removed.

[c] Percentages of stable element by weight comprising total body. The other principal body elements, oxygen (65%), nitrogen (3%), and magnesium (4×10^{-2}%), are omitted because all their radioactive isotopes have very short half-lives.

[d] Obtained by a comparison of recommended values for Sr^{90} with the calculated values in the two cases.

[e] Values of microcuries and microcuries-per-milliliter are given for the parent element in equilibrium with its daughter element(s).

[f] This value actually applies to ingestion; although the submersion equation was used for the calculation, since it is considered that tissue in the gastrointestinal tract is submerged in a fluid. The equation for submersion was applied specifically to an element of tissue in the gastrointestinal tract that was surrounded by water contaminated with radon and its products and by other layers of tissue contaminated with such products.

In this case the total energy leaving the unit volume is approximately equal to the total energy absorbed in a unit volume, and one is justified in using this method of calculation, which gives 2×10^{-6} μc/ml of water. Approximately the same answer is obtained using the ingestion equation and the entire gastrointestinal tract as the critical organ.

If one is concerned with the case of submersion exposure due to a person or animal swimming continuously in the contaminated water, the value would be increased to about 2×10^{-4} μc/ml because in such a case the alpha radiation would not be effective and the value given here could be increased by a relative biological effectiveness of 20 and an energy ratio of 5.5.

F. Recommendations of Various Radiation Protection Committees

Reference numbers used in table 3:

1. Values agreed on by the Advisory Committee on X-ray and Radium Protection (1941).
2. Values agreed on by the Subcommittee on Permissible Internal Dose of the National Committee on Radiation Protection (Feb. 9 and 10, 1950).
3. Values agreed on at a meeting of some of the scientists in the United States who were interested in establishing interim values for the maximum permissible concentrations in air and water of some of the commonly used radioisotopes.
4. Values suggested by the Chalk River, Canada, Conference (Sept. 29 and 30, 1949). This was a meeting of representatives of the radiation protection committees of the United States, Great Britain, and Canada.
5. Values agreed upon at a meeting in Rochester, N. Y. (Sept. 27, 1949). This meeting was called by the University of Rochester Atomic Energy Project and members of the Atomic Energy Commission to discuss the toxicity data of uranium and to attempt to establish interim values for the maximum permissible concentration in air of soluble and insoluble compounds of uranium.
6. The International Commission on Radiological Protection at the Sixth International Congress of Radiology, meeting in London during July 1950, indicated as follows:

   > While the Commission does not, at the moment, consider that there is sufficient information to make firm recommendations concerning maximum permissible exposures to internal radiation from radioactive isotopes, it brings to the notice of users of radioactive isotopes values which are commonly used, at the present time, in the United States of America, Canada, and Great Britain.[8]

7. Values agreed upon by the American Standards Association, Subcommittee on Radium Dust, Radon Gas and Gamma Ray Exposure (Z-37, 1950).

[8] Recommendations of the International Commission on Radiological Protection and of the International Commission on Radiological Units, 1950, NBS Handbook 47, p. 3 (June 29, 1951).

TABLE 4. *Constants for calculating maximum permissible internal concentration of radioisotopes*

1	2	3			4	5	6	7	8	9	10	11	12	13
Element	Effective energy,[b] $\Sigma(bE)$ Mev	Critical organ			Concentration of element per gram of organ	Daily intake of element by ingestion	Half-life			Fraction going from GI tract to blood, f_1	Fraction in critical organ of that in total body, f_3	Fraction from blood to critical organ, f_1'	Fraction reaching critical organ—	
		Organ	Mass	Effective diameter			Physical, T_r	Biological, T_b	Effective, T				By ingestion, f_w	By inhalation, f_s
			g	cm	g	g/day	Days	Days	Days					
H^3	0.006	Total body D.	7×10^4 Ch1.		0.1 Hw1. Ch1.	250 O, Kl1.	4.5×10^3	19 [a]11 H1. Lm1, An1.	19 H4.	1.0 An2.	1.0 D.	1.0 D.	1.0 D.	0.75 H5.
Be^7	0.009	Bone Ha16, Ha23, Ha21, Ur2.	7×10^3 Ch1.	5			54.5	400 Ha16, Ha23.	48 H4.	<0.01 Ur2.	0.9 Ha16, Ha23.	0.35 Ha21, Ha23, Ur2.	3.5×10^{-4} H2.	0.09 H5.
C^{14}	0.053	Fat G.	10^4 Ev1.		0.75 Ev1.	300 Ma1.	2.09×10^6	35 H1, Se1.	35 H4.	0.95 Ma1.	0.6 Ma1, H9.	0.5 H2.	0.5 G, Hw1.	0.36 H5.
		Bone Sk2, Bl2, Bl1, He1, Sr1.	7×10^3 Ch1.	5	0.13 Ev1.	300 Ev1. Ma1.	2.09×10^6	180 Sk2.	180 H4.	0.95 Ma1.	0.07 Hw1, Ev1.	0.05 Na1, G.	4.8×10^{-5} H2.	3.6×10^{-5} H5.
F^{18}	0.24	Bone Gl1, Ev1, Sh1.	7×10^3		1.2×10^{-4} Ev1.	4.7×10^{-3} Sl1, Hw1, Sm1.	0.078	140 Gl1.	0.078 H4.	1.00 Ev1.	0.95 Sh1.	0.1 H2.	0.1 Sh1.	7.5×10^{-3} H5.
		Teeth Gl1, Ev1, Sh1.	20		2×10^{-4} Ev1.									
Na^{24}	2.7	Total body Be1, Bl1.	7×10^4 Ch1.	30	1.5×10^{-3} H9, Hw1.	4 Ma1, Ev1. Sh1.	0.62	29 Tr1. [a]19 H1.	0.61 H4.	0.95 He1.	1.0 D.	1.0 D.	0.95 H2.	0.73 H5.
P^{32}	0.68	Bone Ka1, La1, He1, Ha2.	7×10^3 Ch1.		0.069 Ma1.	1.4 Ma1.	14.3	1,200 H1.	14 H4.	0.7 He1.	0.92 He1. [a]0.69 H9.	0.3 H2.	0.2 He1, At1.	0.2 H5.
S^{35}	0.055	Skin Dd1.	2×10^4 Ma1.		0.009 Sh1.	1.3 Ev1.	87.1	22 Ta1. [a]120 H1.	18 H4.	0.56 Ka1.	0.19 Sh1. [a]0.1 H9.	0.14 Dd1.	0.08 H2.	0.074 H5.
Cl^{36}	0.26	Total body H8, Sb1.	7×10^4 Ch1.		1.5×10^{-4} Hw1. Ma1.	6.7 Ma1. Ev1.	1.6×10^5	29 H8. [a]11 H1.	29 H4.	0.95 H8.	1.0 H8.	1.0 H8.	0.95 H2.	0.73 H5.
A^{37}	1.78	Body	7×10^4 Ch1.	30			0.074				1 D.			
K^{42}	1.59	Muscle Hl1, Ev1, Nt1.	3×10^4 Ch1.	30	0.003 Ma1, Sh1, Ev1.	2.8 Sh1, Ev1.	0.52	33 H1.	0.51 H4.	0.9 He1.	0.75 Hl1, Ev1. [a]0.37 H9.		0.7 H3.	0.53 H6.

See footnotes at end of table.

TABLE 4. *Constants for calculating maximum permissible internal concentration of radioisotopes*—Continued

1	2	3			4	5	6	7	8	9	10	11	12	13
Element	Effective energy,[b] $\Sigma(\delta E)$ Mev	Critical organ			Concentration of element per gram of organ	Daily intake of element by ingestion	Half-life			Fraction going from GI tract to blood, f_1	Fraction in critical organ of that in total body, f_2	Fraction from blood to critical organ, f_1'	Fraction reaching critical organ—	
		Organ	Mass	Effective diameter			Physical, T_r	Biological, T_b	Effective, T				By ingestion, f_w	By inhalation, f_a
			g	*cm*	*g*	*g/day*	*Days*	*Days*	*Days*					
Ca^{45}	0.085	Bone No1, He1, Be1, Pe1, Gr2, No2.	7×10^3 Ch1.	----	0.15 Ma1.	0.8 Ma1.	152	18,000 No2.	151 H4.	0.9 He1, Be1, Gr2.	0.99 Hw1, Gr2, Kl1. [a] 1.0 H9.	0.58 Pe1.	0.25 Gr2, No1, He1, Pe1, Be1. [a] 0.52 H2.	0.41 H5.
Sc^{46}	[c] 0.5	Spleen So6.	150 Ch1.	7	----	----	85	15 So6.	13 H4.	0.0005 So6.	0.04 So6.	0.03 So6	1.5×10^{-4} H2.	7.5×10^{-3} H5.
V^{48}	0.54	Bone Ha16, So9.	7×10^2 Ch1.	5	----	----	16	50 Ha16, So9.	12 H4.	0.005 Ha16, So9.	0.5 Ha16, So9.	0.1 Ha16, So9.	5×10^{-4} H2.	0.025 H5
Cr^{51}	0.01	Kidneys So1.	300 Ch1.	7	2.7×10^{-3} Uo1.	Trace Ma1.	26.5	110 So1.	22 H4.	0.05 G.	0.06 So1.	0.014 So1.	0.0007 H2.	0.004 H5.
Mn^{54}	1.1	Kidneys So1, So6.	300 Ch1.	7	6×10^{-7} Ev1.	4×10^{-3} Ma1.	0.108	2.5 So6. [a] 78 H1.	0.106 H4.	0.05 Be1, Co1.	0.09 So1, So6. [a] 0.009 Ev1. [a] 0.015 H9.	0.08 So1, So6. [a] 0.25 Co1, Gr1.	0.004 H2.	2.2×10^{-7} H5.
		Liver Gr3, Co1, He1.	1.7×10^3 Ch1.	10	1.7×10^{-6} Ev1, Hw1, Sh1.	4×10^{-4} Ma1.	0.108	5 So6. [a] 50 H1.	0.106 H4.	0.1 Gr3.	0.16 Ev1. [a] 0.015 H9.	0.3 Gr1, Gr3, Co1.	0.01 Gr3, Co1.	0.09 H5.
Fe^{55}	0.006	Blood Ev1, Be1.	5×10^3 Ch1.	----	5×10^{-4} Ev1.	0.012 Ma1.	1.06×10^3	65 La1. [a] 180 H1.	61 H4.	0.8 He1, La1.	0.64 Be1, Ev1. [a] 0.8 H9.	1.0 D.	0.8 H2.	0.65 H5.
Fe^{59}	0.54	Blood Ev1, Be1.	5×10^3 Ch1.	15	5×10^{-4} Ev1.	0.012 Ma1.	46.3	65 La1. [a] 180 H1.	27 H4.	0.8 He1, La1.	0.64 Be1, Ev1. [a] 0.8 H9.	1.0 D.	0.8 H2.	0.65 H5
Co^{60}	0.72	Liver Co1, Co2, Co5, He1.	1.7×10^3 Ch1.	10	2×10^{-7} Ev1.	Trace Ma1.	1.90×10^3	8.4 Co5.	8.4 H4.	0.2 Co1, Co5.	0.68 Ev1.	0.02 Co1, Co2, Co5, Gr1, Be1.	0.004 H2.	0.007 H5.
	0.55	Spleen Ev1.	150 Ch1.	7	4.7×10^{-7} Ev1.	Trace Ma1.	1.90×10^3	9 Co5.	9 H4.	0.2 Co1, Co5.	0.14 Ev1.	0.00022 Co1, Co2, Co5.	4.4×10^{-3} H2.	7.7×10^{-4} H5.
Ni^{59}	0.05	Liver H8.	1.7×10^3 Ch1.	----	Trace Ma1.	Trace Ma1.	9.1×10^4	8 G, H8.	8 H4.	0.2 H8.	0.68 H8.	0.02 H8.	0.004 H2, H8.	0.007 H5, H8.

See footnotes at end of table.

TABLE 4. *Constants for calculating maximum permissible internal concentration of radioisotopes*—Continued

1	2	3			4	5	6	7	8	9	10	11	12	13
Element	Effective energy,[b] $\Sigma(bE)$ Mev	Critical organ			Concentration of element per gram of organ	Daily intake of element by ingestion[a]	Half-life			Fraction going from GI tract to blood, f_1	Fraction in critical organ of that in total body, f_2	Fraction from blood to critical organ, f_3'	Fraction reaching critical organ—	
		Organ	Mass	Effective diameter			Physical, T_r	Biological, T_b	Effective, T				By ingestion, f_a	By inhalation, f_a
			g	*cm*	*g*	*g/day*	*Days*	*Days*	*Days*					
Cu^{64}	0.11	Liver He1, Ha22, Sc1, Be1, Co6.	1.7×10^3 Ch1.	10	6×10^{-4} Ev1.	0.002 Ma1.	0.54	39 H1.	0.53 H4.	0.28 Co3, Co6.	0.08 Ev1.	0.33 Co3, Co6. [a] 0.13 Ha22.	0.09 Sc1, Ha22, Be1, Co3, Co6. H2.	0.13 H5.
		Eyes Tn1.	30 Ch1.	.....	2.4×10^{-9} Tu1.	0.002 Ma1.	0.54	21 H1.	0.53 H4.	0.28 Co3, Co6.	5×10^{-4} Tn1, H9.	0.0042 Co3, Co6.	1.2×10^{-3} H2.	0.002 H5.
Zn^{65}	0.085	Bone Sn2, He1.	7×10^3 Ch1.	5	1×10^{-4} Ev1.	0.017 Ev1, Sh1.	250	23 Sn2.	21 H4.	0.1 Sk1, G.	0.15 Sn1, Sn2.	0.15 Sn2.	1.5×10^{-3} H2.	4.5×10^{-3} H5.
Ga^{72}	0.8	Bone Du1, Du2, Du3, Du4, Pk1, Ha20.	7×10^3 Ch1.	.....	$<1\times10^{-6}$ Du1.	.....	0.59	2.4×10^3 Du2.	0.59 H4.	0.001 Du4, Pk1.	0.82 Du2.	0.4 Pk1, Du2, Ha20.	0.0004 H2.	0.1 H5.
Ge^{71}	[c] 0.01	Kidneys Ha21.	300 Ch1.	7	.....	.....	11.4	6 Ha21.	3.9 H4.	0.01 Ha21.	0.35 Ha21.	0.02 Ha21.	2×10^{-4} H2.	5×10^{-6} H5.
As^{76}	1.1	Kidneys Ht1, Sl1, Ha17.	300 Ch1.	7	.....	.....	1.12	37 Ha11. [a] 124 Ha17.	1.09 H4.	0.03 Mo1.	0.02 Ht1, Ha17.	0.01 Dc1, Ht1, Ha17.	0.0003 H2.	2.7×10^{-5} H5.
Rb^{86}	0.73	Muscle Ha21.	3×10^4 Ch1.	30	.....	.....	19.5	13 Ha21.	7.8 H4.	1.00 Ha21.	0.54 Ha21.	0.44 Ha21.	0.42 Ha21.	0.33 H5.
Sr^{89}	0.55	Bone Ha1, Ja1, Su1, Su2, He1, Be1, No1.	7×10^3 Ch1.	.....	6×10^{-5} Ma1, Uc1, Uc2.	3×10^{-4} Ha7, H8.	53	3.9×10^3 H1. [a] 18,000 H8, No2.	52 H4.	0.6 Ha1.	0.7 Ha1, Ha3, Ha4.	0.4 H2. [a] 0.50 Su2.	0.25 H8. [a] 0.42 H3.	0.22 H5.
$Sr^{90}+Y^{90}$	1.0	Bone Ha1, Ja1, Su1, Su2, He1, Be1, No1.	7×10^3 Ch1	.....	6×10^{-5} Ma1, Uc1, Uc2.	3×10^{-4} Ha7, H8.	9.1×10^3	3.9×10^3 H1. [a] 18,000 H8, No2.	2.7×10^3 H4.	0.6 Ha1.	0.7 Ha1, Ha3, Ha4.	0.4 H2. [a] 0.50 Su2.	0.25 H8. [a] 0.42 H3.	0.22 H5.
Y^{91}	[c] 0.57	Bone Ha1, Ha7, Ha9, Ha10, Su2, Su4. Sc3, Hd1, Ha18.	7×10^3 Ch1.	5	.....	.....	57	>500 Ha1, Su4, Ha10, Ha9.	51 H4.	0.0005 Ha1, Ha7, Su2, Su3.	0.65 Ha1, Su4, Sc3, Ha10, Ha9, Ha18.	0.55 Su3, Ha18.	2.8×10^{-4} H2.	0.14 H5.
Nb^{95}	[c] 0.154	Bone Ha1, Ha7, Ha9, Ha10, Su3.	7×10^3 Ch1.	5	.....	.....	35	50 Ha9.	21 H4.	0.45 Su3. [a] 0.01 Ha1, Ha10, Ha9.	0.4 Ha9, Ha10, Ha1.	0.25 Ha9, Su3, H2.	0.13 Su3.	0.12 H5.

See footnotes at end of table.

TABLE 4. *Constants for calculating maximum permissible internal concentration of radioisotopes*—Continued

1	2	3			4	5	6	7	8	9	10	11	12	13
Element	Effective energy,[b] $\Sigma(bE)$ Mev	Critical organ			Concentration of element per gram of organ	Daily intake of element by ingestion	Half-life			Fraction going from GI tract to blood, f_1	Fraction in critical organ of that in total body, f_2	Fraction from blood to critical organ, f_3'	Fraction reaching critical organ—	
		Organ	Mass	Effective diameter			Physical, T_r	Biological, T_b	Effective, T				By ingestion, f_4	By inhalation, f_4
			g	*cm*	*g*	*g/day*	*Days*	*Days*	*Days*					
Mo^{99}	0.22	Bone Co3, Co4, Ne1.	7×10^3 Ch1.	5	Trace Ev1.	Trace Ev1.	2.85	150 G.	2.8 H4.	0.7 Co3, Co4.	0.5 Co3, Co4.	3×10^{-4} H2.	0.0002 Ne1.	1.8×10^{-4} H5.
Tc^{99}	0.49	Kidneys Ha21.	300 Ch1.	7			4.3	4 Ha21.	2.1 H4.	0.5 Ha21.	0.1 Ha21.	0.005 Ha21.	2.5×10^{-3} H2.	2.5×10^{-4} H5.
$Ru^{106}+Rh^{106}$	1.4	Kidneys Ha1, Ha9, Ha10, So8.	300 Ch1.	7			365	20 Ha1, Ha9, Ha10.	19 H4.	<0.0005 Ha1, Ha9, Ha10.	0.04 Ha9, Ha1, Ha10.	0.04 Ha9, So8.	2×10^{-3} H2.	0.01 H5.
Rh^{103}	0.33	Kidneys So8.	300 Ch1.	7			1.52	28 So8.	1.4 H4.	0.2 H8.	0.08 So8.	0.05 So8.	0.01 H2.	1.7×10^{-2} H5.
$Pd^{103}+Rh^{103}$	0.074	Kidneys So8	300 Ch1.	7			17	6 So8.	4.4 H4.	0.2 H8.	0.5 So8.	0.1 So8.	0.02 H2.	3.5×10^{-3} H5.
$Cd^{109}+Ag^{109m}$	0.04	Liver Ha21.	1.7×10^3 Ch1.	10			330	100 G.	77 H4.	0.0025 Ha21.	0.8 Ha21.	0.75 Ha21.	1.9×10^{-2} H2.	0.19 H5.
Ag^{105}	0.74	Liver So7.	1.7×10^3 Ch1.	10			45	3 So7.	2.8 H4.	0.02 So7.	0.1 So7.	0.006 So7.	1.2×10^{-4} H2.	1.6×10^{-3} H5.
Ag^{111}	0.37	Liver So7.	1.7×10^3 Ch1.	10			7.5	3 So7.	2.1 H4.	0.02 So7.	0.1 So7.	0.006 So7.	1.2×10^{-4} H2	1.6×10^{-3} H5
Sn^{113}	[c]0.087	Bone Ha18, Ha19, Ha20.	7×10^3 Ch1.	5			112	72 Ha18.	44 H4.	0.0087 H2.	0.8 Ha18.	0.3 Ha18.	0.0026 Ha18.	0.076 H5.
Te^{127}	0.28	Kidneys Ha1, Ha9, Ha10, Ja2.	300 Ch1.	7			90.4	15 Ha1, Ha9, Ha10, Ja2.	13 H4.	0.25 Ha1, Ha9, Ha10, Ja2	0.2 Ha9.	0.06 Ha1, Ha9, Ha10, Ja2.	0.0007 Ha9, Ja2.	0.02 H5.
Te^{129}	0.89	Kidneys Ha1, Ha9, Ha10, Ja2	300 Ch1.	7			32	15 Ha1, Ha9, Ha10, Ja2	10 H4.	0.25 Ha1, Ha9, Ha10, Ja2	0.2 Ha9.	0.06 Ha1, Ha9, Ha10, Ja2.	0.0007 Ha9, Ja2.	0.02 H5.
I^{131}	0.22	Thyroid Ha1, Ke1, He1, Be1, Ho5, Ha25.	20 Ch1.	3	5.2×10^{-4} Ma1, Ev1, Sb1, Hw1.	2×10^{-4} Ma1, Ba1, Ev1.	8	180 H1. [a]>30 Ha1	7.7 H4.	1.00 Ha1.	0.2 Ha1, Ev1. [a]0.35 H9. [a]0.80 La1.	0.2 Ha1, Ha3, Ha4.	0.2 H2.	0.15 H5.
Xe^{133}	0.183	Body	7×10^4 Ch1	30			5.27				1 D.			
Xe^{134}	0.562	Body	7×10^4 Ch1	30			0.38				1 D.			
$Cs^{137}+Ba^{137m}$	0.57	Muscle Ha1, Ha9, Ha10.	3×10^4 Ch1.	30			1.2×10^4	17 Ha1, Ha9, Ha10.	17 H4.	1.00 Ha1, Ha10, Ha9.	0.45 Ha9.	0.48 Ha1, Ha9, Ha10.	0.48 H2.	0.36 H5.
$Ba^{140}+La^{140}$	1.06	Bone Do1, Ha9, Ha10, Ha1	7×10^3 Ch1.				12.8	~200 Ha9. [a]>50 Ha1, Ha10.	12 H4.	0.1 Do1, Ha9, Ha1.	0.06 Do1, Ha9.	0.7 Do1.	0.07 H2.	0.2 H5.

See footnotes at end of table.

TABLE 4. *Constants for calculating maximum permissible internal concentration of radioisotopes*—Continued

1	2	3			4	5	6	7	8	9	10	11	12	13
Element	Effective energy,[b] $\Sigma(\delta E)$ Mev	Critical organ			Concentration of element per gram of organ	Daily intake of element by ingestion	Half-life			Fraction going from GI tract to blood, f_1	Fraction in critical organ of that in total body, f_2	Fraction from blood to critical organ, f_3'	Fraction reaching critical organ—	
		Organ	Mass	Effective diameter			Physical, T_r	Biological, T_b	Effective, T				By ingestion, f_w	By inhalation, f_v
			g	cm	g	g/day	Days	Days	Days					
La^{140}	0.76	Bone Ha1, Ha9, Ha10.	7×10^3 Ch1.	5			1.67	35 Ha1, Ha9, Ha10.	1.6 H4.	0.003 Ha9, Cr2.	0.3 Ha1, Ha9, Ha10.	0.4 Ha9.	1.2×10^{-1} H2.	0.1 H5.
$Ce^{144}+Pr^{144}$	1.29	Bone Ha1, Ha10, Ha7, Hd1, Ha9, At2, Ha14.	7×10^3 Ch1.	5	Trace		275	500 Ha9, Ha1, Ha10.	180 H4.	0.0005 Ha1, Ha10, Ha9.	0.8 Ha14.	0.4 At2, Ha14.	2×10^{-4} H2.	0.10 H5.
Pr^{143}	0.31	Bone Ha1, Ha9, Ha10, Ha15, Ha16.	7×10^3 Ch1.	5			13.5	50 Ha15. [a]>100 Ha1, Ha9, Ha10.	11 H4.	<0.005 Ha1, Ha9, Ha10, Ha15.	0.6 Ha15, Ha1, Ha9, Ha10.	0.25 Ha15, Ha16.	1.3×10^{-3} H2.	0.063 H5.
Pm^{147}	0.067	Bone Ha1, Ha10, Ha24.	7×10^3 Ch1.	5			1.46×10^3	>100 Ha1, Ha10, 150 Ha24.	140 H4.	>0.0005 Ha1, Ha10.	0.7 Ha24.	0.35 Ha1, Ha10, Ha24.	1.7×10^{-4} H2.	0.09 H5.
Sm^{151}	0.02	Bone Ha18.	7×10^3 Ch1.	5			3.6×10^4	4.3×10^4 H8.	3.9×10^4 H4.	0.00014 H8.	0.65 Ha18.	0.2 Ha18.	2.8×10^{-3} H2.	0.05 H5.
Eu^{154}	0.386	Bone Ha17, Ha18, Ha15.	7×10^3 Ch1.	5			1.97×10^3	1400 Ha18, Ha15.	8.2×10^3 H4.	0.0005 H8.	0.7 Ha17.	0.35 Ha17, Ha18.	1.7×10^{-4} H2.	0.09 H5.
Ho^{166}	0.65	Bone So3.	7×10^3 Ch1.	5			1.14	37 So3.	1.1 H4.	[d] 0.12 So3. 0.0004 H2.	0.5 So3.	0.22 So3.	[d] >0.0001 So3. 0.027 H2.	0.07 H5.
Tm^{170}	0.32	Bone So6.	7×10^3 Ch1.	5			129	110 So6.	59 H4.	0.0005	0.92 So6.	0.7 So6.	3.5×10^{-4} H2.	0.18 H5.
Lu^{177}	0.14	Bone So3.	7×10^3 Ch1.	5			6.7	6 So3.	3.2 H4.	<0.0005 H8.	0.5 So3.	0.3 So3.	0.5×10^{-4} H2.	0.075 H5.
Re^{183}	0.09	Thyroid So2.	20 Ch1.	3			240	12hr So2.	0.5 H4.	0.5 H8.	0.005 So2.	0.0025 So2.	1.3×10^{-3} H2.	1.3×10^{-3} H5.
	0.003	Skin So2, So8.	2,000 Ma1.	0.1			240	5 So8.	5 H4.	0.5 H8.	0.8 So2, So8.	0.23 So2.	0.12 H2.	0.12 H5.
Ir^{190}	0.07	Kidneys So8.	300 Ch1.	7			10.7	23 So8.	7.3 H4.	0.2 H8.	0.15 So8.	0.05 So8.	0.01 H2.	1.75×10^{-2} H5.
Ir^{192}	[c]0.46	Kidneys So8.	300 Ch1.	7			70	23 So8.	17 H4.	0.2 H8.	0.15 So8.	0.05 So8.	0.01 H2.	1.75×10^{-2} H5.
Au^{198}	0.40	Kidneys El1, He1, Bt1.	300 Ch1.	7	Trace Ev1.	Trace Ev1.	2.69	50 G, H8.	2.6 H4.	0.1 El1.	0.06 Bt1.	0.24 He1, Bt1.	0.024 H2.	0.072 H5.
Au^{199}	0.14	Kidneys El1, He1, Bt1.	300 Ch1	7	Trace Ev1.	Trace Ev1.	3.3	50 G, H8.	3.1 H4.	0.1 El1.	0.06 Bt1.	0.24 He1, Bt1.	0.024 H2.	0.072 H5.
Pb^{203}	0.12	Bone So8, Ev1, Au1, Kh1, Kh2.	7×10^3 Ch1.	5	2×10^{-4} Sl1, Ev1.	3×10^{-4} Sl1, Ev1, Kh2.	2.17	<730 Kh1.	2.16 H4.	0.15 Kh2, Kh3.	0.8 So8.	0.3 So8.	4.5×10^{-3} H2.	9.8×10^{-3} H5.

TABLE 4. *Constants for calculating maximum permissible internal concentration of radioisotopes*—Continued

1	2	3			4	5	6	7	8	9	10	11	12	13
Element	Effective energy,[b] $\Sigma(\delta E)$ Mev	Critical organ			Concentration of element per gram of organ	Daily intake of element by ingestion	Half-life			Fraction going from GI tract to blood, f_1	Fraction in critical organ of that in total body, f_2	Fraction from blood to critical organ, f_2'	Fraction reaching critical organ—	
		Organ	Mass	Effective diameter			Physical, T_r	Biological, T_b	Effective, T				By ingestion, f_w	By inhalation, f_a
			g	*cm*	*g*	*g/day*	*Days*	*Days*	*Days*					
Po^{210} (sol.)	5.3α	Spleen Fi2, Fi3, Hu2.	150 Ch1.	7			138.3	57 Hu2.	40 H4.	0.02 Fi2.	0.06 Fi5.	0.015 H2.	0.0003 Fi2	0.004 H5.
Po^{210} (insol.)		Lungs Fi4.	10^3 Ch1.				138.3	40 Fi4.	31 H4.		1.0 D.			0.12 H7.
At^{211}	6.8α	Thyroid Ha25.	20 Ch1.	3			0.31	180 H8.	0.31 H4.	1.00 Ha25, H8.	0.2 H8	0.07 Ha25.	0.07 Ha25.	0.05 H5.
Rn^{222}+ daughter products.	19.5α inside 3.68γ outside.	Lungs	10^3 Ch1.											
		Body	7×10^4 Ch1.	30			3.83				1 D.			
Ra^{226}+ ½daughter products.	14.5α	Bone No1, Ge1, La1, He1.	7×10^3 Ch1.	5	1.7×10^{-11} Hu1.	7×10^{-13} Da1, Ly1, Hu1.	5.9×10^3	1.6×10^4 Si1. =7.9×10^5 H1.	1.6×10^4 H4.	0.2 Si1, No1, St1.	0.99 Ge1.	0.075 Si1.	0.015 H2, Si1, No1, La1.	0.026 H5.
Th^{234}	0.055	Bone Mt1, Ha8, Ha1.	7×10^3 Ch1.	5			24.1	4.3×10^4 H8. =>200 Ha1	24.1 H4.	0.0005 Ha8, Ha1, Ho4. =0.00014 H8.	0.82 Ha8. =0.75 H8.	0.78 Ur1, Si1. =0.7 H8.	3.9×10^{-4} H2.	0.2 H5.
U, natural (sol.)	4.43α	Kidneys Ho2.	300	7	2×10^{-3} Vo1.	2×10^{-6} Da1.	1.64×10^{13}	30 Ho2.	30 Ho2.	0.0005 Ha1.	0.065 Vo1.	0.33 Vo1.	0.0002 H2.	0.08 H5
U, natural (insol.)	...	Lungs Ho3	10^3 Ch1.				1.64×10^{17}	120 Ho3.	120 H4.		1.0 D.			0.12 H7.
U^{233} (sol.)	4.9α	Bone Ha1, Vo1, Ho2.	7×10^3 Ch1.	5	10^{-9} Ly1.	2×10^{-6} Da1.	5.9×10^7	300 Ho2. =2.4×10^4 H1.	300 H4.	0.0005 Ha1.	0.85 Vn1.	0.2 Ha1, Vo1.	10^{-4} H2.	0.05 H5
U^{233} (insol.)		Lungs Ho3.	10^3 Ch1.				5.9×10^7	120 Ho3.	120 H4.		1.0 D.			0.12 H7
Pu^{239} (sol.)	5.16α	Bone Ha1, Kt1, He1, Mi1, Pa1, Ln1.	7×10^3 Ch1.	5			8.8×10^4	4.3×10^4 Lm1.	4.3×10^4 H4.	0.00014 H2, Ln1. =0.00007 Ha1.	0.75 Ha1, He1, Ln1, Ha3, Pa1.	0.7 Pa1	0.0001 Kt1.	0.18 H5.
Pu^{239} (insol.)		Lungs Ah1.	10^3 Ch1.				8.8×10^4	360 Ah1.	360 H4.		1.0 D			0.12 H7.
Am^{241}	5.45α	Bone Ha1, Ha10, Ha12.	7×10^3 Ch1.	5			1.79×10^3	890 Ha13.	890 H4.	0.0005 Ha1, Ha10, Ha12, Ha13, Se2.	0.90 Ha13.	0.25 Ha13, Ha12, Ha1, Ha10.	1.3×10^{-4} H2.	0.063 H5.
Cm^{242}	6.08α	Bone Ba1, Ha19, So5.	7×10^3 Ch1.	5			150	600 So5, Ha1.	120 H4.	<0.0005 Ha1, So5.	0.9 Ha19, So5.	0.25 Ha1, Ha19, So5.	1.25×10^{-4} H2.	0.063 H5.

[a]Values calculated but not used in final determination.
[b]The energy values followed by α are the effective energies in terms of alpha radiation.
[c]The contribution from the short-lived member of the isomeric pair has not been used in the calculation.
[d]The first value differs from the second because once the element enters the bloodstream it is eliminated from the bloodstream very rapidly.

G. General Equations

Some of the values given in table 3 were calculated from the equations given below. (See appendix 2 for a discussion of some of the assumptions made in deriving and using the equations.) The equation numbers to the right are used for references in table 3 to indicate which equations were used for a calculation.

1. For submersion in a radioactive fluid

$$(MPC)_m = \frac{2.6\times10^{-3}\, W \rho_m (P_m/P_t)}{\sum (bE)} \qquad \text{(G1)}$$

microcuries per milliliter of medium, m, to give W of continuous exposure during period of submersion in contaminated fluid.

$$(MPC)_w = \frac{0.8\times10^{-3}}{\sum (bE)} \qquad \text{(G2)}$$

microcuries per milliliter of water to give 0.3 rep/week of continuous exposure to beta or gamma during periods of submersion in contaminated water.

In this case we have set $\rho_m=1$ and $P_m/P_t \doteq 1.02$. For exposure to alpha radiation P_m/P_t would be set equal to about 1, and W in equation G1 would be taken as (0.3/20) rep/week.

$$(MPC)_a = \frac{1.8\times10^{-6}}{\sum (bE)} \qquad \text{(G3)}$$

microcuries per milliliter of air to give 0.3 rep/week of continuous exposure to beta or gamma during period of submersion in contaminated air.

In this case we have set $\rho_m=0.0012$ g/ml and $P_m/P_t \doteq 1/1.13$. For exposure to alpha radiation P_m/P_t would be set equal to about 1/1.22, and W in equation G1 would be taken as (0.3/20) rep/week. Equation G3 is used in determining the maximum permissible exposure of a person to radioactive noble gases. If a noble gas that is a hard beta or gamma emitter is suspended in the atmosphere, the radiation dose a man receives from the gas in his lungs is negligible compared to the dose from a large cloud of gas surrounding him. The above equations are developed for 4π geometry and should be applicable to exposures to small organisms (such as fish eggs in water) or small organs (such as a man's ear when the man is surrounded by a radioactive gas). For general exposure to a large body submerged in a radioactive fluid, the maximum permissible values given in the above equations may be doubled.

2. For radioisotopes inside the body or in the air and water taken into the body

$$q = \frac{2.6\times10^{-3} m W}{\sum (bE) f_2} \qquad \text{(G4)}$$

microcuries in total body to give W exposure to the critical organ of mass, m.

$$(MPC)'_a = \frac{3\times10^{-8} q f_2}{T f_a (1-e^{-0.69t/T})} \qquad \text{(G5)}$$

microcuries per milliliter of air to give W exposure to the critical organ after the exclusive use of contaminated air for time, t.

In equation G5 the breathing rate was taken as 2×10^7 ml/day for a 24-hour day. For exposures of 8 hours' duration a day, the breathing rate would be taken as 10^7 ml/day.

$$(MPC)'_w = \frac{3\times10^{-4} q f_2}{T f_w (1-e^{-0.69t/T})} \qquad \text{(G6)}$$

microcuries per milliliter of water to give W exposure to the critical organ after the exclusive use of contaminated water for time, t.

In equation G6 the rate of water consumption is taken as 2,200 ml/day.

In the case of CO_2,

$$(MPC)'_a = Q/C \times \frac{(\text{ml of } CO_2)}{(\text{ml of alveolar air})} \times \frac{(\text{g of C})}{(\text{ml of } CO_2)}, \qquad \text{(G7)}$$

in which $Q=\mu c/g$ of tissue to give W rep/week, and $C=$ concentration of carbon in critical organ. The London Conference made this substitution:

$$(MPC)'_a = (0.014/0.5)\times0.055\times0.0005 = 0.77\times10^{-6} \doteq 10^{-6}. \qquad \text{(G7a)}$$

Using the values in table 4 and equation G1:

$$(MPC)'_a \doteq \frac{0.015}{0.75}\times0.055\times0.0005 = 0.55\times10^{-6}. \qquad \text{(G7b)}$$

H. Nomenclature and Other Equations

The H numbers in parentheses are the reference numbers used in table 4.

b: $b=1$, for alpha radiation.

$b=1-e^{-(\mu-\sigma_s)x}$, for gamma radiation, where $(\mu-\sigma_s)$ is the total coefficient of absorption minus the Compton scattering coefficient of absorption in tissue (cm^{-1}), and x is the effective diameter of the organ in centimeters.

$b=0.33\,[1-(Z^{1/2}/43)]\,[1+(E^{1/2}/4)]$ for beta radiation, where Z is the atomic number of the radioisotope, and E is the maximum energy in Mev.

bE: effective energy of radiation per disintegration in Mev.

c: concentration of element in critical organ (element in grams/critical tissue in grams).

D: "definition", in table 4.

f_1: fraction going from gastrointestinal tract to blood.

f_2: fraction in critical organ of that in total body.

f_2': fraction going from blood to critical organ.

f_a: fraction retained by inhalation.

$f_a=(0.25+0.5f_1)f_2'$ for soluble compounds. (H5)

When f_2' is not known, the approximation is made for soluble compounds, $f_a \doteq (0.25+0.5f_1)f_2$. (H6)

$f_a=0.12$ for insoluble compounds when the lung is the critical organ. (H7)

f_w: fraction of soluble material reaching critical organ by ingestion $f_w=f_1f_2'$. (H2)

When f_2' is not known, the approximation is made for soluble compounds, $f_w \doteq f_1f_2$. (H3)

g: grams of any element in body$=mc/f_2$. (H9)

Values of g are given in the official Chalk River Report, September 29 and 30, 1949. These values must be considered as very tentative, since in some cases they do not agree with other published data.

G: "guess", in table 4.

I: daily intake of element, in g/day.

m: mass of critical organ, in grams.

MPC: maximum permissible concentration.

MPE: maximum permissible exposure.

P_m/P_t: relative stopping power in the medium compared to tissue.

RBE: relative biological effectiveness.

RBE=1, for beta and gamma radiation.

RBE=20, for alpha radiation, as indicated in table 1.

ρ_m: density of the medium in g/ml.

$\sum(bE)$: effective energy of radiation of both the radioactive isotope in question and its daughters, in Mev.

t: period of exposure (see appendix 3).

T: Effective half-life, in days

$$T=\frac{T_bT_r}{T_b+T_r}. \qquad \text{(H4)}$$

T_b: biological half-life in days. When T_b is not known as a result of direct measurements, one may be able to calculate it by the equation

$$T_b=\frac{0.69mc}{If_w}. \qquad \text{(H1)}$$

T_r: radioactive half-life, in days.

W: (0.3/RBE) rep/week.

When data are not available, direct comparisons are made of Sr with Ca, Th with Pu, Au with Cu, and Ni with Co, etc. Since data available for Cl are limited, it is considered to follow Na in the body. (H8)

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Appendix 1. Calculation of Values of Maximum Permissible Concentration of a Mixture of Radioisotopes

When a person is subject to several different sources of radiation simultaneously, the maximum permissible exposure (MPE) may be given approximately by the equation

$$\mathrm{MPE}=a_1(\mathrm{MPC})_A+a_2(\mathrm{MPC})_B+\ \ldots\ +W_1(MPC)_A+W_2(MPC)_B+\ \ldots\ +e_1(\mathrm{MPE})_x+\ \ldots\ +e_2(MPE)_n+\ \ldots \qquad \text{(K1)}$$

in which

$$a_1+a_2+\ \ldots\ +W_1+W_2+\ \ldots\ +e_1+e_2+\ \ldots\ =1. \qquad \text{(K2)}$$

a_1 = fraction of maximum permissible concentration of radioisotope A in air
a_2 = fraction of maximum permissible concentration of radioisotope B in air, etc.
W_1 = fraction of maximum permissible concentration of radioisotope A in water
W_2 = fraction of maximum permissible concentration of radioisotope B in water, etc.
e_1 = fraction of maximum permissible exposure per week to X-rays
e_2 = fraction of maximum permissible exposure per week to neutrons, etc.

For example, a person might be subject to fractions, a_1, a_2, etc., and W_1, W_2, etc., of the maximum permissible concentrations of radioisotopes as indicated in table 5 and at the same time receive the fraction, e_1, of the maximum permissible exposure to external gamma radiation.

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TABLE 5. *Example of exposures for calculation in appendix 1*

Source of exposure	Organ affected	Maximum permissible concentration in—		Fraction of maximum permissible concentration in—	
		Water	Air	Water	Air
		μc/ml	μc/ml		
Cu^{64}	Liver	8×10^{-3}	6×10^{-6}	W_1	a_1
Co^{60}	do	2×10^{-3}	10^{-8}	W_2	a_2
$Sr^{90}+Y^{90}$	Bone	8×10^{-7}	2×10^{-10}	W_3	a_3
Pu^{239}	do	1.5×10^{-8}	2×10^{-12}	W_4	a_4
Na^{24}	Total body	8×10^{-3}	2×10^{-6}	W_5	a_5
External γ	do	0.3 r/week		e_1	

In the example shown in table 5

$$(\mathrm{MPE})_{\mathrm{liver}}=a_1(6\times10^{-6})_{Cu}+a_2(10^{-8})_{Co}+a_5(2\times10^{-6})_{Na}+W_1(8\times10^{-3})_{Cu}+W_2(2\times10^{-3})_{Co}+W_5(8\times10^{-3})_{Na}+e_1(0.3)_\gamma, \qquad \text{(K3)}$$

in which the fractions (a_1, a_2, a_5, W_1, etc.) can have any values less than 1, provided

$$a_1+a_2+a_5+W_1+W_2+W_5+e_1=1 \qquad \text{(K4)}$$

$$(\mathrm{MPE})_{\mathrm{bone}}=a_3(2\times10^{-10})_{Sr+Y}+a_4(2\times10^{-12})_{Pu}+a_5(2\times10^{-6})_{Na}+W_3(8\times10^{-7})_{Sr+Y}+W_4(1.5\times10^{-8})_{Pu}+W_5(8\times10^{-3})_{Na}+e_1(0.3)_\gamma, \qquad \text{(K5)}$$

in which the fractions can have any values less than 1, provided

$$a_3+a_4+a_5+W_3+W_4+W_5+e_1=1 \qquad \text{(K6)}$$

$$(\mathrm{MPE})_{\mathrm{body}}=a_5(2\times10^{-6})_{Na}+W_5(8\times10^{-3})_{Na}+e_1(0.3)_\gamma, \qquad \text{(K7)}$$

in which the fractions can have any values less than 1, provided

$$a_5+W_5+e_1=1. \qquad \text{(K8)}$$

All the above equations must be satisfied before the radiation exposure to these sources is considered to be satisfactory. This is somewhat of an oversimplification of the problem, because some strontium and plutonium go to the liver and some chromium and cobalt go to the bone, and a gamma-emitting radioisotope in an organ of the body irradiates the whole body to some extent. However, this illustrates the principle upon which the values given in table 3 might be applied, and these errors in application are probably no greater than those in calculating the values given in table 3. Recent experiments have indicated that some of the organs of the body are interdependent in such a way that if half the midlethal dose is delivered to two organs,

it may produce greater damage than if the total midlethal dose is given singly to either of the organs. For example,[9] if albino rats are injected intraperitoneally with half-midlethal doses of P^{32} and Au^{198}, the mortality in 20 days is over 90 percent instead of the expected 50 percent. Most of the Au^{198} goes to the liver and spleen, whereas the P^{32} concentrates primarily in the bone. The supposition is that these organs are interrelated in such a way that simultaneous damage to the reticuloendothelial and hematopoietic systems results in gross body damage that is much greater than that which would result from twice the radiation insult administered separately to either system. There is no evidence that this synergistic effect is of importance when considering chronic damage resulting from extended exposures to concentrations of radioisotopes in the maximum permissible concentration range. However, the evidence of synergistic effects for acute exposure should lead to added caution when applying the MPC values to a mixture of radioisotopes extending over many years of exposure.

Appendix 2. A Discussion of Some of the Units Used and of the Assumptions Made in the Derivation of Equations in this Text

1. The rep as used here corresponds to an energy absorption in tissue of 93 ergs/g. This Subcommittee recognizes that the rep is not a generally accepted unit, and does not subscribe to the fundamental authenticity of any particular conversion value in ergs per gram of tissue.

2. The rem as used in this text corresponds to that amount of energy absorbed in tissue as a result of any type of ionizing radiation in the tissue that leads to the same biological damage as is produced by 1 roentgen. Again, the Subcommittee recognizes that the rem is not a generally accepted unit and uses it because of its convenience in appraising the hazard associated with exposure to various types of radiation in which the relative biological effectiveness (RBE) may differ from unity. By definition 1 rem = 1 rep/RBE. It is recognized that values of RBE are not well known and depend on many conditions involved in each individual case. However, because of the necessity of making an appraisal of the hazards associated with exposure to various types of ionizing radiation, the values of RBE as given in table 1 have been adopted.

3. The microcurie (μc) was assumed to correspond to 3.70×10^4 disintegrations per second. This value is used because of its general acceptance and because it has been recommended for use by an international committee on units.[10] In making comparison with radium it should be kept in mind that the best value for the number of disintegrations per second from 1 μg of radium is $3.608 \pm 0.028 \times 10^4$.[11]

4. The ratio of stopping power in tissue to the value in air used in the calculations is 1.13 for beta and gamma radiation and 1.22 for alpha radiation. These are average values in the energy ranges ordinarily involved here.

5. It is assumed that the radioisotope is uniformly distributed in the body organ. In many cases the distribution is far from uniform, and correction will be made in future calculations when experimental data become available.

[9] H. L. Friedell and J. H. Christie, The synergistic effect of P^{32} and colloidal Au^{198} on survival in male albino rats, NYO-1609.

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Appendix 3. Period of Exposure

The equilibrium period of exposure (when the rate of elimination becomes equal to the rate of deposition in the body) is given by the time, t, in equations G5 and G6 when the term $(1-e^{-0.69t/T}) \doteq 1$. This term is equal to 0.99 when $t=6.6\ T$, in which T is the effective half-life. This 99 percent of equilibrium is reached in a few months for most of the radioisotopes and in less than 20 years for all the radioisotopes listed in table 3, except Pu^{239}, Sm^{151}, Ra^{226}, and Sr^{90}, in which cases it is not reached until 780, 710, 290, and 49 years, respectively. The time of exposure used in the calculation of maximum permissible concentrations in air and water is not critical in most cases. In 70 years, assumed to be equivalent to a lifetime, Pu^{239}, Sm^{151}, and Ra^{226} will have reached 34, 36, and 67 percent respectively, of equilibrium body content.

In the case of occupational exposure of 8 hours per day (assuming half the daily consumption of air and water in the 8-hour work period), 5 days per week, and 49 weeks per year (considering time out for vacations, holidays, etc.), the values of maximum permissible concentrations of radioisotopes in air and water in the working area may be increased by a factor of 3 above those values listed in tables 2 and 3 [i. e., $2 \times (7/5) \times (52/49) \doteq 3$]. In other words, the limited period of exposure for occupational workers reduces the need for the application of a safety factor. In the discussion in the Introduction a safety factor that might be as large as 10 was suggested. Therefore, the safety factor suggested for the maximum permissible concentration values given in tables 2 and 3, when applied to the working area of occupational workers with this limited period of exposure, would be reduced to 3.

Submitted for the National Committee on Radiation Protection.

LAURISTON S. TAYLOR,
Chairman.

WASHINGTON, September 1952.

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F. National Bureau of Standards Handbook 69, "Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and Water for Occupational Exposure," (NCRP Report No.22) June 1959.