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May 1983

INITIAL ASSESSMENT STUDY OF NAVAL WEAPONS SUPPORT CENTER CRANE, INDIANA

NEESA 13-003

NAVAL ENERGY AND ENVIRONMENTAL SUPPORT ACTIVITY
Port Hueneme, California 93043

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NAVY ASSESSMENT AND CONTROL OF INSTALLATION POLLUTANTS:

INITIAL ASSESSMENT STUDY
of
Naval Weapons Support Center
Crane, Indiana
UIC: N00164

May 1983

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EXECUTIVE SUMMARY

This report presents the results of an Initial Assessment Study (IAS) conducted at Naval Weapons Support Center (NWSC), Crane, Indiana during 27 April to 1 May 1981. 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 17 potentially contaminated sites were identified at NWSC. 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 poses an immediate threat to human health or the environment, 14 warrant 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 14 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 14 sites recommended for confirmation are listed below in order of priority:

- Battery Shop, Site 1
- Ordnance Burning Grounds, Site 10
- Demolition Area (High Explosives), Site 9
- Dye Burial Ground, Site 10
- Load and Fill Area, Building 106 Pond, Site 17
- Load and Fill Area, Building 104, Site 13
- Chemical Burial Ground, Site 12
- Cast High Explosives Fill, Building 146, Site 16
- Burning Pit, Site 3
- Mine Fill A and B, Site 14
- ROCKEYE, Site 15
- Pesticide Shop, Site 5
- McComish Gorge, Site 2
- Roads and Grounds Area, Site 6

It should be noted that since the on-site survey in 27 April-1 May 1981, a Confirmation Study has been conducted at many of the sites listed above or are in progress. The results of the Confirmation Study will be used to evaluate the necessity of conducting mitigating actions or cleanup operations.

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- Mine Fill A and B, Site 14
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FOREWORD

The Navy initiated the Navy Assessment and Control of Installation Pollutants (NACIP) program in OPNAVNOTE 6240 ser 45/733503, 11 September 1980. The purpose of the program is to systematically identify, assess, and control contamination of the environment resulting from past hazardous materials management operations.

An Initial Assessment Study was conducted at Naval Weapons Support Center (NWSC), Crane, Indiana, 27 April to 1 May 1981 by a team from the Naval Energy and Environmental Support Activity (NEESA), the Ordnance Environmental Support Office, and the Army Corps of Engineers. Further, confirmation studies under the NACIP program were recommended at several areas at the activity. Sections dealing with significant findings, conclusions, and recommendations are presented in the report. Technical sections provide more in-depth discussion on important aspects of the study. Prior to publishing this report in May 1983, a Confirmation Study has been undertaken by NWSC Crane.

Information or questions concerning the NACIP program should be referred to NEESA 112N, Port Hueneme, CA 93043, AUTOVON 360-3351, FTS 799-3351, or commercial 805-982-3351.

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Naval Energy and Environmental Support Activity

INITIAL ASSESSMENT STUDY
NAVAL WEAPONS SUPPORT CENTER, CRANE, INDIANA

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ACKNOWLEDGEMENT

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- Mr. Dave Smith, Environmental Engineer, NORTHDIV
- CAPT Kenneth Hughes, Commanding Officer, NWSC
- CDR J. Swistock, Public Works Officer, NWSC
- Ms. Cathy Andrews, Environmental Coordinator, NWSC
- LTC Joseph Goss, Commanding Officer, CAAA
- Ms. Karen Whorrall, Environmental Coordinator, CAAA

INITIAL ASSESSMENT STUDY
OF NAVAL WEAPONS SUPPORT CENTER, CRANE INDIANA

SECTION 1. 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 indicating 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:

- o Identify any environmental contamination resulting from past hazardous material storage, handling, and waste disposal operations at shore installations;
- o 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
- o Provide corrective measures, as needed, to prevent contamination from causing any adverse effects on public health or the environment.

1.2 AUTHORITY

The NACIP Program was initiated through OPNAVNOTE 6240 ser 45/733503 of 11 September 1980.

1.3 SEQUENCE OF EVENTS

1.3.1 Notification

The Naval Weapons Support Center (NWSC), Crane, Indiana, was nominated by COMNAVFACENGCOM and approved by CNO for an Initial Assessment Study for FY81. NEESA notified NWSC, Northern Division, Naval Facilities Engineering Command, and Commander, Naval Sea Systems Command of the IAS.

1.3.2 Records Search

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

a. NEESA Information Management Department and Information Services Department, Port Hueneme, Calif.

b. Naval Facilities Engineering Command (NAVFACENGCOM) Historical Office, Port Hueneme, Calif.

c. The National Archives and Records Service, General Services Administration, Cartographic Branch, Pennsylvania Avenue at 8th Street, NW, Washington, D.C.

d. The National Archives and Records Group 80--CNO and Group 71--Bureau of Yards and Docks, Washington, D.C.

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

f. Navy History Office, Washington Navy Yard, Washington, D.C.

g. NORTHNAVFACENGCOM Facilities Planning and Real Estate Department and Facilities Management Department, Philadelphia, Pa.

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

i. NAVSEASYSCOM Documents Branch, Alexandria, Va.

j. NAVSEASYSCOM Safety Office, Alexandria, Va.

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

l. Federal Records Center, 3150 Bertwynn Dr., Dayton, Ohio 45439

1.3.3 On-Site Survey

From 27 April to 1 May 1981, the on-site survey portion of the Initial Assessment Study was performed at Naval Weapons Support Center (NWSC), Crane, Indiana, by a team of specialists from NEESA, OESO, and the Army Corps of Engineers. Prior to performing the on-site survey, the team compiled and evaluated records from various offices, including the Naval Facilities Engineering Command, the Naval Sea Systems Command, the Navy History Office, and the National Archives, to obtain documented evidence of environmental contamination. During the on-site survey, the team reviewed activity records and maps, interviewed long-time employees and retirees of NWSC, and inspected the activity's facilities and environs. Survey findings and recommended actions are summarized in Section 4 of this report.

The on-site team members were as follows:

Wallace Eakes, Chemist, Team Leader

Jeffery Heath, Environmental Engineer

Martha Cavit, Biologist

Kip Rimm, Health Physicist

William Powers, Supvy. Environmental Engineer

Jerald D. Broughton, Research Geological Engineer

H. A. Dodohara, Chemical Engineer, Ordnance

T. J. Sullivan, Chemical Engineer, Ordnance

The Northern Division, Naval Facilities Engineering Command on-site representative was Mr. Dave Smith, Environmental Engineer.

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, recommendations for remedial action are made.

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

1. Sufficient evidence exists to suspect that the installation has contaminated areas, and

2. The contamination may present a potential danger to:

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

   b. The environment within or outside the activity.

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

1.5 RANKING SYSTEM

Hazardous waste sites identified by the IAS team were 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 one of the system is a flowchart which eliminates innocuous sites from further consideration. Step two is a ranking model which assigns a numerical score within a range of 0 to 100, to indicate the potential severity of a site. Scores are a reflection of the characteristics of the wastes disposed of at a site, contaminant migration pathways, and potential 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. CSRS scores assigned to sites recommended for confirmation studies also assist Navy managers to establish priorities for accomplishing the recommended actions. Rankings for NWSC Crane are found in table 4.1-1 in section 4 of this report.

A more detailed description of the Confirmation Study Ranking System is contained in NEESA Report 20.2-042.

1.6 CONFIRMATION STUDY PROGRESS

The confirmation study recommended by the team includes physical and analytical monitoring to confirm or deny contamination or health hazards and to quantify the extent of any problems identified during the Initial Assessment Study.

The Naval Weapons Support Center has taken action on the disposal sites identified in this report. Under a contract with the Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi, NWSC had over 80 monitoring wells drilled at Crane during August to November 1981. Sampling and analysis began on 16 November 1981. The Army Environmental Hygiene Agency is conducting the analysis for NWSC. Preliminary analysis results are now being gathered for interpretation and study.

1.7 CONFIRMATION ACTIONS SINCE MAY 1981

Since the on-site visit during 27 April to May 1981, the following actions have reportedly been taken by NWSC Crane:

Site 1, Battery Shop: Nine soil samples have been analyzed for lead. No significant concentrations of lead have been noted.

Site 10, Ordnance Burning Ground: Twenty-five groundwater monitoring wells have been installed. Monitoring is continuing.

Site 9, Demolition Area: Nineteen groundwater monitoring wells have been installed. Monitoring is continuing.

Site 10, Dye Burial Grounds: Eight groundwater monitoring wells have been installed. Monitoring is continuing.

Site 17, Load and Fill Area, Building 106 Pond: Samples of water and sediment have been collected and analyzed. The results indicate no significant concentration of heavy metals were present.

Site 12, Chemical Burial Ground: Sixteen groundwater monitoring wells have been installed. Monitoring is continuing.

Site 3, Burning Pit: Eighteen groundwater monitoring wells have been installed. Monitoring is continuing.

Site 15, ROCKEYE: Two groundwater monitoring wells have been installed. Monitoring is continuing to determine if water is contaminated with explosives.

Site 5, Pesticide Shop: Nine groundwater monitoring wells have been installed. Monitoring is continuing.

Site 2, McComish Gorge: Six groundwater monitoring wells have been installed. Monitoring is continuing.

Groundwater samples collected from wells are being analyzed for comparison with primary drinking water standards. Groundwater samples collected at sites that may be contaminated with explosive residues are being analyzed for explosive compounds.

Surface water streams exiting the center are being monitored on a monthly frequency for cyanide, explosive compounds, and heavy metals. The center reports the monitoring has not indicated any problem to date.

SECTION 2. SIGNIFICANT FINDINGS

The overall environmental protection program at the Naval Weapons Support Center (NWSC) is excellent. The current Hazardous Waste Management Program is well run. NWSC personnel interviewed during the study know what office to contact concerning disposal of hazardous materials. As indicated in section 1.6 and 1.7, the Center is actively correcting past practices that could potentially result in pollution problems. NWSC personnel display an overall awareness of the environmental program at Crane.

During the installation visit, the Initial Assessment Study (IAS) team investigated 17 suspected disposal sites. The locations of these sites are shown on figure 2.1-1. These sites are discussed in detail in section 6. The significant findings are presented in the following subsections.

2.1 SITE 1, BATTERY SHOP, BUILDING 36

About 2,000 gallons of spent battery acid per year, from 1940 to 1975, were discharged onto a bank behind the Battery Shop, Building 36. Surface drainage from the bank flows into a storm drain, which drains into Lake Greenwood. Lake Greenwood is the local drinking water source. Although the potential for lead salts to migrate to Lake Greenwood exists, routine chemical analyses have not found any significant lead concentration in the water or the soil.

2.2 SITE 2, MCCOMISH GORGE

During the investigative interviews it was reported that ordnance and non-ordnance wastes were placed in McComish Gorge. Specific quantities and types of wastes were not verifiable. If hazardous wastes were disposed of here the potential for groundwater contamination may exist.

2.3 SITE 3, BURNING PIT

From 1942 until 1972, garbage and trash were burned at this site. Ordnance was not burned at this site. Residue from the burning pit was buried in a gully to the north of the pit, along with nonburnable metallic items. Potentially contaminated site leachate could migrate to the groundwater.

2.4 SITE 4, PCB BURIAL AREA (POLE YARD)

In 1977, three PCB capacitors were buried at the pole yard. Subsequent to the on-site survey, NWSC personnel reported that the capacitors were "hermetically sealed" prior to burial. The State of Indiana indicated that NWSC was not required to remove the capacitors if buried previous to 19 February 1978. The state indicated that disturbing the area may pose a more significant problem.

2.5 SITE 5, PESTICIDE SHOP, BUILDING 2189

In the 1960s and early 1970s, pesticide spray tanks and containers were rinsed in the parking lot at Building 2189. A washrack connected to the sanitary sewer was installed in 1977. The accumulation of pesticide residue on the lot and in the surrounding soil presents a potential for

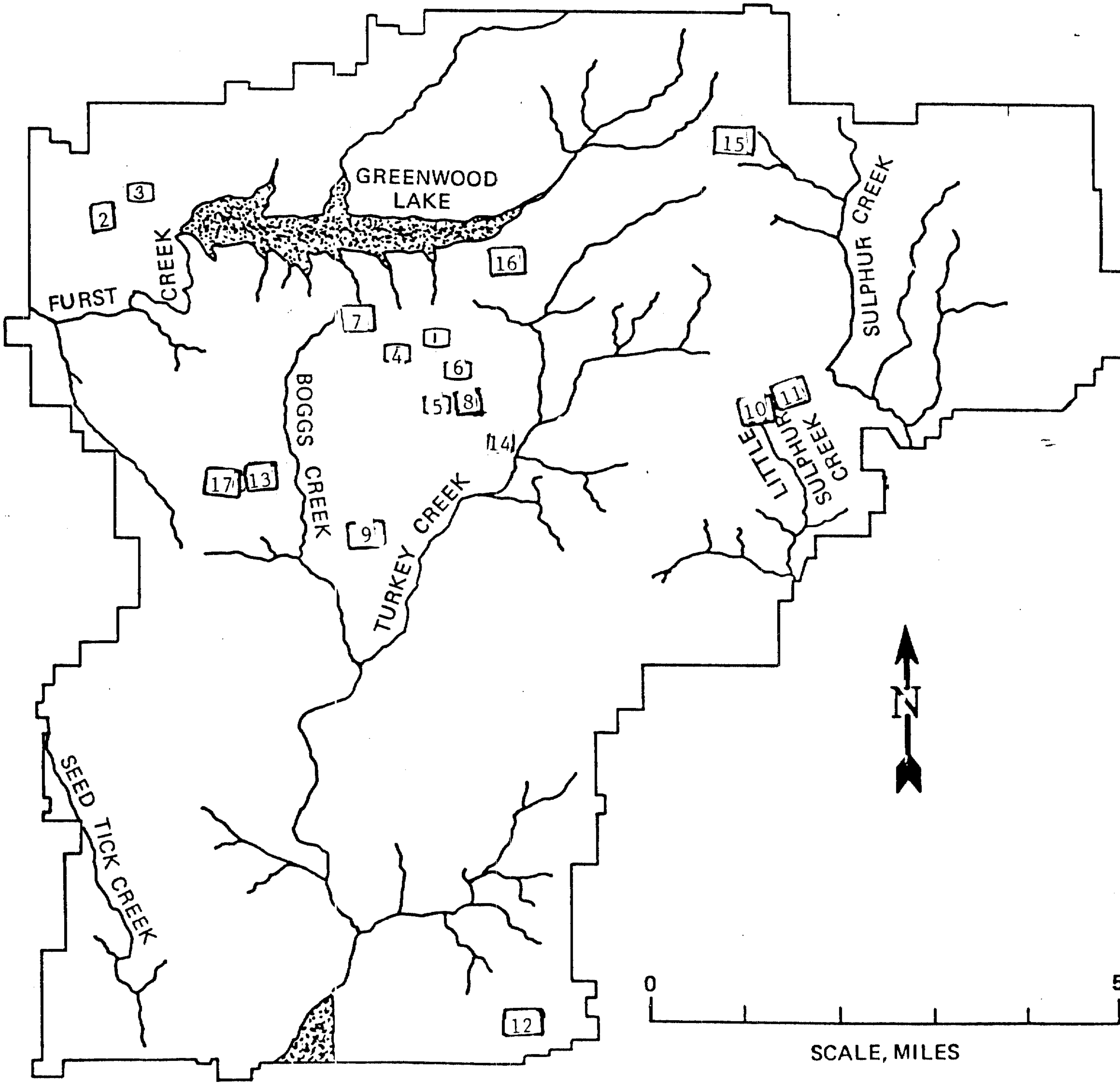


Figure 2.1-1 Locations of Suspected Contamination Sites at NWSC. Site numbers are identified in table 4.1-1 and described in the text.

surface water contamination due to runoff and for groundwater contamination from percolation.

2.6 SITE 6, ROADS AND GROUNDS AREA

Construction rubble and other debris were deposited at the bottom of a hill near the washrack at Building 2716. In addition to this debris, pesticide rinseate was disposed of in this area. The unknown contents of this site, along with the pesticide residues, indicate that the site could potentially have contaminants in the soil that could migrate to surface water or groundwater.

2.7 SITE 7, PCP DIP TANK

A pentachlorophenol (PCP) wood perservation chemical dip tank was located near Building 56. The dip tank was operated between 1950 and 1965. Center personnel reported that the tank leaked. However, inspection revealed that there is no vegetation stress or the evidence confirming this PCP leak.

2.8 SITE 8, LOADING EAD AREA, BUILDING 136

Wastewaters from lead azide and lead styphanate operations in Building 136 were discharged into a retention pond near the building. An estimated 100 pounds of lead salts were discharged in the pond between 1961 and 1977. Reports indicate that this pond was pumped out periodically and that the sediments were taken to the burning grounds (site 11) for disposal. In 1981, the pond was cleaned up. Contaminated soil and effluent were removed from the Center to an approved landfill site by a state certified waste hauler. The pond no longer exists.

2.9 SITE 9, DEMOLITION AREA (HIGH EXPLOSIVES)

High-explosives waste munitions have been disposed of by detonation at the high-explosive demolition area since the 1940s. As much as 10 tons per day were disposed of at this site from 1956 to 1960. The site is located on a ridge. Sedimentation Pond 333 is downslope from the demolition area, but surface runoff may exit the demolition range down the Boggs Creek side and the Turkey Creek side of the ridge. This surface water discharge and percolation into groundwater may potentially transport contaminants to the groundwater, to Boggs Creek, or to Turkey Creek.

2.10 SITE 11, ORDNANCE BURNING GROUNDS

Ordnance and ordnance-contaminated materials from production areas have been taken to the ordnance burning grounds for disposal since 1965. The materials are then burned at the site, which consists of a valley with a stream running through the site. This stream flows into Little Sulfur Creek. Although current monthly surface water analyses have found no significant contamination of Little Sulfur Creek to date, the potential for surface water and groundwater contamination exists.

2.11 SITE 11, DYE BURIAL GROUNDS

From 1952 to 1964, about 50 tons of dyes, including toxic and potentially carcinogenic dyes, were buried at the Dye Burial Grounds site. These dyes are a potential source at groundwater contamination.

2.12 SITE 12, CHEMICAL BURIAL GROUNDS

The chemical burial grounds received materials such as mustard gas bombs and thorium nitrate. The mustard gas bombs were neutralized and the thorium nitrate was removed to an NRC-approved landfill in 1974 and 1980. However, all the contaminated material may not have been removed. This is especially possible because thorium nitrate is highly soluble in water. Any remaining contaminated material could potentially migrate into groundwater.

2.13 SITE 13, LOAD AND FILL AREA (104, 105, 198, and 200)

The load and fill operations produced air and water discharged including heavy metals and explosives. Analyses of these discharges found the following contaminants: mercury, chromium, cadmium, ammonium picrate, RDX, and HMX. This contamination could migrate to surface waters (Boggs Creek) and percolate to the groundwater.

2.14 SITE 14, MINE FILL A, BUILDINGS 152 AND 158, AND MINE FILL B, BUILDINGS 167 and 172

From 1942 until the early 1970s, the Mine Fill Complex, Mine Fill A and Mine Fill B, discharged explosive dust through the ventilation system to the area around the complex. This contamination has been verified by chemical analyses of surface water runoff and of sediments collected at various times in the last decade. This documented evidence shows contamination of the Mine Fill Complex, which potentially could migrate offsite. The contaminants are TNT, RDX, and HMX. The contamination ceased in the mid-1970s, when a particulate abatement system was installed.

2.15 SITE 15, ROCKEYE SITE

Until a treatment facility was installed in 1978, wastewater discharges from the ROCKEYE site, Buildings 2731 and 2734, included TNT, HMX, and RDX consituents. Two discharge points have the potential to drain into surface water tributaries during wet weather and to recharge the upper groundwater table during dry weather.

2.16 SITE 16, CAST HIGH EXPLOSIVES FILL, BUILDING 146

Prior to 1978, before a treatment system was installed, this site discharged potential contaminants by wastewater discharge and by ventilation system exhaust. The wastewater discharge reportedly contained RDX, TNT and ammonium picrate constituents. The ventilation system discharged lead, chromium, and cadmium from a furnace burning miscellaneous items. The potential for soil contamination at this site from earlier operations is significant. Surface water runoff and percolation from earlier operations could transfer this contamination to surface water tributaries and groundwater aquifers.

2.17 SITE 17, LOAD AND FILL AREA, BUILDING 106 POND

The operations in Buildings 106 and 107 generate acid and caustic wastewaters. Prior to 1972, this wastewater was discharged into a small unlined retention pond. The retention pond overflowed into a neutralizing system, and the neutralized wastewater was discharged to the sanitary sewer. Percolation from the pond could cause heavy metals and organic solvents to migrate into the groundwater.

2.18 WATERWAYS EXITING THE BASE

To ensure the quality of the waterways exiting the base, the Center monitors surface waters for cyanides, heavy metals, explosives (TNT, RDX, and HMX), oil and grease, and chlorides. Monthly analyses have shown that the surface waters are within limitations for the above constituents for Turkey, Furst, Boggs, Big Sulfur, Little Sulfur and Seed Tick creeks.

2.19 FIRST/FURST CREEK

The creek downstream from Lake Greenwood is referred to by the Naval Facilities Engineering Command Official General Development Map as Furst Creek. The U.S. Geological Survey maps refer to the same creek at First Creek. This report uses Furst Creek rather than First Creek.

SECTION 3. CONCLUSIONS

3.1 GENERAL

The team met at the Naval Energy and Environmental Support Activity (NEESA) 8-12 June 1981 to discuss the Initial Assessment Study conducted at NWSC Crane. After reviewing information gathered from interviews with key station personnel, from historical records, and from the site survey, the NACIP team concluded that possible contamination exists at several sites at NWSC Crane. The sites and suspected pollutants are summarized in table 3.1-1.

As indicated in section 1.7 of this report, the Center has begun a Confirmation Study. The conclusions drawn in this section are based on the information available in May 1981.

3.2 SITE 1, BATTERY SHOP, BUILDING 36

Because lead salts are potentially presents on the bank behind Building 36 and surface water runoff may migrate to Greenwood Lake, a confirmation study is recommended.

3.3 SITE 2, McCOMISH GORGE

This site contains unidentified wastes which potentially includes ordnance. Surface water runoff or percolation may distribute contaminants to ground and surface water. Therefore, further investigation is necessary to confirm the potential hazard at this site.

3.4 SITE 3, BURNING PIT

Because unknown quantities and types of wastes were burned and disposed of at this site and the leachate may potentially migrate to groundwater, a confirmation study is recommended.

3.5 SITE 4, PCB BURIAL SITE (POLE YARD)

No further action is recommended for this site because the State of Indiana does not require removal of the PCB-containing capacitors and the capacitors were reportedly hermetically sealed prior to disposal.

3.6 SITE 5, PESTICIDE SHOP, BUILDING 2189

The parking lot at Building 2189 has accumulated a residue of pesticide that could migrate off-site by surface runoff, therefore, a confirmation study at this site is recommended.

3.7 SITE 6, ROADS AND GROUND AREA

Debris and pesticides at this site present the potential for surface and groundwater contamination; therefore a confirmation study at this site is recommended.

Table 3.1.1 Suspected Contamination Sites

Site No.	Site	Map* Coordinates	Waste of Concern
1.	Battery Shop (Building 36)	T-24	Lead salts
2.	McComish Gorge	M-6	A variety of toxic and hazardous materials
3.	Burning Pit	L-9	A variety of toxic and hazardous materials
4.	PCB Burial Area (Pole Yard)	T-22	PCB
5.	Pesticide Shop (Building 2189)	Y-24	Pesticides
6.	Roads and Grounds Area	U-26	Organics, metal salts, and pesticides
7.	PCP Dip Tank	R-21	PCP
8.	Loading EAD Area (Building 136)	W-26	Lead salts
9.	Demolition Area (High Explosives)	HH-22	Ordnance materials
10.	Ordnance Burning Ground	BB-45	Solvents, ordnance materials, and pesticides
11.	Dye Burial Grounds	Z-47	Dyes
12.	Chemical Burial Grounds	FFF-29	Thorium and mustard gas
13.	Load and Fill Area		
	By Buildings 104	EE-17	Mercury, cadmium,
	105	CC-14	Chromium, RDX
	198	GG-16	TNT, and
	200	HH-13	Trichloroethylene
14.	Mine Fill A	Z-25	TNT and RDX
	Mine Fill B	BB-22	
15.	ROCKEYE	K-42	TNT and RDX
16.	Cast High Explosives Fill (Building 146)	Q-31	RDX, yellow D, TNT, lead chromium and cadmium
17.	Load and Fill (Building 106)	EE-13	Mercury, chromium, phosphorus, and trichloroethylene

* NAVFAC general development map

3.8 SITE 7, PCP DIP TANK

No evidence of a PCP leak was found. Therefore, no further action is recommended at this site.

3.9 SITE 8, LOADING EAD AREA, BUILDING 136

Wastewaters from lead azide and lead styphanate operations discharged from Building 136 to a pond near the building. The area was decontaminated and the waste was hauled off-station by a state certified hazardous waste hauler. Because the area has been cleaned up, no further action is recommended for this site.

3.10 SITE 9, DEMOLITION AREA (HIGH EXPLOSIVES)

High-explosives ordnance materials have been disposed of by detonation at this site. Surface water runoff and percolation into groundwater may carry explosive contaminants to the groundwater, to Boggs Creek, or to Turkey Creek. Therefore, further confirmation work is required at this site.

3.11 SITE 10, ORDNANCE BURNING GROUNDS

Ordnance-contaminated materials have been burned at this site. The possible pollutants generated may be migrating into the groundwater or may be entering the surface drainage system. Consequently, a confirmation study is recommended.

3.12 SITE 11, DYE BURIAL GROUNDS

An estimated 50 tons of dyes were buried at this site. Some of the dyes may be carcinogenic. These dyes are a potential source of groundwater contamination. Therefore, a confirmation study is recommended.

3.13 SITE 12, CHEMICAL BURIAL GROUNDS

Mustard gas bombs and thorium nitrate were buried at this site. The site was surveyed, and these materials were removed, however, all materials may not have been removed, especially since thorium nitrate is highly soluble. Therefore, a confirmation study is recommended for this site to verify that all contaminants have been removed.

3.14 SITE 13, LOAD AND FILL AREA, BUILDINGS 104, 105, 198, and 200

Heavy metals, ordnance compounds, and organic solvents were discharged to this site. Potential surface contamination exists in this area. Because this contamination could migrate to surface water or groundwater. A confirmation study is recommended for this site.

3.15 SITE 14, MINE FILL A, BUILDINGS 153 and 158, and MINE FILL B, BUILDINGS 167 and 172

The area around these buildings has been contaminated with ordnance materials. This contamination could migrate off-site to surface and groundwater sources, therefore, confirmation work is recommended at this site.

3.16 SITE 15, ROCKEYE SITE

Wastewater discharges from this site contained ordnance materials. The discharges potentially drain into surface water tributaries and potentially recharge the groundwater table. Therefore, a confirmation study is recommended for this site to determine the extent of contamination.

3.17 SITE 16, CAST HIGH-EXPLOSIVES FILL, BUILDING 146

The Navy Assessment and Control of Installation Pollutants (NACIP) on-site survey revealed that this site may be contaminated by ordnance materials and by heavy metals. There is potential for migration of this contamination, thus a confirmation study is recommended.

3.18 SITE 17, LOAD AND FILL AREA, BUILDING 106

The unlined pond behind Building 106 collected acid and caustic wastewaters. Because the pond is unlined, the potential for contaminated leachates, from the pond sediments to migrate to groundwater is present and a confirmation study is recommended. Use of this pond to collect acidic and caustic wastewaters was discontinued in 1979.

3.19 SURFACE WATERWAYS

Five waterways leaving the station are Furst Creek, Boggs Creek, Little Sulfur Creek, Sulfur Creek, and Seedtick Creek. These creeks eventually collect the majority of surface waters from the station. Pollutants leaving the station through surface waters will normally flow into one of these creeks. However, these surface waters are regularly monitored for contamination and are currently within the required limitations.

3.20 SUBSURFACE WATERS

The groundwater flow is predominantly toward the west. Therefore, the probable direction of pollutant migration at NWSC Crane is toward the western boundary of the station.

3.21 MAJOR POTABLE WATER

The major potable water source for the Center is Lake Greenwood. Only two sites--sites 2 and 3--are upgradient of the lake and according to recent chemical analysis of the potable water supply, these sites are not impacting the lake.

SECTION 4. RECOMMENDATIONS

4.1 GENERAL

Based upon the findings and conclusions of this report, the NACIP team recommended a Confirmation Study be conducted at 14 sites located at NWSC and a general monitoring of surface waters at base boundaries. The team judged these 14 sites met the criteria to warrant a Confirmation Study. The evidence at sites 4, 7, and 8 did not warrant a Confirmation Study, therefore, no follow-up action is recommended at these sites. In addition, the NACIP team recommended a general monitoring program be established to monitor surface water flowing off the Center. The Confirmation Study, Phase II of the NACIP Program, is designed to confirm or deny the presence of contaminants at the 14 sites identified by the team. The suspected contaminated sites and recommendations are summarized in table 4.1-1. The general monitoring recommendation is discussed in section 4.2.1.

The recommendations presented in this section are intended to be used as a guide to develop and implement the confirmation study phase. Wherever possible, the recommendations include approximate number of samples to be taken, types of samples to be taken such as soil, water, or sediment, number of wells to be drilled, and specific pollutants to be analyzed. Individual tests could not characterize the suspected contaminants because of the variety of materials dumped at certain locations. Therefore, a screening procedure is recommended at these sites to determine the specific pollutant.

Screening may be accomplished by sampling and analyzing the four general categories of groundwater contamination established by EPA in the Hazardous Waste Regulations (40 CFR 265). The four tests are pH, specific conductance, total organic carbon, and total organic halogen. Well-water samples collected upgradient and downgradient from the dump site will be tested for these four general categories. The results of the comparison of these tests will lead to other specific analytical tests, if groundwater contamination is shown.

Several sites were recommended for testing according to the Environmental Protection Agency extraction procedure toxicity test. This test indicates the potential leachability of a hazardous material to the environment. The test and test procedures are listed in 40 CFR 260 and 261. The test parameters are arsenic, barium, cadmium, chromium, lead, mercury, selenium, silver, endrin, lindane, methoxychlor, toxaphene, 2,4-D, and 2,4,5-TP silvex.

As indicated in section 1.7, NWSC Crane reports that a Confirmation Study is underway at sites 1, 2, 3, 5, 8, 9, 10, 11, 12, 15, and 17 and that over eighty groundwater monitoring wells have been installed at sites 2, 3, 9, 10, 11, and 12.

4.2 SURFACE WATERS DRAINAGE WAYS

4.2.1 General

Five major creeks drain the surface water from NWSC to the surrounding community. These creeks are Furst Creek, Boggs Creek, Little Sulfur Creek, Sulfur Creek, and Seedtick Creek. The NACIP team concluded that any pollutant

Table 4.1-1 Summary of Recommendations

No.	Site	Map Coordinates	Drill Wells	Sample: Water	Sample: Sediment	Sample: Soil	Test*	Remarks	CSRM** Score
1	Battery Shop (Bldg. 36)	T-24			X	X	Lead		26
2	McComish Gorge Dump	M-6	X	X			pH, spec. Cond. TOC, TOH	Test for groundwater contamination indicators, further analysis may be necessary.	3
3	Burning Pit Dump	L-9	X	X			pH, spec. Cond. TOC. TOH	Test for groundwater contamination indicators.	12
4	PCB Burial (Pole Yard)							No further action at this site.	0
5	Pesticide Shop (Bldg. 2189)	Y-24				X	Endrin, Lindane, Methoxychlor, Toxaphone, 2,4-D, Silvex		4
6	Roads and Grounds Dump and Washrack	U-26			X	X	EP Toxcity Test		4
7	PCP Dip Tank	R-21						No further action at this site.	0
8	Loading (Bldg. 136)	W-26						No further action at this site.	0
9	High Explosive Demolition Area	HH-22	X	X			pH, Spec. Cond. TOC TOH, RDX, HMX, Ammonium picrate	Test for groundwater contamination indicator and ordnance materials.	19
10	Ordnance Burning Ground	BB-45	X	X			pH, spec. Cond. TOC, TOH, TNT, RDX, HMX, Ammonium picrate	Test for groundwater contamination indicator and ordnance materials.	21

*Test methods selected from EPA-approved test methods (EPA methods, ASTM methods, and Standard methods).
Test for groundwater contamination indicators listed in 40CFR265.
**Confirmation Study Ranking Model (CSRM)--see section 1.5 for explanation.

Table 4.1-1 Summary of Recommendations (Contd.)

No.	Site	Map Coordinates	Drill Wells	Sample: Water	Sample: Sediment	Sample: Soil	Test*	Remarks	CSRM** Score
11	Dye Burial Ground	Z-47	X				pH, spec. Cond. TOC, TOH, color		15
12	Chemical Burial Ground	FFF-29	X	X			mustard agent thorium		13
13	Load and fill area (Bldg. 104)	EE-17				X	mercury, cadium, chromium, RDX, TNT		13
14	Mine fill A Mine fill B	Z-25 BB-22				X	RDX TNT		9
15	ROCKEYE	K-42	X	X			RDX, TNT		
16	Cast and fill pond (Bldg. 146)	Q-31			X		RDX, TNT, chromium, cadmium, ammonium picrate, lead, and mercury		12
17	Load and fill pond (B-106)	EE-13			X		mercury chromium phosphorus TCE		14

*Test methods selected from EPA-approved test methods (EPA methods, ASTM methods, and Standard methods). Test for groundwater contamination indicators listed in 40CFR265.

**Confirmation Study Ranking Model (CSRM)--see section 1.5 for explanation.

exiting the base boundaries through surface waters would follow one of these major drainage ways. It is recommended that the established monitoring program be continued at these locations.

4.3 NON-ORDNANCE SITES

4.3.1 Site 1, Battery Shop, Building 36

Test for: lead

Sample locations: at the discharge site at the bank top, on the bank below discharge site, and in the drainageway.

Type of Sample: surface soil sample and soil sample collected at 1/2-meter depth at each location.

Number of Samples: approximately 6.

Frequency: One time only.

Remarks: The sampling and analysis should determine if lead salts are migrating toward Lake Greenwood, the source of drinking water for NWSC. If results of sampling and analysis are negative, no further action is required.

4.3.2 Site 2, McComish Gorge

Monitoring Wells: Drill five wells around the dump site. Locations of the wells will be determined by a hydrogeologist.

Test for: pH, specific conductance, total organic carbon, and total organic halogen.

Type of Samples: groundwater.

Number of Samples: 12 samples from each well.

Frequency: monthly from each well for one year or quarterly for three years.

Remarks: Compare the upgradient test results to downgradient test results for well-water analysis to determine if contamination exists. Results from the screening test may indicate further analysis is necessary.

4.3.3 Site 3, Burning Pit

Monitoring Wells: Drill five groundwater-monitoring wells around the dump site. Locations of the wells will be determined by a hydrogeologist.

Test for: the groundwater contamination indicators: pH, specific conductance, total organic carbon, and total organic halogen.

Type of Samples: groundwater.

Number of Samples: 12 samples from each well.

Frequency of Sampling: monthly from each well for one year or quarterly for three years.

Remarks: Compare the upgradient and downgradient groundwater contamination indicators to determine if contamination exists. Results from the screening test may indicate further testing is required.

4.3.4 Site 4, PCB Burial Site (Pole Yard)

Remarks: Properly mark site on general development map. No other action recommended for this site.

4.3.5 Site 5, Pesticide Shop, Building 2189

Test for: pesticides: Endrin, Lindane, Methoxychlor, Toxaphene, 2,4-D and Silvex.

Sample locations: downgradient from washrack at four locations.

Type of Samples: surface soil sample and soil sample collected at 1/2-meter depth at each location.

Number of Samples: 8

Frequency: one-time sampling.

Remarks: The sampling and analysis at this location is designed to determine if pesticides are present because pesticide tanks were rinsed at this location.

4.3.6 Site 6, Roads and Grounds Area

Test for EP toxicity test, arsenic, barium, cadmium, chromium, lead, mercury, selenium, silver, endrin, lindane, methoxychlor, toxaphene, 2,4-D, Silvex.

Sample locations: bottom of hill (downside of dump) and 100 yards downstream from dump.

Type of Samples: soil and sediment.

Number of Samples: one sample at each location (4).

Frequency: one-time sampling.

Remarks: Sampling and analysis may indicate further investigation is required.

4.3.7 Site 7, PCP Dip Tank

Remarks: No further action required at this site.

4.4 ORDNANCE SITES

4.4.1 Site 8, Loading EAD Area, Building 136

Remarks: No further action required at this site.

4.4.2 Site 9, Demolition Area (High Explosives)

Monitoring Wells: Drill 7 to 10 monitoring wells about 50 feet deep downslope on the Turkey Creek side and on the Boggs Creek side of the demolition area. The exact locations of the wells will be determined by a hydrogeologist.

Test for: (1) ordnance compounds: TNT, RDX, HMX, and ammonium picrate and (2) groundwater contamination indicators, pH, specific conductance, TOC, and TOH.

Sample locations: test wells, pond 333, and drainageways from demo area.

Type of Samples: grab groundwater and surface water samples.

Number of Samples: 4 from each well, 4 from the pond, and 4 from each drainageway.

Frequency of Sampling: one sample from each location quarterly for one year.

Remarks: Compare upgradient and downgradient groundwater contamination indicators to determine if contamination exist. Further testing may be required.

4.4.3 Site 10, Ordnance Burning Grounds

Monitoring Wells: Drill five wells to 50 feet deep. Place two wells on either side of the creek that runs through the burning grounds. Locate the fifth well upslope of the area. The exact locations of the wells will be determined by a hydrogeologist.

Test for: (1) the groundwater contaminations indicators: pH, specific conductance, total organic carbon, and total organic halogen and (2) ordnance compounds: TNT, RDX, HMX, and ammonium picrate.

Sample Type: groundwater.

Sample Locations: monitoring wells.

Number of Samples: twelve samples from each well.

Sample Frequency: one sample from each well monthly for one year or quarterly for three years.

Remarks: Compare groundwater contamination indicators for contamination. Results from the screening test may indicate further testing is required.

4.4.4 Site 11, Dye Burial Grounds

Monitoring Wells: Drill six monitoring wells. Two of the wells should be in bedrock (about 100 feet). The exact locations and depths of the wells will be determined by a hydrogeologist.

Test for: (1) the groundwater contamination indicators: pH, specific conductance, total organic carbor, and total organic halogen and (2) color (see remarks).

Type of Samples: groundwater, grab.

Number of Samples: 12 samples from each well.

Frequency: one sample from each well monthly for one year or quarterly for three years.

Remarks: Compare the upgradient and downgradient groundwater contaminant indicator to determine if contamination exists. Results from the screening test may indicate further testing is necessary. Contact the Ordnance Environmental Support Office (OESO) for sampling and analysis procedures, concerning color. The color test may be a good screening method to determine if dyes are migrating from the site.

4.4.5 Site 12, Chemical Burial Grounds

Monitoring Wells: Drill six monitoring wells. The exact locations and depth of the wells will be determined by a hydrogeologist.

Test for: mustard agent and thorium.

Type of Samples: groundwater, grab samples.

Number of Samples: 4 samples from each well.

Frequency: one sample from each well quarterly for one year.

Remarks: The Radiological Affairs Support Office (RASO) of NEESA (113) will provide guidance, review, and instructions for sampling thorium. The Ordnance Environmental Support Office (OESO) at NOS Indian Head can provide mustard agent sampling and testing procedures.

4.4.6 Site 13, Load and Fill Area, Buildings 104, 105, 198, and 200

Test for: mercury, cadmium, chromium, RDX, and TNT.

Sample locations: Collect samples around Building 104.

Type of Samples: soil core down to 1/2-meter depth.

Number of Samples: up to 40 total.

Frequency: one-time only.

Remarks: Building 104 was selected as the most likely of the four buildings to have significant pollutants in the drainageway. If the test results show that significant pollutants are not migrating from this site, do not sample other buildings. If results of analysis show significant migration, sample and analyze discharges from Buildings 105, 198, and 200.

4.4.7 Site 14, Mine Fill A, Buildings 153 and 158, and Mine Fill B, Buildings 167 and 172

Test for: RDX and TNT.

Sample locations: Collect 4 samples around each building.

Type Sample: core soil sample down to 1/2-meter depth.

Number of Samples: 16.

Frequency: one-time sampling.

Remarks: One-time sampling and analysis should show if contamination exists.

4.4.8 Site 15, ROCKEYE

Monitoring Wells: Drill two shallow monitoring wells (less than 50 feet) downstream for the ROCKEYE north discharge, near Building 1569, where the discharge sometimes enters the ground. The exact locations and depths of the wells will be determined by a hydrogeologist.

Test for: RDX and TNT.

Type of Samples: groundwater and surface water.

Sample locations: monitoring wells and downstream from discharge site and at Sulfur Creek.

Number of Samples: Groundwater: 24. Surface water: 24.

Frequency: Sample each well quarterly for three years. Sample the surface water quarter for three years.

4.4.9 Site 16, Cast High Explosives Fill, Building 146

Test for: RDX, ammonium picrate, chromium, cadmium, TNT, lead, and mercury.

Type of Samples: surface soil and surface water samples.

Sample locations: in drainageway and at discharge site.

Number of Samples: 2 soil samples, and 8 surface water.

Frequency: Collect surface water samples at each location quarterly for one year. Soil samples taken one-time only.

Remarks: Analysis should reveal if contamination exists.

4.4.10 Site 17, Load and Fill Area, Building 106

Test for: mercury, chromium, phosphorus, and trichloroethylene.

Type of Sample: sediment (on pond bottom).

Sample location: At bottom of pond (sediment), collect two samples--one at top 3 to 4 inches and one at 1/2-meter depth.

Number of Samples: 2.

Frequency: one-time sampling.

SECTION 5. BACKGROUND

5.1 GENERAL

The Naval Weapons Support Center (NWSC), Crane, is located in southwestern Indiana. The location was chosen because it is remote from congested population areas and because it is far enough from the eastern seaboard to minimize the dangers of enemy air attack. The hilly terrain is ideal for magazine construction and camouflage protection. The territory, though isolated, is traversed by two state highways, a railroad, and an electric power transmission line. A third, hard-surfaced road crosses the Center, and an additional railway line passes in close proximity to the site.

Eighty percent of the land was submarginal, and more than half of the 62,466 acres of the chosen site was already government owned. The presence of an adequate water supply and an 800-acre artificial lake further prompted the choice. Rocks and limestone were available nearby for building and construction purposes.

5.2 HISTORY

5.2.1 Activity Development

In June 1940, Congress authorized construction of a naval ammunition depot in Southern Indiana. Congress appropriated $5 million to build inland ammunition production facilities that would be secure from enemy air attack. Three million dollars were set aside to build the Naval Ammunition Depot, Burns City.

The Navy quickly acquired 35,000 acres of land comprising the White River Project and added 26,830 additional acres from private ownership at an average cost of $20.75 per acre.

The original construction plans were restricted to 23 smokeless powder magazines, officer's quarters, a group of shop buildings, railroads, and service functions as necessary. The Maxon Construction Company broke ground in June 1941, and the Burns City Ammunition Depot was commissioned on 1 December 1941.

Captain E. G. Oberlin, assumed command of the station. By July 1943, the center had approximately 2,000 structures. Some 1,600 were earth-covered magazines, and 400 were used for mine-filling, shell-loading, maintenance-shop, and subsidiary operations. In addition, necessary utilities and services had been installed.

Housing for civil service employees soon became critically short. The town of Crane was built by the Navy to house the civil service employees. On 1 May 1943, NAD Burns City became NAD Crane in honor of Commodore William Montgomery Crane. NAD Crane's overall mission was to load, prepare, renovate, receive, store, and issue ammunition to the fleet.

5.2.2 World War II Operations

The original mission of NAD Crane gradually changed during this period from that of loading and assembling conventional gun ammunition. The World War II mission included the following tasks: load and prepare, renovate, receive, store, and issue all types of ammunition, including pyrotechnics, and act as a principal source of stowage and supply therefore; maintain in readiness for operation, or operate as required, plants for loading major and medium caliber projectiles, cartridge cases, bag charge rocket motors, boosters, cast explosives, and 20MM and pyrotechnics as well as auxiliary plants to support the major production facilities; maintain and operate a quality evaluation laboratory; conduct research and development in the field of torpedo mounts, missile launchers, and fire control equipment, and perform minor modifications and overhaul on such equipment; act as a reserve stock point for all types of inert ordnance equipment, repair parts, tools, and accessories under the inventory control of the Bureau of Ordnance and/or Ordnance Supply Office; maintain technical direction of field inspection program for all synchros procured under Bureau of Ordnance contracts; and dispose of unserviceable and/or dangerous ammunition, explosives, and guided missiles, in accordance with current directives.

First production for the Depot was the loading of TNT boosters in May 1942. By the summer of 1945, 5,500 civilians were employed in ordnance on the Depot--4,500 in production plants, and 1,000 in field activities.

Medium-caliber projectile loading started in December 1942, but loading of Explosive "D" charges did not begin until February 1943. Items loaded were 1,000-pound AP AN bombs; 1,600-pound AP Navy bombs; 12-inch AP projectiles; 14-inch AP projectiles; 5"/38 common projectiles; 8-, 12-, 14-, and 16-inch HC projectiles; 8-inch AP projectiles; and 12-inch AP projectiles.

All production records were broken on the "D" loading of 1,000-pound and 1,600-pound bombs, 12-inch HC, 14-inch HC, 12-inch AP, and 16-inch AP projectiles. Production loading of AP bombs was approximately 40 percent greater than that of any other station in the country.

Bag loading and ignition assembly started in September 1942 with an unstacked 5"/50 service bag charge. Top monthly production was achieved in 1945 when about 40,000 service bag charges of various calibers were produced.

Production in cartridge assembly started in January 1943, with 20 people assembling 5"/38 and 6"/47 semi-fixed cartridges. Later came the assembly of 3"/50 fixed and 3"/50 saluting cartridges, 4"/50 fixed charges, and 5"/50 fixed charges. At the peak of operation in July 1945, two shifts in cartridge assembly employed 160 civilians.

Breakdown and overhaul was conducted at various intervals in connection with target loading. These operations included 20/MM breakdown; refuzing hand-grenades; plaster loading of rocket heads; refuzing 5"/38 projectiles; and tanking of ballistic powder grains for storage.

A tank repair building was commissioned in July 1943. Production consisted of servicing all fleet-returned major-caliber tanks received on the Depot, including reforming, testing, welding, soldering, cleaning, and painting.

The pyrotechnics plant was the largest and best equipped plant of its kind in the country. It supplied both the Atlantic and Pacific fleets with most of their illuminating projectiles, parachute flares, and star shells. At its peak operation, the plant purchased by contract almost $6 million worth of raw materials annually. A few items, such as the projectiles and chemicals, were government-furnished.

Most of the naval experimental work on pyrotechnics was transferred to this plant, and extensive experiments were conducted. To aid in experimental work and production control, a complete laboratory for chemical testing was set up in the pyrotechnics area.

The mine filling area was one of the first production areas on the Depot; 32 employees commenced work on the Mark 6 Depth Charge in September 1942. Mine filling employed 770 persons in 1945.

Rocket assembly started on the Depot with 80 employees in September 1943 and grew to 210 employees by August 1945. During the first two years, over a million rockets were loaded on the Depot.

Although the magazines were built at a rapid rate, incoming shipments were so tremendous at times that the magazines were filled almost before the metal doors were hung and the earthen barricades were completed.

Field storage was the initial ordnance activity on the Depot, employing nine people. By August 1945, 1,000 civilian employees and 650 military personnel handled an average of 3,000 railroad cars per month.

The Torpedo Shop started production in May 1942. Its chief functions were the inspection and storage of incoming torpedos. The inspection included cleaning and preserving.

The Supply Department became a major reserve source of ordnance spare parts. The Depot was designated the central receiving point for all used mobile equipment returned from the east and west coasts. Shops were set up for processing this mobile equipment, and large lots were prepared for storage.

A Survey and Sales Division was set up in 1944 to arrange for the disposal of scrap metal, textiles, paper, and surplus hand tools.

Water supply and sewage disposal were among the first service functions to be developed on the Depot. Lake Greenwood was the source of water supply. Plants were built to treat, pump, and store water. The plants expanded to a processing capacity of 1,440,000 gallons daily, with storage provisions for 1,126,000 gallons. Water shortages have never hampered production at the Depot.

A national coal strike in 1943 forced the Depot into coal production to alleviate the acute shortage of solid fuel. A strip mine was opened on the base. With multiple shift operations, 2,500 tons of mined, crushed, and graded coal were produced in five weeks.

The Medical Department was organized in March 1942 and assumed the responsibility of pre-employment physicals, sanitation inspections, and industrial medicine. The toxicity of the various ingredients used on the Depot required regular employee health examinations as well as pre-employment physicals. Four sub-dispensaries were established near the major work centers.

5.2.3 Post-World War II Period

Crane successfully met its purpose of providing ammunition to the fleet during the Korean and Vietnam conflicts. It reached a high level of ordnance production in 1967-68 by producing approximately one million MK68 and MK82 bombs, one-half million major caliber projectiles, and one-half million MK24 flares.

On 24 June 1952, Captain E. C. Rook, commanding officer, officially broke ground on a 50-acre site for the construction of a $3 million loading plant. This is one of the largest and most automated plants for manufacturing 3-inch ammunition.

A Quality Evaluation Laboratory was established in July 1955 as a division of the Inspection Department. In 1958, it was redesignated as the Quality Evaluation Laboratory Department. This Department is charged with the continuing and special examination and surveillance of naval ammunition, its components and accessories, and such other ordnance items and material as may be directed. The Department provides technical support for the quality control and quality assurance program of the Bureau of Ordnance.

The Pyrotechnic Research & Development Department was established in 1955, and redesignated as the Research & Development Department in 1958. This Department conducts research and development as assigned by the Bureau of Ordnance in the field of pyrotechnics including design, product engineering, test, and technical evaluation. It accomplishes full revision procedures for pyrotechnic drawings and specifications, and acts in an advisory capacity with respect to waiver and deviation requests on pyrotechnics.

NAD Crane was responsible for the receipt, storage, and issue of guided missiles. It provides support for Guided Missile Service Unit 219, whose function is assembly, check-out, maintenance, and alteration of all assigned guided missile material. In addiition, NAD Crane acted as a central storage, assembly, maintenance, and issuing activity for Display Guided Missiles.

The Bureau of Ordnance (BuOrd) implemented a policy in 1955 to decentralize functions to field activities. It transferred certain functions relating to ammunition and explosive ordnance materials at the naval shore establishment to NAD Crane. The first function transferred to Crane was the ammunition loading production engineering center (ALPEC) in 1955. ALPEC's major assigned tasks were to coordinate, standardize, review, develop, test, approve, and promulgate standard operating procedures and standard job procedures governing ammunition production and handling operations; to coordinate and provide competent instruction to the ordnance shore establishments in the field of Methods-Time-Measurement (MTM) Utilization; to receive, coordinate, develop, test, standardize, approve, and promulgate designs of special machinery, tools, equipment, including changes, modifications, and improvements thereto.

In January 1959 the Central Ammunition Supply Control Office (CASCO) was established at Crane. CASCO is responsible for the technical direction and procedures for the production, renovation and demilitarization, and disposition of designated types of ammunition and ammunition components. CASCO recommends funding for these programs to the Bureau of Ordnance; issues work directives to activities of the naval shore establishment; implements Bureau-approved basic stock levels and allowances for ammunition; issues ammunition shipment orders; and administers ammunition pilot production programs including preparation of budget estimates pertaining thereto.

5.2.4 Southeast Asia Crisis

NAD Crane met many challenges in 1968, with the Southeast Asia crisis taxing the Depot to its full capacity. Employment soared to 6,800 full-time employees, not including intermittent workers (those who are permitted to work on a "part-time basis or as needed").

5.2.5 Post-Southeast Asia Crisis

With the announced termination of hostilities in Southeast Asia in 1973, the Depot immediately began restructuring its workload and workforce, but continued to replenish the Nation's ammunition stockpile throughout the world.

On 1 July 1975, NAD Crane was designated Naval Weapons Support Center (NWSC), Crane, Indiana. The new mission assigned by the Chief of Naval Operations states that NWSC Crane will provide material, technical, and logistic support to the Navy for ships and crafts equipments, shipboard weapons systems, and assigned expendable and nonexpendable ordnance items and will perform additional functions as directed by the Commander, Naval Sea Systems Command.

In November 1975, Crane marked the end of bomb production when employees of Mine Fill A processed the last of the Mark 82 500-pound bombs and the Mark 84 2,000-pound bombs. Since 27 February 1969, when the 3-millionth bomb was loaded, Crane's production has been in excess of an additional 3 million.

The single service manager concept program placed conventional ammunition procurement responsibility, for all branches of the military, with a single branch--the Army. NWSC Crane is now one of three Navy ordnance activities involved in phase I of the single manager program. Two installations, NAD Hawthorne and NAD McAlester, were transferred to the Army. At Crane, the Army has assumed only ordnance production, storage, and related responsibilities; all other functions remain Navy. Phase I was implemented at NWSC on 1 October 1977 with the creation of the Crane Army Ammunition Activity (CAAA). CAAA operations correspond roughly to those of the former Crane ordnance department whose employees (approximately 686) were transferred to the Army payroll. Of the remaining Navy personnel (approximately 2,900), 55 percent are directly engaged in RDT&E or related functions. The remaining 45 percent provide support for the primary Navy and Army mission functions.

The Navy retains ownership of all real estate and facilities at Crane; the facilities utilized by the Army are provided through an Army/Navy license agreement. Support and housekeeping services for the Army are provided by the Navy under the terms of an Interservice Support Agreement. The CAAA is headed by a commanding officer, holding rank of Colonel, who maintains a small civilian administrative staff. Responsibility for overall station safety security, and environmental protection remains with the Commanding Officer, NWSC Crane.

5.3 PHYSICAL FEATURES

5.3.1 General

NWSC Crane is located in the northern half of Martin County, in southwestern Indiana. The nearest major metropolitan area is Bloomington, Indiana, approximately 40 miles northeast on State Highway 45. NWSC encompasses more than 100 square miles (62,463.46 acres), which includes 1,006 acres of improved grounds, 10,047 acres of semi-improved grounds, 49,611 acres of unimproved grounds, and 800 acres of water (Lake Greenwood). The surrounding area is woodlands and small farms, with the populace served by the towns of Odon, Loogootee, and Bedford in Daviess, Martin, and Lawrence County, respectively. Figure 5.3-1 shows NWSC and vicinity.

5.3.2 Climate

NWSC Crane, located in a temperate climate zone, has a wide temperature range between summer and winter. The summers are warm and humid, and the winters, though generally mild, often have very cold periods of short duration. The mean minimum temperature in January is 26^{o}F, and the mean average maximum temperature in July is 89^{o}F. Precipitation averages almost 44 inches annually, with 42 inches of rainfall and 15 inches of snowfall. Average humidity ranges 40 to 90 percent in summer and 60 to 90 percent in winter.

5.3.3 Topography

The surface of NWSC is composed of flat to gently undulating terrain dissected by numerous well-defined drainageways. The elevation ranges from approximately 470 feet at the drainage exiting to the south to 860 feet on a ridge in the west-central portion of NWSC. Generally, the ridge crests lie at an elevation of 750 to 800 feet, with the drainageways steadily rising from 470 feet at the southern exit to the north. The V-shaped drainages in the north progress to 2,000-feet-wide floodplains in the south and rise approximately 150 to 200 feet to the ridgelines on slopes of 20 to 30 degrees. Figure 5.3-2 shows the general topography of NWSC.

5.3.4 Geology

NWSC is underlain by unconsolidated deposits of Quaternary (Pleistocene) age and residual soil derived from Pennsylvanian and Mississippian bedrock. The unconsolidated deposits are limited to the small floodplains and are composed of alluvial, colluvial, and paludal silt, sand, and gravel; lacustrine

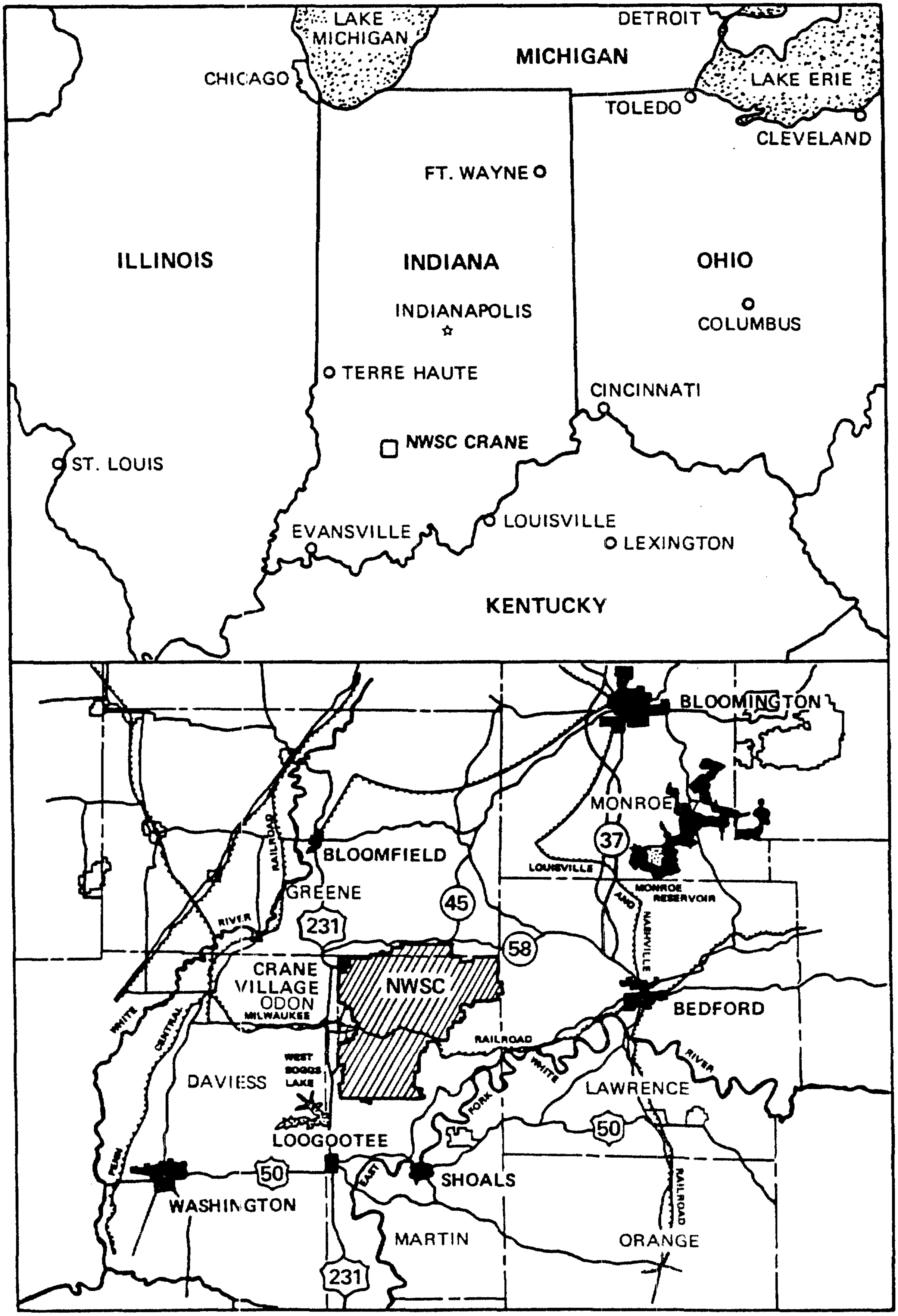


Figure 5.3-1 NWSC and Vicinity

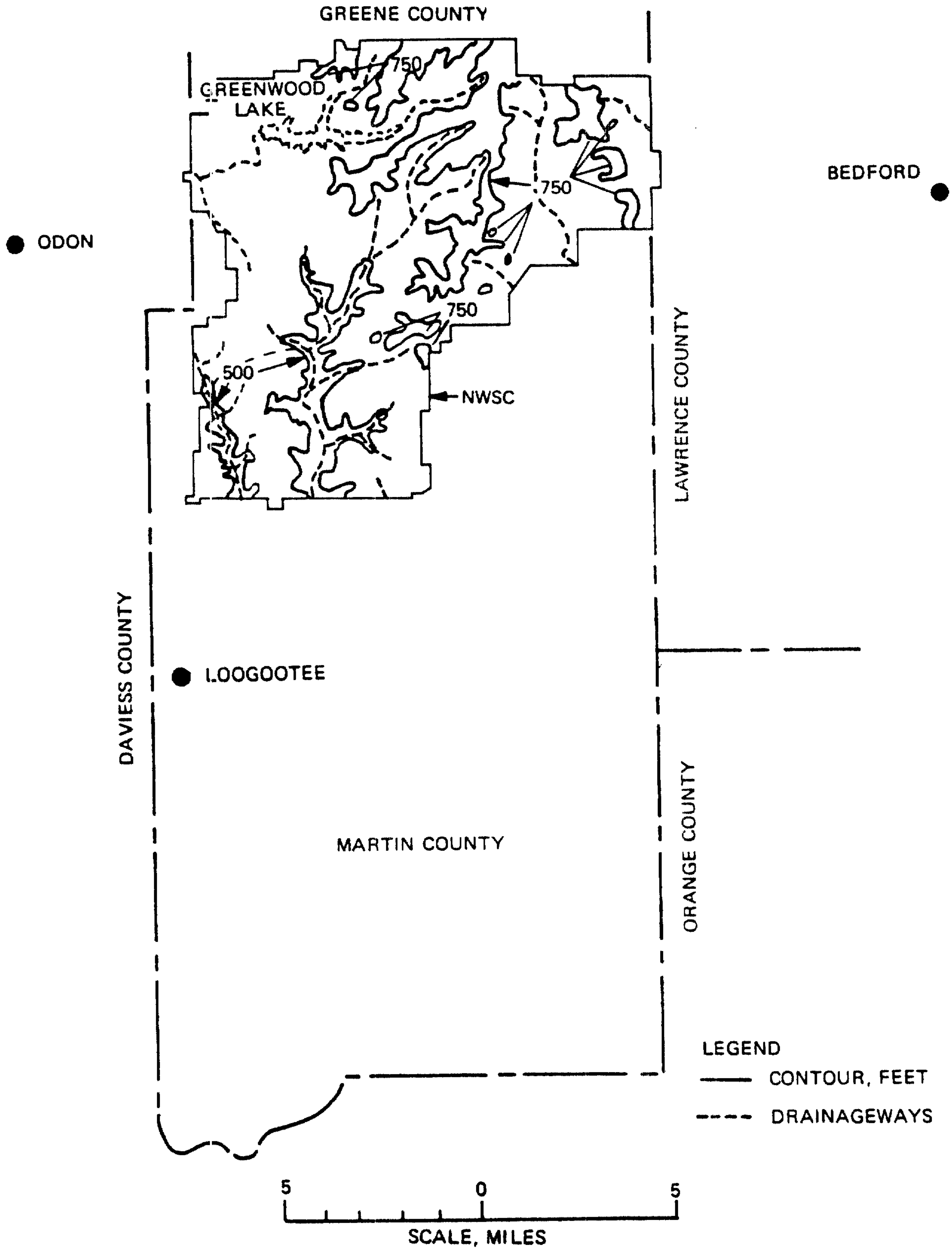


Figure 5.3-2 Topography of NWSC

clay, silt, and sand; and outwash-plain gravel, sand, and silt. The residual clay and silt were derived from the Pennsylvanian Raccoon Group of shale, sandstone, and shale, while the West Baden Group is composed of shale, sandstone, and limestone with isolated deposits of semiconsolidated sand. Figure 5.3-3 shows the extent and distribution of the unconsolidated Quaternary deposits. Table 5.3-1 presents the stratigraphic column of bedrock units underlying NWSC. Figure 5.3-4 shows the distribution of the upper bedrock units underlying NWSC and the location of the section across southern Martin County. Figure 5.3-5 shows the cross section. The bedrock units beneath NWSC are reported to dip gently from the Cincinnati Arch to the Illinois Basin in the southwest, and the geologic section appears to verify this. However, records of the Indiana Geological Survey, which show depths to the base of the Beech Creek limestone of the Stephensport Group, indicate that the local dip of the bedrock units is approximately 25 feet per mile to the west-northwest. Figure 5.3-6 shows the location of these wells and the elevation of the base of the Beech Creek limestone.

Several wells penetrating the bedrock units have been drilled on or near NWSC. Some of these wells were oil or gas explorations; some were attempts to obtain potable water supplies. The locations of the hydrocarbon exploration wells are shown on figure 5.3-7. The locations of the water wells are shown on figure 5.3-8. The available logs of these wells are presented in appendix A.

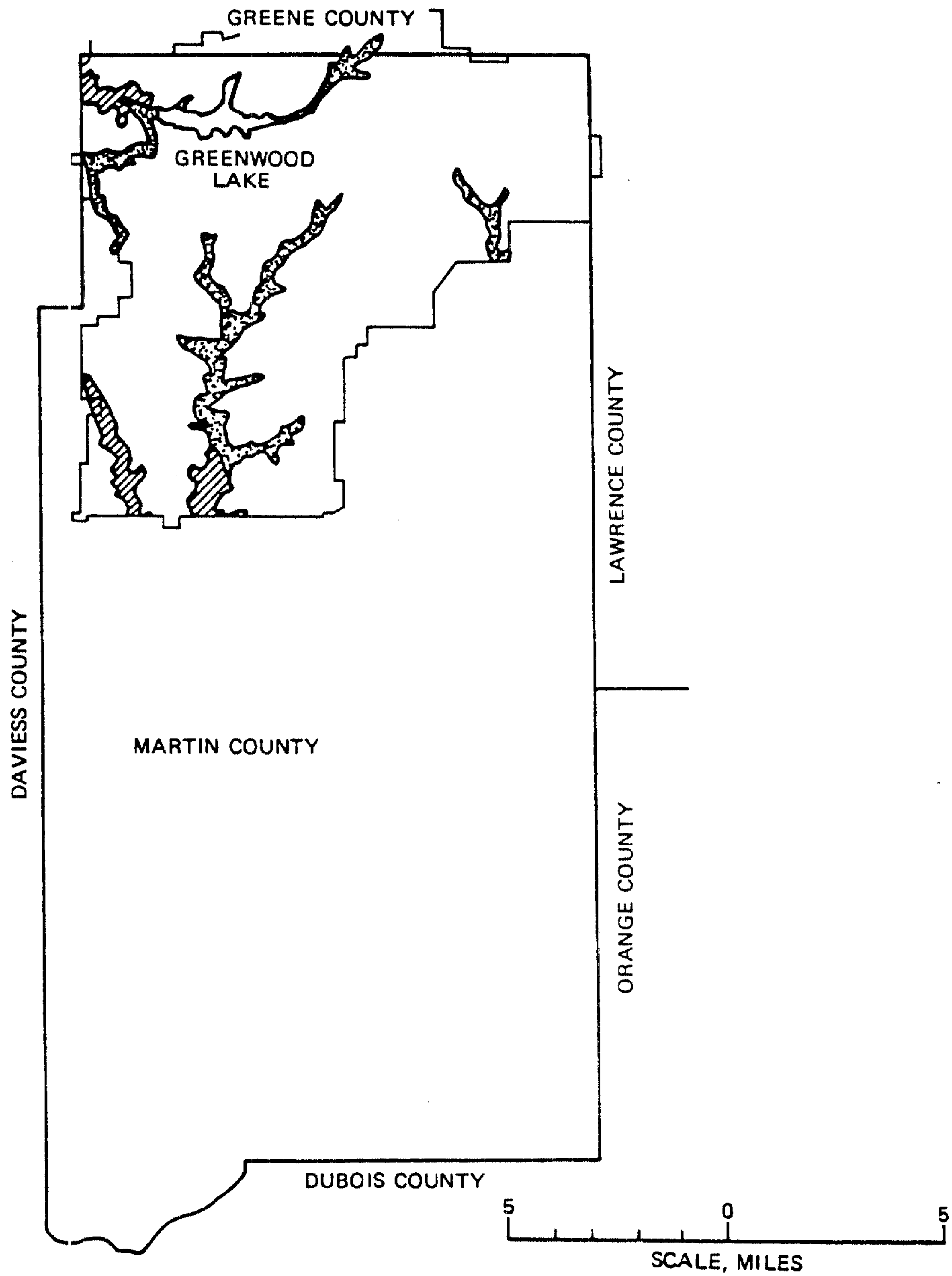
Two other areas of NWSC, the sanitary landfill area and the compactor building, have been subjected to intensive soil boring programs, which penetrated the full thickness of the residual soil cover. The boring logs and plot plans were available for these borings. These areas are shown on figure 5.3-9.

The landfill area borings show 4.6 to 16.5 feet of residual soil, silt, or clay, overlying sandstone or shale. The observation wells penetrated 25 to 30 feet of bedrock and disclosed discrete layers of sandstone and shale with occasional stringers of coal. The logs of these wells are presented in appendix B. The detailed boring locations are on PWO Drawing 4026, code identification number 80091, sheets 1 and 2, dated 4 September 1980 and on PW 3103, coded identification number 80091, NAVFAC Drawing number 2002159, sheet C4, dated 17 November 1971.

The compactor area borings show 14 to 18 feet of residual soil, silt, and clay, overlying sandstone. The logs for these borings are presented in appendix C. The detailed boring locations are on PW 3103, coded identification 80091, NAVFAC Drawing number 20022157, sheet C2, dated 17 November 1971.

5.3.5 <u>Soils</u>

From the boring logs, the major soil type is a 2- to 3-inch-thick surface layer of brown to tan organic clay loam underlain by clay intermixed with silts and sand. The United States Department of Agriculture (USDA) identifies three-fourths of Martin County (which includes the NWSC) as the Zanesville and Muskingum soil series. These series are identified as a dark brown organic silt loam at the surface, underlain by 48 inches of mottled tan, gray, and



LEGEND

QUATERNARY SILT, SAND, AND GRAVEL MOSTLY ALLUVIUM BUT INCLUDES SOME COLLUVIAL AND PALUDAL DEPOSITS.

QUATERNARY CLAY, SILT AND SAND. LACUSTRINE DEPOSITS.

RESIDUAL CLAYS AND SILT FROM PENNSYLVANIAN RACCOON CREEK GROUP AND MISSISSIPPIAN STEPHENSPORT AND WEST BADEN GROUPS.

Figure 5.3-3 Surficial Deposits on NWSC

Table 5.3-1 Columnar Section Showing Bedrock Units.

TIME UNIT: PERIOD	TIME UNIT: EPOCH	MAP UNIT	THICKNESS (FEET)	LITHOLOGY	ROCK UNIT *: SIGNIFICANT MEMBER	ROCK UNIT *: FORMATION	(FORMATIONS MAPPED IN ILLINOIS)	ROCK UNIT *: GROUP
PENNSYLVANIAN	CONEMAUGHIAN	P5	175+		MEROM Ss.	MATTOON Fm.	MATTOON Fm.	MCLEANSBORO
PENNSYLVANIAN	CONEMAUGHIAN	P4	150 to 200		LIVINGSTON Ls. SHOAL CREEK Ls.	BOND Fm.	BOND Fm.	MCLEANSBORO
PENNSYLVANIAN	CONEMAUGHIAN	P3 WF	200 to 350			*PATOKA Fm.*	MODESTO Fm.	MCLEANSBORO
PENNSYLVANIAN	CONEMAUGHIAN	P3 WF	200 to 350		WEST FRANKLIN Ls.	SHELBURN Fm.	MODESTO Fm.	MCLEANSBORO
PENNSYLVANIAN	ALLEGHENIAN	V P2	300 to 400		DANVILLE COAL (VII)	DUGGER Fm.		CARBONDALE
PENNSYLVANIAN	ALLEGHENIAN	V P2	300 to 400		SPRINGFIELD COAL (V)	PETERSBURG Fm.		CARBONDALE
PENNSYLVANIAN	ALLEGHENIAN	V P2	300 to 400		SURVANT COAL (IV)	LINTON Fm.		CARBONDALE
PENNSYLVANIAN	ALLEGHENIAN	B P1	250 to 500		SEELYVILLE COAL (III)	STAUNTON Fm.		*RACCOON CREEK*
PENNSYLVANIAN	POTTSVILLIAN	B P1	250 to 500		BUFFALOVILLE COAL LOWER BLOCK COAL	BRAZIL Fm.		*RACCOON CREEK*
PENNSYLVANIAN	POTTSVILLIAN	B P1	250 to 500			MANSFIELD Fm.		*RACCOON CREEK*

* ROCK-UNIT NAMES FOR PENNYSLVANIAN ROCKS IN INDIANA FOLLOW THE USAGE PROPOSED BY WIER (IN PREPARATION), STRATIGRAPHY OF MIDDLE AND UPPER PENNSYLVANIAN ROCKS IN SOUTHWESTERN INDIANA. NEW NAMES ARE SHOWN IN ITALICS AND ARE TENTATIVE UNTIL FORMAL PRESENTATION.

Table 5.3-1 Columnar Section Showing Bedrock Units (Contd.).

MISSISSIPPIAN	CHESTERIAN	M M_6	250 to 300		KINKAID Ls.	
					MENARD Fm.	
		M_5	120 to 190		GLEN DEAN Ls.	STEPHENSPORT
					HARDINSBURG Fm.	
					GOLCONDA Ls.	
					BIG CLIFTY Fm.	
					BEECH CREEK Ls.	
		M_4	70 to 150		ELWREN Fm.	WEST BADEN
					REELSVILLE Ls.	
					SAMPLE Fm.	
					BEAVER BEND Ls.	
					BETHEL Fm.	
		M_3	250 to 550		PAOLI Ls.	BLUE RIVER
				LEVIAS ROSICLARE FREDONIA	STE. GENEVIEVE Ls.	
	VALMEYERAN				ST. LOUIS Ls.	
		M_2	100 to 160		SALEM Ls.	SANDERS
					HARRODSBURG Ls.	
		M_1	600+		MULDRAUGH Fm.	BORDEN
					CARWOOD AND LOCUST POINT Fms.	
					NEW PROVIDENCE Sh.	

* ROCK–UNIT NAMES FOR PENNSYLVANIAN ROCKS IN INDIANA FOLLOW THE USAGE PROPOSED BY WIER (IN PREPARATION), STRATIGRAPHY OF MIDDLE AND UPPER PENNSYLVANIAN ROCKS IN SOUTHWESTERN INDIANA. NEW NAMES ARE SHOWN IN ITALICS AND ARE TENTATIVE UNTIL FORMAL PRESENTATION.

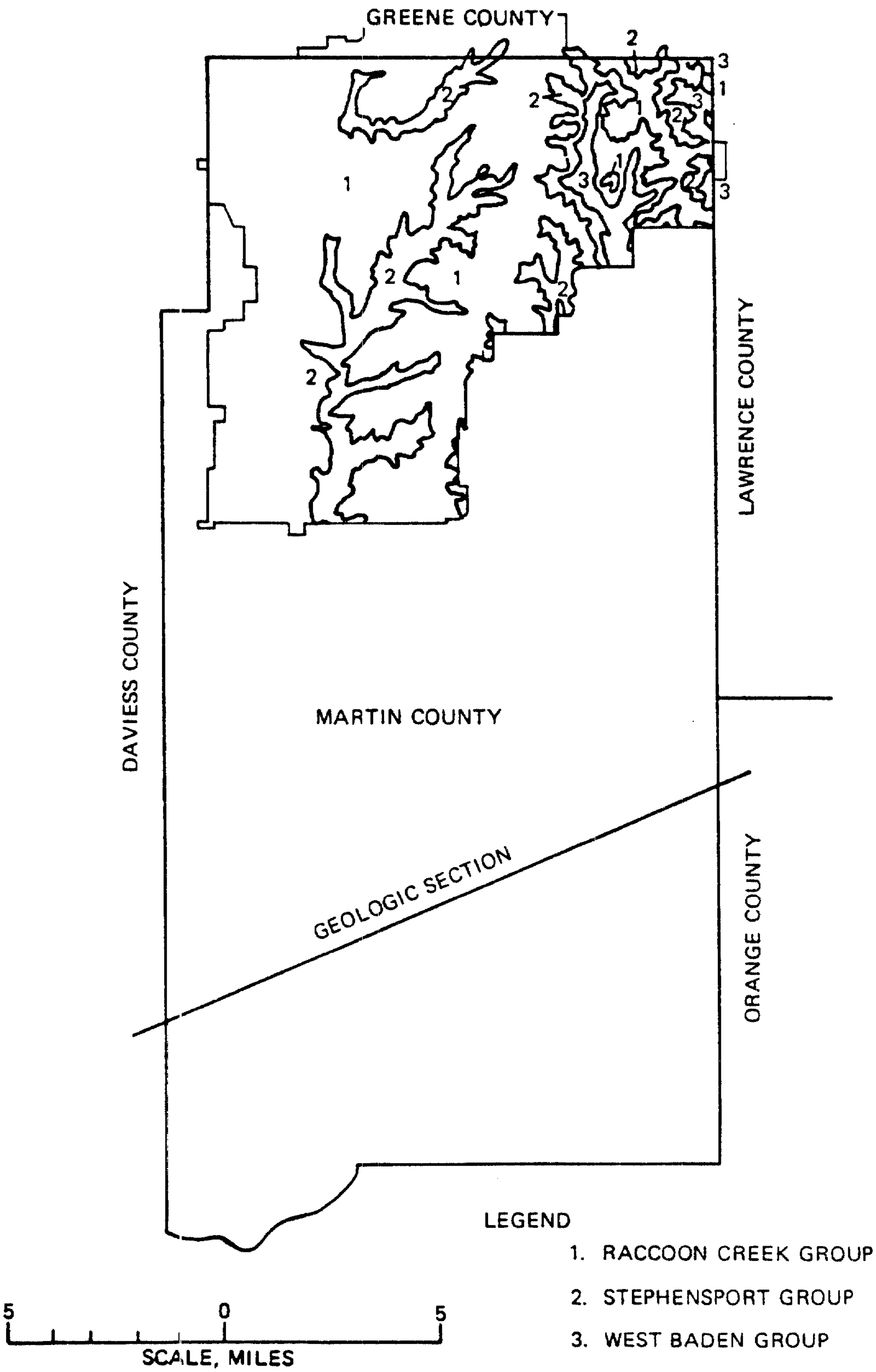


Figure 5.3-4 Geology of NWSC and Cross Section Location

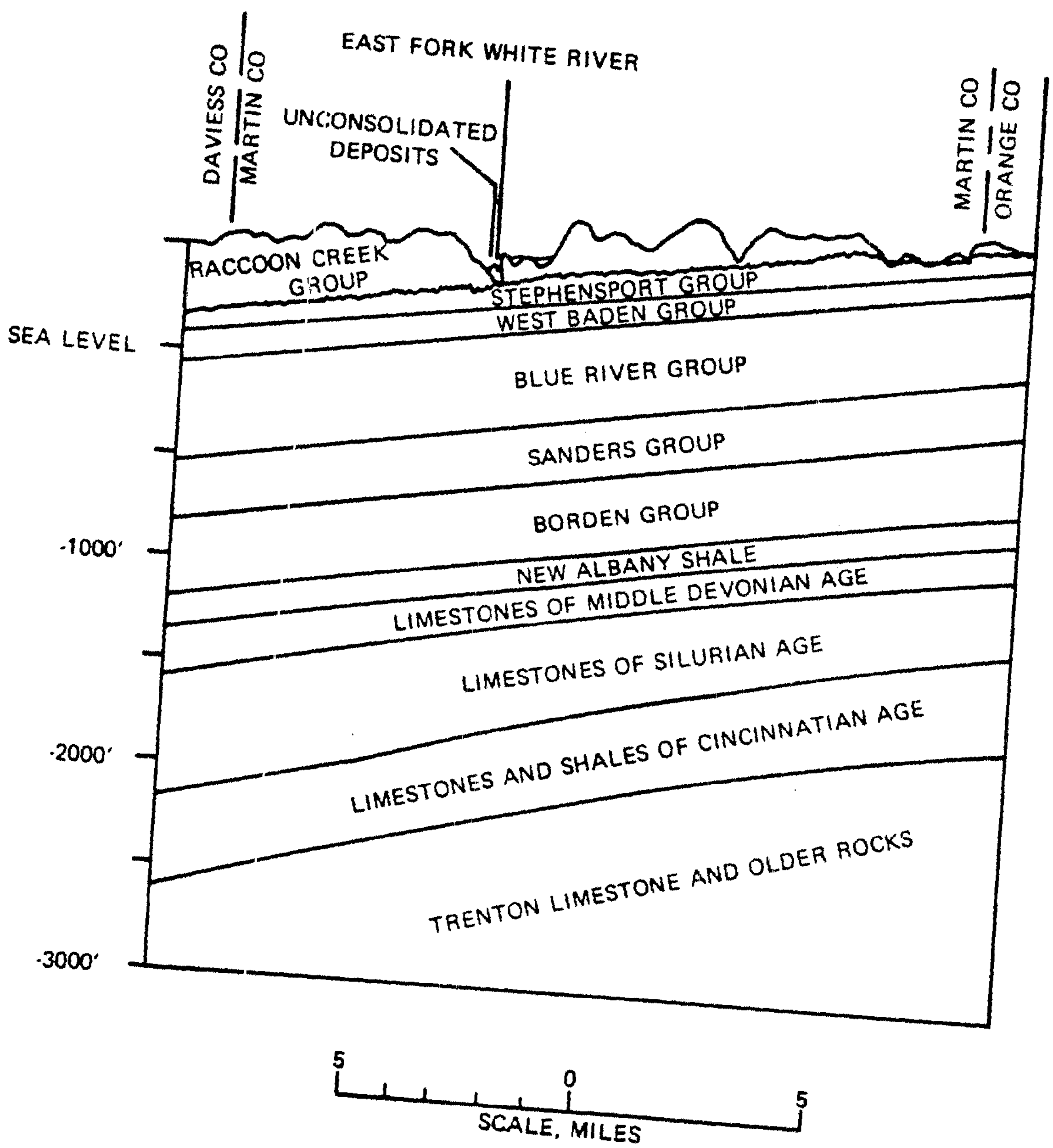


Figure 5.3-5 Geologic Section Across Southern Martin County

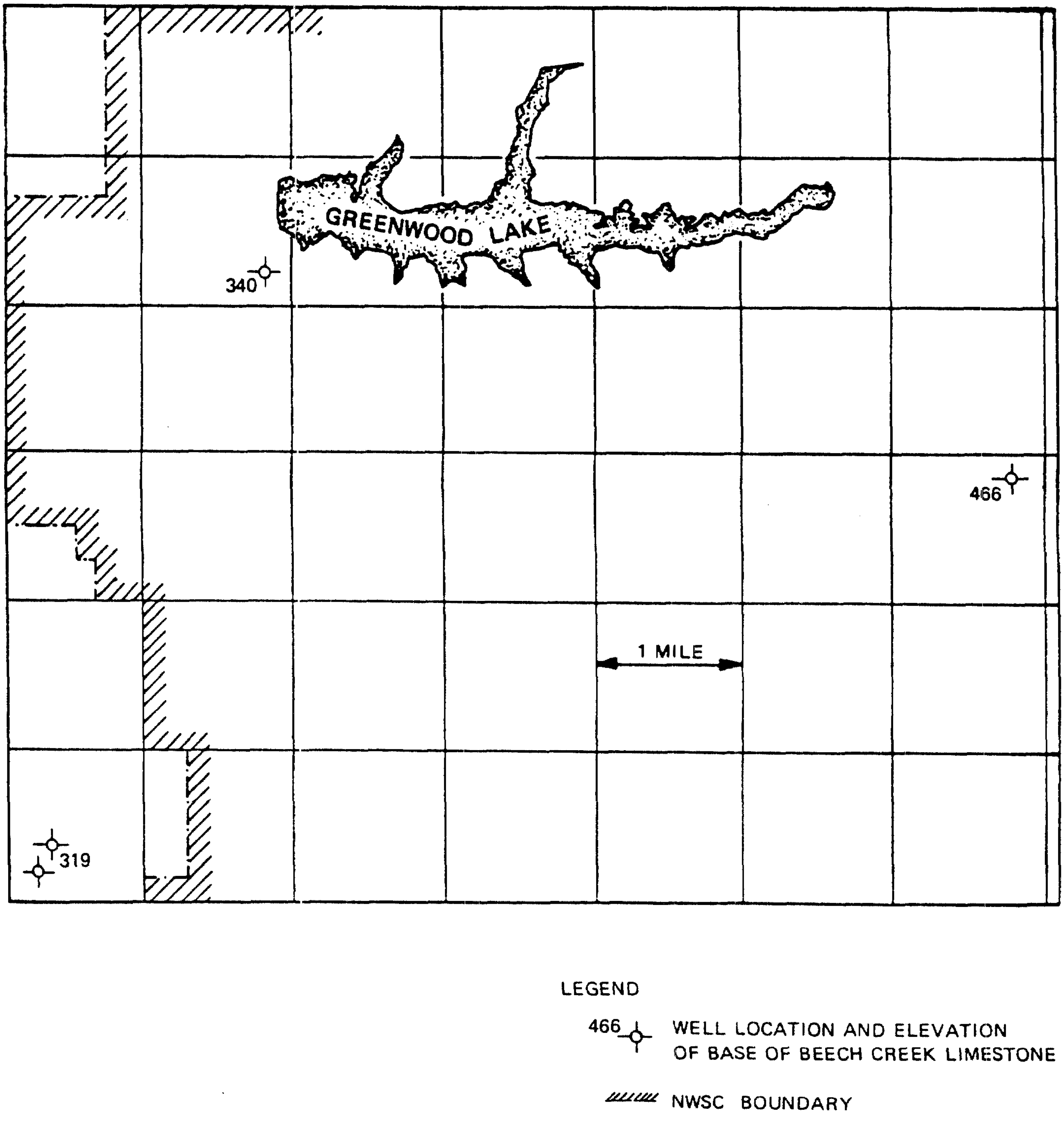


Figure 5.3-6 Location and Elevation of Wells Penetrating the Beech Creek Limestone

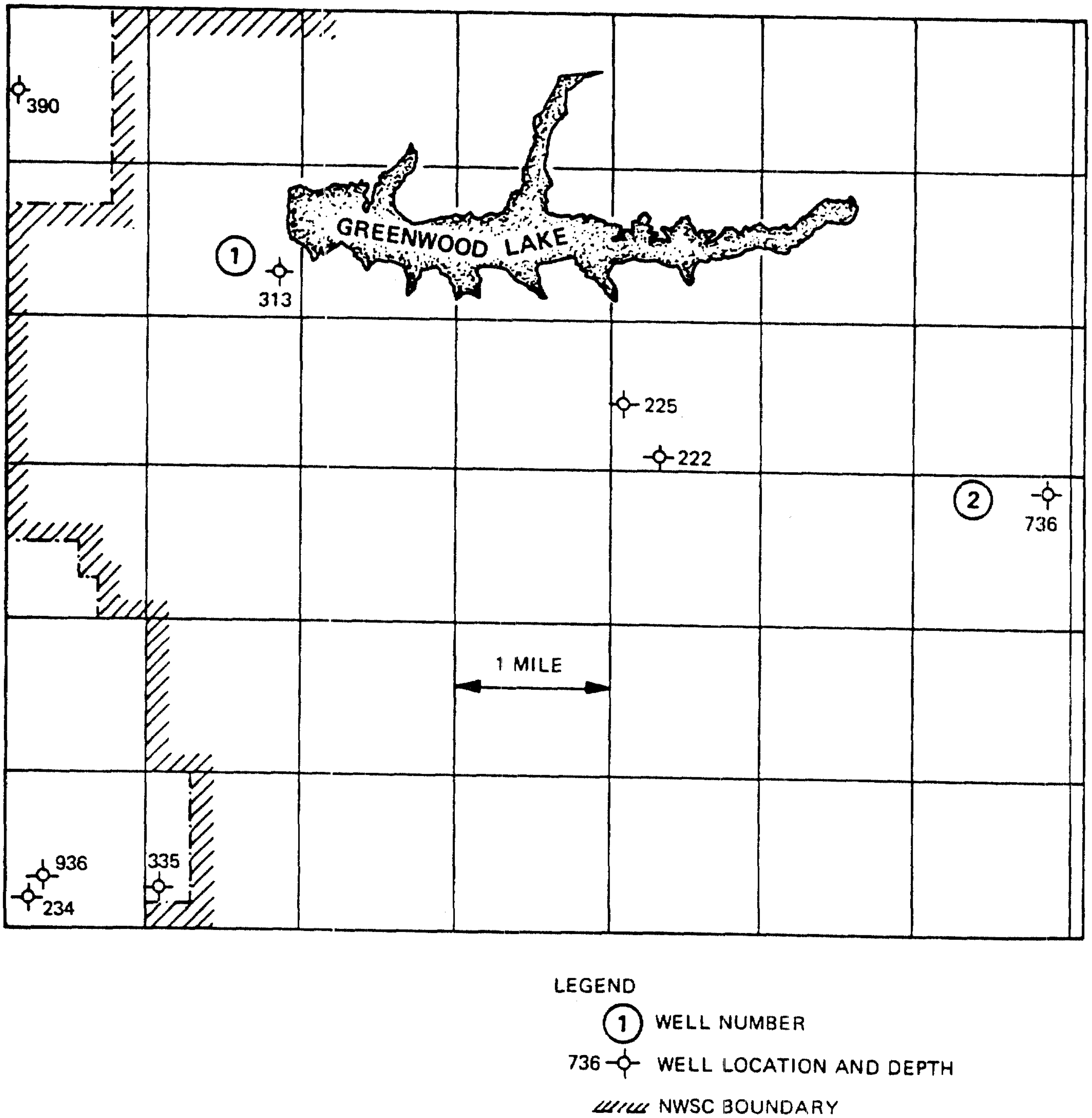


Figure 5.3-7 Location and Depth of Hydrocarbon Exploration Wells Drilled On and Near NWSC

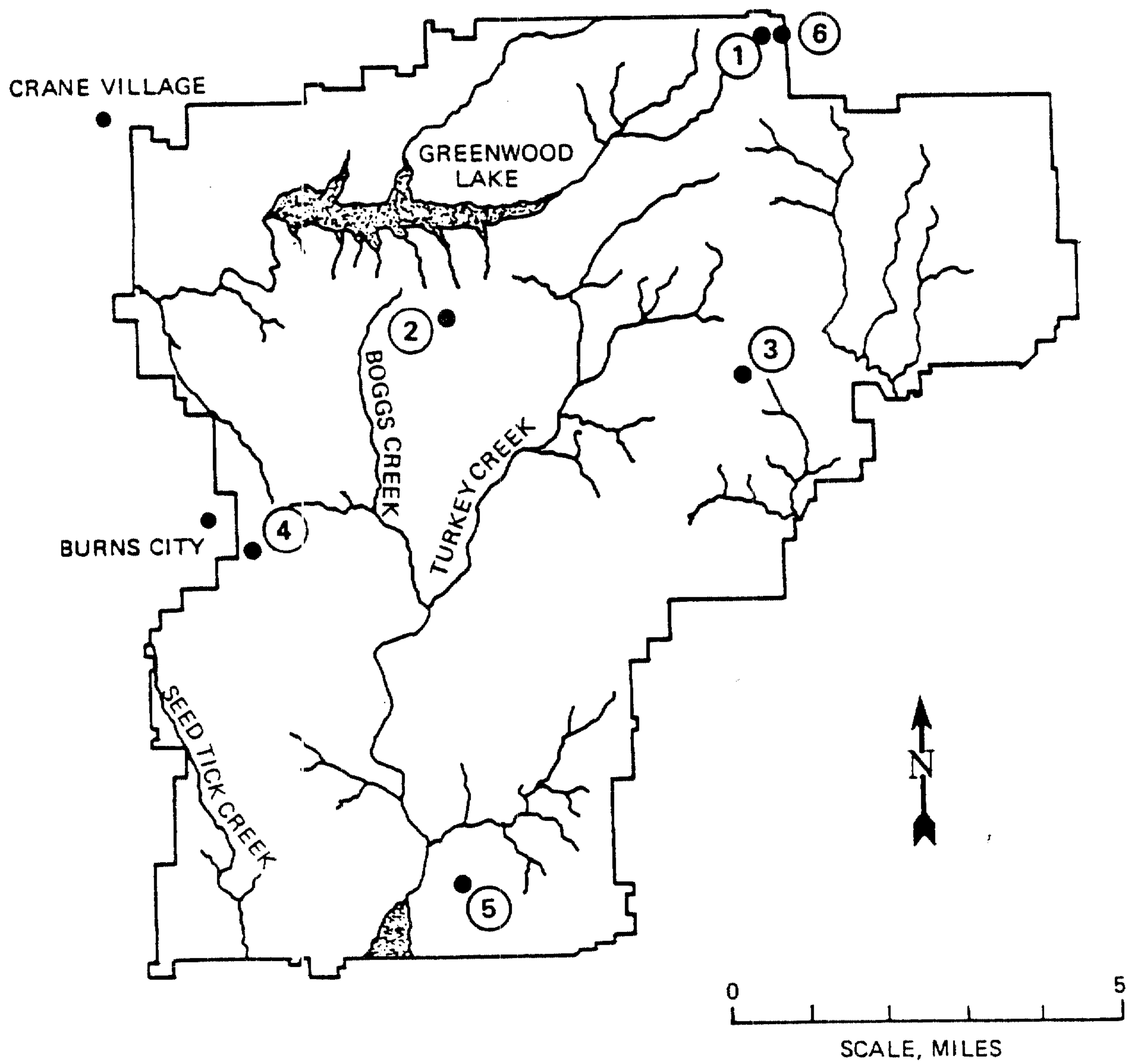


Figure 5.3-8 Potable Water Well Locations

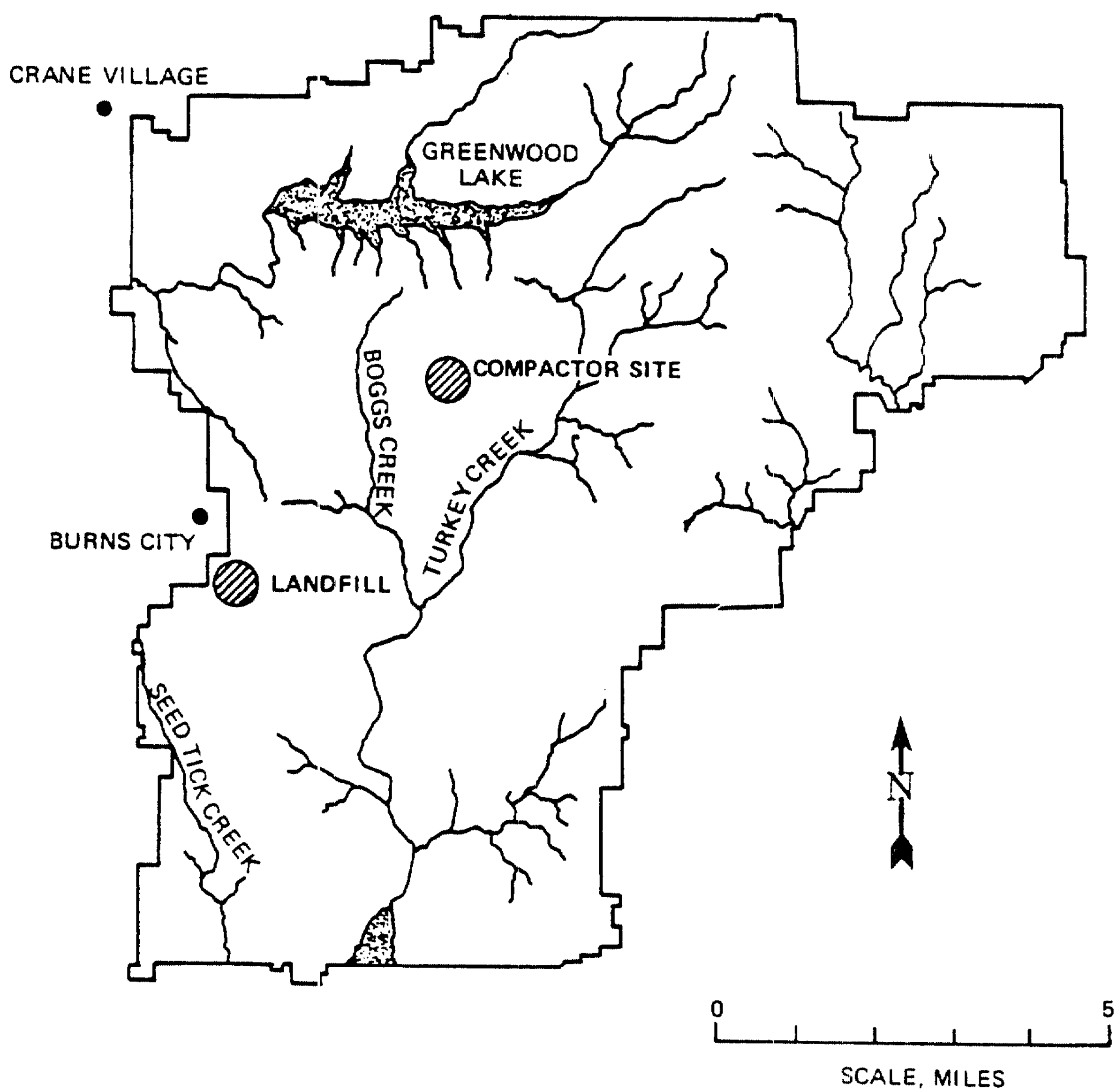


Figure 5.3-9 General Location of Landfill and Compactor Site Borings

yellow clay with varying percentages of sand and silt. Occasionally, a clay hardpan occurs between 25 and 32 inches below the surface. Figure 5.3-10 shows the soil map derived from the USDA report.

Subsurface exploration at the sanitary landfill included observation wells and auger and splitspoon borings. Data from seven observation wells indicate that clay occurs from the surface to a maximum depth of 19 feet. Sand rock, assumed to be sandstone, is at depths between 5 and 19 feet. Data from 15 auger holes show clay to sandy clay down to a maximum depth of 10.5 feet, with the top of sandstone ranging from 4.5 feet to just beyond 10.5 feet. Data from six auger holes show 8.5 to 10.5 feet of red, blue-gray clay over shale. Data from splitspoon borings B50 through B52 provide a more detailed description of the soil above the sandstone that was reached at 16.6 feet. The top 2 feet consist of dark brown soft inorganic silt grading to dark yellow in color and becoming sand down to approximately 3 to 5 feet. The next 2 feet are dark yellowish brown, dry hard lean clay. This clay zone is absent in the data from boring B51. The remainder of the overburden is a light brown, mottled gray hard silty sand with scattered sandstone fragments.

Ten borings at the compactor site identified 14 to 18 feet of light brown to yellow silt and sand with an occasional zone of lean clay overlying sandstone. The general location of the above borings is shown in figure 5.3-9, and the logs are presented in appendixes B and C.

5.3.6 Hydrology

5.3.6.1 Surface Water

The surface drainage from NWSC has formed a dense, dendritic pattern throughout the installation. Six creeks in four drainage basins carry surface water off the installation. Figure 5.3-11 shows the basins and drainage nets of NWSC. Drainage from Basin II in the extreme eastern part of the NWSC consists of several small drainageways. The north and northwest drainage (Basin I), eventually empties into Furst Creek, which flows in a westerly direction and crosses the NWSC boundary. Rainey Hollow, Sulphur Creek, and Little Sulphur Creek drain the eastern sector identified as Basin III. Drainage Basin IV occupies the central portion of the installation where Boggs Creek and Turkey Creek receive the drainage from the industrial area and that portion of the cantonment area south of Roads H43 and H5. This drainage crosses the south-central boundary. All surface drainage from the NWSC empties into the East Fork of the White River south of the installation. Situated within the boundaries of the NWSC is the spring-fed, 800-acre Lake Greenwood, which is used for water supply and recreation, and several soil and water conservation ponds.

5.3.6.2 Groundwater

Data prior to 1981 on groundwater conditions within the installation are extremely limited. The utilization of surface water for domestic consumption and manufacturing has precluded groundwater exploration, leaving a gap in groundwater data.

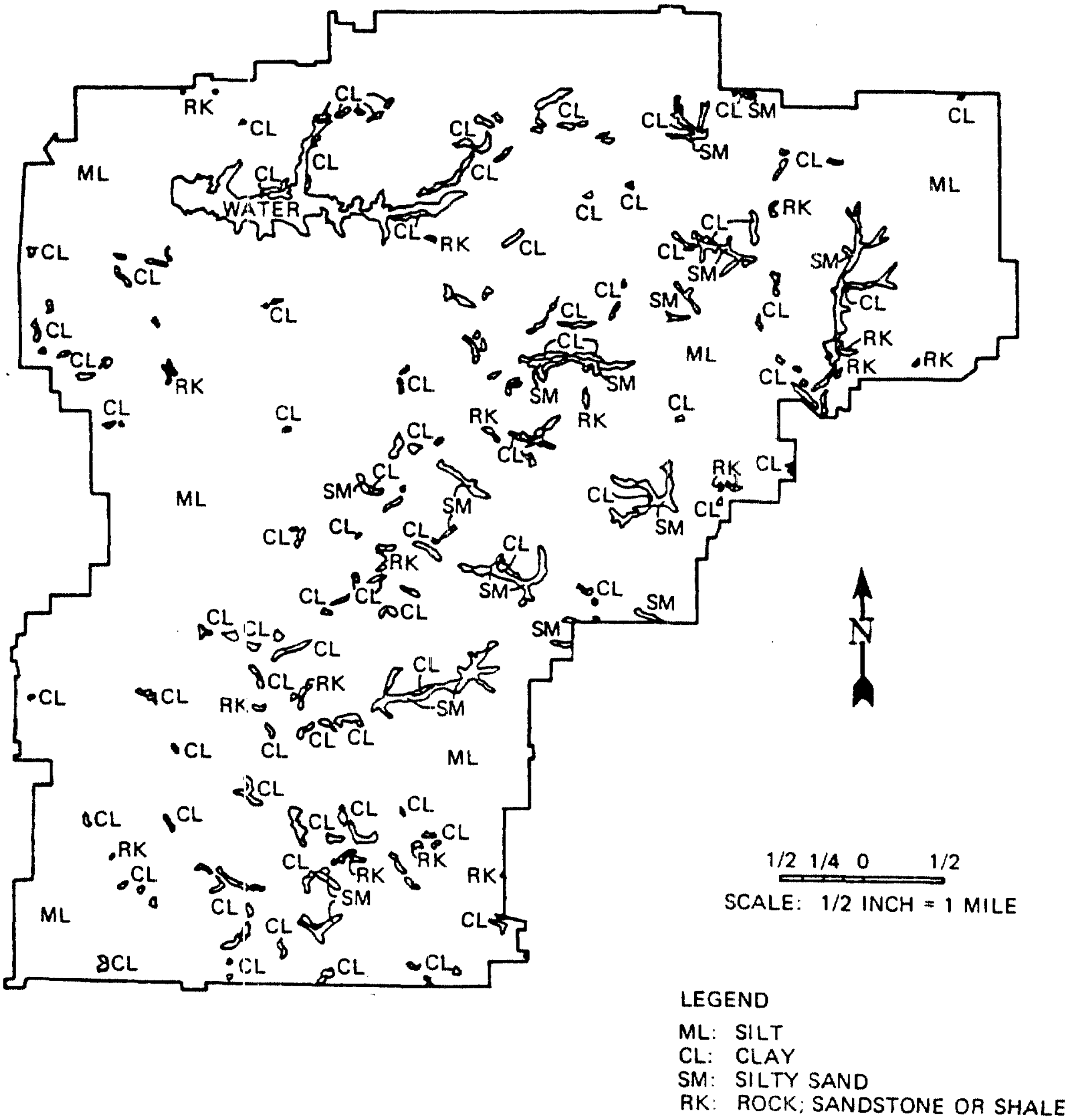


Figure 5.3-10 Unified Soil Classification System Types at NWSC

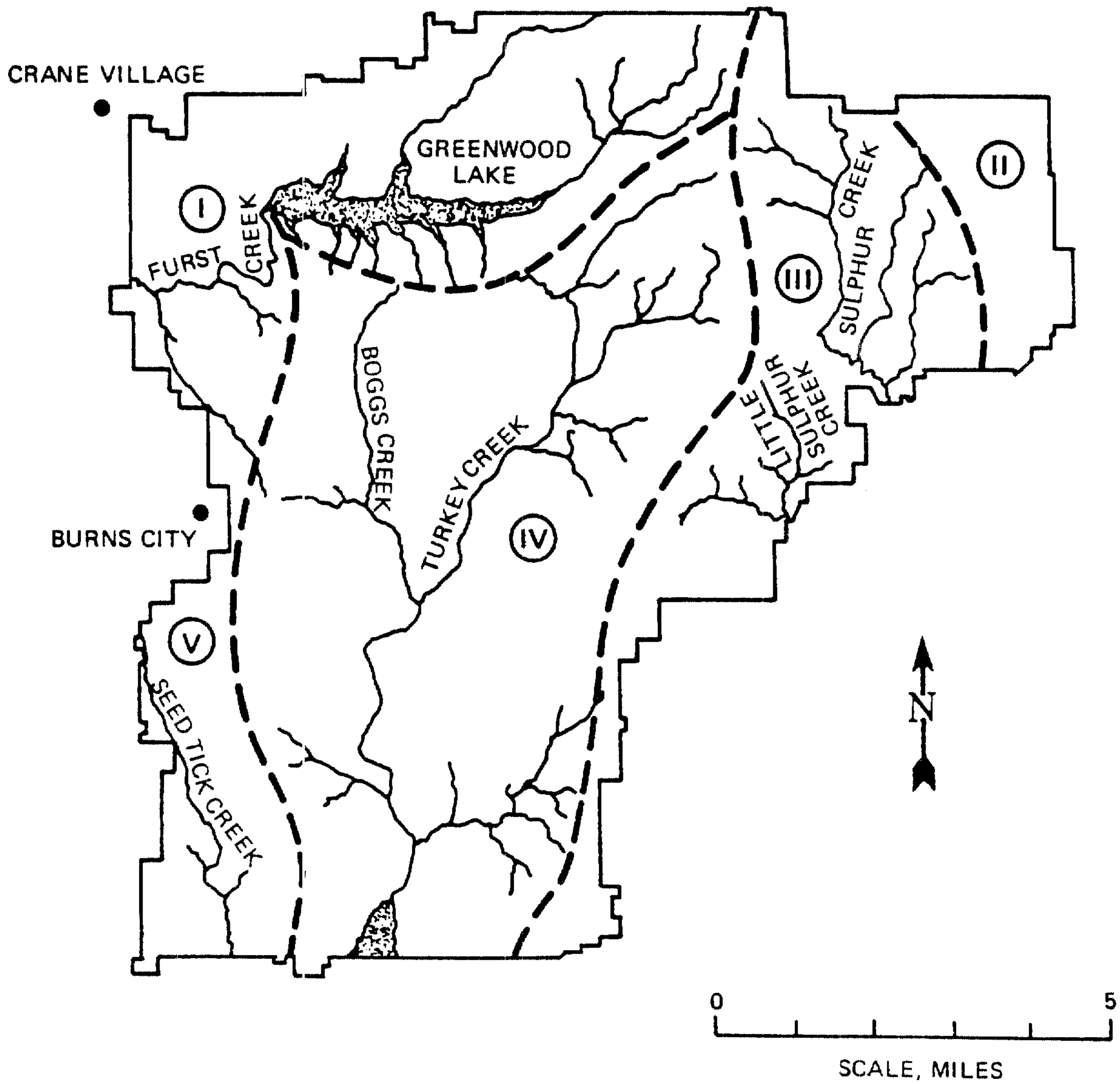


Figure 5.3-11 Surface Drainage of NWSC

The small scale (1:250,000) geologic map series appraises the groundwater potential of the various geologic formations on or near the surface of NWSC. The surficial unconsolidated deposits offer the best potential for groundwater development, but these deposits are thin and limited in a real extent. The bedrock units are characterized as having the potential for adequate domestic, light industrial, or small municipal use. Table 5.3-2 presents these evaluations.

Several wells and numerous soil investigation borings have been drilled on or near NWSC. Other wells have existed since NWSC was established. From time to time these wells have had water samples extracted and, during the drilling process, the presence of water was noted, and occasionally water levels in completed wells were recorded. Unfortunately, the prime requisite for an evaluation of water table gradient, that is surface elevations, is not available for any of the wells. An examination of the logs of the water wells and estimating surface elevations shows the water table in these wells to range from 650 to 700 feet at well 1 to approximately 475 feet at wells 3, 4, and 5 (see figure 5.3-8). These estimates must be evaluated with the understanding that records go back to the early 1940s and considering the fact that well completion data are not available. These data--screen length, screen depth, annulus packing between well casing and boring, and drawdown/recovery rates--are necessary to adequately assess the relationship between wells and to assess the water table gradient.

The landfill and compactor site borings (see figure 5.3-9 and appendix B and D) encountered a 2- to 3-foot layer of wet to moist soil before penetrating 5 to 15 feet of dry soil overlying bedrock. Only the monitoring wells penetrated bedrock, and these logs noted that water was not present during drilling. The water levels in these landfill wells were measured on 3 December 1979 and were reported on PWO 3746, NAVFAC No. 2042329, sheet 2A, dated 22 January 1980. These measurements and information extracted from the boring logs (appendix B) are presented in table 5.3-3. An analysis of these data reveals that the water table gradient for the shallow wells slopes toward both leachate ponds, while the gradient for the deeper wells appears to be to the west. Well completion data are unavailable and the surface elevations were estimated, but the general trend portrayed is the expected one. The small (2-foot) difference in elevations for the deep and shallow well at monitoring point 6 cannot be explained without well completion data and a thorough data collection program.

Additional studies of water quality have been performed at NWSC but, again, surface or water level elevations were not obtained. Undoubtedly, some of the sampling points are previously drilled water wells, but correlations were not made. Tables 5.3-4 and 5.3-5 are presented simply to set forth known sampling points for future use.

The groundwater at NWSC appears to be divided into two distinct regimes--one associated with the soil cover and one associated with bedrock. The shallow groundwater is probably transient; that is, during periods of excessive, prolonged rainfall and during the early spring months, there is probably saturated soil and free water above the soil-rock contact, but this condition dissipates by percolation into the bedrock and into intermittent or

Table 5.3-2. Water-Bearing Properties of Geologic Deposits at NWSC

Geologic Unit	Description	Water Bearing Properties
Qsa	Clay, silt, sand, and gravel deposited by present streams. Organic materials are abundant in places. Limited to valley areas and variable in thickness; thicker along major streams than on minor ones. Generally less than 15 feet thick. Along many major streams this deposit overlies deposits of outwash gravel, Qgv. Also associated with lake deposits, Qcl/Qsl, and older alluvial deposits, Qsi.	Deposits are permeable and yield some water. Major natural resource where associated with and underlain by valley-train gravel, Qgv, an excellent aquifer.
Qcl	Silt, clay, and sand of former lake areas. In southern Indiana, deposits occur as terraces or as extensive flats, mostly in valleys tributary to major streams. As thick as 150 feet near junction of Ohio and Wabash Rivers. Thinner elsewhere and upvalley; average thickness 40 feet. In northern Indiana, deposits are broader and generally less than 40 feet thick. Associated with present alluvium, Qsa, and older alluvial deposits, Qsi.	Deposits contain much water, but permeability is low and water cannot be produced in quantity adequate for any use.
Qgv	Gravel, sand, and silt deposited by glacial meltwater; materials are stratified. Valley-train deposits, Qgv, are long, narrow, and as much as 100 feet thick, along major present or former drainageways and associated with present alluvial deposits, Qsa. Common thickness, 20 to 40 feet. Outwash-plain deposits, Qgp, are broad and 10 to 40 feet thick.	Major natural resource. Deposits are important aquifers. Especially high yields are possible near bodies of surface water that provide continuous recharge. Infiltration areas should be protected from contamination.

Table 5.3-2 Water-Bearing Properties of Geologic Deposits at NWSC (Continued)

Geologic Unit	Description	Water Bearing Properties
Pl	Shale, sandstone, limestone clay, and coal. Maximum thickness 450 feet south,100 feet north. Forms surface unit in much of outcrop area; remainder is covered by unconsolidated deposits, principally Qt, Qti. Underlain by DM (north) through M_6 (south). About 55% shale, 40% sandstone, 5% other rock types. Coalbeds are as thick as 7 feet in some areas. Clay beds as thick as 10 feet underlie coals. Limestone beds are 3 to 10 feet thick. Raccoon Creek Group; includes Staunton, Brazil, and Mansfield Formations.	Wells in thick sandstone beds in lower part of unit may yield water in quantity adequate for domestic, light industrial, or small municipal use. Quality is generally good, but in areas of surface and underground coal mining, contamination may be severe. Principal contaminants are sulphur and iron. Sulphur content, principally as sulphate, may be as high as a few thousand parts per million; iron content may be as high as 50 parts per million.
M5	Limestone, sandstone, and shale. Maximum thickness 200 feet where overlain by M_6; thins and is unconformably overlapped northward where overlain by IP. Forms surface unit in most of outcrop area. About 40% limestone, 35% sandstone, 25% shale, all in beds 10 to 30 feet thick. Stephensport Group; includes Glen Dean Limestone, Hardinsburg Formation, Haney (Golconda) Limestone, Big Clifty Formation, and Beech Creek Limestone.	Springs and wells in limestone and sandstone yield water in quantity generally adequate for domestic use. High bacterial contamination is common in water from limestone because rapid circulation through large open joints and solution features readily brings contaminants from ground surface. Total hardness (principally calcium bicarbonate) may be several hundred parts per million.
M4	Shale, sandstone, and limestone. Maximum thickness 150 feet where overlain by M_5; thins and is unconformably overlapped northward where overlain by IP_1. Forms surface unit in most of outcrop area. About 40% shale, 35% sandstone, 25% limestone, all in beds 5 to 20 feet thick. West Baden Group; includes Elwren Formation, Reelsville Limestone, Sample Formation, Beaver Bend Limestone, and Bethel Formation.	Same as M5.

Table 5.3-3 Landfill Monitoring Well Data

Well No.	Depth, Feet	Surface Elevation*	Rock Depth	Rock Elevation	Water Depth	Water Elevation
1	19	710 feet	12 feet	698 feet	17 feet	693 feet
1A	42	710	12	698	26	684
2	14	670	9	661	3.8	666.2
2A	41.5	670	9	661	--	--
3	10	676	5	671	2.6	673.4
3A	46.5	676	5	671	40.5	635.5
4	26.5	684	19	665	2.5	681.5
4A	47.0	684	19	665	10.6	673.4
5	17.5	690	12	678	1.5	688.5
5A	41.5	690	12	678	18.0	672
6	14.5	684	9	675	5.0	679
6A	42	684	9	675	7.0	677
7	23	707	16	691	--	--
7A	41.5	707	16	691	28.5	678.5

*Estimated from PWO 4026, Code Ident. No. 80091, Sheets 1 and 2 dated 4 September 1980

Table 5.3-4. Water Quality Monitoring Points at NWSC

Station Number	Dev. Map* Location	Depth (ft)	Remarks
W026	L-38	15	Hand-dug open well
W027	M-43	50	Hand-dug open well
W028	A-44	234	Sealed well with pump
W029	J-43	15	Hand-dug open well
W030	JJ-24	15	Hand-dug open well
W031	BB-46	Deep well	Drilled in 1970
W032	BB-45	141	Sealed with pump
W033	FF-47	Spring	Perennial spring Limestone outcrop
W034	V-64	Deep well	Bedford Gate Sealed well with pump
W035	Z-10	15	Hand-dug open well
W036	CC-20	12	Hand-dug open well
W037	JJJ-22	152	Sealed with pump
W038	A-31	156	Sealed with pump
W039	Z-22	6	Hand-dug open well

* NAVFAC General Development Map

Table 5.3-5. Water Quality Monitoring Points at NWSC

Pilot Program	FY-74 NEPDB	NEHC Program	Map* Grid #	
W038	GW01		A-3	Well - In Use
W027	GW02	D	M-43	Well - Abondoned, Security Area, Old Homesite
W026	GW03		L-38	Well - Abandoned
W039	GW04		Z-22	Well - Abandoned
T019	GW05		EE-27	Turkey Cr. Gr. Water Check
W036	GW06	E	CC-20	Well - Abandoned, Old Homesite
B061	GW07		CC-19	Boggs Cr. Gr. Water Check
W035	GW08	A	Z-10	Well - Abandoned, Near Old Homesite
W031	GW09		BB-46	Well - In Use
W032	GW10		BB-45	Well - In Use
W033	GW11	C	FF-47	Spring, Ordnance Burn Area
B059	GW12		FF-18	Boggs Cr. Gr. Water Check
W030	GW13	B	JJ-24	Well - Abandoned
W028	GW14		A-44	Well - In Use
W037	GW15		JJJ-22	Well - In Use
W029	GW16		J-43	Well - Abandoned
W034	GW17		V-64	Well - In Use
B062	GW18		UU-18	Boggs Cr. Gr. Water Check
F056	RW03	J	O-22	Lake Greenwood, Pump House
----	----	F	CC-20	NIEHC Test Well #2, creek near H-521
----	----	G	CC-27	NIEHC Test Well #3, Structure 1852
----	----	H	FF-18	NIEHC Test Well #5, Structure 1851
----	----	I	UU-18	NIEHC Test Well #7, Boggs Cr. at H-496

* NAVFAC General Development Map

perennial streams. The groundwater associated with the bedrock is stable and probably fluctuates only a minor amount (less than 10 feet) per year. Possibly more than one zone of saturation exists in the bedrock due to the successive beds of sandstone, shale, and limestone. The shale beds should be the least permeable of the series and, where underlying a permeable sandstone or limestone, would support a saturated or free water zone. These shale zones grade laterally to zones of sandstone so the downward percolating water would be free to move continually downward until the zone of permanent saturation were reached. These lateral transitions could be defined only by extensive subsurface exploration and monitoring of water levels. These "perched" water tables could be distinguished by more annual fluctuation than the deeper, stable water table fluctuations. The westerly dip (see figure 5.3-6) of the bedrock will tend to constantly move this percolating groundwater in a westward direction.

5.3.6.3 Migration Potential

The potential migration of pollutants from NWSC is much more for surface migration than for subsurface migration. The well-developed surface drainage network (see figure 5.3-11) and the reasonable heavy rainfall (approximately 44 inches), coupled with the multiple streams leaving NWSC, all will promote the off-post migration of any pollutants deposited on the surface of NWSC. The fine-grained soils (silt and clay) will promote the rapid runoff of surface water and, subsequently, the migration of any water-soluble pollutants or any pollutant particles small enough to be carried in suspension. The intermittent nature of the majority of the streams on NWSC and the rocky beds of most of the streams have a dampening effect on this migration. Many of the small showers will be percolated through the permeable stream beds to the groundwater before the surface water could exit the installation. Also small wastewater streams will be percolated to the groundwater before they are transmitted off the station. However, many of the pollutants will be stored in the beds of these streams and will be resuspended and transmitted downstream by subsequent rains.

The subsurface migration of pollutant is much less likely but much more insidious than the surface migration of pollutants. The well-developed drainage network and fine-grained soil cover at NWSC will retard pollutant percolation to the water table and subsequent migration. However, the permeable stream bottoms will speed up the movement of surface pollutants to the groundwater. This has been verified by water quality investigations that included a sample from a shallow well (W036, tables 5.3-4 and 5.3-5) approximately 15 feet from an intermittent stream. Similar circumstances exist at other production areas of NWSC, but convenient sampling points do not exist and have not been installed.

The westward dipping bedrock on NWSC probably controls the regional bedrock groundwater flow and, with the exception of a small portion of east NWSC, any subsurface pollutant migration will be to the west. Boggs Creek (see figure 5.3-11) may intercept some of the groundwater and transmit it off base as surface flow but, in the absence of data, it must be assumed that groundwater is exiting the installation to the west. The groundwater quantities and velocities are probably small because of the preponderance of shales in the upper bedrock formations but, until these can be determined, travel time or quantities of groundwater passing under NWSC cannot be determined.

The ideal way to prevent both surface and subsurface pollution migration is to deny the contamination to the environment. If this is not achieved, remedial actions must be taken. At this point, subsurface migration achieves much more significance. Surface contamination may be neutralized or removed much more easily than subsurface contamination. For this reason, early detection of surface pollutants is desired, but early detection of the subsurface pollutants is nearly mandatory.

5.4 BIOLOGICAL FEATURES

5.4.1 Flora

Eighty percent of NWSC Crane's 63,000 acres is classified as Central Hardwoods Forest of the United States. The major tree species present are listed in appendix D Biological Features. Some old agricultural fields are in various stages of biological succession as well. Openings on dry upland sites contain almost pure stands of grasses with some clumps of woody plants such as persimmon, sassafras, and sumac. Wetter sites have river birch willow, sycamore, and cottonwood. Hillside communities have mostly hickory, white and black oak, red maple, sugar maple, tulip poplar, ash, and beech. About 2 percent of the area has been planted with pines to stabilize the soil.

A great variety of habitats are present at NWSC Crane. Many forest animals need several habitats to complete their life cycles. At Crane this variety is supplied by the many stages of forest succession, streams, ponds, Lake Greenwood, and grassy open spaces, all of which lead to a high diversity of animal species.

Although none of the local plant species are listed as threatened or endangered, some have been listed as rare by the Biology Survey Committee of the Indiana Academy of Sciences. These species are listed in appendix D Biological Features.

As part of the bicentennial celebration, a grove of white oaks on the Center was designated for the future repair and restoration of the USS Constitution. This area is now called Constitution Grove.

Commercial forestry is an important source of income for NWSC Crane. Careful forest management produced 959,820 board feet of sawtimber worth $67,000 in a recent 3-year period.

5.4.2 Fauna

As summarized in appendix D Biological Features, a great variety of animal life is present at NWSC Crane. Both deer and beaver have been reintroduced to the area and have become so numerous that hunting and trapping have been used to control their populations.

Crane is a good example of the biological balance necessary to a healthy environment. Ten years ago, burrowing by many groundhogs became a serious problem.

At approximately the same time, the coyote population began to increase as various government agencies began discouraging their all-out slaughter. Today, through natural population dynamics, there is no longer a groundhog problem and coyotes have become numerous. Large numbers of hawks also inhabit Crane. The presence of many carnivores is usually a sign of a healthy ecosystem, since toxic chemicals would tend to become concentrated up the food chain, which results in the highest level carnivore getting the largest dose.

An environmental concern is for the health of the aquatic habitats since pollutants could concentrate there. Two studies were conducted about 10 years apart to address this problem. The first was done by Region V of the EPA in October 1971, and the second by the U.S. Army Environmental Hygiene Agency in June 1979. The health of the sampling sites was assessed by identifying the species of micromollusca and plankton present. The known degree of pollution tolerance of the species found was used as a measure of the amount of pollution which has existed at the sites. The less tolerant organisms could only be present in areas not subjected to heavy pollution. Figure 5.4-1 illustrates the results of these studies. The streams near pollution sources are of fair to poor quality. However, at the stations near the points where streams exit the Center, the species of both micromolluscan and plankton were found to indicate good quality aquatic habitat. This fact could indicate that the pollutants have been sufficiently diluted and are no longer a problem, or that the pollutant has gone into the groundwater and has reemerged elsewhere.

Part of the Army Environmental Hygiene Agency study in 1979 was water analyses for chemical and physical properties and both discharge and sediment analyses for pesticides and polychlorinated biphenyls (PCBs). Five sites were found to have more cadmium in the water samples than the EPA criteria for protection of freshwater biota. Three sites were found to have PCB in the sediments at concentrations above the EPA criteria for protection of freshwater biota for water samples. (see figure 5.4-2). Subsequent analysis in spring of 1981 at these sites proved negative. The samples were collected by NWSC personnel and analyzed by a state certified lab.

The relationship between sediment concentrations and water concentrations is not simple, but this finding may indicate a possible problem.

Only two species listed as endangered by the Federal government are potential inhabitants of Crane--the Indiana bat and the peregrine falcon. Neither of these species has been sighted on the Center, although both local personnel and Purdue University biologists have been actively looking for them for several years.

5.5 LEGAL ACTIONS

The NACIP team did not find any evidence of legal actions pertaining to envionmental contamination or migration of contaminants at Naval Weapons Support Center, Crane.

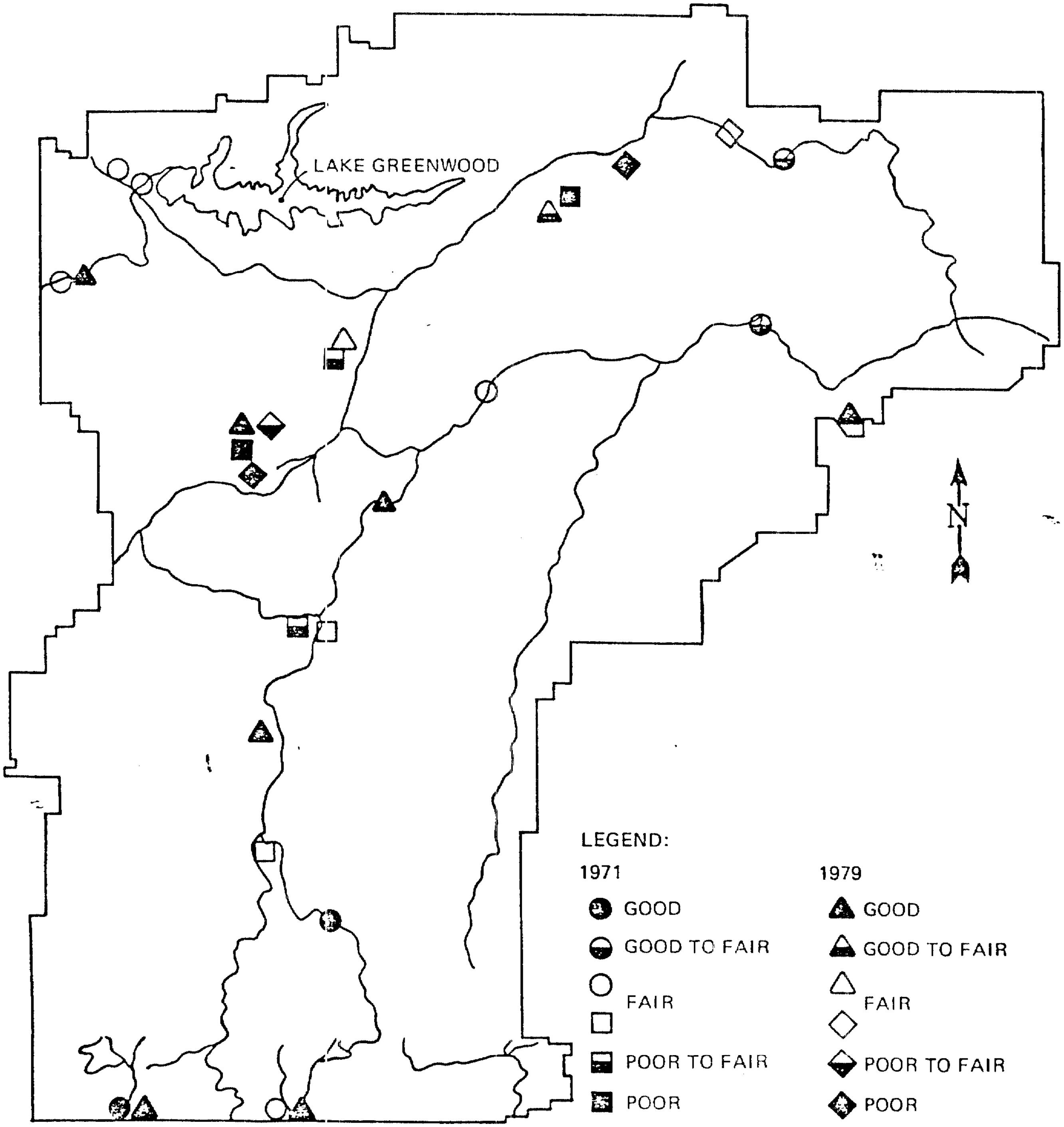


Figure 5.4-1 Degree of Pollution Tolerance of Biota

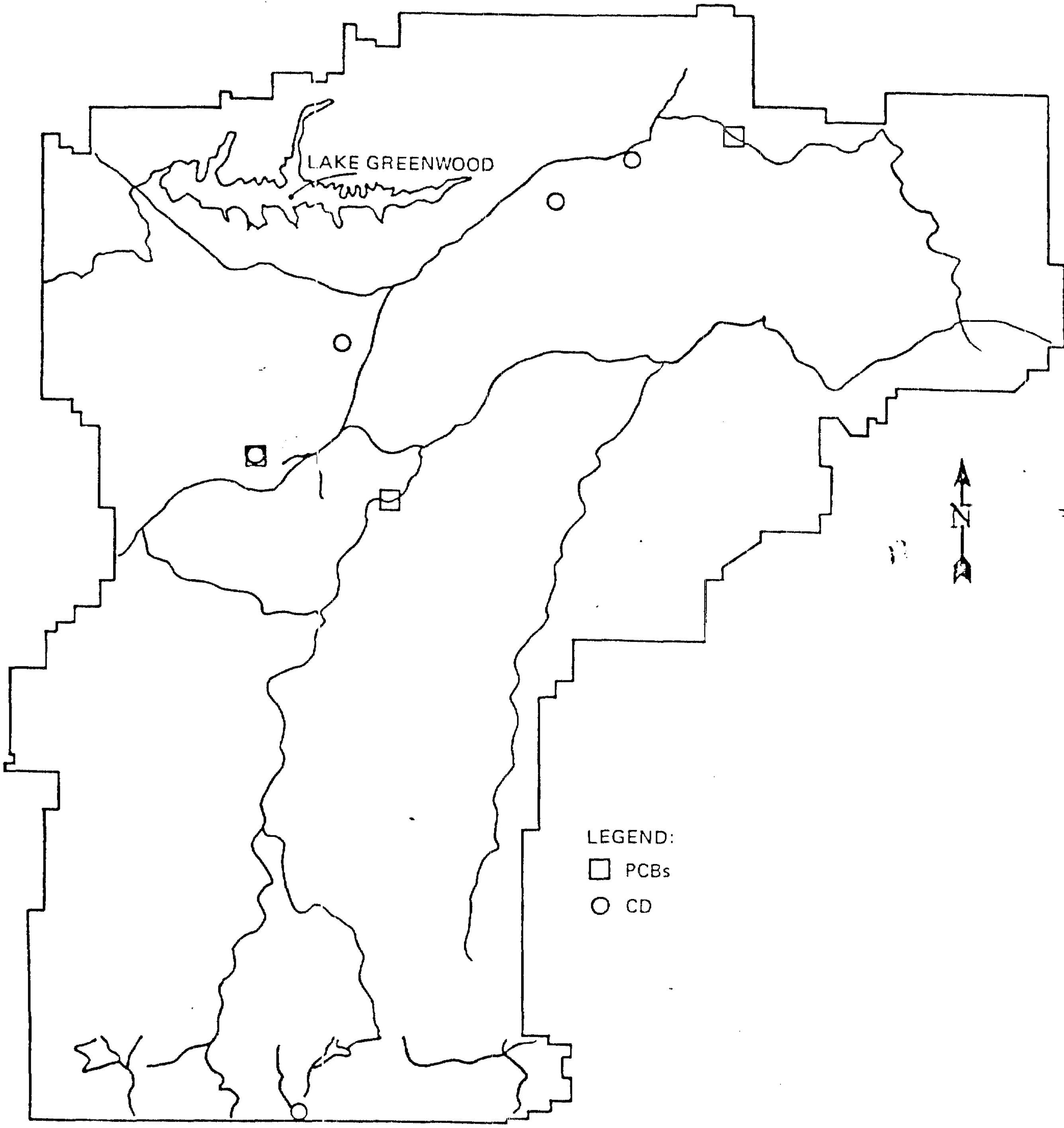


Figure 5.4-2 Location of Samples Found to Contain PCBs and Cadmium in 1979 Study but samples collected in 1981 were negative for PCB and cadmium

SECTION 6. ACTIVITY FINDINGS

6.1 OPERATIONS, ORDNANCE

6.1.1 Pyrotechnics

During World War II, the Pyrotechnics Plant, the largest and best-equipped plant of its kind in the country, supplied both the Atlantic and Pacific fleets with most of their illuminating projectiles, parachute flares, and star shells. At that time, it was the only manufacturing plant at the center.

Early in 1941, construction was started on the 17 buildings comprising the Pyrotechnics Area, of which 6 were production buildings and 6 were magazines.

The production buildings were completed in the following order:

Bldg. 130 -	Flare Fuse Assembly Magazine	- 15 Nov 1942
Bldg. 124 -	Projectile Assembly and Machine Shop	- 15 Feb 1942
Bldg. 122 -	Flare Assembly & Storage Plant	- 15 Apr 1942
Bldg. 126 -	Illuminant Bldg.	- 15 Jun 1942

In April 1942, the Machine Shop was put into operation. The machines installed were used in tool work for the entire Depot and were equipped to turn out metal parts of pyrotechnics production.

During July and August 1942, some TNT boosters were made in the Projectile Assembly to augment those being loaded at Building 104.

In November 1942, loading of the Mark 4 aircarft parachute flares was begun. This was the first production item to be completely manufactured at the Pyrotechnics Plant.

In the early part of December 1942, the installation of production machines in the Machine Shop was completed. Work in the manufacture of projectiles was held up until certain types of screw machines were received and installed. Accordingly, on 16 January 1943, the first 5-inch illuminating projectiles came off the assembly line. By February, the assembly line was in complete operation.

Experimental work started at the same time that production began. Most of the naval experimental work on pyrotechnics was transferred to this plant, and extensive experiments were conducted. All experimental loads were tested at Jefferson and Dahlgren Proving Grounds.

In July 1943, two new designs for the 5"/38 illuminating projectile--the Mark 4 Modified--were also developed. The Mark 4 Mod 5 contents differed from the Mark 4 in that it had a longer candle and a larger awning. After the

Mark 4 Mod 5 contents were approved by the Bureau of Ordnance, it was used in the loading of all 5-inch illuminating projectiles. The same design also was applied to the 3-, 4-, and 6-inch projectiles.

April 1943, experimental and production work was started on the 6-inch illuminating projectiles, and in April 1944, on the window projectiles and the contents for the 5-inch illuminating rocket.

Beginning in January 1945, all the experimental work for the development of the Navy's aircraft parachute flares was centered in the Pyrotechnics Plant. Prior to that time it had been conducted at both the Baldwin Naval Ordnance Plant and at NAD Crane.

The original production of aircraft parachute flares at the Depot was on the Mark 4 and Mark 5 flare types. These were made obsolete by the Mark 6 flare, developed at the Baldwin Ordnance Plant. After the Mark 8 was developed at the Depot and sufficient stock of its component parts became available, the Mark 6 was discontinued. At present, a flare is being developed that will far surpass the Mark 8 in candle power, burning time, ignition, and safety. This new flare will include a waterproof metal casing, a method of expelling contents with an expelling charge (delayed action), and a new type of center-tube ignition.

The peak in production for projectiles was reached in January 1945, and for aircraft parachute flares in June 1945. The peak of the plant's operation was in May 1945, when it produced the following items:

Item	Amount
5"/38 Illuminating projectiles (New)	26,627
5"/38 Illuminating projectiles (Rework)	2,972
5"/25 Illuminating projectiles (New)	3,419
5"/38 Window projectiles	5,984
6"/47 Illuminating projectiles	433
Mark 6 Mod. 4 Aircraft parachute flares (New)	417
Mark 6 Mod. 4 Aircraft parachute flares (Rework)	57
Mark 8 Mod. 1 Aircraft parachute flares	9,035
Mark 8 Mod. 2 Aircraft parachute flares	2,000

During 1943, Pyrotechnics reworked 150,000 defective projectiles produced by other plants.

Some of the most serious difficulties encountered in the operation of the plant are explained in the following two paragraphs.

Production was continually held back by the failure of projectile body manufacturers to provide a sufficient quantity of bodies to meet the scheduled loading requirements established by the Bureau of Ordnance. The projectile production during the entire war period relied entirely on the availability of projectile bodies available for loading. To augment the supply of projectile bodies available for loading, the plant set up a breakdown department, where projectiles with unserviceable contents were broken down for loading with serviceable contents. This rework program provided approximately 25 percent of the plant's total shell production.

Another difficulty was caused by one manufacturer using the upper tolerance on the internal diameter of the projectile and another manufacturer using the lower tolerance. On many occasions, parts had to be machined to match individual manufacturer's bodies.

Since 1943, the organization of the Pyrotechnics Plant has remained essentially the same. An officer was placed in charge of each separate functional division--development, production, administrative, inspection, and maintenance. Divisions were consolidated when enough officers were not available. With either an officer or a civilian in charge of the area, this organization provides for better supervision and coordination of the various types of activities necessary for the proper operation and maintenance of the Pyrotechnics Plant. Figure 6.1-1A and 6.1-1B are locations of ordnance production areas.

6.1.1.1 Production

Pyrotechnics devices usually contain mixtures of an oxidizing agent and a fuel, which produce an exothermic self-containing reaction when heated to ignition temperature. These items include flares, illuminating projectiles, smoke signals, spotting charges, ground and aircraft signals, and incendiaries. Later developments include chemical delay powders, self-releasing bouyant submarine signals, rescue flares, depth charge markers, aircraft signal cartridges, and parachute flares.

The buildings in the plant built in 1942 originally were for producing star shells (750 per day) and aircraft flares (300 per day). The production line consisted of Building 122, flare assembly; Building 123, projectile assembly; Building 124, the machine shop; and Building 126, the illuminant building. Buildings 1885 and 1886, used for phosphorus mixing, were added later, as was the pyro ignition assembly building. In Building 126, the main operating building, pelleting presses used 200 pounds per day of boron-potassium nitrate for igniters. The building is composed of many separate rooms connected to a main interior corridor. Each room has an exit to the outside. The various compositions are prepared here by drying, mixing, blending, and weighing, and are pressed into "candles," which are the flares or smoke generating ordnance items, at a rate of 1,000 per day. Each of the rooms has a drain (figure 6.1-1C). The drain permits each room to be flushed with water, which drains to a common collector under the building. The collector empties into a large sump outside (figure 6.1-2). In 1972 the sump overflow was connected to the sewage treatment plant. Prior to that time, the sump was drained about once a year, and the contents were taken to the burning grounds. Contaminated pyrotechnic sludge is pumped about every six months and taken to the ordnance burning grounds. Building 126 also has a dry dust collection system run by a wet vacuum pump. These collectors (figure 6.1-3) are emptied periodically, and the solids are taken to the ordnance burning grounds. Another sump for the red phosphorous buildings is located between the chemical storage Building 2696, and the ready magazine, Building 135 (figure 6.1-4).

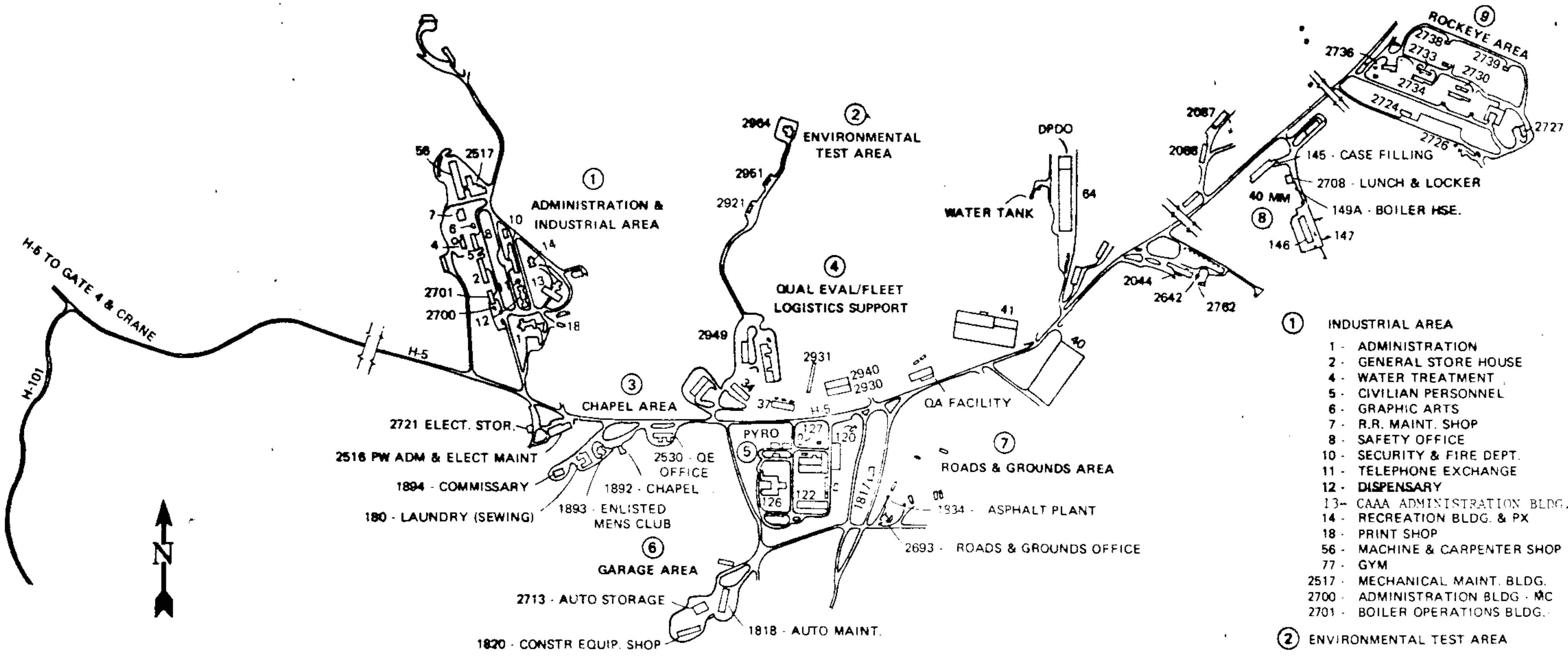


Figure 6.1-1A Location of Ordnance Production

① INDUSTRIAL AREA

- 1 - ADMINISTRATION
- 2 - GENERAL STORE HOUSE
- 4 - WATER TREATMENT
- 5 - CIVILIAN PERSONNEL
- 6 - GRAPHIC ARTS
- 7 - R.R. MAINT. SHOP
- 8 - SAFETY OFFICE
- 10 - SECURITY & FIRE DEPT.
- 11 - TELEPHONE EXCHANGE
- 12 - DISPENSARY
- 13 - CAAA ADMINISTRATION BLDG.
- 14 - RECREATION BLDG. & PX
- 18 - PRINT SHOP
- 56 - MACHINE & CARPENTER SHOP
- 77 - GYM
- 2517 - MECHANICAL MAINT. BLDG.
- 2700 - ADMINISTRATION BLDG - MC
- 2701 - BOILER OPERATIONS BLDG.

② ENVIRONMENTAL TEST AREA

- 2964 - ENVIRONMENTAL TEST FAC.
- 2951 - ENVIRONMENTAL TEST FAC.
- 2921 - ENVIRONMENTAL TEST ENC.

③ CHAPEL AREA

④ QUAL EVAL/FLEET LOGISTICS SUPPORT

- 37 - QUALITY EVALUATION LAB
- 38 - QUALITY EVALUATION LAB
- 39 - QEL EQUIPMENT SHOP
- 2902 - QUALITY EVALUATION LAB
- 2904 - QUALITY EVALUATION LAB
- 2906 - MODULE TEST LAB
- 2917 - TECH SERVICES
- 2930 - LOGISTICS SUPPORT
- 2940 - STD HARDWARE & HYDROFOAM
- 2949 - Q.E. DIVISION OFFICE
- 2931 - SEMI-COND STOWAGE & TEST
- 120 - Q.E. ADMINISTRATION

⑤ PYRO AREA

- 120 - QE OFFICE
- 121 - CAFETERIA
- 122 - FLARE ASSEMBLY
- 123 - ORDNANCE MACH SHOP
- 124 - ORDNANCE MACH SHOP
- 125 - ORDNANCE MACH SHOP
- 126 - ILLUMINANT BLDG.
- 127 - LUNCH & LOCKER/MAGNAFLUX INSPECTION
- 128 - BOILER HOUSE
- 133 - PHOSPHORUS PRESSING
- 1817 - BUS STATION
- 1884 - PLATING & MAINTENANCE
- 2697 - PYRO PRODUCTION
- 2698 - APPLIED SCIENCE FACILITY

⑥ GARAGE AREA

⑦ ROADS & GROUNDS AREA

⑧ 40 MM

⑨ ROCKEYE AREA

- 2723 - WATER TANK
- 2724 - LUNCH & LOCKER
- 2726 - SEWAGE TREATMENT
- 2727 - SHIPPING BLDG.
- 2727A - SHIPPING BLDG
- 2728 - FINAL ASSY
- 2730 - VACUUM SEPARATOR & HYD PUMP
- 2731 - DRILL & INSP.
- 2733 - VACUUM SEPARATOR & HYD. PUMP
- 2734 - CAST HEX FILL PLANT
- 2735 - INERT
- 2736 - OFFICE
- 2737 - BOILER HOUSE
- 2738 - HI-X MAGAZINE
- 2739 - HI-X MAGAZINE

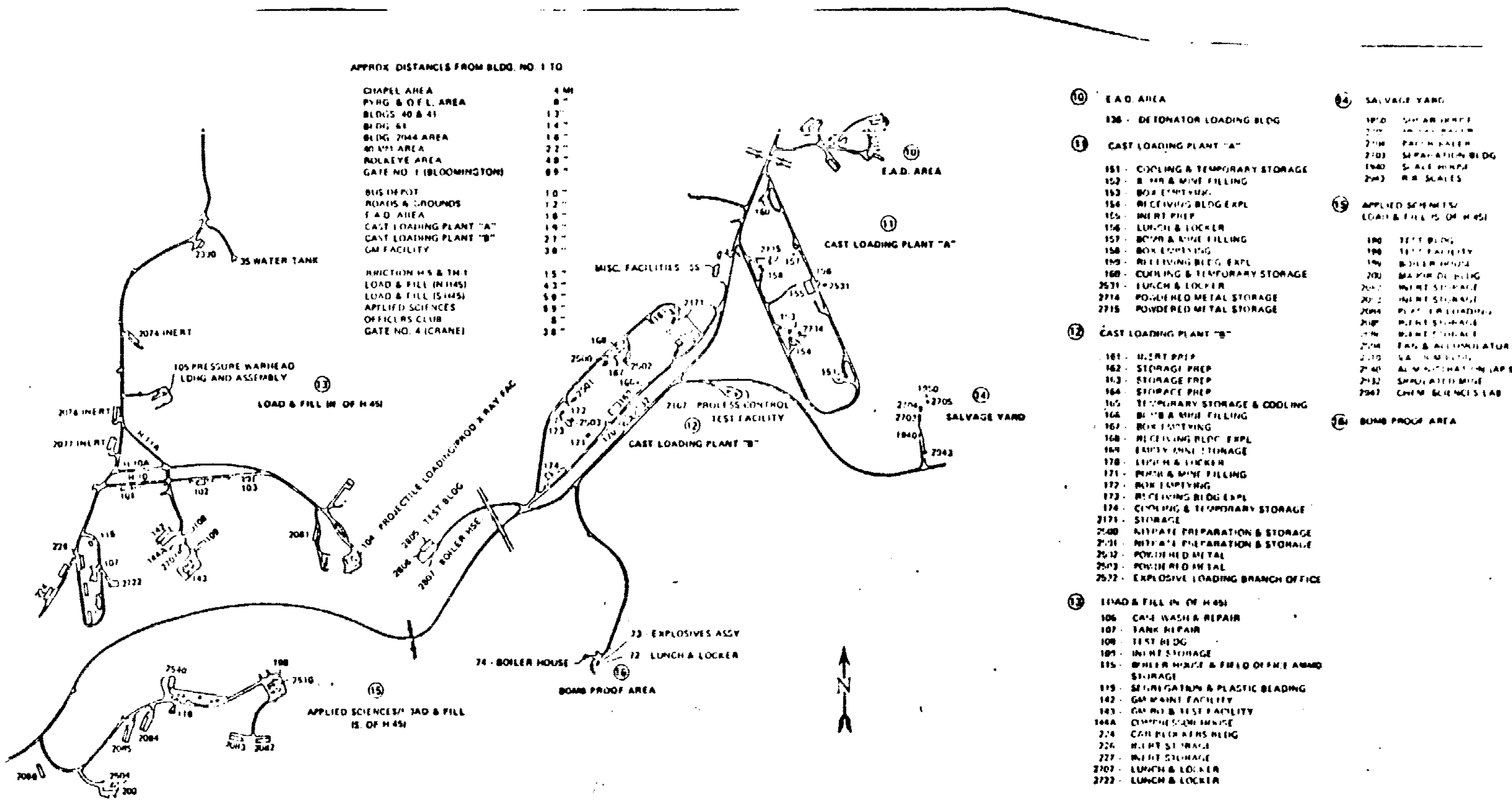


Figure 6.1-1B Ordnance Production Areas

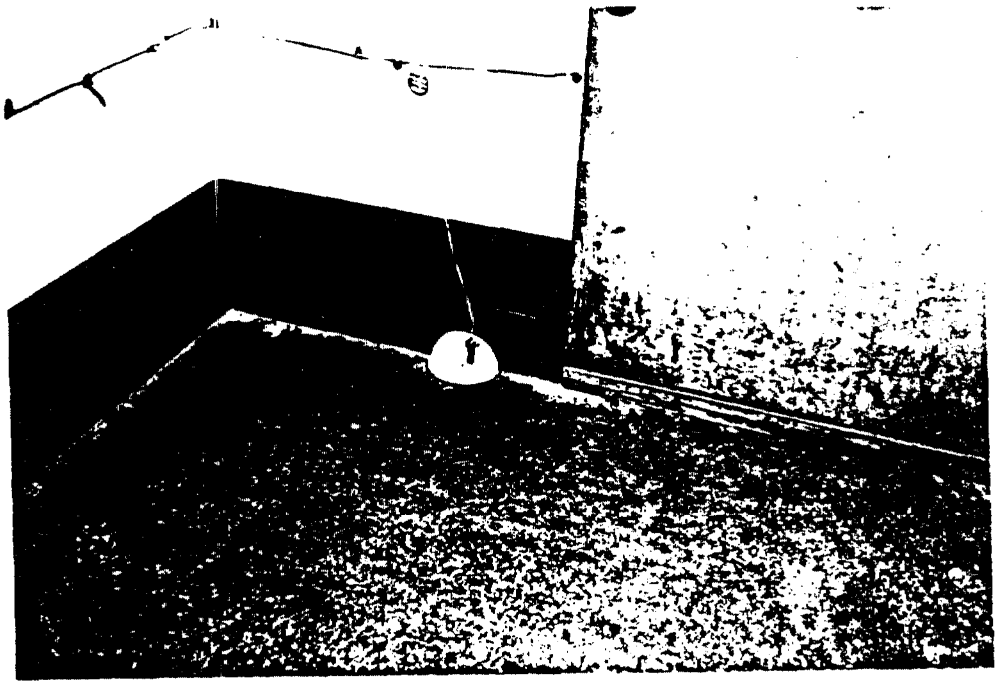


Figure 6.1-1C Floor Drain in Bldg. 126

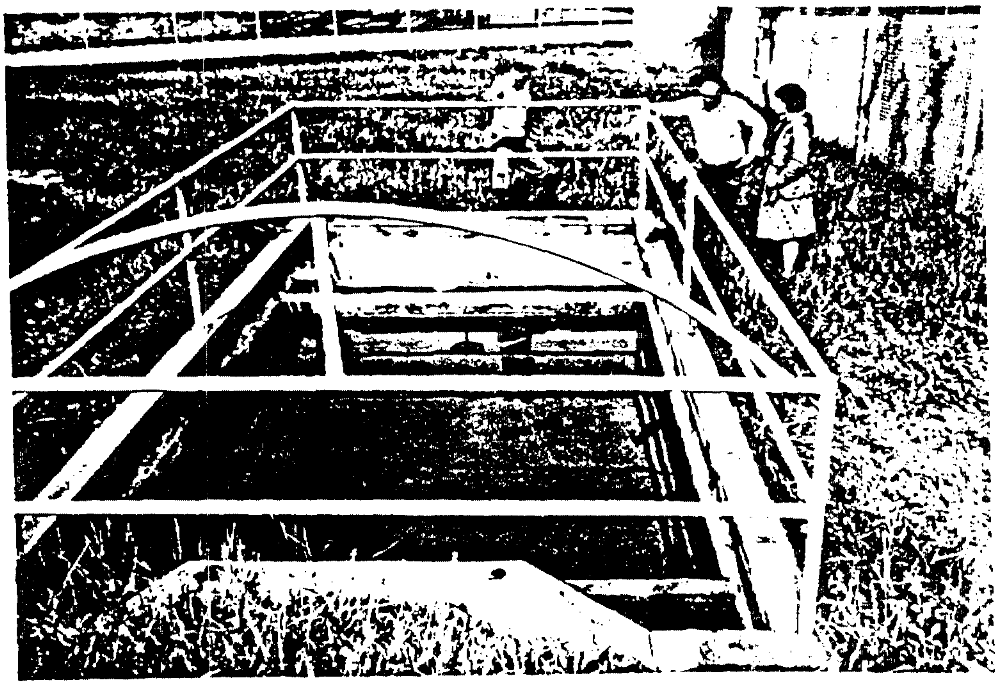


Figure 6.1-2 Sump for Bldg. 126

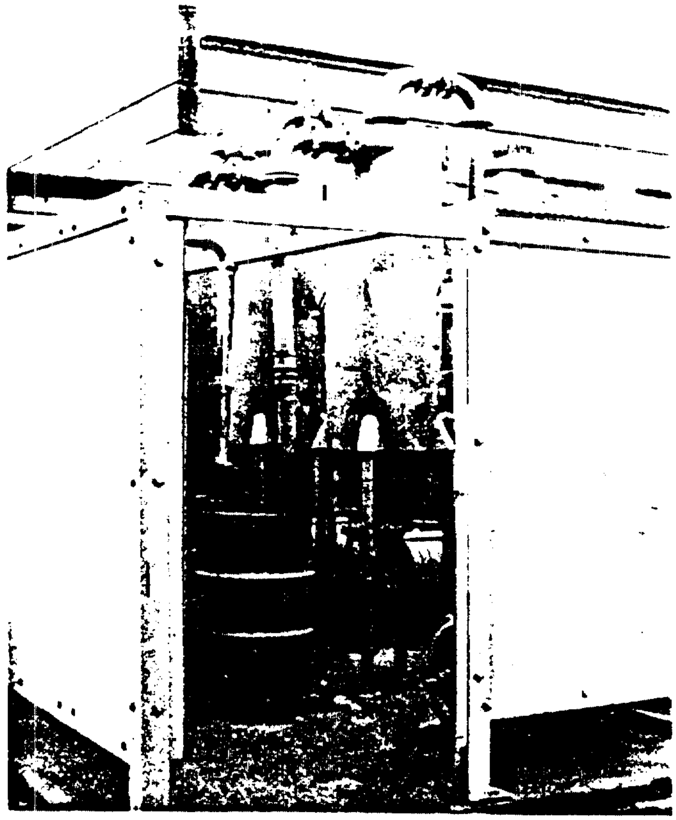


Figure 6.1-3 Bldg. 126, Dust Collector

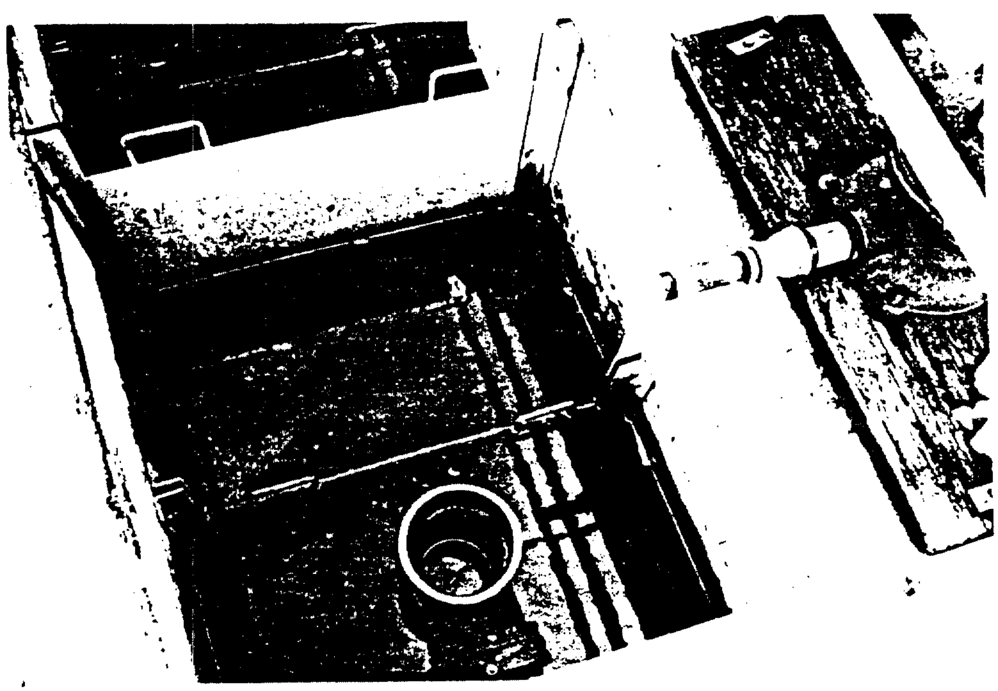


Figure 6.1-4 Sump for Phosphorus Bldgs.

In Building 122, the flare assembly building, 5"/54 parachute flares were placed in the projectiles. The asbestos lines were cut to length and tied to the parachute rig. Excess asbestos line was discarded in the regular trash since it is not the fiber type that is a health hazard. One section of Building 122 is used for the recovery of magnesium and sodium nitrate from the MK45 and MK24 flare candles. The plant operated in 1974 and 1975 and used 2,000 gallons of a mixed methylene chloride and methanol, which was recovered. Building 122 also houses a paint booth and a polyurethane foam machine for the MK58 marine marker. Prior to 1979, out-of-specification foam was sent to the burning grounds. About six 55-gallon drums per year were dumped. Prior to the mid-1970s, paint sludge was sent to the ordnance burning ground. Building 133, the phosphorus pressing house, uses a composition of red phosphorous, manganese dioxide, magnesium, zinc oxide, and linseed oil. This is a wet operation, requiring wet floors, wet walls, etc. A sump behind Building 133 is operated the same as others in the area. Building 2697 in the pyro area is operated the same as others in the area. Building 2698 in the pyro area is operated by the Applied Science Department. Building 2698 houses a foam machine and other process equipment. Oxalic acid is used here. The TMAE (tetrakis diaminoethylene) is chemilumninescent compound which is used in Building 2698.

Figure 6.1-5 is an aerial view, looking north, of the Pyro Plant taken on 29 April 1981. In the lower left are the ready magazines, Buildings 134 and 135; in the lower center are Buildings 1885 and 1886, the phosphorus mixing buildings. The larger building in the right foreground is the flare assembly Building, 122. A general discussion of Pyrotechnics used at NWSC is presented in Appendix H.

6.1.1.2 Pyrotechnics Testing

Compositions manufactured were tested for luminous intensity, color production, obscuring power, and burning rate. The test areas, including Pond 330, also known as Pond 333 in some cases, were used to test flares. These ponds are not currently used for testing.

6.1.1.3 Explosive-Actuated Devices

Explosive-actuated devices (EADs) include detonators, squibs, boosters, cartridge-actuated devices (CADs), primers leads, relays, and delays. These are initiated electrically, or by friction. EADs usually are loaded with explosives such as lead azide, lead styphinate, tetryl, RDX and black powder pressed into an item directly or made into a pellet and merely assembled, being held in place by a bonding agent, by press fitting, or by compression pads. The initiating materials are manufactured elsewhere and are shipped water-or alcohol-wet. In the Booster area (EAD area), the raw materials are received in Building 2855 and stored in the wet magazine, Building 2856. They are dried in Buildings 2857 and 2858 and screened in Buildings 2859 and 2860. They are stored in dry magazines, Buildings 2861 and 2862. Building 2863 has the final weighing and blending operation before the actual loading into the ordnance item in Building 136. There it may be press loaded, or poured into the item.

In Building 138, booster pellets are pressed. In the 1950s about 1,200 pounds of black powder per day were used in the preparation of color burst charges.

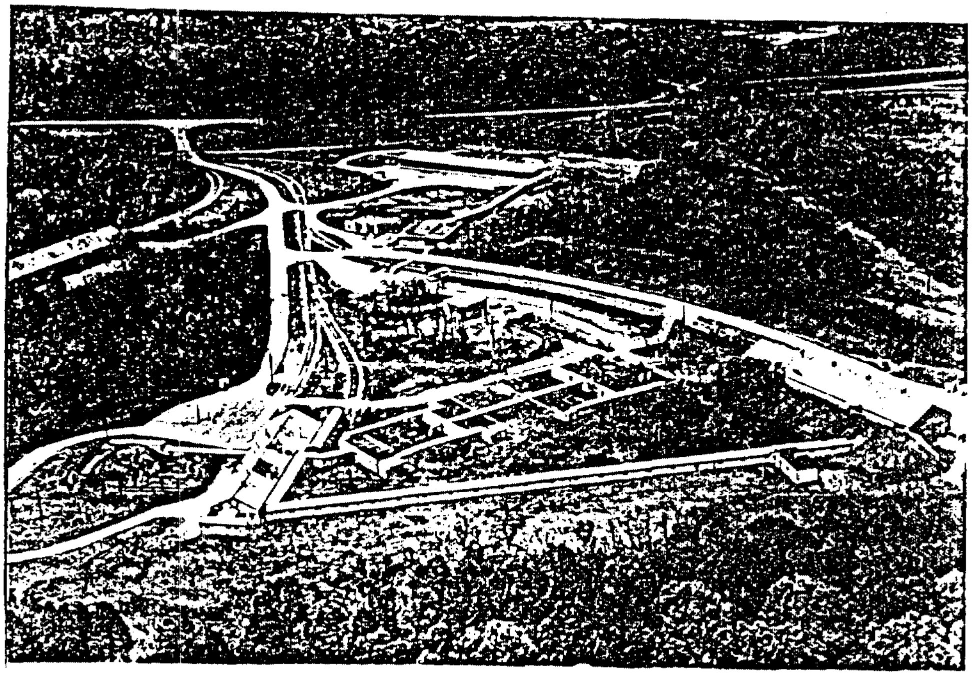


Figure 6.1-5 EAD Area

The 5"/54 illuminating round has replaced the assembly of finished items, such as the MK95 detonators or boosters, which took place in Building 2520, the explosives assembly building, in earlier years. Building 2803 was used to test rocket components in live firing tests. These were small EAD items. In figure 6.2-3, looking northwest, the EAD area may be seen, with Building 2520 on the right and Building 136 in the left foreground. Building 138 is at the top.

The wastewaters from leads azide and lead styphinate operations in Building 136 were rendered insensitive and poured into a pond. The pond was pumped periodically, and the material was taken to the burning grounds for disposal. A new sump was built to intercept the effluent before it reached the site. That sump is 7 foot by 8 foot 6 inches, with connections to the sanitary sewer. The sump was plugged to isolate it, and the flow has continued to the original pond, which is a 15 foot by 8 foot by 3 foot deep unlined earthen pit. The flow rate is about 2,300 gallons per week. Sludge samples have shown the presence of lead, varying from 0.03 parts per million (ppm) to 17 ppm, barium from less than 0.1 to 1.0 ppm, antimony from 0.5 t0 2.0 ppm, and chromium from less than 1.0 to about 1,300 ppm.

In 1981, after the liquid and sediment in the pond was analyzed, the contaminated material was removed and hauled off station to an approved landfill site by a state certified waste hauler. The pond is no longer in existence. A treatment facility completed in 1982, now treats the waste generated from Building 136.

6.1.2 Black Powder Operations

Quilting black powder operations were conducted in Building 103 during World War II. The ignition ends of bag charges contain some 360 grams of black powder to facilitate the ignition of smokeless powder in bag charge. As much as 40,000 charges were manufactured in July 1945 when production peaked. Service magazines in Buildings 110 and 111 provided storage for these operations. Documentation indicates that sewing machine operators in quilting black powder operations wore asbestos aprons, but the impact of this practice could not be determined, because personnel interviewed had little or no knowledge of the use of asbestos aprons.

Saluting charges were loaded in Building 101. These charges contain black powder and are used when firing guns to pay honor. No projectiles are involved. Burster charges of mix fill were loaded into 5"/51 and 4"/50 projectiles in Building 104. Mix fill consists of charges of black powder and TNT.

During the Southeast Asia conflict, Building 103 was active in repacking of black powder (as much as 58,000 units in 1965) and fabricating 2-ounce expelling charges (50,000 in 1967). Sixteen-inch bag charges were also manufactured. About 77,000 charges were filled in 1968. Miscellaneous projectiles such as non-fragmenting, illuminating, and window projectiles contain pellets or charges of black powder for expelling and/or igniting color burst units or other types of loads. These projectiles were loaded in various areas, including Buildings 104, 145, and 123.

In black powder operations, common practice is to sweep up loose powder and dispose of it at the burning ground. Little or no process water is associated with this type of operation. Consequently, the potential for contamination is minimal.

6.1.3 Smokeless Powder Operations

Smokeless powder is used as propelling charges for projectiles. The variety of smokeless powder is usually classified into two types: single-base and multi-base. The major component of single-base powder is nitrocellulose. Additives, such as ethyl centralite or potassium sulfate, impart greater stability, reduce flashing, and alter other characteristics. The two basic types of multi-base powders are double-base and triple-base. Double-base powder consists of nitrocellulose and nitroglycerin.

During World War II, smokeless powder was loaded into medium-calibre cartridges in Building 101, and into bag charges ranging from 5"/50 to 16"/50 in Building 102. Typically daily production rates in Building 101 were 4,500 5"/38 cartridges; 1,000 5"/25 cartridges; and 1,000 4"/50 cartridges.

Production in Building 102 peaked in July 1945 when 40,000 bag charges of various calibre were produced. Cartridge loading of 3"/50 ammunition began in Building 145 in March 1944. In the 28 months of operation during World War II, over two million 3"/50 charges were assembled. More recently, in the early 1970s, smokeless powder operations were conducted in Building 145 where 3"/50 cartridges were loaded and 16" bag charges were rebagged (figure 6.1-9). Typical production rates, as in 1968, were 53,500 for 3"/50 cartridges and 3,700 for 16" charges. As in the black powder operation, the use of smokeless powder involves little or no process water consumption. Dust or spillage resulting from the operation is swept up and disposed of at the burning ground.

The small amount of contamination from these operations would be localized in and around the process building. It would constitute a fire hazard rather than a toxic hazard, owing to the non-toxic nature of nitrocellulose, the major component of smokeless powder.

6.1.4 Projectile Loading Operations

6.1.4.1 Press Loading

Press loading of projectiles consists of mechanically consolidating increments of explosive charges into the cavities of projectiles. At NWSC Crane, during the World War II, four explosive projectiles pressing facilities operated in Buildings 104, 105, and 198. Major calibre projectiles were press loaded in Buildings 105 and 200.

Operations began in Building 104 (figure 6.1-10) in December 1942 with the loading of mix fill (black powder and TNT) and of Explosive D in 5" and production in 1944, 97,113 projectiles were assembled during the month of November. An inspection of the operation in November 1944 reported "Much D dust about."

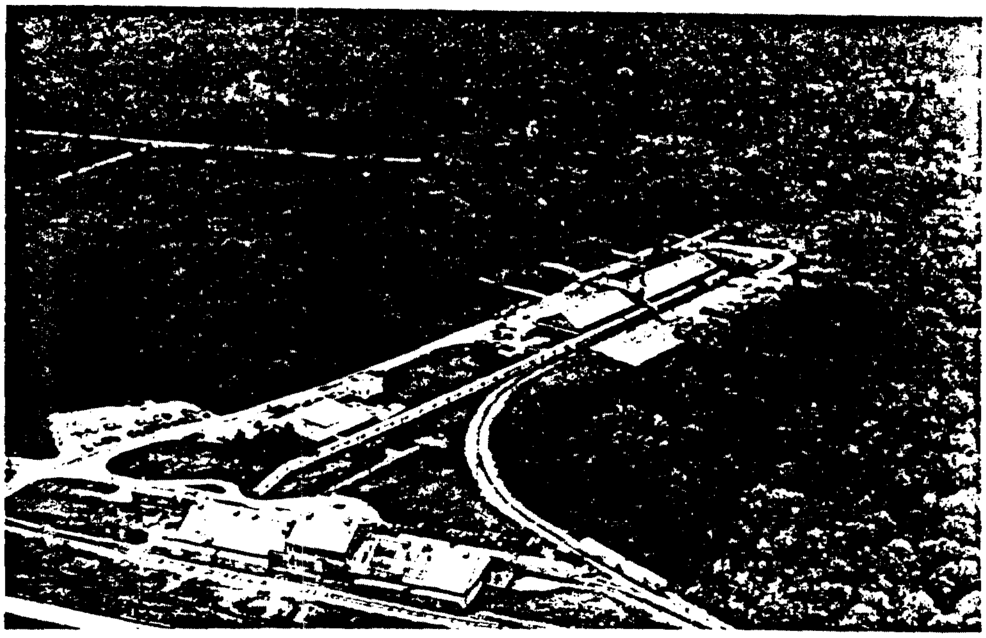


Figure 6.1-9 Building 145, Case Filling Plant

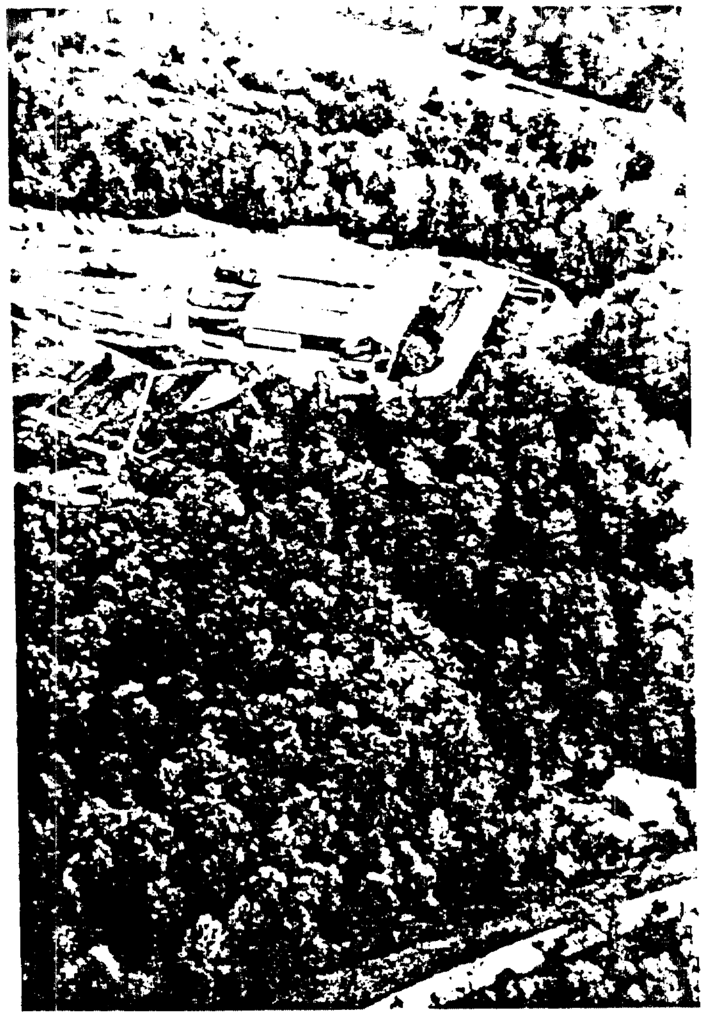


Figure 6.1-10 Medium Calibre Loading Plant, Bldg. 104

Production started in Building 198 in November 1944 with the loading of 5" projectiles. In June 1945, operations peaked with the assembling of 62,418 5"/38 and the reworking of 4,784 5"/30 common projectiles. Comp A-3 processing in Building 198 began in July 1945.

During the Vietnam War, activity in Building 104 increased, and in 1968 and 1969 over 500,000 projectiles were produced each year. Production activity is not recorded for Building 198, which is currently a part of the Applied Science complex.

Wastewater effluent associated with the operations in Building 104 contains runoff from cleaning of projectile casings, phosphate coating of casings, paint booth operations, and the vacuum system scrubber in the pressing operations (figure 6.1-11). Heavy metals and explosives in the effluent were reported in a 1972 study conducted by the Naval Civil Engineering Laboratory. Results are listed below.

Parameter	Average Concentration	Average Effluent Concentration
RDX	13.1 ppm	0.005 MGD
HMX	2.5 ppm	
Ammonium Picrate	272.1	
RDX	1.3 ppm	0.122 MGD
Ammonium Picrate	7.8 ppm	
Mercury	0.625 ppb (5.0 max)	0.083 MGD
Chromium	1.45 ppm (4.4 max)	
Cadmium	0.05 ppm (1.7 max)	

Prior to 1979, the wastewater was discharged into storm drains that flowed into Boggs Creek. A pollution control system was recently installed in Building 104 to prevent polluted water from paint spray booths, phosphatizing lines, and yellow D water from being discharged to the environment.

Pressing operations were also conducted in the ROCKEYE or 3" loading plant. Press loading of 3"/50 and 3"/70 projectiles with Comp A-3 was operational for two years, in the late 1950s or early 1960s.

Explosives are sifted prior to the loading and pressing operation, to eliminate large particles and agglomerates. This operation was conducted in Buildings 189 (figure 6.1-12) and 190. During World War II, a considerable amount of Explosive D was spilled on the driveway. A proposal, dated July 1944, to install concrete aprons around the two buildings, states "the accumulation of this powder in the rough surfaces of unpaved driveway areas presents a hazard which cannot be overlooked." Extensive activity in Building 189 was reported during the Vietnam War.

During World War II, major calibre pressing operations were conducted in Buildings 105 and 200. Loading of Explosive D began in February 1943 in Building 105, and in March 1945 in Building 200. Projectiles ranging from 8

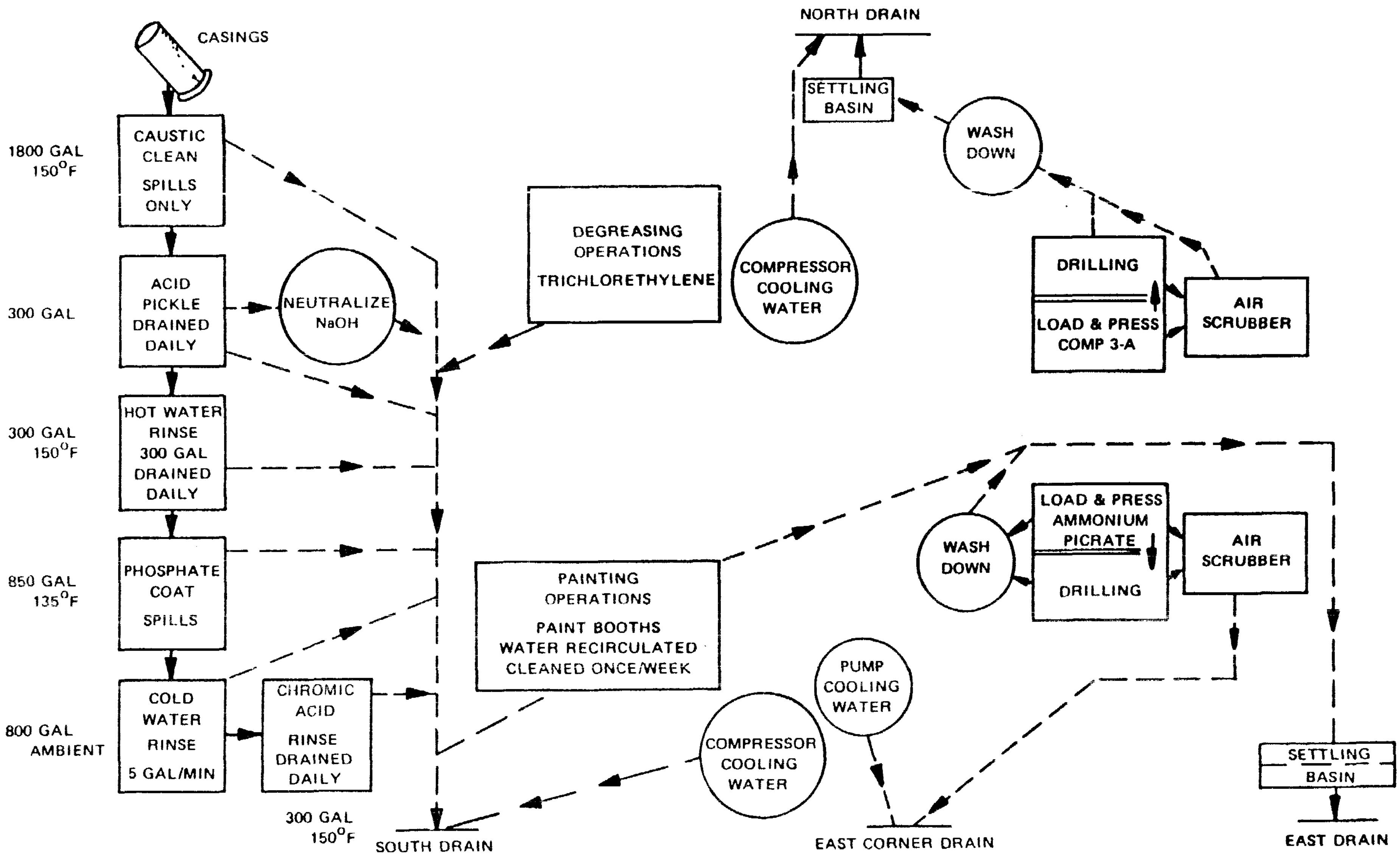


Figure 6.1-11 Bldg. 104, Medium Calibre Projectile Loading 5" Projectile Process Flow Diagram Until 1979

Figure 6.1-12 Guided Missile Maintenance Facility
Bldg. 189

inches to 16 inches were manufactured in these facilities. In addition, 5"/38 and 1,000-pound as well as 1,600-pound bombs were loaded in Building 105. No significant water usage occurred in these buildings.

Estimations indicate that over 10 million pounds of Comp A-3 and 20 million pounds of Explosive D have been processed throughout the major and medium calibre loading facilities. Five million pounds of the total of Explosive D processed was estimated to be the demilitarization operations (discussed in section 6.1.7).

6.1.4.2 Cast Loading

Cast loading or melt-pouring of explosives into projectiles took place for the most part in Building 146 (figure 6.1-13). Over 2.5 million 3-inch projectiles were loaded from December 1943 through the end of the war. The cast loading of 3-inch projectiles was initially conducted in Mine Fill B, with the function being transferred to Building 146 in December 1943. Over 500,000 projectiles were loaded with TNT in the mine fill area. Contamination associated with these operations came from the exhaust ventilation system and from wastewater associated with washdown and steam melting processes.

6.1.4.3 Warhead Pressing

In Building 105, Warhead Loading Plant, the press molding of SPARROW missiles has been conducted for 5 to 6 years. Formerly the Major Calibre Loading Plant, Building 105's operations now consist of the vacuum press molding of MK71 half-charges, machining, and loading into the warhead casting. PBXN-4 explosives are currently processed, soon to be changed over to PBXN-3. Some 40,000 MK71 and 60,000 to 70,000 MK38 half-charges are estimated to have been processed.

In the machining operation, a vacuum exhaust system maintains explosive dust to a minimum. The exhaust system is a dry unit. The warhead halfcharges are joined together with a single-component curing adhesive. The explosive is then "potted" into the casing, using a polyester/MEKP/cobalt napthuenate mixture. The excess polyester mixture, a plastic-like material after curing, is sent to the landfill. Explosive scrap from sweeping and from the dust collector is sent to the burning ground. Contamination from this operation is limited to the operating and supporting buildings.

6.1.5 Bomb Loading

High explosives were cast loaded into bombs and similar charges in the Mine Fill area and ROCKEYE.

6.1.5.1 Mine Fill Area

The two production facilities have been inactive since the close of the Southeast Asia conflict. A wet scrubber exhaust ventilation system and a contaminated water collection system production line were recently installed in Mine Fill A (figure 6.1-14). Mine Fill B does not have any pollution abatement modifications (figure 6.1-15). Mine Fill A houses a steam-out/washout demil system in Building 160, which is currently being modified to eliminate effluent pollutants.

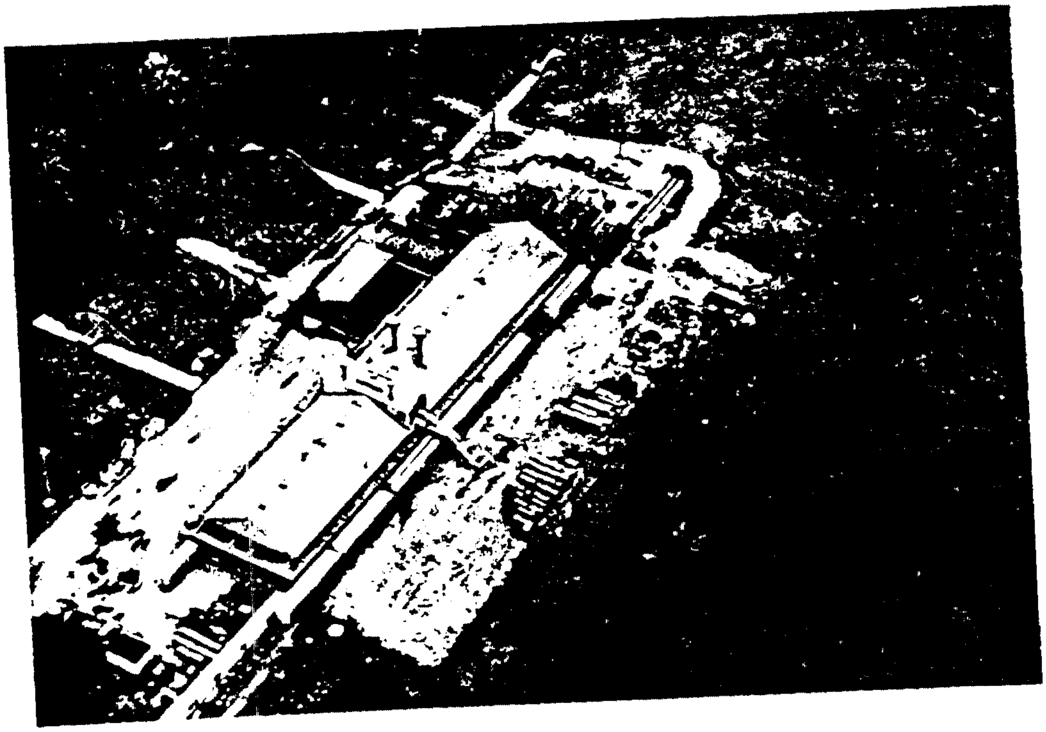


Figure 6.1-13 Cast High Explosives Filling Plant, Bldg. 146

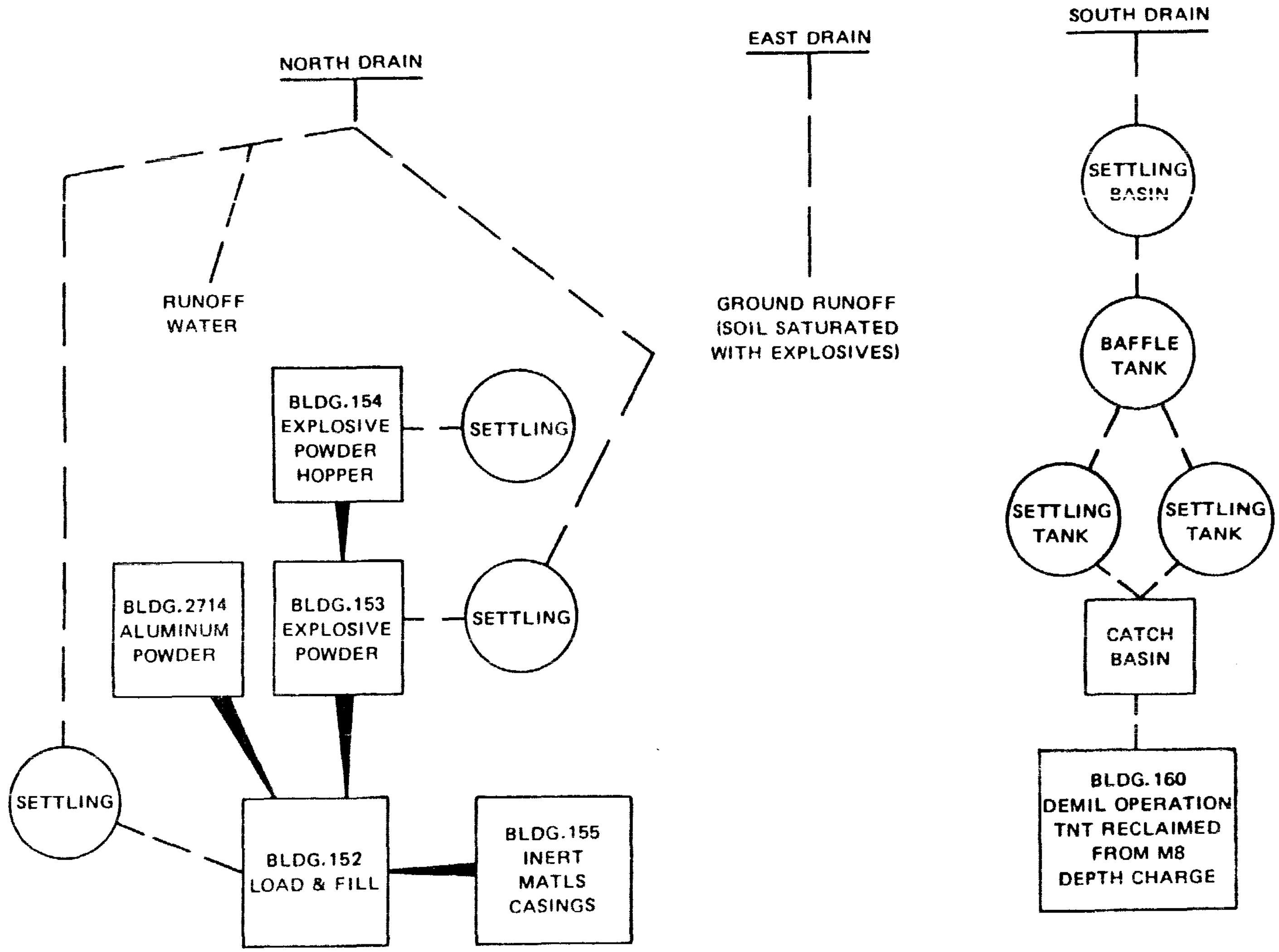


Figure 6.1-14 Mine Filling "A" Process Flow Diagram Prior to 1979

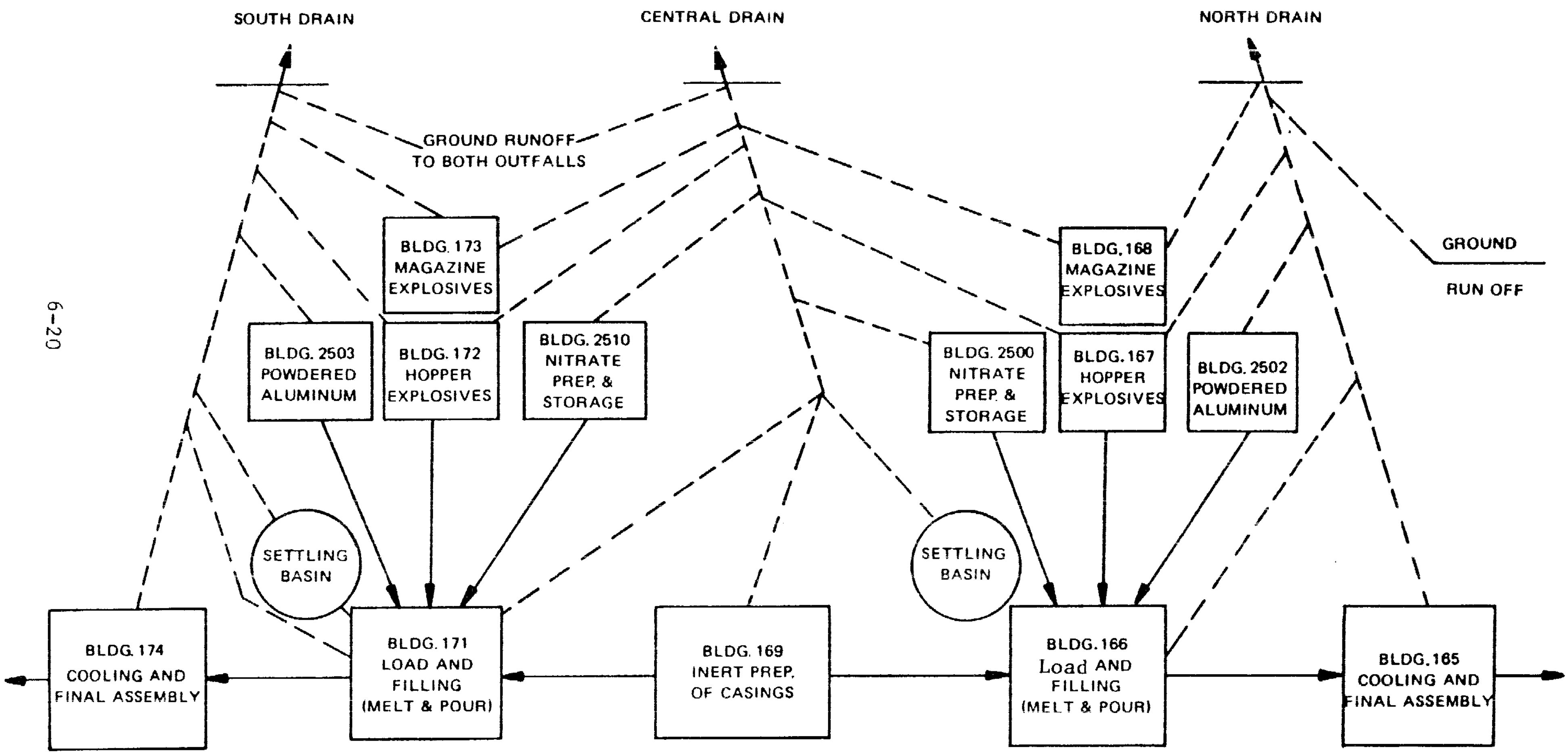


Figure 6.1-15 Mine Filling "B" Process Flow Diagram

In September 1942, the Mine Fill complex began production with the loading of depth charge bombs. Numerous items were produced. A partial list and total production of each item during the war is listed below.

Item	Total Production
4"5 Rocket Heads	963,000
5" Rocket Heads	570,000
Depth Charges	134,000
Projector Charger	364,000
3"/50 Ammunition	540,000

Mine Fill A had the capability of handling TNT only. Mine Fill B was modified to process Torpex, HBX, and Amatol.

The area was utilized to some extent during the Korean War. Aerial depth bombs were loaded with TNT, then switched to HBX. Prior to 1957, when the Navy decided to load its own low drag bombs, these were the only bombs loaded here. Up to that time, the Army had loaded all bombs. A small-scale operation, low drag bombs of 250-, 500-, 1,000-, and 2000-pound weight were loaded with H6. In Mine Fill B, 7.2 projectile heads, the Hedge Hog, and anti-submarine depth charges were loaded. MK25, 36, and 39 mines were loaded with HBX. Other items include ash-can-type depth charges (TNT) and MK25 rocket warheads (Comp B). Production rates were not obtained.

During the Vietnam War, the mine filling complex manufactured over six million bombs. Types of explosives processed included TNT, Comp B, H-6, Tritanol, and Minol.

Surface water and effluent collected at various times around the mine fill area reveal a degree of explosives contamination. Some data are presented in the following listing.

Year	Location	Parameter	Concentration ppm	Flow MGD
1972	MF A, Demil	TNT	5.8	0.047
	MF A, Ground Runoff	TNT	0.175	0.075
		RDX	3.55	
	MF A, Plant	TNT	27.0	0.028
		RDX	35.0	
	MF B, North Drain	TNT	10.1	0.030
		RDX	0.4	
		HMX	0.26	
	MF B, Central Drain	TNT	15.4	0.022
		RDX	1.6	
	BF B, South Drain	TNT	13.2	0.056
		RDX	20.4	
		HMX	2.4	
1978	MF B, North Drain	TNT	0.24	---
		RDX	0.86	
	MF B, Runoff, South	TNT	7.7	---
		RDX	16.0	
1979	MF A, Ditch, West	TNT	0.005	---
		RDX	0.02	
		HMX	0.1	
	MF A, Ditch, West	TNT	0.005	---
		RDX	0.05	
		HMX	0.1-0.5	
	MF B, Ditch, North	TNT	0.005	---
		RDX	0.1	
		HMX	0.1	
	MF B, Ditch, Central	TNT	0.253	---
		RDX	2.7	
		HMX	0.3	
	MF B, Ditch, South	TNT	0.005	---
		RDX	0.1	
		HMX	0.1	

The study conducted in 1979 does not reflect conditions at or adjacent to the Mine Fill area. Water and sediment samples were collected from storm ditches at locations of considerable distances from the facilities. Significant dilution of wastewater is anticipated. Analysis of the sediment revealed concentrations of TNT, RDX, and HMX in the 0.002 ppm region.

The major sources of contamination from the plant were from washdown operations and through the exhaust ventilation system. The exhaust system reduced the dust that settled on the roofs of the buildings adjacent to the facilities. It was reported that an explosive dust layer would accumulate on the roof and would require hosing down. The explosive would then be washed onto the surrounding ground (see figure 6.1-16). Measured estimates of dust through the exhaust system was approximately 40,000 pounds per year. Documented evidence shows significant contamination in the Mine Fill area. The contaminants suspected are TNT, RDX, and HMX. In 1982, a treatment facility was completed to treat discharges.

6.1.6 ROCKEYE/3" Explosives Load

Since 1967-1968, the ROCKEYE facility has been loading the cluster bomb ROCKEYE, which is in the 500-pound category (figure 6.1-17). Octol was initially loaded in the ROCKEYE and subsequently switched to Comp B. Some 50 million bomblets have been processed, of which 70 percent were loaded with Octol.

A cast-filling operation, the ROCKEYE activity generates wastewater from bomblet and tray washdown, which in the past has discharged to the north, and from melt and pour operations, which discharged to the south (figure 6.1-18). Sludges collected in sumps are disposed of at the burning ground. All wastewaters are now treated through activated carbon columns, except for one small discharge. The one exception will soon be tied in to the treatment unit.

Wastewater analysis from past studies are presented in the following list.

Year	Location	Parameters	Concentration, ppm	Flow
1972	North Drain	TNT	50.8	.048 MGD
		HMX	8.4	
	South Drain	TNT	35.2	.015 MGD
		HMX	1.8	
1979	North Drain	TNT	45.0	20 GPM
		RDX	36.0	
		HMX	16.0	
	South Drain	TNT	10.0	20 GPM
		RDX	1.9	
		HMX	1.9	

An interesting observation is that the discharge to the north flows into a rivulet that dries up during dry periods. The stream stops about one mile downstream of the ROCKEYE plant just short of the underpass west of Road H-166 by magazine Building 1569 (figures 6.1-19 and 6.1-20). Apparently, the stream flows underground. No attempt has been made to trace the flow.

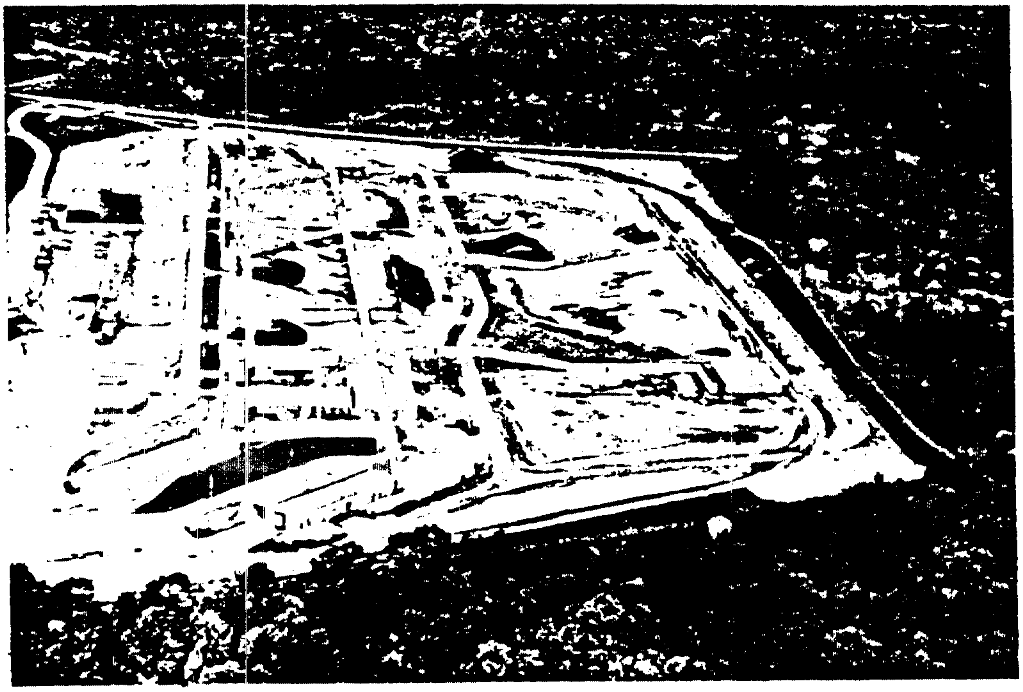


Figure 6.1-16 Mine Fill B Near Building 167

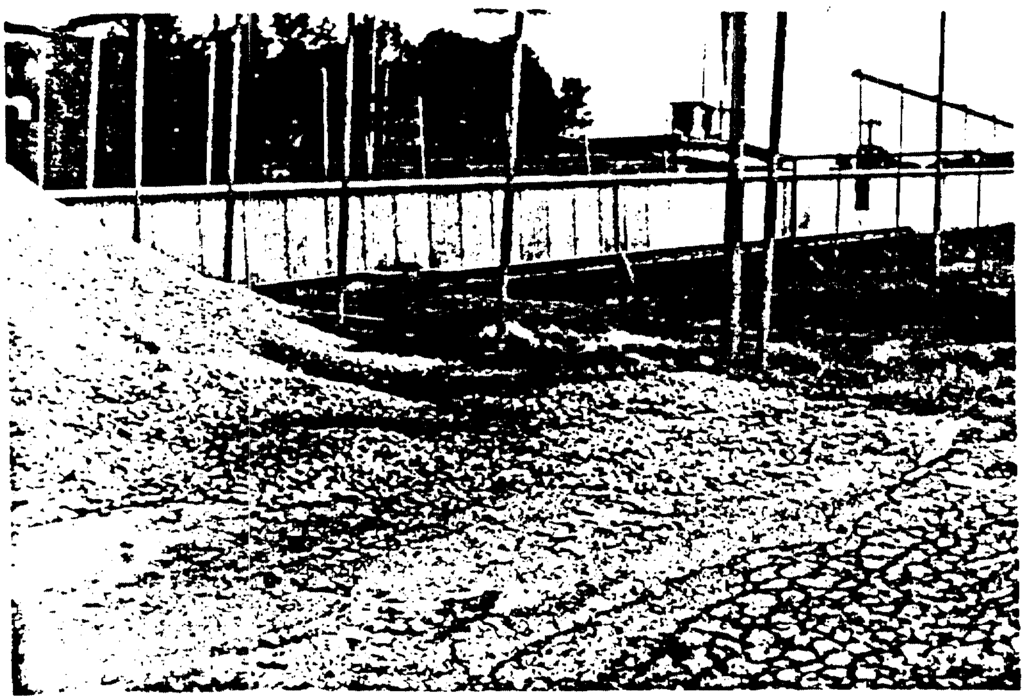


Figure 6.1-17 ROCKEYE/3-Inch Loading Area

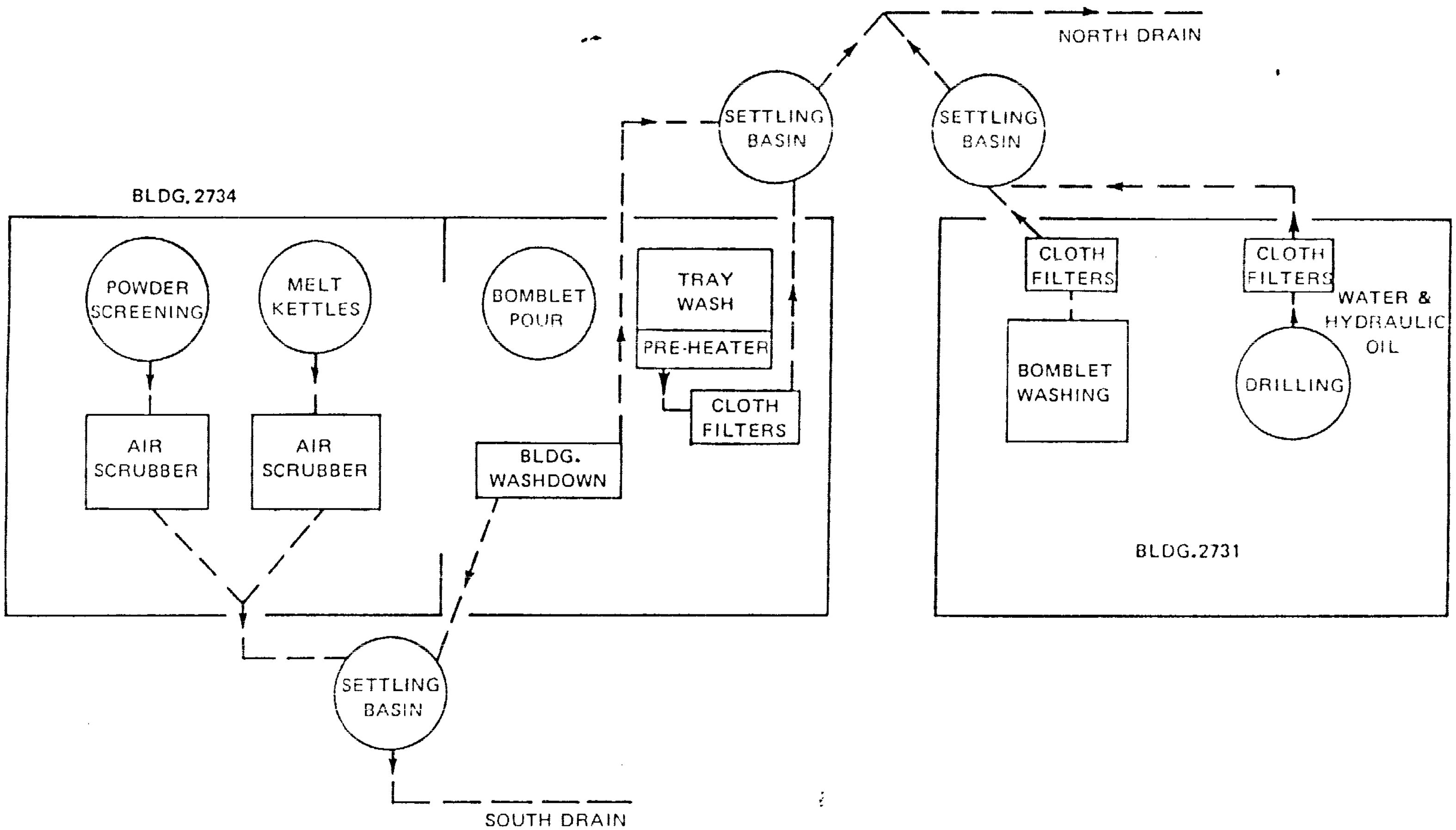


Figure 6.1-18 ROCKEYE/3-Inch Loading Area Process Flow Diagram
(Discharge drains now flow to a treatment system)

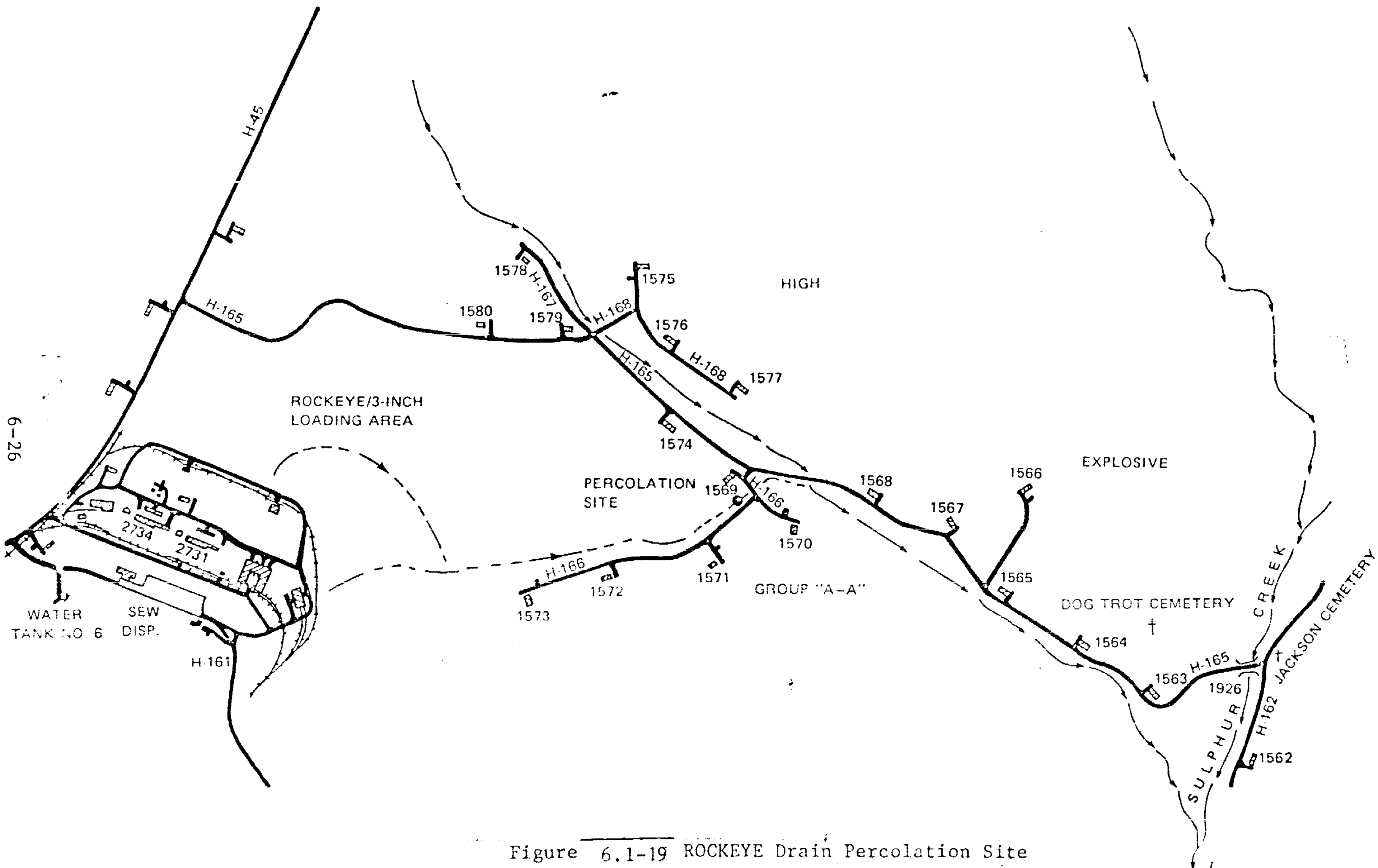


Figure 6.1-19 ROCKEYE Drain Percolation Site
Test wells and a treat facility have been installed at the ROCKEYE Loading Area

Figure 6.1-20 ROCKEYE Drain Percolation Site, Near Bldg. 1569

Figure 6.1-21 Rockeye North Drain ½ Mile Downstream, 1977

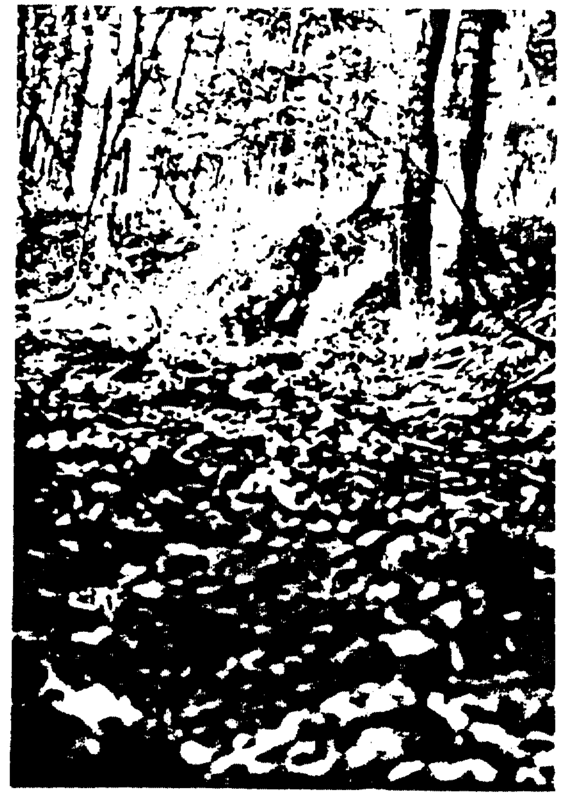


Figure 6.1-22 Rockeye North Drain Percolation Site, 1977

Figure 6.1-23 Rockeye North Drain Former Percolation Site, 1981

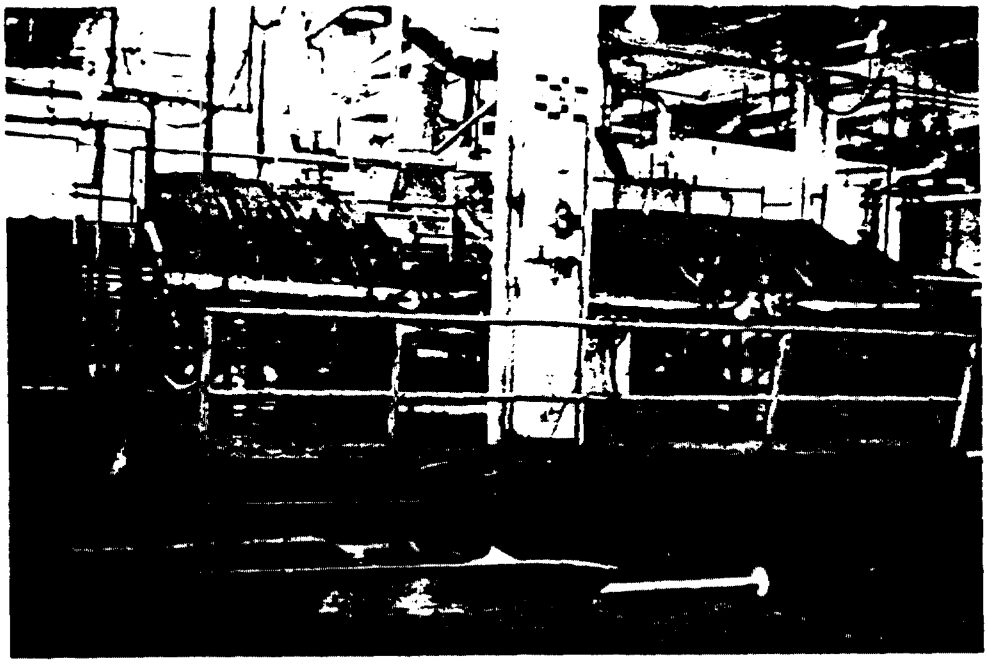


Figure 6.1-24 Steam-out Demilitarization System, Bldg. 160

Figure 6.1-25 Holding Tank for Steam-out from Bldg. 160 in 1981

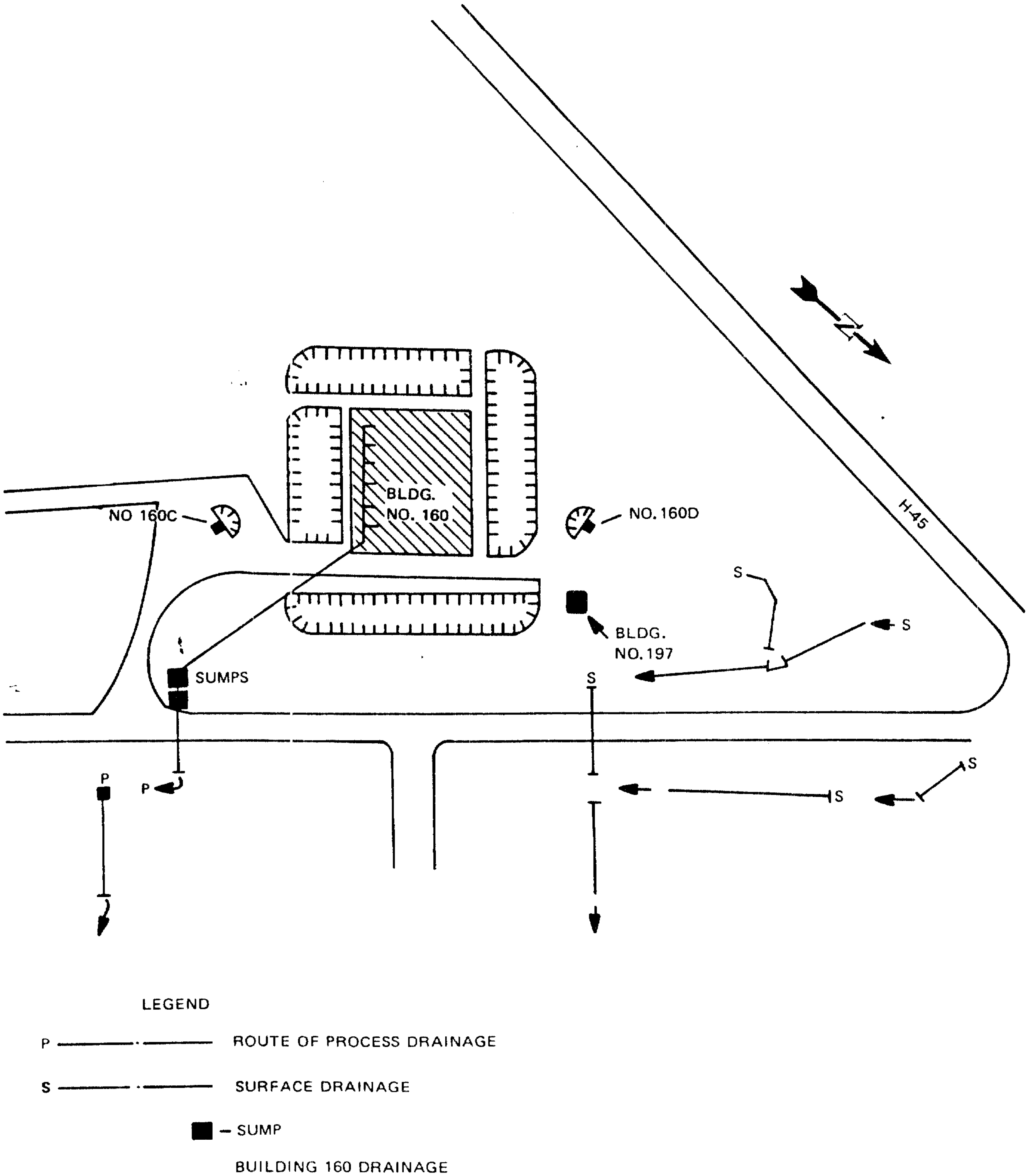


Figure 6.1-26 Drainage, Bldg. 160
Prior to 1981

The high-pressure washout unit in Building 146 handles only Comp 1. About five pounds of powder is initially drilled out and recovered for sale. The remaining three pounds or so is washed out, collected, and disposed of at the burning ground. The system is presently a closed system, the process water being reused. Prior to 1976, the water discharged to a storm drain. In 1954-1956, steamout of Army ammunition and rockets was reported as being conducted. These contained TNT and Comp B.

A 1979 study revealed low concentrations of TNT, RDX, and HMX (0.1ppm) in surface runoff from the area; however, sediment samples gave higher concentrations--TNT (109 and 382 ppm), RDX (31 and 44 ppm), and HMX (7 and 10.2 ppm).

A potential exists for soil and groundwater contamination from these demilitarization operations (figure 6.1-27). Residue of TNT, RDX, and HMX from past operations may exist in the soil in the vicinity of drains from the buildings. Heavy metals may contaminate the area around the ammunition incinerators.

6.1.8 Non-Explosive Ordnance Operations

In the load fill complex, Buildings 106 and 107 are equipped to recondition and test various types of cartridge cases, as well as to repair all types of ammunition containers (figure 6.1-28).

In Building 106, a cleaning process, consisting of a caustic wash, a degreaser, and an acid wash, in previous years discharged wastewater from the acid and caustic washes into a small unlined pond. The pond overflowed into a neutralizing system and subsequently into the sanitary sewage system (figure 6.1-29). In 1981, cooling water from degreasers was discharged to a storm drain until the discharge was connected to the sanitary sewer in 1982.

Building 107 houses grit blasters, degreasers, and paint booths. The neutralizer unit has been recently installed, that is, subsequent to 1972, and the settling pond, referred to an "leaching pits", was constructed in 1972 (figure 6.1-30).

Samples from effluent discharging from the settling pond, collected in 1972, revealed high heavy metals concentrations. Values as high as 10 ppm lead, 3.5 ppm chromium, 1 part per billion (ppb) mercury, 20 ppm zinc, and 0.2 ppm cadmium were recorded. Solvents used for degreasing such as explosives are minimal, because the parts for reconditioning have been flashed or exposed to flame and high temperatures at the burning ground. Sample analysis confirmed this. Flow rates average about 20,000 to 25,000 gallons per day.

The Small Arms Shop in Building 2521 (figure 6.1-31) contains a hardware reconditioning process line, initially operated around 1968. The line includes a cleaning system using caustic cleaning and degreasing (trichloroethylene). A coating process (phosphate, black oxide, or nickel) is integrated in the line. The following chemicals were used in the building.

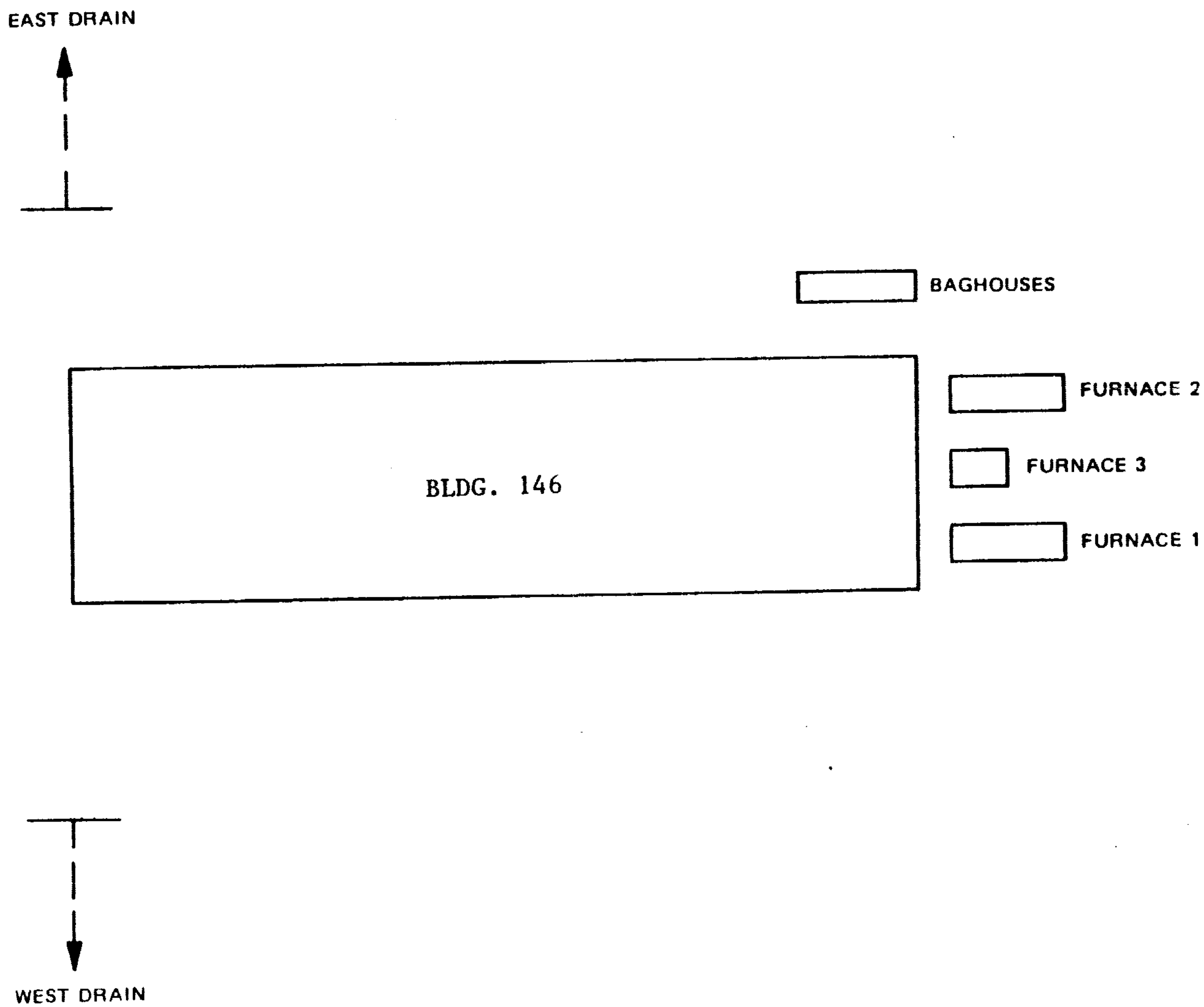


Figure 6.1-27 Cast High Explosives Filling Plant, Bldg. 146
1981

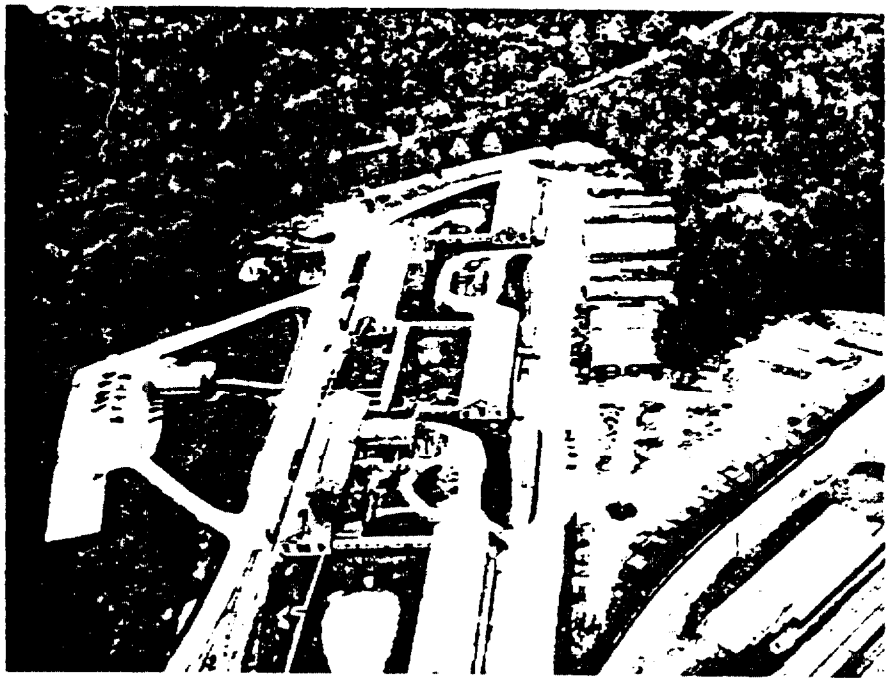


Figure 6.1-28 Projectile Prep, Case Overhaul and Tank Repair Area

Figure 6.1-29 Neutralizing Unit and Settling Pond by Building 106
Used Prior to 1980

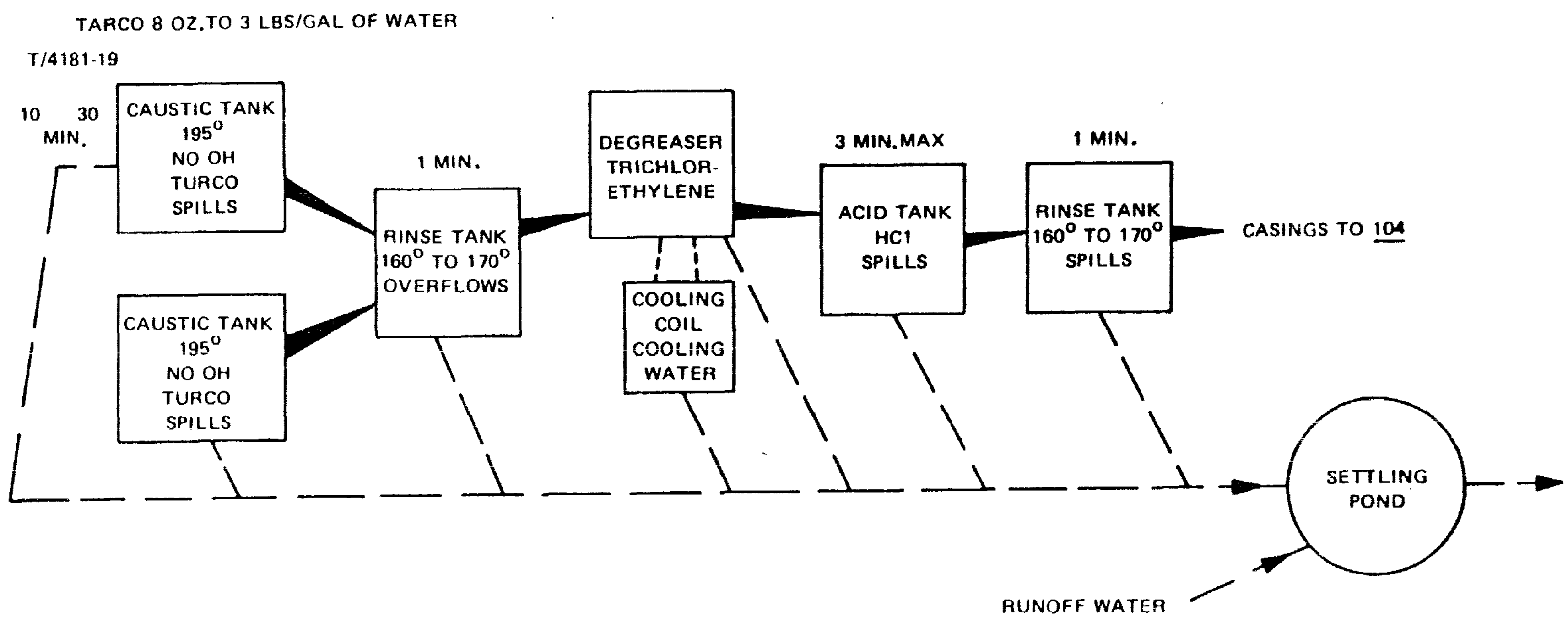


Figure 6.1-30 Projectile Preparation Process Flow Diagram, Bldg. 106 Prior to 1979

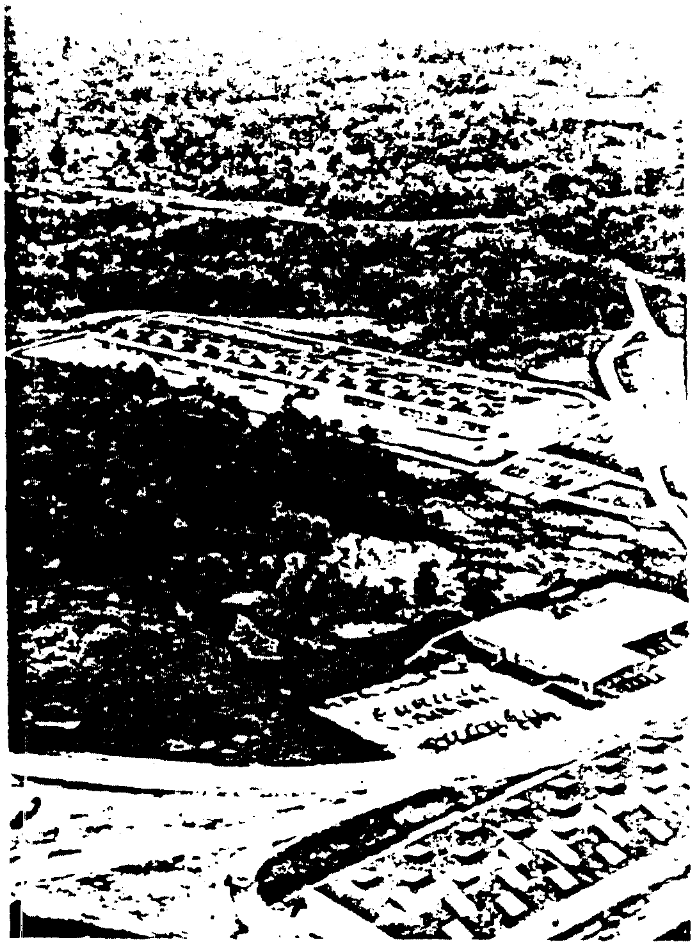


Figure 6.1-31 Small Arms Shop, Bldg. 2521

Chemical	Quantity
Trichloroethylene	55 gal/week
Lube Oil	500 gal/yr
Fingerprint Remover	150 gal/yr
Petroleum Solvent	25-55 gal/yr
Lubrite 2	550 gal/yr
Parcolene 1	15 gal/yr
Pentrate Cleaner	200 lb/yr
Nickel Pentrate	1,200 lb/yr
Black Oxide w.sodium dichromate	700 lb/yr
Hydrochloric Acid	Used rarely

Analytical data for the effluent is not available; however, chemical usage indicates potential for heavy metals in the wastewater. The wastewater presently is discharged into the sanitary sewage; however, a discharge pipe originating from this building (figure 6.1-32) emits a small stream. A sample of this effluent taken in 1978 showed no signs of heavy metals. Resampling in 1982 also proved negative.

Smokeless powder bag charges have the ignition ends colored red. Dying operations to color the silk cloth red were conducted in Buildings 105 and 106 during World War II. The production rate in Building 105 was 300 yards per day. Usage rate for the red dye (sodium salt of ditolyl-diazo-bis-Xnaphthylamine-4 sulfonic acid, sodium salt of 4 sulfoaphthalene-aza-napththol or a dispersion of 6 methyl sulfonyl-Z_1- benzothiazoleazo-N, -cyanoethyl-N, -acetoxyethyle aniline or equivalent) was about one-quarter pound per 110 yards of silk cloth. Toxic data for these compounds were not found; however, most of the napthalene sulfonic acid sodium salt family of compounds possess LD50 (rats) in the range of 100 to 1100 milligram per kilogram of weight, which would put them in the very toxic to moderately toxic ranking. The small usage rate would preclude any significant environmental impact in the area.

Because of the high volume of production in Buildings 106 and 107 in prior years, the potential for contamination of surface water and groundwater is significant. Heavy metals and trichloroethylene may have contaminated the drainage-way around the building.

6.1.9 Firing Ranges

Small-arms firing ranges exist at NWSC Crane. One is a rifle range (for military personnel) located near the Crane City gate (coordinates L-8, figure 6.1-33). The second is the small-arms test firing range north of Lake Greenwood (coordinates G-23, figure 6.1-34). The Small Arms Shop has cognizance over this firing range and reportedly only small arms have been tested there. The production line arms are tested in an indoor small-arms firing range in Building 2521.

The third firing range is designated the Rifle Range and Ordnance Burning Ground, located near the Ordnance Demolition Area, on coordinates GG-24. This area has been used for bomb cook-off tests and similiar activities. Reportedly, TNT, tritanol, and other explosives including black powder were burned there.

Figure 6.1-32 Discharge Pipe North of Small Arms Shop

Figure 6.1-33 Rifle Range/Ordnance Burning Area (Left)

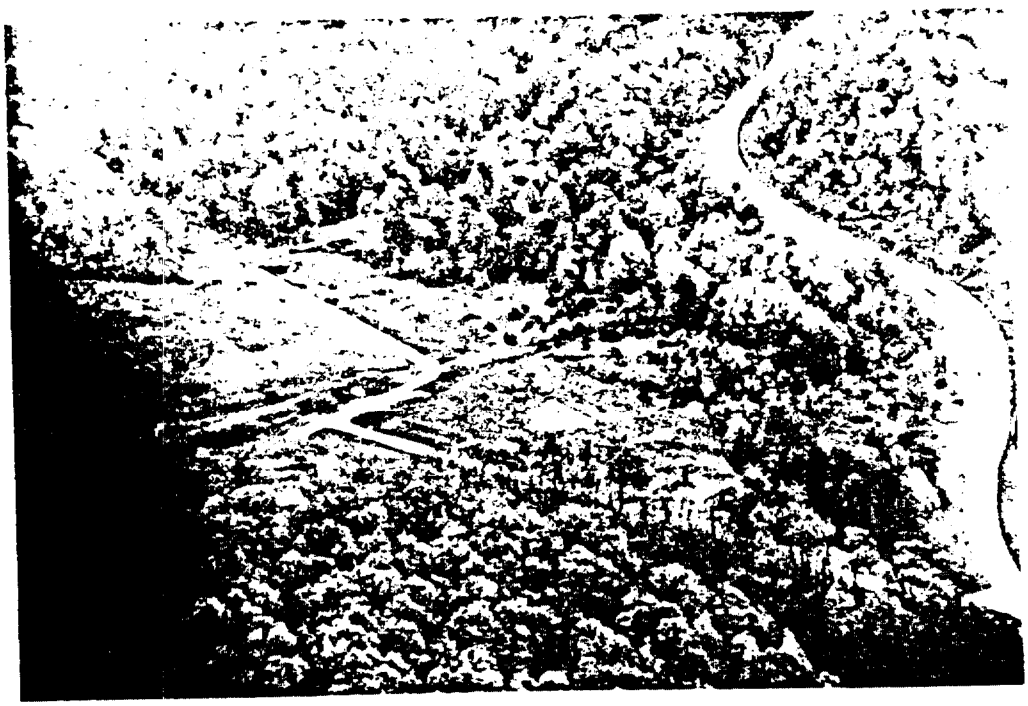


Figure 6.1-34 Firing Range, Small Arms

The potential for contamination at these firing ranges is small, owing to the low volume of activity at these sits.

6.1.10 Miscellaneous Operation

6.1.10.1 Building 180, Laundry/Dry Cleaning Plant

The Depot laundry takes care of the only ordnance contaminated employee's clothes, and impregnates the worker's clothes with flameproofing compound. In the past, effluent from the operation was discharged to a surface drain leading to Boggs Creek. The laundry currently discharges into the station sewage system. The wastewater contained high solids, ammonia, phosphates explosives, and heavy metals.

Chemical usage per day is:

Washing Compound "Impax"	75 pounds
Diligent Oil	1.5 pounds
X-12 Flame Retardant (primarily ammonium salts)	400 pounds

A 1972 study obtained the following average values from the effluent.

Flow	18,000 gpd
Total Suspended Solids	147 ppm
Total Dissolved Solids	8,521
Ammonia, Nitro	895
Phosphate	35 ppm
Oil and Grease	35 ppm
Copper	3.8 ppm
Zinc	4.4 ppm
Mercury	2.5 ppb
Lead	5.0 ppm
TNT	0.25 ppm
RDX	2.0 ppm
HMX	1.5 ppm

6.1.10.2 Building 181, Composition Testing Facility

A chemical warfare decontamination or "change house" was sparingly used during World War II. The facility now houses a saw unit for EOD operations. With a water-cooled blade, this band-type saw is used to machine bombs for subsequent dispcsal. The operation occurs irregularly. The cooling water discharges into a drum used for settling purposes and overflows onto the ground into an intermittent stream. In 1979, soil samples taken downstream of the drum revealed the following compositions:

	RDX, ppm	HMX, ppm	TNT, ppm
Soil (surface)	2	14	6,930
Soil (surface	3,284	0.2	12
Soil (1-ft. depth)	12.5	0.2	0.6

6.1.10.3 Building 600, Transfer Depot

At this munitions transfer depot, an open storage and trailer parking area to the southwest contains a hose and truck washout facility. Explosives-carrying vehicles are hosed down in this area. The 1979 study gave the following values for soil samples taken in the vicinity of the washrack.

	TNT, ppm	RDX, ppm	HMX, ppm
Soil (surface)	6.0	2	3.0
Soil (surface)	2.8	1,032	12.4
Soil (1-ft. depth)	1.7	418	60.0

6.1.10.4 Conservation Dam No. 2845

This conservation pond, located south of the Pyrotechnic Test Area, was reportedly used for testing floating-type pyrotechnics in the past. Only limited testing was conducted, and the potential contamination is minimal.

6.1.10.5 Old Phyrotechnic Test Area

This test area, inactive since the early 1970s, is located on the north side of Highway H-5 northeast of Building 2940. Extensively used for testing flares, ignition devices, and smoke markers, the area has small potential for significant contamination.

6.1.10.6 Lake Greenwood

Some four sites were reported as past test areas for floating-type markers and flares on this 800-acre lake. Also reported was testing of MK25 and MK72 flares in the 1950s, as well as the testing of mine location markers in the late 1960s. The testing of bombs in the lake during World War II is documented, but could not be substantiated as to type, quantity, or whether the rounds were live or inert.

6.1.10.7 Miscellaneous Summary

The comparatively low volume of operations throughout these miscellaneous facilities results in low potential for contamination. The high concentrations from soil samples near Building 181 and the washrack near Building 600 are localized. Soil samples taken some distance from the facilities give contaminant levels below 1.0 ppm.

6.1.11 Explosives Operating Building

The following subparagraphs list buildings that have housed significant explosives operations, e.g., black powder, smokeless powder, and explosives compositions. The present building title is listed, with the past title or function, along with ordnance material handled, enclosed in parentheses.

6.1.11.1 Load and Fill Area

101 Underwater Sound Signal Assemby (Case Filling--smokeless powder)

102 Equipment Test and Development (Bag Loading--smokeless powder)

103 Bag Charge Filling Plant (Ignition Assembly--black powder)

104 Medium Calibre Loading Plant (Projectile Loading--Explosive D, Comp A-3)

105 Warhead Loading Plant (Major Calibre Loading--Explosive D, PBXN-3 and 4)

108 General Warehouse--Build (Breakdown and Overhaul, Target Loading--smokeless powder, explosives comps)

119 Ammo Rework & Overhaul (Segregation and Plastic Beading--smokeless powder)

142 20mm Loading Plant (Breakdown and Overhaul--smokeless powder, explosives comps)

189 Guided Missile Maintenance Facility (Sifting building for Building 104--Explosive D, Comp A-3)

190 Photometric Lab (Sifting building for Building 198--Explosive D)

198 R&D Test Facility (Medium Calibre Loading--Explosive D)

200 Pyrothechnic Loading Building (Major Calibre Load--Explosive D)

2518 Accumulator Building (Dry collector for Building 105--Explosive D, PBXN-3 and 4)

2519 Accumulator Building (Wet exhaust system for Building 104--Explosive D, Comp A-3)

6.1.11.2 40mm Loading Area

145 Case Filling Plant (Smokeless powder)

146 Cast High Explosives Filling Plant (TNT Demil, Small Arms Incinerators, Fuze Drilling--Explosives Comps)

148 Small Arms Re-Packing (Smokeless powder)

6.1.11.3 Mine Fill A (various explosives Comps)

151 Cooling and Temporary Storage

152 Bomb and Mine Filling

153 Box Emptying

154 Receiving Building, Explosives

155 Inert Preparation

157 Bomb and Mine Filling

158 Box Emptying

159 Receiving Building, Explosives

160 Cooling and Temporary Storage

6.1.11.4 <u>Mine Fill B</u>

161 Inert Prep

162 Storage Prep

163 Storage Prep

164 Storage Prep

165 Temporary Storage and Cooling

166 Bomb and Mine Filling

167 Box Emptying

168 Receiving Building, Explosives

169 Empty Mine Storage

171 Bomb and Mine Filling

172 Box Emptying

173 Receiving Building, Explosives

174 Cooling and Temporary Storage

2171 Storage

2500 Nitrate Preparation and Storage (Ammonium Nitrate)

2502 Powdered Metal (Aluminum)

2503 Powdered Metal (Aluminum)

6.1.11.5 Rockeye/3-inch Loading Area (comp B, Octol)

2727 Shipping Building

2728 Final Assembly

2730 Vacuum Separator and Hydraulic Pump

2731 Drill and Inspection

2733 Vacuum Separator and Hydraulic Pump

2734 Cast High Explosive Fill Plant

2735 Inert

6.1.11.6 Miscellaneous Operations

180 Laundry (Ordnance Contaminated Clothing)

181 Compass Test Facility (Chemical Warfare Decontaminating Station--Sawing-explosives comps)

600 Transfer Depot Washrack (various explosives Comps)

6.2 OPERATIONS, NON-ORDNANCE

6.2.1 General

The majority of public works and industrial functions have not changed greatly since their initiation in the early 1940s. The size of these functions and the amounts of wastes generated about doubled the amounts reported herein during World War II, the Korean Conflict, and the Vietnam Conflict.

This section of the report refers only to past hazardous material operations. Current hazardous material handling procedures are covered in detail in NWSC Crane's Hazardous Materials Management Plan.

6.2.2 Battery Shop, Building 36

The battery shop personnel perform maintenance operations on electric vehicles, primarily forklifts, for all users at NWSC Crane. The shop was built around 1942.

Approximately 150 gallonss per month of battery acid is dumped out of worn-out batteries. The acid is neutralized in a tank and discharged into the sewer system. Prior to about 1975, the acid was disposed of down the hillside behind the building. Visual examination of the disposal site revealed about ten 10-gallon barrels and 50 5-gallon barrels at the base of the hill.

Old batteries, with acid removed, are sent to DPDO for salvage.

About 200 to 400 gallons per month of oil is generated from forklift servicing. The oil is collected and then hauled away by the boiler shop to the Defense Property Disposal Office (DPDO) for sale. Wastewaters containing oil are processed through an oil/water separator adjacent to the building. The boiler shop removes about 50 gallons per month of oil from the separator. Prior to about 1972, the oily water flowed down behind the building and eventually ended up in Lake Greenwood.

One small solvent tank is located at Building 36. Prior to 1980, the 10 to 20 gallons of solvent were drained out of the tank twice yearly and dumped down the hillside behind the building.

6.2.3 Battery shop, Building 38

Since 1959, the battery shop in Building 38 has tested and developed various types of batteries. Approximately 500 used batteries, primarily lead acid batteries and nickel-cadmium batteries, are disposed of by this operation yearly. Other batteries tested at Building 38 include silver-zinc batteries and, in the last 10 years, lithium batteries. Until 1968, waste battery acid, about 10 liters/year, was disposed of down the side of a ravine to the west of the building. Since 1968, the battery acid is either neutralized and flushed down the sink into the sanitary sewer or taken to Building 36, the main battery shop, for disposal. Silver-zinc batteries have always been sent, with electrolyte, to Naval Ammunition Depot Earle for disposal. Lithium batteries are given to the Explosive Ordnance Disposal (EOD) team for disposal by explosion. All transformers and capacitors are the dry type and are disposed of with the activity's garbage. Since 1981 these items are collected and turned in to DPDO for salvage and disposal.

6.2.4 Railroad Equipment Shop

The Railroad Equipment Shop performs maintenance on locomotives used at NWSC Crane. This shop was building about 1942.

Approximately 1,000 gallons per year of waste oil is generated from locomotive maintenance. The oil is collected and placed in 55-gallon drum barrels. The boiler shop personnel periodically pump the oil out of the drums into a tank truck. Reportedly, the oil has always been collected and in the past was used for lubricating railroad switches. Now waste oil is taken to DPDO for sale.

Old batteries, containing the acid, are taken to the battery shop, Building 36.

Various cleaning solvents are used in Building 7. In most cases the solvent is brushed or sprayed into the object, and the solvent evaporates. Two small dip tanks, one about 10-gallons volume and the other about 8-gallon volume, are used at the building. About 50 gallons per year of waste solvents were drained from these tanks and disposed of with the waste oil in 55-gallon drums. The current practice is to segregate waste solvents and oils, prior to disposal, through DPDO.

An oil/water separator is located adjacent to the shop to remove oil from wastewaters generated at the shop. About 100 gallons per month of oil is removed from the separator by the boiler shop. Prior to about 1972, oily waters flowed via several ditches and streams to Lake Greenwood. Waste oils are presently taken to DPDO for disposal.

NWSC has about 170 miles of railroad tracks. Derailments have occurred throughout the history of the base. However, accidents where chemicals could have been spilled or released to the environment have not occurred at NWSC Crane on the base railroad or on the Milwaukee Railroad running through the base.

6.2.5 Automotive and Heavy Equipment Maintenance Shops and Garage Area

About 50 to 75 gallons per year of carwash cleaner is used at the washrack in the north end of Building 1820. Also, 50 to 75 gallons per year of steam cleaners is used in the adjacent steam washrack. Wastes flow into an oil/water separator adjacent to Building 1820. Prior to about 1972, the oily wastewater flowed into a ditch and eventually into Boggs Creek. Waste oil is collected in a tank at Building 1820. Boiler shop personnel remove approximately 500 gallons of oil per month from this tank and from the oil/water separator. Salvageable oil is burned as fuel in the Building 150 boiler.

About 200 to 300 automotive batteries are disposed of near the garage area. In past years,the battery acid was dumped out of the battery and down the side of the ravine behind buildings 1820 and 1818.

Two solvent dip tanks are located in Building 1820. Each tank, which holds about 20 gallons of solvent, agitene, is emptied about twice a year. The waste solvent was disposed of in the waste oil tank at Building 1820. Currently, waste solvents and oils are segregated and disposed through DPDO.

A washrack is located at the northwest corner of the garage area. The rack is used to clean mud off trucks and to clean out concrete mixer trucks. Only water is used at this washrack. Visual inspection of the washrack and surrounding area revealed that mud and concrete had been washed into the ravine that starts under the rack, but signs of chemical contamination were not present.

6.2.6 Pesticides Shop

2,4D (also known as Tordon) is a broad-leaf killer, 2,4,5-T and 2,4-D are used on lawns at NWSC Crane.

In 1980, 2,4,5-T was applied to 59 miles of fenceline at a rate of 245 gallons per acre. Fencelines were sprayed previously in 1960, 1965, and 1968. Prior to 1960, fencelines were not sprayed.

In 1969, MH30 (maleic, hydrazide, and diethanolamine salt of 6-Hydroxy-3-(2H) Pyridazinone, 58%) was applied on 100 magazines and to both sides of Route 45 from the Bloomington gate to four miles southward, as a trial. The chemical did not work satisfactorily and was not used again.

From about 1950 to 1970, Telvan (80% Monuraon (3-(p-chlorophenyl)-1, 1-dimethylurea), made by Dupont, was applied yearly at a rate of 10 to 80 pounds per acre on railroad right of ways.

From about 1950 to 1970, Urealer, by U.S. Borax and Chemical Co., was applied yearly at a rate of 1 to 3 pounds per 100 square feet on magazine gravel drives and electrical substations.

From about 1950 to 1965, DDT was fogged twice a week in July and August in the residential area at a rate of 8.0% or 8 gals/mile for mosquito control. Currently, DDT is not stored or used on base. Other pesticides used since about 1950 include Lindane and Chlordane.

Prior to about 1950, pesticides were not used at NWSC Crane. Pesticide sprayers and containers were rinsed in the parking lot at Building 2189 and at the washrack, Building 2716 (Roads and Grounds Office). All empty pesticide containers were punched with a hole, rinsed, and sent to the landfill or burning pit (garbage) for disposal.

6.2.7 Carpenter Shop--Building 56

From about 1950 until 1965, a tank of pentachlorophenol (PCP) was used for treating wood. The tank was located to the northeast of Building 56. Reportedly, PCP dripped on the ground surrounding the tank. Visual inspection of the area revealed no tank or any other evidence of PCP.

6.2.8 Motor Shop--Building 2517

The motor shop performs maintenance on electric motors at NWSC Crane. A small (approx. 10-gallon) solvent dip tank is used to clean motor parts. Chemicals are not used in significant amounts in this shop.

6.2.9 Refrigeration Shop--Building 2517

The indoor electric shop does not use hazardous materials in significant amounts. The shop replaces 1 to 5 flourescent lighting ballasts per week. The ballasts, which contain some PCB in each unit, are disposed of with the activity garbage.

6.2.10 Electronics--Building 56

Solvents are used in this shop for servicing electronic equipment. The solvents, in 16-ounce and smaller spray cans, are appplied in small amounts and are allowed to evaporate or are wiped off with a rag. No significant amount of hazardous material has been used in this shop.

6.2.11 Sheet Metal Shop--Building 2517

In the past, small quantities of muriatic acid (hydrochloric acid) was reported to be used to prepare metal. Flux is currently used to do this operation. No significant amount of hazardous material has been used in this shop.

6.2.12 Mechanical Maintenance--Building 56

Three solvent dip tanks are located at this shop. The tanks each hold about 15 gallons of Agitene and are drained twice a year. The wastes went into a 400-gallon solvent tank located next door by the paint shop. In the past, about 200 gallons per year of waste hydraulics oils were spread on dirt roads at NWSC Crane and on the vehicle storage lot near Route 99. Hydraulic oil is currently disposed with waste oil through DPDO. Solvent disposal is done by contracted chemical waste disposal service.

6.2.13 Mill Shop--Building 56

No significant hazardous wastes are generated by this operation.

6.2.14 Paint Shop--Building 2889

Approximately 50 to 100 gallons per year of paint thinner and acetone waste are generated by the paint shop. In the past the wastes were dumped down the side of the ravine next to Building 2889. About 15 one-gallon empty paint cans are disposed of in the garbage. Paint wastes are currently being collected and disposed through a service contract with a chemical disposal service.

6.2.15 Welder Shop--Building 2517

No significant hazardous wastes are generated by this operation.

6.2.16 Water Treatment Plant

Potable water used at NWSC Crane is obtained from Lake Greenwood. The raw water from the lake is aerated; then alum, lime, and, in the spring, carbon are added to the water. The water is then filtered and chlorinated before entering the potable water distribution system. Potable water is supplied to all of NWSC Crane and to Crane Village, a civilian community adjacent to the activity. Sludge from the treatment process was discharged down a ditch that empties into Lake Greenwood. In February 1981, the potable water was tested for heavy metals including mercury, lead, silver, and cadmium, and was found to meet Safe Drinking Water Act criteria. The activity is currently testing raw lake water and lake sediments for TNT, RDX, and PCBs and reports that all testing for these compounds are negative.

6.2.17 Steam Plants

Seven major boiler rooms are located in Buildings 115, 128, 150, 199, 2674, and 2737. Feedwater chemicals in use at NWSC Crane consist of caustic, phosphates, sulfite,and sludge conditioners. Boiler blowdown was discharged to the storm drainage system until about 1975 when it was diverted to the sanitary sewer. No. 2 and No. 6 fuel oils are used for the boilers. On two occasions, fuel oil spillage occurred but was cleaned up. About 4,000 gallons of fuel were spilled at Building 225 in the early 1960s and about 150 gallons were spilled at Building 115 in the 1970s.

Prior to 1980 waste oil collected at NWSC Crane was disposed of through DPDO. Since 1980, a portion of the waste oils are burned at the boiler plants. About 2,000 gallons of waste oil is recovered and burned each year. Waste oil not burned in the boiler is sold through DPDO.

Some of the older insulation covering boiler plant steam pipes is asbestos. The asbestos is disposed of in a state-approved site at the sanitary landfill at the Center.

6.3 OPERATIONS, RADIOLOGICAL

6.3.1 General

From available records and interviews with long-time employees at NWSC Crane, the first introduction and use of radioactive material at NWSC Crane occurred in 1974 with the use of thorium 232 and of rare earth metals in the manufacture of illuminating candles in the Pyrotechnics Plant. Utilization of radioactivity continues at NWSC Crane for a variety of safe and beneficial applications and operations. The only known on-site burial of radioactive material that has occurred was the burial of the thorium 232 solid used by the Pyrotechnics Plant. Known burial sites of the thorium 232 have been excavated, decontaminated, surveyed, and released for unrestricted use. The thorium 232 has been shipped to the Nuclear Regulatory Commission (NRC) approved burial site at Hanford, Washington. The use, burial, or excavation/-decontamination operations did not present a health hazard to NWSC Crane personnel or to the general public, then or now.

Currently, NWSC Crane is licensed by the Nuclear Regulatory Commission (NRC) to utilize any byproduct material with atomic number 3-83, inclusive, in the form of irradiated transistors and integrated circuits for missile guidance systems (1 curie total), nickel-63 in a gas chromatograph (6 foils not to exceed 2 millicuries each and 3 sources not to exceed 15 millicuries each), tritium in a gas chromatograph (not to exceed 200 millicuries per foil), and Krypton-85 in a Radioflow Unit (60 curies).

The Crane Army Ammunition Activity (CAAA) utilized two sources of radiation on NWSC Crane. They are two iridium-192 radiography source (no more than 100 curies) and a cobalt-60 radiography source (1 source of 2,000 curies and one cobalt-60 source of 1000 curies). CAAA has a license for up to 24,000 curies of cobalt-60 for use in the Gammacell 220 iradiator. Analysis and investigation indicate that all known applications and operations dealing with radioactive material are being and have been conducted in a safe manner in accordance with current directives and practices.

6.3.2 Industrial Operations

6.3.2.1 Depleted Uranium (DU)

Records indicate that in November 1976, 112 experimental rounds of 20mm cartridges containing DU were received by NWSC Crane and stored in Building 2318. An October 1980 inventory indicated that 106 rounds were in storage and that the original number (112) was in error. Subsequently, the 106 experimental rounds of 20mm cartridges containing depleted uranium were shipped at Naval Weapons Station, Seal Beach, California, which is licensed by the NRC for storage of DU.

Depleted uranium is also utilized as radiation shielding in the gamma radiography exposure devices. The use and storage of depleted uranium or devices containing depleted uranium present no current or past health hazard at NWSC Crane.

6.3.2.2 Radium-226

The MK26, Mod 0 Firing Device (Inert), NSN 1375 00 910 1961, utilizes 692 microcuries of radium-226. One device, serial number 257, stored in magazine 1197, has been shipped to an NRC-approved disposal site.

The MK28, Mod 0 Firing Devices utilize 0.4 microcuries of radium 226. A total of 159 devices were shipped to the NRC-approved disposal site at Barnwell, South Carolina, in December 1975.

The last four "Alphatron" vacuum gauges containing radium-226 were removed from service on 17 March 1977 and have been shipped to an NRC-approved disposal site. Three "Alphatron" gauges containing a total of 600 microcuries of radium-226 were shipped to the NRC-approved disposal site at Barnwell, South Carolina, in December, 1975.

The use, storage, packaging, and transport of radium-226 present no current or past health hazard at NWSC Crane.

6.3.2.3 Tantalite and Columbite Ores

National Defense stockpiles of tantalite and columbite ores are maintained at NWSC Crane. Representative samples of these ores were submitted to the Naval Nuclear Power Unit for analysis in September 1977. Analysis indicated that the ore contains natural uranium and natural thorium. However, the level or amount of radioactivity in the ore is not higher than other naturally occurring rock samples. The storage of trantalite and columbite ore presents no current or past health hazard at NWSC Crane.

6.3.2.4 Tritium

Tritium is utilized in night-vision tubes to provide illumination of the range indicators. One night-vision tube containing an unknown quantity of tritium was shipped to the NRC-approved disposal site at Barnwell, South Carolina, in December 1975.

Tritium is also utilized in "Betalight" exist signs, Model CPI 700, to provide illumination to indicate exists. Currently, one "Betalight" exit sign (SN 1128), containing 125 curies of tritium, has been packaged and is stored in magazine 1197 awaiting shipment to the NRC-approved disposal site at Barnwell, South Carolina.

The use, shipment, storage, and disposal of tritium presents no current or past health hazard at NWSC Crane.

6.3.2.5 Promethium-147

Promethium-147 is used in the "Microderm" model thickness gauge to determine and then control the thickness of manufactured goods. This device contains a sealed source of promethium-147 and is still in use. Two "Microderm" thickness gauges are in use at NWSC, one of which contains 10 microcuries of strontium-90 and the other contains 100 microcuries of tellurium-204.

Promethium-147 is also utilized in the 66mm Light Antitank Weapons System (LAWS) on the front sights of those weapons designed for use at night to illuminate the 100- and 150-meter markings. A total of 3,894 LAWS front sights were removed, packaged, and shipped to the Defense Property Disposal Office, Building 1197, on 20 February 1981.

The use and storage of promethium 147 presents no current or past health hazard at NWSC Crane.

6.3.2.6 Magnesium-thorium

Magnesium-thorium, in solid metal plates, is utilized for the production of lightweight structural pieces. The magnesium-thorium scrap plates were collected, and a total of 850 pounds were shipped on 23 June 1977 to Halaco Engineering Company of Oxnard, California, for refinement and recovery of the magnesium.

No health hazard exists from the use, collection, and shipping of magnesium-thorium alloy at NWSC Crane.

6.3.2.7 Krypton-85

Krypton-85 is used in a radioflow Mark IV detector unit for leak testing sealed items. There are several check sources containing Krypton-85 at NWSC. The Radioflow unit utilizes up to 60 curies of Krypton-85 gas and a total of 100 millicuries of Krypton-85 in a sealed source. NWSC Crane holds NRC License 13-02515-07 for the use of Krypton-85 in Building 2931. The use and storage of Krypton-85 presents no current or past health hazard at NWSC Crane.

6.3.2.8 Gas Chromatography Operations (Nickel 63 and Tritium)

NWSC Crane holds NRC License 13-02515-05 for the utilization of six foils, not to exceed 2 millicuries each, of Nickel-63 in a Hewlett-Packard Model 2-6195 detector cell gas chromatograph; three plated sources, not to exceed 15 millisures each, of Nickel-63 in a Hewlett-Packard Model 18713A detector cell gas chromatographic; and tritium in the form of titanium tritium foils, not to exceed 200 millicuries per foil, has chromatograph detector. Gas chromatograph operations present no current or past health hazard.

6.3.2.9 Cobalt-60

Crane Army Ammunition Activity, under NRC License 13-18235-01, maintains and uses one source of not more than 2,000 curies of cobalt-60 in a radiography exposure device and another 1,000 curies cobalt-60 radiation exposure device.

The storage and use of cobalt-60 at NWSC Crane presents no current or past health hazard.

6.3.2.10 Iridium-192

The Crane Army Ammunition Activity,, under NRC License 13-18235-01, maintains and uses two sources of not more than 100 curies of iridium-192 in a radiography exposure device. The storage and use of iridium-192 at NWSC Crane presents no current or past health hazard.

6.3.2.11 Carbon-14

TNT was laced with carbon-14 in order to perform various experiments that require the tracing of small amounts of TNT. All materials utilized in the experiments (that is, pipettes, gloves, paper) were packaged and shipped to the NRC-approved disposal site at Barnwell, South Carolina, in December 1975. Excess solid-form TNT laced with 100 millicuries of carbon-14 was burned at the NWSC Crane ammunition burning ground. The use, storage, packaging, shipment, and disposal of carbon-14 presents no current or past health hazard at NWSC Crane.

6.3.2.12 Thorium-232

Night-vision tubes and electron tubes utilize radioactive material to provide illumination and to enhance electron emission from the cathode. Fourteen night-vision tubes and 14 electron tubes were identified to contain unknown quantities of thorium-232. The 28 devices were collected, packaged, and shipped to the NRC-approved disposal site at Barnwell, South Carolina, in March 1976.

During the early 1950s, unknown quantities of thorium nitrate and thorium nitrate-illuminating compounds were buried in the Chemical Burial Ground at NWSC Crane. During the period of 13-24 May 1974 the disposal site was excavated and the buried thorium nitrate material and contaminated soil was exhumed, packaged, and stored awaiting shipment.

The surrounding soil in the burial ground was surveyed and certified to be free of radioactive material. In March 1976, the 3,710 pounds of thorium nitrate and contaminated soil were shipped to the NRC-approved disposal site at Barnwell, South Carolina, for burial.

Three additional locations of thorium nitrate burial were identified in the Chemical Burial Site during 1980 (figure 6.3-1). On 15 September 1980, the Naval Sea Systems Command (NAVSEASYSCOM) approved operation plans to exhume the three sites. Operations continued through 24 September 1980. The thorium nitrate and surrounding soil were removed and placed in Department of Transportation (DOT) 17H 55-gallon drums. At the conclusion of the cleanup operations, 14 barrels containing thorium nitrate canisters and/or contaminated soil remained for disposal. Based on the analysis of soil samples performed at NWSC Crane and verified by health physicists at the Radiological Affairs Support Office of the Naval Energy and Environmental Support Activity, the thorium nitrate disposal sites identified in figure 6.3-1 were released for radiologically unrestricted use. The 14 barrels containing thorium nitrate and/or contaminated soil are stored in magazine 1197 prior to being shipped to an NRC burial site in Hanford, Washington.

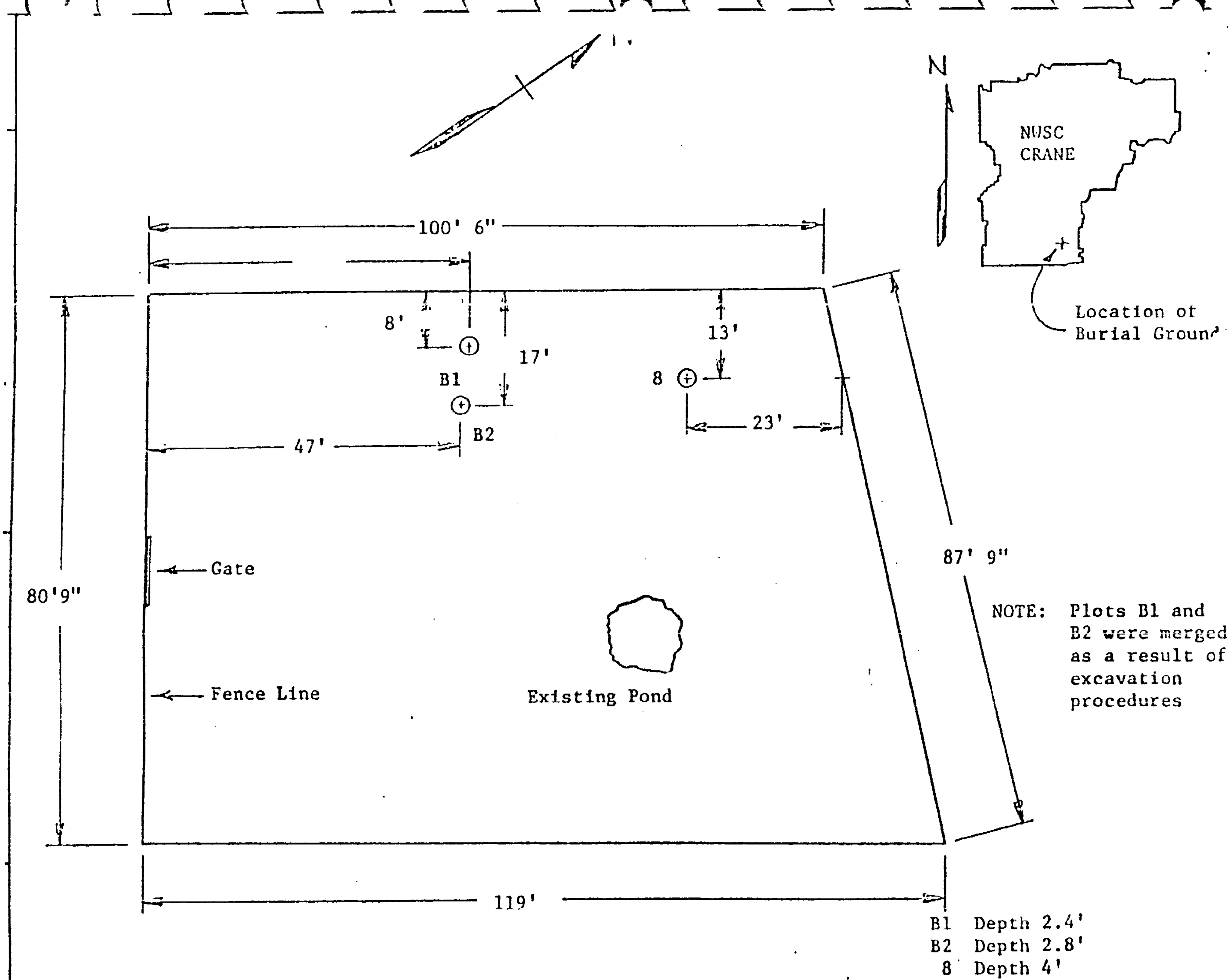


Figure 6.3-1 Thorium Nitrate Disposal Sites with Respect to Chemical Burial Ground Located at NWSC Crane

The use, storage, packaging, disposal, exhumation, and shipment of thorium-232 presents no current or past health hazard at NWSC Crane.

6.3.2.13 Neutron-Activated Electronic Components

Currently, 25 packages of neutron-activated electronic components are stored in Building 2906. The storage of these electronic components presents no current or past health hazard.

6.4 MATERIAL STORAGE

6.4.1 Chemical Storage

Prior to 1968, flammable materials such as paints and solvents have been stored in Building 2059. Flammable materials are now stored in buildings 479 and 480, that are designed for flammmable storage. Hazardous waste is stored in Building 2993.

From prior to 1968 until 1978, acids were stored in Building 1845. Since 1978, acids have been stored in Building 2748. Items that had an expired shelf life have been sent to DPDO for disposal. Any leaking containers were thrown into the trash. Empty drums were taken to DPDO for resale.

On 13 July 1976, a fire occurred at the inert warehouse, Building 225. The activity's fire department used over 600,000 gallons of water to control and extinguish the fire. Building 225 and its contents were destroyed. Stored at the building were over 70,000 pounds of pentachlorophenol (PCP, a wood preservative), about 50,000 gallons of paints, about 500 pounds of sodium fluoroscein dye, about 5,000 gallons of solvents (acetone, toluene, and methyl ethyl ketone), and various other items including inks, gaugem staples, and wax paraffin.

Environmental concern was generated by the observation that runoff water used in fighting the fire was colored a brilliant fluorescent green and was entering an intermittent stream know as Broom Branch. This stream flows into Furst Creek, which has as its source, Lake Greenwood, on this Center. Furst Creek flows off the Center and into White River near Newberry, Indiana. Broom Branch at this time had little flow other than the water used in fighting the fire. A series of dams was constructed to contain the polluted water on the Center.

On 16 July, heavy rains added an estimated 10 million to 20 million gallons of water to the watershed. Several of the dams were washed away, and visibly green water exited the activity. The remaining greem water was disposed of on 19 July by diluting it with water from Lake Greenwood and releasing it down Furst Creek so no visibly green water exited the activity.

Sampling of the green water was performed prior to disposal. The fire department investigation of the fire, contains a list showing quantities of items stored in Building 225 just prior to the fire. After the fire, the building site was properly cleaned to remove any remaining debris. Only the foundation of the building remains at the site. The NACIP team judged the clean up operation to satisfactorily remove contamination that was caused by the fire.

No other significant spills or accidents involving chemicals were reported.

6.4.2 Disaster Preparedness Chemicals

Disaster preparedness chemicals are stored in Buildings 379 and 381, which are smokeless powder magazines. DS2, super tropical bleach (STB), and ethylene oxide have been stored on base. In 1977, the only chemical present on base was 200 15-pound cylinders of ethylene oxide. All the ethylene oxide was disposed of by the EOD Team in 1977, because the cylinders were deteriorated. The EOD team blew up several cylinders at a time in the pit at the demolition area. Since 1977, ethylene oxide has not been stored on base.

In 1969, DS2 was acquired and stored on base. In about 1974, the old DS2 was replaced with new DS2; the first DS2 was declared to be a bad lot and was turned in to DPDO. Currently, about 150 quarts of DS2 are stored on base.

In about 1978, NWSC Crane acquired about 150 30-pound cans of STB. Some of this STB was used for decontamination at the mustard gas burial ground.

No incidents were reported from the storage or use of disaster preparedness chemicals.

6.4.3 POL Storage

NWSC has about 700,000 gallons fuel storage capacity consisting of gasoline and fuel oils. The major storage area is located at the fuel farm near the Crane gate; additional storage is located near the burning pit by the Scale House.

The only fuel spill uncovered during the study was a gasoline spill consisting of an estimated 4,000 gallons from tank B28.

6.4.4 Radioactive Material Storage

Radioactive material in 1981, was being stored in Magazine 1197, building 2931 and 2906, NWSC Crane, and at the National Defense Stocksite. The material was shipped to a disposal site and is no longer stored in these buildings. The following table provides a listing of the isotopes, a description of their form, and the quantity.

Isotopes Stored at NWSC Crane and at National Defense Stocksite

Isotope	Description	Location	Quantity
Radium-226	MD 26, Mod 0 Firing Device	Mag. 1197	692 microcuries
Tantalite & Columbite Ore	National Defense Stockpile	Stockpile	Unknown
Tritium	"Betalight" Exit Sign	Mag. 1197	125 curies
Promethium-147	"Microderm" thickness gauge	Bldg. 2917/2906	
Krypton-85	"Radioflo" Leak Tester	Bldg. 2931	60 curies
Nickel-63	Foils and plate in Gas Chromatograph	unknown	67 millicuries
Cobalt-60	Radiography Exposure Device	Bldg. 104	2,000 curies
Iridium-192	Radiography Exposure Device	Bldg. 104	up to 100 curies
Neutron Activated	Electronic Components	Bldg. 2906	

6.5 WASTE DISPOSAL OPERATIONS

6.5.1 Sewage Treatment and Disposal

In the past, four sewage treatment plants were located at NWSC Crane.

Around 1940, a 200,000-gallon-per-day secondary treatment plant was built to serve most of the base. This plant is located about a half mile west of mine fill B. Unit operations at the plant include primarily settling (Imhoff tank), trickling filtration, secondary settling, chlorination, anaerobic sludge digestion, and sludge drying. The sludge, dried in sand beds, was spread around the base as fertilizer. Approximately 6,000 cubic feet of sludge was disposed of on base each year. Effluent from the plant discharged into Boggs Creek.

In 1978, this plant was replaced with a new plant located at the same site. The new plant treats all sewage flows at the activity and uses rotating biological contactors to provide secondary treatment to the wastewater. The sludge is not dried; it is spread as a liquid at various locations on the activity. The sludge has been tested for EP toxicity, heavy metals, and explosives. The results of the tests show that the compounds are within EPA limits. Four hundred thirty-eight thousand gallons of sludge was disposed of between April 1980 and December 1980.

Around 1950, a small sewage treatment plant was constructed to service Buildings 2521 thru 2524, located to the north of Lake Greenwood. Unit operations at the plant include primary settling (Imhoff tank), trickling filtration, and sludge drying. Chlorination was added to the plant about 1965. Average flow to the plant is 4,000 gallons per day. The sludge, about two wheelbarrowloads a year, is disposed of on the ground near the plant. This plant was closed in April 1980. It's flows were directed to the new rotating biological contractor plant.

Around 1960, a small secondary sewage treatment plant was constructed adjacent to the Rockeye line to treat domestic wastes generated at the line. The package sewage treatment plant, which treats about 4,000 gallons per day, consists of an activated sludge aeration tank and settling tank. Sludge from the plant, about two wheelbarrowloads a year, was disposed of on the hillside adjacent to the plant. Effluent from the plant discharges into Turkey Creek. This plant was closed in April 1980. It's flows were directed to the new rota- ting biological contactor plant.

Around 1952, a sewage treatment plant was constructed at Crane Village to provide secondary treatment to about 65,000 gallons per day of domestic wastewater. Unit operations at the plant include primary settling (Imhoff tank), trickling filtration, secondary settling, chlorination, and sludge drying. This plant was closed in April 1980. It's flows were directed to the new rotating biological contractor plant.

In 1978, all the small sewage treatment was replaced by one central sewage treatment plant. The small sewage treatment plants are no longer in operation.

6.5.2 Solid Waste Disposal

Prior to 1942, garbage was disposed of at an abandoned stone quarry located just east of Turkey Creek, about 1,000 feet south of the H-99 highway bridge over Turkey Creek. The garbage was burned before it was buried. This site was not inspected by the NACIP Team.

Records and the site investigation indicate that ordnance and non-ordnance wastes were placed in McComish Gorge, which is near the Crane Gate at the northwest corner of the Base. The specific contents of this site were not verified.

From about 1942 to 1972, garbage, except for ordnance items, was disposed of at the garbage burn pit. The pit was located near the Crane Gate, east of the junction of H-5 and H-331 (figure 6.5-1). Garbage was burned daily in the pit. Residuals from the pit were buried in a gully to the north of the pit, along with nonburnable items such as refrigerators, and, reportedly, transformers and barrels. It is unknown whether barrels were burned before burial.

Since 1972, garbage has been buried at the sanitary landfill (figure 6.5-2). Two holding ponds, located downslope of the landfill, are used to collect the landfill leachate. The ponds are connected to the sanitary sewer. Records indicate that landfilled material may have been placed directly on the fractured rock surfaces.

In 1977, three hermetically-sealed PCB capacitors were buried at the Pole Yard. The State of Indiana has indicated that the capacitors could remain undisturbed at the site because of their solid nature and because they were buried there prior to 19 February 1978, the cut-off date allowed for such disposal of PCB contaminated material by EPA regulations.

6.5.3 Defense Property Disposal Office

The Defense Property Disposal Office (DPDO) located at NWSC collects all used items turned in for disposal at the Center. The overwhelming majority of material turned in to DPDO at Crane is scrap metal. The scrap metal includes shells, bombs, old gun mounts and other ordnance materials that have been cleaned of ordnance residues by burning at the burning grounds or otherwise. The Metal Salvage operation at NWSC is the largest such operation in the United States, according to DPDO personnel, with projected annual sales in 1981 of over $2 million.

Nonordnance items turned in to DPDO are handled according to the material. Metal shavings containing cutting oil are placed on a pad, which collects the oil for recycling. Prior to the late 60s the oil in metal shavings drained onto the ground in the area.

6.5.4 Disposal--Radioactive Material

With the exception of the initial operations dealing with thorium-232, the disposal practices at NWSC Crane have been in accordance with current directives, and all radioactive material requiring disposal has been shipped to an NRC-approved disposal site.

Figure 6.5-1 Abandoned Burning Pit Near Crane Gate (Site 3)

Figure 6.5-2 Sanitary Landfill

The burial of thorium-232, in the form of thorium nitrate, at the Chemical Burial Ground, was an acceptable practice at the time of burial. During exhumation operations in May 1974, identified thorium nitrate and contaminated soil were removed and shipped to the NRC-approved burial site at Barnwell, South Carolina. During exhumation operations conducted in 1980, at the three newly identified sites within the Chemical Burial Ground, additional quantities of thorium nitrate and contaminated soil were removed and shipped to the NRC-approved disposal site at Barnwell, South Carolina. It is assumed that most of the contaminated soil was able to be removed during these exhumation operations, enabling the release of these areas for radiologically unrestricted use. This may indicate that the thorium nitrate did not contaminate the water table and did not migrate out of the Chemical Burial Ground (figure 6.5-3). Monitoring wells have been installed in this area.

6.5.5 Disposal Operations

The Demolition Area, or Demo Area, as it is known, is primarily used by Army EOD (Explosive Ordnance Disposal) personnel to dispose of ordnance items that have been rendered safe for transportation and disposal. Most items are detonated in pits or on pads after being primed. Figure 6.5-4 shows the main and spoils areas. During 1968, which phosphorus rounds and ethylene oxide bottles were destroyed in the area known as the spoils area at the east end of the range. Red phosphorus was not destroyed here.

Another area of the demolition grounds was the old marine rifle range. From 1956 to 1960, areas on both sides of road H-467A were used for destroying material, mostly from drillout and steamout. About 46,000 pounds per day was destroyed. Material destroyed included H-6, "D," amatol, Minol, Comp A-3, TNT, Tritonal, and black powder.

In 1976, some black powder in 25-pound shipping cans had been soaked in water. The water was poured off and the residue was burned on the ground.

The demolition area is bare ground with a ring of bare, dead, and dying trees, which were subjected to the blast pressure wave and shrapnel. In most detonations, the explosive is consumed by reacting instantaneously to produce the gases nitrogen and carbon dioxide, and water. A loud noise results and some earth moves from the blast hole to the immediate area. The dust cloud settles within minutes, while the hot gases rise and moisture condenses in a cloud. Groundwater monitoring is currently in progress at this site.

6.5.6 Ordnance Burning Grounds

The ordnance burning grounds are used extensively for destroying unwanted materials contaminated with explosives, bare explosives, rocket motors, candles, flares, solvents, red phosphorus, small detonators, and fuse material. Several separate areas are located within the overall area (figure 6.5-5). The largest quantities were destroyed from 1956 to 1960, when 15,000 pounds per day of smokeless powder, mostly 40mm, was destroyed. During this same time, about 46,000 pounds per day of high explosives (H-6 and Comp B) were burned. In 1977, only 120,000 pounds of CH-6, 22,000 pounds of black

Figure 6.5-3 Chemical Burial Ground (Site 12)

Figure 6.5-4 High Explosive Demolition Ground (Site 9)

powder, and 126,000 pounds of miscellaneous powder was burned. The area also is used for flashing (burning) the residue from bombs and projectiles after they have been subjected to meltout or drill out operations for removal of the bulk of the explosive. From 1970 to the present, over 10,000 major weapons were destroyed. Figure 6.5-6 shows demilitarized MK82 bombs. Figure 6.5-7 is a telephoto picture of the candleburning cage.

During the late 1950s or early 1960s, several pallets of color burst units were buried at the old burning pit near the Crane Gate. These were dug up and taken to the ordnance burning ground for disposal.

Around 1976, a one-time operation was performed in Building 181, the decontamination building. About 250 MK82 (500-pound) bombs were cut under a water-cooling stream. The water drained to a tank, where the sludge was collected and taken to the burning grounds. The water overflow drained into a ditch. The cut bombs were burned out at the burning ground.

The materials from the pyrotechnic production, detonator loading, and fuze lines were also burned at the ordnance burning grounds. The materials included MK45 flares and rocket motors as well as all the phosphorus scrap from the pyrotechnic line sumps and dust collectors.

Figure 6.5-8 is a rough diagram of the ordnance burning grounds. A good idea of the layout can be formed by comparing figure 6.5-8 and figure 6.5-5, which are similar in orientation.

The drainage pattern is clearly indicated flowing south to Little Sulfur Creek.

Most of the propellant and explosives that were burned are listed in Table 6.5-1. The main difference in burning of explosives as opposed to detonating explosives is the rate of reaction, that is, the rate in which the energetic materials decompose to form gases. The open burning process results in more solid residue because of more incomplete combustion--the heated cloud carries more unreacted explosive. Normally, the contamination from open burning is wider spread than that from open detonation, although the noise level and pressure wave is less.

All standard military explosives have been present at NWSC Crane from World War II years to the present. The ground in the nearby area is probably contaminated with ppm levels of unreacted remnants of the explosives. Table 6.5-1 is a listing of typical explosives and chemicals used in explosives.

The surface waters in drainage ways leading from the burning grounds are currently analyzed monthly for explosives and heavy metals. No significant contamination of water has been found in Little Sulfur Creek to date.

6.5.7 Dye Burial

From 1952 until 1964, an estimated 50,000 pounds of various dyes and dye-contaminated materials were deposited into open trenches. The three main trenches were about 10 feet wide, 6 feet deep, and 50 feet long. Materials included magnesium, boxes, rags, etc., contaminated with dyes that were not burned because of policy. Reports indicate that, during 1956, about 60 drums

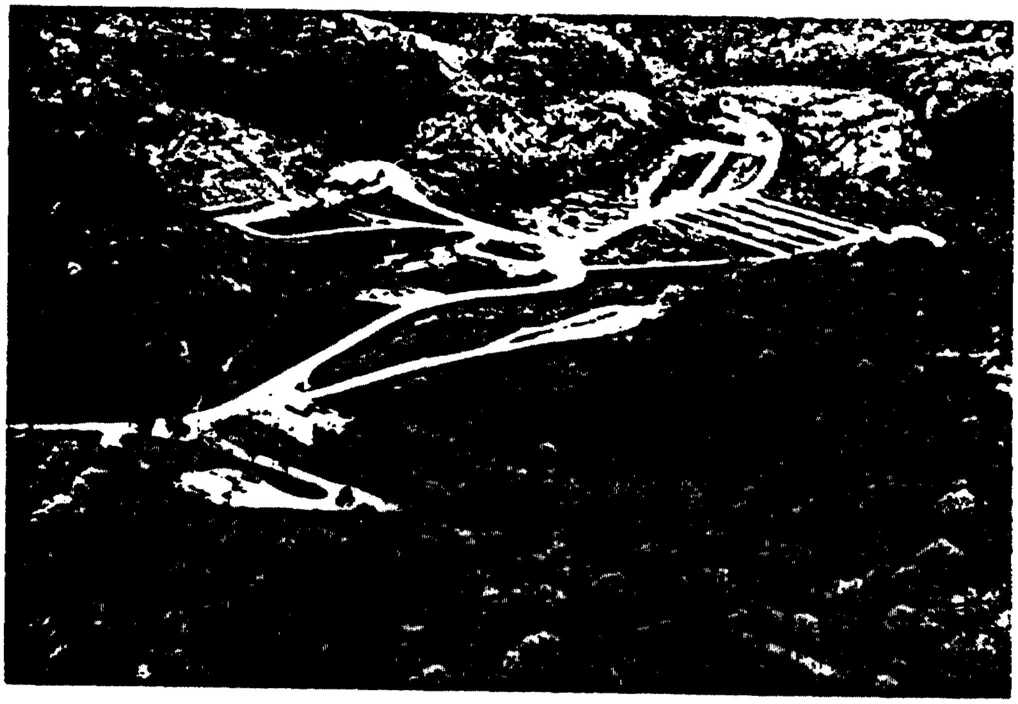


Figure 6.5-5 Ordnance Burning Ground (Site 10)

Figure 6.5-6 Demilitarized Bombs

Figure 6.5-7 Candle Burning Cage at Ordnance Burning Ground (Site 10)

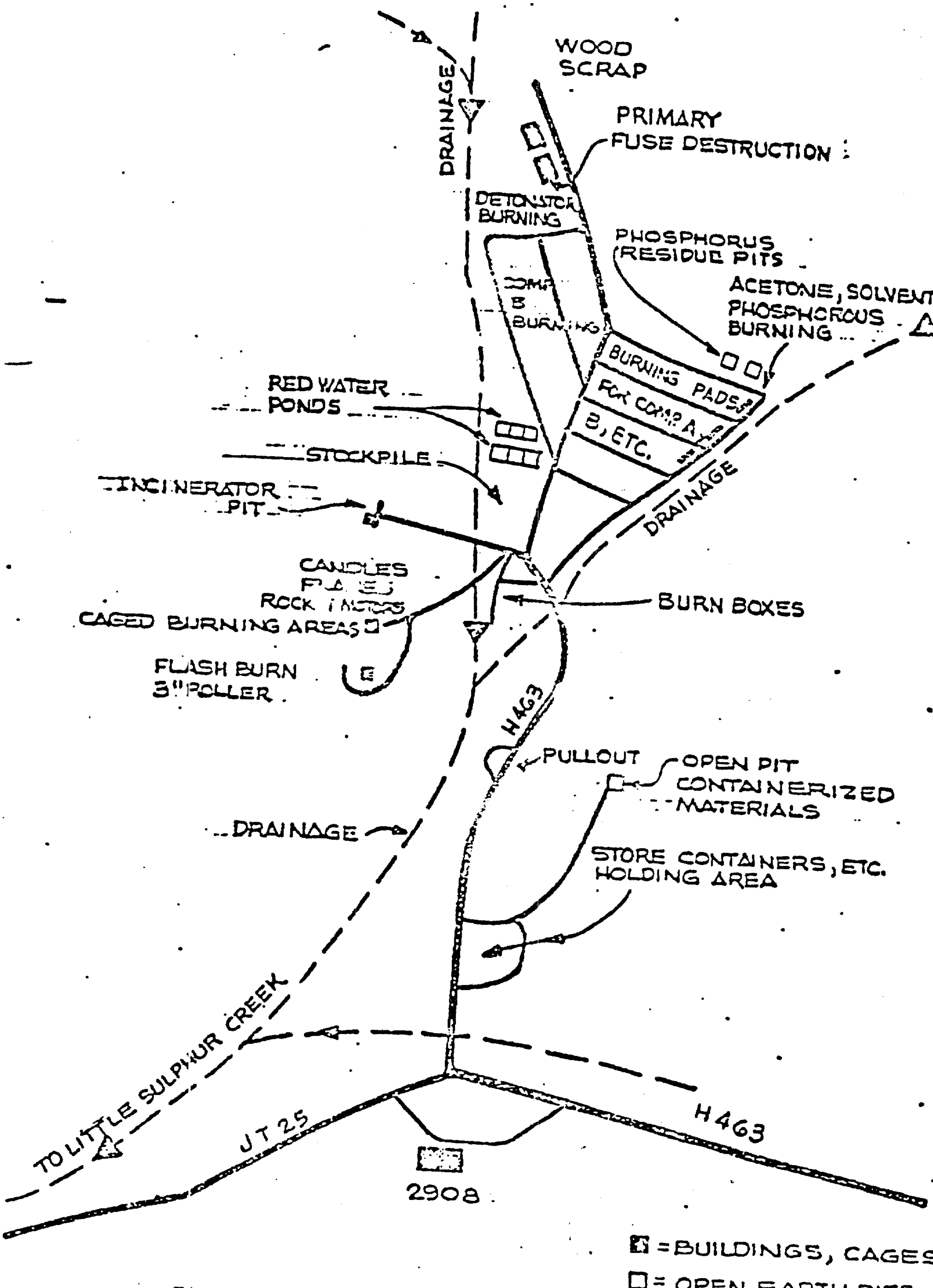


Figure 6.5-8 Ordnance Burning Grounds in 1978

Table 6.5-1 Propellants and Explosives Burned at the Ordnance Burning Ground

Explosives

CH-6	RDX (cyclotrimethylene trinitramine)
H-6	HMX (cyclotetramethylene tetranitramine)
Composition A-3	TNT (trinitrotoluene)
Minol	Tetryl
Tritonal	Ammonium Picrate
Explosive D	DATB (diaminotrinitro benzylene)
Dynamite	PETN (pentaerythritol tetranitrate)
Black Powder	NG (nitroglycerine)
Composition B	Sulfur
Octol	Charcoal
Amatol	SN (sodium nitrate)
Amatex	AN (ammonium nitrate)
HBX	Lead Azide
PBX	Lead Styphnate

of dye were left uncovered and that some deer actually walked through the trench and appeared to enjoy tasting or licking the area. Monitoring wells have been installed in the dye burial grounds area to determine the potential level of contamination.

In preparation for studying infiltration of groundwater and soils contamination by this practice, metal detectors were used to spot what was expected to be cans or drums or dyes. These areas were staked and red flagged. See figures 6.5-9, 6.5-10, and 6.5-11.

6.5.7.1 Dye Contamination

During visual inspection of the dye burial ground in 1981, by the NACIP team, no evidence of typical dye colors was noted. The rainfall averages 40 to 60 inches per year, so most of the water soluble dyes will migrate with the water. The smoke markers are insoluble and probably are still reasonably intact.

A listing of typical military dyes appears in appendix E.

Figure 6.5-9 Dye Burial Grounds (Site 11)

Figure 6.5-10 Markers Show Metal Location in Dye Burial Grounds (Site 11)

Figure 6.5-11 Dye Burial Area (Right of Center)
(Site 11)

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Appendix A
Hydrocarbon and Water Well Logs
for Naval Weapons Support Center, Crane, Indiana

Hydrocarbon Exploration

Well No.: 1
Surface Elevation: 620
Date Drilled: 4 Jan 28
Water Level: _____ Date: __________

Depth, Feet	Description
0-24	Sand and sandstone
24-32	Gray Lime, hard
32-55	Blue shale
55-80	Sandstone, brown
80-95	White Sand (water)
95-112	Gray Lime, hard
112-143	Shale, blue
143-155	Lime, gray
155-173	Shale, Blue
173-182	Sand (slight oil show)
182-189	Shale, blue
189-229	Sand, light, hard
229-238	Shale, blue
238-242	Sand, light (Cypress)
242-248	Lime, broken
248-255	Sand, white
255-260	Lime, gray
260-285	Sand, white
285-329	Lime, broken
329-336	Lime, blue (Heavy Water)
336-400	Lime, white
400-426	Lime
426-432	(Core)
432-463	Lime, hard (Core)
463-485	Lime, blue, hard
485-504	Lime, gray
504-545	Lime, blue, hard
545-590	Lime, broken
590-605	Shale, light, soft
605-620	Lime, brown
620-632	Oil sand, brown, soft
632-638	Lime, white, hard
638-654	Shale, soft
654-677	Lime, white, hard
677-684	Break, broken
684-695	Lime, blue white
695-722	Shale, blue
722-735	Lime, white, hard, sandy, broken
736-	Lime

(Continued)

Hydrocarbon Exploration (Contd.)

ilrg

Well No.: 2
Surface Elevation: 650
Date Drilled: _____.
Water Level: ________ Date: __________

Depth, Feet	Description
0-21	Not logged
21-24	Sandstone, tan
24-40	Clay, gray
40-48	Sandstone, tan
48-55	Clay, gray
55-79	Sandstone, tan
79-95	Clay, gray with thin coal
95-104	Sandstone and clay, tan and gray
104-133	Sandstone, white
133-138	Shale, gray, soft
138-145	Sandstone, gray
145-147	Sandstone, white
147-160	Sandstone, gray
160-165	Shale, gray, soft (Mansfield)
165-172	Sandstone, gray with thin coal
172-212	Sandstone, gray to tan
212-216	Sandstone, gray
216-218	Sandstone, pinkish
218-222	Sandstone, gray to pink (Cypress)
222-245	Sandstone, white
245-253	Sandstone, gray to pink
252-262	Sandstone, white
262-266	Sandstone, gray
266-270	Sandstone, white to pink
270-275	Sandstone, white
275-280	Sandstone, white to pink
280-290	Sandstone, white
290-313	Limestone, light tan to pink
313- -	Limestone, gray, soft

Water Wells

Well No.: 1
Surface Elevation: ______
Date Drilled: 12/3/55
Water Level: _____ Date: _______

Depth, Feet	Description
0-9	Clay top soil
9-16	Soft Gray Shale
16-27	Soft Blue Shale
27-29	Soft Coal Shale
29-37	Soft Blue Shale
37-40	Hard Blue Shale
40-41	Coal
41-54	Hard Blue Shale
54-51	Soft Shale
81-112	Soft Gray shale
112-137	Hard Gray shale
137-142	Limestone (water)
142-149	Hard Gray shale
149-158	Soft Dark Shale
158-164	Very Soft Dark Shale, Sandy

Well No.: 2
Surface Elevation: ______
Date Drilled: 1/27/1941
Water Level: _______ Date: ______

Depth, Feet	Description
0-7	Surface Clay
7-13	Sandstone and clay
13-28	Light shale grading to dark
28-48	Sandstone
48-50	Shale, dark
50-51	Sandstone
51-52	Shale, dark
52-53	Coal
53-55	Shale
55-62	Sandstone
62-64	Shale (some water)
64-75	Sandstone
75-78	Shale
78-83	Sandstone

(Continued)

Well No.: 2 (Contd.)

Depth, Feet	Description
83-85	Shale, dark
85-87	Sandstone
87-92	Shale, dark
92-110	Sandstone
110-111	Limestone, brown
111-122	Sandstone, white
122-125	Shale, dark
125-129	Limestone, gray
129-138	Sandstone, white
138-141	Shale, dark
141-146	Sandstone
146-190	Shale, dark
190-192	Shale, light (water)
192-224	Shale, dark

Well No. 3
Surface Elevation: ________
Date Drilled: 1/7/54
Water Level: 121 Date: 1/7/54

Depth, Feet	Description
0-90	Not logged
90-141	Sandstone

Well No.: 4
Surface Elevation: _____
Date Drilled: 11/5/42
Water Level: 239.5 Date: 11/5/42

Depth, Feet	Description
0-45	Yellow sandstone
45-55	Blue shale
55-56	Coal (some water)
56-89	Blue sandstone
89-90	Blue shale
90-131	Blue sandstone
131-147	Blue shale
147-155	Blue sand
155-186	White sand
186-194	Hard Blue sand
194-210	Blue shale

(Continued)

Well No.: 4 (Contd.)

Depth, Feet	Description
210-220	Gray shale
220-225	Blue Sand
225-229	Blue Shale
239-261	Gray limestone
261-264	Dark Shale
264-271	Brown limestone
271-310	White Sandstone
310-313	Gray Limestone

Well No. 5
Surface Elevation:
Date Drilled: 1/26/44
Water Level: 68' Date: 1/26/44

Depth, Feet	Description
0-26	Clay
26-31	Sandstone
31-55	Light shale
55-56	Gray Limestone
56-58	Light shale
58-69	Gray Limestone
69-90	Dark Shale
90-109	Gray Sandstone
109-129	White Sandstone (water flow 2 qpm)
129-135	Brown Limestone
135-138	Gray Limestone
138-139	Dark Shale (water)
139-144	Gray Limestone
144-146	Light Shale
146-152	White Sandstone

Well No.: 6
Surface Elevation:
Date Drilled: 2/7/54
Water Level: 204 Date: 2/7/54

Depth, Feet	Description
0-35	Drift material
35-234	Limestone

Appendix B
Landfill Boring Logs
for Naval Weapons Support Center, Crane, Indiana

Landfill Observation Wells

Well No.	Depth (ft)	Material
1	0-12	Clay
	12-40	Sandrock
2	0-9	Clay
	9-20	Sandrock
	20-24	Shale
	24-39	Sandrock
	39-40	Coal
3	0-5	Clay
	5-18	Sandrock
	18-48	Shale
	48-50	Coal
	50-70	Shale
	70-72	Limerock
	72-100	Sandrock
4	0-19	Clay
	19-25	Sandrock
	25-38	Shale
	32-40	Sandrock
6	0-9	Clay
	9-18	Sandrock
	18-28	Shale
	28-40	Sandrock
7	0-16	Clay
	16-40	Sandrock

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CLIENT U. S. Navy | BORING NO. 101

PROJECT NAME Landfill | JOB NO. D-79873 | DATE 11-29-79

PROJECT LOCATION Crane, Indiana | STATION

BORING METHOD HSA | FOREMAN R. Jones

ROCK CORE DIA. ______ in. | INSPECTOR

SHELBY TUBE O.D. ______ in.

SOIL CLASSIFICATION / SURFACE ELEVATION-	Stratum Depth, Ft.	Ground Water	Depth Scale, Ft.	Sample No.	SPT ** Blows/6 In. 3-6 In. Increments	Recovery, %	Shelby Tube No.	BORING & SAMPLING NOTES
Top soil	0.3							
Light Brown moist stiff CLAYEY SILT (ML)			5	1	4 7/8	75		
	6.5							
Light Brown dry hard CLAYEY SILT (ML)			10	2	9 18/35	100		
	14.2							
Brown dry hard CLAYEY SILT (ML) with trace fine Sand			15	3	15 14/50 0.3	100		
Bottom test boring @ 15.5'								

BORING METHOD
HSA – HOLLOW STEM AUGER
CFA – CONTINUOUS FLIGHT AUGER
DC – DRIVEN CASING
MD – MUD DRILLING

GROUND WATER-
NOTED ON RODS ______ FT.
AT COMPLETION dry FT.
AFTER ______ HRS. ______ FT.

*THESE SHELBY TUBE SAMPLES OBTAINED IN BORING ______ DRILLED A FEW FEET FROM BORING ______

ATEC Associates, Inc.
Consulting Geotechnical & Materials Engineers

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Affiliates: Beckley/Norfolk/Riyadh

CLIENT: U. S. Navy
BORING NO.: 102
PROJECT NAME: Landfill
JOB NO.: D-79873
DATE: 11-29-79
PROJECT LOCATION: Crane, Indiana
STATION:
BORING METHOD: HSA
FOREMAN: R. Jones
ROCK CORE DIA. ______ in.
INSPECTOR:
SHELBY TUBE O.D. ______ in.

SOIL CLASSIFICATION SURFACE ELEVATION–	Stratum Depth, Ft.	Ground Water	Depth Scale, Ft.	SPT ** Sample No.	SPT ** Blows/6 In. 3–6 In. Increments	SPT ** Recovery, %	Shelby Tube No.	BORING & SAMPLING NOTES
Top soil	0.3							
Brown slightly moist hard SILTY CLAY (CL) with sand Seams							1	Pushed Shelby Tube from 2.0' to 4.0'
			5					
				1	14 14/23			
			10					
Black wet SILTY CLAY (CL) with trace coarse SAND	11.5 12.5							Took auger sample of Black soil from 11.5' to 12.5'
Light Gray dry hard CLAYEY SILT (ML)				2	16 38/50 0.3			
			15					
Auger refusal @ 18.0' Bottom test boring @ 18.0'	18.0							
			20					

BORING METHOD
HSA – HOLLOW STEM AUGER
CFA – CONTINUOUS FLIGHT AUGER
DC – DRIVEN CASING
MD – MUD DRILLING

GROUND WATER
NOTED ON RODS 8.5 FT.
AT COMPLETION ____ FT.
AFTER ____ HRS 7.1 FT.

*THESE SHELBY TUBE SAMPLES OBTAINED IN BORING ________ DRILLED A FEW FEET FROM BORING ________

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Affiliates: Beckley/Norfolk/Riyadh

CLIENT U. S. Navy — BORING NO. 103
PROJECT NAME Landfill — JOB NO. D-79873 — DATE 11-29-79
PROJECT LOCATION Crane, Indiana — STATION
BORING METHOD HSA — FOREMAN R. Jones
ROCK CORE DIA. ____ in. — INSPECTOR
SHELBY TUBE O.D. ____ in.

SOIL CLASSIFICATION SURFACE ELEVATION –	Stratum Depth, Ft.	Ground Water	Depth Scale, Ft.	SPT** Sample No.	SPT** Blows/6 in. 3-6 in. Increments	SPT** Recovery, %	Shelby Tube No.	BORING & SAMPLING NOTES
Top soil	0.3							
Brown moist soft SILTY CLAY with trace Sand						80	1	Pushed Shelby Tube from 3.0' to 5.0'
	6.5		5					
Gray dry hard CLAYEY SILT (ML) with coal Seams Auger refusal @ 9.1'	9.1							
Bottom test boring @ 9.1'			10	1	35/50 0.1	100		

BORING METHOD
HSA – HOLLOW STEM AUGER
CFA – CONTINUOUS FLIGHT AUGER
DC – DRIVEN CASING
MD – MUD DRILLING

GROUND WATER
NOTED ON RODS ____ FT.
AT COMPLETION dry FT.

*THESE SHELBY TUBE SAMPLES OBTAINED IN BORING ____ DRILLED A FEW FEET FROM BORING ____

ATEC Associates, Inc.

Consulting Geotechnical & Materials Engineers

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CLIENT U. S. Navy
BORING NO. 104
PROJECT NAME Landfill
JOB NO. D-79873 DATE 11-29-79
PROJECT LOCATION Crane, Indiana
STATION
BORING METHOD HSA
FOREMAN R. Jones
ROCK CORE DIA. in.
INSPECTOR
SHELBY TUBE O.D. in.

SOIL CLASSIFICATION SURFACE ELEVATION–	Stratum Depth, Ft.	Ground Water	Depth Scale, Ft.	SPT ** Sample No.	SPT ** Blows/6 in. 3–6 in. Increments	SPT ** Recovery, %	Shelby Tube No.	BORING & SAMPLING NOTES
Top soil	0.3							
Brown moist SILTY CLAY (CL)						75	1	Pushed Shelby Tube from 3.0' to 5.0'
			5					
	7.5							
Brown slightly moist very stiff CLAYEY SILT (ML)				1	12 14/15	75		
Coal	9.8							
Brown dry hard CLAYEY SILT (ML)	10.0		10					
	13.6							
Coal	13.8			2	50 / 0.4	100		
Gray dry hard CLAYEY SILT (ML) Auger refusal @ 15.5'	15.5		15					
Bottom test boring @ 15.5'								

BORING METHOD
HSA – HOLLOW STEM AUGER
CFA – CONTINUOUS FLIGHT AUGER
DC – DRIVEN CASING

GROUND WATER
▽ NOTED ON RODS ____ FT.
▽ AT COMPLETION ____ FT.

*THESE SHELBY TUBE SAMPLES OBTAINED IN BORING ____ DRILLED A FEW FEET FROM BORING

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CLIENT U. S. Navy
BORING NO. 105
PROJECT NAME Landfill
JOB NO. D-79873 DATE 12-1-79
PROJECT LOCATION Crane, Indiana
STATION
BORING METHOD HSA
FOREMAN R. Jones
ROCK CORE DIA. ____ in.
INSPECTOR
SHELBY TUBE O.D. ____ in.

SOIL CLASSIFICATION (SURFACE ELEVATION–)	Stratum Depth, Ft.	Ground Water	Depth Scale, Ft.	SPT** Sample No.	SPT** Blows/6 In. 3–6 In. Increments	SPT** Recovery, %	Shelby Tube No.	BORING & SAMPLING NOTES
Top soil	0.3							
Brown moist medium stiff SILTY CLAY						100	1	Pushed Shelby Tube from 2.0' to 4.0'
	5.0		5					
Brown dry hard CLAYEY SILT with Sandstone clay Seams Auger refusal @ 7.0'	7.0							
Bottom test boring @ 7.0'								

BORING METHOD
HSA – HOLLOW STEM AUGER
CFA – CONTINUOUS FLIGHT AUGER
DC – DRIVING CASING

GROUND WATER
▽ NOTED ON RODS ____ FT.
▽ AT COMPLETION dry FT.

*THESE SHELBY TUBE SAMPLES OBTAINED IN BORING ____ DRILLED A FEW FEET FROM BORING

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CLIENT U. S. Navy — BORING NO. 106

PROJECT NAME Landfill — JOB NO. D-79873 — DATE 12-1-79

PROJECT LOCATION Crane, Indiana — STATION

BORING METHOD HSA — FOREMAN R. Jones

ROCK CORE DIA. ____ in. — INSPECTOR

SHELBY TUBE O.D. ____ in.

SOIL CLASSIFICATION / SURFACE ELEVATION–	Stratum Depth, Ft.	Ground Water	Depth Scale, Ft.	SPT** Sample No.	SPT** Blows/6 in. 3–6 in. Increments	SPT** Recovery, %	Shelby Tube No.	BORING & SAMPLING NOTES
Top soil	0.3							
Brown moist medium stiff SILTY CLAY	3.0							
Brown moist very stiff CLAYEY SILT (ML)	7.9		5	1	4 8/10	100		
Gray dry hard CLAYEY SILT (ML) with Siltstone Seams			10	2	6 21/40	100		
Auger refusal @ 12.3	12.3							
Bottom test boring @ 12.3'								Boring is standing in water

BORING METHOD
HSA – HOLLOW STEM AUGER
CFA – CONTINUOUS FLIGHT AUGER
DC – DRIVING CASING

GROUND WATER
NOTED ON RODS 3.0 FT.
AT COMPLETION dry FT.

*THESE SHELBY TUBE SAMPLES OBTAINED IN BORING ____ DRILLED A FEW FEET FROM THIS ...

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CLIENT U. S. Navy
BORING NO. 107
PROJECT NAME Landfill
JOB NO. D-79873 DATE 12-1-79
PROJECT LOCATION Crane, Indiana
STATION
BORING METHOD HSA
FOREMAN R. Jones
ROCK CORE DIA. in.
INSPECTOR
SHELBY TUBE O.D. in.

SOIL CLASSIFICATION SURFACE ELEVATION –	Stratum Depth, Ft.	Ground Water	Depth Scale, Ft.	SPT ** Sample No.	SPT ** Blows/6 in. 0–6 in. Increments	SPT ** Recovery, %	Shelby Tube No.	BORING & SAMPLING NOTES
Top soil	0.3							
Brown moist stiff SILTY CLAY	2.5							
Brown slightly moist very stiff CLAYEY SILT (ML)	6.5		5	1	8 11/13	100		
Brown dry hard CLAYEY SILT (ML) with Siltstone Seams Auger refusal @ 11.2'	11.2		10	2	17 46/50 0.3	100		
Bottom test boring @ 11.2'								

BORING METHOD
HSA – HOLLOW STEM AUGER
CFA – CONTINUOUS FLIGHT AUGER
DC – DRIVING CASING
MD – MUD DRILLING

GROUND WATER
NOTED ON RODS ____ FT.
AT COMPLETION dry FT.

*THESE SHELBY TUBE SAMPLES OBTAINED IN BORING ____ DRILLED A FEW FEET FROM BORING ____

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RECORD OF SOIL EXPLORATION

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CLIENT: U. S. Navy
BORING NO. 108
PROJECT NAME: Landfill
JOB NO. D-79873 DATE 12-1-79
PROJECT LOCATION: Crane, Indiana
STATION
BORING METHOD: HSA
FOREMAN: R. Jones
ROCK CORE DIA. ______ in.
INSPECTOR
SHELBY TUBE O.D. ______ in.

SOIL CLASSIFICATION (SURFACE ELEVATION–)	Stratum Depth, Ft.	Ground Water	Depth Scale, Ft.	SPT ** Sample No.	SPT ** Blows/6 in. 3-6 in. Increments	SPT ** Recovery, %	Shelby Tube No.	BORING & SAMPLING NOTES
Top soil	0.3							
Brown moist CLAYEY SILT (ML)						100	1	Pushed Shelby tube from 2.0' to 4.0'
	6.0		5					
Brown dry hard CLAYEY SILT (ML)			10	1	13 33/50 0.4	100		
Auger refusal @ 12.0'	12.0							
Bottom test boring @ 12.0'								

BORING METHOD
HSA – HOLLOW STEM AUGER
CFA – CONTINUOUS FLIGHT AUGER
DC – DRIVING CASING

GROUND WATER
▽ NOTED ON RODS ______ FT.
▽ AT COMPLETION dry FT.

*THESE SHELBY TUBE SAMPLES OBTAINED IN BORING ______ DRILLED A FEW FEET FROM BORING ______

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CLIENT U. S. Navy
PROJECT NAME Landfill
PROJECT LOCATION Crane, Indiana
BORING METHOD HSA
ROCK CORE DIA. ______ in.
SHELBY TUBE O.D. ______ in.

BORING NO. 109
JOB NO. D-79873 DATE 12-1-79
STATION
FOREMAN R. Jones
INSPECTOR

SOIL CLASSIFICATION SURFACE ELEVATION–	Stratum Depth, Ft.	Ground Water	Depth Scale, Ft.	SPT ** Sample No.	SPT ** Blows/6 in. 3-6 in. Increments	SPT ** Recovery, %	Shelby Tube No.	BORING & SAMPLING NOTES
Top soil	0.3							
Brown moist soft SILTY CLAY	3.0							
Light Brown slightly moist stiff CLAYEY SILT (ML)	6.5		5	1	3 8/10	100		
Light Brown and Gray dry hard CLAYEY SILT (ML) with Siltstone Seams Auger refusal @ 11.0'	11.0		10	2	17/50 0.4	100		
Bottom test boring @ 11.0'								

BORING METHOD
HSA – HOLLOW STEM AUGER
CFA – CONTINUOUS FLIGHT AUGER
DC – DRIVEN CASING
MD – MUD DRILLING

GROUND WATER
NOTED ON RODS ______ FT.
AT COMPLETION dry FT.
AFTER ______ HRS ______ FT.

*THESE SHELBY TUBE SAMPLES OBTAINED IN BORING ______ DRILLED A FEW FEET FROM BORING ______

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CLIENT U. S. Navy

BORING NO. 110

PROJECT NAME Landfill

JOB NO. D-79873 DATE 12-1-79

PROJECT LOCATION Crane, Indiana

STATION

BORING METHOD HSA

FOREMAN R. Jones

ROCK CORE DIA. ______ in.

INSPECTOR

SHELBY TUBE O.D. ______ in.

SOIL CLASSIFICATION SURFACE ELEVATION–	Stratum Depth, Ft.	Ground Water	Depth Scale, Ft.	SPT ** Sample No.	SPT ** Blows/6 In. 3–6 In. Increments	SPT ** Recovery, %	Shelby Tube No.	BORING & SAMPLING NOTES
Top soil	0.3							
Brown slightly moist very stiff CLAYEY SILT (ML)	5.5		5	1	7 10/15	100		
Light Gray hard CLAYEY SILT(ML) with Weathered Siltstone Seams Auger refusal @ 10.0'	10.0		10	2	50 0.5	100		
Bottom test boring @ 10.0'								

BORING METHOD
HSA – HOLLOW STEM AUGER
CFA – CONTINUOUS FLIGHT AUGER
DC – DRIVEN CASING
MD – MUD DRILLING
RC – ROCK CORING

GROUND WATER
NOTED ON RODS ______ FT.
AT COMPLETION dry FT.
AFTER ______ HRS. ______ FT.

*THESE SHELBY TUBE SAMPLES OBTAINED IN BORING ______ DRILLED A FEW FEET FROM BORING ______

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CLIENT U. S. Navy

BORING NO. 201

PROJECT NAME Landfill

JOB NO. D-79873 DATE 11-25-79

PROJECT LOCATION Crane, Indiana

STATION

BORING METHOD HSA

FOREMAN R. Jones

ROCK CORE DIA. in.

INSPECTOR

SHELBY TUBE O.D. in.

SOIL CLASSIFICATION SURFACE ELEVATION–	Stratum Depth, Ft.	Ground Water	Depth Scale, Ft.	SPT ** Sample No.	Blows/6 In. 3–6 In. Increments	Recovery, %	Shelby Tube No.	BORING & SAMPLING NOTES
Top soil	0.3							
Brown slightly moist very stiff CLAYEY SILT (ML)								Sandstone ledge 6.3' to 6.4'
				1	4 8/10	50		Back filled with gravel and set Bentonite Seal
			5					
Auger refusal @ 6.9'	6.9							Set Observation well to 6.9'
Bottom test boring @ 6.9'								
			10					

BORING METHOD
HSA – HOLLOW STEM AUGER
CFA – CONTINUOUS FLIGHT AUGER
DC – DRIVEN CASING

GROUND WATER
NOTED ON RODS ___ FT.
AT COMPLETION dry FT.

*THESE SHELBY TUBE SAMPLES OBTAINED IN BORING ___ DRILLED A FEW FEET FROM BORING

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RECORD OF SOIL EXPLORATION

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CLIENT U. S. Navy
BORING NO. 202
PROJECT NAME Landfill
JOB NO. D-79873 DATE 11-29-79
PROJECT LOCATION Crane, Indiana
STATION
BORING METHOD HSA
FOREMAN R. Jones
ROCK CORE DIA. in.
INSPECTOR
SHELBY TUBE O.D. in.

SOIL CLASSIFICATION / SURFACE ELEVATION–	Stratum Depth, Ft.	Ground Water	Depth Scale, Ft.	SPT ** Sample No.	SPT ** Blows/6 in. 3-6 in. Increments	SPT ** Recovery, %	Shelby Tube No.	BORING & SAMPLING NOTES
Top soil								
Brown moist SILTY CLAY (CL)	3.7							Pushed Shelby Tube from 3.0' to 3.9'
Brown dry hard CLAYEY SILT with trace fine to medium Sand			5			40	1	
Auger refusal @ 6.2'	6.2							Set Observation well to 6.2' with Bentonite Seal
Bottom test boring @ 6.2'								

BORING METHOD
HSA – HOLLOW STEM AUGER
CFA – CONTINUOUS FLIGHT AUGER
DC – DRIVEN CASING
MD – MUD DRILLING
[illegible]

GROUND WATER
NOTED ON RODS ____ FT.
AT COMPLETION dry FT.
AFTER ____ HRS. ____ FT.

*THESE SHELBY TUBE SAMPLES OBTAINED IN BORING ____ DRILLED A FEW FEET FROM BORING ____

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CLIENT: U. S. Navy
BORING NO.: 203
PROJECT NAME: Landfill
JOB NO.: D-79873
DATE: 11-29-79
PROJECT LOCATION: Crane, Indiana
STATION:
BORING METHOD: HSA
FOREMAN: R. Jones
ROCK CORE DIA. ______ in.
INSPECTOR:
SHELBY TUBE O.D. ______ in.

SOIL CLASSIFICATION SURFACE ELEVATION–	Stratum Depth, Ft.	Ground Water	Depth Scale, Ft.	SPT ** Sample No.	SPT ** Blows/6 in. 3–6 in. Increments	SPT ** Recovery, %	Shelby Tube No.	BORING & SAMPLING NOTES
Top soil	0.3							
Brown moist stiff SILTY CLAY								
			5				1	Pushed Shelby Tube from 3.0' to 5.0'
								Set Observation well to 7.0'
Auger refusal @ 7.0'	7.0							
Bottom test boring @ 7.0'								

BORING METHOD
HSA – HOLLOW STEM AUGER
CFA – CONTINUOUS FLIGHT AUGER
DC – DRIVEN CASING
MD – MUD DRILLING
RC – ROCK CORING

GROUND WATER
NOTED ON RODS ______ FT.
AT COMPLETION dry FT.
AFTER ______ HRS. ______ FT.

*THESE SHELBY TUBE SAMPLES OBTAINED IN BORING ______ DRILLED A FEW FEET FROM BORING ______

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CLIENT U. S. Navy
PROJECT NAME Landfill
PROJECT LOCATION Crane, Indiana
BORING METHOD HSA
ROCK CORE DIA. ______ in.
SHELBY TUBE O.D. ______ in.

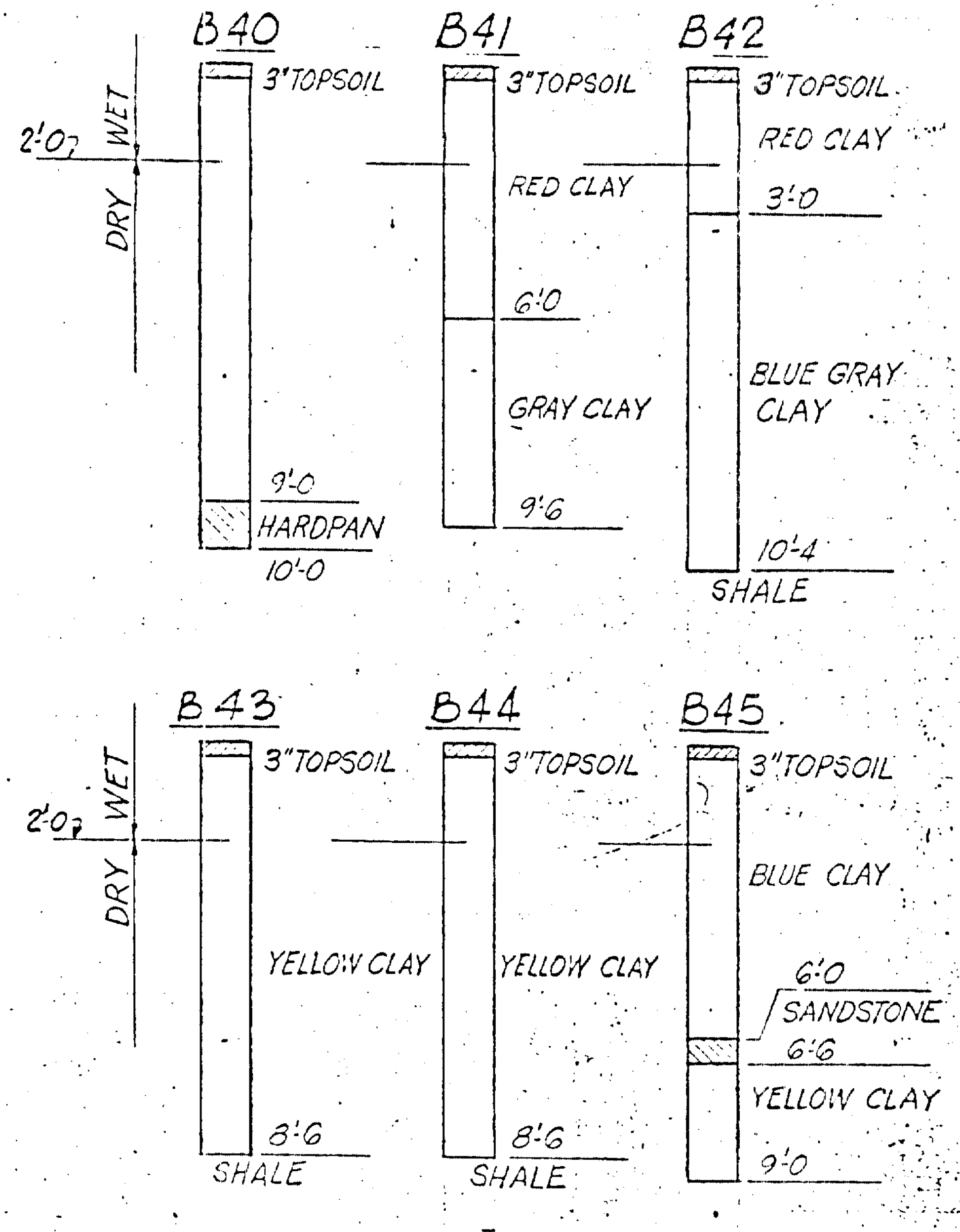
BORING NO. 204
JOB NO. D-79873 DATE 12-1-79
STATION
FOREMAN R. Jones
INSPECTOR

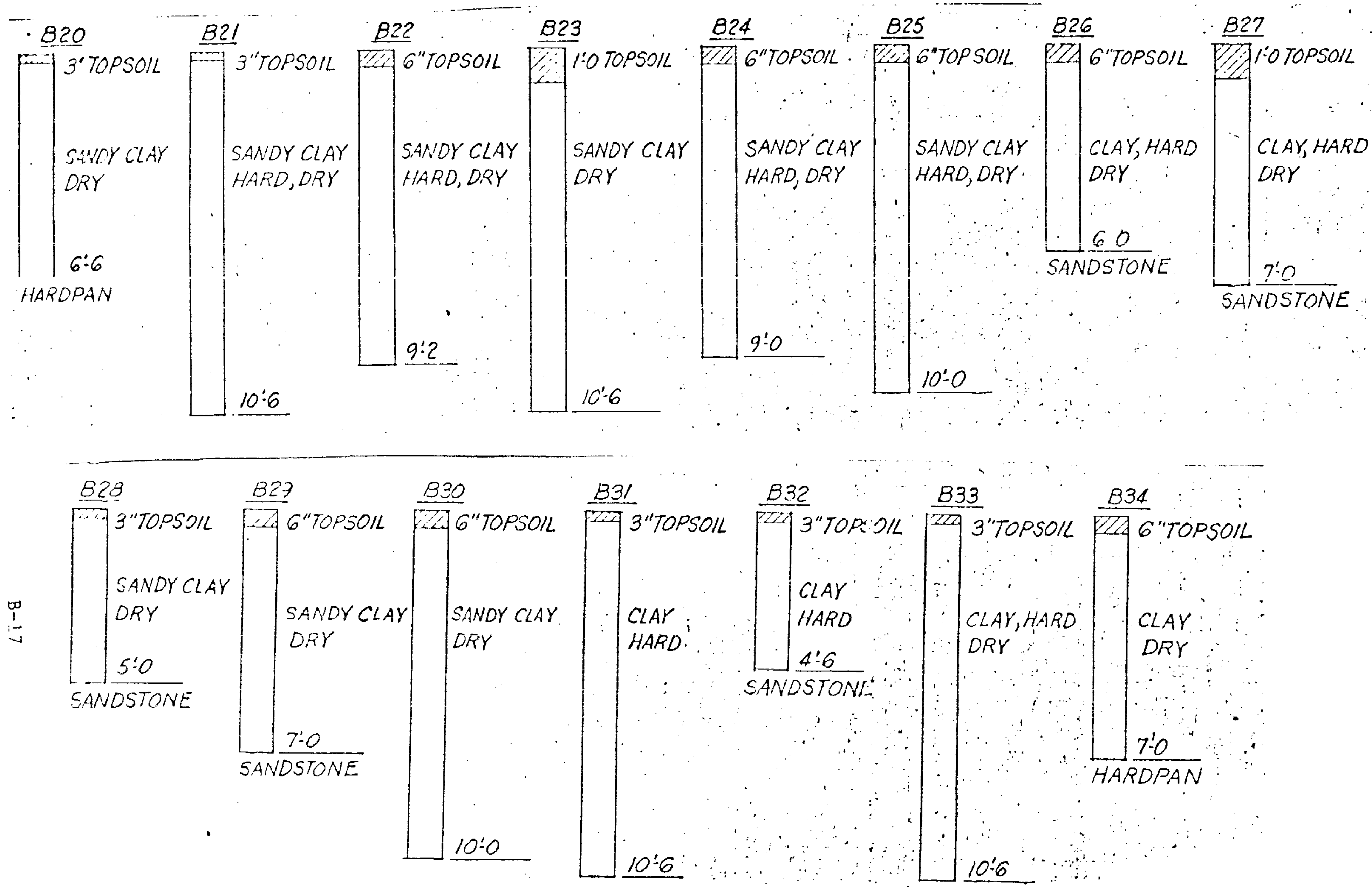
SOIL CLASSIFICATION SURFACE ELEVATION–	Stratum Depth, Ft.	Ground Water	Depth Scale, Ft.	SPT ** Sample No.	SPT ** Blows/6 In. 3–6 In. Increments	SPT ** Recovery, %	Shelby Tube No.	BORING & SAMPLING NOTES
Topsoil								
Brown moist soft SILTY CLAY						100	1	Could only push tube 18" 3.0' 4.5'
	5.0		5					
Brown dry hard CLAYEY SILT with Sandstone Seams								
Auger refusal @ 7.4'	7.4							Set Observation well to 7.4'
Bottom test boring @ 7.4'								

BORING METHOD
HSA – HOLLOW STEM AUGER
CFA – CONTINUOUS FLIGHT AUGER
DC – DRIVEN CASING
MD – MUD DRILLING

GROUND WATER
NOTED ON RODS ______ FT.
AT COMPLETION dry FT.
AFTER ______ HRS ______ FT.

*THESE SHELBY TUBE SAMPLES OBTAINED IN BORING ______ DRILLED A FEW FEET FROM BORING ______


B40
3" TOPSOIL
2'-0
WET
DRY
9'-0
HARDPAN
10'-0
B41
3" TOPSOIL
RED CLAY
6'0
GRAY CLAY
9'6
B42
3" TOPSOIL
RED CLAY
3'-0
BLUE GRAY CLAY
10'-4
SHALE
B43
3" TOPSOIL
2'-0
WET
DRY
YELLOW CLAY
8'-6
SHALE
B44
3" TOPSOIL
YELLOW CLAY
8'-6
SHALE
B45
3" TOPSOIL
BLUE CLAY
6'-0
SANDSTONE
6'-6
YELLOW CLAY
9'-0


B20
3" TOPSOIL
SANDY CLAY DRY
6'-6
HARDPAN
B21
3" TOPSOIL
SANDY CLAY HARD, DRY
10'-6
B22
6" TOPSOIL
SANDY CLAY HARD, DRY
9'-2
B23
1'-0 TOPSOIL
SANDY CLAY DRY
10'-6
B24
6" TOPSOIL
SANDY CLAY HARD, DRY
9'-0
B25
6" TOP SOIL
SANDY CLAY HARD, DRY
10'-0
B26
6" TOPSOIL
CLAY, HARD DRY
6 0
SANDSTONE
B27
1'-0 TOPSOIL
CLAY, HARD DRY
7'-0
SANDSTONE
B28
3" TOPSOIL
SANDY CLAY DRY
5'-0
SANDSTONE
B29
6" TOPSOIL
SANDY CLAY DRY
7'-0
SANDSTONE
B30
6" TOPSOIL
SANDY CLAY DRY
10'-0
B31
3" TOPSOIL
CLAY HARD
10'-6
B32
3" TOPSOIL
CLAY HARD
4'-6
SANDSTONE
B33
3" TOPSOIL
CLAY, HARD DRY
10'-6
B34
6" TOPSOIL
CLAY DRY
7'-0
HARDPAN

Appendix C
Compactor Boring Logs
for Naval Weapons Support Center, Crane, Indiana

BORING NO.				B50
GROUND ELEVATION				702.0
	ELEV		DEPTH	
				SURFACE
705				DARK BROWN, MOIST, SOFT, INORGANIC SILT AND SAND (ML)
	702.0		0	YELLOWISH-BROWN, MOIST, SOFT, INORGANIC SILT AND SAND (ML)
	700.5		1.5	
700	699.0		3.0	
	697.0		5.0	YELLOWISH-BROWN, DRY, SOFT, INORGANIC SILT AND SAND (ML)
695	695.0		7.0	DARK YELLOWISH-BROWN MOTTLES GRAY, DRY, HARD, INORGANIC LOW PLASTIC, CLAY (CL)
	692.0		9.2	
690				LIGHT BROWN, DRY, VERY STIFF, SILTY SAND (SM)
	786.0		16.0	LIGHT BROWN MOTTLED GRAY, HARD, SILTY SAND (SM)
685	786.0		16.0	SANDSTONE BEDROCK SURFACE

BORING NO.			B51
GROUND ELEVATION			704.0
ELEV		DEPTH	
			SURFACE
			DARK BROWN, MOIST, SOFT, INORGANIC SILT AND SAND (ML)
704.0		0	DARK YELLOWISH-BROWN, DRY STIFF, INORGANIC SILT AND SAND (ML)
702.0		2.0	
700.7		3.3	DARK YELLOWISH-BROWN MOTTLED GRAY, DRY, VERY STIFF, INORGANIC SILT AND SAND (ML)
697.5		6.5	
			LIGHT BROWN MOTTLED GRAY, DRY, VERY STIFF, SILTY SAND (SM) WITH FRAGMENTS OF SANDSTONE
687.5		16.5	
687.5		16.5	SANDSTONE BEDROCK

BORING NO.			B52
GROUND ELEVATION			706.8
ELEV		DEPTH	
			SURFACE
706.8		0	DARK BROWN, MOIST, SOFT, INORGANIC SILT AND SAND (ML)
704.8		2.0	
703.3		3.5	DARK YELLOWISH-BROWN, DRY STIFF, INORGANIC SILT AND SAND (ML)
701.3		5.5	YELLOWISH-BROWN MOTTLED GRAY, INORGANIC CLAY, (CL), DRY, HARD
			LIGHT BROWN MOTTLED GRAY, DRY, HARD, SILTY SAND (SM)
691.8		15.0	

BORING NO.				B1
GROUND ELEVATION				737.2
	ELEV		DEPTH	
				SURFACE
740	737.2		0	DARK BROWN, MOIST, SOFT, INORGANIC SILT AND SAND (ML)
	735.4		1.8	YELLOWISH-BROWN, MOIST, SOFT, INORGANIC SILTS & SAND (ML)
	734.9		2.3	LIGHT YELLOWISH-BROWN DRY, MOTTLED GRAY, VERY STIFF, INORGANIC, LOW PLASTIC CLAYS (CL)
735	731.7		5.5	GRAYISH-BROWN MOTTLED YELLOW, DRY, VERY STIFF, INORGANIC SILTS AND SAND (ML) WITH NUMEROUS SANDSTONE FRAGMENTS.
730	725.7		11.5	YELLOWISH-BROWN, DRY DENSE, SAND (SW) WITH NUMEROUS SANDSTONE FRAGMENTS
	725.0		12.2	GRAYISH-BROWN MOTTLED YELLOW AND GRAY, DRY, VERY STIFF, INORGANIC LOW PLASTIC CLAYS (CL) WITH NUMEROUS FRAGMENTS OF SANDSTONE
725				
	718.8		18.4	
720				

BORING NO.			B2
GROUND ELEVATION			736.5
ELEV	N	DEPTH	
			SURFACE
736.5		0	DARK GRAYISH-BROWN, MOIST, SOFT, INORGANIC SILTS & SAND (ML)
			YELLOWISH-BROWN, DRY, STIFF, INORGANIC SILTS AND SAND (ML)
733.0	37	3.5	YELLOWISH-BROWN MOTTLED GRAY, INORGANIC, LOW PLASTIC CLAY (CL) DRY, STIFF
732.0		4.5	GRAY MOTTLED YELLOW AND BROWN, DRY, VERY STIFF, SILTY SAND (SM)
730.6		5.9	YELLOWISH BROWN, DRY, DENSE, SAND (SW)
728.5		8.0	YELLOW AND GRAY, DRY, DENSE, INORGANIC SILTS AND SAND (ML) WITH NUMEROUS FRAGMENTS OF SANDSTONE
724.3	40	12.2	
722.5		14.0	SANDSTONE

BORING NO.			B3
GROUND ELEVATION			734.5
ELEV	N	DEPTH	
			SURFACE
			CRUSHED LIMESTONE
			DARK BROWN, MOIST, MEDIUM STIFF, INORGANIC SILTS AND SAND (ML)
734.5		0	
733.5		1.0	YELLOWISH BROWN MOTTLED GRAY, DRY, STIFF, INORGANIC SILTS AND SAND (ML)
732.4		2.1	
731.5		3.0	GRAY MOTTLED YELLOW AND BROWN, DRY, HARD, INORGANIC CLAY OF LOW PLASTICITY (CL)
729.5	38	5.0	YELLOWISH BROWN MOTTLED GRAY, DRY, VERY DENSE, SAND (SW)
725.0	67	9.5	GRAY MOTTLED BROWN, DRY SILTY SAND (SM) HARD
717.5		17.0	

BORING NO.			B4
GROUND ELEVATION			731.5
ELEV	N	DEPTH	
			SURFACE
			CRUSHED LIMESTONE
			DARK BROWN, MOIST, MEDIUM STIFF, INORGANIC SILT AND SAND (ML)
731.5		0	YELLOWISH BROWN MOTTLED GRAY, DRY, VERY STIFF, INORGANIC SILT AND SAND (ML)
730.5		1.0	DARK YELLOWISH - BROWN, DRY, HARD, SILTY SAND (SM)
728.5		3.0	DARK GRAY MOTTLED YELLOW AND BROWN, DRY, DENSE, SAND(SW)
725.3	27	6.2	DARK REDDISH YELLOW, DRY VERY DENSE, SAND (SW) WITH FRAGMENTS OF SAND STONE
720.5	37	11.0	
717.0		14.5	
713.7	48	17.8	
713.7		17.8	SANDSTONE SURFACE

BORING NO.			B4A
GROUND ELEVATION			733.2
ELEV	N	DEPTH	
			SURFACE
733.2		0	CRUSHED LIMESTONE
732.3		0.9	DARK GRAYISH-BROWN, MOIST, SOFT INORGANIC SILT AND SAND (ML)
730.4		2.8	DARK YELLOWISH-BROWN MOTTLED GRAY, INORGANIC LOW PLASTIC CLAY, VERY STIFF (CL)
728.2	28	5.0	BROWN MOTTLED GRAY, DRY HARD, SILTY SAND (SM)
	35		
715.1		18.1	
715.1		18.1	SANDSTONE

BORING NO.				B5
GROUND ELEVATION				731.5
	ELEV	N	DEPTH	
				SURFACE
735				
	731.5		0	CRUSHED LIMESTONE
730	730.5		1.0	DARK BROWN, SOFT, MOIST, INORGANIC SILT AND SAND (ML)
	729.2		2.3	DARK YELLOWISH BROWN, MEDIUM STIFF, INORGANIC SILT AND SAND (ML)
	728.2		3.3	DARK YELLOWISH BROWN MOTTLED GRAY, DRY, SILTY SAND (SM) HARD
	726.0	37	5.5	DARK YELLOWISH BROWN MOTTLED GRAY, DRY, HARD INORGANIC SILT AND SAND (ML) WITH SANDSTONE FRAGMENTS
725				
720		41		
715				
	714.0		17.5	
	714.0		17.5	SANDSTONE SURFACE

BORING NO.			B6
GROUND ELEVATION			731.0
ELEV	N	DEPTH	
			SURFACE
731.0		0	DARK BROWN, MOIST, MEDIUM STIFF INORGANIC SILT AND SAND (ML)
729.9		1.1	YELLOWISH BROWN, MOIST, FIRM INORGANIC SILT AND SAND (ML)
728.5		2.5	YELLOWISH BROWN MOTTLED YELLOW, INORGANIC LOW PLASTIC CLAY (CL) HARD
726.2	36	4.8	GRAY, DRY, VERY STIFF, SILTY SAND (SM)
724.0		7.0	DARK YELLOWISH BROWN, DRY, STIFF, SILTY SAND (SM)
	14		
714.0		17.0	SANDSTONE
714.0		17.0	

BORING NO.			B7
GROUND ELEVATION			727.0
ELEV		DEPTH	
			SURFACE
727.0		0	DARK GRAYISH BROWN MOIST, SOFT, INORGANIC SILT AND SAND (ML)
725.2		1.8	DARK YELLOWISH BROWN WITH SOME MOTTLES OF GRAY, STIFF, DRY, LOW PLASTIC CLAY (CL)
722.5		4.5	YELLOWISH BROWN DRY, DENSE, SAND (SW)
720.5		6.5	DARK YELLOWISH BROWN MOTTLED GRAY, DRY, VERY STIFF, SILTY SAND (SM)
713.0		14.0	
713.0		14.0	AUGER REFUSAL (SANDSTONE)

BORING NO.	B8
GROUND ELEVATION	723.5

ELEV		DEPTH	
			SURFACE
			DARK BROWN, MOIST, SOFT, INORGANIC SILT AND SAND (ML)
			DARK YELLOWISH -BROWN, DRY, INORGANIC, LOW PLASTIC, CLAY(CL) VERY STIFF.
723.5		0	
721.5		2.0	DARK YELLOWISH-BROWN MOTTLED GRAY, DRY, STIFF, SILTY SAND (SM)
718.7		4.8	
716.2		7.3	

BORING NO.	B9
GROUND ELEVATION	729.5

ELEV		DEPTH	
			SURFACE
			CRUSHED LIMESTONE
			YELLOWISH BROWN, MOIST, MEDIUM STIFF, INORGANIC SILT AND SAND (ML)
729.5		0	
728.5		1.0	
727.0		2.5	YELLOWISH-BROWN MOTTLED GRAY, DRY, VERY STIFF, SILTY SAND (SM)
725.0		4.5	REDDISH-BROWN TO GRAY, DRY, DENSE TO STIFF, SILTY SAND (SM) WITH SEAMS OF SAND (SW)
712.5		17.0	
712.5		17.0	SANDSTONE SURFACE

Appendix D

Biological Features

Major Tree Species at NWSC Crane

Black Ash
White Ash
Large-toothed Aspen
Baldcypress
Basswood
Beech
River Birch
Boxelder
Ohio Buckeye
Butternut
Black Cherry
Black Maple
Red Maple
Sugar Maple
Yellow Poplar
Black Oak
Chestnut Oak
Chinquapin Oak
Pin Oak
Red Oak
Scarlet Oak
Shingle Oak
Cottonwood

American Elm
Red Elm
Hackberry
Bitternut Hickory
Monhernut Hickory
Pignut Hickory
Shagbark Hickory
Honeylocust
Black Locust
White Oak
Austrian Pine
Jack Pine
Pitch Pine
Scotch Pine
Shortleaf Pine
Virginia Pine
White Pine
Yellow Poplar
Sweetgum
Black Walnut
Sycamore
Willow

Partial List of Rare Plants at NWSC Crane
(Not listed as threatened or endangered)

Showy Orchis	Sessile Trillium
Lesser Fringed Orchis	Twinleaf
Ginseng	Sullivantia sullvantii
Nodding Trillium	Asplenium penvatifidum
Large White Trillium	Asplenium trechomanes
Yellow Trillium	Vittaria lineata

Partial List of Fauna at NWSC Crane

Reintroduced Mammals

- White-tailed deer
- Beaver

Small Mammals

- Opossum
- Mice
- Raccoon
- Cottontail rabbit
- Red fox
- Gray fox
- Long-tailed weasel
- Striped skunk
- Mink
- Coyote

Larger Rodents

- Muskrat
- Woodchuck (Groundhog)
- Gray squirrel
- Fox squirrel
- Eastern chipmunk
- Flying squirrel

Water Fowl and Shore Birds

- Canada goose
- Mallard duck
- Ringnecked duck
- Lesser scaup
- Hooded mergansers
- Black duck
- Redhead
- Common merganser
- Bufflehead
- Common loon

Game Birds

- Wild turkey
- Ruffed grouse
- Bobwhite quail
- Woodcock

Raptors that Rest on Center

- Red-tailed hawk
- Red-shouldered hawk
- Broad-winged hawk
- Sparrow hawk
- Coopers hawk
- Sharp-shinned hawk
- Great horned owl
- Barred owl
- Screech owl
- Turkey vulture

Fall and Winter Raptor Visitors

- Rough legged hawk
- Marsh hawk
- Short-eared owl
- Long-eared owl
- Saw-whet owl
- Bald eagle
- Golden eagle

Other Birds

- American coot
- Rock dove
- Common flicker
- Yellow-bellied sapsucker
- Blue jay
- Tufted titmouse
- Red-breasted nuthatch
- Mockingbird
- Golden-crowned kinglet
- House sparrow
- Rufous-sided towhee
- Field sparrow
- Red-winged blackbird
- Song sparrow
- Killdeer
- Mourning dove
- Hairy woodpecker
- Downy woodpecker
- Common crow
- Brown creeper

Partial List of Fauna at NWSC Crane (Continued)

Other Birds (Continued)

Winter wren
American rober
Cedar waxwing
Cardinal
Dark-eyed junco
Whippoorwill
Swamp sparrow
Great blue heron
Herring gull
Belted kingfisher
Red-bellied woodpecker
Horned lark
Carolina chickadee
White-breasted nuthatch
Carolina wren
Eastern bluebird
Starling
American goldfinch
Tree sparrow
Purple martin
White-throated sparrow
Ruby-throated hummingbird

Salamanders

Eastern newt
Redbacked salamander
Two-lined salamander

Frogs and Toads

Fowlers toad
Chorus frog
Cricket frog
Spring frog
Grey tree frog
Leopard frog
Bull frog
Green frog

Turtles

Spring softshell turtle
Snapping turtle
Box turtle
Painted turtle

Lizards

Five lined skink
Fence lizard
Ground skink

Snakes

Garter snake
Bended water snake
Dekays snake
Black racer
Black rat snake
Milk snake
Rough green snake
Hognose snake
Copper head
Rattle snake

Aquatic Animals

Crayfish
Freshwater mussels
Golden shiner
Redear sunfish
Channel catfish
Spotted sucker
Carp
Yellow perch
Warmouth
Largemouth bass
White bass
Brown bullhead
Bluegill sunfish
Walleye pike
White crappie
Yellow bullhead
Longear sunfish

Appendix E

Pyrotechnics Used at NWSC

Description of Pyrotechnics used at NWSC

a. Complete Round

Pyrotechnics are generally issued assembled with all the elements essential for proper functioning. Exceptions to this rule are certain aircraft flares and photoflash bombs for which the fuzes are issued separately for assembly in the field.

b. Ignition Train

Pyrotechnics generally function by means of an ignition train. The train begins with an initiator, usually a primer, which may be of the percussion, friction, or electric type. The flame produced on initiation is transmitted successively to a propelling charge, a delay element, an expelling charge, and finally to the main charge of pyrotechnic composition. One or more of the intermediate elements between initiator and main charge may be absent, depending upon the requirements of the pyrotechnic.

c. Explosives

Explosives used in the parts of the ignition train leading up to the main charge are specially selected primer compositions (mixtures) for the initiator: loose black powder for boosters, propelling charges, and expelling charges, and compressed black powder and special nongaseous compositions for delay elements.

Main Charge Pyrotechnic Compositions

The earliest pyrotechnic compositions consisted of varying mixtures of the constituents of black powder--namely, charcoal, sulfur, and saltpeter (potassium or sodium nitrate). Other materials, such as iron filings, coarse charcoal, or realgar (arsenic sulfide), were added or substituted as additional knowledge was acquired.

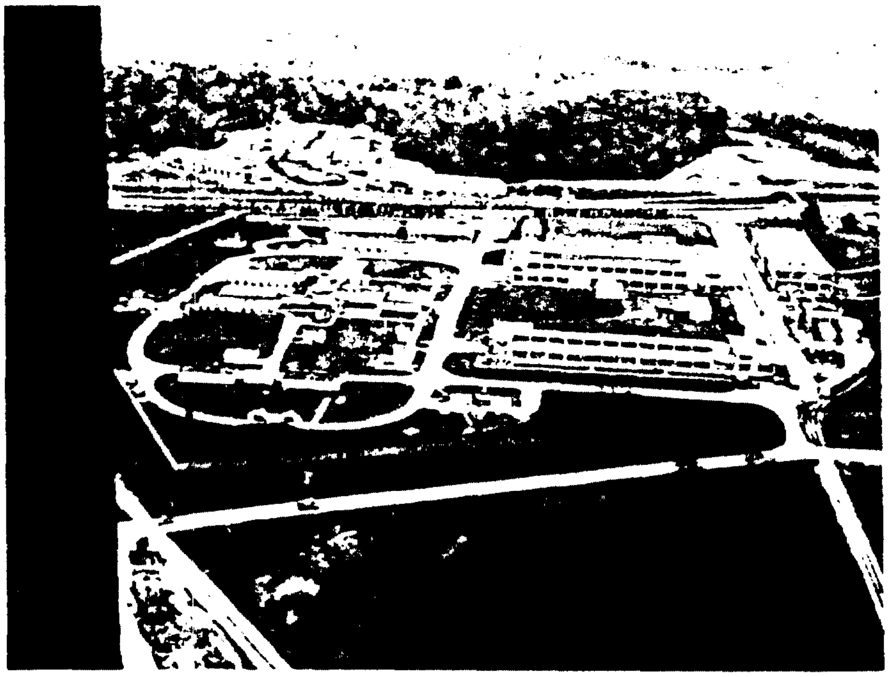
Present-day pyrotechnic compositions generally are physical mixtures of various chemicals. In some cases, a single material (listed below) may perform more than one function.

a. Oxidizers, such as chlorates, perchlorates, peroxides, chromates, and nitrates, provide oxygen for burning. Additional oxygen may be obtained from the air. Nongaseous powders, such as barium chromate-boron mixtures, which do not require oxygen from the air, are used in obturated delay columns.

b. Fuels, such as aluminum and magnesium powder, their alloys, sulfur, lactose, and other easily oxidizable materials.

c. Combustible binding and waterproofing agents, such as shellac, linseed oil, resins, resinates, and paraffin.

d. Color intensifiers, such as polyvinyl chloride, hexachlorobenzene, or other organic chlorides are mixed with barium and copper salts to produce green or with strontium salts to produce red.



Aerial View of Pyro Plant Line

e. Dyes, such as methylaminoanthraquinone, produce red, and auramine produce yellow.

f. Coolants, such as magnesium carbonate and sodium bicarbonate.

Pyrotechnic smoke compositions are of two general types.

a. Those that burn with practically no flame but give off a dense, colored smoke as a combustion product.

b. Those that burn at a temperature so low that an organic dye volatilizes, instead of burns, and colors the smoke.

Ignition Elements

Friction igniter consists of a primer cup and a ripple wire. The primer cup contains a mixture of potassium chlorate, charcoal, and dextrin binder. The ripple wire is coated with red phosphorus in shellac and has a nitrocellulose coating. The wire extends through the primer cup.

Quickmatch is a term applied to strands of cotton soaked in a mixture of black powder and gum arabic and coated with mealed powder. It is used as an initiator to transmit flame to igniting, priming, or pyrotechnic charges.

The priming charge is a dried black-powder paste in intimate contact with the first-fire composition. Newer pyrotechnic items use a special nonhygroscopic priming paste containing barium nitrate, zirconium hydride, silicon, tetranitro-carbazole, and a plastic binder.

The first-fire composition is generally a mechanical mixture of illuminant charge and black powder. For certain items it may be a special nonhygroscopic, easily ignitible composition that burns with a high temperature.

Classification and Use

Pyrotechnics are classified according to purpose, such as illuminants (photoflash cartridges and flares), signals, combination signaling and illuminating items, and simulators. Other types of ammunition that are modified to produce a pyrotechnic effect are classed with the parent type (for example, illuminating projectiles), but the effect produced generally falls into one of the following pyrotechnic classes:

a. Photoflash Cartridges. These produce a single flash of light for photographic purposes.

b. Flares. A flare produces a single source of illumination, which is generally of high candle-power and substantial duration. Flares may be parachute supported, towed, or stationary. Their primary function is illumination, but they may be used for identification, ignition, location of position, targets, or warning.

List of Pyrotechnic Items Produced

Title	Title
Signal, Illumination, Marine, Mk 2 Mod 0.................	Projectile Load, Illuminating Mk 9 Mods 0 and 1..........
Signal, Smoke, Marine, Mk 2 Mods 0...................	* Projectile Load, Illuminating Mk 11 Mod 0................
Signal, Illumination, Aircraft, AN-M37A2 Thru AN-M42A2; AN-43A2 thru AN-M45A2 AN-M53A2 thru AN-M58A2.......	Projectile Load, Illuminating Mk 12 Mod.................
Signal, Smoke, Ground, M62, M64 and M65.............	Flare, Surface, High Altitude, Parachute Mk 20............
Signal, Smoke and Illumination, Marine, Mk 13 Mod 0..........	Cartridge, 81MM Illuminating M301A2...................
* Signal, Smoke and Illumination, Marine, Mk 38 Mod 0..........	Flare, Surface M49
Signal, Illumination, Ground, Green, M125A1..............	Grenade, Hand Illuminating Mk 1 Mods 2 and 3.......
Signal, Smoke, Ground, M128A1 and M129A1...	* Flare, Aircraft, Parachute Mk 45 Mod 0.............
Signal, Hand Fired, Mk 80 Mods 0 and 1...........	Warhead, 5.0 Inch Rocket, Illuminating Mk 33 Mod 1
Signal, Illumination, Aircraft, Mk 6 Mod 0...................	* Marker, Location, Marine Mk 2 Mods 0 and 1.....
Signal, Smoke, Aircraft, Mk 7 Mod 0.....................	Signal, Smoke and Illuminating, Aircraft Mk 5 Mods 3 and 4...
Fuse, Warning, Railroad M72	Signal, Smoke and Illumination, Aircraft Mk 6 Mod 3..........
Cartridge, Signal, Mk 130, Mk 138, Mk 139, and Mk 140 Mods 0....................	Marker, Location, Marine Mk 7 Mods 2 and 3.....
Cartridge, Signal, Mk 121, Mk 122, and Mk 123 Mods.	Marker, Location, Marine Mk 9 Mod 0............
Flare, Aircraft, Parachute, Mk 5 Mods................	* Marker, Location, Marine Mk 25 Mods 0, 1, 2 and 3
Flare, Aircraft, Parachute, Mk 6 Mods 3 thru 6.......	* Marker, Location, Marine Mk 58 Mod 0...........
Projectile Load, Illuminating, Mk 7 Mod 0..................	* Signal, Smoke, Aircraft Mk 89 Mod 0..........
Flare, Aircraft, Parachute, Mk 24 Mods 2, 2A, 3 and 4	Signal, Illumination, Marine, Mk 3 Mods 1, 2 and 3.......
Projectile Load, Illuminating Mk 4 Mods..................	Signal, Smoke and Illumination, Marine Mks 51, 52, and 53 Mods
	Marker, Location, Marine, Mk 26 Mod 0 and Marker Location, Submarine.... Mk 75 Mod 0............

*Major items produced

(Continued)

List of Pyrotechnic Items Produced (Continued)

Title

- Signal, Smoke, Marine (Submarine) Mk 2 Mods 0, 1 and 2....................
- * Marker, Location, Submarine Mks 21, 22, 23, 24, 76, 77, 78 and 79 Mods 0...........
- * Signal, Smoke and Illuminating, Marine Mks 66, 67 and 68..... Mods 0......................
- Signal, Illumination, Marine Mks 41, 45 and 46 Mods 0..
- * Marker, Location, Marine, Mk 28 Mod 0 and Marker, Location, Submarine, Mk 80 Mod 0....................
- False Target, Submarine Mk 2 Mod 0...........
- Marker, Location, Marine AN-Mk 1 Mods 0 and 1..
- * Marker, Location, Marine, Mk 1 Mods 2 (Green) and 3 (Yellow)............
- Marker, Location, Marine Mk 8 Mod 0............
- Bomb, Photoflash M120 and M120A1................
- Cartridge, Photoflash M112A1 Series...................
- Cartridge, Photoflash M123A1 Series...................
- Cartridge, Signal, Practice Bomb Mk 4 Mods 3 and 4...
- Cartridge, Signal, Practice Bomb, Mk 111 Mod 0.......
- * Marker, Location, Marine Mk 38 Mod 0...........
- Signal Assembly Mk 25 Mod 2
- Unit, Color Burst Mk 7 Mod 0...............
- Signal Assembly Mks 39, 40, 43 and 44 Mod 0...............
- Signal, Smoke and Illumination, Marine Mk 55 Mod 0...........
- Signal, Flash, Guided Missile Mk 33 Mods 0 and 1.........
- Signal, Flash, Guided Missile Mk 37 Mod 1................
- Signal, Flash, Guided Missile Mk 42 Mod 0................
- Unit, Color Burst Mk 1, Mk 2 Mods 0..........

Title

- Unit, Color Burst Mk 3 Mods 0 and 1........
- Unit, Color Burst Mk 5 Mod 0..............
- Unit, Color Burst Mk 6 Mod 0...............
- Marker Kit, Location Mk 19 Mod 0..................
- Projector, Marker Mk 23 Mod 0................
- Signal, Float, Torpedo Mk 21 Mod 1....................
- * Flare, Target, Mk 28........
- Flare, Guided Missile Mk 21 Mod 0...................
- Tracer Mk 21 Mod 0.........
- Flare, Guided Missile Mk 27 Mod 0...................
- Tracking Device, Smoke, Mk 1 Mod 0....................
- Flare, Guided Missile Mk 25 Mod 0...................
- * Flare, Decoy, Mk 42, Mk 43, Mk 46 and Mk 47 Mod 0....
- Flare, Guided Missile Mk 23 Mod 0...................
- Simulator, Detonation, Explosive Mk 2......
- Simulator, Booby Trap, Flash M117.....................
- Simulator, Booby Trap, Illuminating M118...
- Simulator, Booby Trap, Whistling M119......
- Simulator, Projectile, Air Burst M74A1.............
- Simulator, Projectile, Ground Burst M115A2...............
- Smoke Pot, HC, Mk 3 Mod 0....
- Grenade, Hand, Smoke, WP, M15...................
- Smoke Pot M6.............
- Cartridge, Igniter, Turbo-Jet Engine Mk 243 Mod 2........
- Flare, Ground, Parachute XM-184................
- Light, Chemical, Aerosol Mk 11 Mod 0..........
- * Marker, Location, Chemical, Mk 46 Mod 0.............

*Major items produced

Typical Smoke Compositions

Type	Composition	Percent	Application	Typical Devices
WHITE:				
HC-Type C	Hexachloroethane	45.5	Screening	Smoke pots
	Zinc Oxide	47.5	and	Smoke bombs
	Aluminum (grained)	7.0	Signaling	Grenades
Modified HC	Hexachlorobenzene	34.4	Screening	Smoke
	Zinc Oxide	27.6	and	projectiles
	NH_4ClO_4	24.0	Signaling	
	Zinc Dust	6.2		
	Laminac w/catalyst	7.8		
Modified HC	Dechlorane	33.9	Screening	Smoke
	Zinc Oxide	37.4	and	projectiles
	NH_4ClO_4	20.5	Signaling	
	Laminac w/catalyst	8.2		
Plasticized White Phosphorus (PWP)	White Phosphorus	65.0	Screening	Chemical projectiles
	Plasticizer	35.0	(antipersonnel)	
	(Neoprene 100 parts)			
	(Carbon 75 parts)			
	(Xylene 44 parts)			
	(Litharge 15 parts)			
BLACK:				
	$KClO_3$ (200 mesh)	52.0	Screening	Grenades, etc.
	Anthracene (40 mesh)	48.0		
COLORED:				
Red	Dye-MIL D-3718	40.0	Signaling	Navy floating
	$KClO_3$	24.0		drift signal
	$NaHCO_3$	17.0		
	Sulfur	5.0		
	Polyester resin	14.0		
Red	1-methylamino (AQ)*	45.0	Signaling	Rocket type
	1,4-di-p-toluidino (AQ)*	3.0		parachute
	$KClO_3$ (23µ)	35.0		ground
	Sugar, fine (11µ)	17.0		signals
Red	1-(methoxyphenylaze)-2-naphthol	80.0	Air marker	Red
			Marking	marker
	NaCl	20.0	ground targets	projectile

*(AQ)=Anthraquinone

(Continued)

Typical Smoke Compositions (Continued)

Type	Composition	Percent	Application	Typical Devices
Red	Dye (R)	40.0		
	$KClO_3$	28.0	Signaling	Improved
(plastic)	$NaHCO_3$	23.0		grenade
	Sulfur	5.0		fillings
	Polyviryl acetate in ethyl acetate	3.0		
Yellow	Benzanthrene	32.0	Signaling	Rocket type
	Indanthrene GK	15.0		parachute
	$KClO_3$ (23μ)	30.0		ground
	Sugar, fine (11μ)	20.0		signals
	$NaHCO_3$ (20μ)	3.0		
Yellow	Auramine Hydrochloride	40.0	Air marker, etc.	90 mm yellow
	NaCl	60.0		marker projectile
Yellow (plastic)	Dye (Y)	40.0	Signaling	Improved
	$KClO_3$	29.3		grenade
	$NaHCO_3$	23.2		fillings
	Polyviryl acetate in ethyl acetate	7.0		
Green	1,4-dip-toluidine (AQ)*	28.0	Signaling	Rocket type
	Indanthrene GK (golden yellow)	12.0		parachute
	$KClO_3$ (23μ)	35.0		ground
	Sugar, fine (11μ)	23.0		signals
	$NaHCO_3$ (20μ)	2.0		
Green (plastic)	Dye (G)	40.0	Signaling	Improved
	$KClO_3$	26.0		grenade
	$NaHCO_3$	24.0		fillings
	Sulfur	6.0		
	Polyvinyl acetate w/ethyl acetate	4.0		
Violet	Violet dye, Spec. MIL-D-3691	47.5	Signaling	Rocket type
	$KClO_3$ (25μ)	28.0		parachute
	Sugar, fine (10μ)	18.0		ground
	$NaHCO_3$	4.5		signals
	Asbestos	2.0		
Orange	8-chloro-1-amino (AQ)*	39.0	Signaling	Grenades
	Auramine	6.0		
	$KClO_3$	22.3		
	Sulfur	8.7		
	$NaHCO_3$	24.0		

*(AQ)=Anthraquinone

Dyes That Have Been Used In Burning-Type Colored Smoke Munitions

	Dye(s)
Red Smoke:	9-diethylamino-phenyl-5-benzo (a) phenazinone. Also known as 9-diethylamino rosindone 1-methylaminoanthraquinone 1-(2-methoxyphenylazo)-2-naphthol 2-quinolyl-2-indandione-1,3 (Rhodamine B) plus 1-(4-phenylazo)-2-naphthol 2-aminoanthraquinone plus 1-methylaminoanthraquinone O-tolylazo-o-tolylazo-B-naphthol (Sudan IV); plus 2-quinolyl-2indandione-1,3 (Rhodamine B); plus auramine hydrochloride 1-(tolylazoxylylazo)-2-naphthol
Green Smoke:	1,8-di-p-toluidinoanthraquinone 1,4-di-p-toluidinoanthraquinone 1-methylamino-4-p-toluidinoanthraquinone plus auramine hydrochloride 1,4-di-p-toluidinoanthraquinone plus dimethylaminoazobenzene 1,4-di-p-toluidinoanthraquinone plus auramine hydrochloride 1,4-di-p-toluidinoanthraquinone with quinophthalone (quinoline yellow)
Orange Smoke:	1-aminoanthraquinone 1-amino-8-chloroanthraquinone plus quinizarin 1-(4-phenylazo)-2-naphthol 9,10-dianilinoanthracene plus phthaloperinone 1-(4-phenylazo)-2-naphthol plus 9,10-dianilinoanthracene
Orange-Red Smoke:	1-(4-nitrophenylazo)-2-naphthol

(Continued)

Dyes Which Have Been Used In Burning-Type Colored Smoke Munitions (Continued)

Yellow Smoke:	Dye(s)
	Auramine hydrochloride 1-(4-dimethylaminophenylazo)-2-naphthol 1-(4-phenylazo)-2-naphthol (Sudan I) plus either auramine hydrochloride or quinophthalone (quinoline yellow) N,N-dimethyl-p-phenylazoaniline
Blue Smoke:	
	1-hydroxy-4-p-toluidinoanthraquinone Indigo 1-amino-2 bromo-4-p-toluidinoanthraquinone 1-amino-2-methyl-4-p-toluidinoanthraquinone (Alizarin Sapphire, Blue R. Base) 1,4-dimethylaminoanthraquinone 1hydroxy-4-p-toluidinoanthraquinone 1-methylamino-4-p-toluidinoanthraquinone N-(p-dimethylaminophenyl)-1,4-naphtholquinonimine
Violet Smoke:	
	1,4-diaminoanthraquinone 1,4-diamino-2,3-dihydroanthraquinone 1,5-di-p-toluidinoanthraquinone 1-methylamino-4-p-toluidinoanthraquinone plus 2-quinolyl-2-indandione-1,3 (Rhodamine B) 1-methylamino-4-p-toluidinoanthraquinone plus 1,5-di-p-toluidinoanthraquinone

Some Dyes Which Have Been Used In Explosive-Type Colored Smoke Munitions	
Red Smoke:	Dye(s)
	1-(2-methoxyphenylazo)-2-naphthol 1-methylaminoanthraquinone (Celanthrene Red)
Yellow Smoke:	
	2,4-diaminoazobenzene (Chrysoidine G, base) Auramine Hydrochloride
Green Smoke:	
	1,4-di-p-toluidinoanthraquinone (Quinizarin Green) plus quinophthalone (Quinoline Yellow, base) in the ratio of 65/35 1,4-di-p-toluidinoanthraquinone plus auramine hydrochloride

Typical Compositions for Photoflash and Spotting Charges

Type	Class	Nominal Composition	Specification	Microns	Percent
PHOTOFLASH POWDERS					
I	--	34% Magnesium 26% Aluminum 40% Potassium Perchlorate			
II	A	60% 50/50 Magnesium-Aluminum Alloy 40% Potassium Perchlorate			
	B	45.5% 50/50 Magnesium-Aluminum Alloy 54.5% Barium Nitrate			
III	A	40% Aluminum, Class C 30% Potassium Perchlorate 30% Barium Nitrate	JAN-A-289 PA-PD-254 PA-PD-253	15 24 147	40 30 30
	B	Same as III-A except that the Potassium Perchlorate is coarser			
IV	--	80% Calcium 20% Sodium Perchlorate			
SPOTTING CHARGES					
--	--	30% Atomized Aluminum 10% Flake Aluminum 60% Barium Nitrate			

Typical Illuminating, Signaling, and Tracer Compositions

SOURCE	COLOR	FUEL: Mag-nesium	FUEL: Alumi-num	FUEL: Misc.	OXIDIZERS: Barium Nitrate	OXIDIZERS: Sodium Oxalate	OXIDIZERS: Sodium Nitrate	OXIDIZERS: Stron-tium Nitrate	OXIDIZERS: Misc.	Binder: Oil Linseed /Castor	Binder: Wax Paraffin	Binder: Misc.
A	White	26.[illegible]			38.3				25.2(d)	2.9	6.7	
A	White	28.5	6.5		57.0						8.0	
A	White	36	4		43	12.5				1	2.5	
										1		
A	White	48			21	5	21			1	3	
										1		
C	Yellow	52					35					13(j)
C	Yellow	58					37					5(k)
												0.5(l)
C	Green	23			53							2(m)
												20(n)
												2(o)
C	Red	40						18	22(c)			6(n)
												7(o)
C			21		68	5				2		4(p)
D		58.0					37.5					4.5(s)
											(29)(k)	
B	Red	26.7						33.3	26.7(f)			6.7(q)
									5(g)			1.6(q)
B	Red	28						55				17(r)
B	Red	26						52				16(r)
D				90(a)								
				10(a)								
D	Dark			34(b)					28(h)			
									38(i)			
D	Dark			20(c)	50							15(t)
												5(u)

A.Naval Ammunition Depot, Crane, Indiana
B.Frankford Arsenal
C.Picatinny Arsenal
D.NOL White Oak, Maryland
a.Pyrotechnic compositions
b.Manganese
c.Silicon
d.Potassium Nitrate
e.Potassium Perchlorate
f.Strontium Peroxide
g.Strontium Oxalate
h.Barium Chromate
i.Lead Chromate

j.Thiokol
k.Laminac
l.Pluronic
m.Copper Powder
n.Hexachlorobenzene
o.Asphaltum
p.Sulphur
q.Calcium Resinate
r.Polyvinyl Chloride
s.Binder Composition
t.Zirconium Hydride
u.Tetranitrocarbazole

Note: Details of preparation and material specifications should be obtained from source installations.

c. Signals. Two types of effects are obtained with signals; light and smoke. A particular model may produce both effects. Light-producing signals are much smaller and faster burning than flares and may consist of a single parachute-supported star or one to five freely falling stars, with or without colored tracers. Smoke signals are of either the slow-burning, streamer type, which leave a trail of smoke, or the parachute-suspended type, which produce a cloud of smoke.

d. Simulators. Simulators imitate actual battle sounds and flashes of light produced by service items of ammunition. They are designed for use in training.

e. Miscellaneous Types. Pyrotechnics that have nomenclatures other than those above have a variety of uses.

(1) In illuminating ammunition, the pyrotechnic elements are assembled in projectile bodies such as the 5"/54 and 5"/38.

(2) Smoke grenades have the form of high-explosive hand and rifle grenades but resemble smoke signals in effect.

The pyro line produced nearly all the items listed in table 6.1-1; the major items are indicated by an asterisk (*). Table 6.1-2 is a list of typical smoke compositions. Table 6.1-3 is a list of some dyes that have been used in burning-type colored-smoke munitions. Table 6.1-4 lists some dyes used in burster munitions. Table 6.1-5 gives typical photoflash and spotting charge compositions. Table 6.1-6 shows typical illuminating, signaling, and tracer compositions. The predominant materials used were magnesium, aluminum, sodium nitrate, and laminac. Strontium nitrate was used for the red flare, and barium nitrate for the green. The other flares and the color burst and smoke rounds used dyes, mainly benzanthrone, Yellow Vat No. 4, sodium fluorescein, and anthracene. One dye in particular, auramine hydrochloride, has not been used since 1970. Because colored smokes involve vaporization and condensation, constitutent dyes must be thermally stable and fairly volatile, and must possess the requisite purity of color when disseminated as a smoke. These properties are closely related to the chemical constitution of the dye. A dye has never been specifically developed for smoke application; only those available were considered and used.

Phosphorus

From 1965 to 1970 the MK58 red phosphorus candles were made on the pyro line and tested in an area north of Building 2940 and Building 2930. On a fairly continuous basis, red phosphorus is burned in Building 2167 in the process control area.

Although dead trees have been reported in both areas, on-site visits could not identify the cause as phosphoric acid burn. During the growing season before leaves appear, the phosphorus acts as fertilizer. When leaves are full, too much acid on the leaves tends to kill the trees. Pesticides were reported to have been used in all areas.

The mechanism of the reactions for phosphorus are as follows.

White smoke consisting of small droplets of phosphoric acid have been widely used for military purposes. These droplets result from the reaction of phosphorus pentoxide, formed by the burning of phosphorus or phosphorus-containing compounds in the air, and the water vapor in the air, or

$$3P_4 + 1CO_2 \longrightarrow 4P_3O_5$$

$$P_2O_5 + 3H_2O \longrightarrow 2H_3PO_4$$

$$H_3PO_4 + nH_2O \longrightarrow H_3PO_4 \text{ (dilute)}$$

The concentration of phosphoric acid in the droplets is determined by the relative humidity. Methods that have been used to form phosphorus pentoxide for military smokes utilizing phosphorus include

a. burning in air of white phosphorus (which is spontaneously flammable),

b. burning in air of the phosphorus vapor (produced by the evaporation of red phosphorus in a fuel-oxidant mixture), and

c. burning in air of phosphine (produced by the action of a metal phosphide with water).

Phosphorus vapor is extremely toxic and causes bone decay; however, it is not present after the smoke is formed. Phosphorus pentoxide and phosphoric acid are not toxic in small concentrations, although they may be irritating to the eyes, respiratory tract, and skin. Phosphorus smokes have relatively little effect on metals. Red phosphorus, the comparatively inert allotropic form of phosphorus, is used in burning-type munitions, mainly for signaling purposes. Compositions consisting of red phosphorus and certain oxidants or fuels are relatively slow-burning and are sometimes used in sea markers. The chemical reactions may be quite involved. For example, the main reaction for a burning mixture of calcium sulfate and red phosphorus appears to be

$$30CaSO_4 + 19P_4 \longrightarrow 6Ca\,(PO_3)_2 + 12Ca_2P_2O_2 + 10P_4S_3$$

The heat produced by this reaction vaporizes the remaining red phosphorus contained in the smoke mixture. The phosphorus vapor burns on contact with air. Some sulphur dioxide is formed when the P_4S_3, produced in the above reaction, burns along with the phosphorus vapor.

$$P_4S_3 + 8O_2 \rightarrow 3SO_2 + 2P_2O_5$$

Solid Metal Chlorides

Solid metal chlorides are normally disseminated by thermal vaporization followed by condensation. In most cases, the energy required to vaporize these agents is provided by a pyrotechnic heat source. The hydrolyses reactions for the metal chlorides that have been used as smoke agents are

$$CuCl2 + 2H_2O \rightarrow Cu(OH)_2 + 2HCl$$

$$FeCl_2 + 2H_2O \rightarrow Fe(OH)_2 + 2HCl$$

$$FeCl_3 + 3H_2O \rightarrow Fe(OH)_3 + 3HCl$$

$$AlCl_3 + 3H_2O \rightarrow Al(OH)_3 + 3HCl$$

$$ZnCl_2 + 2H_2O \rightarrow Zn(OH)_2 + 2HCl$$

$$CdCl_2 + 2H_2O \rightarrow Cd(OH)_2 + 2HCl$$

$$HgCl_2 + 2H_2O \rightarrow HgO \cdot H_2O + 2HCl$$

$$SnCl_2 + 2H_2O \rightarrow Sn(OH)_2 + 2\ HCl$$

It may be seen from this that some heavy metals and HCl (hydrochloric acid) are end products. Zinc chloride is one of the most reactive of the solid metal chlorides as a smoke agent. Although toxic, zinc chloride produced as the result of a pyrotechnic reaction is widely used for screening and signaling purposes. Inasmuch as hydrochloric acid is produced by the reaction between zinc chloride and water vapor in air, the smoke is irritating to personnel and will react with any materials affected by hydrochloric acid.

Toxicity of Colored Smoke Mixture

As standardized, the colored smoke clouds are nontoxic in ordinary field concentrations. In general, toxic materials should not be employed as ingredients in signaling and screening munitions. Certain dyes reportedly exhibit carcinogenic characteristics which should be guarded against when they are used.

The problem in determining whether or not a dye is a carcinogenic hazard is complex, because the products of metabolism of the dye must also be considered for carcinogenic activity even though the original dye may be harmless. The hazards of handling carcinogenic materials are not in the quantities involved but in the frequency of exposure, no matter how small the dosage.

One of the smoke dyes, Indanthrene Golden yellow GK, has been tested and found to be noncarcinogenic, but it is closely related to 3,4,8,9-dibenzpyrere (Indanthrene Golden Yellow without the two oxygens), which is known to be a very potent carcinogen. If this compound should be present or formed by a process of reduction as an impurity in even as small a quantity as 0.01%, it would present a considerable hazard. Red dye, 1-methylaminoanthraquinone, has not been tested for carcinogenicity but has the possibility of being a potential liver carcinogen. Two other smoke dyes, Sudan Orange R (1-phenylazo-2-napthol) and 1-(2-methoxyphenylazo)-2-naphthol are reported as carcinogenic. Blue dye, 1,4-diamino-2,3-dihydroanthraquinone, has not been tested but is expected to be relatively safe by its structure.

Diethylamino Rosindone might undergo metabolic reduction in the body to yield carcinogenic -naphthylamine. Green smoke dye 1,4-di-toluidinoanthraquinone is on the current approved list for drugs and cosmetics (Food and Drug Administration).